OAK RIDGE RESERVATION

Annual Site Environmental Report

2019

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Oak Ridge Reservation

Annual Site Environmental Report 2019

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Acronyms and Abbreviations

A

AAM	ambient air monitor
ACM	asbestos-containing material
AFFF	aqueous film-forming foams
AFV	alternative fuel vehicle
ALARA	as low as reasonably achievable
ANSI	American National Standards Institute
AOC	area of concern
AOEC	Agent Operations Eastern Command
ASER	*Oak Ridge Reservation Annual Site Environmental Report*
AWQC	ambient water quality criterion

B

BCG	biota concentration guide
BCK	Bear Creek kilometer
BFK	Brushy Fork kilometer
BMAP	Biological Monitoring and Abatement Program

C

C&D	construction and demolition
CAA	Clean Air Act
CAP-88	Clean Air Act Assessment Package (software)
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CEUSP	Consolidated Edison Uranium Solidification Project
CFR	*Code of Federal Regulations*
CFTF	Carbon Fiber Technology Facility
CH	contact-handled
COLEX	column exchange
CRK	Clinch River kilometer
CROET	Community Reuse Organization of East Tennessee
CRSP	Chestnut Ridge Security Pits
CWA	Clean Water Act
CWTS	Chromium Water Treatment System (ETTP)
CX	categorical exclusion
CY	calendar year

D

D&D	decontamination and decommissioning
DCE	dichloroethene/dichloroethylene
DCS	derived concentration standard
DOE	US Department of Energy
DOI	US Department of Interior

E

EC&P	environmental compliance and protection
ED	effective dose
EESP	Energy Efficiency and Sustainability Program
EFK	East Fork Poplar Creek kilometer
EFPC	East Fork Poplar Creek
EISA	Energy Independence and Security Act
EM	environmental management
EMS	environmental management system
EMWMF	Environmental Management Waste Management Facility
EO	executive order
EPA	US Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
EPEAT	Electronic Product Environmental Assessment Tool
EPSD	Environmental Protection Services Division (UT-Battelle)
EPT	ephemeroptera, plecoptera, and trichoptera (taxa)
ES&H	environment, safety, and health
ESS	Environmental Surveillance System (ORNL)
ETTP	East Tennessee Technology Park
EU	exposure unit
EUI	energy use intensity
EV	electric vehicle

F

FCK	First Creek kilometer
FFA	Federal Facility Agreement for the Oak Ridge Reservation
FFCA	Federal Facilities Compliance Agreement
FFK	Fifth Creek kilometer
FMD	ORNL Facilities Management Division
FWS	US Fish and Wildlife Service
FY	fiscal year

G

GHG	greenhouse gas
GI	green infrastructure
GP	guiding principle
GSF	gross square feet

H

HAP	hazardous air pollutant
HFIR	High Flux Isotope Reactor
HPSB	high-performance sustainable building
HQ	hazard quotient
HVC	Hardin Valley Campus

I

ID	identification number
IDMS	Integrated Document Management System (UT-Battelle)
IRIS	Integrated Risk Information System

	ISMS	Integrated Safety Management System
	ISO	International Organization for Standardization
	Isotek	Isotek Systems, LLC
L	LEED	Leadership in Energy and Environmental Design
	LID	low-impact design
	LLW	low-level (radioactive) waste
M	MARSAME	*Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual*
	MARSSIM	*Multi-Agency Radiation Survey and Site Investigation Manual*
	MBK	Mill Branch kilometer
	MCK	McCoy Branch kilometer
	MCL	maximum contaminant level
	MDF	Manufacturing Demonstration Facility
	MEI	maximally exposed individual
	MEK	Melton Branch kilometer
	MIK	Mitchell Branch kilometer
	MOA	memorandum of agreement
	MSL	mean sea level
	MSRE	Molten Salt Reactor Experiment
	MT	meteorological tower (followed by a numeral as in “MT2”)
N	NAAQS	National Ambient Air Quality Standards
	NCRP	National Council on Radiation Protection and Management
	NEPA	National Environmental Policy Act
	NESHAPs	National Emission Standards for Hazardous Air Pollutants
	NNSA	National Nuclear Security Administration
	NPDES	National Pollutant Discharge Elimination System
	NPL	National Priorities List (EPA)
	NRC	US Nuclear Regulatory Commission
	NRCS	Natural Resources Conservation Service
	NRHP	National Register of Historic Places
	NSF-ISR	National Science Foundation International Strategic Registrations, Ltd.
	NTRC	National Transportation Research Center
	NWSol	North Wind Solutions, LLC
O	ODS	ozone-depleting substance
	OMP	operational monitoring plan
	OREM	DOE Oak Ridge Office of Environmental Management
	ORGDP	Oak Ridge Gaseous Diffusion Plant
	ORISE	Oak Ridge Institute for Science and Education
	ORNL	Oak Ridge National Laboratory
	ORO	DOE Oak Ridge Office

ORR	Oak Ridge Reservation
ORRLF	Oak Ridge Reservation Landfill
ORSSAB	Oak Ridge Site Specific Advisory Board
ORWMA	Oak Ridge Wildlife Management Area
OST	Office of Secure Transportation
OTC	once-through cooling

P

P2	pollution prevention
P2/WMin	pollution prevention/waste minimization
PAM	perimeter air monitoring (station)
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
PEMS	Predictive Emissions Monitoring System
PFAS	per- and polyfluoroalkyl substances
PFOA	perfluorooctanoic acid
PFOS	perfluorooctane sulfonate
PFP	pre-fire plan
PM	particulate matter
PM_{10}	particulate matter with an aerodynamic diameter ≤ 10 μm
$PM_{2.5}$	fine particulate matter with an aerodynamic diameter ≤ 2.5 μm
PWTC	Process Waste Treatment Complex

Q

QA	quality assurance
QC	quality control
QMS	quality management system

R

R&D	research and development
RA	remedial action
Rad-NESHAPs	National Emission Standards for Hazardous Air Pollutants for Radionuclides
RATA	relative accuracy test audit
RCRA	Resource Conservation and Recovery Act
RH	remote-handled
RICE	reciprocating internal combustion engine
ROD	record of decision
RSI	Restoration Services, Inc.

S

SARA	Superfund Amendments and Reauthorization Act
SBMS	Standards-Based Management System (UT-Battelle)
SC	DOE Office of Science
SD	storm water outfall/storm drain
SDWA	Safe Drinking Water Act
SNS	Spallation Neutron Source
SODAR	sonic detection and ranging

	SOF	sum of fractions
	SOP	state operating permit
	SPCC	spill prevention, control, and countermeasures
	SPMD	semipermeable membrane device
	STP	sewage treatment plant
	SWMU	solid waste management unit
	SWPP	storm water pollution prevention
	SWPPP	storm water pollution prevention plan
	SWSA	solid waste storage area
T	TCE	trichloroethene/trichloroethylene
	TDEC	Tennessee Department of Environment and Conservation
	TM	technical memorandum
	TMDL	total maximum daily load
	TMI	Tennessee Macroinvertebrate Index
	TRI	toxic (chemical) release inventory
	TRO	total residual oxidant
	TRU	transuranic
	TSCA	Toxic Substances Control Act
	TSS	total suspended solids
	TVA	Tennessee Valley Authority
	TWPC	Transuranic Waste Processing Center
	TWRA	Tennessee Wildlife Resources Agency
U	UMC	unneeded materials and chemicals
	USDA	US Department of Agriculture
	USGBC	US Green Building Council
	UST	underground storage tank
	UT	University of Tennessee
	UT-Battelle	UT-Battelle, LLC
	UT-Dallas	University of Texas at Dallas
V	VOC	volatile organic compound
W	WBK	Walker Branch kilometer
	WCK	White Oak Creek kilometer
	WIPP	Waste Isolation Pilot Plant
	WOC	White Oak Creek
	WOD	White Oak Dam
	WQC	water quality criterion
	WQPP	water quality protection plan
	WRRP	Water Resources Restoration Program
	WSR	waste services representatives

Y	Y-12 or Y-12 Complex	Y-12 National Security Complex
Z	ZPR	Zero-power Reactor

Units of Measure and Conversion Factors*

Units of measure and their abbreviations

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

Quantitative prefixes

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

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

Unit conversions

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

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Executive Summary

Overview

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

ORR is managed by three DOE Program Secretarial Offices and their management, operating, and support contractors. This calendar year 2019 *Oak Ridge Reservation Annual Site Environmental Report* (ASER) contains detailed and complex information furnished to the DOE ORR integrating contractor by other contractors including UT-Battelle, LLC; Consolidated Nuclear Security, LLC; UCOR, an Amentum-led partnership with Jacobs; North Wind Solutions, LLC; Oak Ridge Associated Universities; and Isotek Systems, LLC.

DOE's signature integrated safety management system (ISMS), which integrates safety in all aspects of work, helps ensure safety at all DOE facilities. Safety, as defined in ISMS, encompasses protection of the public, the worker, and the environment and includes all safety, health, and environmental disciplines: radiation protection, fire protection, nuclear safety, environmental protection, waste management, and environmental management.

Chapter 3 of this report was prepared by UCOR, the lead environmental management contractor for ETTP. Chapter 4 was developed by Consolidated Nuclear Security, LLC, which manages and operates the Y-12 Complex. Chapter 5 was written by UT-Battelle, LLC, manager of ORNL. These contractors are also responsible for independently carrying out the various DOE missions at the three major ORR facilities. They manage and implement environmental protection programs through environmental management systems that adhere to International Organization for Standardization Standard 14001, Environmental Management Systems, and are integrated with ISMS to provide unified strategies for managing resources. Chapters 3, 4, and 5 include detailed information on each contractor's environmental management systems.

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

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

Impacts

DOE ORR operations resulted in minimal impact to the public and the environment in 2019. Permitted discharges to air and water continued to be below regulatory standards, and potential radiation doses to the public from activities on the reservation were less than the 100 mrem standard established for DOE sites in DOE Order 458.1, Radiation Protection of the Public and the Environment.

The maximum radiation dose a hypothetical off-site individual could have received from DOE activities on ORR in 2019 was estimated to be 0.4 mrem from air pathways, 4 mrem from water pathways (drinking water, fish consumption, swimming, recreation, and other uses), and 2 mrem from consumption of wildlife harvested on ORR. This is about 6.4 percent of the DOE 100 mrem standard for all pathways and is significantly less than the 300 mrem annual average dose to people in the United States from natural or background radiation.

Environmental Monitoring

Each year extensive environmental monitoring is conducted across ORR. Site-specific environmental protection programs are carried out at ORNL, the Y-12 Complex, and ETTP. ORR-wide environmental surveillance programs, which include locations and media both on and off the reservation, are carried out to enhance and supplement data from site-specific efforts. In 2019 many thousands of samples and measurements of air, water, direct radiation, vegetation, fish, and wildlife were collected from across the reservation and analyzed for radioactive and nonradioactive contaminants. Sample media, locations, frequencies, and parameters were selected based on environmental regulations and standards, public and environmental exposure pathways, environmental permits, and measurement capabilities. Chapters 2 through 7 of this report summarize the environmental protection and surveillance programs on ORR. These extensive sampling and monitoring efforts demonstrate DOE's commitment to ensuring safety; protecting human health; complying with regulations, standards, DOE Orders, and "as low as reasonably achievable" principles; reducing the risks associated with past, present, and future operations; and improving cost-effectiveness.

Compliance with Environmental Regulations

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

Compliance with applicable regulations during 2019 for the three major ORR sites is summarized as follows:

- ETTP had no notices of environmental violations or penalties.
- Y-12 had no environmental permit violations or exceedances.
- ORNL had two violations of Tennessee’s hazardous waste management regulations, an underground storage tank testing violation, and four National Pollutant Discharge Elimination System permit noncompliances.

Chapter 2 provides a detailed summary of ORR environmental compliance during 2019. Chapters 3, 4, and 5 further discuss each site’s compliance status for the year.

Environmental Management, Pollution Prevention, and Site Sustainability

Numerous environmental management, pollution prevention, and sustainability programs across ORR embody efforts to achieve enduring sustainability in facilities, operations, and organizational culture. These programs conserve water and energy, minimize waste, and promote building efficiency, sustainable landscaping, green transportation, and sustainable acquisition, which in turn decrease the life cycle costs of programs and projects and reduce risks to the environment. While implementing their work in 2019, ORR contractors achieved a high level of excellence in environmental management, pollution prevention, and sustainability programs as described in Chapters 3, 4, and 5.

Environmental Management

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

ETTP achievements included complete demolition of the K-1037 Building, which once produced barrier material used in the gaseous diffusion process, and demolition of the K-131 and K-631 Poplar Creek Facilities, which were some of the most contaminated facilities remaining at ETTP. K-131 provided purified uranium hexafluoride to the uranium enrichment cascade, and K-631 withdrew gaseous depleted uranium hexafluoride from the cascade, converted it to liquid, and transferred it to transport cylinders. The K-1232 Chemical Recovery Facility, the K-1423 Toll Enrichment Facility (which was used to transfer liquefied uranium hexafluoride), and the K-1414 Garage were also demolished, and the former K-29 uranium enrichment facility foundation slab was removed. Other notable demolitions in the area include a cooling tower, a cooling water pump house, and a test loop facility that was used to evaluate the performance of gaseous diffusion equipment.

Y-12 achievements in 2019 included removing an additional 1.5 tons of elemental mercury from column exchange equipment in the Alpha-4 Building, draining the column exchange process piping, and completing the characterization of 22 tanks. Construction of the Outfall 200 Mercury Treatment Facility continued and secant pile walls were installed near East Fork Poplar Creek. The Mercury Treatment

Facility, when complete, will be capable of treating 3,000 gallons of water per minute and will include a 2-million-gallon storage tank to handle storm water peak flow conditions. More than 4,000 cubic yards of soil from an oil retention pond was dispositioned. The report *2019 Cleanup Progress: Annual Report to the Oak Ridge Regional Community* (OREM-19-2579) provides a detailed description of each study area and findings from studies performed in fiscal year 2019. Also during fiscal year 2019, the Environmental Management Waste Management Facility received 10,555 waste shipments, totaling 75,074 cubic yards, from ORR cleanup projects.

ORNL achievements in 2019 included completing work on a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) project initiated in 2018 for limited environmental remediation in the 3500 Area of the Central Campus to facilitate future brownfield redevelopment. ORNL also initiated a utilities upgrade project to address the aging utilities that provide electrical service and handle potable water, steam, storm water, and wastewater. Although utilities work is not typically performed under CERCLA, these are large-scale upgrades that may generate significant volumes of soils for disposition. The soils may be contaminated from legacy research and development, and may be remediated as a consequence of the utilities modernization efforts.

Isotek Systems, LLC began processing uranium-233 material inside glove boxes in Building 2026 in the fall of 2019 to produce a solidified, low-level waste form acceptable for disposal.

Environmental Management Waste Management Facility operations collected, analyzed, and disposed of approximately 4.5 million gallons of leachate treated by the Liquid and Gaseous Waste Operations facility, an increase of more than 40 percent over the previous year.

Transuranic Waste Processing Center achievements included completing 85 contact-handled transuranic shipments containing 2,739 drums to the Waste Isolation Pilot Plant in Carlsbad, New Mexico. To date, approximately 76 percent of the contact-handled transuranic waste and 56 percent of the remote-handled transuranic waste have been dispositioned at the Waste Isolation Pilot Plant. Key progress for the Sludge Project in 2019 included receiving vendor proposals for the sludge mobilization system, the slurry mixing and characterization tank, and the sludge test area construction. A contract was awarded for testing the mobilization measurements instrumentation.

Pollution Prevention and Sustainability

The three main ORR sites made significant strides in sustainability and pollution prevention in 2019, and highlights are summarized below.

Y-12 has demolished more than 1.6 million gross square feet of excess facilities. More than 72 excess DOE facilities are located on the Y-12 site, with a total of 2.8 million gross square feet. This progress is in line with meeting the DOE site sustainability plan reduction goal of 25 percent by fiscal year 2025. Y-12 also achieved a 66 percent reduction in water use and a 6 percent reduction in energy intensity, and 52.7 percent of non-hazardous waste was diverted from the landfill. Y-12 received renewable energy credits of 7.5 percent. More than 98.8 percent of eligible electronic acquisitions were registered through EPEAT, the Electronic Product Environmental Assessment Tool. Greenhouse gas emissions were reduced by 58 percent compared to the 2008 baseline.

ORNL saw a number of significant achievements in 2019. Operations at the National Transportation Research Center and Carbon Fiber Technology Facility were regulated as conditionally exempt small-quantity generators, meaning that less than 100 kg of hazardous waste was generated per month. No hazardous or mixed wastes were generated, accumulated, or shipped by DOE or UT-Battelle, LLC at the DOE Office of Scientific and Technical Information or the 0800 Area. Closure documentation for DOE Building 1916-T2 was submitted. A new Permit TNHW-178 was issued by TDEC Division of

Solid Waste Management on August 15, 2019. ORNL also implemented 26 new pollution prevention projects and ongoing reuse/recycle projects during 2019, eliminating more than 3 million kg of waste. ORNL achieved a 32 percent decrease in petroleum consumption; an increase, to 46, in the number of alternative use vehicles; and a 66 percent reduction in water use intensity from fiscal years 1985 through 2019, in compliance with the Executive Order 13834 reduction goal of 36 percent by 2025. ORNL has reduced its energy use by 31.6 percent since 2003.

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

UCOR’s ORNL Operations and Cleanup Enterprise Installed Process Instrumentation Team was commended for developing a method to reduce the number of required instrument calibrations and consolidating the remaining calibrations, conserving resources and saving $20,000 to $25,000 per year. The ORNL Operations and Cleanup Enterprise Project was recognized for identifying and implementing an innovative approach that recycled ten metal and concrete salt casks rather than disposing of them in a landfill. This resulted in a cost savings of $40,000 and conserved 1,640 cubic feet of valuable landfill space. The General Plant and Capital Projects group was also recognized for implementing a design change that safely reduced the amount of materials used in dewatering boxes during the Zeolite Upgrade Project. This resulted in a $36,000 cost savings and conserved future landfill space.

The Oak Ridge Reservation Landfill (ORRLF) Project was recognized for identifying an opportunity to divert uncontaminated soil from disposal at the landfill and reuse it as landfill cover material, thereby saving $58,160, reducing greenhouse gases, and conserving 1,950 cubic yards of limited landfill space. The ORRLF Project was also recognized for identifying materials from ORRLF Sediment Pond 3 upgrades for reuse at Landfill V, which conserved resources, saved $21,500, and diverted 750 cubic yards of material from landfills.

1. Introduction to the Oak Ridge Reservation

It was not shown on any maps. No visitors were allowed without special approval. US Army guards were posted at the entrances to the city, and all residents were required to wear badges at all times outside their homes. Thus, Oak Ridge existed for seven years, from 1942 to 1949, as a truly secret city. It was here and in supporting locations that humankind made the leap from candlepower to nuclear power in a single generation. The engineering marvel that materialized in the Secret City changed the world, helped bring an end to World War II, and launched diagnostic tools such as magnetic resonance imaging and nuclear medicine that save thousands of lives from cancer and other maladies. Today the revealed Secret City exists in two parts: the City of Oak Ridge and the Oak Ridge Reservation (ORR).

ORR covers 52 square miles of land in Anderson and Roane counties and is home to two major US Department of Energy (DOE) operating components: the Oak Ridge National Laboratory (ORNL) and the Y-12 National Security Complex (Y-12 Complex or Y-12). Other ORR facilities include the East Tennessee Technology Park (ETTP), site of a former gaseous diffusion plant that has undergone significant environmental cleanup and transitioned to a private sector business and industrial park; the Oak Ridge Institute for Science and Education (ORISE) South Campus, which includes training facilities, laboratories, and support facilities; several smaller, government-owned, contractor-operated entities involved in environmental cleanup; and the government-owned, government-operated Agent Operations Eastern Command (AOEC) of the National Nuclear Security Administration (NNSA) Office of Secure Transportation (OST). Some things have not changed; personnel seeking entrance to ORR must have proper credentials in accordance with current access security requirements.

President Franklin D. Roosevelt received the famous Einstein-Szilard letter in 1939 informing him that German scientists were working on a nuclear weapon. In utmost secrecy, he formed the agencies leading up to the Manhattan Project. Then, on June 28, 1941, five months and nine days prior to the Japanese attack on Pearl Harbor, he signed Executive Order 8807 which funded the Manhattan Project. The super-secret code name Manhattan Project gave no indication of the classified activities it concealed. So named because its original headquarters were established in June 1942 in New York City's Manhattan district in an office building at 270 Broadway, in the summer of 1943 the project moved to Oak Ridge, where construction of America's first full-scale gaseous diffusion plant was underway. Here scientists began using the gaseous diffusion process to enrich uranium using Graham's Law of Diffusion.

Graham's Law was formulated by Scottish physical chemist Thomas Graham in 1848. He found experimentally that the rate of diffusion of a gas is inversely proportional to the square root of its molecular weight. Thus, if the molecular weight of one gas is four times that of another, it will diffuse through a porous plug or escape through a small pinhole in a vessel at half the rate of the lighter gas. In other words, heavier gases diffuse more slowly. Graham's Law provides a basis for separating isotopes by diffusion—the method that played a crucial role in the development of the atomic bomb 100 years after Graham’s discovery. Today ORR’s mission continues to evolve as it adapts to meet the changing basic and applied research and national security needs of the United States.

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

1.1 Background

The ORR Annual Site Environmental Report (ASER) is a summary of environmental data that characterizes environmental performance, lists environmental occurrences reported during the year, confirms compliance with environmental standards and requirements, and highlights significant environmental program activities. The ASER meets the requirements of DOE Order 231.1B, Environment, Safety, and Health Reporting, and its Attachments 1, 2, 3, 4, and 5 (DOE 2012) regarding the preparation of an integrated annual site environmental report.

Summary results in this report are based on data collected before and continuing through 2019. Not all results of the environmental monitoring associated with ORR are reported here, and this is not intended to be a comprehensive monitoring report. Data collected for other site and regulatory purposes, such as environmental restoration and remedial investigation reports, waste management characterization sampling data, and environmental permit compliance data, are presented in other documents that have been prepared in accordance with applicable laws, regulations, policies, and guidance. These data are referenced herein as appropriate.

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

1.2 History of the Area around the Oak Ridge Reservation

Native Americans first inhabited the ORR area during the Woodland Period (c. 1000 BC to AD 1000). Descendants of these early dwellers, whose ancestors were Neolithic and Stone Age people, still lived in the East Tennessee region when European settlers arrived in the late 1700s. The Cherokee people were dominant in the area following wars with the Shawnee and Creek. The early European settlers of the ORR area lived on farms or in four small communities named Elza, Robertsville, Scarborough, and Wheat. All but Elza were founded shortly after the Revolutionary War. About a thousand families inhabited the area in the early 1940s.

The area that became ORR was selected in 1942 for the Manhattan Project, in part, because the Clinch River provided abundant water and the terrain’s linear and partitioned ridges offered separation and protection that, in the words of General Leslie Groves, "prevented them from blowing up like firecrackers on a string." Nearby Knoxville was a good source of labor, and the Tennessee Valley Authority could supply ample amounts of needed electricity. Families that had occupied homes and farms for generations received orders to vacate within just a few weeks. The federal government's acquisition of property under the right of eminent domain immediately affected more than three thousand individuals. According to data from the US Department of Agriculture’s National Agricultural Statistics Service, the average farm real estate value in 1942 for the 48 contiguous states was $34 per acre. Some property owners were paid this amount for their land, and others were paid less. Many felt they were poorly compensated, especially for their homes.

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

Two years after World War II ended, Oak Ridge shifted to civilian control under the authority of the US Atomic Energy Commission. In 1959 the city was incorporated and the community adopted a city manager and city council form of government. The missions of the three major ORR installations have continued to evolve and operations have adapted to meet America's changing defense, energy, and research needs. Section 1.4 describes their current missions, as well as the missions of several smaller DOE facilities and activities on ORR.

1.3 Site Description

1.3.1 Location and Population

Situated in the Great Valley of East Tennessee between the Cumberland and Great Smoky Mountains, as shown in Figure 1.1, ORR borders the Clinch River (see Figure 1.2). The Cumberland Mountains are 16 km (10 mi) to the northwest and the Great Smoky Mountains are 51 km (31.6 mi) to the southeast. ORR encompasses about 13,055 hectares (33,866.54 acres) of mostly contiguous, federally owned land in Anderson and Roane Counties, and is under the management of DOE.

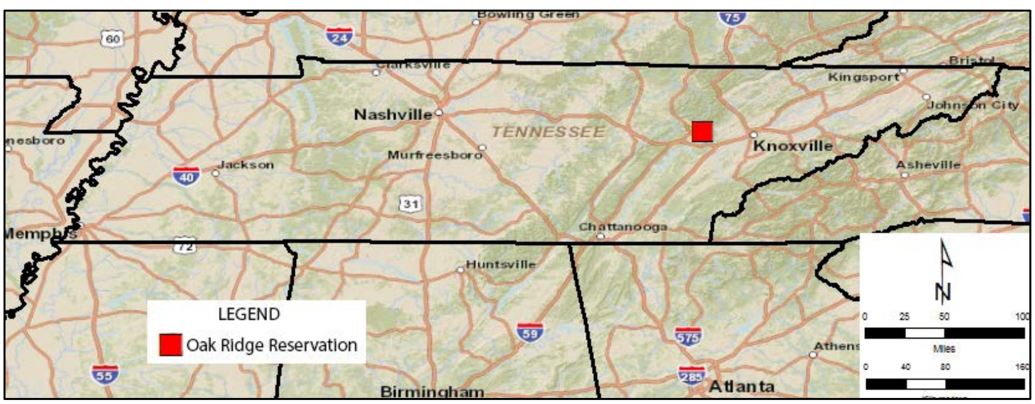

Figure 1.1. Location of the Oak Ridge Reservation in Tennessee

As reported in *US Department of Energy FY 2017 Economic Impact in Tennessee* (East Tennessee Economic Council 2017), ORR employs about 35,000 members of the region's labor force. The July 1, 2019 US Census population estimate for the Knoxville Metropolitan Statistical Area, which includes Oak Ridge, was 869,046. The combined 2019 US Census population estimates for the ten counties surrounding ORR (Anderson, Blount, Campbell, Cumberland, Knox, Loudon, McMinn, Monroe, Morgan, and Roane) was 1,009,993. Knoxville, the major city nearest to Oak Ridge, is about 40 km (25 mi) to the east and had a population of about 187,603, according to the 2019 US census population estimate. Other municipalities within about 30 km (18.6 mi) of ORR include Oliver Springs, Clinton, Rocky Top, Lenoir City, Farragut, Kingston, and Harriman. Except for the city of Oak Ridge, the land within 8 km (5 mi) of ORR is semirural and is used primarily for residences, small farms, and cattle pasture. Fishing, hunting, boating, water skiing, and swimming are popular recreational activities in the area.

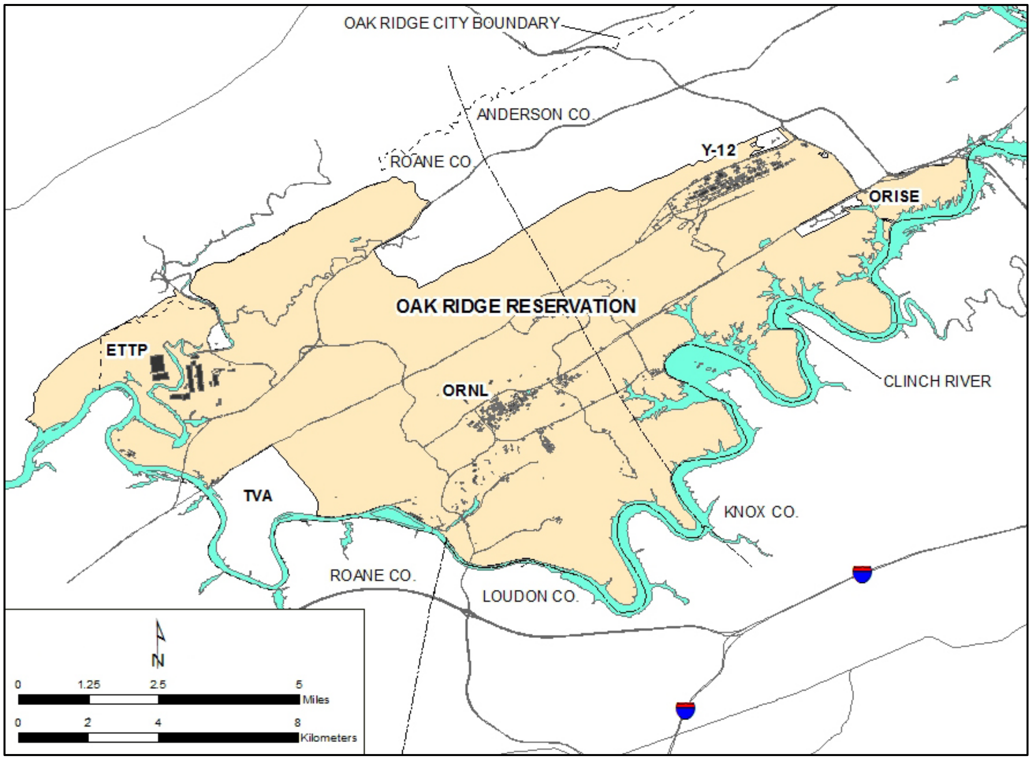

Figure 1.2. Map of the Oak Ridge Reservation

1.3.2 Climate

Although it features significant temperature changes between summer and winter, the climate of the Oak Ridge region qualifies as humid subtropical. The 30-year average temperature for 1981–2010 was 14.7°C (58.5°F). The average high temperature for the Oak Ridge area in 2019 was 21.5°C (70.8°F). January temperatures were coldest in 2019, averaging 0.4°C (32.7°F). July was the warmest month, with average temperatures of 24.5°C (76.1°F). Monthly summaries of temperature averages, extremes, and 2019 values are provided in Appendix B, Table B.1.

Average annual precipitation in the Oak Ridge area for the 30-year period from 1981 to 2010 was 1,337.5 mm (52.64 in.), including about 21.3 cm (8.4 in.) of snowfall (NOAA 2011). Total precipitation during 2019 as measured at meteorological tower (MT)2 was 1,847.7 mm (72.74 in.), which is 38 percent above the 30-year average. Monthly summaries of precipitation averages, extremes, and 2019 values can also be found in Appendix B, Table B.1.

The average annual wind data recovery rates (a measure of acceptable data) across locations used for modeling during 2019 were greater than 99.6 percent for wind sensors at the ORNL sites (towers MT2, MT3, MT4, MT10, and MT12). All other (MT6, MT9, and MT11) instrument recoveries were above 98 percent for both quarterly and annual values.

In 2019 wind speeds at ORNL Tower A (MT4), measured at 15 m (49 ft) above ground level, averaged 0.94 meters per second (2.1 mph). This value remained unchanged for winds at 60 m (198 ft) above ground level. The local ridge-and-valley terrain reduces average wind speeds at valley bottoms, resulting in frequent periods of calm or near calm conditions, particularly during clear early morning hours in weak synoptic weather environments. Wind direction frequencies with respect to precipitation hours for the ORR towers may be reviewed **here** under the heading 2019 Annual Precipitation Wind Roses−Oak Ridge Reservation.

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

1.3.3 Regional Air Quality

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

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

1.3.4 Surface Water

The ORR area comprises a series of drainage basins or troughs containing numerous small streams that feed the Clinch River. Surface water on ORR drains into a series of tributaries, streams, or creeks in different watersheds. Each of these watersheds drains into the Clinch River, which in turn flows into the Tennessee River. On December 31, 2018, the Tennessee Valley Authority declared 2018 the wettest year on record for the Tennessee Valley region with 67.02 inches of precipitation, surpassing a previous record of 65.1 inches set in 1973. With 66.5 inches of rainfall, 2019 was the second wettest year on record. This conclusion is based on more than 100 years of collected weather data.

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

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

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

1.3.5 Geological Setting

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

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

The remaining geologic units on ORR (the Rome Formation, the Conasauga Group below the Maynardville Limestone, and the Chickamauga Group) are composed predominantly of shale, siltstones, and sandstones with a subordinate and locally variable amount of carbonate bedrock. These formations are primarily composed of insoluble minerals such as clays and quartz that were derived from ancient continental erosion. Groundwater occurs in and moves through fractures in these bedrock units. Groundwater availability in such settings depends on the abundance and interconnectedness of fractures and the connection of fractures to sources of recharge, such as alluvial soils along streams, which can provide some sustained infiltration. The shale and sandstone formations are the poorest aquifers in the Valley and Ridge Province (Zurawski 1978). Well yields are generally low in the Rome, Conasauga, and Chickamauga bedrock formations except in localized areas where carbonate beds may provide greater groundwater storage than adjacent clastic bedrock. Detailed information on ORR groundwater hydrology and flow is available in *Oak Ridge Reservation Physical Characteristics and Natural Resources* (Parr and Hughes 2006).

1.3.6 Natural, Cultural, and Historic Resources

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

1.3.6.1 Wetlands

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

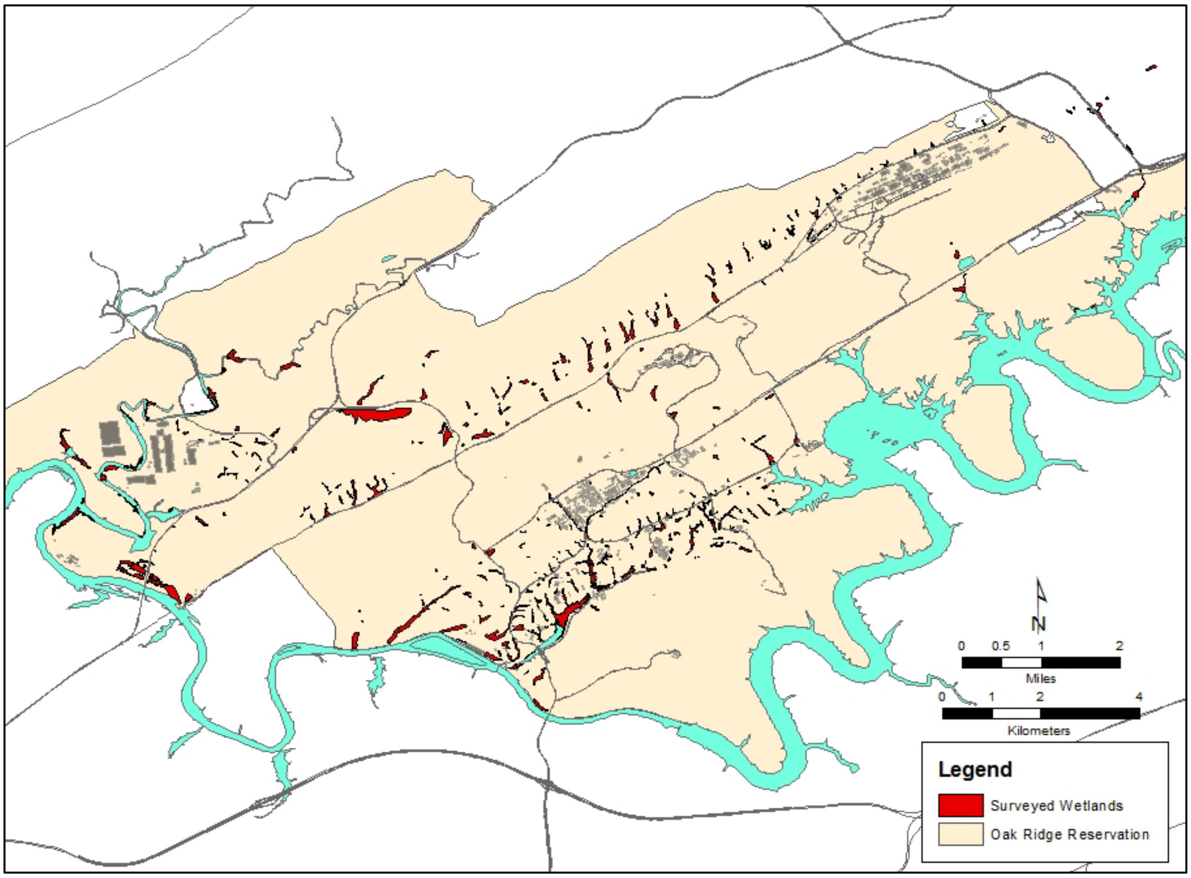

Figure 1.3. Location of Oak Ridge Reservation wetlands

About 243 hectares (600 acres) of wetlands have been identified on ORR; most are classified as forested palustrine, scrub/shrub, and emergent wetlands. Wetlands identified to date range from several square meters at small seeps and springs to about 10 hectares (25 acres) at White Oak Lake. In 2017, wetlands were delineated in the Copper Ridge Borrow Area and 294 Power Line Area. The Tennessee Department of Environment and Conservation's wetland mitigation aquatic resource alteration permits, required by Section 401 of the Clean Water Act, entail monitoring restored or created wetland mitigation sites for five years. Activities and conditions in and around ORNL wetlands are verified by site inspections when appropriate (see Chapter 5, Section 5.3.12).

A haul road constructed as part of the Uranium Processing Facility project inside Y-12 caused the loss of some wetlands that required mitigation, including creating and expanding wetlands in the Bear Creek watershed. Details of this activity are provided in Chapter 4, Section 4.5.8.4. The work was performed under an approved US Army Corps of Engineers Section 404 permit and an aquatic resource alteration permit issued by the Tennessee Department of Environment and Conservation. Monitoring in accordance with these permits began following the completion of mitigation activities. The wetland mitigation carried out under these permits resulted in a more than 3:1 net increase in total wetland area. In all, 3.51 acres of wetlands will be constructed to compensate for the removal of one acre. The compensation ratios are intended to ensure there is no net loss of wetland resource value. Annual monitoring of the remediated wetland sites through 2019 revealed that, in general, the wetlands are responding as intended and have shown remarkable wetland plant coverage over the past few years. The five remediated wetlands had the hydrologic, vegetative, and soil characteristics to be considered wetlands in 2019. The wetlands have responded as intended; minimal alterations were required in two of the wetlands. Data from Wetlands 1 and 7 had shown a trend of decreasing plant coverage as water levels increased. To remedy this, 1,500 plants representing a dozen species were planted in Wetlands 1 and 7 in 2019. The monitoring conducted in 2019 marks the end of wetland monitoring for this project.

1.3.6.2 Wildlife and Endangered Species

Animals listed as species of concern by state, federal, or international organizations and known to have occurred on the reservation (excluding the Clinch River bordering the reservation) are listed, along with their status, in Table 1.1. Some of these, such as hellbender, have been seen only once or a few times; others, including wood thrush, are comparatively common and widespread on ORR. As of July 2016, Tennessee had 93 species listed under the federal Endangered Species Act (75 endangered and 18 threatened). The complete Tennessee Threatened and Endangered List−New Rules is found **here.**

Table 1.1. Animal species of special concern reported on the Oak Ridge Reservation[a]

Scientific name	Common name	Status[b]		
		Federal	State	PIF[c]
	FISH			
Phoxinus tennesseensis	Tennessee dace		NM	
	AMPHIBIANS AND REPTILES			
Crytobranchus alleganiensis	Hellbender		T	
Hemidactylium scutatum	Four-toed salamander		NM	
	BIRDS			
	Swans, Geese, and Ducks			
Branta canadensis	Canada goose	MCOB	NM	
Aix sponsa	Wood duck	MC		
Anas strepera	Gadwall	MC		
Anas americana	American wigeon	MC		
Anas rubripes	American black duck	MC		RC
Anas platyrhynchos	Mallard	MC		
Anas discors	Blue-winged teal	MC		
Anas crecca	Green-winged teal	MC		
Anas clypeata	Northern shovler	MC		
Anas acuta	Northern pintail	MC		
Aythya valisineria	Canvasback	MC		
Aythya americana	Redhead	MC		
Aythya collaris	Ring-necked duck	MC		
Aythya affinis	Lesser scaup	MC*		

Table 1.1. Animal species of special concern reported on the Oak Ridge Reservation[a] (continued)

Scientific name	Common name	Status[b]		
		Federal	State	PIF[c]
	Grebes			
Podilymbus podiceps	Pie-billed grebe	MC		
Podiceps auritus	Horned grebe	MC		
	Frigatebirds, Boobies, Cormorants			
Phalacrocorax auritus	Double-breasted cormorant	MCOB		
	Bitterns and Herons			
Ixobrychus exilis	Least bittern		NM	
Egretta caerulea	Little blue heron		NM	
Nycticorax nycticorax	Black-crowned night heron		NM	
Mycteria americana	Wood stork	T		
	Kites, Hawks, Eagles, and Allies			
Haliaeetus leucocephalus	Bald eagle	MC[d]		
	Rails, Gallinules, and Coots			
Rallus limicola	Virginia rail	MC		
Porzana carolina	Sora	MC		
Fulica americana	American coot	MC		
Actitus macularius	Spotted sandpiper	MC		
Tringa solitaria	Solitary sandpiper	MC		
Tringa flavipes	Lesser yellowlegs	MC		
Scolopax minor	American woodcock	MC*		
	Grouse, Turkey, and Quail			
Bonasa umbellus	Ruffed grouse			RC
Colinus virginianus	Northern bobwhite	MC		RC
	Pigeons and Doves			
Zenaida macroura	Mourning dove	MC		
	Goatsuckers			
Caprimulgus carolinensis	Chuck-will's-widow			RC
Caprimulgus vociferus	Eastern whip-poor-will			RC
	Swifts			
Chaetura pelagica	Chimney swift			RC
	Kingfishers			
Megaceryle alcyon	Belted kingfisher			RC
	Woodpeckers			
Melanerpes erythrocephalus	Red-headed woodpecker			RC
Colaptes auratus	Northern flicker			RC

Table 1.1. Animal species of special concern reported on the Oak Ridge Reservation[a] (continued)

Scientific name	Common name	Status[b]		
		Federal	State	PIF[c]
	Tyrant Flycatchers			
Contopus virens	Eastern wood-pewee			RC
Empidonax virescens	Acadian flycatcher			RC
Contopus cooperi	Olive-sided flycatcher			
Empidonax trailii	Willow flycatcher	MC		
	Swallows			
Progne subis	Purple martin			RC
Hirundo rustica	Barn swallow			RC
	Kinglets, Gnatcatchers, and Thrushes			
Hylocichla mustelina	Wood thrush		NM	RC
	Shrikes			
Lanius ludovicianus	Loggerhead shrike		NM	
	Wood Warblers			
Vermivora chrysoptera	Golden-winged warbler		T	RC
Setophaga cerulea	Cerulean warbler		NM	RC
Setophaga discolor	Prairie warbler			RC
Mniotilta varia	Black-and-white warbler			RC
Protonotaria citrea	Prothonotary warbler			RC
Geothlypis formosa	Kentucky warbler			RC
Cardellina canadensis	Canada warbler			RC
Icteria virens	Yellow-breasted chat			RC
	Tanagers			
Piranga rubra	Summer tanager			RC
	Towhees, Sparrows, and Allies			
Pipilo erythrophthalmus	Eastern towhee			RC
Spizella pusilla	Field sparrow			RC
Ammodramus savannarum	Grasshopper sparrow			RC
Ammodramus henslowii	Henslow’s sparrow		T	RC
Melospiza Georgiana	Swamp sparrow			RC
	Finches and Allies			
Spinus tristis	American goldfinch			RC
	MAMMALS			
Myotis grisescens	Gray bat	E	E	
Myotis lucifugus	Little brown bat		T	
Myotis sodalist	Indiana bat[e]	E	E	
Myotis septentrionalis	Northern long-eared bat	T		
Myotis leibii	Eastern small-footed bat		NM	

Table 1.1. Animal species of special concern reported on the Oak Ridge Reservation[a] (continued)

Scientific name	Common name	Status[b]		
		Federal	State	PIF[c]
Perimyotis subflavus	Tri-colored bat		T	
Corynorhinus rafinesquii	Rafinesque's Big-eared bat		NM	
Sorex dispar	Long-tailed shrew		NM	

[a] Land and surface waters of the Oak Ridge Reservation (ORR) exclusive of the Clinch River, which borders ORR.
[b] Status codes:
E = endangered
FS = Federal Focal species
T = threatened
MC = of management concern
NM = in need of management
OB = overly abundant
RC = regional concern
UR = under federal review
[c] Partners in Flight (PIF) is an international organization devoted to conserving bird populations in the Western Hemisphere.
[d] The bald eagle was federally delisted effective August 9, 2007.
[e] A single specimen was captured in a mist net bordering the Clinch River in June 2013.

Birds, fish, and aquatic invertebrates are the most thoroughly surveyed animal groups on ORR. Nevertheless, the only federally listed animal species observed on ORR in recent years are mammals. Gray bats were seen over the Clinch River bordering ORR in 2003 and over a pond on ORR in 2004. Three gray bats were mist-netted outside a cave on ORR in 2006. Several gray bats and one Indiana bat were caught in mist nets bordering the Clinch River in June and July 2013. Northern long-eared bats, recently federally listed as threatened, are known to be present on ORR; their calls have been identified in various acoustic surveys of the reservation, and in 2013 their presence was confirmed when a number were captured in mist nets (McCracken et al. 2015).

Birds recorded on ORR and its boundary waters include the 228 species documented by Roy et al. (2014) plus the cackling goose (*Branta hutchinsii*), purple gallinule (*Porphyrio martinicus*), American bittern (*Botaurus lentiginosus*) and federally threatened wood stork (*Mycteria Americana*) for a total of 232 species. Most of these species are protected under the Migratory Bird Treaty Act and Executive Order 13186, Responsibilities of Federal Agencies to Protect Migratory Birds. DOE's updated memorandum of understanding on migratory birds with the US Fish and Wildlife Service (FWS) (DOE-FWS 2013) strengthens migratory bird conservation on ORR through enhanced collaboration between DOE and FWS.

Breeding bird surveys conducted along varying numbers of up to 10 routes on ORR provide data for the Partners in Flight Program. Five public nature walks were held on ORR during 2019. Topics included American woodcock and birds of prey, birds, frog calls, a reptiles and amphibians inventory, and history of ORR. In past years ORR has been nominated for the Presidential Migratory Bird Federal Stewardship Award. A technical manuscript, *Oak Ridge Reservation Bird Records and Population Trends* (Roy et al. 2014), documents all known ORR bird records since 1950, as well as population trends for 32 species of birds.

Several state-listed bird species such as the golden-winged warbler, cerulean warbler, and little blue heron are uncommon migrants or visitors to the reservation. The cerulean warbler, listed by the state as in need of management, often appears during the breeding season on ORR but is currently listed as a potential breeding bird on the reservation (Roy et al. 2014) as its actual breeding status is still uncertain. The bald eagle (shown in Figure 1.4), which was removed from the federal list of threatened and endangered species on August 9, 2007, is a year-round resident in Tennessee, though it can be difficult to find on the reservation from September through November. One bald eagle nest was confirmed on the reservation in 2019. This nest was first observed in 2011 and has remained active every year since.

Source: Jason Richards, ORNL photographer

Figure 1.4. Bald eagle nest on the Oak Ridge Reservation

More than two dozen eaglets fledged in East Tennessee during 2017, according to bald eagle information published by the East Tennessee State University College of Arts and Sciences Biological Sciences department. More than 50 sightings in Roane and Anderson counties were reported to eBird (described in Sullivan et al. 2009) during calendar year 2019.

Other species such as the wood thrush and barn swallow are migrants and are known to nest on the reservation. The golden-winged warbler (*Vermivora chrysoptera*), listed by the state as threatened, was sighted once, in May 1998, on the reservation, as was the Lincoln's sparrow (*Melospiza lincolnii*) (no listed status) in May 2014. Barn owls were documented nesting on the reservation in 2019.

With many northern lakes freezing solid during the winter of 2013–2014, white-winged scoters (*Melanitta fusca*) and red-necked grebes (*Podiceps grisegena*) made rare appearances in East Tennessee in February and March of 2014, though they were recorded locally only on boundary waters of the reservation. Other uncommon birds for ORR recorded in recent years include several species associated with wetland habitats. The sora, least bittern, and Virginia rail, shown in Figure 1.5, were observed at the K1007 P1 pond at ETTP in 2013 and were likely attracted to high quality wildlife habitat established through recent restoration efforts. The sora, seen as recently as December 2016, is a fairly common migrant throughout Tennessee but is seldom seen on ORR. The least bittern is an uncommon migrant and summer resident in Tennessee. The Virginia rail, most recently observed in October 2013, was previously known on ORR only through historic records from the early 1950s (Roy et al. 2014). FWS lists all three of these species as of management concern. The least bittern is also deemed in need of management by the State of Tennessee, as shown in Table 1.1.

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

Source: Stock images courtesy of iStock.

Figure 1.5. Interesting bird species sighted on the Oak Ridge Reservation in recent years: (a) sora, (b) least bittern, and (c) Virginia rail

1.3.6.3 Threatened and Endangered Plants

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

The State of Tennessee lists 17 plant species occurring on ORR as endangered, threatened, or of special concern; these are included in Table 1.2. Appalachian bugbane is no longer listed by Tennessee and does not have official federal status; therefore, it does not appear in Table 1.2. An additional 10 threatened, endangered, or special concern species occur in the area and, although currently unconfirmed on ORR, may be present. These are also included in Table 1.2. Other plant populations currently under study on ORR may be added to the table in future years.

Table 1.2. Vascular plant species listed by state or federal agencies and sighted/reported on or near the Oak Ridge Reservation

Species	Common name	Habitat on ORR	Status code[a]
	Currently known to be or previously reported on ORR		
Aureolaria patula	Spreading false foxglove	River bluff	FSC, S
Berberis canadensis	American barberry	Rocky bluff	S
Bolboschoenus fluviatilis	River bulrush	Wetland	S
Delphinium exaltatum	Tall larkspur	Barrens and woodlands	FSC, E
Diervilla lonicera	Northern bush-honeysuckle	Rocky river bluff	T
Draba ramosissima	Branching whitlow-grass	Limestone cliff	S
Elodea nuttallii	Nuttall waterweed	Pond, embayment	S
Eupatorium godfreyanum	Godfrey's thoroughwort	Dry woods edge	S
Fothergilla major	Mountain witch-alder	Woods	T

Table 1.2. Vascular plant speciies listed by state or federal agencies and sighted/reported on or near the Oak Ridge Reservation (continued)

Species	Common name	Habitat on ORR	Status code[a]
Helianthus occidentalis	Naked-stem sunflower	Barrens	S
Juglans cinerea	Butternut	Lake shore	FSC, T
Juncus brachycephalus	Small-head rush	Open wetland	S
Liparis loeselii	Fen orchid	Forested wetland	T
Panax quinquifolius	American ginseng	Rich woods	S, CE
Platanthera flava var. herbiola	Tuberculed rein-orchid	Forested wetland	T
Spiranthes lucida	Shining ladies'-tresses	Boggy wetland	T
Thuja occidentalis	Northern white cedar	Rocky river bluffs	S
Rare plants that occur near and could be present on ORR			
Agalinis auriculata	Earleaf false foxglove	Calcareous barren	FSC, E
Allium burdickii or A. tricoccom[b]	Ramps	Moist woods	S, CE
Lathyrus palustris	Marsh pea	Moist meadows	S
Liatris cylindracea	Slender blazing star	Calcareous barren	T
Lonicera dioica	Mountain honeysuckle	Rocky river bluff	S
Meehania cordata	Heartleaf meehania	Moist calcareous woods	T
Pedicularis lanceolata	Swamp lousewort	Calcareous wet meadow	S
Pseudognaphalium helleri	Heller's catfoot	Dry woodland edge	S
Pycnanthemum torrei	Torrey's mountain-mint	Calcareous barren edge	S
Solidago ptarmicoides	Prairie goldenrod	Calcareous barren	E

[a] Status codes:
CE = Status due to commercial exploitation
E = Endangered in Tennessee
FSC = Federal Special Concern; formerly designated as C2. See Federal Register, February 28, 1996.
S = Special concern in Tennessee
T = Threatened in Tennessee

[b] Ramps have been reported near ORR, but there is not sufficient information to determine which of the two species is present or whether the occurrence may have been the result of planting. Both species of ramps have the same state status.

Acronym: ORR = Oak Ridge Reservation

The latest Tennessee Rare Plant List was published in October 2016. The 2012 Tennessee Rare Plant List reduced the number of state-protected species on ORR by six, and the 2016 Tennessee Rare Plant List reduced this number by an additional two species: the Tennessee coneflower (*Echinacea tennesseensis*) and Egget's sunflower (*Helianthus eggertii*).

1.3.6.4 Historical and Cultural Resources

Efforts continue to preserve ORR's rich prehistoric and historic cultural resources. Compliance with the National Historic Preservation Act is maintained in conjunction with National Environmental Policy Act (NEPA) compliance. The scope of proposed actions is reviewed in accordance with the *Cultural Resource Management Plan, DOE Oak Ridge Reservation, Anderson and Roane Counties, Tennessee* (DOE 2001). ORR has several facilities that were eligible for inclusion on the National Register of Historic Places (NRHP), a National Park Service program to identify, evaluate, and protect historic and archeological resources in the US, as well as numerous facilities that were not eligible for NHRP inclusion. Artifacts of historical or cultural significance are identified prior to demolition and catalogued in a database to aid in historic interpretation. The reservation contains more than 44 known prehistoric sites (primarily archeological evidence of former structures), 254 historic pre-World War II structures, 32 cemeteries, and several historically significant structures from the Manhattan Project era.

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

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

Although Buildings 9731 and 9204-3 at the Y-12 Complex are eligible for listing on the NRHP, at present neither is available for regular public access. Occasional public access to both facilities last occurred on Nov. 12, 2015, when DOE facilitated public tours of both buildings to celebrate the establishment of the National Park. By developing the National Park, DOE aims to enhance safe access to these buildings while protecting the agency's mission capabilities.

DOE will fulfill the objective of enabling safe access to the former site of the K-25 Building. The National Park Service will aid in historic interpretation of the site, although the K-25 Building site is already undergoing extensive historic interpretation activities separate and independent from the National Park. DOE launched the K-25 Virtual Museum as part of the activities to establish the Park. The online exhibit, which details the history of the K-25 Gaseous Diffusion Plant through narrative and photographs, can be viewed **here**. The initial phase of the K-25 History Center was under construction in 2019 and was expected to open in early 2020.

The Graphite Reactor is a National Historic Landmark, and six additional historic ORR properties are listed individually in the NRHP:

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

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

A memorandum of agreement signed in 2012 between DOE Oak Ridge Office, the State Historic Preservation Officer, the Advisory Council on Historic Preservation, the City of Oak Ridge, and the East Tennessee Preservation Alliance ensures consistent interpretation of site historic properties at ETTP. The memorandum of agreement is being implemented through planning for a History Center that will highlight the historic aspects of ETTP and of the communities that were displaced during the construction of the site.

Three site-wide programmatic agreements among the DOE Oak Ridge Office, the State Historic Preservation Officer, and the Advisory Council on Historic Preservation concerning management of historical and cultural properties on ORR, at ORNL, and at Y-12 have been enforced since their respective approvals.

1.4 Oak Ridge Sites

ORR includes a number of sites critical to the mission of DOE. Eight of these sites are described in this section: ORNL, the Y-12 Complex, ETTP, EMWMF, the Oak Ridge Environmental Research Park, ORISE, NNSA OST AOEC, and the Transuranic Waste Processing Center (TWPC) Sludge Buildout Facility.

1.4.1 Oak Ridge National Laboratory

ORNL (shown in Figure 1.6) is managed for DOE by UT-Battelle, LLC, a partnership between the University of Tennessee and Battelle Memorial Institute. The largest science and energy national laboratory in the DOE system, ORNL conducts basic and applied research to deliver transformative solutions to compelling problems in energy and security. The laboratory is home to several of the world's top supercomputers and is a leading neutron science and nuclear energy research facility that includes the Spallation Neutron Source and the High Flux Isotope Reactor. ORNL hosts a DOE leadership computing facility, home of the Summit supercomputer; one of DOE's nanoscience centers, the Center for Nanophase Materials Sciences; one of DOE's energy research centers; and the Bio-Energy Science Center. UT-Battelle, LLC also manages the US ITER project (formerly the International Thermonuclear Experimental Reactor project) for DOE.

Formerly known as X-10, ORNL was established in 1943 to support the Manhattan Project. From an early focus on chemical technology and reactor development, ORNL's research and development portfolio broadened to include programs supporting DOE missions in scientific discovery and innovation, clean energy, and nuclear security. Today ORNL employs about 4,400 workers, and the laboratory's extensive capabilities in scientific discovery and innovation are applied to the delivery of mission outcomes for DOE and other sponsors.

During fiscal year (FY) 2019, DOE remained focused on disposing of a significant inventory of uranium-233 stored in Building 3019 at ORNL. This special nuclear material requires strict safeguards and security controls to protect against access. The objectives of the Uranium-233 Project are to address safeguards and security requirements, eliminate safety and nuclear criticality concerns, and safely dispose of the material. DOE has successfully resolved the concerns associated with the disposition of the Consolidated Edison Uranium Solidification Project material, which originated from a 1960s research and development test of thorium and uranium fuel at Consolidated Edison's Indian Point 1 Nuclear Plant in New York. Isotek Systems, LLC manages activities at the Building 3019 complex for DOE and is responsible for activities associated with processing, down-blending, and packaging the DOE inventory of uranium-233 stored in the complex.

UCOR is the DOE ORR cleanup contractor. The scope of UCOR activities at ORNL includes long-term surveillance, maintenance, and management of inactive waste disposal sites, structures, and buildings such as former reactors and isotope production facilities. Other UCOR activities include groundwater monitoring, transuranic waste storage, and operation of the liquid low-level and process waste systems and the off-gas collection and treatment system.

Figure 1.6. Aerial view of the Oak Ridge National Laboratory

1.4.2 Y-12 National Security Complex

The Y-12 Complex (shown in Figure 1.7) was originally constructed as part of the World War II Manhattan Project and began operations in November 1943. The first site mission was the separation of uranium-235 from natural uranium by an electromagnetic separation process. At its peak in 1945, more than 22,000 workers were employed at the Y-12 site.

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

Outfall 200 Mercury Treatment Facility

In December 2017, UCOR (the cleanup contractor for ORR) issued the *Construction Execution/ Management Plan, Outfall 200 Mercury Treatment Facility at the Y-12 Nuclear Security Complex, Oak Ridge, Tennessee* (UCOR 2017). The goal of the Mercury Treatment Facility is to reduce the mercury concentration in water exiting the Y-12 Complex. The west end Y-12 storm drain system discharges to Upper East Fork Poplar Creek at Outfall 200, and mercury from historic operations is present at Outfall 200 where storm water enters Poplar Creek.

Three lines of investigation were developed for East Fork Poplar Creek: to examine potential downstream sources such as bank soil and sediment control, to study the ecology and investigate how differences in food chain processes may influence the uptake of mercury in fish, and to investigate the water chemistry and flow characteristics of the creek and their influence. In support of mercury cleanup efforts, research and technology development activities focused on the major factors influencing the accumulation of mercury in fish, which are the major route of both human and wildlife exposure. The *Mercury Remediation Technology Development for Lower East Fork Poplar Creek−2017 Progress Report* (ORNL 2018) provided details of each study area and findings.

Figure 1.7. Aerial view of the Y-12 National Security Complex

Construction of the Mercury Treatment Facility at Outfall 200 continued in 2019. OREM completed early site preparation activities, which included constructing utilities necessary for the treatment facility, installing secant pile walls near East Fork Poplar Creek, and relocating and demolishing existing infrastructure and structures to prepare the site.

The Mercury Treatment Facility is designed to treat up to 3,000 gallons of storm water per minute. It includes a 2-million-gallon storage tank to collect storm water during peak flow conditions of up to 40,000 gallons per minute. The stored water can then be treated after storm flow subsides. Captured storm water will be piped to a treatment facility located on an available site east of Outfall 200. Mercury treatment will be accomplished using chemical precipitation, clarification, and media filtration. Treated water will be discharged back into Upper East Fork Poplar Creek.

At the end of FY 2019, the Y-12 Complex had achieved seven of nine established environmental targets, and the remaining targets were carried into future years. Highlights include the following; further details and additional successes are presented in other sections of this report.

- **Clean Air:** The Y-12 Complex finalized modification of the Title V air permit to include the calciner operations.

- **Energy Efficiency:** Y-12 completed a project to replace the Building 9117 computer room air conditioner.
- **Hazardous Materials:** A project to disposition and ship legacy mixed waste per Site Treatment Plan milestones was completed in 2019, and FY 2019 priorities for unneeded materials and chemicals were completed to disposition unneeded production equipment in Building 9201-5N. Asbestos abatement and material removal in the Biology Complex also began in 2019.
- **Land, Water, and Natural Resources:** Reroofing projects for seven buildings were completed to reduce risks to storm and surface water. In addition, Phase 1 of a project to improve protection of the sanitary sewer drainage system from infill and infiltration was completed. Smoke testing and camera inspection of four lateral lines around Alpha-3 was completed to determine what future improvements are required.
- **Mercury Removal:** More than 4.6 tons of mercury have been removed from column exchange equipment at Alpha-4, and 22 tanks were characterized for disposal.

In FY 2019, the Y-12 Complex implemented 97 pollution prevention initiatives resulting in a reduction of more than 68.6 million lb of waste and projected cost efficiencies of more than $19.6 million. Also in 2019, the Y-12 Complex diverted 52.7 percent (2.6 million lb) of municipal and 38.6 percent (65.5 million lb) of construction and demolition waste from landfill disposal through reuse and recycling. Also in FY 2019, more than 1,000 lb of waste generation prevention was realized by transferring materials for on-site reuse, and more than 3.29 million lb of materials were diverted from landfills into viable recycle processes.

The Y-12 Complex has achieved a 47 percent reduction in energy intensity as of FY 2019. Specific initiatives that helped reduce energy consumption at the Y-12 Complex include the following:

- Completing a new, more-efficient Air Compressor Plant at the end of FY 2016
- Upgrading light fixtures with T-8 fluorescent lighting and light-emitting diodes
- Replacing steam with natural gas
- Upgrading chillers with new high-efficiency variable speed modes; retrofitting existing chillers with efficient controls; replacing constant-speed chilled water pumps with a variable-speed type; and replacing tower pumps, steam controls, and control valves
- Replacing cooling towers

Sustainability goals and performance status for the Y-12 Complex are listed in Chapter 4, Table 4.1.

1.4.3 East Tennessee Technology Park

ETTP (see Figure 1.8), originally named K-25, is the site of the nation's first gaseous diffusion uranium enrichment plant. It was established as part of the World War II Manhattan Project. Additional uranium enrichment facilities K-29, K-31, and K-33 were built adjacent to K-25 during the Cold War, and these facilities formed a complex officially known as the Oak Ridge Gaseous Diffusion Plant. Uranium enrichment operations at the site ceased in 1986, and restoration and decontamination and decommissioning activities began soon after in preparation for ultimate conversion of the site to a private sector industrial park, to be called the Heritage Center. Reindustrialization of the site began in 1996, when it was renamed the East Tennessee Technology Park. Today restoration of the environment, decontamination and decommissioning of facilities, disposition of wastes, and reindustrialization are the major activities at the site.

Figure 1.8. Aerial view of East Tennessee Technology Park

In 2019, ETTP landlord contractor functions and the majority of the ETTP cleanup program actions were managed by UCOR. Decontamination and demolition of K-1423 was completed on October 30, 2019. Samples collected during rainfall events at demolition sites did not exhibit any screening level exceedances. Based on total greenhouse gas emissions from all ETTP stationary sources during 2019, the threshold limit was not exceeded. Greenhouse gas emissions totaled 50 metric tons of carbon dioxide, which is 0.2 percent of the yearly threshold for reporting.

In 2017, a proposed plan to build an airport on the ETTP site reached a major milestone with the completion of a master plan, which was submitted to the Federal Aviation Administration for approval. Metropolitan Knoxville Airport Authority is leading the project. The Federal Aviation Administration granted conditional approval of the airport layout plan in 2019, and the Metropolitan Knoxville Airport Authority is proceeding with final design work. The airport would serve primarily corporate planes such as the Beechcraft King Air 350, Cessna 500, and Cirrus SF-50 Vision Jet.

1.4.4 Environmental Management Waste Management Facility

The EMWMF (shown in Figure 1.9) is located in eastern Bear Creek Valley near the Y-12 Complex and is managed by UCOR. EMWMF was built for the disposal of waste resulting from Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) cleanup actions on ORR. The original design was for the construction, operation, and closure of a projected 1.3 million cubic meter (1.7 million cubic yard) disposal facility. The approved capacity was subsequently increased to 1.8 million cubic meters (2.4 million cubic yards) to maximize use of the footprint designated in a 1999 record of decision. The facility currently consists of six disposal cells.

Figure 1.9. Aerial view of the Environmental Management Waste Management Facility

EMWMF is an engineered landfill that accepts low-level, mixed low-level, and hazardous wastes from CERCLA cleanup activities on ORR that meet specific waste acceptance criteria developed in accordance with agreements with state and federal regulators. Waste types that qualify for disposal include soil, dried sludge and sediment, solidified waste, stabilized waste, building debris, scrap equipment, and secondary waste such as personal protective equipment, all of which must meet land disposal restrictions. In addition to the solid waste disposal facility, EMWMF operates a leachate collection system. In FY 2019 the facility collected, analyzed, and disposed of approximately 4.5 million gallons of leachate. The leachate is treated at the ORNL Liquids and Gaseous Treatment Facility, which is also operated by UCOR. ORR landfills disposed of 123,376 cubic yards of waste during 2019.

During FY 2019 the EMWMF received 10,555 waste shipments, accounting for 75,074 tons, from cleanup projects at ETTP, ORNL, and Y-12. EMWMF will reach its capacity before OREM completes its cleanup at Y-12 and ORNL. Planning continued throughout FY 2019 for a new facility, the Environmental Management Disposal Facility, which will provide the additional disposal capacity needed to complete the cleanup at Oak Ridge.

1.4.5 Oak Ridge Environmental Research Park

DOE established the Oak Ridge Environmental Research Park (see Figure 1.10) in 1980. Managed for DOE by UT-Battelle, LLC, the research park serves as an outdoor laboratory to evaluate the environmental consequences of energy use and development and strategies to mitigate those effects. Its large blocks of forest and diverse communities of vegetation offer unparalleled resources for ecosystem-level and large-scale research. Major national and international collaborative research initiatives use it to address issues such as multiple stress interactions, biodiversity, sustainable development, tropospheric air quality, global climate change, innovative power conductors, solar radiation monitoring, ecological recovery, and monitoring and remediation.

Field sites at the research park provide maintenance and support facilities that permit sophisticated and well-instrumented environmental experiments. These facilities include elaborate monitoring systems that enable users to precisely and accurately measure environmental factors for extended periods. Because the park is under the jurisdiction of the federal government, public access is restricted and experimental sites and associated equipment are therefore not disturbed.

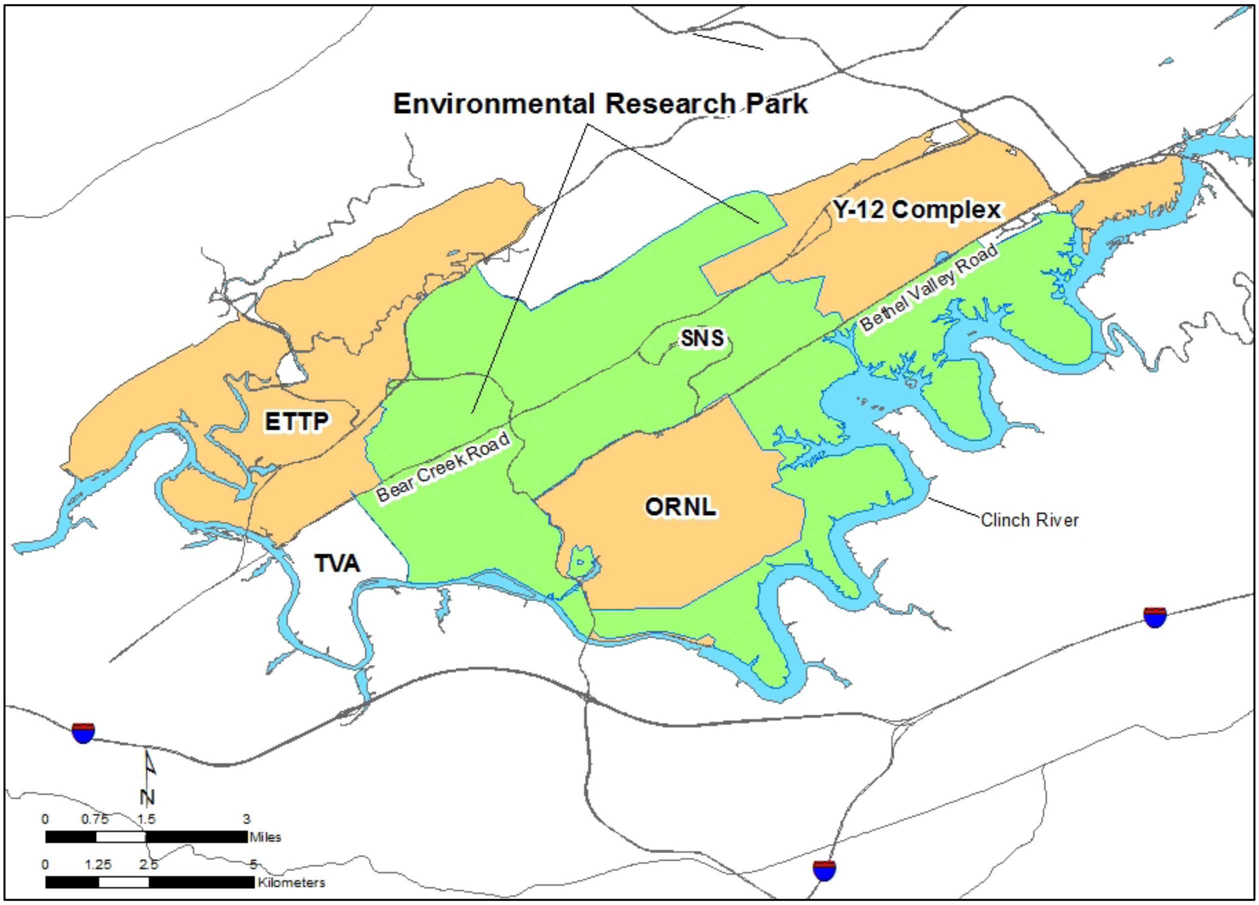

Figure 1.10. Location of the Oak Ridge Environmental Research Park

National recognition of the research park's value has led to its use in both regional- and continental-scale research projects. Research park sites offer opportunities for aquatic and terrestrial ecosystem analyses of topics such as biogeochemical cycling of pollutants resulting from energy production, landscape alterations, ecosystem restoration, wetland mitigation, and forest and wildlife management.

1.4.6 Oak Ridge Institute for Science and Education

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

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

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

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

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

1.4.8 Transuranic Waste Processing Center

TWPC is located on an approximately 10.5-hectare (26-acre) tract of land in the Melton Valley area of ORNL about 120 feet west of the existing Melton Valley Storage Tanks. North Wind Solutions, LLC manages TWPC for DOE. TWPC's mission is to receive transuranic waste for processing, treatment, repackaging, and shipment to DOE's Waste Isolation Pilot Plant near Carlsbad, New Mexico.

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

Key progress for the project during FY 2019 included the following actions:

- In 2019, 85 shipments containing 2,739 drums of contact-handled transuranic waste were sent to the Waste Isolation Pilot Plant.
- Construction permit 974744 was issued November 19, 2018 to implement proposed modifications to the Title V operating permit, and significant modification No. 1 to the Title V operating permit, incorporating the proposed modifications, was issued on April 15, 2019.
- Design work continued on the Sludge Mobilization System and the Slurry Mixing and Characterization Tank.
- Testing of the mobilization measurement instrumentation was initiated.

- Sludge Processing Facility Build-out technical basis documents were updated, including the safety design strategy, integrated system test plan, waste certification strategy, flowsheet and material balance, and revised simulant strategy.
- A contract change proposal for extending utilities to the Sludge Test Area site was submitted to DOE for review and approval. The Sludge Test Area construction subcontractor submitted a worker safety and health plan and construction waste management and disposal plans for approval; a draft memorandum of understanding with UCOR was sent for review; and site preparation began at the Sludge Test Area site in preparation for the concrete slab to be poured in 2020.
- Quarterly Safety Design Integration Team meetings were conducted.

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2. Compliance Summary and Community Involvement

DOE operations are compliance-driven activities. All activities conducted on ORR must conform to environmental standards established by federal and state statutes and regulations including Executive Orders, DOE Orders, contract-based standards, and compliance and settlement agreements. The US Environmental Protection Agency (EPA) and the Tennessee Department of Environment and Conservation (TDEC) are the principal regulating agencies that issue permits, review compliance reports, participate in joint monitoring programs, inspect facilities and operations, oversee compliance with applicable regulations, and issue a notice of violation when appropriate.

Environmental concerns or problems identified during routine operations or during ongoing self-assessments of compliance status require reporting or discussions with the respective regulatory agencies. The following sections summarize the major environmental statutes and their 2019 status for DOE operations on ORR. Note that the DOE Reindustrialization Program has leased several facilities at ETTP and the Oak Ridge Science and Technology Park to private entities over the past several years. This report does not discuss the compliance status of these lessee operations.

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

2.1 Laws and Regulations

Table 2.1, which begins on the following page, is a summary of the principal environmental standards applicable to DOE activities on ORR, their 2019 status, and the sections in this report that provide more detailed information.

2.2 External Oversight and Assessments

Table 2.2 (see page 2-7) lists the inspections of ORR environmental activities conducted by regulatory agencies for each of the ORR sites (ORNL, ETTP, and Y-12) during 2019. This table does not include internal DOE or DOE contractor assessments, audits, or evaluations.

Table 2.1. Applicable environmental laws and regulations and 2019 status

Regulatory program description	2019 status	Report sections
The Clean Air Act and corollary State of Tennessee requirements regulate the release of air pollutants through permits and air quality limits. Emissions of airborne radionuclides are regulated by EPA via National Emission Standards for Hazardous Air Pollutants for radionuclides authorization. Greenhouse gas emissions inventory tracking and reporting are regulated by EPA and by DOE internal oversight.	In 2019 all activities on ORR were conducted in accordance with Clean Air Act requirements.	3.3.3 4.3.3 5.3.3
The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) provides a regulatory framework for remediation of the release or threat of release of hazardous substances from past practices on ORR.	ORR was placed on the EPA National Priorities List in 1989. The ORR Federal Facility Agreement, initiated in 1992 between EPA, TDEC, and DOE, established the framework and schedule for developing, implementing, and monitoring remedial actions on ORR. The on-site CERCLA Environmental Management Waste Management Facility (EMWMF) is operated by UCOR for DOE. Located in Bear Creek Valley, EMWMF is used for disposal of waste resulting from CERCLA cleanup actions on ORR. EMWMF is an engineered landfill that accepts low-level radioactive, hazardous, asbestos, and polychlorinated biphenyl (PCB) wastes (and combinations of these wastes) in accordance with specific waste acceptance criteria under an agreement with state and federal regulators. No notices of violations were issued for CERCLA-related ORR actions during 2019.	3.3.8 4.3.7 5.3.8 3.3.10
The Clean Water Act seeks to protect and improve surface water quality by establishing surface water standards enabled by a system of permits. Wastewater discharges are regulated by National Pollutant Discharge Elimination System (NPDES) permits issued by TDEC.	Discharges to surface water at each of the three major ORR sites are governed by NPDES permits. In 2019, ETTP and Y-12 achieved a compliance rate of 100% and the ORNL NPDES permit limit compliance rate for all discharge points was greater than 99%. ETTP and Y-12 had no permit noncompliances; At ORNL there was one concentration and one loading effluent exceedance and two nonnumeric permit noncompliances. See Appendix D for more information.	3.3.4 4.3.4 5.3.4
The Energy Independence and Security Act (EISA) § 438 establishes requirements for federal agencies to reduce storm water runoff from development projects to protect water resources.	A variety of storm water management techniques, referred to as green infrastructure or low impact design practices, have been implemented on ORR to comply with EISA. The site sustainability plans and associated reporting provide data on sustainability projects and support EISA Section 438 compliance.	4.2.6.4 5.2.1.5

Table 2.1. Applicable environmental laws and regulations and 2019 status (continued)

Regulatory program description	2019 status	Report sections
The Emergency Planning and Community Right-to-Know Act, also referred to as the Superfund Amendments and Reauthorization Act Title III, requires reporting emergency planning information, hazardous chemical inventories, and environmental releases of certain toxic chemicals to federal, state, and local authorities.	In 2019, DOE facilities on ORR were operated in accordance with emergency planning and reporting requirements. ETTP and Y-12 had no reportable releases of hazardous or extremely hazardous substances. ORNL had no releases of extremely hazardous substances but exceeded the reporting threshold and reported on the otherwise use of nitric acid and the manufacture of nitrate compounds, as defined by the Emergency Planning and Community Right-to-Know Act, in 2019.	3.3.11 4.3.9 5.3.10
The National Environmental Protection Act (NEPA) requires consideration of how federal actions may impact the environment and an examination of alternatives to the actions. NEPA also requires that decisions include public input and involvement through scoping and review of NEPA documents.	During 2019, DOE planning and decision-making activities at ETTP, Y-12, and ORNL were conducted via site-level procedures that provide requirements for project reviews and NEPA compliance. Over 50 environmental reviews were completed at Y-12 during 2019. Seven reviews were completed at ETTP in 2019. At ORNL, 87 NEPA reviews were completed during 2019.	3.3.2 4.3.2 5.3.2
The National Historic Preservation Act provides protection for the nation's historic resources by establishing a comprehensive national historic preservation policy.	ORR has several facilities eligible for inclusion in the National Register of Historic Places. Proposed activities are reviewed to determine potential adverse effects on these properties, and methods to avoid or minimize harm are identified. During 2019, activities on ORR were conducted in compliance with National Historic Preservation Act requirements.	3.3.2 4.3.2 5.3.2
ORR Protection of Wetlands Programs are implemented to minimize the destruction, loss, or degradation of ORR wetlands and to preserve and enhance their beneficial value.	Surveys to determine the presence of wetlands are conducted as needed for projects or programs through NEPA and other reviews to facilitate compliance with TDEC and US Army Corps of Engineers wetlands protection requirements. Wetland protection on ORR is conducted in accordance with 10 *Code of Federal Regulations* 1022 and Executive Order (EO) 11990, *Protection of Wetlands*. No new wetlands delineations were made at ETTP, Y-12, or ORNL in 2019. The monitoring conducted at Y-12 in 2019 marked the end of wetland monitoring for the Upper Bear Creek Remediation wetlands.	1.3.6.1 4.5.8.4 5.3.12
The Resource Conservation and Recovery Act (RCRA) governs the generation, storage, handling, and disposal of hazardous wastes. RCRA also regulates underground storage tanks containing petroleum and hazardous substances, universal waste, and recyclable used oil.	Y-12, ORNL, and ETTP are defined as large-quantity generators of hazardous waste because each generates more than 1,000 kg of hazardous waste per month. Each site is also regulated as a handler of universal waste. In addition, several permits have been issued for hazardous waste management units on ORR. No notices of violation were issued for ETTP or Y-12 in 2019. At ORNL, two violations were identified and both violations were corrected when identified, returning the facility to compliance.	3.3.7 4.3.6 5.3.6

Table 2.1. Applicable environmental laws and regulations and 2019 status (continued)

Regulatory program description	2019 status	Report sections
The Safe Drinking Water Act establishes minimum drinking water standards and monitoring requirements.	The City of Oak Ridge supplies potable water to the facilities on ORR and is responsible for meeting all regulatory requirements for drinking water. Sampling results in 2019 for residual chlorine levels, bacterial constituents, and disinfectant by-products in ORR's water system were all within acceptable limits.	3.3.8 4.3.5 5.3.5
The Toxic Substances Control Act regulates the manufacture, use, and distribution of a number of toxic chemicals.	PCB waste generation, transportation, disposal, and storage at ORR are regulated under EPA identification numbers TN1890090003 and TN0890090004. ETTP operated five PCB waste storage areas at ETTP in 2019. These five PCB storage areas were in RCRA-permitted facilities that meet the PCB regulations for long-term storage when PCB waste is being stored for longer than 30 days, which may be necessary for PCB radioactive waste. In 2019, UT-Battelle, LLC operated nine PCB storage areas and one PCB waste storage area was operated at a UT-Battelle, LLC facility in the Y-12 Complex. The ORR PCB Federal Facilities Compliance Agreement between EPA and DOE continues to provide a mechanism to address legacy PCB-use issues across ORR. The agreement specifically addresses the unauthorized use of PCBs, storage and disposal of PCB waste, PCB spill cleanup and decontamination, PCBs mixed with radioactive materials, PCB research and development, and ORR records and reporting requirements. EPA is updated annually on the status of DOE actions regarding management and disposition of legacy PCBs covered by the ORR PCB Federal Facilities Compliance Agreement.	3.3.12 4.3.8 5.3.9
The Bald and Golden Eagle Protection Act (16 US Code 668-668d) protects bald and golden eagles by prohibiting, except under certain specified conditions, the taking or possession of and commerce in such birds. The act imposes criminal and civil penalties for any such actions.	Bald eagles are known to frequent ORR year-round. The one active bald eagle nest on ORR is protected in accordance with this act. Eaglets have been successfully fledged from a Poplar Creek nesting location in the past.	1.3.6.2
The Endangered Species Act prohibits activities that would jeopardize the continued existence of an endangered or threatened species or cause adverse modification to a critical habitat.	ORR is host to several plant and animal species categorized as endangered, threatened, or of special concern, and these species are protected in accordance with this act.	1.3.6.2
The Migratory Bird Treaty Act protects migratory birds by governing the taking, killing, possession, transportation, and importation of such birds, including their eggs, parts, and nests and any product, manufactured or not, from such items.	ORR hosts numerous migratory birds that are protected under this act.	1.3.6.2

Table 2.1. Applicable environmental laws and regulations and 2019 status (continued)

Regulatory program description	2019 status	Report sections
DOE Order 231.1B, *Environment, Safety, and Health Reporting,* ensures timely collection, reporting, analysis, and dissemination of information on environment, safety, and health issues.	The *2019 Oak Ridge Reservation Annual Site Environmental Report* summarizes ORR environmental activities during 2019 and characterizes environmental performance.	All chapters
DOE Order 435.1, Change 1, ***Radioactive Waste Management,*** is implemented to ensure that all DOE radioactive waste is managed in a manner that protects workers, public health and safety, and the environment.	Waste certification programs that are protective of workers, the public, and the environment have been implemented for all activities on ORR to ensure compliance with this DOE Order.	3.8 4.8 5.8
DOE Order 436.1, *Department Sustainability,* provides requirements and responsibilities for managing sustainability within DOE to ensure the department carries out its missions in a sustainable manner that addresses national energy security and global environmental challenges and advances sustainable, efficient, and reliable energy for the future.	DOE contractors on ORR have developed site sustainability plans and have implemented environmental management systems that are incorporated with the contractors' integrated safety management systems to promote sound stewardship practices and ensure compliance with this DOE Order.	3.2 4.2 5.2
DOE Order 458.1, ***Radiation Protection of the Public and the Environment,*** issued in June 2011, canceled DOE Order 5400.5 and was established to protect members of the public and the environment from undue risk from radiation. This order established standards and requirements for operations of DOE and DOE contractors.	In 2019, DOE Order 458.1 was the primary contractual obligation for radiation protection programs for UT-Battelle, LLC and Consolidated Nuclear Security LLC, and for all UCOR work scope areas where existing CERCLA decision documents do not specifically identify DOE Order 5400.5 requirements. A dose assessment was performed to ensure that the total dose to members of the public from all DOE ORR pathways did not exceed the 100 mrem annual limit established by this order. The assessment estimated the maximum 2019 dose to a hypothetically exposed member of the public from all ORR potential exposure pathways combined would be about 6.4 mrem. The 2019 maximum effective dose was about 6.4% of the 100 mrem annual limit given in DOE Order 458.1. Clearance of property from ORNL, ETTP, and the Y-12 Complex was conducted in accordance with approved procedures that comply with DOE Order 458.1. There were no unplanned radiological air emission releases from the three major ORR sites in 2019. No limits were exceeded in 2019.	4.3.13 5.3.13 3.2.6 Chapter 7 5.4.3.2 4.3.11

Table 2.1. Applicable environmental laws and regulations and 2019 status (continued)

Regulatory program description	2019 status	Report sections
DOE Order 5400.5, *Radiation Protection,* was established to protect members of the public and the environment against undue risk from radiation. This order established standards and requirements for operations of DOE and DOE contractors.	DOE Order 5400.5 is the primary environmental surveillance radiological applicable, relevant, and appropriate requirement for most CERCLA activities across ORR. It will remain in force until the individual CERCLA decision documents are reissued or revised to incorporate DOE Order 458.1. A dose assessment, performed to ensure the total dose to members of the public from all ORR pathways did not exceed the 100 mrem annual limit established by this order, estimated the maximum 2019 dose to a hypothetical exposed member of the public from all ORR potential exposure pathways combined would be about 6.4 mrem.	Chapter 7
Executive Order 13186, *Responsibilities of Federal Agencies to Protect Migratory Birds,* identifies the responsibilities of federal agencies to promote the conservation of migratory bird populations.	A memorandum of understanding entered into by DOE and the US Fish and Wildlife Service meets the requirements under Section 3 of EO 13186. ORR hosts numerous migratory birds that are present either seasonally or year-round. This memorandum, which was updated in September 2013, strengthens migratory bird conservation on ORR through enhanced collaboration between DOE and the US Fish and Wildlife Service.	1.3.6.2
Executive Order 13834, *Efficient Federal Operations*, directs federal agencies to manage their buildings, vehicles, and overall operations to optimize energy and environmental performance, reduce waste, and cut costs.	EO 13834, *Efficient Federal Operations*, superseded EO 13693. Progress toward meeting the requirements of the EO and achieving DOE sustainability goals is summarized in this report. ORNL, Y-12, and ETTP all have sustainability processes and management systems to comply with the EO and subsequent federal instructions for implementing the EO.	3.2.4 3.2.1 4.2.3.4 5.2.1.4

Acronyms:
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
DOE = US Department of Energy
EISA = Energy Independence and Security Act
EMWMF = Environmental Management Waste Management Facility
EO = Executive Order
EPA = US Environmental Protection Agency
ETTP = East Tennessee Technology Park
NEPA = National Environmental Protection Act
NPDES = National Pollutant Discharge Elimination System
ORNL = Oak Ridge National Laboratory
ORR = Oak Ridge Reservation
PCB = polychlorinated biphenyl
RCRA = Resource Conservation and Recovery Act
TDEC = Tennessee Department of Environment and Conservation
Y-12 or Y-12 Complex = Y-12 National Security Complex

Table 2.2. Summary of regulatory environmental evaluations, audits, inspections, and assessments conducted at Oak Ridge Reservation in 2019

Date	Reviewer	Subject	Issues
		Oak Ridge National Laboratory **(including UT-Battelle, LLC; UCOR; Isotek Systems, LLC; and North Wind Solutions, LLC activities)**	
January 8	TDEC	Notice of Termination for Construction Storm Water Permit Coverage	0
February 11-13	EPA/TDEC	Unannounced EPA/TDEC RCRA Inspection	2
February 26	City of Oak Ridge	Carbon Fiber Technology Facility (CFTF) Wastewater Inspection	
March 25	Knox County Department of Air Quality Management	National Transportation Research Center Clean Air Act Inspection	0
May 14	TDEC	NPDES Permit Inspection	0
August 22	TDEC	Underground Storage Tanks Compliance Inspection	1
September 27	City of Oak Ridge	CFTF Wastewater Inspection	0
October 24	TDEC	Annual Clean Air Act Inspection for ORNL and CFTF	0
		East Tennessee Technology Park	
January 17	City of Oak Ridge	Sewage Network Discharge Inspection	0
October 2	TDEC	Annual RCRA Compliance Inspection	0
December 5	TDEC	NPDES Storm Drain Inspection	0
December 10	TDEC	K-1065-B and -C Closure Inspection	0
		Y-12 National Security Complex	
January 24	City of Oak Ridge	Semiannual Industrial Pretreatment Compliance Inspection	0
March 5-6	TDEC	Annual RCRA Hazardous Waste Compliance Inspection (Y-12 National Security Complex)	0
April 3	TDEC	Annual Air Quality Compliance Inspection	0
May 21	TDEC	NPDES Compliance Evaluation Inspection	0
September 19	TDEC	RCRA Hazardous Waste Compliance Inspection (Union Valley)	0
October 2	City of Oak Ridge	Semiannual Industrial Pretreatment Compliance Inspection	0

Acronyms:
CFTF = Carbon Fiber Technology Facility
EPA = US Environmental Protection Agency
NPDES = National Pollutant Discharge Elimination System
ORNL = Oak Ridge National Laboratory
RCRA = Resource Conservation and Recovery Act
TDEC = Tennessee Department of Environment and Conservation

2.3 Reporting of Oak Ridge Reservation Spills and Releases

CERCLA hazardous substances are substances considered to be harmful to human health and the environment. Many are commonly used substances that are harmless in normal uses but can be dangerous when released. CERCLA establishes reportable quantities for hazardous substance releases. Any hazardous substance release exceeding a reportable quantity triggers reports to the National Response

Center, the State Emergency Response Center, and community coordinators. Discharges of oil must be reported if they "cause a film or sheen upon or discoloration of the surface of the water or adjoining shorelines or cause a sludge or emulsion to be deposited beneath the surface of the water or upon adjoining shorelines" (40 *Code of Federal Regulations* 110.3[b]).

Neither ETTP, Y-12, nor ORNL had any reportable releases of extremely hazardous substances, as defined by the Emergency Planning and Community Right-to-know Act, in 2019. See Sections 3.3.11, 4.3.11, and 5.3.10 of this report for more information.

2.4 Notices of Violations and Penalties

ETTP had no notices of environmental violations or penalties in 2019. Y-12 had no environmental permit violations or exceedances in 2019. ORNL had two violations of Tennessee's hazardous waste management regulations, an underground storage tank testing violation, and four NPDES permit noncompliances in 2019.

2.5 Community Involvement

DOE and its contractors provided or supported numerous community involvement activities in 2019 that addressed a range of subjects. These included ETTP historic interpretation efforts, Manhattan Project National Historical Park public meetings and public engagement efforts, Historic American Engineering Record activities, American Museum of Science and Energy community meetings hosted by the City of Oak Ridge, ETTP airport public meetings, public bus tours of ORR, public comment periods for draft environmental assessments, and Community Relations Council meetings.

During 2019, organizations such as Great Smoky Mountains National Park, the East Tennessee Foundation, and Girls, Inc., America Recycles Day and Earth Day activities, and many local charities benefited from DOE and its contractors' efforts in the community.

2.5.1 Public Comments Solicited

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

2.5.2 Oak Ridge Site Specific Advisory Board

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

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

2.5.3 DOE Information Center

The DOE Information Center, located at 1 Science.Gov Way, Oak Ridge, Tennessee, is a one-stop information facility that maintains a collection of more than 40,000 documents describing environmental activities in Oak Ridge. The center is open Monday through Friday from 8 a.m. to 5 p.m. An online catalog that can be used to search for DOE documents by author, title, date, and other fields is available at **https://www.energy.gov/orem/services/community-engagement/doe-information-center**.

2.5.3.1 Telephone Contacts

- Agency for Toxic Substances and Disease Registry: 1-800-232-4636
- DOE Information Center: 865-241-4780; toll free 1-800-382-6938 (option 6)
- DOE Public Affairs Office: 865-576-0885
- EPA Region 4: 1-800-241-1754
- ORSSAB: 865-241-4583, 865-241-4584, 1-800-382-6938 (option 4)
- TDEC, DOE Oversight Division: 865-481-0995

2.5.3.2 Internet Sites

- Agency for Toxic Substances and Disease Registry: **http://www.atsdr.cdc.gov**
- American Recovery and Reinvestment Act: **http://www.energy.gov/recovery-act**
- DOE Main Website: **http://www.energy.gov**
- DOE Information Center: **https://www.energy.gov/orem/services/community-engagement/doe-information-center**
- EPA Region 4: **http://www.epa.gov/region4**
- ETTP: **https://www.energy.gov/orem/cleanup-sites/east-tennessee-technology-park**
- ORNL: **https://www.ornl.gov/**
- ORSSAB: **http://www.energy.gov/ORSSAB**
- TDEC: **https://www.tn.gov/environment/program-areas/rem-remediation/rem-oak-ridge-reservation-clean-up.html**
- Y-12 National Security Complex: **http://www.y12.doe.gov/**

2.6 References

DOE 2019. *2019 Remediation Effectiveness Report for the U.S. Department of Energy Oak Ridge Reservation, Oak Ridge, Tennessee, Data and Evaluations*. DOE/OR/01-2787&D1. US Department of Energy, Oak Ridge, Tennessee, March.

UCOR 2018. *2018 Annual Report to the Oak Ridge Regional Community, Oak Ridge, Tennessee*, OREM-18-2555. UCOR, Oak Ridge, Tennessee.

3. East Tennessee Technology Park

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

EM and remediation operations consist of operations such as waste management, the cleanup of outdoor storage and disposal areas, the demolition and cleanup of facilities, land restoration, and environmental monitoring. Proper disposal of huge quantities of waste that were generated over the course of production operations is also a major task. Beginning in the 1990s, reindustrialization (the conversion of underused government facilities for use by the private sector) also became a major mission at ETTP. Reindustrialization allows private industry to lease and purchase underused land and facilities, thus providing both jobs and a new use for facilities that otherwise would have to be demolished. State and federally mandated effluent monitoring and environmental surveillance at ETTP involve the collection and analysis of samples of air, water, soil, sediment, and biota from ETTP and the surrounding area. Monitoring results are used to assess exposures to members of the public and the environment, to evaluate the performance of treatment systems, to help identify areas of concern, to plan remediation efforts, and to evaluate the efficacy of remediation efforts. In 2019, there was 100 percent compliance with permit standards for emissions/discharges from ETTP operations.

On November 10, 2015, DOE and the US Department of Interior (DOI) signed a memorandum of agreement (MOA) establishing the Manhattan Project National Historical Park (MPNHP). The MOA defines the respective roles and responsibilities of the departments in administering the park and includes provisions for enhanced public access, management, interpretation, and historic preservation. A portion of ETTP (the K-25 Gaseous Diffusion Building footprint) is included within the MPNHP. As part of the activities to establish the park, DOE released the K-25 Virtual Museum, which is a website that details the history of the K-25 Gaseous Diffusion Plant through narrative and photographs, and can be found **here**.

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

3.1 Description of Site and Operations

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

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

Figure 3.1. East Tennessee Technology Park

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

Figure 3.3 shows the ETTP areas designated for D&D activities through 2019. The ETTP mission is to reindustrialize and reuse site assets through leasing and/or transferring excess or underused land and facilities and through incorporating commercial industrial organizations as partners in the ongoing environmental restoration, D&D, and waste treatment and disposal.

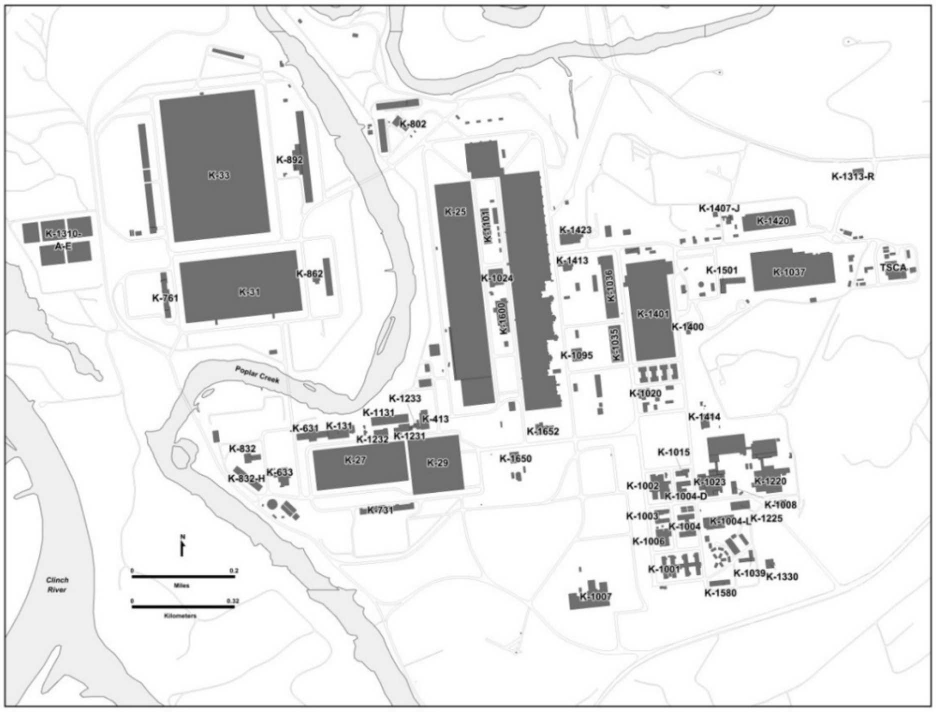


Figure 3.2. East Tennessee Technology Park before the start of decontamination and decommissioning activities in 1991

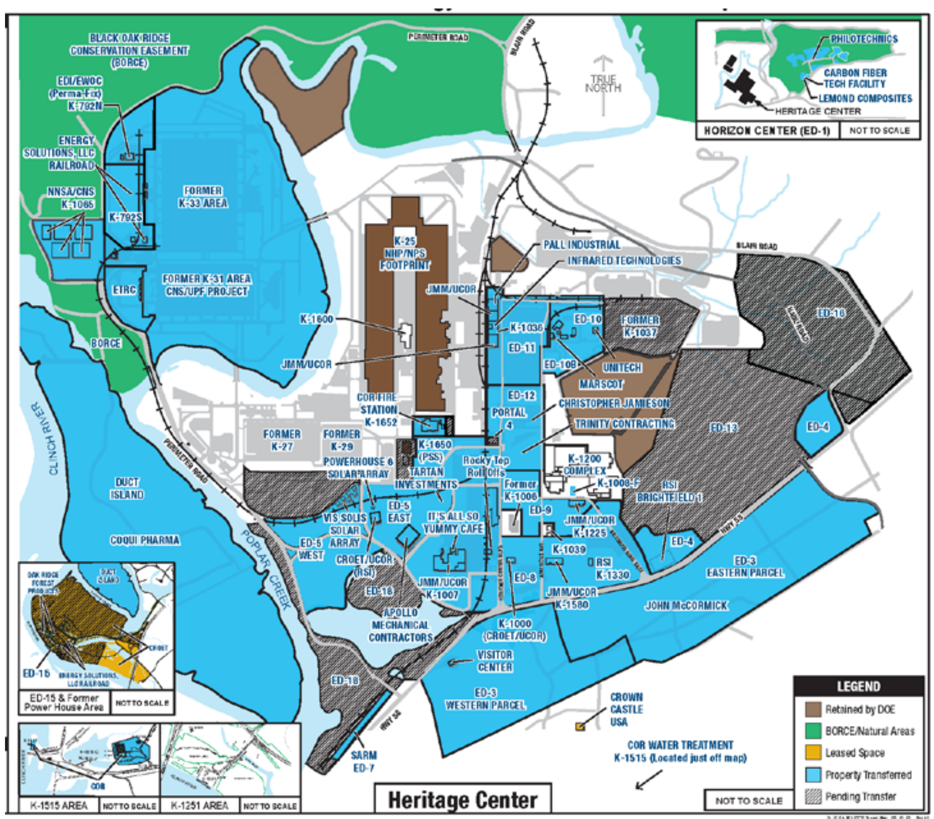


Figure 3.3. East Tennessee Technology Park in 2020, showing progress in reindustrialization

The site is undergoing environmental cleanup of its land, as well as D&D of most of its buildings. The cleanup approach makes land and various types of buildings (e.g., office, manufacturing) suitable for private industrial use and for title transfer to the Community Reuse Organization of East Tennessee (CROET) or other entities such as the City of Oak Ridge (COR). The long-term DOE goal for ETTP is to transfer as much of the site property as practicable out of DOE ownership and into CROET's control for the development of a commercial business and industrial park. The facilities may then be subleased or sold, with the goal of stimulating private industry and recruiting business to the area. These transfers also reduce maintenance costs for DOE, which frees up additional money for environmental cleanup. The reuse of key facilities through title transfer is part of the site's closure plan.

UCOR, an Amentum-led partnership with Jacobs, the lead environmental management contractor for ETTP, supports DOE in the reindustrialization program as part of the continuing effort to transform ETTP into a private-sector industrial park. Unless otherwise noted, information on non-DOE entities located on the ETTP site is not provided in this document.

3.2 Environmental Management System

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

- **Leadership Commitment**—Integrate responsible environmental practices into project operations.
- **Environmental Compliance and Protection (EC&P)**—Comply with all environmental regulations and standards.
- **Sustainable Environmental Stewardship**—Minimize the effects of our operations on the environment through a combination of source reduction, recycling, and reuse; sound waste management practices; and pollution prevention (P2).
- **Partnership/Stakeholder Involvement**—Maintain partnerships through effective two-way communications with our customers and other stakeholders.

3.2.1 Sustainable Environmental Stewardship

UCOR incorporates environmental sustainability principles, the procurement of environmentally preferable products, recycling, and P2 and waste minimization practices in its work processes and activities. As an example, Figure 3.4 presents a selection of information on UCOR's 2019 P2 recycling activities related to solid waste reduction at ETTP. UCOR recycles much of its universal waste, municipal solid waste and scrap metal, reuses large amounts of construction and demolition debris, and encourages the reduction of waste wherever possible.

UCOR's exceptional electronics stewardship earned it an award in 2019 from the Green Electronics Council (GEC) for its use of Electronic Product Environmental Assessment Tool (EPEAT) methods. A list of the awards given to UCOR for electronics stewardship and sustainability practices in 2019 are:

- The Green Electronics Council awarded UCOR four stars for purchasing 100-percent EPEAT-registered information technology products, which included displays, monitors, computers, laptops, and servers.
- The US Environmental Protection Agency's (EPA) Federal Green Challenge Award for recycling 16.2 tons of electronic equipment with a third-party recycler, which highlights UCOR's leadership in reducing the federal government's environmental impact.
- The Tennessee Recycling Coalition recognized UCOR for finding innovative ways to reuse materials that would otherwise be disposed of in a landfill. The award came with a $1,500 prize, which was donated to the Michael Dunn Center, a vocational rehabilitation agency that provides, in part, litter control and recycling services in East Tennessee.

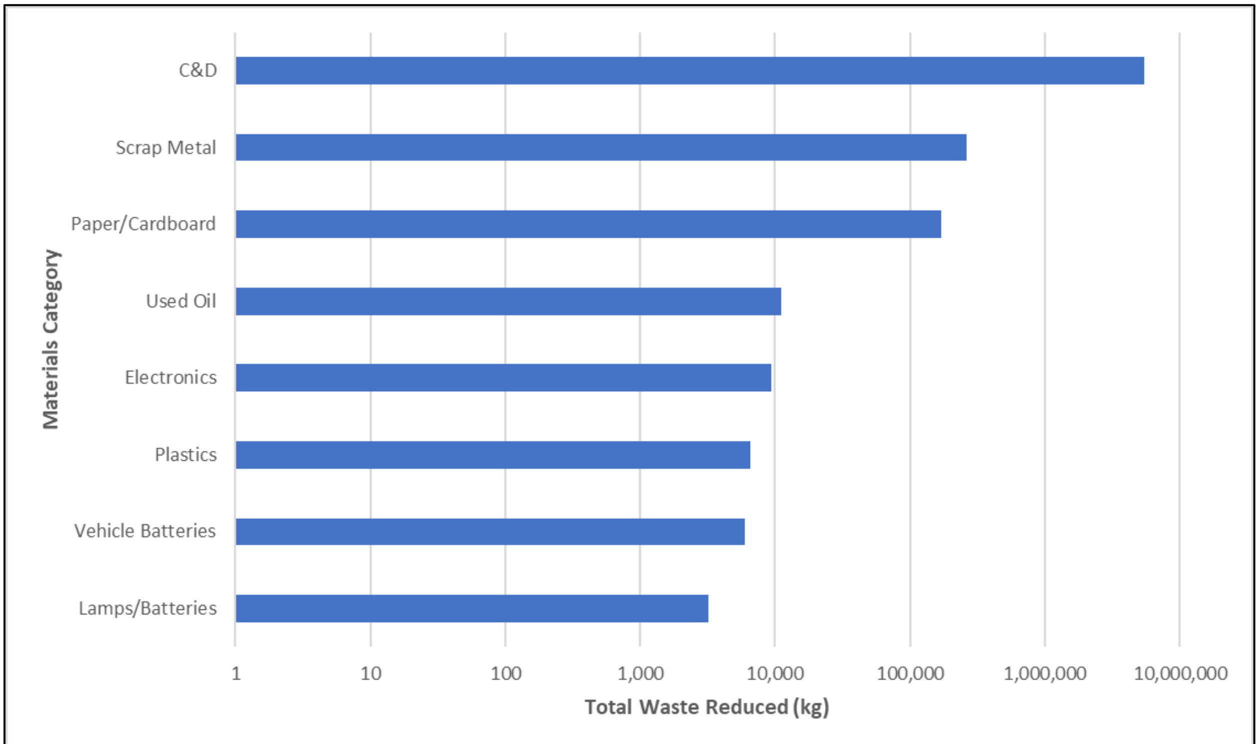


Figure 3.4. Pollution prevention recycling activities related to solid waste reduction at the East Tennessee Technology Park in Calendar Year 2019

Additionally, UCOR internally recognized five projects for their P2/waste minimization (P2/WMin) accomplishments in 2019, which are summarized below.

- The Oak Ridge National Laboratory Operations and Cleanup Enterprise Installed Process Instrumentation Team was recognized for developing a method to reduce the amount of required instrument calibrations and consolidating the remaining calibrations, conserving resources, and saving $20,000–$25,000 per year.
- The Oak Ridge National Laboratory Operations and Cleanup Enterprise project was recognized for identifying and implementing an innovative approach to accomplish the recycling of ten metal and concrete salt casks rather than disposing of them in a landfill. This resulted in a cost savings of $40,000 and conservation of 1,640 ft^3 of valuable landfill space.

- The General Plant and Capital Projects was recognized for implementing a design change that safely reduced the amount of materials used in dewatering boxes during the Zeolite Upgrade Project. This resulted in $36,000 cost savings and saved future landfill space.
- The Oak Ridge Reservation Landfill (ORRLF) Project was recognized for identifying an opportunity to divert uncontaminated soil from disposal at the landfill and reuse it as landfill cover material, saving $58,160, reducing greenhouse gases, and saving 1,950 yd^3 of limited landfill space.
- The ORRLF Project was recognized for identifying materials from ORRLF Sediment Pond 3 upgrades for reuse at Landfill V, which resulted in the conservation of resources, a cost saving of $21,500, and 750 yd^3 of landfill space saved.

Together, the projects represented sustainability accomplishments in resource conservation, waste diversion, waste reduction, and P2. These accomplishments were the result of teamwork, leveraging a number of work control and management tools to save landfill space, reduce the use of virgin material, mitigate hazards to the environment and workers, and increase work efficiencies. In addition to lessening the impact on the environment, P2 measures may also save money. In 2019, an estimated total in excess of $180,000 with an additional savings of $20,000–$25,000 per year was saved as a result of implementation of P2 measures by the projects.

In 2016, a significant improvement in the diversion of scrap metal was made, by petitioning and receiving agreement from EPA and the Tennessee Department of Environment and Conservation (TDEC) to apply an unprecedented Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) screening process that allows noncontaminated scrap metal from CERCLA areas, previously excluded from commercial recycling services, to be safely shipped to commercial scrap-metal dealers for recycle. Effectively, the screening process removes the noncontaminated scrap metal from regulation under CERCLA; therefore, any non-CERCLA commercial scrap-metal recyclers can receive the material for recycle. This agreement continues to be successfully employed, allowing approximately 47,220 lb. (21.42 MT) of scrap metal to be recycled in fiscal year (FY) 2019 in lieu of land disposal and provides a path forward for additional waste diversion for the duration of the contract.

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

- Provides funds from the recycling payments that are available to go back into the programs and support further actions in the Oak Ridge cleanup program.
- Conserves valuable landfill space. To date, the scrap metal recycled as a result of the screening process has saved approximately 260 yd^3 of valuable landfill space, which translates into a considerable cost savings, which takes into consideration capital cost, landfill capacity, historical operating costs, packing, and transportation.
- Supports EPA, TDEC, and DOE programmatic environmental stewardship goals for waste diversion.

The CERCLA screening process will continue to be used as more demolition and cleanup are continued at ETTP, Oak Ridge National Laboratory (ORNL), and the Y-12 National Security Complex (Y-12).

In the area of alternative energy, Restoration Services, Inc. (RSI), in concert with UCOR, continued operations of ETTP's solar parks (Figure 3.5). Brightfield 1 is a 200-kW solar array located on a 0.405-ha (1-acre) tract purchased from CROET and built by RSI as part of UCOR's commitment to the revitalization of the former K-25 Site.

RSI self-financed the project using solar panels manufactured in Tennessee and partnering with other local small businesses for the installation. Power generated from Brightfield 1 is being sold to the Tennessee Valley Authority (TVA) through the City of Oak Ridge Electric Department using a TVA Generation Partners contract. The completed project was commissioned in April 2012 and is part of RSI's Brownfields to Brightfields initiative that works to develop restricted-use properties into solar farms. Brightfield 1 energy production in its first year was 110 percent more than projected, with no downtime due to maintenance issues. In calendar year (CY) 2019, Brightfield 1 produced 235,000 kWh of energy. During December 2019, Brightfield 1 had a single downtime due to maintenance activities, with the seasonal timing resulting in only a negligible increase in the use of conventionally supplied power.

Figure 3.5. Oak Ridge Solar Park

In addition, through the cooperative efforts of DOE, UCOR, RSI, Vis Solis, Inc., CROET, and COR, a second solar farm—the Powerhouse 6 Solar Farm—was constructed on the west end of the park. It is a 1-MW solar farm that became operational in April 2015 and provides renewable energy, long-term lease income to CROET and bolsters development at ETTP. This project continues to provide numerous benefits to the environment and the community at large, which include the following:

- Generates enough clean energy to power more than 100 homes.
- Prevents pollution by removing the equivalent of 240 cars from the road annually (1,141 MT of CO_2).
- Provides brownfield reuse/redevelopment at ETTP.

- Supports COR renewable energy goals.
- Supports TVA renewable energy initiatives.
- Offers community economic development jobs and property tax income to COR.
- Demonstrates benefits of ETTP reindustrialization.
- Supports DOE renewable energy goals.
- Demonstrates collaborative success between DOE and a public utility for renewable energy development.

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

UCOR is one of the DOE contractors having responsibilities for land management of portions of the Oak Ridge Reservation (ORR). The Natural Resources Management Team for ORR, centered at ORNL, is partially funded by UCOR, and is responsible for the creation and implementation of an Invasive Plant Management Plan. At ETTP, these efforts have included:

- Exposure Unit (EU)-29 demonstration field invasive plant control
- Powerhouse Trail privet control
- Wheat Church Vista invasive plant control
- Black Oak Ridge Conservation Easement kudzu and invasive plant control
- Black Oak Ridge Conservation Easement greenway and trail invasive plant control

For additional information, please see Chapter 6.

3.2.2 Environmental Compliance

UCOR maintains various layers of oversight to ensure compliance with legal and other requirements. The methods of evaluation include independent assessments by outside parties, management and self-assessments conducted by functional or project organizations, and routine field walkdowns conducted by a variety of functional and project personnel. Management, self, and independent assessments are prioritized and scheduled based on risk management principles and performed in accordance with procedures. Records are maintained for all formal assessments and audits. Issues identified in assessments are handled, as required, by ISO 14001:2004, Section 4.5.3, "Nonconformity, Corrective Action, and Preventive Action" (ISO 2004). For additional information see Section 3.4.1.

3.2.3 Environmental Aspects/Impacts

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

3.2.4 Environmental Performance Objectives and Targets

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

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

- Comply with all environmental regulations, permits, and regulatory agreements.
- Reduce or eliminate the acquisition, use, storage, generation, and/or release of toxic, hazardous, and radioactive materials; waste; and greenhouse gas emissions through acquisition of environmentally preferable products, conduct of operations, waste shipment, and P2/WMin and sustainable practices.
- Reduce degradation and depletion of environmental resources and potential impact on climate change through post-consumer material recycling, energy, fuel, and water conservation efforts, use or promotion of renewable energy, and transfer for reuse valuable real estate assets.
- Reduce the environmental impact on surface water and groundwater resources.
- Reduce the environmental impact associated with project and facility activities.

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

The Office of Management and Budget's Environmental Stewardship Scorecard is used to track and measure site-level EMS performance. During FY 2019, UCOR received a "green" for EMS performance, indicating full implementation of EMS requirements.

3.2.5 Implementation and Operation

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

3.2.6 Pollution Prevention/Waste Minimization/Release of Property

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

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

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

Materials and equipment that are to be recycled or reused may follow one of two paths. If process knowledge is sufficient to establish that the materials and equipment have never been in contaminated areas (for example, empty beverage cans from a specified break area or an office building) then the materials may be released for recycling or reuse. Materials and equipment from areas that have, or in the past have had, radiologic areas must be examined by trained radiologic control technicians and the results documented before the materials and equipment may be released. Materials and equipment that fail to meet the free release criteria are either decontaminated to the point that they meet the free release criteria, or are properly disposed of at an appropriate disposal facility. The release of property from radiologic areas is governed by procedure PROC-RP-4516, *Radioactive contamination Control and Monitoring* (Table 3.1). Figure 3.4 shows a summary of the types and quantities of recycled materials and equipment. Additionally, 80,443 kg of office furniture, office supplies, electronics, electrical equipment, and building materials were released to the public through property sales.

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

Radionuclide	Removable	Total (Fixed + Removable)
Natural Uranium, ^{235}U, ^{238}U, and associated decay products	1,000	5,000
Transuranics, ^{226}Ra,^{228}Ra,^{230}Th,^{228}Th,^{231}Pa,^{227}Ac,^{125}I,^{129}I	20	100/500
Natural Th, ^{232}Th,^{90}Sr,^{223}Ra,^{224}Ra,^{232}U,^{126}I,^{131}I,^{133}I	200	1,000
Beta-gamma emitters except ^{90}Sr and others noted above	1,000	5,000
Tritium and Special Tritium Compounds	10,000	

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

Real property to be transferred must meet the release criteria established by DOE O 458.1 and the appropriate Record of Decision. DOE ensures that these requirements are met through independent verification by a third party. Currently, this verification is performed by Oak Ridge Associated

Universities (ORAU) through a direct contract with DOE. The direct contract with DOE ensures that the evaluation is performed independently of UCOR, the Department of Energy's clean up contractor. ORAU reviews historic data, facility use history, verification strategies, methodologies, techniques, and equipment. When ORAU deems it appropriate, additional sampling and /or radiological surveys are conducted. Results of the evaluation and verification are summarized in a report to DOE that is then submitted to DOE Headquarters for approval as part of the transfer package. Section 3.8 contains a summary of the real property releases to the public.

3.2.7 Competence, Training, and Awareness

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

3.2.8 Communication

UCOR communicates externally regarding environmental aspects through the **UCOR public web site**, which includes a link to its environmental policy statement in *Environmental Management and Protection,* POL-UCOR-007, and a list of environmental aspects.

A number of other documents and reports that address environmental aspects and cleanup progress are also published and made available to the public (e.g., the Annual Site Environmental Report [ASER] [DOE 2018a, DOE/ORO-2512] and the annual cleanup progress report [UCOR 2019a, *2019 Cleanup Progress—Annual Report to the Oak Ridge Regional Community,* OREM-19-2579]).

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

3.2.9 Benefits and Successes of Environmental Management System Implementation

An EMS program provides many benefits to an organization's success. Based upon the simplified model of Plan-Do-Act-Check, it provides a framework by which work incorporates mitigation of environmental hazards into its work control and planning. This translates into many returns to the organization. UCOR uses EMS objectives and targets, an internal P2 recognition program, environmentally preferable purchasing, work control processes, and a recycle program to meet sustainability and environmental stewardship goals and requirements. The approach is outlined in UCOR's *Pollution Prevention and Waste Minimization Program Plan for the East Tennessee Technology Park, Oak Ridge, Tennessee* (UCOR 2019b, UCOR-4127/R8). The EMS program is audited by a third party triennially as for conformance to the ISO 14001:2004 standard (ISO 2004) as required by DOE Order 436.1, *Departmental Sustainability, Attachment1 Contractor Requirements Document* (DOE 2011a), with the most recent having been conducted in 2018. The results of the audit were zero findings, three observations, and four proficiencies.

3.2.10 Management Review

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

3.3 Compliance Programs and Status

During 2019, ETTP operations were conducted in compliance with contractual and regulatory environmental requirements. There were no National Pollutant Discharge Elimination System (NPDES) permit noncompliances and no Clean Air Act (CAA) noncompliances in 2019. Figure 3.6 shows the trend of NPDES compliance at ETTP since 2012. The following sections provide more detail on each compliance program and the environmental remediation-related activities in 2019.

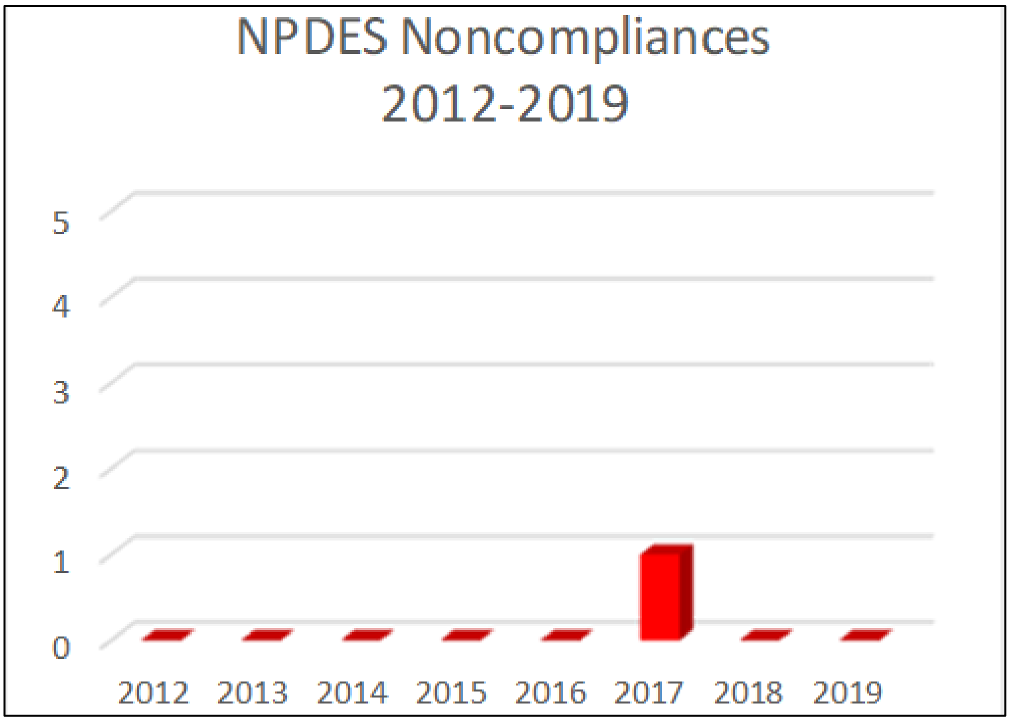


Figure 3.6. East Tennessee Technology Park National Pollutant Discharge Elimination System permit noncompliances since 2012

3.3.1 Environmental Permits Compliance Status

Table 3.2 contains a list of environmental permits that were in effect at ETTP in 2019.ETTP received no notices of environmental violations or penalties in 2019

Table 3.3 presents a summary of environmental audits and oversight visits conducted at ETTP in 2019.

Table 3.2. East Tennessee Technology Park environmental permits, 2019

Regulatory driver	Permit title/description	Permit number	Issue date	Expiration date	Owner	Operator	Responsible contractor
CAA	State permit to operate an air contaminant source—internal combustion engine–powered emergency generators and fire water pump replaced by PBR when NOA received from TDEC	069346P, NOA Number R74133	03-03-2015 Amended 11-22-2016 NOA issued 7-19-2018	10-01-2024, none for NOA	DOE	UCOR	UCOR
CWA	NPDES permit for storm water discharges	TN0002950	02-01-2015	03-31-2020	DOE	UCOR	UCOR
CWA	SOP—waste transportation project; Blair Road and Portal 6 sewage pump and haul permit	SOP-05068	07-01-2014	02-28-2019	TFE	TFE	TFE
CWA	SOP—ETTP holding tank/haul system for domestic wastewater	SOP-99033	07-01-2015	06-30-2020	UCOR	UCOR	UCOR
UST	Authorized/certified USTs at K-1414 Garage	Customer ID 30166 Facility ID 073008	03-20-1989	Ongoing	DOE	UCOR	UCOR
RCRA	ETTP container storage and treatment units	TNHW-165	09-15-2015	09-15-2025	DOE	UCOR	UCOR
RCRA	Hazardous waste corrective action document (encompasses entire ORR)	TNHW-164	09-15-2015	09-15-2025	DOE	DOE/All[a]	DOE/All[a]

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

Acronyms:
CAA = Clean Air Act
CWA = Clean Water Act
DOE = US Department of Energy
ETTP = East Tennessee Technology Park
ID = identification (number)
NOA = Notice of Authorization
NPDES = National Pollutant Discharge Elimination System
ORR = Oak Ridge Reservation
PBR = Permit-by-Rule
RCRA = Resource Conservation and Recovery Act of 1976
SOP = state operating permit
TDEC = Tennessee Department of Environment and Conservation
TFE = Technical and Field Engineering, Inc.
UCOR = UCOR, an Amentum-led partnership with Jacobs
UST = underground storage tank

Table 3.3. Regulatory oversight, assessments, inspections, and site visits at East Tennessee Technology Park, 2019

Date	Reviewer	Subject	Issues
June 17	COR	Sewage Network Discharge Inspection	0
October 2	TDEC	RCRA Compliance Inspection	0
December 5	TDEC	NPDES Storm Drain Inspection	0
December 10	TDEC	K-1065-B and -C Closure Inspection	0

Acronyms:
COR = City of Oak Ridge
RCRA = Resource Conservation and Recovery Act
TDEC = Tennessee Department of Environment and Conservation

3.3.2 National Environmental Policy Act/National Historic Preservation Act

The National Environmental Policy Act (NEPA) provides a means to evaluate the potential environmental impact of proposed federal activities and to examine alternatives to those actions. ETTP maintains compliance with NEPA through the use of site-level procedures and program descriptions that establish effective and responsive communications with program managers and project engineers to ensure NEPA is a key consideration in the formative stages of project planning. Many of the current operations at ETTP are conducted under CERCLA. NEPA reviews are part of the CERCLA planning process to ensure that NEPA values are incorporated into CERCLA projects and documentation. NEPA reviews identify new or changing environmental aspects associated with proposed activities.

During 2019, ETTP continued to operate under site-level, site-specific procedures that provide requirements for project reviews and NEPA compliance. These procedures call for a review of each proposed project, activity, or facility to determine the potential for impacts on the environment. To streamline the NEPA review and documentation process, DOE Oak Ridge Office (ORO) has approved generic categorical exclusion (CX) determinations that cover certain proposed activities (i.e., maintenance activities, facility upgrades, personnel safety enhancements). A CX is one of a category of actions defined in 40 *Code of Federal Regulations* (CFR) Part 1508.4 (EPA 1978) that does not individually or cumulatively have a significant effect on the human environment and for which neither an environmental assessment nor an environmental impact statement is normally required. UCOR activities on ORR are in full compliance with NEPA requirements, and procedures for implementing NEPA requirements have been fully developed and implemented. At ETTP, a checklist incorporating NEPA and EMS requirements has been developed as an aid for project planners. For routine, recurring activities, DOE generic CX determinations are used. During 2019, seven review reports were generated to document UCOR activities such as construction of small support buildings, storage yards, and access road improvements.

Compliance with the National Historic Preservation Act at ETTP is achieved and maintained in conjunction with NEPA compliance. The scope of proposed actions is reviewed in accordance with the ORR cultural resource management plan (Souza et al. 2001). At ETTP, there were 135 facilities eligible for inclusion on the National Register of Historic Places (NRHP), a US National Park Service program to identify, evaluate, and protect historic and archeological resources in the United States, as well as numerous facilities that were not eligible for inclusion on NRHP. To date, more than 800 facilities have been demolished. Artifacts of historical and/or cultural significance are identified before demolition and are catalogued in a database to aid in the historic interpretation of ETTP.

On December 14, 2014, Congress authorized the establishment of the Manhattan Project National Historical Park to commemorate the history of the Manhattan Project (DOI 2015). It will comprise the three major sites: Los Alamos, New Mexico; Oak Ridge, Tennessee; and Hanford, Washington, which were dedicated to accomplishing the Manhattan Project mission.

Consultation for the development of a MOA for D&D of the K-25 and K-27 buildings started in 2001; the document, approved in 2003, required a third-party analysis of the preservation and interpretive strategies for those two buildings. In 2005, DOE, the Tennessee State Historic Preservation Office, and the Advisory Council on Historic Preservation entered into an MOA that included the retention of the north end tower (also known as the north wing and the north end) of the K-25 Building and Portal 4 (K-1028-45), among other features, as the "best and most cost-effective mitigation to permanently commemorate, interpret, and preserve the significance" of ETTP. After another series of consultation meetings from 2009 through 2011, a final mitigation plan was developed by DOE that permitted demolition of the entire K-25 Building and called for, among other mitigation measures, the designation of a commemorative area around the building's perimeter from which future surface development would largely be restricted; the retention, if possible, of the entire concrete slab or the demarcation of the building's footprint; the construction of a viewing tower and structure for equipment display; and the development of a history center within the ETTP Fire Station #4. A final MOA was signed in August 2012, finalizing the aspects set forth in the mitigation plan. A Professional Design Team and Museum Professional were selected in 2014. The museum design was completed in 2017 and a construction subcontract was awarded for the K-25 History Center in 2018. Construction of the K-25 History Center began in 2018 and is scheduled to open in 2020.

The *Memorandum of Agreement Between the United States Department of the Interior and the United States Department of Energy for the Manhattan Project National Historical Park* was signed by DOI and DOE on November 10, 2015 (DOE 2015), creating the new Manhattan Project National Historical Park (MPNHP). The K-25 Virtual Museum website was launched in conjunction with the signing of the MOA.

The Historic American Engineering Record (HAER) documentation is being prepared for the K-25 Building. The documentation will be transmitted to the National Park Service upon completion.

3.3.3 Clean Air Act Compliance Status

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

Full compliance with CAA regulations and permit conditions was demonstrated in 2019. The ETTP ambient air-monitoring program, permitted source operations tracking, and record keeping provided documentation fully supporting a 100 percent compliance rate.

3.3.4 Clean Water Act Compliance Status

The objective of the Clean Water Act (CWA) is to restore, maintain, and protect the integrity of the nation's waters. This act serves as the basis for comprehensive federal and state programs to protect the waters from pollutants (see Appendix C for water reference standards). One of the strategies developed to achieve the goals of CWA was EPA establishment of limits on specific pollutants allowed to be discharged in US waters by municipal sewage treatment plants (STPs) and industrial facilities. EPA established the NPDES permitting program to regulate compliance with pollutant limitations. The program was designed to protect surface waters by limiting effluent discharges into streams, reservoirs, wetlands, and other surface waters. EPA has delegated authority for implementation and enforcement of the NPDES program to the state of Tennessee. In 2019, ETTP discharged storm water to the waters of the state of Tennessee under the individual NPDES permit TN0002950, which regulates storm water discharges.

In 2019, sewage discharges from routine breakrooms, restrooms, and change house showers were discharged to the COR Rarity Ridge Wastewater Treatment Plant collection network and sewage holding tanks under permits SOP-05068 and SOP-99033.

3.3.5 National Pollutant Discharge Elimination System Permit Noncompliances

In 2019, compliance with ETTP NPDES storm water permit TN0002950 was determined by more than 150 laboratory analyses, field measurements, and flow estimates. The NPDES permit compliance rate for all discharge points for 2019 was 100 percent. There were no permit noncompliances in 2019.

3.3.6 Safe Drinking Water Act Compliance Status

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

3.3.7 Resource Conservation and Recovery Act Compliance Status

ETTP is regulated as a large-quantity generator of hazardous waste because the facility generates more than 1,000 kg of hazardous waste per month. At the end of 2019, ETTP had two generator accumulation areas for hazardous or mixed waste.

In addition, ETTP is permitted to store and treat hazardous and mixed waste under the Resource Conservation and Recovery Act (RCRA) Part B Permit TNHW-165. Hazardous waste may be treated and stored at permitted locations at the K-1065 complex. This hazardous waste permit was reissued on September 15, 2015, as a replacement for TNHW-117. The hazardous waste corrective action document, TNHW-164, which covers ORR areas of concern and solid waste management units, was also reissued on September 15, 2015, as a replacement for TNHW-121.

In CY 2019, ETTP prepared and submitted to the TDEC Division of Solid Waste Management the CY 2018 annual report of hazardous waste activities. This report identifies the type and amount of hazardous waste that was generated, shipped off site, or is currently in storage. In 2019, ETTP was in full compliance with this Act.

The K-1414 Garage had two permitted underground storage tanks of the storage of fuel. On June 11, 2019, these two tanks were certified as closed.

3.3.8 Comprehensive Environmental Response, Compensation, and Liability Act Compliance Status

CERCLA, also known as “Superfund,” was passed in 1980 and was amended in 1986 by the Superfund Amendments and Reauthorization Act (SARA). Under CERCLA, a site is investigated and remediated if it poses significant risk to health or the environment. The EPA National Priorities List (NPL) is a comprehensive list of sites and facilities that have been found to pose a sufficient threat to human health and/or the environment to warrant cleanup under CERCLA. ORR is on the NPL and numerous CERCLA decision documents are approved for ETTP site cleanup actions for both facility demolitions and soil remediation. In 2019, ETTP was in full compliance with this Act.

3.3.9 East Tennessee Technology Park RCRA-CERCLA Coordination

The *Federal Facility Agreement for the Oak Ridge Reservation* (FFA, DOE 2018b, DOE/OR-1014) is intended to coordinate the corrective action processes of RCRA required under the *Hazardous and Solid Waste Amendments* permit with CERCLA response actions.

3.3.10 Toxic Substances Control Act Compliance Status—Polychlorinated Biphenyls

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

PCB waste generation, transportation, disposal, and storage at ETTP are regulated under EPA ID number TN0890090004. In 2019, ETTP operated five PCB waste storage areas in ETTP generator buildings and when longer-term storage of PCB/radioactive wastes was necessary, RCRA-permitted storage buildings were used. These facilities were operated under 40 CFR Part 761.65(b)(2)(iii) (EPA 1979), which allows PCB storage permitted by the state authorized under Section 3006 of RCRA to manage hazardous waste in containers, and spills of PCBs are cleaned up in accordance with Subpart G of this part. ETTP operated one long-term PCB waste storage area on site where nonradioactive PCB waste was stored in a facility that was not a RCRA-permitted storage facility. The continued use of authorized PCBs in electrical systems and/or equipment (e.g., transformers, capacitors, rectifiers) is regulated at ETTP. At this time, no PCB-contaminated electrical equipment is in service at ETTP.

Because of the age of many ETTP facilities and the varied uses for PCBs in gaskets, grease, building materials, and equipment, DOE self-disclosed unauthorized use of PCBs to EPA in the late 1980s. As a result, DOE ORO and EPA Region 4 consummated a major compliance agreement known as the *Oak Ridge Reservation Polychlorinated Biphenyl Federal Facilities Compliance Agreement* (DOE 2018c, ORR-PCB-FFCA), which became effective December 16, 1996, and was last revised on October 8, 2018, to Revision 6. The modification in 2018 allowed the continued use of the Chuck Vacuum System in Building 9215 and the Foundry Hydraulic System in Building 9998 located at Y-12.

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

The ETTP site prepares a PCB Annual Document Log (PCBADL) per 40 CFR Part 761.180(a) (EPA 1979). The written PCBADL is prepared by July 1 of each year and covers the previous calendar year. The PCBADL documents such things as container inventory, shipments, and PCB spills at the facility. Authorized representatives of EPA may inspect the PCBADL at the facility where they are maintained during normal business hours. The PCBADL must be maintained on site for a minimum of three years. In 2019, ETTP was in full compliance with this Act.

3.3.11 Emergency Planning and Community Right-to-Know Act Compliance Status

The Emergency Planning and Community Right-to-Know Act (EPCRA) that is also identified as Title III of SARA requires that facilities report inventory that exceed threshold planning quantities and releases of hazardous and toxic chemicals. The reports are submitted electronically and are available online for the local emergency planning committee, the state emergency response commission, and the local fire department. ETTP complied with these requirements in 2019 through the submittal of required reports as applicable under EPCRA Sections 302, 311, 312, and 313. ETTP had no reportable releases of hazardous substances or extremely hazardous substances, as defined by EPCRA, in 2019.

3.3.11.1 Chemical Inventories (EPCRA Section 312)

Inventories, locations, and associated hazards of hazardous and extremely hazardous chemicals were submitted in an annual report to state and local emergency responders, as required by EPCRA Section 312. Of the ORR chemicals identified for 2019, 12 were located at ETTP. These chemicals were nickel metal, lead metal (including large, lead-acid batteries), diesel fuel, sulfuric acid (including large, lead-acid batteries), Chemical Specialties, Inc. Ultrapoles, unleaded gasoline, Sakrete™ Type S or N mortar mix, CCA Type C pressure-treated wood, Flexterra FGM erosion control agent, crystalline silica, acetic acid, and various lubricating oils (including motor, lubricants, distillates, hydraulic and gear oils).

3.3.11.2 Toxic Chemical Release Reporting (EPCRA Section 313)

EPCRA Section 313 requires facilities to complete and submit a toxic chemical release inventory (TRI) form (Form R) annually. Form R must be submitted for each TRI chemical that is manufactured, processed, or otherwise used in quantities above the applicable threshold quantity. The reports address releases of certain toxic chemicals to air, water, land, and waste management, recycling, and P2 activities. Threshold determinations and reports for each of the ORR facilities are made separately. Operations involving TRI chemicals were compared with regulatory thresholds to determine which chemicals exceeded the reporting thresholds based on amounts manufactured, processed, or otherwise used at each facility. After threshold determinations were made, releases and off-site transfers were calculated for each chemical that exceeded the threshold quantity. In 2019, there were no chemicals that met the reporting requirements.

3.4 Quality Assurance Program

Integrated Assessment and Oversight Program

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

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

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

3.5 Air Quality Program

The state of Tennessee has been delegated authority by EPA to convey the clean air requirements that are applicable to ETTP operations. New projects are governed by construction and operating permit regulatory requirements. The owner or operator of air pollutant emitting sources is responsible for ensuring full compliance with any issued permit or other generally applicable CAA requirement. During 2019, ETTP DOE EM operations were under UCOR responsibility for regulatory compliance.

3.5.1 Construction and Operating Permits

UCOR ETTP operations are subject to CAA regulations and permitting under TDEC Air Pollution Control rules that are specific to stationary fossil-fueled reciprocating internal combustion engines (RICE) for emergency use. TDEC originally issued an operating permit (069346P) covering six stationary emergency RICE (e-RICE) units on March 3, 2015. An amended permit was issued on November 22, 2016, that removed one permanently shut-down unit. The last operating permit was amended on November 22, 2016, and covered four stationary e-RICE generators and one stationary e-RICE firewater booster pump. Three generators have diesel-fueled engines, one generator has a natural gas-fueled engine, and the firewater booster pump engine is diesel fueled. On July 19, 2018, TDEC provided a Notice of Authorization (NOA) to UCOR for coverage under Permit-by-Rule (PBR) for all of the ETTP stationary e-RICE.

Although the PBR subsumed the previous operating permit for the ETTP stationary e-RICE generators and firewater booster pump, the compliance requirements remained essentially the same. Compliance for all units is demonstrated by following specified maintenance schedules, limiting hours of operations for nonemergencies to 100 hours per year, and record keeping. Regulations exempt any operating hours of these units during nonscheduled (emergency) power outages.

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

3.5.1.1 Generally Applicable Permit Requirements

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

Control of Asbestos

ETTP's asbestos management program ensures all activities involving demolitions and all other actions involving asbestos-containing materials (ACM) are fully compliant with 40 CFR Part 61, Subpart M, *National Emission Standards for Hazardous Air Pollutants*, "National Emission Standard for Asbestos." This includes using approved engineering controls and work practices, inspections, and monitoring for proper removal and waste disposal of ACM. ETTP has numerous buildings and equipment that contain ACMs. Major demolition activities during 2019 involved the abatement of ACM that were subject to the requirements of 40 CFR Part 61, Subpart M. Most demolition and ACM abatement activities are governed under CERCLA. Under this act, notifications of asbestos demolition or renovations, as specified in 40 CFR Part 61.145(b), are incorporated into CERCLA document regulatory notifications. All other non-CERCLA planned demolition or renovation activities were individually reviewed for applicability of the TDEC notification requirements of the rule. During 2019, 11 Notifications of Demolition and/or Asbestos Renovation were submitted to TDEC for non-CERCLA ETTP activities. All of these notifications were for non-asbestos demolition. The rule also requires an annual notification for all nonscheduled, minor asbestos renovations if the accumulated total amount of regulated or potentially regulated asbestos exceeds stipulated thresholds. For 2019, the total ETTP projected nonscheduled amounts were below thresholds that would require the submittal of an annual notification to TDEC. No releases of reportable quantities of ACM occurred at ETTP during 2019.

Stratospheric Ozone Protection

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

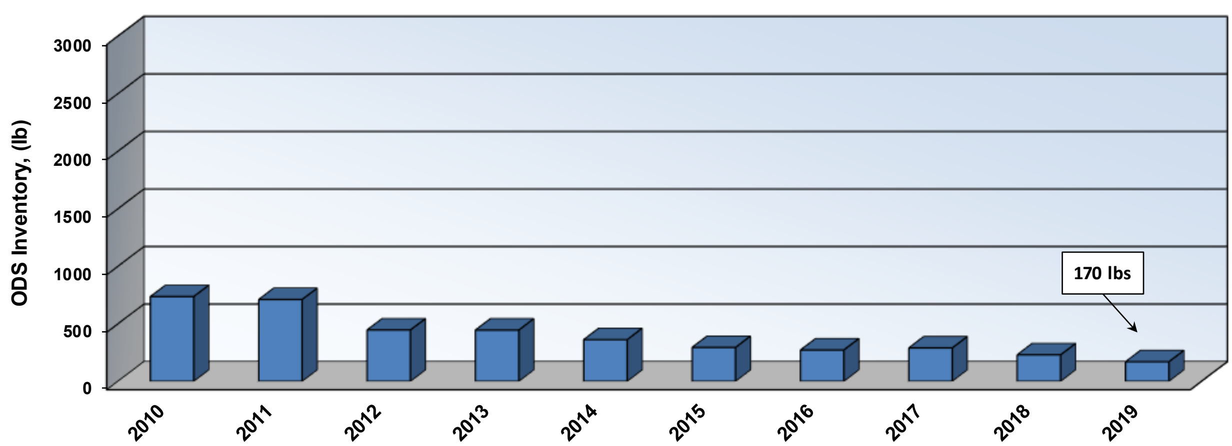


Figure 3.7. East Tennessee Technology Park total on-site ozone-depleting substances inventory, 10-year history

Fugitive Particulate Emissions

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

3.5.1.2 Radionuclide National Emission Standards for Hazardous Air Pollutants

Radionuclide airborne emissions from ETTP are regulated under 40 CFR Part 61, *National Emission Standards for Hazardous Air Pollutants (Rad-NESHAP)*. Characterization of the impact on public health of radionuclides released to the atmosphere from ETTP operations was accomplished by conservatively estimating the dose to the maximally exposed member of the public. The dose calculations were performed using the Clean Air Assessment Package (CAP-88) computer codes, which were developed under EPA sponsorship for use in demonstrating compliance with the 10 mrem/year effective dose National Emission Standards for Hazardous Air Pollutants for radionuclides (Rad-NESHAP) emission standard for the entire DOE ORR. Source emissions used to calculate the dose are determined using EPA-approved methods that can range from continuous sampling systems to conservative estimations based on process and waste characteristics. Continuous sampling systems are required for radionuclide-emitting sources that have a potential dose impact of not less than 0.1 mrem per year to any member of the public. ETTP Rad-NESHAP sources that operated during 2019—the K-1407 Chromium Water Treatment System (CWTS) Volatile Organic Compound (VOC) Air Stripper and K-2500-H Segmentation Shop C—are considered minor based on emissions evaluations using EPA-approved calculation methods. A minor Rad-NESHAP source is defined as having a potential dose impact on the public that is less than 0.1 mrem/year. Compliance is demonstrated using data collected by the ETTP ambient air monitoring program.

Quarterly radiochemical analyses are performed on composited samples collected at all ETTP ambient air sampling stations. The selected isotopes of interest were ^{234}uranium (^{234}U), ^{235}uranium (^{235}U), and ^{238}uranium (^{238}U), with the ^{99}technetium (^{99}Tc) inorganic analysis results included as a dose contributor. The concentration for each of the nuclides and the total dose at each monitoring station are presented in Table 3.4 for the 2019 reporting period.

Table 3.4. Radionuclides in ambient air at East Tennessee Technology Park, January 2019 through December 2019

Station	Concentration (µCi/mL)				
	^{99}Tc	^{234}U	^{235}U	^{238}U	
K2[a]	ND[b]	1.56E-17	8.93E-19	1.63E-17	
K11[c]	2.25E-16	1.45E-16	1.30E-17	2.71E-16	
K12[c]	ND	7.04E-17	1.07E-17	2.21E-16	
	40 CFR 61, Effective Dose (mrem/year)				Total Dose
K2					0.006
K11					0.040
K12					0.030

[a] K2 result represents a residential exposure.
[b] ND = not detectable.
[c] K11 and K12 represent an on-site business exposure equivalent to half of a yearly exposure at this location.

Stations K11 and K12 are near on-site businesses, therefore the estimated doses based upon residential exposures were divided by two to account for occupational exposures following approved procedures. This conservatively assumes that the on-site member of the public is at his or her workstation for half of the year.

During 2019, the on-site annual dose remained very low at 0.04 mrem at ambient air station K11 and 0.03 mrem at ambient air station K12. The highest uranium concentrations were measured in the second and third quarters at K11 and K12 and are attributed to K-131/K-631 demolition that involved radiologically contaminated materials. The results are based on actual ambient air sampling in locations conservatively representative of on-site business locations. All data continue to show potential exposures are all well below the 10 mrem annual dose limit.

3.5.1.3 Quality Assurance

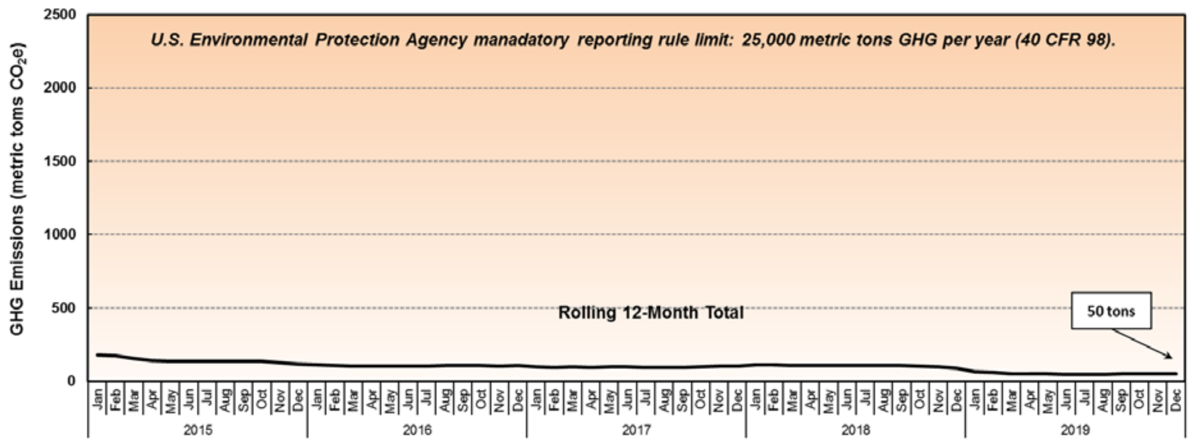
QA activities for the Rad-NESHAP program are documented in the *Quality Assurance Program Plan for Compliance with Radionuclide National Emission Standards for Hazardous Air Pollutants, East Tennessee Technology Park, Oak Ridge Tennessee* (UCOR 2018b, UCOR-4257/R2). The plan satisfies the QA requirements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

3.5.1.4 Greenhouse Gas Emissions

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

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

A 2019 review was performed of ETTP processes and equipment categorically identified under 40 CFR Part 98.2 whose emissions must be included as part of a facility annual GHG report, starting with the CY 2010 reporting period. Based on total GHG emissions from all ETTP stationary sources during 2019, ETTP did not exceed the annual threshold limit and therefore was not subject to mandatory annual reporting under the GHG rule during this performance period. The total GHG emissions for any continuous 12-month period beginning with CY 2008 have not exceeded 12,390 MT CO_2e of GHGs. The most significant decrease in stationary source emissions was due to the permanent shutdown of the TSCA Incinerator in 2009. The remaining sources are predominantly small comfort heating systems, hot water systems, and power generators. Figure 3.8 shows the 5-year trend up through 2019 of ETTP total GHG stationary emissions. For the 2019 CY, GHG emissions totaled only 50 MT CO_2e, which is 0.2 percent of the 25,000 MT CO_2e per year threshold for reporting.



Note: Shown in carbon dioxide equivalent (CO_2e)

Acronyms:
CFR = *Code of Federal Regulations*
GHG = greenhouse gas

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

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

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

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

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

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

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

With respect to EOs 13514 and 13693, emissions for FY 2019 Scope 1 and 2 including the landfills totaled 19,186 MT CO_2e, which is well below both the FY 2020 target level of 37,478 MT CO_2e and the FY 2025 target level of 31,232 MT CO_2e.

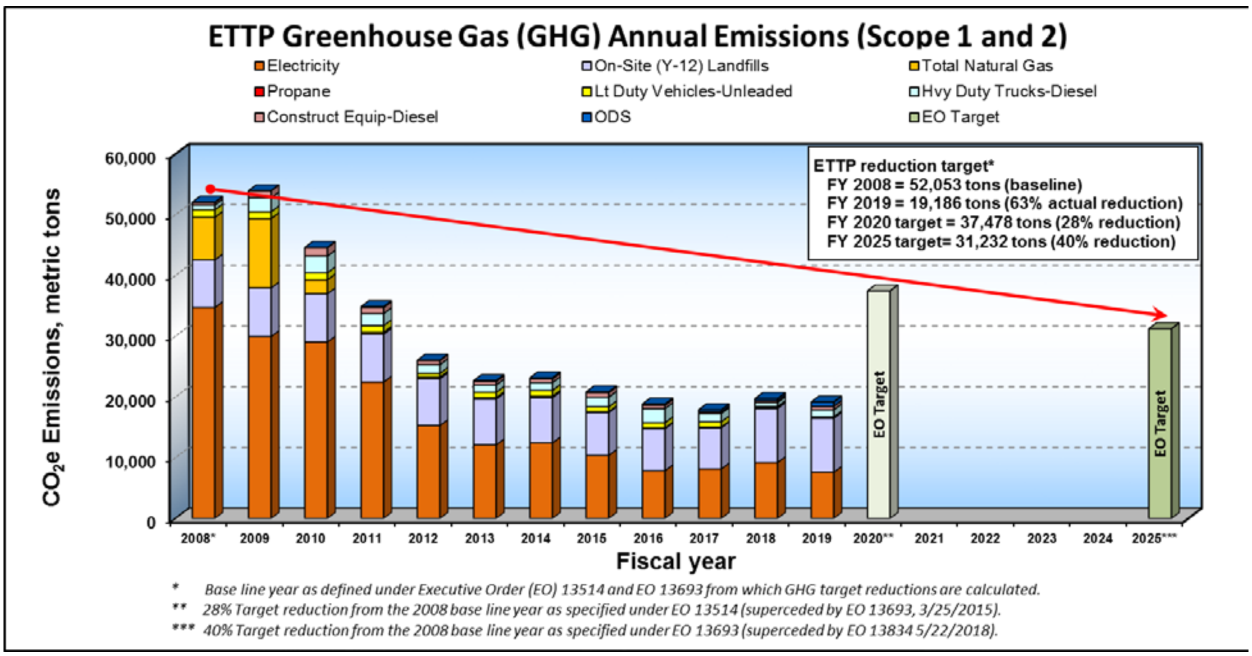
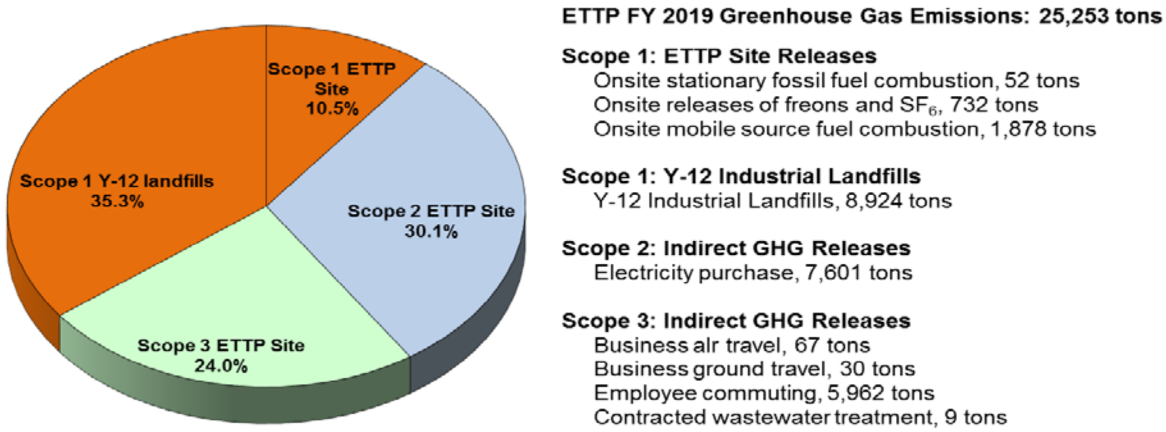


Figure 3.9. East Tennessee Technology Park greenhouse gas annual emissions (Scopes 1 and 2, including industrial landfills at Y-12)

Figure 3.10 shows the relative distribution and amounts of all ETTP FY 2019 GHG emissions for Scopes 1, 2, and 3 including the industrial landfills at Y-12. Total GHG emissions remain well below the levels first reported in the 2008 baseline year as demolition and remediation efforts continue at ETTP. Many of the early reductions were due to lower on-site combustion of fuels (stationary and mobile sources), lower consumption of electricity, and a smaller workforce. The total amount of GHG emissions for Scopes 1, 2, and 3, including landfills at Y-12, for FY 2019 was 25,253 MT CO_2e. Total reduction to date starting with the 2008 baseline year of 61,453 MT CO_2e of GHG emissions is 58.9 percent.



