Oak Ridge Reservation

DOE/ORO-2511

Annual Site Environmental Report

2017

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7. Dose

Appendices

Acronyms and Abbreviations

A

AAS	ambient air (monitoring) station
ABC	aluminum beverage can (recycling)
AC	administrative control
ACHP	Advisory Council on Historic Preservation
ACM	asbestos-containing material
ACO	Analytical Chemistry Organization (Y-12 Complex)
AFV	alternative fuel vehicle
AGL	above ground level
ALARA	as low as reasonably achievable
AMP	asset management program
aMSL	above mean sea level
ANSI	American National Standards Institute
ANSI/HPS	ANSI Health Physics Society (standard)
AOC	area of concern
AOEC	Agent Operations Eastern Command (NNSA OST)
ARAP	aquatic resource alteration permit
ARAR	applicable or relevant and appropriate requirement
ASER	*Oak Ridge Reservation Annual Site Environmental Report*
ATSDR	Agency for Toxic Substances and Disease Registry
AWQC	ambient water quality criterion

B

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

C

C&D	construction and demolition
CAA	Clean Air Act
CAP-88	Clean Air Act Assessment Package (software)
CAS	condition assessment survey
CCA	chromated copper arsenate (as in CCA Type C pressure-treated wood)
CCR	climate change resiliency
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CEUSP	Consolidated Edison Uranium Solidification Project
CFL	Computers for Learning
CFR	*Code of Federal Regulations*
CFTF	Carbon Fiber Technology Facility

CH	contact-handled
CIP	capacity increase project
CNF	Central Neutralization Facility
CNS	Consolidated Nuclear Security, LLC
CO_2e	CO_2 equivalent
COC	contaminant of concern
COR	City of Oak Ridge
CPU	central processing unit
CRK	Clinch River kilometer
CROET	Community Reuse Organization of East Tennessee
CWA	Clean Water Act
CWTS	Chromium Water Treatment System (ETTP)
CX	categorical exclusion
CY	calendar year

D

D&D	decontamination and decommissioning
DAC	derived air concentration
DCA	dichloroethane
DCE	dichloroethene/dichloroethylene
DCS	derived concentration standard
DNAPL	dense nonaqueous phase liquid
DOE	US Department of Energy
DOE ORO	DOE Oak Ridge Office
DOI	US Department of Interior
DOT	US Department of Transportation
DPT	direct push technology

E

EA	environmental assessment
EC&P	environmental compliance and protection
ECD	Environmental Compliance Department (Y-12)
ECM	energy conservation measure
ED	effective dose
EDTA	ethylenediaminetetraacetic acid
EFK	East Fork Poplar Creek kilometer
EFPC	East Fork Poplar Creek
EHD	epizootic hemorrhagic disease
EISA	Energy Independence and Security Act
EM	environmental management
EMMIS	Environmental Monitoring Management Information System (Y-12)
EMS	environmental management system
EMWMF	Environmental Management Waste Management Facility
ENIGMA	Ecosystems and Networks Integrated with Genes and Molecular Assemblies
EO	executive order
EOC	emergency operations center

	EPA	US Environmental Protection Agency
	EPCRA	Emergency Planning and Community Right-to-Know Act
	EPEAT	Electronic Product Environmental Assessment Tool
	E-Plan	Emergency response information system
	EPSD	Environmental Protection Services Division (UT-Battelle)
	EPT	ephemeroptera, plecoptera, and trichoptera (taxa)
	ES&H	environment, safety, and health
	ESPC	Energy Savings Performance Contract
	ESS	Environmental Surveillance System (ORNL)
	ETTP	East Tennessee Technology Park
	EU	exposure unit
	EUI	energy use intensity
	EV	electric vehicle
F	FAR	Federal Acquisition Regulation
	FCK	First Creek kilometer
	FEMP	Federal Energy Management Program
	FFA	Federal Facility Agreement (for the Oak Ridge Reservation)
	FFCA	Federal Facilities Compliance Agreement
	FFK	Fifth Creek kilometer
	FONSI	finding of no significant impact
	FWS	US Fish and Wildlife Service
	FY	fiscal year
	FYNSP	Future Years Nuclear Security Plan
G	GET	general employee training
	GHG	greenhouse gas
	GI	green infrastructure
	GI/LID	green infrastructure/low impact development
	GM	Geiger–Müller tube for detection of ionizing radiation
	GP	guiding principle
	GSA	General Services Administration
	GSF	gross square feet
H	HAP	hazardous air pollutant
	HCN	hydrogen cyanide
	HEMSF	high-energy mission-specific facility
	HEPA	high-efficiency particulate air
	HEU	highly enriched uranium
	HFIR	High Flux Isotope Reactor
	HPSB	high-performance sustainable building
	HQ	hazard quotient
	HVAC	heating, ventilation, and air conditioning
	HVC	Hardin Valley Campus