Acronyms and abbreviations:
ETTP = East Tennessee Technology Park
GHG = greenhouse gas
SF_6 = sulfur (hexafluoride)
Y-12 = Y-12 National Security Complex

Figure 3.10. FY 2019 East Tennessee Technology Park greenhouse gas emissions by scope, as defined in Executive Order 13514

3.5.1.5 Source-Specific Criteria Pollutants

ETTP operations included one functioning minor stationary source, the CWTS, with a potential to emit any form of criteria air pollutant. This unit is equipped with an air stripper to remove VOCs from the effluent stream. All process data records and the calculated potential maximum VOC emission rates for the CWTS air stripper were below levels that would require permitting. The calculated VOC annual emissions during 2019 for CWTS were only 0.007 ton/year as compared to an emission limit of 5 tons/year. The annual potential emissions for this facility would be well below the 5 ton/year limit assuming it operated at the maximum hourly emission rate continuously for the entire year.

Federal regulations amended in January 2013 require TDEC permitting for existing and new stationary RICE-powered emergency generators and firewater booster pumps. Permitting actions do not apply to e-RICE covered under CERCLA projects. However, specific maintenance and recordkeeping requirements specified in the federal regulations are applicable to CERCLA projects operating e-RICE. The 2019 operations included four e-RICE powered emergency generators (K-1007, K-1039, K-1095, and K-1652), and one e-RICE powered firewater booster pump (K-1310-RW). TDEC issued a NOA to UCOR on July 19, 2018, for e-RICE at ETTP to operate under the PBR provisions of Rule 1200-03-09-.07 for stationary emergency internal combustion engines. This authorization (number R74133) subsumed the previous operating permit.

Regulations limit e-RICE nonemergency and maintenance operations to 100 h of operations per 12-month rolling total (i.e., 100 h of running the engines for testing and maintenance purposes per year). Additionally, nonemergency operations are limited to 50 h of the 100-h annual limit. PBR provisions also require performing scheduled maintenance and recordkeeping. These requirements were met in CY 2019.

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

3.5.1.6 Hazardous Air Pollutants (Nonradionuclide)

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

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

3.5.2 Ambient Air

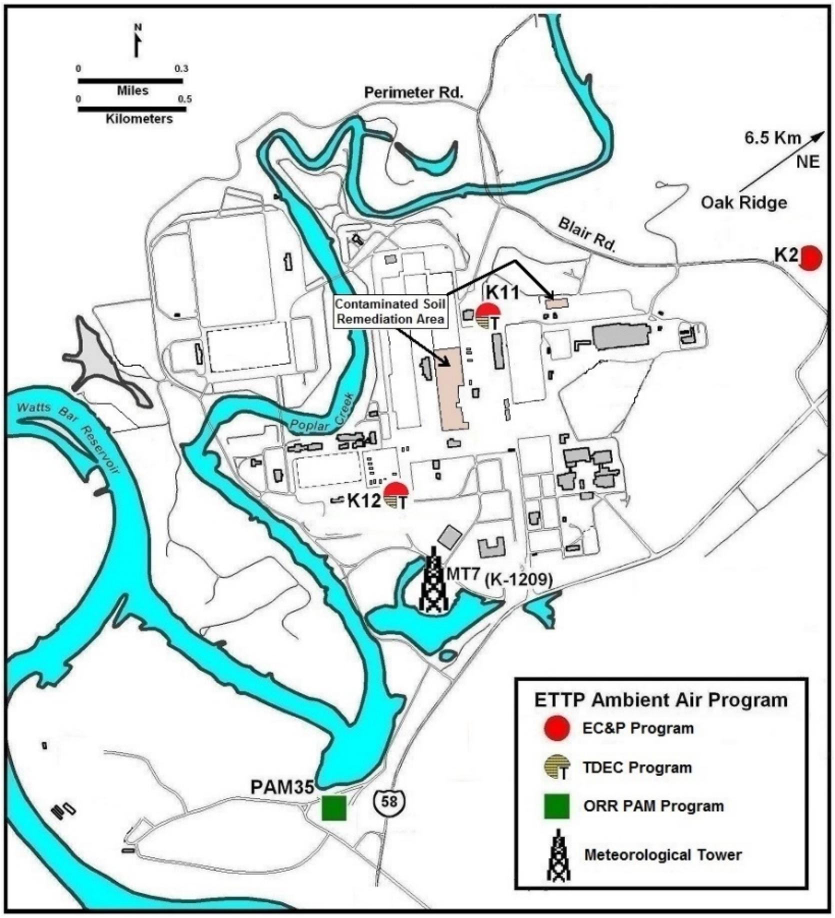
Compliance of fugitive and diffuse sources is demonstrated based on environmental measurements. The ETTP Ambient Air Quality Monitoring Program is designed to provide environmental measurements to accomplish the following:

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

The three sampling programs in the ETTP area are designated as the EC&P program, TDEC program, and the ORR perimeter air monitoring (PAM) program. Figure 3.11 shows the locations of all ambient air sampling stations in and around ETTP that were active during the 2019 reporting period. Figure 3.12 shows an example of a typical EC&P program air monitoring station.

The EC&P program consisted of three sampling locations throughout 2019. All projects are operating similar high-volume sampling systems. The EC&P, TDEC, and PAM samplers operate continuously with exposed filters collected weekly. The radiological monitoring results for samples collected at the one ETTP area PAM station are the responsibility of UT-Battelle, LLC. TDEC is responsible for the data collected from their samplers. UT-Battelle, LLC and TDEC results are not included with the EC&P data presented in this section. However, periodic requests for results from the other programs are made for comparison purposes.

The analytical parameters were chosen with regard to existing and proposed regulations and with respect to activities at ETTP. The principle reason for EC&P program stations is to demonstrate that radiological emissions from the demolition of ETTP gaseous diffusion buildings, supporting structures, and associated remediation activities are in compliance with the annual dose limit to the most exposed members of the public that is either on-site (on ORR) or off-site. K11 and K12 were key sampling locations regarding the potential dose impact on the most exposed member of the public at an on-site business location during the demolition and debris removal of Buildings K-131 and K-631 and the removal of ^{99}Tc-contaminated soil from the Building K-25 footprint.



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

Figure 3.11. East Tennessee Technology Park ambient air monitoring station locations

Changes of emissions from ETTP will warrant periodic reevaluation of the parameters being sampled. Ongoing ETTP reindustrialization efforts will also introduce new locations for members of the public that may require adding or relocating monitoring site locations. To ensure understanding of the potential impacts on the public and to establish any required emissions monitoring and emissions controls, a survey of all on-site tenants is reviewed every 6 months through a request for the most recent ETTP reindustrialization map.

All EC&P program stations collected continuous samples for radiological analyses during 2019. Radiological analyses of samples from the EC&P stations test for the isotopes ^{234}U, ^{235}U, ^{238}U, and ^{99}Tc.

Station K2 is in the prevailing topography of influenced downwind directions that are for identifying the impact to off-site members of the public. Stations K11 and K12 are located to provide a conservative measurement of the impact to on-site members of the public.

Figure 3.12. East Tennessee Technology Park ambient air monitoring station

3.6 Water Quality Program

3.6.1 NPDES Permit Description

The latest ETTP NPDES permit became effective on April 1, 2015. The permit expired on March 31, 2020. The application for renewal was submitted on September 18, 2019. A total of 27 representative outfalls are monitored on an annual basis for oil and grease, total suspended solids (TSS), pH, and flow. Outfall 170 is also monitored quarterly for total chromium and hexavalent chromium.

In addition to periodic monitoring requirements specified in the ETTP NPDES permit, several additional monitoring efforts were included to support the CERCLA actions that are ongoing at ETTP. This monitoring was conducted as part of the Storm Water Pollution Prevention (SWPP) Program and/or the ETTP Biological Monitoring and Abatement Program (BMAP).

3.6.1.1 RA Activities, CERCLA, and Legacy Pollutant Monitoring

In addition to periodic monitoring requirements specified in the ETTP NPDES permit, several additional monitoring efforts were included to support the CERCLA actions that are ongoing at ETTP. This monitoring was conducted as part of the SWPP Program and/or the ETTP BMAP. Storm water monitoring is conducted at outfalls that drain areas affected by RA activities in order to provide a pre-RA baseline, to determine the efficacy of RA activities, and to suggest area for future RA activities.

3.6.1.2 Permit Renewal Monitoring

Sampling required for the completion of the NPDES permit renewal application was conducted as part of the ETTP SWPP Program. The application for this permit renewal was submitted to TDEC on

September 18 2019, approximately 2 weeks ahead of the submittal deadline. Based on previous TDEC guidance, composite samples were collected as time-weighted composites due to the short travel time for storm water runoff in the storm drain piping system and to site conditions within the watersheds. Monitoring was conducted to ensure all required samples were collected to complete EPA Form 2F, *Application for Permit to Discharge Storm Water Discharges Associated with Industrial Activity* for each representative outfall.

Representative outfalls were sampled to ensure completion of EPA Form 2F, Section VII, Discharge Information, Parts A, B, and C, as required. Information collected included:

- Part A—Parameters were collected in compliance with Form 2F. Oil and grease, total nitrogen, total phosphorus, and pH were collected as grab samples per EPA guidance. Biochemical oxygen demand, chemical oxygen demand, and TSS were collected either as grab samples or as time-weighted composites.
- Part B—All facilities generating process wastewater at ETTP have been closed, and the respective NPDES permits have expired. Therefore, ETTP is no longer subject to any effluent guidelines, and there are no sampling requirements under Part B at any storm water outfall at ETTP.
- Part C—Each representative storm water outfall was sampled only for pollutants that could potentially be present based on the characteristics and uses of the drainage area for that outfall. The potential pollutants to be considered for monitoring are shown in Tables 2F-2, 2F-3, and 2F-4 of EPA Form 2F. Based upon historical site knowledge and analytical monitoring results, metals, mercury, and PCBs were collected from all representative outfalls. In addition, each representative outfall was evaluated, and VOCs, radionuclides, and other selected parameters were collected as required. Part C parameters that must be collected by grab sample, per analytical method or regulatory guidance, were collected as grab samples only. All other Part C parameters were collected as time-weighted composites only.

3.6.1.3 Investigative Monitoring

Investigative sampling was performed as part of the ETTP SWPP Program. This included sampling of storm drain networks for bioaccumulative parameters and investigations triggered by analytical results, CERCLA requirements, changes in site conditions, etc. (UCOR 2018b, UCOR-4028, *East Tennessee Technology Park Storm Water Pollution Prevention Program Sampling and Analysis Plan, Oak Ridge, Tennessee).*

Storm water sampling results were reviewed and evaluated to provide feedback for the next round of investigative sampling, generate suggested modifications and improvements to storm water runoff controls, and provide input for CERCLA project cleanup decisions.

3.6.2 Storm Water Pollution Prevention Program

3.6.2.1 Flux Monitoring of Storm Water

In addition to periodic monitoring requirements specified in the ETTP NPDES permit, additional long-term monitoring of pollutant loading was included as part of the current ETTP NPDES permit related to ongoing CERCLA actions. This monitoring, which was conducted as part of the ETTP SWPP Program, included flow monitoring and legacy mercury sampling at two storm water outfalls (Outfalls 180 and 190) and flow monitoring only at two additional outfalls (Outfalls 100 and 170). In order to properly monitor mercury flux, accurate flow estimates and mercury concentrations measured during storm events are required.

Flow monitoring was conducted at Outfalls 100, 170, 180, and 190 in accordance with ETTP NPDES permit requirements and the SWPP Program SAP. Flows for three ranges of rainfall events specified in the ETTP NPDES permit were required. The flows that were obtained were used to increase the accuracy of the TR-55 flow model employed at ETTP for estimation of flow for the ETTP NPDES Discharge Monitoring Report (DMR).

Flow measurements were collected at Outfall 170 in CY 2015–2016. Because the results of the flow monitoring at Outfall 170 have been discussed in previous reports, they will not be discussed in this report.

For this study, flow data and rainfall data for designated time periods were collected. In addition, the discharge flow at the beginning of the data event was also recorded. This provided an indication as to whether the flow at the outfall had returned to near base flow conditions after the previously recorded rainfall event, or if the flow was still elevated at the outfall due to the previous rainfall event. Generally speaking, the more the flow returned to base flow readings before the next recorded data event, the more representative were the flow measurements for the subsequent rainfall event. Flow data for each of these 24-h periods (a total of 288 readings per 24-h period) were averaged to determine the average flow over the 24-h period. The rainfall for the corresponding 24-h period was also totaled.

The metered flow data were then compared to the calculated flow from the outfall using the NRCS TR-55 model. A description of this model and the input information required by the model can be found in the U.S. Department of Agriculture (USDA) TR-55, *Urban Hydrology for Small Watersheds*. This model uses information about the individual outfall's piping system and drainage area to calculate the amount of runoff that would be generated as part of a specified rainfall event. When a rainfall amount is entered into the model, the amount of discharge from the outfall resulting from this rainfall event is calculated.

The objective of performing the flow study at the selected outfalls was to calibrate the TR-55 model by adjusting the model's variable inputs to more closely match the metered flows. The TR-55 model will always produce a consistent and predictable graph with a well-fitted trend line. Calibration of the curve number (CN), impervious area measurements, and base flows in the TR-55 program were performed to achieve a better correlation of metered flow and calculated flow for a given rainfall event.

Outfall 100 drains an area of approximately 4.2M ft^2 or 97 acres. The estimated hydraulic length of the Outfall 100 piping system is 14,000 linear feet (LF). At its point of discharge, Outfall 100 is a 48-in. corrugated metal pipe (CMP), but the Outfall 100 drainage system piping network is composed of piping of various sizes and materials.

Flow data from a flume and rainfall data for February 17, 2018–March 15, 2019, were collected at Outfall 100. A new base flow for Outfall 100 was determined by using the average of the flows measured by the flow meter immediately before the start of rainfall events. The new base flow at Outfall 100 is 112,000 GPD using this method. This base flow is considerably lower than the previous base flow, attributable to demolition of numerous structures in the Outfall 100 drainage area. The new base flow will be used with the TR-55 program to provide flow estimates for Outfall 100.

As seen in Figure 3.13, by using the new base flow of 112,000 GPD the new NRCS CN of 89, and the new percent impermeable value of 55 percent, a relatively close correlation between the actual flow metered at Outfall 100 using ISCO flow measurement equipment and the flow at Outfall 100 derived by using the TR-55 model was obtained, except during high flow periods. The high flow deviation may be due to instrumentation limitations.

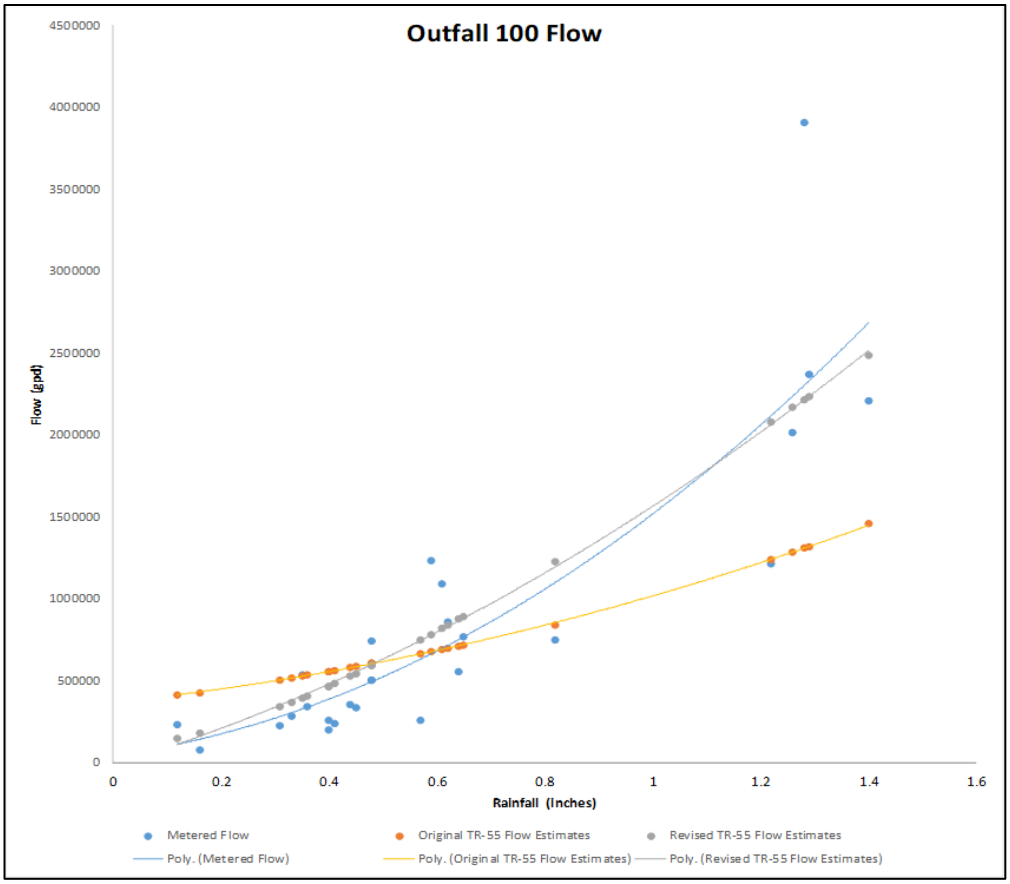


Figure 3.13. Adjusted flow curve for Outfall 100

In addition to mercury sampling, flow-paced sampling for PCBs was also performed at Outfall 100. Outfall 100 has had several historical discharges of PCBs and is considered a contributor of PCB contamination to the K-1007-P1 pond. The PCB data collected as part of this sampling effort will be utilized in the calculation of PCB flux from this outfall.

On February 11, 2019, a flow-paced PCB sample was collected at Outfall 100 after a rainfall event of 0.86 in. No detectable PCBs were identified in this sample.

Flow-paced mercury and PCB samples were collected on February 18, 2019, after a rainfall event of 1.64 in. Mercury was detected in this sample at a level of 9.69 ng/L, and PCB-1254 was detected in the sample at a level of 0.0385 µg/L.

Flow-paced mercury and PCB samples were collected at Outfall 100 on March 11, 2019, after a rainfall event of 2.53 in. Mercury was detected in this sample at a level of 36 ng/L, and PCB 1254 was detected in the sample at a level of 0.0384 µg/L. Flow-paced mercury and PCB samples were collected at Outfall 100 on March 18, 2019, after a rainfall event of 0.64 in. Mercury was detected in this sample at a level of 10.2 ng/L. No detectable PCBs were identified in this sample.

Additional flow-paced sampling for mercury and/or PCBs may be conducted at Outfall 100 as part of future SWPP Program sampling plans.

Outfall 180 drains an area of approximately 1.4M ft^2 or 32.5 acres. The estimated hydraulic length of the Outfall 180 piping system is 4100 LF. At its point of discharge, Outfall 180 is a 42-in. concrete pipe, but the Outfall 180 drainage system piping network is composed of piping of various sizes and materials.

Specifications for a flume to be installed at Outfall 180 were developed in late summer of 2016. This flume was purchased during FY 2017. Installation of the flume was completed in the summer of 2018, and flow data have been collected since that time. Because of the configuration of the Outfall 180 piping system, the flume could not be installed at the end of the piping system. Therefore, it was designed to be installed inside the pipe rather than at the end of the pipe.

Flow data using a flume installed in 2018 and rainfall data for the period from August 30, 2018–January 31, 2019, were collected at Outfall 180. A new base flow for Outfall 180 was determined by averaging the flows metered immediately before the start of rainfall events. The new base flow at Outfall 180 was determined to be 10,600 (GPD). The new base flow will be used with the TR-55 program to provide flow estimates for Outfall 180. Samples collected during the flow proportional monitoring were analyzed for mercury. Table 3.5 shows these results as well as the recorded rainfall amounts and resultant flows.

Table 3.5. Mercury results from flow-proportional composite sampling at Outfall 180

Location	Date sampled	Rainfall recorded during sampling event (in.)	Flow total during time samples were being collected (gal)	Mercury results (ng/L)
Outfall 180	9/11/18	0.25	6,239	497
Outfall 180	9/25/18	0.79	31,857	342
Outfall 180	1/25/19	1.20	456,840	39.5
Outfall 180	2/18/19	0.50	156,309	510
Outfall 180	3/11/19	1.91	767,568	73.5
Outfall 180	3/18/19	0.45	51,861	215
Outfall 180	4/15/19	0.62	249,955	163

As seen in Figure 3.14, by using the new base flow of 10,600 GPD, the percent impervious value of 35 percent, and the NRCS CN of 86, a relatively close correlation between the actual flow metered at Outfall 180 using flow measurement equipment and the calculated flow at Outfall 180 derived by using the TR-55 model was developed.

Figure 3.15 shows the relationship between the metered rainfall events discharge volumes and mercury flux in milligrams that was determined from the flow proportional sampling. The data generally indicate that mercury flux at Outfall 180 increased as rainfall event flows increased. This may be due to an increased amount of legacy mercury-contaminated sediments being flushed from the outfall during heavier rainfall events and the heavier flows from the outfall that are associated with these rainfall events. The single large variance from this trend is unexplained.

Applying the flow and mercury concentrations data from the long-term monitoring of legacy pollutant loadings presented above, the mercury flux at Outfall 180 for CY 2019 was calculated. The volume of the discharge was determined using TR-55 model, calibrated using the flow monitoring results, and rainfall data from CY 2019. Each qualifying rain event in CY 2019 was used with the TR-55 program to generate average flow (pervious plus impervious plus base flow). The TR-55 average flow and flow-paced mercury results were used to calculate the approximate mercury flux from Outfall 180 for CY 2019. The Outfall 180 mercury flux (average, maximum, and minimum) for CY 2019 is presented in Table 3.6.

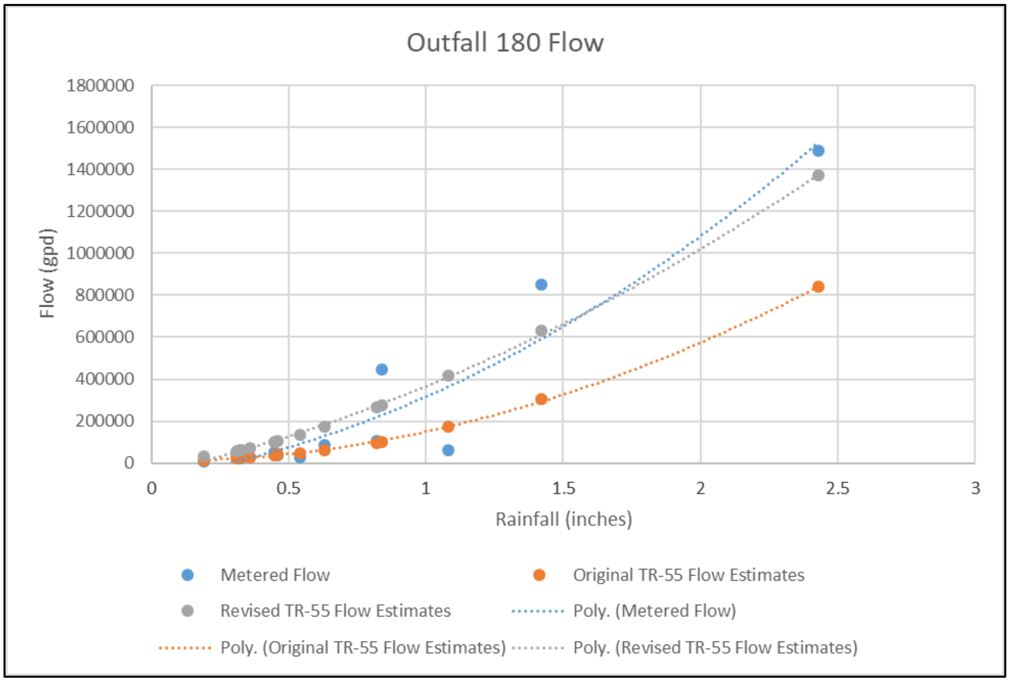


Figure 3.14. Adjusted flow curve for Outfall 180

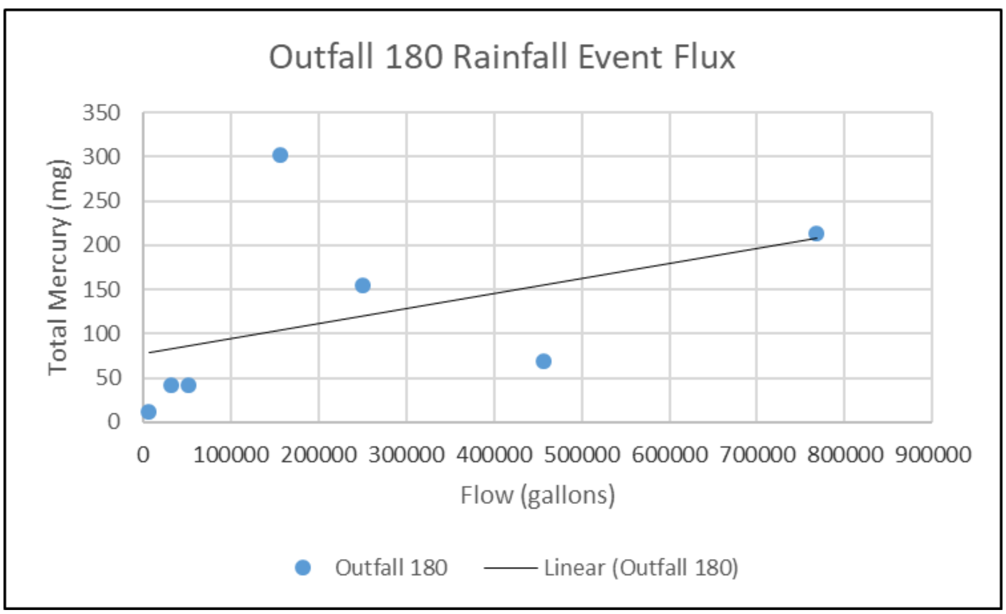


Figure 3.15. Flow-proportional mercury sampling at Outfall 180

Outfall 190 drains an area of approximately 1.25M ft^2 or 28.7 acres. The estimated hydraulic length of Outfall 190 piping system exceeds 7200 LF. At its point of discharge, Outfall 190 is a 42-in. concrete pipe, but the Outfall 190 drainage system piping network is composed of piping of various sizes and materials. A flume was installed in 2015 to measure flow from Outfall 190.

Table 3.6. Mercury flux at Outfall 180 for CY 2019

Outfall	CY 2019 Average Flow Rate (GPD)	Average Mercury Concentration (ng/L)	Average Mercury Flux (g/yr)	Maximum Mercury Concentration (ng/L)	Maximum Mercury Flux (g/yr)	Minimum Mercury Concentration (ng/L)	Minimum Mercury Flux (g/yr)
180	71,529	200.2	19.79	510	50.40	39.5	3.90

A new base flow for Outfall 190 was determined by averaging the flows measured by the flow meter immediately before the start of rainfall events that occurred December 5, 2015–March 31, 2017. The new base flow calculated from these measurements was 23,500 gal.

As illustrated in Figure 3.16, by using the new base flow of 23,500 GPD and the revised NRCS CN of 86, a relatively close match was accomplished between the flow metered at Outfall 190 using flow measurement equipment and the flow at Outfall 190 derived by using the TR-55 model. Both the new base flow and the revised NRCS CN will be used with the TR-55 program to provide flow estimates for Outfall 190.

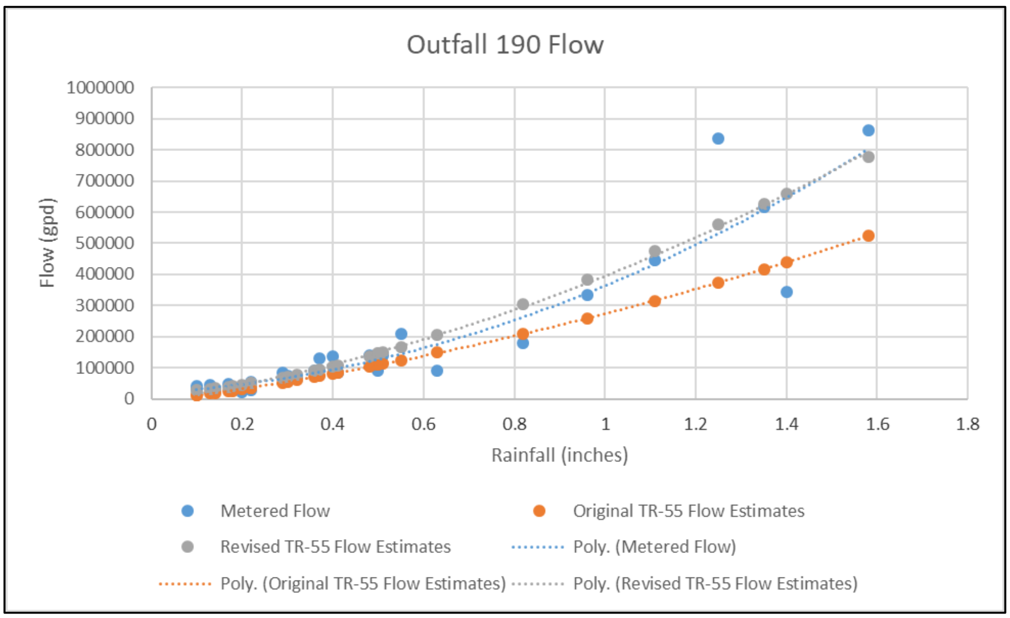


Figure 3.16. Adjusted flow curve for Outfall 190

In support of future CERCLA evaluations, such as those conducted as part of the CERCLA five-year review process, legacy mercury sampling was conducted at Outfall 190. Three flow-composite mercury samples were collected at Outfall 190 between February 2016 and February 2017. In early 2019, it was determined that insufficient data had been collected at Outfall 190 to allow for conclusions to be made concerning mercury flux at the outfall. Composite sampling equipment was reinstalled at Outfall 190, and several additional flow-composite samples were collected between February and April 2019. The results from all of these samples are shown in Table 3.7.

Figure 3.17 shows the relationship between metered rainfall event discharge volume and legacy mercury flux in milligrams that was determined from the flow proportional sampling effort. The data generally indicates that mercury flux at Outfall 190 increased as rainfall event flows increased. This may be due to an increased amount of mercury-contaminated sediments being flushed from the outfall during heavier rainfall events and the heavier flows from the outfall that are associated with these rainfall events. The two large variances from this trend are unexplained.

Table 3.7. Mercury results from flow-proportional composite sampling at Outfall 190

Location	Date sampled	Rainfall recorded during sampling event (in.)	Flow total during time samples were being collected (gal)	Mercury results (ng/L)
Outfall 190	2/2/16	1.56	1,363,753	96.5
Outfall 190	1/12/17	0.55	73,646	162.0
Outfall 190	9/7/17	1.42	695,018	566.0
Outfall 190	2/18/19	0.42	163,700	67.8
Outfall 190	3/11/19	1.97	1,209,886	328.0
Outfall 190	3/18/19	0.43	184,120	92.9
Outfall 190	4/15/19	0.63	199,001	559.0

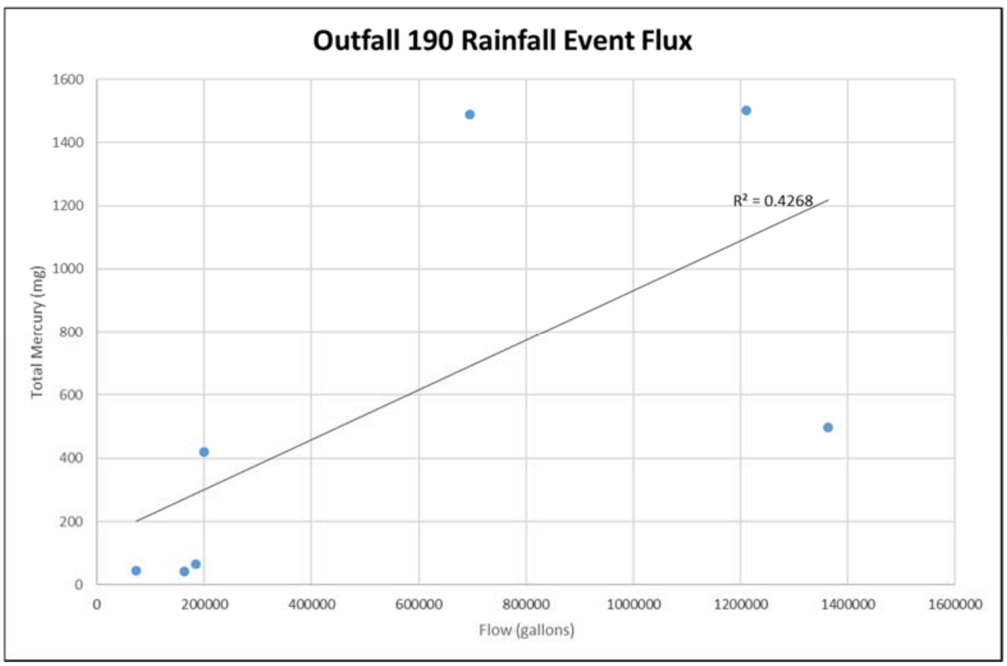


Figure 3.17. Flow-proportional mercury sampling at Outfall 190

Applying the flow and mercury concentrations data from the long-term monitoring of legacy pollutant loadings presented above, the mercury flux at Outfall 190 for CY 2019 was calculated. The volume of the discharge was determined using TR-55 model, calibrated using the flow monitoring results, and rainfall data from CY 2019. Each qualifying rain event in CY 2019 was used with the TR-55 program to generate average flow (pervious plus impervious plus base flow). The TR-55 average flow and flow-paced mercury results were used to calculate the approximate mercury flux from Outfall 190 for CY 2019. The Outfall 190 mercury flux (average, maximum, and minimum) are presented in Table 3.8.

Table 3.8. Mercury flux at Outfall 190 for 2019

Outfall	CY 2019 average flow rate (GPD)	Average mercury concentration (ng/L)	Average mercury flux (g/yr)	Maximum mercury concentration (ng/L)	Maximum mercury flux (g/yr)	Minimum mercury concentration (ng/L)	Minimum mercury flux (g/yr)
190	83,961	261.9	30.38	559	64.85	67.8	7.87

3.6.2.2 Radiologic Monitoring of Storm Water

ETTP conducts radiological monitoring of storm water discharges to determine compliance with applicable dose standards. ETTP also applies the as low as reasonably achievable (ALARA) process to minimize potential exposures to the public. Sampling for gross alpha and gross beta radioactivity, as well as specific radionuclides, is conducted as part of the ongoing SWPP Program sampling efforts. Analytical results are used to estimate the total discharge of each radionuclide from ETTP via the storm water discharge system.

Table 3.9 contains the results of this sampling effort. Screening levels for individual radionuclides are established at 4 percent of the derived concentration standards (DCS) values listed in DOE Standard 1196 (DOE 2011b, DOE-STD-1196). Radiological data are reported as fractions of DCSs for reported radionuclides, and the fractions for all of the isotopes are added together to produce the sum of fractions (SOF) and averaged to produce a rolling 12-month average. The average SOF is recalculated whenever new data become available. If the average SOF for a location exceeds the DCS requirement of remaining below 1.0 (100 percent) for the year, a formal source investigation is required. Sources exceeding DCS requirements would need an analysis of the best available technology to reduce the SOF of the radionuclide concentrations to less than 1.0 (100 percent). Table 3.10 lists the cumulative activity levels of each of the major isotopes that were discharged from the overall ETTP storm water system in 2019.

Elevated radiological results were noted at Outfalls 160 and 292 as part of this sampling effort. Neither of these results exceeded the SOF of the DCS, but they did exceed reference standards. Outfall 160 receives storm water runoff from a portion of the K-1420 pad as well as radiologically contaminated paved and grassy areas north of the building. Outfall 292 receives storm water runoff from the former converter shell storage yard that was located on the K-1064 peninsula. Historical analytical results from both of these outfalls have had elevated levels of radiological contaminants.

Investigative samples were collected at Outfall 158 on November 11, 2018. The SOF of the derived concentration standard (DCS) values for Outfall 158 equaled 1.4. Because the SOF at Outfall 158 was above 1.0, it was determined that monthly monitoring of radiological parameters would be initiated in December 2018 and would be conducted for as long as was determined to be necessary.

Follow-up sampling was performed at Outfall 158 on December 20, 2018. These samples were collected after a one-day rainfall event of 1.22 in. that occurred on December 20. In addition, sampling was also performed at Outfall 158 on January 3, February 12, and March 11, 2019, after rainfall events of approximately 1.16 in., 2.94 in., and 2.55 in., respectively. Validated analytical results from monitoring conducted at Outfall 158 in December 2018 and the first quarter of CY 2019 are shown in Table 3.11.

No screening criteria were exceeded at Outfalls 100, 142, 170, 180, 190, 195, 250, 280, 360, 430, 510, 560, 690, 730, or 930.

Table 3.9. Analytical results for radiological monitoring at ETTP storm water outfalls

Parameter	Reference standard (pCi/L)	Outfall 142	Outfall 150	Outfall 158	Outfall 160	Outfall 170	Outfall 180	Outfall 190	Outfall 195	Outfall 250	Outfall 280	Outfall 292	Outfall 360	Outfall 510	Outfall 560	Outfall 690	Outfall 730	Outfall 930
Alpha activity (pCi/L)	15 (DWS)	4.3	1.49 U	**1010**	**295**	11.2	9.3	9.68	1.26 U	2.68 U	5.36	**96.5**	9.24	10.3	3.15	2.07	4.43	0.515 U
Beta activity (pCi/L)	50 (DWS)	4.38	2.18	**241**	**59.1**	14.5	10.7	7.14	5.28	1.08 U	8.6	25.1	4.6	15.9	5.45	4.98	5.03	0.445 U
Tc-99 (pCi/L)	44,000 (DCS) 100,000 (DCG)	-3.15	0.756 U	60.3	41.2	2.23	5.37 U	-2.44 U	-2.12 U	-1.85 U	1.32 U	13.2	5.33 U	-1.41	-1.68	1.08	3.96 U	1.13 U
U-233/234 (pCi/L)	680 (DCS) 500 (DCG)	1.48	1.26	**584**	208	2.2	3.61	4.32	0.946	0.0429 U	2.65	**59**	4.24	0.818	1.08	0.399	2.23	0.553
U-235/236 (pCi/L)	720 (DCS) 600 (DCG)	0.0905	0.0925 U	48.8	14	0.178	0.232 U	0.484 U	0.294	0.0779 U	0.357 U	3.2	0.198 U	0.0475	0.048	0.709	0.131 U	0.317 U
U-238 (pCi/L)	750 (DCS) 600 (DCG)	2.92	0.762	354	42	0.807	1.17	2.89	0.753	0.089 U	0.983	36.7	2.6	0.482	1.1	0.222	2.94	0.565

Bold text indicates reference standard exceeded.

Reference standards sources are defined as follows:
DWS TDEC Rule 0400-40-03-.03, *Domestic Water Supply*

Reference standards for radionuclides equal Derived Concentration Standard (DCS) for ingested water (DOE-STD-1196-2011, *Derived Concentration Technical Standard*), and reference standards equal 4 percent of DCS values. Derived Concentration Guide (DCG) values for ingested water (DOE Order 5400.5 Chg. 2, Radiation Protection of the Public and the Environment, Chap. III) are also listed because they remain in effect for certain CERCLA activities. Reference standards for gross alpha and gross beta measurements correspond to national primary drinking water standards (40 CFR Part 141, *National Primary Drinking Water Regulations*, Subparts B and G).

Table 3.10. Radionuclides released to off-site waters from the ETTP storm water system in 2019

Isotope	^{234}U	^{235}U	^{238}U	^{99}Tc
Activity level (Ci)	0.031	0.0034	0.043	0.085

Table 3.11. Analytical results for radiological monitoring at Outfall 158

Parameter	Reference standard	Outfall 158 11/11/18	Outfall 158 12/20/18	Outfall 158 1/3/19	Outfall 158 2/12/19	Outfall 158 3/11/19	Outfall 158 4/9/19
Alpha activity (pCi/L)	15 (DWS)	**1010**	**103**	**594**	**617**	**354**	**241**
Beta activity (pCi/L)	50 (DWS)	**241**	34.4	**96.2**	**101**	**96.1**	**50.9**
^{99}Tc (pCi/L)	44,000 (DCS) 100,000 (DCG)	60.3	12.5	12.7	13.8	5.07 U	71.2
$^{233/234}$U (pCi/L)	680 (DCS) 500 (DCG)	584	52.2	364	305	210	150
$^{235/236}$U (pCi/L)	720 (DCS) 600 (DCG)	48.8	4.36	30.6	31.8	21.8	10.1
^{238}U (pCi/L)	750 (DCS) 600 (DCG)	354	32.4	224	193	134	91.1

Bold text indicates reference standard exceeded.

Reference standards sources are defined as follows:
DWS TDEC Rule 0400-40-03-.03, *Domestic Water Supply*

The precipitation pattern for the January 3, February 12, and March 11, 2019, samples greatly resembled the precipitation pattern for the elevated gross alpha/beta sample collected on November 11, 2018. All of these samples were collected at the end of a rainfall event that lasted for a period of several days, whereas the December 20 sample was collected after a fairly intense one-day rainfall event. From this information, it can be surmised that sustained rainfall events may be a primary cause for the elevated radiological results, and the rainfall events that come on quickly and dissipate quickly may be of lesser concern.

Outfall 362 drains an area to the west side of the K-25 Building. Historic activities in this area included degreasing and maintenance of process equipment, and the refilling of spent cascade trap material from the enrichment cascade. Water samples were collected at Outfall 362 on July 17, 2019, for a broad suite of parameters as a follow-up to a review of radiological soil samples previously collected from the legacy contamination area in the outfall's drainage watershed. The key water results are shown in Table 3.12; as noted above, several individual parameters exceeded the respective analyte DCS limits as well as contributed to the overall SOF exceedance. Follow up monitoring served to map the distribution of contamination within the drainage area. Soil removal actions began in late 2019, and in the interim measures were taken to minimize flow from these areas to Outfall 362, including plugging some drainage lines and constructing berms around some areas. Results of recent monitoring indicate that these measures have been successful in lowering the SOF at Outfall 362 to below the DCS limits. For information on additional monitoring conducted at the K-25 Building area, see Section 3.6.3.1 below.

Table 3.12. Analytes with DCS exceedances from 7/17/19 water sampling event at Outfall 362

Date	^{226}Radium (pCi/L)		^{230}Thorium (pCi/L)		$^{233/234}$Uranium (pCi/L)		235Uranium (pCi/L)		^{238}Uranium (pCi/L)		Uranium Total (pCi/L)
	Actual	DCS	Actual	DCS	Actual	DCS	Actual	DCS	Actual	DCS	
7/17/19	270	87	255	160	1570	660	182	720	1720	750	3472

Outfall 382 drained an area to the north of the K-131 and K-631 facilities. Monitoring in 2019 indicated several results that exceeded the DCS limits (Table 3.13). In response, demolition debris in the drainage area was removed, a layer of clean fill was placed over the area, and the storm drain was plugged, eliminating storm water discharges from Outfall 382. These measures eliminated the need to any further action at this location. For information on additional monitoring conducted at the K-131/K-631 area, see Section 3.6.3.3 below.

Table 3.13. Analytes with DCS exceedances from monitoring at Outfall 382

Date	$^{233/234}$Uranium (pCi/L)		^{238}Uranium (pCi/L)	
	Actual	DCS	Actual	DCS
7/23/19	3270	660	6980	750
7/23/19	3380	660	7030	750
8/8/19	599	660	1080	750
8/13/19	705	660	1480	750

3.6.3 Storm Water Monitoring Associated with D&D Activities

3.6.3.1 Monitoring Associated with the K-25 Building

Demolition of the K-25 Building was completed in CY 2014. The last section of the east wing that was demolished was contaminated with the radioactive isotope ^{99}Tc. Rain and dust control water that contacted the ^{99}Tc-contaminated piping and other building materials is believed to have caused the migration of ^{99}Tc into the soils beneath the east wing debris pile during the demolition. During CY 2019, contaminated soils in this area were excavated and transported to the Environmental Management Waste Management Facility (EMWMF) or at offsite facilities, depending upon the radiological levels, for disposal.

Sampling is conducted following each qualifying rainfall event during the phased excavation of the contaminated soils from the K-25 pad area. Storm water runoff monitoring will be performed for each qualifying rain event for the duration of the excavation activities, as well as for any potential post-excavation mitigation actions. A final monitoring event will occur at the conclusion of actions in this area.

Sampling was conducted as part of this D&D effort on numerous occasions during CY 2019. Analytical results are shown in Table 3.14.

Table 3.14. Results for the K-25 Building pad D&D monitoring

Sampling location	^{99}Tc (pCi/L)	$^{233/234}$U (pCi/L)	$^{235/236}$U (pCi/L)	^{238}U (pCi/L)
Reference standards	**44,000 pCi/L (DCS)** **100,000 pCi/L (DCG)**	**680 pCi/L (DCS)** **500pCi/L (DCG)**	**720 pCi/L (DCS)** **600 pCi/L (DCG)**	**750 pCi/L (DCS)** **600 pCi/L (DCG)**
Outfall 210 (9/26/18)	18.3	1.47	0.382	0.5985
Outfall 210 (1/24/19)	6.8 U	1.69	0.395	0.603
Outfall 210 (7/23/19)	15.2	2.04	0.203 U	1.03
Outfall 490 (9/26/18)	131	2.1	0.0263 U	0.471

Table 3.14. Results for the K 25 Building pad D&D monitoring (continued)

Sampling location	^{99}Tc (pCi/L)	$^{233/234}$U (pCi/L)	$^{235/236}$U (pCi/L)	^{238}U (pCi/L)
Outfall 490 (11/12/18)	132	1.35	0.1543 U	0.285 U
Outfall 490 (12/31/18)	230	2.06	0.5	0.585
Outfall 490 (1/24/19)	176	2.06	0.306	0.839
Outfall 490 (4/23/19)	126	1.38	0.129 U	0.357 U
Outfall 490 (5/13/19)	157	2.1	0.0856 U	0.574
Outfall 490 (7/24/19)	146	2.51	0.299 U	0.913
Outfall 490 (8/14/19)	301	1.33	0.223 U	0.414
Outfall 490 (8/26/19)	111	1.48	0.0669 U	0.453
Outfall 490 (10/28/19)	203	1.5	0.148 U	0.537
Outfall 490 (10/31/19)	73.8	1.16	0.136 U	0.212 U
Outfall 490 (12/23/19)	115	1.06	0.104 U	0.374
Sanitary Sewer Manhole 10 (9/25/18)	21.1	1.12	0.0554 U	0.178 U
Sanitary Sewer Manhole 10 (12/31/18)	30.6	1.48	0.253 U	0.775
Sanitary Sewer Manhole 10 (1/24/19)	13.7	1.08	0.0759 U	0.273 U
Sanitary Sewer Manhole 10 (4/23/19)	36.5	0.513	0.0288 U	0.316 U
Sanitary Sewer Manhole 10 (5/13/19)	29.6	1.02	0.0355 U	0.668
Sanitary Sewer Manhole 10 (7/24/19)	26.9	0.792 U	0.0568 U	0.568 U
Sanitary Sewer Manhole 10 (8/14/19)	26.4	0.454	0.0733 U	0.268 U
Sanitary Sewer Manhole 10 (8/26/19)	26.4	0.199 U	0.125 U	0.116 U
Sanitary Sewer Manhole 10 (10/28/19)	15.6	0.916	0.0663 U	0.45
Sanitary Sewer Manhole 10 (10/31/19)	19.9	0.614	0.0783 U	0.308
Sanitary Sewer Manhole 10 (12/23/19)	13.2	0.859	0.0905 U	0.288
Sanitary Sewer Manhole 92 (9/26/18))	35.9	-0.00582 U	-0.057 U	-0.057 U
Sanitary Sewer Manhole 92 (12/31/18)	216	2.23	0.332 U	0.864
Sanitary Sewer Manhole 92 (1/24/19)	220	2.31	0.0548 U	0.868
Sanitary Sewer Manhole 92 (4/23/19)	86.2	0.198 U	0.0159 U	0.0486 U
Sanitary Sewer Manhole 92 (5/13/19)	39	0.257 U	0.0407 U	0.161 U
Sanitary Sewer Manhole 92 (7/23/19)	294	0.74 U	0.373 U	0.278 U
Sanitary Sewer Manhole 92 (8/14/19)	30.2	0.137 U	0.12 U	0.111 U
Sanitary Sewer Manhole 92 (8/26/19)	16.2	0.135 U	0.0398 U	0.159 U
Sanitary Sewer Manhole 92 (10/28/19)	0.391 U	0.0839 U	0.0197 U	0.118 U
Sanitary Sewer Manhole 92 (10/31/19)	18.5	0.749	0.0723 U	0.434
Sanitary Sewer Manhole 92 (12/23/19)	6.15 U	0.492	0.0344 U	0.112

Reference standards for radionuclides equal Derived Concentration Standard (DCS) for ingested water (DOE-STD-1196-2011, *Derived Concentration Technical Standard*), and reference standards equal 4 percent of DCS values. Derived Concentration Guide (DCG) values for ingested water (DOE Order 5400.5 Chg. 2, *Radiation Protection of the Public and the Environment,* Chap. III) are also listed because they remain in effect for certain CERCLA activities. Reference standards for gross alpha and gross beta measurements correspond to national primary drinking water standards (40 CFR Part 141, *National Primary Drinking Water Regulations,* Subparts B and G).

Acronym: D&D = decontamination and decommissioning

Based on these results, it appears that efforts to prevent the migration of ^{99}Tc from the K-25 Building pad D&D area into the storm drain system and the sanitary sewer system have been successful. Additional monitoring will be conducted during qualifying rainfall events for the duration of D&D activities at the K-25 Building pad. Remediation of the area is expected to be completed in early CY 2020.

To collect data that is to be reported in the RER and the ASER, and to collect data that can be compared to information that is being gathered by TDEC on an ongoing basis, a sample for ^{99}Tc is collected at Outfall 190 each time a quarterly mercury sample is collected at this outfall. The analytical data from this sample will assist in determining if groundwater contaminated with ^{99}Tc from the K-25 D&D project could be migrating toward the Outfall 190 drainage area and discharging into Mitchell Branch via Outfall 190. Table 3.15 contains analytical data from CY 2017 through part of CY 2019 for this monitoring effort.

As shown in Table 3.15, the storm water results for the Mitchell Branch watershed area indicate that ^{99}Tc was not detected in samples collected at Outfall 190 during sampling conducted in CY 2018 or CY 2019. Based on this data, it does not appear that ^{99}Tc-contaminated groundwater from the K-25 Building D&D project is discharging to Mitchell Branch via storm water Outfall 190.

The cumulative radionuclide measurements at the Mitchell Branch exit weir K-1700 location are calculated to be less than 1 percent of the DCS SOF values. The maximum ^{99}Tc measurement at K-1700 in 2019 was 19.8 pCi/L (Figure 3.18), which is orders of magnitude below the ^{99}Tc DCS value of 44,000 pCi/L. For further information on radiologic monitoring along Mitchell Branch, see Section 3.6.8.

Table 3.15. Results from quarterly ^{99}Tc monitoring at Outfall 190

	1/9/18	4/26/18	7/10/18	10/15/18	1/17/19	4/2/19	7/18/19	11/14/19
pCi/L	8.12 U	7.44 U	1.07 U	6.38 U	5.8 U	3.95 U	2.69 U	7 U

Reference standards for radionuclides equal Derived Concentration Standard (DCS) for ingested water (DOE-STD-1196-2011, *Derived Concentration Technical Standard*) of 44,000 pCi/L. Derived Concentration Guide (DCG) values for ingested water (DOE Order 5400.5 Chg. 2, *Radiation Protection of the Public and the Environment,* Chap. III) of 100,000 pCi/L is also listed because they remain in effect for certain CERCLA activities. Reference standards for gross alpha and gross beta measurements correspond to national primary drinking water standards (40 CFR Part 141, *National Primary Drinking Water Regulations,* Subparts B and G).

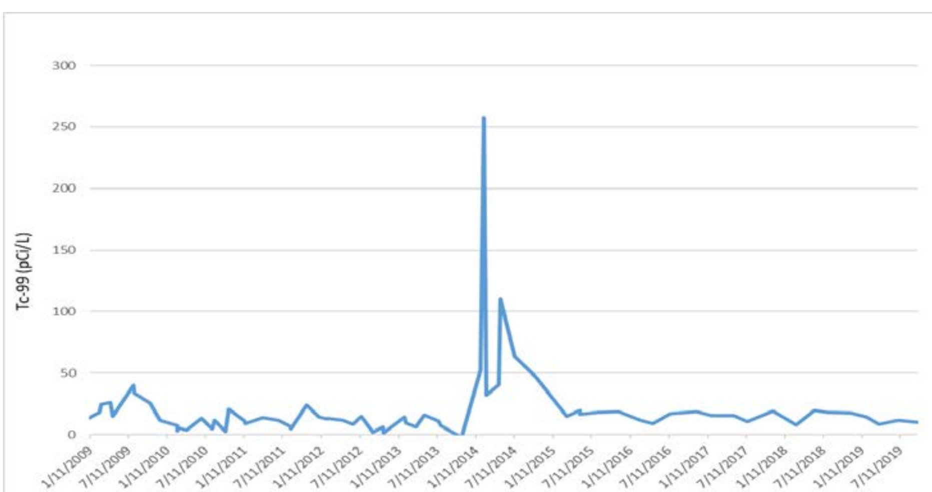


Figure 3.18. Tc-99 levels at K-1700 Weir

3.6.3.2 Monitoring Associated with the K-31/K-33 Area

The K-31 parcel (46.8 acres) was made available by DOE EM for transfer to CROET. CNS leased the property before the start of construction for the UPF/Mechanical Electrical Building. As part of the lease of the K-31 area to CNS, and in an effort to determine the feasibility of leasing other portions of the K-31/K-33 area, each of the outfalls that are located in the K-31/K-33 area were considered to determine whether they should be sampled as part of the investigation of storm water discharges from the area. In order to determine if storm water outfalls in the K-31/K-33 area could be removed from the ETTP NPDES permit as part of the transfer of the property to CNS, sampling was performed in CY 2018 at outfalls within the drainage areas of these building footprints to obtain current analytical information. In CY 2019, follow-up sampling was performed at several outfalls where reference standards were exceeded as part of the CY 2018 sampling effort. Table 3.16 contains information on the analytical results collected from the K-31/K-33 area storm water outfalls that exceeded reference standards as part of the ETTP SWPP Program sampling effort.

Table 3.16. Analytical results exceeding reference standards from the K-31/K-33 area monitoring

Location	Lead	Mercury	Hexavalent chromium	PCB-1254
	Reference standard 2.5 µg/L (CCC) 65 µg/L (CMC)	Reference standard 0.051 µg/L (REC OO and REC WO)	Reference standard 11 µg/L (CCC) 16 µg/L (CMC)	Reference standard 0.00064 µg/L (REC OO and REC WO)
Outfall 590	—	—	23	—
Outfall 690	—	—	—	0.0464
Manhole 6014 (part of Outfall 510)	5.43	—	—	—

Reference standards sources are defined as follows:
CCC TDEC Rule 0400-40-03-.03(3)(g), *Criterion Continuous Concentration*
CMC TDEC Rule 0400-40-03-.03(3)(g), *Criterion Maximum Concentration*
REC OO TDEC Rule 0400-40-03-.03(4)(j), *Organisms Only Criteria*
REC WO TDEC Rule 0400-40-03-.03(4)(j), *Water & Organisms Criteria*

As a result of this investigation, some outfalls were plugged and abandoned and removed from the NPDES permit (Outfalls 510 and 590), and one (Outfall 690) was slated for further investigation.

3.6.3.3 Monitoring Associated with the Demolition of Support Facilities

The J-Laboratory Complex, also known as "J-Labs," consists of Bldgs. K-1004-J, K-1004-Q, K-1004-R, K-1004-S, K-1004-T, K-1004-U, K-797 (including the K-700-A-57 substation), and the K-1005 office area. Outfall 100 receives storm water drainage from the J-Lab/K-1023 area.

Sampling was performed at Outfall 100 on August 13, 2019, prior to the initiation of D&D activities at the J-Lab facilities and Building K-1023. Analytical results that exceeded reference standards for this sampling event are shown in Table 3.17.

Additional sampling was performed during J-Lab/K-1023 D&D activities and after all D&D and waste cleanup activities had been concluded. Sampling was performed on October 31 and on December 23, 2019. None of the analytical results exceeded reference standards for these sampling events.

Initial D&D activities such as transite removal, etc. were initiated at building K-1037 in January 2019. Demolition of the building began in February 2019 and was completed in July 2019. Removal of the building's concrete slab and placement of topsoil and seed were completed in October 2019. Storm water runoff sampling before, during, and after demolition of K-1037 was conducted at Outfalls 150 and 170, which are the major outfalls that drain this area.

Table 3.17. Analytical results exceeding reference standards from pre-D&D J-Lab/Building K-1023 monitoring

Location	Copper	Lead	PCB-1248	PCB-1254
	Reference standard 9 µg/L (CCC) 13 µg/L (CMC)	Reference standard 2.5 µg/L (CCC) 65 µg/L (CMC)	Reference standard 0.00064 µg/L (REC OO and REC WO)	Reference standard 0.00064 µg/L (REC OO and REC WO)
Outfall 100	2.55	0.25	0.116	2.55

Reference standards sources are defined as follows:
CCC TDEC Rule 0400-40-03-.03(3)(g), *Criterion Continuous Concentration*
CMC TDEC Rule 0400-40-03-.03(3)(g), *Criterion Maximum Concentration*
REC OO TDEC Rule 0400-40-03-.03(4)(j), *Organisms Only Criteria*
REC WO TDEC Rule 0400-40-03-.03(4)(j), *Water & Organisms Criteria*

On February 7, 2019, baseline pre-demolition samples were collected at Outfalls 150 and 170. Sampling was performed on April 22, and May 13, 2019, during demolition of Building K-1037. Additionally, sampling was performed on July 23, 2019, after D&D activities at Building K-1037 had been completed. Sampling was conducted on August 14, 2019, before the removal of the K-1037 building slab was initiated. No contaminants were identified at concentrations exceeding reference standards in samples collected on February 7, 2019, before D&D activities at Building K-1037 began. The analytical results indicate that several metals were present in the discharges from Outfalls 150 and 170 during the demolition of Building K-1037, which could indicate possible issues with the storm water controls used during D&D activities. Other than the presence of copper and lead at levels just above the reference standards, no contaminants were observed in samples from Outfalls 150 and 170 that were collected after the completion of D&D activities at Building K-1037.

Although the K-1037 structure was removed during D&D activities that were completed in July 2019, the building slab was left in place for a future remedial action. Subsequent sampling at Outfalls 150 and 170 was conducted after each qualifying rainfall event as part of the K-1037 slab removal work, which was completed in October 2019. Analytical results that exceeded reference standards for this monitoring are shown in Table 3.18.

Table 3.18. Results over reference standards for the K-1037 D&D monitoring

Sampling location	Copper	Lead	Mercury	Thallium
Reference standards	**9 µg/L (CCC) 13 µg/L (CMC**	**2.5 µg/L (CCC) 65 µg/L (CMC)**	**51 ng/L (REC OO)**	**0.47 µg/L (REC OO) 0.24 µg/L (REC WO)**
Outfall 150—2/7/19	—	—	—	—
Outfall 150—4/22/19	---	—	63.3	—
Outfall 150—5/13/19	---	—	—	—

Table 3.18 Results over reference standards for the K 1037 D&D monitoring (continued)

Sampling location	Copper	Lead	Mercury	Thallium
Outfall 150—7/23/19	---	—	—	—
Outfall 150—8/14/19	11.1	4.09	—	0.657
Outfall 150—10/22/19	---	---	---	---
Outfall 170—2/7/19	—	—	—	—
Outfall 170—4/22/19	10.7	—	—	—
Outfall 170—5/13/19	---	—	—	—
Outfall 170—7/23/19	—	—	—	—
Outfall 170—8/14/19	—	—	—	—
Outfall 170—8/26/19	—	—	—	1.15
Outfall 170—10/22/19	---	---	---	---

Reference standards sources are defined as follows:
CCC TDEC Rule 0400-40-03-.03(3)(g), *Criterion Continuous Concentration*
CMC TDEC Rule 0400-40-03-.03(3)(g), *Criterion Maximum Concentration*
DWS TDEC Rule 0400-40-03-.03, *Domestic Water Supply*
FISH TDEC Rule 0400-40-03-.03(3)(a), (b), and (e)
REC OO TDEC Rule 0400-40-03-.03(4)(j), *Organisms Only Criteria*
REC WO TDEC Rule 0400-40-03-.03(4)(j), *Water & Organisms Criteria*
Permit NPDES Permit TN0002950, Part III
No Criteria Sources not listed in the TDEC General Water Quality Criteria or NPDES Permit No. TN0002950
Reference standards for radionuclides equal Derived Concentration Standard (DCS) for ingested water (DOE-STD-1196-2011, *Derived Concentration Technical Standard*), and reference standards equal 4 percent of DCS values. Derived Concentration Guide (DCG) values for ingested water (DOE Order 5400.5 Chg. 2, *Radiation Protection of the Public and the Environment,* Chap. III) are also listed because they remain in effect for certain CERCLA activities. Reference standards for gross alpha and gross beta measurements correspond to national primary drinking water standards (40 CFR Part 141, *National Primary Drinking Water Regulations,* Subparts B and G).

Removal of the K-1232 building slab, as well as other building slabs in the area (e.g., K-413, K-1131) will be completed in CY 2020. Storm water runoff sampling began in 2018 and will be conducted at Outfall 380 as part of these remedial action activities in accordance with the FY 2020 ETTP SWPPP Sampling and Analysis Plan (SAP) (UCOR-4028/R9) (Table 3.19).

Table 3.19. Results over reference standards for the K-1232 D&D monitoring

Sampling location	Lead	Mercury	Selenium	Gross alpha radiation
Reference standards	**2.5 µg/L (CCC) 65 µg/L (CMC)**	**51 ng/L (REC OO)**	**3.1 µg/L (CCC)**	**15 pCi/L (DWS)**
Outfall 380—8/20/18	28.2	119	—	—
Outfall 380—2/12/19	—	—	—	15.5
Outfall 380—7/23/19	4.87	—	10.3	—

Reference standards sources are defined as follows:
CCC TDEC Rule 0400-40-03-.03(3)(g), *Criterion Continuous Concentration*
CMC TDEC Rule 0400-40-03-.03(3)(g), *Criterion Maximum Concentration*
DWS TDEC Rule 0400-40-03-.03, *Domestic Water Supply*
REC OO TDEC Rule 0400-40-03-.03(4)(j), *Organisms Only Criteria*

Building K-1423 operated from 1969 until 1986 as a Toll Enrichment Facility, which involved the transfer of liquefied uranium hexafluoride (UF_6) product from 10- and 14-ton cylinders into 2.5-ton privately owned cylinders. Storm water Outfall 200 receives storm water drainage from the K-1423 area**.**

Samples were collected at Outfall 200 on August 13, 2019, prior to the initiation of D&D activities. Analytical results that exceeded reference standards are shown in Table 3.20.

Table 3.20. Analytical results exceeding reference standards from pre-D&D Building K-1423 D&D monitoring

	Copper	Lead	Zinc	PCB-1260
Location	**Reference standard 9 µg/L (CCC) 13 µg/L (CMC)**	**Reference standard 2.5 µg/L (CCC) 65 µg/L (CMC)**	**Reference standard 120 µg/L (CCC) 120 µg/L (CMC)**	**Reference standard 0.00064 µg/L (REC OO and REC WO)**
Outfall 200	36.4	11.5	130	0.344

Reference standards sources are defined as follows:
CCC TDEC Rule 0400-40-03-.03(3)(g), *Criterion Continuous Concentration*
CMC TDEC Rule 0400-40-03-.03(3)(g), *Criterion Maximum Concentration*
REC OO TDEC Rule 0400-40-03-.03(4)(j), *Organisms Only Criteria*
REC WO TDEC Rule 0400-40-03-.03(4)(j), *Water & Organisms Criteria*

D&D of Building K-1423 was completed on August 16, 2019. A final monitoring event was conducted on October 30, 2019, at the conclusion of demolition, waste handling, and any potential post-demolition mitigation actions. Analytical results that exceeded reference standards are shown in Table 3.21.

Table 3.21. Analytical results exceeding reference standards from K-1423 post-D&D monitoring

	Copper	Lead	PCB-1254
Reference Standards[a]	**Reference standard 9 µg/L (CCC) 13 µg/L (CMC)**	**Reference standard 2.5 µg/L (CCC) 65 µg/L (CMC)**	**Reference standard 0.00064 µg/L (REC OO and REC WO)**
Outfall 200	9.25	6.34	0.0488 J

[a] Reference standards sources are defined as follows:
CCC TDEC Rule 0400-40-03-.03(3)(g), *Criterion Continuous Concentration*
CMC TDEC Rule 0400-40-03-.03(3)(g), *Criterion Maximum Concentration*
REC OO TDEC Rule 0400-40-03-.03(4)(j), *Organisms Only Criteria*
REC WO TDEC Rule 0400-40-03-.03(4)(j), *Water & Organisms Criteria*

The EU-19 area encompasses the former K-1410 building area, the former K-1410 neutralization pit, the former K-1410-B Effluent Treatment Facility, the former K-1031 building area, and the gravel, soil, and paved areas in the vicinity of where these structures were once located. The EU-19 area receives storm water runoff from Outfalls 350, 360, and 362.

Remedial actions for the EU-19 area began in late summer of CY 2019. Samples were collected from Outfall 362 on July 17, 2019, to provide background information on discharges from the area. Analytical results from samples taken at Outfall 362 indicate the presence of mercury and PCBs at levels exceeding water quality criteria, as well as elevated levels of several radiological contaminants. These results are shown in Table 3.22.

Table 3.22. Analytical results exceeding reference standards as part of the Outfall 362/EU-19 monitoring

Location	**Nickel** Reference standards 52 µg/ (CCC) 470 µg/L CMC)	**Copper** Reference standards 9 µg/ (CCC) 13 µg/L CMC)	**Lead** Reference standards 2.5 µg/ (CCC) 65 µg/L CMC)	**Mercury** Reference standards 21 µg/ (CCC) 51 ng/L CMC)	**Selenium** Reference standards 3.1 µg/ (CCC) 20 µg/L (CMC)	**Gross alpha radiation** Reference standard 15 pCi/L (DWS)	**Gross beta radiation** Reference standard 50 pCi/L (DWS)	**U-233/234** Reference standard 680 pCi/L (DCS) 500 pCi/L (DCG)	**U-235/236** Reference standard 720 pCi/L (DCS) 600 pCi/L (DCG)	**U-238** Reference standard 750 pCi/L (DCS) 600 pCi/L (DCG)	**Radium-226** Reference standard 87 pCi/L (DCS) 100 pCi/L (DCG)	**Thorium-230** Reference standard 160 pCi/L (DCS) 300 pCi/L (DCG)	**PCB-1254** Reference standards 0.00064 µg/L (REC OO and REC WO)	**PCB-1260** Reference standards 0.00064 µg/L (REC OO and REC WO)
Outfall 362	59.9	54.1	9.86	60.8	9.25	5100	1920	1570	182	1720	270	255	0.852	0.193

Reference standards sources are defined as follows:
CCC TDEC Rule 0400-40-03-.03(3)(g), *Criterion Continuous Concentration*
CMC TDEC Rule 0400-40-03-.03(3)(g), *Criterion Maximum Concentration*
DWS TDEC Rule 0400-40-03-.03, *Domestic Water Supply*
REC OO TDEC Rule 0400-40-03-.03(4)(j), *Organisms Only Criteria*
REC WO TDEC Rule 0400-40-03-.03(4)(j), *Water & Organisms Criteria*
Reference standards for radionuclides equal Derived Concentration Standard (DCS) for ingested water (DOE-STD-1196-2011, *Derived Concentration Technical Standard*), and reference standards equal 4 percent of DCS values. Derived Concentration Guide (DCG) values for ingested water (DOE Order 5400.5 Chg. 2, *Radiation Protection of the Public and the Environment,* Chap. III) are also listed because they remain in effect for certain CERCLA activities. Reference standards for gross alpha and gross beta measurements correspond to national primary drinking water standards (40 CFR Part 141, *National Primary Drinking Water Regulations,* Subparts B and G).

Each of the analytical results from samples collected at Outfall 362 that exceeded reference standards is believed to have been a result of legacy operations conducted at Building K-1410 and associated facilities. Results of the radiologic monitoring are discussed in Section 3.6.2.2 above. There are three pipes—a 6-in. diameter pipe, an 8-in. diameter pipe, and a 36-in. diameter pipe—that discharge storm water from the area drained by the Outfall 362 drainage system.

From this information, it was determined that the 8-in. pipe was likely a contaminated process pipe that storm water had entered through infiltration. The 36-in. pipe received relatively uncontaminated storm water runoff from area building slabs, pavement, and gravel areas. The 6-in. line may have also been a process line from K-1410. The larger drainage area that discharges to the 36-in. pipe results in a much greater discharge from this pipe that from the smaller pipes. This dilution of the flows from the smaller pipes is evident in the lower analytical results indicated in the Outfall 362 combined flow samples.

For CY 2019, the SOF result for Outfall 362 was 5.07 (primarily associated with ^{234}U, ^{238}U, ^{230}thorium [^{230}Th], ^{226}radium [^{226}Ra]), exceeding the SOF administrative limit of 1.0. The discharge of radiological contaminants from Outfall 362 were routinely communicated to DOE throughout the CY 2019 annual period.

Also in association with the EU-19 soil removal action, background samples were collected at Outfalls 350 and 360, which receive runoff from the northernmost portion of the EU-19 area. Samples were collected at Outfall 350 on October 22, 2019. Analytical results that exceeded reference standards are shown in Table 3.23. Soil removal work is ongoing in the Outfall 350 drainage area. These analytical results were considered during the planning of soil removal activities in this area.

Table 3.23. Analytical results exceeding reference standards from monitoring at Outfall 350

Reference Standard[a]	Gross Alpha Activity
	15 pCi/L (DWS)
Outfall 350	190

Reference standards sources are defined as follows:
DWS TDEC Rule 0400-40-03-.03, *Domestic Water Supply*

Monitoring was conducted at Outfall 360 on October 22, 2019. Analytical results that exceeded reference standards are shown in Table 3.24.

Table 3.24. Analytical results exceeding reference standards from monitoring at Outfall 360

Reference Standard[a]	Gross Alpha Activity
	15 pCi/L (DWS)
Outfall 360	23

Reference standards sources are defined as follows:
DWS TDEC Rule 0400-40-03-.03, *Domestic Water Supply*

The Outfall 360 drainage area has been recontoured to promote sheet flow and eliminate discharges from the Outfall 360 piping system. Since discharges from Outfall 360 have been eliminated, permission will be sought from TDEC to remove the outfall from the ETTP NPDES permit coverage.

Monitoring of Outfall 382 in 2019 produced a single result for nickel that exceeded the NPDES permit limit of 500 µg/L, and that was more than 10 times higher than previous results. In response, demolition debris in the drainage area was removed, a layer of clean fill was placed over the area, and the storm drain was plugged, eliminating storm water discharges from Outfall 382. These measures eliminated the need to any further action at this location.

3.6.3.4 Mercury Monitoring Conducted as Part of the Previous NPDES Permit

As part of the previous NPDES permit compliance program, mercury was sampled on a quarterly basis at Outfalls 05A, 180, and 190. These locations were selected because information gathered as part of the permit application process indicated that mercury levels at these outfalls occasionally exceeded the Ambient Water Quality Criterion (AWQC) level of 51 ng/L. Outfalls 180 and 190 collect storm water from large areas on the north side of ETTP and discharge to Mitchell Branch. Outfall 05A was the discharge point for the former K-1203-10 overflow sump. This sump, which was part of the K-1203 STP, collected storm water runoff from a large portion of the K-1203 area and discharged it into Poplar Creek on the east side of ETTP. Final D&D actions, including the filling of the Imhoff tanks and the K-1203-10 sump, removal of the sludge drying beds, and final filling and contouring of the K-1203-STP area, were completed in 2019. Storm water runoff and storm water and groundwater infiltration from the K-1203 area has been rerouted to the former discharge pipe formerly used by the K-1203 STP for the discharge of treated effluent into Poplar Creek. This pipe is located approximately 50 yd south of the location of the former Outfall 05A. Outfall 05A now discharges by gravity flow rather than the discharge being pumped by a lift pump. Table 3.25 contains analytical data from monitoring for mercury at Outfalls 180, 190, and 05A from CY 2018 through CY 2019.

The current NPDES permit no longer requires quarterly mercury monitoring. However, to continue collecting data for the analysis of trends in mercury discharges from these outfalls, quarterly mercury monitoring was conducted as part of the ETTP SWPP Program.

Table 3.25. Quarterly NPDES/SWPP Program mercury monitoring results, CY 2018 through CY 2019

Sampling location	1st Quarter CY 2018 (ng/L)	2nd Quarter CY 2018 (ng/L)	3rd Quarter CY 2018 (ng/L)	4th Quarter CY 2018 (ng/L)	1st Quarter CY 2019 (ng/L)	2nd Quarter CY 2019 (ng/L)	3rd Quarter CY 2019 (ng/L)	4th Quarter CY 2019 (ng/L)
Outfall 180	28.4	**235**	33.5	61	23.9	27.7	**157**	48.7
Outfall 190	39.1	29.1	23.2	15.5	11.9	17.6	16	11.6
Outfall 05A	**68.4**	**87.3**	**232**	**333**	**211**	**217**		**

Results in **bold** exceed the reference standard for mercury (51 ng/L).

Outfalls 180 and 190 are two of the major outfalls that contribute flow to Mitchell Branch. Because the discharges from Outfalls 180 and 190 routinely contain mercury at levels above screening criteria, these outfalls are thought to be the major contributors of mercury to Mitchell Branch as well. Mitchell Branch mercury levels are monitored routinely at the K-1700 weir as part of the ETTP Environmental Monitoring Program. Please note that Figures 3-19 and 3-20 indicate results from the quarterly monitoring performed at Outfalls 180 and 190, respectively, as well as other SWPP Program sampling that was conducted at the outfall during the period covered by these graphs. Figure 3.21 shows mercury levels at the K-1700 Weir from CY 2010 through CY 2019 (For additional information on monitoring along Mitchell Branch, see Section 3.6.8).

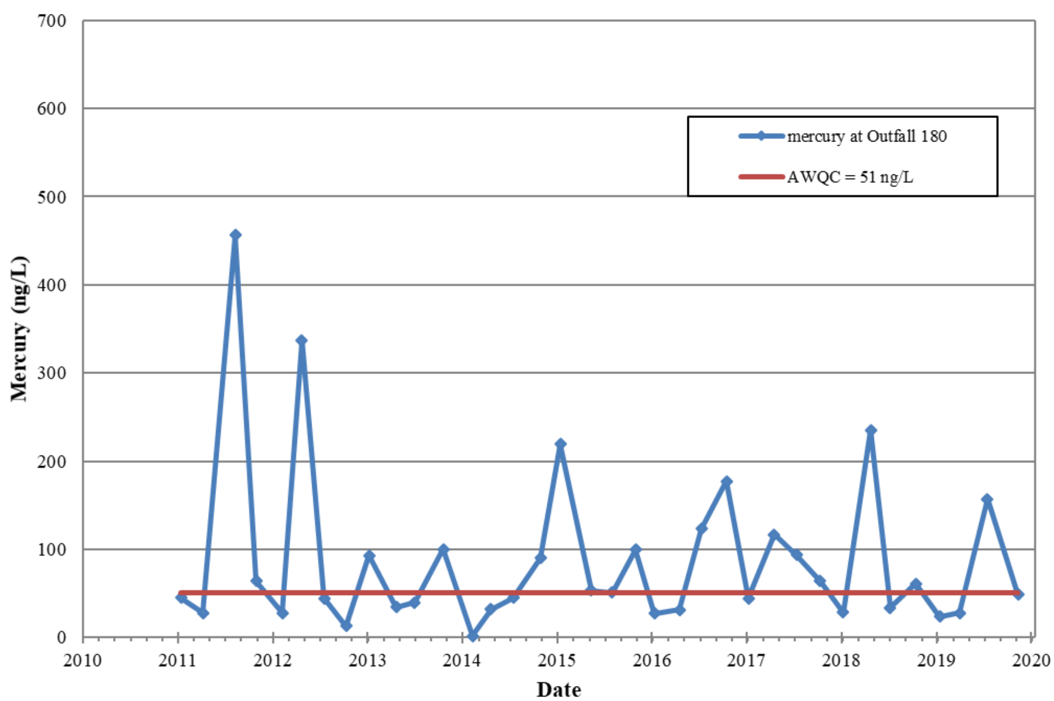


Figure 3.19. Mercury concentrations at Outfall 180

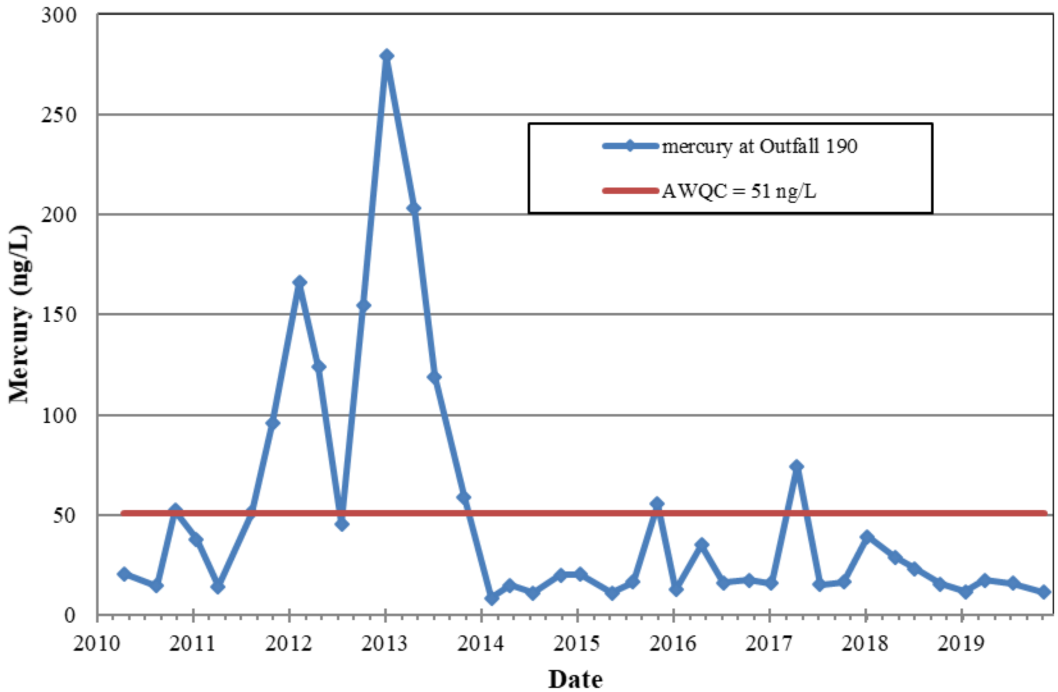


Figure 3.20. Mercury concentrations at Outfall 190

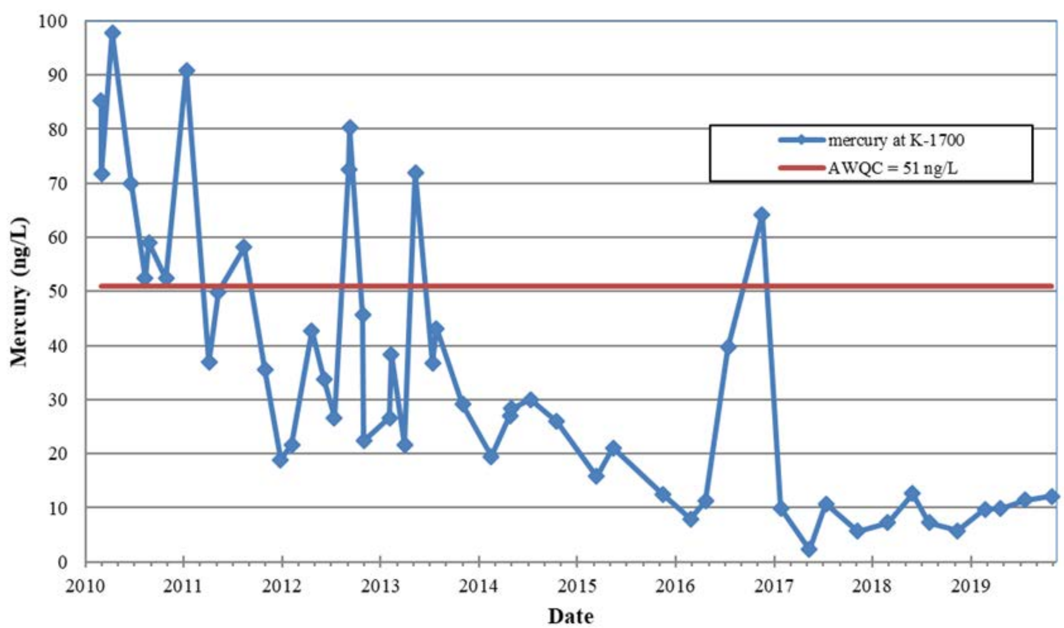


Figure 3.21. Mercury concentrations at the K-1700 Weir

Storm water Outfall 05A once drained portions of the former K-1203 STP that discharged into the K-1203-10 sump. The D&D of the K-1203 STP was completed in 2019. Figure 3.22 shows mercury concentrations at storm water Outfall 05A from CY 2010 through CY 2019. No mercury sample was collected at Outfall 05A during the fourth quarter of CY 2019 due to remedial activities being conducted in the outfall watershed.

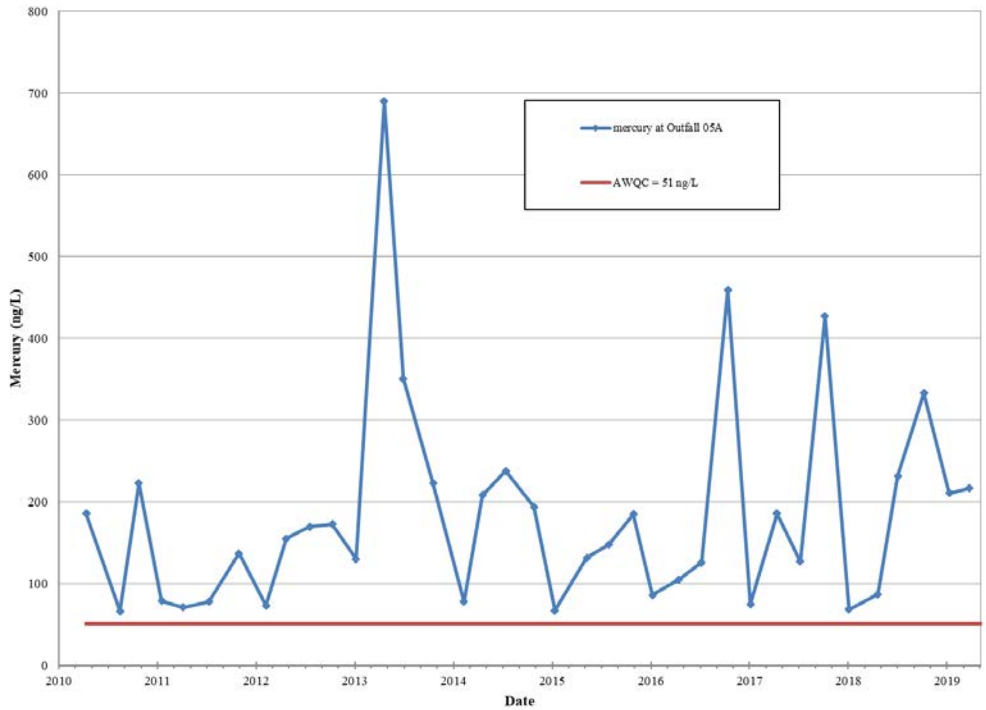


Figure 3.22. Mercury concentrations at Outfall 05A

3.6.3.5 PCB Monitoring at ETTP Storm Water Outfalls

An evaluation of PCB data collected as part of the ETTP SWPP Program from CY 2000 to the present was performed to identify locations where PCBs have been detected at storm water outfall locations. Non representative outfalls that have been grouped with representative outfalls where PCBs have been identified and have not been sampled in several years were selected to be sampled as part of the ETTP SWPP monitoring program.

PCB 1260 was detected at a concentration of 0.45 µg/L in samples collected from Outfall 830 in March 2019. Outfall 830 receives storm water runoff from the area where the K-734 building was once located. Building K-734 was constructed in 1944 and served as a pumphouse for the Fercleve S-50 Thermal Diffusion Plant. The mechanism for PCBs entering this drainage system and discharging through Outfall 830 is currently unknown.

Analytical PCB data collected as part of the storm water monitoring effort will be used to provide information for evaluating cleanup decisions and to measure the effectiveness of RAs.

Over the past several years, detectable PCBs (PCB 1254) have been noted in analytical data from Outfall 690. As part of the ETTP SWPP Program, an investigation was conducted in an effort to determine where and how PCBs may have entered this drainage system, where ongoing sources of PCBs may be located within this drainage system, and what to do about addressing the PCB concern at this outfall. This investigation involved the collection of samples from several locations in the northeast corner and along the entire eastern side of the former K-33 building area (catch basins 6093, 1032, and 1B024).Samples were collected on April 8, 2019. No PCBs were identified in samples collected from Catch Basins 6093 or 1032. No flow was detected in Catch Basin 1B024. There were also no PCBs detected in the sample from Outfall 690. However, a sample collected on November 6, 2018, indicated that PCB 1254 was present at a concentration of 0.464 µg/L.

Because no PCBs were identified in the Outfall 690 drainage network, and PCBs have been identified at Outfall 690 as part of another sampling effort, it is speculated that the source of the PCBs at Outfall 690 is likely the K-897-A oil/water separator. Because the DOE EM mission has been completed in the area drained by Outfall 690, this outfall has been recommended for removal from the ETTP NPDES permit. Final RAs for the ETTP oil/water separators is currently being discussed.

3.6.3.6 Investigative Monitoring of the K-720 Coal Ash Pile and Powerhouse Areas

A total of 5.97 million tons of coal were burned at the K-701 Powerhouse during its operation from 1944–1962. Bottom ash, coal fines, slag, and other by-products of coal combustion were buried at the K-720 coal ash pile. The K-720 coal ash pile is approximately 9 acres in size. In the mid-1990s, the coal ash pile was spread out, covered with soil, limed, and seeded.

In order to collect additional information on the effectiveness of the RAs taken in the K-720 coal ash pile area in the past, as well as to provide additional information to help in determining the long-term actions to be taken at this location in the future, additional monitoring was conducted as part of the ETTP SWPP Program. Table 3.26 provides results of metals that exceeded reference standards during monitoring in the Outfall 992 drainage system in April 2019.

Table 3.26. Analytical results exceeding reference standards from the Outfall 992 drainage area monitoring

Location	Cadmium	Selenium	Thallium
	Reference standard 0.72 µg/L (CCC) 1.8 µg/L (CMC)	Reference standard 3.1 µg/L (CCC) 20 µg/L (CMC)	Reference standard 0.47 µg/L (REC OO) 0.24 µg/L (REC WO)
Outfall 992	1.31	—	9.08
992-3	1.17	—	5.56
992-4	—	—	—
992-8	—	—	6.09
992-9	—	9.53	11.1
K-702-A Slough	1.15	—	6.58

Reference standards sources are defined as follows:
CCC TDEC Rule 0400-40-03-.03(3)(g), *Criterion Continuous Concentration*
CMC TDEC Rule 0400-40-03-.03(3)(g), *Criterion Maximum Concentration*
REC OO TDEC Rule 0400-40-03-.03(4)(j), *Organisms Only Criteria*
REC WO TDEC Rule 0400-40-03-.03(4)(j), *Water & Organisms Criteria*

Due to the elevated metals results indicated at Outfall 992 in the initial sampling effort, a follow-up sample for metals was collected on August 27, 2019. Table 3.27 shows the analytical results that exceeded reference standards as part of this follow-up monitoring.

Table 3.27. Analytical results exceeding reference standards from the Outfall 992 follow-up sampling effort

Location	Arsenic Reference standard 10.0 µg/L (REC OO and REC WO)
Outfall 992	16.6

Reference standards sources are defined as follows:
REC OO TDEC Rule 0400-40-03-.03(4)(j), Organisms Only Criteria
REC WO TDEC Rule 0400-40-03-.03(4)(j), Water & Organisms Criteria

Several alternatives have been developed for the long-term remediation and management of the K-720 fly ash pile, including:

1. Replace the existing soil cover with an engineered cover designed in accordance with TDEC requirements.
2. Upgrade the existing vegetated cap and institute long-term land use controls for the area
3. Remove the fly ash and the existing cap and dispose of the materials in ORRLF.
4. Continue present maintenance activities on the existing cap and take no further actions.

A review of analytical data from storm water outfalls in the Powerhouse Area performed in early 2019 revealed several gaps in information that needed to be addressed if portions or all of the Powerhouse Area are turned over to CROET for potential lease or transfer to industrial interests. Because reference standard exceedances have been observed in historical analytical data from some of the outfalls, sampling was performed to determine if the outfalls might continue to be an ongoing source of contaminants.

A private company specializing in wood products has leased a portion of the Powerhouse Area drained by Outfall 780. Samples collected at Outfall 780 in March 2018 contained legacy mercury above the reference standards as well as elevated levels of legacy PCBs. These materials appear to be legacy contaminants unrelated to the operations of the current leasee. In an effort to identify where potential source(s) of these legacy contaminants may be entering the Outfall 780 drainage system, follow-up sampling was conducted in March 2019. Mercury and PCB samples were collected at Outfall 780 and from two locations upstream of the end of the pipe in an effort to isolate any potential sources of legacy mercury and legacy PCBs entering this system. Analytical parameters from the 2018 and 2019 sampling efforts that exceeded reference standards are indicated in Table 3.28.

Several legacy contaminants were noted at levels above AWQC levels at Outfall 780 and in its drainage network as part of the March 2019 sampling effort. Copper and lead were noted in discharges from the outfall. Mercury, PCB 1254, PCB 1260, gross alpha radiation, gross beta radiation, $^{233/234}U$, and ^{238}U were noted in samples collected upstream from Outfall 780 in the outfall's drainage system.

The mercury, PCBs, and radiological analytes are likely to be legacy contaminants that remain from past Powerhouse operations that were conducted in the drainage area of Outfall 780. Analytical data collected over the past 20 years also indicate the presence of levels of PCBs, metals, mercury, and radiological parameters exceeding AWQC levels in discharges from Outfall 780.

Because levels of several contaminants of concern have been noted in discharges from this outfall, it was determined that Outfall 780 should be proposed for monitoring as a potential representative outfall.

Sampling will be conducted as part of the FY 2020 ETTP SWPP Program for the parameters needed to complete an EPA 2F form for this outfall.

Table 3.28. Results over reference standards for the Powerhouse outfall monitoring effort

Sampling location	Copper µg/L	Lead (µg/L)	Mercury (ng/L)	Selenium (µg/L)	PCB-1254 (µg/L)	PCB-1260 (µg/L)	Gross alpha (pCi/L)	Gross beta (pCi/L)
Reference standards	**9 µg/L (CCC)** **13 µg/L (CMC)**	**2.5 µg/L (CCC)** **65 µg/L (CMC)**	**51 ng/L (REC OO and REC WO)**	**3.1 µg/L (CCC)** **20 µg/L (CMC**	**0.00064 µg/L (REC OO and REC WO)**	**.00064 µg/L (REC OO and REC WO)**	**15**	**50**
Outfall 780 (March 2018 results)			691			0.626		
Outfall 780 (March 2019 results)	14	7.28	—	—	—	—	—	—
Outfall 780 D2	—	—	66.7	—	0.0452	0.041	354	96.1
Outfall 780 D3	—	—	102	—	0.0408	0.0342	—	—
Outfall 800	—	4.02	—	—	—	—	—	—
Outfall 830	—	—	—	6.86		0.045	—	—
Outfall 900	14.4	—	—	—	—	—	—	—

Reference standards sources are defined as follows:
CCC TDEC Rule 0400-40-03-.03(3)(g), *Criterion Continuous Concentration*
CMC TDEC Rule 0400-40-03-.03(3)(g), *Criterion Maximum Concentration*
DWS TDEC Rule 0400-40-03-.03, *Domestic Water Supply*
REC OO TDEC Rule 0400-40-03-.03(4)(j), *Organisms Only Criteria*
REC WO TDEC Rule 0400-40-03-.03(4)(j), *Water & Organisms Criteria*
Reference standards for radionuclides equal Derived Concentration Standard (DCS) for ingested water (DOE-STD-1196-2011, *Derived Concentration Technical Standard*), and reference standards equal 4 percent of DCS values. Derived Concentration Guide (DCG) values for ingested water (DOE Order 5400.5 Chg. 2, *Radiation Protection of the Public and the Environment,* Chap. III) are also listed because they remain in effect for certain CERCLA activities. Reference standards for gross alpha and gross beta measurements correspond to national primary drinking water standards (40 CFR Part 141, *National Primary Drinking Water Regulations,* Subparts B and G).

Elevated levels of several legacy heavy metals were observed in Outfalls 800, 830, and 900. In addition, detectable levels of PCBs were noted in the discharge from Outfall 830. Additional RAs may need to be undertaken in the drainage area of these outfalls to address the metals and PCB issues before the Powerhouse property can be released to lessees for industrial use. No actions on removing the Powerhouse outfalls from the ETTP NPDES permit will be taken until investigation of the discharges from these outfalls can be completed and any necessary RAs to correct discharges of contaminants have been taken.

3.6.3.7 Chromium Water Treatment System and Plume Monitoring

The continued effectiveness of the Chromium Water Treatment System is confirmed by periodic monitoring as part of the ETTP SWPP Program. In CY 2019, monitoring was conducted at Monitoring Well TP-289, the chromium collection system wells, Outfall 170, and Mitchell Branch kilometer (MIK) 0.79. Samples are collected at TP-289 to monitor the concentrations of chromium in the contaminated groundwater plume. Samples are collected from the chromium collection system wells to monitor the chromium in the water recovered by the groundwater collection system. Samples collected at Outfall 170 monitor the concentrations of the chromium and hexavalent chromium plume being discharged directly to Mitchell Branch. Figures 3.23 and 3.24 show the results for the analyses for total chromium and hexavalent chromium, respectively.

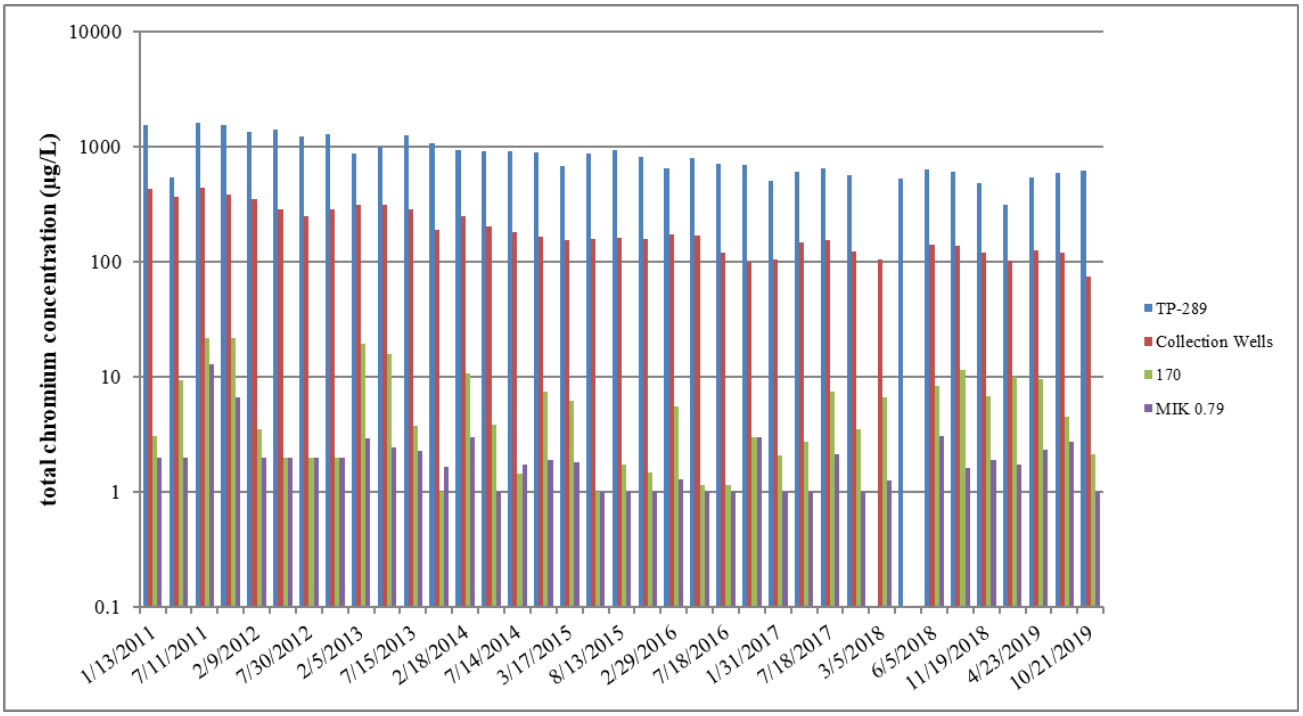


Figure 3.23. Total chromium sample results for the chromium collection system

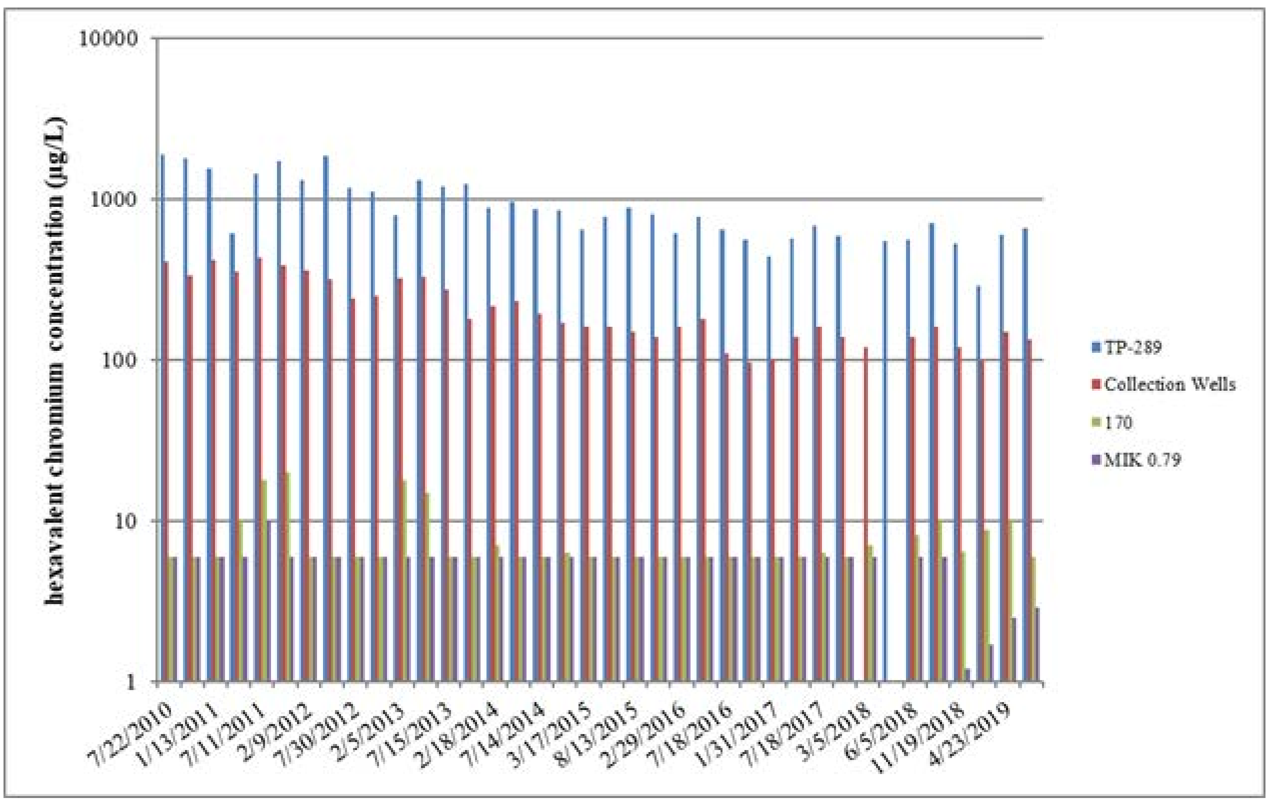
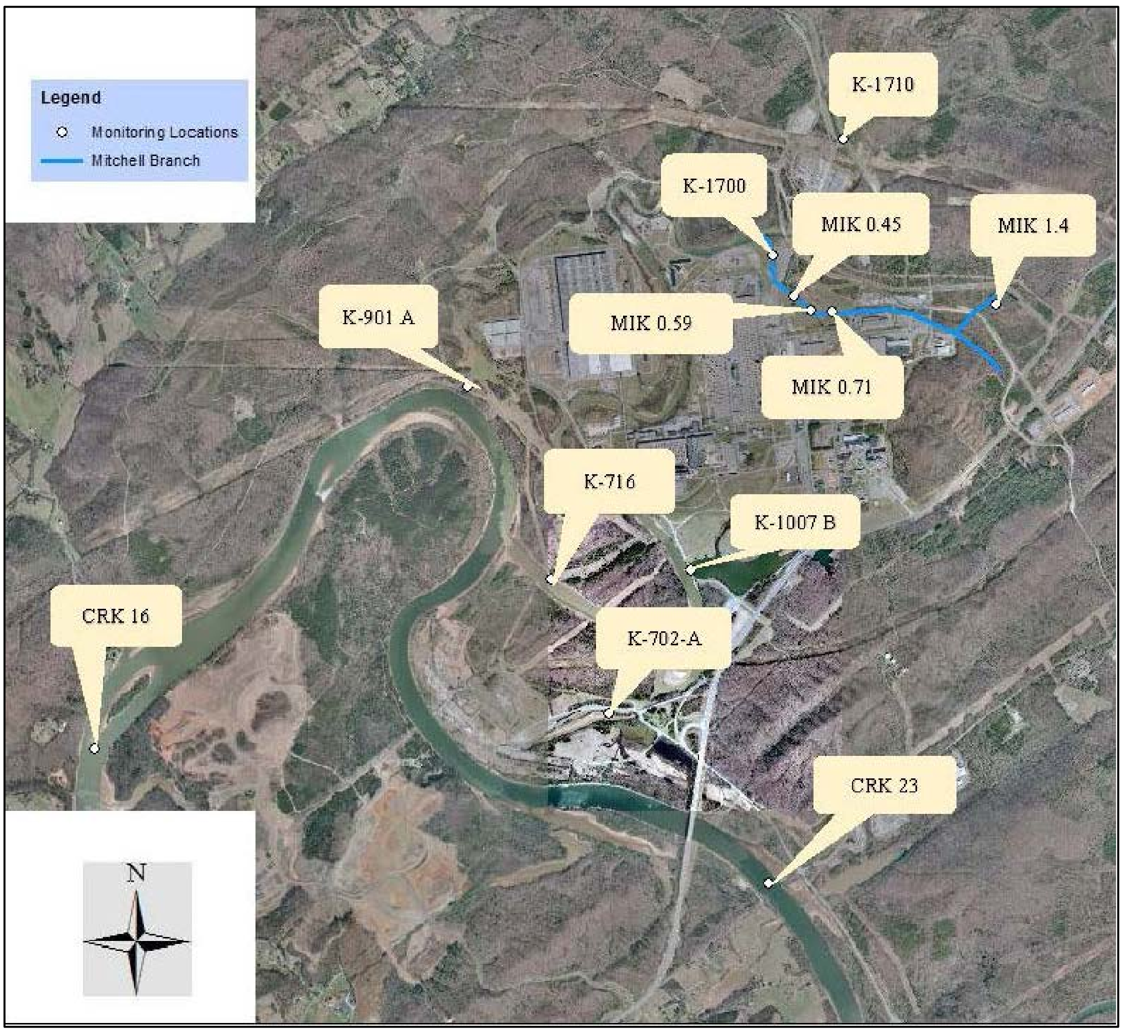


Figure 3.24. Hexavalent chromium sample results for the chromium collection system

The analytical data indicate that both total and hexavalent chromium levels may fluctuate slightly at TP-289 and the collection wells but are relatively consistent over the long term. Total chromium values at Outfall 170 and MIK 0.79 are slightly more variable. This is most likely due to the greater variability in flow rates at these two locations. Figure 3.24 shows the results for total chromium at Outfall 170. Hexavalent chromium levels at Outfall 170 and MIK 0.79 have remained consistent.

3.6.4 Surface Water Monitoring

During 2019, the ETTP EMP personnel conducted environmental surveillance activities at 12 surface water locations (Figure 3.25) to monitor groundwater and storm water runoff at watershed exit pathway locations (K-1700, K-1007-B, and K-901-A) or ambient stream conditions (Clinch River kilometers [CRKs] 16 and 23; K-1710; K-716; the K-702-A slough; and MIKs 0.45, 0.59, 0.71, and 1.4). As part of monitoring the ambient stream conditions, K-1700 and MIKs 0.45, 0.59, 0.71, and 1.4 were sampled quarterly; and CRKs 16 and 23, K-716, and the K-702-A slough were sampled semiannually.

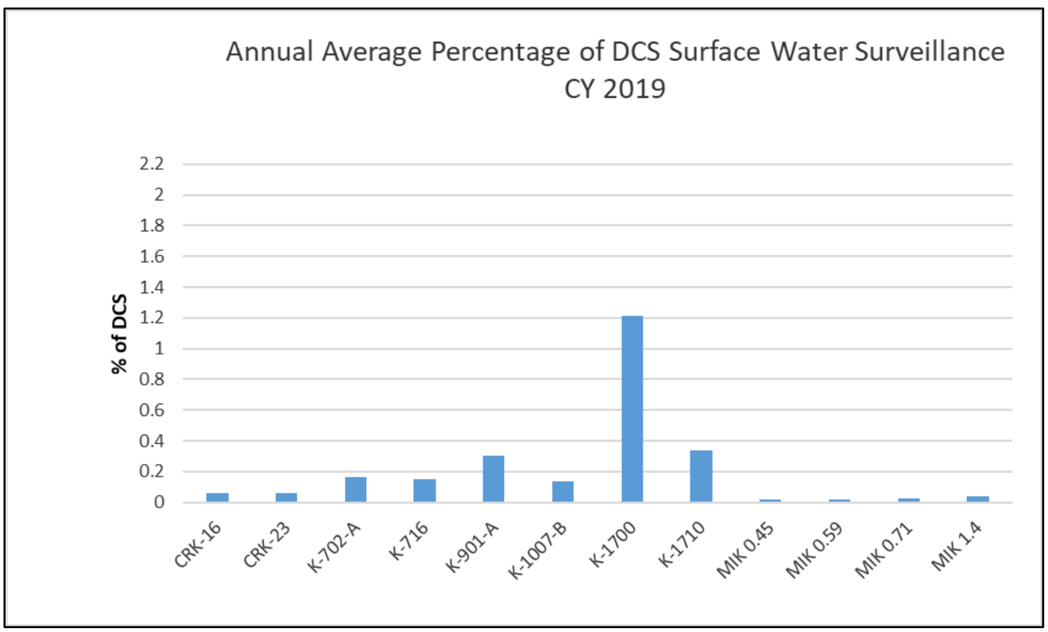


Acronyms:
CRK = Clinch River kilometer
MIK = Mitchell Branch kilometer

Figure 3.25. East Tennessee Technology Park Environmental Monitoring Program surface water monitoring locations

Results of radiological monitoring were compared with the DCS values in DOE Standard 1196 (DOE 2011b). Radiological data are reported as fractions of DCSs for reported radionuclides, and the fractions for all of the isotopes are added together to produce the SOF and averaged to produce a rolling 12-month average. The average SOF is recalculated whenever new data become available. If the average SOF for a location exceeds the DCS requirement of remaining below 1.0 (100 percent) for the year, a formal source investigation is required. Sources exceeding DCS requirements would need an analysis of the best available technology to reduce the SOF of the radionuclide concentrations to less than 1.0 (100 percent). In 2019, the monitoring results yielded SOF values of less than 0.01 (1 percent of the allowable DCS) at all surface water surveillance locations at ETTP, with the exception of monitoring location K-1700 (Figure 3.26). At K-1700, the annual average SOF was 0.012 (1.2 percent). At MIKs 0.45, 0.59, and 0.71, quarterly monitoring is conducted for ^{99}Tc only.

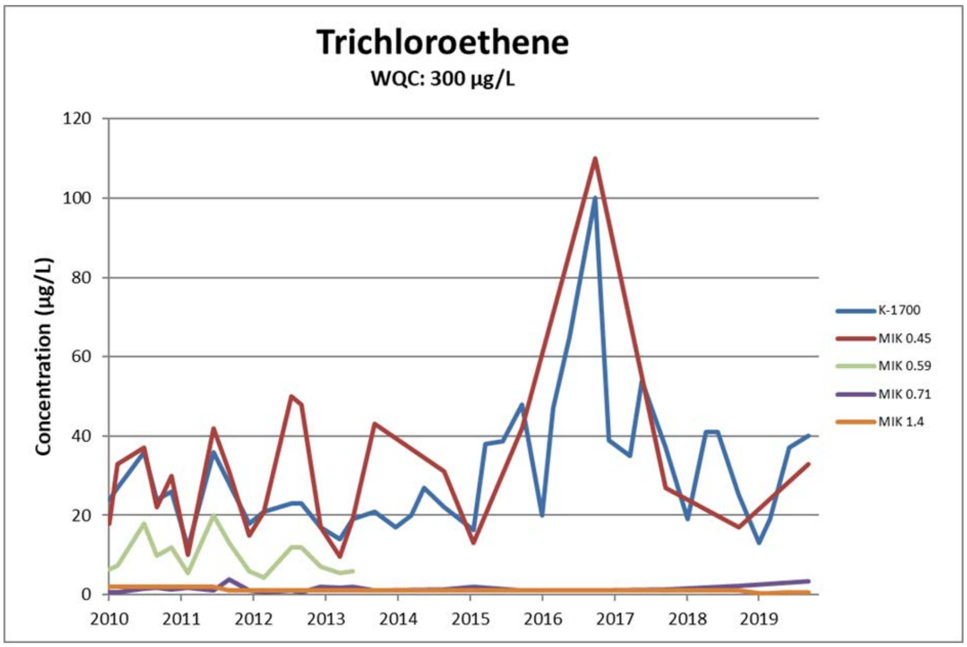
Depending on the monitoring location, water samples may be analyzed for pH, selected metals, and VOCs. In 2019, 1756 analytical results and 236 field readings were collected under the EMP. The vast majority of these results were well within the appropriate AWQC. There were four exceptions in 2019. During the first quarter, cadmium was measured at concentrations exceeding the AWQC at both K-1700 (a result of 0.56 µg/L) and MIK 0.59 (a result of 0.59 µg/L). Since the AWQC for cadmium is dependent upon the hardness of the water in the receiving stream, the AWQC at K-1700 was 0.36 µg/l and at MIK 0.59 it was 0.29 µg/L. During the second quarter of 2019, there was an exceedance of the AWQC for mercury. At K-1710, which monitors Poplar Creek, mercury was measured at 64.8 ng/L, which exceeds the AWQC for mercury of 51 ng/L. During the third quarter, there was one failure to meet the minimum level of dissolved oxygen (5.0 mg/L). Dissolved oxygen levels were measured at 3.6 mg/L at K-901-A. These readings were collected at a time of elevated temperatures and very low flow due to the drought conditions, which favor high biological activity and the resulting depletion of dissolved oxygen. In the fourth quarter monitoring, all results met the AWQC.



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

Figure 3.26. Annual average percentage of derived concentration standards at surface water monitoring locations, 2019

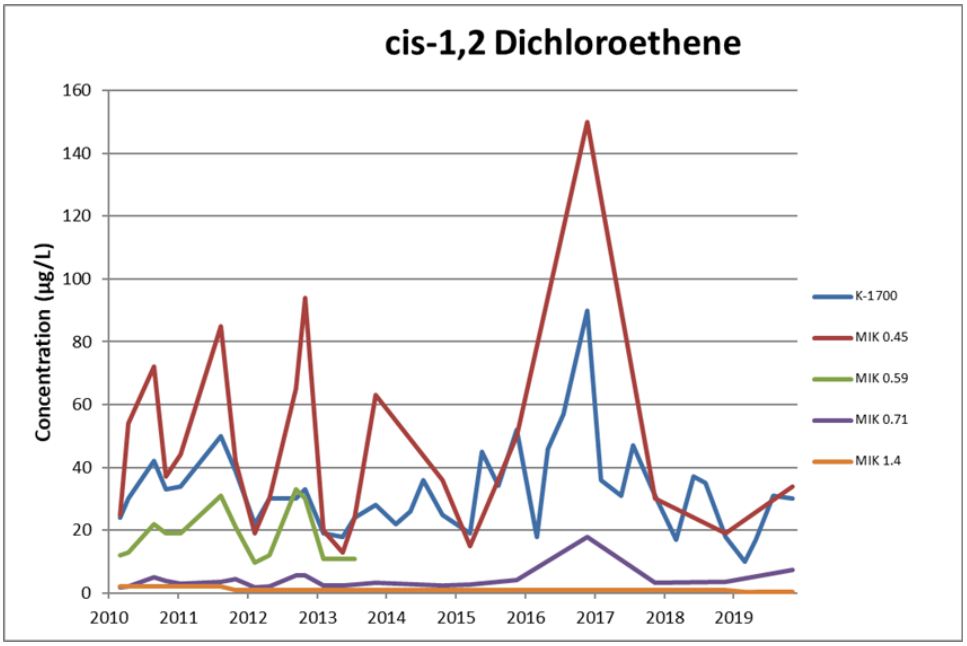
Figures 3.27 and 3.28 illustrate the concentrations of TCE (trichloroethene) and cis-1,2-dichloroethene (cis-1,2-DCE) from the Mitchell Branch monitoring locations., Although VOCs are routinely detected at K-1700 and MIK 0.45, they are rarely detected at other surface water surveillance locations across ETTP. In the samples collected on November 22, 2016, results for several VOCs, including TCE and cis-1,2-dichloroethene, at several of the Mitchell Branch monitoring locations were reported at levels significantly higher than seen in recent monitoring. It should be noted that the November 22, 2016, sample date was at the end of an extended dry weather period that began in August 2016.



Acronym:
MIK = Mitchell Branch kilometer

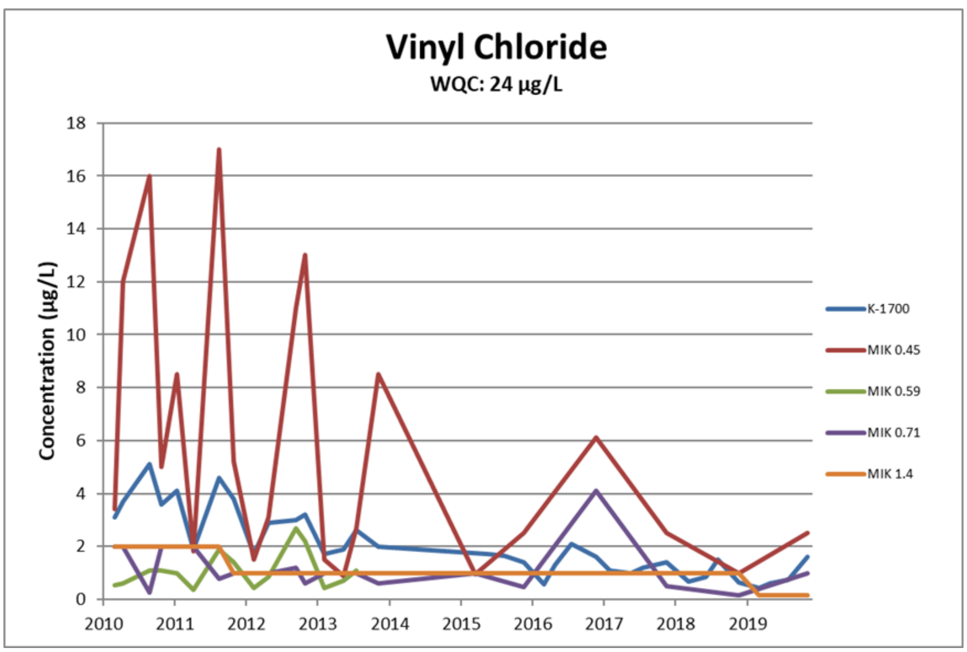
Figure 3.27. Trichloroethene concentrations in Mitchell Branch

An investigation into the cause of the spike in the reported results was inconclusive. It should be noted that even at the increased levels, the results are still well within the AWQC. Concentrations of TCE and total 1,2-DCE are below the AWQCs for recreation, organisms only (300 µg/L for TCE and 10,000 µg/L for trans-1,2-DCE), which are appropriate standards for Mitchell Branch. In addition, vinyl chloride has sometimes been detected in Mitchell Branch water (Figure 3.29). VOCs have been detected in groundwater in the vicinity of Mitchell Branch and in building sumps discharging into storm water outfalls that discharge into the stream; however, these compounds have generally not been detected in storm water during the monitoring of network discharges. Therefore, it appears that the primary source of these compounds is contaminated groundwater.



Acronym:
MIK = Mitchell Branch kilometer

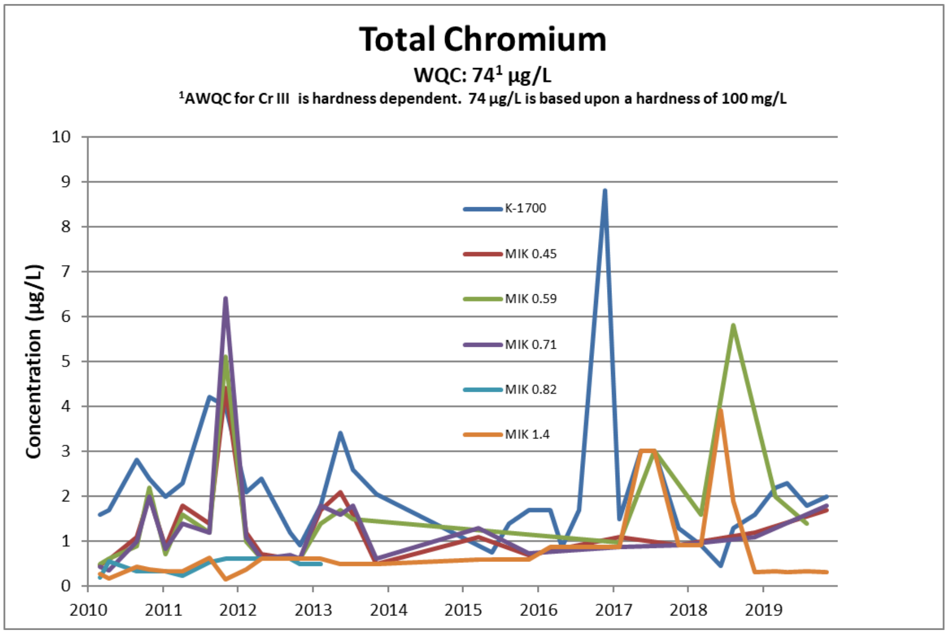
Figure 3.28. Concentrations of cis-1,2-dichloroethene in Mitchell Branch



Acronym:
MIK = Mitchell Branch kilometer

Figure 3.29. Vinyl chloride concentrations in Mitchell Branch

Since CWTS was installed, chromium levels in Mitchell Branch have dropped dramatically, with levels of total chromium being routinely measured at less than 6 µg/L (Figure 3.30). In 2019, hexavalent chromium levels in Mitchell Branch were all below the sample quantitation limit.



The AWQC for Cr(III), which is hardness-dependent, is 74 µg/L, based on a hardness of 100 mg/L. The AWQC for Cr(IV) is 11 µg/L.

Acronyms:
AWQC = ambient water quality criterion
MIK = Mitchell Branch kilometer

Figure 3.30. Total chromium concentrations in Mitchell Branch

3.6.5 Groundwater Monitoring at ETTP

During FY 2019, the US Department of Energy (DOE) prepared the *East Tennessee Technology Park Main Plant Groundwater Feasibility Study, Oak Ridge, Tennessee* (MPFS; DOE/OR/01-2835&D1). This report included a synthesis of existing groundwater data augmented with the data derived from installation of 31 new groundwater monitoring wells, as well as incorporation of opportunistic groundwater samples collected in conjunction with ETTP Zone 2 soil characterization activities. Main Plant area groundwater plumes were updated and revised based on the compilation of all recent groundwater data. The draft MPFS includes plume maps for individual constituents of concern identified in the updated human health risk assessment. Through the ongoing Zone 2 soil investigations and the additional well installations conducted in support of MPFS preparation, additional areas of groundwater contamination and additional groundwater plume areas were identified. The revised sitewide contaminant plume map incorporates the sum of chlorinated volatile organic compound and ^{99}Tc plumes from the MPFS. The interested reader is referred to the MPFS document for additional, detailed information.

In recognition of the emergence during 2019 of polyfluoroalkyl substances (PFAS) compounds as potential contaminants of concern, the Water Resources Restoration Program (WRRP) started planning for sampling and analysis of these compounds at ETTP. Sample planning included review of previous analytical results obtained in 2017 from groundwater and spring sampling in the vicinity of former waste burn areas. Those data indicated presence of very low PFAS concentrations mostly less than 10 ng/L when concentrations were above detection limits. Additional sampling to assess the presence and significance of PFAS will occur during FY 2020.

The principal groundwater contaminants at ETTP are chlorinated VOCs (primarily TCE and its degradation products such as 1,2-DCE and vinyl chloride) and ^{99}Tc. Despite the fact that ETTP is a former gaseous diffusion plant used for uranium enrichment, the occurrence of elevated uranium concentrations in groundwater is relatively uncommon at the site. The reason for this is that the uranium enrichment process used gaseous UF_6, which was contained inside process equipment and depleted UF_6, was returned to storage cylinders where it reverted to solid form upon cooling. Chromium and nickel (and less frequently lead) are the most common metal contaminants in groundwater and they are relatively widespread at ETTP as well as elsewhere on ORR. Chromium was used in the hexavalent form in the recirculating cooling water and fire protection water systems to prevent corrosion of pipes. Leaks of pipes that circulated the corrosion inhibiting additives were common and in some cases were of quite large volume. In a localized area in the Mitchell Branch plume area near the former K-1420 facility, hexavalent chromium in groundwater is collected and treated prior to discharge to protect the water quality in Mitchell Branch and maintain instream chromium concentrations compliant with the 0.011 mg/L AWQC (see Section 3.6.12 for additional information). The origin of nickel as a groundwater contaminant is not readily tied to site processes that would have created releases of soluble nickel to the subsurface. Lead was widely used at the DOE facilities as shielding material and for other typical industrial purposes. Lead materials were sometimes stored outdoors, in the open, and some was disposed in waste burial areas either as material shielding or as waste. Chromium, nickel, and lead are widespread in ORR soils. The sources may be either naturally occurring materials or materials used in general industrial and structural processes.

In the 2020 Remediation Effectiveness Report, DOE has compiled the analytical data for groundwater contaminants in wells included in the routine WRRP monitoring program at ETTP to evaluate contaminant concentrations with respect to the EPA National Primary Drinking Water Regulations maximum contaminant levels (MCLs) and maximum contaminant level derived concentrations (MCL-DCs) and to determine if statistically significant trends are occurring. Data are compared to MCLs or MCL-DC for radionuclides. Two screening levels were used—the full MCL/MCL-DC concentrations and an arbitrary value of 80 percent of the MCL/MCL-DC. The 80-percent level was selected to indicate the presence of contaminants that may be approaching the MCL/MCL-DC in the event that increasing concentration trends are occurring. Mann-Kendall (M-K) trend evaluations were conducted for data compartmentalized into a maximum time period of 10 years for longer duration trend evaluation and a secondary time period of 5 years to evaluate more recent trends. In the M-K trend evaluation it is desirable to have at least 10 data results per analyte to allow the method to attain a 90-percent confidence interval on the trend identification.

Updated VOC plumes are based on the sum of chlorinated VOCs measured in the FY 2019 WRRP groundwater monitoring and data obtained in preparation of the MPFS.

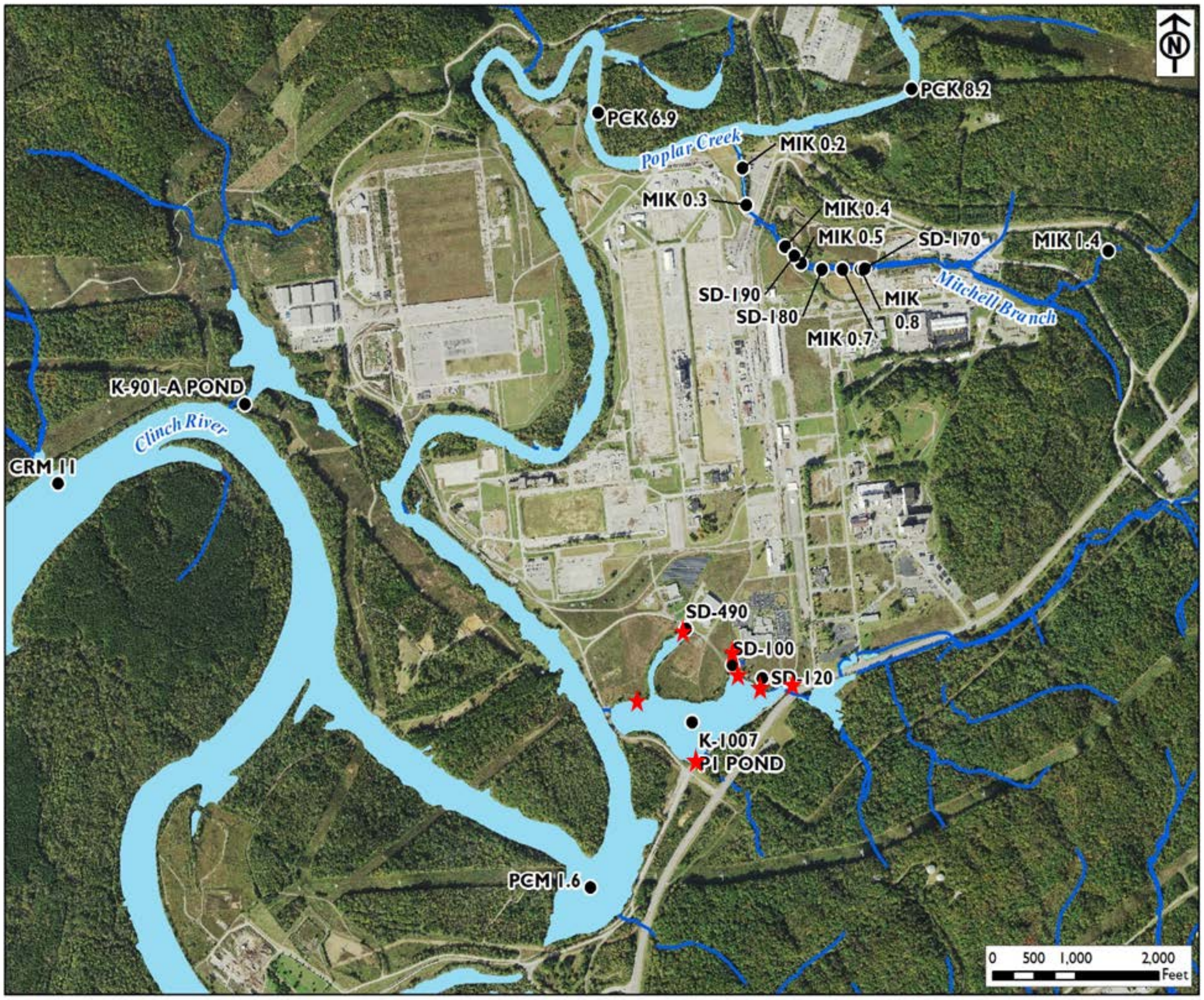
VOC concentrations in wells monitored downgradient of K-1070-C/D show that a broad area is affected by releases from the past disposal of liquid VOCs at G-Pit. While concentrations along one portion of the affected area continue to decrease, there remains an adjacent area with very high concentrations. The persistent, high concentrations of these VOCs suggest an ongoing contaminant source release from residual contamination near and beneath G-Pit.

Contaminant conditions in the groundwater exit pathway areas are generally stable and similar to conditions in recent years.

For additional information, see the *2020 Remediation Effectiveness Report for the U.S. Department of Energy, Oak Ridge Site, Oak Ridge Tennessee* (DOE 2020).

3.7 Biological Monitoring

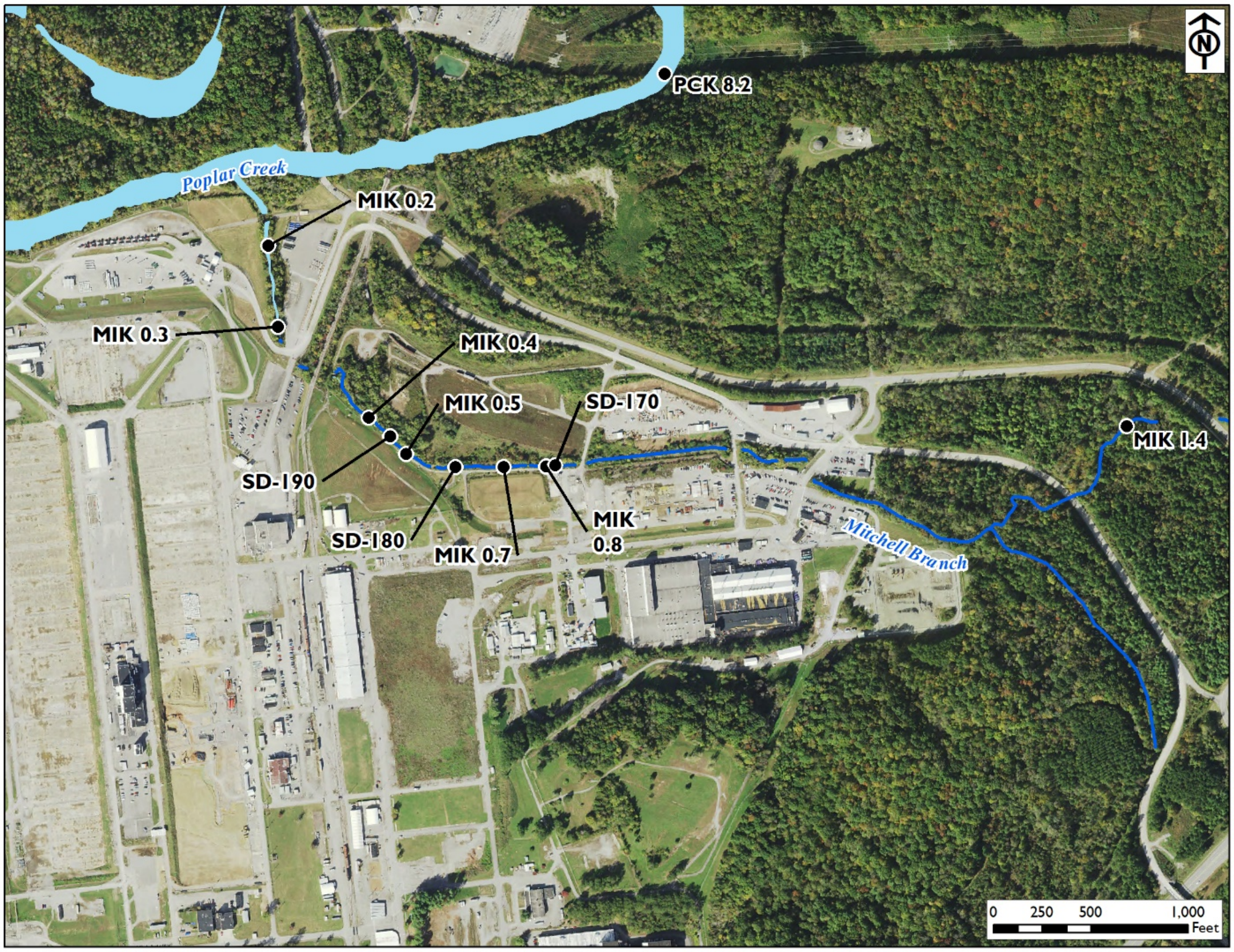
The ETTP BMAP consists of two tasks designed to evaluate the effects of ETTP legacy operations on the local environment, identify areas where abatement measures would be most effective, and test the efficacy of the measures. The results from this program will support future CERCLA cleanup actions. These tasks are: (1) bioaccumulation studies, and (2) instream monitoring of biological communities. Figure 3.31 shows the major water bodies at ETTP and Figure 3.32 shows the BMAP monitoring locations along Mitchell Branch.



Note:
Red stars indicate clam sampling locations in and around the K-1007-P1 Pond in 2019.

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

Figure 3.31. Water bodies at the East Tennessee Technology Park



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

Figure 3.32. Major storm water outfalls and biological monitoring locations on Mitchell Branch

3.7.1 Task 1: Bioaccumulation Monitoring

Bioaccumulation monitoring for the ETTP BMAP has focused on evaluating the impact of PCB discharges into the environment because of historical operations at the ETTP complex. It was previously assumed that mercury (Hg) flux into Poplar Creek and the Clinch River originated largely from Y-12 Complex discharges into East Fork Poplar Creek (EFPC). However, more recently monitoring has shown that water in ETTP storm drains and biota from lower Mitchell Branch have elevated mercury concentrations. Mercury bioaccumulation monitoring is routinely conducted in the watersheds adjacent to ETTP by the Y-12 and ORNL BMAPs, both on and off ORR. The available Hg bioaccumulation monitoring data will be presented in the following subsections with long-term trends in PCB contamination in resident fish and caged clams from ETTP waters. Recent tabular results were provided in the FY 2019 ETTP BMAP Report.

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

For bioaccumulative contaminants such as Hg and PCBs, US fish bioaccumulation data have become important measures of compliance for both the Clean Water Act and CERCLA. For Hg, the EPA National Recommended Water Quality Criterion for Hg in fish (0.3 µg/g) is used as the trigger point for fish consumption advisories in Tennessee, the target concentration for NPDES permit compliance, and the threshold for impairment designations that require a Total Maximum Daily Load (TMDL) assessment. In addition to fish Hg limits, the State of Tennessee continues to use the statewide AWQC for Hg of 51 ng/L in water, based on organisms only, and 50 ng/L for recreation-water and organisms (TDEC 2013). Regulatory guidance and human health risk levels have varied more widely for PCBs, depending on the regulatory program and the assumptions used in the risk analysis. The Tennessee water quality criteria for individual Aroclors and total PCBs are both 0.00064 µg/L under the recreation designated use classification and are the target for PCB-focused TMDLs, including for local reservoirs (Melton Hill, Watts Bar, and Fort Loudon) (TDEC 2010a, 2010b, 2010c). However, most conventional PCB water analyses have detection limits much higher than the PCB AWQC. Therefore, in Tennessee and in many other states, assessments of impairment for water body segments, as well as public fishing advisories for PCBs, are based on fish tissue concentrations. Historically, the US Food and Drug Administration (FDA) threshold limit of 2 µg/g in fish fillet was used for PCB advisories; then for many years in Tennessee, an approximate range of 0.8 to 1 µg/g was used, depending on the data available and factors such as the fish species and size. The remediation goal for fish fillet at the ETTP K-1007-P1 Pond is 1 µg/g. Most recently, the water quality criterion that has been used by TDEC to calculate the fish tissue concentration triggering a determination of impairment and a TMDL, and this concentration is 0.02 µg/g in fish fillet (TDEC 2010a, 2010b, 2010c). The fish PCB concentrations at and near ETTP are well above this most conservative concentration.

In addition to monitoring for human health and ecological risks as well as long-term trends, bioaccumulation monitoring also includes investigations of sources of contamination to ETTP waterways. Caged Asiatic clams (*Corbicula fluminea*) are used as bioindicators of contaminant sources in Mitchell Branch and other sites around ETTP. These clams are collected from an uncontaminated reference site (Little Sewee Creek in Meigs County, Tennessee) and are divided into groups of 10 clams of equal mass. In 2019, clams were placed in baskets to be deployed at strategic locations around ETTP (i.e., in and around storm drains) for a 4-week exposure period (May 13–June 10, 2019). Two clam baskets were placed at each site with 10 clams in each basket.

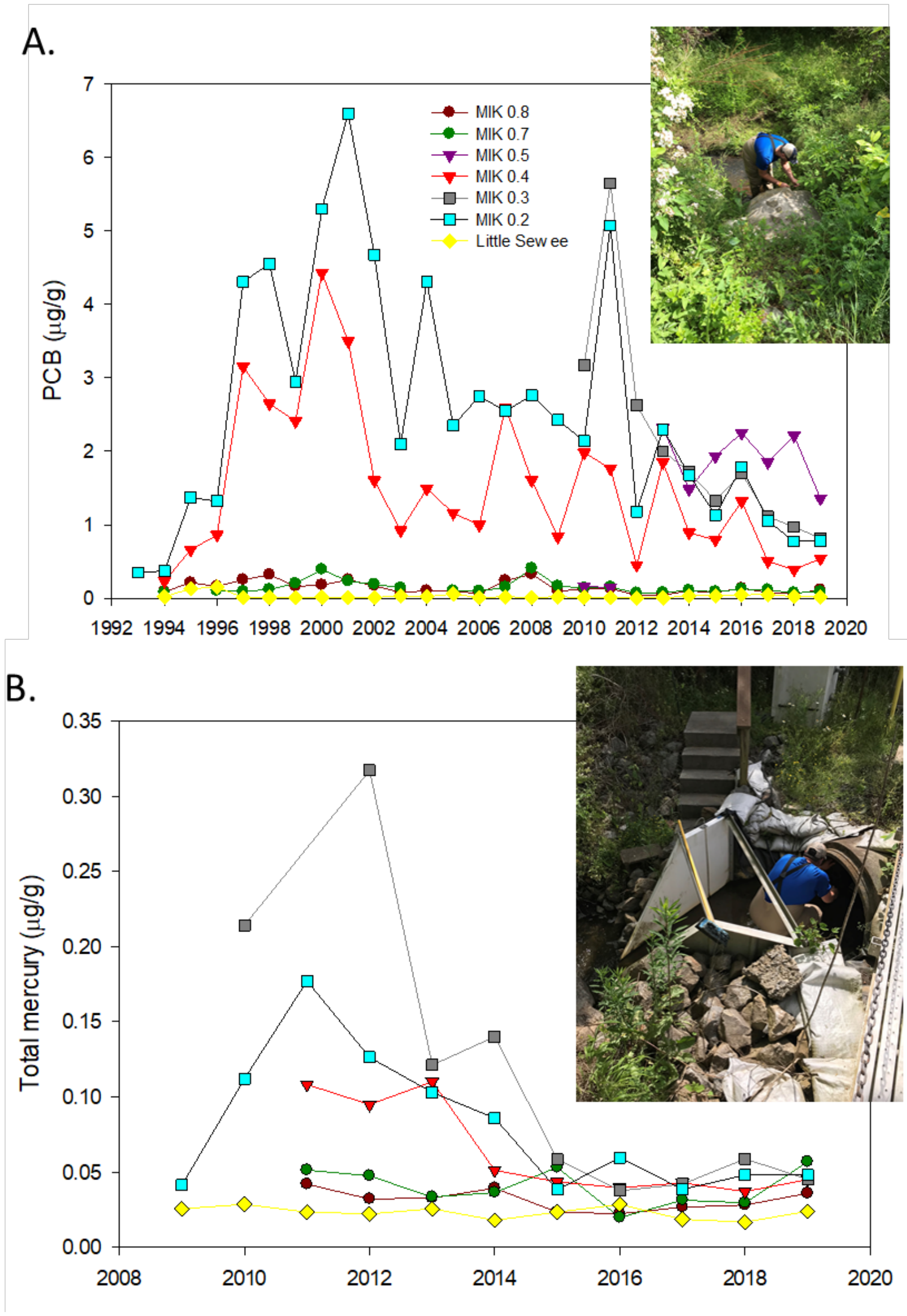
Because these animals are sedentary filter feeders, they accumulate contaminants that are present in the water and in suspended particles at a given site. They are useful indicators of the bioavailable (and therefore potentially toxic) portion of contaminants that enter the environment at a given location,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

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

Mitchell Branch

Figure 3.33 shows long-term monitoring results in caged clams deployed at various sites in Mitchell Branch. The lower portion of this stream (MIK 0.5, SD 190, MIK 0.2) has historically been a “hot spot” for both Hg and PCB contamination, and in 2019 PCB concentrations continued to be elevated (~1–2 µg/g) with respect to other Mitchell Branch and reference sites with concentrations remaining comparable to those seen in recent years. Although there is considerable interannual variability, PCB concentrations in clams placed in lower Mitchell Branch appear to be generally trending downward since peak years in 2000-2001. While there was a slight bump up in PCB concentrations at Mitchell Branch sites in 2016, concentrations since then have dropped back down, continuing the overall decreasing trend. The only exception to this recent trend was a slight increase at MIK 0.5 in 2018 (from 1.8 to 2.2 µg/g); however, in 2019 concentrations at this site decreased from 2.2 µg/g to 1.36 µg/g. PCB concentrations in the upper portion of Mitchell Branch were similar to previous years’ concentrations and were slightly elevated (0.11 µg/g) with respect to the reference site (0.02 µg/g).

Surface water monitoring conducted by various programs (e.g., ETTP Compliance, WRRP) has shown that aqueous Hg concentrations in Mitchell Branch fluctuate significantly, with concentrations exceeding the AWQC. This level of variability is typical of stream systems because aqueous Hg concentrations can change with various environmental factors (e.g., flow, suspended solids, etc.) as well as with sample collection methods. Variation in aqueous Hg concentrations is not uncommon and illustrates that aqueous concentrations in a grab sample taken on a certain day reflect a snapshot of the conditions during that sampling period. Research at ORNL has found changes in aqueous Hg concentrations between day and night, for example. In addition, the relationship between aqueous Hg concentrations and MeHg concentrations is not a straightforward one, leading to further complexities with respect to Hg bioaccumulation. Although monitoring aqueous concentrations is still indicative of gauging the relative importance of different Hg sources to a given watershed, bioaccumulation data are informative in that they reflect an integrative measure of the bioavailable portion of Hg exposure at a given site. Monitoring MeHg concentrations in clams is illustrative in that they highlight the complexity of Hg bioaccumulation—whereas Hg_T concentrations in clams varied greatly between sites, MeHg concentrations in Mitchell Branch were elevated with respect to the reference site but did not vary as much as total Hg between sites or between years.

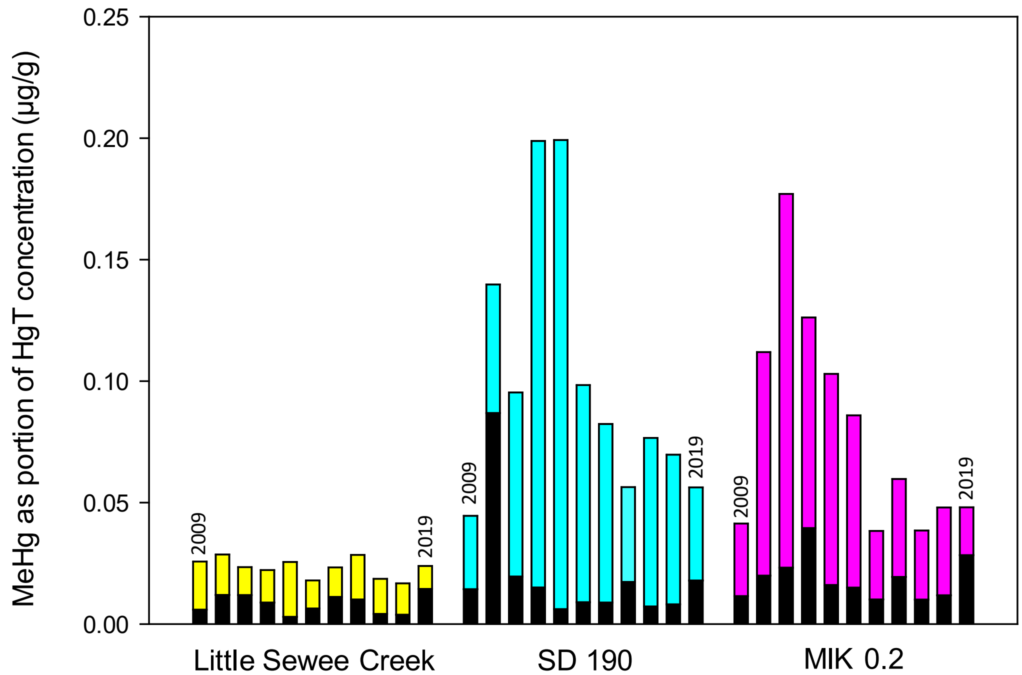


Notes:
1. N = 2 composites of 10 clams each per year.
2. Shown in yellow are data for clams collected from the reference site, Little Sewee Creek (Meigs County, Tennessee).
3. Figure A shows total PCBs defined as the sum of Aroclors 1248, 1254, and 1260.

Acronyms:
MIK = Mitchell Branch kilometer
PCB = polychlorinated biphenyl

Figure 3.33. Mean total PCB (A: µg/g, wet wt; 1993–2019) and mercury (B: µg/g wet wt; 2009–2019) concentrations in the soft tissues of caged Asiatic clams deployed in Mitchell Branch

Mercury concentrations in clams deployed in Mitchell Branch in 2019 were similar to concentrations seen in 2018. In 2019, concentrations throughout Mitchell Branch were only slightly higher than at the reference site. Mercury concentrations in clams deployed at the K-1007-P1 and K-901-A ponds were again comparable to reference site concentrations. Within the Mitchell Branch system, the highest Hg concentrations were seen in clams deployed at SD 180 (0.20 µg/g). Clams deployed at two storm drains on the K-1007-P1 Pond had Hg concentrations similar to those of the reference site. Unlike in fish tissue, MeHg generally makes up a small proportion of Hg_T found in soft tissues of clams (Figure 3.34). Although MeHg concentrations in clams remained low in 2019, they were either comparable to or slightly higher than concentrations in 2018.

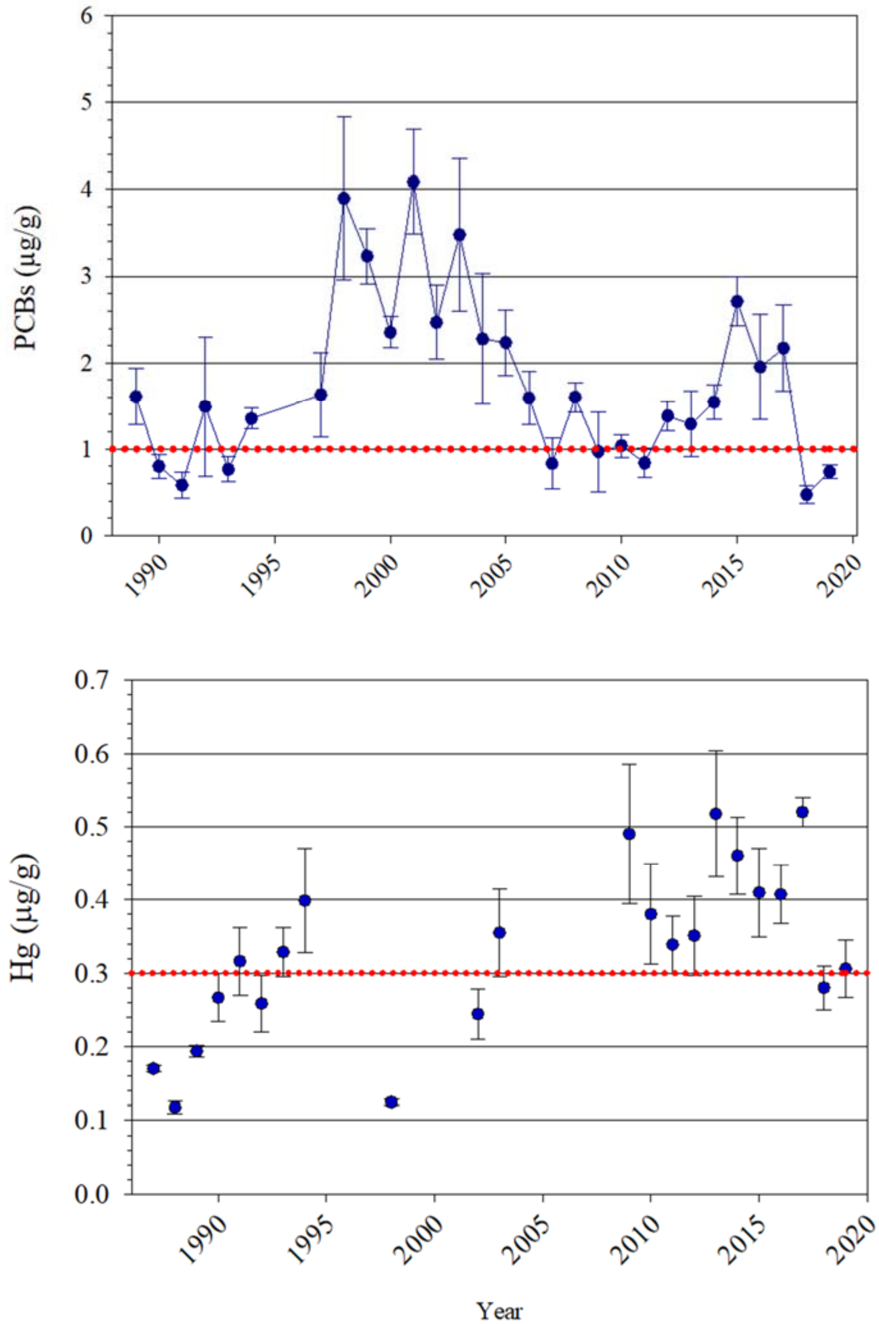


Notes:
1. N = 2 composites of 10 clams each per year.
2. Shown in yellow are data for clams collected from the reference site, Little Sewee Creek (Sweetwater, Tennessee).
3. Black bars denote MeHg concentrations, where the total height of bars (color and black band) represents Hg_T concentration.

Acronyms and abbreviations:
Hg_T = total mercury
MeHg = methylmercury
MIK = Mitchell Branch kilometer
PCB = polychlorinated biphenyl
SD = storm drain

Figure 3.34. Methylmercury as a portion of total mercury concentrations in the soft tissues of caged Asiatic clams deployed in Mitchell Branch (µg/g wet wt; 2009–2019)

Figure 3.35 shows long-term monitoring results in redbreast sunfish (*Lepomis auritus*) at MIK 0.2. Average PCB concentrations in fish collected at MIK 0.2 in 2019 (0.74 ± 0.08 µg/g) were slightly higher than those seen in 2018 (0.48 ± 0.10 µg/g) but remained among the lowest concentrations reported for the past 30 years at this site (Figure 3.34). Although there is not a regulatory limit for PCBs in fish, the level most often used in practice to issue fish consumption advisories in the State of Tennessee, as previously stated, is 1 µg/g. In 2019, the mean PCB concentration in sunfish fillets was below this limit. While the observed fish tissue concentrations in Mitchell Branch are lower than they have historically been, they are still two to three orders of magnitude higher than concentrations seen in the same species at the Hinds Creek reference site in Anderson County.



Notes:
1. 1989–2019 N = 6 fish per year.
2. Shown in red is the fish advisory level for PCBs (1 µg/g) and mercury concentration (0.3 µg/g).

Acronyms and abbreviations:

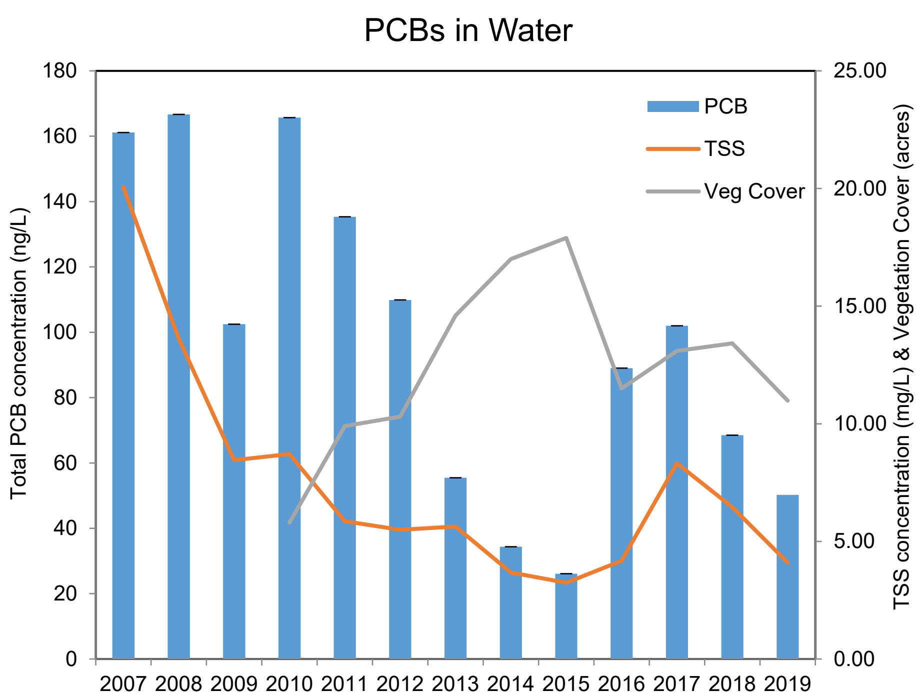
Hg = mercury
MeHg = methylmercury
MIK = Mitchell Branch kilometer
PCB = polychlorinated biphenyl

Figure 3.35. Mean PCB (top panel) and mercury (bottom panel) concentrations (µg/g, wet wt) in redbreast sunfish fillets in Mitchell Branch (MIK 0.2)

Total mercury has been monitored more sporadically in redbreast sunfish fillets at MIK 0.2. Figure 3.35 shows long-term trends in Hg_T concentrations (µg/g) in these fish. A rapid increase in fillet Hg_T concentrations was observed in the early 1990s and generally remained elevated, with mean concentrations exceeding the AWQC (0.3 µg/g) in most years. Similar to the PCB concentrations in fish from this site, Hg_T concentrations at MIK 0.2 have been oscillating around the EPA's recommended AWQC for the past several years. Similar to the trends seen for PCBs, mean mercury concentrations in redbreast at this site increased slightly in 2019, averaging 0.31 $\pm$ 0.04 µg/g, just above the mercury tissue criterion.

1007-P1 Pond

Over the past decade, mean aqueous PCB concentrations in the K-1007-P1 Pond have fluctuated significantly, but have generally been lower than concentrations seen prior to 2009 remediation activities (e.g., 50 ng/L in 2019 compared to 161 ng/L in 2007; Figure 3.36).Concentrations in 2019 were slightly lower than they have been for the past three years, but were above the low of 26 µg/L in 2015. As hydrophobic contaminants, PCBs tend to be particle associated and are positively correlated with total suspended solids (TSS). The fluctuations in PCB and TSS concentrations in water in the K-1007-P1 Pond could be related to fluctuations in aquatic plant coverage which can affect sediment stability. The aqueous PCB concentrations measured in the K-1007-P1 Pond are above concentrations seen at the First Creek reference site (< 0.3 ng/L) and are above the State of Tennessee water quality criterion for the protection of fish and wildlife (14 ng/L) (TDEC 2019).



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

Acronyms:
PCB = polychlorinated biphenyl TSS = total suspended solids

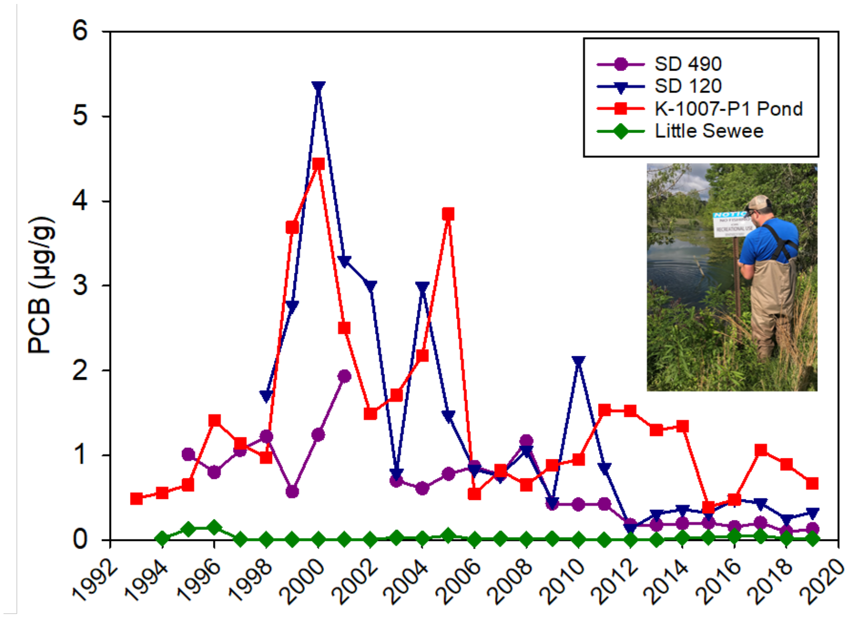
Figure 3.36. Mean aqueous total PCB concentrations, total suspended solids, and vegetation cover in the K-1007-P1 Pond, 2007–2019

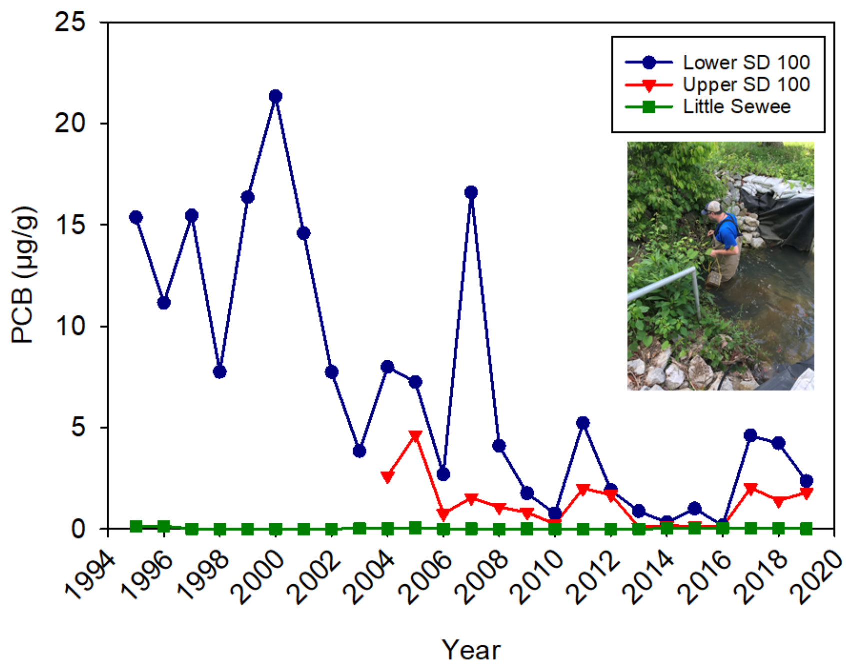
PCB concentrations in clams placed at lower and upper SD-100 locations have fluctuated significantly since remediation actions in 2009, and were on an overall decreasing trajectory until the significant increases seen in 2017 and 2018, and remained elevated with respect to the reference site in 2019 (Figure 3.37). PCB concentrations in clams placed at the K-1007-P1 outfall were also higher the past three years but were comparable to concentrations seen just after remediation actions in this pond (Figure 3.38).

To understand reasons for the fluctuations seen in PCB concentrations in the K-1007-P1 Pond, caged clams were deployed in two new locations in 2019, in outfalls serving the pond. Mean PCB concentrations in clams deployed at Outfall 124 on the northeast side of the pond were low and were comparable to concentrations seen at the reference site (0.04 µg/g). PCB concentrations in clams deployed in an unnamed outfall on the southwest side of the pond (0.94 µg/g) were higher than those deployed at the routine monitoring site in this pond (the K-1007-P1 outfall located on the northwest side of the pond), which averaged 0.67 µg/g in 2019 (Figure 3.34). It is unknown whether there are source(s) of PCB inputs on the south side of the pond or whether water column conditions at this location led to elevated concentrations seen in clams at this new location.

Similar trends have been observed in fish tissue PCB concentrations in the K-1007-P1 Pond. Since 2009, the target species for bioaccumulation monitoring in the K-1007-P1 Pond has been bluegill sunfish (*Lepomis macrochirus*). As in previous years, fillets from 20 individual bluegill and 6 whole body composites (10 bluegill per composite) from the K-1007-P1 Pond were analyzed for PCBs in 2019 to assess the ecological and human health risks associated with PCB contamination in this pond.

Average PCB concentrations in fish fillets and whole-body composites have decreased significantly over the past 10 years since remediation activities, with significant fluctuations. Concentrations were lowest in the 2013-2015 time period but have slightly increased over the past three years. The mean concentration in whole body composites of bluegill collected from the K-1007-P1 Holding Pond was lower in 2019 (3.20µg/g) than in 2018 (4.00 µg/g), remaining above the target concentration for whole body fish in this pond (2.3 µg/g) (Table 3.29, Figures 3.38 and 3.39). The mean concentration (0.71 µg/g) in bluegill fillets in 2019 decreased, such that it fell below the remediation goal of 1 µg/g. The interannual fluctuations in PCB concentrations could be due to water quality changes that have taken place in this pond, (e.g., higher TSS, PCB inputs, fluctuations in vegetation cover; Figures 3.32, 3.34, and 3.35). The observed fluctuations in PCB concentrations seen in biota suggest that this system is still in transition and that as the fish and plant communities stabilize, further decreases in PCB bioaccumulation may become apparent.

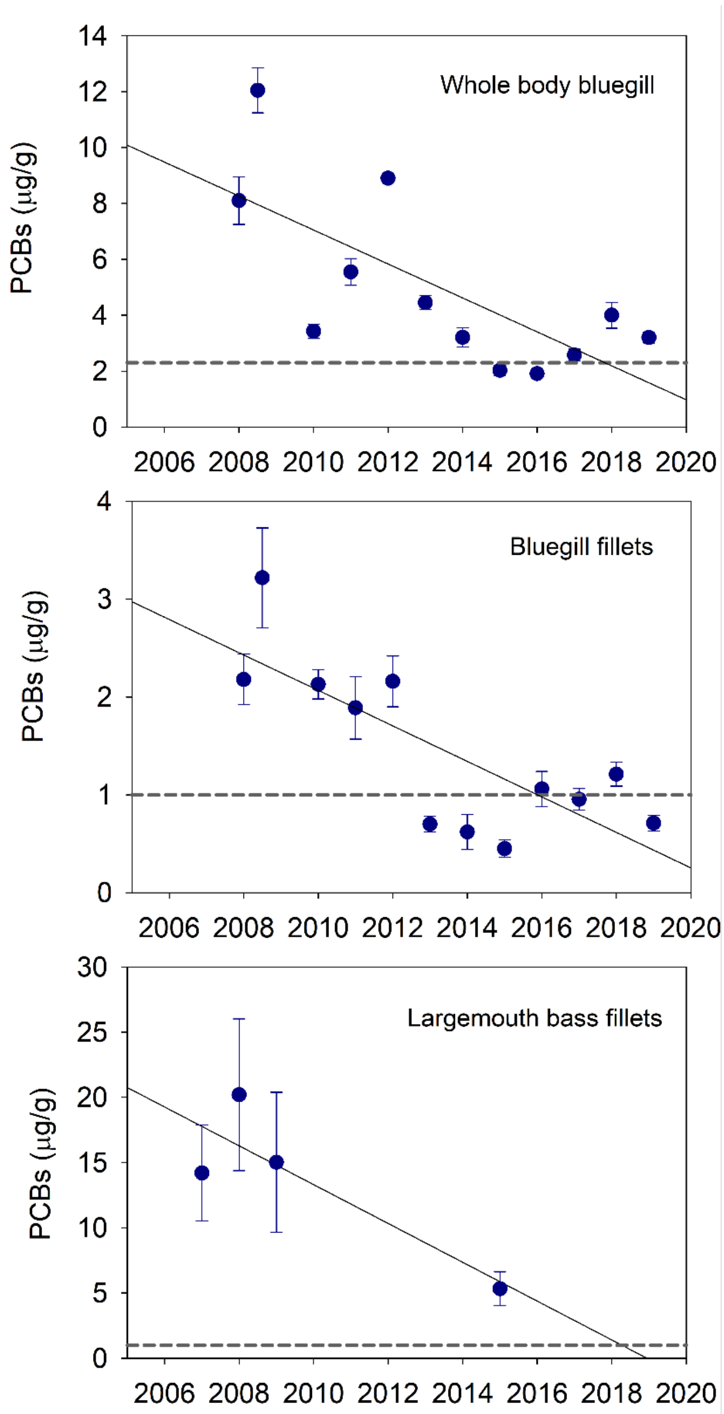




Notes:
1. N = 2 clam composite samples per site/year.
2. Total PCBs defined as the sum of Aroclors 1248, 1254, and 1260.
3. Photos upper graph show a clam basket in a storm drain, and Little Sewee Creek, lower graph photos show placement of clam cages in Upper SD-100 (upper photo) and Lower SD-100 locations.

Acronyms:
PCB = polychlorinated biphenyl
SD = storm drain

Figure 3.37. Mean total PCB concentrations (µg/g, wet wt) in caged clams placed at K-1007-P1 outfalls compared with reference stream clams (Little Sewee Creek), 1993–2019



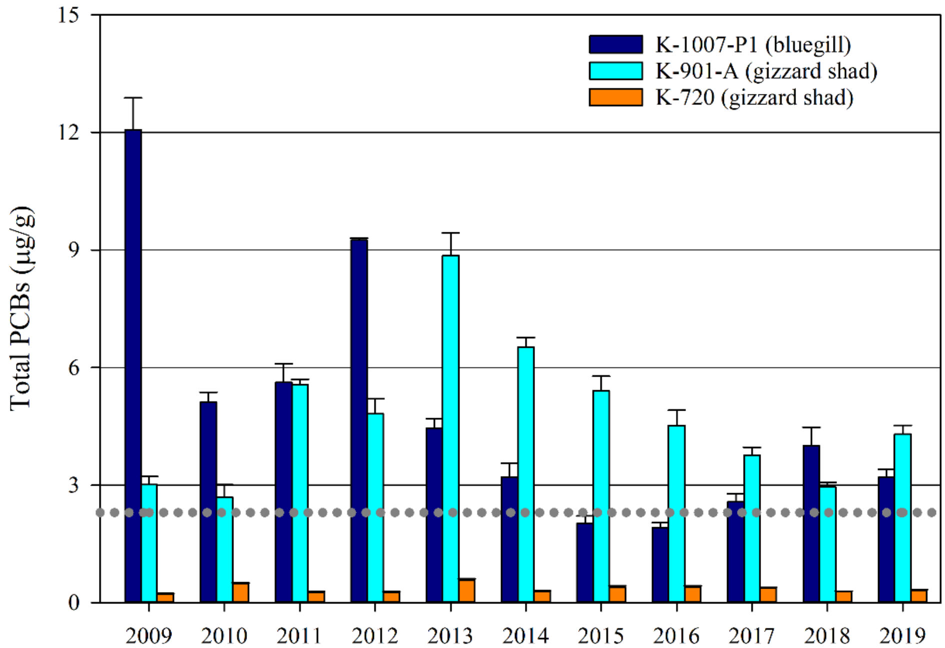
Notes:

1. For largemouth bass, N = 6 fish per site/year. For bluegill sunfish, N = 20 for fillets and N = 6 composites of 10 whole body fish.
2. The target for fillet (1 µg/g) and whole body concentrations (2.3 µg/g) is shown with the gray dotted lines.

Acronym:

PCB = polychlorinated biphenyl

Figure 3.38. Mean PCB concentrations (µg/g, wet wt) in fish from the K-1007-P1 Pond, 2007–2019



Notes:
1. Total PCBs are defined as the sum of Aroclors 1248, 1254, and 1260.
2. The dotted line signifies the target PCB concentration of 2.3 µg/g in whole body fish.

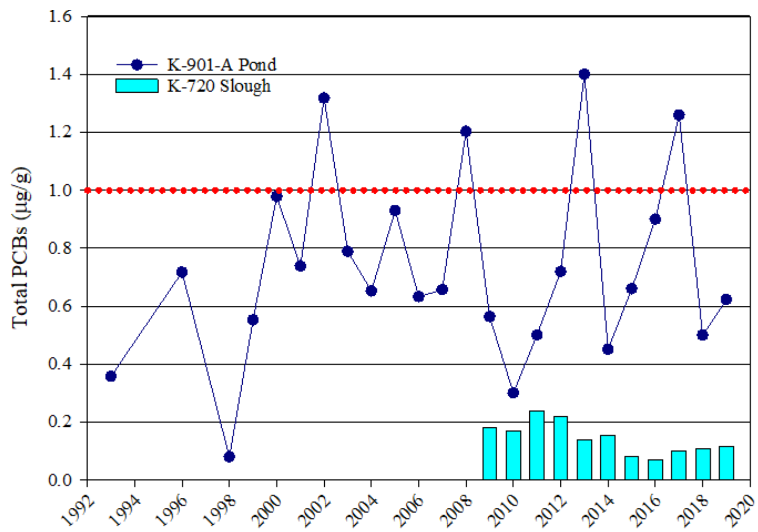
Acronym:
PCB = polychlorinated biphenyl

Figure 3.39. Mean (+ 1 standard error) total PCB concentrations (µg/g, wet wt) in whole body fish from K-1007-P1 Pond, K-901-A Holding Pond, and K-720 Slough, 2009–2019

K-901-A Pond

The target fish species for analysis of PCBs in the K-901-A Holding Pond and K-720 Slough were gizzard shad (*Dorosoma cepedianum*) and largemouth bass (*Micropterus salmoides*). It was not possible to collect the target number of 20 bass from each body of water, so common carp (*Cyprinus carpio*) also were collected to provide a combined total of 20 fish. Carp were selected as a surrogate species for bass because they are widely distributed, are present at both locations, and have been used historically in other monitoring efforts on ORR for contaminant analyses.

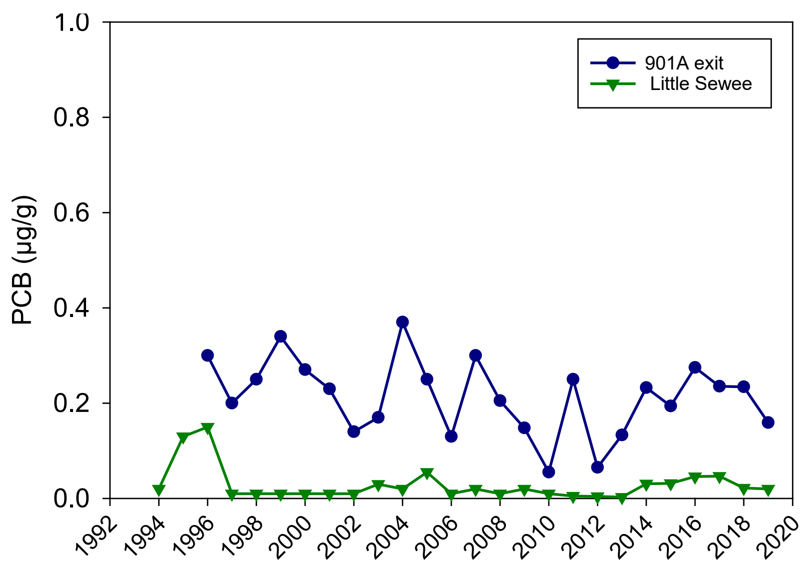
At the K-901-A Holding Pond, PCB concentrations in largemouth bass have fluctuated annually, but in 2019 were below the target concentration set for the K-1007-P1 Pond of 1 µg/g total PCBs (0.62 µg/g) (Figure 3.40). Mean PCB concentrations in carp collected from the K-901-A Holding Pond were just above this target concentration (1.22 µg/g). Whole body gizzard shad from the K-901-A Holding Pond, collected as a measure of potential ecological risk to terrestrial wildlife, were substantially higher in concentration (4.30 µg/g) than the fillets of bass and carp, and were higher than the concentrations seen in this species in the past two years, remaining above the target concentration set for the K-1007-P1 Holding Pond for whole body fish (2.3 µg/g) (Figure 3.39). PCB concentrations in clams deployed in the K-901-A Pond were lower than those deployed in the K-1007-P1 Pond and were similar in 2019 (0.16 µg/g) to concentrations seen in 2018 (Figure 3.41).



Notes:
1. Mean PCBs (± 1 SE) in largemouth bass fillets, 1993–2019 (µg/g).
2. N = 6 fish per year, when possible.
3. The dotted red line shows the advisory level for PCBs in fish fillets (1 µg/g).

Acronyms:
PCB = polychlorinated biphenyl SE = standard error

Figure 3.40. Mean total PCB concentrations in largemouth bass from the K-901-A Pond and the K-720 Slough



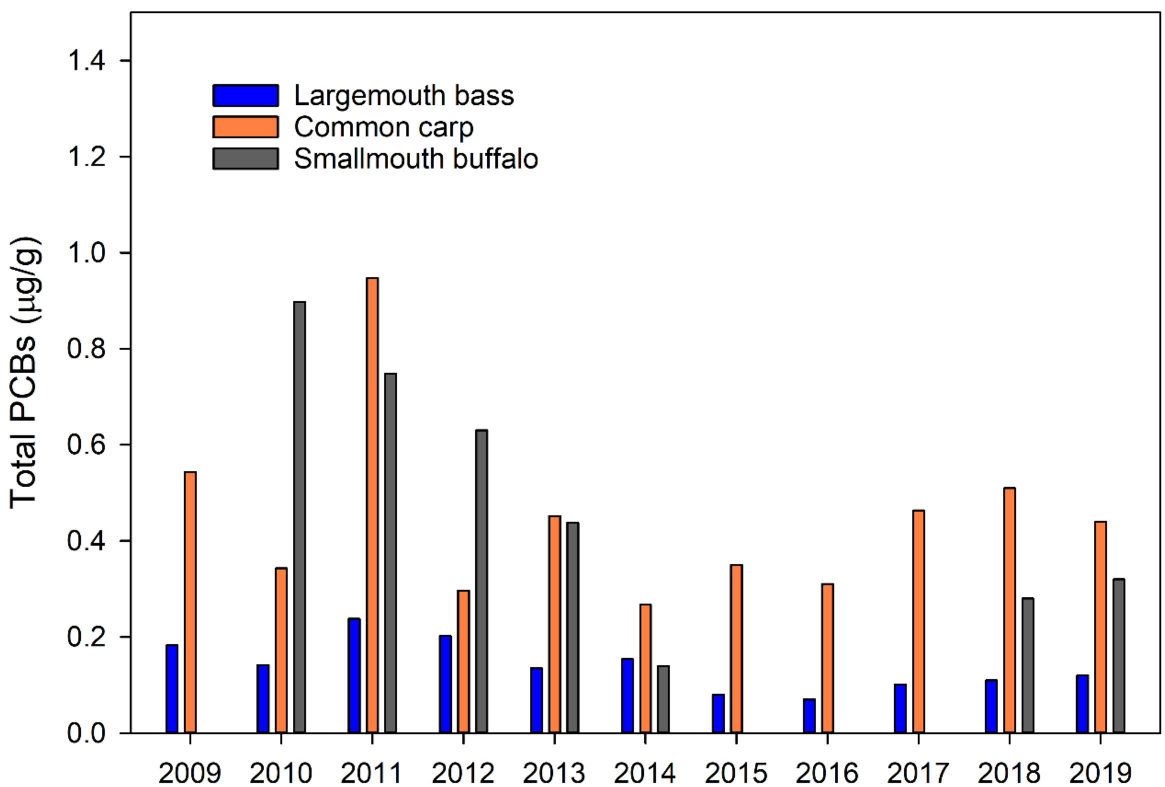
Notes:
1. Total PCBs defined as the sum of Aroclors 1248, 1254, and 1260.
2. N = 2 composites of 10 clams each per year.
3. Shown in green are data for clams collected from the reference site, Little Sewee Creek (Sweetwater, Tennessee).

Acronym:
PCB = polychlorinated biphenyl

Figure 3.41. Mean total PCB (µg/g, wet wt; 1993–2019) concentrations in the soft tissues of caged Asiatic clams deployed in the K-901-A Pond for a 4-week period

K-720 Slough

Routine bioaccumulation monitoring in the K-720 Slough began in 2009. Although the target species for fish fillet monitoring in this slough is largemouth bass, as in the K-901-A Pond it has been difficult to collect a full sample of 20 fish of this species; to complete the collection, common carp also are collected for a total of 20 fish. Figure 3.42 shows the temporal trends in fish fillet concentrations in the slough. In 2019, PCB concentrations in both fish species monitored were below the state advisory limit of 1 µg/g. In all cases PCB levels in fish collected from the K-720 Slough were significantly lower than in the K-901-A Holding Pond for the same species (Table 3.29). PCB concentrations in largemouth bass collected from the K-720 Slough were significantly lower than those in the other monitored ponds, averaging 0.12 µg/g in 2019. Concentrations in carp and smallmouth buffalo collected from the slough were higher than concentrations in bass, averaging 0.44 µg/g and 0.36 µg/g, respectively. Total PCBs in whole body gizzard shad from the K-720 Slough were similar to those seen in recent years and were lower than those seen in whole body fish collected from the other monitored ponds, averaging 0.32 µg/g in 2019.



Notes:
1. Total PCBs defined as the sum of Aroclors 1248, 1254, and 1260.
2. The target sample was 20 largemouth bass, but because these fish are not abundant in the slough, carp and smallmouth buffalo were collected to complete the sample size of 20 fish.

Acronym:
PCB = polychlorinated biphenyl

Figure 3.42. Mean total PCB (µg/g, wet wt; 2009–2019) concentrations in the fillets of largemouth bass, common carp, and smallmouth buffalo collected from the K-720 Slough

Table 3.29. Average concentrations (µg/g, wet wt) of total PCBs (Aroclors 1248, 1254, and 1260) in fillets and whole-body composites of fish collected in 2019 near the East Tennessee Technology Park.

Site	Species	Sample type	Sample size (n)	Total PCBs (mean ± SE)	Range of PCB values	No. > target (PCBs)/n
K-1007-P1 Pond	Bluegill	Fillets	20	0.71 ± 0.08	0.24–1.61	3/20
		Whole-body composites	6	3.20 ± 0.19	2.61–3.72	6/6
K-901-A Pond	Largemouth bass	Fillets	4	0.62 ± 0.13	0.36–0.92	0/4
	Common carp	Fillets	16	1.22 ± 0.11	0.67–2.23	10/16
	Bluegill	Fillets	20	0.43 ± 0.08	0.15–1.73	1/20
		Whole-body composites	6	1.29 ± 0.08	1.03–1.56	0/6
	Gizzard shad	Whole-body composites	6	4.30 ± 0.22	3.62–5.03	6/6
K-720 Slough	Largemouth bass	Fillets	6	0.12 ± 0.03	0.06–0.21	0/6
	Smallmouth buffalo	Fillets	9	0.36 ± 0.10	0.06–0.84	0/9
	Common carp	Fillets	5	0.44 ± 0.09	0.11–0.67	0/5
	Gizzard shad	Whole-body composites	6	0.32 ± 0.01	0.27–0.36	0/6
CRM 11.0	Bluegill	Whole-body composites	6	0.07 ± 0.002	0.06–0.08	0/6
	Gizzard shad	Whole-body composites	6	0.20 ± 0.05	0.13–0.45	0/6
PCM 1.0	Bluegill	Whole-body composites	6	0.19 ± 0.01	0.14–0.22	0/6
	Gizzard shad	Whole-body composites	6	0.29 ± 0.03	0.22–0.30	0/6

Notes:
1. Values are mean concentrations (µg/g) ± 1 SE.
2. Each whole body composite sample is composed of 10 individual fish.
3. Also shown are the ranges of values observed for PCBs and the number of fish whose fillet PCB concentrations exceeded 1 µg/g out of the total number of fish (or composites) sampled (n). (1 µg/g total PCBs in fish fillets and 2.3 µg/g in whole-body composites).

Acronyms and abbreviations:
CRM = Clinch River mile
No. = number
PCB = polychlorinated biphenyl
PCM = Poplar Creek mile
SE = standard error

3.7.2 Task 2: Instream Benthic Macroinvertebrate Communities

Benthic macroinvertebrate communities in Mitchell Branch are sampled using ORNL and TDEC protocols (Figures 3.43 and 3.44). Evaluation of long-term trends of macroinvertebrate communities in the stream make it possible to document the effectiveness of pollution abatement activities or remediation efforts as well as to assess the potential consequences of unanticipated events as sitewide remediation continues (e.g., chromium release into Mitchell Branch).

Figure 3.43. Collecting an invertebrate sample using Oak Ridge National Laboratory Biological Monitoring and Abatement Program protocols

Figure 3.44. Sampling for benthic macroinvertebrates with TDEC protocols

Benthic Macroinvertebrates

The major objectives of the benthic macroinvertebrate task are: (1) to help assess the ecological condition of Mitchell Branch, and (2) to evaluate changes in stream ecology associated with changes in facilities operations and RAs within the Mitchell Branch watershed. To meet these objectives, the condition of the benthic macroinvertebrate community of Mitchell Branch has been monitored routinely since late 1986. This summary includes results of samples collected each April from 1987 to 2019 following ORNL BMAP quantitative sampling protocols and samples collected annually (August/September) with TDEC semi-quantitative sampling protocols for estimating the Tennessee Stream Biotic Index and Habitat Biotic Index (TDEC 2011; TDEC 2017). TDEC protocol guidance was updated in August 2017 and the most recent 2017 guidance was used for the 2018 and 2019 invertebrate and habitat surveys. For both sets of protocols, four sites were assessed in Mitchell Branch—MIKs 0.4, 0.7, 0.8, and 1.4. MIK 1.4 serves as the primary reference site, but narrative Biotic Index results for TDEC protocols are based on reference conditions established by TDEC from a suite of reference sites in the same ecoregion as Mitchell Branch. Finally, also included in this summary is a comparison between the macroinvertebrate community structure at the four Mitchell Branch sites and five other reference sites on ORR. Most of these reference sites - spanning a range of stream sizes both smaller and larger than Mitchell Branch (based on watershed area) - have been monitored using ORNL protocols since the mid-1980s for other biological monitoring projects on ORR (ORNL BMAP and WRRP/Bear Creek Biological Monitoring Program) (Table 3.30). This summary provides information on how invertebrate community structure at Mitchell Branch sites, including MIK 1.4, compares with the community structure of a range of relatively unaffected reference sites on ORR.

Table 3.30. Stream sites included in the comparison between Mitchell Branch and other reference sites on the Oak Ridge Reservation (ORR)

Site	Location		Watershed area (km^2)	Program
	Latitude (N)	Longitude (W)		
Mitchell Branch				
MIK 0.4	35.93859	84.39040	1.554	ETTP BMAP
MIK 0.7	35.93786	84.38792	1.347	ETTP BMAP
MIK 0.8	35.93786	84.38682	1.269	ETTP BMAP
MIK 1.4 (reference)	35.93790	84.37662	0.311	ETTP BMAP
Other ORR reference sites				
First Creek (FCK 0.8)	35.92670	84.32355	0.596	ORNL BMAP
Fifth Creek (FFK 1.0)	35.93228	84.31746	0.596	ORNL BMAP
Gum Hollow Branch (GHK 2.9)	35.96385	84.31594	0.777	Bear Creek BMP/WRRP
Walker Branch (WBK 1.0)	35.95805	84.27953	1.010	ORNL BMAP
White Oak Creek (WCK 6.8)	35.94106	84.30145	2.072	ORNL BMAP

Acronyms:
BMAP = Biological Monitoring and Abatement Program
BMP = Biological Monitoring Program
ETTP = East Tennessee Technology Park
MIK = Mitchell Branch kilometer
ORNL = Oak Ridge National Laboratory
ORR = Oak Ridge Reservation
WBK = Walker Branch
WRRP = Water Resources Restoration Program

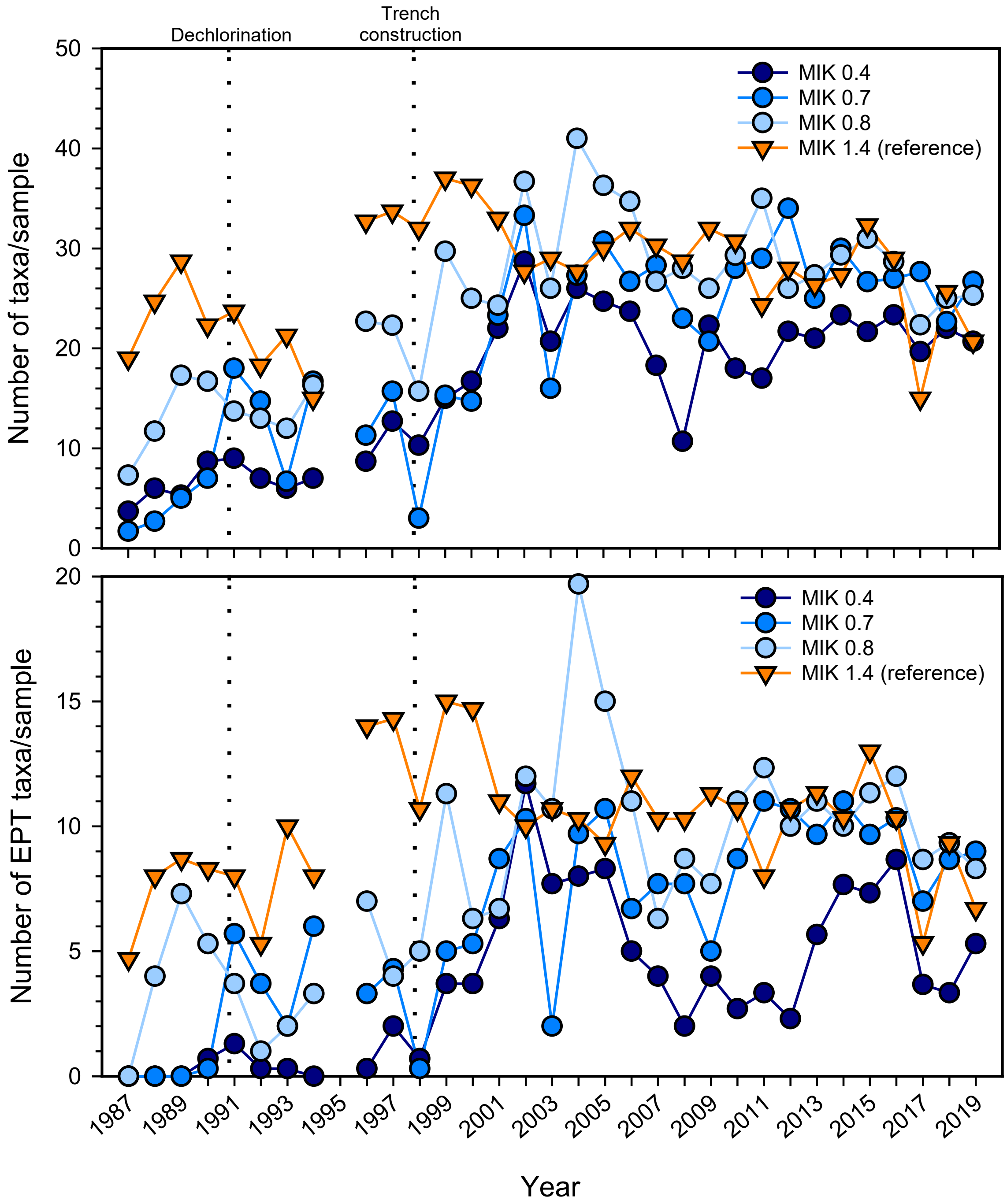
Mitchell Branch—ORNL and TDEC Protocols

Total taxa richness (i.e., the total number of taxa per sample) and Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa richness (i.e., the total number of pollution-intolerant EPT taxa [mayflies, stoneflies, and caddisflies] per sample) measured using ORNL protocols has varied over the measurement period (1986–2019) in all Mitchell Branch sites (Figure 3.45). Both total taxa richness and EPT taxa richness increased in MIKs 0.4, 0.7, and 0.8 from 1987 to the late 1990s, and then reached fairly consistent values, albeit with considerable year to year variation (Figure 3.45). Total taxa richness and EPT taxa richness have been fairly consistent throughout the measurement period in the reference site, MIK 1.4 (Figure 3.46). In April 2019, total taxa richness and EPT taxa richness were highest at MIK 0.8 and lowest in MIK 0.4 (Figure 3.45). EPT taxa richness patterns among sites in 2019 diverted from the pattern observed in 2018 and in 2010–2016, where EPT taxa richness was highest upstream at MIK 1.4 and lowest downstream at MIK 0.4 (Figure 3.45). In April 2019, EPT taxa richness was lowest in both MIK 1.4 and MIK 0.4 and higher at MIK 0.7 and MIK 0.8 (Figure 3.45).

The percent density of the pollution-intolerant taxa (higher values are indicative of good condition) was highest at MIK 1.4, the reference site, and lowest at MIK 0.4 in April 2019, which is a pattern that has been observed in most years since monitoring began in 1987 (Figure 3.46). In most years, the percent density of pollution-tolerant taxa (lower values are indicative of good conditions) was lowest at the reference site, MIK 1.4. However, in April 2019, the percent density of pollution-tolerant taxa was higher at MIK 1.4 than MIK 0.8 but still lower than at MIK 0.4 and MIK 0.7 (Figure 3.46). The percent of pollution-tolerant taxa at MIK 1.4 in 2019 was one of the highest values seen since monitoring began and only in 1988 and 1992 were these values higher (Figure 3.46). Continued monitoring will determine if these higher values at MIK 1.4 persist or rather reflect interannual variability.

Based on TDEC 2017 protocols, scores for the Tennessee Macroinvertebrate Biotic Index (TMI) in 2019 rated the invertebrate community as passing biocriteria guidelines at MIK 1.4 and MIK 0.7 while TMI scores at MIK 0.4 and MIK 0.8 fell below these guidelines (Figure 3.47). TMI scores in 2019 improved at all sites over 2018 scores except at MIK 0.4 (Figure 3.47). In 2019, MIK 1.4 received the highest scores possible for all invertebrate metrics used to calculate TMI except for total taxa and EPT taxa richness and the percentage of clingers (Table 3.31). TDEC protocol states that TMI scores should only be calculated for samples with 160–240 invertebrates identified to genus (TDEC 2017). In August 2019, only 88 individuals were collected from MIK 1.4, so results from this site should be interpreted with caution. Both MIK 0.8 and MIK 0.7 received low scores for EPT taxa richness and MIK 0.8 also received low scores for percentage EPT (Table 3.31). MIK 0.4 received low scores for total taxa richness, EPT taxa richness, and percentage EPT, but received the highest scores possible for all other invertebrate metrics (Table 3.26). Since sampling using TDEC protocols began in 2008 in Mitchell Branch, TMI scores at have almost always rated the invertebrate community at MIK 1.4 as passing biocriteria guidelines, MIK 0.4 as falling below biocriteria guidelines, and MIK 0.7 and MIK 0.8 as oscillating between passing and falling below biocriteria guidelines (Figure 3.47).

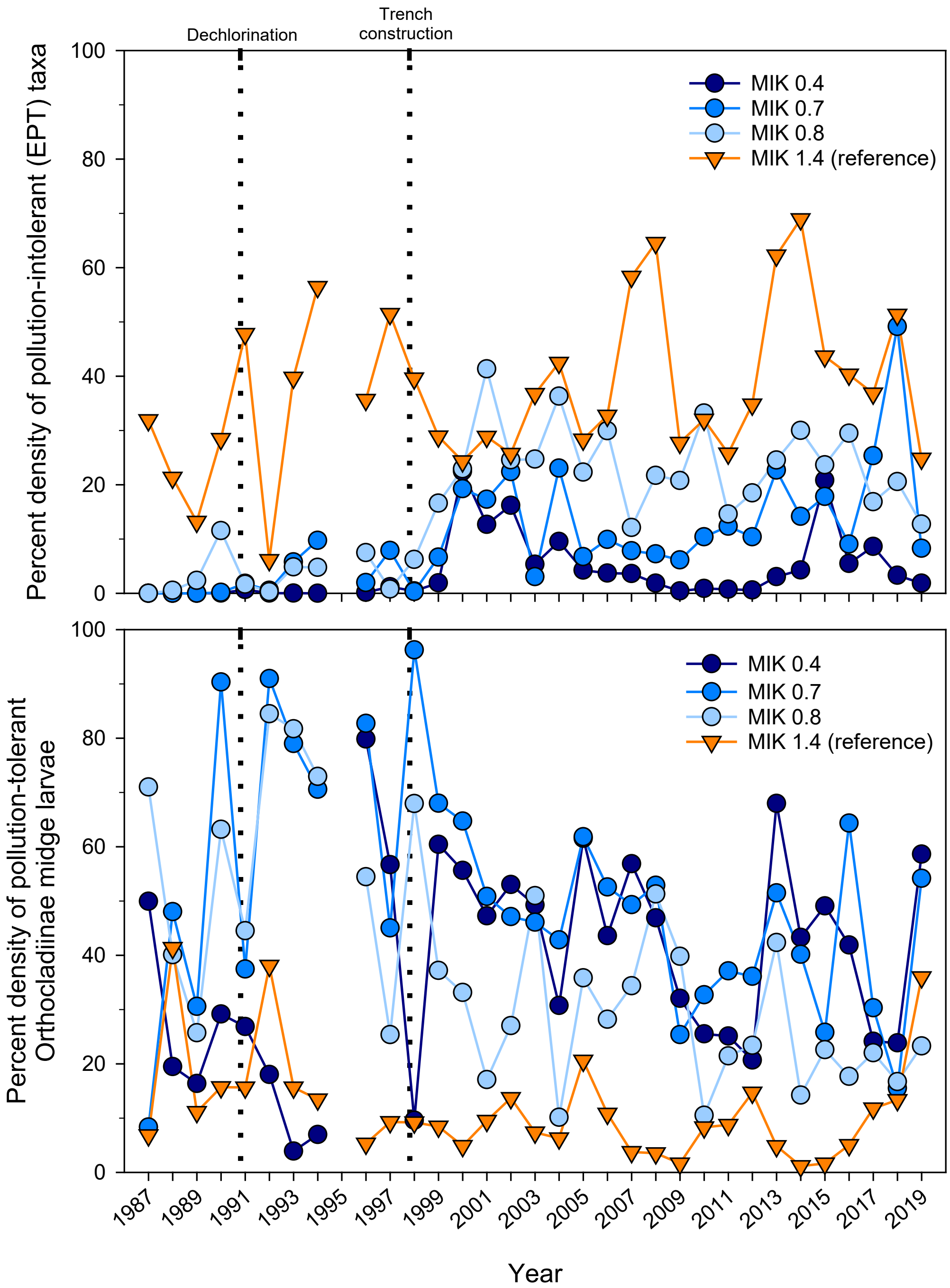
Based on TDEC stream habitat protocols, habitat quality was above the ecoregion 67f guideline at MIK 1.4, 0.8, and 0.7, and below the ecoregion guideline at MIK 0.4 (Figure 3.47). Habitat scores increased at all sites from 2018 to 2019. In general, improvements from the previous two years were primarily seen in epifaunal substrate/available cover, channel flow, and vegetative protection. However, poor substrate quality (dominance of gravel instead of cobble and excessive embeddedness) and unstable, highly erodible banks continued to be an issue at multiple sites. Habitat conditions related to riffle stability (i.e., frequency of reoxygenation zones) decreased at all sites except MIK 1.4.



Note: Samples were not collected in April 1995, as indicated by the gaps in the lines.

Acronyms:
EPT = Ephemeroptera, Plecoptera, and Trichoptera
MIK = Mitchell Branch kilometer

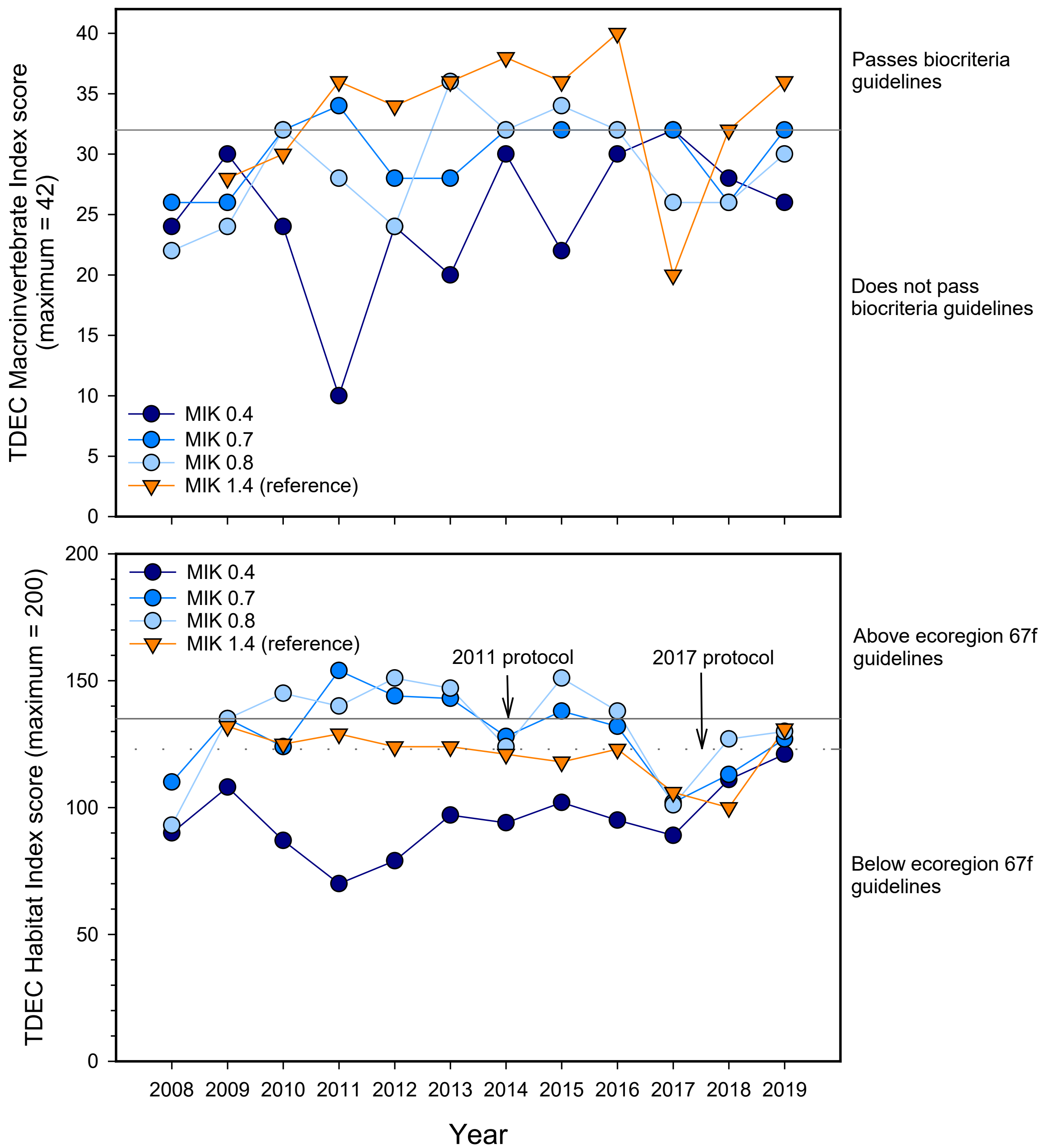
Figure 3.45. Mean total taxonomic richness (top) and richness of the pollution-intolerant Ephemeroptera, Plecoptera, and Trichoptera taxa per sample (bottom) for Mitchell Branch sites, April 1987–2019



Notes:
1. Percentages were based on total densities for each site.
2. Samples were not collected in April 1995, as indicated by the gaps in the lines.

Acronym:
MIK = Mitchell Branch kilometer

Figure 3.46. Mean percent density of the pollution-intolerant Ephemeroptera, Plecoptera, and Trichoptera taxa (i.e., stoneflies, mayflies, and caddisflies), and percent density of the pollution-tolerant Orthocladiinae midge larvae (Chironomidae) at four Mitchell Branch sites, April 1987–2019



Notes:
1. Mitchell Branch site MIK 1.4 was not sampled with TDEC protocols in 2008.
2. The horizontal lines on each graph show the rating thresholds for each index; respective narrative ratings for each threshold are shown on the right side of each graph.
3. TDEC 2011 guidance used in 2008-2017, TDEC 2017 guidance used in 2018 and 2019.

Figure 3.47. Temporal trends in the Tennessee Department of Environment and Conservation Biotic Index (top) and Stream Habitat Index (bottom) scores for four Mitchell Branch sites, August 2008–2019

Table 3.31. Tennessee Macroinvertebrate Index (TMI) metric values and scores and index score for Mitchell Branch, August 19, 2019[a,b,c]

Site	Metric values							Metric scores							TMI[d]
	Taxa rich	EPT rich	%EPT	%OC	NCBI	%Cling	%TN Nuttol	Taxa rich	EPT rich	%EPT	%OC	NCBI	%Cling	%TN Nuttol	
MIK 0.4	12	2	5.7	3.4	4.09	64.8	25.0	2	0	0	6	6	6	6	**26**
MIK 0.7	20	6	32.5	9.0	4.96	59.9	45.8	4	2	4	6	6	6	4	**32 [pass]**
MIK 0.8	24	4	21.2	5.5	5.05	80.2	46.1	4	2	2	6	6	6	4	**30**
MIK 1.4	29	11	50.6	22.0	3.68	44.0	26.2	4	4	6	6	6	4	6	**36[e] [pass]**

[a] TMI metric calculations and scoring and index calculations are based on Tennessee Department of Environment and Conservation (TDEC) protocols for Ecoregion 67f: TDEC 2017, *Quality System Standard Operating Procedures for Macroinvertebrate Stream Surveys*, TDEC Division of Water Pollution Control, Nashville, Tennessee. Available here.

[b] Taxa rich = Taxa richness; EPT rich = Ephemeroptera, Plecoptera, and Trichoptera (mayflies, stoneflies, and caddisflies) taxa richness; %EPT = EPT abundance excluding *Cheumatopsyche* spp.; %OC = percent abundance of oligochaetes (worms) and chironomids (nonbiting midges); NCBI = North Carolina Biotic Index; %Cling = percent abundance of taxa that build fixed retreats or otherwise attach to substrate surfaces in flowing water; %TN Nuttol. = percent abundance of nutrient-tolerant organisms.

[c] MIK = Mitchell Branch kilometer.

[d] TMI = Tennessee Macroinvertebrate Index score. TMI is the total index score and higher index scores indicate higher quality conditions. A score of ≥ 32 is considered to pass biocriteria guidelines (green shading). TMI scores < 32 are indicated by yellow shading.

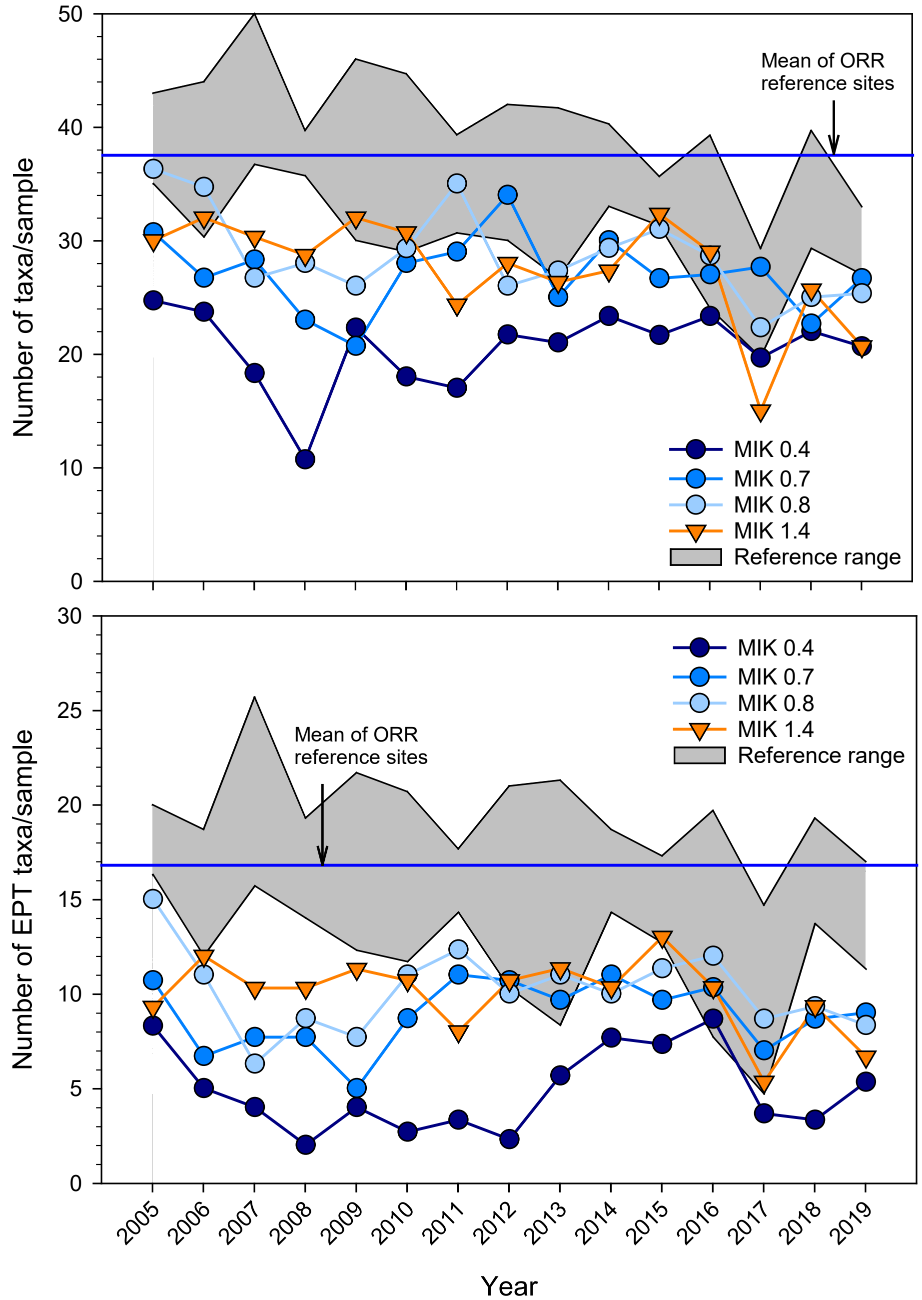
[e] TDEC protocol states that TMI scores should only be calculated for samples with 160–240 invertebrates identified to genus (TDEC 2017). In August 2019, only 88 individuals were collected from MIK 1.4, so results from this site should be interpreted with caution.

Comparison between Mitchell Branch and Other Reference Sites on ORR

Here the benthic macroinvertebrate communities in Mitchell Branch are compared to ORR reference streams over a 15-year period since 2005. Mean values for total taxa richness and taxa richness of pollution-intolerant (EPT) taxa for Mitchell Branch are shown in Figure 3.48, and percent density of the pollution-intolerant and pollution-tolerant taxa are shown in Figure 3.49. Also shown in Figures 3.48 and 3.49 is the range of metric means for the five reference sites on ORR, First Creek kilometer 0.8, Fifth Creek kilometer 1.0, White Oak Creek kilometer 6.8, Walker Branch kilometer 1.0, and Gum Hollow Branch kilometer 2.9, in gray shading.

In 2019, total taxa richness and taxa richness of pollution-intolerant taxa at Mitchell Branch sites, including MIK 1.4, were less than both the range of means at the five reference sites and the 15-year mean of all reference sites (Figure 3.48). This trend was observed since these comparisons began in 2005, with some exceptions (e.g., 2016, 2017). In contrast to richness metrics, the mean percent densities of pollution-intolerant and pollution-tolerant taxa at MIK 1.4 were rarely outside of the range for the reference sites (Figure 3.49). As noted above, the percent density of pollution-tolerant taxa at MIK 1.4 in 2019 was the one of the highest values measured since monitoring began; however, higher values were also observed at some of the reference sites (Figure 3.49). Since 2005, the mean percent density of pollution-intolerant taxa at MIK 0.8 fluctuated in and out of the reference range, while the percent density of pollution-tolerant taxa was mostly higher than the reference range (except for the past two years; 2018 and 2019). MIK 0.7 showed marked improvement in percent density of both pollution-intolerant and pollution-tolerant taxa in 2018, but fell outside the reference range for both metrics in 2019. Except for in 2015, percent densities of both groups were outside of the reference ranges at MIK 0.4 in every year (Figure 3.49).

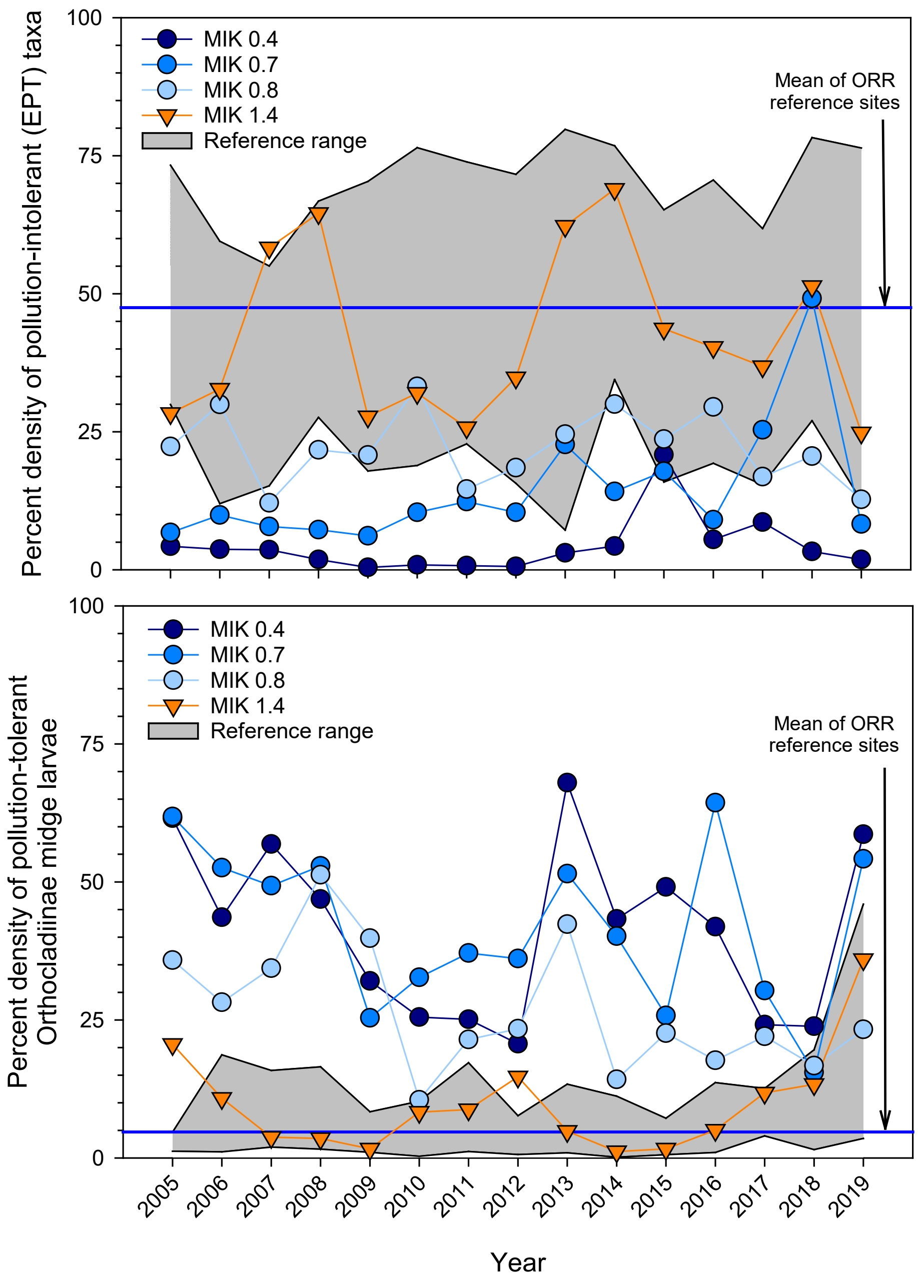
These results from the comparison of Mitchell Branch sites with the reference sites, combined with the long-term results for all Mitchell Branch sites discussed above, suggest that from the standpoint of reference sites, MIK 1.4 falls within the lower range of expected reference conditions on ORR. Factors potentially contributing to frequent excursions of invertebrate community metrics outside of the range of other reference sites include the somewhat smaller size of MIK 1.4 compared with the other reference sites (based on watershed area, Table 3.31), which may limit the range of invertebrate species that can colonize and thrive at the site, and habitat characteristics that have typically contributed to the lower quality habitat at the site, such as low flow and poor substrate quality (Figure 3.47). These results also support the contention that sites downstream of MIK 1.4 continue to exhibit evidence of mild to moderate degradation.



Note:
The gray shading on each graph shows the range of values at five additional reference stream sites on ORR from 2005 to 2019, and the solid blue horizontal line on each graph is the mean of the reference sites for the same period.

Acronyms:
MIK = Mitchell Branch kilometer
MIK 1.4 = reference site;
ORR = Oak Ridge Reservation

Figure 3.48. Mean total taxonomic richness (top) and taxonomic richness of the pollution-intolerant Ephemeroptera, Plecoptera, and Trichoptera taxa per sample (bottom) for the benthic macroinvertebrate community at four Mitchell Branch sites, and the range of mean values from five reference sites on ORR, April 2005–2019



Notes:

1. Percentages were based on total densities for each site.
2. The gray shading on each graph shows the range of values at five additional reference stream sites on ORR from 2005 to 2019, and the solid blue horizontal line in each graph is the mean of the reference sites for the same period.

Acronyms:

MIK = Mitchell Branch kilometer
ORR = Oak Ridge Reservation
MIK 1.4 = reference site

Figure 3.49. Mean percent density of the pollution-intolerant taxa (i.e., stoneflies, mayflies, and caddisflies; top), and percent density of the pollution-tolerant Orthocladiinae midge larvae (Chironomidae; bottom) in four Mitchell Branch sites, and the range of mean values from five reference sites on ORR, April 2005–2019

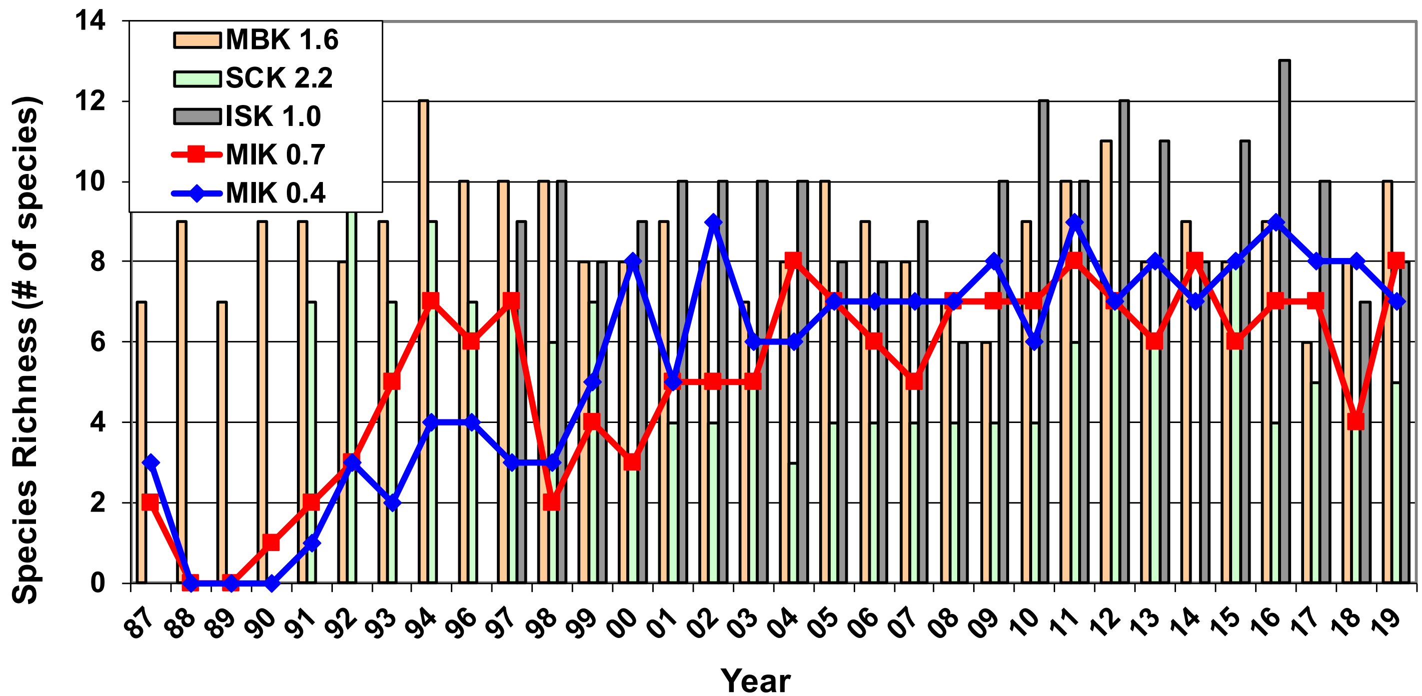
3.7.3 Task 3: Fish Community

Fish population and community studies are used to evaluate the biotic integrity (or general ecological health) of Mitchell Branch. The fish community is sampled quantitatively at two sites in Mitchell Branch, MIK 0.4 (downstream of SD 190) and MIK 0.7 (downstream of SD 170) and at local reference streams each spring.

Historically, the fish community in Mitchell Branch was most severely affected in the late 1980s and early 1990s. After some recovery in the mid-1990s, Mitchell Branch was affected negatively again in 1998 in association with a remedial activity that replaced a large section of stream bottom with a liner and interlocking rock substrate (Figure 3.50). In recent years, this reach of stream appears to be developing more natural habitat, including a more robust riparian plant community and some instream riffle/pool sequences as substrate is slowly beginning to accumulate throughout the reach. This has added to the complexity of the habitat available for fishes to colonize.

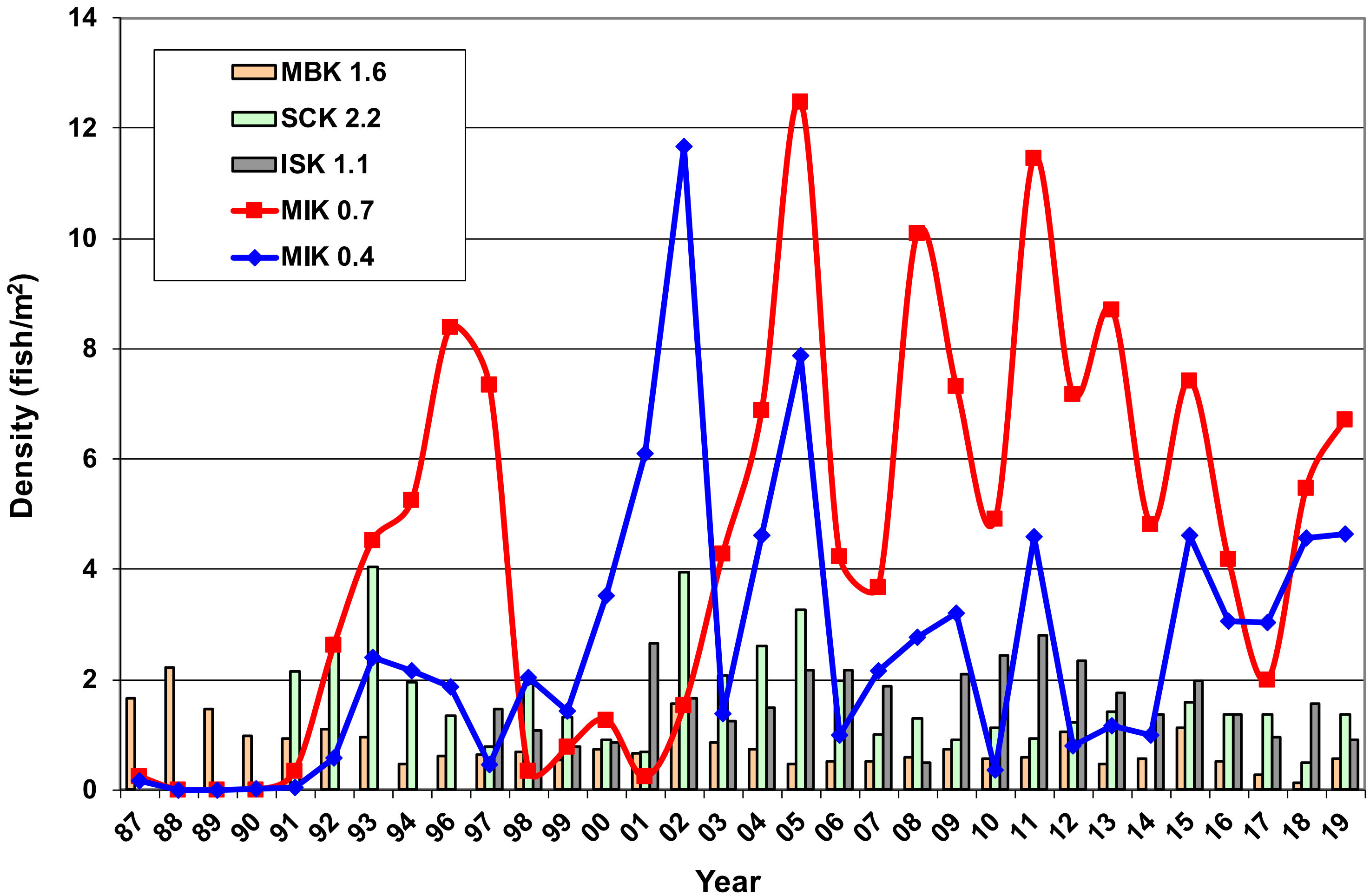
Since 2000, the fish community has had relatively stable species diversity but rather large variations in fish density and biomass (Figures 3.51-3.53), which are often reflective of unstable, impaired streams. Streams that experience high density and biomass of tolerant fish species are often indicative of either high nutrient influences on a fish community (i.e., more algal growth means more food at the base of the food chain) or poor instream habitat—and often a combination of both. Of the two sites sampled for fish community, MIK 0.7 has experienced the greatest fluctuations in these community parameters. This is likely due to the modified stream channel and riparian areas and poor instream habitat associated with the remediation work in this reach. Similar conditions are seen in other area streams on ORR, including sections of EFPC where tolerant species dominate the concrete- and bedrock-lined channel, which supports little riparian protection. In addition, extremely low precipitation amounts in the summer of 2016 resulted in very low flows in many area streams. Small first and second order streams without springs or groundwater influence were most severely affected by these conditions. This may partially explain the decreased density and biomass numbers observed in spring 2017 samples and the apparent return of higher values since then.

Figure 3.50. Construction of lined section of Mitchell Branch, MIK 0.7, in 1998 (left) and more recent habitat conditions in 2019 (right)



Acronyms:
ISK = Ish Creek
MBK = Mill Branch kilometer
MIK = Mitchell Branch kilometer
SCK = Scarboro Creek

Figure 3.51. Species richness for the fish communities at sites in Mitchell Branch kilometer and in reference streams Mill Branch kilometer, Scarboro Creek, and Ish Creek, 1987–2019



Acronyms:

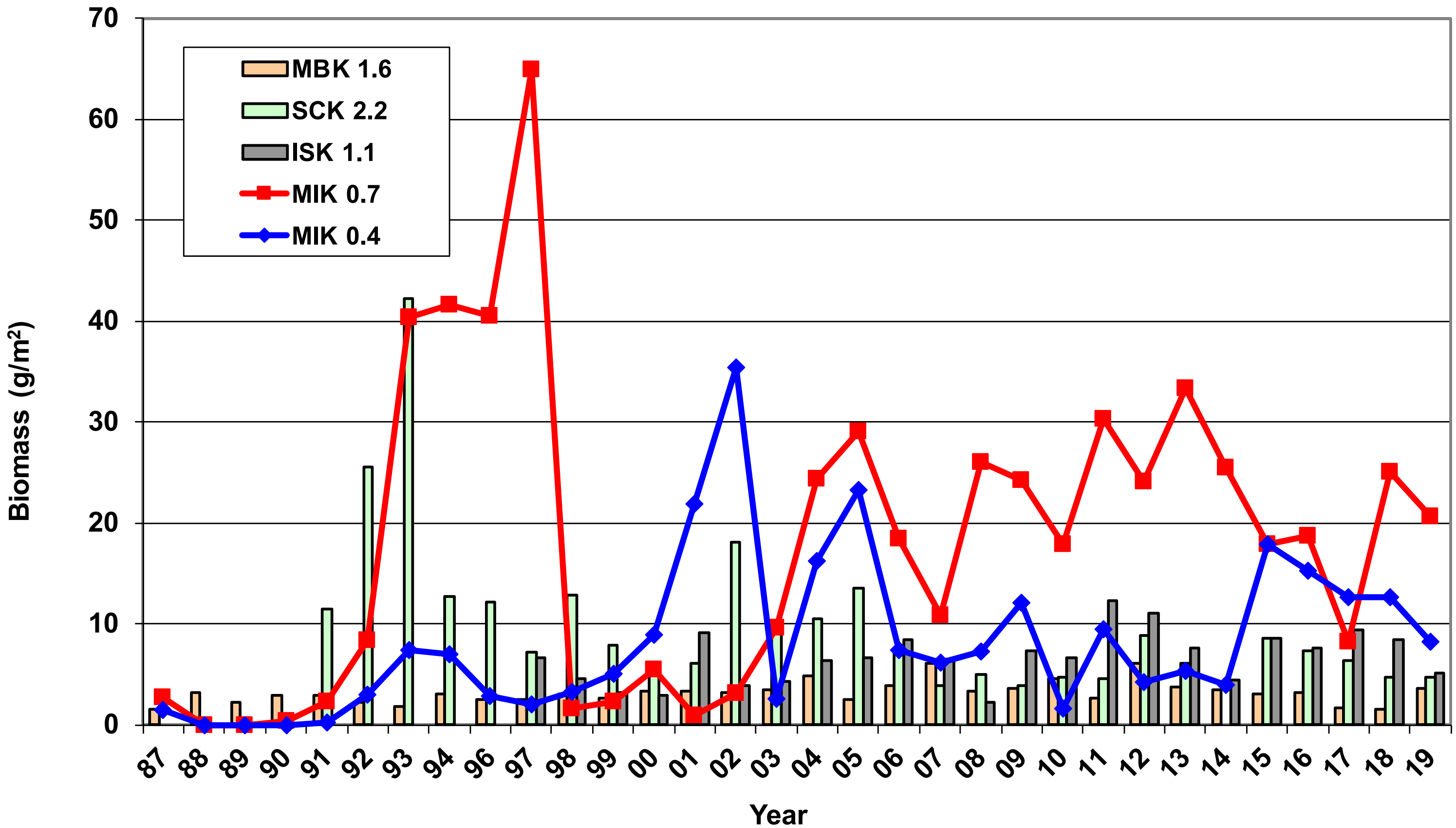
ISK = Ish Creek

MBK = Mill Branch kilometer

MIK = Mitchell Branch kilometer

SCK = Scarboro Creek

Figure 3.52. Density for the fish communities at sites in Mitchell Branch kilometer and in reference streams Mill Branch kilometer, Scarboro Creek, and Ish Creek, 1987–2019



Acronyms:

ISK = Ish Creek

MBK = Mill Branch kilometer

MIK = Mitchell Branch kilometer

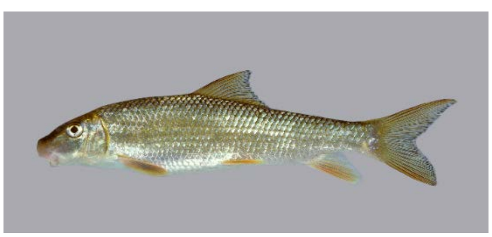
SCK = Scarboro Creek

Figure 3.53. Biomass for the fish communities at sites in Mitchell Branch kilometer and in reference streams Mill Branch kilometer, Scarboro Creek, and Ish Creek, 1987–2019

At both MIK 0.4 and MIK 0.7, the 2019 sample of fish community parameters indicated continued variation, especially regarding fish density and biomass. Species richness (number of species) at MIK 0.7 recovered from 2018 values, while values at the lower site remained stable. Both sites have species richness comparable with similar sized reference streams. As mentioned above, density (number of fish) at both sites increased from 2018 and still remains well above reference conditions. Biomass (weight) decreased slightly in 2019 at both sites. Both the lower Mitchell Branch site and the upper site had reduced diversity and density of sensitive fish species in 2019. Overall the last five years, there has been a slight uptick in sensitive species diversity and density at both sampled sites in Mitchell Branch which can be attributed to the presence of fish such as banded sculpin (*Cottus carolinae*), which appear to be a resident species in Mitchell Branch, and also occasional occurrences of other more sensitive fish. In 2019 two new species were observed in the Mitchell Branch fish community sites. Snubnose darter (*Etheostoma simoterum*) were collected at MIK 0.7, which represents a unique sensitive species in this reach of stream. They have been observed at the very mouth of the system in past samples. In addition, warmouth (*Lepomis gulosus*) were observed at both sites in spring 2019.

In general, the Mitchell Branch fish communities at MIK 0.4 and MIK 0.7 continue to lack diverse resident species that are sensitive to stress or that have specialized feeding or reproductive requirements, such as darters or suckers that occur consistently at higher frequencies in the reference streams. Like the benthic communities, fish community monitoring provides an integrated response to *all* of the various water chemistry and habitat influences in a stream. Identifying the major stressor influences on the community (i.e., causal analysis) would require additional investigatory strategies coupled with the monitoring data.

During routine bioaccumulation sampling, several species of fish are collected regularly at MIK 0.2 that are almost never observed in the Mitchell Branch fish community monitoring activities at the upstream sites. These included four pollution-sensitive species: snubnose darter, greenside darter (*Etheostoma blennioides*), black redhorse (*Moxostoma duquesnei*), and northern hogsucker (*Hypentelium nigricans*) (Figure 3.54). Future monitoring will help determine if these species are becoming established farther upstream in Mitchell Branch or are merely seasonal migrants to the stream's lower section, which is easily accessible from the much larger Poplar Creek.



Black redhorse (*Moxostoma duquesnei*)

Snubnose darter (*Etheostoma simoterum*)

Northern hogsucker (*Hypentelium nigricans*)

Greenside darter (*Etheostoma blennioides*)

Photos: Chris Bryant

Figure 3.54. Sensitive fish species observed in lower Mitchell Branch

3.7.4 K-1007-P1 Pond Fish Community

The fish communities in the K-1007-P1 pond are assessed annually. This sampling is conducted to evaluate the effectiveness of remediation efforts implemented in 2009 and is aimed at reducing the PCBs available for transfer out of the pond via natural routes (i.e., trophic transfer). The RAs included capping contaminated sediment with fill dirt, planting native aquatic vegetation to stabilize sediment, and removing potentially contaminated fish from the pond. Fish initially were removed from the pond using a piscicide (Rotenone), and uncontaminated native fish were stocked in the pond with the goal of establishing a sunfish-dominated community. Sunfish have a shorter lifespan than many other species of fish, especially higher trophic level fish, and they have a prey source that is generally varied but consistently lower on the aquatic food chain compared with species such as largemouth bass, thus reducing the likelihood that contaminants would biomagnify within the system.

Despite efforts to remove all unwanted fish from the pond, an unexpected breach in the weir separating the K-1007-P1 pond from the adjacent Poplar Creek in May 2010 allowed numerous fish to enter the pond during high waters. These unwanted fish constituted several species that were unfavorable to the pond action—including: (1) nonnative species and (2) species with life history traits that undermined the remediation efforts, such as being long-lived and having feeding habits that disturb potentially contaminated sediments. Continued work to remove these unwanted fish has been productive, and only limited numbers of the most long-lived species, such as common carp (*Cyprinus carpio*) and smallmouth buffalo (*Ictiobus bubalus*), are encountered in annual monitoring.

Two additional species that returned to the pond after the weir breach were gizzard shad (*Dorosoma cepedianum*) and largemouth bass (*Micropterus salmoides*). Gizzard shad feed on phytoplankton and zooplankton in natural environments such as larger reservoirs, but in smaller ponds such as P1, they often turn to feeding on algal growth at the surface of the pond sediment, which can disturb soils and potentially resuspend contaminants in the pond substrate. Largemouth bass tend to be a long-lived species and are a top predator in aquatic environments, making them particularly susceptible to bioaccumulation. They also are a game fish highly prized by many anglers as well as a common table fare. These two species also have been targeted for removal during continued remediation efforts and fish surveys.

Overall, the K-1007-P1 Pond fish community surveys conducted in February 2019 revealed the presence of 14 species of fish. An observation of particular importance from previous surveys is the abundance of sunfish species (bluegill, redear sunfish, and warmouth), which constitute approximately 70 percent of the total fish population (Figure 3.55). Bluegill, the most prevalent of these species, were historically the dominant sunfish species in the pond, and they are the desired bioindicator fish species to have in the remediated pond. Although largemouth bass continue to persist in the pond, their abundance remains relatively low. Despite removal efforts, their presence is likely to continue, given the habitat conditions currently in the pond (i.e., abundant prey sources and open water). Gizzard shad continue to be present in the pond and are suspected of reproducing; however, they constitute only approximately 21 percent of the fish population at present.

A few additional strategies were used in 2017–2019 in an effort to further manipulate the fish population and overall pond ecosystem to better reflect the desired end state. These included: more strategic and targeted fish removal efforts, stocking of 61,000 juvenile bluegill over three years, and aquatic and terrestrial plantings of native plants in various areas around the pond. These efforts were designed to reduce nuisance fish presence through removal, adjust the fish community through inundation of specific fish age classes, and increase vegetative cover in areas of the pond that currently lack vegetation. Future monitoring will provide insight on the effectiveness of these efforts and provide guidance for future management techniques.

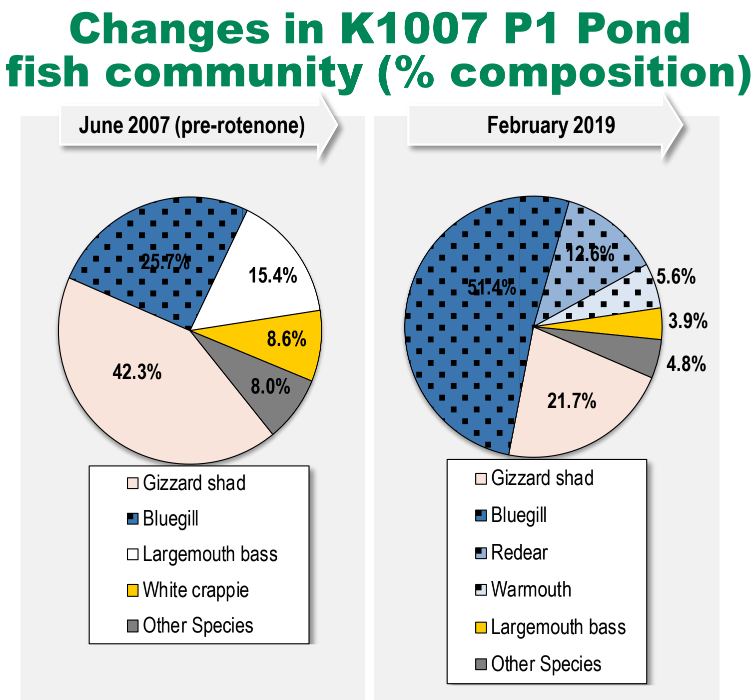


Figure 3.55. Changes in the K-1007-P1 Pond fish community (% composition) from 2007 to 2019

3.8 Environmental Management and Waste Management Activities

3.8.1 Waste Management Activities

Restoration of the environment, D&D of facilities, and management of legacy wastes constitute the major operations at ETTP.

CWTS is a small water treatment unit for chromium-contaminated groundwater that sits within the existing Central Neutralization Facility footprint. CWTS came online in late 2012 and handles purge water from groundwater monitoring, as well as the chromium collection system water. Effluent from CWTS discharges into the Clinch River through an existing Central Neutralization Facility discharge line. Section 3.6.7 provides a more detailed discussion of CWTS operations.

3.8.2 Environmental Remediation Activities

During 2019, substantial progress was made in remediation efforts at the ETTP site. In 2019, the last of the buildings that had conducted or supported the gaseous diffusion process was demolished. The ultimate goal of the remediation work is to make parcels of land available for a general aviation airport, conservation areas, and private-sector development that can economically benefit the region. Highlights of this effort are given below. For details, please see the *2019 Cleanup Progress—Annual Report to the Oak Ridge Regional Community* (OREM-19-2579, UCOR 2019a).

3.8.2.1 Soil Remediation

UCOR's soil remediation efforts at ETTP are helping to prepare the site for future commercial industrial use. The site is divided into two cleanup regions: Zone 1, a 1,400-acre area outside the main plant area, and Zone 2, the 800-acre area that comprises the main plant area. The areas in these zones are divided into EUs that vary in size. Remediation efforts are designed to protect groundwater, wildlife, and the future workforce. Remediation activities include removal of facilities, excavation of soil, and land use covenants.

3.8.2.2 K-1423 Demolition Completed

The K-1423 Toll Enrichment Facility was originally used to support the gaseous diffusion process. After enrichment operations ceased, the facility was used for a variety of waste management operations. The building was demolished in 2019.

3.8.2.3 Poplar Creek Facilities Demolition

Demolition of the last remaining buildings that had supported the gaseous diffusion process was completed in 2019. These facilities housed in these buildings had performed a number of different support functions and were located along Poplar Creek.

3.8.2.4 Building K-1037 Demolition Completed

UCOR completed demolition of Building K-1037 in 2019. The facility was once a warehouse, and was converted to a facility that manufactured all of the barrier material used in the gaseous diffusion process since 1947. This material was a key component of the gaseous diffusion process where workers separated the ^{235}U and ^{238}U isotopes.

3.8.2.5 K-1414 Garage Demolition Completed

The K-1414 Garage opened in 1949 and operated until 2018. It was the longest operating facility at ETTP. Demolition was completed in 2019.

3.8.2.6 K-29 Slab Removal Completed

The K-29 Building was a former gaseous diffusion facility that was demolished in 2006. In 2019, the concrete slab of the building was removed.

3.8.2.7 Commemoration of the K-25 Site

National historic preservation initiatives at ETTP continued in 2019. The K-25 History Center is located on the second floor of the COR-owned Fire Station #4 at ETTP. The K-25 History Center opened in 2020. Visitors to the K-25 History Center will be invited to explore the rich history of this Manhattan Project site. This facility features a theatre experience, period artifacts, equipment replicas, and workers' oral histories, placing K-25 in its proper historical context in World War II and the Cold War. An in-depth look at gaseous diffusion, the thousands of equipment stages housed in K-25, and the people who sacrificed so much to make it a reality are highlighted. The future Equipment Building and Viewing Tower design replicates the exterior appearance of the K-25 Building, and will house a representative cross-section of gaseous diffusion technology. An enclosed observation deck will provide a 360-degree view of the site.

3.8.3 Reindustrialization

As cleanup has progressed extensively at ETTP, more large parcels are becoming available for transfer to the private and commercial industrial sectors. In 2018, DOE completed transfer of Duct Island, a 207-acre parcel on the western portion of ETTP, to CROET. This transfer is the second largest transfer in the history of the program, and the largest at ETTP Heritage Center. This brings the total acreage of land transferred to 1,280 acres, with 789 of those acres at the Heritage Center. Additionally, a large area of

170 acres at the southeast corner of ETTP has been approved for transfer to Metropolitan Knoxville Airport Authority for a potential regional airport project. The general aviation airport runway would accommodate small corporate jets, private airplanes, and EMS aircraft. A final decision from the Federal Aviation Administration (FAA) on this project is anticipated in 2020. Additionally, DOE has entered into discussions with the Tennessee Wildlife Resources Agency (TWRA) to develop a partnership between the two agencies. The plan is for TWRA to acquire hundreds of acres from DOE that will become greenspace that can be used for public recreation as wildlife management areas and greenways. Two canoe launch areas on Poplar Creek have also been identified for transfer. The integration of greenspace into the private-sector industrial park will make ETTP a truly unique federal land reuse project.

DOE completed an Environmental Assessment to support the property transfer and potential construction and operation of the airport. DOE has also received EPA and TDEC approval for future property transfer of the former Powerhouse area, which is over 400 acres. The transfer of large parcels, as more of the site cleanup is completed, provides the best opportunities to date for industrial and commercial development of ETTP.

3.9 References

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4. The Y-12 National Security Complex

Y-12 National Security Complex (Y-12), a premier manufacturing facility operated by Consolidated Nuclear Security, LLC (CNS) for the National Nuclear Security Administration (NNSA), plays a vital role in the U.S. Department of Energy (DOE) Nuclear Security Enterprise. Drawing on more than 75 years of manufacturing excellence, Y-12 helps ensure a safe and reliable United States nuclear weapons deterrent.

Y-12's primary mission includes processing, retrieval, and storage of nuclear materials; dismantlement of nuclear weapons; providing fuels to the nation's naval reactors; and complementary work for other government and private-sector entities.

Today's environment requires Y-12 to have a new level of flexibility and versatility; therefore, while continuing its key role, Y-12 has evolved to become the resource that the nation looks to for support in protecting America's future by developing innovative solutions in manufacturing technologies, prototyping, safeguards and security, technical computing, and environmental stewardship.

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

4.1 Description of Site and Operations

4.1.1 Mission

Charged with maintaining the safety, security, and effectiveness of the United States' nuclear weapons stockpile, Y-12 is a one-of-a-kind manufacturing facility that plays an important role in United States national security. Y-12's core mission is to ensure a safe, secure, and reliable United States nuclear deterrent, which is essential to national security. Every weapon in the United States nuclear stockpile has components manufactured, maintained, or ultimately dismantled by Y-12. Through life extension program activities, Y-12 produces refurbished, replaced, and/or upgraded weapons components to modernize the enduring stockpile. As the nation reduces the size of its arsenal, Y-12 has a central role in decommissioning weapons systems and providing weapons material for non-explosive, peaceful uses. Y-12 provides the expertise to secure highly enriched uranium (HEU), store it with the highest security, and make material available for non-weapons uses (e.g., in research reactors that produce cancer-fighting medical isotopes and in commercial power reactors). Y-12 also processes HEU from weapons removed from the nation's nuclear weapons stockpile for use by the Naval Reactors program to fuel nuclear-powered submarines and aircraft carriers.

Located within the city limits of Oak Ridge, Tennessee, the Y-12 site covers more than 328 ha (810 acres) in the Bear Creek Valley, stretching 4.0 km (2.5 mi) in length down the valley and nearly 2.4 km (1.5 mi) in width across it. Additional NNSA-related facilities are located offsite from Y-12 and include the Central Training Facility, East Tennessee Technology Park (ETTP) Emergency Operations Center (EOC), Uranium Processing Facility (UPF) project laydown storage and offices, Y-12 Material Acquisition Complex (K-1065), and the Union Valley Sample Preparation Facility.

4.1.2 Modernization

Government-owned facilities and operations are becoming smaller, more efficient, and more responsive to changing national and global challenges. NNSA's vision for a smaller, safer, more secure, and less-expensive nuclear weapons complex must leverage the scientific and technical capabilities of its workforce while continuing to meet national security requirements. Nowhere in the National Security Enterprise is this more important than at Y-12.

More than 60 percent of Y-12 mission-critical facilities are over 70 years old (Figure 4.1). To address this situation, Y-12 has been consolidating operations, modernizing facilities and infrastructure, and reducing the legacy footprint for more than a decade. These actions are consistent with and supportive of NNSA enterprise transformation planning. Through continued infrastructure projects, new construction, and the disposition of excess facilities, Y-12 will continue to strive toward becoming a more responsive, sustainable enterprise.

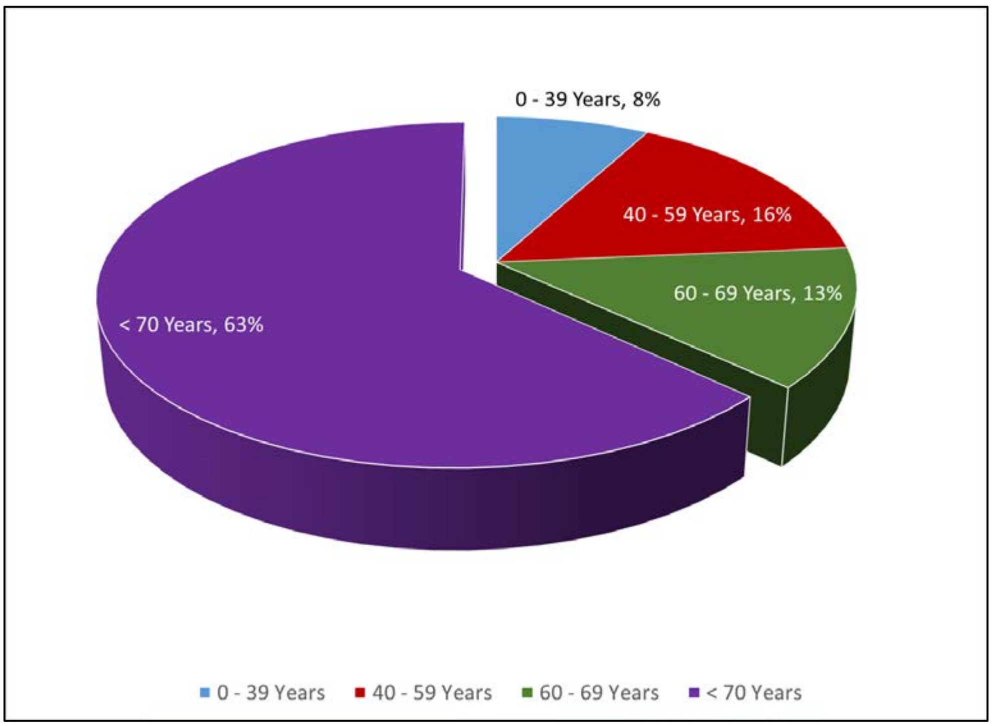


Figure 4.1. Age of mission-critical facilities at the Y-12 National Security Complex

Replacement and revitalization are key elements of the modernization strategy at Y-12. A significant number of facilities at Y-12 are at or beyond design life. Construction at UPF continues to make good progress, and replacement projects for several additional facilities are in the critical design process.

4.1.3 Enriched Uranium Operations

Y-12's enriched uranium (EU) core manufacturing and processing operations are housed in decades-old buildings that are near or past the end of their expected life spans.

UPF will be an integral part of Y-12 transformation efforts and a key component of the NNSA Uranium Center of Excellence. UPF will be a modern manufacturing facility designed and constructed for health, safety, security, and operations efficiency. In Fiscal Year (FY) 2014, NNSA commissioned a Project Peer

Review Team to assess the progress and opportunities for the UPF project. This evaluation produced a number of recommendations to refocus the project to a smaller footprint and to relocate various processes to existing facilities.

When the current UPF construction is complete, it will replace a portion of EU production functions. The remaining EU production capability will be maintained in Buildings 9215 and 9204-02E, which must be sustained to achieve the EU mission strategy. The strategy includes the following:

- Accelerating transition out of Building 9212 and into UPF to reduce nuclear safety and operational risk while maintaining EU capabilities.
- Substantially improving the needed Y-12 infrastructure over the next decade at a risk-based annual funding level that supports safe and secure operations.
- Prioritizing replacement capabilities by risk to nuclear safety, security, and mission continuity.

4.1.4 Lithium Processing Facility

The lithium production equipment and facilities at Y-12 have degraded to the point that repair is no longer an option. Thus, to ensure continued mission availability and to reduce annual operating costs, the lithium capability must be replaced. Production work for lithium and related non-nuclear special material vital to production of canned subassemblies is performed in Building 9204-2, built in 1944. The facility (at approximately 325,000 ft^2) is oversized for today's mission, and for decades, concrete on the inside and outside of the building has deteriorated. The roof, walls, and ceilings have been exposed to corrosive liquids and processing fumes, which have caused significant deterioration of the concrete. Separation of the concrete and rebar poses a realized risk of falling concrete, which requires administrative controls, including restricted access and protective equipment in many areas. Site production risk assessments rate two of the lithium processes as the highest equipment risks at Y-12. Critical process equipment (hydraulic press) failures caused "code blue," or immediate, repair efforts to minimize the negative impact on delivery schedules of directed stockpile work components. Previous concerns with humidity control have improved with recent repair/replacement projects associated with kathabar equipment. Additional concrete and heating, ventilation, and air conditioning projects are underway in support of the life extension program schedules. A proposed new Lithium Processing Facility (LPF) line item project will replace the existing building and eliminate approximately $33 million in deferred maintenance.

4.1.5 Support Facilities

Emergency response capabilities at Y-12 reside in five primary facilities—four located onsite (Buildings 9706-2, 9105, 2005, and 9710-2), and one (Building K-1650) located at ETTP. Building 9706-2 houses the Operations Center (OC) and the Emergency Control Center. The Technical Support Center (TSC) was relocated to Building 9105 due to a flood event in Building 9706-02 in 2014. Building 9710-2 is the principal facility housing Fire Protection Operations, with a backup facility (2005) located on the west end. Building K-1650 houses the Command Center/alternate EOC. A line-item project for construction of a new EOC, scheduled to begin in 2020, includes the replacement of the OC, TSC, and Emergency Response Center. The proposed EOC will more effectively and efficiently support Y-12 missions by consolidating emergency-response capabilities into a habitable, survivable facility that also provides space for a technical support team.

Building 9710-02 is located within the most highly protected area of the plant and close to Y-12's most hazardous operations. Seismic, tornado, hazardous material release, and security events could render the fire station inaccessible. Off-duty personnel augment the duty staff, and thus, their access to the facility is critical. Although upgrades have been performed over the years, the Fire Protection Operations facility has exceeded its useful life and needs to be replaced.

Building 2005 was constructed in 1980 and was originally occupied by Oak Ridge Reservation (ORR) roads and grounds crew. The fire department assumed occupancy of the facility in 2014 and renovated portions for crew support and vehicle staging. Relocation of the fire station away from Y-12 hazardous material facilities is necessary to ensure that the fire department can respond safely and effectively to all emergencies at Y-12. A proposed new fire station is planned for construction beginning in 2020. The new facility will be located on the east end of the plant and is designed to meet current codes and functional requirements.

The Mercury Treatment Facility (MTF) is being constructed to remove mercury contamination from East Fork Poplar Creek (EFPC). The facility is an enabling project for the future demolition of the high-risk mercury-contaminated facilities located on the west end of Y-12. Over the next 25-year horizon, Y-12 will continue to consolidate personnel and processes in support of the vision for long-range footprint reduction and modernization. The planned construction at Y-12 would eliminate many of the World War II-vintage buildings that currently house the nuclear operations. The following projects are under construction or are being initiated during the Future Year Nuclear Security Plan (FYNSP) period:

- UPF
- EOC
- West End Protected Area reduction
- MTF
- Fire Station
- LPF
- West End Production Support Change House

The following projects are planned for construction beyond the FYNSP period:

- Applied Technologies Laboratory
- Consolidated Depleted Uranium Manufacturing Capability
- Maintenance Complex
- Non-Special Nuclear Material Storage and Staging Facility
- Waste Management Complex
- EU Manufacturing Center (Building 9215 replacement capability)
- Assembly and Disassembly Center (Building 9204-02E replacement capability)

4.1.6 Excess Facility Disposition

Since 2002, Y-12 has demolished more than 1.6 million gross square footage of excess facilities. Currently, more than 72 excess DOE facilities are located on the Y-12 site, with a total of 2.8 million gross square footage. In 2016, Y-12 established the Excess Facility Disposition Program to stabilize and de-inventory the three major high-risk process-contaminated facilities and to safely dispose of other excess facilities around the site.

Process-contaminated excess facilities at Y-12 are owned by NNSA as well as the DOE Office of Environmental Management (EM), Office of Science, and Office of Nuclear Energy. These facilities contain radiological or chemical contamination resulting from their mission operations during the Manhattan Project or the Cold War.

Non-process-contaminated excess facilities generally do not contain radiological or chemical contamination from mission operations but may contain hazardous industrial materials associated with their construction materials (e.g., asbestos insulation, paint containing lead, or oil contaminated with polychlorinated biphenyls [PCBs]). The non-process-contaminated excess facilities will be deactivated by NNSA and decommissioned by NNSA or EM, depending on the cost and complexity.

The NNSA Facilities Disposition Program has provided much-needed funding and resources to assist with stabilization and demolition of both process-contaminated and non-process-contaminated excess facilities at Y-12. In partnership with EM, NNSA and CNS will continue to monitor and evaluate excess facilities; prioritize their disposition, including cost and schedule; and actively work towards disposal of excess facilities.

4.2 Environmental Management System

As part of CNS's commitment to environmentally responsible operations, Y-12 has implemented an Environmental Management System (EMS) based on the requirements of the globally recognized International Organization of Standardization (ISO) 14001:2004 standard to plan, implement, control, and continually improve environmental performance at Y-12 (ISO 2004).

DOE Order 436.1, *Departmental Sustainability* (DOE 2011a), provides requirements and responsibilities for managing sustainability within DOE in accordance with applicable Executive Orders (EOs). DOE Order 436.1 further requires implementation of an EMS that is either registered to the requirements of ISO 14001:2004 by an accredited ISO 14001 registrar or self-declared to be in conformance to the standard in accordance with instructions issued by the Office of the Federal Environmental Executive, a chartered task force under the White House Council on Environmental Quality. Y-12 has maintained an EMS with self-declared conformance to ISO 14001 since 2006.

The EMS requirements taken from DOE Order 436.1 have been incorporated into the Environmental Protection functional area of Y-12's Contractor Assurance System.

4.2.1 Integration with Integrated Safety Management System

Y-12's Integrated Safety Management System (ISMS) is the basis for planning and implementing environment, safety, and health (ES&H) programs and systems that provide the necessary structure for any work activity that could affect the public, a worker, or the environment. At Y-12, the elements of the ISO 14001 EMS are incorporated in and are consistent with the ISMS to achieve environmental compliance, pollution prevention, waste minimization, resource conservation, and sustainability. Both the ISMS and EMS are based on an internationally recognized cycle of continual improvement, commonly known as the "plan-do-check-act" cycle, as depicted in Figure 4.2, which shows the relationship between the ISMS and the integrated EMS.

Figure 4.2. Relationship between the Y-12 National Security Complex Environmental Management System and the Integrated Safety Management System depicted in a "plan-do-check-act" cycle

4.2.2 Policy

Y-12's environmental policy and commitment to providing sound environmental stewardship practices through the implementation of an EMS have been defined, are endorsed by top management, and have been made available to the public via company-sponsored forums and public documents such as this one. Y-12's ES&H policy is presented in Figure 4.3.

Y12 Environment, Safety, and Health Policy Statement

As we work to achieve the Y-12 mission and our vision of a modernized Y-12 Complex, we will do so by ensuring the safety and health of every worker, the public, and the environment. Every employee, contractor, and visitor is expected to take personal responsibility for their actions.

- Environmental Policy Statement: We protect the environment, prevent pollution, comply with applicable requirements, and continually improve our environment.
- Safety and Health Policy Statement: The safety and health of our workers and the protection of public health and safety are paramount in all that we do. We maintain a safe work place, and plan and conduct our work to ensure hazard prevention and control methods are in place and effective.

In support of these policies, we are committed to:

- Integrating Environment, Safety and Health into our business processes
- Continuously improving our processes and systems
- Directly, openly, and truthfully communicating this policy and our ES&H performance
- Striving to minimize the impact of our operations on the environment in a safe, compliant, and cost-effective manner using sustainable practices
- Incorporating sustainable design principles into the design and construction of facility upgrades, new facilities, and infrastructure considering life-cycle costs and savings
- Incorporating the use of engineering controls to reduce or eliminate hazards whenever possible into the design and construction of facility upgrades, new facilities, and infrastructure
- Striving to provide a clean and efficient workplace free of occupational injuries and illnesses (Target Zero)
- Fostering and maintaining a work environment of mutual respect and teamwork that encourages free and open expression of ES&H concerns

Figure 4.3. Y-12 National Security Complex's environment, safety, and health policy

In addition to Y-12's ES&H policy, CNS has issued an environmental policy that is a significant component of the CNS ISMS and contributes to sustaining the Pantex and Y-12 imperatives of safe and secure operations. The Y-12 ES&H policy and the CNS environmental policy are communicated to all employees and are incorporated into mandatory training for every employee. The policies are available for viewing on both Y-12's external and internal websites. Y-12 personnel are made aware of the commitments stated in the policies and how the commitments relate to Y-12 work activities.

4.2.3 Planning

4.2.3.1 Y-12 National Security Complex Environmental Aspects

Environmental aspects may be thought of as potential environmental hazards associated with a facility operation, maintenance job, or work activity. The environmental aspects and their impacts (potential effects on the environment) are evaluated to ensure that the significant aspects of Y-12 activities that are identified continue to reflect stakeholder concerns and changes in regulatory requirements. The EMS provides the system to ensure that environmental aspects are systematically identified, monitored, and controlled to mitigate or eliminate potential impacts to the environment.

The analysis identified the following as significant environmental aspects in 2019:

- Storm water (runoff from roofs and outdoor storage areas)
- Surface water (process water and dike emissions to creek)
- Wastewater (sanitary sewer and process water treated and disposed)
- Radiological waste
- Excess facilities and unneeded materials and chemicals
- Aging infrastructure and equipment
- Legacy contamination and disturbance

4.2.3.2 Legal and Other Requirements

To implement the compliance commitments of the ES&H policy and to meet legal requirements, systems are in place to review changes in federal, state, or local environmental regulations and to communicate those changes to affected staff. The environmental compliance status is documented each year in this report (see Section 4.3).

4.2.3.3 Objectives, Targets, and Environmental Action Plans

CNS responds to change and pursues sustainability initiatives at Y-12 by establishing and maintaining environmental objectives, targets (goals), and action plans. Goals and commitments are established annually considering Y-12's significant environmental aspects. They are consistent with Y-12's mission, budget guidance, ES&H work scope, and DOE sustainability goals. Targets and action plans are established for broad objectives to pursue improvement in environmental performance in five areas—clean air; energy efficiency; hazardous materials; stewardship of land and water resources; and waste reduction, recycling, and buying green. Highlights of the 2018 environmental targets achieved at Y-12 are presented in Section 4.2.6.1.

4.2.3.4 Programs

NNSA has developed and funded several important programs to integrate environmental stewardship into all facets of Y-12 missions. The programs also address the requirements in DOE Orders for protecting various environmental media, reducing pollution, conserving resources, and helping to promote compliance with all applicable environmental regulatory requirements and permits.

Environmental Compliance

Y-12's Environmental Compliance Department (ECD) provides environmental technical support services and oversight for Y-12 line organizations to ensure that site operations are conducted in a manner that is protective of workers, the public, and the environment; in compliance with applicable standards, DOE Orders, environmental laws, and regulations; and consistent with CNS environmental policy and Y-12 site procedures. ECD serves as Y-12's interpretive authority for environmental compliance requirements and as the primary point of contact between Y-12 and external environmental compliance regulatory agencies such as the City of Oak Ridge, the Tennessee Department of Environment and Conservation (TDEC), and the U.S. Environmental Protection Agency (EPA). ECD administers compliance programs aligned with the major environmental legislation that affects Y-12 activities. Compliance status and results of monitoring and measurements conducted for these compliance programs are presented in this document.

ECD also maintains and ensures implementation of Y-12's EMS and spearheads initiatives to proactively address environmental concerns, to continually improve environmental performance, and to exceed compliance requirements.

Waste Management

The Y-12 Waste Management Program supports the full life cycle of all waste streams within Y-12. While ensuring compliance with federal and state regulations, DOE Orders, waste acceptance criteria, and Y-12 procedures and policies, the Waste Management Program provides services for day-to-day solid and liquid waste operations, including collection and transport, storage, on-site treatment operations, and shipment to off-site treatment/disposal. The program also provides technical support to Y-12 operations for waste planning, characterizing, packaging, tracking, reporting, and managing waste treatment/disposal subcontracts.

Sustainability and Stewardship

The Sustainability and Stewardship Program has two major missions. The first is to establish and maintain company-wide programs and services to support sustainable material management operations. These sustainable operations include pollution prevention and recycling programs, excess materials programs, the PrYde program, generator services programs, sanitary waste/landfill coordination, and destruction and recycle facility operations. Y-12 has implemented continuous improvement activities, such as an "Items Available for Re-use" section on the Property Accountability Tracking System website and a central telephone number (574-JUNK), to provide employees easy access to information and assistance related to the proper methods for disposing of excess materials.

The second mission is stewardship practices, the programs that manage legacy issues and assist in preventing the development of new problematic issues. Stewardship programs include Clean Sweep, Unneeded Materials and Chemicals (UMC), and Targeted Excess Materials. The Clean Sweep Program provides turnkey services to material generators, including segregation, staging, and pickup of materials for excess, recycle, and disposal. Sustain areas have been established across the site to improve housekeeping through efficient material disposition. Customers place unneeded items into the transition portion of each Sustain area and Clean Sweep Program personnel take care of the rest. Additionally, at Y-12, unneeded materials are not automatically assumed to be wastes requiring disposal. Y-12 uses a systematic disposition evaluation process. The first step in the disposition process is to determine if the items can be reused at Y-12. Items that cannot be used at Y-12 are evaluated for use at other DOE facilities or government agencies. Items are then evaluated for potential sale; recycle; or, as a last resort, disposal as waste.

Combining these programs under a single umbrella improves overall compliance with EOs, DOE Orders, federal and state regulations, and NNSA expectations and eliminates duplication of efforts while providing an overall improved appearance at Y-12.

Additionally, the implementation of these programs directly supports EMS objectives and targets to disposition UMC, continually improve recycle programs by adding new recycle streams as applicable, improve sustainable acquisition (i.e., promote the purchase of products made with recycled content and bio-based products), meet sustainable design requirements, and adhere to pollution prevention reporting requirements.

Energy Management

The mission of Y-12's Energy Management Program is to incorporate energy-efficient technologies sitewide and to position Y-12 to meet NNSA energy requirement needs. The program identifies improvements in energy efficiency in facilities, coordinates energy-related efforts across the site, and promotes employee awareness of energy conservation programs and opportunities.

4.2.4 Implementation and Operation

4.2.4.1 Roles, Responsibility, and Authority

The safe, secure, efficient, and environmentally responsible operation of Y-12 requires the commitment of all personnel. All personnel share the responsibility for successful day-to-day accomplishment of work and the environmentally responsible operation of Y-12.

Environmental and Waste Management technical support personnel assist the line organizations with identifying and carrying out their environmental responsibilities. Additionally, the Environmental Officer Program is in place to facilitate communication of environmental regulatory requirements and to promote EMS as a tool to drive continual environmental improvement at Y-12. Environmental officers coordinate their organizations' efforts to maintain environmental regulatory compliance and to promote other proactive improvement activities.

4.2.4.2 Communication and Community Involvement

Y-12 is committed to keeping the community informed on operations, environmental concerns, safety, and emergency preparedness. The Community Relations Council, composed of more than 20 members from a cross-section of the community, including environmental advocates, neighborhood residents, Y-12 retirees, and business and government leaders, serves to facilitate communication between Y-12 and the community. The council provides feedback to Y-12 regarding its operations and ways to enhance community and public communications. Y-12 supported the Great Smoky Mountains National Park through a financial donation and through the support of Y-12 employees volunteering time to rehabilitate a number of areas in the park. Additionally, an Introduce a Girl Engineering Event was held at Y-12's New Hope Center on February 21, 2019.

As part of Y-12 Earth Day and America Recycles Day activities, eight local charities received $200 donations from funds raised by Y-12 employee aluminum beverage can recycling efforts. Since the program began in 1994, more than $92,000 raised by the collection of aluminum beverage cans has been donated to various local charities.

Y-12 continues to promote sustainable behaviors for environmental improvements at the site and within the community. As a part of Earth Day activities, LiveWise personnel again collected gently used athletic shoes to support the Modular Organic Regenerative Environments Foundation Group. Personal eyeglasses were also collected for donation. A United Way Coat and Toiletries Drive is conducted annually to provide coats and other needed items for the Volunteer Ministry Center for the Homeless. These activities reflect Y-12 employees' commitment to reduce landfill waste and to support community outreach.

4.2.4.3 Emergency Preparedness and Response

Local, state, and federal emergency response organizations are fully involved in Y-12's emergency drill and exercise program. The annual drill and exercise schedule is coordinated with all organizations to ensure maximum possible participation. At a minimum, the Tennessee Emergency Management Agency (TEMA) Operations Office and the DOE Headquarters Watch Office participate in all Y-12 emergency response exercises.

Exercises, performance drills, and training drills were conducted at Y-12 during FY 2019. The drills and exercises focused on topics such as responding to a security condition change, criticality incident, and natural disaster with a radiological fire and release. Building evacuation and accountability drills were also conducted.

4.2.5 Checking

4.2.5.1 Monitoring and Measurement

Y-12 maintains procedures to monitor overall environmental performance and to monitor and measure key characteristics of its operations and activities that can have a significant environmental impact. Environmental effluent and surveillance monitoring programs are well established, and results of 2019 program activities are described throughout this chapter. Progress in achieving environmental goals is reported as a monthly metric on Performance Track, the senior management web portal that consolidates and maintains Y-12 site-level performance. Progress is reviewed in periodic meetings with senior management and the NNSA Production Office (NPO).

4.2.5.2 Environmental Management System Assessments

To periodically verify that EMS is operating as intended, assessments are conducted as part of the Y-12 internal assessment program. The assessments are designed to ensure that nonconformities with ISO 14001 are identified and addressed.

The Environmental Assessment Program comprises several types of assessments, each type serving a distinct but complementary purpose. Assessments range from informal observations of specific activities to rigorous audits of site-level programs.

To self-declare conformance to ISO 14001 in accordance with instructions issued by the Federal Environmental Executive and to adhere to DOE Order 436.1 (DOE 2011a) requirements, EMS must be audited at least every 3 years by a qualified party outside of the control or scope of EMS. To fulfill this requirement, a four-person audit team from The University of Tennessee Center for Industrial Services evaluated Y-12's EMS during June 2018. The Y-12 EMS was found to fully conform, and no issues were identified. The next external verification audit is scheduled for spring 2021.

4.2.6 Performance

The EMS objectives, targets, and other plans, initiatives, and successes that work together to accomplish DOE goals and reduce environmental impacts are discussed in this section. Y-12 used a number of DOE reporting systems, including the following, to report performance:

- The Federal Automotive Statistical Tool, which collects fleet inventory and fuel use.

- The DOE Sustainability Dashboard, which collects data on metering requirements, water use, renewable energy generation and purchases, greenhouse gas (GHG) generation, and sustainable buildings. Pollution prevention waste reduction and recycling data, sustainable acquisition product purchases, electronic stewardship, and best practices data are also collected in this Dashboard system.

The DOE Office of Health, Safety, and Security annual environmental progress reports on implementation of EMS requirements and sustainability goals driven by EOs and the Office of Management and Budget's Environmental Stewardship Scorecard gave Y-12 an EMS scorecard rating for FY 2019 of green, indicating full implementation of EMS requirements.

4.2.6.1 Environmental Management System Objectives and Targets

At the end of FY 2019, Y-12 had achieved seven of nine targets that had been established; the remaining targets were carried into future years. Highlights include the following, with additional details and successes presented in other sections of this report:

- Clean Air—Y-12 finalized modification of the Title V air permit to include the calciner operations.
- Energy Efficiency—Y-12 completed a project to replace the Building 9117 computer room air conditioner.
- Hazardous Materials—A project to disposition and ship legacy mixed waste per Site Treatment Plan milestones was completed in 2019, and UMC FY 2019 priorities were completed to disposition unneeded production equipment in Building 9201-5N.
- Land/Water/Natural Resources—Reroofing projects for seven buildings were completed to reduce risks to storm and surface water. In addition, phase one of a project to improve protection of the sanitary sewer drainage system from infill and infiltration was completed. Smoke testing and camera inspection of four lateral lines around alpha-three was completed to scope the future improvements required.

4.2.6.2 Sustainability and Stewardship

Numerous efforts at Y-12 have reduced its impact on the environment. Efforts include increased use of environmentally friendly products and processes and reductions in waste and emissions. During the past few years, these efforts have been recognized by our customers, our community, and other stakeholders (see Section 4.2.7). Pollution prevention efforts at Y-12 have not only benefited the environment but have also resulted in cost efficiencies (Figure 4.4).

In FY 2019, Y-12 implemented 97 pollution prevention initiatives (Figure 4.5), with a reduction of more than 68.6 million lb of waste and projected cost efficiencies of more than $19.6 million. The completed projects include the activities described below.

Pollution Prevention/Source Reduction

Sustainable initiatives have been embraced across Y-12 to reduce the impact of pollution on the environment and to increase operational efficiency. Many of Y-12's sustainable initiatives have pollution prevention benefits or targets eliminating the source of pollution, including the 2019 activities highlighted in this section.

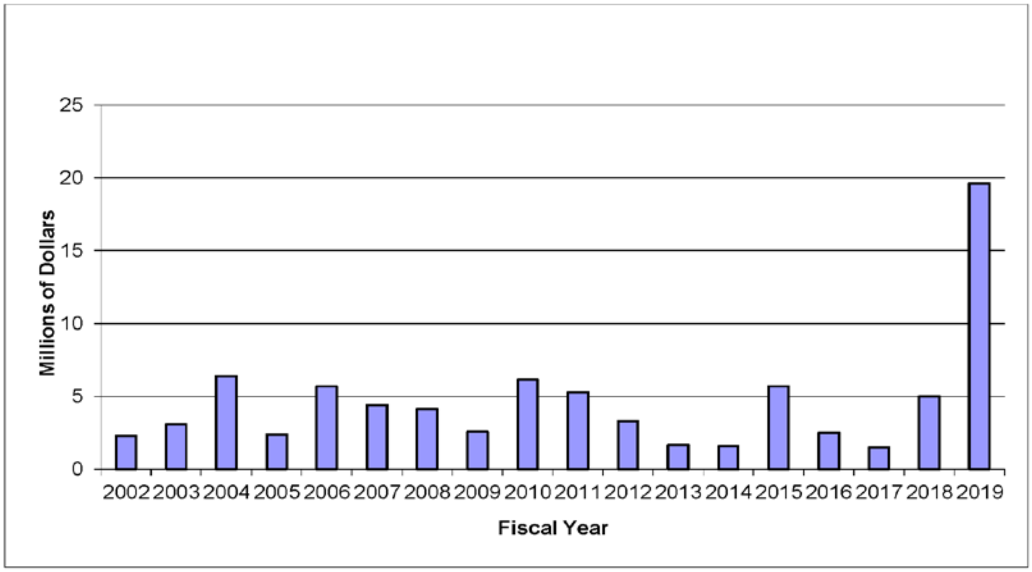


Figure 4.4. Cost efficiencies from Y-12 National Security Complex pollution prevention activities

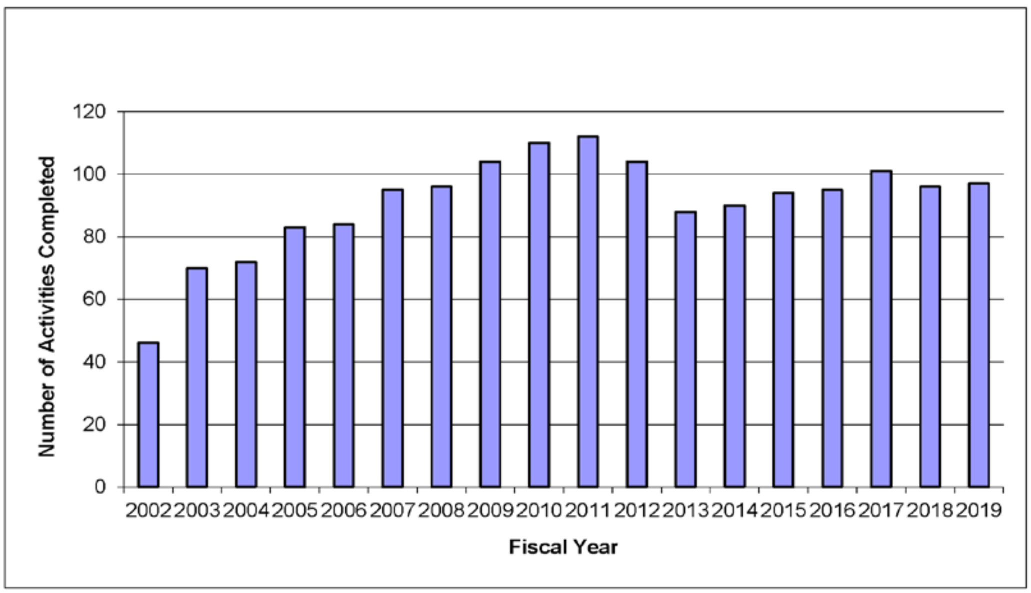


Figure 4.5. Y-12 National Security Complex pollution prevention initiatives

Sustainable Acquisition—Environmentally Preferable Purchasing

Sustainable products, including recycled-content materials, are procured for use across Y-12. In 2019, Y-12 procured recycled-content materials valued at more than $8.3 million for use at the site.

Solid Waste Reduction

At Y-12, unneeded materials are not automatically assumed to be wastes requiring disposal. Y-12 uses a systematic disposition evaluation process. The first step in the disposition process is to determine if the items can be reused at Y-12. Items that cannot be reused at Y-12 are evaluated for use at other DOE facilities or government agencies. Items are then evaluated for potential sale; recycle; or, as a last resort, disposal as waste. There is not a waste-to-energy facility for non-hazardous solid municipal or construction and demolition waste in Tennessee.

In 2019, Y-12 diverted 52.7 percent of municipal and 38.6 percent of construction and demolition waste from landfill disposal through reuse and recycle. Y-12 diverted more than 2.6 million lb of municipal materials from landfill disposal through source reduction, reuse, and recycling in FY 2019. More than 65.5 million lb of construction and demolition materials were diverted from landfill disposal in FY 2019.

Hazardous Chemical Minimization

The Generator Services Group provides a material disposition management service for generators at Y-12, which includes the technical support aspect to assist generators with a determination of whether or not the materials can be recycled, excessed, or reused rather than determining that all materials received must be declared as a waste. Generator Services Group can be used by any department or generator at Y-12. During FY 2019, Generator Services Group personnel, rather than declaring materials as waste, reused or disseminated to other Y-12 organizations for reuse, 500 lb of various excess materials and chemicals. Production and Utilities collaborated to facilitate the reuse of approximately 385 gal of brine solution, which reduced the quantity of hazardous chemicals that were purchased to create new brine solution. The UPF Project identified an alternative non-hazardous blast media to prevent the generation of an estimated 500 lb of hazardous waste.

Recycling

Y-12 has a well-established recycling program and continues to identify new material streams and expand the types of materials that can be recycled by finding new markets and outlets for the materials. As shown in Figure 4.6, more than 3.29 million lb of materials were diverted from landfills and into viable recycle processes during 2019. Currently, recycled materials range from office-related materials to operations-related materials, such as scrap metal, tires, and batteries. Y-12 adds at least one new recycle stream to the Recycle Program each year to continue to increase the waste diversion rate. The Recycle Program was expanded in FY 2019 to include paper briquettes to broaden waste diversion efforts.

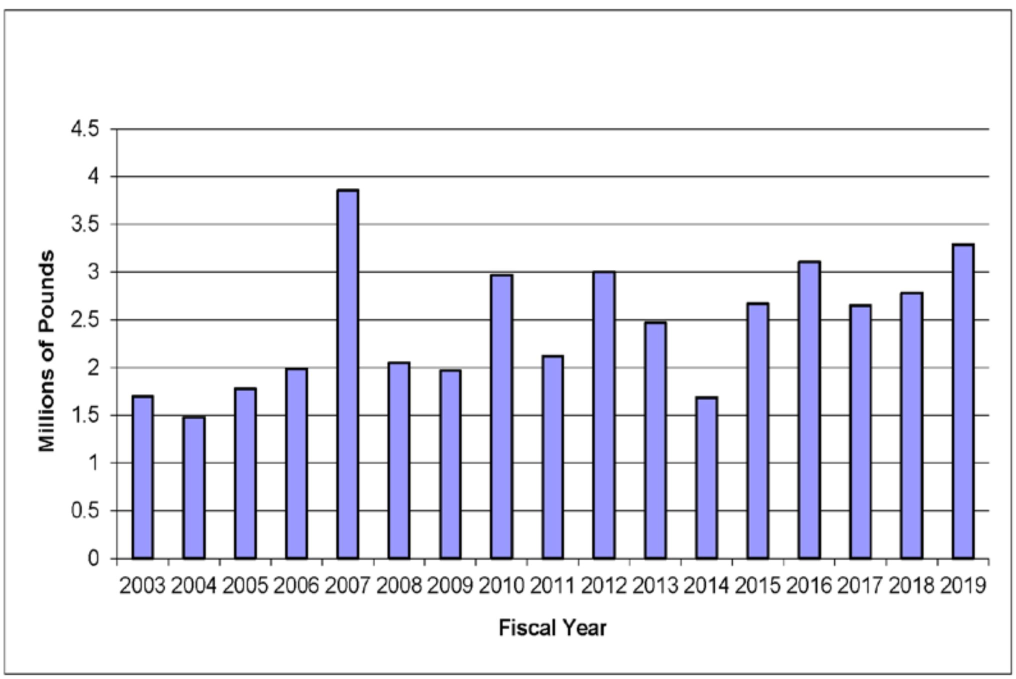


Figure 4.6. Y-12 National Security Complex recycling results

4.2.6.3 Energy Management

The mission of Y-12's Energy Management Program is to incorporate energy-efficient technologies sitewide and to position Y-12 to meet NNSA energy requirement needs. The program identifies improvements in energy efficiency in facilities, coordinates energy-related efforts across the site, and promotes employee awareness of energy conservation programs and opportunities.

Y-12 statuses Energy Management goals in accordance with EO 13834, *Efficient Federal Operations* (Executive Order 2018), and DOE Sustainability Performance Office Guidance. The FY 2019 established goal was a 30-percent energy intensity reduction by FY 2015 from a FY 2003 baseline and a 1-percent reduction each year thereafter. Y-12 had a 39-percent reduction by FY 2015, with an additional 8-percent reduction in the FY 2015 to FY 2019 timeframe, for a total reduction of 47 percent. Significant reductions have been noted with the implementation of Energy Savings Performance Contracts (ESPCs) at Y-12. Specific ESPC initiatives that aided in the reduction of energy consumption at Y-12 include:

- Completing a new, more-efficient Air Compressor Plant at the end of FY 2016.
- Upgrading light fixtures with T-8 fluorescent lighting and light-emitting diode.
- Replacing steam with natural gas.
- Upgrading chillers with new high-efficiency variable speed modes; retrofitting existing chillers with efficient controls; replacing constant-speed chilled water pumps with a variable-speed type; and replacing tower pumps, steam controls, and control valves.
- Replacing Cooling Towers.

4.2.6.4 Dashboard Reporting and the Y-12 National Security Complex Site Sustainability Plan

DOE is required to meet sustainability goals mandated by statute and related EOs, including goals for GHG emissions, energy and water use, fleet optimization, green buildings, and renewable energy. In 2019, the Sustainability Performance Office utilized the web-based DOE Sustainability Dashboard to collect DOE site-level sustainability data and consolidate these data sets on behalf of the Department. The Sustainability Dashboard focuses on specific sustainability goals, and Site Sustainability Plans are completed within the Dashboard. These goals are established by the DOE Sustainability Performance Office and are found in Table 4.1, along with the current Y-12 performance ratings.

Table 4.1. FY 2019 sustainability goals and performance

DOE goal	Current performance status
	Energy management
30% energy intensity (Btu per gross square foot) reduction in goal-subject buildings by FY 2015 from a FY 2003 baseline, and 1% year-to year-reduction thereafter.	**Goal met:** Y-12 achieved a 39% energy intensity reduction in FY 2015 from a FY 2003 baseline. For FY 2019, Y-12 achieved a 6% reduction from FY 2018, which exceeds the targeted 1% reduction.
EISA Section 432 continuous (4-year cycle) energy and water evaluations.	**Goal met:** Y-12 conducts EISA evaluations on a continuous 4-year cycle.
Meter all individual buildings for electricity, natural gas, steam, and water, where cost-effective and appropriate.	Goal not met: Y-12 meters all utilities; however, not all appropriate buildings are currently metered.

Table 4.1. FY 2019 sustainability goals and performance (continued)

DOE goal	Current performance status
Water management	
20% potable water intensity (gal per gross square foot) reduction by FY 2015 from a FY 2007 baseline, and 0.5% year-to-year thereafter.	**Goal met:** A 66% reduction from the 2007 baseline was achieved.
Waste management	
Reduce at least 50% of non-hazardous solid waste, excluding construction and demolition debris, sent to treatment and disposal facilities.	**Goal met:** 52.7% (1,208.4 metric tons/2,294.5 metric tons) of non-hazardous waste diverted from the landfill.
Reduce construction and demolition materials and debris sent to treatment and disposal facilities. Year-to-year reduction; no set target.	Goal not met: 38.6% (29,732.9 metric tons/77,033 metric tons) of construction and demolition materials diverted from the landfill in FY 2019 in comparison to 91.5% diverted in FY 2018. Increased Office of Environmental Management construction and demolition activities resulted in a large volume of construction and demolition debris that was not suitable for reuse and recycle.
Clean and renewable energy	
"Renewable Electric Energy" requires that renewable electric energy account for not less than 7.5% of a total agency electric consumption by FY 2013 and each year thereafter.	**Goal met:** The FY 2019 anticipated amount was 7.5%. Y-12 receives renewable energy credits from Pantex under the shared contract structure. This allows both sites to meet this goal.
Continue to increase non-electric thermal usage. Year-to-year increase; no set target but an indicator in the Office of Management and Budget scorecard.	Goal not met: Y-12 is updating buildings from steam to natural gas. This increases natural gas efficiencies and decreases steam loss.
Green buildings	
At least 15% (by count) of owned, existing buildings to be compliant with the *revised* Guiding Principles for High Performance Sustainable Building goals by FY 2020, with annual progress thereafter.	*Goal at risk:* Y-12 had one DOE-owned building compliant with the High Performance Sustainable Building goals—the LEED Gold Construction Support Building during FY 2019.
Increase regional and local planning coordination and involvement.	**Goal met:** During FY 2019, regional and local involvement included hosting the TDEC East Tennessee Regional Green Star Partnership Workshop, presenting at the DOE Precious Metals Forum, hosting an "Introduce a Girl to Engineering" event, and a Y-12 Earth Day Celebration.
Acquisition and procurement	
Promote sustainable acquisition and procurement to the maximum extent practicable, ensuring biopreferred and biobased requirements and clauses are included in all applicable contracts.	**Goal met:** All contracts issued after 10/01/13 contain the sustainable acquisition requirements.

Table 4.1. FY 2019 sustainability goals and performance (continued)

DOE goal	Current performance status
Measures, funding, and training	
Annual targets for sustainability investment with appropriated funds and/or financed contracts to be implemented in FY 2019 and annually thereafter.	**Goal met:** Y-12 has supported performance contracts issued by NNSA. These contracts have been instrumental in achieving energy, water, building modernization, and infrastructure goals at Y-12.
Electronic stewardship	
Purchases: 95% of eligible acquisitions each year are EPEAT-registered products.	**Goal met:** More than 98.8% (6,849/6,932) of all eligible electronic acquisitions during FY 2019 were EPEAT-registered. More than 99% (6,874/6,932) were either EPEAT-registered or Energy Star-qualified products and 98.8% (6,408/6,489) of all computers, desktops, laptops, tablets, workstations, monitors, scanners, and printers were EPEAT-registered.
Power management: 100% of eligible personal computers, laptops, and monitors have power management enabled.	<u>Goal not met:</u> Y-12 has implemented power management to feasible central processing units and laptops; power management features are enabled on all monitors not deemed mission-critical.
Automatic duplexing: 100% of eligible computers and imaging equipment have automatic duplexing enabled.	<u>Goal not met:</u> During FY 2019, more than 73.8% (4,652/6,303) of the imaging devices were set to automatically duplex. The majority of these devices that are set to non-duplex or are changed to non-duplex are used to support production and other initiatives that require simplex printed materials.
Organizational resilience	
Discuss overall integration of climate resilience in emergency response, workforce, and operations procedures and protocols.	**Goal met:** The Y-12 Severe Event Emergency Response Plan addresses severe natural phenomena events, extended loss of power events, and events that result in the loss of mutual aid. The site is monitoring the increased number of events as related to Grand Solar Minimum of Activity.
Multiple categories	
Year-to-year Scope 1 and Scope 2 GHG emissions reduction from a FY 2008 baseline.	**Goal met:** Site Scope 1 and Scope 2 GHG emissions have been reduced by 58% from a 2008 baseline. Contributing energy-reduction efforts can be attributed to major initiatives involving infrastructure improvements completed through Energy Savings Performance Contract projects.
Year-to-year Scope 3 GHG emissions reduction from a FY 2008 baseline.	<u>Goal not met:</u> Site Scope 3 emissions have increased by 13.5% since 2008. Increasing site population and business travel negatively impact this goal.

Acronyms:
Btu = British thermal unit
DOE = U.S. Department of Energy
EISA = Energy Independence and Securities Act
EPEAT = Electronic Product Environmental Assessment Tool
FY = fiscal year
GHG = greenhouse gas
LEED = Leadership in Energy and Environmental Design
NNSA = National Nuclear Security Administration
TDEC = Tennessee Department of Environment and Conservation
Y-12 = Y-12 National Security Complex

4.2.6.5 Water Conservation

The current DOE water intensity goal is a 20-percent reduction from a FY 2007 baseline by FY 2015 and year-to-year reductions of 0.5 percent thereafter. Y-12 surpassed the initial FY 2015 goal with a 62-percent reduction. In FY 2019, Y-12's water intensity rating was 73.825 gal/ft^2, which is a 2-percent increase from 2018 but still a 65-percent reduction from FY 2007. Although Y-12 is not currently meeting the year-to-year reduction goal, there are still considerable savings from the 2007 baseline. This year's increase can be largely attributed to UPF construction activities, including concrete production at the Concrete Batch Plant.

All potable water consumed at Y-12 originates from Melton Hill Lake as raw water and is pumped across the ridge to the City of Oak Ridge water treatment plant, which is located within the Y-12 boundary. Y-12 purchases potable water from the city for all domestic and industrial applications. Actions that have contributed to the overall reduction in potable water use include:

- Steam trap repairs and improvements
- Condensate return installations, repairs, and reroutes
- Replacement of once-through air handling units
- Low-flow fixture installation
- Chiller replacements
- Cooling tower replacements
- Replacing steam with natural gas in buildings

Most potable water is not metered at the point of use at Y-12, but an evaluation based on known data, facility usage, and other factors provides an estimated assessment of the usage by type. Cooling towers, production facilities, and maintenance-related activities comprise the largest consumers on the Y-12 site. Through ESPC and utility efficiency improvement initiatives, the site is seeing significant improvement in water consumption.

4.2.6.6 Fleet Management

The Y-12 site is currently undergoing a massive construction phase, including the UPF project along with the new MTF and multiple other construction projects. The Y-12 fleet inventory tasked with supporting these projects, along with the normal day-to-day processes at the plant, is comprised of a total of 582 vehicles, which includes 91 Agency-owned units, 483 leased from the General Services Administration (GSA), and 8 commercially leased Special Purpose vehicles during FY 2019. The inventory consists of sedans, light-duty trucks/vans/sport utility vehicles, medium-duty trucks/vans/sport utility vehicles, and heavy-duty trucks. During FY 2019, Y-12 exchanged 38 older GSA-leased vehicles with new units, along with 3 heavy-duty Agency-owned trucks. The new replacements (GSA-leased and Agency-owned) were all ordered with alternative fuel capabilities when available, and these new vehicles all have better fuel consumption and GHG emission figures than the older vehicles that were replaced.

The Y-12 vehicle fleet achieved a 99-percent vehicle utilization rate for FY 2019 compared to 98 percent the previous year, and the six vehicles that did not meet that goal are being reassigned to maximize vehicle utilization at the site. Fuel consumption at Y-12 (diesel and gasoline) was reduced by 4.2 percent compared with FY 2018 figures.

Y-12 currently does not have an on-site fuel station and does not utilize alternative fuel based on a FY 2019 DOE-approved Epact 701 waiver, as alternative fuel is not available near the site. Y-12 continues to implement an interim refueling process using mobile tanker trucks to perform vehicle and equipment fueling operations until a new fuel center is constructed at the site. The mobile tanker trucks only have capacity to provide diesel and unleaded gasoline.

4.2.6.7 Electronic Stewardship

Y-12 has implemented a variety of electronic stewardship activities, including server virtualization, virtual desktop infrastructure, procurement of energy-efficient computing equipment, reuse and recycle of computing equipment, replacement of aging computing equipment with more energy-efficient equipment, and reconfiguration of data centers to achieve more energy-efficient operations. Approximately 99 percent of desktop computers, laptops, monitors, and thin clients purchased or leased during FY 2019 were registered Electronic Product Environmental Assessment Tool (EPEAT) products. Y-12's standard desktop configuration specifies the procurement of EPEAT-registered and Energy Star-qualified products.

4.2.6.8 Greenhouse Gases

Y-12 Scope 1 and Scope 2 GHG emissions have been reduced compared to the FY 2008 baseline. Emission reductions can be attributed primarily to decreased Scope 1 (on-site fuel burning) emissions from more-efficient steam generation and decreased Scope 2 (purchased electricity) emissions from energy efficiency projects.

Purchased electricity is by far the biggest contributor to Y-12's GHG footprint. Energy reduction efforts include major initiatives involving production facilities and utility infrastructure completed through ESPC projects.

4.2.6.9 Storm Water Management and the Energy Independence and Security Act of 2007

The Energy Independence and Security Act of 2007, Section 438 requires federal agencies to reduce storm water runoff from development and redevelopment projects to protect water resources. Y-12 complies with these requirements using a variety of storm water management practices, often referred to as "green infrastructure" or "low-impact development" practices. During the last few years, several green infrastructure initiatives have been implemented to reduce the size and number of impervious surfaces through the use of sustainable vegetative practices and porous pavements. Actions that have contributed to the overall prevention of storm water runoff during Calendar Year (CY) 2019 include the installation of a pervious pavement parking lot for UPF and another adjacent to Building 9201-03. The two lots added about 3 acres of green space within Y-12.

4.2.7 Awards and Recognition

Since November 2000, the commitment to environmentally responsible operations at Y-12 has been recognized with more than 149 external environmental awards from local, state, and national agencies. The awards received in 2019 are summarized below.

4.2.7.1 Electronic Product Environmental Assessment Tool Award

In FY 2019, Y-12 received an EPEAT Purchaser 5 Star Level Award for Excellence in Green Procurement of Electronics in recognition of Y-12's procurement of sustainable information technology products. Y-12 was recognized by the Green Electronics Council at the 5 Star Level for purchasing EPEAT electronics in the following categories during FY 2018: computers and displays (including desktops, notebooks, workstations, integrated systems, and tablets), imaging equipment (copiers, scanners, multi-function devices, etc.), televisions, mobile phones, and servers.

4.2.7.2 U.S. Department of Energy and National Nuclear Security Administration Sustainability Awards

Y-12 received the following 2019 DOE Sustainability Award:

- The Sustainability Champion Award was presented to Y-12’s Charlie Sexton for his role in the Y-12 Energy Program and High Performance Sustainable Building compliance.

4.3 Compliance Status

4.3.1 Environmental Permits

Table 4.2 lists environmental permits in force at Y-12 during 2019. More-detailed information can be found in the following sections.

4.3.2 National Environmental Policy Act/National Historic Preservation Act

As federal agencies, DOE and NNSA comply with National Environmental Policy Act (NEPA) requirements (procedural provisions, 40 Code of Federal Regulations [CFR] 1500 through 1508), as outlined in DOE’s Implementing Procedures for NEPA (Title 10 CFR 1021). NNSA’s commitment to NEPA is performed by thoroughly evaluating the potential impacts of proposed federal actions that affect the quality of the environment at Y-12. NNSA ensures that reasonable alternatives for implementing such actions have been considered in the decision-making process and that such decisions are documented in accordance with DOE/NNSA and the Council on Environmental Quality regulations. Such a prescribed evaluation process ensures that the proper level of environmental review (called a NEPA review), while considering other statutory requirements (NEPA is often referred to as the umbrella law; see Figure 4.7), is performed before an irreversible commitment of resources is made.