I	IC_{25}	inhibition concentration (the concentration of effluent that causes a 25% reduction in survival, reproduction, and/or growth of monitored species)
	ID	identification (number)
	IDMS	Integrated Document Management System (UT-Battelle)
	ILA	industrial, landscaping, and agricultural
	ISMS	Integrated Safety Management System
	ISO	International Organization for Standardization
	Isotek	Isotek Systems LLC
J	JCI	Johnson Controls, Inc.
L	LC_{50}	a concentration lethal to 50% of a test species
	LCD	liquid crystal display
	LEDP	Laboratory Equipment Donation Program
	LEED	Leadership in Energy and Environmental Design
	LEP	life extension program
	LID	low impact development
	LIMS	Laboratory Information Management System (Y-12 Complex)
	LLW	low-level waste
M	M&E	material and equipment
	M&TE	measurement and test equipment
	MACT	maximum achievable control technology
	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
	MDA	minimum detectable activity
	MDF	Manufacturing Demonstration Facility
	MEI	maximally exposed individual
	MEK	Melton Branch kilometer
	MIK	Mitchell Branch kilometer
	MOA	memorandum of agreement
	MSL	mean sea level
	MT	meteorological tower (when followed by a numeral as in “MT2”)
	MTF	Mercury Treatment Facility
N	NAAQS	National Ambient Air Quality Standards
	NEPA	National Environmental Policy Act
	NESHAPs	National Emission Standards for Hazardous Air Pollutants
	NHPA	National Historic Preservation Act

	NIST	National Institute of Standards and Technology
	NNSA	National Nuclear Security Administration
	NNSS	Nevada National Security Site
	NOV	notice of violation
	NPDES	National Pollutant Discharge Elimination System
	NPL	National Priorities List (EPA)
	NPO	NNSA Production Office
	NPS	US National Park Service
	NRC	US Nuclear Regulatory Commission
	NRCS	Natural Resources Conservation Service
	NRHP	National Register of Historic Places
	NSC	National Security Complex
	NSF-ISR	NSF International Strategic Registrations, Ltd.
	NTRC	National Transportation Research Center
	NWSol	North Wind Solutions, LLC
O	O&M	operations and maintenance
	ODS	ozone-depleting substance
	OF	outfall
	OMP	operational monitoring plan
	ORAU	Oak Ridge Associated Universities
	OREIS	Oak Ridge Environmental Information System
	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	Oak Ridge Office (DOE)
	ORPS	Occurrence Reporting and Processing System
	ORR	Oak Ridge Reservation
	ORR-PCB-FFCA	Oak Ridge Reservation Polychlorinated Biphenyl Federal Facilities Compliance Agreement Facilities Compliance Agreement
	ORSSAB	Oak Ridge Site Specific Advisory Board
	ORWMA	Oak Ridge Wildlife Management Area
	OS	DOE Office of Science
	OST	Office of Secure Transportation
P	P2/WMin	pollution prevention/waste minimization
	PAM	perimeter air monitoring (station)
	Pantex	Pantex Plant
	PCB	polychlorinated biphenyl
	PCE	tetrachloroethene
	PEMS	Predictive Emissions Monitoring System
	PHEV	plug-in hybrid electric vehicle
	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
	PS	performance specification
	PSS	plant shift superintendent
	PUE	power usage effectiveness
	PWTC	Process Waste Treatment Complex
Q	QA	quality assurance
	QAS	quality assurance system
	QC	quality control
	QMS	quality management system
R	R2	responsible recycling
	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
	RCW	recirculating cooling water
	REC	renewable energy credit (also renewable energy certificate)
	REDC	Radiochemical Engineering Development Center
	RESRAD	residual radioactivity
	RH	remote-handled
	RI	remedial investigation
	RI/FS	remedial investigation/feasibility study
	RICE	reciprocating internal combustion engine
	RMP	risk management plan
	ROD	record of decision
	RQ	reportable quantity (CERCLA)
	RSI	Restoration Services, Inc.
S	S&M	surveillance and maintenance
	SAP	sampling and analysis plan
	SARA	Superfund Amendments and Reauthorization Act
	SBMS	Standards-Based Management System (UT-Battelle)
	SC	DOE Office of Science
	SCI	sustainable campus initiative
	SCP	standards and calibration program
	SD	storm water outfall/storm drain
	SDWA	Safe Drinking Water Act
	SHPO	State Historic Preservation Office (Tennessee)
	SIC	Standard Industrial Classification (code)
	SNAP	Significant New Alternatives Program (EPA)