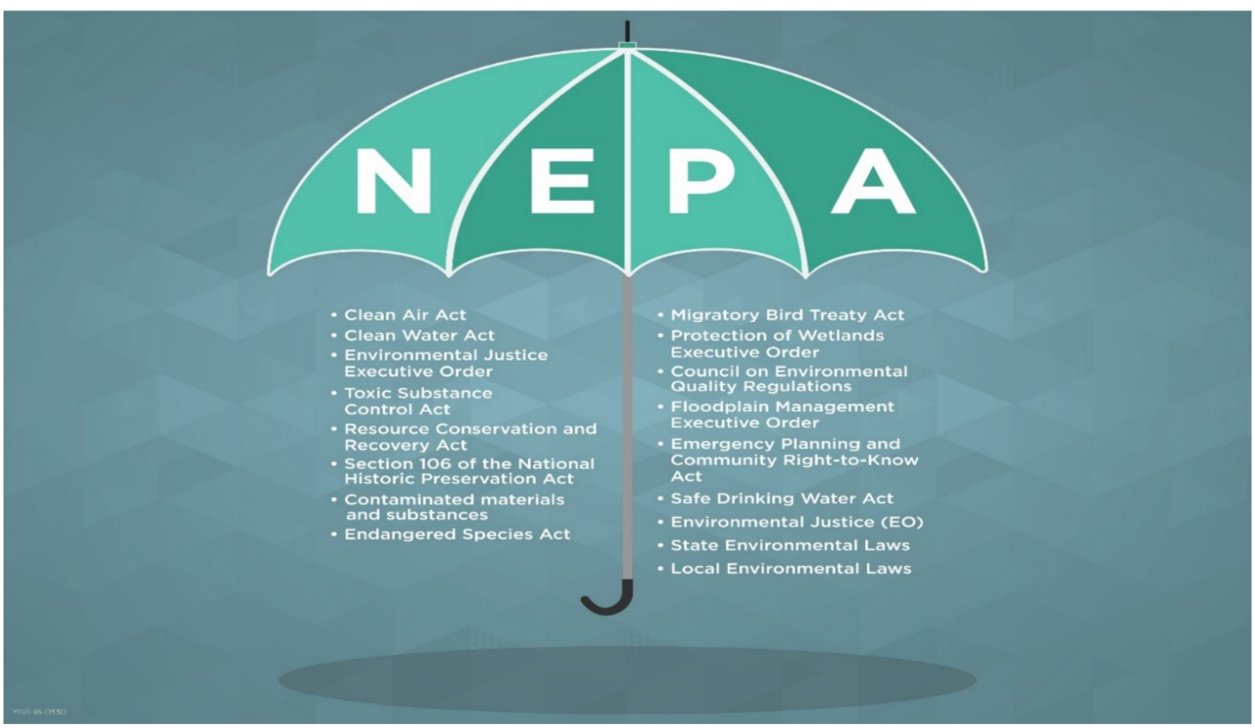


Figure 4.7. National Environmental Policy Act – an umbrella law

Table 4.2. Y-12 environmental permits, CY 2019

Regulatory driver	Title/description	Permit number	Issue date	Expiration date	Owner	Operator	Responsible contractor
CAA	Title V Major Source Operating Permit	571832	12/01/17	11/30/22	DOE	DOE	CNS
CAA	Permit to Construct or Modify an Air Contaminant Source	974225	09/14/18	09/13/20	DOE	DOE	CNS
CWA	Industrial and Commercial User Wastewater Discharge (Sanitary Sewer) Permit	1-91	07/01/17	03/31/21	DOE	DOE	CNS
CWA	NPDES Permit	TN0002968	10/31/11	11/30/16[a]	DOE	DOE	CNS
CWA	UPF 401 Water Quality Certification/Aquatic Resource Alteration Permit Access/Haul Road	NRS10.083	06/10/10	06/09/15[b]	DOE	DOE	CNS
CWA	UPF Department of Army Section 404 CWA Permit	2010-00366	09/02/10	09/02/20	DOE	DOE	CNS
CWA	UPF General Storm Water Permit Y-12 (41.7 ha/103 acres)	TNR 134022	10/27/11	09/30/21	DOE	CNS	CNS
CWA	Central Training Facility Berm Reinvestment Project NPDES Construction General Permit	TNR 135924	10/01/19	Upon Notice of Termination	DOE	DOE	CNS
CWA	Y-12 Outfall 014 Repair Aquatic Resource Alteration Permit	NR1903.116	06/21/19	04/12/21	DOE	DOE	CNS
CWA	Central Training Facility Berm Aquatic Resource Alteration Permit	NR1903.096	05/15/19	04/06/21	DOE	DOE	CNS
CWA	No Discharge Portal 20 Pump and Haul Permit	SOP-170-14	07/08/17	07/01/22	DOE	DOE	CNS

Table 4.2. Y-12 environmental permits, CY 2019 (continued)

Regulatory driver	Title/description	Permit number	Issue date	Expiration date	Owner	Operator	Responsible contractor
CWA	No Discharge Portal 23 Pump and Haul Permit	SOP-170-15	07/08/17	07/01/22	DOE	DOE	CNS
CWA	No Discharge Portal 19 Pump and Haul Permit	SOP-130-31	06/26/18	06/30/23	DOE	DOE	CNS
CWA	No Discharge Environmental Management Waste Management Facility Pump and Haul Permit	SOP-01043	09/01/17	09/31/22	DOE	UCOR	UCOR
RCRA	Hazardous Waste Transporter Permit	TN3890090001	12/16/19	01/31/21	DOE	DOE	CNS
RCRA	Hazardous Waste Corrective Action Permit	TNHW-164	09/15/15	09/15/25	DOE	DOE, NNSA, and all ORR co-operators of hazardous waste permits	UCOR
RCRA	Hazardous Waste Container Storage Units	TNHW-122	08/31/05	08/31/15 [a]	DOE	DOE/CNS	CNS/ Navarro co-operator
RCRA	Hazardous Waste Container Storage and Treatment Units	TNHW-127	10/06/05	10/06/15 [a]	DOE	DOE/CNS	CNS co-operator
Solid Waste	Industrial Landfill IV (Operating, Class II)	IDL-01-000-0075	Permitted in 1988—most recent modification approved 12/18/18	N/A	DOE	DOE/UCOR	UCOR
Solid Waste	Industrial Landfill V (Operating, Class II)	IDL-01-000-0083	Initial permit, most recent modification approved 12/18/18	N/A	DOE	DOE/UCOR	UCOR

Table 4.2. Y-12 environmental permits, CY 2019 (continued

Regulatory driver	Title/description	Permit number	Issue date	Expiration date	Owner	Operator	Responsible contractor
Solid Waste	Construction and Demolition Landfill (overfilled, Class IV subject to CERCLA ROD)	DML-01-000-0012	Initial permit 01/15/86	N/A	DOE	DOE/UCOR	UCOR
Solid Waste	Construction and Demolition Landfill VI (post-closure care and maintenance)	DML-01-000-0036	Permit terminated by TDEC 03/15/07	N/A	DOE	DOE/UCOR	UCOR
Solid Waste	Construction and Demolition Landfill VII (operating, Class IV)	DML-01-000-0045	Initial permit most recent modification approved 11/16/18	N/A	DOE	DOE/UCOR	UCOR
Solid Waste	Centralized Industrial Landfill II (post-closure care and maintenance)	IDL-01-000-0189	Most recent modification approved 05/08/92	N/A	DOE	DOE/UCOR	UCOR
SDWA	Underground Injection Control Class V Injection Well Permit	Permit by Rule TDEC Rule 0400-45-06	03/12/02	None	DOE	DOE	CNS

[a] Continue to operate in compliance pending TDEC action on renewal and reissuance.
[b] Monitoring and maintenance phase.

Acronyms:
CAA = Clean Air Act
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
CNS = Consolidated Nuclear Security LLC
CWA = Clean Water Act
CY = calendar year
DOE = U.S Department of Energy
N/A = not applicable
Navarro = Navarro Research and Engineering, Inc.
NNSA = National Nuclear Security Administration
NPDES = National Pollutant Discharge Elimination System
ORR = Oak Ridge Reservation
RCRA = Resource Conservation and Recovery Act
ROD = record of decision
SDWA = Safe Drinking Water Act
TDEC = Tennessee Department of Environment and Conservation
UPF = Uranium Processing Facility
Y-12 = Y-12 National Security Complex

In March 2011, the *Final Site-Wide Environmental Impact Statement for the Y-12 National Security Complex* (DOE 2011b) was issued. The Site-Wide Environmental Impact Statement (SWEIS) analyzed the potential environmental impacts of ongoing and future operations (missions) and activities at Y-12, including alternatives to changes in site infrastructure (including UPF) and levels of operation. The SWEIS and the Notice of Availability were published on March 4, 2011 (DOE-EIS-0387). NNSA issued a Record of Decision (ROD) in July 2011 (EIS-0387 ROD) (DOE 2011c). Since the ROD, NNSA has updated the strategy and design approach for the UPF. NNSA would use a hybrid approach of upgrading existing Y-12 facilities and building multiple UPF facilities, which was consistent with recommendations from a project peer review of the UPF, *Final Report of the Committee to Recommend Alternatives to the Uranium Processing Facility Plan in Meeting the Nation's Enriched Uranium Strategy* (ORNL 2014). The updated UPF strategy was addressed in detail in a Supplement Analysis (SA) for the Final SWEIS (DOE 2016a; EIS-0387-SA-01), and NNSA amended the ROD (DOE 2016b, 81 FR 45138) on July 22, 2017.

In July 2017, the Oak Ridge Environmental Peace Alliance, Nuclear Watch New Mexico, and the Natural Resources Defense Council and four individual plaintiffs filed a federal lawsuit asserting that NNSA had violated NEPA by failing to prepare a supplemental SWEIS. Among other things, the plaintiffs argued that NNSA should prepare a supplemental SWEIS due to significant new information that came to light after the publication of the 2011 SWEIS. More specifically, plaintiffs asserted that the seismic risk in East Tennessee had increased as evidenced by seismic hazard maps published in 2014 by the U.S. Geological Survey (USGS).

In August 2018, NNSA prepared another SA to the Y-12 SWEIS (2018 SA; DOE/EIS-0387-SA-03) (NNSA 2018), which evaluated the environmental impacts of continuing site operations against the existing Y-12 SWEIS to determine if significant changes or new information warranted a supplemental or new SWEIS. In the 2018 SA, NNSA determined that Y-12 continuing operations were not significantly different than those evaluated in the 2011 SWEIS.

On September 24, 2019, a Memorandum Opinion and Order was issued by the U.S. District Court for the Eastern District of Tennessee as a result of the July 2017 federal lawsuit (USDC 2019). The Court ruled that NNSA is not required to prepare a new or supplemental SWEIS due to the decision to construct a smaller-scale UPF project and continue some EU operations in the ELP facilities. However, the Court also ruled that "new information revealed since the 2011 SWEIS requires further analysis," and consistent with that ruling, the Court vacated the 2016 SA, the 2016 amended ROD, and the 2018 SA. Further, the Court ordered that NNSA "shall conduct further NEPA analysis—including at a minimum, a supplemental analysis—that includes an unbounded accident analysis of earthquake consequences at the Y-12 site, performed using updated seismic hazard analyses that incorporated the 2014 USGS map." The Court also ruled that 69 categorical exclusion determinations were in violation of NEPA and ordered that "the relevant exclusions should be prepared in a manner consistent with the letter of the relevant DOE regulations." Consistent with the Court Order, DOE/NNSA has appropriately revised those 14 categorical exclusion determinations for projects that were still ongoing at the time of the Court's Order.

On October 4, 2019, NNSA amended its July 2011 ROD for the Y-12 SWEIS to reflect its decision to continue to implement, on an interim basis, the hybrid approach previously approved in the vacated 2016 AROD. As the Court previously ruled in its Order, that hybrid approach, which combined elements of the two alternatives previously analyzed in the Y-12 SWEIS, was adequately analyzed within the range of alternatives considered in the Y-12 SWEIS. The 2019 AROD enables NNSA to conduct the required additional NEPA documentation which is contained in this SA, while continuing to implement safety improvements previously approved in the 2016 AROD, pending the completion of the additional analysis ordered by the Court. Once this process is completed, NNSA plans to issue a new AROD describing what, if any, changes it has decided to make in light of that analysis.

Pursuant to the Court's Order, NNSA published the *Draft Supplemental Analysis for the Site-Wide Environmental Impact Statement for the Y-12 National Security Complex, Earthquake Accident Analysis* (NNSA 2020) for public comment on April 9, 2020. The purpose of the SA was to determine whether the earthquake consequences constitute a substantial change that is relevant to environmental concerns, or if there are significant new circumstances or information relevant to environmental concerns and bearing on continued operations at Y-12 compared to the analysis in the 2011 SWEIS. The draft SA was made available for public review and comment and 142 comments were received. The final SA was issued on July 15, 2020, and NNSA determined that the potential impacts associated with an earthquake accident at Y-12 would not be significantly different than the impacts presented in the Y-12 SWEIS. Based on the results of this Final SA, NNSA determined that: (1) the earthquake consequences and risks do not constitute a substantial change; (2) there are no significant new circumstances or information relevant to environmental concerns; and (3) no additional NEPA documentation is required at this time.

During 2019, CNS completed over 50 evaluations for proposed actions at Y-12, and 40 such actions (internal NEPA reviews) were categorically excluded by the NNSA NEPA Compliance Officer and consistent with Y/TS-2312, *National Environmental Policy Act General Categorical Exclusion, Appendix B to Subpart D of Part 1021* (B&W Y-12 2012a). The majority of the proposed actions involved the modernization of facilities and equipment, sustainment of enduring facilities, bridging strategies for facilities identified with an out-year replacement, and the deactivation and demolition of facilities deemed excess to Y-12's needs. As many facilities have, or are, approaching the end of design life, substantial investment is required to ensure that they remain viable for the near future. NEPA reviews and evaluation were conducted for the following projects under the Extended Life Program (for existing EU facilities):

- Nuclear Facility Electrical Maintenance Project (multiple electrical improvements as well as transformer upgrades)
- Fire Suppression Upgrade Project (wet pipe sprinkler head replacements and replacement of fire and potable water building laterals)
- upgrades to Building 9995 laboratories
- upgrades to multiple machining tools, equipment, and controllers

The following projects continued for FY 2019 also were reviewed:

- West End Protection Area Reduction project (including utility re-routes and disconnects)
- LPF
- bridging and sustainment of current lithium production capabilities in Building 9204-02
- Energy Savings Performance Contract, Phase III, Mod 4, CHAMP project (environmental systems and control upgrades)
- Excess Facility Disposition Program (deactivation and demolition of excess facilities and structures)

The K-1065 Material Acquisition Complex, Central Training Facility Berm Refurbishment Project, Research and Development projects for production support capabilities, Sanitary Sewer Lining Project, Culver Replacement Project, Old Salvage Yard Parking Lot Project, and the upgrade and remodeling production area change-houses and bathrooms were also evaluated in FY 2019.

Table 4.3 lists the 2019 categorically excluded determination forms approved by NPO and posted on the public website.

Table 4.3. NNSA-approved categorical exclusions

Date issued	Title
06/2019	NEPA 4869, Demolition of 9204-04 Complex Ancillary Facilities
08/2019	NEPA 4886, Energy Savings Performance Contract, Phase III, Mod 4
09/2019	Lease office space in the Oak Ridge Technical Center - Buildings 1060 and 1099 Commerce Park
11/2019	NEPA 4721, Y-12 Fire Station Construction Project
11/2019	NEPA 4779, Building 9204-2 Annex Demolition Project

Acronyms:
NEPA = National Environmental Policy Act
NNSA = National Nuclear Security Administration

In March 2018, an environmental assessment determination (EAD) was approved by NNSA for a new LPF. NNSA concurred that an environment assessment was required to evaluate an alternative (and potential environmental impacts) for the construction of a replacement facility for the manufacturing and production capability for lithium components. A new LPF will provide administrative and manufacturing space for the production of lithium components. The new facility will ensure Y-12 maintains the required lithium production capabilities, reduces the annual operating cost, and increases processing efficiencies—using safer, more-modern, more-agile, and more-responsive processes. The construction footprint is located within the Biology Complex, located on the east end of Y-12. DOE Office of Real Estate Management (OREM) has committed to the demolition of several of the Biology Complex buildings, removing slabs and/or footings, and the remediation of any contaminated soil. DOE OREM will need to gain regulatory concurrence that no further action will be required to address soil contamination (within the defined construction footprint) for NNSA to proceed. The LPF is anticipated to be a non-nuclear, hazardous material facility.

In accordance with the National Historic Preservation Act of 1966, NNSA is committed to identifying, preserving, enhancing, and protecting its cultural resources. The prescribed evaluation process ensures that the proper level of environmental review is performed before an irreversible commitment of resources is made. Compliance activities in 2019 included completing Section 106 reviews of ongoing and new projects, collecting and storing historic artifacts, conducting tours, maintaining the Y-12 History Center, and participating in various outreach projects with local organizations and schools.

Over 50 proposed projects were evaluated to determine whether any historic properties eligible for inclusion in the National Register of Historic Places would be adversely impacted. It was determined that several of the proposed projects were part of the Infrastructure Disposition Program and would have an adverse effect on 16 historic properties eligible for listing in the National Register. In accordance with the Programmatic Agreement, the required Section 106 recordation, interpretation, and documentation information was submitted to the State Historical Preservation Office for the demolition of Buildings 9401-3, 9404-13, 9404-16, 9404-17, 9404-18, 9706-2, 9710-2, 9720-17, 9722-2, 9752, 9768, 9808-2, 9803, 9804, 9977, and 9977-1. The State Historical Preservation Office reviewed and concurred that the Section 106 documentation adequately mitigated project effects upon properties eligible for listing in the National Register of Historic Places. The Y-12 Oral History Program continues efforts to identify leads to conduct oral interviews and to document the knowledge and experience of those who worked at Y-12 during World War II and the Cold War era. The interviews also provide information on day-to-day operations of Y-12, the use and operation of significant components and machinery, and how technological innovations occurred over time. Some of the information collected from past interviews is available in various media, including digital versatile discs shown in the Y-12 History Center.

The Y-12 History Center, located in the New Hope Center, continues to be a work in progress (see Figure 4.8) The Y-12 History Center features many historical photographs and artifacts, a history library, and a video viewing area. More interactive and video-based exhibits are planned for the future. The

Y-12 History Center is open to the public Monday through Thursday from 8:00 a.m. to 5:00 p.m. and on Fridays by special request. A selection of materials, including brochures, books, pamphlets, postcards, and fact sheets, is available free to the public. A new display area highlighting current and future missions of Y-12 was also developed and installed in the New Hope Center (see Figure 4.9).

Y-12 partnered with the National Park Service during the annual Earth Day events on April 18, 2019 (see Figure 4.10). These events were held in Y-12's Jack Case Center cafeteria lobby area. The DOE Earth Day Theme was "Earth Day—There is No Planet B." Information was made available to help individuals take action on behalf of the environment.

Figure 4.8. Photograph of the Y-12 History Center

Figure 4.9. Photograph of new exhibit showing Y-12 National Security Complex's current and future missions

Figure 4.10. Photographs of National Park Service personnel at Y-12 National Security Complex's Earth Day celebration

Congress passed the National Defense Authorization Act of 2015, which included provisions authorizing a park to be located at three sites—Oak Ridge, Tennessee; Hanford, Washington; and Los Alamos, New Mexico. A foundational document has been completed, which establishes a baseline for park planning and interpretive activities and provides basic guidance for planning and management decisions. President Obama signed the National Defense Authorization Act into law on December 19, 2014.

On November 10, 2015, the Secretary of the Interior and the Secretary of Energy signed a Memorandum of Agreement between the two agencies defining the respective roles in creating and managing the park. The agreement included provisions for enhanced public access, management, interpretation, and historic preservation. With the signing, the Manhattan Project National Historical Park officially was established.

Outreach activities in 2019 consisted of partnering with the City of Oak Ridge, the Oak Ridge Convention and Visitor's Bureau, and the Arts Council of Oak Ridge, which sponsor the annual Secret City Festival.

In June 2019, the Secret City Festival promoted the history of the Manhattan Project by providing information to visitors regarding the history of Y-12 and directions for them to visit the Y-12 History Center. Y-12 provided visitors with windshield tours of the perimeter of Y-12 and a more in-depth tour inside Building 9731, also known as the "Pilot Plant."

Y-12 also continues to partner with the American Museum of Science and Energy by providing guided public tours of the Y-12 History Center from March through November. Other outreach activities to local and visiting schools, agencies, and organizations include tours and presentations on the rich and significant history of Y-12 and Oak Ridge.

4.3.3 Clean Air Act Compliance Status

Permits issued by the State of Tennessee are the primary vehicle used to convey the clean air requirements that are applicable to Y-12. New projects are governed by construction permits and modifications to the Title V operating air permit, and eventually the requirements are incorporated into the sitewide Title V operating permit. Y-12 is currently governed by Title V Major Source Operating Permit 571832.

The permit requires recordkeeping and annual and semiannual reports. More than 2,000 data points are obtained and reported each year. All reporting requirements were met during CY 2019, and there were no permit violations or exceedances during the report period.

Ambient air monitoring, while not specifically required by any permit condition, is conducted at Y-12 to satisfy DOE Order 458.1, *Radiation Protection of the Public and the Environment* (DOE 2011e), requirements as a best management practice and/or to provide evidence of sufficient programmatic control of certain emissions. Ambient air monitoring conducted specifically for Y-12 (i.e., mercury monitoring) is supplemented by additional monitoring conducted for ORR and by both on- and off-site monitoring conducted by TDEC.

Section 4.4 provides detailed information on 2019 activities conducted at Y-12 in support of the Clean Air Act (CAA).

4.3.4 Clean Water Act Compliance Status

During 2019, Y-12 continued its excellent record for compliance with the National Pollutant Discharge Elimination System (NPDES) water discharge permit. Data obtained as part of the NPDES program are provided in a monthly report to TDEC. Compliance with permit discharge limits for 2019 was 100 percent.

Approximately 2,200 data points were obtained from sampling required by the NPDES permit; no non-compliances were reported. Y-12's NPDES permit in effect during 2019 (TN0002968) was issued on October 31, 2011, and became effective on December 1, 2011. A modification was effective in May 2014. It expired on November 30, 2016. An application for a new permit was prepared and submitted to TDEC in May 2016. The currently expired NPDES permit continues in effect until the new permit is issued by the State of Tennessee.

4.3.5 Safe Drinking Water Act Compliance Status

The City of Oak Ridge supplies potable water to Y-12 and meets all federal, state, and local standards for drinking water. The water treatment plant, located north of Y-12, is operated by the City of Oak Ridge. Y-12 potable water distribution is operated by a State-certified distribution system operator. The distribution system is regulated by TDEC as a public water system, with public water distribution system identification number 0001068.

Tennessee Regulations for Public Water Systems and Drinking Water Quality, Chapter 0400-45-01 (TDEC 2019), sets limits for biological contaminants, chemical activities, and chemical contaminants. Sampling for total coliform, chlorine residuals, lead, copper, and disinfectant byproducts is conducted by Y-12's ECD, with oversite by a State-certified operator.

Y-12's potable water distribution system was last reviewed by TDEC in 2018 and received a sanitary survey score of 100 out of a possible 100 points and, thus, retained its approved status as a public water system in good standing with TDEC. The next sanitary survey is scheduled for 2020. All total coliform samples collected during 2019 were analyzed by the State of Tennessee laboratory, and all results were negative. Analytical results for disinfectant byproducts (total trihalomethanes and haloacetic acids) for Y-12's water distribution system were within allowable TDEC and Safe Drinking Water Act limits for the yearly average. Y-12's potable water system is currently sampled triennially for lead and copper. The system sampling was last completed in 2017. These results were below TDEC and Safe Drinking Water Act limits and met the established requirements.

4.3.6 Resource Conservation and Recovery Act Compliance Status

The Resource Conservation and Recovery Act (RCRA) regulates hazardous wastes that, if mismanaged, could present risks to human health or the environment. The regulations are designed to ensure that hazardous wastes are managed from the point of generation to final disposal. In Tennessee, EPA delegates the RCRA program to TDEC, but EPA retains an oversight role. Y-12 is considered a large-quantity generator because it may generate more than 1,000 kg of hazardous waste in a month and because it has

RCRA permits to store hazardous wastes for up to 1 year before shipping offsite to licensed treatment and disposal facilities. Y-12 also has a number of satellite accumulation areas and 90-day waste storage areas.

Mixed wastes are materials that are both hazardous (under RCRA guidelines) and radioactive. The Federal Facilities Compliance Act of 1992 requires that DOE work with local regulators to develop a Site Treatment Plan to manage mixed waste. Development of the plan has two purposes—to identify available treatment technologies and disposal facilities (federal or commercial) that can manage mixed waste produced at federal facilities, and to develop a schedule for treating and disposing of the waste streams.

The ORR Site Treatment Plan is updated annually and submitted to TDEC for review. The current plan (TDEC 2017) documents the mixed-waste inventory and describes efforts undertaken to seek new commercial treatment and disposal outlets for various waste streams. NNSA has developed a disposition schedule for the mixed waste in storage and will continue to maintain and update the plan as a reporting mechanism as progress is made. Y-12 has developed disposition milestones to address its remaining inventory of legacy mixed waste. Disposition milestones for the final inventory are FYs from 2016 through 2026 (see Figure 4.11). In FY 2019, Y-12 staff completed disposition of 53 percent of the inventory of legacy mixed waste listed on the ORR Site Treatment Plan.

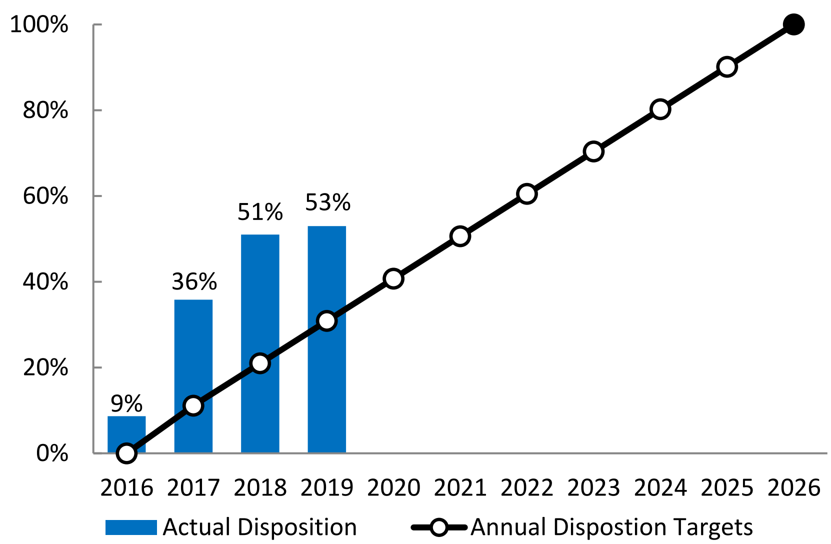


Figure 4.11. Y-12 National Security Complex's path to elimination of its inventory of legacy mixed waste as part of the Oak Ridge Reservation Site Treatment Plan by fiscal year

The quantity of hazardous and mixed wastes generated by Y-12 increased in 2019 (Figure 4.12). Y-12 currently reports waste on 74 active waste streams. Y-12 is a State-permitted treatment, storage, and disposal facility. Under its permits, Y-12 received 2,412 kg of hazardous and mixed waste from the off-site Union Valley analytical chemistry laboratory and ETTP in 2019.

In addition, 475,968 kg of hazardous and mixed waste was shipped to DOE-owned and commercial treatment, storage, and disposal facilities. More than 11 million kg of hazardous and mixed wastewater was treated at on-site wastewater treatment facilities.

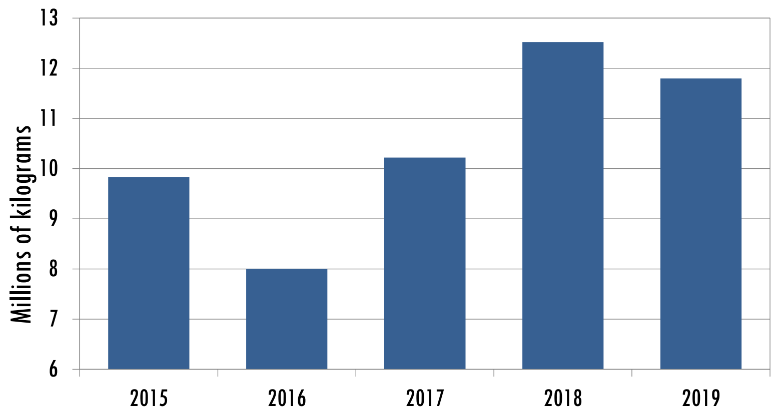


Figure 4.12. Hazardous waste generation, 2014–2019

4.3.6.1 Resource Conservation and Recovery Act Underground Storage Tanks

TDEC regulates active petroleum underground storage tanks (USTs). Existing UST systems that remain in service must comply with performance requirements described in TDEC UST regulations (TN 0400-18-01).

Closure and removal of the last two petroleum USTs at the East End Fuel Station were completed in August 2012. There are no petroleum USTs remaining at Y-12.

4.3.6.2 Resource Conservation and Recovery Act Subtitle D Solid Waste

ORR landfills operated by the DOE EM Program are located within the boundary of Y-12. The facilities include two Class II, operating, industrial, solid waste disposal landfills and one Class IV, operating, construction demolition landfill. The facilities are permitted by TDEC and accept solid waste from DOE operations on ORR. In addition, one Class IV facility (Spoil Area 1) is overfilled by 8,945 m^3 and has been the subject of a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) remedial investigation/feasibility study. A CERCLA ROD for Spoil Area 1 was signed in 1997 (DOE 1997a). One Class II facility (Landfill II) has been closed and is subject to post-closure care and maintenance. Associated TDEC permit numbers are noted in Table 4.2. Additional information about the operation of these landfills is addressed in Section 4.8.4.

4.3.7 Resource Conservation and Recovery Act–Comprehensive Environmental Response, Compensation, and Liability Act Coordination

The ORR Federal Facility Agreement (FFA) (DOE 2017) is intended to coordinate the corrective action processes of RCRA required under the Hazardous Waste Corrective Action document (formerly known as the Hazardous and Solid Waste Amendments permit) with CERCLA response actions. During CY 2015, the renewal of ORR Corrective Action document TNHW-164 was issued for the 10-year period from September 15, 2015, through September 15, 2025. As required in TNHW-164, the annual update of solid waste management units and areas of concern was submitted to TDEC in January 2018 as an update of the previous CY 2017 activities.

4.3.8 Toxic Substances Control Act Compliance Status

The storage, handling, and use of PCBs are regulated under the Toxic Substances Control Act (TSCA). Capacitors manufactured before 1970 that are believed to be oil-filled are handled as though they contain

PCBs, even when that cannot be verified from manufacturer records. Certain equipment containing PCBs and PCB waste containers must be inventoried and labeled. The inventory is updated by July 1 of each year and was last submitted on June 12, 2019.

Given the widespread historical uses of PCBs at Y-12 and fissionable material requirements that must be met, an agreement between EPA and DOE was negotiated to assist ORR facilities in becoming compliant with TSCA regulations. This agreement, the ORR PCB Federal Facility Compliance Agreement (FFCA), which became effective in 1996, provides a forum with which to address PCB compliance issues that are truly unique to these facilities. Y-12 operations involving TSCA-regulated materials were conducted in accordance with TSCA regulations and the ORR PCB FFCA.

The removal of legacy PCB waste, some of which had been stored since 1997, in accordance with the terms of the ORR PCB FFCA, was completed in 2011.

4.3.9 Emergency Planning and Community Right-to-Know Act Compliance Status

The Emergency Planning and Community Right-to-Know Act (EPCRA) requires that facilities report inventories (i.e., Tier II Report sent to state and local emergency responders) and releases (i.e., toxic release inventory report submitted to state and federal environmental agencies) of certain chemicals that exceed specified thresholds. Y-12 submitted reports for reporting year 2019 in accordance with requirements under EPCRA Sections 302, 303, 311, 312, and 313.

Y-12 had no unplanned release of a hazardous substance that required notification of the regulatory agencies (see Section 4.3.11 for more information). During a routine review of chemical inventories, it was determined that nickel, Chemical Abstracts Service Number 7440-02-0, and 1,1,1,2,2,3,4,5,5,5-decafluoropentane, Chemical Abstracts Service Number 138495-42-8, exceeded the 10,000-lb reporting threshold. The product, DuPont Vertrel® XF, contains 1,1,1,2,2,3,4,5,5,5--decafluoropentane and is used as a solvent. Notifications were sent to TEMA and local emergency responders on March 21, and April 11, 2019. Inventories, locations, and associated hazards of over-threshold hazardous and extremely hazardous chemicals were submitted to TEMA and local emergency responders in the annual Tier II Report required by Section 312. Data submittal was through the E-Plan web-based reporting system, as requested by TEMA. Some local emergency responders also accepted data through the E-Plan system, but others require that electronic copies of the Tier II Reports be submitted via email. Y-12 reported 40 chemicals that were over Section 312 inventory thresholds in 2019.

Y-12 operations are evaluated annually to determine the applicability for submittal of a toxic release inventory report to TEMA and EPA in accordance with EPCRA Section 313 requirements. The amounts of certain chemicals manufactured, processed, or otherwise used are calculated to identify those that exceed reporting thresholds. After threshold determinations are made, releases and off-site transfers are calculated for each chemical that exceeds a threshold. Submittal of the data to TEMA and EPA is made through the Toxics Release Inventory-Made Easy (abbreviated as TRI-ME) web-based reporting system operated by EPA. Total 2018 reportable toxic releases to air, water, and land and waste transferred off-site for treatment, disposal, and recycling were 51,882 kg (114,380 lb). Table 4.4 lists the reported chemicals for Y-12 for 2018 and 2019 and summarizes releases and off-site waste transfers for those chemicals.

Table 4.4. Emergency Planning and Community Right-to-Know Act Section 313 toxic chemical release and off-site transfer summary for Y-12, 2018 and 2019

Chemical	Year	Quantity[a] (lb)[b]
Chromium	2018	10,513
	2019	11,361
Cobalt	2018	[c]
	2019	862
Copper	2018	4,635
	2019	4,030
Lead compounds	2018	32,472
	2019	46,346
Manganese	2018	5,245
	2019	6,052
Mercury	2018	7,466
	2019	10,435
Methanol	2018	49,191
	2019	25,945
Nickel	2018	11,501
	2019	9,349
Total	2018	121,203
	2019	114,380

[a] Represents total releases to air, land, and water and includes off-site waste transfers. Also includes quantities released to the environment as a result of remedial actions, catastrophic events, or one-time events not associated with production processes.

[b] 1 lb = 0.4536 kg

[c] Not reported in previous year.

Acronym:
Y-12 = Y-12 National Security Complex

4.3.10 Spill Prevention, Control, and Countermeasures

The Clean Water Act, 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. The major requirements for SPCC plans are contained in Title 40 CFR Part 112. These regulations require that SPCC plans be reviewed, evaluated, and amended at least once every 5 years or earlier if significant changes occur. The SPCC rule includes requirements for oil spill prevention, preparedness, and response to prevent oil discharges to navigable waters and adjoining shorelines. The rule requires specific facilities to prepare, amend, and implement SPCC plans.

Y-12's SPCC Plan (CNS 2015) was revised in September 2015 to update general Y-12 changing site infrastructure. This plan presents the SPCC to be implemented by Y-12 to prevent spills of oil and hazardous constituents and the countermeasures to be invoked should a spill occur. In general, the first response of an individual discovering a spill is to call the Plant Shift Superintendent. Spill response materials and equipment are stored near tanks and drum storage areas and other strategic areas of Y-12 to facilitate spill response. All Y-12 personnel and subcontractors are required to have initial spill and emergency response training before they can work on the site.

4.3.11 Unplanned Releases

Y-12 has procedures for notifying off-site authorities for categorized events at Y-12. Off-site notifications are required for specified events according to federal statutes, DOE Orders, and the Tennessee Oversight Agreement. As an example, any observable oil sheen on EFPC and any release impacting surface water must be reported to the EPA National Response Center in addition to other reporting requirements. Spills of CERCLA reportable quantity limits must be reported to the EPA National Response Center, DOE, TEMA, and the Anderson County Local Emergency Planning Committee.

In addition, Y-12's occurrence reporting program provides timely notification to the DOE community of Y-12 events and site conditions that could adversely affect the public or worker health and safety, the environment, national security, DOE safeguards and security interests, functioning of DOE facilities, or the reputation of DOE.

Y-12 occurrences are categorized and reported through the Occurrence Reporting and Processing System, which provides NNSA and the DOE community with a readily accessible database of information about occurrences at DOE facilities, causes of those occurrences, and corrective actions to prevent recurrence of the events. DOE analyzes aggregate occurrence information for generic implications and operational improvements.

There were no reportable releases to the environment in 2019. During 2019, there were no unplanned radiological air emission releases for Y-12.

4.3.12 Audits and Oversight

A number of federal, state, and local agencies oversee Y-12 activities. In 2019, Y-12 was inspected by federal, state, or local regulators on four occasions. Table 4.5 summarizes the results, and additional details follow.

Table 4.5. Summary of external regulatory audits and reviews, 2019

Date	Reviewer	Subject	Issues
January 24	City of Oak Ridge	Semiannual Industrial Pretreatment Compliance Inspection	0
March 5-6	TDEC	Annual RCRA Hazardous Waste Compliance Inspection (Y-12)	0
April 3	TDEC	Annual Air Quality Compliance Inspection	0
May 21	TDEC	NPDES Compliance Evaluation Inspection	0
September 19	TDEC	RCRA Hazardous Waste Compliance Inspection (Union Valley)	0
October 2	City of Oak Ridge	Semiannual Industrial Pretreatment Compliance Inspection	0

Acronyms:
NPDES = National Pollutant Discharge Elimination System
RCRA = Resource Conservation and Recovery Act
TDEC = Tennessee Department of Environment and Conservation
Y-12 = Y-12 National Security Complex

As part of the City of Oak Ridge's pretreatment program, City personnel collect samples from the Y-12 monitoring station to conduct compliance monitoring, as required by the pretreatment regulations. City personnel also conduct compliance inspections twice yearly. No issues were identified in 2019.

Personnel from the TDEC Division of Solid Waste Management conducted a RCRA hazardous waste compliance inspection of Y-12 on March 5 and 6, 2019. The inspections covered 50 waste storage areas and records reviews. No issues were identified. In addition, a hazardous waste compliance inspection was conducted at the Union Valley Facility, an analytical chemistry laboratory. No issues were identified.

Personnel from the TDEC Division of Air Pollution Control conducted an air quality inspection on April 3, 2019. The inspection covered 10 air emission sources, including some emergency generators, and inspections of the facilities. Title V air permit records were also reviewed. No issues were identified.

Personnel from TDEC Division of Water Resources performed an NPDES Compliance Evaluation Inspection on May 21, 2019. The inspections covered 22 outfalls, 4 wastewater treatment facilities, and outdoor storage areas. There were some areas of concern, but no issues.

In July 2019, as the result of a self-identified issue, solid waste shipments to the Nevada National Security Site were suspended due to non-compliant material being included in a weapons-related component. Consequently, investigations, a series of improvement activities, and layers of self-critical audits have been conducted. Process improvements in handling, characterization, and certification of waste are underway prior to resuming shipments to this disposal cell. Real-time radiography imaging is planned as a final check of waste that can benefit from this step.

4.3.13 Radiological Release of Property

Clearance of property from Y-12 is conducted in accordance with approved procedures that comply with DOE Order 458.1, *Radiation Protection of the Public and the Environment* (DOE 2011e). Property consists of real property (i.e., land and structures), personal property, and material and equipment (M&E). At Y-12, there are three paths for releasing property to the public based on the potential for radiological contamination:

- Survey and release of property potentially contaminated on the surface (using pre-approved authorized limits for releasing property).
- Evaluation of materials with a potential to be contaminated in volume (volumetric contamination).
- Evaluation using process knowledge (surface and volumetric).

These three release paths are discussed in the following sections. Table 4.6 summarizes some examples of the quantities of property released in 2019. During FY 2019, Y-12 recycled more than 3.8 million lb of materials offsite for reuse, including but not limited to computers, electronic office equipment, used oil, scrap metal, tires, batteries, lamps, and pallets.

Table 4.6. Summary of materials released in 2019

Category	Amount released
Real property (land and structures)	None
Computer equipment recycle	119,053 lb
–Computers, monitors, printers, and mainframes	
Recycling examples	
–Used oils	22,840 gal
–Used tires	12,560 lb
–Scrap metal	1,380,673 lb
–Lead acid batteries	67,844 lb
Public/negotiated sales[a]	
–Brass	7,979 lb
–Miscellaneous furniture	17,964 lb
–Vehicles and miscellaneous equipment	403,674 lb
External transfers[b]	23,600 lb

[a] Sales during Fiscal Year 2019.
[b] Vehicles, miscellaneous equipment, and materials transferred to various federal, state, and local agencies for reuse during Fiscal Year 2019.

4.3.13.1 Property Potentially Contaminated on the Surface

Property that is potentially contaminated on the surface is subject to a complete survey, unless it can be released based on process knowledge or via a survey plan that provides survey instructions, along with technical justification (process knowledge) for the survey plan based on the *Multi-Agency Radiation Survey and Site Investigation Manual* (NRC 2000) and the *Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual* (MARSAME) (NRC 2009)[1]. The surface contamination limits used at Y-12 to determine whether M&E are suitable for release to the public are provided in Table 4.7.

Table 4.7. DOE Order 458.1 pre-approved authorized limits[a,b]

Radionuclide[c]	Average[d,e]	Maximum[d,e]	Removable[f]
Group 1—Transuranics, ^{125}I, ^{129}I, ^{227}Ac, ^{226}Ra, ^{228}Ra, ^{228}Th, ^{230}Th, ^{231}Pa	100	300	20
Group 2—Th-natural, ^{90}Sr, ^{126}I, ^{131}I, ^{133}I, ^{223}Ra, ^{224}Ra, ^{232}U, ^{232}Th	1,000	3,000	200
Group 3—U-Natural, ^{235}U, ^{238}U, associated decay products, alpha emitters	5,000	15,000	1,000
Group 4—Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission), except ^{90}Sr and others noted above[g]	5,000	15,000	1,000
Tritium (applicable to surface and subsurface)[h]	N/A	N/A	10,000

[a] The values in this table (except for tritium) apply to radioactive material deposited on but not incorporated into the interior or matrix of the property. No generic concentration guidelines have been approved for release of material that has been contaminated in depth, such as activated material or smelted contaminated metals (e.g., radioactivity per unit volume or per unit mass). Authorized limits for residual radioactive material in volume must be approved separately.
[b] As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by counts per minute measured by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.
[c] Where surface contamination by both alpha- and beta-gamma-emitting radionuclides exists, the limits established for alpha- and beta-gamma-emitting radionuclides should apply independently.
[d] Measurements of average contamination should not be averaged over an area of more than 1 m^2. Where scanning surveys are not sufficient to detect levels in the table, static counting must be used to measure surface activity. Representative sampling (static counts on the areas) may be used to demonstrate by analyses of the static counting data. The maximum contamination level applies to an area of not more than 100 cm^2.
[e] The average and maximum dose rates associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 millirad per hour (mrad/h) and 1.0 mrad/h, respectively, at 1 cm.
[f] The amount of removable material per 100 cm^2 of surface area should be determined by wiping an area of that size with dry filter or soft absorbent paper, applying moderate pressure, and measuring the amount of radioactive material on the wiping with an appropriate instrument of known efficiency. When removable contamination of objects on surfaces of less than 100 cm^2 is determined, the activity per unit area should be based on the actual area, and the entire surface should be wiped. It is not necessary to use wiping techniques to measure removable contamination levels if direct scan surveys indicate the total residual surface contamination levels are within the limits for removable contamination.
[g] This category of radionuclides includes mixed fission products, including the ^{90}Sr that is present in them. It does not apply to ^{90}Sr that has been separated from the other fission products or mixtures where the ^{90}Sr has been enriched.
[h] Measurement should be conducted by a standard smear measurement but using a damp swipe or material that will readily absorb tritium, such as polystyrene foam. Property recently exposed or decontaminated should have measurements (smears) at regular time intervals to prevent a buildup of contamination over time. Because tritium typically penetrates material it contacts, the surface guidelines in Group 4 do not apply to tritium. Measurements demonstrating compliance of the removable fraction of tritium on surfaces with this guideline are acceptable to ensure non-removable fractions and residual tritium in mass will not cause exposures that exceed U.S. Department of Energy dose limits and constraints.

Acronyms:
DOE = U.S. Department of Energy
N/A = not applicable

[1] The *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM) provides guidance on how to demonstrate that a site complies with a radiation dose or risk-based regulation, otherwise known as a release criterion. The *Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual* is a supplement to MARSSIM that provides technical information on approaches for determining proper disposition of materials and equipment.

Source: Vázquez 2011.

Y-12 uses an administrative limit for average and maximum activity of 240 dpm/100 cm^2 for radionuclides in Group 3 and 2,400 dpm/100 cm^2 for radionuclides in Group 4 (see Table 4.7). Y-12 also uses an administrative limit for removable activity of 240 dpm/100 cm^2 for radionuclides in Group 3 (see Table 4.7). The use of the more-restrictive administrative limits ensures that M&E do not enter into commerce exceeding the definition of contamination for high-toxicity alpha emitters and for beta and gamma emitters, respectively, found in 49 CFR 173, "Shippers—General Requirements for Shipments and Packagings."

4.3.13.2 Property Potentially Contaminated in Volume (Volumetric Contamination)

Materials, such as activated materials, smelted-contaminated metals, liquids, and powders, are subject to volumetric contamination (e.g., radioactivity per unit volume or per unit mass) and are treated separately from surface-contaminated objects. Materials that may be subject to volumetric contamination are evaluated for release by one of the following three methods:

1. Unopened, Sealed Containers—Material is still in an original commercial manufacturer's sealed, unopened container. A seal can be a visible manufacturer's seal (i.e., lock tabs, heat shrink) or a manufacturer's seal that cannot be seen (e.g., unbroken fluorescent bulbs, sealed capacitors), as long as the container remains unopened once received from the manufacturer.
2. Process Knowledge—If it can be determined that there is no likelihood of contamination being able to enter a system, then process knowledge is documented and used as the basis for release. Often, this is accompanied by confirmatory surveys.
3. Analytical—The material is sampled, and the analytical results are evaluated against measurement-method critical levels or background levels from materials that have not been impacted by Y-12 activities. If the results meet defined criteria, then they are documented and the material is released. Alternatively, if volumetric authorized limits exists (per DOE Order 458.1) for a specified material stream, then the analytical results are evaluated and compared with the authorized limits for potential release (NPO 2018, 2019a, 2019b).

4.3.13.3 Process Knowledge

Process knowledge is used to release property from Y-12 without monitoring or analytical data and to implement a graded approach (less than 100 percent monitoring) for monitoring of some M&E (MARSAME Classes II and III) (NRC 2009). A conservative approach (nearly 100 percent monitoring) is used to release older M&E for which a complete and accurate history is difficult to compile and verify (MARSAME Class I). The process knowledge evaluation processes are described in Y-12 procedures.

The following M&E are released without monitoring based on process knowledge; this does not preclude conducting verification monitoring, for example, before sale:

- All M&E from buildings evaluated and designated as "RAD-Free Zones."
- Pallets generated from administrative buildings.
- Pallets that are returned to shipping during the same delivery trip.
- Lamps from administrative buildings.
- Drinking water filters.
- M&E approved for release by Radiological Engineering Technical Review.
- Portable restrooms used in non-radiological areas.

- Documents, mail, diskettes, compact disks, and other office media; personal M&E; paper, plastic products, water bottles, aluminum beverage cans, and toner cartridges; office trash, house-keeping materials, and associated waste; breakroom, cafeteria, and medical wastes; and medical and bioassay samples generated in non-radiological areas.
- Subcontractor/vendor/privately owned vehicles, tools, and equipment used in non-radiological areas.
- M&E that are administratively released.
- M&E that were delivered to stores in error and that have not been distributed to other Y-12 locations.
- New computer equipment distributed from Building 9103.
- Subcontractor/vendor/privately owned vehicles, tools, and equipment that have not been used in contaminated areas or for excavation activities. Subcontractor/vendor/privately owned vehicles, tools, and equipment that have not been used in contaminated areas or for excavation activities.
- New cardboard.
- Consumer glass containers.

4.4 Air Quality Program

Sections of Y-12's Title V Permit 571832 contain requirements that are generally applicable to most industrial sites. Examples include requirements associated with asbestos controls, control of stratospheric ozone-depleting chemicals, control of fugitive emissions, and general administration of the permit. The Title V permit also contains a section of specific requirements directly applicable to individual sources of air emissions at Y-12. Major requirements in that section include the Radiological National Emission Standards for Hazardous Air Pollutants (Rad-NESHAPs) (40 CFR 61) requirements and the numerous requirements associated with emissions of criteria pollutants and other, non-radiological hazardous air pollutants (HAPs). In addition, a number of sources that are exempt from permitting requirements under State rules but subject to listing on the Title V Permit application are documented, and information about them is available upon request from the Y-12 Clean Air Program.

4.4.1 Construction and Operating Permits

The following Title V permitting actions were submitted and approved in 2019:

- Minor permit modifications to remove Building 9201-1W Emission Source Operation, to remove Stack 12 Process Equipment from the Third Mill Metal Working Operations, and to add a new stationary emergency engine/generator to the Title V air permit.
- Declaration of insignificant activity to reclassified stationary emergency engines/generators and fire water pumps as an insignificant activity.
- Initial notification report for a new stationary emergency engine/generator that exceeds 500 hp.
- Notification of change to CNS Complex responsible official was submitted to the regulators.
- Air permit insignificant activity/exemption was completed for the White Sands Missile Range Mobile Uranium Facility.

Demonstrating compliance with the conditions of air permits is a significant effort at Y-12. Key elements of maintaining compliance are maintenance and operation of control devices, monitoring, record keeping, and reporting. High-efficiency particulate air (HEPA) filters and scrubbers are control devices used at Y-12. HEPA filters are found throughout the complex, and in-place testing of HEPA filters to verify the integrity of the filters is routinely performed. Scrubbers are operated and maintained in accordance with source-specific procedures. Monitoring tasks consist of continuous stack sampling, one-time stack sampling, and monitoring the operation of control devices. Examples of continuous stack sampling are the radiological stack monitoring systems on numerous sources throughout Y-12.

The Y-12 sitewide permit requires annual and semiannual reports. One report is the overall Annual ORR Rad-NESHAPs Report, which includes specific information regarding Y-12 radiological emissions; another is an Annual Title V Compliance Certification Report, which indicates compliance status with all conditions of the permit. A third is a Title V Semiannual Report, which covers a 6-month period for some specific emission sources and consists of monitoring and record-keeping requirements for the sources. Another annual report is the Boiler Maximum Available Control Technology Report for the Y-12 Steam Plant, which requires the boilers to be tuned-up on an annual basis. Table 4.8 gives the actual emissions versus allowable emissions for the Y-12 steam plant.

Table 4.8. Actual versus allowable air emissions from the Y-12 steam plant, 2019

Pollutant	Emissions (tons/year)[a]		
	Actual	Allowable	Percentage of allowable
Particulate	3.00	41.0	7.3
Sulfur dioxide	0.24	39.0	0.6
Nitrogen oxides[b]	12.62	81.0	15.6
VOCs[b]	2.17	9.4	23.1
Carbon monoxide[b]	33.12	139.0	23.8

NOTE: The emissions are based on fuel usage data for January through December 2019. The VOC emissions include VOC hazard air pollutant emissions.

[a] 1 ton = 907.2 kg.

[b] When there is no applicable standard or enforceable permit condition for a pollutant, the allowable emissions are based on the maximum actual emissions calculation, as defined in Tennessee Department of Environment and Conservation Rule 1200-3-26-.02(2)(d)3 (maximum design capacity for 8,760 hr/year). Both actual and allowable emissions were calculated based on the latest U.S. Environmental Protection Agency compilation of air pollutant emission factors (EPA 1995, 1998).

Acronyms:
VOC = volatile organic compound
Y-12 = Y-12 National Security Complex

4.4.1.1 Generally Applicable Permit Requirements

Y-12, like many industrial sites, has a number of generally applicable requirements, such as those pertaining to the management and control of asbestos, ozone-depleting substances (ODSs), and fugitive particulate emissions.

Control of Asbestos

Y-12, like many industrial sites, has a number of general requirements applicable to removal and disposal of asbestos-containing materials, including monitoring, notification to TDEC of demolitions and renovations, and prescribed work practices for abatement and disposal of asbestos materials. There was no reportable release of asbestos in 2019. There were four notifications of management and control. Asbestos, ODSs, and fugitive particulate emissions are notable examples.

Stratospheric Ozone Protection

As required by the CAA Title VI Amendments of 1990 and in accordance with 40 CFR Part 82, actions have been implemented to comply with the prohibition against intentionally releasing ODSs during maintenance activities performed on refrigeration equipment. During 2017, EPA enacted major revisions to the stratospheric ozone rules to include the regulation of non-ODS substitutes as part of 40 CFR 82 Subpart F. These revisions were effective January 1, 2018, for disposal of small appliances and January 1, 2019, for the leak rate provisions for large appliances. There were no appliances on Y-12 that leaked refrigerant in 2019 triggering these reporting.

Fugitive Particulate Emissions

As modernization reduction efforts increase at Y-12, the need also increases for good work practices and controls to minimize fugitive dust emissions from construction and demolition activities. Y-12 personnel continue to use a mature project-planning process to review, recommend, and implement appropriate work practices and controls to minimize fugitive dust emissions. Precautions used to prevent particulate matter from becoming airborne include, but are not limited to, the following:

- Use, where possible, of water or chemicals for control of dust in demolition of existing buildings or structures, construction operations, grading of roads, or the clearing of land.
- Application of asphalt, water, or suitable chemicals on dirt roads, material stockpiles, and other surfaces that can create airborne dusts.
- Installation and use of hoods, fans, and fabric filters to enclose and vent dusty materials.

4.4.1.2 National Emission Standards for Hazardous Air Pollutants for Radionuclides

The release of radiological contaminants, primarily uranium, into the atmosphere at Y-12 occurs almost exclusively as a result of plant production, maintenance, and waste management activities. The major radionuclide emissions contributing to the dose from Y-12 are ^{234}U, ^{235}U, ^{236}U, and ^{238}U, which are emitted as particulates (Figure 4.13). The particle size and solubility class of the emissions are determined based on review of the operations and processes served by the exhaust systems to determine the quantity of uranium handled in the operation or process, the physical form of the uranium, and the nature of the operation or process. The four categories of processes or operations that are considered when calculating the total uranium emissions are:

- Those that exhaust through monitored stacks.
- Unmonitored processes for which calculations are performed per Appendix D of 40 CFR 61.
- Processes or operations exhausting through laboratory hoods, also involving 40 CFR 61 Appendix D calculations.
- Emissions from room ventilation exhausts (calculated using radiological control monitoring data from the work area).

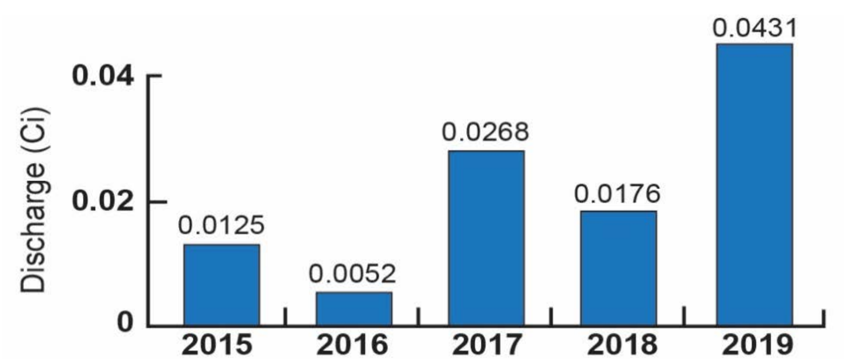


Figure 4.13. Total curies of uranium discharged from the Y-12 National Security Complex to the atmosphere, 2015–2019

Continuous sampling systems are used to monitor emissions from a number of process exhaust stacks at Y-12. In addition, a probe-cleaning program is in place, and the results from the probe cleaning at each source are incorporated into the respective emission point source terms. In 2019, 31 process exhaust stacks were continuously monitored, 23 of which were major sources; the remaining 8 were minor sources. Monitoring for seven of these minor sources was discontinued during the first quarter of 2019, and their contributions to Y-12's air emissions were conservatively accounted for using Appendix D calculations, as noted below. The use of these conservative, calculated values, rather than actual monitored values, resulted in an increase in the reported curies of uranium discharged. The sampling systems on the stacks have been approved by EPA Region 4.

During 2019, unmonitored uranium emissions at Y-12 occurred from 43 points associated with on-site unmonitored processes and laboratories operated by CNS. Emission estimates for the processes and laboratory stacks were made using inventory data with emission factors provided in 40 CFR Part 61, Appendix D. The Y-12 source term includes an estimate of these emissions.

Y-12's Analytical Chemistry Organization (ACO) operates out of two main laboratories. One is located onsite in Building 9995. The other is located in a leased facility on Union Valley Road, about 0.3 mi east of Y-12, and is not within the ORR boundary. In 2019, there were no radionuclide emission points (or sources) in the off-site laboratory facility.

Additionally, estimates from room ventilation systems are considered using radiological control data on airborne radioactivity concentrations in the work areas. Where applicable, exhausts from any area where the monthly concentration average exceeds 10 percent of the derived air concentration, as defined in the ORR Radionuclide Compliance Plan (DOE 2013), are included in the annual source term. Annual average concentrations and design ventilation rates are used to arrive at the annual emission estimate for those areas. Nine emission points from room ventilation exhausts were identified in 2019 where emissions exceeded 10 percent of the derived air concentration. Six of these emission points fed to monitored stacks, and any radionuclide emissions were accounted for as noted for monitored emission points. The remaining three emission points were the result of cleanup activities only (no mechanical or chemical processes) and are considered fugitive emissions. Therefore, they are not included in the total overall source term for Y-12.

Y-12 Title V (Major Source) Operating Permits contain a sitewide, streamlined alternate emission limit for enriched and depleted uranium process emission units. A limit of 907 kg/year of particulate was set for the sources for the purposes of paying fees. The compliance method requires the annual actual mass emission particulate emissions to be generated using the same monitoring methods required for Rad-NESHAPs compliance. An estimated 0.0431 Ci (33.1 kg) of uranium was released into the atmosphere in 2019 as a result of Y-12 process and operational activities.

The calculated radiation dose to the maximally exposed off-site individual from airborne radiological release points at Y-12 during 2019 was 0.36 mrem. This dose is well below the National Emission Standards for Hazardous Air Pollutant (NESHAP) standard of 10 mrem and is less than 0.12 percent of the roughly 300 mrem that the average individual receives from natural sources of radiation. See Chapter 7 for an explanation of how the airborne radionuclide dose was determined.

Lastly, a UPF is presently being designed and constructed. It is intended that this facility house some of the processes that are currently in existing production buildings. The UPF project was issued a Construction Air Permit (967550P) in March 2014. With concurrence from TDEC Air Division, the UPF was included in the 2018 update of Y-12's Site Title V Operating Permit 571832. The facility will be maintained on the permit as inactive until operations commence in approximately 2025.

4.4.1.3 Quality Assurance

Quality assurance (QA) activities for the Rad-NESHAPs program are documented in the *Y-12 National Security Complex Quality Assurance Project Plan for National Emission Standards for Hazardous Air Pollutants for Radionuclide Emission Measurements* (B&W Y-12 2010). The plan satisfies the QA requirements in 40 CFR Part 61, Method 114, for ensuring that the radionuclide air emission measurements from Y-12 are representative to known levels of precision and accuracy and that administrative controls are in place to ensure prompt response when emission measurements indicate an increase over normal radionuclide emissions. The requirements are also referenced in TDEC Regulation 1200-3-11-.08. The plan ensures the quality of Y-12 radionuclide emission measurements data from the continuous samplers and minor radionuclide release points. It specifies the procedures for managing activities affecting the quality of data. QA objectives for completeness, sensitivity, accuracy, and precision are discussed. Major programmatic elements addressed in the QA plan are the sampling and monitoring program, emissions characterization, analytical program, and minor source emission estimates.

4.4.1.4 Source-Specific Criteria Pollutants

Proper maintenance and operation of a number of control devices (e.g., HEPA filters and scrubbers) are key to controlling emissions of criteria pollutants. The primary source of criteria pollutants at Y-12 is the steam plant, where only natural gas and Number 2 fuel oil are permitted to be burned. Information regarding actual versus allowable emissions from the steam plant is provided in Table 4.8.

Particulate emissions from point sources result from many operations throughout Y-12. Demonstration of compliance is achieved via several activities, including monitoring the operations of control devices, limiting process input materials, and using certified readers to conduct emission evaluations of visible stacks.

Use of solvent 140/142 and methanol throughout Y-12 and use of acetonitrile at a single source are primary sources of volatile organic compound (VOC) emissions. Material mass balances and engineering calculations are used to determine annual emissions. The calculated amounts of solvent 140/142 and methanol emitted for CY 2019 are 466.77 lb (0.233 tons) and 4,205 lb (13.88 tons), respectively. The highest calculated amount of acetonitrile and isopropyl alcohol (VOCs) emitted to the atmosphere during any period of 12 consecutive months in CY 2019 was 2.972 tons, which was less than the permitted value of 9 tons/year.

4.4.1.5 Mandatory Reporting of Greenhouse Gas Emissions under 40 Code of Federal Regulations 98

Title 40 of CFR Part 98, *Mandatory Greenhouse Gas Reporting* (EPA 2010), establishes mandatory GHG reporting requirements for owners and operators of certain facilities that directly emit GHGs and for certain fossil fuel suppliers and industrial GHG suppliers. The purpose of the rule is to collect accurate and timely data on GHG emissions that can be used to inform future policy decisions.

The mandatory reporting of GHGs rule requires reporting of annual emissions of carbon dioxide, methane, nitrous oxide, sulfur hexafluoride, hydrofluorocarbons, perfluorochemicals, and other fluorinated gases (e.g., nitrogen trifluoride and hydrofluorinated ethers). These gases are often expressed in metric tons of carbon dioxide equivalent (CO_2e).

Y-12 is subject only to the Subpart A general provisions and reporting from stationary fuel combustion sources covered in 40 CFR 98, Subpart C, *General Stationary Fuel Combustion* (EPA 2010). Currently, the rule does not require control of GHGs; rather, it requires only that sources emitting above the 25,000-CO_2e threshold level monitor and report emissions.

The Y-12 steam plant is subject to this rule. The steam plant consists of four boilers. The maximum heat input capacity of each boiler shall not exceed 99 MM British thermal unit (Btu)/hr. Natural gas is the primary fuel source for the boilers; Number 2 fuel oil is a backup source of fuel. Other limited, stationary combustion sources are metal-forming operations and production furnaces that use natural gas. In Building 9212, a gas-fired furnace used for drying wet residues and burning solids in a recovery process has a maximum heat input of 700,000 Btu/hr. In Building 9215, 10 natural gas torches, each at 300 standard ft^3/hr, are used to preheat tooling associated with a forging and forming press. In Building 9204-2, natural gas is used to heat two electrolytic cells. The maximum rated heat input to the burners on each cell is 550,000 Btu/hr.

All of the combustion units burning natural gas are served through the fuel supply and distribution system and are reported as combined emissions consistent with the provisions of 40 CFR 98.36(c)(3). The Tier 1 Calculation Method was used to calculate GHGs from Y-12. The amount of natural gas supplied to the site, along with the fuel use logs, provides the basic information required for calculation of the GHG emissions.

The emissions report is submitted electronically in a format specified by the EPA administrator. Each report is signed by a designated representative of the owner or operator, certifying under penalty of law that the report has been prepared in accordance with the requirements of the rule. The total amount of GHGs, subject to the mandatory reporting rule, emitted from Y-12 is shown in Table 4.9. The decrease in emissions from 2010 to 2017 is associated with the fact that coal is no longer burned since the natural-gas-fired steam plant came on line. The slight increase in CO_2e emissions was due to the fact that fuel oil was burned for a few days in December 2018.

Table 4.9. GHG emissions from Y-12 stationary fuel combustion sources

Year	GHG emissions (metric tons CO_2e)
2010	97,610.0
2011	70,187.0
2012	63,177.0
2013	61,650.0
2014	58,509.0
2015	51,706.9
2016	50,671.6
2017	50,292.7
2018	51,010.7
2019	45,971.3

Acronyms:
CO_2e = CO_2 equivalent
GHG = greenhouse gas

4.4.1.6 Hazardous Air Pollutants (Non-radiological)

Beryllium emissions from machine shops are regulated under a State-issued permit and are subject to a limit of 10 g/24 hr. Compliance is demonstrated through a one-time stack test and through monitoring of control device operations. Hydrogen fluoride is used at one emission source, and emissions are controlled through the use of scrubber systems. The beryllium control devices and the scrubber systems were monitored during 2019 and were found to be operating properly.

Methanol is released as fugitive emissions (e.g., pump and valve leaks) as part of the brine/methanol system. Methanol is subject to State air permit requirements; however, due to the nature of its release (fugitive emissions only), there are no specific emission limits or mandated controls. Mercury is a significant legacy contaminant at Y-12, and cleanup is being addressed under the environmental remediation program. Like methanol emissions, mercury air emissions from legacy sources are fugitive in nature and, therefore, are not subject to specific air emission limits or controls. On-site monitoring of mercury is conducted and is discussed under Section 4.4.2.1.

In 2007, EPA vacated a proposed Maximum Achievable Control Technology (MACT) standard that was intended to minimize HAP emissions. At that time, a case-by-case MACT review was conducted as part of the construction-permitting process for the Y-12 replacement steam plant. The new natural-gas-fired steam plant came online on April 20, 2010, and coal is no longer combusted. Specific conditions aimed at minimizing HAP emissions from the new steam plant were incorporated into the operating permit issued on January 9, 2012 (see Section 4.4.1). In addition, the boiler MACT standard was revised and reissued on January 31, 2013. TDEC issued a minor modification to the Title V air permit on October 29, 2014, which included the new boiler MACT requirements. The new requirements (work practice standards) include conducting annual tune-ups and a one-time energy assessment of the boilers to meet these requirements.

There are no numeric emission-limit requirements for the steam plant. The new rule requires that a one-time energy assessment for the steam plant must be completed on or after January 1, 2008. The new rule requires that tune-ups for the boilers must be completed 13 months from the previous tune-ups. To comply with that requirement, an energy assessment for the Y-12 steam plant, performed by a qualified energy assessor, was completed in July 2013. The tune-ups for boilers were completed on January 8 and 9, 2019.

Unplanned releases of HAPs are regulated through the Risk Management Planning regulations. Y-12 personnel have determined no processes or facilities contain inventories of chemicals in quantities exceeding thresholds specified in rules pursuant to CAA, Title III, Section 112(r), *Prevention of Accidental Releases* (EPA 1990). Therefore, Y-12 is not subject to that rule. Procedures are in place to continually review new processes and/or process changes against the rule thresholds.

EPA has created multiple national air pollution regulations to reduce air emissions from Reciprocating Internal Combustion Engines (RICEs). Two types of federal air standards are applicable to RICEs—new source performance standards (Title 40 CFR Part 60, Subpart IIII), and NESHAPs (EPA 2013; Title 40 CFR Part 63, Subpart DDDDD). The compression ignition engines/generators located at Y-12 are subject to these rules. EPA is concerned about how RICEs are used and the emissions generated from these engines in the form of both HAPs and criteria pollutants.

All previous stationary emergency engines/generators were listed in Y-12's Title V air permit application as "insignificant activities." However, on January 16, 2013, EPA finalized revisions to standards to reduce air pollution from stationary engines that generate electricity and power equipment at sites of major sources of HAPs. Regardless of engine size, the rules apply to any existing, new, or reconstructed stationary RICE located at a major source of HAP emissions.

To comply with the rules, Y-12 prepared a significant permit modification to Y-12's Title V (Major Source) Operating Air Permit to add numerous stationary, emergency-use engines/generators located throughout Y-12. The permit application was submitted to TDEC on May 6, 2013, for review and approval. TDEC downgraded the significant modification to a minor modification per EPA's review and request. In a prior, updated permit application for renewal of Y-12's Title V (Major Source) Operating Air Permit dated March 9, 2011, Y-12 staff identified Title 40 CFR, Part 60, Subpart IIII, and "Standards of Performance for Stationary Compression Ignition Internal Combustion Engines," as requirements applicable to the stationary emergency-use engines located at Y-12. TDEC issued Y-12 a minor permit modification to the Title V air permit on March 3, 2014, for the emergency engines/generators. Compliance for the engines/generators is determined through monthly records of the operation of the engines/generators that are recorded through a non-resettable hour meter on each engine/generator. Documentation must be maintained of how many hours are spent for emergency operation, maintenance checks and readiness testing, and non-emergency operation. Each engine/generator must use only diesel fuel with low sulfur content (15 parts per million) and acetane index of 40.

Since the above rules were adopted into the Tennessee Air Pollution Control Regulations (TAPCR) 0400-30, Chapters 38 and 39, the emergency engines/generators can be considered an insignificant activity if the potential to emit is below the significance thresholds (less than 5 tons/year of each criteria pollutant and less than 1,000 lb/year of any hazardous air pollutant evaluated at a 500-hr/year limit). There was also a change to Chapter 9 of TAPCR that allows for stationary engines to be eligible to be considered insignificant activities. Condition D14 of the Title V Operating Air Permit 571832 was amended to incorporate new language specifying stationary reciprocating internal combustion engines are eligible to be considered insignificant activities that must comply with any underlying applicable rules associated with a stationary internal combustion engine.

The emergency engines/generators are used to provide power for critical systems in the event of electrical power failures/outages at Y-12. The engines/generators operate exclusively as emergency engines/generators. Based upon historical usage of the emergency engines/generators and fire water pumps and EPA's 500-hr default assumption (maximum hour usage), calculations verify and confirm that the potential emissions from each stationary emergency internal combustion engine less than 645 hp qualifies, or should be reclassified as an insignificant activity, because the potential to emit is well below the significance thresholds of less than 5 tons/year of each regulated air pollutant that is not an HAP, and less than 1,000 lb/year of any HAP in accordance with TAPCR 1200-03-09-.04(5)(a)4(i). Approximately 95 percent of Y-12 stationary emergency engines/generators and fire water pumps are considered and/or reclassified as an insignificant activity in accordance with TAPCR Rule 1200-03-09-.04(5)(a)4.(i). These engines are listed in Y-12's Title V Air Permit.

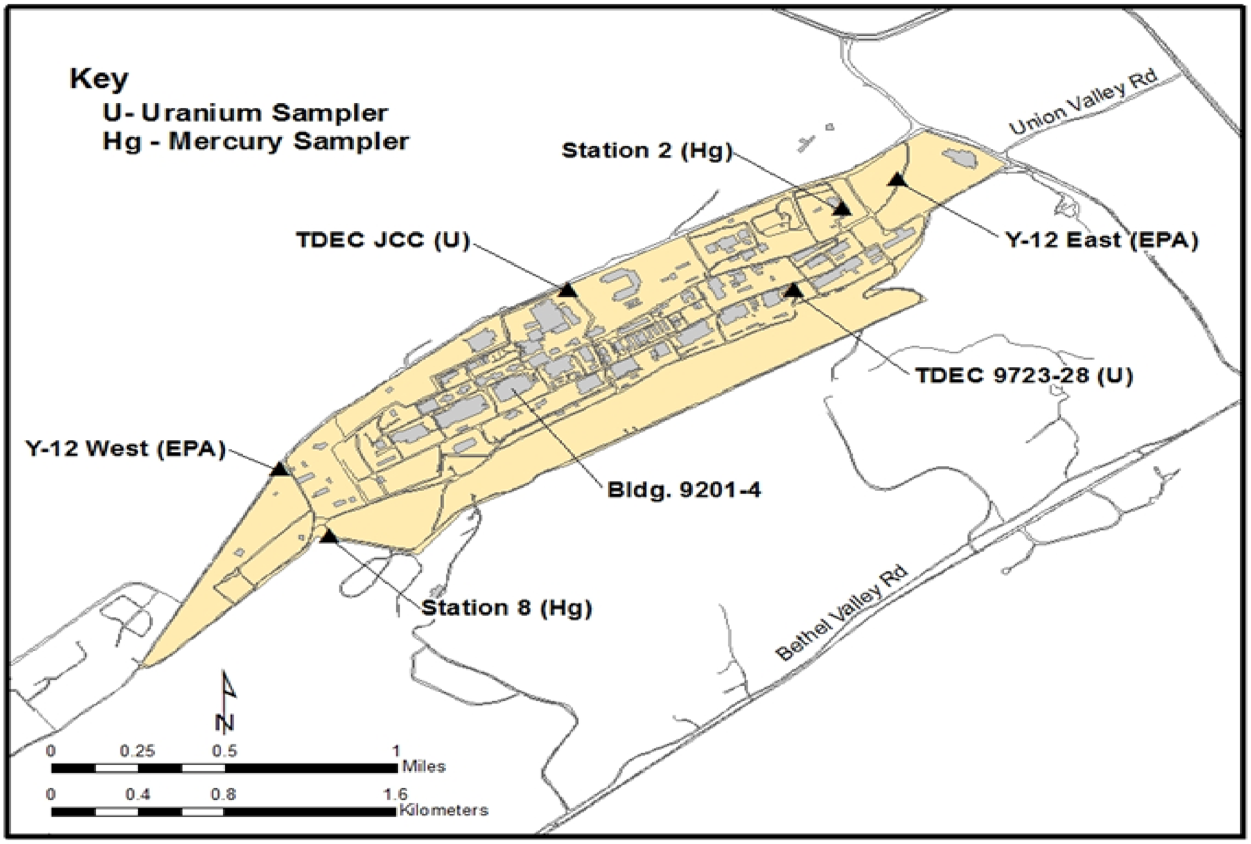
4.4.2 Ambient Air

To understand the complete picture of ambient air monitoring in and around Y-12, data from on- and off-site monitoring conducted specifically for Y-12, DOE reservation-wide monitoring, and on- and off-site monitoring conducted by EPA and TDEC personnel must be considered.

No federal regulations, state regulations, or DOE Orders require ambient air monitoring within the Y-12 boundary; however, on-site ambient air monitoring for mercury and radionuclides is conducted as a best management practice. With the reduction of plant operations and improved emission and administrative controls, levels of measured pollutants have decreased significantly during the past several years. In addition, major processes that result in emission of enriched and depleted uranium are equipped with stack samplers that have been reviewed and approved by EPA to meet requirements of the NESHAPs regulations.

4.4.2.1 Mercury

The Y-12 ambient air monitoring program for mercury was established in 1986 as a best management practice. The objectives of the program have been to maintain a database of mercury concentrations in ambient air, to track long-term spatial and temporal trends in ambient mercury vapor, and to demonstrate protection of the environment and human health from releases of mercury to the atmosphere at Y-12. Originally, four monitoring stations were operated at Y-12, including two within the West End Mercury Area (i.e., the former west end mercury-use area at Y-12). The two atmospheric mercury monitoring stations currently operating at Y-12, ambient air (monitoring) station (AAS)2 and AAS8, are located near the east and west boundaries of Y-12, respectively (Figure 4.14). Since their establishment in 1986, AAS2 and AAS8 have monitored mercury in ambient air continuously, with the exception of short intervals of downtime because of electrical or equipment outages. In addition to the monitoring stations located at Y-12, two additional monitoring sites were operated—a reference site (rain gauge 2) was operated on Chestnut Ridge in the Walker Branch Watershed for a 20-month period in 1988 and 1989 to establish a reference concentration, and a site was operated at New Hope Pond for a 25-month period from August 1987 to September 1989.



Acronyms:
EPA = U.S. Environmental Protection Agency (sampler)
TDEC = Tennessee Department of Environment and Conservation
JCC = Jack Case Center

Figure 4.14. Locations of ambient air monitoring stations at Y-12 National Security Complex

To determine mercury concentrations in ambient air, airborne mercury vapor is collected by pulling ambient air through a sampling train consisting of a Teflon filter and an iodinated-charcoal sampling trap. A flow-limiting orifice upstream of the sampling trap restricts airflow through the sampling train to approximately 1 L/min. Actual flows are measured bi-weekly with a calibrated Gilmont flowmeter in conjunction with the bi-weekly change-out of the sampling trap. The charcoal in each trap is analyzed for total mercury using cold vapor atomic fluorescence spectrometry after acid digestion. The average concentration of mercury vapor in ambient air for each 14-day sampling period is then calculated by dividing the total mercury per trap by the volume of air pulled through the trap during the corresponding 14-day sampling period.

As reported previously, average mercury concentration at the ambient air monitoring sites has declined significantly since the late 1980s. Recent average annual concentrations at the two boundary stations are comparable to concentrations measured in 1988 and 1989 at the Chestnut Ridge reference site (Table 4.10). Average mercury concentration at the AAS2 site for 2019 is 0.0025 µg/m^3 (N = 25), comparable to averages measured since 2003. After an increase in average concentration at AAS8 for the period 2005 through 2007, thought to be possibly due to increased decontamination and decommissioning work on the west end, the average concentration at AAS8 for 2019 was 0.0036 µg/m^3 (N = 25), similar to levels reported for 2008 and the early 2000s.

Table 4.10. Summary of data for the Y-12 ambient air monitoring program for mercury, CY 2019

Ambient air monitoring stations	Mercury vapor concentration (µg/m^3)			
	2019 Minimum	2019 Maximum	2019 Average	1986–1988[a] Average
AAS2 (east end of Y-12)	0.0014	0.0054	0.0025	0.010
AAS8 (west end of Y-12)	0.0015	0.0061	0.0036	0.033
Reference site, rain gauge 2 (1988[b])	N/A	N/A	N/A	0.006
Reference site, rain gauge 2 (1989[c])	N/A	N/A	N/A	0.005

[a] Period in late 1980s with elevated ambient air mercury levels; shown for comparison.
[b] Data for period from February 9 through December 31, 1988.
[c] Data for period from January 1 through October 31, 1989.

Acronyms:
AAS = ambient air (monitoring) station
CY = calendar year
N/A = not applicable
Y-12 = Y-12 National Security Complex

Table 4.10 summarizes the 2019 mercury results, with results from the 1986 through 1988 period included for comparison. Figure 4.15 illustrates temporal trends in mercury concentration for the two active mercury monitoring sites for the period since the inception of the program in 1986 through 2019 [parts (a) and (b)] and seasonal trends at AAS8 from 1994 through 2019 [part (c)]. The dashed line superimposed on plots (a) and (b) in Figure 4.15 is the EPA reference concentration of 0.3 µg/m^3 for chronic inhalation exposure.

The large increase in mercury concentration at AAS8 observed in the late 1980s [part (b)] was thought to be related to disturbances of mercury-contaminated soils and sediments during the Perimeter Intrusion Detection Assessment System installation and storm drain restoration projects under way at that time within the West End Mercury Area. In Figure 4.15(c), a monthly moving average has been superimposed over the AAS8 data to highlight seasonal trends in mercury at AAS8 from January 1994 through December 2019, with higher concentrations generally measured during the warm weather months.

In conclusion, 2019 average mercury concentrations at the two mercury monitoring sites were comparable to reference levels measured for the Chestnut Ridge reference site in 1988 and 1989. More importantly, measured concentrations continue to be well below current environmental and occupational health standards for inhalation exposure to mercury vapor (i.e., the National Institute for Occupational Safety and Health recommended exposure limit of 50 µg/m^3, time-weighted average [TWA] for up to a 10-hr workday, 40-hr workweek; the American Conference of Governmental Industrial Hygienists workplace threshold limit value of 25 µg/m^3 as a TWA for a normal 8-hr workday and 40-hr workweek; and the current EPA reference concentration of 0.3 µg/m^3 for elemental mercury for a continuous inhalation exposure to the human population without appreciable risk of harmful effects during a lifetime).

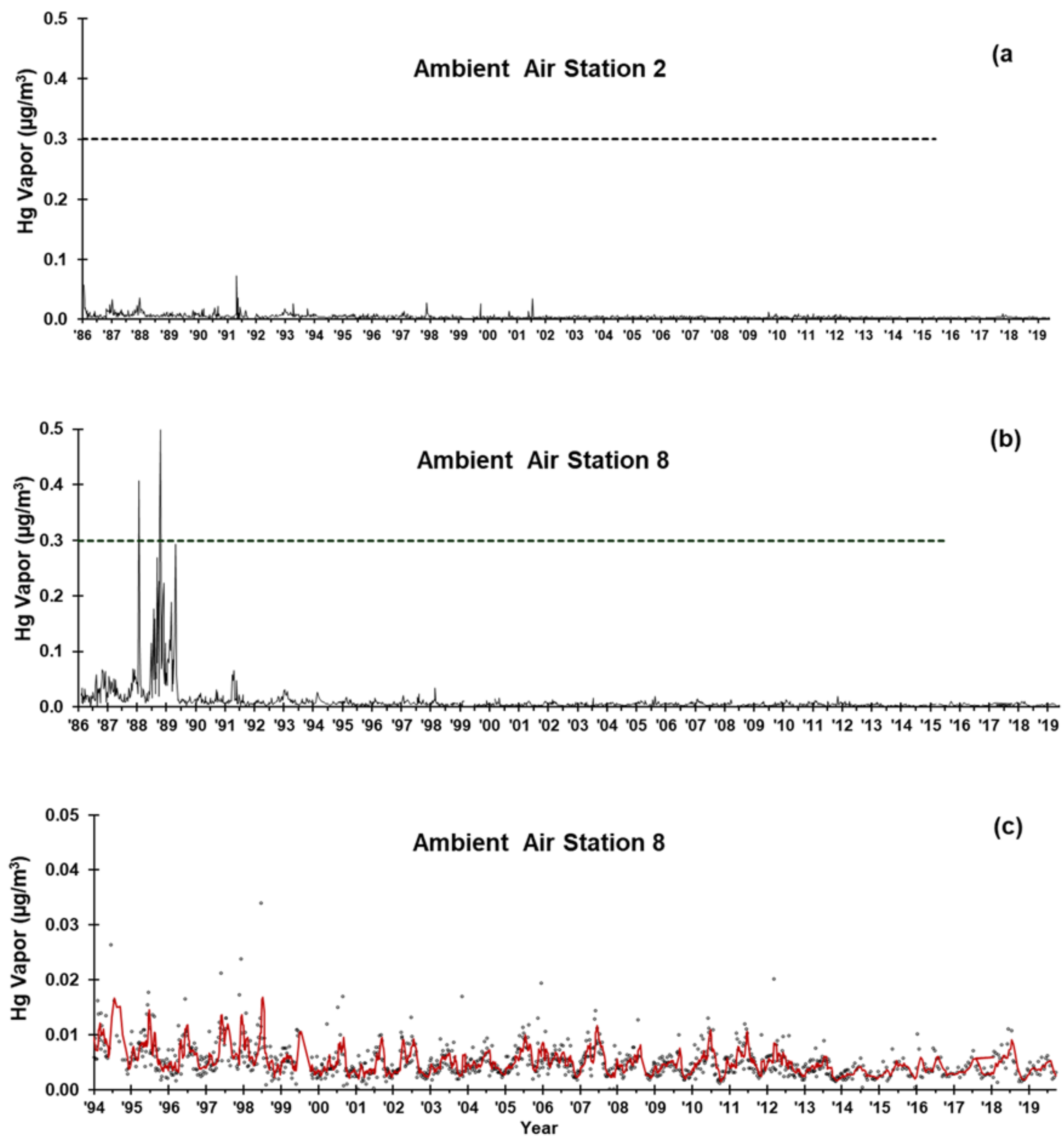


Figure 4.15. Temporal trends in mercury vapor concentration for the boundary monitoring stations at Y-12 National Security Complex, July 1986 to December 2019 [(a) and (b)] and January 1994 to December 2019 for ambient air station 8 [(c)]

4.4.2.2 Quality Control

A number of QA/quality control (QC) steps are taken to ensure the quality of the data for the Y-12 mercury in ambient air monitoring program.

An hour meter records the actual operating hours between sample changes. This allows for correction of total flow in the event of power outages during the weekly sampling interval.

The Gilmont correlated flowmeter, used for measuring flows through the sampling train, is purchased annually or, if not new, shipped back to the manufacturer annually for calibration in accordance with standards set by the National Institute of Standards and Technology.

A minimum of 5 percent of the samples in each batch submitted to the analytical laboratory are blank samples. The blank sample traps are submitted "blind" to verify trap blank values and to serve as a field blank for diffusion of mercury vapor into used sample traps during storage before analysis.

To verify the absence of mercury breakthrough, 5 to 10 percent of the field samples have the front (upstream) and back segments of the charcoal sample trap analyzed separately. The absence of mercury above blank values on the back segment confirms the absence of breakthrough.

Chain-of-custody forms track the transfer of sample traps from the field technicians all the way to the analytical laboratory.

A field performance evaluation is conducted annually by the project manager to ensure that sampling technicians follow proper procedures. No issues were identified in the last evaluation conducted on May 30, 2019.

Analytical QA/QC requirements include the following:

- Use of prescreened and/or laboratory-purified reagents
- Analysis of at least two method blanks per batch
- Analysis of standard reference materials
- Analysis of laboratory duplicates (1 per 10 samples; any laboratory duplicates differing by more than 10 percent at 5 or more times the detection limit are to be rerun [third duplicate] to resolve the discrepancy)
- Archiving all primary laboratory records for at least 1 year

4.4.2.3 Ambient Air Monitoring Complementary to Y-12 National Security Complex Ambient Air Monitoring

Ambient air monitoring is conducted at multiple locations near ORR to measure radiological and other selected parameters directly in the ambient air. These monitors are operated in accordance with DOE Orders. Their locations were selected so that areas of potentially high exposure to the public are monitored continuously for parameters of concern. This monitoring provides direct measurement of airborne concentrations of radionuclides and other HAPs, allows facility personnel to determine the relative level of contaminants at the monitoring locations during an emergency, verifies that the contributions of fugitive and diffuse sources are insignificant, and serves as a check on dose-modeling calculations. As part of the ORR network, an AAS located in the Scarboro Community of Oak Ridge (Station 46) measures off-site impacts of Y-12 operations. This station is located near the theoretical area of maximum public pollutant concentrations as calculated by air-quality modeling. ORR network stations are also located at the east end of Y-12 (Station 40) and just south of the Country Club Estates neighborhood (Station 37).

In addition to the monitoring described above, the State of Tennessee (TDEC) and EPA perform ambient air monitoring to characterize the region in general and to characterize and monitor DOE operations locally. Specific to Y-12 operations, there are three uranium ambient air monitors within the Y-12 boundary that, since 1999, have been used by TDEC personnel in their environmental monitoring program. Each of the monitors uses 47-mm, borosilicate glass-fiber filters to collect particulates as air is pulled through the units. The monitors control airflow with a pump and rotometer set to average about 2 standard ft^3/min. During 2012, these uranium monitors at stations 4, 5, and 8 were phased out of service, and two additional high-volume samplers (Figure 4.15) are now being used by TDEC to provide isotopic uranium monitoring capability. These are located on the east side of the Jack Case Center and on the south side of the Building 9723-28 change house. EPA performs ambient air monitoring on the east end of the plant near the intersection of Scarboro Road and Bear Creek Road and on the west end of the plant near the intersection of Bear Creek Road and Old Bear Creek Road.

In addition, TDEC DOE Oversight Division air quality monitoring includes several other types of monitoring on ORR, for example:

- RADNet air monitoring
- Fugitive radioactive air emission monitoring
- Ambient VOC air monitoring
- Perimeter air monitoring
- Real-time monitoring of gamma radiation
- Ambient gamma radiation monitoring using external dosimetry
- Program-specific monitoring associated with infrastructure-reduction activities

Results of these activities are summarized in annual status reports, which are issued by TDEC DOE Oversight Division.

The State of Tennessee also operates a number of regional monitors to assess ambient concentrations of criteria pollutants, such as sulfur dioxide, particulate (various forms), and ozone, for comparison against ambient standards. The results are summarized and available through EPA and state reporting mechanisms.

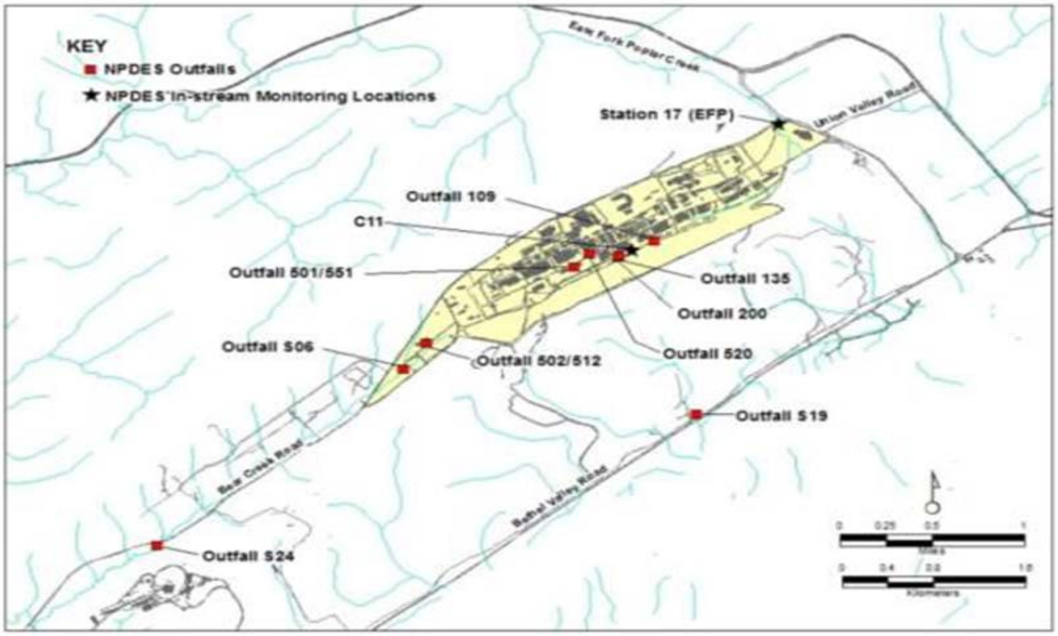
4.5 Water Quality Program

4.5.1 National Pollutant Discharge Elimination System Permit and Compliance Monitoring

The current Y-12 NPDES Permit (TN0002968) requires sampling, analysis, and reporting for about 56 outfalls. Major outfalls are depicted in Figure 4.16. The number is subject to change as outfalls are eliminated or consolidated or if permitted discharges are added. Currently, Y-12 has outfalls and monitoring points in the following water drainage areas: EFPC, Bear Creek, and several tributaries on the south side of Chestnut Ridge, all of which eventually drain to the Clinch River.

Discharges to surface water allowed under the permit include storm drainage; cooling water; cooling tower blowdown; steam condensate; and treated process wastewaters, including effluents from wastewater treatment facilities. Groundwater inflow into sumps in building basements and infiltration to the storm drain system are also permitted for discharge to the creek. The monitoring data collected by the sampling and analysis of permitted discharges are compared with NPDES limits where applicable for each parameter. Some parameters, defined as "monitor only," have no specified limits.

The water quality of surface streams in the vicinity of Y-12 is affected by current and legacy operations. Discharges from Y-12 processes flow into EFPC before the water exits Y-12. EFPC eventually flows through the city of Oak Ridge to Poplar Creek and into the Clinch River. Bear Creek water quality is affected by area source runoff and groundwater discharges. The NPDES permit requires regular monitoring and storm water characterization in Bear Creek and several of its tributaries.



Acronyms: EFP = East Fork Poplar NPDES = National Pollutant Discharge Elimination System

Figure 4.16. Major Y-12 National Security Complex National Pollutant Discharge Elimination System outfalls and monitoring locations

Requirements of the NPDES permit for 2019 were satisfied, and monitoring of outfalls and instream locations indicated excellent compliance. Data obtained as part of the NPDES program, along with other events and observations, are provided in a monthly discharge monitoring report to TDEC. The percentage of compliance with permit discharge limits for 2019 was 100 percent (see Table 4.11).

Table 4.11. NPDES compliance monitoring requirements and record for Y-12, January–December 2019

Discharge point	Effluent parameter	Daily average (lb)	Daily maximum (lb)	Monthly average (mg/L)	Daily maximum (mg/L)	Percentage of compliance	Number of samples
Outfall 501 (Central Pollution Control)	pH, standard units			*a*	9.0	*b*	0
	Total suspended solids			31.0	40.0	*b*	0
	Total toxic organic				2.13	*b*	0
	Hexane extractables			10	15	*b*	0
	Cadmium	0.16	0.4	0.07	0.15	*b*	0
	Chromium	1.0	1.7	0.5	1.0	*b*	0
	Copper	1.2	2.0	0.5	1.0	*b*	0
	Lead	0.26	0.4	0.1	0.2	*b*	0
	Nickel	1.4	2.4	2.38	3.98	*b*	0
	Nitrate/Nitrite				100	*b*	0
	Silver	0.14	0.26	0.05	0.05	*b*	0
	Zinc	0.9	1.6	1.48	2.0	*b*	0
	Cyanide	0.4	0.72	0.65	1.2	*b*	0
	PCB				0.001	*b*	0

Table 4.11. NPDES compliance monitoring requirements and record for Y-12, January–December 2019 (continued)

Discharge point	Effluent parameter	Daily average (lb)	Daily maximum (lb)	Monthly average (mg/L)	Daily maximum (mg/L)	Percentage of compliance	Number of samples
Outfall 502 (West End Treatment Facility)	pH, standard units			*a*	9.0	100	2
	Total suspended solids		31		40	100	2
	Total toxic organic				2.13	100	2
	Hexane extractables			10	15	100	2
	Cadmium		0.4		0.15	100	2
	Chromium		1.7		1.0	100	2
	Copper		2.0		1.0	100	2
	Lead		0.4		0.2	100	2
	Nickel		2.4		3.98	100	2
	Nitrate/Nitrite				100	100	2
	Silver		0.26		0.05	100	2
	Zinc		0.9		1.48	100	2
	Cyanide		0.72		1.20	100	2
	PCB				0.001	100	2
Outfall 512 (Groundwater Treatment Facility)	pH, standard units			*a*	9.0	100	12
	PCB				0.001	100	1
Outfall 520	pH, standard units			*a*	9.0	*b*	0
Outfall 200 (North/South pipes)	pH, standard units			*a*	9.0	100	55
	Hexane extractables			10	15	100	13
	Cadmium			0.001	0.023	100	12
	IC_{25} *Ceriodaphnia*			37% Minimum		100	1
	IC_{25} *Pimephales*			37% Minimum		100	1
	Total residual chlorine			0.024	0.042	100	12
Outfall 551	pH, standard units			*a*	9.0	100	53
	Mercury			0.002	0.004	100	53
Outfall C11	pH, standard units			*a*	9.0	100	14
Outfall 135	pH, standard units			*a*	9.0	100	12
	IC_{25} *Ceriodaphnia*			9% Minimum		100	1
	IC_{25} *Pimephales*			9% Minimum		100	1
Outfall 109	pH, standard units			*a*	9.0	100	5
	Total residual chlorine			0.010	0.017	100	4
Outfall S19	pH, standard units			*a*	9.0	100	1
Outfall S06	pH, standard units			*a*	9.0	100	2
Outfall S24	pH, standard units			*a*	9.0	100	1
Outfall EFP	pH, standard units			*a*	9.0	100	12
Category I outfalls	pH, standard units			*a*	9.0	100	32
Category II outfalls	pH, standard units			*a*	9.0	100	17
	Total residual chlorine				0.5	100	16
Category III outfalls	pH, standard units			*a*	9.0	100	7
	Total residual chlorine			*a*	0.5	100	6

[a] Not applicable.
[b] No discharge.

Acronyms:
IC_{25} = 25% inhibition concentration
NPDES = Nation Pollutant Discharge Elimination System
PCB = polychlorinated biphenyl
Y-12 = Y-12 National Security Complex

4.5.2 Radiological Monitoring Plan and Results

A radiological monitoring plan is in place at Y-12 to address compliance with DOE Orders and NPDES Permit TN0002968. The permit requires Y-12 to submit results from the radiological monitoring plan quarterly as an addendum to the NPDES Discharge Monitoring Report. There were no discharge limits set by the NPDES permit for radionuclides; the requirement is to monitor and report. The radiological monitoring plan was developed based on an analysis of operational history, expected chemical and physical relationships, and historical monitoring results. Under the existing plan, effluent monitoring is conducted at three types of locations—treatment facilities, other point-source and area-source discharges, and instream locations. Operational history and past monitoring results provide a basis for parameters routinely monitored under the plan (Table 4.12). The current Radiological Monitoring Plan for Y-12 (B&W Y-12 2012b) was last revised and reissued in January 2012.

Table 4.12. Radiological parameters monitored at Y-12, 2019

Parameters	Specific isotopes	Rationale for monitoring
Uranium isotopes	^{238}U, ^{235}U, ^{234}U, total U, weight % ^{235}U	These parameters reflect the major activity, uranium processing, throughout the history of Y-12 and are the dominant detectable radiological parameters in surface water.
Fission and activation products	^{90}Sr, ^{99}Tc, ^{137}Cs	These parameters reflect a minor activity at Y-12, processing recycled uranium from reactor fuel elements from the early 1960s to the late 1980s, and will continue to be monitored as tracers for beta and gamma radionuclides, although their concentrations in surface water are low.
Transuranium isotopes	^{241}Am, ^{237}Np, ^{238}Pu, $^{239/240}$Pu	These parameters are related to recycle uranium processing. Monitoring has continued because of their half-lives and presence in groundwater.
Other isotopes of interest	^{232}Th, ^{230}Th, ^{228}Th, ^{226}Ra, ^{228}Ra	These parameters reflect historical thorium processing and natural radionuclides necessary to characterize background radioisotopes.

Acronym:
Y-12 = Y-12 National Security Complex

Radiological monitoring during storm water events is accomplished as part of the storm water monitoring program. Uranium is monitored at three major EFPC storm water outfalls, two instream monitoring locations, and an outfall on Bear Creek. In addition, the monthly 7-day composite sample for radiological parameters taken at Station 17 on EFPC likely includes rain events.

Radiological monitoring plan locations sampled in 2019 are noted on Figure 4.17. Table 4.13 identifies the monitored locations, the frequency of monitoring, and the sum of the percentages of the derived concentration standards (DCS) for radionuclides measured in 2019. Radiological data were well below the allowable DCS.

In 2019, the total mass of uranium and associated curies released from Y-12 at the easternmost monitoring station, Station 17 on Upper EFPC, was 203 kg or 0.079 Ci (Table 4.14).

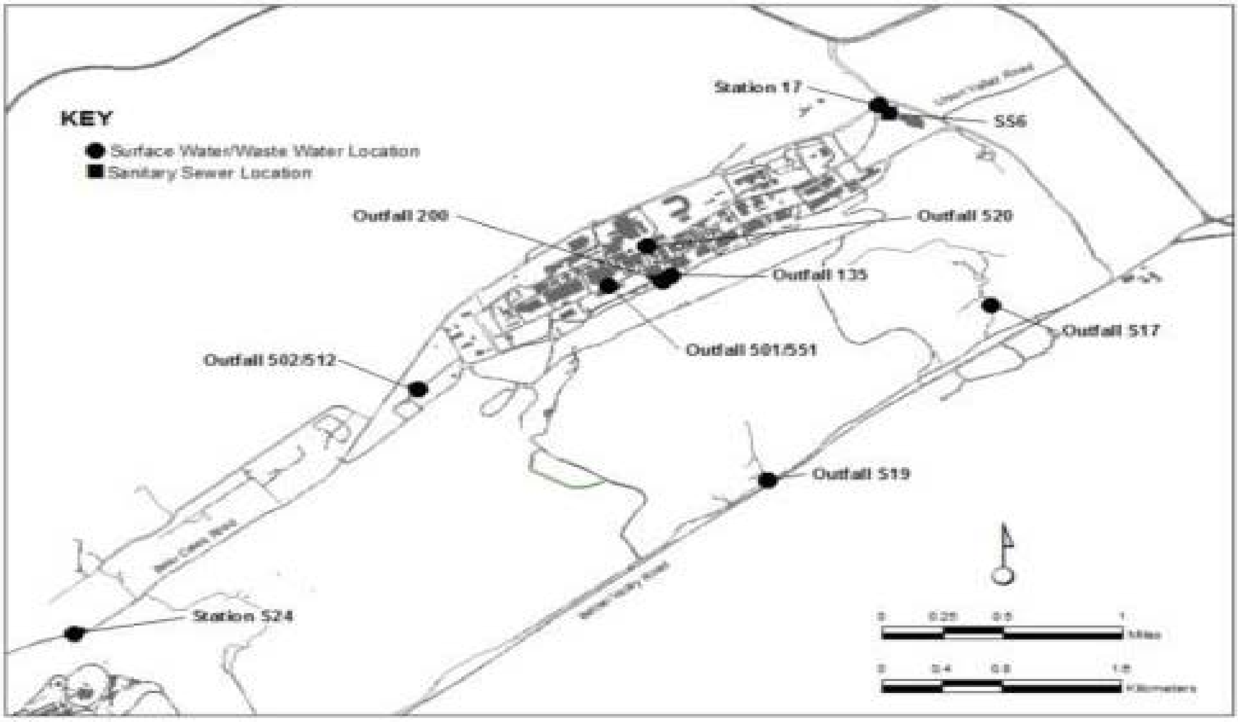


Figure 4.17. Surface water and sanitary sewer radiological sampling locations at Y-12 National Security Complex

Table 4.13. Summary of Y-12 radiological monitoring plan sample requirements and 2019 results

Location	Sample frequency	Sample type	Sum of DCS percentages
	Y-12 wastewater treatment facilities		
Central Pollution Control Facility	1/batch	Composite during batch operation	No flow
West End Treatment Facility	1/batch	24-hr composite	69.4
Groundwater Treatment Facility	4/year	24-hr composite	2.91
Steam	1/year	Grab	No flow
Central Mercury Treatment Facility	4/year	24-hr composite	0.41
	Other Y-12 point- and area-source discharges		
Outfall 135	4/year	24-hr composite	3.42
Kerr Hollow Quarry	1/year	24-hr composite	0.45
Rogers	1/year	24-hr composite	0.91
	Y-12 instream locations		
Outfall S24	1/year	7-day composite	3.8
East Fork Poplar Creek, complex exit (east)	1/month	7-day composite	1.9
North/south	1/month	24-hr composite	3.8
	Y-12 sanitary sewer		
East End Sanitary Sewer Monitoring Station	1/year	7-day composite	12.9

Acronyms:
DCS = derived concentration standard
Y-12 = Y-12 National Security Complex

Table 4.14. Release of uranium from Y-12 to the off-site environment as a liquid effluent, 2013–2019

Year	Quantity released Ci[a]	kg
Station 17		
2014	0.061	90
2015	0.068	116
2016	0.045	88
2017	0.080	154
2018	0.084	205
2019	0.079	203

[a] 1 Ci = 3.7E+10 Bq.

Acronym:
Y-12 = Y-12 National Security Complex

Figure 4.18 illustrates a 5-year trend of these releases. The total release is calculated by multiplying the average concentration (g/L) by the average flow (million gallons per day). Converting units and multiplying by 365 days per year yields the calculated discharge.

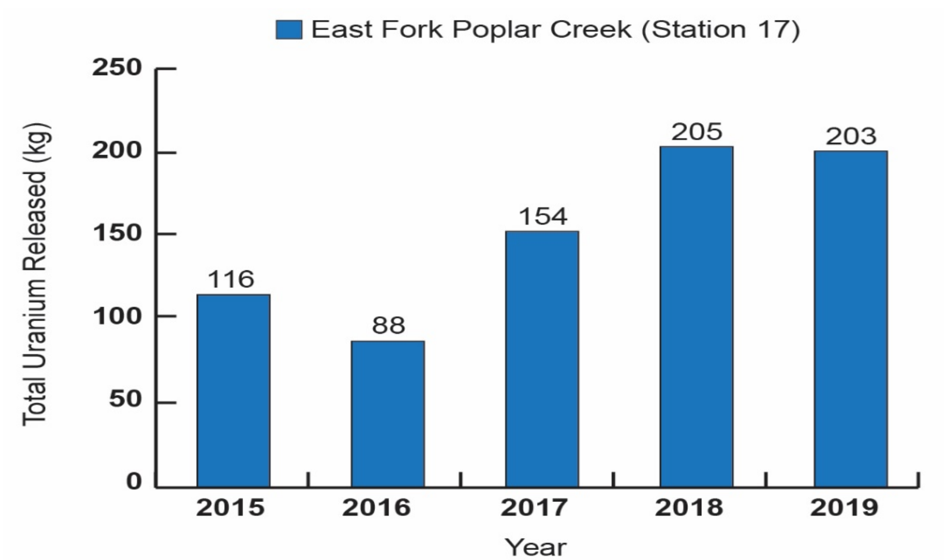


Figure 4.18. Five-year trend of Y-12 National Security Complex releases of uranium to East Fork Poplar Creek

Y-12 is permitted to discharge domestic wastewater to the City of Oak Ridge's publicly owned treatment works. Radiological monitoring of the sanitary sewer system discharge is conducted and reported to the City of Oak Ridge, although there are no City-established radiological limits. Alpha and beta levels are measured weekly, and subsequent uranium analyses are performed if the alpha or beta levels are above prescribed levels. Potential sources of radionuclides discharging to the sanitary sewer have been identified in previous studies at Y-12 as part of an initiative to meet goals to keep levels as low as reasonably achievable. Results of radiological monitoring were reported to the City of Oak Ridge in 2019 quarterly monitoring reports.

4.5.3 Storm Water Pollution Prevention

The Storm Water Pollution Prevention Plan (SWPPP) at Y-12 is designed to minimize the discharge of pollutants in storm water runoff. The plan identifies areas that can reasonably be expected to contribute contaminants to surface water bodies via storm water runoff and describes the development and implementation of storm water management controls to reduce or eliminate the discharge of such pollutants. This plan requires characterization of storm water by sampling during storm events and implementation of measures to reduce storm water pollution, facility inspections, and employee training.

Y-12's SWPPP underwent a significant rewrite in September 2012 in response to issuance of a modified NPDES permit in November 2011. Significant changes included the elimination of two instream monitoring locations (C05 and C08) and the removal of the requirement to perform instream base-load sediment sampling. Other requirements remained essentially the same, with the exception of the lowering of a few benchmark values for certain sector outfalls. The NPDES permit defines the primary function of Y-12 to be a fabricated metal products industry. However, it also requires that storm water monitoring be conducted for three additional sectors—scrap/waste recycling activities; landfill and land application activities; and discharges associated with treatment, storage, and disposal facilities as they are defined in the Tennessee Storm Water Multi Sector General Permit for Industrial Activities (TNR050000). Each sector has prescribed benchmark values, and some have defined sector mean values. The "rationale" portion of the NPDES permit for Y-12 states "These benchmark values were developed by the EPA and the State of Tennessee and are based on data submitted by similar industries for the development of the multi-sector general storm water permit. The benchmark concentrations are target values and should not be construed to represent permit limits."

Storm water sampling was conducted in 2019 during rain events that occurred on April 8, June 5, October 16, and October 30. Results were published in the *Annual Storm Water Report* (CNS 2019), which was submitted to TDEC, Division of Water Pollution Control in January 2020. Consistent with permit requirements, storm water monitoring is performed each year for sector outfalls, three major outfalls that drain large areas of Y-12, and two instream monitoring locations on EFPC (Figure 4.19).

An area of concern continues to be the concentration of mercury being measured in the discharge from Outfall 014. Since the first unexpected elevated result in 2013 (7.12 µg/L), this sector outfall has been on an annual monitoring schedule; however, it was not monitored in 2018 or 2019 due to the degraded condition of the outfall piping and the inability to gather reliable flow rate data. This outfall has since been repaired, and storm water monitoring is currently scheduled to resume in 2020. Data collected to date are presented in Table 4.15.

Sampling conducted in 2018 revealed unusually high concentrations of *Escherichia coli* in the two instream locations and two of the major outfalls. The reason for the elevated concentrations was unknown. Additional sampling and analysis for this contaminant occurred in 2019, and concentrations returned to pre-2018 levels.

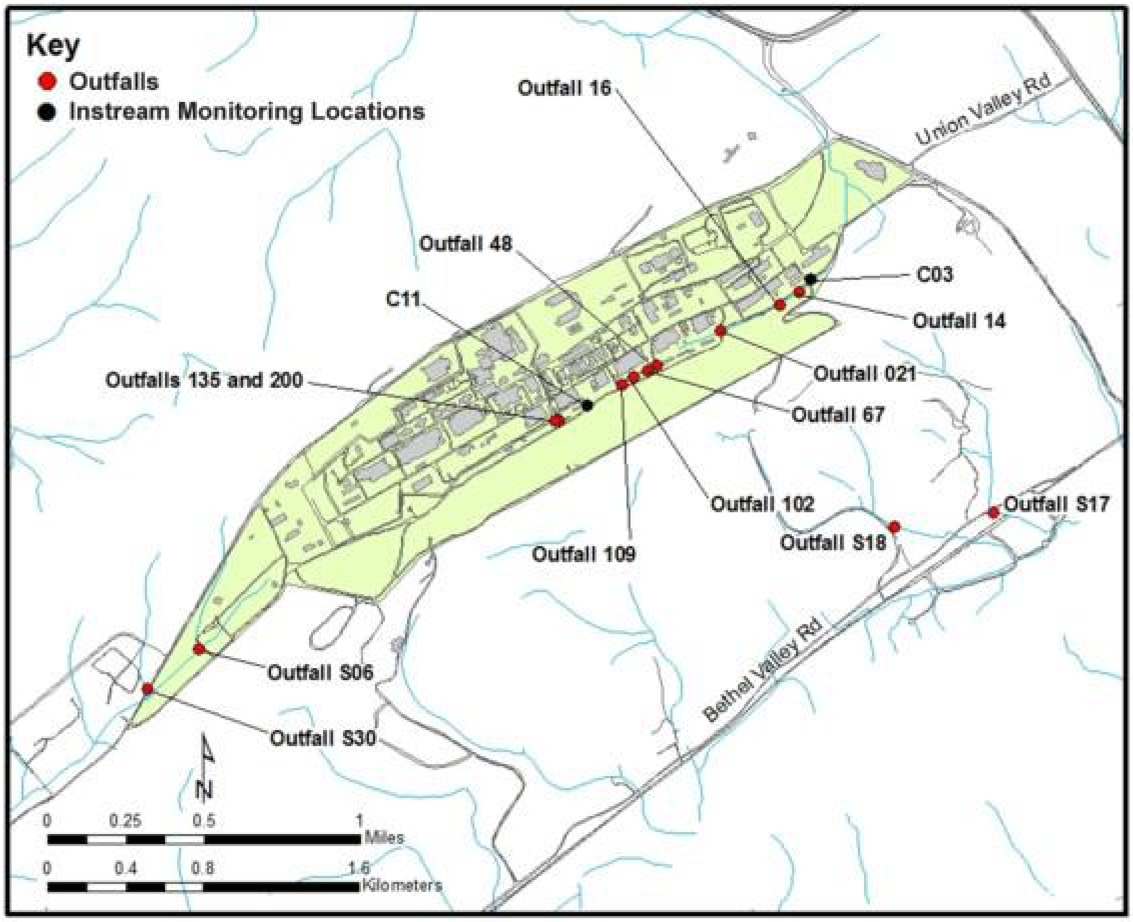


Figure 4.19. Y-12 National Security Complex storm water monitoring locations, East Fork Poplar Creek

Table 4.15. Mercury concentrations at Outfall 014

Calendar year	2013	2014	2015	2016	2017	2018	2019
Mercury concentration (µg/L)	7.12	0.892	9.11	0.49	0.237	N/A	N/A

Acronym:
N/A = not available

4.5.4 Y-12 National Security Complex Ambient Surface Water Quality

To monitor key indicators of water quality, a network of real-time monitors located at three instream locations along Upper EFPC is used. The Surface Water Hydrological Information Support System (SWHISS) is available for real-time water quality measurements, such as pH, temperature, dissolved oxygen, conductivity, and chlorine. The locations are shown in Figure 4.20. The primary function of SWHISS is to indicate potential adverse conditions that could be causing an impact on the quality of water in Upper EFPC. It is operated as a best management practice.

Additional sampling of springs and tributaries is conducted in accordance with Y-12's Groundwater Protection Program (GWPP) to monitor trends throughout the three hydrogeologic regimes (see Section 4.6).

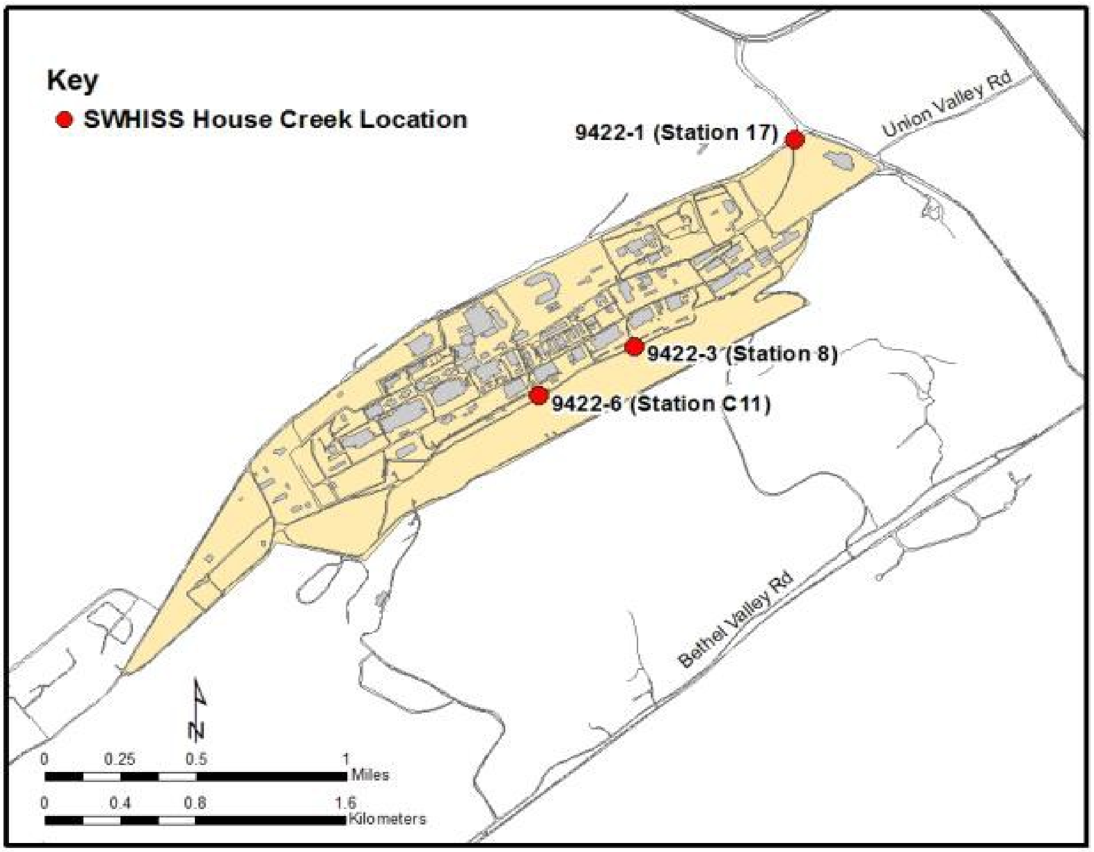


Figure 4.20. Surface Water Hydrological Information Support System monitoring locations

4.5.5 Industrial Wastewater Discharge Permit

Industrial and Commercial User Wastewater Discharge Permit 1-91 defines requirements for the discharge of wastewaters to the sanitary sewer system as well as prohibitions for certain types of wastewaters. It prescribes requirements for monitoring certain parameters at the East End Sanitary Sewer Monitoring Station. The permit sets limits for most parameters. Samples for gross alpha, gross beta, and uranium are taken in a weekly 24-hr composite sample. The sample is analyzed for uranium if the alpha and beta values exceed certain levels. Other parameters (including metals, oil and grease, solids, and biological oxygen demand) are monitored on a monthly basis. Organic parameters are monitored once per quarter. Results of compliance sampling are reported quarterly. Flow is measured continuously at the monitoring station.

As part of the City of Oak Ridge's pretreatment program, city personnel also use the east end monitoring station (also known as SS6, see Figure 4.20) to conduct compliance monitoring as required by the pretreatment regulations. City personnel also conduct twice-yearly compliance inspections.

Monitoring results from 2019 are contained in Table 4.16. There were a total of three exceedances of permit limits in 2019—two exceedances of the 2,100-gal per min instantaneous limit; and one exceedance of the average daily flow limit.

Table 4.16. Y-12 discharge point SS6 (Sanitary Sewer Station 6), CY 2019 (all units are mg/L unless noted otherwise)

Effluent parameter	Number of samples	Average value	Daily maximum (gpm)[a]	Monthly average (effluent limit)[a]	Number of limit exceedances
Max flow rate (gpm)	365	N/A	2,100	N/A	2
Flow (average kgpd) January through March	90	530.2	N/A	500	1
Flow (average kgpd) April through June	91	327.5	N/A	500	0
Flow (average kgpd) July through September	92	303.3	N/A	500	0
Flow (average kgpd) October through December	92	367.0	N/A	500	0
pH (standard units)	27	N/A	N/A	9/6[b]	0
Biochemical oxygen demand	14	120.6	N/A	200	1
Kjeldhal nitrogen	16	30.7	N/A	45	0
Phenols—total recoverable	14	<0.053	N/A	0.15	0
Oil and grease	14	<9.1	N/A	25	0
Suspended solids	16	108.3	N/A	200	0
Cyanide	19	<0.0037	N/A	0.005	0
Arsenic	14	<0.005	N/A	0.010	0
Cadmium	14	<0.0005	N/A	0.0033	0
Chromium, hexavalent	13	0.0054	N/A	0.053	0
Copper	14	0.029	N/A	0.14	0
Iron	14	0.683	N/A	10	0
Lead	14	<0.0025	N/A	0.049	0
Mercury	14	0.00081[d]	N/A	0.035[c]	0
Nickel	14	<0.005	N/A	0.021	0
Silver	14	0.0047	N/A	0.05	0
Zinc	14	0.1358	N/A	0.35	0
Molybdenum	14	0.0538	N/A	0.05[d]	N/A
Selenium	14	<0.01	N/A	0.01[d]	N/A
Toluene	4	0.005	N/A	0.005[d]	N/A
Ammonia	4	14.1	N/A	0.10[d]	N/A
Methanol	4	0.985	N/A	1.0[d]	N/A
Benzene	4	0.005	N/A	0.005[d]	N/A
1,1,1-Trichloroethane	4	0.005	N/A	0.005[d]	N/A
Ethylbenzene	4	0.005	N/A	0.005[d]	N/A
Carbon tetrachloride	4	0.005	N/A	0.005[d]	N/A
Chloroform	4	0.0035	N/A	0.005[d]	N/A
Tetrachloroethene	4	0.0038	N/A	0.005[d]	N/A
Trichloroethene	4	0.005	N/A	0.005[d]	N/A
trans-1,2-Dichloroethylene	4	0.005	N/A	0.005[d]	N/A
Methylene chloride	4	0.005	N/A	0.005[d]	N/A

[a] Industrial and commercial users wastewater permit limits.
[b] Maximum value/minimum value.
[c] There is not a permit limit for this parameter. This value is the required detection limit.
[d] Average value and effluent limit are pounds per day.

Acronyms:
CY = calendar year
gpm = gallons per minutes
kgpm = thousand gallons per minute
N/A = not applicable
Y-12 = Y-12 National Security Complex

An Industrial Waste Water Survey (Permit Application) was submitted to the City of Oak Ridge in December 2019. A new Industrial Waste Water Permit is expected to be issued to Y-12 sometime in the first half of 2020.

4.5.6 Quality Assurance/Quality Control

The Environmental Monitoring Management Information System (EMMIS) is used to manage surface water monitoring data at Y-12. EMMIS uses standard sample definitions to ensure that samples are taken at the correct location at a specified frequency using the correct sampling protocol.

Field sampling QA encompasses many practices that minimize error and evaluate sampling performance. Some key quality practices include the following:

- Use of standard operating procedures for sample collection and analysis.
- Use of chain-of-custody and sample identification, customized chain-of-custody documents, and sample labels provided by EMMIS.
- Instrument standardization, calibration, and verification.
- Sample technician training.
- Sample preservation, handling, and decontamination.
- Use of QC samples such as field and trip blanks, duplicates, and equipment rinses.

Surface water data are entered directly by the analytical laboratory into the Laboratory Information Management System on the day of approval. EMMIS routinely accesses the Laboratory Information Management System electronically to capture pertinent data. Generally, the system will store data in the form of concentrations.

A number of electronic data management tools enable automatic flagging of data points and allow for monitoring and trending data over time. Field information on all routine samples taken for surface water monitoring is entered in EMMIS, which also retrieves data nightly from the analytical laboratory. The system then performs numerous checks on the data, including comparisons of the individual results against any applicable screening criteria, regulatory thresholds, compliance limits, best management practices, or other water quality indicators, and produces required reports.

4.5.7 Biomonitoring Program

The NPDES permit for Y-12 (TN0002968, Part III, Section E) contains chronic toxicity testing requirements. These requirements specify that chronic toxicity testing (a 3-Brood *Ceriodaphnia dubia* survival and reproduction test and a 7-day fathead minnow larval survival and growth test) is required annually at Outfalls 135 and 200 to determine whether the effluent is contributing chronic toxicity to the receiving water. According to permit requirements, chronic toxicity testing is to be performed using 100-percent effluent and the dilution series shown below in Table 4.17.

Table 4.17. Serial dilutions for whole effluent toxicity testing, as a percent of effluent

Outfall 200	**Control**	**0.25 x PL**	**0.50 x PL**	**PL**	**(100+ PL)/2**	**100% Effluent**
	0	9.3	18	37	74	100
Outfall 135	**Control**	**0.25 x PL**	**0.50 x PL**	**PL**	**2 x PL**	**4 x PL**
	0	2.3	4.5	9	18	36

NOTE: The effluent water is diluted with control laboratory water.
PL = permit limit

Table 4.18 summarizes the results of the 2019 outfall biomonitoring tests in terms of the 25 percent inhibition concentration (IC_{25}), which is the concentration (i.e., a percentage of full-strength effluent diluted with laboratory control water) of each outfall effluent that causes a 25-percent reduction in the survival or reproduction of water fleas (*Ceriodaphnia dubia*) or the survival or growth of fathead minnow (*Pimephales promelas*) larvae (with respect to these same endpoints for these animals measured in control laboratory water). The lower the value of the IC_{25}, the more toxic the effluent. According to the NPDES permit, toxicity is demonstrated if the IC_{25} is less than or equal to the permit limit (9 percent whole effluent for Outfall 135 and 37 percent whole effluent for Outfall 200).

Table 4.18. Y-12 biomonitoring program summary information for Outfalls 200 and 135, 2019[a]

Water collection dates	Outfall	Test type	Test organism	End point	Metric	IC_{25}[b] (%)
02/12/19–02/17/19	200	Chronic	Fathead minnow (*Pimephales promelas*)	Survival	IC_{25}	>100%
				Growth	IC_{25}	>100%
			Water fleas (*Ceriodaphnia dubia*)	Survival	IC_{25}	>100%
				Reproduction	IC_{25}	>100%
07/16/19–07/22/19	135	Chronic	Fathead minnow (*Pimephales promelas*)	Survival	IC_{25}	>36%
				Growth	IC_{25}	>36%
			Water fleas (*Ceriodaphnia dubia*)	Survival	IC_{25}	>36%
				Reproduction	IC_{25}	>36%
07/16/19–07/22/19	200	Chronic	Water fleas (*Ceriodaphnia dubia*)	Survival	IC_{25}	>100%
				Reproduction	IC_{25}	>100%
			Fathead minnow (*Pimephales promelas*)	Survival	IC_{25}	>100%
				Growth	IC_{25}	>100%

[a] IC_{25} is summarized for the discharge monitoring locations, Outfalls 200 and 135.
[b] IC_{25} as a percentage of full-strength effluent from Outfalls 200 and 135 diluted with laboratory control water. IC_{25} is the concentration that causes a 25% reduction in water fleas (*Ceriodaphnia dubia*) survival or reproduction or fathead minnow (*Pimephales promelas*) survival or growth; 36% is the highest concentration of Outfall 135 tested.

Acronyms:
IC_{25} = 25% inhibition concentration
Y-12 = Y-12 National Security Complex

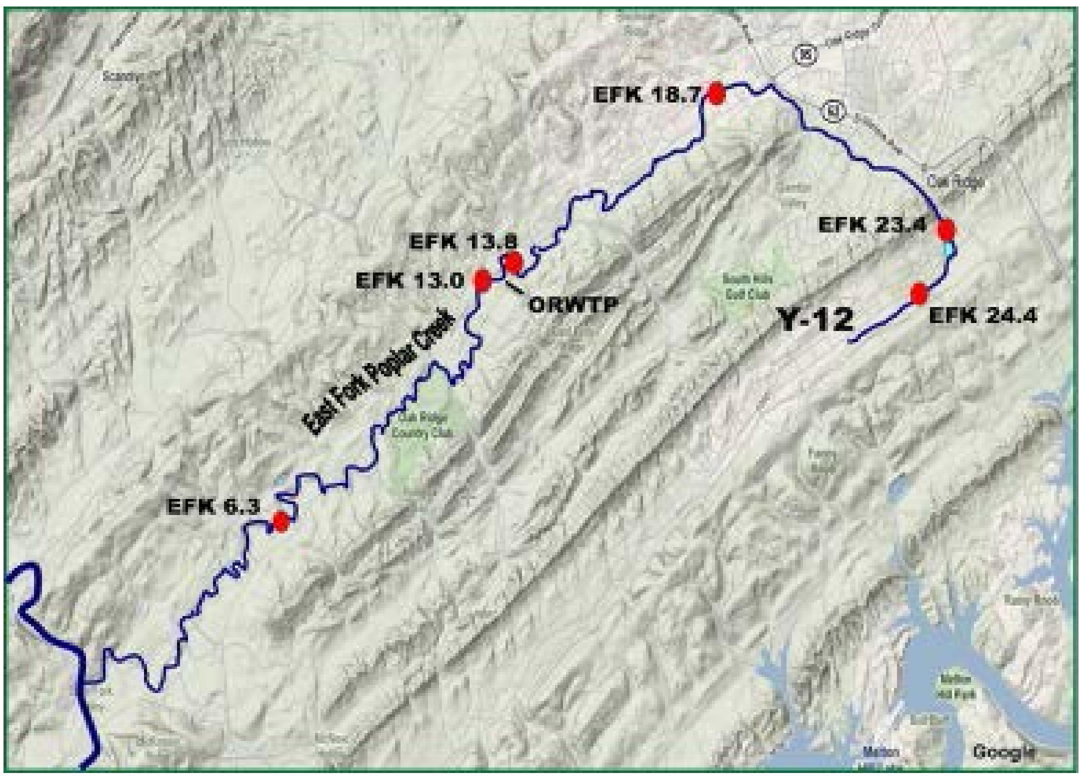
In July 2018, toxicity was observed in Outfall 200 effluent, and a toxicity identification/evaluation reduction (TIE/TRE) plan was conducted (Mathews et al. 2019). The observed toxicity in 2018 appears to be the result of a one-time flux of mercury that occurred during construction and demolition activities at the west end of Y-12. The final test from the TIE/TRE plan was conducted in February 2019, and no toxicity was observed (Table 4.18), which placed the chronic testing schedule back to an annual event.

Annual NPDES permit testing was conducted in July 2019 with effluent from Outfall 200 and Outfall 135. Effluent from Outfall 135 did not reduce fathead minnow (*Pimephales promelas*) survival or growth of water fleas (*Ceriodaphnia dubia*) survival or reproduction by 25 percent or more at any of the tested concentrations. For both species, the IC_{25} for survival, growth, or reproduction was greater than 36 percent (the highest concentration of this effluent that was tested) (Table 4.18). Effluent from Outfall 200 did not reduce fathead minnow (*Pimephales promelas*) survival or growth of water fleas (*Ceriodaphnia dubia*) survival or reproduction by 25 percent or more at any of the tested concentrations. For both species, the IC_{25} for survival, growth, or reproduction was greater than 100 percent (Table 4.18).

4.5.8 Biological Monitoring and Abatement Program

The NPDES permit issued for Y-12 mandates a Biological Monitoring and Abatement Program (BMAP), with the objective of demonstrating that the effluent limitations established for the facility protect the classified uses of the receiving stream, EFPC. The 2019 BMAP sampling efforts reported in this chapter follow the NPDES-required Y-12 BMAP Plan (Peterson et al. 2013). Y-12's BMAP, which has been monitoring the ecological health of EFPC since 1985, currently consists of three major tasks that reflect complementary approaches to evaluating the effects of Y-12 discharges on the aquatic integrity of EFPC. These tasks include: (1) bioaccumulation monitoring, (2) benthic macroinvertebrate community monitoring, and (3) fish community monitoring. Data collected on contaminant bioaccumulation and the composition and abundance of communities of aquatic organisms provide a direct evaluation of the effectiveness of abatement and remedial measures in improving ecological conditions in the stream.

Monitoring is currently being conducted at five primary EFPC sites, although sites may be excluded or added depending on the specific objectives of the various tasks. The primary sampling sites include Upper EFPC at EFPC kilometers (EFKs) 24.4 and 23.4 (upstream and downstream of Lake Reality, respectively); EFK 18.7 and EFK 18.2, located off-ORR and below an area of intensive commercial and light industrial development; EFK 13.8 and EFK 13.0, located upstream and downstream of the Oak Ridge Wastewater Treatment Facility, respectively; and EFK 6.3, located about 1.4 km downstream of the ORR boundary (Figure 4.21). Brushy Fork at Brushy Fork kilometer (BFK) 7.6 is used as a reference stream in two BMAP tasks. Additional sites off-ORR are also occasionally used for reference, including Beaver Creek, Bull Run, Cox Creek, Hinds Creek, Paint Rock Creek, and Emory River in the Watts Bar Reservoir (Figure 4.22).



Acronyms: EFK = East Fork Poplar Creek kilometer ORWTP = Oak Ridge Water Treatment Plant

Figure 4.21. Locations of biological monitoring sites on East Fork Poplar Creek in relation to Y-12 National Security Complex

Significant increases in the number of invertebrate and fish species in EFPC over the last three decades demonstrate that the overall ecological health of the stream continues to improve. However, the pace of improvement in Upper EFPC near Y-12 has slowed in recent years, and fish and invertebrate communities continue to have fewer species than the corresponding communities in reference streams.

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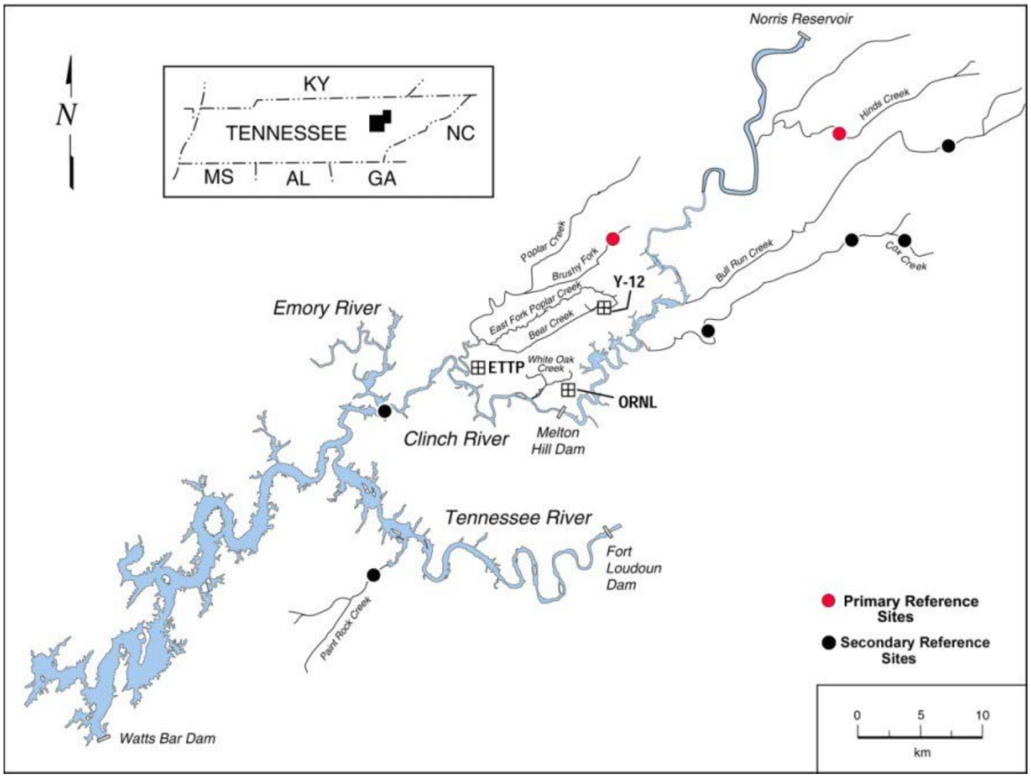


Acronyms:

ETTP = East Tennessee Technology Park
ORNL = Oak Ridge National Laboratory
Y-12 = Y-12 National Security Complex

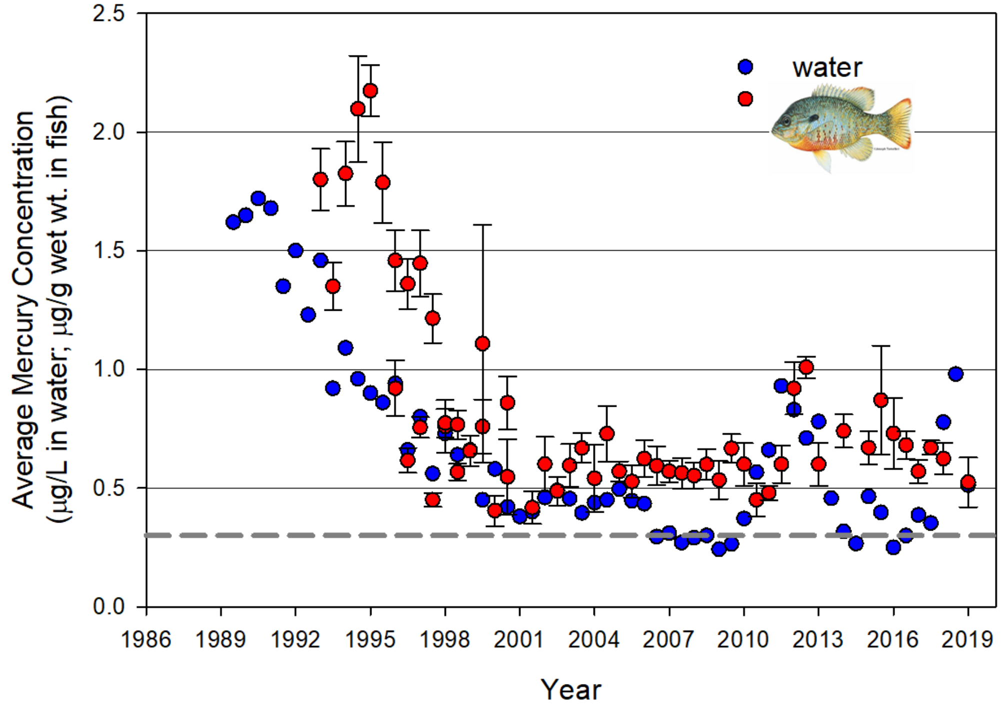
Figure 4.22. Locations of biological monitoring reference sites in relation to Y-12 National Security Complex

4.5.8.1 Bioaccumulation Studies

Historically, mercury and PCB levels in fish from EFPC have been elevated relative to fish in uncontaminated reference streams. Fish in EFPC are monitored regularly for mercury and PCBs to assess spatial and temporal trends in bioaccumulation associated with ongoing remedial activities and Y-12 operations.

As part of this monitoring effort, redbreast sunfish (Lepomis auritus) and rock bass (Ambloplites rupestris) are collected twice a year from five sites throughout the length of EFPC and are analyzed for tissue concentrations of mercury (twice yearly) and PCBs (annually) (Figure 4.23). Mercury concentrations remained higher in fish from EFPC in 2019 than in fish from reference streams. Elevated mercury concentrations in fish from the upper reach of EFPC indicate that Y-12 remains a continuing source of mercury to fish in the stream.

Figure 4.23 shows temporal trends for mercury concentrations in water collected from EFK 23.4 (Station 17) and in fish collected just upstream of this monitoring station at EFK 24.4. Water-borne mercury concentrations in the upper reach of EFPC have decreased substantially over the years in response to various remedial actions, first over the 1990s time period and then again in response to the Big Springs Treatment System in 2006. Although mercury concentrations in fish over time have not decreased commensurate with mercury levels in water in the lower sections of EFPC, mercury concentrations in fish at the uppermost sampling site (EFK 24.4) decreased steadily in the 1990s, consistent with decreased concentrations in water (Figure 4.23). Significant fluctuations in aqueous mercury concentrations (thought to be the result of storm drain relining and cleanout) have been seen at EFK 23.4 since 2009. Redbreast sunfish collected from the EFK 24.4 sampling site, about 1 km upstream of Station 17, appear to have responded to the recent peak and decline in aqueous mercury concentrations. Mean concentrations at EFK 24.4 increased from approximately 0.6 µg/g in 2011 to above 1 µg/g in 2012 and dropped back down in 2013 through 2018 (approximately 0.6 µg/g). In July 2018, aqueous mercury concentrations spiked as a result of a one-time flux of mercury that occurred during construction and demolition activities at the west end of Y-12. The elevated mercury concentrations were associated with toxicity (Section 4.5.7) and a fish kill (Mathews et al. 2019) such that no fish were available for collection at the EFK 24.4 site in fall 2018. The fish that were collected in spring 2019 were generally smaller than those routinely encountered, and mercury concentrations in these fish were slightly lower than in 2018, averaging 0.52 µg/g. These concentrations are above the EPA-recommended ambient water quality criterion for mercury (0.3 µg/g mercury as methylmercury in fish fillet).

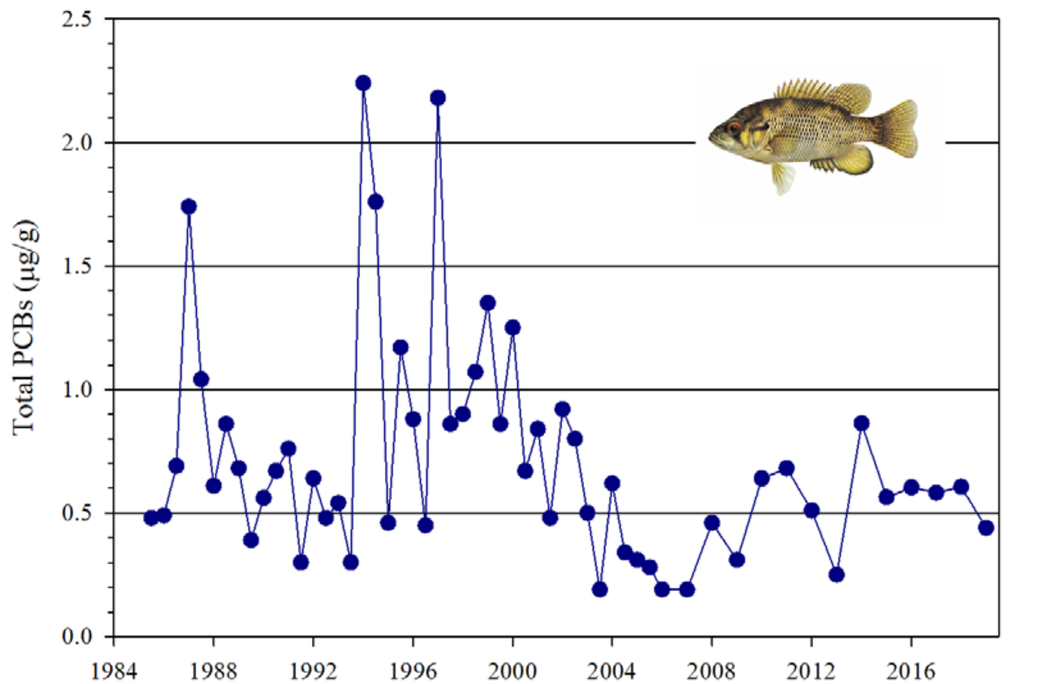


Dashed grey line represents the ambient water quality criterion for methylmercury in fish fillets (0.3 µg/g)

Figure 4.23. Semiannual average mercury concentration in muscle fillets of redbreast sunfish and water from East Fork Poplar Creek at East Fork Poplar Creek kilometer 23.4 (water) and East Fork Poplar Creek kilometer 24.4 (fish), Fiscal Year 2019

The observation that this species appears to have responded to changes in water mercury concentrations in the upper reaches of the creek is interesting, given it has not responded to decreases in aqueous total mercury concentrations at downstream sites throughout EFPC in the past 20 years. The relationship between aqueous total mercury concentrations and fish tissue concentrations is complex. Aqueous mercury concentrations vary by orders of magnitude throughout the various watersheds across ORR, but fish tissue concentrations tend not to vary greatly (twofold to threefold). Multiple ongoing investigations are being conducted to better understand mercury bioaccumulation dynamics in EFPC and to better predict how remedial changes may impact mercury concentrations in fish in the future.

The mean total PCB concentration in sunfish fillets at EFK 23.4 was 0.44 µg/g in FY 2019, slightly lower than concentrations seen FY 2018 (0.61 µg/g) (Figure 4.24). Regulatory guidance and human health risk levels have varied widely for PCBs, depending on the regulatory program and the assumptions used in the risk analysis. The Tennessee water quality criteria for individual aroclors and total PCBs are both 0.00064 µg/L under the recreation designated-use classification and are the targets for PCB-focused total maximum daily loads, including for local reservoirs (Melton Hill, Watts Bar, and Fort Loudoun; TDEC 2010a, 2010b, 2010c).



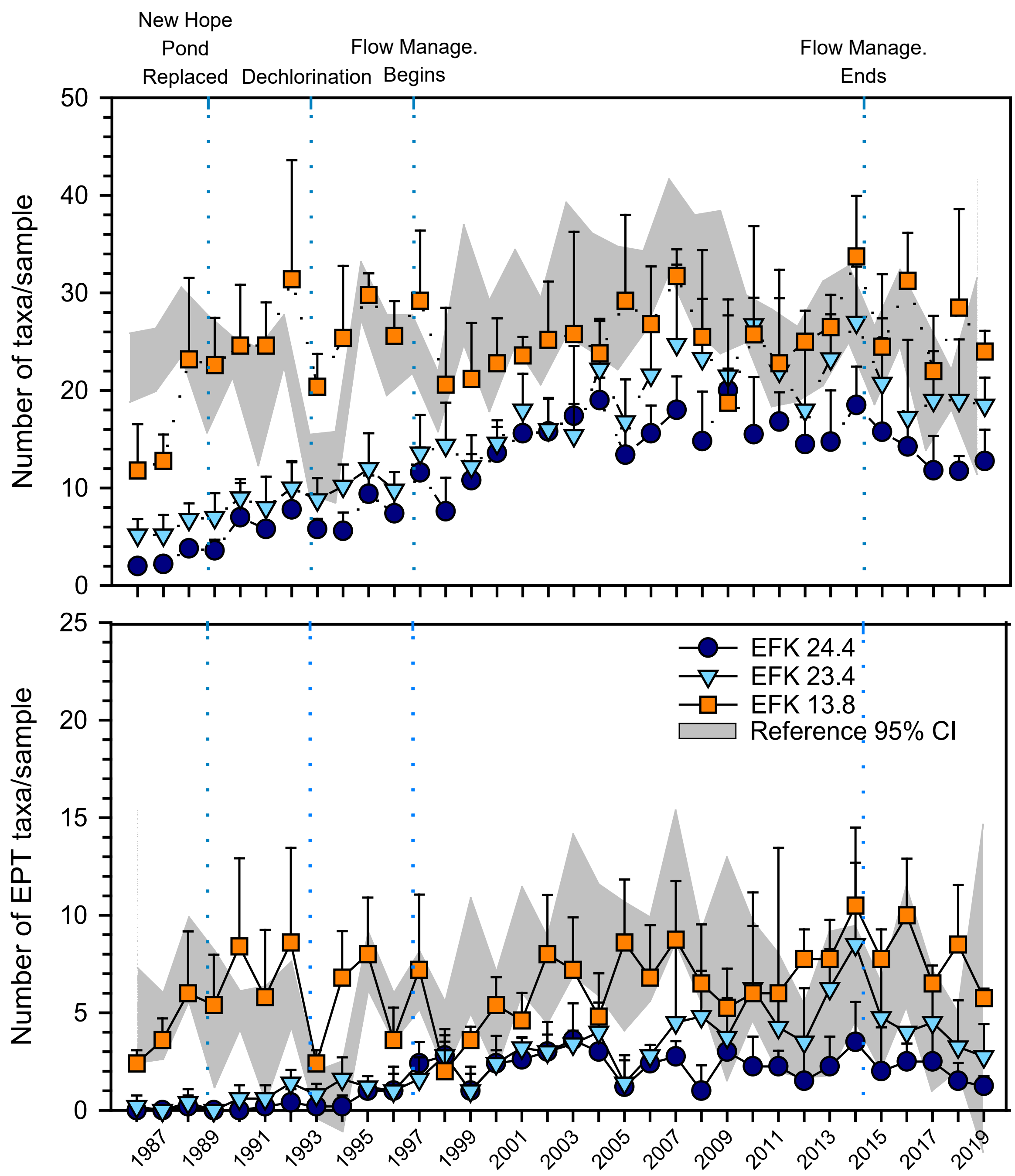
Acronym: PCB = polychlorinated biphenyl

Figure 4.24. Annual mean concentrations of polychlorinated biphenyls in rock bass muscle fillets at East Fork Poplar Creek kilometer 23.4, Fiscal Year 2019

In the state of Tennessee, assessments of impairment for water body segments, as well as public fishing advisories, are based on fish tissue concentrations. Historically, the U.S. Food and Drug Administration threshold limit of 2-µg/g PCBs in fish fillets was used for advisories, and then for many years, an approximate range of 0.8 to 1 µg/g was used, depending on the data available and factors such as the fish species and size. The remediation goal for fish fillets at ETTP K-1007-P1 pond on ORR is 1-µg/g PCBs. Most recently, the water quality criterion has been used to calculate the fish tissue concentration triggering impairment and a total maximum daily load (TDEC 2007). This concentration is 0.02 µg/g PCBs in fish fillets (TDEC 2010a, 2010b, 2010c). The mean fish PCB concentration in Upper EFPC, 0.60 µg/g in fish fillets, is well above this concentration.

4.5.8.2 Benthic Invertebrate Surveys

Monitoring of the benthic macroinvertebrate community continued in the spring of 2019 at three sites in EFPC and at two reference streams (Brushy Fork and Hinds Creek). There have been long-term changes in the macroinvertebrate community at EFPC sites since the start of monitoring (1986) (Figure 4.25).



NOTE: (top) total taxonomic richness (mean number of taxa per sample plus 95 percent confidence interval), and (bottom) taxonomic richness of the pollution-intolerant taxa, Ephemeroptera, Plecoptera, and Trichoptera (mean number of Ephemeroptera, Plecoptera, and Trichoptera taxa per sample plus 95 percent confidence interval), April, 1986–2019. The timing of various activities within the watershed is shown in vertical blue lines.

Acronym: EFK = East Fork Poplar Creek kilometer; EPT = Ephemeroptera, Plecoptera, and Trichoptera

Figure 4.25. Benthic macroinvertebrate communities in three sites along East Fork Poplar Creek and the 95 percent confidence interval for two nearby reference streams (Brushy Fork and Hinds Creek)

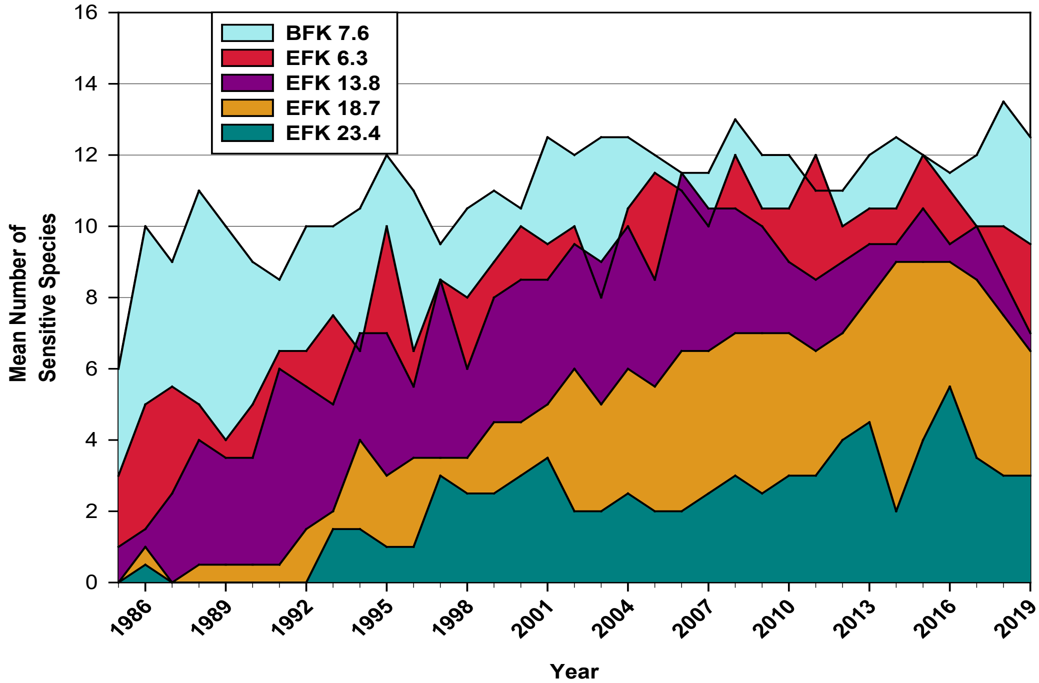
Total taxa richness (number of taxa/sample) increased at EFK 24.4 from 1986 until the mid 2000s, and then remained steady for approximately 14 years (Figure 4.25). After flow management ended in 2014, total taxa richness decreased at EFK 24.4 and has remained at these lower values since that time. Total taxa richness at EFK 23.4 steadily increased since monitoring began, and values also decreased after flow management ceased (Figure 4.25). Total taxa richness at EFK 13.8 and the reference sites have been fairly consistent over the entire monitoring period, except for lower total taxa richness values during the first two monitoring years at EFK 13.8 (Figure 4.25). Total taxa richness at EFK 24.4 has consistently been lower than reference sites throughout the monitoring period, while total taxa richness at EFK 13.8 has almost always been within or above the 95-percent confidence interval (CI) of reference site values (Figure 4.25). Total taxa richness at EFK 23.4 was lower than the 95-percent CI of the reference sites from 1986 to 2009 but since then, richness has mostly been within the 95-percent CI of the reference sites (Figure 4.25).

Temporal patterns in the number of pollution-intolerant taxa (Ephemeroptera, Plecoptera, and Trichoptera [EPT] taxa richness) were similar to those observed for total taxa richness (Figure 4.25). EPT taxa richness at EFK 24.4 was very low (less than 1 EPT taxa/sample) from 1986 until 1994 (Figure 4.25). EPT taxa richness then increased slightly (greater than 1 but less than 5 taxa/sample) until 2014. EPT taxa richness has been slightly lower since 2014 compared to values in previous years (Figure 4.25). EPT richness at EFK 23.4 has steadily increased since 1986, but decreased after flow management ended (Figure 4.25). EPT taxa richness at EFKs 24.4 and 23.4 have typically been lower than the 95-percent CI of EPT taxa richness at reference streams, indicative of degraded conditions. However, EPT taxa richness at EFK 23.4 has been within the lower bounds of the 95-percent CI of reference streams within the past decade, suggesting some improvement in site conditions. The number of pollution-intolerant taxa at EFK 13.8 has continued to exceed the upper bound of the reference site confidence limits since 2012 (except for the most recent year; 2019) (Figure 4.25).

The implications of ending flow management in 2014 on invertebrate communities in EFPC are still uncertain. After flow augmentation ceased, EPT taxa richness at EFK 23.4 has consistently declined (Figure 4.25). EPT taxa richness at EFK 24.4 has also shown a slight decrease since flow augmentation ended; a more substantial decrease was observed in total taxa richness (Figure 4.25). The effects of ending flow augmentation on Lower EFPC (EFK 13.8) do not seem as evident, which makes intuitive sense as flow augmentation contributed a smaller percentage of total discharge at downstream sites. The long-term effects on the invertebrate community of ending flow management in EFPC will become more evident as conditions stabilize and additional data become available.

4.5.8.3 Fish Community Monitoring

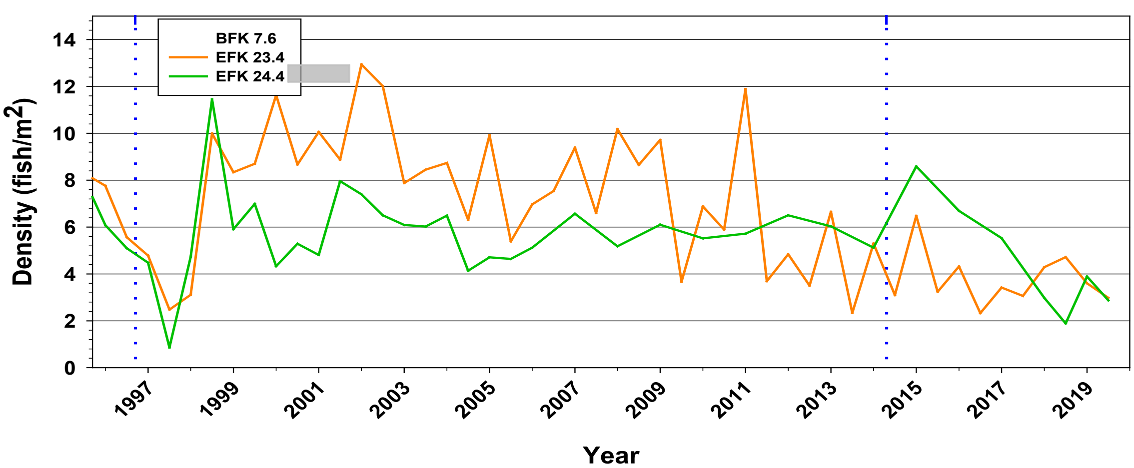
Fish communities were monitored in the spring and fall of 2019 at six sites along EFPC and at a comparable local reference stream (Brushy Fork). In the past three decades, overall species richness, density, biomass, and number of pollution-sensitive fish species improved at all sampling locations below Lake Reality. Some seasonal conditions, such as flooding and drought, can cause minor fluctuations in values but rarely cause long-term impacts on larger systems such as EFPC. However, some species of fish are considered sensitive and require very specific habitat conditions to survive and can only tolerate a narrow range of environmental disturbance. The mean number of sensitive species at four sites in EFPC and the reference stream is shown in Figure 4.26, dramatically highlighting major improvements in the fish community in the middle to lower sections (EFK 6.3 and EFK 13.8) of the stream. However, the EFPC fish community continues to lag behind the reference stream community (BFK 7.6) in the most important metrics of fish diversity and community structure, especially at the monitoring sites closest to Y-12 (EFK 23.4 and EFK 24.4).



Acronyms: BFK = Brushy Fork kilometer EFK = East Fork Poplar Creek kilometer

Figure 4.26. Comparison of mean sensitive species richness (number of species) collected each year (1985–2019) from four sites in East Fork Poplar Creek and a reference site (Brushy Fork)

Fish communities in Upper EFPC in 2019 continued to experience some fluctuation in density. Reduced stream flows associated with the termination of flow augmentation from Melton Hill in April 2014 and the extreme drought in 2016 are likely factors driving the decrease in fish densities in these upper sites (Figure 4.27). Despite this, the fish diversity remained relatively consistent. Very high densities are not always a positive indicator of fish health, and the most abundant species within these sites continue to be those that are considered tolerant. Continued monitoring will provide additional insight into these variabilities.



Acronyms: BFK = Brushy Fork kilometer EFK = East Fork Poplar Creek kilometer
The interval of time between the dashed lines represents the period of flow management in East Fork Poplar Creek.

Figure 4.27. Fish density (number of fish per square meter) for two sites in Upper East Fork Poplar Creek and a reference site (Brushy Fork), 1996–2019

The fish communities in Upper EFPC were impacted in 2019 by one incident that resulted in a fish kill. On October 14, 2019, a chlorine spike at Outfall 200 occurred and seven dead fish were collected just downstream. No further fish kills occurred in 2019.

A larger fish kill incident in 2018 resulted in the need for additional monitoring of the communities in Upper EFPC. Fish community surveys were conducted in fall (August) 2018 and again in spring and fall of 2019 to assess the potential impact of the fish kill and current status of the communities. These surveys initially indicated that the fish community in Upper EFPC (EFK 25.1 and EFK 24.4) was considerably lower than in spring 2018. However, spring 2019 samples were within the expected variability of this community as observed since flow augmentation was turned off in 2014. There is little evidence that either of these events will have long-term impacts on the community. Future monitoring of these sites will provide additional insight into the condition of these fish communities and any unforeseen impacts.

4.5.8.4 Upper Bear Creek Remediation

As part of the construction of the UPF inside Y-12, a haul road was constructed in 2013 and 2014, and several wetlands were lost or negatively affected. This resulted in the need for mitigation, including the creation and expansion of wetlands in the Bear Creek watershed. All wetland mitigation sites were constructed during the haul road expansion except one, which will be completed in the future. Wetland soils available after road construction, with their associated wetland plant seed banks, were used to support the establishment of hydric soils and wetland plant species in the mitigation areas. In all, 3.51 acres of wetlands will be constructed to compensate for the removal of 1 acre. The compensation ratios are intended to ensure that there is no net loss of wetland resource value.

As part of haul road construction, it was also necessary to culvert two sections of north tributary streams to Bear Creek. To mitigate the loss of natural streams, a previously impacted section of Bear Creek was identified for restoration to more natural conditions. Approximately 300 ft of upper Bear Creek was remediated in 2014 by diverting the stream out of a channelized section and back into its original channel. This remediated section was lined extensively with erosion matting along both banks, and various-size river rocks were added to the channel to create pool/riffle complexes throughout the site. The natural meander of the channel was kept, and only slight modifications were made. All disturbed soils were seeded, and native plants were added to the site to stabilize sediments and to re-establish the stream's riparian zone following the construction.

The five remediated wetlands had the hydrologic, vegetative, and soil characteristics to be considered wetlands in 2019. The wetlands have responded as intended, only requiring minimal alterations in two of the wetlands. Data from Wetlands 1 and 7 had been showing a trend of decreasing plant coverage as water levels increased. To remedy this, 1500 plants representing a dozen species were planted into Wetlands 1 and 7 in 2019. In addition, a clogged gabion structure was removed from Wetland 1, and a temporary pond leveler was placed in the beaver dam in Wetland 7. These actions successfully lowered water levels by approximately 2 ft, helping the new planting survive and allowing for natural revegetation in the wetlands.

The monitoring conducted in 2019 marks the end of wetland monitoring for this project. One wetland remains to be created in the future. Overall, the wetland mitigation sites are successful and have shown remarkable increases in wetland plant coverage and diversity over the years. The stream remediation site in upper Bear Creek appears to be a remediation success story. After some initial issues with drainage in the new channel, the old channel was backfilled to prevent this issue, and now flows appear to be much more stable. Native flora is abundant in the area adjacent to the stream. The fish and aquatic invertebrate communities in the remediated section of Bear Creek were slightly impacted by the drought in summer 2016, but the fish community appears to be recovering in the following years' samples.

4.6 Groundwater at the Y-12 National Security Complex

Groundwater monitoring is performed to comply with federal, state, and local requirements and to determine the environmental impact from legacy and current operations. There are 160 known or potential sources of contamination identified in the FFA for the Y-12 National Security Complex (DOE 2020a). Groundwater monitoring provides information on the nature and extent of contamination, which is used to identify actions needed to protect the worker, the public, and the environment. Figure 4.28 depicts the major areas for which groundwater monitoring is performed.

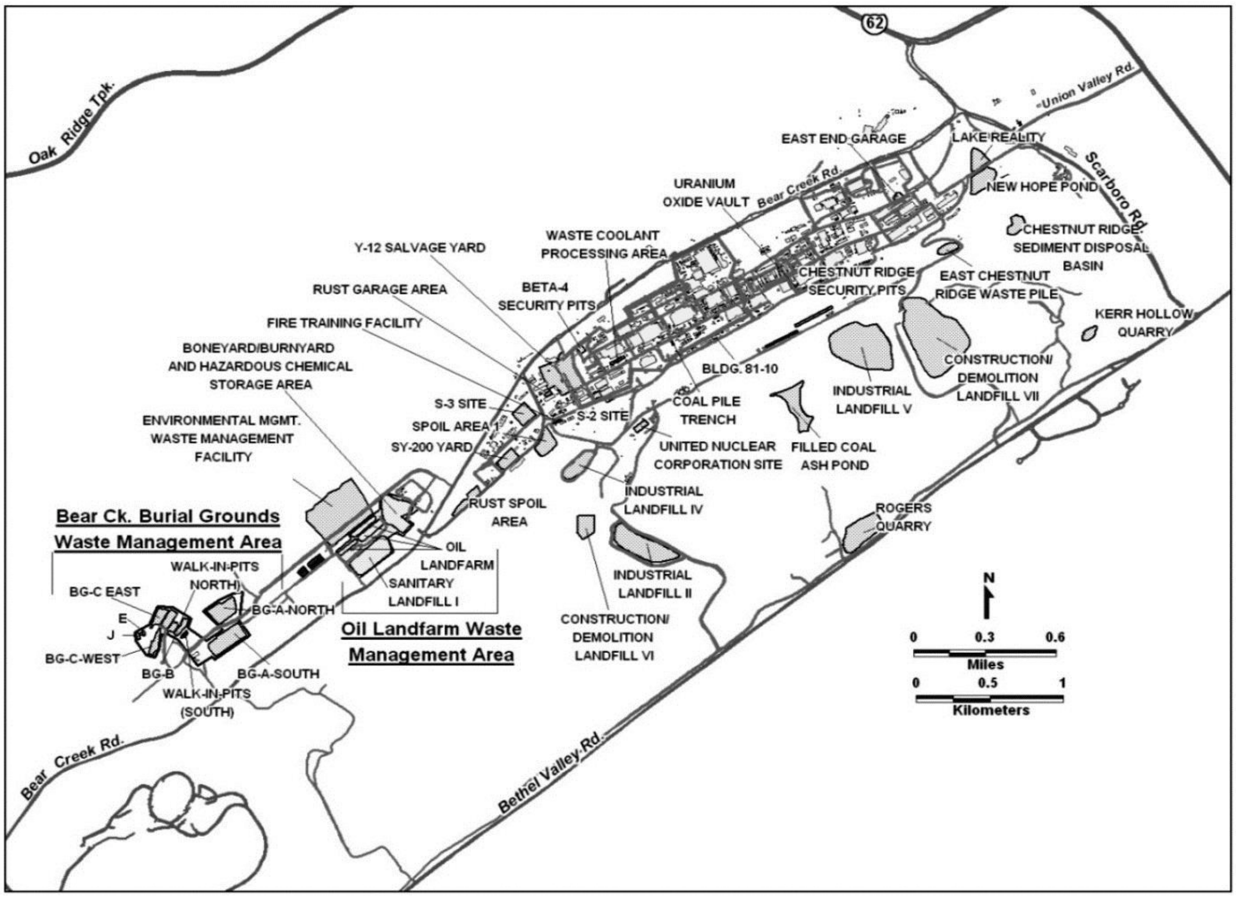
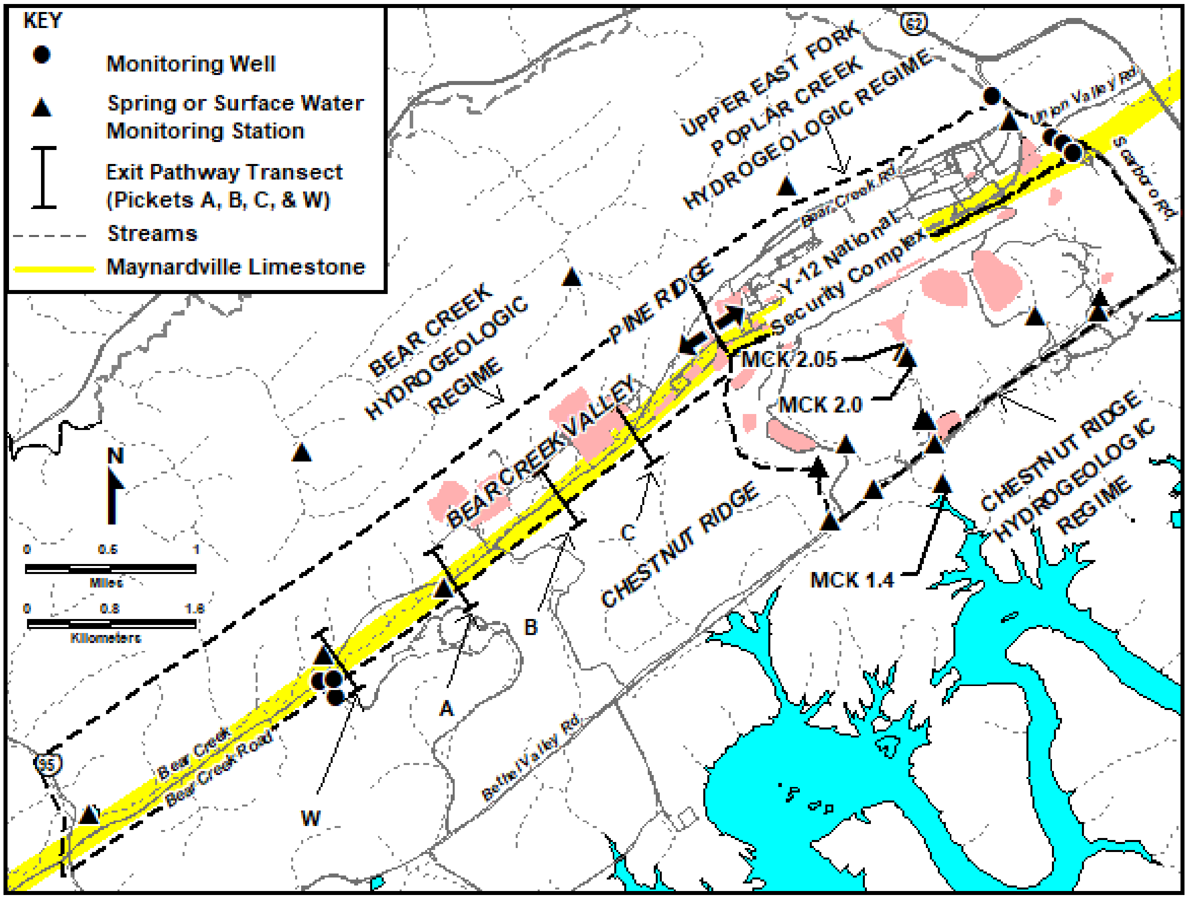


Figure 4.28. Known or potential contaminant sources for which groundwater monitoring is performed at the Y-12 National Security Complex

4.6.1 Hydrogeologic Setting

Y-12 is divided into three hydrogeologic regimes (Bear Creek, Upper EFPC, and Chestnut Ridge) (Figure 4.29). Most of the Bear Creek and Upper EFPC regimes are underlain by shale, siltstone, and sandstone bedrock, which act as an aquitard. An aquitard can contain water but does not readily yield that water to pumping wells. However, the southern portion of the Bear Creek and Upper EFPC regimes is underlain by the Maynardville Limestone, which is part of the Knox aquifer. (An aquifer more readily yields water to pumping wells.) The Chestnut Ridge regime is almost entirely underlain by the Knox aquifer.



Acronyms: MCK = McCoy Branch kilometer

Figure 4.29. Hydrogeologic regimes; flow directions; and perimeter/exit pathway wells, springs, and surface water monitoring stations, and the position of the Maynardville Limestone in Bear Creek Valley at the Y-12 National Security Complex

In general, groundwater flow in the water table interval follows the topography; therefore, it flows off areas of higher elevation into the valleys and then flows parallel to the valley, along geologic strike (Figure 4.30). Shallow flow in the Bear Creek and Upper EFPC regimes is divergent from a topographic and groundwater divide located near the western end of Y-12. In the Chestnut Ridge regime, a groundwater divide nearly coincides with the crest of the ridge. On Chestnut Ridge, shallow groundwater flow tends to be toward either flank of the ridge, with discharge primarily to surface streams and springs in Bethel Valley to the south and Bear Creek Valley to the north. The groundwater sampling technician shown in Figure 4.31 is taking water quality samples from a well on the northern flank of Chestnut Ridge with the heart of the Y-12 industrial plant in Bear Creek Valley in the background below and the crest of Pine Ridge at the top of the photograph. (View direction is to the northwest.)

In Bear Creek Valley, groundwater in the intermediate and deep intervals moves through fractures in the aquitard, converging on and then moving through fractures and solution conduits in the Maynardville Limestone (Figure 4.29). Karst development in the Maynardville Limestone has a significant impact on groundwater flow paths in the water table and intermediate intervals. Groundwater flow rates in Bear Creek Valley vary; they are slow within the deep interval of the fractured non-carbonate rock (less than 10 ft/year) but can be quite rapid within solution conduits in the Maynardville Limestone (10 to 5,000 ft/day).

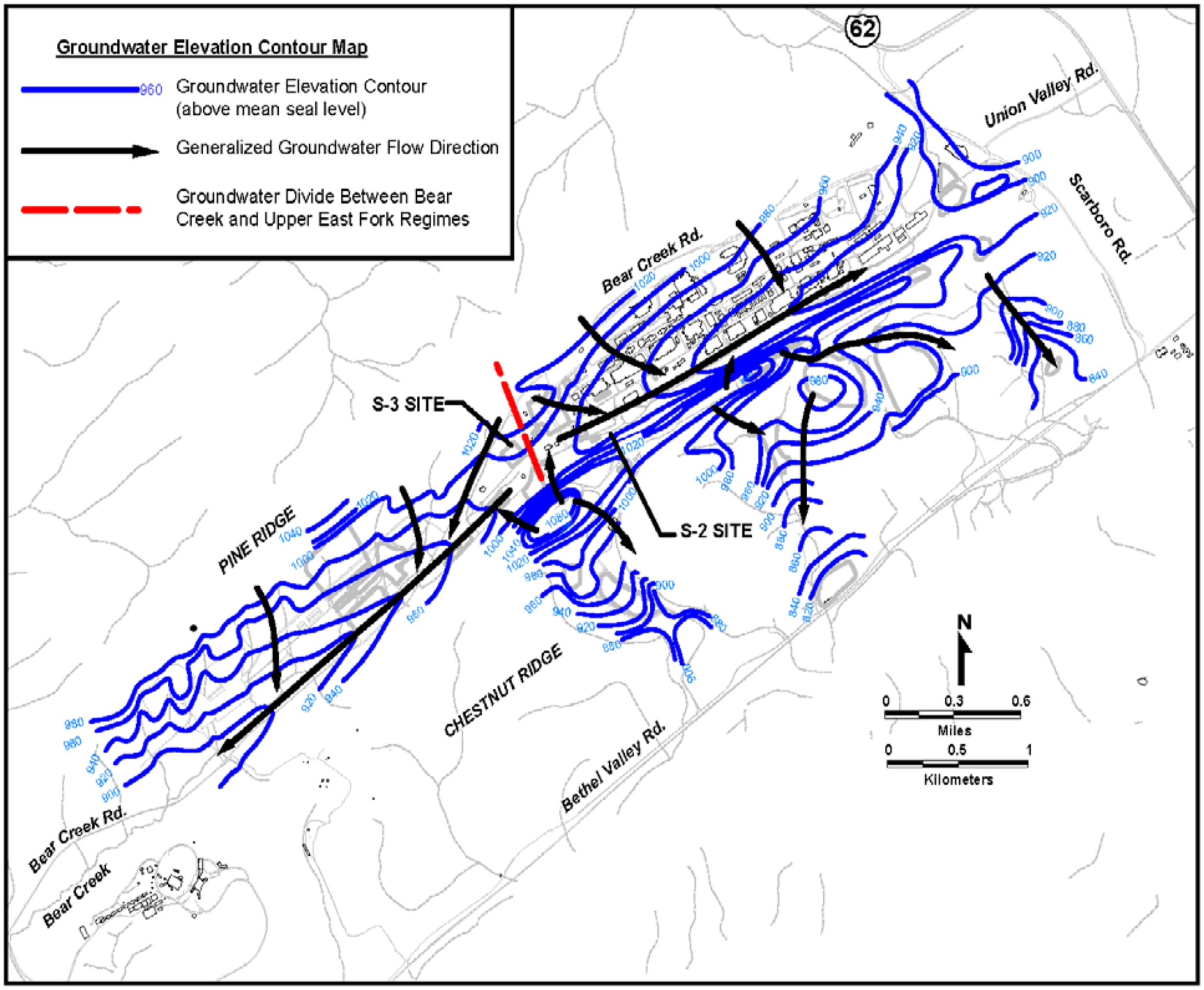


Figure 4.30. Groundwater elevation contours and flow directions at the Y-12 National Security Complex

Contaminants are transported along with flowing groundwater through the pore spaces, fractures, or solution conduits of the hydrogeologic system. Strike-parallel transport of some contaminants can even occur within the aquitard units for significant distances, where they discharge to surface water tributaries or underground utility and storm water distribution systems in Y-12's industrial area. For example, elevated levels of nitrate (a contaminant from legacy waste disposals) within the fractured bedrock of the aquitard are known to extend east and west from the S-2 and S-3 sites for thousands of feet. VOC contamination from multiple sources is observed in both the Bear Creek and Upper EFPC regimes, and to a lesser extent in the Chestnut Ridge regime. VOCs (e.g., petroleum products, coolants, and solvents) in groundwater within the-fractured bedrock of the aquitard units can remain close to source areas because they tend to adsorb to the bedrock matrix, diffuse into pore spaces within the matrix, and degrade before migrating to exit pathways, where more rapid transport occurs for longer distances.

Groundwater flow in the Chestnut Ridge regime is through fractures and solution conduits in the Knox Group aquifer. Discharge points for intermediate and deep flow are not well known. However, following the crest of the Chestnut Ridge, water table elevations decrease from west to east, demonstrating an overall easterly trend in groundwater flow.

4.6.2 Well Installation and Plugging and Abandonment Activities

No wells were installed and no wells were plugged and abandoned in CY 2019.

4.6.3 Calendar Year 2019 Groundwater Monitoring

Groundwater monitoring in CY 2019 was performed as part of Y-12's GWPP, DOE EM programs such as the Water Resources Restoration Program, and other projects. Compliance requirements were met by monitoring 183 wells and 50 surface water locations and springs (Table 4.19). (Locations sampled for research projects [not compliance requirements] are shown in column D of Table 4.19 and are not included in the totals in the previous sentence.) Specific wells of interest based on the CY 2019 data are called out later in this section. However, Figure 4.29 shows the locations of perimeter/exit pathway stations that are monitored closely because they are the locations closest to the reservation boundaries.

Water quality results of groundwater monitoring activities in CY 2019 are presented in the *Calendar Year 2019 Groundwater Monitoring Report* (CNS 2020).

Monitoring efforts performed specifically for CERCLA baseline and remediation evaluation are published in the FY 2019 and FY 2020 Water Resources Restoration Program Sampling and Analysis Plans (UCOR 2018, 2019, respectively) and the Annual CERCLA Remediation Effectiveness Reports (DOE 2019, 2020b).

Source: Kathryn Fahey, Y-12 National Security Complex photographer

Figure 4.31. Groundwater monitoring well sampling at the Y-12 National Security Complex

Table 4.19. Summary of groundwater monitoring at the Y-12 National Security Complex, 2019

	Purpose for which monitoring was performed				
	Restoration[a]	Waste management[b]	Surveillance[c]	Other[d]	Total
Number of active wells	50	33	100	36	219
Number of other monitoring stations (e.g., springs, seeps, and surface water)	29	6	15	3	53
Number of samples taken[e]	166	116	122	9,044	9,448
Number of analyses performed	8,348	8,845	10,017	70,005	97,215
Percentage of analyses that are non- detects	65.5	84.8	81.4	16.6	33.7
Ranges of results for positive detections, VOCs (µg/L)[f]					
Chloroethenes	0.19-2,600	0.39-17.6	1–37,000	NA	
Chloroethanes	0.22–250	0.71-81.7	1–1,500	NA	
Chloromethanes	0.3–1,500	ND	1–660	NA	
Petroleum hydrocarbons	0.35–4,700	ND	1–840	NA	
Uranium (mg/L)	0.00011–0.51	0.000101–0.0371	0.000513–0.226	0.00261–2323.5	
		0.00392	0.397	1.71555	
Nitrates (mg/L)	0.0043–470	0.783–1.4	0.0502–10,200	3.81–119.1	
Ranges of results for positive detections, radiological parameters (pCi/L)[g]					
Gross-alpha activity	2.87–302	1.15–5.77	5.1–86	NA	
Gross-beta activity	3.13–44.8	2.68–14.1	11-780	NA	

[a] Monitoring to comply with Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requirements and with Resource Conservation and Recovery Act (RCRA) post-closure detection and corrective action monitoring.
[b] Solid waste landfill detection monitoring and CERCLA landfill detection monitoring.
[c] US Department of Energy (DOE) Order surveillance monitoring.
[d] Research-related groundwater monitoring associated with activities of the DOE Oak Ridge Field Research Center and Ecosystems and Networks Integrated with Genes and Molecular Assemblies.
[e] The number of unfiltered samples, excluding duplicates, determined for unique location/date combinations.
[f] These ranges reflect concentrations of individual contaminants (not summed VOC concentrations):
Chloroethenes—includes tetrachloroethene; trichloroethene; 1,2-dichloroethene (cis- and trans-); 1,1-dichloroethene; and vinyl chloride.
Chloroethanes—includes 1,1,1-trichloroethane; 1,2-dichloroethane; and 1,1-dichloroethane.
Chloromethanes—includes carbon tetrachloride, chloroform, and methylene chloride.
Petroleum hydrocarbon—includes benzene, toluene, ethylbenzene, and xylene.
[g] pCi = 3.7×10^{-2} Bq

Acronyms:
Bq = becquerel
NA = not analyzed
ND = not detected
pCi/L = picocuries per liter
VOC = volatile organic compound

4.6.4 Y-12 National Security Complex Groundwater Quality

Historical monitoring shows that four primary contaminants adversely affect groundwater quality at Y-12: nitrate, VOCs, metals, and radionuclides. Of those, VOCs are the most widespread. Uranium and technetium-99 (^{99}Tc) are the radionuclides of greatest concern. Trace metals (e.g., arsenic, barium, cadmium, chromium, and mercury), the least extensive groundwater contaminants, generally occur close to source areas because of their high adsorption characteristics. Data show that plumes from multiple-source units have mixed with one another and that contaminants are not always easily associated with a single source.

4.6.4.1 Upper East Fork Poplar Creek Hydrogeologic Regime

Among the three hydrogeologic regimes, the Upper EFPC regime contains most of the known and potential sources of contamination. (Summary descriptions of waste management sites shown on Figure 4.28 were provided in previous year ASERs (e.g., for CY17 and before) and are not repeated this year.) Contaminants from the S-3 site (nitrate and ^{99}Tc) and VOCs from multiple source areas are observed in the groundwater in the western portion of the Upper EFPC regime; whereas, groundwater in the eastern portion of the regime is predominantly contaminated with VOCs.

Plume Delineation

Sources of contaminants monitored during CY 2019 include the S-2 site, the Fire Training Facility, the S-3 site, the Waste Coolant Processing Facility, former petroleum UST sites, New Hope Pond, the Beta-4 Security Pits, the Salvage Yard, and process/production buildings throughout Y-12. The S-3 site is located near the hydrologic divide that separates the Upper EFPC regime from the Bear Creek regime, and the site has contributed to groundwater contamination to both regimes. Contaminant plumes in both regimes (shown in gray shading on Figures 4.32 through 4.35) are elongated as a result of preferential transport of the contaminants parallel to strike (parallel to the valley axis) in both the Knox aquifer and the fractured bedrock of the aquitard.

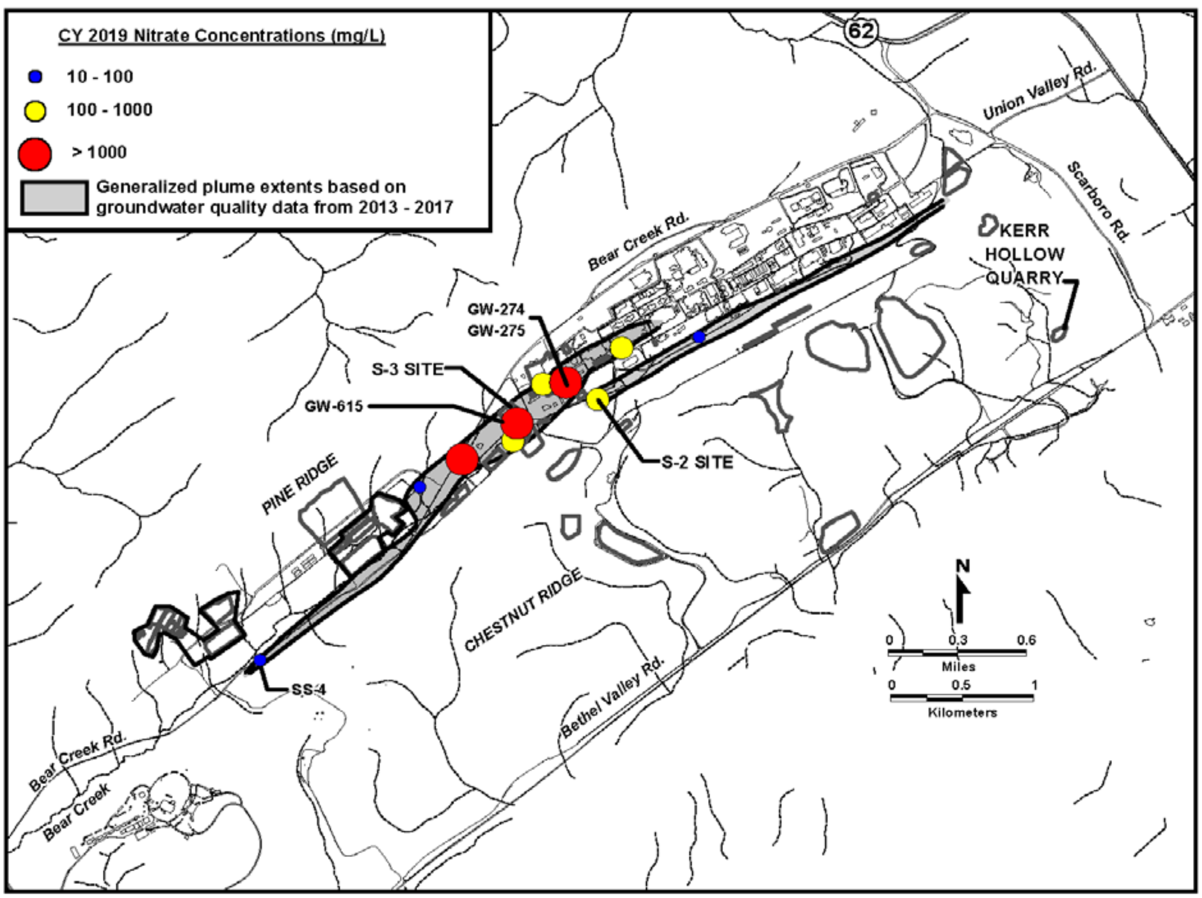
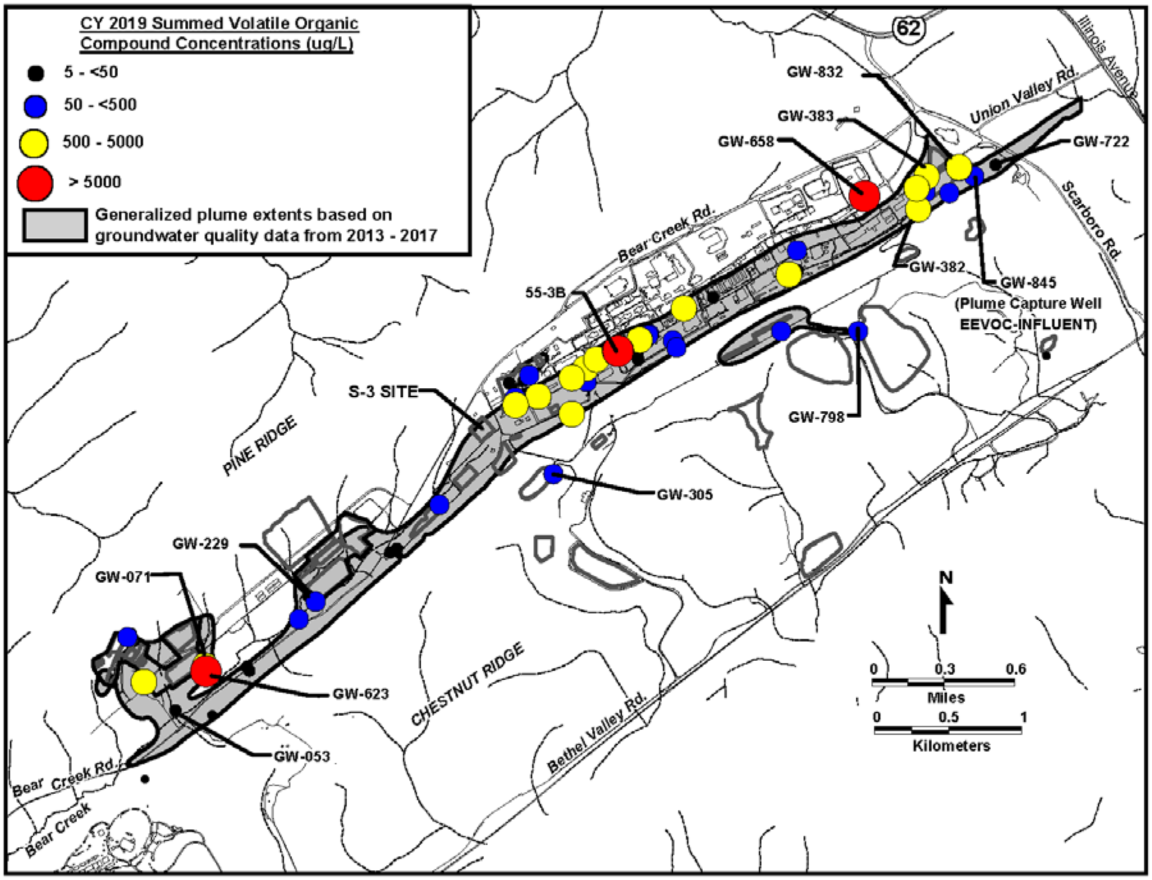


Figure 4.32. Nitrate in groundwater at the Y-12 National Security Complex, 2019

The plumes depicted (gray shading) reflect the average concentrations and radioactivity in groundwater between CYs 2013 and 2017. The circular icons presented on the plume maps (Figures 4.32 through 4.35) represent CY 2019 monitoring results for the Upper EFPC regime (discussed in this section), the Bear Creek regime (discussed in Section 4.6.4.2), and the Chestnut Ridge regime (discussed in Section 4.6.4.2).



Acronym: EEVOC = east end volatile organic compound

Figure 4.33. Summed volatile organic compounds in groundwater at the Y-12 National Security Complex, 2019

Nitrate

Nitrate is highly soluble and moves easily with groundwater. In the central and western portions of Upper EFPC, nitrate concentrations exceed the 10-mg/L drinking water standard. (A list of the national drinking water standards is presented in Appendix C.) The two primary sources of nitrate contamination are the S-2 and S-3 sites. In CY 2019, there was a maximum nitrate concentration of 9,200 mg/L in well GW-275. This well, which also showed the maximum concentration in CY 2018 (9,250 mg/L), is located about 396 m (1,300 ft) east of the S-3 site and is screened in the shallow-intermediate bedrock interval about 20 m (65 ft) below ground surface (Figure 4.32). The next highest nitrate concentration was found in GW-274 at 535 mg/L. This well is near GW-275, but is screened at 31 ft bgs. The complex nature of the subsurface in Bear Creek Valley is represented by the fact that over the last two decades the deeper well (GW-275) has shown an increasing trend (from ~7,000 mg/L to ~9,000 mg/L), while the nearby shallow well (GW-274) has a decreasing trend (from ~5,500 mg/L to ~500 mg/L).

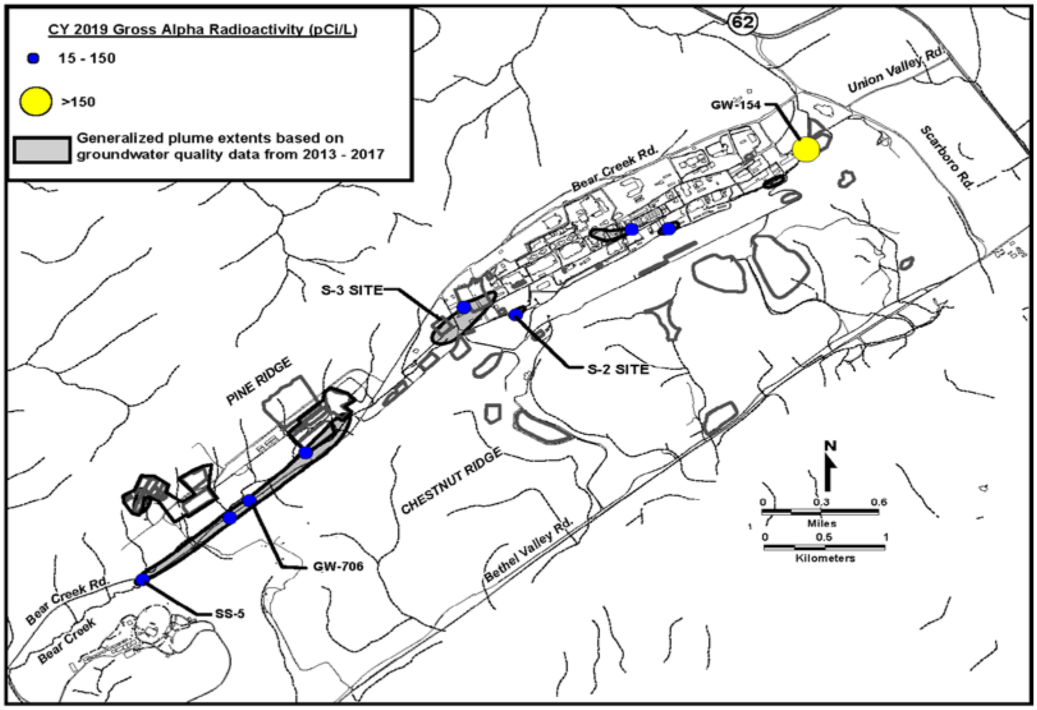


Figure 4.34. Gross-alpha activity in groundwater at the Y-12 National Security Complex, 2019

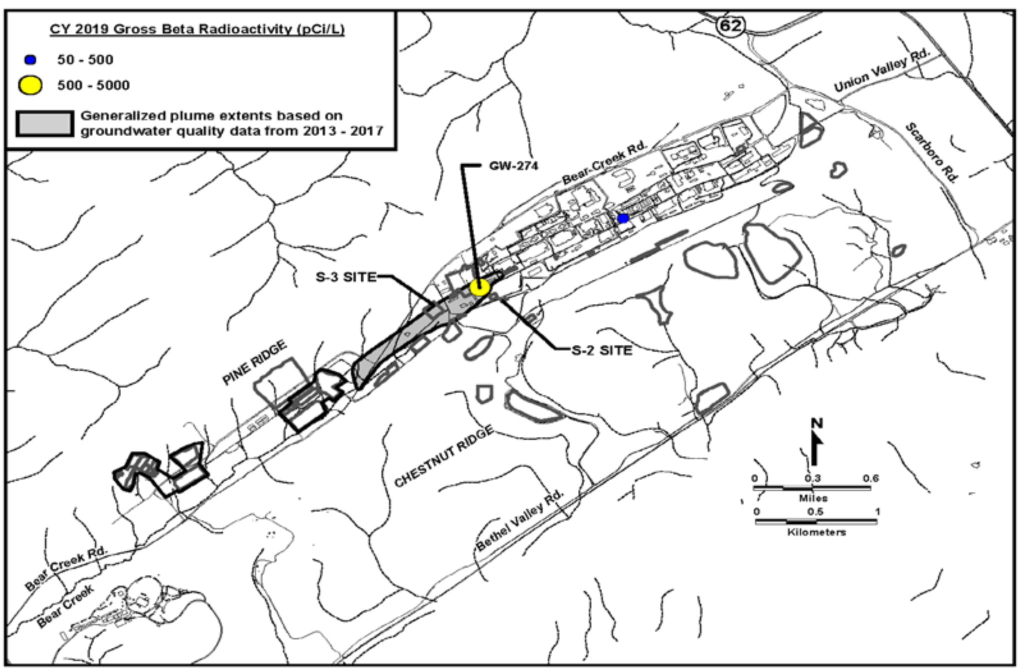


Figure 4.35. Gross-beta activity in groundwater at the Y-12 National Security Complex, 2019

Trace Metals

In CY 2019, antimony, barium, beryllium, cadmium, chromium, copper, nickel, thallium, and uranium exceeded primary drinking water standards in groundwater samples across the Upper EFPC regime, but for uranium predominately at and downgradient of the S-2, S-3, and NHP sites. Trace metal concentrations above standards tend to occur adjacent to source areas because of their low solubility and high adsorption to the clay-rich soils and bedrock.

Volatile Organic Compounds (VOCs)

VOCs are the most widespread contaminants in the Upper EFPC regime. VOC contaminants in the regime primarily consist of chlorinated and petroleum hydrocarbons. In CY 2019, the highest summed concentration of dissolved chlorinated hydrocarbons (44,103 µg/L) was again found at well 55-3B in the western portion of Y-12, adjacent to currently inactive manufacturing facilities. The highest dissolved concentration of petroleum hydrocarbons (11,360 µg/L) was, again, from well GW-658 at the closed East End Garage; however the concentration was ~5,000 µg/L lower than that measured in CY 2018.

Most monitoring results are consistent with data from the previous years because a dissolved plume of legacy VOCs in the bedrock zone extends eastward from the S-3 site over the entire length of the regime (Figure 4.33). Additional sources are the Waste Coolant Processing Facility, fuel facilities (Rust Garage and East End Garage), and other waste disposal and production areas. Chloroethene compounds (tetrachloroethene [PCE], trichloroethene [TCE], dichloroethene [DCE], and vinyl chloride) tend to dominate the VOC plume in the western and central portions of Y-12. However, PCE is almost ubiquitous throughout, indicating many source areas. Chloromethane compounds (carbon tetrachloride, chloroform, and methylene chloride) are the predominant VOCs in the eastern portion of Y-12.

Variability in concentration trends of chlorinated and petroleum VOCs is seen within the Upper EFPC regime. While data from most of the monitoring wells have remained relatively constant since the late 80s/early 90s, some wells show encouraging trends in recovery from legacy contamination. In Figure 4.36 note that GW-382 (the shallow well) has remained constant for summed VOCs for 28 years, but the adjacent GW-383 (screened at 250 ft bgs) has shown a marked decrease in summed VOCs for most of that same time. These decreasing and stable trends west of New Hope Pond are indicators that the contaminants are attenuating due to factors such as: (1) dilution by uncontaminated groundwater, (2) dispersion through a network of fractures and conduits, (3) degradation by chemical or biological means, and/or (4) adsorption by surrounding bedrock and soil media. However, in addition to the factors mentioned above, in October 2000, plume capture well GW-845 began pumping operations to capture the east end VOC plume, thus mitigating migration off ORR into Union Valley (see additional information in the Exit Pathway and Perimeter Monitoring section below).

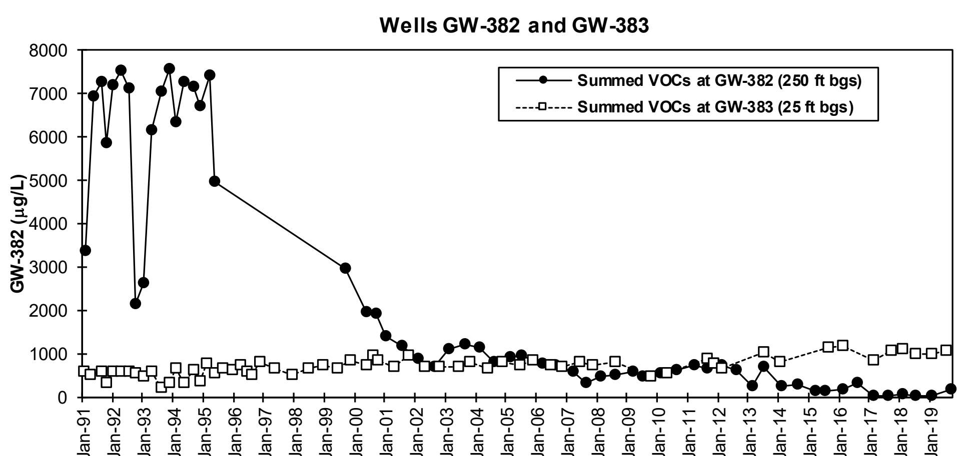


Figure 4.36. Summed volatile organic compounds for GW-382 and GW-383 in the East Fork Regime

Alternatively, increasing trends have been observed in wells associated with the Rust Garage, and S-3 site; some legacy sources at production/process facilities in central areas; and even the east end VOC plume. See Figure 4.37. These trends near the east end VOC plume show that contaminants in wells located perpendicular to strike/across lithologic units from the plume capture system installed in GW-845 may be mobilized by the system. However, no downgradient detection of these compounds is apparent; therefore, migration is limited.

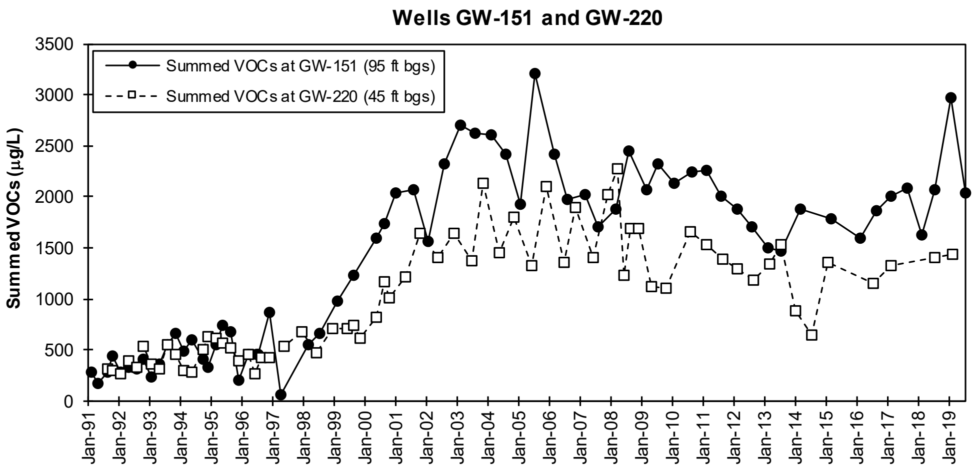


Figure 4.37. Summed volatile organic compounds for GW-151 and GW-220 in the East Fork Regime

Radionuclides

The primary alpha-emitting radionuclides found in the Upper EFPC regime during CY 2019 are isotopes of uranium. Exceedances of the drinking water standard for gross alpha (15 pCi/L) have been observed near the S-3 site, the Salvage Yard, and other western source areas; in the central areas near production facilities and the Uranium Oxide Vault; and also in the east end near the former oil skimmer basin at the former inlet to the New Hope Pond, which was capped in 1988. In CY 2019, the maximum occurrence of gross-alpha activity in groundwater in the Upper EFPC regime was 302 pCi/L, again at well GW-154 near the former oil skimmer basin.

The primary beta-emitting radionuclides observed in the Upper EFPC regime are ^{99}Tc and isotopes of uranium. Elevated gross-beta activity in groundwater shows a pattern similar to that observed for gross-alpha activity.

Technetium-99 is the primary contaminant exceeding the gross-beta screening level of 50 pCi/L; the source is the S-3 site. The highest gross-beta activity in groundwater was observed during CY 2019 from well GW-274 (780 pCi/L).

Exit Pathway and Perimeter Monitoring

In the Upper EFPC regime, VOCs have been observed at depths of up to 500 ft below ground surface. The deep fractures and solution channels in the Maynardville Limestone (the primary exit pathway) appear to be well connected and facilitate contaminant migration into Union Valley offsite to the east of Y-12.

Because of the off-site migration of contaminants, a plume capture system (the East End VOC Treatment System [EEVOCTS]) was constructed in and around well GW-845 (shown on Figure 4.33) and began continuous operation in October 2000. Groundwater is continuously pumped from the Maynardville

Limestone at about 95 L/min (25 gal/min), passes through a treatment system to remove the VOCs, and then discharges to Upper EFPC. The effectiveness of this system is reported annually in Remediation Effectiveness Reports published by DOE-EM (DOE 2019, DOE 2020b).

As explained in the previous section for GW-382 and GW-383, monitoring wells near the plume capture system continue to show an encouraging response. Another example can be observed in the Westbay system installed in well GW-722 downgradient of the system. This multiport well permits sampling of several vertically discrete zones within the Maynardville Limestone. Monitoring results from well GW-722 indicate reductions in VOCs due to the plume capture system from summed VOC levels above 1,000 µg/L before the treatment system was installed to below 50 µg/L in CY 2019.

Five zones in well GW-722 were sampled in CY 2019, with four of the five zones showing summed VOCs greater than 5 µg/L. Only four zones exceeded individual drinking water standards (from carbon tetrachloride and PCE, the highest of which was 33 µg/L of carbon tetrachloride and 7.1 µg/L of PCE, both at zone 20 at a depth of 333 ft bgs).

In addition to the deep system in the eastern portion of Upper EFPC, VOCs have also been observed in the shallow groundwater where it flows north-northeast (mimicking the flow of the creek) east of the New Hope Pond site and Lake Reality. In this area, GW-832 has been installed in a distribution channel underdrain associated with the former New Hope Pond. During CY 2019, the observed concentrations of VOCs at the New Hope Pond distribution channel underdrain remained low (26.9 µg/L).

Upper EFPC flows north exiting Y-12 through a gap in Pine Ridge. As mentioned previously, shallow groundwater mimics the creek and also moves through this exit pathway. One well was monitored in CY 2019, and the only detection was a gross alpha activity (6.7 +/- 4 pCi/L) which is less than the drinking water standard.

Perimeter sampling locations continue to be monitored north and northwest of Y-12 to evaluate possible contaminant transport, even though those locations are considered unlikely contaminant exit pathways. One of the stations monitored is a tributary that drains the north slope of Pine Ridge and discharges into the adjacent Scarboro Community. One location monitors an upper reach of Mill Branch, which discharges into the residential areas along Wiltshire Drive. The remaining location monitors Gum Hollow Branch as it flows adjacent to the Country Club Estates community. There were no indications that contaminants were being discharged from ORR into those communities.

Union Valley Monitoring

Groundwater monitoring data obtained in the early 1990s provided the first indication that VOCs were being transported off ORR through the deep Maynardville Limestone exit pathway. The Upper EFPC remedial investigation (DOE 1998) discussed the nature and extent of the VOC contamination in Union Valley.

In CY 2019, monitoring of locations in Union Valley continued, showing overall decreasing or low concentration stable trends. Vinyl chloride at 1.5 µg/L (below the maximum contaminant level of 2 mg/L) was detected at monitoring well GW-230, located east of Illinois Avenue in the University of Tennessee Arboretum (off the map and approximately 3,500 ft east of the ORR boundary). A groundwater flow divide west of well GW-230, coincident with Scarboro Creek, Illinois Ave, and a gap in Chestnut Ridge, probably restricts transport of VOCs from ORR further east (MMES 1995). This would indicate that the VOCs observed in the well are from a source other than Y-12.

Under the terms of an Interim ROD, administrative controls such as restrictions on potential future groundwater use have been established and maintained. Additionally, the previously discussed plume capture system (well GW-845) was installed to mitigate the migration of groundwater contaminated with VOCs into Union Valley (DOE 1997b).

In July 2006, the Agency for Toxic Substances and Diseases Registry, the principal federal public health agency charged with evaluating the human health effects of exposure to hazardous substances in the environment, published a report in which groundwater contamination across ORR was evaluated (ATSDR 2006). In the report, it was acknowledged that groundwater contamination exists throughout ORR, but the authors concluded that there is no public health hazard from exposure to contaminated groundwater originating on ORR. The Y-12 east end VOC groundwater contaminant plume was acknowledged as the only confirmed off-site contaminant plume migrating across the ORR boundary. The report recognized that the institutional and administrative controls established in the ROD do not provide for reduction in toxicity, mobility, or volume of contaminants of concern, but it concluded that the controls are protective of public health to the extent that they limit or prevent community exposure to contaminated groundwater in Union Valley.

4.6.4.2 Bear Creek Hydrogeologic Regime

Located west of Y-12 in Bear Creek Valley, the Bear Creek regime is bounded to the north by Pine Ridge and to the south by Chestnut Ridge. The regime encompasses the portion of Bear Creek Valley extending from the west end of Y-12 to State Highway 95. Descriptions of waste management sites in the Bear Creek regime and shown on Figure 4.28 were provided in previous year ASERs (e.g., in CY 2017 and previous) and are not repeated this year.

Plume Delineation

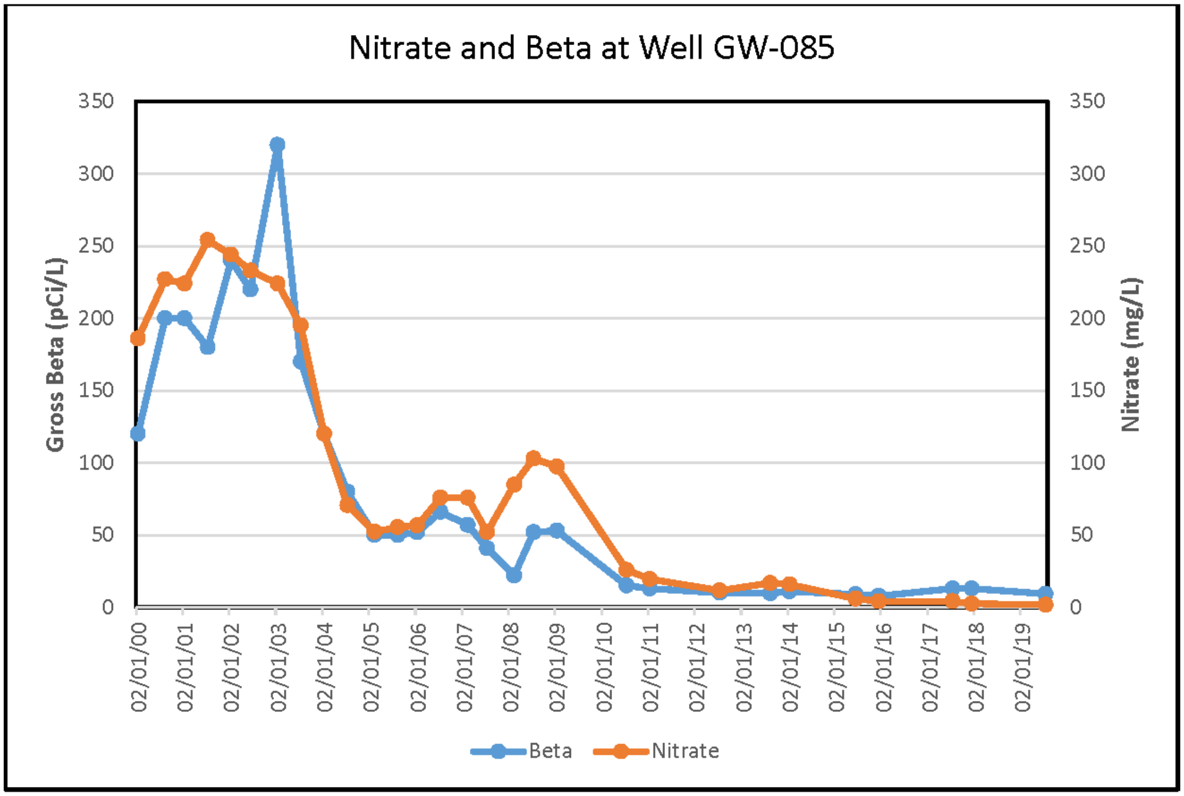
The primary contaminants in the Bear Creek regime are nitrate, trace metals, VOCs, and radionuclides. The S-3 site is a source of all four contaminants. The Bear Creek Burial Grounds and the Oil Landfarm waste management areas are sources of uranium, other trace metals, and VOCs. Chlorinated hydrocarbons and PCBs have been observed in groundwater as deep as 82 m (270 ft) below the Bear Creek Burial Grounds (MMES 1990).

Contaminant plume boundaries are constrained by the bedrock formations (particularly the Nolichucky Shale) that underlie the waste disposal areas in the Bear Creek regime. This fractured aquitard unit is north of and adjacent to the exit pathway unit, the Maynardville Limestone (an aquifer). The elongated shape of the plumes in the Bear Creek regime is the result of preferential transport of the contaminants parallel to strike (parallel to the valley axis).

The plumes in the Bear Creek regime (shown by gray shading on Figures 4.32 through 4.35) represent the average concentrations and radioactivity between CYs 2013 and 2017. The circular icons presented on the figures represent CY 2019 monitoring results.

Nitrate

CY 2019 data indicate that nitrate in groundwater continues to exceed the drinking water standard (10 mg/L) in an area that extends west from the S-3 site. The highest nitrate concentration (10,200 mg/L) was observed at well GW-615 adjacent to the S-3 site at a depth of 75m (245 ft) below ground surface. Historically elevated concentrations of nitrate (>1,000 mg/L) have been detected at greater depths (>700 ft below ground surface) near the S-3 site. In CY 2019 (and CY 2018) a concentration exceeding the drinking water standard was detected in groundwater as far as 2,438 m (8,000 ft) west of the S-3 site, from spring location SS-4 (17 mg/L, both years). However, encouraging trends in both nitrate and gross beta contamination are evident in the aquitard (the Nolichucky Formation) approximately 910 m (2,985 ft) west of the S-3 Site (see Figure 4.38).



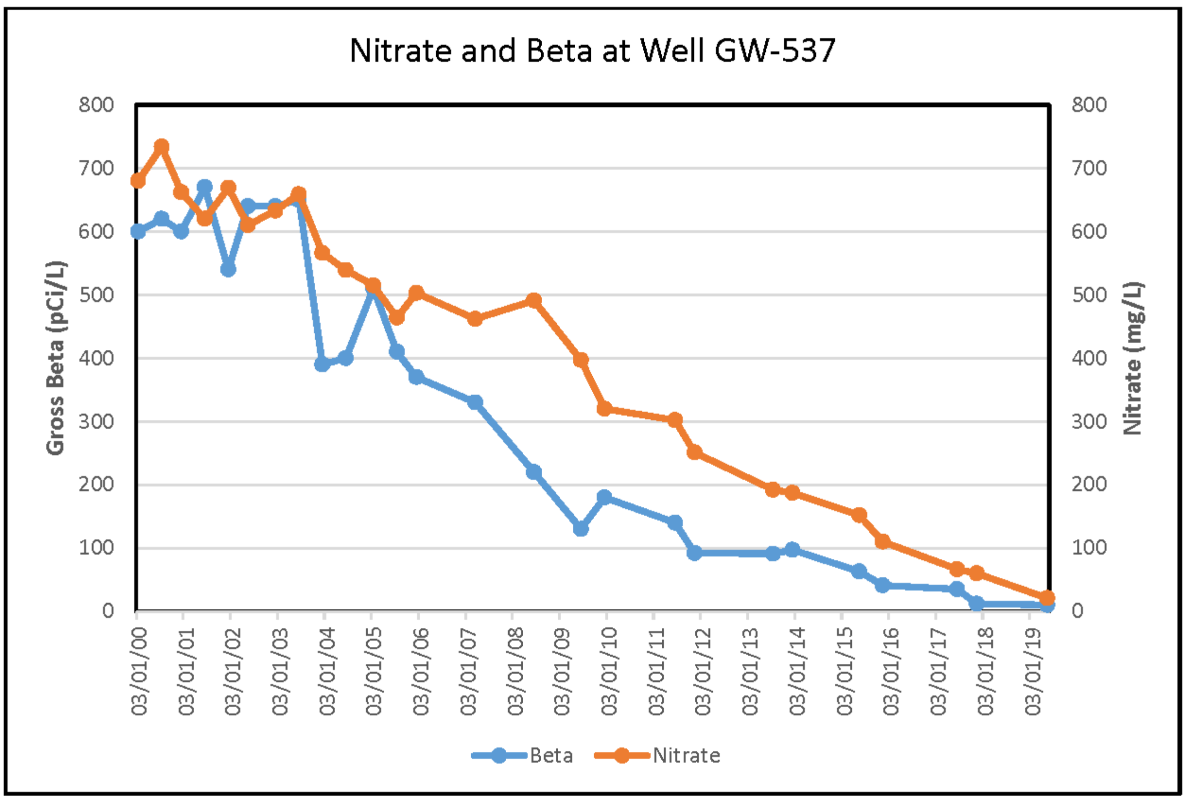


Figure 4.38. Nitrate and gross-beta trends for GW-085 and GW-537 in the Bear Creek Regime

Trace Metals

During CY 2019, antimony, arsenic, barium, chromium, and uranium were identified as trace metal contaminants in the Bear Creek regime that exceeded primary drinking water standards. Elevated concentrations of many of the trace metals were observed at shallow depths near the S-3 site. Disposal of acidic liquid wastes at the S-3 site reduced the pH of the groundwater, which allows the metals to remain in solution longer and migrate further from the source area. In other areas of the Bear Creek regime, where natural geochemical conditions prevail, the trace metals may occur sporadically and in close association with source areas because conditions are typically not favorable for dissolution and migration.

The most prevalent trace metal contaminant is uranium. There has been a decrease in uranium in Bear Creek since 1990 (Table 4.20); however, uranium concentrations in the upper reaches of Bear Creek have been stable, indicating that this contaminant still presents an impact in surface water and groundwater.

Table 4.20. Nitrate and uranium concentrations in Bear Creek

Bear Creek Monitoring station (distance from S-3 site)	Contaminant	Average concentration[a] (mg/L)					
		1990–1994	1995–1999	2000–2004	2005–2009	2010–2014	2015–2019
BCK-11.84 to 11.97	Nitrate	116	65.7	89.5	43.3	53.3	29.4
(approximately 0.5 miles downstream)	Uranium	0.203	0.112	0.129	0.112	0.172	0.199
BCK-09.20 to 09.47	Nitrate	16.1	7.8	12.1	8.4	4.4	5.1
(approximately 2 miles downstream)	Uranium	0.098	0.093	0.135	0.060	0.051	0.070
BCK-04.55	Nitrate	4.7	2.3	3.5	1.1	0.8	1.12
(approximately 5 miles downstream)	Uranium	0.034	0.030	0.033	0.020	0.016	0.020

[a] Excludes results that do not meet data quality objectives.

Acronym:
BCK = Bear Creek kilometer

Volatile Organic Compounds

VOCs are widespread in groundwater in the Bear Creek regime. The primary compounds are PCE; TCE; cis-1,2-DCE; vinyl chloride; and 1,1-dichoroethane. In most areas, they are dissolved in the groundwater and can occur in bedrock at depths up to 92 m (300 ft) below ground surface. VOCs that occur in groundwater of the fractured bedrock aquitard units are found within about 305 m (1,000 ft) laterally of source areas.

The highest concentration observed in CY 2019 occurred in the Nolichucky Shale aquitard at the Bear Creek Burial Ground waste management area, with a maximum summed VOC concentration of 8,342 µg/L in well GW-623 (Figure 4.33; TCE at 4,400 µg/L, PCE at 1,900 µg/L, and 1,1-dichloroethane at 1,500 µg/L comprised most of the summed total.

Near contaminant source areas, such as the Bear Creek Burial Grounds waste management area, a variety of concentration trends are observed. These trends are dependent upon proximity to sources and hydrogeologic conditions. Decreasing and stable VOC trends dominate, as observed in wells GW-053 and GW-071 (Figure 4.39).

Increasing trends of VOCs have been seen in GW-229 downgradient of the Oil Landfarm waste management area (Figure 4.40). However, the most recent data show levels of VOCs are decreasing.

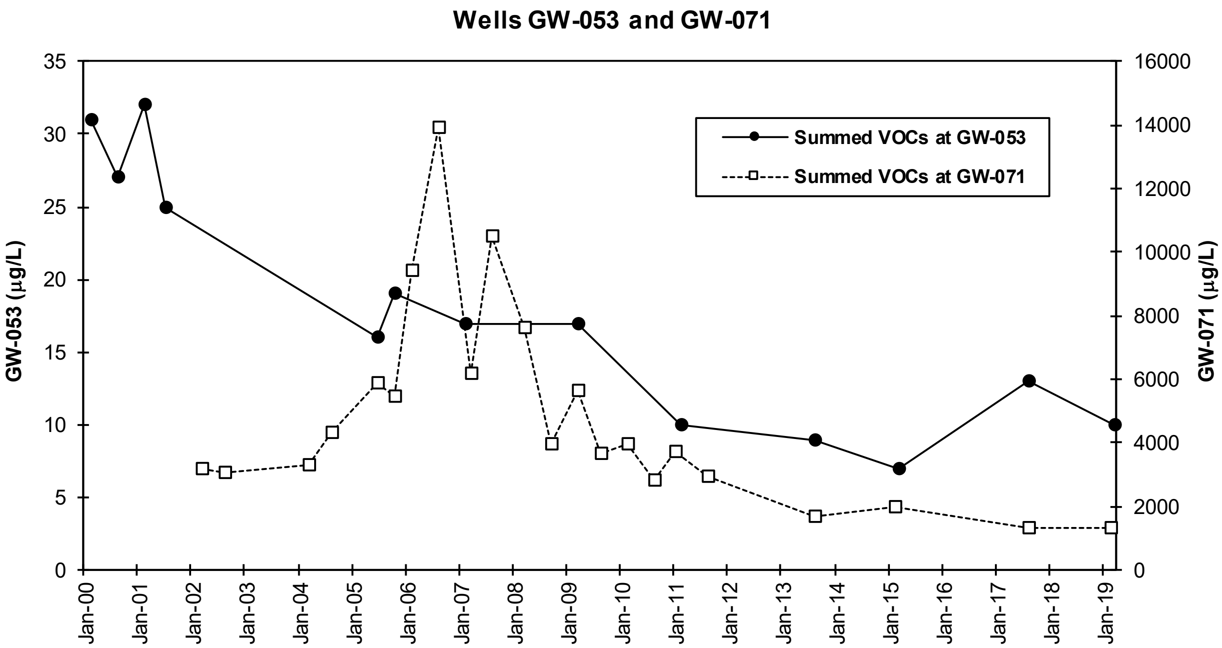


Figure 4.39. Volatile organic compounds in wells GW-053 and GW-046-71 at the Bear Creek Burial Grounds, 2019

In CY 2019, wells at exit pathway transect W (Figure 4.29) showed a trace concentration (0.54 µg/L) of TCE (below drinking water standards), thus indicating migration of contaminants through the Maynardville Limestone a distance of 4,785 m (15,700 ft) from the S-3 Ponds.

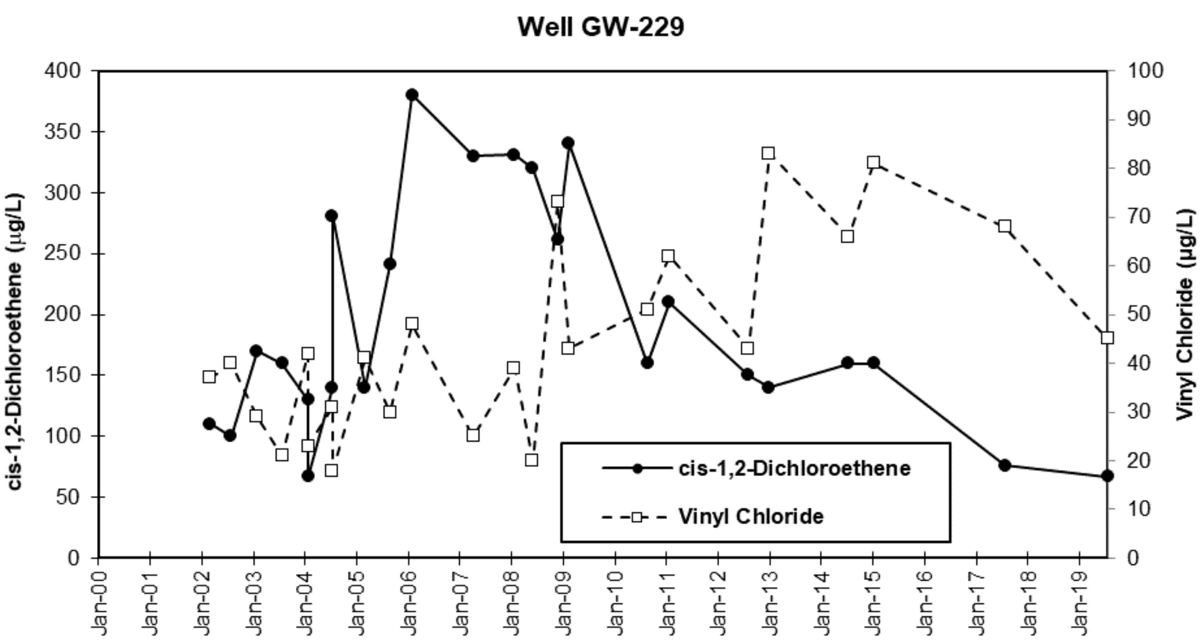


Figure 4.40. Volatile organic compounds in GW-229 at the Oil Landfarm, 2019

Radionuclides

As in the EFPC regime, the primary radionuclides identified in the Bear Creek regime are isotopes of uranium and ^{99}Tc. The extent of radionuclides in groundwater in the Bear Creek regime during CY 2019 was based primarily on measurements of gross-alpha and gross-beta activity. If the gross-alpha activity in a well exceeded 15 pCi/L (the drinking water standard for gross-alpha activity), then one (or more) of the alpha-emitting radionuclides (e.g., uranium) is assumed to be present and, at certain monitoring locations, is evaluated isotopically. A similar rationale is used for gross-beta activity that exceeds 50 pCi/L. Technetium-99, a more volatile radionuclide, is qualitatively screened by gross-beta activity analysis.

Groundwater in the Bear Creek regime with elevated gross-alpha activity occurs near the S-3 site and the Oil Landfarm waste management area. In the bedrock interval, gross-alpha activity has exceeded 15 pCi/L in groundwater in the fractured bedrock of the aquitard units only near source areas (Figure 4.34).

Exit pathway monitoring stations sampled in CY 2019 show that gross-alpha activity in the Maynardville Limestone and in the surface waters of Bear Creek exceeds the drinking water standard for over 3,353 m (11,000 ft) west of the S-3 site (SS-5, 17 pCi/L). In CY 2019 the highest gross-alpha activity observed in a monitoring well in the Bear Creek Regime (24.6 pCi/L) was in GW-706 Transect B (Figure 4.34). No sampling locations in the Bear Creek regime exceeded the drinking water standard for gross-beta activity. Figure 4.38 shows the decreasing trend for gross beta at two wells in the Bear Creek regime.

Exit Pathway and Perimeter Monitoring

Bear Creek, which flows along the Maynardville Limestone (the primary exit pathway for groundwater) in much of the Bear Creek regime, is the principal exit pathway for surface water. Studies have shown that the surface water in Bear Creek, the springs along the valley floor, and the groundwater in the Maynardville Limestone are hydraulically connected. Surveys have been performed that identify gaining (groundwater discharging into surface waters) and losing (surface water discharging into a groundwater system) reaches of Bear Creek. The western exit pathway well transect (Picket W) serves as the perimeter designation for the Bear Creek regime (Figure 4.29).

Exit pathway monitoring consists of continued monitoring at four well transects (pickets) and selected springs and surface water stations. Data obtained during CY 2019 indicate that groundwater is contaminated above drinking water standards in the Maynardville Limestone between Pickets A and C. Total antimony and radium alpha results from the two deepest (666 and 744 ft below ground surface, respectively) monitoring wells at Picket W have exceeded their respective drinking water standards. Considering the depths and the geochemistry of the groundwater, these elements are considered to be of natural origin rather than being attributable to man-made sources or wastes (DOE 2020b). Trends continue to be generally stable to decreasing (Figure 4.41).

Surface water samples collected in CY 2019 indicate that water in Bear Creek contains many of the same compounds found in the groundwater. Uranium concentrations exceeding the drinking water standard have been observed in surface water west of the Burial Grounds as far as Picket W. The concentrations in the creek generally decrease with distance downstream of the waste disposal sites (Table 4.20).

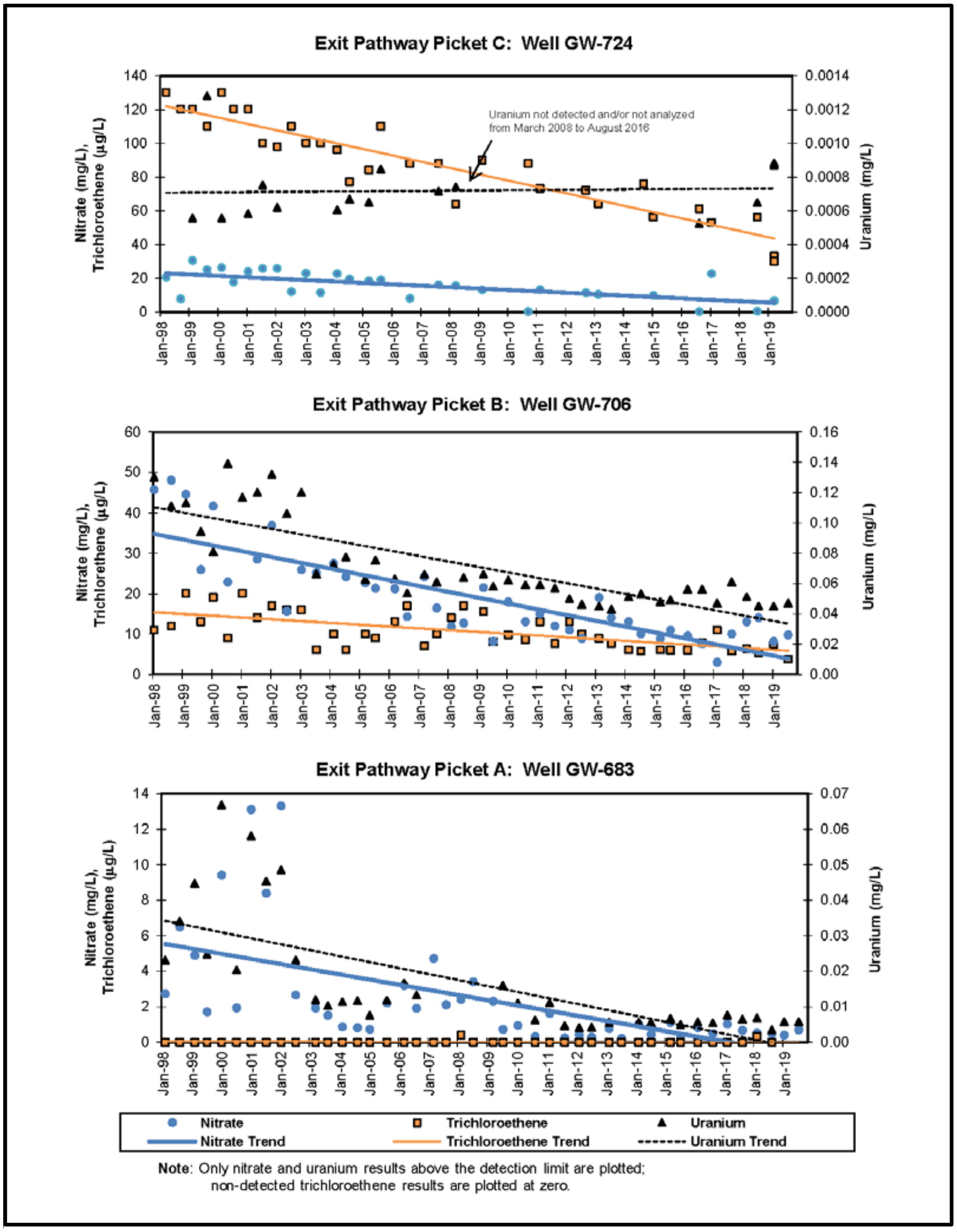


Figure 4.41. Calendar Year 2019 concentrations of selected contaminants in exit pathway monitoring wells in the Bear Creek hydrogeologic regime

4.6.4.3 Chestnut Ridge Hydrogeologic Regime

The Chestnut Ridge hydrogeologic regime is flanked to the north by Bear Creek Valley and to the south by Bethel Valley Road (Figure 4.29). The regime encompasses the portion of Chestnut Ridge extending from Scarboro Road, east of the complex, to Dunaway Branch, located just west of Industrial Landfill II. Descriptions of waste management sites in the Chestnut Ridge regime and shown on Figure 4.28 were provided in previous year ASERs (i.e., CY 2017 and previous) and are not repeated this year.

The Chestnut Ridge Security Pits area is the primary source of groundwater contamination in the regime. Contamination from the security pits is distinct and does not mingle with plumes from other sources.

Plume Delineation

The extent of the VOC plume at the Chestnut Ridge Security Pits (CRSP) is reasonably well defined in the water table and shallow bedrock zones. With two exceptions, mentioned in the next paragraph, historical monitoring indicates that the VOC plume from the CRSP has shown minimal migration in any direction (<305 m [<1,000 ft]).

Data obtained during CY 2019 indicate that the western lateral extent of the plume of VOCs at the site has not changed significantly. VOC contaminants at a well about 458 m (1,500 ft) southeast and downgradient of the CRSP (well GW-798 at 65.66 µg/L summed total VOCs; Figure 4.33) continue to show that some migration of the eastern plume has occurred. Additionally, previously performed dye tracer test results and the intermittent detection of trace concentrations of VOCs (similar to those found in wells adjacent to the CRSP) and at a natural spring about 2,745 m (9,000 ft) to the east and along geologic strike may suggest that CRSP contaminants have migrated further than the monitoring well network indicates. However, as in CY 2018, no VOCs were detected at this spring in CY 2019.

The CRSP plume in the Chestnut Ridge regime (shown by gray shading on Figure 4.33) represents the average VOC concentrations between CYs 2013 and 2017. The circular icons presented on the figure represent CY 2019 monitoring results.

Nitrate

As in CY 2018, nitrate concentrations were below the drinking water standard at all monitoring stations in the Chestnut Ridge regime again in CY 2019.

Trace Metals

Concentrations of arsenic above drinking water standards have been observed in two surface water monitoring locations downstream from the Filled Coal Ash Pond, which is monitored under a CERCLA ROD (DOE 1996). Under the ROD, migration of contaminated effluent from the Filled Coal Ash Pond is being reduced by a constructed wetland area. In recent years it became apparent that the wetland efficiency was decreasing, in part, because of erosion channels forming around the wetland. During CY 2019 a significant maintenance activity was conducted at the site to improve the aquatic habitat for plant growth and to increase retention time for water within the wetland. (DOE 2020b). The elevated arsenic levels were detected both upgradient (McCoy Branch kilometer [MCK] 2.05) and downgradient (MCK 2.0) of this wetland area (Figure 4.29). In CY 2019 the passive wetland treatment area reduced dissolved arsenic by about 69 percent and total arsenic by 78%. A surface water monitoring location (MCK 1.4) about 1,021 m (3,900 ft) downstream from the Filled Coal Ash Pond was also sampled during CY 2019; arsenic was detected below drinking water standards at 0.0039 mg/L in both February and August. These results are below the drinking water standard of 0.010 mg/L and are about an order of magnitude below the MCK 2.0 and MCK 2.05 locations.

Volatile Organic Compounds

Concentrations of VOCs in groundwater at the CRSPs have decreased since 1988. However, stable to increasing trends in VOCs from well GW-798 (Figure 4.33) have been developing since CY 2000. The maximum summed VOC concentration observed at well GW-798 during CY 2019 was 65.66 µg/L. The VOCs detected in well GW-798 continue to be characteristic of the CRSP.

At Industrial Landfill IV, VOCs have been observed in the groundwater since 1992. Well GW-305, located immediately to the southeast of the facility (Figure 4.33), continues to exhibit increasing trends of summed VOCs with the CY 2019 concentration at 96.57 µg/L being the highest concentration in CR in CY 2019. Because samples from this well exceeded the drinking water standard for 1,1-DCE (7 µg/L), quarterly monitoring was initiated in CY 2015 to further evaluate the trend. In CY 2019 one sample at 8.15 µg/L for 1,1-DCE exceeded the drinking water standard. Quarterly sampling ended at this well in July 2019 and the well will be sampled semiannually beginning in 2020.

Radionuclides

In CY 2019, no gross-alpha or gross-beta activity above the drinking water standard of 15 and 50 pCi/L, respectively, was observed in the Chestnut Ridge hydrogeologic regime.

Exit Pathway and Perimeter Monitoring

Contaminant and groundwater flow paths in the karst bedrock underlying the Chestnut Ridge regime have not been well characterized. Tracer studies have been conducted that show groundwater from Chestnut Ridge discharging into Scarboro Creek and other tributaries that feed into Melton Hill Lake. However, no springs or surface streams that represent discharge points for groundwater have been conclusively correlated to a waste management unit or operation at Y-12 that is a known or potential groundwater contaminant source. Springs along Scarboro Creek are monitored for water quality, and trace concentrations of VOCs are intermittently detected. The detected VOCs are suspected to originate from the CRSP; however, this has not been confirmed. In CY 2019, two springs were sampled with no detected concentrations of VOCs.

Monitoring natural groundwater exit pathways is a basic monitoring strategy in a karst regime such as that of Chestnut Ridge. Perimeter springs and surface water tributaries were monitored to determine whether contaminants are exiting the downgradient (southern) side of the regime. Six springs and four surface water monitoring locations were sampled during CY 2019. No contaminants at any of these monitoring stations were detected at levels above primary drinking water standards.

PFAS

No groundwater or surface water sampling activities were conducted in CY 2019 for per- and polyfluoroalkyl substances (PFAS); however, the following information has been obtained and the following actions have been taken in preparation to address these emerging contaminants of concern:

- Tracking or monitoring of current and historic usage of 172 PFAS or PFAS-related substances is being performed using the Y-12 Hazardous Material Information System (HMIS).
- Identification of potential PFAS sources at two waste storage buildings (9720-09 and 9720-58) which had Aqueous Film Forming Foam (AFFF) fire suppression systems installed in 1995. AFFF is a common source of PFAS contamination in soils, groundwater, and surface waters.
    - The AFFF system in building 9720-09 is currently operational and there have been three unintentional system activations resulting in a release of AFFF (2000, 2007, and 2008). The AFFF was contained within the building during the 2007 and 2008 events. It is unknown whether containment was achieved during the 2000 event.
    - In 2018 the AFFF system in Building 9720-58 was removed and replaced with a water-based dry pipe fire suppression system. In 1995 there was an unintentional system activation. It is unknown if the AFFF released during this activation was contained within the building.

- In addition to the buildings mentioned above with fire suppression systems, the Y-12 Plant has a fire department and fire training facility on site. The Y-12 Fire Department has one firetruck with a foam induction system for using AFFF. The AFFF used contains PFAS. AFFF is stored at the Fire training Facility (Building 9718-2) and at the West End Fire Hall (Bldg 2005) south of the S-3 Ponds parking lot. There are three known events where AFFF has been discharged by the Y-12 Fire Department since 2000. It is unknown if it has ever been used during training.
- No production related activities, equipment, or processes are known to have generated or released PFAS to the environment. However, a number of products/chemicals containing PFAS have been used in small quantities, primarily in the Analytical Chemistry Organization laboratories and in the Development Organization Facilities.
- Disposal of AFFF can be tracked through the Y-12 Waste Management Database, SAP-WASTE.
- Coordination between the DOE EM contractor's WRRP and Y-12 GWPP personnel. A tiered sampling approach is planned by the WRRP. Preliminary sampling at strategic locations may occur in CY 2020 and/or 2021.

4.7 Quality Assurance Program

Y-12's QA program establishes a quality policy and requirements for the overall QA program for the Y-12 site. Management requirement E-SD-0002, *Quality Assurance Program Description*, details the methods used to carry out work processes safely and securely and in accordance with established procedures (CNS 2019b). It also describes mechanisms in place to seek continuous improvements by identifying and correcting findings and preventing recurrences.

Many factors can potentially affect the results of environmental data collection activities, including sampling personnel, methods, and procedures; field conditions; sample handling, preservation, and transport; personnel training; analytical methods; data reporting; and record keeping. QA programs are designed to minimize these sources of variability and to control all phases of the monitoring process.

Field sampling QA encompasses many practices that minimize error and evaluate sampling performance. Some key quality practices include the following:

- Use of work control processes and standard operating procedures for sample collection and analysis.
- Use of chain-of-custody and sample identification procedures.
- Instrument standardization, calibration, and verification.
- Sample technician and laboratory analyst training.
- Sample preservation, handling, and decontamination.
- Use of QC samples, such as field and trip blanks, duplicates, and equipment rinses.

Y-12's Environmental Sampling Services perform field sampling, sample preservation and handling, and chain-of-custody and take field control (QC) samples in accordance with Y-12 Environmental Compliance's internal procedures. Environmental Sampling Services developed a Standards and Calibration Program that conforms to ISO/International Electrotechnical Commission (IEC) 17025, *General Requirements for Competence of Testing and Calibration Laboratories* (ISO 2005), and provides a process for uniform standardization, calibration, and verification of measurement and test equipment. The Standards and Calibration Program ensures measurements are made using appropriate, documented methods; traceable standards; appropriate measurement and test equipment of known accuracy; trained personnel; and technical best practices.

Analytical results may be affected by a large number of factors inherent to the measurement process. Laboratories that support Y-12 environmental monitoring programs use internal QA/QC programs to ensure the early detection of problems that may arise from contamination, inadequate calibrations, calculation errors, or improper procedure performance. Internal laboratory QA/QC programs include routine calibrations of counting instruments; yield determinations; include frequent use of check sources and background counts, replicate and spiked sample analyses, and matrix and reagent blanks; and include maintenance of control charts to indicate analytical deficiencies. These activities are supported by the use of standard materials or reference materials (e.g., materials of known composition that are used in the calibration of instruments, methods standardization, spike additions for recovery tests, and other practices). Certified standards traceable to National Institute of Standards and Technology, DOE sources, or EPA are used (when available) for such work.

Y-12's ACO QA Manual describes QA program elements that are based on Y-12's QA program; customer-specific requirements; certification program requirements; ISO/IEC 17025, *General Requirements for Competence of Testing and Calibration Laboratories*; federal, state, and local regulations (ISO 2017); and waste acceptance criteria. As a government-owned, contractor-operated laboratory that performs work for DOE, the ACO laboratory operates in accordance with DOE Order 414.1D, *Quality Assurance* (DOE 2011d).

Other internal practices used to ensure that laboratory results are representative of actual conditions include training and managing staff; maintaining adequacy of the laboratory environment; safety; controlling the storage, integrity, and identity of samples; record keeping; maintaining and calibrating instruments; and using technically validated and properly documented methods.

Y-12's ACO participated in both Mixed Analyte Performance Evaluation Program studies conducted in 2019 for water, soil, and air filter matrices for metals, organics, and radionuclides. The overall acceptability rating from both studies was greater than 98 percent.

Verification and validation of environmental data are performed as components of the data collection process, which includes planning, sampling, analysis, and data review. Some level of verification and validation of field and analytical data collected for environmental monitoring and restoration programs is necessary to ensure that data conform to applicable regulatory and contractual requirements. Validation of field and analytical data is a technical review performed to compare data with established quality criteria to ensure that data are adequate for the intended use. The extent of project data verification and validation activities is based on project-specific requirements.

For routine environmental effluent monitoring and surveillance monitoring, data verification activities may include processes of checking whether:

- Data have been accurately transcribed and recorded
- Appropriate procedures have been followed
- Electronic and hard copy data show one-to-one correspondence
- Data are consistent with expected trends.

Typically, routine data verification actions alone are sufficient to document the validity and accuracy of environmental reports. For restoration projects, routine verification activities are more contractually oriented and include checks for data completeness, consistency, and compliance with a predetermined standard or contract.

Certain projects may require a more thorough technical validation of the data, as mandated by the project's data quality objectives. Sampling and analyses conducted as part of a remedial investigation to support the CERCLA process may generate data that are needed to evaluate risk to human health and the environment, to document that no further remediation is necessary, or to support a multimillion-dollar construction activity and treatment alternative. In these cases, the data quality objectives of the project may mandate a thorough technical evaluation of the data against rigorous predetermined criteria. The validation process may result in the identification of data that do not meet predetermined QC criteria or in the ultimate rejection of data for their intended use. Typical criteria evaluated in the validation of contract laboratory program data include the percentage of surrogate recoveries, spike recoveries, method blanks, instrument tuning, instrument calibration, continuing calibration verifications, internal standard response, comparison of duplicate samples, and sample holding times.

4.8 Environmental Management and Waste Management Activities

4.8.1 Environmental Management

4.8.1.1 Mercury Technology Development Activities

Mercury remediation is OREM's highest priority at Y-12 due to the large historical losses of the element in buildings, soils, and surface waters. Mercury contamination in the environment poses significant technical and regulatory challenges and can benefit from development of new tools and approaches that might be more effective, reduce costs, and accelerate cleanup schedules.

The importance of technology development was highlighted by Secretary of Energy Rick Perry and Undersecretary Paul Dabbar during a visit to Oak Ridge National Laboratory's Aquatic Ecology Laboratory on May 6, 2019. OREM is making significant investments into the development of new remediation technologies to help address the complex mercury challenge in Oak Ridge. In the near term, mercury technology development activities will support the successful completion of the demolition of Y-12's mercury-contaminated facilities and soils remediation, waste disposition, and reduction of mercury-related ecological risks in EFPC.

In the downstream environment, field characterization and research during the 2015–2020 time period will support an evaluation of potential remediation alternatives for the creek in the mid-2020s. Activities to modernize Oak Ridge National Laboratory's Aquatic Ecology Laboratory will allow for mesocosm testing of various remediation technologies, more closely simulating creek conditions in the laboratory. With a better understanding of mercury transport processes in the watershed system, specific technologies and strategies can be assessed and implemented to aid future cleanup. Quantitative modeling was initiated in FY 2018–2019 to simulate various remediation and technology development scenarios and better inform future remedial decision-making.

Studies have been conducted to evaluate alternative treatment chemicals on mercury flux, the effect of sorbents on mercury and methylmercury concentrations in the presence of dissolved organic matter, and the use of mussels as a tool for reducing particle-associated mercury in the water column. Oak Ridge National Laboratory scientists have prepared a report titled "Mercury Remediation Technology Development for Lower EFPC—FY 2019 Update," which provides a detailed description of each of the study areas and findings from studies performed in FY 2019.

4.8.1.2 Mercury Removed from COLEX

At the Alpha-4 building, workers removed more than a ton of mercury from the building's east Column Exchange (COLEX) equipment. Combined with the mercury previously removed from the West COLEX equipment, more than 4.6 tons of mercury have been removed.

The four-story, 500,000-ft^2 Alpha-4 facility was used for uranium separation from 1944 to 1945. Workers finished installing the COLEX equipment in 1955 for lithium separation, a process that required large amounts of mercury. A significant amount of the element was lost into the equipment, buildings, and surrounding soils, and its cleanup is one of OREM's top priorities.

Workers have completed the East COLEX risk reduction project, including activities to tap and drain the East COLEX piping and inspect, clean, and characterize 22 tanks. The COLEX mercury removal project is part of a broader initiative to address large quantities of mercury resulting from decades of Y-12 operations.

4.8.1.3 Major Soil Disposition Project Completed

Workers disposed of 4,071 yd^3 of soil that had been in storage since 1989, resulting from the closure of oil retention ponds. The ponds were constructed decades earlier to collect oils, preventing them from seeping from below-ground waste sites to nearby surface streams. The project was completed for $1.2 million—nearly $75 million under its original estimated budget.

During the closure project in 1989, the soil from the oil retention ponds was labeled as containing solvents based on the contents of the below-ground waste sites near the soil retrieval location. The presence of solvents would require treatment and disposal offsite, a significant cost reflected in the original budget.

Years later, reviews of the original sampling data revealed the need for new samples and analysis to determine the appropriate path to address the soil. OREM contracted with small business Alliant Corporation to conduct that work. Results of the sampling revealed that the soil, spanning a facility the size of an Olympic-sized swimming pool, did not contain solvents.

EPA and TDEC agreed with OREM's technical basis for eliminating the previous requirements to treat the soil and allowed OREM to safely dispose of most of it onsite. With the change, OREM awarded a contract to small business Cherokee National Environmental Solutions to complete the soil disposal project.

The removal of soil paves the way for OREM to reuse the building where the soil was stored. Workers conducted sampling to confirm the facility is safe for future projects. OREM expects to use the facility for research on waste treatment and cleanup at Y-12.

4.8.1.4 Biology Complex Deactivation

OREM is preparing to remove five high-risk excess contaminated facilities, known as the Biology Complex, at Y-12. The 350,000-ft^2 area poses asbestos hazards as well as structural deterioration risks. Demolition of these facilities is part of an effort to eliminate excess contaminated facilities throughout the DOE complex. Asbestos abatement and material removal were initiated in FY 2019.

Originally constructed in the 1940s to recover uranium from process streams, the complex later housed DOE's research on the genetic effects of radiation. The facilities once housed more individuals with doctorates than anywhere in the world.

The complex originally consisted of 11 buildings until OREM demolished 4 of them in 2010 as part of the American Recovery and Reinvestment Act of 2009. Buildings 9743-2 and 9770-2 were demolished in FY 2018, and mobilization started for the demolition of the remaining buildings. The completion of this project will clear land for important future national security missions.

4.8.1.5 Mercury Treatment Facility

Construction is underway on the Outfall 200 MTF. It will reduce mercury in water exiting the site through EFP. Outfall 200 is the point where the west end of the Y-12 storm drain system creates the headwaters of Upper EFPC.

The MTF will help OREM achieve compliance with regulatory criteria for EFP. It also facilitates large-scale facility demolition to begin at Y-12 by helping to control potential mercury releases that could occur when disturbing the mercury-contaminated buildings and soil.

In FY 2019, OREM completed early site preparation activities ahead of the treatment facility construction. Early site preparation activities began in 2018 and included construction of utilities necessary for the treatment facility, installation of secant pile walls near EFPC, and relocation and demolition of existing infrastructure and structures to prepare the site for construction of the MTF.

4.8.2 Waste Management

4.8.2.1 Comprehensive Environmental Response, Compensation, and Liability Act Waste Disposal

Most of the waste generated during FY 2019 cleanup activities in Oak Ridge went to disposal facilities on ORR. The Environmental Management Waste Management Facility received 10,555 waste shipments, totaling 75,074 yd^3, from cleanup projects at ETTP, Oak Ridge National Laboratory, and Y-12. This engineered landfill consists of six disposal cells that only accept low-level radioactive and hazardous waste meeting specific criteria. These wastes include soil, dried sludge and sediment, building debris, and personal protective equipment.

4.8.2.2 Solid Waste Disposal

DOE operates and maintains solid waste disposal facilities called the ORR Landfills. In FY 2019, these three active landfills received 11,100 waste shipments, totaling 123,376 yd^3 of waste.

In FY 2019, OREM also completed improvements to the sediment control ponds and erosion controls at the ORR Landfills. These actions significantly reduce the amount of sediment released from these landfills.

4.8.2.3 Wastewater Treatment

NNSA at Y-12 treats wastewater generated from both production activities and environmental cleanup activities. Safe and compliant treatment of more than 127 million gal of wastewater was provided at various facilities during CY 2019:

- The West End Treatment Facility and the Central Pollution Control Facility at Y-12 processed approximately 499,000 gal of wastewater, primarily in support of NNSA operational activities.
- The Big Springs Water Treatment System treated more than 109 million gal of mercury-contaminated groundwater. The EEVOCTS treated 12.7 million gal of VOC-contaminated groundwater.
- The Liquid Storage Facility and Groundwater Treatment Facility treated more than 2.7 million gal of leachate from burial grounds and well purge waters from remediation areas.
- The Central Mercury Treatment System treated approximately 2.0 million gal of mercury-contaminated sump waters from the Alpha-4 building.

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TDEC 2010b. *Proposed Total Maximum Daily Loads (TMDLs) for Polychlorinated Biphenyls (PCBs) and Chlordane in Watts Bar Reservoir: Watts Bar Lake Watershed (HUC 06010201), Lower Clinch River Watershed (HUC 06010207), and Emory River Watershed (HUC 06010208), Loudon, Meigs, Morgan, Rhea, and Roane Counties, Tennessee.*

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5. Oak Ridge National Laboratory

ORNL is the largest DOE science and energy laboratory. Basic and applied research at ORNL delivers transformative solutions to compelling problems in energy and security.

Diverse capabilities at ORNL span a broad range of scientific and engineering disciplines, enabling the exploration of fundamental science challenges and the research needed to accelerate the delivery of solutions to the marketplace. ORNL supports DOE's national missions of scientific discovery, clean energy, and security through four major areas:

- **Neutrons**—The Spallation Neutron Source and the High Flux Isotope Reactor, two of the world's leading neutron sources, are operated at ORNL, enabling scientists and engineers to gain new insights into materials and biological systems.
- **Computing—**ORNL programs accelerate scientific discovery through modeling and simulation on powerful supercomputers and advance data-intensive science and US leadership in high-performance computing.
- **Materials**—Basic research and applied research are integrated at ORNL to develop advanced materials for energy applications.
- **Nuclear—**ORNL programs advance the scientific basis for 21st century nuclear fission and fusion technologies and systems and produce isotopes for research, industry, and medicine.

In addition, nine world-class facilities that support ORNL's research and development activities are also available to users from universities, industry, and other institutions:

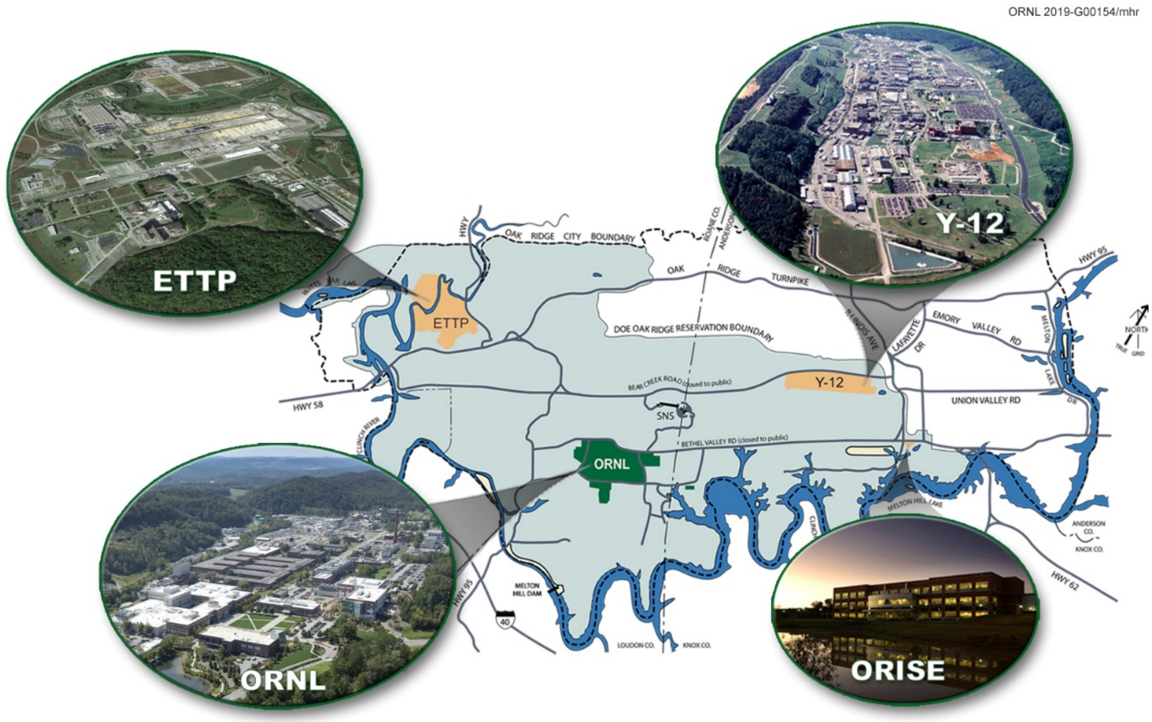
- Building Technologies Research and Integration Center
- Carbon Fiber Technology Facility
- Center for Nanophase Materials Sciences
- Center for Structural Molecular Biology
- High Flux Isotope Reactor
- Manufacturing Demonstration Facility
- National Transportation Research Center
- Oak Ridge Leadership 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 conducting activities at ORNL in 2019 included North Wind Solutions, LLC; UCOR, an Amentum-led partnership with Jacobs; and Isotek Systems, LLC. Activities of these contractors were conducted to comply with contractual and regulatory environmental requirements.

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

5.1 Description of Site, Missions, and Operations

ORNL, which is managed for DOE by UT-Battelle, LLC, a partnership of the University of Tennessee and Battelle Memorial Institute, 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.



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 Oak Ridge National Laboratory within ORR and its relationship to other local DOE facilities

In March 2007, Isotek Systems, LLC (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 "alternatives analysis" 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 (ZPR) plate canisters to the National Nuclear Security Administration and disposal of Consolidated Edison Uranium Solidification Project (CEUSP) material canisters and (2) completing a Phase II alternatives analysis for processing the remaining 50 percent of the inventory. The transfer of the ZPR plate canisters was completed in 2012. Disposal of the CEUSP material canisters began in 2015 and was completed in 2017. Building 2026 was transferred from UT-Battelle to Isotek in May of 2017. Isotek began processing ^{233}U material inside glove boxes in Building 2026 in the fall of 2019. The processing of the ^{233}U material produces a solidified, low-level waste form acceptable for disposal.

Additionally, Isotek is extracting ^{229}Th from the material and is transferring it to a customer for use as source material for medical isotope production.

UT-Battelle provides air and water quality monitoring support for the Building 3019 complex; results are included in the UT-Battelle air and water monitoring discussions in this chapter.

UCOR, an Amentum-led partnership with Jacobs, is the DOE ORR cleanup contractor. The scope of UCOR activities at ORNL includes long-term surveillance, maintenance, and management of inactive waste disposal sites, structures, and buildings. Characterization and deactivation of former reactors and isotope production facilities began in FY 2020. Other activities include groundwater monitoring, transuranic (TRU) waste storage, and operation of the wastewater treatment facility and the waste-processing facility for liquid low-level radioactive waste (LLW).

As of December 11, 2015, North Wind Solutions, LLC, (NWSol) has been the prime contractor for the Transuranic Waste Processing Center (TWPC), which is located on the western boundary of ORNL on about 26 acres of land adjacent to the Melton Valley Storage Tanks along State Route 95. TWPC's mission is to receive TRU wastes for processing, treatment, repackaging, and shipment to designated facilities for final disposal. TWPC consists of the waste-processing facility, the personnel building, and numerous support buildings and storage areas. TWPC began processing supernatant liquid from the Melton Valley Storage Tanks in 2002, contact-handled (CH) debris waste in December 2005, and remotely handled (RH) 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 this chapter. 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 is 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) **here** and the Manufacturing Demonstration Facility (MDF) **here**. HVC is located on a 6 acre site owned by Pellissippi Investors, LLC, and is leased to UT-Battelle and the University of Tennessee. Approximately 152 industry partners work at the HVC to shape America's mobility future. NTRC is DOE's only user facility dedicated to transportation and serves as the gateway to UT-Battelle's comprehensive capabilities for transportation research and development (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 cyber security, and intelligent transportation systems.

MDF focuses on advanced manufacturing research, including the development of carbon fiber composites and additive manufacturing involving polymers, metal wires, and metal powders. The facility hosts the Institute for Advanced Composites Manufacturing Innovation lab space and 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 (Figure 5.2). 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.

Photo by Jason Richards.

Figure 5.2. Production of lower-cost carbon fiber at the Carbon Fiber Technology Facility

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 2011), UT-Battelle, NWSol, UCOR, and Isotek have implemented environmental management systems (EMSs), modeled after International Organization for Standardization (ISO) 1400: 2015, to measure, manage, and control environmental impacts. 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 FY 2018 a management decision was made to transition from registration to a declaration of conformance to ISO 14001:2015. Because of that decision, the external registration audits have been discontinued.

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 policy 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 the workers, the environment, and the public. The UT-Battelle EMS and the 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 Oak Ridge National Laboratory

UT-Battelle's Environmental Policy for ORNL, which can be found **here,** clearly states expectations and provides the framework for setting and reviewing environmental objectives.

5.2.1.3 Planning

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 both the division 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 **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; applicable 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 and indicators for monitoring progress for appropriate functions and activities. Laboratory-level environmental objectives are documented in the annual *Site Sustainability Plan* (DOE 2019) **here**. Line organization objectives are developed annually, entered into a commitment tracking system, and tracked to completion. In all cases, the objectives and indicators for monitoring progress are consistent with the UT-Battelle Policy for ORNL (found online here), are supportive of 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 UT-Battelle's 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 2019 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
- Transportation safety
- Environmental sampling and data evaluation
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA 1980) interface

UT-Battelle also has subject matter experts on its staff who provide critical waste management, transportation, and disposition support services to research, operations, and support divisions:

- Pollution prevention staff manage recycling programs, 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.
- 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 an 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 2011)*, The Oak Ridge National Laboratory FY 2020 Site Sustainability Plan* (SSP) (DOE 2019) (found online here) was completed in December 2019 in compliance with annual DOE guidance.

To meet the goals articulated in the SSP, opportunities for continuous improvements in operational and business processes must be identified, and the changes must be implemented to maximize the return on investment from modernizing facilities and equipment. The Sustainable ORNL program (**here**) promotes system-wide best practices, management commitment, and employee engagement that will lead ORNL into a future of efficient, sustainable operations.

In 2019, The Energy Efficiency and Sustainability Program (EESP) in ORNL's Facilities Management Division (FMD) was successful in the attainment of DOE's 50001 Ready certification. The program recognizes organizations that demonstrate outstanding energy management standards and best practices in their facilities. The certification covers more than 3 million ft^2 in 65 FMD buildings that are equipped with advanced metering. ORNL's advanced metering system aids in the reporting of quality energy data and supports the monitoring of facility energy performance toward the goal of savings in utility use and operations cost. FMD's EESP led the certification effort, but contributions and support from many other divisions were necessary for achievement of the project goals.

DOE launched the 50001 Ready Program in 2017, and ORNL is the third federal location and the second national laboratory to receive the certification (Figure 5.3). The program is a self-guided approach for facilities to validate an energy management system and self-attest to the structure of ISO 50001 standards for energy-efficient operations. To achieve the 50001 Ready certification, organizations are responsible for completing all 25 tasks in the 50001 Ready Navigator online tool and for measuring and improving energy performance over time.

Figure 5.3. Oak Ridge National Laboratory is the third federal location and the second national laboratory to receive the 50001 Ready Program certification

FY 2019 SSP Performance Summary Data for Energy, Water, and Waste

Executive Order (EO) 13834 (EO 2018), "Efficient Federal Operations," directs federal agencies to manage buildings, vehicles, and operations to optimize energy and environmental performance, reduce waste, and cut costs. In April 2019, instructions for implementing EO 13834 were finalized (CEQ 2019). The SSP guidance and ORNL's submittal were updated to reflect the goals of the final EO 13834 implementation.

Energy Use Intensity

Based on FY 2019 data, energy use in the buildings category at ORNL is 1,273 billion Btu. That total excludes certain buildings (e.g., some buildings at ORNL defined under the Energy Policy Act of 1992 [EPACT 1992]). Given an area of 5,291,856 GSF of energy-consuming buildings, trailers, and other structures and facilities identified in the ORNL Facilities Information Management System, the FY 2019 calculated energy use intensity (EUI) is 240,567 Btu/GSF, a reduction of 3.4% from FY 2018 (Figure 5.4).

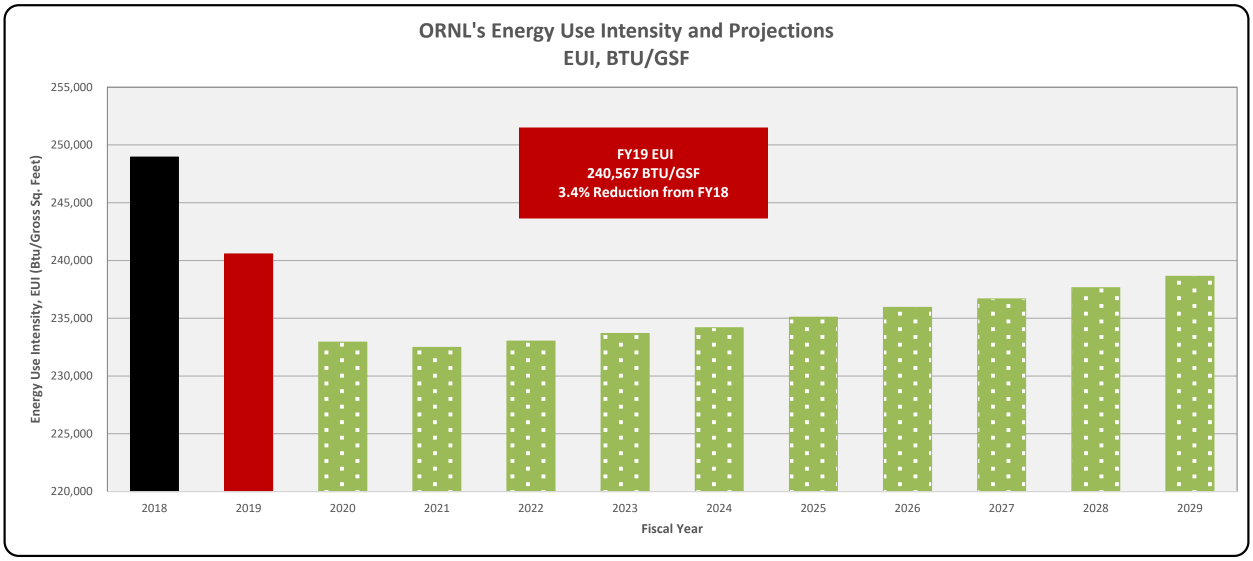


Figure 5.4. Historical, current (FY 2019), and projected energy use intensity at Oak Ridge National Laboratory

To maintain steady progress toward EUI reductions, ORNL focuses on energy-efficient and sustainable design in new construction projects, smart repurposing of existing facilities, and continuous improvement in facility and utility operations. ORNL continues to modernize by demolishing old, energy-inefficient buildings to make way for the construction of new, high-performance buildings that better serve the ORNL mission. Improvements in utilities services have reduced the costs of energy, fuel, water, and maintenance and have increased reliability in the delivery of steam, chilled water, and potable water.

EUI reduction in existing ORNL facilities is data-driven, and efforts are made to quantify and bring awareness to building energy performance so that operations staff can make informed decisions. The establishment of the standards-driven DOE 50001 Ready program will allow FMD and the EESP staff to concentrate limited resources on the most significant energy users to better influence the return on investments. Initiatives in FY 2019 included new approaches to energy consumption awareness using data visualization and reporting. Building data analytics, including fault detection and diagnostics, are also being evaluated as energy conservation tools. To bolster this effort, ORNL has elected to participate in the DOE Better Buildings Smart Energy Analytics Campaign. New and innovative methods are being employed with time-tested approaches to energy conservation, including lighting upgrades; existing building commissioning; and heating, ventilation, and air-conditioning control system improvements.

Water Use Intensity

ORNL procures potable water from the City of Oak Ridge for domestic use (handwashing, flushing), cooling (cooling towers, chillers), heating (steam generation, hot water generation), laboratories, and special research processes.

The benefits of water management practices have been demonstrated at ORNL by the achievement of a 66% reduction in water use compared with the highest level, which occurred in FY 1985. An established, aggressive plan continues to be deployed. The numerous strategies engaged to reduce water consumption include repairing leaks, replacing old lines in the site water distribution system, and eliminating once-through cooling (OTC) where possible. The extended shutdown of the High Flux Isotope Reactor (HFIR) during FY 2019 further reduced water consumption this year; resulting in a 37% reduction in water use intensity since FY 2007 (Figure 5.5). HFIR is expected to return to normal operations in FY 2020. An anticipated 53% increase in water consumption is also expected by 2029 to support additional high-performance computing and Spallation Neutron Source (SNS) activities.

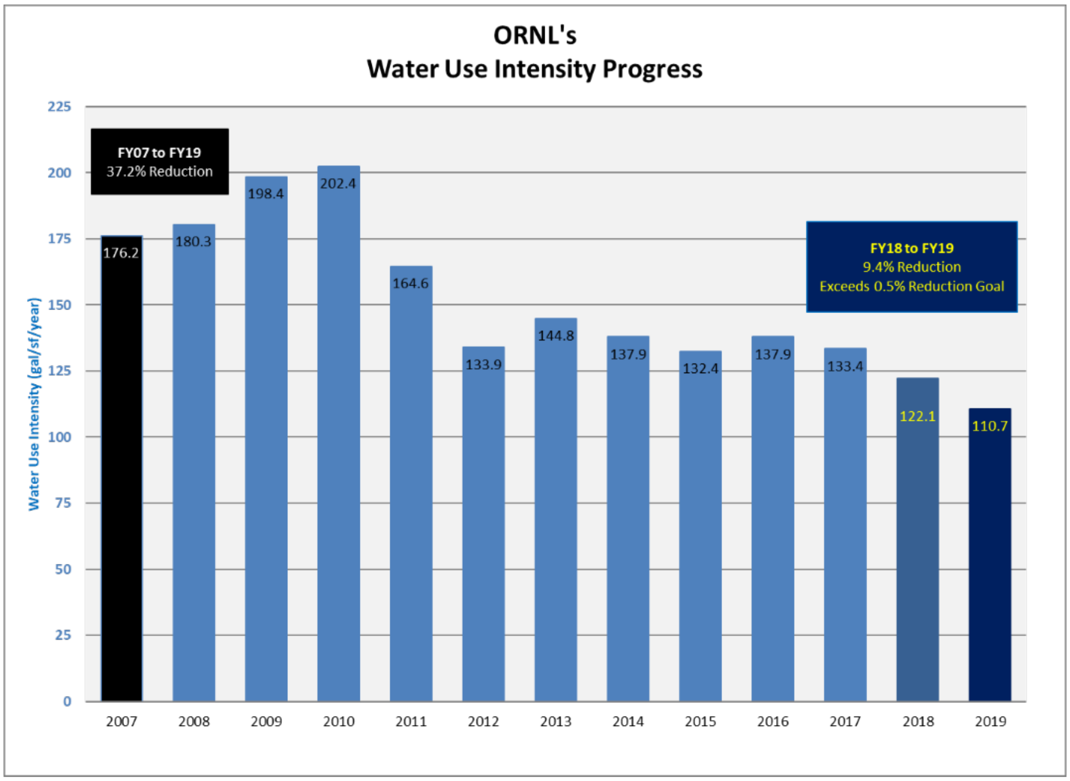


Figure 5.5. Historical and current (FY 2019) water use intensity at Oak Ridge National Laboratory

Waste Diversion

In FY 2019, ORNL's diversion rate for municipal solid waste reached 50 percent and reached 64 percent for construction and demolition (C&D) waste materials and debris.

Pollution Prevention

ORNL source reduction efforts include increases in the use of acceptable nontoxic or less-toxic alternative chemicals and processes while minimizing the acquisition of hazardous chemicals and materials through material substitution, operational assessments, and inventory management. In cases where the complete elimination of a particular hazardous material is not possible, ORNL pursues a combination of actions, including controls to limit use, procurement alternatives, and recycling processes to mitigate the environmental impact. UT-Battelle implemented 26 new pollution prevention projects and ongoing reuse/recycle projects at ORNL during 2019, eliminating more than 3 million kg of waste. An innovative project encompassed the effort to procure recycled-content carpet along with recycling old carpet back through the carpet manufacturer. That effort totally closes the recycling loop for carpeting material (Figure 5.6).

Figure 5.6. Oak Ridge National Laboratory received an environmental stewardship carpet recycle certificate in 2019. Pallets of recycled carpet materials are shown in the photo

Sustainable Vehicle Fleet

ORNL recently transitioned to a General Services Administration leased fleet. This change in fleet management positions ORNL to replace older, less fuel-efficient vehicles with new alternative fuel vehicles (AFVs) at a faster rate. ORNL is now better aligned to comply with DOE guidance concerning sustainable fleet management requirements.

Fifty-two fleet vehicles were replaced over the past 3 years. Of those replacements, 46 were AFVs, and the remaining 6 had no alternative fuel options available. With these additions, approximately 75% of ORNL's 466 vehicle fleet are AFVs, and 100% of light-duty vehicles operate on alternative fuels, exceeding DOE fleet management goals.

High-Performance Sustainable Buildings: Guiding Principles

In FY 2019, ORNL's high-performance sustainable building (HPSB) inventory included a total of 20 buildings that are certified as having attained 100% of the current target for DOE Green Buildings as described in the HPSB *Guiding Principles for Sustainable Federal Building*s (CEQ 2016, FEMP 2020); i.e., the 20 buildings represent 15% of ORNL's total site buildings that are applicable according to the guiding principles. In compliance with the most recently revised HPSB guiding principles, no contractor-owned leased facilities, as classified in the Facilities Information Management System (DOE 2020) were included in the total and percentage calculation for the target.

One of the ways that ORNL achieves HPSB success is through a long association with the US Green Building Council (USGBC) Leadership in Energy and Environmental Design (LEED) certification program. For example, ORNL's Research Support Center was awarded USGBC LEED Gold certification in FY 2019 because of performance improvements based on USGBC LEED criteria that were made in FY 2018. LEED Arc, a new USGBC LEED digital platform for performance data, was used to achieve certification. Arc allows buildings and spaces to connect to the built environment[1] in a new way and allows building managers to compare performance metrics and to apply green building strategies. It is a complement to LEED and other green building systems, standards, and protocols. The process uses real-time data to help measure, track, and improve building sustainability performance using a real-time performance metrics score. The platform creates a holistic view of sustainability efforts through five major categories: energy, water, waste, transportation, and human experience. Arc provides greater transparency to building occupants and operations managers through regularly updated data, so more informed decisions can be made for building operations.

Oak Ridge National Laboratory Commuting Options: EV Owners Club

ORNL is a leader in the region in promoting electric vehicle (EV) use and has been actively participating in regional workplace charging efforts. Currently ORNL manages 32 employee EV charging stations at SNS, NTRC, and ORNL's main campus. The program allows employees access to charging stations. In 2019 there were 71 members in the ORNL EV Owner's Club with access to charging station locations. Members pay an annual fee to join the club and can use the charging stations during work hours. Membership fees support the cost and maintenance of the EV chargers devoted to non-fleet charging. There are an additional five charging stations on the ORNL site devoted to fleet (government-owned) EVs.

Electronic Stewardship

Through ORNL property management and environmental management policies and procedures, 100 percent of used electronics are recycled or reused in accordance with environmentally sound disposition guidance. Options include transfer to other DOE contractors, nonprofit organizations, and educational institutions by means of programs such as the General Services Administration's Computers For Learning Program (found online here). Electronics that have reached end of life are recycled through a certified Responsible Recycling Practices recycler.

Sustainable ORNL Highlights and Achievements: FY 2019 Recognition and Award Submittals

ORNL received two awards for its sustainability efforts in FY 2019:

- **Tennessee Green Fleet Certification Award.** Tennessee Clean Fuels certified the ORNL fleet for its emission reductions via the "Tennessee Green Fleets" Certification Program.
- **2019 Tennessee Chamber of Commerce and Industry Environment and Energy Award.** ORNL received this award in the Energy Excellence category for "Innovatively Striving for the Highest Sustainable Level—Integrating LEED ARC into ORNL's HSPB Approach."

[1] The term "built environment" refers to alterations in the surroundings that provide the setting for human activities (in this case work activity). The built environment can include buildings/facilities, transportation options, and landscaping and green spaces. The term often includes supporting infrastructure, such as water supply, or energy systems, and in this case waste disposal systems.

The DOE 50001 Ready Project was nominated for UT-Battelle Awards Night and will be included in the next DOE award nominations.

Three 2019 DOE Sustainability nominations were submitted to the Sustainability Performance Office:

- "ORNL Building 5200 LEED ARC and HPSB Approach" for the Innovative Approach to Sustainability Category
- "ORNL Water Use Efficiency; OTC Reduction for Research Systems (Building 4508)" for the Outstanding Sustainability Project Category
- "Driving Comprehensive National Sustainability through ORNL's Additive Manufacturing Strategic Partnerships" for the Strategic Partnerships for Sustainability Category

Employee Engagement

The integrated Sustainable ORNL program promotes employee engagement through announcements, promotions, and numerous activities, including the following activities during FY 2019:

- Submitting articles to *ORNL Today*, a web-based newsletter
- Submitting articles to the DOE *Sustainability SPOtlight* Newsletter
- Posting public relations information on Scala screens throughout the campus
- Launching and promoting a new web site (http://www.ornl.gov/sustainable-ornl)
- Holding quarterly workshops with Sustainable ORNL Roadmap owners
- Issuing quarterly updates to the ORNL leadership team
- Planning and delivering the Earth Day Campaign
- Managing and promoting the ORNL EV Owners Club (for use of EV charging stations)
- Managing and promoting bus service between the University of Tennessee, Knoxville; Pellissippi State Community College; and the ORNL main campus

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 2007) 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

> 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).

Strategic plans for demolition and renovation of old facilities and construction of new facilities at ORNL incorporate green infrastructure and low-impact development (GI/LID) practices to infiltrate, evapotranspire, and/or harvest and use storm water on site to the maximum extent feasible. GI/LID approaches and technologies have been used to mimic the natural processes of the hydrologic cycle (infiltration, evapotranspiration, and use). The following GI/LID practices have been incorporated at ORNL:

- Trees and tree boxes
- Rain gardens
- Vegetated swales
- Pocket wetlands
- Infiltration planters
- Porous and permeable pavements
- Vegetated median strips
- Reforestation and revegetation
- Protection of riparian buffers and floodplains
- Retention ponds
- Water reuse (e.g., tanks in restrooms to collect water for reuse in irrigation)

A three-step approach is applied as needed to ensure that GI/LID practices at ORNL meet the requirements of EISA Section 438:

- If the necessary volume of runoff can be infiltrated or retained on site, practices are applied to manage the runoff within the project boundaries.
- If the necessary volume of runoff cannot be infiltrated or retained on site, practices are applied that include land immediately adjacent to the project boundaries.
- If the necessary volume of runoff cannot be infiltrated or retained on land immediately adjacent to the project boundaries, practices are applied that keep the runoff within the same valley or ridge area (e.g., within Bethel Valley if the project is within Bethel Valley; within Melton Valley if the project is within Melton Valley).

In addition to GI/LID practices, the projects may remove impervious areas and reestablish pervious areas to allow infiltration or evapotranspiration to occur.

5.2.1.6 Emergency Preparedness and Response

The UT-Battelle Emergency Management Program supplies the resources and capabilities to provide emergency preparedness services and, in the event of an accident, emergency response services. Emergency preparedness 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 performance of the procedures and plans. An environmental subject matter expert is a member of the emergency response team and participates in drills and exercises to ensure that environmental requirements are met and that environmental impacts from an event and the response are mitigated.

5.2.1.7 Checking

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. Several SBMS subject areas include requirements for managers 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 of the compliance evaluation activities are implemented through the EMS or participation in line-organization assessment activities. If a nonconformance were 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, internal and external EMS assessments are performed annually to ensure that the UT-Battelle EMS continues to conform to ISO requirements. An independent internal audit conducted in 2019 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 Other Environmental Management System Assessments

5.2.2.1 Environmental Management System for the Transuranic Waste Processing Center

The National Sanitation Foundation, International Strategic Registrations, Ltd. (NSF-ISR) registered the TWPC EMS for activities to the ISO 14001:2015 standard (ISO 2015) in May 2017. The EMS is integrated with ISMS to provide a unified strategy for the management of resources, the control and reduction of risks, and the establishment and achievement of 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 for continual improvement in both. NSF-ISR conducted a recertification audit in April. No nonconformances or issues were identified, and several significant practices were noted.

The TWPC EMS incorporates applicable environmental laws, DOE orders, and other requirements (i.e., DOE directives and federal, state, and local laws) according to internal NWSol documentation that describes how the various requirements are incorporated into subject area documents (procedures and guidelines). The EMS assists NWSol line organizations in identifying and addressing environmental issues.

Environmental aspects are elements of an organization’s activities, products, or services that can interact with the environment. NWSol has identified environmental aspects associated with TWPC activities, products, and services at both the project and activity level and has identified waste management activities, air emissions, storm water contamination, pollution prevention, habitat alteration, and energy consumption as potentially having significant environmental impacts. Activities that are relative to any of those environmental aspects are carefully controlled to minimize or eliminate impacts to the environment. NWSol has established and implemented objectives and measurable performance indicators 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.

NWSol has a well-established recycling program at TWPC and continues to identify new material-recycling streams and to expand the types of materials included in the program. 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-oriented materials such as cardboard and batteries. The "single stream" recycling program established by NWSol allows the mixing of multiple types of recyclables and thus increases the amount of recyclable items and improves compliance.

"Environmentally preferable purchasing" is a term used to describe an organization's policy to reduce packaging and to purchase products made with recycled material or biobased materials and other environmentally friendly products. NWSol ensures that environmentally preferable products are purchased by incorporating the "green" procurement requirements in NWSol procurement procedures.

NWSol uses several methods to evaluate compliance with legal and other requirements. Most of these compliance evaluation activities are implemented by internal and external environmental and management assessment activities and by routine reporting and reviews. NWSol also uses the results from numerous external compliance inspections conducted by regulators and contractors to verify compliance with requirements.

5.2.2.2 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 ISO14001:2004 standard (ISO 2004) and that 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 at ORNL and two off-site administrative offices in Oak Ridge. The materials currently recycled by Isotek 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 for continual improvement of the EMS.

5.3 Compliance Programs and Status

During 2019 UT-Battelle, UCOR, NWSol, and Isotek operations were conducted to comply with contractual and regulatory environmental requirements. Table 5.1 presents a summary of environmental audits conducted at ORNL in 2019. The following discussions summarize the major environmental programs and activities carried out at ORNL during 2019 and provide an overview of the compliance status for the year.

Table 5.1. Summary of regulatory environmental audits, evaluations, inspections, and assessments conducted at Oak Ridge National Laboratory, 2019

Date	Reviewer	Subject	Issues
January 8	TDEC	Notice of Termination for Construction Storm Water Permit Coverage	0
February 11-13	EPA/TDEC	Unannounced EPA/TDEC RCRA Inspection (including UT-Battelle, TWPC, and UCOR)	2
February 26	City of Oak Ridge	CFTF Wastewater Inspection	0
March 25	KCDAQM	NTRC CAA Inspection	0
May 14	TDEC	NPDES Permit Inspection	0
August 22	TDEC	UST Compliance Inspection	1
September 27	City of Oak Ridge	CFTF Wastewater Inspection	0
October 24	TDEC	Annual CAA Inspection for ORNL and CFTF	0

Acronyms:
CAA = Clean Air Act
CFTF = Carbon Fiber Technology Facility
EPA = US Environmental Protection Agency
KCDAQM = Knox County Department of Air Quality Management
NPDES = National Pollutant Discharge Elimination System
NTRC = National Transportation Research Center
RCRA = Resource Conservation and Recovery Act
TDEC = Tennessee Department of Environment and Conservation
TWPC = Transuranic Waste Processing Center
UST = underground storage tank

5.3.1 Environmental Permits

Table 5.2 contains a list of environmental permits that were in effect in 2019 at ORNL.

Table 5.2. Environmental permits in effect at Oak Ridge National Laboratory in 2019

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	17-0941-R1	DOE	UT-B	UT-B
CAA	Operating Permit, NWSol	071009P	DOE	NWSol	NWSol
CAA	Construction Permit, 3525 Area Off Gas System	971543P	DOE	UT-B	UT-B
CAA	Operating Permit, NWSol emergency generators	071010P	DOE	NWSol	NWSol
CAA	Title V Major Source Operating Permit, ORNL	569768	DOE	UCOR	UCOR
CAA	Title V Major Source Operating Permit, Isotek	568276	DOE	Isotek	Isotek
CAA	Construction Permit, UCOR	974744	DOE	UCOR	UCOR
CWA	ORNL NPDES Permit (ORNL sitewide wastewater discharge permit)	TN0002941	DOE	DOE	UT-B, UCOR, NWSol
CWA	Industrial and Commercial User Waste Water Discharge Permit (CFTF)	1-12	UT-B	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	NWSol
CWA	Construction Storm Water Permit—ROSC Building	TNR 135617	DOE	UT-B	UT-B
CWA	Construction Storm Water Permit— Leadership Imaging Facility Building	TNR 135602	DOE	UT-B	UT-B
CWA	Aquatic Resources Alteration Permit—Leadership Imaging Facility Building	ARAP - NR1803.153	DOE	UT-B	UT-B
CWA	Construction Storm Water Permit—ROSC Building	TNR135617	DOE	UT-B	UT-B
CWA	ARAP – General Permit for Maintenance of the Swan Pond Water Feature 5007	NR1903.038	DOE	UT-B	UT-B
RCRA	Hazardous Waste Transporter Permit	TN1890090003	DOE	DOE	UT-B, UCOR
RCRA	Hazardous Waste Corrective Action Permit	TNHW-164	DOE	DOE/all	DOE/all

Table 5.2. Environmental permits in effect at ORNL in 2019 (continued)

Regulatory driver	Permit title/description	Permit number	Owner	Operator	Responsible contractor
RCRA	Hazardous Waste Container Storage and Treatment Units	TNHW-145	DOE	DOE/ UCOR/ NWSol	UCOR/NWSol
RCRA	Hazardous and Mixed Waste Storage Permit	TNHW-178[a]	DOE	DOE/UT-B	UT-B

[a] Permit TNHW-134 was reissued as TNHW-178 on August 15, 2019.

Acronyms:
ARAP = Aquatic Resources Alteration Permit
CAA = Clean Air Act
CFTF = Carbon Fiber Technology Facility
CWA = Clean Water Act
DOE = US Department of Energy
ETTP = East Tennessee Technology Park
Isotek = Isotek Systems, LLC
NTRC = National Transportation Research Center
NWSol = North Wind Solutions, LLC
ROSC = Research Operations Support Center
RCRA = Resource Conservation and Recovery Act
UT-B = UT-Battelle, LLC

5.3.2 National Environmental Policy Act/National Historic Preservation Act

NEPA provides a means 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 5.3 summarizes NEPA activities conducted at ORNL during 2019.

Table 5.3. National Environmental Policy Act activities, 2019

Types of NEPA documentation	Number of instances
UT-Battelle, LLC	
Approved under general actions or generic CX determinations[a]	85
Project-specific CX determinations[b]	1
North Wind Solutions, LLC	
Approved under general actions[a] or generic CX determinations	1

[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.

Acronyms:
CX = categorical exclusion
DOE = US Department of Energy
NEPA = National Environmental Policy Act

During 2019, UT-Battelle and NWSol continued to operate under site-level procedures that provide requirements for project reviews and NEPA compliance. 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, the DOE has approved generic categorical exclusion (CX) determinations that cover proposed bench-scale and pilot-scale research activities and generic CXs that cover proposed nonresearch activities (e.g., maintenance activities, facilities upgrades, personnel safety enhancements). A CX 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 (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 the US Environmental Protection Agency (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 October 2018. The Title V Major Source Operating Permit for the 3039 stack, operated by UCOR, is scheduled for renewal in 2020. 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 (NO_x), a family of poisonous, highly reactive gases and defined collectively as a criteria pollutant by the 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 pending issuance at the end of 2019. The new NTRC operating permit will be issued in 2020. The CFTF operates under two construction permits issued by TDEC. A permit application to convert them to a Conditional Major operating air permit was submitted in 2018 and was issued for draft review by UT-Battelle at the end of 2019. The final CFTF Condition Major operating permit will be issued in 2020.

In summary, there were no UT-Battelle CAA violations and no Isotek, UCOR, or NWSol CAA violations or exceedances in 2019. Section 5.4 provides detailed information on 2019 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 serves as 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 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 2019, compliance with the ORNL NPDES permit was determined by about 1,800 laboratory analyses and field measurements. ORNL wastewater treatment facilities achieved a >99 percent numeric permit compliance rate in 2019. A large storm in March 2019 caused heavy inflow into the ORNL STP, causing concentration and loading effluent limit numeric noncompliances for total suspended solids. There were two nonnumeric permit noncompliances in 2019; a total suspended solids sample and an oil and grease sample for Outfall X12 were not collected during the required quarterly reporting period. The samples were collected and reported during the next quarterly reporting period. A fish kill at Melton Branch also occurred in May 2019, and is discussed in more detail in Section 5.5.2.

The NPDES permit limit compliance rate for all discharge points for 2019 was > 99 percent.

ORNL received a renewed permit in May 2019. Several conditions in the permit were appealed and remained unresolved.

5.3.5 Safe Drinking Water Act Compliance Status

ORNL's water distribution system is designated as a "nontransient, noncommunity" water system by the TDEC Division of Water Supply. TDEC's water supply rules, Chapter 0400-45-01, "Public Water Systems" (TDEC 2019), set limits for biological contaminants and for chemical activities and chemical contaminants. TDEC requires sampling for the following constituents for 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 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 2019, sampling results for ORNL's water system residual chlorine levels, bacterial constituents, lead/copper, and disinfectant by-products were all within acceptable limits. Sampling for lead and copper will not be required again until 2021.

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 2019, 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 2019.

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 5.4. In 2019, UT-Battelle and UCOR were permitted to transport hazardous wastes under the EPA ID number issued for ORNL activities. On September 15, 2015, the ORR Hazardous Waste Corrective Action Permit TNHW-121 was reissued as TNHW-164. TNHW-164 is a set of conditions pertaining to the current status of all solid waste management units (SWMUs) and areas of concern (AOCs) at East Tennessee Technology Park (ETTP), ORNL, and the Y-12 National Security Complex. The corrective action conditions require that the SWMUs and AOCs be investigated and, as necessary, remediated.

Reporting is required for hazardous waste activities on 12 active waste streams at ORNL, some of which are mixed wastes. The quantity of hazardous/mixed waste generated at ORNL in 2019 was 555,699 kg, with mixed wastewater accounting for 515,050 kg. ORNL generators treated 6,594 kg of hazardous/mixed waste by elementary neutralization, silver recovery, and deactivation. The quantity of hazardous/mixed waste treated in RCRA-permitted treatment facilities at ORNL in 2019 was 2,264 kg. This included waste treated by macroencapsulation, size reduction, stabilization/solidification, and 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 220,539 kg in 2019.

Table 5.4. Oak Ridge National Laboratory Resource Conservation and Recovery Act operating permits, 2019

Permit number	Storage and treatment/description
	Oak Ridge National Laboratory
TNHW-178[a]	Building 7651 Container Storage Unit Building 7652 Container Storage Unit Building 7653 Container Storage Unit Building 7654 Container Storage Unit Portable Unit 2 Storage and Treatment Unit
TNHW-145	Portable Unit 1 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[b] Macroencapsulation Treatment T-2[b] Solidification/Stabilization Treatment T-3[b] Amalgamation Treatment T-4[b] Groundwater Absorption Treatment T-5[b] Size Reduction T-6[b] Groundwater Filtration Treatment T-7[b] Neutralization T-8[b] Oxidation/Deactivation
	Oak Ridge Reservation
TNHW-164[c]	Hazardous Waste Corrective Action Document

[a]Permit TNHW-134 was reissued as TNHW-178 on August 15, 2019.
[b] Treatment methodologies within TWPC facilities.
[c] ORR Hazardous Waste Corrective Action Permit TNHW-121 was reissued as TNHW-164 on September 15, 2015.

In February 2019, TDEC Division of Solid Waste Management and the EPA conducted a Hazardous Waste Compliance Evaluation inspection of ORNL generator areas; universal waste collection areas; RCRA-permitted treatment, storage, and disposal facilities; hazardous waste training records; site-specific contingency plans; and RCRA records. TDEC also reviewed the Hazardous Waste Transporter Permit, hazardous waste manifests, and US Department of Transportation training records. Two violations were identified: (1) Two containers of broken waste lamps destined for disposal were being managed as universal waste and were not labeled “hazardous waste;” (2) during records review, three new-hire personnel failed to acquire hazardous waste training within 6 months of their date of employment. Both violations were corrected when identified, returning the facility to compliance, so no follow-up inspections were conducted.

In 2018 ORNL requested an EPA ID number for hazardous waste activities at 115A Union Valley Road in Oak Ridge. This is ORNL’s property sales warehouse for excessing and surplus sales. A surplus piece of equipment was determined to have contamination and had to be disposed of as hazardous waste. The equipment weighed 1,391 kg, which qualified Property Sales as a large quantity generator for the onetime shipment. The EPA ID number was subsequently deactivated. On March 4, 2020, the TDEC Division of Solid Waste Management conducted a Hazardous Waste Compliance Evaluation inspection to confirm that the status of the property sales warehouse had returned to non-generator status. No violations were observed.

DOE and UT-Battelle operations at NTRC and CFTF were regulated as “conditionally exempt small-quantity generators” in 2019, meaning that less than 100 kg of hazardous waste was generated per month.

In 2019, no hazardous/mixed wastes were generated, accumulated, or shipped by DOE or UT-Battelle at the DOE Office of Scientific and Technical Information, or the 0800 Area.

In 2019 DOE and UT-Battelle submitted closure documentation for DOE Building 1916-T2.

ORNL submitted a RCRA permit application in 2018 to renew Permit TNHW-134. A new Permit TNHW-178 was issued by TDEC Division of Solid Waste Management on August 15, 2019.

5.3.7 Oak Ridge National Laboratory RCRA-CERCLA Coordination

The Federal Facility Agreement for the Oak Ridge Reservation (FFA) (DOE 2014) 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 2018 for ORNL’s SWMUs and AOCs 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 2019.

Periodic updates of proposed C&D 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 C&D projects and facilities that warrant CERCLA oversight. The goal is to ensure that modernization efforts do not adversely affect the effectiveness of previously completed CERCLA environmental remediation actions and that they do not adversely affect future CERCLA environmental remediation actions.

5.3.7.1 CERCLA Activities in Bethel Valley

In 2019, ORNL completed work on a CERCLA project initiated in 2018 to perform limited environmental remediation in the 3500 Area of the Central Campus to facilitate future brownfield redevelopment. Characterization of the area was completed in August 2018, and data were evaluated against remediation levels defined in the Bethel Valley Interim Record of Decision to identify required cleanup scope. An addendum to the approved Waste Handling Plan was developed and approved. Additionally, a technical memorandum (TM) was submitted and received regulatory approval in April 2019 as an appendix to the approved Remedial Design Report/Remedial Action Work Plan for Bethel

Valley Soils and Sediments to document the proposed remedial actions. In May 2019, a contractor was mobilized, and remedial actions and site restoration were completed in September 2019. Following completion of waste disposal, a phased construction completion report was developed and was submitted for regulatory approval in March 2020 to document completed actions, final waste volumes, and waste disposition.

5.3.7.2 Utilities Project Upgrade

In 2019, ORNL also initiated a utilities upgrade project to address the aging utilities services that provide electrical service and handle potable water, steam, storm water, and wastewater. Although utilities work is not typically performed under CERCLA and instead is considered routine maintenance and operations, the utilities upgrade projects are large-scale upgrades that may generate significant volumes of soils for disposition that may be contaminated from legacy R&D and may be remediated as a consequence of the utilities modernization efforts. Therefore, a TM was developed that addresses utilities modernization projects within ORNL Bethel Valley. The TM documents the process for characterization activities to be performed, data evaluation to be conducted to identify areas where contaminated soil will be removed to meet CERCLA requirements under the Bethel Valley Interim Record of Decision and the ORNL Soils and Sediments Remedial Design Report/Remedial Action Work Plan, and the estimated soil volumes to be removed and disposed under CERCLA at the Environmental Management Waste Management Facility (EMWMF). A phased construction completion report will be prepared following completion of ORNL Bethel Valley utilities upgrade projects to document the actual scope of soil removal, waste volumes, and disposal paths.

5.3.7.3 RCRA Underground Storage Tanks

Underground storage tanks (USTs) containing petroleum and hazardous substances are regulated under RCRA Subtitle I (40 CFR 280). TDEC has been granted authority by EPA to regulate USTs containing petroleum under TDEC Rule 400-18-01; however, hazardous-substance USTs are still regulated by EPA.

ORNL has two USTs registered with TDEC under Facility ID 0-730089. These USTs are in service (petroleum) and meet the current UST standards. A compliance inspection by TDEC occurred in August 2019. TDEC noted one violation for the gasoline tank, cathodic protection testing had been performed in an interval greater than 3 years [every 3 years required by TN Rule 0400-18-01-.02(4)(c)2(i)]. No corrective actions were needed, and no fines were assessed.

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 (NPL) is a comprehensive list of sites and facilities that have been found to pose a sufficient threat to human health and/or the environment to warrant cleanup under CERCLA.

In 1989, ORR was placed on the EPA NPL. In 1992, the ORR FFA became effective among EPA, TDEC, and DOE and established the framework and schedule for developing, implementing, and monitoring remedial actions (RAs) on ORR. The on-site CERCLA Environmental Management Waste Management Facility (EMWMF) is operated by UCOR 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 the 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 Substance Control Act (TSCA). PCB waste generation, transportation, and storage at ORNL are reported under EPA ID TN1890090003. In 2019, UT-Battelle operated nine 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/or equipment (e.g., transformers, capacitors, rectifiers) is regulated at ORNL. Most of the equipment at ORNL that required regulation under TSCA 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 PCBs in paint, adhesives, electrical wiring, or floor tile, are identified at ORNL. No new unauthorized uses of PCBs were identified during 2019.

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 University of Texas at Dallas (UT-Dallas) Emergency Response Information System (E-Plan), which is an electronic database managed by UT-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 5.5 describes the main elements of EPCRA. UT-Battelle complied with these requirements in 2019 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.

Table 5.5. 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, Material 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

ORNL had no releases of extremely hazardous substances, as defined by EPCRA, in 2019. Releases of toxic chemicals that were greater than the Section 313 designated reportable threshold quantities are discussed in Section 5.3.10.2.

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 2019, there were 27 hazardous and/or extremely hazardous substances at ORNL that met EPCRA reporting criteria.

Private-sector lessees were not included in the 2019 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.

For 2019, ORNL exceeded the reporting threshold and reported on the otherwise use of nitric acid and the manufacture of nitrate compounds. Most of the nitric acid was used in wastewater treatment operations at the PWTC. Nitrate compounds were coincidentally manufactured as by-products of neutralizing the nitric acid waste and 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. In 2019, UT-Battelle personnel had 19 permits and agreements for the receipt, movement, or controlled release of regulated articles.

5.3.12 Wetlands

Wetland delineations of potential project sites are conducted to facilitate compliance with TDEC and US Army Corps of Engineers wetlands protection requirements. Although no official delineations were conducted in 2019, sensitive resource surveys and knowledge of previous delineations provided general locations of wetlands to project managers. Assessing the potential for jurisdictional wetlands during the site selection process and early planning stages can help projects reduce wetland impacts, design changes, and mitigation costs.

5.3.13 Radiological Clearance of Property at Oak Ridge National Laboratory

DOE Order 458.1, *Radiation Protection of the Public and the Environment* (DOE 2011c), 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 allowed by DOE Order 458.1 (DOE 2011c) 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 2018, UT-Battelle cleared more than 20,000 items through the excess items and property sales processes. A summary of items requested for release through these processes is shown in Table 5.6.

Table 5.6. Excess items requested for release and/or recycling, 2019

Item	Process knowledge	Radiologically surveyed
	Release request totals for 2019	
Totals	16,885	1,811
	Recycling request totals for 2019	
Cardboard (tons)	194.31	
Scrap metal (nonradiological areas) (tons)	602.42	

5.3.13.2 Authorized Limits Clearance Process for Spallation Neutron Source and High Flux Isotope Reactor Neutron Scattering Experiment Samples

The SNS and 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 2011c) 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 [NRC]) licensing regulations). Implementation of the clearance limits involves use of unique instrument screening and methods for prediction of sample activity to provide an efficient and defensible process to release neutron scattering experiment samples to researchers without further DOE control.

In 2019 ORNL cleared a total of 83 samples from neutron scattering experiments using the sample authorized limits process. Of these, 73 samples were from SNS and 10 were from HFIR.

5.4 Air Quality Program

5.4.1 Construction and Operating Permits

Permits issued by the State of Tennessee convey the clean air requirements that are applicable to ORNL. 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 NTRC facilities located 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. A Conditional Major Source Operating Permit for the facility will be issued in 2020.

DOE/NWSol has two non-Title V Major Source Operating Permits for one emission source and two emergency generators at TWPC. During 2019 no permit limits were exceeded. Isotek has a Title V Major Source Operating Permit (568276) for the Radiochemical Development Facility (Building 3019 complex). During 2019 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. During 2019 no permit limits were exceeded.

5.4.2 National Emission Standards for Hazardous Air Pollutants—Asbestos

Numerous facilities, structures, and facility components and various pieces of equipment at ORNL contain asbestos-containing material (ACM). UT-Battelle's Asbestos Management Program manages the compliance of work activities involving the removal and disposal of ACM, which include notifications to TDEC for all demolition activities and required renovation activities, approval of asbestos work authorization requests, current use of engineering controls and work practices, inspections, air monitoring, and waste tracking of asbestos-contaminated waste material. During 2019 there were no deviations or releases of reportable quantities of ACM.

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, adsorbable gases (e.g., iodine), and nonadsorbable gases (e.g., noble gases).

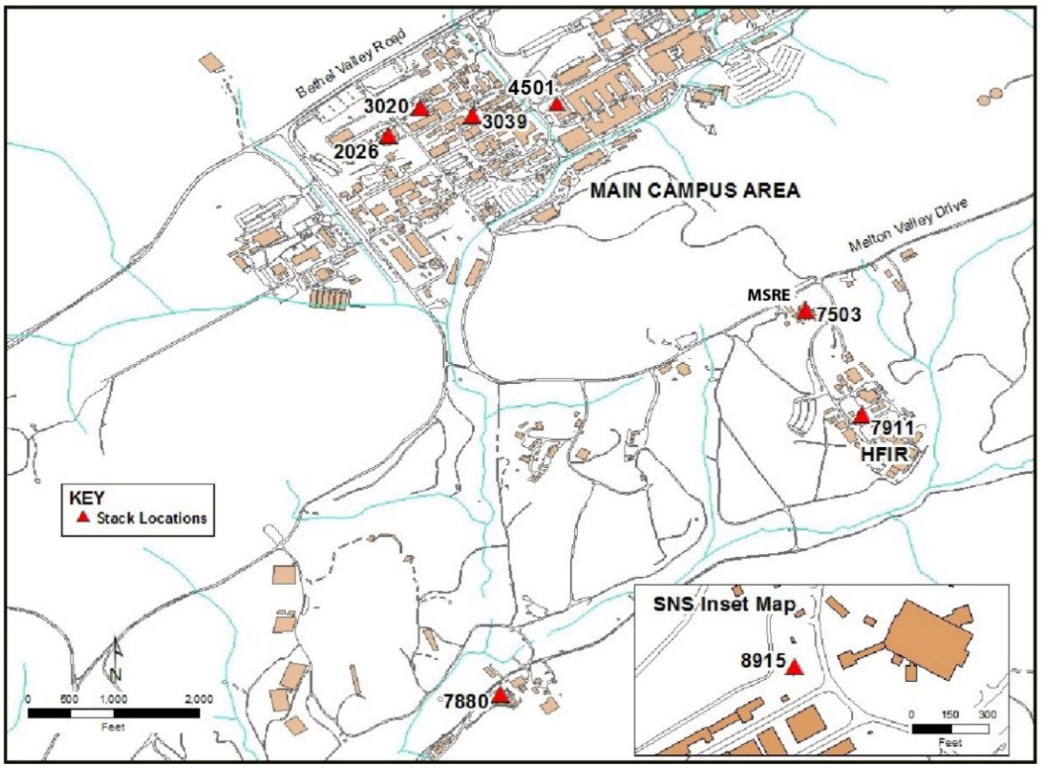
The major radiological emission point sources for ORNL consist of the following eight stacks. Seven are located in Bethel and Melton Valleys, and one, the SNS Central Exhaust Facility stack, is located on Chestnut Ridge (Figure 5.7):

- 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 (MSRE)
- 7880 TWPC
- 7911 Melton Valley complex, which includes HFIR and the Radiochemical Engineering Development Center
- 8915 SNS Central Exhaust Facility stack

In 2019 there were 14 minor point/group sources, and emission calculations/estimates were made for each of them.

ORNL 2020-G00518/mhr



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 Oak Ridge National Laboratory, 2019

5.4.3.1 Sample Collection and Analytical Procedure

Four of the major point sources (stacks 2026, 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). The sampling systems generally consist of 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 4501 (Radiochemistry Laboratory), 7911 (Melton Valley complex), and the 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 4501 and 7911 sampling systems have the same components as the ANSI 1969 sampling systems used for the four major point sources but use a stainless-steel-shrouded probe instead of a multipoint in-stack sampling probe. The 7911 sampling system also consists of 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 (EPA 2010) 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. An annual comparison is performed for the 7880 stack between the effluent flow rate totalizer and EPA Method 2. 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 are calculated using a fixed stack flow rate. A fixed stack flow rate is 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).

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 located 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 various 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/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 then composited quarterly or semiannually and are analyzed for alpha-, beta-, and gamma-emitting isotopes. At stack 7880, the filters are composited monthly and analyzed for alpha-, beta-, and gamma-emitting isotopes. The sampling system on stack 7880 requires no other type of radionuclide collection media. Compositing provides a better opportunity for quantification of the low-concentration isotopes. Silica-gel traps are used to capture water vapor that may contain tritium. Analysis is performed weekly to biweekly. At the end of the year, the sample probes for all of 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. It is not anticipated that contaminant deposits would 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 no more often than every 3 years unless there is an increase in particulate emissions, an increase in detectable radionuclides in the sample media, or process modifications.

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 2019 are presented in Table 5.7. All data presented were determined to be statistically different from zero at the 95 percent confidence level. Any number not statistically different from zero was not included in the emission calculation. Because measuring a radionuclide requires counting random radioactive emissions from a sample, the same result may not be obtained if the sample is analyzed repeatedly. This deviation is referred to as the "counting uncertainty." Statistical significance at the 95 percent confidence level means that there is a 5 percent chance that the results could be erroneous.

Historical trends for tritium (^{3}H) and ^{131}I are presented in Figures 5.8 and 5.9. For 2019, tritium emissions totaled about 1,046 Ci (Figure 5.8), comparable to what was seen in 2016; ^{131}I emissions totaled 0.08 Ci (Figure 5.9), a significant decrease from 2017 but comparable to what was seen in 2018. For 2019, of the 317 radionuclides (excluding radionuclides with multiple solubility type) released from ORNL operations and evaluated, the isotopes that contributed 10% or more to the off-site dose from ORNL included ^{212}Pb, which contributed about 40%, ^{232}Th, which contributed about 22%, and ^{138}Cs, which contributed about 15% to the total ORNL dose. Emissions of ^{212}Pb and ^{232}Th result from research activities and from the radiation decay of legacy material stored on site and areas containing isotopes of ^{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 3000 and 4000 area laboratory hoods. Cesium-138 and ^{41}Ar emissions result from Radiochemical Engineering Development Center research activities and HFIR operations. For 2019, ^{212}Pb emissions totaled 6.47 Ci, ^{138}Cs emissions totaled 1,090 Ci, and ^{41}Ar emissions totaled 462 Ci (see Figure 5.10).

The calculated radiation dose to the maximally exposed individual (MEI) from all radiological airborne release points at ORR during 2019 was 0.4 mrem. The dose contribution to the MEI from all ORNL radiological airborne release points was 1 percent of the ORR dose. This dose is well below the Rad-NESHAPs standard of 10 mrem and is equal to approximately 0.10 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.)

Table 5.7. Radiological airborne emissions from all sources at Oak Ridge National Laboratory, 2019 (Ci)[a]

Isotope	Inhalation form[b]	Chemical form	Stack									
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915	Total minor sources	ORNL total
^{225}Ac	M	particulate									2.18E-06	2.18E-06
^{226}Ac	M	particulate									1.07E-07	1.07E-07
^{227}Ac	M	particulate									1.86E-08	1.86E-08
^{228}Ac	M	particulate									1.6E-27	1.6E-27
^{106}Ag	M	particulate									7.E-34	7.E-34
^{108}Ag	B	unspecified									1.94E-20	1.94E-20
^{108m}Ag	M	particulate									3.67E-14	3.67E-14
^{109m}Ag	B	unspecified									9.79E-21	9.79E-21
^{110}Ag	B	unspecified									3.1E-15	3.1E-15
^{110m}Ag	M	particulate									1.67E-09	1.67E-09
^{111}Ag	M	particulate									4.23E-06	4.23E-06
^{112}Ag	M	particulate									5.62E-08	5.62E-08
^{241}Am	F	particulate			1.03E-07		9.31E-09	3.59E-07			3.24E-09	4.75E-07
^{241}Am	M	particulate	3.81E-08	4.93E-07		5.53E-10			1.4E-08		6.4E-07	1.19E-06
^{242}Am	M	particulate									3.59E-10	3.59E-10
^{242m}Am	M	particulate									3.62E-10	3.62E-10
^{243}Am	M	particulate									2.11E-08	2.11E-08
^{245}Am	M	particulate									3.29E-27	3.29E-27
^{246}Am	M	particulate									3.98E-32	3.98E-32
^{39}Ar	B	unspecified									1.25E-10	1.25E-10
^{41}Ar	B	unspecified							4.43E+02	1.9E+01		4.62E+02
^{217}At	B	unspecified									9.05E-24	9.05E-24
^{131}Ba	M	particulate									2.15E-06	2.15E-06
^{133}Ba	M	particulate									2.65E-05	2.65E-05
^{136m}Ba	M	particulate									8.34E-22	8.34E-22
^{137m}Ba	B	unspecified									2.82E-06	2.82E-06

Table 5.7. Radiological airborne emissions from all sources at ORNL, 2019 (Ci)[a] (continued)

Isotope	Inhalation form[b]	Chemical form	Stack									
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915	Total minor sources	ORNL total
^{139}Ba	M	particulate							3.02E-01			3.02E-01
^{140}Ba	M	particulate							5.57E-04		7.28E-07	5.58E-04
^{7}Be	M	particulate	2.57E-07	4.28E-07		9.69E-07					6.64E-06	8.29E-06
^{7}Be	S	particulate			7.34E-06		7.71E-08				2.79E-06	1.02E-05
^{10}Be	M	particulate									9.67E-20	9.67E-20
^{206}Bi	M	particulate									3.21E-07	3.21E-07
^{208}Bi	B	unspecified									5.14E-35	5.14E-35
^{209}Bi	B	unspecified									1.25E-42	1.25E-42
^{210}Bi	M	particulate									7.8E-25	7.8E-25
^{210m}Bi	M	particulate									3.34E-35	3.34E-35
^{211}Bi	B	unspecified									5.82E-11	5.82E-11
^{212}Bi	M	particulate									4.14E-07	4.14E-07
^{213}Bi	M	particulate									9.06E-24	9.06E-24
^{214}Bi	M	particulate									1.3E-23	1.3E-23
^{249}Bk	M	particulate									7.E-11	7.E-11
^{250}Bk	M	particulate									8.75E-29	8.75E-29
^{82}Br	M	particulate									6.58E-08	6.58E-08
^{11}C	G	dioxide								1.35E+04		1.35E+04
^{14}C	M	particulate									2.74E-11	2.74E-11
^{45}Ca	M	particulate									1.16E-09	1.16E-09
^{47}Ca	M	particulate									1.08E-10	1.08E-10
^{109}Cd	M	particulate									1.59E-11	1.59E-11
^{113}Cd	M	particulate									3.18E-30	3.18E-30
^{113m}Cd	M	particulate									1.27E-10	1.27E-10
^{115}Cd	M	particulate									1.16E-06	1.16E-06
^{115m}Cd	M	particulate									8.84E-17	8.84E-17
^{139}Ce	M	particulate									2.26E-08	2.26E-08

Table 5.7. Radiological airborne emissions from all sources at ORNL, 2019 (Ci)[a] (continued)

Isotope	Inhalation form[b]	Chemical form	Stack									
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915	Total minor sources	ORNL total
^{141}Ce	M	particulate							2.43E-07		5.44E-07	7.87E-07
^{142}Ce	M	particulate									8.26E-27	8.26E-27
^{143}Ce	M	particulate									8.38E-08	8.38E-08
^{144}Ce	M	particulate									5.47E-07	5.47E-07
^{249}Cf	M	particulate									1.11E-11	1.11E-11
^{250}Cf	M	particulate									2.44E-11	2.44E-11
^{251}Cf	M	particulate									1.86E-13	1.86E-13
^{252}Cf	M	particulate							1.13E-08		4.53E-08	5.66E-08
^{253}Cf	M	particulate									2.42E-32	2.42E-32
^{254}Cf	M	particulate									4.26E-30	4.26E-30
^{36}Cl	M	particulate									5.64E-14	5.64E-14
^{241}Cm	M	particulate									1.57E-22	1.57E-22
^{242}Cm	M	particulate									1.47E-11	1.47E-11
^{243}Cm	F	particulate						8.70E-08			3.58E-10	8.74E-08
^{243}Cm	M	particulate	6.55E-08								2.92E-07	3.58E-07
^{244}Cm	F	particulate						8.70E-08			3.58E-10	8.74E-08
^{244}Cm	M	particulate	6.55E-08								4.34E-06	4.41E-06
^{245}Cm	M	particulate									5.46E-09	5.46E-09
^{246}Cm	M	particulate									4.76E-09	4.76E-09
^{247}Cm	M	particulate									1.41E-11	1.41E-11
^{248}Cm	M	particulate									2.51E-09	2.51E-09
^{249}Cm	M	particulate									7.53E-35	7.53E-35
^{250}Cm	M	particulate									2.95E-32	2.95E-32
^{57}Co	M	particulate									2.59E-09	2.59E-09
^{58}Co	M	particulate									2.08E-11	2.08E-11
^{60}Co	S	particulate			6.72E-06							6.72E-06
^{60}Co	M	particulate									7.09E-07	7.09E-07

Table 5.7. Radiological airborne emissions from all sources at ORNL, 2019 (Ci)[a] (continued)

Isotope	Inhalation form[b]	Chemical form	Stack									
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915	Total minor sources	ORNL total
^{51}Cr	M	particulate				2.38E-06					2.53E-04	2.55E-04
^{131}Cs	F	particulate									2.2E-06	2.2E-06
^{132}Cs	F	particulate									1.04E-07	1.04E-07
^{134}Cs	F	particulate									9.66E-07	9.66E-07
^{135}Cs	F	particulate									1.87E-11	1.87E-11
^{136}Cs	F	particulate									8.93E-07	8.93E-07
^{137}Cs	S	particulate			2.27E-05						1.51E-04	1.73E-04
^{137}Cs	F	particulate	9.31E-07	4.87E-06					5.45E-06		2.71E-04	2.82E-04
^{138}Cs	F	particulate							1.09E+03			1.09E+03
^{64}Cu	M	particulate									3.E-05	3.E-05
^{67}Cu	M	particulate									1.06E-08	1.06E-08
^{169}Er	M	particulate									3.31E-30	3.31E-30
^{253}Es	M	particulate									9.4E-31	9.4E-31
^{254}Es	M	particulate									8.72E-29	8.72E-29
^{150}Eu	M	particulate									1.15E-19	1.15E-19
^{152}Eu	M	particulate									3.99E-07	3.99E-07
^{154}Eu	M	particulate									4.3E-07	4.3E-07
^{155}Eu	M	particulate									4.58E-08	4.58E-08
^{156}Eu	M	particulate									4.63E-19	4.63E-19
^{55}Fe	M	particulate									7.24E-06	7.24E-06
^{59}Fe	M	particulate									2.96E-06	2.96E-06
^{221}Fr	B	unspecified									8.86E-24	8.86E-24
^{223}Fr	M	particulate									2.96E-24	2.96E-24
^{68}Ga	M	particulate									7.37E-12	7.37E-12
^{72}Ga	M	particulate									1.13E-11	1.13E-11
^{152}Gd	M	particulate									1.92E-29	1.92E-29
^{153}Gd	M	particulate									2.19E-10	2.19E-10

Table 5.7. Radiological airborne emissions from all sources at ORNL, 2019 (Ci)[a] (continued)

Isotope	Inhalation form[b]	Chemical form	Stack									
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915	Total minor sources	ORNL total
^{68}Ge	M	particulate									7.37E-12	7.37E-12
^{71}Ge	M	particulate									8.44E-10	8.44E-10
^{3}H	V	vapor	2.93E-03		2.36E+00	1.16E-03	4.97E-01		7.63E+01	9.57E+02	9.56E+00	1.05E+03
^{175}Hf	M	particulate									4.11E-08	4.11E-08
^{181}Hf	M	particulate									9.08E-07	9.08E-07
^{166m}Ho	M	particulate									1.9E-12	1.9E-12
^{126}I	F	particulate				9.82E-05					1.57E-07	9.84E-05
^{129}I	F	particulate						1.15E-06			1.37E-05	1.49E-05
^{131}I	F	particulate				1.55E-02			6.65E-02		2.68E-06	8.2E-02
^{132}I	F	particulate				3.55E-02			4.86E-01			5.22E-01
^{133}I	F	particulate							2.84E-01			2.84E-01
^{134}I	F	particulate							5.41E-02			5.41E-02
^{135}I	F	particulate							8.81E-01			8.81E-01
^{113m}In	M	particulate									2.62E-09	2.62E-09
^{114}In	B	unspecified									2.11E-11	2.11E-11
^{114m}In	M	particulate									2.18E-11	2.18E-11
^{115}In	M	particulate									1.53E-27	1.53E-27
^{115m}In	M	particulate									5.95E-21	5.95E-21
^{40}K	M	particulate									3.68E-07	3.68E-07
^{42}K	M	particulate									1.03E-11	1.03E-11
^{81}Kr	B	unspecified									1.08E-11	1.08E-11
^{85}Kr	B	unspecified							2.61E+02		1.57E+02	4.18E+02
^{85m}Kr	B	unspecified							8.73E+00			8.73E+00
^{87}Kr	B	unspecified							5.07E+01	2.8E+01		7.87E+01
^{88}Kr	B	unspecified							5.44E+01	1.5E+01		6.94E+01
^{89}Kr	B	unspecified							3.39E+01			3.39E+01
^{138}La	M	particulate									2.95E-26	2.95E-26

Table 5.7. Radiological airborne emissions from all sources at ORNL, 2019 (Ci)[a] (continued)

Isotope	Inhalation form[b]	Chemical form	Stack									
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915	Total minor sources	ORNL total
^{140}La	M	particulate									7.36E-07	7.36E-07
^{176m}Lu	M	particulate									3.39E-13	3.39E-13
^{177}Lu	M	particulate									6.67E-05	6.67E-05
^{177m}Lu	M	particulate									8.12E-09	8.12E-09
^{54}Mn	M	particulate									3.27E-07	3.27E-07
^{56}Mn	M	particulate									5.33E-12	5.33E-12
^{100}Mo	M	particulate									6.26E-29	6.26E-29
^{93}Mo	M	particulate									4.22E-12	4.22E-12
^{99}Mo	M	particulate									1.75E-06	1.75E-06
^{13}N	B	unspecified								2.92E+02		2.92E+02
^{22}Na	M	particulate									9.36E-10	9.36E-10
^{24}Na	M	particulate									3.95E-06	3.95E-06
^{91}Nb	B	unspecified									1.74E-11	1.74E-11
^{92}Nb	B	unspecified									6.95E-43	6.95E-43
^{93m}Nb	M	particulate									1.17E-09	1.17E-09
^{94}Nb	M	particulate									7.21E-11	7.21E-11
^{95}Nb	M	particulate									3.19E-07	3.19E-07
^{95m}Nb	M	particulate									7.12E-15	7.12E-15
^{96}Nb	M	particulate									9.67E-09	9.67E-09
^{97}Nb	M	particulate									5.95E-09	5.95E-09
^{144}Nd	B	unspecified									2.14E-25	2.14E-25
^{147}Nd	M	particulate									2.12E-07	2.12E-07
^{150}Nd	M	particulate									6.51E-30	6.51E-30
^{59}Ni	M	particulate									7.82E-12	7.82E-12
^{63}Ni	M	particulate									3.39E-03	3.39E-03
^{235}Np	M	particulate									1.24E-16	1.24E-16
^{236}Np	M	particulate									3.35E-19	3.35E-19

Table 5.7. Radiological airborne emissions from all sources at ORNL, 2019 (Ci)[a] (continued)

Isotope	Inhalation form[b]	Chemical form	Stack									
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915	Total minor sources	ORNL total
^{237}Np	M	particulate									9.49E-08	9.49E-08
^{238}Np	M	particulate									7.25E-16	7.25E-16
^{239}Np	M	particulate									3.16E-09	3.16E-09
^{240m}Np	B	unspecified									1.08E-20	1.08E-20
^{32}P	M	particulate									1.65E-09	1.65E-09
^{228}Pa	M	particulate									5.5E-09	5.5E-09
^{230}Pa	M	particulate									3.72E-07	3.72E-07
^{231}Pa	M	particulate									6.63E-16	6.63E-16
^{232}Pa	M	particulate									1.4E-08	1.4E-08
^{233}Pa	M	particulate									3.8E-06	3.8E-06
^{234}Pa	M	particulate									1.41E-20	1.41E-20
^{234m}Pa	B	unspecified									1.1E-17	1.1E-17
^{209}Pb	M	particulate									9.18E-24	9.18E-24
^{210}Pb	M	particulate									7.83E-25	7.83E-25
^{211}Pb	M	particulate									2.16E-22	2.16E-22
^{212}Pb	S	particulate			5.51E+00		6.25E-02				4.93E-02	5.62E+00
^{212}Pb	M	particulate	4.15E-01	4.05E-01		7.87E-03			2.11E-02		4.14E-07	8.49E-01
^{214}Pb	S	particulate			3.18E-01							3.18E-01
^{214}Pb	M	particulate				1.08E-03					1.3E-23	1.08E-03
^{107}Pd	M	particulate									3.74E-12	3.74E-12
^{146}Pm	M	particulate									3.43E-12	3.43E-12
^{147}Pm	M	particulate									8.46E-08	8.46E-08
^{148}Pm	M	particulate									3.E-10	3.E-10
^{148m}Pm	M	particulate									2.75E-08	2.75E-08
^{210}Po	B	inorganic									5.87E-12	5.87E-12
^{211}Po	B	unspecified									6.58E-25	6.58E-25
^{212}Po	B	unspecified									3.51E-25	3.51E-25

Table 5.7. Radiological airborne emissions from all sources at ORNL, 2019 (Ci)[a] (continued)

Isotope	Inhalation form[b]	Chemical form	Stack									
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915	Total minor sources	ORNL total
^{213}Po	B	unspecified									8.85E-24	8.85E-24
^{214}Po	B	unspecified									1.3E-23	1.3E-23
^{215}Po	B	unspecified									2.16E-22	2.16E-22
^{216}Po	B	unspecified									5.65E-19	5.65E-19
^{218}Po	B	unspecified									1.28E-23	1.28E-23
^{143}Pr	M	particulate									5.46E-19	5.46E-19
^{144}Pr	M	particulate									1.73E-09	1.73E-09
^{144m}Pr	B	unspecified									3.52E-13	3.52E-13
^{236}Pu	M	particulate									1.12E-09	1.12E-09
^{237}Pu	M	particulate									2.39E-17	2.39E-17
^{238}Pu	F	particulate			2.93E-08		2.05E-08	4.12E-07			1.91E-09	4.64E-07
^{238}Pu	M	particulate	2.73E-08	1.07E-07					6.4E-08		1.71E-04	1.71E-04
^{239}Pu	F	particulate			2.67E-07		1.08E-08	1.51E-07			2.35E-08	4.52E-07
^{239}Pu	M	particulate	1.52E-08	6.15E-07					2.44E-08		6.32E-05	6.39E-05
^{240}Pu	F	particulate			2.67E-07		1.08E-08	1.51E-07			2.47E-09	4.31E-07
^{240}Pu	M	particulate	1.52E-08	6.15E-07					2.44E-08		1.42E-05	1.49E-05
^{241}Pu	M	particulate									2.61E-03	2.61E-03
^{242}Pu	M	particulate									6.34E-09	6.34E-09
^{243}Pu	M	particulate									4.97E-17	4.97E-17
^{244}Pu	M	particulate									2.85E-12	2.85E-12
^{246}Pu	M	particulate									6.2E-29	6.2E-29
^{222}Ra	B	unspecified									6.71E-30	6.71E-30
^{223}Ra	M	particulate									2.34E-06	2.34E-06
^{224}Ra	M	particulate									9.13E-07	9.13E-07
^{225}Ra	M	particulate									1.09E-07	1.09E-07
^{226}Ra	M	particulate									1.E-07	1.E-07
^{228}Ra	M	particulate									6.41E-10	6.41E-10

Table 5.7. Radiological airborne emissions from all sources at ORNL, 2019 (Ci)[a] (continued)

Isotope	Inhalation form[b]	Chemical form	Stack									
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915	Total minor sources	ORNL total
^{86}Rb	M	particulate									6.82E-17	6.82E-17
^{87}Rb	M	particulate									5.97E-16	5.97E-16
^{186}Re	M	particulate									5.49E-10	5.49E-10
^{188}Re	M	particulate									2.63E-08	2.63E-08
^{102}Rh	M	particulate									6.03E-13	6.03E-13
^{103m}Rh	M	particulate									6.25E-11	6.25E-11
^{105}Rh	M	particulate									5.44E-07	5.44E-07
^{106}Rh	B	unspecified									1.26E-08	1.26E-08
^{218}Rn	B	unspecified									6.39E-27	6.39E-27
^{219}Rn	B	unspecified									3.8E-11	3.8E-11
^{220}Rn	B	unspecified									4.14E-07	4.14E-07
^{222}Rn	B	unspecified									8.58E-11	8.58E-11
^{103}Ru	M	particulate									1.45E-06	1.45E-06
^{106}Ru	M	particulate									9.95E-07	9.95E-07
^{120m}Sb	M	particulate									1.46E-07	1.46E-07
^{122}Sb	M	particulate				7.42E-03					3.01E-07	7.42E-03
^{124}Sb	M	particulate				8.22E-03					1.99E-07	8.22E-03
^{125}Sb	M	particulate				1.07E-03					2.01E-08	1.07E-03
^{126}Sb	M	particulate				1.75E-02					5.26E-07	1.75E-02
^{126m}Sb	M	particulate									2.23E-11	2.23E-11
^{127}Sb	M	particulate									4.53E-07	4.53E-07
^{46}Sc	M	particulate									1.2E-08	1.2E-08
^{47}Sc	M	particulate									7.37E-08	7.37E-08
^{48}Sc	M	particulate									2.36E-07	2.36E-07
^{75}Se	F	particulate									2.08E-05	2.08E-05
^{75}Se	S	particulate			1.1E-05							1.1E-05
^{79}Se	F	particulate									1.65E-13	1.65E-13

Table 5.7. Radiological airborne emissions from all sources at ORNL, 2019 (Ci)[a] (continued)

Isotope	Inhalation form[b]	Chemical form	Stack									
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915	Total minor sources	ORNL total
^{145}Sm	M	particulate									2.91E-10	2.91E-10
^{146}Sm	M	particulate									2.74E-19	2.74E-19
^{147}Sm	M	particulate									1.44E-16	1.44E-16
^{148}Sm	B	unspecified									7.58E-24	7.58E-24
^{151}Sm	M	particulate									1.11E-08	1.11E-08
^{113}Sn	M	particulate									2.61E-09	2.61E-09
^{117m}Sn	M	particulate									9.76E-08	9.76E-08
^{119m}Sn	M	particulate									6.23E-10	6.23E-10
^{121}Sn	M	particulate									1.64E-10	1.64E-10
^{121m}Sn	M	particulate									1.37E-11	1.37E-11
^{123}Sn	M	particulate									1.06E-11	1.06E-11
^{125}Sn	M	particulate									3.63E-07	3.63E-07
^{126}Sn	M	particulate									2.48E-11	2.48E-11
^{85}Sr	M	particulate									1.51E-07	1.51E-07
^{89}Sr	S	particulate			7.7E-06		2.06E-08				2.19E-06	9.91E-06
^{89}Sr	M	particulate	7.9E-08	2.18E-06		5.45E-09			6.45E-06		9.44E-05	1.03E-04
^{90}Sr	S	particulate			7.7E-06		2.06E-08	2.17E-06			2.46E-06	1.24E-05
^{90}Sr	M	particulate	7.9E-08	2.18E-06		5.45E-09			6.45E-06		1.17E-04	1.25E-04
^{91}Sr	M	particulate									1.19E-11	1.19E-11
^{182}Ta	M	particulate									7.3E-08	7.3E-08
^{183}Ta	M	particulate									5.4E-06	5.4E-06
^{160}Tb	M	particulate									3.41E-13	3.41E-13
^{161}Tb	M	particulate						1.22E+01			4.63E-27	1.22E+01
^{96}Tc	M	particulate									1.97E-08	1.97E-08
^{98}Tc	M	particulate									5.13E-19	5.13E-19
^{99}Tc	M	particulate									2.E-05	2.E-05
^{99m}Tc	M	particulate									6.56E-09	6.56E-09

Table 5.7. Radiological airborne emissions from all sources at ORNL, 2019 (Ci)[a] (continued)

Isotope	Inhalation form[b]	Chemical form	Stack									
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915	Total minor sources	ORNL total
^{121}Te	M	particulate									4.05E-08	4.05E-08
^{121m}Te	M	particulate									5.41E-09	5.41E-09
^{123}Te	M	particulate									5.66E-30	5.66E-30
^{123m}Te	M	particulate									1.04E-14	1.04E-14
^{125m}Te	M	particulate									1.58E-09	1.58E-09
^{127}Te	M	particulate									1.56E-11	1.56E-11
^{127m}Te	M	particulate									1.59E-11	1.59E-11
^{128}Te	M	particulate									4.19E-27	4.19E-27
^{129}Te	M	particulate									4.78E-13	4.78E-13
^{129m}Te	M	particulate									7.34E-13	7.34E-13
^{130}Te	M	particulate									2.4E-31	2.4E-31
^{131m}Te	M	particulate									9.13E-08	9.13E-08
^{132}Te	M	particulate									3.03E-07	3.03E-07
^{226}Th	S	particulate									6.48E-27	6.48E-27
^{227}Th	S	particulate									1.61E-06	1.61E-06
^{228}Th	S	particulate	7.7E-09	1.01E-08	1.9E-08	7.04E-10	5.88E-09		1.2E-08		6.02E-07	6.57E-07
^{229}Th	S	particulate									4.09E-08	4.09E-08
^{230}Th	S	particulate	3.67E-09	1.03E-08		5.93E-10			4.27E-09		3.04E-08	4.92E-08
^{230}Th	F	particulate			2.87E-08		1.31E-09				1.71E-09	3.17E-08
^{231}Th	S	particulate									3.57E-10	3.57E-10
^{232}Th	F	particulate			2.04E-08		1.12E-09				1.75E-09	2.33E-08
^{232}Th	S	particulate	3.62E-09	1.34E-09		6.84E-10			4.93E-09		3.7E-03	3.7E-03
^{234}Th	S	particulate									6.37E-09	6.37E-09
^{44}Ti	M	particulate									9.45E-11	9.45E-11
^{206}Tl	B	unspecified									3.36E-35	3.36E-35
^{207}Tl	B	unspecified									2.16E-22	2.16E-22
^{208}Tl	B	unspecified									4.14E-07	4.14E-07

Table 5.7. Radiological airborne emissions from all sources at ORNL, 2019 (Ci)[a] (continued)

Isotope	Inhalation form[b]	Chemical form	Stack									
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915	Total minor sources	ORNL total
^{209}Tl	B	Unspecified									1.95E-25	1.95E-25
^{170}Tm	M	Particulate									1.96E-20	1.96E-20
^{171}Tm	M	Particulate									1.75E-19	1.75E-19
^{230}U	M	Particulate									6.38E-30	6.38E-30
^{232}U	M	Particulate									1.74E-07	1.74E-07
^{233}U	S	Particulate			4.93E-08		7.7E-09				2.58E-08	8.28E-08
^{233}U	M	Particulate	3.52E-08	2.83E-07		2.50E-09			1.91E-08		3.63E-08	3.76E-07
^{234}U	S	Particulate			4.93E-08		7.7E-09				2.58E-08	8.28E-08
^{234}U	M	Particulate	3.52E-08	2.83E-07		2.50E-09			1.91E-08		5.14E-07	8.53E-07
^{235}U	S	Particulate			4.96E-09		4.98E-10				1.79E-09	7.25E-09
^{235}U	M	Particulate	3.31E-10	9.26E-09							7.08E-06	7.09E-06
^{236}U	M	Particulate									1.83E-11	1.83E-11
^{237}U	M	Particulate									1.78E-16	1.78E-16
^{238}U	S	Particulate			4.64E-08		3.52E-09				8.18E-09	5.81E-08
^{238}U	M	Particulate	7.58E-09	4.05E-08		2.30E-09			3.17E-08		2.01E-05	2.02E-05
^{240}U	M	Particulate									3.44E-17	3.44E-17
^{49}V	M	Particulate									7.35E-09	7.35E-09
^{181}W	M	Particulate									4.94E-11	4.94E-11
^{185}W	M	Particulate									2.39E-08	2.39E-08
^{187}W	M	Particulate									2.74E-09	2.74E-09
^{188}W	M	Particulate									4.31E-08	4.31E-08
^{127}Xe	B	Unspecified								6.4E+01	5.43E-22	6.4E+01
^{129m}Xe	B	Unspecified									1.25E-30	1.25E-30
^{131m}Xe	B	Unspecified							1.51E+02		7.68E-22	1.51E+02
^{133}Xe	B	Unspecified				9.64E-04			1.03E+01		1.1E-31	1.03E+01
^{133m}Xe	B	Unspecified							2.83E+01			2.83E+01
^{135} Xe	B	Unspecified							5.26E+01			5.26E+01

Table 5.7. Radiological airborne emissions from all sources at ORNL, 2019 (Ci)[a] (continued)

Isotope	Inhalation form[b]	Chemical form	Stack									
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915	Total minor sources	ORNL total
^{135m}Xe	B	Unspecified							3.88E+01			3.88E+01
^{136}Xe	B	Unspecified									3.67E-31	3.67E-31
^{137}Xe	B	Unspecified							1.08E+02			1.08E+02
^{138}Xe	B	Unspecified							2.22E+02			2.22E+02
^{90}Y	M	Particulate									2.3E-06	2.3E-06
^{91}Y	M	Particulate									2.1E-11	2.1E-11
^{169}Yb	M	Particulate									2.33E-08	2.33E-08
^{175}Yb	M	Particulate									4.92E-06	4.92E-06
^{65}Zn	M	Particulate									2.4E-05	2.4E-05
^{69}Zn	M	Particulate									9.87E-07	9.87E-07
^{69m}Zn	M	Particulate									9.2E-07	9.2E-07
^{93}Zr	M	Particulate									7.6E-08	7.6E-08
^{95}Zr	M	Particulate									7.73E-07	7.73E-07
^{97}Zr	M	Particulate									3.72E-09	3.72E-09
Totals			**4.18E-01**	**4.05E-01**	**8.19E+00**	**9.64E-02**	**5.6E-01**	**4.57E-06**	**2.64E+03**	**1.49E+04**	**1.67E+02**	**1.77E+04**

[a]Emissions given in curies (Ci). 1 Ci = 3.7E+10 Bq
[b]The designation of F, M, and S refers to the lung clearance type—fast (F), moderate (M), and slow (S) for the given radionuclide. G stands for gaseous, V stands for vapor, and B stands for blank, unspecified form.

Acronym:
ORNL = Oak Ridge National Laboratory

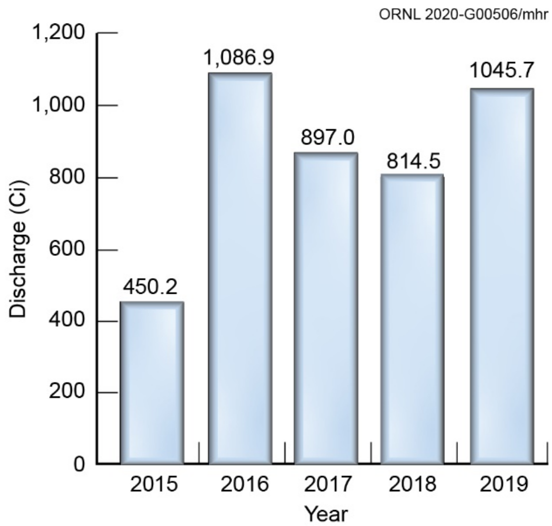


Figure 5.8. Total curies of tritium discharged from Oak Ridge National Laboratory to the atmosphere, 2015–2019

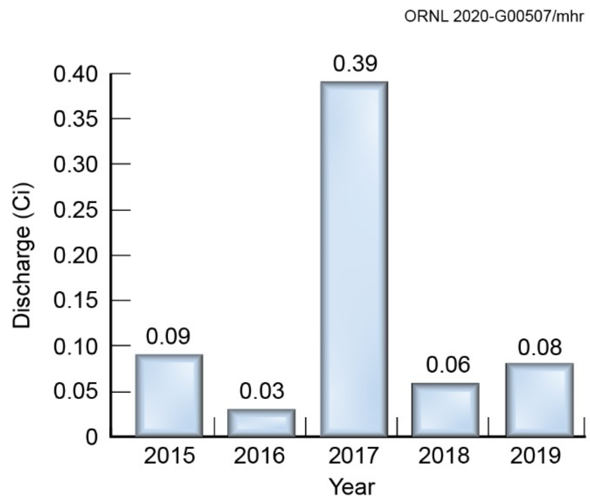


Figure 5.9. Total curies of ^{131}I discharged from Oak Ridge National Laboratory to the atmosphere, 2015–2019

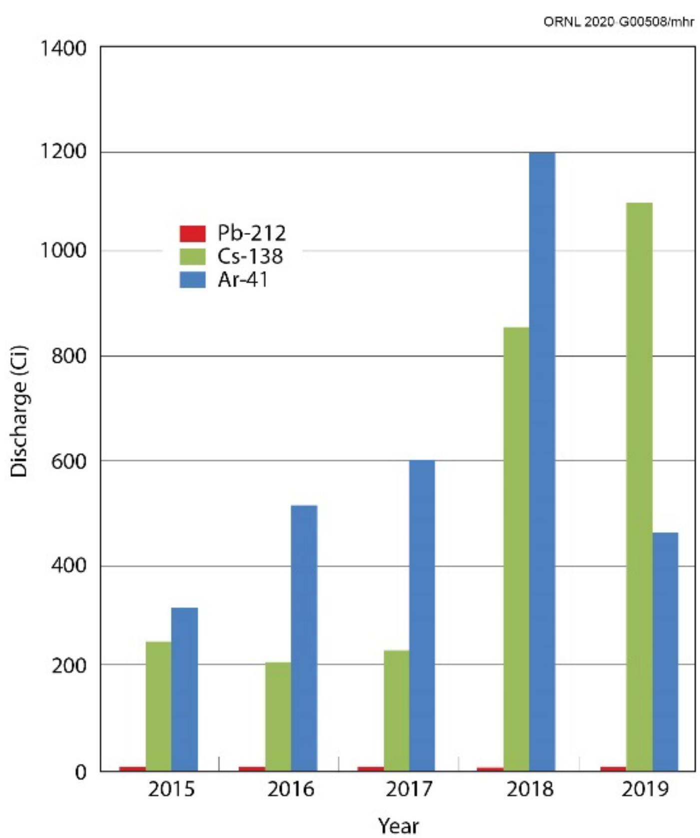


Figure 5.10. Total curies of ^{41}Ar, ^{138}Cs, and ^{212}Pb discharged from Oak Ridge National Laboratory to the atmosphere, 2015–2019

5.4.4 Stratospheric Ozone Protection

As required by the CAA Title VI Amendments of 1990 and in accordance with 40 CFR Part 82, actions have been implemented to comply with the prohibition against intentionally releasing ozone-depleting substances (ODSs) during maintenance activities performed on refrigeration equipment. In 2017, EPA enacted major revisions to the Stratospheric Ozone rules to include the regulation of non-ODS substitutes as part of 40 CFR 82 Subpart F. These revisions were effective January 1, 2018, for disposal of small appliances and January 1, 2019, for the leak rate provisions for large appliances. 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.

5.4.5 Ambient Air

Station 7 in the ORNL 7000 maintenance area is the site-specific ambient air monitoring location. During 2019, the sampling system at Station 7 was used to quantify levels of tritium; 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 tritium as tritiated water. The silica gel was collected biweekly or weekly, depending on ambient humidity, and was composited quarterly for tritium analysis. Station 7 sampling data (Table 5.8) are compared with derived concentration standards (DCSs) for air established by DOE as guidelines for controlling exposure to members of the public (DOE 2011a). During 2019 average radionuclide concentrations at Station 7 were less than 1 percent of the applicable DCSs in all cases.

Table 5.8. Radionuclide concentrations measured at Oak Ridge National Laboratory air monitoring Station 7, 2019

Parameter	Concentration (pCi/mL)[a]
Alpha	5.79E-09
^{7}Be	3.46E-08
Beta	1.86E-08
^{40}K	-2.74E-10[b]
Tritium	4.42E-06
^{234}U	1.87E-11
^{235}U	3.48E-13
^{238}U	1.69E-11
Total U	3.59E-11

[a] 1 pCi = 3.7×10^{-2} Bq.

[b] At very low sample activity levels, close to the instrument background, it is possible to obtain a sample result that is less than the background. When the background activity is subtracted from the sample activity to obtain a net value, a negative value results.

5.5 Oak Ridge National Laboratory Water Quality Program

NPDES permit TN 0002941, issued to DOE for the ORNL site and renewed by the State of Tennessee in 2019, 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 the development and implementation of 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 utilizing an adaptive management approach (Figure 5.11) whereby results of investigations are routinely evaluated and strategies for achieving goals are modified based on those evaluations. The goals established for 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 UT-Battelle 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 (BMAP), a chlorine control strategy, a storm water pollution prevention plan, a non-storm water best management practices plan, and an NPDES radiological monitoring plan.

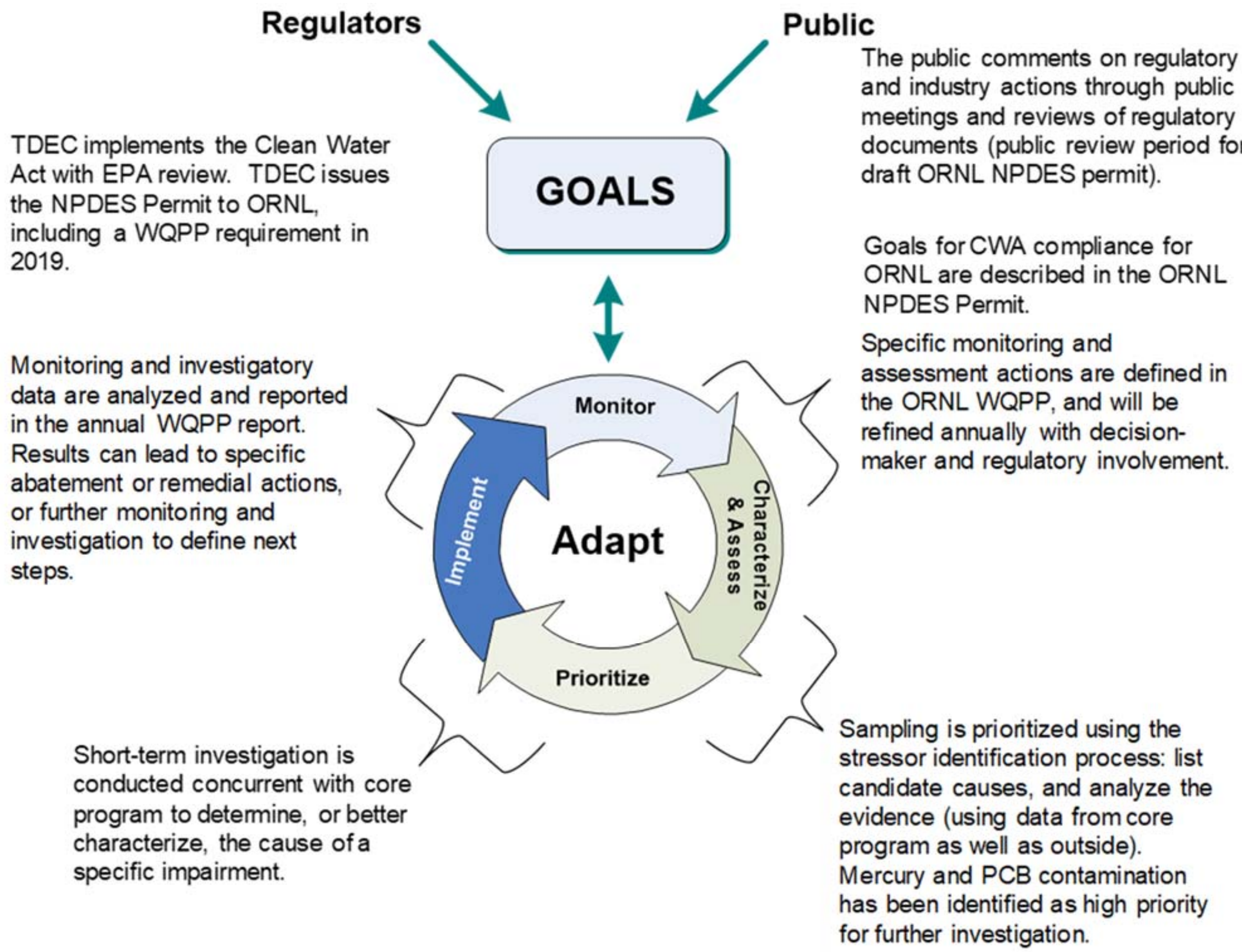
To prioritize the stressors and/or contaminant sources that may be of greatest concern to water quality and to define conceptual models that would guide any special investigations, the WQPP strategy was defined using EPA's Stressor Identification Guidance Document (EPA 2000a). Figure 5.12 summarizes that process. 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.

The first two steps of the stressor identification process were initiated in 2009, focusing first on mercury impairment (Figure 5.12) and then on PCB impairment because mercury and PCB concentrations in fish from White Oak Creek (WOC) are at or near human health risk thresholds (e.g., EPA ambient water quality criteria [AWQCs] and TDEC fish advisory limits). Some of the major sources of mercury to biota in the WOC watershed are known, providing a good basis from which to define an appropriate conceptual model for mercury contamination in WOC. A list of potential causes of PCB contamination was also developed.

After potential causes were listed and the available evidence of mercury and PCB contamination in the WOC watershed was analyzed, it was clear that additional investigation was needed to 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.

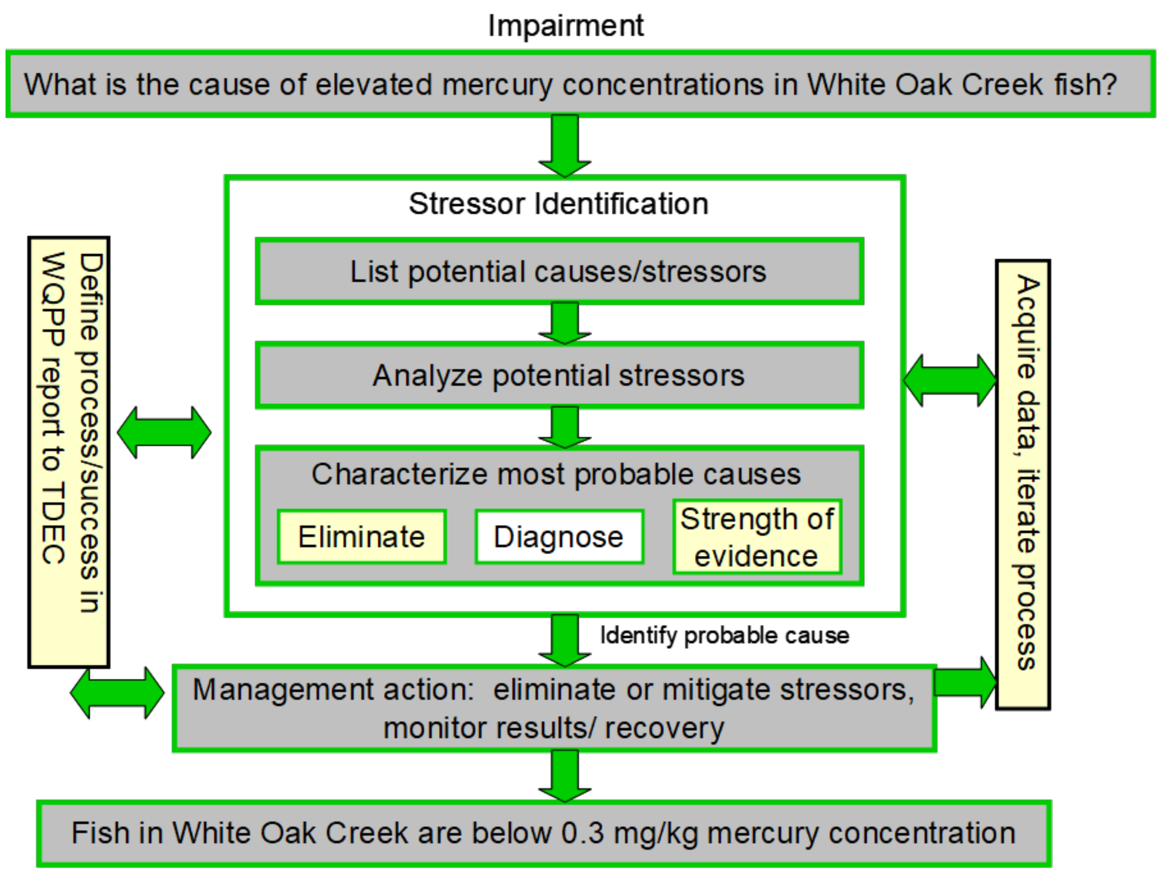
Monitoring and investigation data collected under the ORNL WQPP are analyzed, interpreted, reported, and compared with past results at least annually. The significant findings are reported in the *Annual Site Environmental Report*, and a more comprehensive report of findings is submitted to TDEC on a biannual basis. This information provides an assessment of 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.



Adapted from the US Environmental Protection Agency (EPA) stressor guidance document (EPA 2000a).

Acronyms:
CWA = Clean Water Act
NPDES = National Pollutant Discharge Elimination System
PCB = polychlorinated biphenyl
TDEC = Tennessee Department of Environment and Conservation
WQPP = Water Quality Protection Plan

Figure 5.11. Diagram of the adaptive management framework with step-wise planning specific to the Oak Ridge National Laboratory Water Quality Protection Plan



Modified from Figure 1-1 in the US Environmental Protection Agency stressor guidance document (EPA 2000a).

Acronyms:
TDEC = Tennessee Department of Environment and Conservation
WQPP = water quality protection plan

Figure 5.12. Application of stressor identification guidance to address mercury impairment in the White Oak Creek watershed

5.5.1 Treatment Facility Discharges

Two on-site wastewater treatment systems were operated at ORNL in 2019 to provide appropriate treatment of the various R&D, operational, and domestic wastewaters generated by site staff and activities. Both were permitted to discharge treated wastewater and were monitored under NPDES Permit TN0002941, issued by TDEC to DOE for the ORNL site. These are the ORNL STP (Outfall X01) and the ORNL PWTC (Outfall X12). 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 ORNL NPDES permit was last renewed by TDEC in May 2019. 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 Table 5.9. ORNL wastewater treatment facilities achieved 100 percent compliance with permit limits in 2019. One permit condition was not in compliance in 2019; a total suspended solids sample for Outfall X12 was not collected during the required quarterly reporting period. The sample was collected and reported during the next quarterly reporting period.

Table 5.9. National Pollutant Discharge Elimination System compliance at Oak Ridge National Laboratory, January through December 2019

Effluent parameters[a]	Permit limits					Permit compliance		
	Monthly average (lb/day)	Daily max. (lb/day)	Monthly average (mg/L)	Daily max. (mg/L)	Daily min. (mg/L)	Number of numeric noncompliances	Number of samples	Percentage of compliance[b]
				X01 (Sewage Treatment Plant)				
Ammonia, as N (summer)	6.26	9.39	2.5	3.75		0	26	100
Ammonia, as N (winter)	13.14	19.78	5.25	7.9		0	26	100
Carbonaceous biological oxygen demand	19.2	28.8	10	15		0	52	100
Dissolved oxygen					6	0	52	100
Escherichia coliform (col/100 mL)			941	126		0	52	100
Oil and grease				15		0	1	100
Peracetic acid			1			0	11	100
pH (standard units)				9	6	0	52	100
Total suspended solids	57.5	86.3	30	45		2[c]	52	>98
				X12 (Process Waste Treatment Complex)[d]				
Arsenic, total				0.014		0	1	100
Chromium, total				0.44		0	1	100
Copper, total				0.11		0	1	100
Cyanide, total				0.046		0	1	100
Lead, total				0.69		0	1	100
Oil and grease				15		0	7	100
pH (standard units)				9.0	6.0	0	52	100
Temperature (ºC)				30.5		0	52	100

[a] The Oak Ridge National Laboratory (ORNL) National Pollutant Discharge Elimination System (NPDES) Permit was reissued with modified effluent parameters limits, and monitoring frequencies which went into effect in June 2019.
[b] Percentage compliance = 100 – [(number of noncompliances/number of samples) × 100].
[c] A large storm in March 2019 caused heavy inflow into the ORNL sewage treatment plant, causing concentration and loading effluent limit noncompliances for total suspended solids.
[d] There were two nonnumeric permit noncompliances in 2019. A total suspended solids sample and an oil and grease sample for Outfall X12 were not collected during the required quarterly reporting period. The samples were collected and reported during the next quarterly reporting period.

Toxicity testing provides an assessment of any harmful effects that could occur from the total combined constituents in discharges from ORNL wastewater treatment facilities. Effluents from the STP have been required to be tested for toxicity to aquatic species under the NPDES permit every year 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. PWTC effluent has always been shown to be nontoxic. The STP has 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% was used in the testing.[2] In June 2019, chronic toxicity test results for the STP demonstrated (IC_{25}) values of > 100% for survival in *C. dubia*, and survival and growth in *P. promelas*. However, this test also indicated reduced fecundity in *C. dubia* (IC_{25} = 48.36%). While this value was not in violation of permit requirements (44.3%), confirmatory tests were initiated. Monthly follow-up chronic tests were conducted on STP effluent with *C. dubia,* with all results indicating IC_{25} values > 100%. Results from chronic tests using PWTC effluent in 2019 did not indicate toxicity in either species with all IC_{25} values > 100% (Table 5.10).

Table 5.10. Whole effluent toxicity testing, National Pollutant Discharge Elimination System compliance at Oak Ridge National Laboratory, 2019

Testing parameters[a]	Permit limits[a]		Permit compliance		
	IC_{25} permit limit (%)	IC_{25} test result (%)	Number of noncompliances	Number of samples	Percentage of compliance[b]
		X01 (Sewage Treatment Plant)			
C. dubia survival	44.3	100	0	1	100
C. dubia reproduction	44.3	48.36	0	1	100
P. promelas survival	44.3	100	0	1	100
P. promelas growth	44.3	100	0	1	100
		X12 (Process Waste Treatment Complex)			
C. dubia survival	44.3	100	0	1	100
C. dubia reproduction	44.3	100	0	1	100
P. promelas survival	44.3	100	0	1	100
P. promelas growth	44.3	100	0	1	100

[a] IC_{25} = inhibition concentration; the concentration (as a percentage of full-strength wastewater) that reduces survival or reproduction of the test species by 25% when compared to a control treatment.
[b] Percentage compliance = 100 – [(number of noncompliances/number of samples) × 100]

5.5.2 Residual Bromine and Chlorine Monitoring

ORNL receives its water supply from the City of Oak Ridge Water Treatment Plant, which uses chlorine as a final disinfectant. Before the water is distributed, 2.0 to 3.0 mg/L of free chlorine is typically added. On the ORNL site, this water is used for drinking, sanitary, and housekeeping purposes as well as for

[2] An inhibition concentration is a point estimate of the effluent concentration or dilution that would cause a given percentage (25 percent in this case) reduction with respect to a control in a toxicological endpoint such as survival, growth, or reproduction.

research and in cooling systems. After water is used, residual chlorine remains. If discharged to surface water, the residual chlorine can be toxic to fish and other aquatic life. Residual chlorine in sewage routed to the STP would damage the bacterial treatment system used in the biological digestion process if it were not used up en route. Any residual chlorine routed to process wastewater treatment is removed by final filtration. In the past, older water-cooled air-conditioning systems commonly discharged once-through cooling water to storm outfalls; all but one of these units have been replaced with air-cooled systems that discharge condensate to the ground or storm drains.

Although once-through cooling discharges have declined, the year-round demand has grown for cooling towers to condition/dehumidify space and to remove heat from instrumentation and computer systems. Additional chlorine- and bromine-based chemicals are added to already chlorinated supply water to control bacterial growth in cooling towers; anticorrosion chemicals are also added. When chlorine and bromine do not evaporate or are not consumed by bacterial growth in the tower, they are residual in the discharge. As the cooling towers lose water via evaporation, higher conductivity (caused by minerals such as calcium, which occur naturally in the water and do not evaporate), triggers blowdown that may contain these residual oxidants. ORNL uses 92 percent sodium sulfite tablets or a 38 to 40 percent liquid sodium bisulfite drip proportionate to flow to neutralize/dechlorinate these discharges. Twice a month, once-through cooling water and outfalls that receive cooling tower discharges are monitored for total residual oxidant (TRO). The remaining water-cooled air-conditioning system is monitored seasonally; less frequent monitoring is done at outfalls where infrastructure leaks have been found and fixed. In 2019, 23 locations (20 outfalls and 3 pipes above the instream dechlorinators) were monitored for TRO semimonthly, monthly, quarterly, or semiannually if flow was present. The TDEC NPDES permit load action level is 1.20 g/day TRO at the outfall. If TRO concentration is found at or above the field analytical detection limit (> 0.05 mg/L), steps are taken to improve dechlorination.

By the end of 2016, dechlorination systems had been installed at each cooling tower or cooling tower system source to reduce dependence on dechlorination performed at the creek level. In 2017, TRO exceedances continued, and all tablet feeder boxes at the sources were inspected. Eight of the boxes were repaired or replaced to keep tablets dry between flows and to improve contact between the discharged water and the sodium sulfite tablets. Since then, procedures have been implemented to stock fewer sodium sulfite tablets and to remove swollen tablets, which, although still chemically active, prevent appropriate water circulation around the tablets in the feed tubes.

Table 5.11 shows 2019 cooling tower discharges exceeding the TRO permit action level, despite multiple dechlorination checks each week and increased removal and replacement of swollen sodium sulfite tablets. In November 2018, the target range for oxidant used in cooling towers was modified from 1.50 to 1.00 mg/L of free halogen; it is not clear that the new target has been reached. It is hoped that lower levels of oxidant use in the main plant area will make dechlorination more effective and that it will eliminate TRO discharges from cooling towers.

Observation of discharge from Outfall 014 is scheduled twice a month; however, since the discharge consists only of cooling tower blowdown, up to three attempts to sample are made each month. During 2019, all but one of the monitored discharges exceeded the TRO load of 1.20 g/day. A sodium bisulfite dechlorination box is estimated to remove 2.0 mg/L Cl, so discharges prior to dechlorination may have contained up to 3.50 mg/L TRO. Weekly observations at Outfall 014 are scheduled in 2020 in an attempt to collect two samples per month.

Outfall 227 receives large blowdowns from the Building 5600 and 5511 cooling towers. There were no TRO exceedances at this Outfall in 2019. An old secondary dechlorination box located at the creek, is still utilized as a backup. Its use enables a total of about 4.0 mg/L TRO to be removed before the flow enters WOC. During 2019 each time TRO was monitored at the outfall, measurements were also taken above the secondary dechlorination box. There were five instances (February, June, July, and twice in September) when TRO discharge action limits would have been exceeded at the outfall without secondary treatment (+ 0.2–0.7 mg/L).

Outfall 363 is similar to Outfall 227 in that it receives multiple cooling tower flows, but from newer buildings, so a secondary dechlorinator is not installed at the creek. Instead, if source dechlorination is found to be inadequate, bags of sodium sulfite tablets are placed below the outfall pipe. Since 2017, the bags have been kept in place as backup and have been replenished multiple times a week. There were four TRO exceedances in 2019 at Outfall 363 despite the use of the bags, and simultaneous monitoring above the bags shows TRO present in June and August that was neutralized by the bags. Table 5.11 shows that an additional 0.2–0.6 mg/L TRO remains after dechlorination at the source.

There were two 2019 TRO exceedances at Outfall 281, located at HFIR. The first incident, in May, occurred while the towers were off-line for maintenance, and a temporary dechlorination system that had been working well for a month ran low on sodium bisulfide. Environmental Sciences Division staff who were doing a fish survey in Melton Branch found fish conspicuously absent below the outfall. HFIR personnel were notified and immediately fixed the problem. The creek was surveyed, and 13 dead fish were reported to TDEC. No further difficulties were encountered with the temporary dechlorination system, which was utilized through July 2. The second exceedance occurred in October as HFIR was restarting after being shut down. Between shift changes the sodium bisulfite level in the dechlorination system dropped below levels required for effective treatment. The problem was noticed within 12 hours, and the sodium bisulfite was replenished. The monitored flow was 100 gpm, less than one-fourth of the flow in May. Probably less than half the calculated load per day of sodium bisulfite was delivered by the time more was added; any adverse effects are unknown.

Research-generated once-through cooling water is still discharged through Outfalls 210 and 211, but due to water-recycling efforts, the flows are much lower than they were several years ago. There were no TRO exceedances at Outfall 210 in 2019. However, there were three exceedances at Outfall 211. That outfall receives multiple small cooling water sources, and two dechlorinator boxes are mounted in a weir where discharge enters the creek. When creek water rises, the dechlorinator boxes flood, and function is minimized until the water subsides and tablets are restocked. The February and March flow values at Outfall 211 of 100 gpm and 70 gpm indicate that there was abundant storm water mixing with the cooling water. Cooling water flows there in 2019 averaged 57 gpm but are generally < 25 gpm. The November flow of 5.0 gpm was low enough that it may not have received adequate contact with sodium sulfite tablets in either box (each set up for 50 gpm). Outfall 207 on WOC, downstream of the Fifth Creek confluence, receives no known chlorinated discharges, but TRO was found there on two occasions. Dry and wet catch-basin sampling is planned during 2020 to determine the source.

Outfall 231 currently receives blowdown from multiple Building 5800 cooling towers, and more towers are being installed during 2020. In 2019 there were three TRO exceedances at Outfall 231. Plans are being made to implement a liquid sodium bisulfite dechlorination system at the Building 5800 location.

In 2019, steps were taken to correct issues with the dechlorination systems at Outfalls 082 and 282, which are outfalls associated with MSRE. (The outfalls are monitored, but they are not listed on Table 5.11.) Outfall 082, which is located east of MSRE, receives once-through cooling water from a water-cooled air-conditioning system. Fresh tablets were added to the dechlorination system at Outfall 82 in May, after it was discovered that they needed to be replenished. In 2019, two issues were addressed at Outfall 282, which is located west of MSRE. A dechlorinator is installed at Outfall 282 to treat water from a small unidentified source. Fresh tablets were added to the dechlorination system in May, when it was found that they needed to be replenished, and the system was repaired in December, after high storm water flow had caused it to malfunction. UCOR, DOE's primary cleanup contractor for ORR, has offices at MSRE and has asked UT-Battelle Utilities for help in finding the unidentified source.

Table 5.11. Outfalls exceeding total residual oxidant National Pollutant Discharge Elimination System permit action level in 2019[a]

Outfall	Sample Date	TRO (mg/L)	Flow (gpm)	Load (g/day)	Receiving stream	Downstream integration point	Instream TRO point	TRO Source
014	5/9/19	0.40	80	84.07	WOC	WCK 4.4	X23	4510/4521 CTs
014	6/14/19	1.50	40	157.63	WOC	WCK 4.4	X23	4510/4521 CTs
014	8/19/19	1.40	35	128.73	WOC	WCK 4.4	X23	4510/4521 CTs
014	9/19/19	0.70	20	36.78	WOC	WCK 4.4	X23	4510/4521 CTs
207	7/30/19	0.10	0.1	0.03	WOC	WCK 4.1	X21	Unknown
207	12/16/19	0.10	8	2.10	WOC	WCK 4.1	X21	Unknown
211	02/27/19	0.70	100	183.90	WOC	WCK 4.4	X22	CW
211	03/06/19	0.10	70	18.39	WOC	WCK 4.4	X22	CW
211	11/11/19	1.04	5	13.66	WOC	WCK 4.4	X22	CW
231	5/9/19	0.10	10	2.63	WOC	WCK 4.4	X25	5800 CTs
231	5/23/19	0.10	15	3.94	WOC	WCK 4.4	X25	5800 CTs
231	7/5/19	1.20	10	31.53	WOC	WCK 4.4	X25	5800 CTs
281	5/23/19	0.20	450	236.44	MB	MEK.06	X27	7902 CTs
281	10/21/19	1.00	100	262.71	MB	MEK.06	X27	7902 CTs
363	5/9/19	0.60	15	23.64	Fifth Creek	FFK 0.2	X18	5300/5309 CTs
363	5/23/19	0.30	30	23.64	Fifth Creek	FFK 0.2	X18	5300/5309 CTs
363	7/5/19	0.30	30	23.64	Fifth Creek	FFK 0.2	X18	5300/5309 CTs
363	9/19/19	0.20	12	6.31	Fifth Creek	FFK 0.2	X18	5300/5309 CTs

[a] The NPDES action level is 1.2 g/day

Acronyms:
CT = cooling tower
CW = once-through cooling water
FFK = Fifth Creek kilometer MB = Melton Branch
MEK = Melton Branch kilometer
NPDES = National Pollutant Discharge Elimination System
TRO = total residual oxidant
WCK = White Oak Creek kilometer
WOC = White Oak Creek

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 details the analyses performed on samples collected in 2019 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). 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 2019, dry-weather grab samples were collected at 15 of the 20 category outfalls targeted for sampling. Five category outfalls (refer to Table 5.12) were not sampled because there was no discharge present during sampling attempts.

The two ORNL treatment facility outfalls that were monitored for radioactivity in 2019 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 5.13). At each treatment facility and instream monitoring location, monthly flow-proportional composite samples were collected using dedicated automatic water samplers.

For each radioisotope, a DCS is published in DOE directives and is used to evaluate discharges of radioactivity from DOE facilities (DOE 2011a). 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 NPDES Outfalls 085, 204, 302, 304, X01,and X12 and at instream sampling location WOD (X15) (Figure 5.14).

In 2019, two outfalls (085 and 304) had an annual mean radioactivity concentration greater than 100 percent of a DCS. Samples from both outfalls had an average total radioactive strontium ($^{89/90}$Sr) concentration that exceeded the DCS for ^{90}Sr (it is reasonable, for an ORNL environmental sample, to assume that $^{89/90}$Sr activity is comparable to ^{90}Sr activity due to the relatively short half-life of ^{89}Sr—50.55 days). The concentration of $^{89/90}$Sr was 200 and 130 percent of the DCS at Outfalls 085 and 304, respectively. Consequently, concentrations of radioactivity in the discharge from Outfalls 085 and 304 was also greater than the DCS level on a sum-of-fractions basis (i.e., the summation of DCS percentages of multiple radiological parameters); and the sum of the fractions was 213 and 137 percent for Outfalls 085 and 304, respectively.

Levels of radioactivity at Outfall 085 have been elevated since early 2015, when a water leak occurred in Building 7830A. The foundation drain for that building is connected to Outfall 085. The water leaked from a pipe in the building's fire suppression system that ruptured when it froze in the early morning hours of February 23, 2015. It is believed that leaked water mobilized underground contamination to a location where it could enter the building foundation drain. Concentrations have been declining since April 2015, although the rate of decline slowed in the latter part of 2016 and concentrations have not yet returned to levels that existed prior to 2015.

Levels of radioactivity in discharges from Outfall 304 have been elevated since 2014 because of two unrelated infrastructure issues. In 2014, a pump failed in a groundwater suppression sump near the DOE Office of Environmental Management (OREM) low-level liquid waste tank WC-9, which is within a CERCLA soil and groundwater contamination area. Without groundwater suppression in the tank farm area, contaminated groundwater enters the Outfall 304 storm drain system. A second infrastructure issue, which had an even greater influence on Outfall 304 radiological concentrations, occurred in 2015. A leak developed in a pipe leading from Pump Station #2 in the Process Waste Collection System to a downstream diversion box. A dye tracer test confirmed a hydraulic connection between the pipe and the storm water collection system that discharges through Outfall 304, and the pipe was subsequently bypassed and taken out of service. Before the leaky pipe was bypassed, the 89/90Sr concentration at Outfall 304 peaked at 29,000 pCi/L (August and September 2015). Since the bypass was implemented, 89/90Sr levels in the outfall effluent have trended downward, but they remained above DCS levels in 2019. No additional infrastructure issues affecting Outfall 304 have been discovered, and it is believed that concentrations of radioactivity at the outfall will slowly decline as concentrations of radioactivity in the groundwater surrounding the outfall pipe decline by means of normal hydrologic processes.

Table 5.12. Radiological monitoring conducted under the Oak Ridge National Laboratory Water Quality Protection Plan, 2019

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	Monthly	X	X	X		X			X[a]	X
Outfall 081	Annual	X								
Outfall 085	Quarterly	X	X	X		X				
Outfall 203	Annual	X	X			X				
Outfall 204	Semiannual	X	X			X				
Outfall 205[b]	Annual									
Outfall 207	Quarterly	X								
Outfall 211	Annual	X								
Outfall 234[b]	Annual									
Outfall 241[b]	Quarterly									
Outfall 265[b]	Annual									
Outfall 281	Quarterly	X		X						
Outfall 282	Quarterly	X								
Outfall 302	Monthly	X	X	X		X	X[a]	X[a]	X[a]	X[a]
Outfall 304	Monthly	X	X	X		X	X[a]	X[a]	X[a]	X[a]
Outfall 365	Semiannual	X								
Outfall 368[b]	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 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 May 2012 update to the Water Quality Protection Plan).
[b] The outfall was included in the monitoring plan, but samples were not collected because no discharge was present during sampling attempts.

Acronyms:
PWTC = Process Waste Treatment Complex
STP = Sewage Treatment Plant
WOC = White Oak Creek
WOD = White Oak Dam

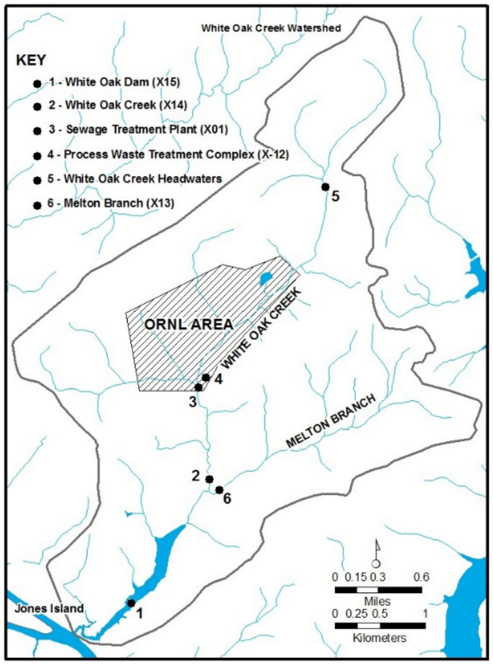


Figure 5.13. Selected surface water, National Pollutant Discharge Elimination System, and reference sampling locations at Oak Ridge National Laboratory, 2019

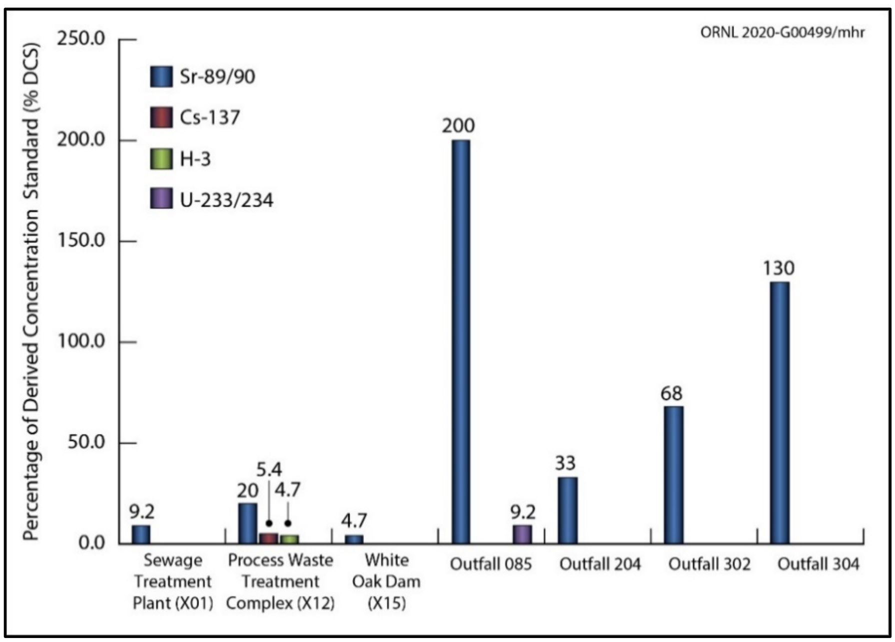


Figure 5.14. Outfalls and instream locations at Oak Ridge National Laboratory with average radionuclide concentrations greater than 4 percent of the relevant derived concentration standards in 2019

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 5.15 through 5.19. Because discharges of radioactivity are somewhat correlated to stream flow, annual flow volumes measured at the WOD monitoring station are given in Figure 5.20. Discharges of radioactivity at WOD in

2019 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 2019 also included monitoring during storm runoff conditions. Ten storm water outfalls were monitored. Storm water samples were analyzed for gross alpha, gross beta, $^{89/90}$Sr, and tritium activities. A gamma scan analysis was also performed. The monitoring plan calls for additional analyses to be added when sufficient gross alpha and/or beta activity is present in a sample to indicate that levels of radioactivity may exceed DCS levels, but in 2019 no additional analyses were required for storm water samples.

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 2019, the radionuclide $^{89/90}$Sr exceeded 4 percent of the relevant DCS concentration in wet-weather discharges from Outfall 304.

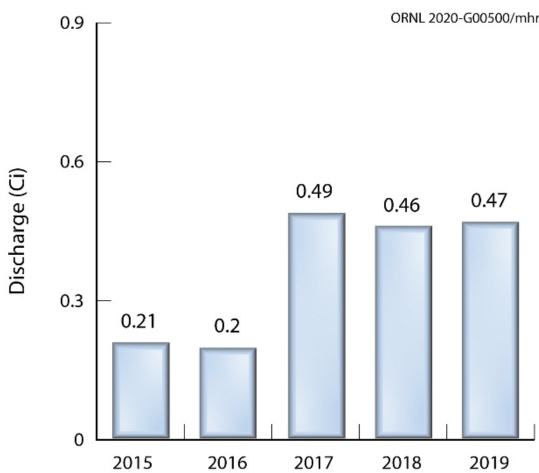


Figure 5.15. Cesium-137 discharges at White Oak Dam, 2015−2019

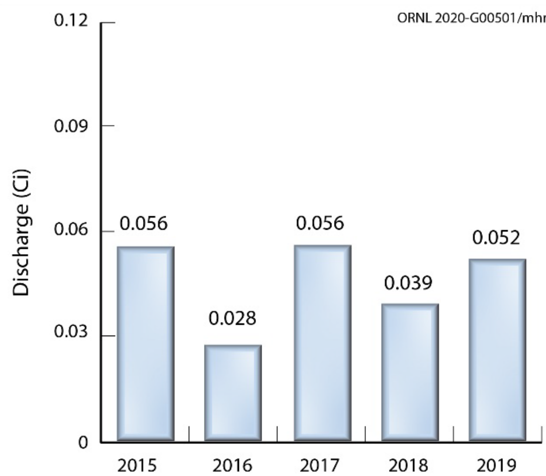


Figure 5.16. Gross alpha discharges at White Oak Dam, 2015−2019

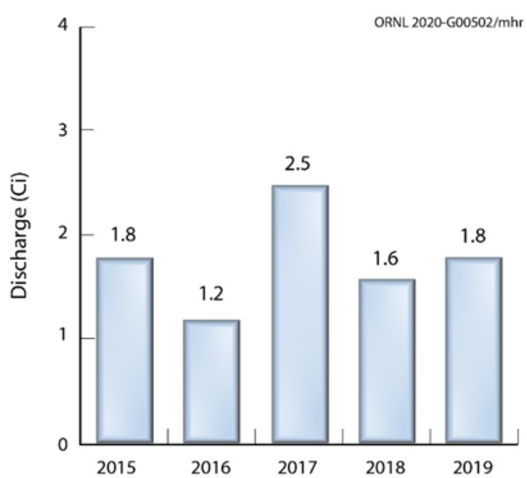


Figure 5.17. Gross beta discharges at White Oak Dam, 2015−2019

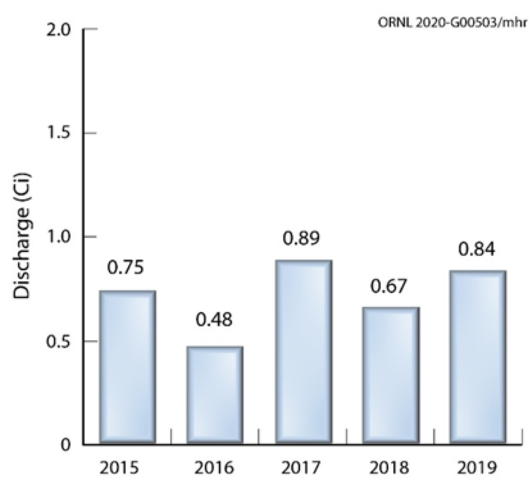


Figure 5.18. Total radioactive strontium discharges at White Oak Dam, 2015−2019

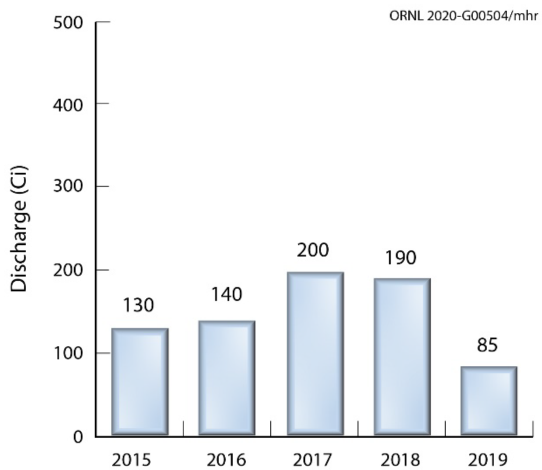


Figure 5.19. Tritium discharges at White Oak Dam, 2015−2019

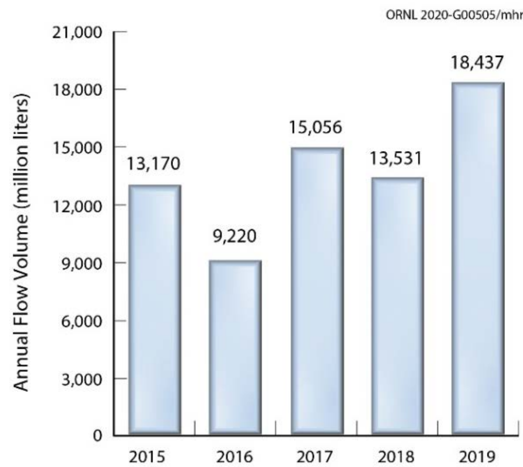


Figure 5.20. Annual flow volume at White Oak Dam, 2015−2019

5.5.4 Mercury in the White Oak Creek Watershed

During the mid-1950s, mercury was used for pilot-scale isotope separation work in Buildings 4501, 4505, and 3592 and in spent-fuel reprocessing in Building 3503.

5.5.4.1 Buildings 4501 and 4505

Buildings 4501 and 4505 are still active research facilities located east of Fifth Creek and north of WOC As active facilities, process wastewater discharges are routed to the PWTC. Building foundation sumps that had been routed south to storm Outfall 211 on WOC (Figure 5.21) and west to storm Outfall 363 on Fifth Creek were found to contain mercury and were re-routed to the PWTC between December 2007 and November 2010. Outfall 211 piping still receives storm, cooling water, and steam condensate discharges. Due to the persistence of elemental mercury, its volatility, and the complexity of its interactions in piping and soil, mercury continues to be a contaminant associated with Outfall 211.

5.5.4.2 Buildings 3592 and 3503

Buildings 3592 and 3503 were removed 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 has been found associated with process infrastructure 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.

ORNL 2018-G00384/mhr

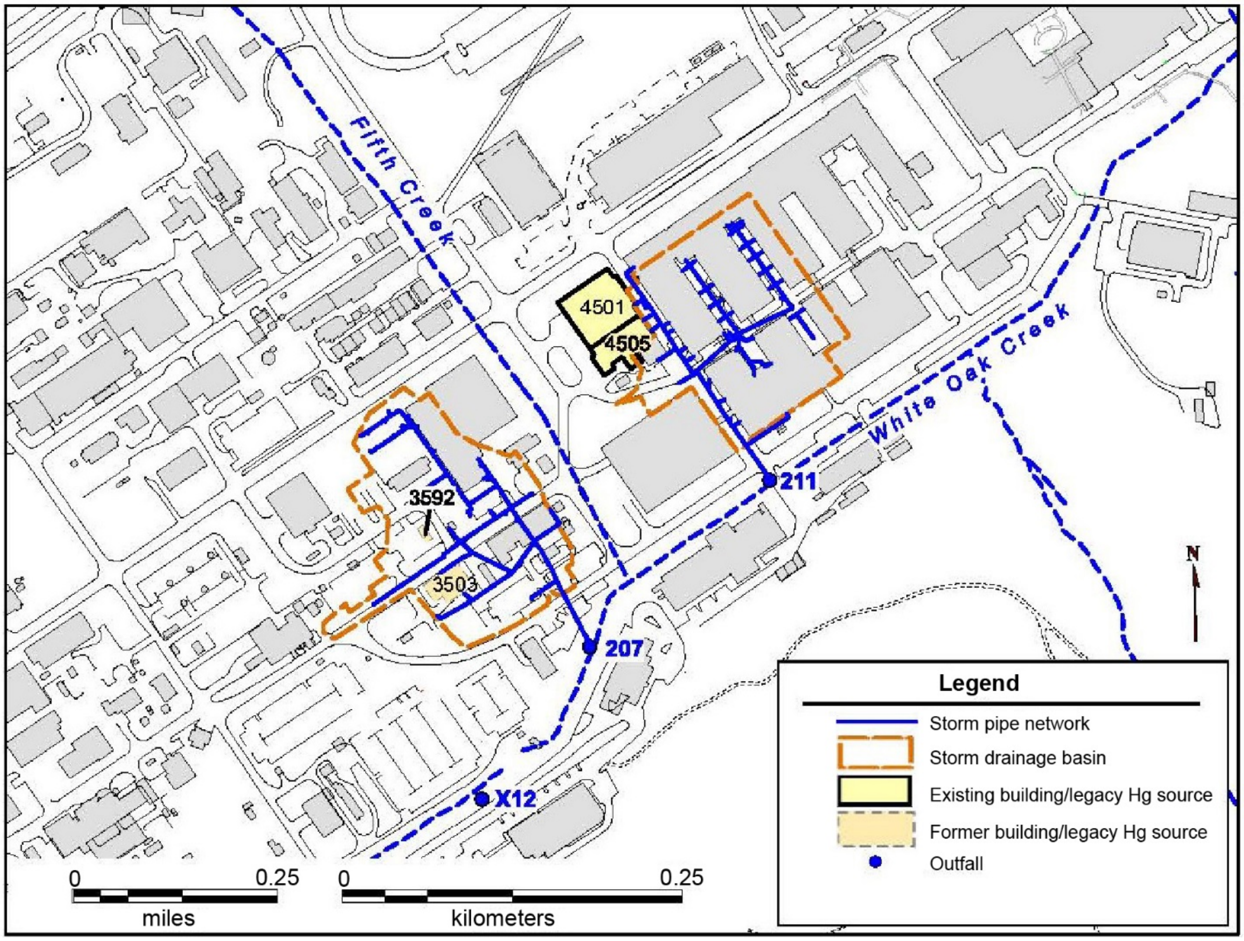


Figure 5.21. Outfalls with known historic mercury sources to White Oak Creek

5.5.4.3 Ambient Mercury in Water

Aqueous mercury monitoring in WOC, started in 1997, continues with quarterly water samples collected at four sites: White Oak Creek kilometer (WCK) 1.5, WCK 3.4, WCK 4.1, and WCK 6.8 (Figure 5.22). Stream conditions were selected to be representative of seasonal base-flow conditions (dry weather, clear flow) based on historical results that indicate higher mercury concentrations under those conditions.

Long-term trends in waterborne mercury in the WOC system downstream of ORNL are shown in Figure 5.23. The concentration of mercury in WOC upstream from ORNL (WCK 6.8) was less than 10 ng/L in 2019. Waterborne mercury concentrations downstream of ORNL were elevated but declined abruptly in 2008 and remained low through 2019 as a result of actions: (1) to lessen mercury discharges to WOC at Outfall 211 (sump reroutes to PWTC) and (2) to reduce discharges from PWTC (X12). In general, ambient concentrations have remained low since that time, with a few exceptions. A significant spike in mercury concentrations was seen at WCK 3.4 (downstream of Outfalls X12 and X01) in September 2018, and was likely due to issues with filters at the PWTC. Filters were changed in 2019 and mercury concentrations measured at WCK 3.4 dropped below the AWQC, averaging 13.84 $\pm$ 6.64 ng/L in 2019, compared with 55.49 ± 76.05 ng/L in 2018. In contrast, the mean total mercury concentration at WCK 4.1 increased to 26.46 $\pm$ 26.82 ng/L in 2019, from 17.17 ± 9.88 ng/L in 2018. Increases in concentration (~70 ng/L) exceeding the AWQC occurred in September 2019. In general, though, concentrations have been low with occasional spikes. The average aqueous mercury concentration at

WOD (WCK 1.5) was 34.01 ± 18.93 ng/L compared to 52.55 ± 27.59 ng/L in 2018. Mercury concentrations at WCK 1.5 are more variable than at other sites in WOC, likely because of the variability in total suspended solids at this site.

ORNL 2019-G00162/mhr

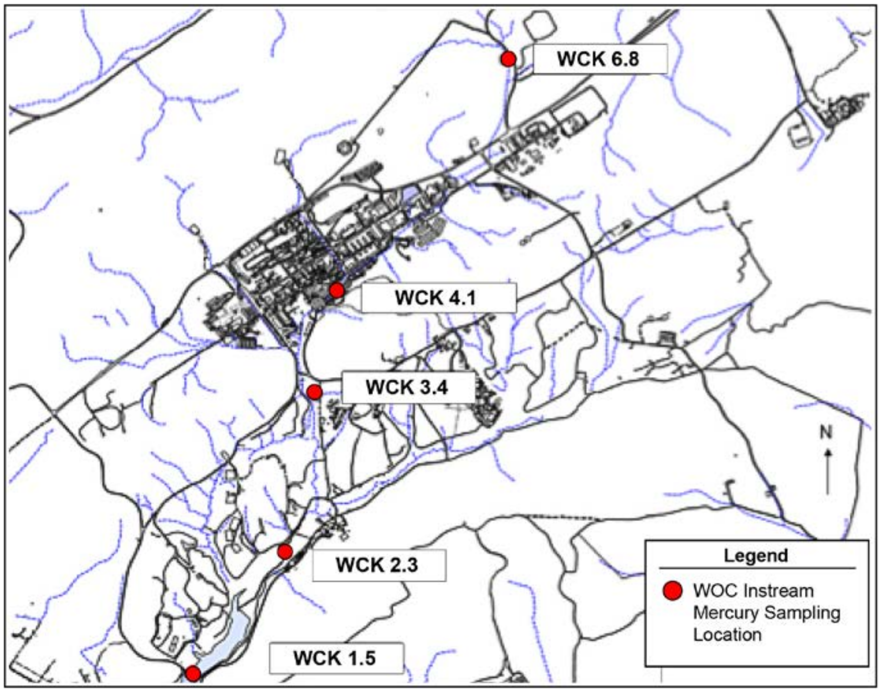
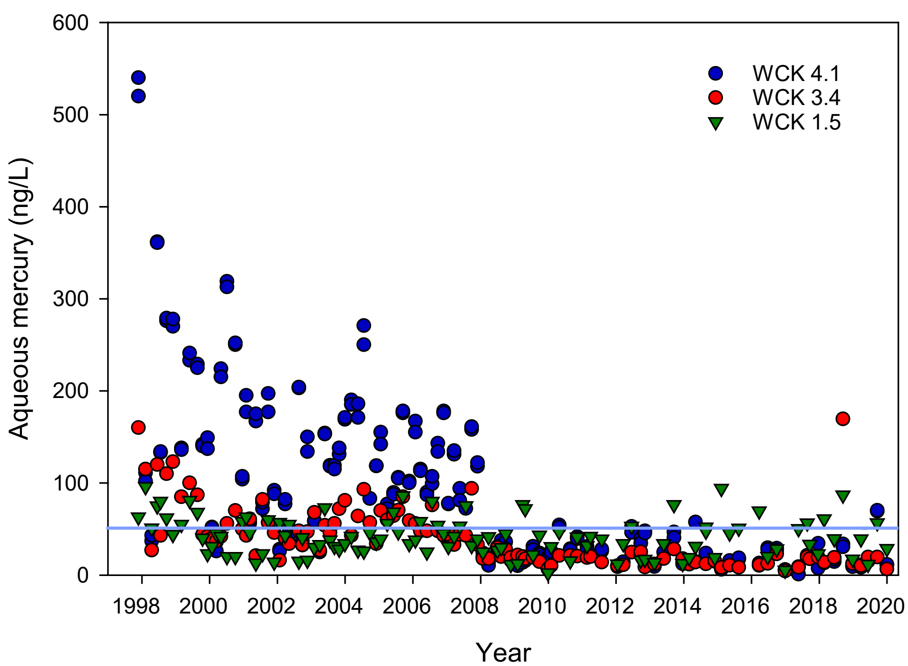


Figure 5.22. Instream mercury monitoring and data locations, 2019



The blue line at 51 ng/L shows the Recreational Water Quality Criteria for Water and Organisms.

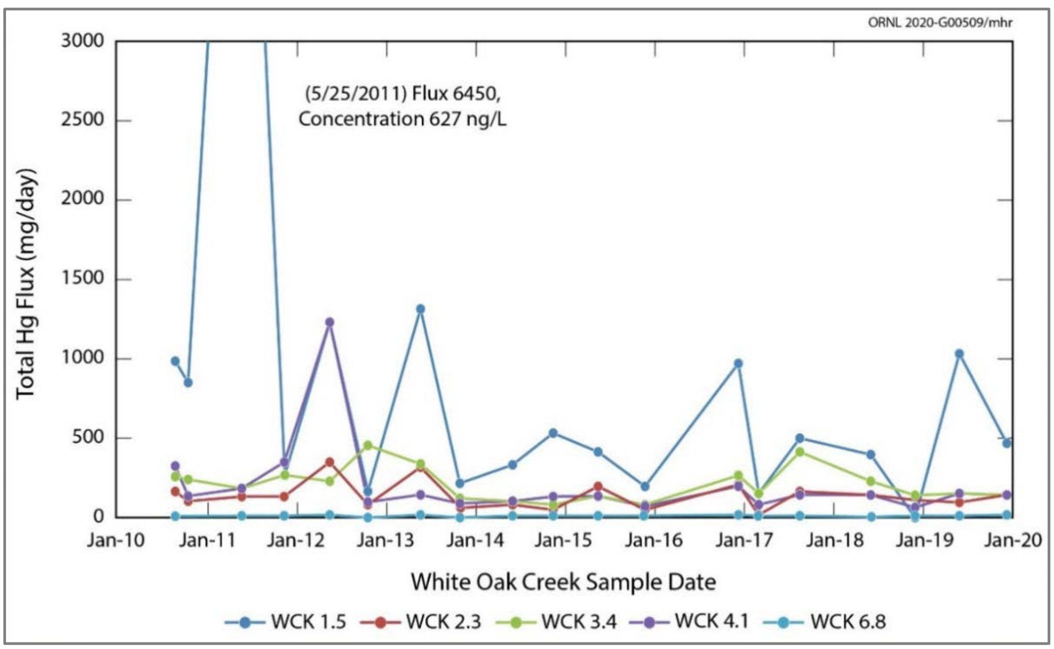
Acronym: WCK = White Oak Creek kilometer

Figure 5.23. Total aqueous mercury concentrations at sites in White Oak Creek downstream from Oak Ridge National Laboratory, 1998–2019

Water Quality Protection Plan Mercury Investigation

Twice a year, additional dry weather samples have been taken at instream locations shown in Figure 5.24, for calculation of total and dissolved mercury fluxes (i.e., the amount of a substance per unit time in flowing water) based on instream mercury concentrations and stream flow. It is now thought that the very low November 2018 mercury flux calculation for mercury at WOD is a data anomaly because it is lower than any other historical result at that site. In contrast, 2019 data show a higher mercury flux at WOD than has been seen since 2016: 1,020 mg/day (based on a concentration of 40 ng/L). Operational events during 2019 were examined to possibly explain the spring 2019 increase.

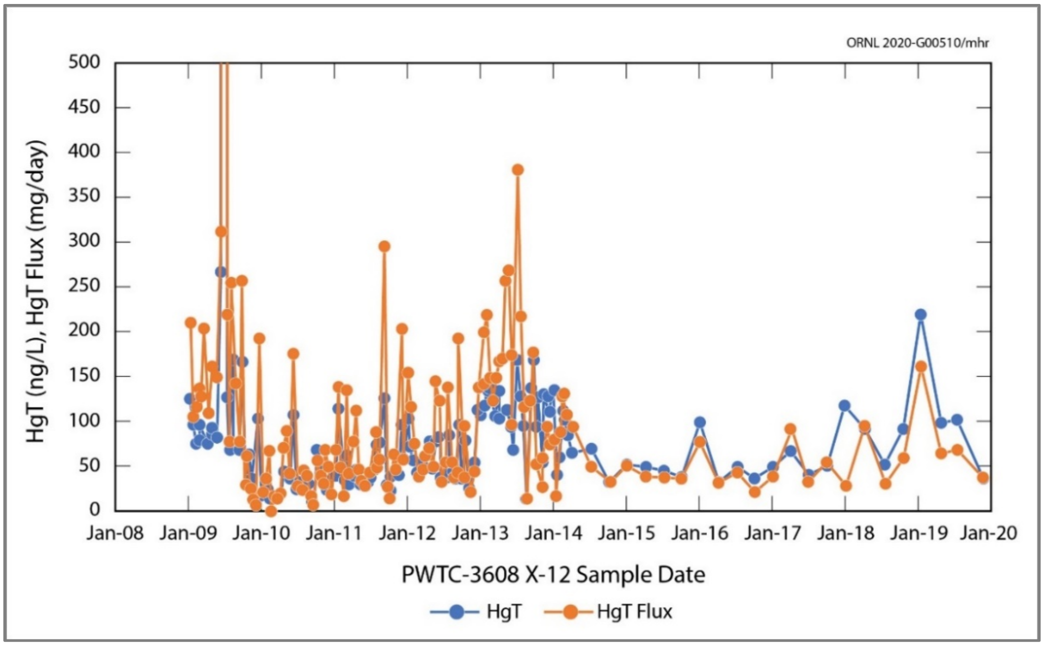
Monitoring of Hg concentrations in discharges from the two ORNL wastewater treatment plants is performed quarterly under the NPDES permit. Mercury discharge concentrations reached 219 ng/L at Outfall X12 (PWTC-3608) in January 2019, higher than any concentration measured since June 2009 (Figure 5.25). It is thought that in the process of changing out PWTC-3608 filters (September 2018–July 2019) the fluctuation in HgT discharge concentration increased. After final replacement of dual-media and MERSORB filters on July 25, 2019, mercury concentrations and fluxes through X12 dropped to 36 ng/L New sand filter media was also installed at the STP on July 14, 2019, lowering HgT concentrations in discharge through X01 from 46 ng/L in May to 2 ng/L in July. These filtration improvements appear to have also lowered concentrations at instream sampling points WCK 3.4 and at WCK 1.5 downstream of the treatment facilities. The HgT flux at WOD in December 2019 was about half of what it was in May.



Acronym: WCK = White Oak Creek kilometer

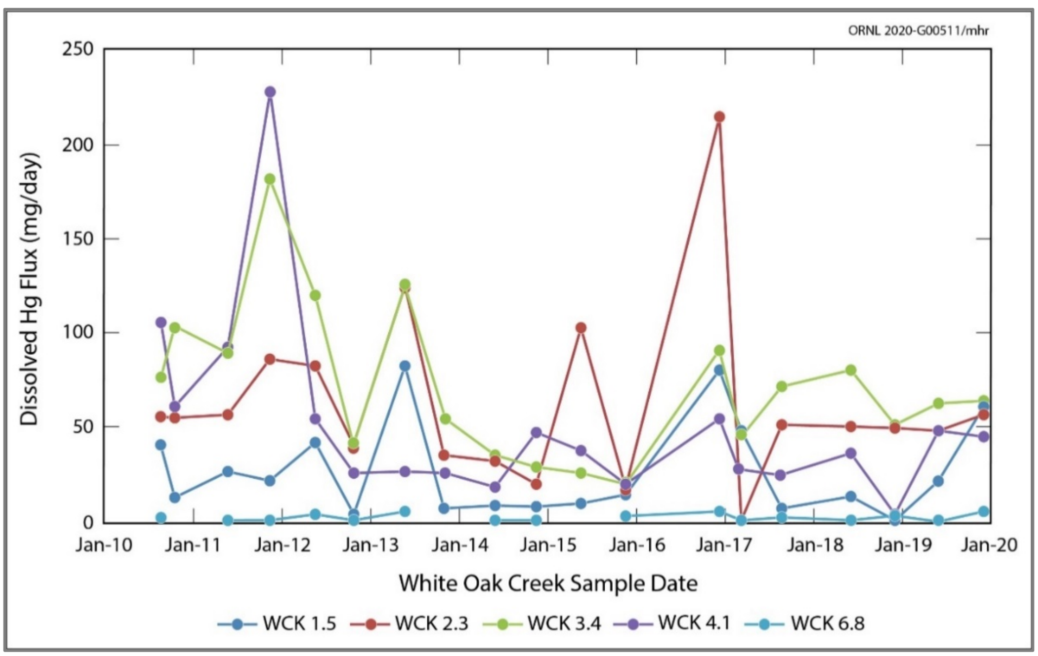
Figure 5.24. Total mercury fluxes (HgT, mg/day) at White Oak Creek instream monitoring locations WCK 1.5, WCK 2.3, WCK 3.4, WCK 4.1, and WCK 6.8; 2010–2019

Most of the total mercury flux at X15 (WOD) is associated with particulates and was three times higher in December 2019 (61 mg/day) than in May (22 mg/day). The corresponding dissolved mercury flux (Figure 5.26) is an order of magnitude lower. Dissolved mercury flux at WCK 2.3, upstream of the dam, was also slightly higher in December but remained relatively consistent at the four instream points (WCK1.5, WCK 2.3, WCK 3.4, and WCK 4.1). Between May and December 2019 three incidents occurred at storm outfalls that may have contributed mercury to WOC: a local rainfall on August 28, 2019 caused a PWTC pump station overflow to a storm drain (Outfall 304, at Third Street above WCK 3.4); a chilled water leak (September 13–October 2, 2019) to Outfall 211 increased flows by up to 15 gpm upstream of WCK 4.1; and a process transfer line began leaking to storm Outfall 403 (September 25, 2019), also located near Third Street above WCK 3.4. Those issues may have temporarily contributed mercury through storm piping.



Acronym: PWTC = Process Waste Treatment Complex

Figure 5.25 Total mercury concentration and total mercury flux (HgT) of PWTC-3608 discharges to White Oak Creek (Outfall X12), 2009–2019



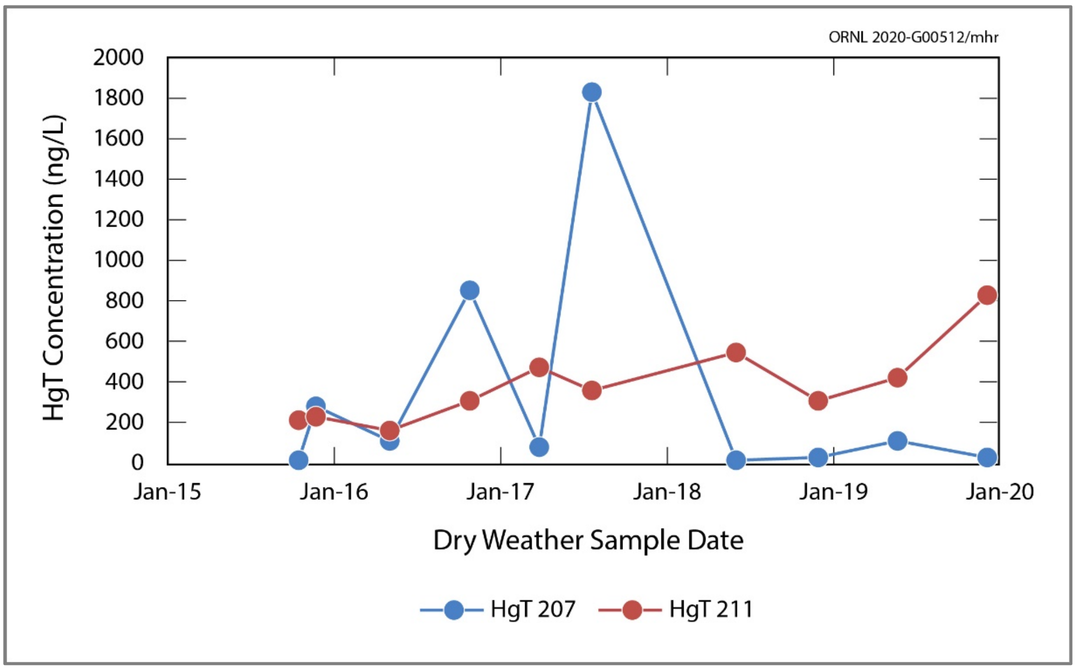
Acronym: WCK = White Oak Creek kilometer

Figure 5.26. Dissolved mercury fluxes (mg/day) at White Oak Creek instream monitoring locations WCK 1.5, WCK 2.3, WCK 3.4, WCK 4.1, and WCK 6.8; 2010–2019

Outfall Source Investigation

Individual outfalls that contribute mercury are investigated as part of the WQPP to better delineate mercury sources and to prioritize future abatement actions. Storm and treatment plant infrastructure improvements have historically reduced legacy mercury release to WOC. Discharges of mercury at Outfall 211 were reduced between 2007 and 2011 when foundation sumps (in Buildings 4501 and 4500N) were removed from storm drains and were redirected to the PWTC. In November 2009, pretreatment was installed on the main 4501 foundation sump, reducing the Hg concentrations in the outgoing sump wastewater (going to PWTC). Infrastructure upgrades in filtration technology at the PWTC have also reduced mercury release. In 2014 a MERSORB (sulfur-impregnated carbon filter optimized for mercury removal) filter replaced one granular activated carbon filter. On July 25, 2019, a new dual media filter and new MERSORB filters were installed at the PWTC. Figure 5.25 shows the effect that filtration improvements at the PWTC made in 2014 and again in May 2019; mercury concentrations discharged through Outfall X-12 dropped dramatically.

Historically, dry- and wet-weather samples taken at storm water Outfalls 211 and 207 have contained the highest concentrations of legacy mercury. Total mercury concentrations in the dry weather discharges are usually lower at Outfall 207 but have been similar to or higher than at Outfall 211 on several occasions (Figure 5.27).



(HgT = total mercury flux)

Figure 5.27. Dry weather total mercury concentration at Outfall 207 vs. Outfall 211

Outfall 207 does not receive any once-through cooling water, and very little steam condensate or foundation water reaches the outfall discharge. Thus flows during dry weather can be less than 1.0 gpm. Dry-weather flows and total mercury fluxes for Outfall 207 and 211 are compared in Figure 5.28, and Figure 5.29 shows only the small Outfall 207 dry weather flows and fluxes not discernable in Figure 5.28.

After water-recycling efforts were implemented in 2012, Outfall 211 cooling water discharge rates were reduced from flows often reaching 150 gpm to flows of generally less than 25 gpm. However, Outfall 211 discharges (above outfall dechlorination) contain once-through cooling water with residual chlorine, and the flows are still an order of magnitude larger than at Outfall 207. Much lower flows at Outfall 207 result in much lower mercury fluxes; even the highest mercury concentration (1,830 ng/L, measured on July 20, 2017), with a flow of 0.25 gpm, had a calculated flux of only about 1.0 mg Hg/day, resulting in the flux for Outfall 207 shown in Figure 5.28 being consistently less than 1.0 mg/day. The relationship between small dry-weather flows and flux (< 1.0 mg/day) at Outfall 207 is shown in Figure 5.29.

During larger storm flows, both Outfall 207 and Outfall 211 have contributed higher mercury fluxes to WOC, so attempts have been made to sample during larger storms. The highest HgT storm flux shown for Outfall 207 (see Figure 5.30) occurred in February 2017 (261 mg/day) due to a storm flow of 50 gpm with total mercury concentration of 956 ng/L. Associated dissolved mercury concentration was only 3 ng/L. Most mercury in Outfall 207 storm flow appears to be associated with particulates; dissolved mercury flux has not exceeded 30 mg/day, and higher dissolved amounts are not necessarily aligned with the largest storm flows. A sampling plan for storm catch basins within the Outfall 207 and adjacent storm drainage pipe networks is being developed to determine piping branches or sections that may contain sources of mercury. Utilities improvements and building construction are planned at the intersection of Outfalls 207 and 304 drainages west of Building 3500. There may be old piping as has been found in the Outfall 211 drainage that can be targeted for abatement/replacement.

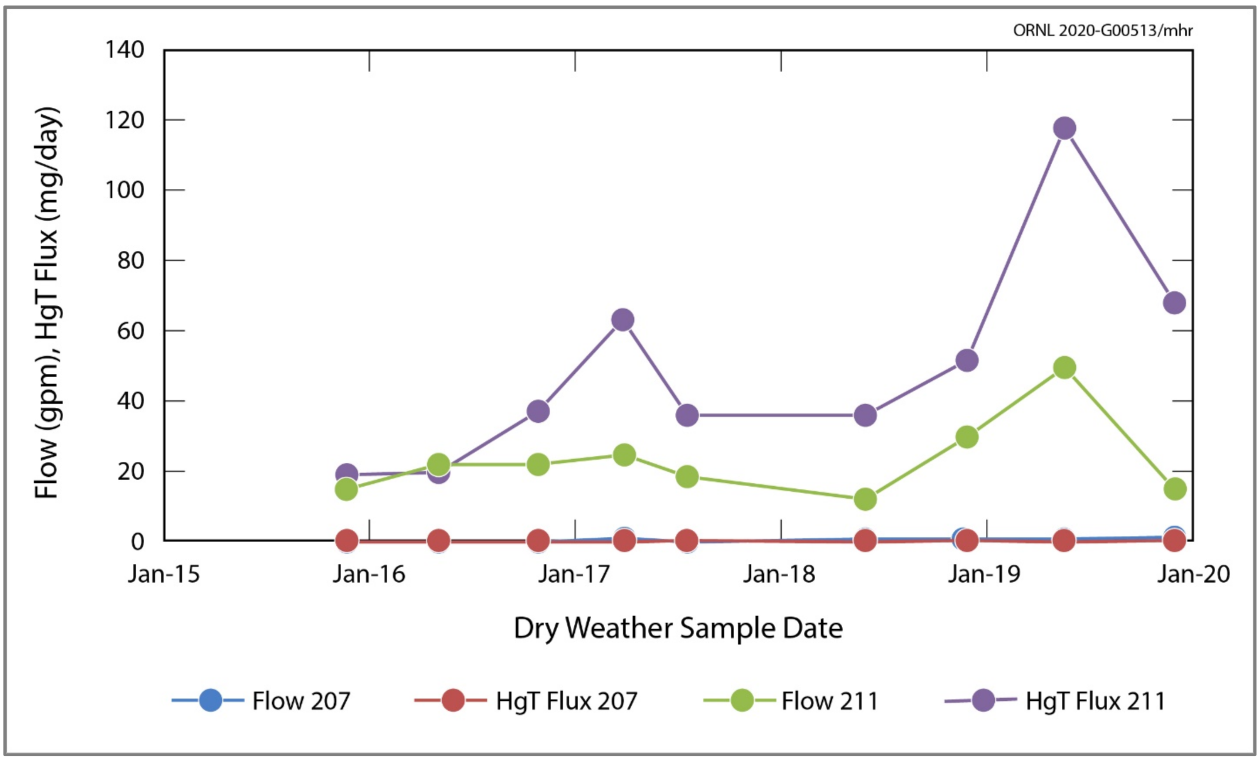


Figure 5.28. Dry-weather flows and fluxes at Outfall 207 vs. Outfall 211, 2015–2019

In 2010 a camera system was used to conduct an inspection inside the main Outfall 211 storm pipe. The upper older pipe sections had debris upstream of each pipe joint. In places, pipe sections had settled, and gaps had formed. Mercury can reside behind and within these irregularities. It is thought that sheltered mercury beads oxidize during dry periods; then the coatings are disturbed and dissolved by storm water and particularly by chlorinated once-through cooling water moving through the pipes. The volumes of dry-weather discharges have dropped at Outfall 211 since 2012, when water conservation efforts were made to recirculate once-through cooling water. Figure 5.31 shows that mercury concentrations of dry-weather discharges to Outfall 211 have been gradually increasing since then, with the highest in December of 2019 (830 ng/L) as flux has remained at about 50 mg/day.

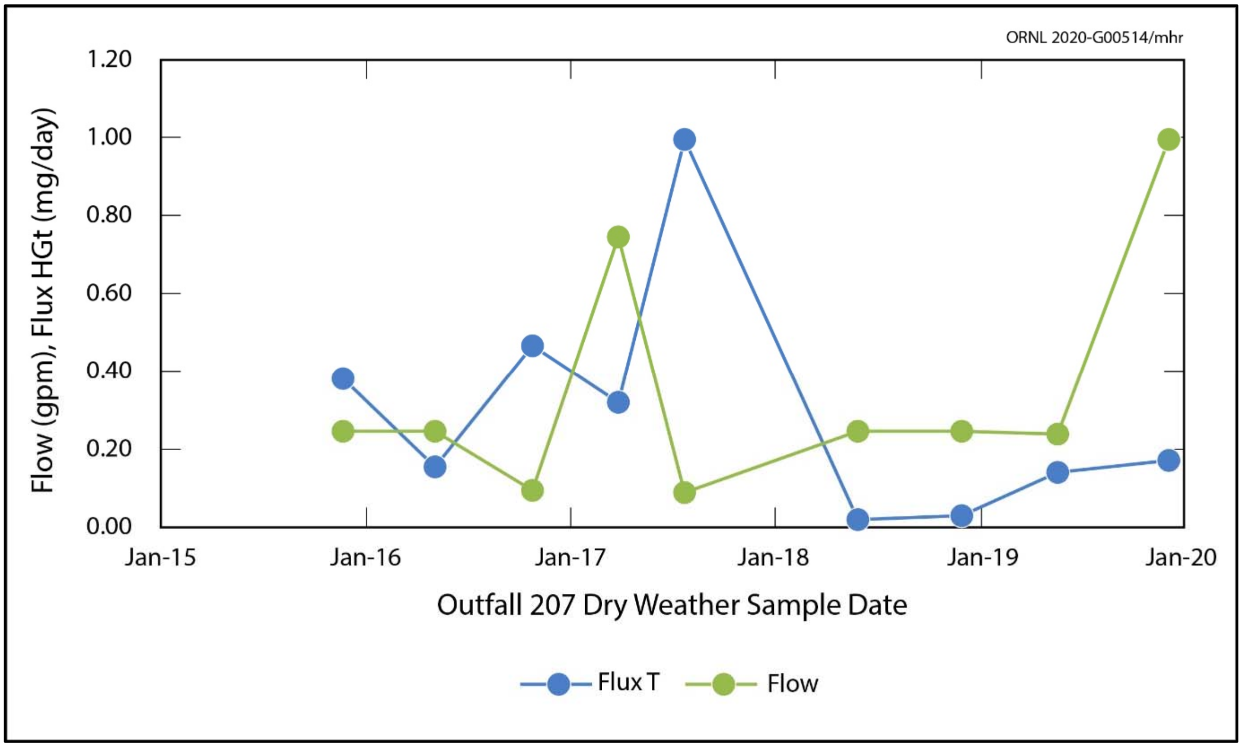


Figure 5.29. Outfall 207 dry weather flow and flux of total mercury, 2015–2019

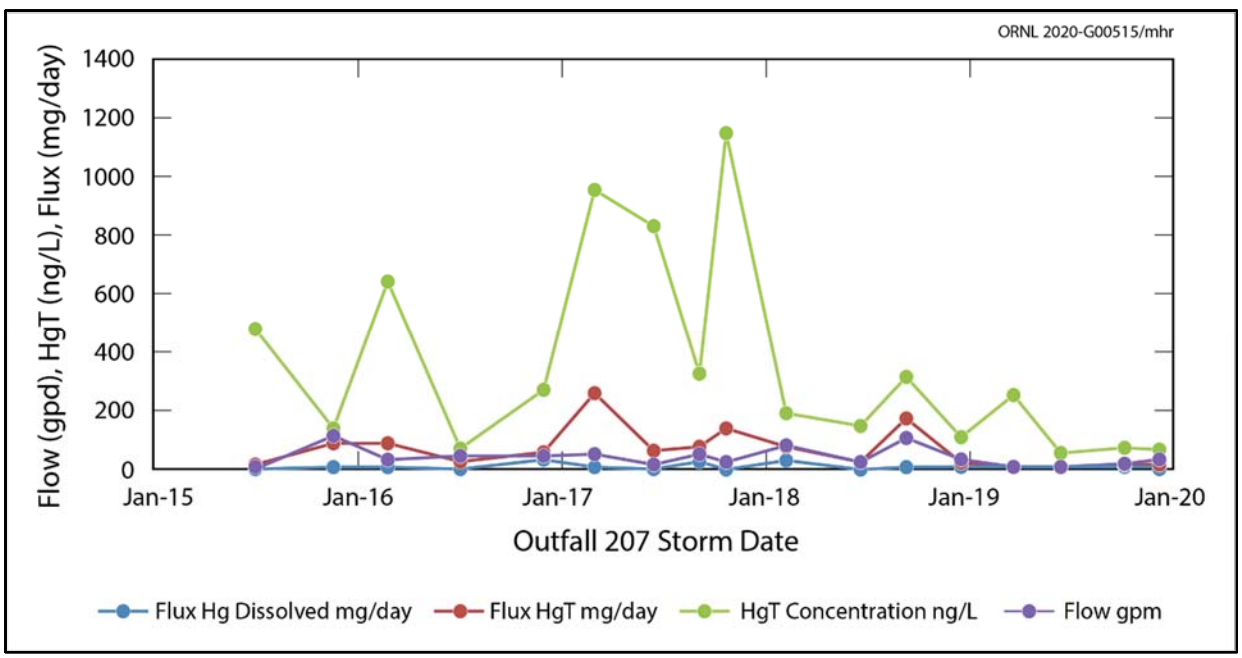


Figure 5.30. Storm flow at Outfall 207, mercury concentration, total and dissolved mercury flux, 2015−2019

At the terminus of the Outfall 211 pipe, a weir plate directs flow through two sodium sulfite tablet dechlorination boxes. During large storms, discharges from the dechlorination boxes enter below creek water level, and the weir fills with creek water. Sediment, deposited by the creek and by the storm pipe network during storms, accumulates behind the weir. An environmental action was implemented in 2018–2019 to remove the sediment on a quarterly basis (March 20, 2018, August 1, 2018, November 8, 2018, and April 1, 2019). It was thought that sediment removal might decrease mercury discharges when water backs up into this area. After the removal actions, HgT dry-weather mercury flux increased slightly with increased flow and concentration. In September 2019, water was found to be discharging to Outfall 211 from a leaking chilled water line southeast of Building 4508. The water line was repaired October 2. Dry weather concentrations continued to increase as flow and HgT flux decreased to about 70 mg/day in December 2019.

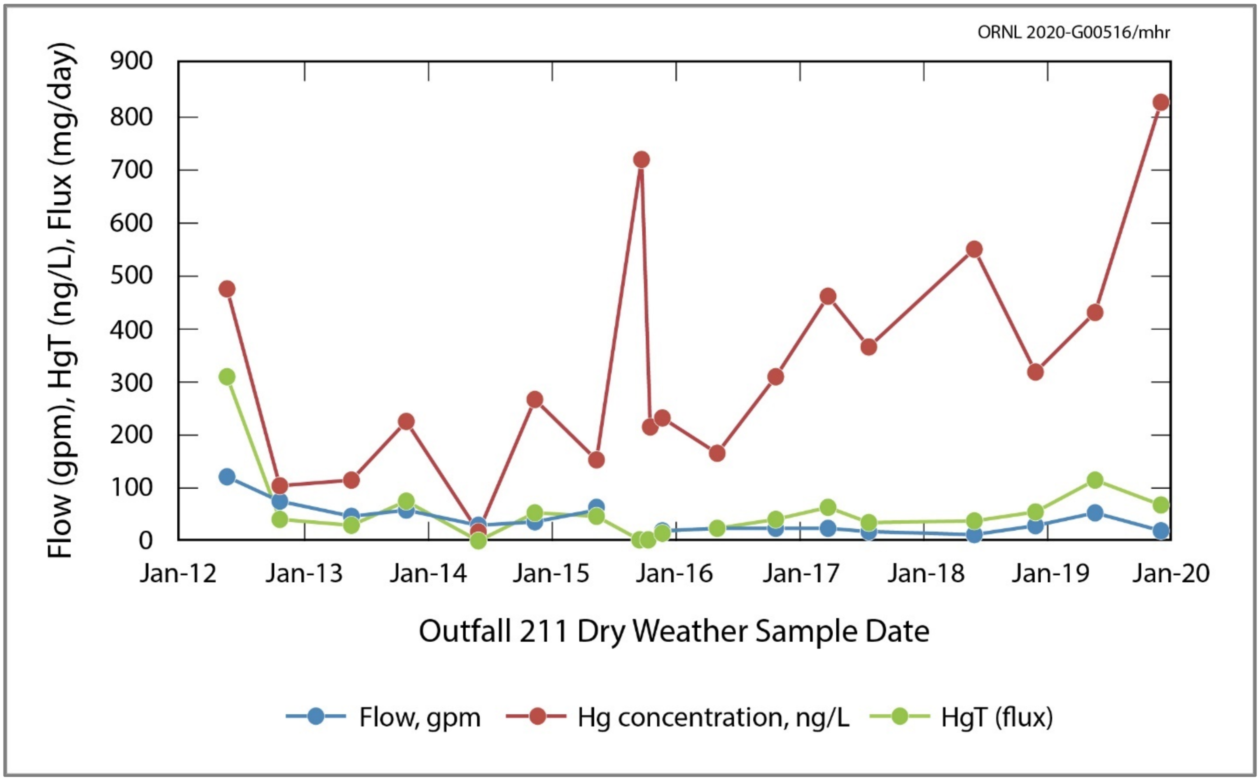


Figure 5.31. Outfall 211 dry weather flow, Hg concentration, and HgT flux, 2012−2019

During storms, Outfall 211 discharges much higher fluxes of total mercury than Outfall 207. The storm flow rates for the Outfall 211 piping system are estimated to be 50 to 225 gpm. The highest dissolved mercury fluxes do not always correlate with highest total mercury fluxes (Figure 5.32). The particulate-bound portion of the total creates the large spikes. Total fluxes have been lower since the high of 9,490 mg/day on February 24, 2016. It is possible that the high total count was caused by mercury-rich particulate matter that was suspended in the discharge from the upper Outfall 211 storm pipe or that was already present in the Outfall 211 weir box and was resuspended. In 2018 the maximum HgT flux was 1,070 mg/day (June 21). During 2019 the maximum total flux was a much lower 250 mg/day (October 7), and of that, a larger portion (141 mg/day) was dissolved. Since October 2017, the total flux has been moving closer to the dissolved flux; fewer particulates have been found in the storm discharges. This could be due to less mobilization of particulates within the pipe, or it may be due to 2018 efforts to remove accumulated sediment from the Outfall 211 weir box.

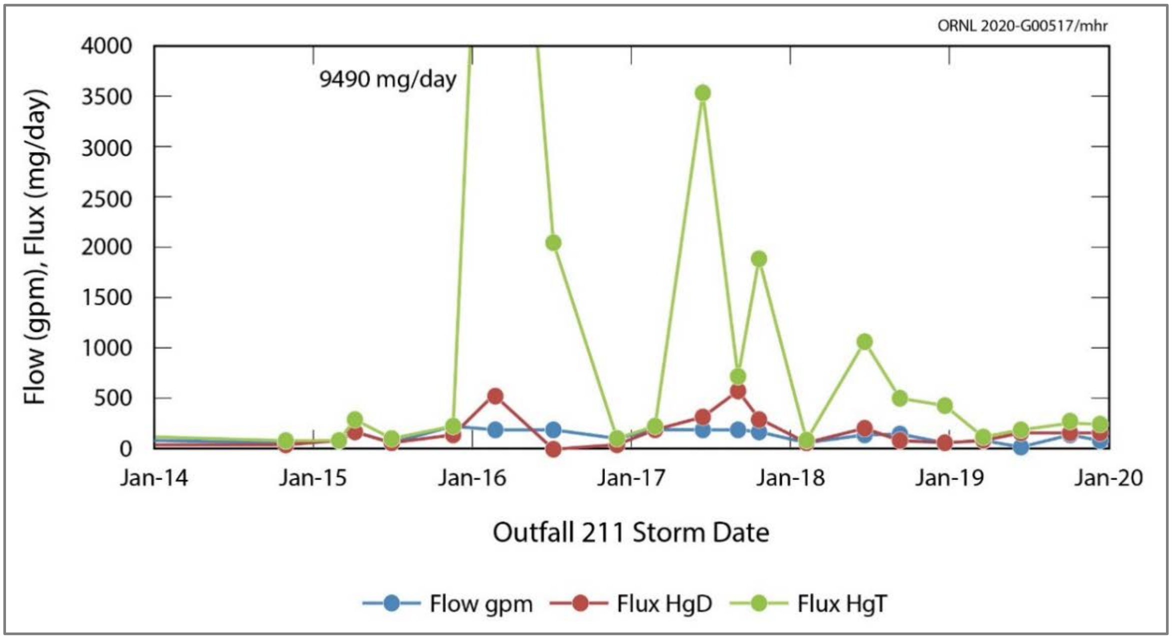


Figure 5.32. Outfall 211 storm flow, dissolved and total mercury flux 2014–2019

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/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 takes place in the 7000 area, which is located on the east end of the ORNL site and where most of the craft and maintenance shops are located. Smaller outdoor storage areas are located throughout the facility in and around loading docks and material delivery areas at laboratory and office buildings. The 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. While sites that are covered by a Tennessee construction general permit are considered to have more significant potential for runoff impacts, inspections and controls required by an approved storm water pollution prevention plan have proven effective at minimizing short-term 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. There are mechanisms 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/emergency responses, and other key issues.

5.5.6 Biological Monitoring

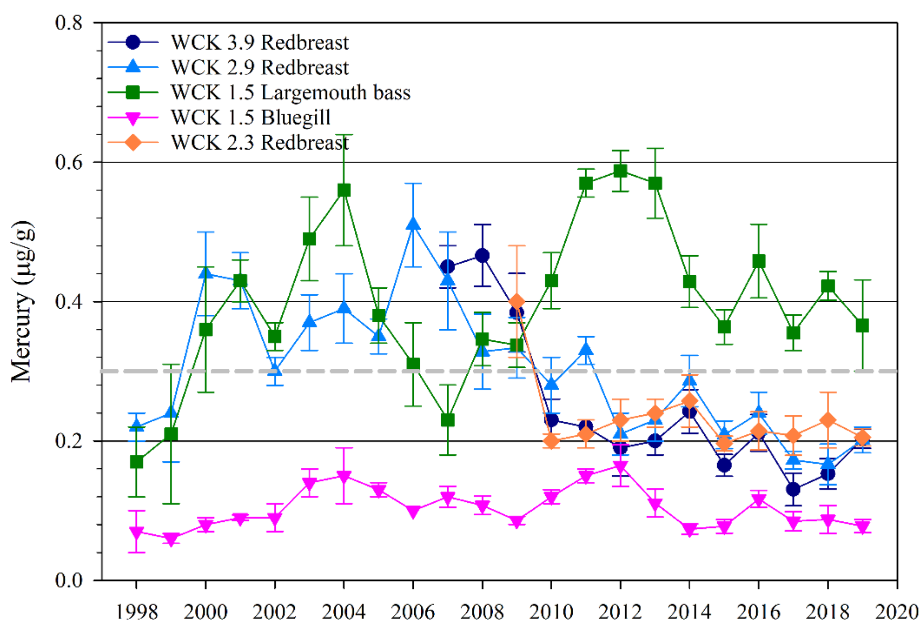
5.5.6.1 Bioaccumulation Studies

The bioaccumulation task for BMAP addresses two NPDES permit requirements at ORNL: (1) evaluate whether mercury at the site is contributing to a stream 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 mercury in fish in the WOC watershed are monitored annually and are evaluated relative to the EPA 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

In WOC, mercury and PCB concentrations in fish have been at or near human health risk thresholds (e.g., EPA recommended fish-based AWQC [0.3 µg/g for mercury], TDEC fish advisory limits for PCBs). Actions taken in 2007 to treat a mercury-contaminated sump resulted in significant decreases in mercury concentrations in fish throughout WOC. The decreases were most apparent at upstream locations closest to the sump water reroute (Figure 5.33). While the overall trends in the uppermost locations sampled in the creek suggest that fish tissue concentrations are decreasing overall, there is some interannual variability. Fillet concentrations increased slightly at the two uppermost stream sites in 2019 but remained below the AWQC for mercury in fish. Mean fillet concentrations increased from 0.15 µg/g in 2018 to 0.20 µg/g in 2019 at WCK 3.9 and increased from 0.17 µg/g in 2018 to 0.20 µg/g in 2019 at WCK 2.9 (Figure 5.33). Mercury concentrations in largemouth bass collected from WCK 1.5 (White Oak Lake) have been fluctuating in recent years and decreased from 0.42 µg/g in 2018 to 0.37 µg/g in 2019, but remained above the guideline. Mercury concentrations in bluegill collected from WCK 1.5 also decreased very slightly, from 0.088 µg/g in 2018 to 0.078 µg/g, and remained below the recommended guideline.

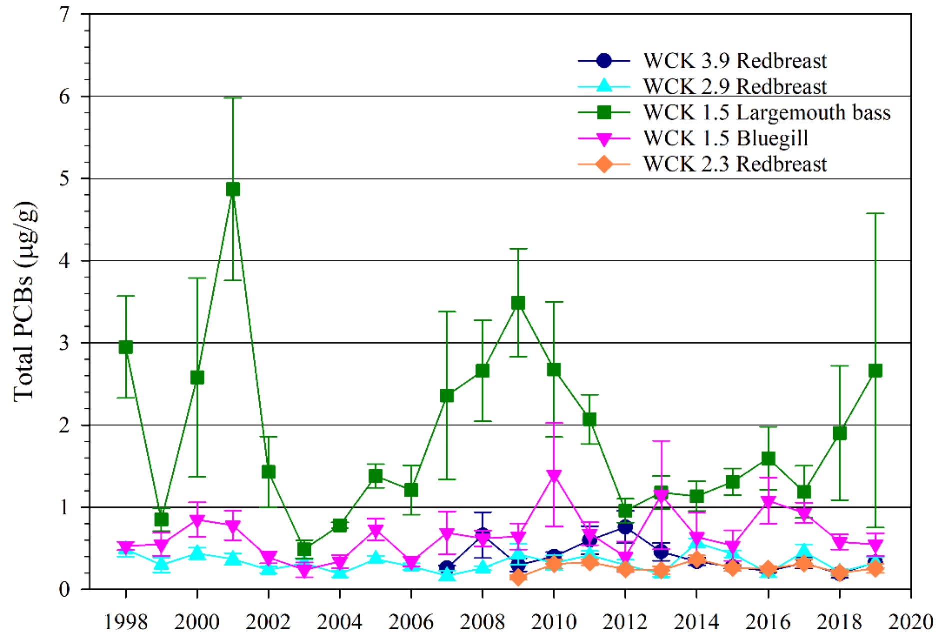
PCB concentrations (defined as the sum of Aroclors 1248, 1254, and 1260) in redbreast sunfish from the WOC watershed remained within historical ranges, with mean concentrations of 0.33 µg/g at WCK 3.9, 0.32 µg/g at WCK 2.9, and 0.26 µg/g at WCK 2.3 (compared to 0.19 µg/g at WCK 3.9, 0.21 µg/g at WCK 2.9, and 0.20 µg/g at WCK 2.3 in 2018 [Figure 5.33]). PCB concentrations in bluegill collected from WCK 1.5 decreased from 0.58 µg/g in 2018 to 0.55 µg/g in 2019; concentrations in largemouth bass collected from WCK 1.5 increased from 1.90 µg/g in 2018 to 2.66 µg/g in 2019 (Figure 5.34).



Dashed grey line indicates the US Environmental Protection Agency ambient water quality criterion for mercury (0.3 µg/g in fish tissue).

Acronym: WCK = White Oak Creek kilometer

Figure 5.33. Mean concentrations of mercury (± standard error, N = 6) in muscle tissue of sunfish and bass from WCKs 3.9, 2.9, and 2.3 and White Oak Lake (WCK 1.5), 1998–2019



Acronyms:
PCB = polychlorinated biphenyl
WCK = White Oak Creek kilometer

Figure 5.34. Mean total PCB concentrations (± standard error, N = 6) in fish fillets collected from the White Oak Creek watershed, 1998–2019

5.5.6.2 Benthic Macroinvertebrate Communities

Monitoring of benthic macroinvertebrate communities in WOC, First Creek, and Fifth Creek continued in 2019. 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 1986). The protocols developed by ORNL staff provide a long-term record (34 years) of spatial and temporal trends in the invertebrate community from which the effectiveness of pollution abatement and remedial actions 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.

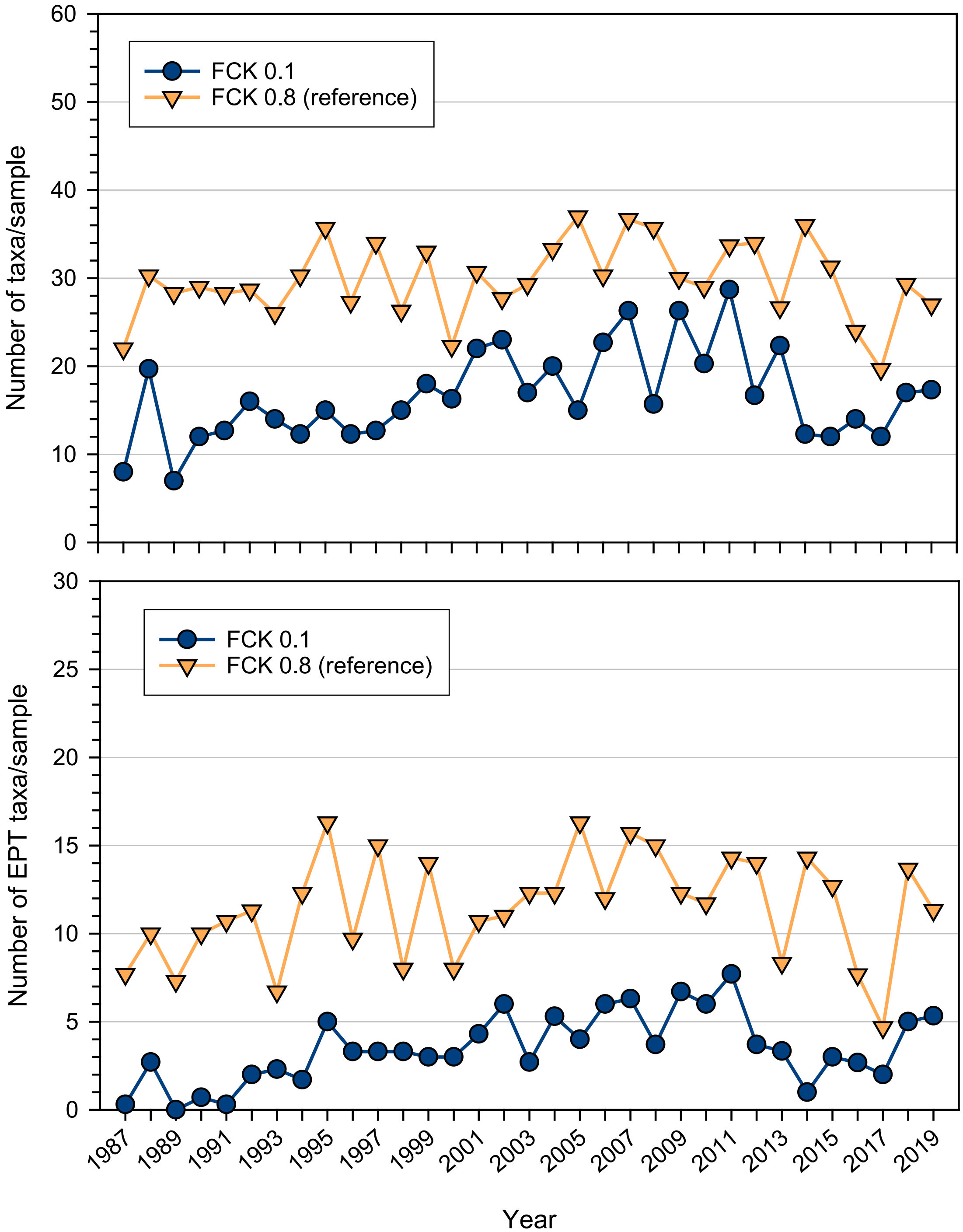
General trends in the results of ORNL protocols indicated significant recovery in these communities since 1987, but community characteristics suggest that ecological impairment remains (Figures 5.35–5.37). Relative to respective upstream reference sites, total taxonomic richness (i.e., the mean number of different species per sample) and richness of the pollution-intolerant taxa (i.e., the mean 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 5.35). Total taxa richness has increased at FCK 0.1 in the past 2 years (2018, 2019), reaching values that were previously observed in the late 1990s. Similarly, the number of pollution-intolerant EPT taxa decreased in 2012, and in 2014, EPT taxa richness was the lowest it had been since the early 1990s. After 6 consecutive years of low EPT taxa richness, values increased in 2018 and 2019 to levels previously recorded in the late 2000s. Additionally, upper First Creek (FCK 0.8), which serves as a reference for FCK 0.1, displayed 3 years of consecutive declines in total taxa richness and EPT taxa richness from 2014 to 2017, but in 2018 and 2019, levels returned to values in previous years. The 6-year period of extremely low values in FCK 0.1 did not mirror those in FCK 0.8. This suggests that while climate or hydrological change may have influenced conditions within the entire stream (both FCK 0.1 and FCK 0.8), a more localized change may have also 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. Additionally, it is unclear at this time whether conditions at FCK 0.1 have improved temporarily or for the long term.

Total taxa richness at Fifth Creek kilometer (FFK) 0.2 increased in the late 1980s, and then reached a fairly consistent level until exhibiting a large decrease between 2007 and 2008 (Figure 5.36), suggesting a change in conditions occurred at the site during that time. It took ~5 years for total taxa richness to return to predecline levels (Figure 5.36). EPT taxa richness at FFK 0.2 increased slowly from the late 1980s to early 2000s before decreasing for several years (~2003–2011). More recently, EPT taxa richness has remained fairly steady at ~5–6 EPT taxa per sample (2011–2018). However, EPT taxa richness in 2019 decreased by 4 (from 6 EPT taxa/sample in 2018 to 2 EPT taxa/sample in 2019). It is not known whether this decrease will persist in future years or whether it instead reflects interannual variation in invertebrate community composition.

Invertebrate metric values for WCK 2.3 and WCK 3.9 continued to remain within the ranges of values found since the early 2000s, although total taxa richness and EPT taxa richness were lower at WCK 2.3 and WCK 3.9 over the past 4 to 5 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 those for the reference sites. Since 2001, Walker Branch has served as an additional reference site for WOC mainstem sites downstream of Bethel Valley Road (Figure 5.35). Comparisons of WCK 6.8 to WBK 1.0 show that communities in WCK 6.8 represent ideal reference conditions. Additionally, the comparison of Walker Branch to downstream sites in WOC show that those WOC communities remain impaired. Interestingly, a pattern similar to FCK 0.8 occurred in both WCK 6.8 and WBK 1.0, where consecutive declines in total taxa richness and EPT taxa richness have been observed in the past few years, followed by a return to higher levels in 2018 and 2019. This suggests that similar climatological or environmental changes may be driving some of these patterns across the entire watershed, if not the entire ORR.

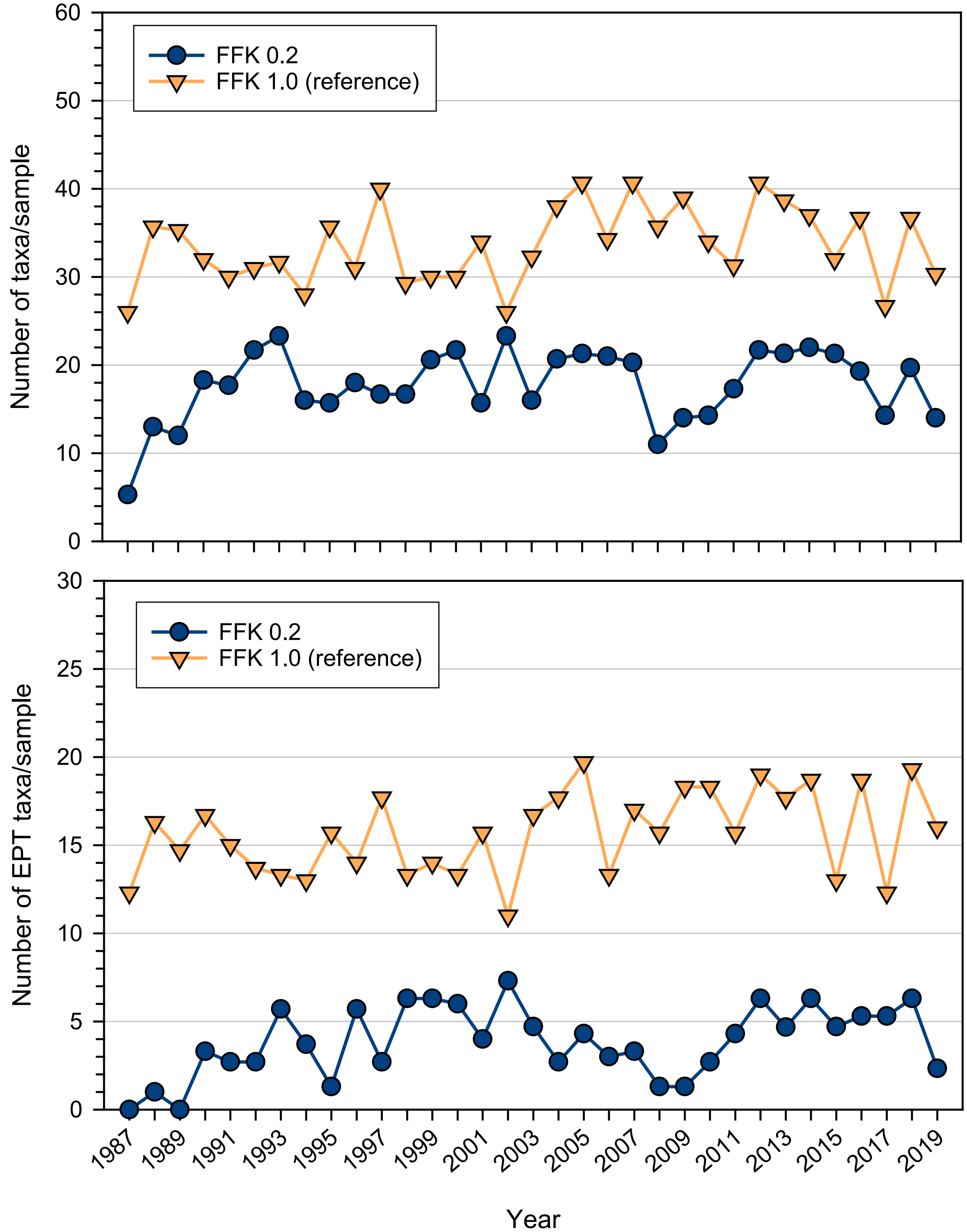
Macroinvertebrate metrics for lower Melton Branch (MEK 0.6) suggested that total taxa and EPT taxa richness continued to be similar to those in reference sites in 2019 (Figure 5.35). However, other invertebrate community metrics at MEK 0.6 potentially sensitive to more specific types of pollutants, such 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 3 years (2017–2019), EPT density was lower in MEK 0.6 than WCK 6.8 and WBK 1.0 while the density of pollution-tolerant species (oligochaetes and chironomids) was higher in MEK 0.6 than in those two reference sites.



(Top) total taxonomic richness (mean number of all taxa/sample) and (bottom) taxonomic richness of the pollution-intolerant taxa, Ephemeroptera, Plecoptera, and Trichoptera (EPT); mean number of EPT taxa/sample, April sampling periods, 1987−2019Figure 5.35. Benthic macroinvertebrate communities in First Creek

Acronym: FCK = First Creek kilometer

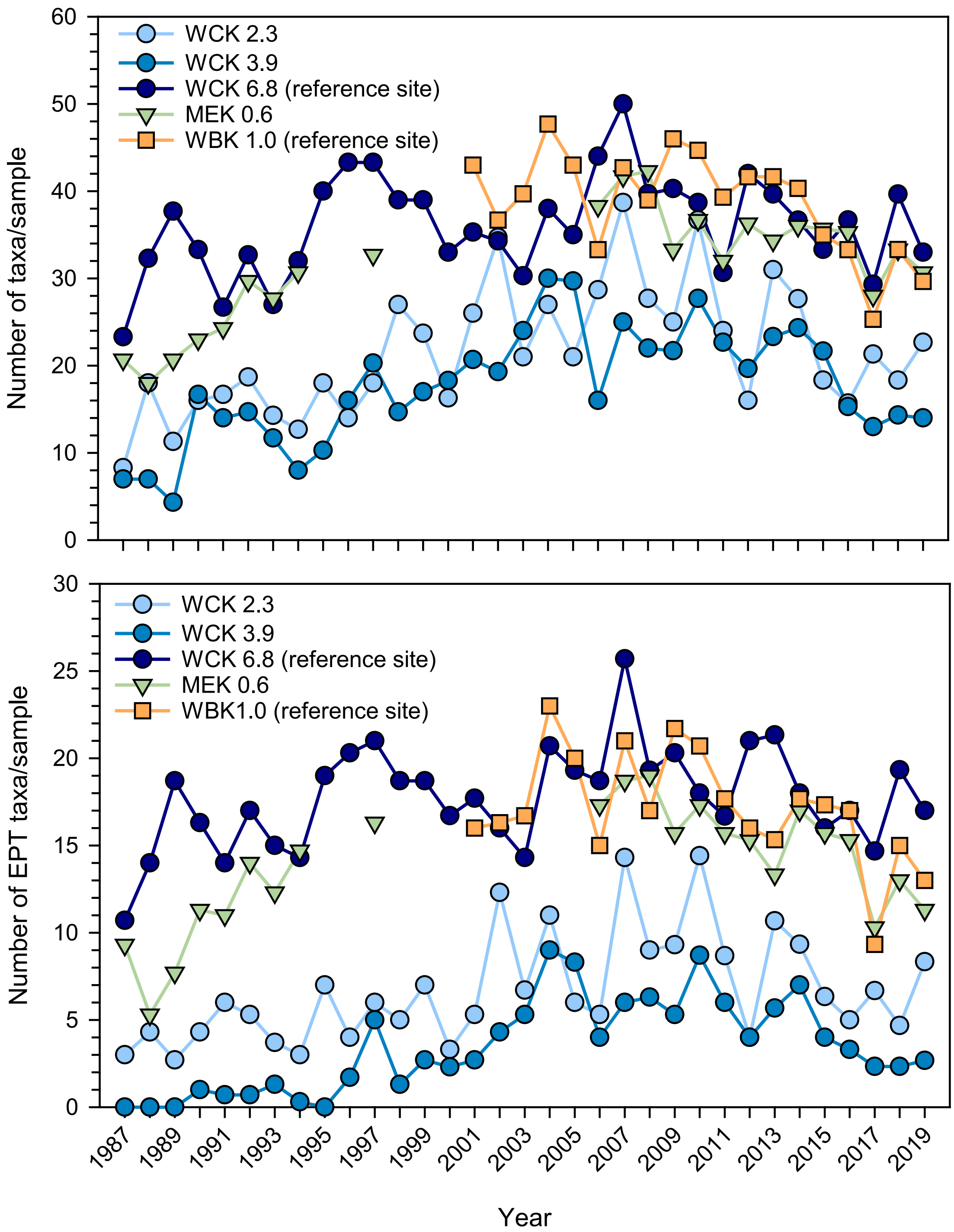
Figure 5.35. Benthic macroinvertebrate communities in First Creek



(Top) total taxonomic richness (mean number of all taxa/sample) and (bottom) taxonomic richness of the pollution-intolerant taxa, Ephemeroptera, Plecoptera, and Trichoptera (EPT) (mean number of EPT taxa/sample), April sampling periods, 1987−2019

Acronym: FFK = Fifth Creek kilometer

Figure 5.36. Benthic macroinvertebrate communities in Fifth Creek



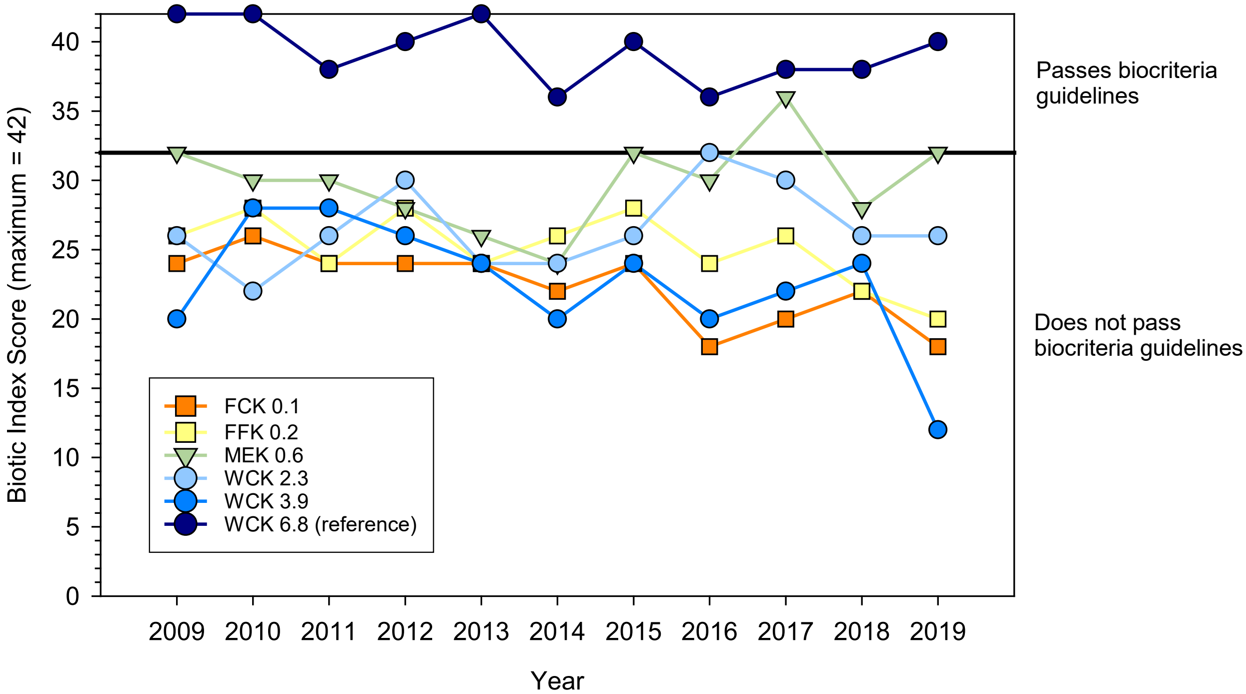
(Top) total taxonomic richness (mean number of all taxa/sample) and (bottom) taxonomic richness of the pollution-intolerant taxa, Ephemeroptera, Plecoptera, and Trichoptera (EPT); mean number of EPT taxa/sample), April sampling periods, 1987−2019

Acronyms:
MEK = Melton Branch kilometer
WBK = Walker Branch kilometer
WCK = White Oak Creek kilometer

Figure 5.37. Benthic macroinvertebrate communities in Walker Branch, Melton Branch, and White Oak Creek

Based on 2017 TDEC protocols, scores for the Tennessee Macroinvertebrate Index (TMI) in 2019 rated the invertebrate communities of WCK 6.8 and MEK 0.6 as passing biocriteria guidelines, while scores from FCK 0.1, FFK 0.2, WCK 2.3, and WCK 3.9 were below these guidelines (Figure 5.38, Table 5.13). In 2019, TMI scores at these four latter sites either stayed the same or decreased from 2018 scores. In contrast, 2019 TMI scores at WCK 6.8 and MEK 0.6 were higher than 2018 scores.

Low TMI scores in FCK 0.1, FFK 0.2, 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 of these sites, except WCK 3.9, had low percentages of oligochaetes and chironomids (worms and non-biting midges) and thus received high scores for this category (Table 5.13). MEK 0.6 scored highly for most TMI categories, except for a lower score for EPT percentage. WCK 6.8 received the highest attainable scores for all categories except for total taxa richness (Table 5.13). However, per the 2017 TDEC protocol, TMI scores should only be calculated for samples with 160 to 240 invertebrates identified to genus (TDEC 2017). In August 2019, only 50 individuals were collected from WCK 3.9 and 66 individuals from FFK 0.2, so TMI scores for those sites should be interpreted with caution.



The black horizontal line shows the threshold for Tennessee Macroinvertebrate Index scores; respective narrative ratings above and below the threshold are shown to the right of the graph.

Acronyms:
FCK = First Creek kilometer
FFK = Fifth Creek kilometer
MEK = Melton Branch kilometer
WCK = White Oak Creek kilometer

Figure 5.38. Temporal trends in Tennessee Department of Environment and Conservation macroinvertebrate scores for White Oak Creek watershed streams, August sampling periods 2009–2019

Table 5.13. Tennessee Macroinvertebrate Index metric values, metric scores, and index scores for White Oak Creek, First Creek, Fifth Creek, and Melton Branch, August 15 and 16, 2019[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	27	6	26.4	14	5.47	28.7	54.6	6	2	2	6	4	2	4	**26**
WCK 3.9	12	2	2	54	5.64	26	68	2	0	0	2	4	2	2	**12[d]**
WCK 6.8	28	14	48.1	8.3	2.96	76.7	12.6	4	6	6	6	6	6	6	**40 [pass]**
FCK 0.1	13	4	10.3	2	5.16	19.6	72.1	2	2	0	6	4	2	2	**18**
FFK 0.2	15	5	7.6	24	5.08	42.4	57.6	2	2	0	6	4	4	2	**20[d]**
MEK 0.6	26	9	20.5	6.8	3.95	57.1	29.2	4	4	2	6	6	6	4	**32 [pass]**

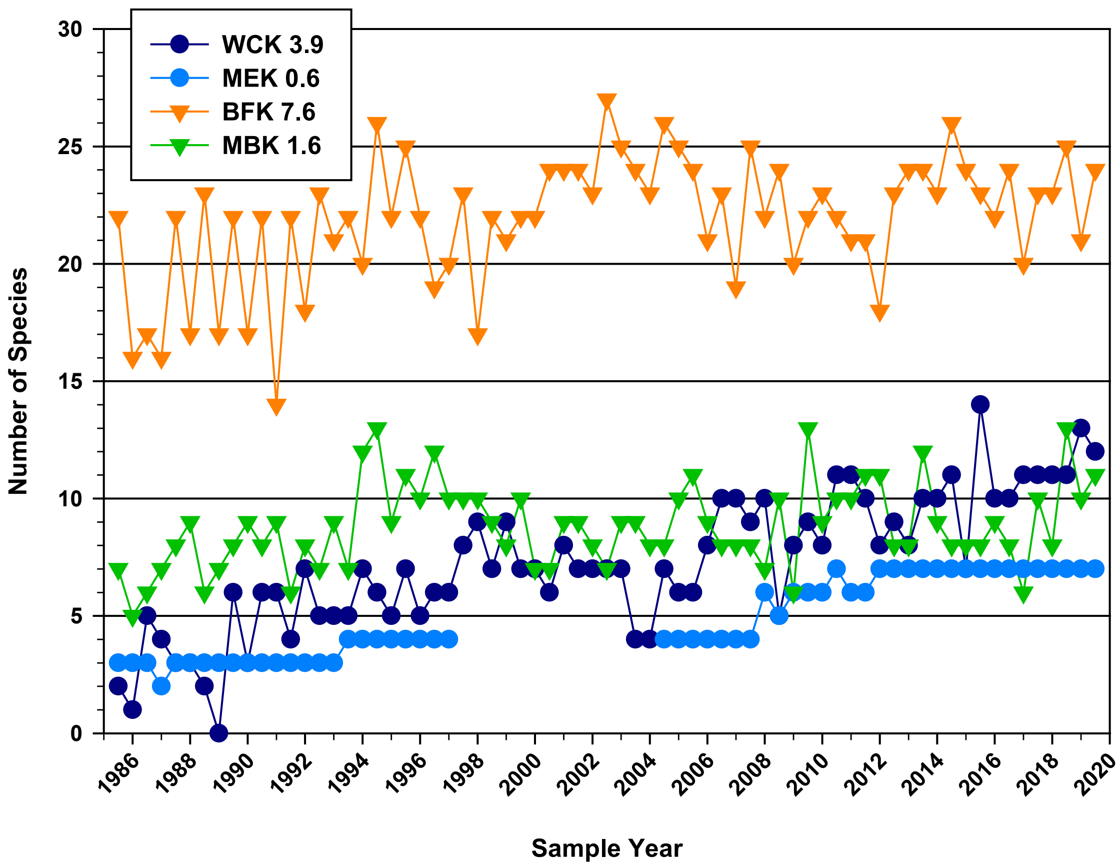
[a]TMI metric calculations and scoring and index calculations are based on TDEC protocols for Ecoregion 67f (TDEC. 2017. *Quality System Standard Operating Procedures for Macroinvertebrate Stream Surveys*, TDEC Division of Water Pollution Control, Nashville, Tennessee. Available at https://www.tn.gov/content/dam/tn/environment/water/documents/DWR-PAS-P-01-Quality_System_SOP_for_Macroinvertebrate_Stream_Surveys-081117.pdf).
[b]Taxa rich = Taxa richness; EPT rich = taxa richness of (mayflies, stoneflies, and caddisflies); %EPT = EPT abundance excluding *Cheumatopsyche* spp.; %OC = percent abundance of oligochaetes (worms) and chironomids (nonbiting midges); NCBI = North Carolina Biotic Index; %Cling = percent abundance of taxa that build fixed retreats or otherwise attach to substrate surfaces in flowing water; %TN Nuttol. = percent abundance of nutrient-tolerant organisms.
[c]TMI is the total index score and higher index scores indicate higher quality conditions. A score of ≥ 32 is considered to pass biocriteria guidelines (green shading). TMI scores < 32 are indicated by yellow shading
[d]TDEC protocol states that TMI scores should only be calculated for samples with 160 to 240 invertebrates identified to genus. In August 2019, only 50 individuals were collected from WCK 3.9, and 66 individuals from FFK 0.2, so results from these sites should be interpreted with caution.

Acronyms:
EPT = Ephemeroptera, Plecoptera, and Trichoptera
FCK = First Creek kilometer
FFK = Fifth Creek kilometer
MEK = Melton Branch kilometer
NCBI = North Carolina Biotic Index
Nuttol = nutrition-tolerant organism
OC = percent abundance of oligochaetes (worms) and chironomids (nonbiting midges)
TDEC = Tennessee Department of Environment and Conservation
TMI = Tennessee Macroinvertebrate Index Score
WCK = White Oak Creek kilometer

5.5.6.3 Fish Communities

Monitoring of the fish communities in WOC and its major tributaries continued in 2019. 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 2019 compared with communities in reference streams. Sites closest to outfalls within the ORNL campus had lower species richness (number of species) (Figure 5.39), 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 also continued to be negatively affected by ORNL effluent in 2019 relative to reference streams and upstream sites.



Acronyms:
BFK = Brushy Fork kilomete
MBK = Mill Branch kilometer
MEK = Melton Branch kilometer
WCK = White Oak Creek kilometer

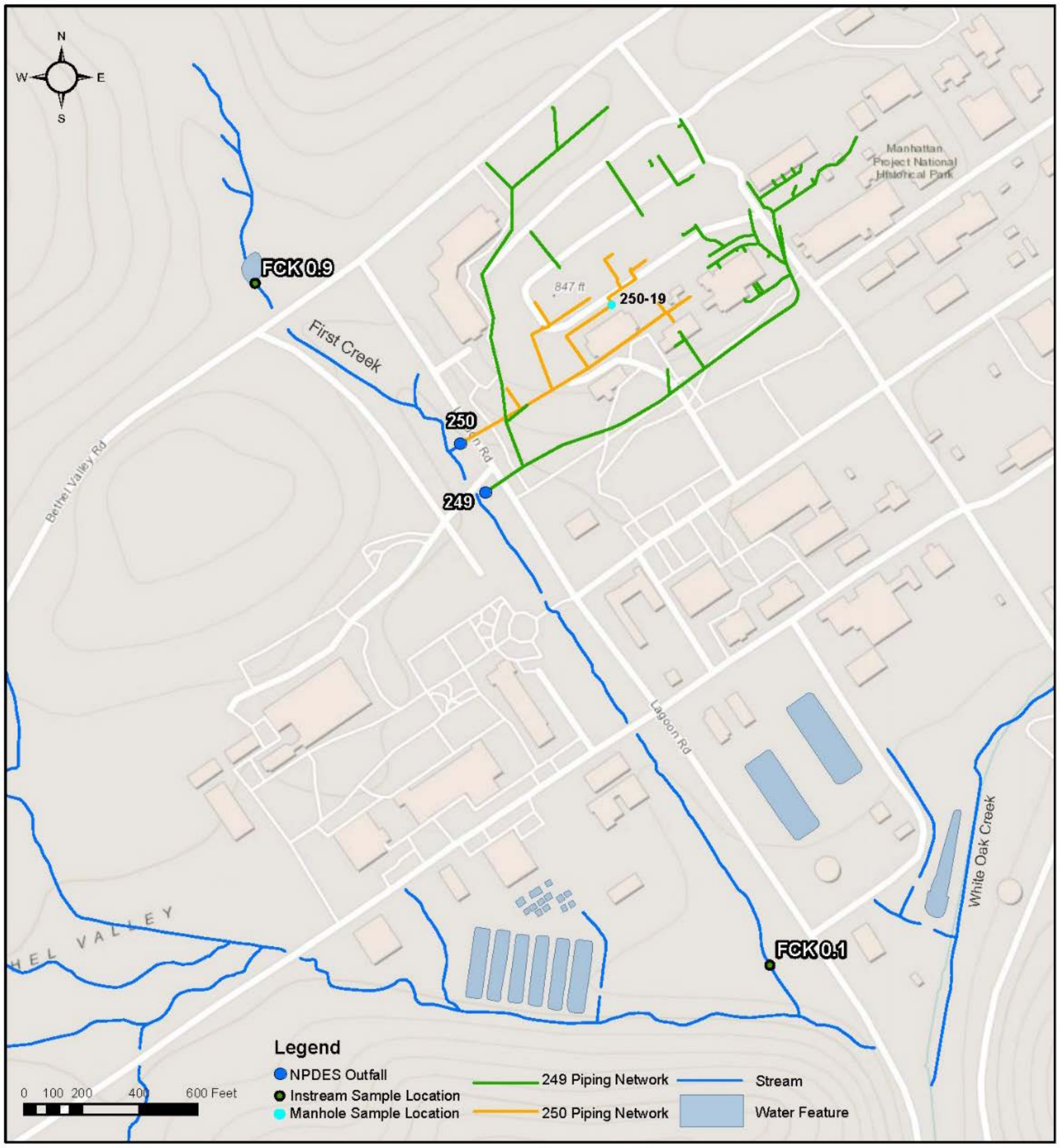
Figure 5.39. Fish species richness (number of species) in upper White Oak Creek and lower Melton Branch compared with two reference streams, Brushy Fork and Mill Branch, 1985–2019

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. As a result, introductions to supplement the small populations of those fish species have continued at sites within the watershed. One exception to this 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 of those locations. The introductions have enhanced species richness at almost all sample locations within the watershed and illustrate 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.

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 (Figure 5.40). Sample results for largemouth bass collected from White Oak Lake showed tissue PCB concentrations higher than those recommended by TDEC and EPA for frequent consumption, but the mobility of the fish precluded the possibility of source identification. PCBs are hydrophobic and tend not to be dissolved in water, resulting in undetected PCB concentrations in water samples, using conventional analytical methods, even if collected from a contaminated site. Therefore, semipermeable membrane devices (SPMDs) are used to assess the chronic low-level sources of PCBs at critical sites on the reservation. 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 10 years, ORNL’s PCB monitoring efforts have identified upper parts of First Creek as a source of PCBs. In 2018, SPMDs were deployed in First Creek at Outfall 250 and in the piping network of Outfall 250, which contributes to First Creek (Figure 5.40). Results from this assessment indicate that PCBs remained available in the area despite previous actions to remove PCB-contaminated materials from the upper part of outfall 250 watershed. In September 2019, catch basin sediment in this drainage network was cleaned out and disposed of as solid waste. The focus of future monitoring will be to determine the effectiveness of the 2019 sediment removal. SPMDs will be deployed in locations that were previously monitored in First Creek and in the Outfall 250 drainage network.



Acronym: FCK = First Creek kilometer

Figure 5.40. Locations of monitoring points for First Creek source investigation

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" (EPA 2000). Each ORR facility implements a site-specific SPCC plan. The HVC (home of NTRC and MDF), 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 and HVC SPCC plans were not changed in 2019. There were no regulatory actions related to oil pollution prevention at ORNL or HVC in 2019. An oil-handler training program exists to comply with training requirements in 40 CFR 112.

5.5.9 Surface Water Surveillance Monitoring

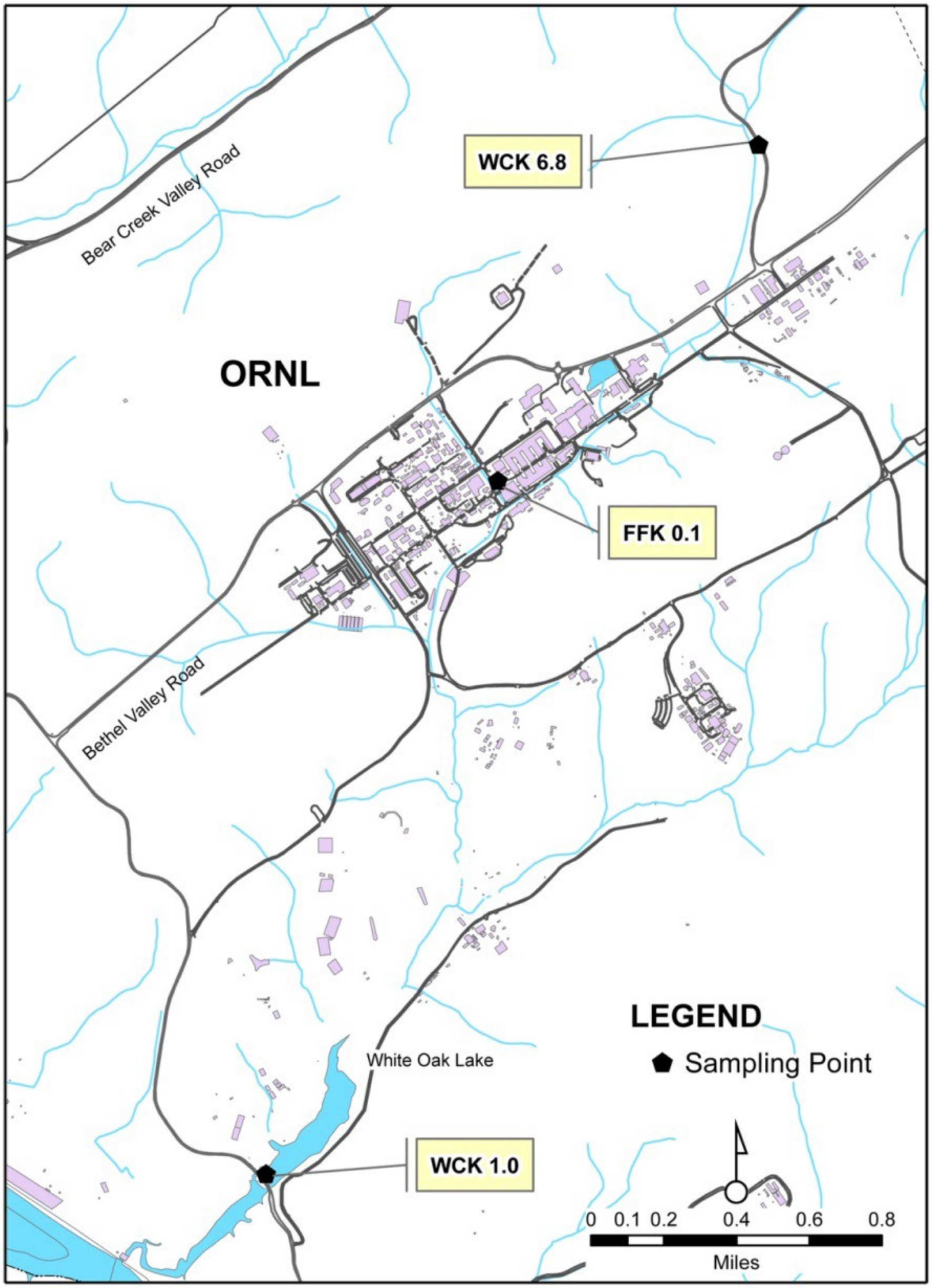
The ORNL surface water monitoring program is conducted in conjunction with the ORR surface water monitoring activities discussed in Section 6.4 to enable assessing the impacts of ongoing DOE operations on the quality of local surface water. The sampling locations (Figure 5.41) are used to monitor conditions 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. Radiological monitoring at the discharge point downstream of ORNL (White Oak Lake at WOD) is conducted monthly under the ORNL WQPP (Section 5.5.3) and, therefore, is not duplicated by this program. Radiological monitoring at a point upstream of ORNL is conducted monthly under the ORNL WQPP and therefore is not duplicated by the surface water monitoring program. Total radioactive strontium is monitored quarterly by this surveillance program.

Samples are collected and analyzed for general water quality parameters and are screened for radioactivity at all locations (either under this program or under WQPP). Samples are further analyzed for specific radionuclides when general screening levels are exceeded. Samples from White Oak Lake at WOD are also checked for volatile organic compounds (VOCs), PCBs, and mercury. WCK 6.8 is also checked for PCBs. WCK 6.8 and WCK 1.0 are classified by the State of Tennessee for freshwater fish and aquatic life. Tennessee Water Quality Criteria (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 2011a) is used for radionuclide comparison.

There were no radionuclides reported above 4 percent of DCS at the Fifth Creek location (FFK 0.1) in 2019. The beta activity and $^{89/90}$Sr concentrations 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 DCS were reported for samples collected at the upstream WOC sampling location (WCK 6.8). The other radionuclide results from WCK 6.8 and the radionuclide results from samples collected at WOD (before WOC empties into the Clinch River) are discussed in Section 5.5.3.

No PCBs were detected downstream of ORNL at WOD in 2019. Four VOCs were detected in samples from WOC at WOD during 2019: acetone was detected in the samples collected in June, September, and December; methylene chloride and tetrachloroethene were detected in the March sample; and chloroform was detected in the June sample. All VOC detections were at low, estimated values. Each of the VOCs has been detected in surface water samples from WOC at WOD before, and methylene chloride and acetone have occasionally been detected in at least one on-site groundwater well in past monitoring, including wells located in nearby Solid Waste Storage Area (SWSA) 6. Mercury was not detected at WOD in 2019.



Acronyms:
FFK = Fifth Creek kilometer
WCK = White Oak Creek kilometer

Figure 5.41. Oak Ridge National Laboratory surface water sampling locations, 2019

Table 5.14. Oak Ridge National Laboratory surface water sampling locations, frequencies, and parameters, 2019

Location[a]	Description	Frequency and type	Parameters
WCK 1.0[b]	White Oak Lake at WOD	Quarterly, grab	Volatiles, mercury, PCBs, field measurements[c]
WCK 6.8[d]	WOC upstream from ORNL	Quarterly, grab	PCBs, Total radioactive strontium, field measurements[c]
FFK 0.1	Fifth Creek just upstream of WOC (ORNL)	Semiannually, grab	Gross alpha, gross beta, total radioactive strontium, gamma scan, tritium, 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 White Oak Creek and the Clinch River).
[b] For this location, radiological parameters are monitored under another program (the WQPP) and therefore are not included in this plan.
[c] Field measurements consist of dissolved oxygen, pH, and temperature.
[d] For this location, gross alpha, gross beta, gamma scan, and tritium are monitored under another program (the WQPP) so those radiological parameters are not included in this plan.

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

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 2019 compliance status for this permit are summarized in Table 5.15.

Table 5.15. Industrial and commercial user wastewater discharge permit compliance at the Oak Ridge National Laboratory Carbon Fiber Technology Facility, 2019

Effluent parameters	Permit limits		Permit compliance		
	Daily max. (mg/L)	Daily min. (mg/L)	Number of noncompliances	Number of samples	Percentage of compliance[a]
		Outfall 01 (Underground Quench Water Tank)			
Cyanide	3.9		0	0	100
pH (standard units)	9.0	6.0	0	0	100
		Outfall 02 (Electrolytic Bath Tank)			
pH (standard units)	9.0	6.0	0	7	100
		Outfall 03 (Sizing Bath Tank)			
Copper	0.87		0	0	100
Zinc	1.24		0	0	100
Total phenol	4.20		0	0	100
pH (standard units)	9.0	6.0	0	0	100

[a] Percentage compliance = 100 – [(number of noncompliances/number of samples) × 100]

5.6 Oak Ridge National Laboratory Groundwater Monitoring Program

Groundwater monitoring at ORNL was conducted under two sampling programs in 2019: DOE OREM monitoring and DOE Office of Science (SC) surveillance monitoring. The DOE OREM groundwater monitoring program was conducted by UCOR in 2019. 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 remedial actions (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 2019, including monitoring at ORNL, are evaluated and reported in the 2020 remediation effectiveness report (DOE 2020a) as required by the ORR FFA. The monitoring results and remedial effectiveness evaluations for Bethel and Melton Valleys are reported in Sections 2 and 3, respectively, in that report.

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 activities on a groundwater treatability study at the Bethel Valley 7000 Services 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.

During FY 2019 postremediation monitoring continued at SWSA 3 to evaluate the effectiveness of the 2011 hydrologic isolation of the area that included construction of a multilayer cap and an upgradient stormflow/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 postremediation groundwater-level suppression. Sampling and analysis of groundwater quality and contaminants were also conducted. Postremediation 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 2019 monitoring results showed that the cap was effective, although target groundwater elevations have not yet been attained at three of eight wells. Drinking water standards are used as screening water quality concentrations to evaluate the site response to remediation. Strontium-90, a signature contaminant at SWSA 3, shows decreasing annual maximum concentrations with 6 of 10 monitored wells exhibiting ^{90}Sr concentrations less than the 8 pCi/L maximum contaminant level (MCL) derived concentration. Benzene, potentially from natural sources, shows decreasing annual maximum concentrations with FY 2019 maxima of 0.006 mg/L in two wells, which is just slightly greater than the 0.005 mg/L MCL. During FY 2019, 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, along with the exit pathway, and 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 2020 remediation effectiveness report (DOE 2020a).

Groundwater monitoring continued at the ORNL 7000 Area during FY 2019 to evaluate treatability of the VOC plume at that site. Site characterization testing of the endemic microbial community showed that microbes were present that 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 show 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. The remedy had performed well until the latter portion of FY 2008, when conditions changed and ^{90}Sr and $^{233/234}$U concentrations in monitoring wells and the groundwater collection system began increasing. During FY 2009 the remedy did not meet its performance goal. In March 2012 DOE completed refurbishment and enhancement of the groundwater collection system to increase the effectiveness of the plume containment.

Between FY 2012 and FY 2015 the Bethel Valley ROD goal for ^{90}Sr concentrations at the 7500 Bridge Weir monitoring location was met. During FY 2016 and FY 2017 that goal was exceeded because of contaminant releases from a deteriorated radiological wastewater drain that caused ^{90}Sr discharges from storm drain Outfall 304 into WOC. During FY 2019 the Bethel Valley ROD goal for ^{90}Sr at the 7500 Bridge Weir site was met. Continuing ^{90}Sr influxes to WOC from groundwater and storm drain discharges fed by releases from deteriorated infrastructure comprise the majority of ^{90}Sr measured at the 7500 Bridge Weir site.

5.6.1.2 Melton Valley

The Melton Valley ROD (DOE 2000) established goals for a reduction of contaminant levels in surface water, groundwater-level fluctuation reduction goals within hydrologically isolated areas, and minimization of the spread of groundwater contamination. 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 on ORR during FY 2019 was about 70 in., which is about 16 in. greater 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. Groundwater quality monitoring that is substantively equivalent to the former RCRA monitoring continues at SWSA 6. Several VOCs continue to be detected in wells along the eastern edge of the site.

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, tritium, uranium, and VOCs have been detected intermittently in a number of the multizone sampling locations. Groundwater in the exit pathway wells has high alkalinity and sodium and exhibits elevated pH. During FY 2019 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 2020 remediation effectiveness report (DOE 2020a).

5.6.2 DOE Office of Science Groundwater Surveillance Monitoring

DOE Order 458.1 (DOE 2011c) 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.

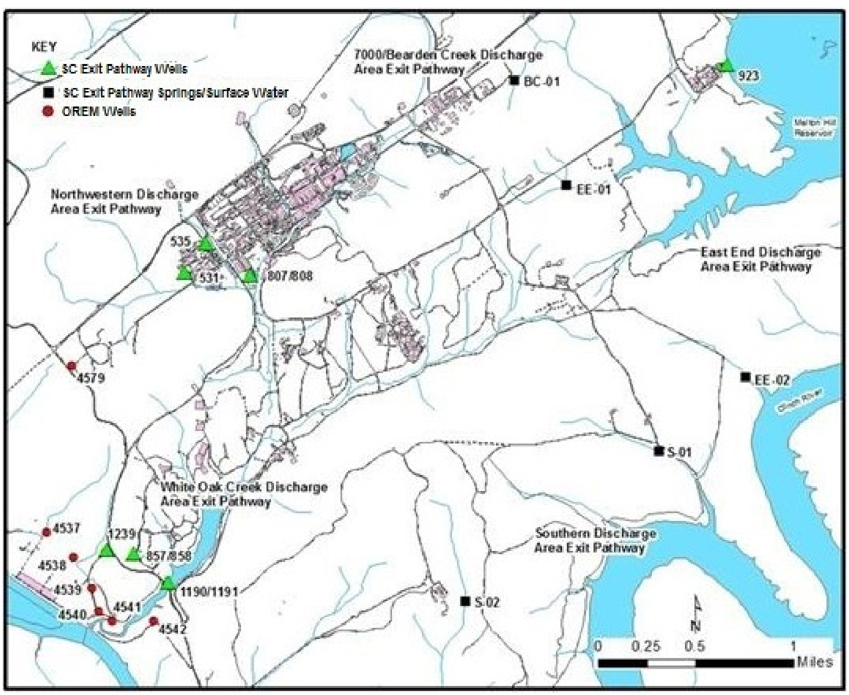
Exit pathway and active-sites groundwater surveillance monitoring points sampled during 2019 included seep/spring and surface-water monitoring locations in addition to groundwater surveillance monitoring wells. Seep/spring and surface-water monitoring points located in appropriate groundwater discharge 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 between locations, results were compared to 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 2011a). 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 2019, exit pathway groundwater surveillance monitoring was performed in accordance with the exit pathway sampling and analysis plan (Bonine 2012). 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 5.42 shows the locations of the exit pathway monitoring points sampled in 2019. :

- 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



Acronyms: OREM = DOE Office of Environmental ManagementSC = DOE Office of Science

Figure 5.42. UT-Battelle exit pathway groundwater monitoring locations at Oak Ridge National Laboratory, 2019

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 10-year staggered groundwater monitoring schedule and analytical suite selection. This approach was initiated in 2012. The groundwater monitoring program implemented in 2019 is outlined in Table 5.16.

Unfiltered samples were collected from the exit pathway groundwater surveillance monitoring points in 2019. The organic suite was composed of VOCs and semivolatile organic compounds; the metallic suite included heavy and non-heavy metals; and the radionuclide suite was composed of gross alpha/gross beta activity, gamma emitters, $^{89/90}$Sr, and tritium. Under the monitoring strategy outlined in the exit pathway sampling and analysis plan (Bonine 2012), samples were collected semiannually during the wet (May–June) and dry (August–November) seasons.

Table 5.16. 2019 exit pathway groundwater monitoring schedule

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	Radiological[a]	Radiological[a]
	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	Radiological[a]	Radiological[a]
S-02	Radiological, organics, and metals	Radiological
	White Oak Creek Discharge Area	
857	Radiological	Radiological
858	Radiological	Radiological
1190	Radiological, organics, and metals	Radiological
1191	Radiological, organics, and metals	Radiological
1239	Radiological, organics, and metals	Radiological

[a] Locations EE-02 and S01(stream locations) were not sampled in the 2019 dry season due to lack of water flow at those locations.

Exit Pathway Monitoring Results

Table 5.17 provides a summary of radiological parameters detected in samples collected from exit pathway monitoring points during 2019. Metals are ubiquitous in groundwater exit pathways and so are not summarized in the table.

Table 5.17. Radiological parameters detected in 2019 exit pathway groundwater monitoring

Monitoring location	Parameter	Wet season concentration[a] (pCi/L)	Dry season concentration[a] (pCi/L)	Reference value[b] (pCi/L)
7000 Bearden Creek Discharge Area				
Spring BC-01	Beta activity	3.4	U0.745	50
Spring BC-01	^{214}Bi	6.83	37.7	10,400
Spring BC-01	^{214}Pb	14.6	38.9	8,000
Spring BC-01	Tritium	198	U37.1	20,000
East End Discharge Area				
Well 923	Beta activity	2.13	2.6	50
Well 923	^{214}Bi	8.26	ND	10,400
Stream EE-01	Alpha activity	2.94	U0.329	15
Stream EE-01	Beta activity	3.5	U0.96	50
Stream EE-01	^{214}Bi	ND	95.3	10,400
Stream EE-01	^{40}K	25.2	U-22.8[c]	192
Stream EE-01	^{214}Pb	ND	107	8,000
Stream EE-01	^{208}Tl	3.25	ND	NA
Stream EE-02	^{214}Bi	64.6	NF	10,400
Stream EE-02	^{214}Pb	68.3	NF	8,000
Northwestern Discharge Area				
Well 531	Beta activity	1.54	3.07	50
Well 531	Tritium	U35	312	20,000
Well 535	Alpha activity	31.4	U0.39	15
Well 535	Beta activity	27.1	2.94	50
Well 535	^{214}Bi	ND	11.6	10,400
Well 535	^{214}Pb	ND	12.6	8,000
Well 535	Tot. Ra alpha	3.1	NM	5
Well 535	^{232}Th	1.15	NM	5.6
Well 807	Beta activity	4.28	5.1	50
Well 808	Beta activity	2.89	5.57	50
Well 808		ND	43.2	4,400
Southern Discharge Area				
Stream S-01	^{212}Bi	26.5	NF	4,400
Stream S-01	^{214}Bi	26.6	NF	10,400
Stream S-01	^{214}Pb	31.8	NF	8,000
Stream S-02	^{214}Bi	12.3	57.4	10,400
Stream S-02	^{214}Pb	7.9	64.2	8,000
White Oak Creek Discharge Area				
Well 857	Beta activity	5.11	U2.85	50
Well 857	^{214}Bi	27.2	ND	10,400
Well 857	^{214}Pb	28.8	5.5	8,000
Well 1190	Beta activity	5.45	2.45	50

Table 5.17. Radiological concentrations detected in 2019 exit pathway groundwater monitoring (continued)

Monitoring location	Parameter	Wet season concentration[a] (pCi/L)	Dry season concentration[a] (pCi/L)	Reference value[b] (pCi/L)
Well 1190	^{214}Bi	153	36.4	10,400
Well 1190	^{212}Pb	4.38	ND	152
Well 1190	^{214}Pb	172	43.4	8,000
Well 1190	Tritium	14,500	14,800	20,000
Well 1191	Alpha activity	5.49	U2.59	15
Well 1191	Beta activity	229	234	50
Well 1191	^{214}Bi	102	27.5	10,400
Well 1191	^{212}Pb	6.02	ND	152
Well 1191	^{214}Pb	105	31.6	8,000
Well 1191	$^{89/90}Sr$	110	109	44
Well 1191	Tritium	14,900	15,300	20,000
Well 1239	Alpha activity	U2.59	3.93	15
Well 1239	Beta activity	5.21	9.86	50
Well 1239	^{214}Bi	8.91	ND	10,400
Well 1239	^{214}Pb	8.72	ND	8,000
Well 1239	Tritium	417	U142	20,000

[a] U = the analyte was measured but not detected above the practical quantitation limit/contractor-required detection limit; ND = the analyte was not detected in the gamma scan that was performed.
[b] Current federal and state standards were used as reference values. If no federal or state standard exists for the analyte, 4% of the derived concentration standard is used as the reference value.

Exit Pathway Groundwater Surveillance Summary

Concentrations of metals and man-made radionuclides observed in groundwater exit pathway discharge areas in 2019 at ORNL were generally consistent with observations reported in past annual site environmental reports for ORR. Based on the results of the 2019 monitoring effort, there is no indication that current SC operations are significantly introducing contaminants to the groundwater at ORNL.

Twelve radiological contaminants were detected in exit pathway groundwater samples collected in 2019. Gross alpha, gross beta, and $^{89/90}Sr$ were the only radiological parameters exceeding reference values at any of the discharge areas. Consistent with previous monitoring, gross beta and $^{89/90}Sr$ were observed at concentrations above their respective reference values in the WOC discharge area in 2019. The reported result for gross alpha activity in the wet season sample from well 535, in the northwest discharge area, was above the reference value, but it is believed that that result is likely a data anomaly resulting from analytical testing. The laboratory performed multiple additional analyses to identify the alpha-emitting radionuclides responsible for the gross alpha activity in the sample and was only able to identify a small fraction of it. Analyses were added to measure ^{241}Am, $^{243/244}Cm$, ^{237}Np, ^{238}Pu, $^{239/240}Pu$, ^{228}Th, ^{230}Th, ^{232}Th, $^{233/234}U$, $^{235/236}U$, ^{238}U, and radium alpha activity; most of those parameters were below the minimum detectable activity concentrations of the tests. The gross alpha activity was reported to be 30.4 pCi/L; the only alpha emitters that were detected were ^{232}Th (1.15 pCi/L) and alpha-emitting radium isotopes, measured collectively as total radium alpha activity (3.1 pCi/L). Gross alpha activity in the following dry-season sample from well 535 was below the analytical minimum detectable activity, which is typical for that well. No other radiological contaminants exceeded reference values at other discharge areas.

New maximum concentrations were measured for two parameters at one monitoring location in the east end discharge area—surface water location EE-01—in the dry-season sampling event. The concentration of ^{214}Pb activity was measured at 107 pCi/L (compared to a previous maximum of 23.9 pCi/L); the concentration of ^{214}Bi activity was measured at 95.3 pCi/L (compared to a previous maximum of 22.6 pCi/L). Both radionuclides are short-lived radioisotopes in the decay chain of ^{226}Ra (NIST 2020). Radon is a naturally occurring radioactive metal and the ^{226}Ra isotope is part of the uranium decay series (EPA 2019). Although these newest concentrations are the highest measured to date at the EE-01 location, both ^{214}Pb and ^{214}Bi are often detected, sometimes at higher concentrations, in other surface water locations in the east end discharge area (location EE-02) and southern discharge area (locations S-01 and S-02).

Twenty-seven metallic contaminants were detected in exit pathway groundwater samples collected in 2019; however, only four metals (iron, manganese, mercury, and thallium) were detected at concentrations exceeding reference values. Iron and manganese are commonly found in groundwater at ORNL. Mercury and thallium were detected in samples from one well each at concentrations slightly above the report limits, and in both cases the metal was also found in the associated method blank.

No organic compounds were detected at a quantifiable concentration in exit pathway groundwater monitoring in 2019.

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 for a discussion of results.)

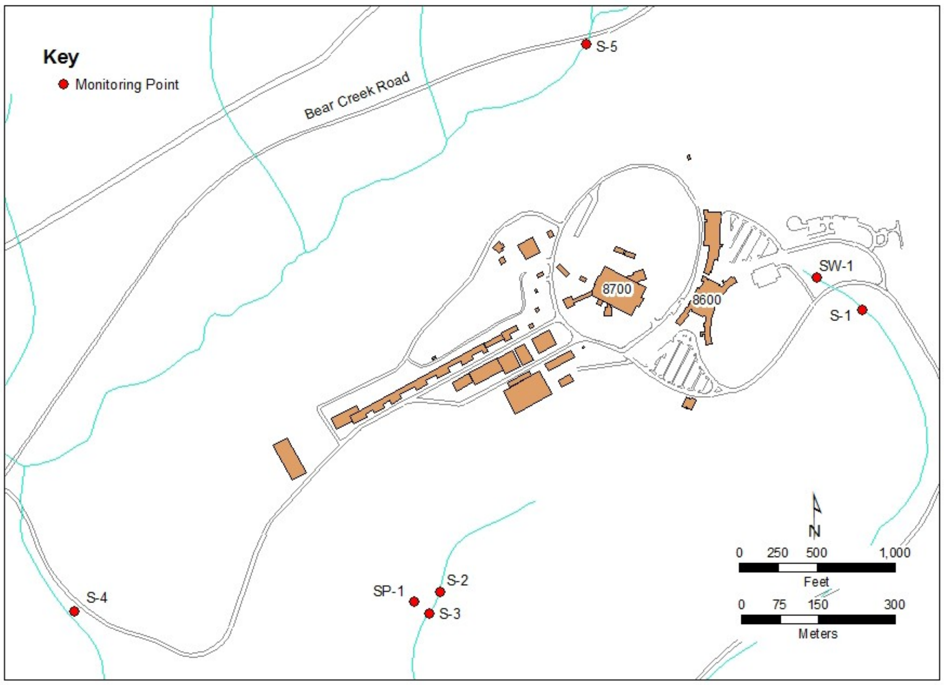
5.6.2.3 Active Sites Monitoring—Spallation Neutron Source

Active sites groundwater surveillance monitoring was performed in 2019 at the SNS site under the SNS operational monitoring plan (OMP) (Bonine, Ketelle, and Trotter 2007) due to 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, and/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 OMP include the following: (1) maintain compliance with applicable DOE contract requirements and environmental quality standards and (2) provide 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. Figure 5.43 shows the locations of the specific monitoring points sampled during 2019.



Acronyms: S = springs, SP = seeps, SW = surface water sampling areas

Figure 5.43. Groundwater monitoring locations at the Spallation Neutron Source, 2019

In November 2011 the SNS historical tritium data were evaluated to determine whether sampling could be optimized. The influence of flow condition on the proportion of tritium 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 indicated 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 tritium detects to nondetects.

The results of the statistical analysis of the April 2004–September 2011 data set were the basis for the modified OMP monitoring scheme implemented in 2012.

Quarterly sampling at each monitoring point continued in 2019, allowing the opportunity for monitoring in wet and dry seasons. All sampling performed in 2019 was performed in conjunction with rainfall events, with samples being collected during rising or falling (recession) limb flow conditions. In Figure 5.44, the curves represent spring or seep flow (base flow, through flow, overland flow, peak flow);

the bars represent rainfall amounts. Table 5.18 shows the sampling and parameter analysis schedule followed in 2019.

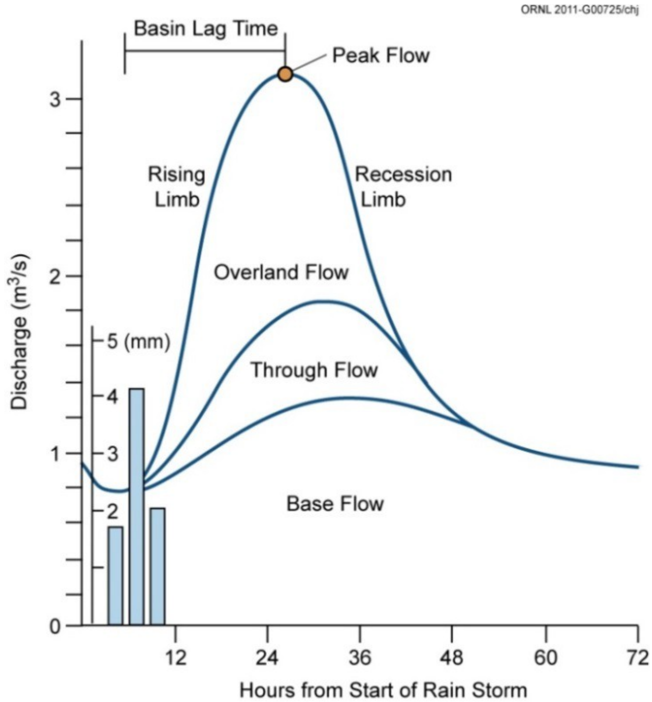


Figure 5.44. Simple hydrograph of spring discharge vs. time after initiation of rainfall

Table 5.18. 2019 Spallation Neutron Source monitoring program schedule

Monitoring location	Quarter 1 January–March	Quarter 2 April–June	Quarter 3 July–September	Quarter 4 October–December
SW-1	Tritium	Tritium	Tritium and expanded suite[a]	Tritium
S-1	Tritium	Tritium	Tritium and expanded suite[a] tritium	Tritium
S-2	Tritium	Tritium	Tritium	Tritium and expanded suite[a]
S-3	Tritium	Tritium	Tritium	Tritium and expanded suite[a]
S-4	Tritium and expanded suite[a]	Tritium	Tritium	Tritium
S-5	Tritium and expanded suite[a]	Tritium	Tritium	Tritium
SP-1	Tritium and expanded suite[a]	Tritium	Tritium	Tritium

[a] The expanded suite includes gross alpha and gross beta activity, ^{14}C, and gamma emitters.

Spallation Neutron Source Site Results. In 2019 sampling at the SNS site occurred during each quarter. Low concentrations of several radionuclides were detected numerous times during 2019. The ^{214}Bi and ^{214}Pb are daughter radionuclides in the uranium decay series and are considered to be of natural origins in the SNS water samples since no man-made uranium sources are present at the site. The low value of beta activity detected at the S-5 monitoring location is attributed to CERCLA contaminants in Bear Creek Valley associated with legacy waste management practices at the Y-12 facility. Table 5.19 provides a summary of the locations for radionuclide detections observed during 2019.

Sampling results were compared with reference values. Reference values used for comparison are current federal or state standards or 4 percent of the DCS. No detected radionuclide exceeded its reference value at SNS monitoring locations in 2019.

Table 5.19. Radiological concentrations detected in samples collected at the Spallation Neutron Source during 2019

Parameter	Concentrations[a] (pCi/L)				Reference Value[b]
	January	June	August	October	
			SW-1		
			ND[c]		
^{214}Bi			85		10,400
Tritium	2,410	1,760	1,990	3,930	20,000
			S-1		
			ND[c]		
^{214}Bi			40.1		10,400
^{214}Pb			35.5		8,000
Tritium	2,420	2,250	449	3,350	20,000
			S-2		
			ND[c]		
^{214}Pb			32.2		8,000
Tritium	622	741	646	1,150	20,000
			S-3		
			ND[c]		
^{214}Pb			33.9		8,000
Tritium	844	374	ND	269	20,000
			S-4		
	ND[d]				
^{214}Bi	42.9				10,400
^{214}Pb	40.3				8,000
Tritium	1,630	488	225	682	20,000
			S-5		
	ND[c]				
Beta	7.27				50
^{214}Bi	108				10,400
^{214}Pb	125				8,000
Tritium	534	295	ND	279	20,000
			SP-1		
		ND[d]			
Tritium	454	336	451	462	20,000

[a] ND: not detected. "U" means that the analyte was analyzed for 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 a particular radionuclide, 4 percent of the derived concentration standard for a radionuclide is used.
[c] Only some of the parameters of the expanded suite (gross alpha and gross beta activity, ^{14}C, and gamma emitters) for this location/quarter were detected, and they are listed with their results.
[d] None of the parameters of the expanded suite (gross alpha and gross beta activity, ^{14}C, and gamma emitters) for this location/quarter was detected.

5.6.2.4 Emerging Contaminant Assessment—Potential for Per- and Polyfluoroalkyl Substances in Oak Ridge National Laboratory Area Groundwater

A group of fluorinated organic chemical compounds collectively referred to as per- and polyfluoroalkyl substances (PFASs) are contaminants of emerging concern. PFAS compounds are persistent in the environment, and some are known to bioaccumulate in humans and/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 received the most study. In May 2017, EPA established a drinking water health advisory of 70 µg/L of combined PFOA and PFOS, but EPA has not established an MCL for drinking water. 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 paragraph was summarized from EPA's *Technical Fact Sheet—Perfluorooctane Sulfonate (PFOS) and Perfluorooctanoic Acid (PFOA)* (EPA 2017).

Historically, training of firefighters at ORNL included training in the use of AFFFs, and it is believed that the foams that were used in past training activities contained PFAS compounds. It is suspected that discharges of these foams to the environment during the training activities are the most significant potential source of PFAS releases to the environment 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. In 2019, a sampling and analysis plan (SAP) was developed to assess these areas for the presence of PFAS compounds in groundwater and in surface water bodies draining these areas. The SAP also includes monitoring of 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 of time (typically 4-week deployment periods) and which can accumulate PFAS compounds and allow the detection of trace concentrations that might not be detectable with traditional water sampling techniques. The SAP will be implemented in 2020.

Neither groundwater nor surface water at ORNL is a direct source of drinking water; ORNL's water supply is municipal water from the City of Oak Ridge.

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 (DOE 2011d). The methods used for successful implementation of the QMS rely on the integration and implementation of quality elements/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 upon 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 (IDMS).

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 employees and nonemployee staff of UT-Battelle 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.

Likewise, the NWSol Training and Qualification program 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

5.7.3.1 Calibration

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 the environmental monitoring programs conducted by

UT-Battelle for the ORNL site and ORR through a maintenance recall program to ensure that equipment is functioning properly and within defined tolerance ranges. 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 (RATA) is performed annually to certify the Predictive Emissions Monitoring System (PEMS) for nitrogen oxides and oxygen. The purpose of a RATA is to provide a rigorous QA assessment in accordance with *Performance Specification 16* (EPA 2009). The accuracy of PEMS 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

The UT-Battelle IDMS provides the necessary functionality and controls to ensure that controlled documents are managed, distributed, revised, and maintained in accordance with ORNL document control requirements. EPSD sampling procedures are maintained in IDMS 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 follow 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 5.1 presents a list of environmental audits and assessments performed at ORNL in 2019 and information on the number of findings identified, if any. EPSD also conducts internal management assessments of UT-Battelle environmental monitoring procedural compliance, safety performance, and work planning and control. Surveillance results, recommendations, and completion of corrective actions, if required, are also documented and tracked in the UT-Battelle Assessment and Commitment Tracking System.

NWSol and Isotek perform independent audits, surveillances, and internal management assessments to verify that requirements have been accurately specified and that activities that have been performed conform to expectations and requirements. NWSol corrective actions, if required, are documented and tracked in an issues management database or a deficiency reporting database, and Isotek corrective actions are tracked in its Assessment and Commitment Tracking System.

5.7.5 Analytical Quality Assurance

The contract laboratories that perform analyses of environmental samples from the UT-Battelle environmental monitoring programs at ORNL and on ORR are required to have documented QA/QC programs, trained and qualified staff, appropriately maintained equipment and facilities, and applicable certifications. Several laboratories are contracted under basic ordering agreements to perform analytical work to characterize UT-Battelle environmental samples. As applicable, the laboratories participate in accreditation, certification, and performance evaluation programs, including the National Environmental Laboratory Accreditation Program, Mixed Analyte Performance Evaluation Program, Discharge Monitoring Report Quality Assurance Study, and DOE Environmental Management Consolidated Audit Program. Any issues of concern identified through accreditation/certification programs or performance evaluation testing are addressed with analytical laboratories and are considered when determinations are made on data integrity.

A statement of work for each project specifies any additional QA/QC requirements and includes detailed information on data deliverables, turnaround times, and required methods and detection limits. Blank and duplicate samples are routinely submitted along with ORR environmental samples to provide an additional check on analytical laboratory performance.

5.7.6 Data Management and Reporting

Management of data collected by UT-Battelle in conjunction with ORR and ORNL environmental surveillance programs and with CWA activities at ORNL is accomplished 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 Records Management System provides the requirements for managing all UT-Battelle records. Requirements include creating and identifying record material; scheduling, protecting, and storing records in office areas and in the UT-Battelle Inactive Records Center; and destroying records.

NWSol and Isotek maintain all records specific to their projects at ORNL, 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 Oak Ridge National Laboratory

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 remaining from past operations. The contaminated portions of ORR are on the EPA NPL, 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 the EPA and TDEC. The *2019 Cleanup Progress Annual Report to the Oak Ridge Regional Community* (UCOR 2019) provides detailed information on DOE OREM's 2019 cleanup activities.

5.8.1 Wastewater Treatment

At ORNL, DOE OREM operates PWTC and the Liquid Low-Level Waste Treatment Facility. In 2019 321.6 million L of wastewater was treated and released at PWTC. In addition, the liquid LLW system at ORNL received 294,465 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 a by-product 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. Waste streams that can be treated by on-site liquid and/or gaseous waste treatment facilities operated by OREM are treated via these systems. 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 2019, ORNL performed 100 waste and recycle shipments to off-site hazardous/radiological/mixed waste treatment and/or disposal vendors with no shipment rejections.

5.8.3 Transuranic Waste Processing Center

TRU waste-processing activities carried out for DOE in 2019 by NWSol addressed CH solids/debris and RH solids/debris, which involved processing, treating, and repackaging of waste. In 2019, LLW/mixed LLW was transported to the Nevada National Security Site or to another approved offsite facility for disposal. TRU waste disposal at the Waste Isolation Pilot Plant resumed in 2017. In 2019, NWSol shipped 226.0 m^3 of CH TRU waste from TWPC in 29 shipments (1,076 containers).

During 2019, 32.1 m^3 of CH waste and 6.4 m^3 of RH waste were processed, and 114.1 m^3 of mixed LLW (TRU waste that was recharacterized as LLW) was shipped off the site.

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6. Oak Ridge Reservation Environmental Monitoring Program

Environmental monitoring is performed on ORR to measure radiological and nonradiological parameters directly in environmental media adjacent to the facilities. Data from the environmental monitoring program are analyzed to assess the environmental impact of DOE operations on the entire reservation and the surrounding area. Dose assessment information based on data from this program is presented in Chapter 7.

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

6.1 Meteorological Monitoring

Ten meteorological towers provide data on meteorological conditions and on the transport and diffusion qualities of the atmosphere on ORR. Data collected at the towers are used in routine dispersion modeling to predict impacts from facility operations and as input to emergency response atmospheric models, which are used for simulated and actual accidental releases from a facility. Data from the towers are also used to support various research and engineering projects.

6.1.1 Data Collection and Analysis

The 10 meteorological towers on ORR are described in Table 6.1 and are depicted in Figure 6.1. In this document, the individual ORR-managed towers are designated by "MT" followed by a numeral. Other commonly used names for these sites are also provided in Table 6.1. Meteorological data are collected at different levels above the ground (2, 10, 15, 30, 33, 35, and 60 m) to assess the vertical structure of the atmosphere, particularly with respect to wind shear and stability. Stable boundary layers and significant wind shear zones (associated with the local ridge-and-valley terrain and the Great Valley of Eastern Tennessee; see Appendix B) can significantly affect the movement of a plume after a facility release (Bowen et al. 2000). Data are collected at the 10 or 15 m level at most towers, but the wind measurement height is 25 m for MT11 and 20 m for MT13. Data are collected at some towers at 30, 33, 35, and 60 m levels. Temperature, relative humidity, and precipitation are measured at some sites at 2 m, but wind speed and wind direction typically are not. Atmospheric stability (a measure of the vertical mixing properties of the atmosphere) is measured at most towers; however, measurements involving vertical temperature profiles (i.e., measurements made by the solar radiation delta-T method) limit accurate determination of nighttime stability to the 60 m towers. Stability is also calculated for most sites using the sigma phi method, which relies heavily on the measurement of the standard deviation of vertical wind speed using three-dimensional sonic wind monitors. Barometric pressure is measured at one or more of the towers at each ORR plant (MT2, MT4, MT6, MT7, MT9, MT12, and MT13). Precipitation is measured at MT6 and MT9 at the Y-12 Complex; at MT7 and MT13 at ETTP; and at MT2, MT3, MT4, and MT12 at ORNL. Solar radiation is measured at MT6 and MT9 at the Y-12 Complex, MT7 at ETTP, and at MT2 and MT12 at ORNL. Instrument calibrations are managed by UT-Battelle and are performed every 6 months by an independent auditor (Holian Environmental).

Table 6.1. Oak Ridge Reservation meteorological towers

Tower	Alternate tower names	Location (lat., long.)	Altitude (m above MSL)	Measurement heights (m)
		ETTP		
MT7	L, 1209	35.92522N, -84.39414W	233	2, 15, 30
MT13	J, YEOC	35.93043N, -84.39346W	237	20
		ORNL		
MT2	D,[a] 1047	35.92559N, -84.32379W	261	2, 15, 35, 60
MT3	B, 6555	35.93273N, -84.30254W	256	15, 30
MT4	A, 7571	35.92185N, -84.30470W	266	15, 30
MT10	M, 208A	35.90947N, -84.38796W	244	10
MT12	F	35.95285N, -84.30314W	354	10
		Y-12 Complex		
MT6	W, West	35.98058N, -84.27358W	326	2, 10, 30, 60
MT9	Y, PSS Tower	35.98745N, -84.25363W	290	2, 15, 33
MT11	S, South Tower	35.98190N, -84.25504W	352	25

[a] Tower “C” before May 2014.

Acronyms:
ETTP = East Tennessee Technology Park
MSL = mean sea level
ORNL = Oak Ridge National Laboratory
PSS = plant shift superintendent
Y-12 Complex = Y-12 National Security Complex
YEOC = Y-12 Complex Emergency Operations Center

Sonic detection and ranging (SODAR) devices have been installed at the east end of the Y-12 Complex and adjacent to Tower MT2 at ORNL. The SODAR devices use acoustic waves to estimate wind direction, wind speed, and turbulence at altitudes higher than the reach of meteorological towers (40 m up to 800 m above ground level). Although SODAR measurements are somewhat less accurate than measurements made on the meteorological towers, the SODAR devices provide useful information regarding stability, upper air winds, and mixing depth. Mixing depth represents the thickness of the air layer adjacent to the ground over which an emitted or entrained inert nonbuoyant tracer could potentially be mixed by turbulence within 1 h or less.

Meteorological data are collected in real time for 1 min, 15 min, and hourly average intervals for emergency response purposes and for dispersion modeling at the ORNL and Y-12 Complex Emergency Operations Centers.

Annual dose estimates are calculated from the archived hourly data. Data quality is checked continuously against predetermined data constraints, and out-of-range parameters are marked as invalid and are excluded from compliance modeling. Appropriate substitution data are identified when possible. Quality assurance records of missing and erroneous data are routinely kept for the 10 ORR towers.

ORNL 2018-G00374/mhr

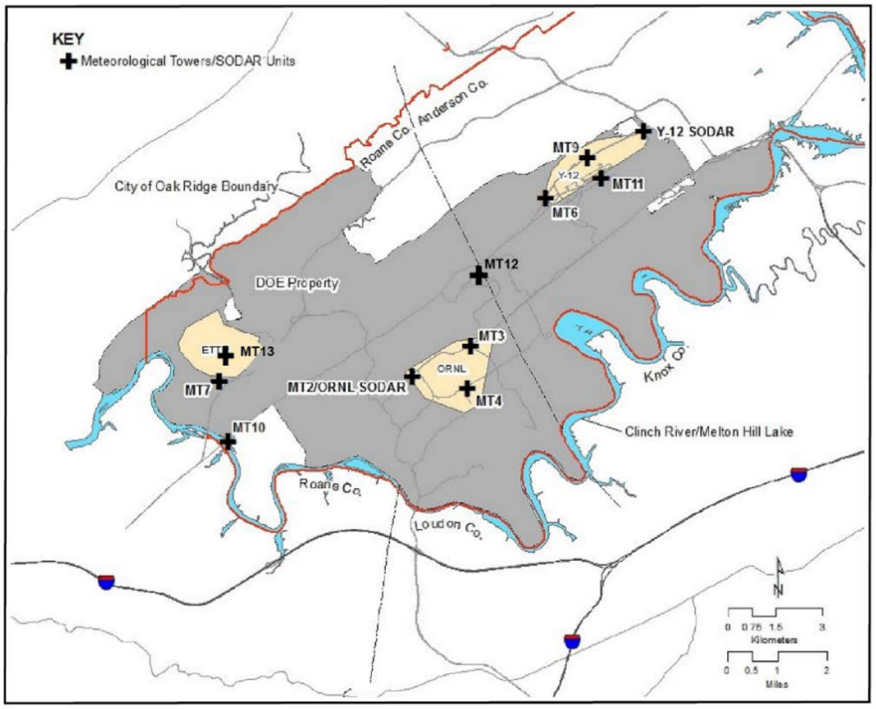


Figure 6.1. The Oak Ridge Reservation meteorological monitoring network, including sonic detection and ranging (SODAR) devices

6.1.2 Results

Prevailing winds are generally up-valley from the southwest and west-southwest or down-valley from the northeast and east-northeast, a pattern that typically results from channeling effects produced by the parallel ridges flanking ORR sites. Winds in the valleys tend to follow the ridge axes, limiting cross-ridge flow within local valley bottoms. These conditions dominate over most of ORR, but flow variation is greater at ETTP, which is located within a less-constrained open valley bottom.

On ORR, low wind speeds dominate near the valley surfaces, largely because of the decelerating influence of nearby ridges and mountains. Wind acceleration sometimes is observed at ridgetop level, particularly when flow is not parallel to the ridges (see Appendix B).

The atmosphere over ORR is often dominated by stable conditions at night and for a few hours after sunrise. These conditions, when coupled with low wind speeds and channeling effects in the valleys, result in poor dilution of emissions from the facilities. However, high roughness values (caused by terrain and obstructions such as trees and buildings) may significantly mitigate these factors through an increase in turbulence (atmospheric mixing). These features are captured in dispersion model data input and are reflected in modeling studies conducted for each facility.

Precipitation data from tower MT2 are used in stream-flow modeling and in certain research efforts. The data indicate the variability of regional precipitation: the high winter rainfall resulting from frontal systems and the uneven, but occasionally intense, summer rainfall associated with frequent air mass thunderstorms. The total precipitation at ORNL during 2019 (1,846.4 mm or 72.93 in.) was almost 40 percent above the long-term average of 1,337.5 mm (52.64 in.). The average annual wind data recovery rates (a measure of acceptable data) across locations used for modeling during 2019 were greater than 99.6 percent for wind sensors at ORNL sites MT2, MT3, MT4, MT10, and MT12. Annual wind data recovery from Y-12 meteorological towers during 2019 exceeded 99.8 percent (towers MT6, MT9, and MT11). At ETTP, annual wind data recovery exceeded 98.8%.

6.2 External Gamma Radiation Monitoring

6.2.1 Data Collection and Analysis

External gamma exposure rates are continuously recorded by dual-range Geiger-Müller tube detectors co-located with ORR ambient air stations. Figure 6.2 shows locations that were monitored during 2019, and Table 6.2 summarizes the data for each station.

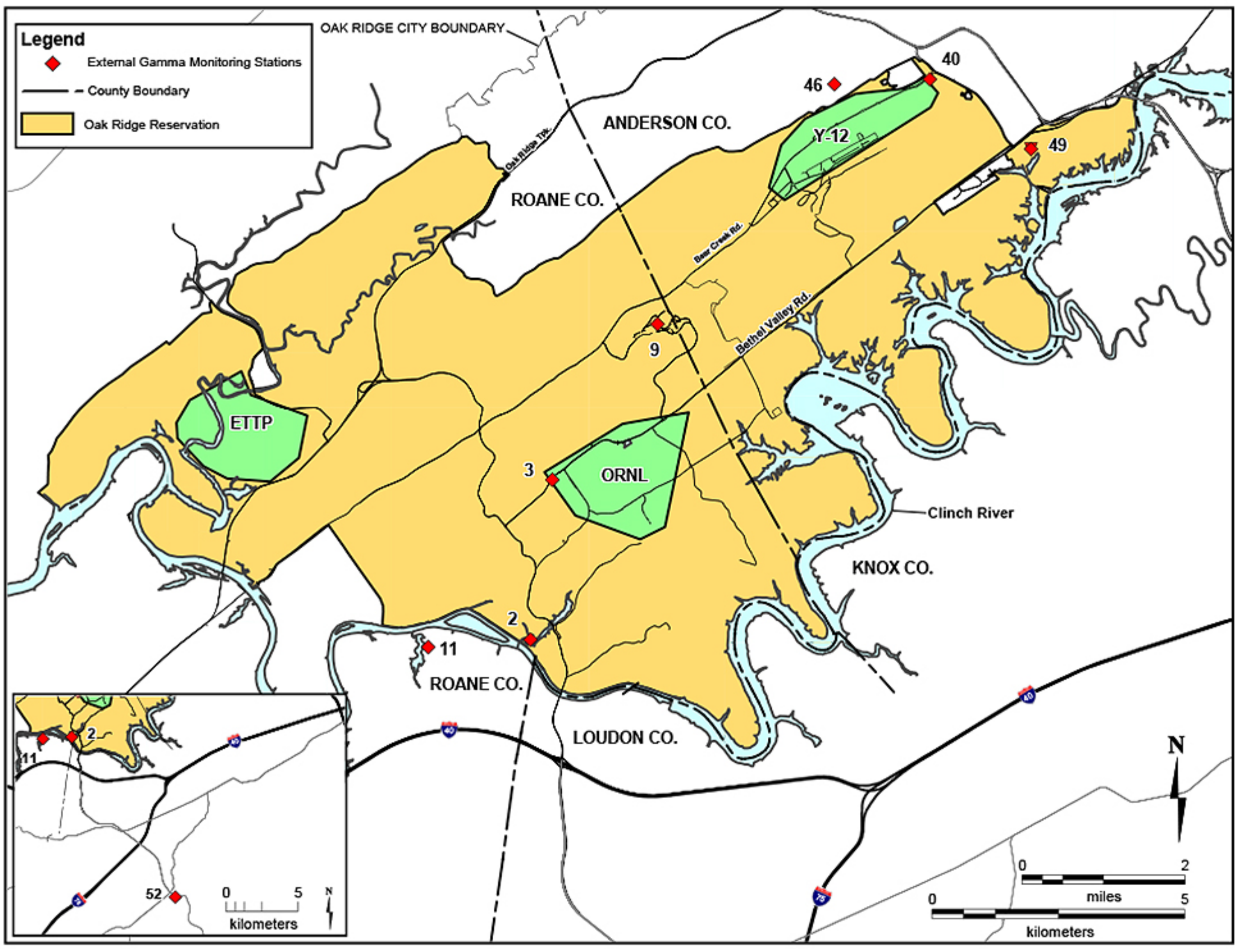


Figure 6.2. External gamma radiation monitoring locations on the Oak Ridge Reservation

6.2.2 Results

The mean exposure rate for the reservation network in 2019 was 9.9 μR/h, and the mean rate at the reference location was 9.1 μR/h. Background direct radiation exposure rates have been collected at an off-site location for many years. From 2009 through 2018 (the preceding 10 years), the exposure rates at the background off-site location ranged from 5.6 to 11.4 μR/h. The average exposure rate for the ORR network for those years was 7.9 μR/h (rounded to 8 μR/h).

Table 6.2. External gamma (exposure rate) averages for the Oak Ridge Reservation, 2019

Monitoring location	Number of data points (daily)	Measurement (μR/h)[a]		
		Min	Max	Mean
02	323	8.5	10.6	9.2
03	354	8.9	10.6	9.4
09	361	8.7	12.5	9.4
11	365	10.0	12.0	10.7
40	364	9.2	11.4	10.0
46	347	10.0	12.1	10.8
49	363	9.1	11.2	9.7
52	361	8.5	10.6	9.1

[a] To convert microroentgens per hour (μR/h) to milliroentgens per year, multiply by 8.760.

6.3 Ambient Air Monitoring

In addition to exhaust stack monitoring conducted at ORR installations (see chapters 3, 4, and 5), ambient air monitoring is performed to measure radiological parameters directly in the ambient air adjacent to the facilities (Figure 6.3). Ambient air monitoring provides a means to verify that contributions of fugitive and diffuse sources are insignificant, serves as a check on dose-modeling calculations, and would allow determination of contaminant levels at monitoring locations in the event of an emergency.

Figure 6.3. Oak Ridge Reservation ambient air station

6.3.1 Data Collection and Analysis

Ambient air monitoring conducted by individual site programs is discussed in chapters 3, 4, and 5. The ORR ambient air monitoring program complements the individual site programs and permits the impacts of ORR operations to be assessed on an integrated basis.

The objectives of the ORR ambient air monitoring program are to perform surveillance of airborne radionuclides at the reservation perimeter and to collect reference data from a location not affected by activities on ORR. The perimeter air monitoring network was established in the early 1990s. Since then there have been significant operational changes on ORR (e.g., addition of Spallation Neutron Source and Transuranic Waste Processing Center operations and shutdown of the Toxic Substances Control Act Incinerator), and significant cleanup and remediation projects have been completed. The network was modified in 2016 to better reflect current DOE activities and operations. The stations monitored in 2019 are shown in Figure 6.4. Reference samples are collected from Station 52 (Fort Loudoun Dam). Sampling was conducted at each ORR station during 2019 to quantify levels of alpha-, beta-, and gamma-emitting radionuclides.

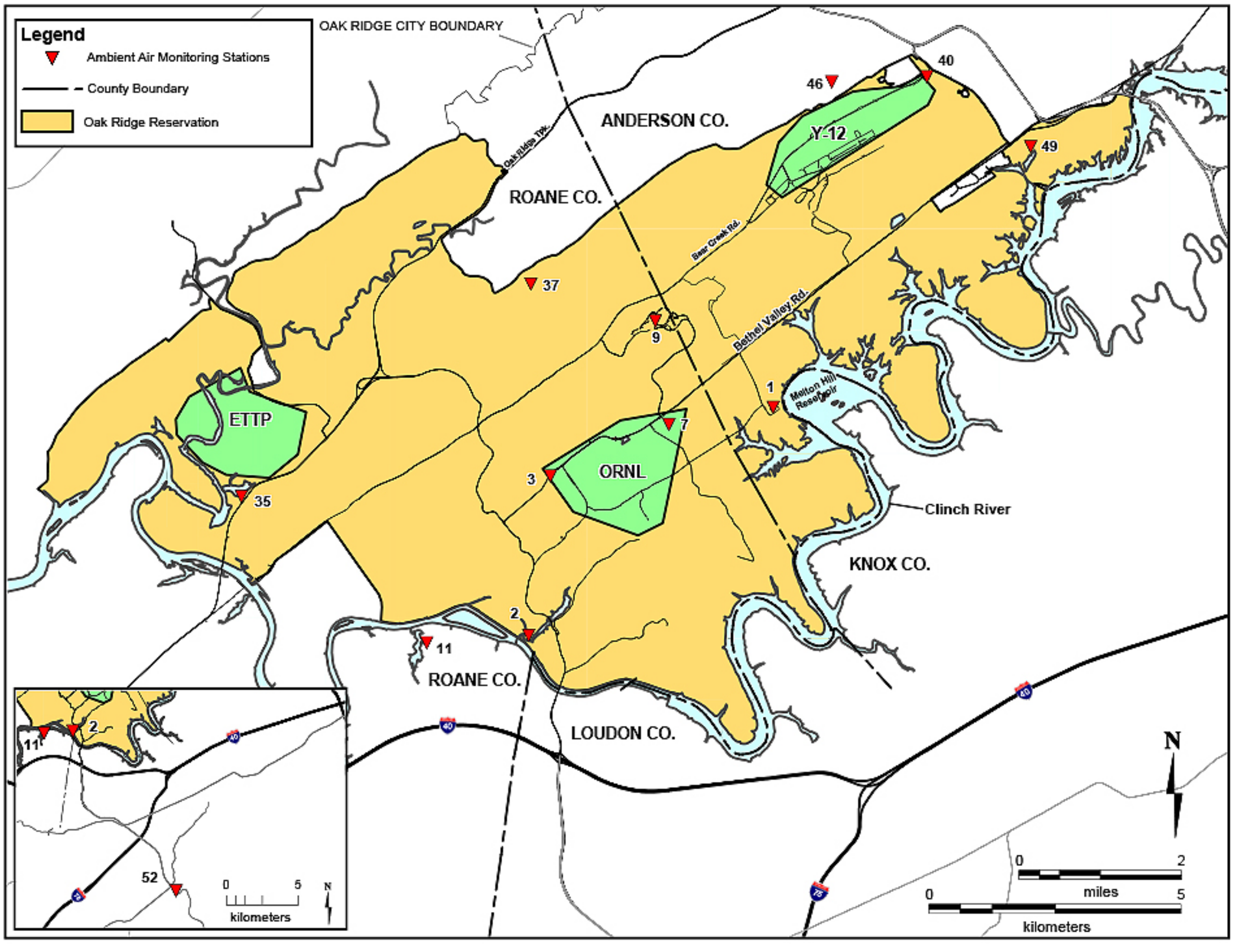


Figure 6.4. Locations of Oak Ridge Reservation perimeter air monitoring stations

Atmospheric dispersion modeling was used to select appropriate sampling locations. The locations selected are those likely to be affected most by releases from the Oak Ridge facilities. Therefore, in the event of a release, no residence or business near ORR should receive a radiation dose greater than doses calculated at the sampled locations.

The sampling system consists of two separate instruments. Particulates are captured by high-volume air samplers equipped with glass-fiber filters. The filters are collected weekly, composited quarterly, and then submitted to an analytical laboratory to quantify gross alpha and beta activity and to determine the concentrations of specific isotopes of interest on ORR. The second system is designed to collect tritiated water vapor. The sampler consists of a prefilter followed by an adsorbent trap that contains indicating silica gel. The samples are collected weekly or biweekly, composited quarterly, and then submitted to an analytical laboratory for tritium analysis.

6.3.2 Results

Data from the ORR ambient air network are analyzed to assess the impact of DOE operations on the local air quality. Each measured radionuclide concentration (Table 6.3) is compared with derived concentration standards (DCSs) for air established by DOE as guidelines for controlling exposure to members of the public (DOE 2011). All radionuclide concentrations measured at the ORR ambient air stations during 2019 were less than 1 percent of applicable DCSs.

Table 6.3. Radionuclide concentrations at Oak Ridge Reservation perimeter air monitoring stations, 2019

Parameter	N detected/N total	Concentration (pCi/mL)[a]		
		Average	Minimum	Maximum
		Station 1		
^{7}Be	4/4	4.90E-08	2.55E-08	8.27E-08
^{40}K	0/4	-4.79E-10[b]	-1.11E-09[b]	-1.95E-11[b]
Tritium	0/4	5.46E-06	3.00E-06	6.96E-06
^{234}U	4/4	2.21E-12	9.03E-13	5.21E-12
^{235}U	0/4	1.81E-13	1.20E-13	2.32E-13
^{238}U	4/4	1.79E-12	1.15E-12	2.43E-12
		Station 2		
^{7}Be	4/4	4.62E-08	3.39E-08	7.77E-08
^{40}K	0/4	-5.77E-10[b]	-9.71E-10[b]	-2.88E-10[b]
Tritium	0/4	3.76E-06	9.60E-07	6.34E-06
^{234}U	4/4	2.00E-12	1.54E-12	2.38E-12
^{235}U	1/4	4.62E-13	5.31E-14	1.21E-12
^{238}U	4/4	2.04E-12	8.25E-13	4.59E-12
		Station 3		
^{7}Be	4/4	3.29E-08	2.60E-08	3.79E-08
^{40}K	0/4	-2.78E-11[b]	-3.59E-10[b]	7.35E-10
Tritium	1/4	2.41E-06	-3.38E-06[b]	6.15E-06
^{234}U	4/4	1.74E-12	1.17E-12	2.82E-12
^{235}U	1/4	2.21E-13	6.67E-14	3.54E-13
^{238}U	3/4	1.41E-12	4.08E-13	2.68E-12
		Station 9		
^{7}Be	4/4	3.62E-08	2.73E-08	4.81E-08
^{40}K	0/4	-2.77E-10[b]	-5.74E-10[b]	1.60E-10
Tritium	4/4	4.53E-05	2.20E-05	8.94E-05
^{234}U	3/4	4.04E-12	1.16E-12	5.80E-12
^{235}U	1/4	4.23E-13	1.44E-13	9.17E-13
^{238}U	4/4	2.18E-12	1.11E-12	4.26E-12
		Station 11		
^{7}Be	4/4	3.51E-08	1.93E-08	4.35E-08
^{40}K	0/4	-1.12E-10[b]	-2.37E-10[b]	1.02E-10
Tritium	0/4	2.30E-06	1.23E-06	4.17E-06
^{234}U	4/4	1.67E-12	1.48E-12	1.94E-12
^{235}U	0/4	2.44E-13	1.40E-13	3.85E-13
^{238}U	3/4	1.51E-12	6.48E-13	3.40E-12

Table 6.3 Radionuclide concentrations at Oak Ridge Reservation perimeter air monitoring stations, 2019 (continued)

Parameter	N detected/N total	Concentration (pCi/mL)[a]		
		Average	Minimum	Maximum
		Station 35		
^{7}Be	4/4	4.21E-08	2.86E-08	7.02E-08
^{40}K	0/4	-3.60E-10[b]	-9.07E-10[b]	-1.26E-11[b]
^{99}Tc	1/4	5.55E-11	-4.26E-11	3.15E-10
Tritium	1/4	5.16E-06	2.51E-06	6.70E-06
^{234}U	4/4	2.46E-12	1.53E-12	4.52E-12
^{235}U	1/4	3.34E-13	2.01E-13	5.56E-13
^{238}U	4/4	3.38E-12	9.54E-13	9.43E-12
		Station 37		
^{7}Be	4/4	3.96E-08	3.04E-08	5.59E-08
^{214}Bi	2/4	7.19E-11	0.00E+00	1.68E-10
^{40}K	0/4	-2.54E-10[b]	-4.60E-10[b]	1.91E-10
Tritium	0/4	3.15E-06	8.97E-07	4.37E-06
^{234}U	4/4	1.80E-12	1.09E-12	2.77E-12
^{235}U	2/4	3.03E-13	1.81E-14	5.81E-13
^{238}U	3/4	1.90E-12	7.23E-13	3.62E-12
		Station 40		
^{7}Be	4/4	4.03E-08	2.56E-08	5.79E-08
^{40}K	0/4	1.48E-13	-6.05E-10[b]	2.14E-10
Tritium	0/4	2.57E-06	2.18E-07	4.34E-06
^{234}U	4/4	9.66E-12	4.43E-12	1.57E-11
^{235}U	2/4	6.55E-13	3.15E-13	1.24E-12
^{238}U	4/4	3.22E-12	1.49E-12	5.00E-12
		Station 46		
^{7}Be	4/4	2.85E-08	1.97E-08	3.27E-08
^{40}K	0/4	-7.91E-11[b]	-3.37E-10[b]	3.69E-10
Tritium	0/4	2.17E-06	-4.40E-07[b]	4.84E-06
^{234}U	4/4	3.48E-12	2.30E-12	4.02E-12
^{235}U	0/4	3.36E-13	1.28E-13	6.03E-13
^{238}U	4/4	1.90E-12	8.59E-13	3.09E-12
		Station 49		
^{7}Be	4/4	3.38E-08	1.97E-08	4.53E-08
^{40}K	0/4	-1.55E-10[b]	-3.37E-10[b]	1.43E-10
Tritium	0/4	2.22E-06	1.88E-07	3.83E-06
^{234}U	4/4	2.72E-12	1.32E-12	4.54E-12
^{235}U	2/4	3.51E-13	2.27E-13	5.67E-13
^{238}U	4/4	1.51E-12	1.03E-12	2.18E-12

Table 6.3 Radionuclide concentrations at Oak Ridge Reservation perimeter air monitoring stations, 2019 (continued)

Parameter	N detected/N total	Concentration (pCi/mL)[a]		
		Average	Minimum	Maximum
		Station 52[c]		
^{7}Be	4/4	3.65E-08	2.19E-08	5.43E-08
^{40}K	0/4	-1.55E-10[b]	-6.55E-10[b]	7.36E-11
^{99}Tc	1/4	1.16E-10	-4.56E-11[b]	5.70E-10
Tritium	0/4	2.71E-07	-6.90E-07[b]	2.67E-06
^{234}U	4/4	1.56E-12	8.36E-13	2.46E-12
^{235}U	1/4	1.90E-13	-1.64E-14[b]	5.19E-13
^{238}U	4/4	1.48E-12	1.09E-12	2.27E-12

[a] 1 pCi = 3.7×10^{-2} Bq.

[b] A negative concentration of radioactivity is reported by the laboratory when the sample count rate minus the background count rate is negative (i.e., the background count rate was greater than the sample count rate).When the background activity is subtracted from the sample activity to obtain a net value, a negative value results.

[c] Station 52 is the reference location.

6.4 Surface Water Monitoring

The ORR surface water monitoring program consists of sample collection and analysis from four locations on the Clinch River, including public water intakes (Figure 6.5). The program is conducted in conjunction with site-specific surface water monitoring activities to enable an assessment of the impacts of past and current DOE operations on the quality of local surface water.

6.4.1 Data Collection and Analysis

Grab samples are collected quarterly at all four locations and are analyzed for general water quality parameters, screened for radioactivity, and analyzed for mercury and specific radionuclides when appropriate. Table 6.4 lists the specific locations and associated sampling frequencies and parameters.

At the sampling locations, the Clinch River is classified by the State of Tennessee for multiple uses, including recreation and domestic supply. These two designated uses have numeric Tennessee Water Quality Criteria (WQCs) related to protection of human health. These WQCs are used as references where applicable (TDEC 2014). The Tennessee WQCs do not include criteria for radionuclides. Four percent of the DOE DCS is used for radionuclide comparison.

6.4.2 Results

In 2019, as has been the case since 2009, there were no statistical differences in radionuclide concentrations in surface water samples collected from the Clinch River upstream and downstream of DOE inputs. No radionuclides were detected above 4 percent of the respective DCSs.

Mercury was not detected in 2019 in samples from any of the three sampling locations where mercury samples are collected, Clinch River kilometer (CRK) 66, CRK 32, and CRK 16.

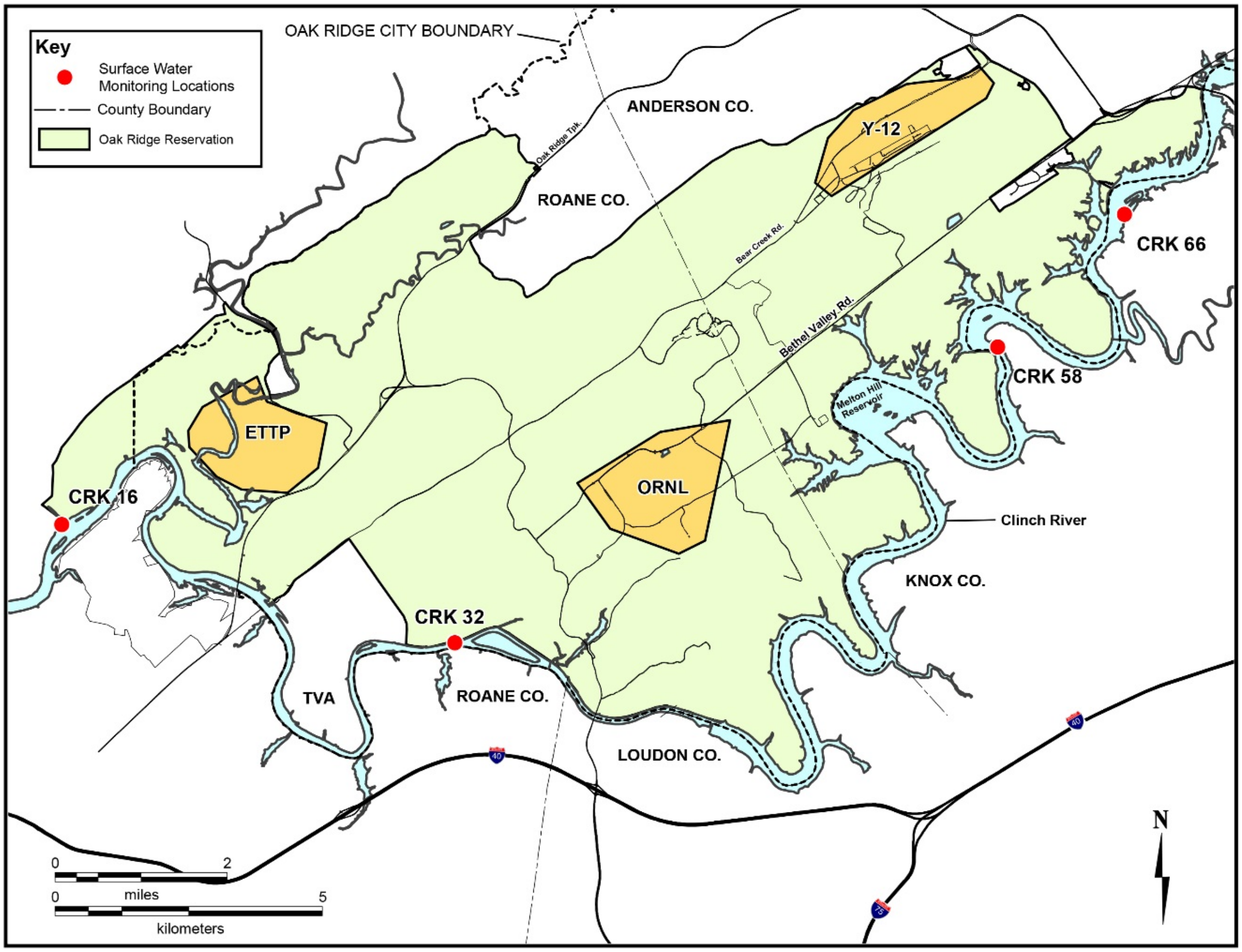


Figure 6.5. Oak Ridge Reservation surface water surveillance sampling locations

Table 6.4. Oak Ridge Reservation surface water sampling locations, frequencies, and parameters, 2019

Location[a]	Description	Frequency	Parameters
CRK 16	Clinch River downstream from all DOE ORR inputs	Quarterly	Mercury, gross alpha, gross beta, gamma scan, ^{3}H, field measurements[b]
CRK 32	Clinch River downstream from ORNL	Quarterly	Mercury, gross alpha, gross beta, gamma scan, total radioactive strontium, ^{3}H, field measurements[b]
CRK 58	Water supply intake for Knox County	Quarterly	Gross alpha, gross beta, gamma scan, ^{3}H, field measurements[b]
CRK 66	Melton Hill Reservoir above City of Oak Ridge water intake	Quarterly	Mercury, gross alpha, gross beta, gamma scan, total radioactive strontium, ^{3}H, field measurements[b]

[a] Locations indicate the water body and distances upstream of the confluence of the Clinch and Tennessee Rivers (e.g., CRK 16 is 16 km upstream from the confluence of the Clinch River with the Tennessee River in the Watts Bar Reservoir).
[b] Field measurements consist of dissolved oxygen, pH, and temperature.

Acronyms:
CRK = Clinch River kilometer
DOE = US Department of Energy
ORNL = Oak Ridge National Laboratory
ORR = Oak Ridge Reservation

6.5 Groundwater Monitoring

Work continued in 2019 to implement key recommendations from the *Groundwater Strategy for the U.S. Department of Energy Oak Ridge Reservation* (DOE 2013), which was agreed to in 2014 by DOE, EPA, and the Tennessee Department of Environment and Conservation (TDEC). During 2019 the ORR Groundwater Program transitioned from previous tasks, including off-site groundwater quality assessment and regional-scale groundwater flow model development, to planning continued off-site monitoring and development of site-scale groundwater flow models for the ORNL site.

6.5.1 Off-Site Groundwater Assessment

During FY 2019 the Oak Ridge Office of Environmental Management (OREM) continued to collect and analyze samples from the off-site groundwater monitoring well array west of the Clinch River adjacent to Melton Valley. In addition, exit pathway groundwater monitoring in Melton Valley is conducted as part of the OREM program, including sampling at six multiport monitoring wells in western Melton Valley (wells 4537, 4538, 4539, 4540, 4541, and 4542). Results of this monitoring are summarized in the 2020 remediation effectiveness report (DOE 2020).

DOE completed an off-site groundwater assessment project and issued a final report on the off-site groundwater study in October 2017 (DOE 2017). The project was a cooperative effort among the parties to the ORR Federal Facility Agreement to investigate off-site groundwater quality and potential movement. As follow-on work from the off-site groundwater assessment, DOE conducts annual sampling and analysis of groundwater from several off-site residential wells and springs.

6.5.2 Regional and Site-Scale Flow Model

During FY 2017 DOE completed a project to construct and calibrate a regional-scale groundwater flow model that encompasses ORR and adjacent areas. The regional model provides an underlying framework to support creation of smaller, site-scale groundwater flow models for use in planning and monitoring effectiveness of future cleanup decisions and actions. During FY 2019 DOE developed more refined groundwater flow models for the ORNL site to support the *Bethel Valley Final Groundwater Record of Decision Remedial Investigation Work Plan*, which will be published during FY 2020. The new models can be used for evaluating groundwater contaminant migration in the vicinity of Bethel and Melton Valleys.

6.6 Food

Food sources are analyzed to evaluate potential radiation doses to consumers of local food crops, fish, and harvested game and to monitor trends in environmental contamination and possible long-term accumulation of radionuclides. Samples of hay, vegetables, milk, fish, deer, Canada geese, and turkeys are usually collected every year from areas that could be affected by activities on the reservation and from off-site reference locations. Milk was not collected in 2019 because the dairy that had supplied milk samples went out of business in 2016. The areas identified as potential areas of impact from DOE activities will be checked during 2020 for dairy operations.

The wildlife administrative release limits associated with deer, turkey, and geese harvested on ORR are conservative and were established based on the "as low as reasonably achievable" (ALARA) principle to ensure that doses to consumers are managed at levels well below regulatory dose thresholds. The ALARA concept is not a dose limit but rather a philosophy that has the objective of maintaining exposures to workers, members of the public, and the environment below regulatory limits and as low as can be reasonably achieved. An administrative release limit of 5 pCi/g ^{137}Cs is based on the assumption that one person consumes all of the meat from a maximum-weight deer, goose, or turkey. This limit ensures that members of the public who harvest wildlife on the reservation will not receive significant radionuclide doses from that consumption pathway. In addition, a conservative administrative limit of 1.5 times background for gross beta activity has been established, a threshold that is near the detection limit for field measurements of $^{89/90}$Sr in deer leg bone.

6.6.1 Hay

Hay is sampled because eating beef and drinking milk obtained from "hypothetical" cattle that eat hay is an environmental pathway to potential radiation doses to consumers.

6.6.1.1 Data Collection and Analysis

Hay is collected and analyzed from one location on ORR. Hay samples collected on ORR during May and July 2019 were analyzed for gross alpha, gross beta, gamma emitters, and uranium isotopes.

6.6.1.2 Results

Radionuclides detected in hay are shown in Table 6.5. Statistically significant concentrations of gross alpha activity, gross beta activity, ^{7}Be, ^{40}K, ^{234}U, and ^{238}U were detected at that sampling location for at least one of the two collection events.

Table 6.5. Concentrations of radionuclides detected in hay, 2019 (pCi/kg)[a]

Collection	Gross alpha	Gross beta	^{7}Be	^{40}K	^{234}U	^{235}U	^{238}U
May	*b*	7,840	*b*	11,600	4.7	*b*	*b*
July	160	12,400	*b*	*b*	*b*	*b*	2.7

[a] Detected radionuclides are those at or above minimum detectable activity. 1 pCi = 3.7×10^{-2} Bq.
[b] Value was less than or equal to minimum detectable activity.

6.6.2 Vegetables

6.6.2.1 Data Collection and Analysis

Tomatoes, turnip greens, and turnips were purchased in 2019 from farms near ORR and from reference locations outside the potential DOE impact area. The locations were chosen based on availability and on the likelihood of effects from routine releases from the Oak Ridge facilities. Samples were analyzed for gross alpha, gross beta, gamma emitters, and uranium isotopes.

6.6.2.2 Results

Analytical results for vegetable samples are provided in Table 6.6. No gamma-emitting radionuclides were detected above the minimum detectable activity, except for the naturally occurring radionuclides ^{7}Be and ^{40}K.

Table 6.6. Concentrations of radionuclides detected in vegetables, 2019 (pCi/kg)[a]

Location	Gross alpha	Gross beta	^{7}Be	^{40}K	^{234}U	^{235}U	^{238}U
			Turnips				
North of Y-12	128	5,100	*b*	8,300	7.3	1.9	7.9
South of ORNL	*b*	1,300	*b*	1,800	2.5	*b*	*b*
West of ETTP	*b*	700	*b*	2,100	3.3	*b*	*b*
Reference location	*b*	1,100	*b*	*b*	*b*	*b*	*b*
			Turnip Greens				
North of Y-12	*b*	3,500	*b*	5,300	3.0	*b*	1.8
South of ORNL	*b*	3,900	*b*	6,300	*b*	*b*	2.8
East of ORNL	*b*	3,800	*b*	5,500	8.8	*b*	9.1
West of ETTP	150	2,400	2,100	3,500	21	1.5	18
Reference location	180	2,000	2,800	4,700	32	3.6	32
			Tomatoes				
East of Y-12, Claxton vicinity	33	1,700	*b*	*b*	5.9	*b*	*b*
North of Y-12	22	2,300	*b*	2,000	*b*	*b*	*b*
South of ORNL	*b*	2,000	*b*	2,300	*b*	*b*	*b*
East of ORNL	43	1,600	*b*	*b*	3.6	*b*	*b*
West of ETTP	*b*	1,000	*b*	*b*	3.0	*b*	*b*
Reference location	134	1,800	*b*	*b*	*b*	2.2	*b*

[a] Detected radionuclides are those at or above minimum detectable activity. 1 pCi = 3.7×10^{-2} Bq.
[b] Value was less than or equal to minimum detectable activity.

Acronyms:
ETTP = East Tennessee Technology Park
ORNL = Oak Ridge National Laboratory
Y-12 = Y-12 National Security Complex

6.6.3 Milk

Milk is a potentially significant exposure pathway to humans for some radionuclides deposited from airborne emissions because of the relatively large surface area on which a cow can graze daily, the rapid transfer of milk from producer to consumer, and the importance of milk in the diet.

6.6.3.1 Data Collection and Analysis

The one dairy that had been supplying milk samples to ORNL went out of business in 2016. During the 3 years since, surveys to locate dairies in areas that could receive deposition from ORR activities were conducted; however, no dairies were identified to replace the one that closed.

6.6.3.2 Results

When a dairy or dairies in potential ORR deposition areas are located, milk-sampling and analyses will resume.

6.6.4 Fish

Members of the public could be exposed to contaminants originating from DOE ORR activities through consumption of fish caught in area waters. This potential exposure pathway is monitored annually by collecting fish from three locations on the Clinch River and by analyzing edible flesh for specific contaminants. The locations are as follows (Figure 6.6):

- Clinch River upstream from all DOE ORR inputs (CRK 70)
- Clinch River downstream from ORNL (CRK 32)
- Clinch River downstream from all DOE ORR inputs (CRK 16)

6.6.4.1 Data Collection and Analysis

Sunfish (*Lepomis macrochirus*, *L. auritus*, and *Ambloplites rupestris*) and catfish (*Ictalurus punctatus*) are collected from each of the three locations to represent both top-feeding and bottom-feeding-predator species. In 2019, a composite sample of each of those species at each location was analyzed for selected metals, polychlorinated biphenyls (PCBs), tritium, gross alpha, gross beta, gamma-emitting radionuclides, and total radioactive strontium. To accurately estimate exposure levels to consumers, only edible portions of the fish were submitted for analysis. Once every five years, additional radiological analyses are performed to confirm the dosing model (see Chapter 7). In 2019, additional radionuclides detected included neptunium, plutonium, thorium, and uranium isotopes. Results are presented in Table 6.7.

TDEC issues advisories on consumption of certain fish species caught in specified Tennessee waters. These advisories apply to fish that could contain potentially hazardous contaminants. TDEC has issued a “do not consume” advisory for catfish in the Melton Hill Reservoir in its entirety, not just in areas that could be affected by ORR activities, because of PCB contamination. Similarly, a precautionary advisory for catfish in the Clinch River arm of Watts Bar Reservoir has been issued because of PCB contamination (TDEC 2020). TDEC also issues advisories for consumption of fish when mercury levels are over 0.3 ppm; the three locations on the Clinch River where ORR fish are collected do not have mercury “do not consume” advisories waters (Denton 2007). See additional information **here**.

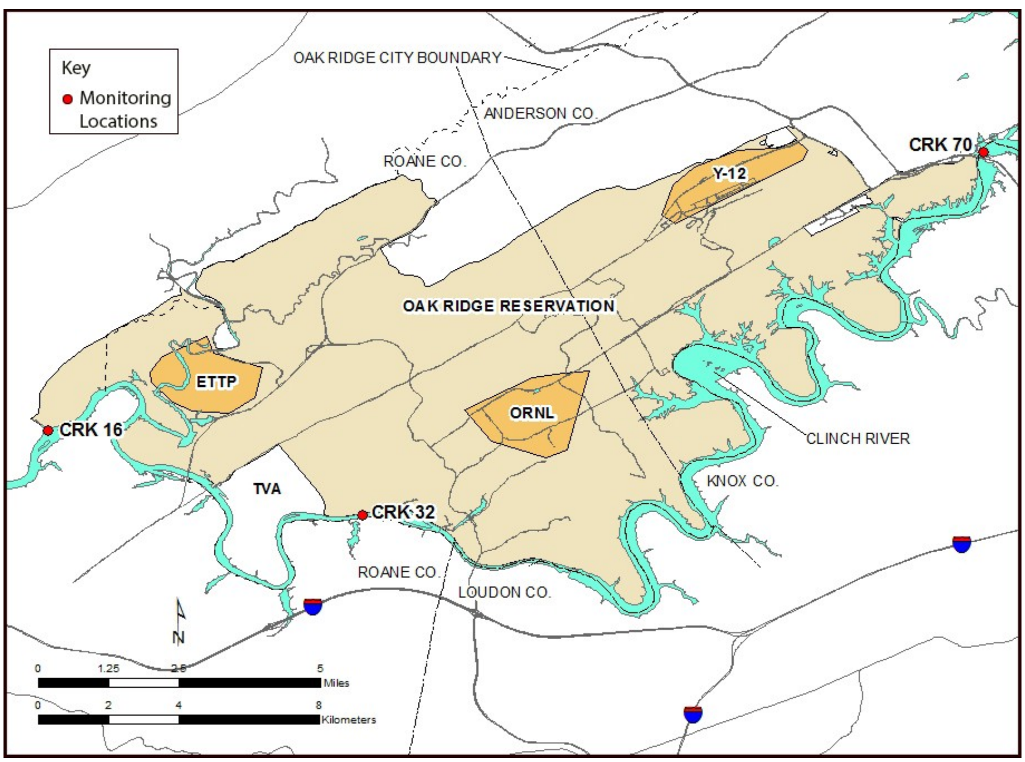


Figure 6.6. Fish-sampling locations for the Oak Ridge Reservation Surveillance Program

6.6.4.2 Results

PCBs, specifically Aroclor-1260, and mercury were detected in both sunfish and catfish at all three locations in 2019. These results are consistent with the TDEC advisories. Detected PCBs, mercury, and radionuclide concentrations are shown in Table 6.7.

Table 6.7. Tissue concentrations in catfish and sunfish for detected mercury, PCBs, and radionuclides, 2019[a]

Parameter	Catfish	Sunfish
Clinch River downstream from all DOE ORR inputs (CRK 16)		
Metals (mg/kg)		
Hg	0.045	0.042
Pesticides and PCBs (µg/kg)		
PCB-1260	310	J9.9[b]
Radionuclides (pCi/g)		
Alpha activity	0.15	*c*
Beta activity	2.7	1.4
^{40}K	3	2
Tritium	0.15	0.18
^{241}Am	0.039	*c*
^{237}Np	*c*	0.011
$^{239/240}$Pu	0.094	0.0095
^{234}U	0.031	0.014
^{238}U	*c*	0.015
Clinch River downstream from ORNL (CRK 32)		
Metals (mg/kg)		
Hg	0.033	J0.022[b]
Pesticides and PCBs (µg/kg)		
PCB-1260	97	J12[b]
Radionuclides (pCi/g)		
Beta activity	1.2	0.89
^{40}K	3.2	2.6
Tritium	0.18	0.15
^{237}Np	0.018	*c*
^{238}Pu	*c*	0.0057
^{228}Th	0.052	*c*
^{230}Th	0.029	*c*
^{234}U	*c*	0.015
Clinch River (Solway Bridge) upstream from all DOE ORR inputs (CRK 70)		
Metals (mg/kg)		
Hg	0.1	0.034
Pesticides and PCBs (µg/kg)		
PCB-1260	92	J11[b]
Radionuclides (pCi/g)		
Alpha activity	*c*	0.11
Beta activity	0.92	1.8

Table 6.7. Tissue concentrations in catfish and sunfish for detected mercury, PCBs, and radionuclides, 2019[a] (continued)

Parameter	Catfish	Sunfish
^{40}K	2.0	2.6
Tritium	0.24	0.25
^{238}Pu	*c*	0.0038
$^{239/240}Pu$	0.039	0.0038
^{234}U	0.022	0.023

[a] Only parameters that were detected for at least one species are listed in the table.
[b] "J" indicates that the result is an estimated value.
[c] Value was less than or equal to minimum detectable activity.

Acronyms:
CRK = Clinch River kilometer
DOE = US Department of Energy
ORNL = Oak Ridge National Laboratory
ORR = Oak Ridge Reservation
PCB = polychlorinated biphenyl

6.6.5 White-Tailed Deer

Three weekend quota deer hunts were held on ORR during the final quarter of 2019. The hunts took place November 2 and 3, November 9 and 10, and December 7 and 8. Each hunt was limited to 450 shotgun/muzzleloader permittees and 600 archery permittees. UT-Battelle staff; Tennessee Wildlife Resources Agency (TWRA) personnel; and student members of the Wildlife Society, University of Tennessee (UT) chapter, performed most of the necessary operations at the checking station.

6.6.5.1 Data Collection and Analysis

Approximately 25,053 acres were available to deer hunters on the Oak Ridge Wildlife Management Area (ORWMA) in 2019 (15,227 acres for gun hunting and 9,826 acres for archery hunting). The ORWMA includes some properties not owned by DOE, including Haw Ridge Park (city of Oak Ridge), the Clinch River Small Modular Reactor Site (the Tennessee Valley Authority [TVA]), and the UT Arboretum.

6.6.5.2 Results

The total harvest in 2019 was 221 deer, of which 125 (~56.6 percent) were bucks and 96 (~43.4 percent) were does. The heaviest buck weighed 181 lb, was 4 years old, and had 13 antler points, which was the greatest number of antler points on any buck harvested. The heaviest doe weighed 112 lb and was 3.5 years old. The harvest was higher than it was in 2018 but still somewhat lower than it had been, which corresponds more with previous years. This is most likely due to the inclement weather during the last weekend hunt, which resulted in a lower hunter turnout than in years past. The outbreak of epizootic hemorrhagic disease in the Tennessee deer herds during the summer of 2017 impacted deer populations on the ORWMA, as evidenced by the number of 2017's dead deer reports and low harvest numbers.

Since 1985, 13,334 deer have been harvested from the ORWMA, of which 218 (~1.67 percent) have been retained because of potential radiological contamination. The heaviest buck ever harvested weighed 218 lb (1998), and the heaviest doe ever harvested weighed 139 lb (1985). The average weight of all harvested deer is ~86 lb. The oldest deer harvested was a doe estimated to be 12 years old (1989); the average age of all harvested deer is ~2 years. See ORR hunt information website **here** for more information.

None of the 221 deer harvested on ORR during the 2019 hunts were retained for exceeding the administrative release limit of 1.5 times background for beta activity in bone (~20 pCi/g $^{89/90}$Sr) or for exceeding 5 pCi/g ^{137}Cs in edible tissue.

6.6.6 Canada Geese

On the Three Bends Area of ORR (excluding the shoreline of Gallaher Bend), Canada goose hunting was allowed during the statewide season, one half-hour before sunrise until noon on 4 days during September and 4 days during October. The consumption of Canada geese is a potential pathway for exposing members of the public to radionuclides released from ORR operations.

6.6.6.1 Data Collection and Analysis

To determine concentrations of gamma-emitting radionuclides accumulated by waterfowl that feed and live on ORR, Canada geese are rounded up each summer for noninvasive gross radiological surveys.

6.6.6.2 Results

Thirty geese (15 adults, 15 goslings) were captured during the June 21, 2019, roundup on ORR. All 30 captured geese were subjected to live whole-body gamma scans. Gamma scan results for the 15 adult geese and 15 goslings showed that all were well below the administrative release limit of 5 pCi/g ^{137}Cs.

6.6.7 Turkey Monitoring

Two wild turkey hunts, managed by DOE and TWRA, were held on the reservation in 2019 (April 13 and 14 and April 27 and 28). Each hunt was limited to 225 hunters, preselected in a quota drawing. Approximately 21,879 acres were available to turkey hunters in 2019 because the 255 acres that were designated as archery-only in 2017 were eliminated and were converted to safety zones in 2018.

6.6.7.1 Data Collection and Analysis

Thirty-two male turkeys were harvested on the two hunts, of which 4 (~ 12.5 percent) were juveniles and 28 (~ 87.5 percent) were adults. The average weight of all turkeys harvested during spring 2019 hunts was ~18.9 lb, and the largest turkey weighed 23.6 lb. The average beard length was ~9.1 in., and the longest beard was 11.2 in. The average spur length was ~ 0.9 in., and the longest spur was 1.2 in. The largest turkey harvested to date on ORR weighed 25.7 lb (harvested in 2009).

6.6.7.2 Results

None of the 33 (32 in spring, 1 in fall) turkeys harvested in 2019 exceeded the administrative release limits established for radiological contamination. Since 1997, 924 turkeys have been harvested on spring turkey hunts. Eleven additional turkeys have been harvested (since 2012) by archery hunters during fall deer hunts. Of all turkeys harvested, only three (~< 0.34 percent) have been retained because of potential radiological contamination; one in 1997, one in 2001, and one in 2005. Additional information is available here.

6.7 Invasive Plant Management on the US DOE Oak Ridge Reservation

Invasive non-native plant species are among the greatest ecological threats across the country and around the world. Maintaining ecosystems, protecting natural areas, and ensuring functioning of facilities and their support infrastructures, power and communications rights-of-way, roadways, and waterways through actively managing invasive plant incursions is crucial not only in nature, but in developed areas as well. Invasive plants can threaten forests, wetlands, cultural assets, and other resources through increased risk of fire, storm damage, and encroachment onto roads, railroads, power structures, waterways, and farmland. Invasive plants disrupt vital habitats of threatened and endangered species as well as other native wildlife and plant life by decreasing native plant diversity through crowding out native plants and disrupting natural plant-animal interactions.

The Federal Noxious Weed Act (1974) was amended and incorporated into the Federal Plant Protection Act (2000), which mandates federal agencies to develop and coordinate a management program for control of invasive plants on lands under each agency's respective jurisdiction. Each agency must adequately fund the publication of an integrated pest management plan that will meet the regulatory requirements of federal laws, executive orders, presidential memorandums, contracts, and agreements. Other federal directives regarding control of invasive plants and subsequent restoration practices include the following:

- Presidential Memorandum, "Environmentally and Economically Beneficial Practices on Federal Landscaped Ground" (1994), which was replaced in 2000 by Executive Order 13148, "Greening the Government Through Leadership in Environmental Management" (2000)
- "Federal Memorandum of Understanding to Establish a Federal Inter-agency Committee for the Management of Noxious and Exotic Weeds" (1994)
- Executive Order 13112, "Invasive Species" (1999)
- Presidential Memorandum, "Creating a Federal Strategy to Promote the Health of Honey Bees and Other Pollinators," (2014), which involves "creating a federal strategy to promote the health of honeybees and other pollinators," including control and removal of invasive plants and restoration and establishment of natural habitats
- Executive Order 13751, "Safeguarding the Nation from the Impacts of Invasive Species." (2016)

The DOE has maintained an invasive plant management plan on ORR since 2004. For details of federal and state laws and regulations driving the DOE plan, see *Invasive Plant Management Plan for the Oak Ridge Reservation* (*Invasive Plant Management Plan for the Oak Ridge Reservation* (Parr et al. 2004, Quarles et al. 2011, McCracken and Giffen 2017).

A technical report, *Assessment of Nonnative Invasive Plants in the DOE Oak Ridge National Environmental Research Park*" (Drake et al. 2002) details the results of extensive survey efforts. These and subsequent surveys have been done to identify invasive plant problems on ORR. The data are used to develop control plans identifying which invasive species to target and in which locations.

More than 1,100 species of plants are found on ORR, and of these approximately 170 plant species are non-native plants. Fifty-seven aggressive non-native (invasive) plant species have been identified on ORR, but control efforts are primarily focused on a subset of 10 species (see Table 6.8). The selected invasive species have been found across ORR in disturbed areas; on powerline and gas line rights-of-way; throughout riparian buffer zones; and along state highways, railroad lines, and remote-access fire roads. They have invaded natural areas to varying degrees, causing vast ecological harm in both plant and animal communities. Other invasive plant species are targets for control as well, using Early Detection/Rapid Response (DOI 2020) and in concert with control efforts on the 10 highly invasive species listed in Table 6.8.

The 32,800-acre ORR consists mostly of undeveloped land, such as forested land, extensive areas of undisturbed wetlands, open waterways and riparian vegetation, and several hundred acres of grassland communities and fallow fields. Three major developed facilities lie within ORR boundaries—ORNL, the

Y-12 National Security Complex, and the East Tennessee Technology Park. Surrounding these developed facilities and woven throughout ORR are safety and security areas, utility corridors, access roads, research and education areas, cultural and historic preservation sites, contamination areas that are undergoing cleanup and remediation, regulatory and monitoring sites, emergency corridors, new facility construction and laydown areas, and public use areas. This multiplicity of land uses presents challenges for effectively preventing and managing invasive species.

Table 6.8. Ten most problematic invasive plants on the Oak Ridge Reservation

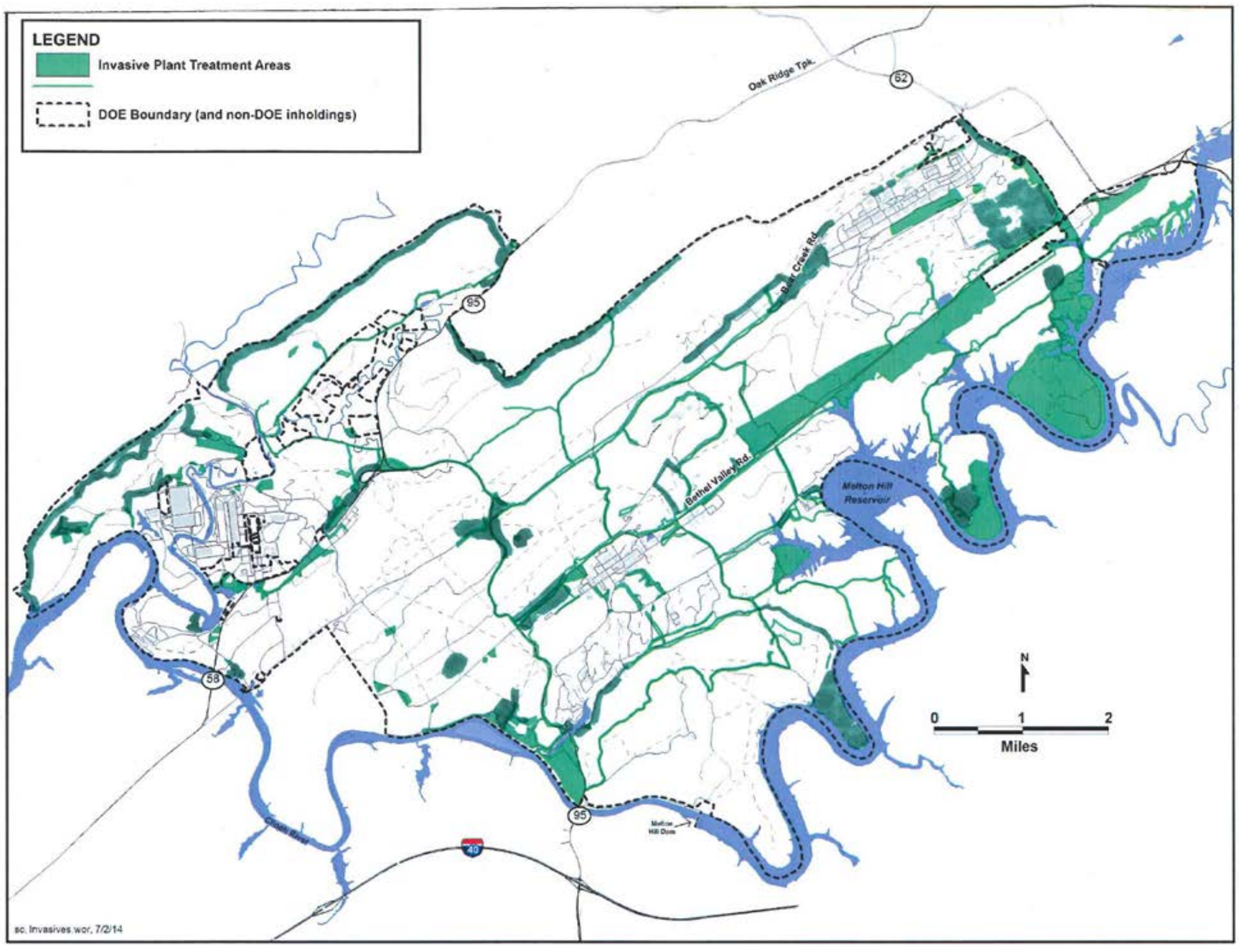
Common name	Scientific name
Japanese grass, Nepal grass	*Microstegium vimineum*
Japanese honeysuckle	*Lonicera japonica*
Chinese privet	*Ligustrum sinense*
Kudzu	*Pueraria montana*
Multiflora rose	*Rosa multiflora*
Tree-of-heaven	*Ailanthus altissima*
Autumn olive	*Elaeagnus umbellate*
Oriental bittersweet	*Celastrus orbiculatus*
Princess tree	*Paulownia tomentosa*
Winter creeper	*Euonymus fortunei*

Numerous DOE contractors have responsibilities for land management of portions of the Oak Ridge Reservation, as do other federal and state agencies, such as TVA and TWRA. The Natural Resources Management Team for ORR receives site-wide funding annually, a portion of which is designated for creation and implementation of an invasive plant management plan, mainly directed toward control efforts in natural areas and reference areas; however, efforts have included specific invasive plant incursions into locations within and surrounding campuses of developed facilities on ORR. The *Invasive Plant Management Plan for the Oak Ridge Reservation*, (Parr et al. 2004), and two subsequent revisions (Quarles et al. 2011 and McCracken et al. 2017) explain options for addressing the problem of invasive plants on ORR and discuss selection of appropriate control measures. Areas selected for invasive plant control tend to cover several acres or are spread out across portions of ORR. Use of selected herbicides is the most cost-effective treatment method in most cases, and the invasive plants present inform which herbicides will be most effective without causing harm to surrounding native plant and animal habitats.

Invasive plant control on ORR has been conducted annually from 2003, when the invasive plant management program began, through 2019. Table 6.9 indicates the extent of annual invasive plant treatments; Figure 6.7 shows the major treatment areas.

Table 6.9. Invasive plant control on the Oak Ridge Reservation, 2003–2019

Area treated	Year																
	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19
Acres	98	136	125	254	236	427	526	884	806	615	329	950	629	952	542	507	450
Road miles															47	53	57



Areas shown in green have been treated for invasive plants between 2003 and 2019.

Figure 6.7. Map of cumulative invasive plant treatment areas on the Oak Ridge Reservation

Restoration of selected natural areas is done in addition to herbicide treatment of invasive plants. *The Native Grass Community Management Plan for the Oak Ridge Reservation* (Ryon et al. 2007) and the *Grassland Ecosystem Management Plan for the Oak Ridge Reservation* (Herold and McCracken 2007) discuss demonstration projects and larger grassland restoration projects across ORR. Demonstration projects have been done at the East Tennessee Technology Park, Y-12 National Security Complex, and ORNL. Native plant restoration projects totaling several hundred acres across ORR are located within the Oak Ridge National Environmental Research Park's natural areas.

Invasive Plant management and grassland restoration completed in 2019 at each of the three facilities on ORR include the following:

- ORNL
  - First Creek grassland area management
  - Demonstration plot at Spallation Drive and Bethel Valley Road management
  - Bethel Valley Road and Old Bethel Valley Road invasive plant control
  - Haw Ridge former steam line kudzu control
  - Park City Road/Price Road invasive plant treatment

  - Fire road invasive plant control
  - Three Bends Area invasive plant control

- Y-12
  - Y-12 Native Grassland Area invasive plant treatment
  - Bear Creek restoration site invasive plant treatment
  - Kudzu control on Pine Ridge and Chestnut Ridge overlooking Y-12 campus
  - Midway Turnpike invasive plant control
  - Bear Creek Road invasive plant control
  - Coal ash ponded area kudzu control
  - Fire road invasive plant control

- ETTP
  - EU-29 demonstration field invasive plant control
  - Powerhouse Trail privet control
  - Wheat Church Vista invasive plant control
  - Black Oak Ridge Conservation Easement kudzu and invasive plant control
  - Black Oak Ridge Conservation Easement greenway and trail invasive plant control

6.8 Fire Protection Management and Planning

Wildland fire management plays a major part in DOE's overall management of ORR. Responsibilities are laid out in DOE orders, policies, and directives. *ORR Wildland Fire Implementation Plan* (DOE ORO 2006) defines shared responsibilities of UT-Battelle, LLC (ORR Forester and ORNL Fire Department); the DOE roads and grounds contractor; the DOE Consolidated Service Center; the DOE ORNL Site Office Reservation Management; Y-12; ETTP; the City of Oak Ridge; and the State of Tennessee Division of Forestry.

DOE actions associated with wildland fire management include the following:

- Development of burn plans and authorization by the reservation manager
- Conducting routine operational controlled burns
- Incorporation of wildland fire mitigation and response activities and procedures into the ORR land-use planning process
- Preparing and updating pre-fire planning maps. Ensuring that hard-copy maps of ORR are available for wildland fire response and mitigation
- Conducting wildland fire scenarios in emergency management exercises as necessary or appropriate. Developing after-action reports identifying areas of weakness or needs for improvement
- Development of stakeholder involvement plans in support of the wildland fire program
- Review of current wildland fire-potential data, including indications of wildland fire risk
- Preparing a wildland fire risk report, including a wildland fire hazard severity analysis based on the National Fire Protection Association *Standard for Wildland Fire Management* (NFPA 2018)
- Identifying equipment necessary to perform forest management activities and assignments

DOE maintains a detailed wildland fire management plan for ORR with an associated wildland fire management implementation plan. Specific responsibilities of different entities associated with wildland fire management on ORR are outlined in the plans. The DOE roads and grounds contractor has the responsibility for establishing and maintaining the wildland fire roads, many of which delineate wildland management units (Figure 6.8), and maintaining barricades that control access to ORR secondary roads. The sites—ORNL, Y-12, and ETTP—are responsible for providing personnel and equipment for initial response to wildland fire events and for establishing incident command. The City of Oak Ridge has entered into a mutual aid agreement with DOE to provide assistance for wildland fire activities. The State of Tennessee Department of Agriculture Division of Forestry has entered into a memorandum of understanding to provide personnel who are trained and equipped to respond to wildland fires and heavy equipment, including fire plows, when requested to assist with wildland fires.

Because ORR is a large (32,800 acres), mainly forested property with access restrictions, it is a challenge for most site emergency personnel to maintain familiarity with all remote areas and back roads and to quickly recognize and size up concerns associated with those areas**.** The ORR wildland management unit pre-fire plans (PFPs) were therefore developed to serve on-site first responders and are designed both to aid those not familiar with an area and to assist the recall of those who are. Because DOE's wildfire strategy now relies on outside agencies for assistance with large or difficult wildfires, the plans also serve as guidance for those responders who may have little or no experience on ORR. The plans offer awareness of ORR's unique hazards and can help avoid inadvertent impacts to structural, cultural, environmental, and research assets.

The PFPs are a series of brief documents covering each of 28 ORR wildlife management units (Figure 6.8). Each plan summarizes access issues, assets, and hazard concerns within its area. Hard copies of the plans are intended to remain in responder vehicles for immediate reference during remote events. Terse and compact in format, the plans are easily updated, stored, and shared electronically. Pre-fire plan copies are also maintained at site fire departments and emergency operations centers and by shift superintendents and certain managers. The plans are meant to influence quick decisions but are not meant to dictate tactics.

The format of the PFPs includes a single-page synopsis that provides a wildlife management unit's unit identification number and name, general location within ORR, and its boundaries and size. The most important information or hazards are highlighted near the top of the form, followed by topical guidance on tactics, access, vegetation and fuels, water sources, topographic considerations, and hazards. Plan maps depict access, fuel types, water sources, and urban interface areas. Utilities, hazards, research areas, and sensitive resources are also depicted.

Gradually, the information within each plan may become outdated. PFPs are reviewed on a 3-year cycle and are updated as significant changes occur. The ORR forester is the point of contact for plan distribution.

Events during 2016 demonstrated that large fires, more frequent in the western states, can occur in the region containing ORR. As a result, issues related to its wildland/urban interface are a growing concern. These areas may feature relatively high housing density and increasing recreational use by the public. DOE has prioritized interface areas and has conducted controlled wildfire fuel reduction burns to limit fire spread to and from the community. Actions have also been taken in areas exposed to potential high-intensity wildfires due to the presence of dense pine forests, including harvests to thin or replace dense pine, mechanical treatments to proactively thin younger pine, and mulching heavy logging slash and insect-damaged timber to interrupt fuel beds.

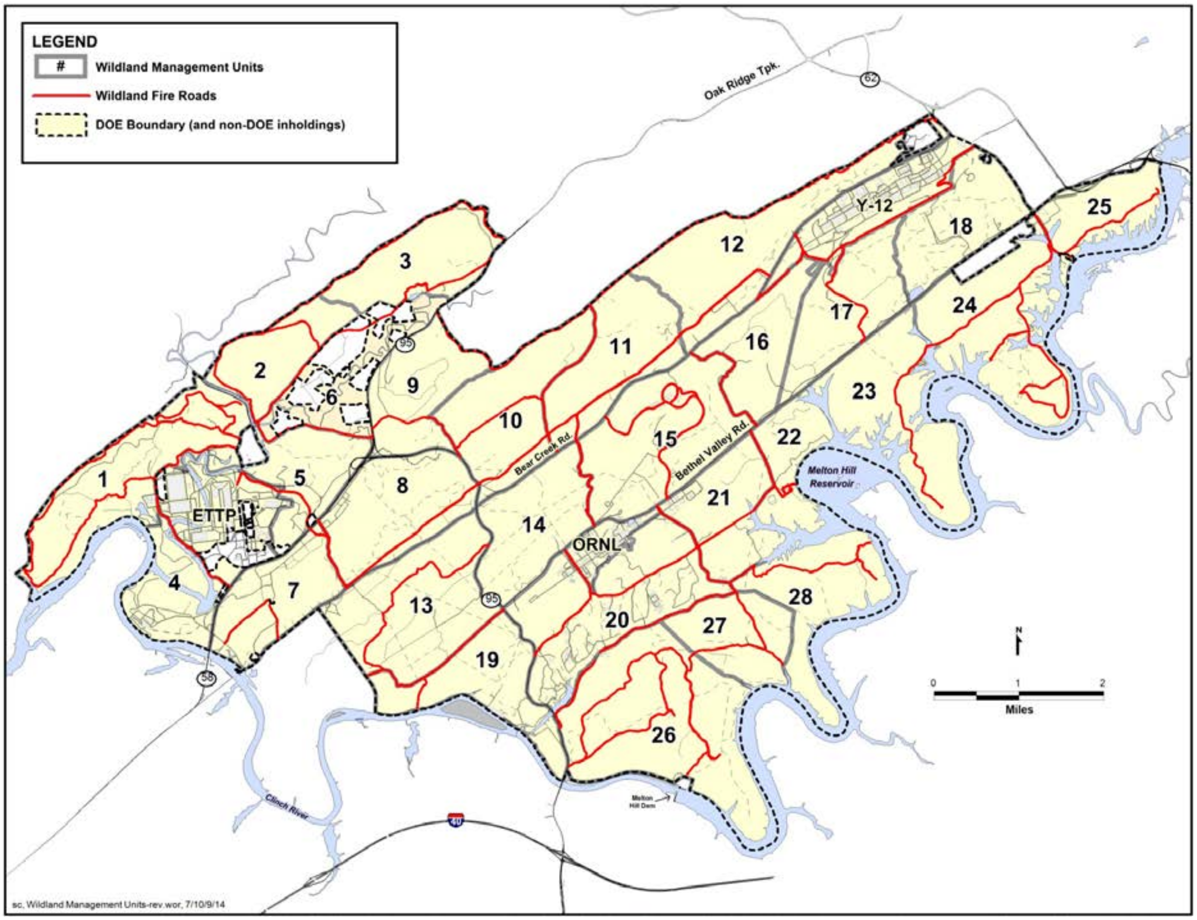


Figure 6.8. Wildland management units on the Oak Ridge Reservation

6.9 Quality Assurance

UT-Battelle performs the activities associated with administration, sampling, data management, and reporting for ORR environmental surveillance programs. Project scope is established by a task team whose members represent DOE; UT-Battelle; Consolidated Nuclear Security, LLC; and UCOR. UT-Battelle integrates quality assurance, environmental, and safety considerations into every aspect of ORR environmental monitoring. (See Chapter 5, Section. 5.7, for a detailed discussion of UT-Battelle quality assurance program elements for environmental monitoring and surveillance activities.)

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7. Dose

Activities on ORR have the potential to release small quantities of radionuclides and hazardous chemicals to the environment. These releases could expose members of the public to low concentrations of radionuclides or hazardous chemicals. Monitoring of materials released from the reservation and environmental monitoring and surveillance on and around the reservation provide data used to show that doses from released radionuclides and chemicals are in compliance with the law.

In 2019, a hypothetical maximally exposed individual (MEI) could have received an effective dose (ED) of about 0.4 mrem from radionuclides emitted to the atmosphere from all ORR sources; this is well below the National Emission Standards for Hazardous Air Pollutants for Radionuclides standard of 10 mrem/year for protection of the public.

A worst-case analysis of exposures to waterborne radionuclides for all pathways combined gives a maximum possible individual ED of about 4 mrem. This dose is based on a person eating 27 kg/year (60 lb/year) of fish, drinking 730 L/year (193 gal/year) of drinking water, and using the shoreline for 60 h/year as well as swimming, boating, and irrigation. In addition, if a hypothetical person consumed two harvested deer, one turkey, and two geese (containing the maximum ^{137}Cs concentration and maximum weights), that person could have received an ED of about 2 mrem. This calculation is conducted to provide an estimated upper-bound ED from consuming wildlife harvested from ORR.

Therefore, the annual dose to an MEI from all these potential exposure pathways combined was estimated to be about 6 mrem. There are no known significant doses from discharges of radioactive constituents from ORR other than those reported. DOE Order 458.1, *Radiation Protection of the Public and the Environment* (DOE 2011), limits the ED that an individual may receive from all exposure pathways from all radionuclides released from ORR during 1 year to no more than 100 mrem. The 2019 maximum ED was about 6 percent of the limit given in DOE Order 458.1.

The potential doses to aquatic and terrestrial biota from contaminated soil and water were evaluated using a graded approach. Results of the screening calculations indicate that contaminants released from ORR site activities do not have an adverse impact on aquatic or terrestrial biota.

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

7.1 Radiation Dose

Small quantities of radionuclides were released to the environment from operations at ORR facilities in 2019. Those releases were described, characterized, and quantified in previous chapters of this report. This chapter presents estimates of potential radiation doses to the public from the releases. Dose estimates were obtained using monitored and estimated release data, environmental monitoring and surveillance data, estimated exposure conditions that tend to maximize calculated doses, and environmental transport and dosimetry codes that may also tend to overestimate the calculated doses. Therefore, the presented doses are likely overestimates of the doses received by actual people in the ORR vicinity.

7.1.1 Terminology

Exposures to radiation from nuclides located outside the body are called "external exposures"; exposures to radiation from nuclides deposited inside the body are called "internal exposures." This distinction is important because external exposures occur only when a person is near or in a radionuclide-containing medium, whereas internal exposures continue while the radionuclides remain inside a person. Also, external exposures may result in uniform irradiation of the entire body, including all organs, while internal exposures usually result in nonuniform irradiation of the body and organs. When taken into the body, most radionuclides deposit preferentially in specific organs or tissues and typically do not irradiate the body uniformly.

Several specialized terms and units used to characterize exposures to ionizing radiation are defined in Appendix E. "Effective dose" (ED) is a risk-based equivalent dose that is used to estimate health effects or risks to exposed persons. It is a weighted sum of dose equivalents to specified organs and is expressed in rem or sieverts (1 rem = 0.01 Sv). One rem of ED, regardless of radiation type or method of delivery, has the same total radiological (in this case, also biological) risk effect. Because the doses discussed here are very small, EDs are expressed in millirem (mrem), which is one one-thousandth of a rem.
(See Appendix E for a comparison and description of various dose levels.)

7.1.2 Methods of Evaluation

7.1.2.1 Airborne Radionuclides

The radiological consequences of radionuclides released to the atmosphere from ORR operations during 2019 were characterized by calculating EDs to maximally exposed on- and off-site members of the public and to the entire population residing within 80 km (50 miles) of ORR center. The calculations were performed for each major facility and for the entire ORR. The dose calculations were made using the Clean Air Act Assessment Package—1988 (CAP-88 PC) Version 4 (EPA 2015), a software program developed under sponsorship of the US Environmental Protection Agency (EPA) to demonstrate compliance with 40 CFR 61, Subpart H, which governs the emissions of radionuclides other than radon from DOE facilities. CAP-88 PC implements a steady-state Gaussian plume atmospheric dispersion model to calculate concentrations of radionuclides in the air and on the ground and uses food-chain models to calculate radionuclide concentrations in foodstuffs (vegetables, meat, and milk) and subsequent intakes by humans.

In this assessment, adult dose coefficients were used to estimate doses. The coefficients are weighted sums of equivalent doses to 12 specified tissues or organs plus a remainder term that accounts for the rest of the tissues and organs in the body.

A total of 27 emission points on ORR were modeled during 2019. The total includes 3 (2 combined) points at Y-12, 22 points at ORNL, and 2 points at the ETTP. Table 7.1 lists the emission-point parameter values and receptor locations used in the dose calculations.

Meteorological data used in the calculations for 2019 were in the form of joint frequency distributions of wind direction, wind speed class, and atmospheric stability category. (See Table 7.2 for a summary of tower locations used to model the various sources.) During 2019, rainfall, as averaged over the six rain gauges located on ORR, was about 183.6 cm (72 in.). The average air temperature was 15.4°C (59.7°F) at the 10 to 15 m levels. The average mixing-layer height was 833.9 m (2,736 ft) for ETTP, 829.7 m (2,722 ft) for ORNL, and 842.5 m (2,764 ft) for Y-12. The mixing height is the depth of the atmosphere adjacent to the surface within which air is mixed.

Table 7.1. Emission point parameters and receptor location used in the dose calculations, 2019

Source	Stack height (m)	Stack diameter (m)	Effective exit gas velocity (m/s)[a]	Distance (m) and direction to the maximally exposed individual			
				From each site		From ORR	
Oak Ridge National Laboratory							
X-Laboratory Hoods							
X-1000	15	0.5	0	4,270	SW	11,260	NE
X-2000	15	0.5	0	4,630	SW	10,910	NE
X-3000	15	0.5	0	5,030	SW	10,510	NE
X-4000	15	0.5	0	5,200	SW	10,360	NE
X-6000	15	0.5	0	5,780	SW	9,800	NE
X-7000	15	0.5	0	5,210	WSW	10,750	NNE
X-2026	22.9	1.05	8.34	4,750	SW	10,790	NE
X-2099	3.66	0.18	16.88	4,740	SW	10,800	NE
X-2531 East Pipe Tunnel	1.07	0.31	0[b]	4,710	SW	10,830	NE
X-Portable Ventilation Units	0.20	0.15	3.23	4,770	SW	10,780	NE
X-3018	61	1.75	0.95	4,960	SW	10,570	NE
X-3020	61	1.22	13.83	4,900	SW	10,640	NE
X-3039	76.2	2.44	6.57	4,970	SW	10,570	NE
X-3544	9.53	0.28	21.66	4,740	SW	10,820	NE
X-3608 Filter Press	8.99	0.36	9.27	4,860	SW	10,720	NE
X-4501	19.81	0.66	10.34	5,150	SW	10,400	NE
X-7503	30.5	0.91	12.88	5,230	SW	10,580	NNE
X-7830 Group	4.6	0.25	8.38	3,840	WSW	12,130	NNE
X-7856-CIP	18.29	0.48	8.83	3,840	WSW	12,190	NNE
X-7877	13.9	0.41	13.56	3,810	WSW	12,180	NNE
X-7880	27.7	1.52	16.97	3,770	WSW	12,200	NNE
X-7911	76.2	1.52	15.14	5,160	WSW	10,810	NNE
X-7935 Building Stack	15.24	0.51	27.18	5,170	SW	10,740	NNE
X-7935 Glove Box	9.14	0.25	0[b]	5,170	SW	10,740	NNE
X-7966	6.10	0.29	6.33	5,240	SW	10,660	NNE
X-8915	104.0	1.22	6.91	8,000	SSW	7,580	NE
X-Decom Areas	15	0.5	0	5,240	SW	10,310	NE
East Tennessee Technology Park							
K-1407-AL CWTS	2.74	0.15	0[b]	270	SSW	14,770	ENE
K-2500-H-C	8.23	0.61	12.9	870	ESE	15,400	ENE
Y-12 National Security Complex							
Y-Monitored	20	0.5	0	2,270	NE	2,270	NE
Y-Unmonitored Processes	20	0.5	0	2,270	NE	2,270	NE
Y-Unmonitored Lab Hoods	20	0.5	0	2,270	NE	2,270	NE

[a] Exit gas temperatures are "ambient air" unless noted otherwise.
[b] The direction of exhaust is horizontal, therefore a zero exit velocity is used.

Acronyms:
CIP = Capacity Increase Project
CWTS = Chromium Water Treatment System
Decom = Decommissioned
ORR = Oak Ridge Reservation

For occupants of residences, the dose calculations assume that the occupant remained at home during the entire year and obtained food according to the rural pattern. This pattern specifies that 70 percent of the vegetables and produce, 44 percent of the meat, and 40 percent of the milk consumed are produced in the local area (e.g., a home garden). The remaining portion of each food category is assumed to be produced within 80 km (50 miles) of ORR. The same assumptions are used for occupants of businesses, but the resulting doses are divided by 2 to compensate for the fact that businesses are occupied for less than half a year and less than half of a worker's food intake occurs at work. For collective ED estimates, production of beef, milk, and crops within 80 km (50 miles) of ORR was calculated using the production rates provided with CAP-88 PC Version 4.

Table 7.2. Meteorological towers and heights used to model atmospheric dispersion from source emissions, 2019

Tower	Height (m)	Source
		Y-12 National Security Complex
MT6 (West Y-12)	30	All Y-12 sources
		East Tennessee Technology Park
MT7 (L1209)	15	K-1407-AL CWTS, K-2500-H-C
		Oak Ridge National Laboratory
MT4 (Tow A)	15	X-7830, X-7935 Glove Box, X-7935 Building, X 7966, and X-7000 Lab Hoods
	30	X-7503, X-7856-CIP, X-7877, X-7880, and X-7911
MT3 (Tow B)	15	X-6000 Lab Hoods
MT2 (Tow D)	15	X-2099, X-2351 East Pipe Tunnel, X-Portable Ventilation Units, X-3544, X-3608 FP, X-Decom Hoods, X-1000, X-2000, X-3000, and X-4000 Lab Hoods
	35	X-2026, X-4501
	60	X-3018, X-3020, and X-3039
MT12 (Tow F)	10	X-8515 (SNS)

Acronyms:
CWTS = Chromium Water Treatment System
Decom = Decommissioned
FP = Filter Press
ORNL = Oak Ridge National Laboratory
SNS = Spallation Neutron Source

Results

EDs from radionuclides released to the atmosphere from ORR were calculated for ORR as a whole and for each site on ORR for (1) maximally exposed individuals (MEIs) and (2) for the collective population (1,172,530 persons) residing within 80 km (50 miles) of ORR (based on 2010 census data). CAP-88 PC Version 4 was used in 2019 to calculate both individual and collective doses.

The location of the MEI with reference to ORR (i.e., the location where a hypothetical individual would receive the maximum ED from radionuclides emitted to the atmosphere on ORR) is about 2,270 m northeast of the main Y-12 release point, about 10,810 m north-northeast of the 7911 stack at ORNL, and about 14,770 m east-northeast of the K-1407-AL Chromium Water Treatment System (CWTS) at ETTP (see Figure 7.1). This individual could have received an ED of about 0.4 mrem, which is well below the National Emission Standards for Hazardous Air Pollutants for Radionuclides standard of 10 mrem and is about 0.1 percent of the roughly 300 mrem that the average individual receives from natural sources of radiation (40 CFR 61 Subpart H). The maximum individual EDs calculated for each site and for ORR are listed in Table 7.3.

ORNL 2020-G00523/mhr

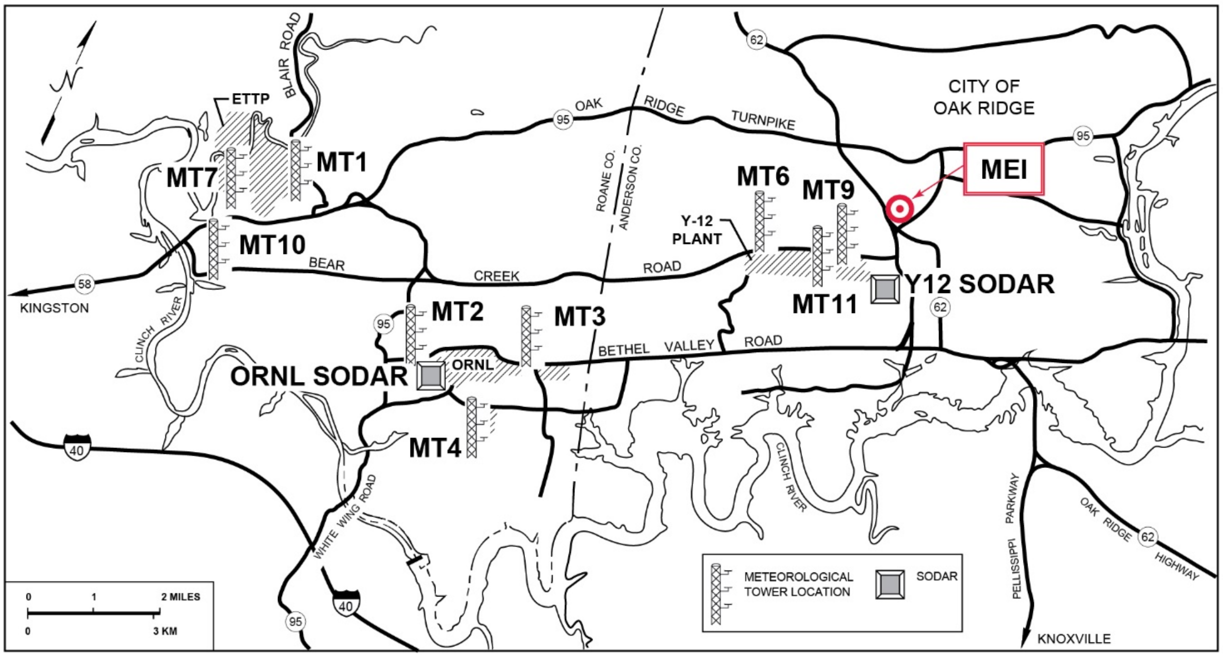

Figure 7.1. Location of the maximally exposed individual (MEI) for ORR (2019 Data)

Table 7.4 lists the collective EDs. The calculated collective ED was about 12.4 person-rem, which is about 0.004 percent of the 351,759 person-rem that this population received from natural sources of radiation (based on an individual dose of about 300 mrem/year).

Table 7.3. Calculated radiation doses to maximally exposed individuals from airborne releases from the Oak Ridge Reservation, 2019

Plant	Maximum effective dose, mrem (mSv)			
	From each site		From ORR	
	mrem	mSv	mrem	mSv
Oak Ridge National Laboratory	0.2[a]	0.002	0.07	0.0007
East Tennessee Technology Park	0.0003[b]	3×10^{-6}	3×10^{-6}	3×10^{-8}
Y-12 National Security Complex	0.36[c]	0.0036	0.36	0.0036
Entire Oak Ridge Reservation	*d*	*d*	0.4[e]	0.004

[a] The MEI was located 4,970 m SW of X-3039 and 5,160 m WSW of X-7911.
[b] The MEI was located 270 m SSW of K-1407-AL Chromium Water Treatment System.
[c] The MEI was located 2,270 m NE of Y-12 National Security Complex release point.
[d] Not applicable.
[e] The MEI for the entire Oak Ridge Reservation is also the Y-12 MEI.

Acronym:
MEI = maximally exposed individual

Table 7.4. Calculated collective effective doses from airborne releases, 2019

Plant	Collective effective dose[a]	
	Person-rem	Person-Sv
Oak Ridge National Laboratory	7.3	0.073
East Tennessee Technology Park	0.0002	2×10^{-6}
Y-12 National Security Complex	5.1	0.051
Entire Oak Ridge Reservation	12.4	0.124

[a] Collective effective dose to the 1,172,530 persons residing within 80 km (50 miles) of the Oak Ridge Reservation (based on 2010 census data).

The MEI for Y-12 was located at a residence about 2,270 m (1.4 miles) northeast of the main Y-12 release point. This individual could have received an ED of about 0.36 mrem from Y-12 airborne emissions. Inhalation and ingestion of uranium radioisotopes (i.e., ^{233}U, ^{234}U, ^{235}U, ^{236}U, and ^{238}U) accounted for about 96 percent, and other radionuclides accounted for about 4 percent of the dose (Figure 7.2). The contribution of Y-12 emissions to the 50-year committed collective ED to the population residing within 80 km (50 miles) of ORR was calculated to be about 5.1 person-rem, which is about 41 percent of the collective ED for ORR.

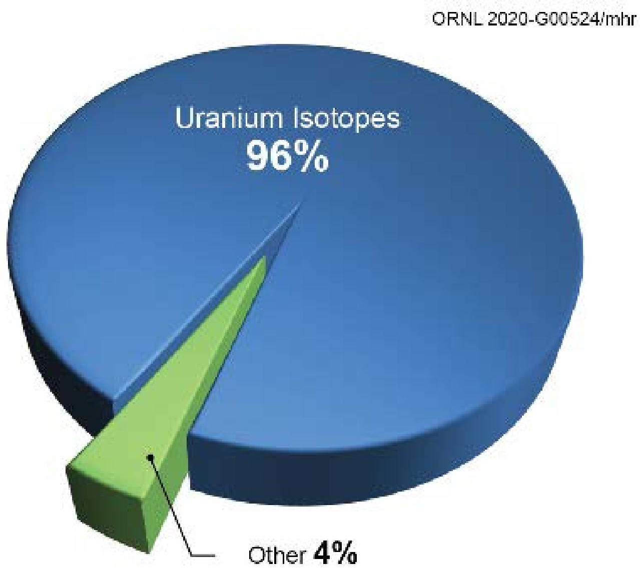

Figure 7.2. Nuclides contributing to the effective dose at Y-12 National Security Complex, 2019

The MEI for ORNL was located at a residence about 4,970 m (3.1 miles) southwest of the 3039 stack and 5,160 m (3.2 miles) west-southwest of the 7911 stack. This individual could have received an ED of about 0.2 mrem from ORNL airborne emissions. Lead-212 contributed 40 percent, ^{232}Th contributed 22 percent, and ^{138}Cs contributed 15 percent of the ORNL dose (Figure 7.3). The total contribution from uranium radioisotopes (i.e., ^{230}U, ^{232}U, ^{233}U, ^{234}U, ^{235}U, ^{236}U, ^{238}U, ^{239}U, and ^{240}U) accounted for about 0.02 percent of the dose, and ^{238}U contributed about 0.01 percent of the dose. The contribution of ORNL emissions to the collective ED to the population residing within 80 km (50 miles) of ORR was calculated to be about 7.3 person-rem or about 59 percent of the collective ED for ORR.

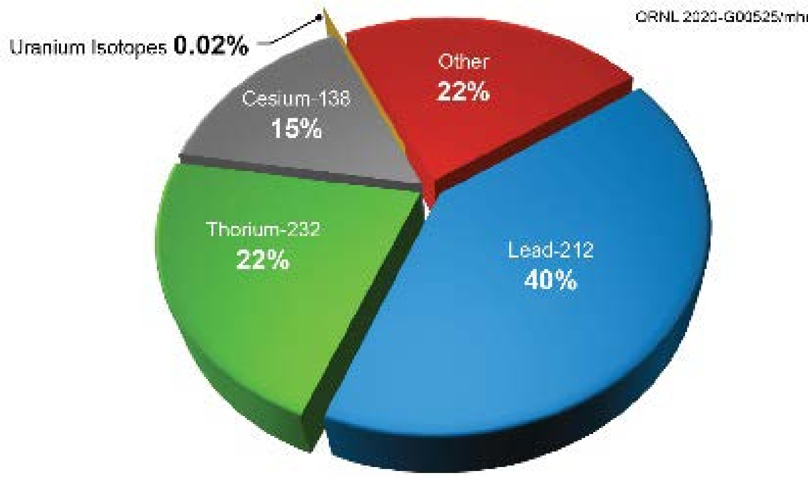

Figure 7.3. Nuclides contributing to effective dose at Oak Ridge National Laboratory, 2019

The MEI for ETTP was located at a business about 270 m (0.2 miles) south-southwest of the K-1407-AL CWTS. The ED received by this individual from airborne emissions was calculated to be about 0.0003 mrem. About 95 percent of the dose is from uranium radioisotopes (^{233}U, ^{234}U, ^{235}U, ^{236}U, and ^{238}U), and about 4 percent of the dose is from ^{99}Tc (Figure 7.4). The contribution of ETTP emissions to the collective ED to the population residing within 80 km (50 miles) of ORR was calculated to be about 0.0002 person-rem, or about 0.002 percent of the collective ED for ORR.

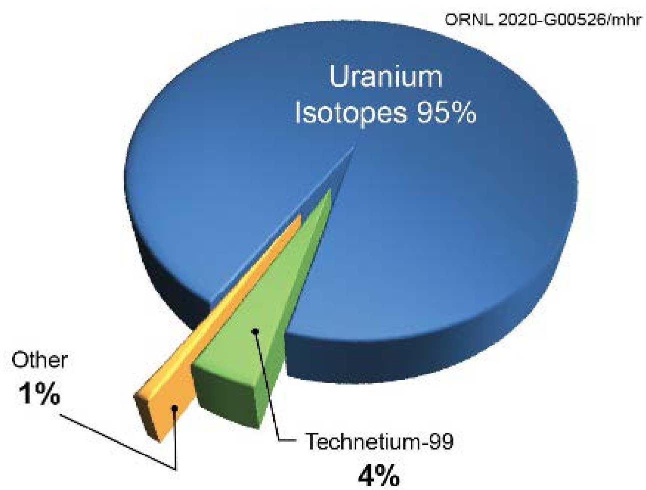

Figure 7.4. Nuclides contributing to effective dose at East Tennessee Technology Park, 2019

To evaluate the validity of the estimated doses calculated using CAP-88 PC Version 4 and emissions data (Table 7.5), the doses were compared to the EDs calculated using measured air concentrations of radionuclides (excluding naturally occurring ^{7}Be and ^{40}K) at ORR perimeter air monitoring (PAM) stations and at ORNL ambient air monitors 1, 2, 3, and 11 (AAM1, AAM2, AAM3, and AAM11). Based on measured air concentrations, hypothetical individuals assumed to reside at AAM1, AAM2, AAM3, AAM11, and PAM stations 35–49 could have received EDs between 0.0005 and 0.02 mrem/year. Based on emissions data using CAP-88 PC Version 4, the above individuals could have received EDs between

0.06 and 0.7 mrem/year. As shown in Table 7.5, EDs calculated using CAP-88 PC Version 4 and emissions data tend to be greater than or equivalent to EDs calculated using measured air concentrations.

Table 7.5. Hypothetical effective doses from living near the Oak Ridge Reservation, Oak Ridge National Laboratory, and East Tennessee Technology Park ambient air monitoring stations, 2019

Station	Calculated effective doses			
	Using air monitor data		Using CAP-88[a] and emission data	
	mrem/year	mSv/year	mrem/year	mSv/year
		ORR and ORNL		
1	0.0007	7×10^{-6}	0.4	0.004
2	0.0008	8×10^{-6}	0.2	0.002
3	0.007	7×10^{-5}	0.7	0.007
11	0.0005	6×10^{-6}	0.3	0.003
35[b]	0.02	0.0002	0.06	0.0006
37	0.0007	7×10^{-6}	0.2	0.002
40	0.002	2×10^{-5}	0.5	0.005
46	0.0009	9×10^{-6}	0.2	0.002
49	0.0008	8×10^{-6}	0.2	0.002
52[b,c]	0.004	4×10^{-5}	0.02	0.0002
		ETTP		
K2	0.006	6×10^{-5}	0.07	0.0007
K11	0.04	0.0004	0.03	0.0003
K12	0.03	0.0003	0.03	0.0003

[a] CAP-88 PC Version 4 software, developed under US Environmental Protection Agency sponsorship to demonstrate compliance with 40 CFR 61, Subpart H.
[b] At Stations 35 and 52, ^{99}Tc was requested for analyses as well as other radionuclides.
[c] Background ambient air monitoring station.

Acronyms:
ETTP = East Tennessee Technology Park
ORNL = Oak Ridge National Laboratory
ORR = Oak Ridge Reservation

Station 52, located remotely from ORR, gives an indication of potential EDs from background sources. Technetium-99 was analyzed at Station 35 and Station 52, and the ^{99}Tc air concentration at Station 52 was nearly twice the concentration at Station 35. Based on measured air concentrations, the ED was estimated to be 0.004 mrem/year (the isotopes ^{7}Be and ^{40}K were not included in the background air monitoring station calculation); based on air concentrations calculated using CAP-88 PC Version 4, the ED was estimated to be 0.02 mrem/year. The measured air concentrations of ^{7}Be were similar at the PAM stations and at the background air monitoring station.

Of interest is a comparison of EDs calculated using measured air concentrations of radionuclides at PAM stations located near the MEIs for each plant and EDs calculated for those individuals using source emissions data. Station K11 is located near the on-site MEI for ETTP. The ED calculated with measured air concentrations was 0.04 mrem/year, which is slightly higher than the ED of 0.03 mrem/year estimated using source emissions data. AAM11 is located near the off-site MEI for ORNL. The ED calculated with measured air concentrations was 0.0005 mrem/year, which is lower than the ED of 0.3 mrem/year estimated using source emissions data. PAM station 40 is located near the off-site MEI for the Y-12

Complex and ORR, and the ED calculated with measured air concentrations was 0.002 mrem/year, which is also less than the ED of 0.5 mrem/year estimated using source emissions data.

7.1.2.2 Waterborne Radionuclides

Radionuclides discharged to surface waters from ORR enter the Tennessee River system by way of the Clinch River. Discharges from Y-12 enter the Clinch River via Bear Creek and East Fork Poplar Creek (EFPC), each of which enters Poplar Creek before it enters the Clinch River, and discharges from Rogers Quarry enter into McCoy Branch and then into Melton Hill Lake. Discharges from ORNL enter the Clinch River via White Oak Creek (WOC) and enter Melton Hill Lake via some small drainage creeks. Discharges from ETTP enter the Clinch River either directly or via Poplar Creek. This section discusses the potential radiological impacts of these discharges to persons who drink water; eat fish; and swim, boat, and use the shoreline at various locations along the Clinch and Tennessee Rivers.

For assessment purposes, surface waters potentially affected by ORR are divided into seven segments:

- Melton Hill Lake above all possible ORR inputs
- Melton Hill Lake
- Upper Clinch River (from Melton Hill Dam to confluence with Poplar Creek)
- Lower Clinch River (from confluence with Poplar Creek to confluence with the Tennessee River)
- Upper Watts Bar Lake (from near the confluence of the Clinch and Tennessee Rivers to below Kingston)
- the lower system (the remainder of Watts Bar Lake and Chickamauga Lake to Chattanooga)
- Poplar Creek (including the confluence of EFPC)

Two methods are used to estimate potential radiation doses to the public. The first method uses radionuclide concentrations in the medium of interest (i.e., in water and fish) determined by laboratory analyses of water and fish samples (see Sections 6.4 and 6.6). The second method calculates possible radionuclide concentrations in water and fish from measured radionuclide discharges and known or estimated stream flows. In both methods, reported concentrations of radionuclides were used if the reported value was statistically significant and/or detected. The advantage of the first method is the use of radionuclide concentrations measured in water and fish; disadvantages are the inclusion of naturally occurring radionuclides (e.g., ^{40}K, uranium and its progeny, thorium and its progeny, and unidentified alpha and beta activities); the possible inclusion of radionuclides discharged from sources not part of ORR; and the possibility that some radionuclides of ORR origin might be present in quantities too low to be measured. The advantages of the second method are that most radionuclides discharged from ORR can be quantified and that naturally occurring radionuclides may not be considered or may be accounted for separately. The disadvantage is the use of models to estimate the concentrations of the radionuclides in water and fish. Both methods use the same models (Hamby 1991) to estimate radionuclide concentrations in media and at locations other than those that are sampled (e.g., downstream). However, utilizing the two methods to estimate potential doses takes into account both field measurements and discharge measurements.

Drinking Water Consumption

Surface Water

Water treatment plants that draw water from the Clinch and Tennessee River systems could be affected by discharges from ORR. No in-plant radionuclide concentration data are available for these plants; however, the dose estimates given in this section likely are high because they are based on radionuclide concentrations in water before it enters a processing plant. Based on a nationwide food consumption survey (EPA 2011) and weighted based on the combined population of Anderson, Knox, Loudon, and Roane counties, the drinking water consumption rate for the MEI is 730 L/year (193 gal/year), and the drinking water consumption rate for the average person is 370 L/year (98 gal/year). The average drinking water consumption rate is used to estimate the collective ED. At all locations in 2019, estimated maximum EDs to a person drinking water were calculated using both measured radionuclide concentrations in off-site surface water and measured radionuclide discharges to the off-site surface water, excluding naturally occurring radionuclides such as ^{40}K and ^{7}Be.

- **Upper Melton Hill Lake above all possible ORR inputs.** Based on samples from Melton Hill Lake above possible ORR inputs (at Clinch River kilometer [CRK] 66 near the City of Oak Ridge Water Intake Plant), an MEI drinking water at this location could have received an ED of about 3×10^{-10} mrem. The collective ED to the 49,253 persons who drink water from the City of Oak Ridge Water Plant would be 6×10^{-9} person-rem.
- **Melton Hill Lake.** The only water treatment plant located on Melton Hill Lake that could be affected by discharges from ORR is a Knox County plant. This plant is located near surface water sampling location CRK 58. An MEI could have received an ED of about 2×10^{-8} mrem; the collective dose to the 65,346 persons who drink water from this plant could have been 5×10^{-7} person-rem.
- **Upper Clinch River.** The ETTP (Gallaher) water plant, which drew water from the Clinch River near CRK 23, was deactivated in 2014. Therefore, doses from drinking water are no longer calculated. ETTP and the Rarity Ridge community receive drinking water from the City of Oak Ridge Water Plant, which is located near CRK 66.
- **Lower Clinch River.** There are no known drinking water intakes in this river segment (from the confluence of Poplar Creek with the lower Clinch River to the confluence of the lower Clinch River with the Tennessee River).
- **Upper Watts Bar Lake.** The Kingston and Rockwood municipal water plants draw water from the Tennessee River not far from its confluence with the Clinch River. An MEI could have received an ED of about 0.01 mrem. The collective dose to the 31,190 persons who drink water from these plants could have been about 0.2 person-rem.
- **Lower system.** Several water treatment plants are located on tributaries of Watts Bar Lake and Chickamauga Lake. Persons drinking water from those plants could not have received EDs greater than about 0.01 mrem. The collective dose to the 311,562 persons who drink water within the lower system could have been about 1 person-rem.
- **Poplar Creek/Lower EFPC.** No drinking water intakes are located on Poplar Creek or on Lower EFPC.

Groundwater

During FY 2019 the Oak Ridge Office of Environmental Management (OREM) continued to collect and analyze samples from the off-site groundwater monitoring well array west of the Clinch River adjacent to Melton Valley. Currently, no water is consumed from these off-site groundwater wells.

Fish Consumption

Fishing is quite common on the Clinch and Tennessee River systems. Based on a nationwide food consumption survey (EPA 2011) and weighted based on the combined population of Anderson, Knox, Loudon, and Roane counties, it was assumed that avid fish consumers would have eaten 27 kg (60 lb) of fish during 2019. For the average person used for collective dose calculations, it was assumed that 11 kg (24 lb) of fish was consumed in 2019. The estimated maximum ED is based on either the first method, measured radionuclide concentrations in fish, or by the second method, which calculates possible radionuclide concentrations in fish from measured radionuclide discharges and known or estimated stream flows. The number of individuals who could have eaten fish is based on lake creel surveys conducted annually by the Tennessee Wildlife Resources Agency (TWRA 2019a). In 2019, the maximum ED from fish consumption was determined using measured radionuclide concentrations in fish samples, which were collected at three different locations. An expanded analysis was conducted on fish samples as compared to previous years. Plutonium-239/240 was the primary contributor to dose due to fish consumption at CRK 70 (92%), which is above all ORR discharge locations. However, a reanalysis of the sample from this location resulted in a lower concentration of $^{239/240}$Pu than was reported for the original analysis, and the result was below the minimum detectable concentration for the analytical method. Although the results from the second analysis were more consistent with expectations for this background location, a conservative approach was taken, and the original (higher) concentrations were used for dose calculations. The primary contributors to dose at CRK 32 were ^{228}Th, ^{230}Th, and ^{237}Np (39%, 47%, and 14%, respectively). Plutonium-239/240 contributed 71% of the dose at CRK 16, and ^{241}Am was responsible for 24% of the dose at that location.

- **Upper Melton Hill Lake above All Possible ORR Inputs.** For reference purposes, a hypothetical avid fish consumer who ate fish caught at CRK 70, which is above all possible ORR inputs, could have received an ED of about 1 mrem. The collective ED to the nine persons who could have eaten such fish was about 0.005 person-rem.
- **Upper Clinch River.** An avid fish consumer who ate fish from the upper Clinch River (CRK 32) could have received an ED of about 2 mrem. The collective ED to the 67 persons who could have eaten such fish could have been about 0.04 person-rem.
- **Lower Clinch River.** An avid fish consumer who ate fish from the lower Clinch River (CRK 16) could have received an ED of about 4 mrem. The collective ED to the 157 persons who could have eaten such fish could have been about 0.2 person-rem.

Other Uses

Other uses of ORR area waterways include swimming or wading, boating, and use of the shoreline. A highly exposed "other user" was assumed to swim or wade for 30 h/year, boat for 63 h/year, and use the shoreline for 60 h/year. The average individual, who is used for collective dose estimates, was assumed to swim or wade for 10 h/year, boat for 21 h/year, and use the shoreline for 20 h/year. The potential EDs from these activities were estimated from measured and calculated concentrations of radionuclides in water; the equations that were used were derived from the LADTAP XL code (Hamby 1991) and were modified to account for radioactive data and shoreline use. The number of individuals who could have been other users are different for each section of water. Recreational activities for Melton Hill Reservoir are based on surveys conducted by the University of Tennessee (Stephens et al. 2006). A recent survey was conducted regarding visitor and property owner activities for Chickamauga and Watts Bar Reservoirs (Poudyal et al. 2017). The survey data from these reports were used to identify the variety of recreational activities on these water bodies. It was found that respondents often participated in more than one recreational activity. This information has replaced earlier assumptions regarding number of people involved in water recreational activities.

- **Upper Melton Hill Lake above all possible ORR inputs.** A hypothetical maximally exposed other user of upper Melton Hill Lake above possible ORR inputs (CRK 66) could have received an ED of about 0.002 mrem. The collective ED to the 14,483 other users could have been 0.003 person-rem.
- **Melton Hill Lake.** An individual other user of Melton Hill Lake could have received an ED of about 0.003 mrem. The collective ED to the 40,044 other users could have been about 0.02 person-rem.

- **Upper Clinch River.** An individual other user of the upper Clinch River could have received an ED of about 0.0008 mrem. The collective ED to the 13,114 other users could have been about 0.001 person-rem.
- **Lower Clinch River.** An individual other user of the lower Clinch River could have received an ED of about 5×10^{-8} mrem. The collective ED to the 30,599 other users could have been about 1×10^{-7} person-rem.
- **Upper Watts Bar Lake.** An individual other user of upper Watts Bar Lake could have received an ED of about 2×10^{-8} mrem. The collective ED to the 87,424 other users could have been about 1×10^{-7} person-rem.
- **Lower system (Watts Bar and Chickamauga Lakes).** An individual other user of the lower system could have received an ED of about 1×10^{-8} mrem. The collective ED to the 3,173,423 other users could have been about 3×10^{-6} person-rem.
- **Poplar Creek/Lower EFPC.** An individual other user of Lower EFPC, above its confluence with Poplar Creek, could have received an ED of about 0.0007 mrem. The collective ED to the 200 other users of Poplar Creek and Lower EFPC could have been about 2×10^{-5} person-rem.

Irrigation

Although there are no known locations that use water from water bodies around ORR to irrigate food or feed crops, it was decided to determine whether irrigation could contribute to radiation doses to a member of the public. To make this determination, the method described by the Nuclear Regulatory Commission (NRC 1977) was used. Based on measured and calculated concentrations of radionuclides at CRK 16, which is a location on the lower Clinch River and downstream of ORR, the maximum potential dose (excluding the naturally occurring radionuclides ^{7}Be and ^{40}K) to an individual due to irrigation ranged from 0 to 0.06 mrem in 2019. The individual was assumed to consume 24 kg of leafy vegetables, 90 kg of produce, 321 L of milk, and 63 kg of meat (beef) during the year.

Summary

Table 7.6 is a summary of potential EDs from identified waterborne radionuclides around ORR. Excluding Lower EFPC and Poplar Creek from the other water systems evaluated (Melton Hill, Clinch River, Watts Bar Lake, and Chickamauga Lake), the estimated maximum individual ED would be about 4 mrem to a person obtaining his or her drinking water and annual complement of fish from those water systems, and participating in other water uses throughout those systems. The maximum collective ED to the 80 km (50 mile) population was estimated to be 2 person-rem. The percentages of individual and collective doses are small and are attributable to natural background radiation. They constitute about 1 percent of the average individual background dose of roughly 300 mrem/year and 0.0006 percent of the 351,759 person-rem that this population received from natural sources of radiation.

Table 7.6. Summary of annual maximum individual (mrem) and collective (person-rem) effective doses from waterborne radionuclides, 2019[a,b]

Effective dose	Source			Total[d]
	Drinking water	Eating fish[c]	Other uses	
Upstream of all Oak Ridge Reservation discharge locations (CRK 66, City of Oak Ridge Water Plant)				
Individual	3×10^{-10}	1	0.002	1
Collective	6×10^{-9}	0.005	0.003	0.008

Table 7.6. Summary of annual maximum individual (mrem) and collective (person-rem) effective doses from waterborne radionuclides, 2019[a,b] (continued)

Effective dose	Source			Total[d]
	Drinking water	Eating fish[c]	Other uses	
Melton Hill Lake (CRK 58, Knox County Water Plant)				
Individual	2×10^{-8}	NA[e]	0.003	0.003
Collective	5×10^{-7}	NA[e]	0.02	0.02
Upper Clinch River (CRK 23, 32)				
Individual	NA[f]	2	0.0008	2
Collective	NA[f]	0.04	0.001	0.04
Lower Clinch River (CRK 16)				
Individual	NA[f]	4	5×10^{-8}	4
Collective	NA[f]	0.2	1×10^{-7}	0.2
Upper Watts Bar Lake, Kingston Municipal Water Plant				
Individual	0.01	NA[e]	2×10^{-8}	0.01
Collective	0.2	NA[e]	1×10^{-7}	0.2
Lower system (Lower Watts Bar Lake and Chickamauga Lake)				
Individual	0.01	NA[e]	1×10^{-8}	0.01
Collective	1.3	NA[e]	3×10^{-6}	1.3
Lower East Fork Poplar Creek and Poplar Creek				
Individual	NA[f]	NA[e]	0.0007	0.0007
Collective	NA[f]	NA[e]	2×10^{-5}	2×10^{-5}

[a] 1 mrem = 0.01 mSv.
[b] Doses based on measured radionuclide concentrations in water or estimated from measured discharges and known or estimated stream flows.
[c] Doses based on measured radionuclide concentrations in fish samples collected at CRK 16, CRK 32, and CRK 70.
[d] Total doses and apparent sums over individual pathway doses may differ because of rounding.
[e] Not a fish sample collection location.
[f] Not at or near drinking water supply locations.

Acronym:
CRK = Clinch River kilometer

7.1.2.3 Radionuclides in Other Environmental Media

The CAP-88 PC computer codes are used to calculate radiation doses from ingestion of meat, milk, and vegetables that contain radionuclides released to the atmosphere. These doses are included in the dose calculations for airborne radionuclides. Some environmental media, including milk and vegetables, have been sampled in previous years as part of the ORR surveillance program. However, milk samples were not available in 2019.

7.1.2.4 Food

Milk

During 2019, no milk samples were collected. Milk samples had been collected from a nearby dairy in Claxton, Tennessee, for several years; however it went out of business in 2016. Surveys to locate nearby dairies in areas that may be impacted by ORR activities are conducted periodically. The recent survey did not identify any dairies to replace the one that went out of business. The milk-sampling program will resume when a replacement for that dairy is identified.

Vegetables

The food-crop sampling program is described in Chapter 6. Samples of leafy greens, root vegetables, and tomatoes were obtained from a total of five local gardens and two distant background locations. Leafy greens were collected at four locations, root vegetables were collected at three locations, and tomatoes were collected at all five local garden locations. The background location was the same for leafy greens and root vegetables, and a separate background location was used for tomatoes. All radionuclides detected in the food crops can be found in the natural environment, and all but ^{7}Be and ^{40}K may also be emitted from ORR. Dose estimates are based on hypothetical consumption rates of vegetables that contain statistically significant amounts and/or detected radionuclides that could have come from ORR. Based on a nationwide food consumption survey (EPA 2011), a hypothetical home gardener (weighted based on the combined population of Anderson, Knox, Loudon, and Roane counties) was assumed to have eaten a maximum of about 24 kg (53 lb) of homegrown leafy greens, 90 kg (198 lb) of homegrown root vegetables, and 72 kg (159 lb) of homegrown tomatoes. The hypothetical local gardener could have received an ED of between 0.1 and 0.4 mrem, depending on garden location and vegetable consumed, as shown in Table 7.7. Of this total, between 0.02 and 0.2 mrem could have come from eating leafy greens, between 0.06 and 0.3 mrem from eating root vegetables, and between 0.03 and 0.1 mrem from eating tomatoes. The highest dose to a hypothetical local gardener could have been about 0.6 mrem from consuming all three types of homegrown vegetables using the maximum doses for each, regardless of collection location. A person eating vegetables from the two distant (background) gardens could have received a committed ED of 0.3 mrem from eating leafy greens, 0 mrem from eating root vegetables, and 0.1 mrem from eating tomatoes.

Table 7.7. Summary of estimated effective doses from consumption of homegrown vegetables, 2019

Vegetable	Local doses (mrem)	Background doses (mrem)
Leafy greens	0.02–0.2	0.3
Root vegetables	0.06–0.3	0
Tomatoes	0.03–0.1	0.1
Max dose all garden locations	0.6	0.4

An example of a naturally occurring and fertilizer-introduced radionuclide is ^{40}K, which is specifically identified in the samples and accounts for most of the beta activity found in them. The presence of ^{40}K in the samples adds, on average, about 13 mrem to the hypothetical home gardener’s ED. In 2019, the gardeners were asked about water sources and fertilizers used. It was reported that fertilizers were used at four garden locations. Water was used at two of the garden locations, and the water sources included a well and a creek. It is believed ^{40}K and most of the excess unidentified alpha activities are due to naturally occurring radionuclides, not radionuclides discharged from ORR.

Hay

Another environmental pathway that was evaluated was eating beef and drinking milk obtained from hypothetical cattle that ate hay harvested from one location on ORR. Hay samples collected on ORR during May and July 2019 were analyzed for gross alpha, gross beta, gamma emitters, and uranium isotopes. Radionuclides detected in hay are shown in Chapter 6, Table 6.5. Statistically significant concentrations of ^{40}K, ^{234}U, and ^{238}U were detected at that sampling location. Excluding the doses from ^{7}Be and ^{40}K (both naturally occurring), the average ED from drinking milk and eating beef was estimated to be 0.004 mrem.

White-Tailed Deer

The Tennessee Wildlife Resources Agency (TWRA) conducted three 2-day deer hunts during 2019 on the Oak Ridge Wildlife Management Area, which is part of ORR (see Chapter 6). During the hunts, 221 deer were harvested and were brought to the TWRA checking station. At the station, a bone sample and a muscle tissue sample were taken from each deer. The samples were field-counted for radioactivity to ensure that the deer met the wildlife release criteria of less than net counts not greater than 1½ times background (~20 pCi/g $^{89/90}$Sr) of beta activity in bone or the administrative limit of 5 pCi/g of ^{137}Cs in edible tissue (ORNL 2011; ORNL 2020).[1] No deer exceeded the wildlife release criteria.

The average ^{137}Cs concentration in muscle tissue of the 221 released deer, as determined by field counting, was 0.5 pCi/g; the maximum ^{137}Cs concentration in released deer was 0.6 pCi/g. Most of the ^{137}Cs concentrations were less than minimum detectable levels. The average weight of released deer was approximately 40 kg (87 lb); the maximum weight was 82 kg (181 lb). The EDs attributed to field-measured ^{137}Cs concentrations and actual field weights of the released deer ranged from about 0.1 to 1 mrem, with an average of about 0.5 mrem.

Potential doses attributed to deer that might have moved off ORR and been harvested elsewhere were also evaluated. In this scenario, an individual who consumed one hypothetical average-weight deer (40 kg [87 lb], assuming that 55 percent of the field weight is edible meat) containing the 2019 average field-measured concentration of ^{137}Cs (0.5 pCi/g) could have received an ED of about 0.5 mrem. The maximum field-measured ^{137}Cs concentration was 0.6 pCi/g, and the maximum deer weight was 82 kg (181 lb). A hunter who consumed a hypothetical deer of maximum weight and ^{137}Cs content could have received an ED of about 1 mrem.

Muscle tissue samples collected in 2019 from seven released deer were subjected to laboratory analyses. Requested radioisotopic analyses included ^{137}Cs, ^{90}Sr, and ^{40}K radionuclides. Comparison of the released-deer field results to analytical ^{137}Cs concentrations found that the field concentrations were greater than the analytical results and that all were less than the administrative limit of 5 pCi/g (ORNL 2011; ORNL 2020).[1] Using analytically measured ^{137}Cs and ^{90}Sr (excluding ^{40}K, a naturally occurring radionuclide) and actual deer weights, the estimated doses for the seven released deer ranged from about 0.1 to 0.5 mrem.

The maximum ED to an individual consuming venison from two or three deer was also evaluated. Twenty-eight hunters harvested either two or three deer from ORR. Based on ^{137}Cs concentrations determined by field counting and actual field weight, the ED range to a hunter who consumed two or more harvested deer was estimated to be between about 0.4 and 2 mrem.

The collective ED from eating all the harvested venison from ORR with a 2019 average field-derived ^{137}Cs concentration of 0.5 pCi/g and an average weight of 40 kg (87 lb) is estimated to be about 0.1 person-rem. The collective dose is based on number of harvested deer. It is possible that additional

[1] The 2020 version of CSD-AM-RML-RA01 supersedes the 2011 version.

individuals may also consume the harvested venison; however, the collective dose would be essentially the same.

Canada Geese

Thirty geese were captured during the 2019 goose roundup and were subjected to live whole-body gamma scans. The geese were field-counted for radioactivity to ensure that they met wildlife release criteria (< 5 pCi/g of ^{137}Cs in tissue). The average ^{137}Cs concentration was 0.2 pCi/g, with a maximum ^{137}Cs concentration in the released geese of 0.4 pCi/g. All ^{137}Cs concentrations were below minimum detectable activity levels. The average weight of the geese screened during the roundup was about 3.4 kg (8 lb), and the maximum weight was about 4.9 kg (11 lb).

The EDs attributed to field-measured ^{137}Cs concentrations of the geese ranged from 0.017 to 0.02 mrem. However, for bounding purposes, if a person consumed a released goose with an average weight of 3.4 kg (8 lb) and an average ^{137}Cs concentration of 0.2 pCi/g, the estimated ED would be approximately 0.02 mrem. It is assumed that about half the weight of a Canada goose is edible. The estimated ED to an individual who consumed a hypothetical goose with the maximum ^{137}Cs concentration of 0.4 pCi/g and maximum weight of 4.9 kg (11 lb) is about 0.04 mrem.

It is possible that a person could eat more than one goose that spent time on ORR. The average seasonal goose bag per active hunter from Tennessee in the Mississippi Flyway has ranged from 1.9 to 3.0 geese per hunting season between 1999 and 2010 (TWRA 2010). Hypothetically, if one person consumed two geese of maximum weight with the highest measured concentration of ^{137}Cs, that person could have received an ED of about 0.1 mrem.

Between 2000 and 2009, 22 samples of goose tissue were analyzed. An evaluation of potential doses was made based on laboratory-determined concentrations of the following radionuclides: ^{40}K, ^{137}Cs, ^{90}Sr, thorium (^{228}Th, ^{230}Th, ^{232}Th), uranium ($^{233/234}$U, ^{235}U, ^{238}U), and transuranic elements (^{241}Am, $^{243/244}$Cm, ^{238}Pu, $^{239/240}$Pu). The total dose, less the contribution of ^{40}K, ranged from 0.01 to 0.5 mrem, with an average of 0.2 mrem (EP&WSD 2010).

Eastern Wild Turkey

Two wild turkey hunts took place on the reservation in 2019: April 13 and 14 and April 27 and 28. Participating hunters are permitted to harvest one turkey from the reservation in a given season unless a harvested turkey is retained, in which case, the hunter is permitted to hunt for another turkey. Thirty-two turkeys were harvested during that time frame, and 1 additional turkey was harvested during the deer hunt, for a total of 33 turkeys. No harvested turkeys were retained. The average weight of the released turkeys was about 8.6 kg (19 lb). The maximum turkey weight was about 11 kg (24 lb). Turkeys were field-counted for radioactivity to ensure that they met wildlife release criteria (< 5 pCi/g of ^{137}Cs in tissue). The average ^{137}Cs concentration was 0.1 pCi/g, with a maximum ^{137}Cs concentration in the released turkeys of 0.2 pCi/g. Almost all ^{137}Cs concentrations were below minimum detectable activity levels.

The EDs attributed to ^{137}Cs concentrations field-measured in the turkeys ranged from 0.004 to 0.03 mrem. However, for bounding purposes, if a person consumed a released turkey with an average weight of 8.6 kg (19 lb) and an average ^{137}Cs concentration of 0.1 pCi/g, the estimated ED would be approximately 0.02 mrem. It is assumed that about half the weight of a turkey is edible. The estimated ED to an individual who consumed a hypothetical turkey with the maximum ^{137}Cs concentration of 0.2 pCi/g and maximum weight of 11 kg (24 lb) is about 0.04 mrem.

The collective ED from eating all the harvested turkeys from ORR with a 2019 average field-derived ^{137}Cs concentration of 0.1 pCi/g and an average weight of 8.6 kg (19 lb) is estimated to be about 0.0007 person-rem. The collective dose is based on number of harvested turkeys. It is possible that additional individuals may also consume the harvested turkeys; however, the collective dose would be essentially the same.

No tissue samples were analyzed in 2019. Earlier evaluations of doses based on laboratory-determined concentrations of radionuclides included ^{40}K, ^{137}Cs, ^{90}Sr, ^{230}Th, ^{3}H, ^{234}U, ^{235}U, ^{238}U, and transuranic elements (^{241}Am, ^{244}Cm, ^{237}Np, ^{239}Pu). The total dose, less the contribution of ^{40}K, ranged from 0.06 to 0.2 mrem (EP&WSD 2010).

Direct Radiation

The principal sources of natural external exposure are the penetrating gamma radiations emitted by ^{40}K and the series originating from ^{238}U and ^{232}Th (NCRP 2009). Due to radiological activities on ORR, external radiation exposure rates are measured at PAM stations. External gamma exposure rates were continuously recorded by dual-range Geiger-Müller tube detectors co-located with ORR ambient air stations. In 2019, exposure rates averaged about 10 µR/h and ranged from 8.6 to 12.1 µR/h. These exposure rates correspond to an annual average dose of about 61 mrem with a range of 52 to 74 mrem. At the background ambient air station, the exposure rate averaged about 9.1 µR/h and ranged from 8.5 to 10.6 µR/h. The resulting average annual dose was about 56 mrem with a range of 52 to 65 mrem. The annual doses based on measured exposure rates at or near ORR boundaries were typically within the range of the doses measured at the background location; slightly higher exposure rates were observed at AAM11 and AAM46.

7.1.3 Current-Year Summary

A summary of the maximum EDs to individuals by pathway of exposure is given in Table 7.8. In the unlikely event that any person was exposed to all those sources and pathways for the duration of 2019, that person could have received a total ED of about 6 mrem. Of that total, 0.4 mrem would have come from airborne emissions, approximately 4 mrem from waterborne emissions (0.01 mrem from drinking water, 4 mrem from consuming fish, 0.003 mrem from other water uses along the Clinch River, and 0.06 mrem from irrigation at CRK 16) and about 2 mrem from consumption of wildlife. Current direct radiation measurements at PAM stations are at or near background levels. There are no known significant doses from discharges of radioactive constituents from ORR other than those reported.

The dose of 6 mrem is about 2 percent of the annual dose (roughly 300 mrem) from background radiation. The ED of 6 mrem includes the person who received the highest EDs from eating wildlife harvested on ORR. If the MEI did not consume wildlife harvested from ORR, the estimated dose would be about 4 mrem. DOE Order 458.1 limits the ED that an individual may receive from all exposure pathways from all radionuclides released from ORR during 1 year to no more than 100 mrem. The 2019 maximum ED should not have exceeded about 6 mrem, or about 6 percent of the limit given in DOE Order 458.1.

The total collective ED to the population living within an 80 km (50 mile) radius of ORR was estimated to be about 14.3 person-rem. This dose is about 0.004 percent of the 351,759 person-rem that this population received from natural sources during 2019.

Table 7.8. Summary of maximum estimated effective doses from Oak Ridge Reservation activities to an adult by exposure pathway, 2019

Pathway	Dose to maximally exposed individual		Percentage of DOE mrem/year limit (%)	Estimated collective radiation dose[a]			
				Pathway		Background (person-rem)	Total Population
	mrem	mSv		person-rem	person-Sv		
				Airborne effluents			
All pathways	0.4	0.004	0.4	12.4	0.124		1,172,530[b]
				Liquid effluents			
Drinking water	0.01	0.0001	0.01	1.5	0.015		457,351[c]
Eating fish	4	0.04	4	0.3	0.003		233[d]
Other activities	0.003	3×10^{-5}	0.003	0.02	0.0002		3,359,287[d]
Irrigation	0.06	0.0006	0.06				
				Other pathways			
Eating deer	2[e]	0.02	2	0.1	0.001		221
Eating geese	0.1[f]	0.001	0.1	*g*	*g*		
Eating turkey	0.04[h]	0.0004	0.04	0.0007	7×10^{-6}		33
Direct radiation	NA[i]	NA					
				All pathways			
Total	**6**[j]	**0.06**	**6**	**14.3**	**0.143**	**351,759**	

[a] Estimated background collective dose is based on the roughly 300 mrem/year individual dose and the population within 80 km (50 miles) of the Oak Ridge Reservation (ORR).
[b] Population based on 2010 census data.
[c] Population estimates based on community and non-community drinking water supply data from the Tennessee Department of Environment and Conservation Division of Water.
[d] Population estimates for fish based on creel data and fraction of fish harvested from Melton Hill, Watts Bar, and Chickamauga Reservoirs. Melton Hill, Watts Bar and Chickamauga recreational use information was obtained from the Tennessee Valley Authority (Stephens et al. 2006 and Poudyal et al. 2017). Other activities include swimming, boating, and shoreline use; the population estimates include individuals involved in more than one activity and also include visitors that may live outside the 80 km radius.
[e] Estimates for eating deer are based on hunters that harvested two or three deer on ORR in 2019. It is assumed that one individual may have consumed these deer. The collective dose is based on the number of harvested deer.
[f] Estimates for eating geese are based on consuming two hypothetical worst-case geese, each a combination of the heaviest goose harvested and the highest measured concentrations of ^{137}Cs in released geese.
[g] Collective doses were not estimated for the consumption of geese because no geese were harvested for consumption during the goose roundup.
[h] Estimates for eating turkey are based on consuming one hypothetical worst-case turkey, a combination of the heaviest turkey harvested and the highest measured concentrations of ^{137}Cs in released turkey on ORR. The collective dose is based on the number of harvested turkey.
[i] Current exposure rate measurements at perimeter air monitoring stations are at or near background levels.
[j] Dose estimates have been rounded.

7.1.4 Five-Year Trends

EDs associated with selected exposure pathways for years 2015 to 2019 are given in Table 7.9. In 2019, the air pathway dose is within the range of air pathway doses that have been estimated over the last 5 years. Starting in 2016, dose estimates take into account terrain height for the Spallation Neutron Source because it is located on a ridge above most of ORR. In 2016, some issues associated with cross-contamination in analytical equipment used to quantify radionuclides in ORR-wide surface water samples from CRK 66, 58, 32, 23, and 16 led to biased results for several 2016 sampling events. The increase in the 2019 fish consumption dose was due to a catfish sample collected at CRK 16, in which $^{239/240}$Pu was a primary dose contributor; however, the catfish sample collected at CRK 70, which is above ORR discharge locations, also contained $^{239/240}$Pu. Catfish and sunfish samples from both CRK 16 and CRK 70 were reanalyzed, and while results were generally lower, there was not a statistically significant difference, and the original results were used in dose calculations. There was a decrease in drinking water dose in 2019, but the doses are comparable to other earlier estimated doses. Recent direct radiation measurements indicate doses near background levels. Doses from consumption of wildlife have been similar for the last 5 years with a slight increase in dose due to consumption of geese in 2016.

Table 7.9. Trends in effective dose from Oak Ridge Reservation activities, 2015–2019 (mrem)[a]

Pathway	2015	2016	2017	2018	2019
All routes—inhalation	0.4	0.2	0.3	0.2	0.4
Fish consumption (Clinch River)	0.03	1.3	0.05	0.09	4
Drinking water (Kingston)	0.02	0.03	0.01	0.03	0.01
Deer	1	1	2	2	2
Geese	0.08	0.2	0.08	0.1	0.1
Turkey	0.05	0.05	0.08	0.05	0.04

[a] 1 mrem = 0.01 mSv

7.1.5 Doses to Aquatic and Terrestrial Biota

7.1.5.1 Aquatic Biota

DOE Order 458.1 (DOE 2011) sets an absorbed dose rate limit of 1 rad/day to native aquatic organisms from exposure to radioactive material in liquid wastes discharged to natural waterways (see Appendix E for definitions of absorbed dose and rad). To demonstrate compliance with this limit, the aquatic organism assessment was conducted using the RESRAD-Biota code (1.8), a companion tool for implementing DOE technical standard *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE 2019). The code serves as DOE's biota dose evaluation tool and uses the screening (i.e., biota concentration guides [BCGs]) and analysis methods in the technical standard. The BCG is the limiting concentration of a radionuclide in sediment or water that would not cause dose limits for protection of aquatic biota populations to be exceeded.

The intent of the graded approach is to protect populations of aquatic organisms from the effects of exposure to anthropogenic ionizing radiation. Certain organisms are more sensitive to ionizing radiation than others. Therefore, it is generally assumed that protecting the more-sensitive organisms will adequately protect other, less-sensitive organisms. Depending on the radionuclide, either aquatic organisms (e.g., crustaceans) or riparian organisms (e.g., raccoons) may be the more sensitive and are typically the limiting organisms for the general screening phase of the graded approach for aquatic organisms.

At ORNL, doses to aquatic organisms are based on surface water concentrations at the following instream sampling locations:

- Melton Branch (X13)
- WOC headwaters (WOC 6.8), WOC (X14), and White Oak Dam (WOD) (X15)

- WOC 7500 Bridge
- First Creek
- Fifth Creek
- Northwest Tributary
- Raccoon Creek
- Clinch River CRKs 16, 32, 58, and 66

All locations, except WOD (X15) passed the general screening phase (comparison of maximum radionuclide water concentrations to default BCGs). WOD (X15) passed when average water concentrations and adjusted bioaccumulation factors for ^{137}Cs and ^{90}Sr were used to reflect site-specific bioaccumulation of these radionuclides in fish. Riparian organisms are the limiting receptor for ^{137}Cs and ^{90}Sr in surface water; however, the best available bioaccumulation data for this area are for fish. Because fish are consumed by riparian organisms (e.g., raccoons), adjustment of the fish bioaccumulation factor modified the bioaccumulation of ^{137}Cs and ^{90}Sr in riparian organisms. This resulted in absorbed dose rates to aquatic organisms below DOE aquatic dose limit of 1 rad/day at the ORNL sampling locations.

At Y-12, doses to aquatic organisms were estimated from surface water concentrations and sediment concentrations (at Station 9422-1 and S24) at the following instream sampling locations:

- Surface Water Hydrological Information Support System Station 9422-1 (also known as station 17)
- Bear Creek at Bear Creek kilometer 9.2 (BCK 9.2)
- Discharge Point S24 (Bear Creek at BCK 9.4)
- Discharge Point S17 (unnamed tributary to the Clinch River)
- Discharge Point S19 (Rogers Quarry)

All locations passed the general screening phase (maximum water concentrations and default parameters for BCGs). This resulted in absorbed dose rates to aquatic organisms below DOE aquatic dose limit of 1 rad/day at the Y-12 locations.

At ETTP, doses to aquatic organisms were estimated from surface water concentrations at the following instream sampling locations:

- Mitchell Branch at K1700; Mitchell Branch kilometers 0.45, 0.59, 0.71, and 1.4 (upstream location)
- Poplar Creek at K-716 (downstream)
- K1007-B and K-1710 (upstream location)
- K-702A and K901-A (downstream of ETTP operations)
- Clinch River (CRK 16 and CRK 23)

All these locations passed the initial general screening (using maximum concentrations and default parameters for BCGs). This resulted in absorbed dose rates to aquatic organisms that were below the DOE aquatic dose limit of 1 rad/day at the ETTP sampling locations.

7.1.5.2 Terrestrial Biota

A terrestrial organism assessment was conducted to evaluate impacts on biota in accordance with requirements in DOE Order 458.1 (DOE 2011). An absorbed dose rate of 0.1 rad/day is recommended as the limit for terrestrial animal exposure to radioactive material in soils. As for aquatic and riparian biota, certain terrestrial organisms are more sensitive to ionizing radiation than others, and it is generally assumed that protecting the more-sensitive organisms will adequately protect other, less-sensitive organisms. Initial soil sampling for terrestrial dose assessment was initiated in 2007 and reassessed in 2014. This biota sampling strategy was developed by taking into account guidance provided in *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE 2019) and existing radiological information on the concentrations and distribution of radiological contaminants on ORR. In 2014, as well as in 2007, the soil sampling focused on unremediated areas, such as floodplains and some upland areas. Floodplains are often downstream of contaminant source areas and are dynamic systems where soils are eroding in some places and being deposited in others. Soil sampling locations are identified as follows:

- WOC floodplain and upland location
- Bear Creek Valley floodplain
- Mitchell Branch floodplain
- Two background locations: Gum Hollow and near Bearden Creek

The soil samples collected in 2014 were in similar locations as in 2007; except one location where a soil sample was not collected due to site inaccessibility. Except for samples collected on the WOC floodplain (collected on the WOC floodplain upstream from WOD), samples collected at all other soil sampling locations passed either the initial-level screening (comparison of maximum radionuclide soil concentrations to default BCGs) or second-level screening, for which BCG default parameters and average soil concentrations were used. Cesium-137 is the primary dose contributor in the soil samples collected on the WOC floodplain. The next evaluation of exposure to terrestrial organisms will be conducted within the next couple years or if an abnormal event occurs that could have adverse effects on terrestrial organisms.

Biota sampling in the WOC floodplain was conducted in 2009. White-footed mice (*Peromyscus leucopus*), deer mice (*Peromyscus maniculatus*), and hispid cotton rats (*Sigmodon hispidus)* were selected for sampling because they live and forage in these areas, are food for other mammals, and have relatively small home ranges. The biota sampling locations were at the confluence of Melton Branch and WOC and in the floodplain upstream of White Oak Lake. Based on the current measured concentrations in soil and tissue concentrations collected, the absorbed doses to the terrestrial organisms collected along the confluence of Melton Branch and WOC and in the floodplain upstream of White Oak Lake were less than 0.1 rad/day.

7.2 Chemical Dose

7.2.1 Drinking Water Consumption

7.2.1.1 Surface Water

To evaluate the drinking water exposure pathway, hazard quotients (HQs) and risks were estimated downstream of ORNL and downstream of ORR discharge points (Table 7.10). The HQ is a ratio that compares the estimated exposure dose or intake to the reference dose for noncarcinogens. HQ values of less than 1 indicate an unlikely potential for adverse noncarcinogenic health effects. Likewise, risks are evaluated from estimated exposure dose or intake and cancer slope factors. Acceptable risk levels for carcinogens range from 10^{-4} (risk of developing cancer over a human lifetime is 1 in 10,000) to 10^{-6} (risk of developing cancer over a human lifetime is 1 in 1,000,000) (see Appendix F). Based on a nationwide food consumption survey (EPA 2011) and weighted based on the combined population of Anderson, Knox, Loudon, and Roane Counties, it was assumed that the drinking water consumption rate for the MEI is 730 L/year (2 L/day). This is the same drinking water consumption rate used in the estimation of the maximum exposed radiological dose from consumption of drinking water. Chemical analytes were measured in surface water samples collected at CRK 66, CRK 32, CRK 23, and CRK 16. The water intake for ETTP used to be located near CRK 23 but was deactivated in 2014. Mercury concentrations were measured but not detected above the analytical method detection limit in surface water samples collected at CRK 66 and CRK 32.

As shown in Table 7.10, at all locations, HQs were less than 1 for detected chemical analytes for which there are reference doses or a maximum contaminant level. CRK 16 is located downstream of all DOE discharge points. Although CRK 16 is not a source of drinking water, data from this location were used as a surrogate to evaluate potential exposure to drinking water from the Clinch River.

Acceptable risk levels for carcinogens typically range in magnitude from 10^{-4} to 10^{-6}. Risk values of 6×10^{-6} and 5×10^{-6} were calculated for the intake of arsenic in water collected at CRK 16 and CRK 23, respectively. Risk values of 1×10^{-6} and 3×10^{-6} were calculated for the intake of chromium in water collected at CRK 16 and CRK 23, respectively.

Table 7.10. Chemical hazard quotients and estimated risks for drinking water from the Clinch River at CRK 23 and 16, 2019[a]

Analyte	Hazard quotient	
	CRK 23[b]	CRK 16[c]
Metals		
Antimony	0.003	0.002
Arsenic	0.03	0.03
Cadmium	0.001	0.001
Chromium	0.005	0.003
Copper	0.0007	0.0006
Lead	0.02	0.02
Mercury	4×10^{-5}	0.0002
Nickel	0.0008	0.0005
Selenium	0.0007	0.001
Silver	4×10^{-5}	4×10^{-5}
Thallium	0.04	0.04
Uranium	0.02	0.02
Zinc	0.0004	4×10^{-5}
Volatile organics		
1,1,1-Trichloroethane	4×10^{-6}	4×10^{-6}
cis-1,2-Dichloroethene	0.004	0.004
Trichloroethane	0.02	0.02
Vinyl chloride	0.001	0.001
Risks for carcinogens		
Arsenic	5×10^{-6}	6×0^{-6}
Chromium	3×10^{-6}	1×10^{-6}
Lead	6×10^{-9}	6×10^{-9}

[a] CRK = Clinch River kilometer
[b] CRK 23, is located across from East Tennessee Technology Park, no longer a water intake location.
[c] CRK 16 is downstream of all US Department of Energy inputs and not a water intake location.

Acronym:
CRK = Clinch River kilometer.

7.2.1.2 Groundwater

As mentioned in Section 6.5, during FY 2019 OREM continued to collect and analyze samples from the off-site groundwater monitoring well array west of the Clinch River adjacent to Melton Valley. Currently, no water is consumed from these off-site groundwater wells.

7.2.2 Fish Consumption

Chemicals in water can be accumulated by aquatic organisms that may be consumed by humans. To evaluate the potential health effects from the fish consumption pathway, HQs were estimated for the consumption of noncarcinogens, and risk values were estimated for the consumption of carcinogens detected in sunfish and catfish collected both upstream and downstream of ORR discharge points. Based on a nationwide food consumption survey (EPA 2011) and weighted based on the combined population of Anderson, Knox, Loudon, and Roane counties, it was assumed that avid fish consumers would have eaten 27 kg (60 lb) of fish during 2019. This fish consumption rate of 74 g/day (27 kg/year) is assumed for estimating exposure for both the noncarcinogenic and carcinogenic chemicals. This is the same fish consumption rate used in the estimation of the radiological dose from consumption of fish.

As shown in Table 7.11, for consumption of sunfish and catfish, HQ values of less than 1 were calculated for all detected analytes except for Aroclor-1260, a polychlorinated biphenyl (PCB), also referred to as PCB-1260. An HQ greater than 1 for Aroclor-1260 was estimated in catfish at all three locations (CRKs 16, 32, and 70).

For carcinogens, risk values at or greater than 10^{-6} were calculated for the intake of chromium (as Cr^{+6}) and Aroclor-1260 for sunfish and catfish collected at all three locations except for catfish at CRK 32. All concentrations for chromium were estimated at or below the analytical detection limit. The Tennessee Department of Environment and Conservation (TDEC) has issued a fish advisory that states that catfish should not be consumed from Melton Hill Reservoir (in its entirety) because of PCB contamination (TDEC 2019). TDEC has issued a precautionary fish consumption advisory for catfish in the Clinch River arm of Watts Bar Reservoir (TWRA 2019b).

Table 7.11. Chemical hazard quotients and estimated risks for fish caught and consumed from locations on the Oak Ridge Reservation, 2019[a]

	Sunfish			Catfish		
	CRK 70[b]	CRK 32[c]	CRK 16[d]	CRK 70[b]	CRK 32[c]	CRK 16[d]
			Hazard quotients for metals			
Barium	J0.0007	J0.001	J0.0008			J0.002
Chromium	J0.03	J0.02	J0.02	J0.02	J0.001	J0.02
Copper	J0.004	J0.002	J0.002	0.01	J0.0004	0.008
			Hazard quotients for metals			
Iron	0.008	0.004	0.003	0.005	0.0006	0.004
Manganese	0.006	0.01	0.005	J0.001	J9E-5	0.002
Mercury	0.1	J0.07	0.1	0.3	0.1	0.1
Selenium	0.1	0.1	0.1	J0.1	J0.01	0.1
Strontium	0.002	0.002	0.002			J0.0001
Thallium	J0.1	J0.2	J0.1		J0.009	
Zinc	0.03	0.03	0.02	0.01	0.001	0.02
			Hazard quotients for Aroclors			
Aroclor-1260	J0.5	J0.5	J0.4	4	4	14

Table 7.11. Chemical hazard quotients and estimated risks for fish caught and consumed from locations on the Oak Ridge Reservation, 2019[a] (continued)

	Sunfish			Catfish		
	CRK 70[b]	CRK 32[c]	CRK 16[d]	CRK 70[b]	CRK 32[c]	CRK 16[d]
			Risks for carcinogens			
Chromium	J2E-5	J1E-5	J1E-5	J8E-6	J7E-7	J1E-5
Aroclor-1260	J7E-6	J8E-6	J7E-6	6E-5	6E-5	2E-4
PCBs (mixed)[e]	J7E-6	J8E-6	J7E-6	6E-5	6E-5	2E-4

[a] A blank space for a location indicates that the parameter was undetected. A prefix "J" indicates that the concentration was estimated at or below the analytical detection limit by the laboratory.
[b] Melton Hill Reservoir, above the City of Oak Ridge Water Plant.
[c] Clinch River downstream of Oak Ridge National Laboratory.
[d] Clinch River downstream of all US Department of Energy inputs.
[e] Mixed polychlorinated biphenyls (PCBs) consist of the summation of Aroclors detected or estimated.

Acronyms:
CRK = Clinch River kilometer
ORR = Oak Ridge Reservation

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Appendix A: Glossary

Appendix
A. Glossary

accuracy—The closeness of the result of a measurement to the true value of the quantity.

aliquot—The quantity of a sample being used for analysis.

alkalinity—The capacity of an aqueous solution to neutralize an acid. Alkalinity measurements are important in determining the sensitivity of a body of water to acid inputs such as acidic pollution from rainfall or wastewater.

alpha particle—A positively charged particle emitted from the nucleus of an atom; it has the same charge and mass as that of a helium nucleus (two protons and two neutrons).

ambient air—The surrounding atmosphere as it exists around people, plants, and structures.

analyte—A constituent or parameter that is being analyzed.

analytical detection limit—The lowest reasonably accurate concentration of an analyte that can be detected; this value varies depending on the method, instrument, and dilution used.

anion—A negatively charged ion.

aquifer—A saturated, permeable geologic unit that can transmit significant quantities of water under ordinary hydraulic gradients.

aquitard—A geologic unit that inhibits the flow of water.

beta particle—A negatively charged particle emitted from the nucleus of an atom. It has a mass and charge equal to those of an electron.

biota—The animal and plant life of a particular region considered as a total ecological entity.

blank—A control sample that is identical in principle to the sample of interest, except the substance being analyzed is absent. In such cases, the measured value or signal for the substance being analyzed is believed to be a result of artifacts. Under certain circumstances, that value may be subtracted from the measured value to give a net result reflecting the amount of the substance in the sample. EPA does not permit the subtraction of blank results in EPA-regulated analyses.

calibration—Determination of variance from a standard of accuracy of a measuring instrument to ascertain necessary correction factors.

CERCLA Off-site Rule—Requires that CERCLA wastes be placed only in a facility operating in compliance with the Resource Conservation and Recovery act or other applicable federal or state requirements. The regulatory citation is 40 *CFR* 300.440.

CERCLA-reportable release—A release to the environment that exceeds reportable quantities as defined by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

chemical oxygen demand—Indicates the quantity of oxidizable materials present in water and varies with water composition, concentrations of reagent, temperature, period of contact, and other factors.

closure—Specifically, closure of a hazardous waste management facility under Resource Conservation and Recovery Act (RCRA) requirements.

compliance—Fulfillment of applicable requirements of a plan or schedule ordered or approved by government authority.

concentration—The amount of a substance contained in a unit volume or mass of a sample.

conductivity—A measure of water's capacity to convey an electric current. This property is related to the total concentration of the ionized substances in water and the temperature at which the measurement is made.

confluence—The point at which two or more streams meet; the point where a tributary joins the main stream.

contamination—Deposition of unwanted material on the surfaces of structures, areas, objects, or personnel.

cosmic radiation—Ionizing radiation with very high energies, originating outside the earth's atmosphere. Cosmic radiation is one source contributing to natural background radiation.

count—A measure of the radiation from an object or device; the signal that announces an ionization event within a counter.

curie (Ci)—A unit of radioactivity. One curie is defined as 3.7×10^{10} (37 billion) disintegrations per second. Several fractions and multiples of the curie are commonly used:

> **kilocurie (kCi)**—10^{3} Ci, one thousand curies; 3.7×10^{13} disintegrations per second.
>
> **millicurie (mCi)**—10^{-3} Ci, one-thousandth of a curie; 3.7×10^{7} disintegrations per second.
>
> **microcurie (µCi)**—10^{-6} Ci, one-millionth of a curie; 3.7×10^{4} disintegrations per second.
>
> **picocurie (pCi)**—10^{-12} Ci, one-trillionth of a curie; 0.037 disintegrations per second.

daughter—A nuclide formed by the radioactive decay of a parent nuclide.

decay, radioactive—The spontaneous transformation of one radionuclide into a different radioactive or nonradioactive nuclide, or into a different energy state of the same radionuclide.

dense nonaqueous phase liquid (DNAPL)—The liquid phase of chlorinated organic solvents. These liquids are denser than water and include commonly used industrial compounds such as tetrachloroethene and trichloroethene.

derived concentration guide (DCG)—The concentration of a radionuclide in air or water that, under conditions of continuous exposure for 1 year by one exposure mode (i.e., ingestion of water, submersion in air, or inhalation), would result in either an effective dose equivalent of 0.1 rem (1 mSv) or a dose equivalent of 5 rem (50 mSv) to any tissue, including skin and lens of the eye. The guides for radionuclides in air and water are given in DOE Order 5400.5.

derived concentration standard (DCS)—Quantities used in the design and conduct of radiological environmental protection programs at US Department of Energy facilities and sites. These quantities represent the concentration of a given radionuclide in either water or air that results in a member of the public receiving a 1 mSv (100 mrem) effective dose following continuous exposure for 1 year for each of the following pathways: ingestion of water, submersion in air, and inhalation.

disintegration, nuclear—A spontaneous nuclear transformation (radioactivity) characterized by the emission of energy and/or mass from the nucleus of an atom.

dissolved oxygen—A measurement of the amount of gaseous oxygen in an aqueous solution. Adequate dissolved oxygen is necessary for good water quality.

dose—A general term for absorbed dose, equivalent dose, or effective dose.

> **absorbed dose**—The average energy imparted by ionizing radiation to the matter in a volume element per unit mass of irradiated material. The absorbed dose is expressed in units of rad (or gray) (1 rad = 0.01 gray).
>
> **collective dose/collective effective dose**—The sum of the total effective dose to all persons in a specified population received in a specified period of time. It can be approximated by the sum of the average effective dose for a given subgroup i, and Ni is the number of individuals in this subgroup. Collective dose is expressed in units of person-rem (or person-sievert).
>
> **effective dose (E or ED)**—The summation of the products of the equivalent dose (HT) received by specified tissues or organs of the body and the appropriate tissue weighting factor (wT). It includes the dose from radiation sources internal and/or external to the body. The effective dose is expressed in units of rems (or sieverts).
>
> **equivalent dose (HT)**—The product of average absorbed dose (DT,R) in rad (or gray) in a tissue or organ (T) and a radiation (R) weighting factor (wR).

dosimetry—Measurement and calculation of radiation doses from exposure to ionizing radiation.

drinking water standard (DWS)—Federal primary drinking water standards, both proposed and final, as set forth by the US Environmental Protection Agency.

duplicate samples—Two or more samples collected simultaneously into separate containers.

effluent—A liquid or gaseous waste discharge to the environment.

effluent monitoring—The collection and analysis of samples or measurements of liquid and gaseous effluents for purposes of characterizing and quantifying the release of contaminants, assessing radiation exposures of members of the public, and demonstrating compliance with applicable standards.

energy intensity—Energy consumption per square foot of building space, including industrial or laboratory facilities [EO 13514, Section 19(f)].

Environmental Management—A US Department of Energy program that directs the assessment and cleanup (remediation) of its sites and facilities contaminated with waste as a result of nuclear-related activities.

exposure (radiation)—The incidence of radiation on living or inanimate material by accident or intent. Background exposure is the exposure to natural background ionizing radiation. Occupational exposure is the exposure to ionizing radiation that takes place during a person's working hours. Population exposure is the exposure to the total number of persons who inhabit an area.

external radiation—Exposure to ionizing radiation when the radiation source is located outside the body.

flux—A flow or discharge of a substance (in units of mass, radioactivity, etc.) per unit of time.

gamma ray—High-energy, short-wavelength electromagnetic radiation emitted from the nucleus of an excited atom. Gamma rays are identical to x-rays except for the source of the emission.

grab sample—A sample collected instantaneously with a glass or plastic bottle placed below the water surface to collect surface water samples (also called dip samples).

greenhouse gas (GHG)—Gas that traps heat in the atmosphere. The four major greenhouses gases are carbon dioxide, methane, nitrous oxide, and fluorinated gases.

groundwater—The water located beneath the earth's surface in soil pore spaces and in the fractures of rock formations.

hardness—Water hardness is caused by polyvalent metallic ions dissolved in water. In fresh water, these are mainly calcium and magnesium, although other metals such as iron, strontium, and manganese may contribute to hardness.

hectare—A metric unit of area equal to 10,000 square meters or 2.47 acres.

hydrology—The science dealing with the properties, distribution, and circulation of natural water systems.

internal radiation—Internal radiation occurs when radionuclides enter the body by ingestion of foods, milk, and water, and by inhalation. Radon is the major contributor to the annual dose equivalent for internal radionuclides.

ion—An atom or compound that carries an electrical charge.

irradiation—Exposure to radiation.

isotopes—Forms of an element having the same number of protons in their nuclei but differing in the number of neutrons.

Leadership in Energy and Environmental Design (LEED)—A suite of rating systems for the design, construction, operation, and maintenance of green buildings, homes, and neighborhoods. LEED is intended to help building owners and operators find and implement ways to be environmentally responsible and resource-efficient.

maximally exposed individual (MEI)—A hypothetical individual who, because of proximity, activities, or living habits, could potentially receive the maximum possible dose of radiation from a given event or process.

microbes—Microscopic organisms.

migration—The transfer or movement of a material through the air, soil, or groundwater.

millirem (mrem)—The dose equivalent that is one one-thousandth of a rem.

milliroentgen (mR)—A measure of x-ray or gamma radiation. The unit is one-thousandth of a roentgen.

minimum detectable activity (MDA)—The smallest activity of a radionuclide that can be distinguished in a sample by a given measurement system at a preselected counting time and at a given confidence level.

monitoring—A process whereby the quantity and quality of factors that can affect the environment and/or human health are measured periodically to regulate and control potential impacts.

natural radiation—Radiation arising from cosmic and other naturally occurring radionuclide sources (such as radon) present in the environment.

nuclide—An atom specified by its atomic weight, atomic number, and energy state. A radionuclide is a radioactive nuclide.

outfall—The point of conveyance (e.g., drain or pipe) of wastewater or other effluents into a ditch, pond, or river.

ozone—A gas made up of three oxygen atoms that occurs both in earth's upper atmosphere and at ground level. Ozone can be "good" or "bad" for human health and the environment, depending on its location in the atmosphere. Ozone acts as a protective layer high above the earth, but it can be harmful to breathe.

parts per billion (ppb)—A unit measure of concentration equivalent to the weight/volume ratio expressed as micrograms per liter or nanograms per milliliter.

parts per million (ppm)—A unit measure of concentration equivalent to the weight/volume ratio expressed as milligrams per liter or milligrams per kilogram.

person-rem—Collective dose to a population group. For example, a dose of 1 rem to 10 individuals results in a collective dose of 10 person-rem.

pH—A measure of the hydrogen ion concentration in an aqueous solution. Acidic solutions have a pH from 0 through < 7, basic solutions have a pH > 7, and neutral solutions have a pH $= 7$.

precision—The degree to which repeated measurements under unchanged conditions show the same results (also called reproducibility or repeatability).

quality assurance (QA)—Any action in environmental monitoring to ensure the reliability of monitoring and measurement data.

quality control (QC)—The routine application of procedures within environmental monitoring to obtain the required standards of performance in monitoring and measurement processes.

rad—The unit of absorbed dose deposited in a volume of material.

radioactivity—The spontaneous emission of radiation, generally alpha or beta particles or gamma rays, from the nucleus of an unstable isotope.

radioisotopes—Radioactive isotopes.

radionuclide—An unstable nuclide capable of spontaneous transformation into other nuclides by changing its nuclear configuration or energy level. This transformation is accompanied by the emission of photons or particles.

reclamation—Recovery of wasteland, desert, etc. by ditching, filling, draining, or planting.

reference material—A material or substance with one or more properties that is sufficiently well established and is used to calibrate an apparatus, to assess a measurement method, or to assign values to materials.

release—Any discharge to the environment. "Environment" is broadly defined as any water, land, or ambient air.

rem—The unit of dose equivalent (absorbed dose in rads × the radiation quality factor). Dose equivalent is frequently reported in units of millirem (mrem), which is one one-thousandth of a rem.

remedial investigation/feasibility study (RI/FS)—An in-depth study designed to gather data needed to determine the nature and extent of contamination at a Superfund site; establish site cleanup criteria; identify preliminary alternatives for remedial action; and support technical and cost analyses of alternatives. The remedial investigation is usually done with the feasibility study. Together they are usually referred to as the "RI/FS."

remediation—The correction of a problem. On the Oak Ridge Reservation remediation efforts focus on the safe cleanup of the environmental legacy resulting from research activities and weapons production over the past 5 decades.

roentgen—A unit of radiation exposure equal to the quantity of ionizing radiation that will produce one electrostatic unit of electricity in one cubic centimeter of dry air at 0°C and standard atmospheric pressure. One roentgen equals 2.58×10^{-4} coulombs per kilogram of air. [Note: A coulomb is a unit of electric charge—the SI (International System of Units) unit of electric charge equal to the amount of charge transported by a current of one ampere in one second.]

sensitivity—The capability of a methodology or an instrument to discriminate among samples with differing concentrations or containing varying amounts of analyte.

sievert (Sv)—The SI (International System of Units) unit of dose equivalent; 1 Sv = 100 rem.

spike—The addition of a known amount of reference material containing the analyte of interest to a blank sample.

spiked sample—A sample to which a known amount of some substance has been added.

stable—Not radioactive or not easily decomposed or otherwise modified chemically.

stack—A vertical pipe or flue designed to exhaust airborne gases and suspended particulate matter.

standard reference material (SRM)—A reference material distributed and certified by the National Institute of Standards and Technology.

storm water runoff—Rainfall that flows over the ground surface.

stratospheric ozone—The stratosphere or "good" ozone layer extends upward from about 6 to 30 miles above the earth's surface and protects the earth from the sun's harmful ultraviolet rays.

substrate—The substance, base, surface, or medium in which an organism lives and grows.

Superfund—The Superfund Amendments and Reauthorization Act amended the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) in 1986. CERCLA, the federal program to clean up the nation's uncontrolled hazardous waste, is now known as Superfund.

surface water—All water on the surface of the earth, as distinguished from groundwater.

terrestrial radiation—Ionizing radiation emitted from radioactive materials, primarily potassium-40, thorium, and uranium, in the earth's soils. Terrestrial radiation contributes to natural background radiation.

total activity—The total number of atoms of a radioactive substance that decay per unit of time.

total dissolved solids—Dissolved solids and total dissolved solids (generally associated with freshwater systems) consist of inorganic salts, small amounts of organic matter, and dissolved materials.

transect—A line across an area being studied. The line is composed of points where specific measurements or samples are taken.

transuranic (or transuranium)—Of or relating to elements with higher atomic weights than uranium; all 13 known transuranic elements are radioactive and are produced artificially.

transuranic waste—Solid radioactive waste containing primarily alpha-emitting elements heavier than uranium.

trip blank—A sample container of deionized water that is transported to a sampling location, treated as a sample, and sent to the laboratory for analysis; trip blanks are used to check for contamination resulting from transport, shipping, and site conditions.

turbidity—A measure of the concentration of sediment or suspended particles in solution.

volatile organic compounds—Organic chemicals that have a high vapor pressure at ordinary conditions. They include both human-produced and naturally occurring chemical compounds and are used in many industrial processes. Common examples include trichloroethane, tetrachloroethene, and trichloroethene.

watershed—The region draining into a river, river system, or body of water. Large watersheds may be subdivided into smaller units called **subwatersheds**, which collectively flow together to form larger sub-basins and river basins.

wetlands—Lowland areas, such as a marshes or swamps, sufficiently inundated or saturated by surface water or groundwater to support aquatic vegetation or plants adapted for life in saturated soils. Wetlands are those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands include swamps, marshes, bogs, and similar areas.

wind rose—A diagram that summarizes statistical information concerning wind direction and speed at a specific location.

Appendix B:
Climate Overview of the Oak Ridge Area

Appendix
B. Climate Overview of the Oak Ridge Area

B.1 Regional Climate

The climate of the Oak Ridge area and its surroundings may be broadly classified as humid subtropical. The term “humid” indicates that the region receives an overall surplus of precipitation compared to the level of evaporation and transpiration normally experienced throughout the year. The “subtropical” designation indicates that the region experiences a wide range of seasonal temperatures. Such areas are typified by significant differences in temperature between summer and winter. More specifically, the coldest month’s average temperature is above –3°C (27°F), and at least one summer month has an average temperature above 22°C (72°F). Also, the definition of the humid subtropical climate means that at least 4 months have an average temperature above 10°C (50°F). There are no major differences in monthly precipitation throughout the year, but the sources of precipitation may vary.

Oak Ridge winters are characterized by synoptic midlatitude cyclones that produce significant precipitation events roughly every 3 to 5 days. These wet periods are occasionally followed by arctic air outbreaks. Although snow and ice are not associated with many of these systems, occasional snowfall does result. Winter cloud cover tends to be enhanced by the regional terrain due to cold air wedging and moisture trapping.

Severe thunderstorms, which can occur at any time of the year, are most frequent during spring and rarely occur in winter. The Cumberland Mountains and Cumberland Plateau frequently inhibit the intensity of severe systems that traverse the region, particularly those moving from west to east, due to the downward momentum created as the storms move off higher terrain into the Great Valley. Summers are characterized by very warm, humid conditions. Occasional frontal systems may produce organized lines of thunderstorms and rare damaging tornados. More frequently, however, summer precipitation results from “air mass” thundershowers that form as a consequence of daytime heating, rising humid air, and local terrain features. Although fall precipitation is usually adequate, August through October often are the driest months of the year. The occurrence of precipitation during the fall tends to be less cyclical than for other seasons, but is occasionally enhanced by decaying tropical cyclones moving north from the Gulf of Mexico. In November, midlatitude cyclones again begin to dominate the weather and typically continue to do so until May.

Decadal-scale climate change regularly affects the East Tennessee region. Most of these changes appear related to the hemispheric temperature and precipitation effects caused by the frequency and phase of the El Niño–Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO), and the Atlantic Multidecadal Oscillation (AMO). The ENSO and PDO patterns, with cycles of 3 to 7 years and about 60 years, respectively, affect Pacific Ocean sea surface temperature patterns. The AMO, with a cycle of 40 to 70 years, affects Atlantic sea surface temperature similar to the PDO. These medium- and long-range sea surface temperature patterns collectively modulate decadal-scale and longer regional temperature and precipitation trends in eastern Tennessee. The AMO shifted from a cold to a warm sea surface temperature phase in the mid-1990s and may continue in its present state for another decade or so. The PDO entered an either cool or transitional sea surface temperature state around 2000. Although the ENSO pattern had frequently brought about warmer Eastern Pacific sea surface temperatures during the 1990s, that phenomenon had subsided somewhat in the 2000s. A very strong El Niño occurred in 2015–2016, leading to above-normal temperatures both locally and across much of the globe by 2016. In general, a return to the dominance of El Niño has occurred during the 2010s. Additionally, evidence exists that human-induced climate change may be producing some effect on local temperatures via an array of first-order influences such as well-mixed greenhouse gases, land cover change, carbon soot, aerosols, and other effects. Solar influences on the jet stream, via changes to the stratospheric temperature gradient with respect to the 11-year solar cycle (and perhaps longer cycles), also play a role in inter-annual climate variability (Ineson et al. 2011). Perhaps in part due to the effects of the AMO and ENSO, the Oak Ridge climate warmed about 1.2°C from the 1970s to the 1990s but has remained within 0.2°C of the 1990s observed value through the 2010s. The late-20th-century warming appears to have lengthened the growing season (i.e., the period with temperatures above 0°C, or 32°F) by about 2 to 3 weeks over the last 30 years. This warming has primarily affected minimum temperature over the last 30 years; the effect is presumably related to changes in the interaction of the surface boundary layer with greenhouse gases and/or aerosol concentration changes. The effects of greenhouse gases on the nocturnal inversion layer (and thus on minimum temperatures) represent a redistribution of heat in the lower portion of the surface atmospheric layer. Temperature averages for individual years may vary significantly, as noted by the recent contrast of greater than 1°C between 2014 (14.8°C average) and 2015 (16.0°C average), largely the result of the recent strong El Niño. During the post-El Niño years of 2017 and 2018, the annual average temperature at ORNL returned to approximately the same level as in 2014 (i.e., 14.5°C in 2018). However, values rose again in 2019 under the influence of weak El Niño conditions to 15.2°C.

B.2 Winds

Five major terrain-related wind regimes regularly affect the Great Valley of eastern Tennessee:

- Pressure-driven channeling
- Downward-momentum transport or vertically coupled flow
- Forced channeling
- Along-valley and mountain-valley thermal circulations
- Down sloping

Pressure-driven channeling and vertically coupled flow affect winds on scales comparable to those of the Great Valley (hundreds of kilometers). Forced channeling occurs on similar scales but is also quite important at small spatial scales, such as those characterizing the ridge-and-valley terrain within ORR (Birdwell 2011). Along-valley and mountain-valley circulations are thermally driven and occur within a broad range of spatial scales. Thermally driven flows are more prevalent under conditions of clear skies and low humidity, favoring summer and especially fall months. Down sloping frequently is responsible for a slight temperature elevation when the Cumberland Mountains are on the windward side of ORR. Such windward flow also favors reduced wind speeds.

Forced channeling is defined as the direct deflection of wind by terrain. This form of channeling necessitates some degree of vertical motion transfer, implying that the mechanism is less pronounced during strong temperature-inversion conditions. Although forced channeling may result from interactions between large valleys and mountain ranges (such as the Great Valley and the surrounding mountains), the mechanism is especially important in narrow, small valleys such as those within ORR and the Great Valley (Kossman and Sturman 2002).

Forced channeling within the Central Great Valley is the dominant large-scale wind mechanism, influencing 50 to 60 percent of all winds observed in the area. For up-valley (southwest to northeast) flow cases, these winds are frequently associated with large wind shifts (45°–90°) when they initiate or terminate. At small scales, ridge-and-valley terrain produces forced-channeled local flow in more than 90 percent of cases. Most forced-channeled winds prefer weak to moderate synoptic pressure gradients of less than 0.010 mb/km (Birdwell 2011).

Large-scale forced channeling occurs regularly within the Great Valley when northwest to north winds (perpendicular to the axis of the central Great Valley) coincide with vertically coupled flow. The phenomenon sometimes results in a split-flow pattern, with winds southwest of Knoxville moving down-valley and those east of Knoxville moving up-valley. The causes of such a flow pattern may include the shape characteristics of the Great Valley (Kossman and Sturman 2002) but also may be associated with the specific location of the Cumberland and Smoky Mountains relative to upper-level wind flow (Eckman 1998). The convex shape of the Great Valley with respect to a northwest wind flow may lead to a divergent wind flow pattern in the Knoxville area, resulting in downward air motion.Horizontal flow is also reduced by the windward mountain range, the Cumberland Mountains, which increases buoyancy and Coriolis effects (also known as Froude and Rossby ratios). Consequently, the leeward mountain range, the Smoky Mountains, becomes more effective at blocking or redirecting the winds.

Vertically coupled winds tend to occur when the atmosphere is unstably or neutrally buoyant. When a strong horizontal wind component is present, as in conditions behind a winter cold front or during strong regional cold air advection, winds tend to override the terrain, flowing roughly in the same direction as the winds aloft. This phenomenon is a consequence of the horizontal transport and momentum aloft being transferred to the surface. However, Coriolis effects may turn the winds by up to 40° to the left (Birdwell 1996).

In the Central Valley, vertically coupled winds dominate about 25 to 35 percent of the time; however, most such winds are turned toward an up-valley or down-valley direction when small-scale ridge-and-valley terrain is factored in. Wintertime vertically coupled flow is typically dominated by strong, large-scale pressure forces, whereas the summertime cases tend to be associated with a deep mixing depth (greater than 500 m). Most vertically coupled flows are associated with major wind shifts (90°–135°) when they begin or terminate (Birdwell 2011).

Another wind mechanism, pressure-driven channeling, is the redirection of synoptically induced wind flow through a valley channel. The direction of wind flow through the valley is determined by the axis of the pressure gradient superimposed on a valley axis (Whiteman 2000). The process is affected by Coriolis forces, a leftward deflection of winds in the Northern Hemisphere. Eckman (1998) suggested that pressure-driven channeling plays a significant role in the Great Valley. Winds driven purely by such a process shift from up-valley to down-valley flow or conversely as large-scale pressure systems induce reversals in air pressure gradients across the axis of the Great Valley. Since the processes involved in pressure-driven flow primarily affect the horizontal motion of air, the presence of a temperature inversion enhances this pattern significantly. Weak vertical air motion and momentum associated with such inversions allow different layers of air to slide over each other with varied direction of movement (Monti et al. 2002).

Within the Central Great Valley, and especially for ORR, winds dominated by down-valley pressure-driven channeling range in frequency from 2 to 10 percent, with the lowest values in summer and the highest in winter. Up-valley pressure-driven channeling usually does not dominate winds in the Central Great Valley but co-occurs with forced-channeled winds 50 percent of the time. Winds dominated by pressure-driven channeling often result in large wind shifts (90°–180°) before and after the occurrence of the wind pattern. These wind shifts occur about twice as frequently within and near ORR when compared with wind shifts that take place in other parts of the Great Valley (Birdwell 2011). Most pressure-driven channeled winds occur in association with moderate (0.006–0.016 mb/km) synoptic pressure gradients.

Thermally driven winds are common in areas of significant complex terrain. These winds occur as a result of pressure and temperature differences caused by varied surface-air energy exchange at similar altitudes along a valley's axis, sidewalls, or slopes. Thermal flows operate most effectively when synoptic winds are light and when thermal differences are exacerbated by clear skies and low humidity (Whiteman 2000). Ridge-and-valley terrain may be responsible for enhancing or inhibiting such flow, depending on ambient weather conditions. Large-scale thermally driven wind frequency varies from 2 percent to 20 percent with respect to season in the Central Great Valley. Frequencies are highest during summer and especially fall, when intense surface heating and/or low humidity help drive flow patterns (Birdwell 2011).

Annual wind roses have been compiled for 2019 for each of the 10 DOE-managed ORR meteorological towers (towers MT2, MT3, MT4, MT6, MT7, MT9, MT10, MT11, MT12, and MT13). These, along with other annual wind rose data, may be viewed online here. The wind roses represent large-scale trends and should be used with caution for estimates involving short-term variations.

A wind rose depicts the typical distribution of wind speed and direction for a given location. The winds are represented in terms of the direction from which they originate. The rays emanating from the center correspond to points of the compass. The length of each ray is related to the frequency at which winds blow from the given direction. The concentric circles represent increasing frequencies from the center outward, given in percentages. Precipitation wind roses display similar information except that wind speed frequencies are replaced with data associated with the rate of hourly precipitation. Likewise, wind direction stability and wind direction mixing height roses replace wind speeds with data on stability class and mixing height, respectively. Wind direction peak gust roses reflect the frequency of peak 1 to 10 s wind gusts for various wind directions.

B.3 Temperature and Precipitation

Temperature and precipitation normals (1981–2010) and extremes (1948–2019) and their durations for the city of Oak Ridge and ORNL are summarized in Table B.1. Decadal temperature and precipitation averages for the five decades of the 1970s to 2010s are provided in Table B.2. Hourly freeze data (1985–March 2020) are given in Table B.3. Overall, at ORNL, 2019 was 0.2°C above normal with regard to temperatures compared to the 1981–2010 Oak Ridge base period, and precipitation was 38 percent above normal compared to the 1981–2010 mean. ORNL became the official reporting site for the purposes of ORNL and this report in 2015 instead of the Oak Ridge townsite. This change was made in response to the implementation of climate data quality measurements initiated at ORNL in 2014 and in response to siting problems at the Oak Ridge townsite (KOQT).

Recent Climate Change with Respect to Temperature and Precipitation

Table B.2 presents a decadal analysis of temperature patterns for the decades of the 1970s to the 2010s. In general, temperatures in the Oak Ridge area rose from the 1970s to the 1990s and then nearly stabilized since the 1990s. Based on these average decadal temperatures, temperatures have risen 1.2°C between the decades of the 1970s and the 1990s, from 13.8°C to 15.0°C (56.8°F to 59.0°F). The warmest decade of the last five was the 2000s at 15.2°C (59.3°F), although the 2010s where virtually the same (15.2°C or 59.2°F). More detailed analysis reveals that these temperature changes have been neither linear nor equal with respect to the seasons.

From the 1970s to the 1990s, January and February average temperatures have seen increases of about 2.5°C, followed by a decline of just over 1°C since the 1990s. The observed peak in the 1990s may be associated with the effects of the AMO, though this climate response may include both natural and anthropogenic effects. The Arctic has seen the largest increase in temperatures anywhere in the Northern Hemisphere over the last 30 years, and this has an effect on Oak Ridge temperatures in winter due to the presence of Arctic air masses during that season.

During the winter months of January and February, much of the air entering eastern Tennessee comes from the Arctic. As a result, Oak Ridge temperatures have warmed more dramatically during those months in which Arctic air dominates. However, the changes affecting the months of January and

February do not seem to be the case for December temperature averages. December averages were relatively warm in the 1970s (4.6°C), bottomed out in the 1980s (3.1°C), returned to approximately 1970s levels in the 1990s and 2000s, and finally warmed (to about 6.0°C) by the 2010s.

Compared to the 1970s, temperatures have warmed 1.0°C, 1.5°C, and 2.1°C during the climatological spring months of March, April, and May, respectively. However, most of that warming did not occur until the 2000s for the months of March and April. The tendency toward warmer springs has had the effect of slightly lengthening the growing season.

Summer months (June, July, and August) were 1.8°C, 1.3°C, and 0.9°C warmer on average in the 2010s versus the 1970s; however, most observed warming during summer can be attributed to a rise in minimum temperatures. In fact, August maximum temperatures have declined about 1.0°C since the 2000s. Warming for June and July has virtually stopped since the 2000s.

Climatological fall months (September, October, and November) generally had the weakest average temperature increases (of 0.9°C, 1.3°C, and 0.1°C) since the 1970s. In fact, September and October have seen virtually no change in average temperature since the 1990s, while November has not shown a clear trend across the decades since the 1970s.

Considering annual mean temperatures only, the mean annual temperature increased by 1.4°C between the 1970s and the 2000s and then remained about the same in the 2010s (1.3°C warming compared to the 1970s). About 90 percent of the observed increase occurred between the 1980s and 1990s. Mean annual decadal-averaged temperatures have varied by only 0.2°C since the 1990s.

Decadal precipitation averages suggest some important changes in precipitation patterns in Oak Ridge over the period from the 1970s to 2010s. Although overall decadal precipitation averages have remained within a window of about 48 to 60 in. annually, there have been some decadal shifts in the patterns of rainfall on a monthly and seasonal scale. During winter (December, January, and February), precipitation remained fairly constant since the 1970s, but there has been a significant increase in February precipitation in the 2010s (as well as an increase for winter overall since the 2000s). Spring precipitation (March, April, and May) has declined about 20 percent since the 1970s. For summer precipitation (June, July, and August), changes in precipitation are mixed. June values have changed little in the 2010s versus the 1970s, but July values have increased about 20 percent, and August values declined about 20 percent. Similar patterns are revealed for the fall months. September in the 2010s shows about a 10 percent increase compared to the 1970s while October shows about a 10 percent decrease. There was little change in precipitation for November. Overall, annual average precipitation in the 2010s is only about 3 percent less than in the 1970s (59.68 versus 58.18 in.). Also, both the 1980s and 2000s were 10 percent to 20 percent drier than the 2010s while the 1990s exhibited similar precipitation. The most recent calendar year (2019) yielded precipitation totals about 40 percent above the 30-year mean, with a total of 1,847 mm (72.72 in.). The total period of observed precipitation for Oak Ridge covers the period from 1948 to 2019.

The previously discussed increase in winter temperatures by the 2000s and 2010s has affected monthly and annual snowfall amounts. During the 1970s and 1980s, snowfall averaged about 25.4 to 28 cm (10 to 11 in.) annually in Oak Ridge. However, during the most recent two decades (2000s and 2010s), snowfall has averaged only 9.8 cm (3.9 in) per year. This decrease seems to have occurred largely since the mid-1990s. There has been a slight cooling of January and February temperatures in the 2010s compared to the 2000s, which seems to have reversed the decrease in snowfall slightly, with annual averages of 13.2 cm (5.2 in.). Concurrent with the overall decrease in snowfall, the annual number of hours of subfreezing weather has generally declined since the 1980s (see Table B.3). However, the number of subfreezing hours during 2010 (1,123 h) was the highest recorded since 1988. January 2014 was the coldest January since 1985, with 371 subfreezing hours, and February 2015 was the coldest February since 1978, also with 371 subfreezing hours.

Table B.1. Climate normals (1981–2010) and extremes (1948–2019) for Oak Ridge National Laboratory, Oak Ridge, Tennessee

Monthly variables	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Temperature, °C (°F)													
30-Year Average Max	8.3 (46.9)	11.2 (52.1)	16.4 (61.6)	21.6 (70.8)	25.9 (78.6)	29.8 (85.7)	31.4 (88.5)	31.2 (88.1)	27.7 (81.9)	22.0 (71.6)	15.7 (60.2)	9.4 (49.0)	20.9 (69.6)
2019 Average Max	9.1 (48.4)	13.2 (55.8)	14.6 (58.4)	22.8 (73.0)	27.9 (82.3)	28.4 (83.1)	31.0 (87.8)	29.6 (85.2)	32.1 (89.7)	23.3 (74.0)	13.4 (56.2)	13.0 (55.4)	21.5 (70.8)
72-Year Record Max	25 (77)	27 (80)	30 (86)	33 (92)	35 (95)	41 (105)	41 (105)	39 (103)	39 (102)	35 (96)	28 (83)	26 (78)	41 (105)
30-Year Average Min	-2.2 (28.0)	-0.6 (30.9)	3.1 (37.5)	7.4 (45.4)	12.6 (54.7)	17.3 (63.1)	19.7 (67.5)	18.9 (66.1)	15.2 (59.3)	8.4 (47.2)	3.1 (37.6)	-0.9 (30.4)	8.5 (47.3)
2019 Average Min	-0.4 (31.3)	3.5 (38.3)	2.2 (35.9)	8.6 (47.5)	14.5 (58.1)	17.1 (62.8)	19.7 (67.4)	18.9 (66.0)	17.3 (63.1)	9.9 (49.9)	0.8 (33.5)	1.7 (35.0)	9.5 (49.1)
72-Year Record Min	-27 (-17)	-25 (-13)	-17 (1)	-7 (20)	-1 (30)	4 (39)	9 (49)	10 (50)	1 (33)	-6 (21)	-16 (3)	-22 (-7)	-27 (-17)
30-Year Average	3.1 (37.5)	5.3 (41.5)	9.8 (49.6)	14.6 (58.3)	19.3 (66.7)	23.6 (74.5)	25.6 (78.1)	25.2 (77.4)	21.5 (70.7)	15.2 (59.4)	9.4 (48.9)	4.3 (39.7)	14.7 (58.5)
2019 Average	4.0 (39.2)	9.5 (49.1)	8.4 (47.1)	15.7 (60.2)	20.9 (69.7)	22.2 (71.9)	24.5 (76.1)	24.1 (75.4)	23.5 (74.3)	16.1 (60.9)	6.5 (43.6)	6.8 (44.3)	15.2 (59.3)
2019 Departure from Average	0.9 (1.7)	1.3 (2.3)	-1.4 (-2.5)	1.1 (1.9)	1.6 (3.0)	-1.4 (-2.6)	-1.1 (-2.0)	-1.1 (-2.0)	2.0 (3.6)	0.9 (1.5)	-2.9 (-5.3)	2.5 (4.6)	0.2 (0.4)
30-year average heating degree days, °C (°F)[a]													
	332 (598)	273 (491)	243 (473)	49(88)	42(75)	0	0	0	14 (25)	107 (192)	224 (403)	428 (770)	1711 (3079)
30-year average cooling degree days, °C (°F)[a]													
	0	0	2 (4)	16 (29)	68 (122)	164 (296)	228 (410)	217 (390)	108 (194)	18 (32)	1 (2)	0	822 (1479)
Precipitation, mm (in.)													
30-Year Average	120.9 (4.76)	124.2 (4.89)	120.9 (4.76)	112.6 (4.43)	116.6 (4.59)	98.3 (3.87)	134.4 (5.29)	82.1 (3.23)	98.1 (3.86)	76.0 (2.99)	122.2 (4.81)	131.1 (5.16)	1337.5 (52.64)
2019 Totals	155.0 (6.10)	384.7 (15.14)	113.8 (4.48)	99.3 (3.91)	117.1 (4.61)	205.8 (8.10)	143.3 (5.64)	148.6 (5.85)	0.3 (0.01)	203.8 (8.02)	133.4 (5.25)	142.5 (5.61)	1847.7 (72.72)
2019 Departure from Average	34.0 (1.34)	260.4 (10.25)	-7.1 (-0.28)	-13.2 (-0.52)	0.5 (0.02)	107.5 (4.23)	8.9 (0.35)	66.6 (2.62)	-97.8 (-3.85)	127.8 (5.03)	11.2 (0.44)	11.4 (0.45)	510.2 (20.08)
72-Year Max Monthly	337.2 (13.27)	384.7 (15.14)	311.0 (12.24)	356.5 (14.03)	271.9 (10.70)	283.0 (11.14)	489.6 (19.27)	265.8 (10.46)	257.4 (10.14)	176.6 (6.95)	310.5 (12.22)	321.2(12.64)	1939.4 (76.33)
72-Year Max 24-h	108.0 (4.25)	131.6 (5.18)	120.4 (4.74)	158.5 (6.24)	112.0 (4.41)	94.0 (3.70)	124.8 (4.91)	190.1 (7.48)	160.1 (6.30)	67.6 (2.66)	130.1 (5.12)	130.1 (5.12)	190.1 (7.48)
72-Year Min Monthly	23.6 (0.93)	21.3 (0.84)	54.1 (2.13)	46.2 (1.82)	20.3 (0.80)	13.5 (0.53)	31.3 (1.23)	13.7 (0.54)	Trace	Trace	34.8 (1.37)	17.0 (0.67)	911.4 (35.87)
Snowfall, cm (in.)													
30-Year Average	7.4 (2.9)	6.6 (2.6)	2.5 (1.0)	7.6 (0.3)	0	0	0	0	0	0	Trace	4.1 (1.6)	21.3 (8.4)
2019 Totals	1.3 (0.5)	Trace	0	0	0	0	0	0	0	Trace	1.5 (0.6)	2.5 (1.0)	5.3 (2.1)
72-Year Max Monthly	24.4 (9.6)	43.7 (17.2)	53.4 (21.0)	15.0 (5.9)	Trace	0	0	0	0	Trace	16.5 (6.5)	53.4 (21.0)	105.2 (41.4)
72-Year Max 24-h	21.1 (8.3)	28.7 (11.3)	30.5 (12.0)	13.7 (5.4)	Trace	0	0	0	0	Trace	16.5 (6.5)	30.5 (12.0)	30.5 (12.0)
Days w/temp													
30-Year Max ≥ 32°C	0	0	0	0.2	0.8	8.0	14.5	13.1	3.9	0	0	0	40.5
2019 Max ≥ 32°C	0	0	0	0	6	3	2	13	15	3	0	0	42
30-Year Min ≤ 0°C	21.6	16.6	10.7	2.7	0	0	0	0	0	1.7	10.4	18.8	82.5
2019 Min ≤ 0°C	15	9	11	2	0	0	0	0	0	0	15	12	64
30-Year Max ≤ °C	2.8	0.9	0.1	0	0	0	0	0	0	0	0	1.6	5.4
2019 Max ≤ 0°C	2	0	0	0	0	0	0	0	0	0	0	0	2
Days w/precipitation													
30-Year Avg ≥ 0.01 in.	11.5	11.0	11.7	10.4	11.7	11.1	12.4	9.6	8.4	8.4	9.6	12.0	127.8
2019 Days ≥ 0.01 in.	13	17	12	11	8	16	14	9	1	11	7	14	133
30-Year Avg ≥ 1.00 in.	1.3	1.4	1.2	1.2	1.3	1.0	1.4	0.8	1.3	1.0	1.5	1.6	15.0
2019 Days ≥ 1.00 in.	2	4	2	2	1	2	2	3	0	3	2	0	23

Table B.2. Decadal climate change (1970–2019) for city of Oak Ridge/Oak Ridge National Laboratory, Tennessee, with 2019 comparisons

Monthly variables	January	February	March	April	May	June	July	August	September	October	November	December	Annual
						Temperature, °C (°F)							
1970–1979 Avg Max	6.6 (43.8)	9.7 (49.5)	15.6 (60.1)	21.4 (70.6)	24.8 (76.7)	28.5 (83.3)	30.0 (85.9)	29.7 (85.5)	26.8 (80.2)	20.8 (69.4)	14.5 (58.2)	10.0 (49.9)	19.9 (67.8)
1980–1989 Avg Max	6.9 (44.4)	10.2 (50.3)	15.9 (60.7)	21.0 (69.8)	25.6 (78.1)	29.8 (85.7)	31.6 (88.8)	30.7 (87.3)	27.1 (80.8)	21.3 (70.3)	15.6 (60.2)	8.6 (47.5)	20.3 (68.6)
1990–1999 Avg Max	9.4 (48.8)	12.3 (54.1)	16.2 (61.2)	21.9 (71.3)	26.2 (79.1)	29.7 (85.5)	32.1 (89.8)	31.4 (88.6)	28.4 (83.2)	22.6 (72.8)	15.2 (59.4)	10.4 (50.8)	21.3 (70.4)
2000–2009 Avg Max	8.8 (47.9)	11.2 (52.1)	17.0 (62.7)	21.4 (70.6)	25.8 (78.4)	29.8 (85.6)	30.8 (87.5)	31.4 (88.5)	27.6 (81.8)	21.8 (71.2)	15.9 (60.6)	9.8 (49.6)	21.0 (69.7)
2010–2019 Avg Max	8.1 (46.7)	11.2 (52.1)	16.3 (61.3)	22.6 (72.7)	26.8 (80.2)	30.2 (86.4)	31.2 (88.4)	30.8 (87.4)	28.5 (83.3)	22.3 (72.1)	15.1 (59.2)	11.4 (51.6)	21.2 (70.1)
1980s vs. 2010s	1.2 (2.2)	1.0 (0.6)	0.3 (0.6)	1.6 (2.8)	1.2 (2.1)	0.4 (0.8)	-0.2 (-0.4)	0.0 (0.1)	1.4 (2.6)	1.0 (1.8)	-0.5 (-0.9)	2.3 (4.1)	0.8 (1.5)
2000s vs. 2010s	-0.7 (-1.2)	0.0 (0.0)	-0.8 (-1.4)	1.2 (2.1)	1.0 (1.8)	0.4 (0.8)	0.5 (1.0)	-0.6 (-1.1)	0.9 (1.6)	0.5 (0.9)	-0.8 (-1.4)	1.1 (2.0)	0.2 (0.4)
2019 Avg Max	9.1 (48.4)	13.7 (55.8)	14.6 (58.4)	22.8 (73.0)	28.0 (82.3)	28.4 (83.1)	31.0 (87.8)	31.1 (88.0)	32.0 (89.7)	23.3 (74.0)	13.4 (56.2)	13.0 (55.4)	21.5 (70.8)
1970–1979 Avg Min	-3.4 (25.8)	-2.4 (27.6)	3.0 (37.4)	6.7 (44.1)	11.6 (52.8)	15.7 (60.2)	18.3 (64.9)	18.1 (64.6)	15.5 (59.9)	7.5 (45.5)	2.6 (36.8)	-0.8 (30.5)	7.7 (45.8)
1980–1989 Avg Min	-4.1 (24.7)	-2.1 (28.3)	1.7 (35.0)	6.0 (42.9)	11.4 (52.4)	16.2 (61.2)	19.0 (66.2)	18.4 (65.1)	14.4 (57.9)	7.5 (45.4)	3.1 (37.5)	-2.3 (27.8)	7.4 (45.3)
1990–1999 Avg Min	-0.9 (30.3)	0.0 (32.0)	2.9 (37.1)	7.2 (45.0)	12.5 (54.5)	17.2 (63.0)	20.0 (67.9)	18.9 (66.1)	15.1 (59.2)	8.2 (46.8)	2.2 (36.0)	0.1 (32.2)	8.6 (47.6)
2000–2009 Avg Min	-1.4 (29.5)	0.0 (32.0)	4.4 (39.9)	8.6 (47.5)	13.6 (56.4)	18.0 (64.3)	20.0 (67.9)	20.0 (68.0)	16.1 (61.0)	9.5 (49.0)	3.9 (39.0)	-0.4 (31.4)	9.4 (48.9)
2010–2019 Avg Min	-2.0 (28.3)	0.6 (33.0)	4.2 (39.5)	8.8 (47.7)	14.1 (57.3)	18.2 (64.9)	20.3 (68.5)	19.5 (67.1)	16.4 (61.4)	9.4 (48.9)	2.7 (36.9)	1.2 (34.2)	9.5 (49.1)
1980s vs. 2010s	2.0 (3.6)	2.6 (4.8)	2.5 (4.4)	2.7 (4.9)	2.7 (4.9)	2.1 (3.8)	1.3 (2.4)	1.1 (2.0)	2.0 (3.5)	2.0 (3.5)	-0.4 (-0.6)	3.6 (6.5)	2.1 (3.8)
2000s vs. 2010s	-0.6 (-1.2)	0.6 (1.0)	-0.2 (0.4)	0.1 (0.2)	0.5 (0.9)	0.4 (0.6)	0.3 (0.6)	-0.5 (-1.0)	0.3 (0.5)	-0.1 (-0.1)	-1.2 (-2.1)	1.6 (2.9)	0.1 (0.2)
2019 Avg Min	-0.3 (31.3)	3.5 (38.3)	2.1 (35.9)	8.6 (47.5)	14.5 (58.1)	17.1 (62.8)	19.7 (67.4)	18.9 (66.0)	17.3 (63.1)	9.9 (49.9)	0.8 (33.5)	1.7 (35.0)	9.5 (49.1)
1970–1979 Avg	1.6 (34.9)	3.7 (38.6)	9.3 (48.8)	14.1 (57.4)	18.1 (64.7)	22.1 (71.8)	24.1 (75.4)	23.9 (75.0)	21.1 (70.0)	14.2 (57.5)	8.6 (47.5)	4.6 (40.3)	13.8 (56.8)
1980–1989 Avg	1.4 (34.6)	4.1 (39.3)	8.8 (47.9)	13.5 (56.4)	18.5 (65.3)	23.0 (73.4)	25.3 (77.5)	24.6 (76.2)	20.8 (69.4)	14.4 (57.9)	9.4 (48.8)	3.1 (37.7)	13.9 (57.0)
1990–1999 Avg	4.2 (39.6)	6.2 (43.1)	9.6 (49.2)	14.5 (58.2)	19.4 (66.8)	23.5 (74.3)	26.0 (78.9)	25.2 (77.4)	21.9 (71.4)	15.5 (59.8)	8.8 (47.8)	5.3 (41.5)	15.0 (59.0)
2000–2009 Avg	3.7 (38.7)	5.6 (42.1)	10.7 (51.3)	15.3 (59.6)	19.7 (67.5)	23.9 (75.1)	25.4 (77.7)	25.7 (78.3)	21.9 (71.4)	15.6 (60.1)	9.9 (49.8)	4.7 (40.5)	15.2 (59.3)
2010–2019 Avg	3.0 (37.3)	5.3 (42.5)	10.3 (50.5)	15.7 (60.1)	20.3 (68.5)	24.0 (75.1)	25.4 (77.8)	24.6 (76.5)	21.9 (71.5)	15.4 (59.8)	8.7 (47.6)	6.4 (42.7)	15.1 (59.2)
1980s vs. 2010s	1.5 (2.8)	1.8 (3.2)	1.5 (2.6)	2.1 (3.8)	1.8 (3.2)	0.9 (1.7)	0.1 (0.3)	0.2 (0.3)	1.2 (2.1)	1.1 (1.9)	-0.7 (-1.2)	2.8 (5.0)	1.2 (2.2)
2000s vs. 2010s	-0.7 (-1.3)	0.2 (0.4)	-0.4 (-0.8)	0.3 (0.6)	0.6 (1.0)	0.0 (0.1)	0.0 (0.1)	-1.0 (-1.8)	0.1 (0.1)	-0.2 (-0.3)	-1.2 (-2.2)	1.2 (2.2)	-0.1 (-0.1)
2019 Avg	4.5 (39.2)	8.2 (46.8)	8.4 (47.1)	15.7 (60.2)	20.9 (69.7)	22.1 (71.9)	24.5 (76.1)	24.1 (75.4)	23.5 (74.3)	15.4 (59.8)	6.4 (43.6)	6.9 (44.3)	15.2 (59.3)
						Precipitation, mm (in.)							
1970–1979 Avg	143.4 (5.65)	94.6 (3.72)	169.4 (6.67)	118.3 (4.66)	149.8 (5.89)	120.5 (4.74)	130.4 (5.13)	109.8 (4.32)	107.2 (4.22)	99.8 (3.93)	129.6 (5.10)	145.3 (5.72)	1516.4 (59.68)
1980–1989 Avg	100.4 (3.95)	109.1 (4.29)	112.6 (4.43)	88.8 (3.49)	110.6 (4.35)	84.1 (3.31)	120.4 (4.74)	82.6 (3.25)	108.9 (4.29)	79.8 (3.14)	128.0 (5.04)	107.6 (4.23)	1236.2 (48.66)
1990–1999 Avg	141.4 (5.57)	136.5 (5.37)	149.0 (5.86)	126.3 (4.97)	113.4 (4.47)	110.0 (4.33)	134.8 (5.31)	83.6 (3.29)	71.9 (2.83)	67.3 (2.65)	109.8 (4.32)	161.0 (6.34)	1429.4 (56.26)
2000–2009 Avg	116.9 (4.60)	121.8 (4.80)	115.6 (4.55)	125.0 (4.92)	117.8 (4.64)	95.2 (3.75)	138.9 (5.47)	78.4 (3.09)	108.8 (4.28)	74.0 (2.91)	121.4 (4.78)	124.4 (4.90)	1333.4 (52.48)
2010–2019 Avg	130.1 (5.12)	146.6 (5.77)	117.4 (4.62)	131.9 (5.19)	93.8 (3.69)	132.4 (5.21)	156.8 (6.17)	92.5 (3.64)	114.1 (4.49)	91.0 (3.58)	128.0 (5.04)	151.7 (5.97)	1478.2 (58.18)
1980s vs. 2010s	29.5 (1.16)	37.6 (1.48)	4.6 (0.18)	42.9 (1.69)	-16.8 (-0.66)	15.2 (0.60)	36.3 (1.43)	9.9 (0.39)	5.3 (0.21)	11.2 (0.44)	0.0 (0.00)	44.3 (1.74)	239.3 (9.42)
2000s vs. 2010s	13.2 (0.52)	24.9 (0.98)	1.7 (0.07)	6.9 (0.27)	-24.1 (-0.95)	13.5 (0.53)	17.8 (0.70)	14.0 (0.55)	5.3 (0.21)	17.0 (0.67)	6.7 (0.26)	27.2 (1.07)	146.9 (5.78)
2019 Totals	155.0 (6.10)	384.7 (15.14)	113.8 (4.48)	99.4 (3.91)	117.1 (4.61)	205.8 (8.10)	143.3 (5.64)	148.6 (5.85)	0.3 (0.01)	203.8 (8.02)	133.4 (5.25)	142.5 (5.61)	1847.7 (72.72)
						Snowfall, cm (in.)							
1970–1979 Avg	11.1 (4.4)	12.5 (4.9)	4.2 (1.7)	0.2 (0.1)	0	0	0	0	0	0	0.5 (0.2)	4.4 (1.8)	35.1 (13.8)
1980–1989 Avg	11.4 (4.5)	8.8 (3.5)	2.2 (0.9)	2.2 (0.9)	0	0	0	0	0	0	0	7.5 (3.0)	32.8 (12.9)
1990–1999 Avg	6.9 (2.7)	7.8 (3.1)	8.1 (3.2)	Trace	0	0	0	0	0	0	0.3 (0.1)	3.1 (1.2)	10.9 (4.3)
2000–2009 Avg	2.1 (0.8)	4.5 (1.8)	Trace	Trace	0	0	0	0	0	0	Trace	1.7 (0.7)	8.3 (3.3)
2010–2019 Avg	5.3 (2.1)	6.4 (2.5)	0.3 (0.1)	Trace	0	0	0	0	0	0	0.3 (0.1)	1.4 (0.6)	13.2 (5.2)
1980s vs. 2010s	-5.2 (-2.0)	-1.8 (-0.7)	-1.0 (-0.4)	0.0 (0.0)	0	0	0	0	0	0	0.3 (0.1)	-2.8 (-1.2)	-12.4 (-4.9)
2000s vs. 2010s	3.6 (1.4)	2.8 (1.1)	0.3 (0.1)	0.0 (0.0)	0	0	0	0	0	0	0.3 (0.1)	0.3 (0.1)	6.6 (2.6)
2019 Totals	1.2 (0.5)	Trace	0.0	0.0	0	0	0	0	0	0	1.4 (0.6)	2.5 (1.0)	5.3 (2.1)

Table B.3. Hourly subfreezing temperature data for Oak Ridge, Tennessee, January 1985–March 2020[a]

(Hours at or below 0, −5, −10, and −15°C)

Year	January				February				March			April		May		October		November			December				Annual			
	≤0	<-5	<-10	<-15	≤0	<-5	<-10	<-15	≤0	<-5	<-10	≤0	<-5	≤0	<-5	≤0	<-5	≤0	<-5	<-10	≤0	<-5	<-10	<-15	≤0	<-5	<-10	<-15
1985	467	195	103	39	331	127	26	0	105	6	0	43	3	0	0	0	0	22	0	0	431	201	66	2	1399	532	195	41
1986	308	125	38	10	161	29	3	0	124	28	0	17	0	0	0	0	0	32	10	0	232	34	0	0	874	226	41	10
1987	302	53	7	0	111	19	3	0	95	0	0	55	4	0	0	36	0	103	18	0	151	16	0	0	853	110	10	0
1988	385	182	43	0	294	102	19	0	97	9	0	6	0	0	0	45	0	62	3	0	301	55	0	0	1190	351	62	0
1989	163	27	0	0	190	66	10	0	35	0	0	18	0	3	0	7	0	125	14	0	421	188	71	30	962	295	81	30
1990	142	13	0	0	115	5	0	0	35	0	0	35	0	0	0	19	0	62	1	0	172	43	5	0	580	62	5	0
1991	186	44	0	0	158	47	15	0	49	0	0	0	0	0	0	4	0	148	16	0	192	38	0	0	737	145	15	0
1992	230	65	8	0	116	22	0	0	116	4	0	27	2	0	0	7	0	100	0	0	166	9	0	0	762	102	8	0
1993	125	11	0	0	245	47	8	0	124	32	9	3	0	0	0	0	0	152	2	0	223	44	0	0	872	136	17	0
1994	337	191	85	26	196	46	3	0	66	0	0	18	0	0	0	0	0	53	1	0	142	0	0	0	812	238	88	26
1995	240	45	6	0	217	84	18	0	37	0	0	0	0	0	0	0	0	142	3	0	288	84	10	0	924	216	34	0
1996	301	91	0	0	225	110	62	27	182	49	6	23	0	0	0	3	0	101	0	0	194	40	4	0	1029	290	72	27
1997	254	101	24	0	67	0	0	0	25	0	0	6	0	0	0	6	0	96	10	0	232	14	0	0	686	125	24	0
1998	97	10	7	0	25	0	0	0	74	20	0	0	0	0	0	0	0	38	0	0	132	4	0	0	366	34	7	0
1999	181	68	0	0	113	14	0	0	62	0	0	0	0	0	0	4	0	41	0	0	177	23	0	0	578	105	0	0
2000	273	62	5	0	127	30	0	0	18	0	0	8	0	0	0	11	0	94	11	0	345	124	7	0	876	227	12	0
2001	281	60	5	0	79	9	0	0	53	0	0	2	0	0	0	18	0	28	0	0	137	35	0	0	598	104	5	0
2002	185	28	0	0	121	16	0	0	91	17	0	2	0	0	0	0	0	41	0	0	82	6	0	0	522	67	0	0
2003	345	123	26	0	117	12	0	0	19	0	0	0	0	0	0	0	0	37	0	0	102	9	0	0	620	144	26	0
2004	285	50	2	0	76	0	0	0	18	0	0	0	0	0	0	0	0	9	0	0	247	41	4	0	635	91	6	0
2005	151	65	6	0	52	1	0	0	81	1	0	0	0	0	0	1	0	55	0	0	176	28	0	0	516	95	6	0
2006	70	0	0	0	169	19	0	0	44	0	0	0	0	0	0	15	0	37	0	0	126	41	1	0	461	60	1	0
2007	189	30	5	0	283	70	0	0	29	0	0	32	0	0	0	0	0	60	0	0	83	8	0	0	673	111	5	0
2008	242	86	11	0	114	7	0	0	69	6	0	0	0	0	0	15	0	89	18	0	157	34	5	0	686	151	16	0
2009	238	93	29	0	178	64	5	0	55	15	0	5	0	0	0	0	0	8	0	0	178	22	0	0	662	194	34	0
2010	384	181	14	0	289	32	0	0	40	2	0	0	0	0	0	0	0	46	0	0	364	109	11	0	1123	324	25	0
2011	300	61	0	0	108	14	0	0	2	0	0	0	0	0	0	5	0	29	0	0	91	0	0	0	535	75	0	0
2012	169	27	0	0	78	19	0	0	9	0	0	1	0	0	0	0	0	46	0	0	76	0	0	0	379	46	0	0
2013	245	49	0	0	120	12	0	0	95	7	0	0	0	0	0	11	0	121	0	0	173	6	0	0	765	74	0	0
2014	371	208	76	12	109	5	0	0	68	0	0	5	0	0	0	0	0	122	10	0	94	1	0	0	769	224	76	12
2015	228	52	16	0	371	120	31	6	52	16	0	0	0	0	0	0	0	11	0	0	41	0	0	0	703	188	47	6
2016[a]	333	82	12	0	211	17	0	0	35	0	0	9	0	0	0	0	0	44	3	0	163	32	0	0	795	134	12	0
2017	130	47	11	1	64	5	0	0	82	8	0	0	0	0	0	8	0	67	0	0	252	20	0	0	603	44	10	0
2018	362	199	86	4	67	7	0	0	49	2	0	11	0	0	0	0	0	89	6	0	102	11	0	0	680	225	86	4
2019	146	46	1	0	46	0	0	0	80	9	0	5	0	0	0	0	0	93	11	0	90	0	0	0	466	66	1	0
2020[b]	124	14	0	0	102	11	0	0	20	1	0																	
Avg.	244	77	17	3	151	33	6	1	62	6	0	9	0	0	0	6	0	69	4	0	187	38	5	1	720	158	29	4

[a] Source: 1985–2015 National Oceanic and Atmospheric Administration, Atmospheric Turbulence and Diffusion Division, KOQT Station, Automated Surface Observing System; 2016–2020 Oak Ridge National Laboratory, Tower “D”

[b] 2020 values through March 31, 2020

Selected wind roses for ORR towers that show wind direction for hours with precipitation and other relevant meteorological parameters have been compiled for 2019 and may be reviewed here.

Hourly values of subfreezing temperatures in Oak Ridge are presented in Table B.3 for January 1985 through March 2020. During the middle to late 1980s, a typical year experienced about 900–1,000 hours of subfreezing temperatures. In recent years, the value has fallen to about 600–700 hours, though higher values have occurred relatively recently (2010 at 1,123 hours). However, some years within the 2010s only experience 350 to 500 hours of subfreezing weather. Other statistics on winter precipitation may be found here.

B.4 Moisture

ORR's humid environment results in frequent saturation of the surface layer, especially at night. Average annual humidity at ORNL (Tower MT2) is 74.6 percent (2015–2019) at 2 m above ground level and 72.1 percent at 15 m above the ground. In terms of absolute humidity (grams per cubic meter), the average annual humidity for the same location is 10.3 g/m^3 at both 2 and 15 m above ground level. This value varies greatly throughout the annual cycle, ranging from a monthly minimum of about 4.7 g/m^3 during winter to a maximum of about 17.4 g/m^3 during summer. These data are summarized for absolute and relative humidity and dew point here.

B.5 Severe Weather

On average, thunderstorms and associated lightning occur in the Oak Ridge area at a rate of 48.5 days per year, with a monthly maximum between 10 and 11 days occurring in July. About 41 of these thunderstorm days occur during the 7-month period from April through October, with the remainder spread evenly throughout the late fall and winter. The highest number of thunderstorm days at ORNL (65) was observed during 2012; the lowest (34) was observed during 2007. Monthly and annual average numbers of thunderstorm days for ORNL and Knoxville McGhee-Tyson Airport, respectively, during 2001–2019 can be viewed here.

Hailstorms are infrequent on ORR and typically occur in association with severe thunderstorms. The phenomenon usually occurs as a result of high-altitude thunderstorm updrafts, which propel water droplets above the freezing level. Some hail events have been known to occur in association with non-thunder rain showers and low freezing levels (particularly during winter or spring). Most hailstorm occurrences (77 percent) do not produce hailstones larger than 2 cm (about ¾ in.). During the period from 1961 through 1990, about six hail events (with hailstones larger than about 2 cm) were documented to have occurred at locations within 40 km (25 miles) of ORNL. Nearly all of these events occurred during the summer and fall seasons. During the 2011 significant tornado outbreak in East Tennessee, large hail (greater than 2 cm) was observed in Farragut, Tennessee, about 15 km (9 miles) southeast of ORNL.

East Tennessee experiences a tornado "outbreak" about once every 3 to 6 years on average. Tornadoes occur more frequently in Middle and West Tennessee. Tornado indices from the National Weather Service in Morristown, Tennessee, show that since 1950, three tornadoes have been documented within 10 km (6 miles) of ORNL, represented by two F0 (Fujita Scale) tornadoes and one F3 tornado. A moderately strong F3 tornado occurred in February 1993 and moved through Bear Creek Valley near the Y-12 National Security Complex, with winds damaging the roofs of several buildings along Union Valley Road. To date, the February 1993 tornado has been the only documented tornado to occur within ORR.

Nine additional tornadoes have been documented since 1950 within 20 km (12 miles) of ORNL, ranging in intensity from F0/EF0 (Enhanced Fujita Scale) to F2/EF2. The most recent of these were three EF0–EF1 tornadoes that occurred during the April 27, 2011 tornado outbreak and an EF0 tornado near

Kingston, Tennessee on June 10, 2014. The storm system that produced the latter tornado brought a squall line through ORNL that produced high winds and some minor damage. The remaining group of tornadoes that were within 20 km (12 miles) of ORNL affected eastern Roane County to the south and the Edgemoor Road area to the northeast of ORR. Another 10 tornadoes, ranging from F0/EF0 to F3/EF3 in intensity, have occurred within 35 km (22 miles) of ORNL since 1950. Most of them occurred to the east and south of ORR in Knox and Roane Counties; however, a few occurred in the Rocky Top and Norris areas. Tornado statistics relevant to ORR are provided here for Anderson, Knox, Loudon, and Roane Counties.

The annual probability that a tornado will strike any location in a grid square may be estimated by multiplying the number of tornadoes per year per square kilometer (in that particular grid square) by the path area of a tornado. The result of such a calculation is seen to be greatly affected by the assumption of the size of the path area of a tornado. In total, about 22 tornadoes have been documented within 35 km (22 miles) of ORNL since 1950. This represents a surface area of 3,848 km^2 (1,485 $miles^2$) and yields a probability of about 0.006 tornadoes per square kilometer per 50-year period.

B.6 Stability

The local ridge-and-valley terrain plays a role in the development of stable surface air under certain conditions and influences the dynamics of airflow. Although ridge-and-valley terrain creates identifiable patterns of association during unstable conditions as well, strong vertical mixing and momentum tend to reduce these effects. “Stability” describes the tendency of the atmosphere to mix (especially vertically) or overturn. Consequently, dispersion parameters are influenced by the stability characteristics of the atmosphere. Stability classes range from A (very unstable) to G (very stable), with D being a neutral state.

The suppression of vertical motions during stable conditions increases the effect of local terrain on air motion. Conversely, stable conditions isolate wind flows within the ridge-and-valley terrain from the effects of more distant terrain features and from winds aloft. These effects are particularly significant with respect to mountain waves. Deep, stable layers of air tend to reduce the vertical space available for oscillating vertical air motions caused by local mountain ranges (Smith et al. 2002). This effect on mountain wave formation may be important to the impact that the nearby Cumberland Mountains may have on local airflow.

A second factor that may decouple large-scale wind flow effects from local ones (and thus produce stable surface layers) occurs with overcast sky conditions. Clouds overlying the Great Valley may warm due to direct insolation on the cloud tops. Warming may also occur within the clouds as latent energy, which is released due to the condensation of moisture. Surface air underlying the clouds may remain relatively cool as the layer remains cut off from direct exposure to the sun. Consequently, the vertical temperature gradient associated with the air mass becomes more stable (Lewellen and Lewellen 2002). Long wave cooling of fog decks has also been observed to help modify stability in the surface layer (Whiteman et al. 2001).

Stable boundary layers typically form as a result of radiational cooling processes near the ground (Van De Weil et al. 2002); however, they are also influenced by the mechanical energy supplied by horizontal wind motion, which is in turn influenced by the synoptic-scale weather-related pressure gradient. Ridge-and-valley terrain may have significant ability to block such winds and their associated mechanical energy (Carlson and Stull 1986). Consequently, radiational cooling at the surface is enhanced since there is less wind energy available to remove chilled air.

Stable boundary layers also exhibit intermittent turbulence, which has been associated with the above factors. The process results from a give-and-take between the effects of friction and radiational cooling.

As a stable surface layer intensifies via a radiational cooling process, it tends to decouple from air aloft, thereby reducing the effects of surface friction. The upper air layer responds with an acceleration in wind speed. Increased wind speed aloft results in an increase in mechanical turbulence and wind shear at the boundary with the stable surface layer. Eventually, the turbulence works into the surface layer and weakens it. As the inversion weakens friction again increases, reducing wind speeds aloft. The reduced wind speeds aloft allow enhanced radiation cooling at the surface, which re-intensifies the inversion and allows the process to start again. Van De Weil et al. (2002) have shown that cyclical temperature oscillations up to 4°C (7°F) may result from these processes. Since these intermittent processes are driven primarily by large-scale horizontal wind flow and radiational cooling of the surface, ridge-and-valley terrain significantly affects the intensity of these oscillations.

Wind roses for stability and mixing depth have been compiled for all ORR tower sites for 2019. They may be viewed here. The wind roses in general reveal that both unstable conditions and/or deep mixing depths are associated with less channeling of winds and that stable conditions and/or shallow mixing depths tend to promote channeled flow. Associated mixing height tables for 2019 can be accessed here.

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Appendix C:
Reference Standards and Data for Water

Appendix
C. Reference Standards and Data for Water

Table C.1. Reference standards for radionuclides in water

Parameter[a]	National primary drinking water standard[b]	DCS[c]
^{241}Am		170
^{214}Bi		260,000
^{109}Cd		16,000
^{143}Ce		26,000
^{60}Co		7,200
^{51}Cr		790,000
^{137}Cs		3,000
^{155}Eu		87,000
Gross alpha[d]	15	
Gross beta (mrem/year)	4	
^{3}H		1,900,000
^{131}I		1,300
^{40}K		4,800
^{237}Np		320
^{234m}Pa		71,000
^{238}Pu		150
$^{239/240}$Pu		140
^{226}Ra		87
^{228}Ra		25
^{106}Ru		4,100
^{90}Sr		1,100
^{99}Tc		44,000
^{228}Th		340
^{230}Th		160
^{232}Th		140
^{234}Th		8,400
^{234}U		680
^{235}U		720
^{236}U		720
^{238}U		750

[a]Only the radionuclides included in the Oak Ridge Reservation monitoring programs are listed. Unless labeled otherwise, units are pCi/L.
[b]40 *Code of Federal Regulations* Part 141, *National Primary Drinking Water Regulations,* Subparts B and G. The drinking water standards are presented strictly for reference purposes and have regulatory applicability only for public water supplies.
[c]DOE. "Derived Concentration Technical Standard, DOE-STD-1196-2011, April 2011."
[d]Excludes radon and uranium.

Table C.2. TDEC and EPA nonradiological water quality standards and criteria (µg/L)

Chemical	TDEC and EPA Drinking Water Standards[a]	TDEC Fish and Aquatic Life Criteria		TDEC recreation criteria water + organisms, organisms only[b]
		Maximum	Continuous	
Acenaphthene				670, 990
Acrolein				6, 9
Acrylonitrile (c)				0.51, 2.5
Alachlor	2 (E1, T)			
Aldrin (c)		3.0	–	0.00049, 0.00050
Aldicarb	3 (E1)			
Aldicarb sulfoxide	4 (E1)			
Aldicarb sulfone	2 (E1)			
Aluminum	200 (E2)			
Anthracene				8,300, 40,000
Antimony	6 (E1, T)			5.6, 640
Arsenic (c)	10 (E1, T)			10.0, 10.0
Arsenic(III)[c]		340[c]	150[c]	
Asbestos	7 million fibers/L (MFL) (E1)			
Atrazine	3 (E1, T)			
Barium	2,000 (E1, T)			
Benzene (c)	5 (E1, T)			22, 510
Benzidine (c)				0.00086, 0.0020
Benzo(a)anthracene (c)				0.038, 0.18
Benzo(a)pyrene (c)	0.2 (E1, T)			0.038, 0.18
Benzo(b)fluoranthene (c)				0.038, 0.18
Benzo(k)fluoranthene (c)				0.038, 0.18
Beryllium	4 (E1, T)			
a-BHC (c)				0.026, 0.049
b-BHC (c)				0.091, 0.17
g-BHC (Lindane)	0.2 (E1, T)	0.95	–	0.98, 1.8
Bis(2-chloroethyl)ether (c)				0.30, 5.3
Bis(2-chloro-isopropyl) ether				1,400, 65,000
Bis(2-ethylhexyl) phthalate (c)				12, 22
Bis (Chloromethyl) ether (c)				12, 22
Bromate	10 (E1)			
Bromoform (c)				43, 1,400
Butylbenzyl phthalate				1,500, 1,900
Cadmium	5 (E1, T)	2.0[d]	0.25[d]	
Carbofuran	40 (E1, T)			
Carbon tetrachloride (c)	5 (E1, T)			2.3, 16
Chlordane (c)	2 (E1, T)	2.4	0.0043	0.0080, 0.0081
Chloride	250,000 (E2)			
Chlorine (TRC)	4,000 (E1)	19	11	
Chlorite	1,000 (E1)			
Chlorobenzene				130, 1,600
Chlorodibromomethane (c)				4.0, 130
Chloroform (c)				57, 4,700
Chloromines (as Cl2)	4,000 (E1)			
Chlorine dioxide (as Cl2)	800 (E1)			

Table C.2. TDEC and EPA nonradiological water quality standards and criteria (µg/L) (continued)

Chemical	TDEC and EPA Drinking Water Standards[a]	TDEC Fish and Aquatic Life Criteria		TDEC recreation criteria water + organisms, organisms only[b]
		Maximum	Continuous	
2-Chloronaphthalene				1,000, 1,600
2-Chlorophenol				81, 150
Chromium (total)	100 (E1, T)			
Chromium(III)		570[d]	74[d]	
Chromium(VI)[c]		16[c]	11[c]	
Chrysene (c)				0.038, 0.18
Coliforms	no more than 5% of samples per month can be positive for total coliforms (E1)	2880/100 mL, *E. coli* (single sample)	630/100 mL, *E. coli* (geometric mean)	126/100 mL, geometric mean, *E. coli* 487, maximum lakes/reservoirs, *E. coli* 941, maximum, other water bodies, *E. coli*
Color	15 color units (E2)			
Copper	1,000 (E2) 1,300 (E1 "Action Level")	13[d]	9.0[d]	
Cyanide (as free cyanide)	200 (E1, T)	22	5.2	140, 140
2,4-D (Dichlorophennoxyacetic acid)	70 (E1, T)			
4,4'-DDT (c)		1.1	0.001	0.0022, 0.0022
4,4'-DDE (c)				0.0022, 0.0022
4,4'-DDD (c)				0.0031, 0.0031
Dalapon	200 (E1, T)			
Demeton			0.1	
Diazinon		0.1	0.1	
Dibenz(a,h)anthracene (c)				0.038, 0.18
1,2-dibromo-3-chloropropane (DBCP)	0.2 (E1, T)			
1,2-Dichlorobenzene (*ortho*-)	600 (E1, T)			420, 1,300
1,3-Dichlorobenzene (*meta*-)				320, 960
1,4-Dichlorobenzene (*para*-)	75 (E1, T)			63, 190
3,3-Dichlorobenzidine (c)				0.21, 0.28
Dichlorobromomethane (c)				5.5, 170
1,2-Dichloroethane (c)	5 (E1, T)			3.8, 370
1,1-Dichloroethylene	7 (E1, T)			330, 7,100
Cis-1,2-Dichloroethylene	70 (E1, T)			
trans 1,2-Dichloroethylene	100 (E1, T)			140, 10,000
Dichloromethane	5 (E1, T)			
2,4-Dichlorophenol				77, 290
1,2-Dichloropropane (c)	5 (E1, T)			5.0, 150
1,3-Dichloropropene (c)				3.4, 210
Dieldrin (b)(c)		0.24	0.056	0.00052, 0.00054
Diethyl phthalate				17,000, 44,000
Di (2-ethylhexyl) adipate	400 (E1, T)			
Di (2-ethylhexyl) phthalate	6 (E1, T)			
Dinoseb	7 (E1, T)			
Dimethyl phthalate				270,000, 1,100,000

Table C.2. TDEC and EPA nonradiological water quality standards and criteria (µg/L) (continued)

Chemical	TDEC and EPA Drinking Water Standards[a]	TDEC Fish and Aquatic Life Criteria		TDEC recreation criteria water + organisms, organisms only[b]
		Maximum	Continuous	
Dimethylphenols				380, 850
Di-n-butyl phthalate				2,000, 4,500
2,4-Dinitrophenol				69, 5,300
2,4-Dinitrotoluene (c)				1.1, 34
Dioxin (2,3,7,8-TCDD) (c)	3 E-5 (E1, T)			0.000001, 0.000001
Diquat	20 (E1, T)			
1,2-Diphenylhydrazine (c)				0.36, 2.0
a-Endosulfan		0.22	0.056	62, 89
b-Endosulfan		0.22	0.056	62, 89
Endosulfan sulfate				62, 89
Endothall	100 (E1, T)			
Endrin	2 (E1, T)	0.086	0.036	0.059, 0.06
Endrin aldehyde				0.29, 0.30
Ethylbenzene	700 (E1)			530, 2100
Ethylene dibromide	0.05 (E1, T)			
Fluoranthene				130, 140
Fluorene				1,100, 5,300
Fluoride	2,000 (E2) 4,000 (E1,T)			
Foaming agents	500 (E2)			
Glyphosate	700 (E1, T)			
Guthion			0.01	
Haloacetic acids (five)	60 (E1)			
Heptachlor (c)	0.4 (E1, T)	0.52	0.0038	0.00079, 0.00079
Heptachlor epoxide (c)	0.2 (E1, T)	0.52	0.0038	0.00039, 0.00039
Hexachlorobenzene (b)(c)	1 (E1, T)			0.0028, 0.0029
Hexachlorobutadiene (b)(c)				4.4, 180
Hexachlorocyclopentadiene	50 (E1, T)			40, 1,100
Hexachloroethane (c)				14, 33
Ideno(1,2,3-cd)pyrene (c)				0.038, 0.18
Iron	300 (E2)			
Isophorone (c)				350, 9,600
Lead	15 (E1 "Action Level")	65[d]	2.5[d]	
Lindane	0.2 (T)			
Malathion			0.1	
Manganese	50 (E2)			
Mercury (inorganic)[c]	2 (E1)	1.4[c]	0.77[c]	0.05, 0.051
Methoxychlor	40 (E1, T)		0.03	
Methyl bromide				47, 1,500
2-Methyl-4,6-dinitrophenol				13, 280
Methylene chloride (Dichloromethane) (c)				46, 5,900
Mirex (b)			0.001	
Monocholorobenzene	100 (E1, T)			
Nickel	100 (T)	470[d]	52[d]	610, 4,600

Table C.2. TDEC and EPA nonradiological water quality standards and criteria (µg/L) (continued)

Chemical	TDEC and EPA Drinking Water Standards[a]	TDEC Fish and Aquatic Life Criteria		TDEC recreation criteria water + organisms, organisms only[b]
		Maximum	Continuous	
Nitrate as N	10,000 (E1,T)			
Nitrite as N	1,000 (E1, T)			
Nitrobenzene				17, 690
Nitrosamines				0.0008, 1.24
Nitrolsodibutylamine (c)				0.063, 2.2
Nitrosodiethylamine (c)				0.008, 12.4
Nitrosopyrrolidine (c)				0.16, 340
N-Nitrosodimethylamine (c)				0.0069, 30
N-Nitrosodi-n-propylamine (c)				0.05, 5.1
N-Nitrosodiphenylamine (c)				33, 60
Nonylphenol		28.0	6.6	
Odor	3 threshold odor number (E2)			
Oxamyl (Vydate)	200 (E1, T)			
Parathion		0.065	0.013	
Pentachlorobenzene (b)				1.4, 1.5
Pentachlorophenol (c)	1 (E1, T)	19[e]	15[e]	2.7, 30
pH	6.5 to 8.5 units (E2) 6.0 to 9.0 units (T)		6.0 to 9.0 units, wade-able streams 6.5 to 9.0 units, larger rivers, lakes, etc.	6.0 to 9.0 units
Phenol				10,000, 860,000
Picloram	500 (E1,T)			
PCBs, total (c)	0.5 (E1, T)	–	0.014	0.00064, 0.00064
Pyrene				830, 4,000
Selenium	50 (E1, T)	20	5	170, 4,200
Silver	100 (E2)	3.2[d]	–	
Simazine	4 (E1, T)			
Styrene	100 (E1, T)			
Sulfate	250,000 (E2)			
1,1,2,2-Tetrachloroethane (c)				1.7, 40
1,2,4,5-Tetrachlorobenzene (b)				0.97, 1.1
Tetrachloroethylene (c)	5 (E1, T)			6.9, 33
Thallium	2 (E1, T)			0.24, 0.47
Toluene	1,000 (E1, T)			1,300, 15,000
Total dissolved solids	500,000 (E2)			
Total Nitrate and Nitrite	10,000 as N (E1,T)			
Total trihalomethanes	80 (E1)			
Toxaphene (b)(c)	3 (E1, T)	0.73	0.0002	0.0028, 0.0028
2,4,5-TP (Silvex)	50 (E1, T)			1,800, 3,600
Tributyltin (TBT)		0.46	0.072	
1,2,4-Trichlorobenzene	70 (E1, T)			35, 70
1,1,1-Trichloroethane	200 (E1, T)			

Table C.2. TDEC and EPA nonradiological water quality standards and criteria (µg/L) (continued)

Chemical	TDEC and EPA Drinking Water Standards[a]	TDEC Fish and Aquatic Life Criteria		TDEC recreation criteria water + organisms, organisms only[b]
		Maximum	Continuous	
1,1,2-Trichloroethane (c)	5 (E1, T)			5.9, 160
Trichloroethylene (c)	5 (E1, T)			25, 300
2,4,6-Trichlorophenol (c)				14, 24
Vinyl chloride (c)	2 (E1, T)			0.25, 24
Xylenes (total)	10,000 (E1, T)			
Zinc	5,000 (E2)	120[d]	120[d]	7,400, 26,000

[a]E1 = EPA Primary Drinking Water Standards; E2 = EPA Secondary Drinking Water Standards; T = TDEC domestic water supply criteria.
[b]For each parameter, the first recreational criterion is for "water and organisms" and is applicable on the Oak Ridge Reservation (ORR) only to the Clinch River because the Clinch is the only stream on ORR that is classified for both domestic water supply and for recreation. The second criterion is for "organisms only" and is applicable to the other streams on ORR. TDEC uses a 10^{-5} risk level for recreational criteria for all carcinogenic pollutants (designated as (c) under "Chemical" column). Recreational criteria for noncarcinogenic chemicals are set using a 10^{-6} risk level. (Note: All federal recreational criteria are set at a 10^{-6} risk level.)
[c]Criteria are expressed as dissolved.
[d]Criteria are expressed as dissolved and are a function of total hardness (mg/L). Criteria displayed correspond to a total hardness of 100 mg/L.
[e]Criteria are expressed as a function of pH; values shown correspond to a pH of 7.8.

Acronyms:
TDEC = Tennessee Department of Environment and Conservation
EPA = US Environmental Protection Agency

Appendix D:
National Pollutant Discharge Elimination System Noncompliance Summaries for 2019

Appendix
D. National Pollutant Discharge Elimination System Noncompliance Summaries for 2019

D.1 Y-12 National Security Complex

The Y-12 National Security Complex was in full compliance with the National Pollutant Discharge Elimination System (NPDES) permit in 2019. Adequate data points were obtained from sampling required by the NPDES permit. Compliance with permit discharge limits for 2019 was 100 percent.

D.2 East Tennessee Technology Park

The East Tennessee Technology Park program was 100 percent compliant with the numerical permit limits during 2019. The current ETTP NPDES permit was effective on February 1, 2015 and will remain in effect until March 31, 2020.

D.3 Oak Ridge National Laboratory

In 2019, compliance with the Oak Ridge National Laboratory NPDES permit was determined by 1,800 laboratory analyses and field measurements. The NPDES permit limit compliance rate for all discharge points for 2019 was greater than 99 percent. At ORNL there were one concentration and one loading limit exceedance and two nonnumeric permit noncompliances: a total suspended solids sample and an oil and grease sample were not collected during the required quarterly reporting period.

Appendix E:
Radiation

Appendix E. Radiation

This appendix presents basic information about radiation. The information is intended as a basis for understanding the potential doses associated with releases of radionuclides from the Oak Ridge Reservation, not as a comprehensive discussion of radiation and its effects on the environment and on biological systems.

Radiation comes from natural and human sources. People are constantly exposed to naturally occurring radiation. For example, cosmic radiation, radon in air, potassium in food and water, and uranium, thorium, and radium in the earth's crust are all sources of radiation. The following discussion describes important aspects of radiation and its types, sources, and pathways; radiation measurement; and dose information.

E.1 Atoms and Isotopes

All matter is made up of atoms. An atom is "a unit of matter consisting of a single nucleus surrounded by a number of electrons equal to the number of protons in the nucleus" (Alter 1986). The number of protons in the nucleus determines an element's atomic number or chemical identity. With the exception of hydrogen, the nucleus of each type of atom also contains at least one neutron. Unlike protons, the neutrons may vary in number among atoms of the same element. The number of neutrons and protons determines the atomic weight. Atoms of the same element that have different numbers of neutrons are called isotopes. In other words, isotopes have the same chemical properties but different atomic weights, as illustrated in Figure E.1.

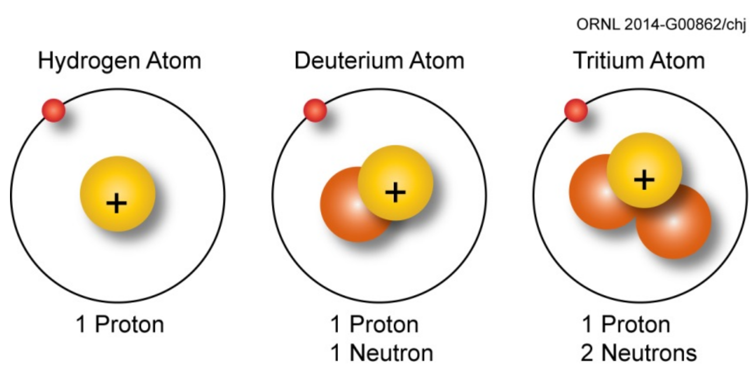

Figure E.1. The hydrogen atom and its isotopes

For example, the element uranium has 92 protons. All isotopes of uranium, therefore, have 92 protons. However, each uranium isotope has a different number of neutrons:

- Uranium-238 has 92 protons and 146 neutrons
- Uranium-235 has 92 protons and 143 neutrons
- Uranium-234 has 92 protons and 142 neutrons

Some isotopes are stable, or nonradioactive, and some are radioactive. Radioactive isotopes are called radionuclides or radioisotopes. In an attempt to become stable, radionuclides emit rays or particles. This emission of rays and particles is known as radioactive decay. Each radioisotope has a radioactive half-life, which is the average time required for half of a specified number of atoms to decay. Half-lives can be very short (fractions of a second) or very long (millions of years), depending on the isotope. Table E.1 shows the half-lives of selected radionuclides.

Table E.1. Selected radionuclide half-lives

Radionuclide	Symbol	Half-life (in years unless otherwise noted)	Radionuclide	Symbol	Half-life (in years unless otherwise noted)
Americium-241	^{241}Am	432.2	Plutonium-238	^{238}Pu	87.74
Americium-243	^{243}Am	7.37E+3	Plutonium-239	^{239}Pu	2.411E+4
Argon-41	^{41}Ar	1.827 hours	Plutonium-240	^{240}Pu	6.564E+3
Beryllium-7	^{7}Be	53.22 days	Potassium-40	^{40}K	1.251E+9
Californium-252	^{252}Cf	2.645	Radium-226	^{226}Ra	1.6E+3
Carbon-11	^{11}C	20.39 minutes	Radium-228	^{228}Ra	5.75
Carbon-14	^{14}C	5.70E+3	Ruthenium-103	^{103}Ru	39.26 days
Cerium-141	^{141}Ce	32.508 days	Samarium-153	^{153}Sm	46.5 hours
Cerium-144	^{144}Ce	284.91 days	Strontium-89	^{89}Sr	50.53 days
Cesium-134	^{134}Cs	2.0648	Strontium-90	^{90}Sr	28.79
Cesium-137	^{137}Cs	30.167	Technetium-99	^{99}Tc	2.111E+5
Cesium-138	^{138}Cs	32.41 minutes	Thorium-228	^{228}Th	1.9116
Cobalt-58	^{58}Co	70.86 days	Thorium-230	^{230}Th	7.538E+4
Cobalt-60	^{60}Co	5.271	Thorium-232	^{232}Th	1.405E+10
Curium-242	^{242}Cm	162.8 days	Thorium-234	^{234}Th	24.1 days
Curium-244	^{244}Cm	18.1	Tritium	^{3}H	12.32
Iodine-129	^{129}I	157E+7	Uranium-234	^{234}U	2.455E+5
Iodine-131	^{131}I	8.02 days	Uranium-235	^{235}U	7.04E+8
Krypton-85	^{85}Kr	10.756	Uranium-236	^{236}U	2.342E+7
Krypton-88	^{88}Kr	2.84 hours	Uranium-238	^{238}U	4.468E+9
Lead-212	^{212}Pb	10.64 hours	Xenon-133	^{133}Xe	5.243 days
Manganese-54	^{54}Mn	312.12 days	Xenon-135	^{135}Xe	9.14 hours
Neptunium-237	^{237}Np	2.144E+6	Yttrium-90	^{90}Y	64.1 hours
Niobium-95	^{95}Nb	34.991 days	Zirconium-95	^{95}Zr	64.032 days

Source: ICRP 2008

E.2 Radiation

Radiation, or radiant energy, is energy in the form of waves or particles moving through space. Visible light, heat, radio waves, and alpha particles are examples of radiation. When people feel warmth from sunlight, they are actually absorbing the radiant energy emitted by the sun.

Electromagnetic radiation is radiation in the form of electromagnetic waves. Examples include gamma rays, ultraviolet light, and radio waves. Particulate radiation is radiation in the form of particles, such as alpha and beta particles. Radiation also is characterized as ionizing or nonionizing because of the way in which it interacts with matter.

Ionizing Radiation

Normally an atom has an equal number of protons and electrons; however, atoms can lose or gain electrons in a process known as ionization. Some forms of radiation (called ionizing radiation) can ionize atoms by knocking electrons off atoms. Examples of ionizing radiation include alpha and beta particles and gamma and x-rays.

Ionizing radiation is capable of changing the chemical state of matter and subsequently causing biological damage. By this mechanism, it is potentially harmful to human health.

Nonionizing Radiation

Nonionizing radiation is described as a series of energy waves composed of oscillating electric and magnetic fields traveling at the speed of light. Nonionizing radiation includes the spectrum of ultraviolet light, visible light, infrared, microwave, radio frequency, and extremely low frequency waves. Lasers commonly operate in the ultraviolet, visible, and infrared frequencies. Microwave radiation is absorbed near the skin, while radio frequency radiation may be absorbed throughout the body. At high enough intensities, both will damage tissue through heating. Excessive visible radiation can damage the eyes and skin (Department of Labor, Occupational Safety and Health Administration, *Safety and Health Topics*). However, in the discussion that follows, the term “radiation” is used to describe ionizing radiation.

E.3 Measuring Ionizing Radiation

To determine the possible effects of radiation on the health of the environment and the public, the radiation must be measured. More precisely, its potential to cause damage must be ascertained.

Activity

To determine the level of radiation in the environment, the rate of radioactive decay or activity is measured. The rate of decay varies widely among radioisotopes. For that reason, 1 gram of a radioactive substance may contain the same amount of activity as several tons of another material. This activity is expressed in a unit of measure known as a curie (Ci). More specifically, 1 Ci equals 3.7×10^{10} (37,000,000,000) atomic disintegrations per second (dps). In the International System of Units, 1 dps equals 1 becquerel (Bq).

Absorbed Dose

The total amount of energy absorbed per unit mass of an exposed material as a result of exposure to radiation is expressed in a unit of measure known as a rad. The effect of the absorbed energy (the biological damage that occurs) is important, not the actual amount. In the International System of Units, 100 rad equals 1 gray (Gy).

Effective Dose

The measure of potential biological damage to the body caused by exposure to and subsequent absorption of radiation is expressed in a unit of measure known as a rem. For radiation protection purposes, 1 rem of any type of radiation has the same damaging effect. Because a rem represents a fairly large dose, the measure is usually expressed as millirem (mrem), which is 1/1000 of a rem. In the International System of Units, 1 sievert (Sv) equals 100 rem; 1 millisievert (mSv) equals 100 mrem. The effective dose (ED) is the weighted sum of equivalent dose over specified tissues or organs. The ED is based on tissue-weighting factors for 12 specific tissues or organs plus a weight factor for the remaining organs and tissues. In addition, the ED is based on the recent lung model, gastrointestinal absorption fractions, and biokinetic models used for selected elements. Specific types of EDs are defined as follows:

- Committed ED – the weighted sum of the committed ED in specified tissues in the human body during the 50-year period following intake
- Collective ED – the product of the mean ED for a population and the number of persons in the population

E.4 Radiation Exposure Pathways

People can be exposed to radionuclides in the environment through a number of routes, as shown in Figure E.2. Potential routes for internal and external exposure are referred to as pathways. For example, radionuclides in air could be inhaled directly or could fall on grass in a pasture. If the grass were then consumed by cows, it would be possible for the radionuclides to impact the cow's milk, and people drinking the milk would be exposed to this radiation. Similarly, radionuclides in water could be ingested by fish, and fishermen or other consumers could then ingest the radionuclides in the fish tissue. People swimming in the water also would be exposed. Exposure to ionizing radiation varies significantly with geographic location, diet, drinking water source, and building construction.

Figure E.2. Examples of radiation pathways

E.5 Radiation Sources and Doses

Basically, radioactive decay, or activity, generates radiant energy. People absorb some of the energy to which they are exposed, either from external or internal radiation. The effect of this absorbed energy is responsible for an individual's dose. Whether radiation is natural or human-made, it has the same effect on people.

There are five broad categories for radiation exposure to the US population (NCRP 2009):

- Exposure to ubiquitous background radiation, including radon in homes
- Exposure to patients from medical procedures
- Exposure from consumer products or activities involving radiation sources
- Exposure from industrial, security, medical, educational, and research radiation sources
- Exposure to workers that results from their occupations

Figure E.3 shows the percent contributions of various sources of exposure to the total collective dose for the US population in 2006. As shown, the major sources are radon and thoron (37 percent), computed tomography (24 percent), and nuclear medicine (12 percent) (NCRP 2009). Consumer, occupational, and industrial sources contribute about 2 percent to the total US collective dose.

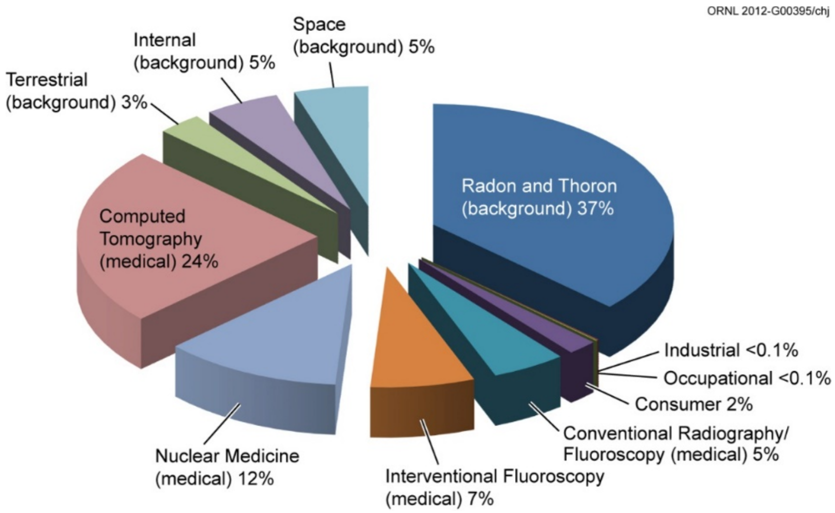

Figure E.3. All exposure categories for collective effective dose for 2006 (NCRP 2009)

E.5.1 Background Radiation

Naturally occurring radiation is the major source of radiation in the environment. Sources of background radiation exposure include the following:

- External exposure from space or cosmic radiation
- External exposure from terrestrial radiation
- Internal exposure from inhalation of radon, thoron, and their progeny
- Internal exposure from radionuclides in the body

E.5.1.1 External Exposures

Space or Cosmic Radiation

Energetically charged particles from outer space continuously hit the earth's atmosphere. These particles and the secondary particles and photons they create are called cosmic radiation. Because the atmosphere provides some shielding against cosmic radiation, the intensity of this radiation increases with altitude above sea level. For example, a person in Denver is exposed to more cosmic radiation than a person in New Orleans.

The average annual effective dose to people in the United States from cosmic radiation is about 33 mrem, or 0.33 mSv (NCRP 2009). Effective dose rates from cosmic radiation depend on geomagnetic latitude and elevation above sea level.

Terrestrial Radiation

Terrestrial radiation refers to radiation emitted from radioactive materials in the earth's rocks, soils, and minerals. Radon (Rn), radon progeny (the relatively short-lived decay products from the decay of the radon isotope ^{222}Rn), potassium (^{40}K), isotopes of thorium (Th), and isotopes of uranium (U) are the elements responsible for most terrestrial radiation.

The average annual dose from terrestrial gamma radiation is about 21 mrem (0.21 mSv) in the United States, but it varies geographically across the country (NCRP 2009). Typical reported values are about 23 mrem (0.23 mSv) on the Atlantic and Gulf coastal plains, about 90 mrem (0.9 mSv) on the eastern slopes of the Rocky Mountains, and about 46 mrem (0.46 mSv) elsewhere (EPA 2014).

E.5.1.2 Internal Exposures

Radionuclides in the environment enter the body with the air people breathe and the foods they eat. They also can enter through an open wound. Natural radionuclides that can be inhaled and ingested include isotopes of uranium and their progeny, especially radon (^{222}Rn) and its progeny, thoron (^{220}Rn) and its progeny, potassium (^{40}K), rubidium (^{87}Rb), and carbon (^{14}C). Radionuclides contained in the body are dominated by ^{40}K and polonium (^{210}Po); others include ^{87}Rb and ^{14}C (NCRP 1987).

Radon and Thoron and Decay Products

The major contributors to the annual effective dose from background radiation sources are radon and thoron and their short-lived decay products. As shown in Figure E.3, 37 percent of the dose from all exposure categories is from radon and thoron and their decay products, which contribute an average dose of about 228 mrem (2.28 mSv) per year (NCRP 2009). Radon is an inert gas and a small fraction is retained in the body; however, the dose to the lung comes from the short-lived radon decay products. Radon levels vary widely across the United States. Elevated levels are most commonly found in the Appalachians, the upper Midwest, and the Rocky Mountain states (NCRP 2009).

Other Internal Radiation Sources

Other sources of internal radiation include ^{40}K, ^{232}Th, and the ^{238}U series. The primary source of ^{40}K in body tissues is food, primarily fruits and vegetables. Sources of radionuclides from the ^{232}Th and ^{238}U series are food and water (NCRP 2009). The average dose from these other internal radionuclides is about 29 mrem (0.29 mSv) per year. This dose is attributed predominantly to the naturally occurring radioactive isotope of potassium, ^{40}K.

E.5.2 Human-Made Radiation

In addition to background radiation, most people are exposed to human-made sources of radiation such as consumer products, medical sources, industrial by-products, and fallout from atmospheric atomic bomb tests. No atmospheric testing of atomic weapons has occurred since 1980 (NCRP 1987).

Consumer Products

Some consumer products are sources of radiation. The radiation in these products, which include smoke detectors, radioluminous products such as self-illuminating exit signs in commercial buildings, and airport x-ray baggage inspection systems, is essential to the performance of the device. In other products, such as tobacco products and building materials, the radiation occurs incidentally to the product's function (NCRP 1987, NCRP 2009).

The US annual dose to an individual from consumer products and activities averages about 13 mrem (0.13 mSv), ranging between 0.1 and 40 mrem (0.001 and 0.4 mSv). Cigarette smoking accounts for about 35 percent of this dose. Other important sources are building materials (27 percent), commercial air travel (26 percent), mining and agriculture (6 percent), miscellaneous consumer-oriented products (3 percent), combustion of fossil fuels (2 percent), highway and road construction materials (0.6 percent), and glass and ceramics (less than 0.003 percent). Television and video, sewage sludge and ash, and self-illuminating signs contribute negligible doses (NCRP 2009).

Medical Sources

Radiation is an important tool in diagnostic medicine and treatment, which are the main sources of exposure to the public from human-made radiation. Exposure is deliberate and is directly beneficial to the patients exposed. In general, medical exposures from diagnostic or therapeutic x-rays result from beams directed to specific areas of the body, so not all organs are uniformly irradiated. Nuclear medicine examinations and treatments involve the internal administration of radioactive compounds, or radiopharmaceuticals, by injection, inhalation, consumption, or insertion. Even then, radionuclides are not distributed uniformly throughout the body. Radiation and radioactive materials also are used in preparing medical instruments, including sterilizing heat-sensitive products such as plastic heart valves.

Nuclear medicine examinations, which internally administer radiopharmaceuticals, generally account for the largest portion of dose from human-made sources. However, the radionuclides used for specific tests are not uniformly distributed throughout the body. In these cases the concept of ED, which relates the significance of exposures of organs or body parts to the effect on the entire body, is useful in making comparisons. The average annual ED from medical examinations is roughly 300 mrem (3 mSv), including 147 mrem (1.47 mSv) from computed tomography scans, 77 mrem (0.77 mSv) from nuclear medicine procedures, 43 mrem (0.43 mSv) from interventional fluoroscopy, and 33 mrem (0.33 mSv) from conventional radiography and fluoroscopy (NCRP 2009). Not everyone receives such exams each year.

Other Sources

Other sources of radiation include emissions of radioactive materials from nuclear facilities such as uranium mines, fuel-processing plants, and nuclear power plants; transportation of radioactive materials; and emissions from mineral-extraction facilities. The dose to the general public from nuclear fuel cycle facilities, such as uranium mines, mills, fuel-processing plants, nuclear power plants, and transportation routes, has been estimated at less than 1 mrem (0.01 mSv) per year (NCRP 1987).

Small doses to individuals occur because of radioactive fallout from atmospheric atomic bomb tests, emissions of radioactive materials from nuclear facilities, emissions from certain mineral extraction facilities, and transportation of radioactive materials. The combination of these sources contributes less than 1 mrem (0.01 mSv) per year to an individual's average dose (NCRP 1987).

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Appendix F:
Chemicals

Appendix
F. Chemicals

This appendix presents basic information about chemicals. The information is intended as a basis for understanding the dose or relative toxicity assessment associated with possible releases from the Oak Ridge Reservation (ORR), and is not a comprehensive discussion of chemicals and their effects on the environment and biological systems.

F.1 Perspective on Chemicals

The lives of modern humans have been greatly improved by the development of chemicals such as pharmaceuticals, building materials, housewares, pesticides, and industrial chemicals. Through the use of chemicals we can increase food production, cure diseases, build more efficient houses, and send people into space. At the same time, we must be cautious to ensure uncontrolled and over-expanded use of chemicals does not endanger our own existence (Chan et al. 1982).

Just as all humans are exposed to radiation in their normal daily routines, humans are also exposed to chemicals. Some potentially hazardous chemicals exist in the natural environment. In many areas of the country, soils contain naturally elevated concentrations of metals such as selenium, arsenic, or molybdenum, which may be hazardous to humans or animals. Even some of the foods we eat contain natural toxins. Aflatoxins are found in chili peppers, corn, millet, peanuts, rice, sorghum, sunflower seeds, tree nuts, and wheat. Cyanide is found in apple seeds. However, exposure to many more hazardous chemicals results from direct or indirect human actions. Building materials used in home construction may contain chemicals such as formaldehyde (in some insulation materials), asbestos (formerly used in insulation and ceiling tiles), and lead (formerly used in paints and gasoline). Some chemicals are present as a result of applying pesticides and fertilizers to soil. Other chemicals may have been transported long distances through the atmosphere from industrial sources and then deposited on soil or water.

F.2 Pathways of Chemicals from the Oak Ridge Reservation to the Public

“Pathways” are the routes or ways through which a person can come in contact with a chemical substance. Chemicals released to the air may remain suspended for long periods, or they may be rapidly deposited on plants, soil, and water. Chemicals may also be released as liquid wastes, called “effluents,” which can enter streams and rivers.

People are exposed to chemicals by inhalation (breathing air), ingestion (eating exposed plants and animals or drinking water), or direct contact (touching soil or swimming in water). For example, fish that live in a river that receives effluents may take in some of the chemicals present in the water. People eating fish and drinking water from the river would then be exposed to the chemicals. The public is not normally exposed to chemicals on ORR because access to the reservation is limited. However, chemicals released as a result of ORR operations can move through the environment to off-site locations, resulting in potential exposure of the public.

F.3 Definitions

F.3.1 Toxicity

Health effects from chemicals vary. Chemical health effects are divided in two broad categories: adverse or systemic effects (noncarcinogens) and cancer (carcinogens). A chemical can have both carcinogenic and noncarcinogenic effects. The toxic effect can be acute (a short-term, possible severe health effect) or chronic (a longer term, persistent health effect). Noncarcinogenic toxicity is often evident in a shorter length of time than a carcinogenic effect. The potential health effects of noncarcinogens range from skin irritation to death (or mortality). Carcinogens cause or increase the incidence of malignant neoplasms or cancers.

Toxicity refers to an adverse effect of a chemical on human health. Every day we ingest chemicals in food, water, and sometimes in medications. Even chemicals typically considered toxic are usually nontoxic or harmless below a certain concentration.

Concentration limits or advisories are set by government agencies for some chemicals that are known or thought to have adverse effects on human health. These concentration limits can be used to calculate chemical doses that would not harm even those individuals who may be particularly sensitive to the chemical.

F.3.2 Dose Terms for Noncarcinogens

Reference Dose

A reference dose is an estimate of a daily exposure level for the human population, including sensitive subpopulations. These reference doses are likely to be without appreciable risk of deleterious effects during a lifetime. Units are expressed as milligrams of chemical per kilogram of an adult's body weight per day (mg/kg-day). Values for reference doses are derived from doses of chemicals that resulted in no adverse effect, or the lowest dose that showed an adverse effect, on humans or laboratory animals.

Uncertainty factors are typically used in deriving reference doses. Uncertainty adjustments may be made if animal toxicity data are extrapolated to humans to account for human sensitivity; extrapolated from subchronic to chronic no-observed-adverse-effect levels; extrapolated from lowest-observed-adverse-effect levels to no-observed-adverse-effect levels; and to account for data deficiencies. The use of uncertainty factors in deriving reference doses is thought to help protect sensitive human populations. The US Environmental Protection Agency (EPA) maintains the Integrated Risk Information System (IRIS) database, which contains verified reference doses and up-to-date health risk and EPA regulatory information for numerous chemicals.

Primary Maximum Contaminant Levels

For chemicals for which reference doses are not available in IRIS, Tennessee Water Quality Criteria for domestic water supply, which reflect maximum contaminant levels expressed in milligrams of chemical per liter of drinking water, are converted to reference dose values by multiplying by 2 liters (the average daily adult water intake) and dividing by 80 kg (the reference adult body weight). The result is a "derived" reference dose expressed in mg/kg-day.

F.3.3 Dose Term for Carcinogens

Slope Factor

A slope factor is a plausible upper-bound estimate of the probability of a response per unit intake of a chemical during a lifetime. The slope factor is used to estimate an upper-bound probability of an individual developing cancer as a result of a lifetime exposure to a particular level of a chemical. Units are expressed as risk per dose in mg/kg-day.

The slope factor converts the estimated daily intake averaged over a lifetime exposure to the incremental risk of an individual developing cancer. Because it is unknown for most chemicals whether a threshold (a dose below which no adverse effect occurs) exists for carcinogens, units for carcinogens are set in terms of risk factors. Acceptable risk levels for carcinogens range from 10^{-4} (risk of developing cancer over a human lifetime is 1 in 10,000) to 10^{-6} (risk of developing cancer over a human lifetime is 1 in 1,000,000). In other words, a certain chemical concentration in food or water could cause a risk of one additional cancer for every 10,000 (10^{-4}) to 1,000,000 (10^{-6}) exposed persons, respectively.

F.4 Measuring Chemicals

Environmental samples are collected in areas surrounding ORR and are analyzed for those chemical constituents most likely to be released from ORR. Typically, chemical concentrations in liquids are expressed in milligrams or micrograms of chemical per liter of water; concentrations in solids (soil and fish tissue) are expressed in milligrams or micrograms of chemical per gram or kilogram of sample material.

The instruments used to measure chemical concentrations are sensitive; however, there are limits below which they cannot detect chemicals of interest. Concentrations below the reported analytical detection limits of the instruments are recorded by the laboratory as estimated values, which have a greater uncertainty than concentrations detected above the detection limits of the instruments. Health effect calculations that use these estimated values are indicated by the less-than symbol (<), which indicates that the value for a parameter could not be quantified at the analytical detection limit.

F.5 Risk Assessment Methodology

Exposure Assessment

To estimate an individual's potential exposure via a specific exposure pathway, the intake amount of the chemical must be determined. For example, chemical exposure from drinking water and eating fish from the Clinch River is assessed in the following manner: Clinch River surface water and fish samples are analyzed to measure chemical contaminant concentrations. For this assessment, it is assumed that individuals drink about 2 liters (0.5 gal) of water per day directly from the river, which amounts to 730 liters (193 gal) per year, and that they eat 0.07 kg (roughly 0.2 lb) of fish per day from the river (27 kg or 60 lb per year). Estimated daily intakes or estimated doses to the public are calculated by multiplying measured (statistically significant) chemical concentrations in Clinch River surface water by 2 liters, or those in fish from the Clinch River by 0.07 kg. This intake is first multiplied by the exposure duration (26 years) and exposure frequency (350 days per year) and then divided by an averaging time (26 years for noncarcinogens and 70 years for carcinogens) and an 80 kg adult body weight. These exposure assumptions are conservative, and in many cases result in higher estimated intakes and doses than an individual would actually receive.

Dose Estimate

Once the oral daily intake of a chemical contaminant has been estimated, the dose is determined. The chemical dose to humans is measured in mg/kg-day. In this case, "kilogram" refers to the body weight of an adult. When a chemical dose is calculated, the length of time an individual is exposed to a certain concentration is important. To assess off-site chemical doses, it is assumed that the exposure duration occurs over 30 years. Such exposures are called "chronic" in contrast to short-term exposures, which are called "acute."

Calculation Method

Current risk assessment methodologies use the term "hazard quotient" to evaluate noncarcinogenic health effects. Because intakes are calculated in mg/kg-day in the hazard quotient methodology, they are expressed in terms of dose. Hazard quotient values of less than 1 indicate an unlikely potential for adverse noncarcinogenic health effects, whereas hazard quotient values greater than 1 indicate a concern for adverse health effects or the need for further study.

Risk methods evaluating carcinogenic risk use slope factors instead of reference doses. To estimate the potential carcinogenic risk from ingestion of water and fish, the estimated dose or intake (I) is multiplied by the slope factor (risk per mg/kg-day). As mentioned earlier, acceptable risk levels for carcinogens range from 10^{-4} (risk of developing cancer over a human lifetime is 1 in 10,000) to 10^{-6} (risk of developing cancer over a human lifetime is 1 in 1,000,000). Carcinogenic risks greater than 10^{-4} indicate a concern for adverse health effects or the need for further study.

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