SNS	Spallation Neutron Source
SODAR	sonic detection and ranging
SOF	sum of fractions
SOP	state operating permit
SPCC	spill prevention, control, and countermeasures (plan)
SPMD	semipermeable membrane device
SPO	Sustainability Performance Office
SSP	site sustainability plan
SSPP	Strategic Sustainability Performance Plan (DOE)
STP	sewage treatment plant
SVOC	semivolatile organic compound
SWEIS	sitewide environmental impact statement
SWHISS	Surface Water Hydrological Information Support System (Y-12 Complex)
SWMU	solid waste management unit
SWPP	storm water pollution prevention
SWPPP	Storm Water Pollution Prevention Plan
SWSA	solid waste storage area

T

T&D	transmission and distribution
TCA	trichloroethane
TCE	trichloroethene/trichloroethylene
TDEC	Tennessee Department of Environment and Conservation
TEMA	Tennessee Emergency Management Agency
TMDL	total maximum daily load
TMSP	Tennessee Stormwater Multi-Sector General Permit
TOA	Tennessee Oversight Agreement
TRI	toxic (chemical) release inventory
TRO	total residual oxidant
TRU	transuranic
TSC	Technical Support Center
TSCA	Toxic Substances Control Act
TSS	total suspended solids
TVA	Tennessee Valley Authority
TWA	time-weighted average
TWPC	Transuranic Waste Processing Center
TWRA	Tennessee Wildlife Resources Agency

U

UCOR	URS | CH2M Oak Ridge LLC
UMC	unneeded materials and chemicals
UMS	Utilities Management System (Y-12 Complex)
UNW	unconsolidated well
UPF	Uranium Processing Facility (Y-12 Complex)
USDA	US Department of Agriculture
UST	underground storage tank
UT	University of Tennessee

	UT-Dallas	University of Texas at Dallas
	UT-B	UT-Battelle, LLC
V	VC	vinyl chloride
	VOC	volatile organic compound
W	WBK	Walker Branch kilometer
	WCK	White Oak Creek kilometer
	WEMA	west end mercury-use area (Y-12)
	WET	whole effluent toxicity
	WOC	White Oak Creek
	WOD	White Oak Dam
	WPB	waste-processing building
	WQC	water quality criterion
	WQPP	water quality protection plan
	WRRP	Water Resources Restoration Program
	WSR	waste services representatives
	WUI	water use intensity
Y	Y-12	Y-12 National Security Complex
	Y-12 Complex	Y-12 National Security Complex
	YEOC	Y-12 Complex Emergency Operations Center
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	day	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 gage	psig
kilowatt	LF	quart	qt
linear feet	kW	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	$\times 0.45 \times 10^{9}$	$\mu Ci/cm^3$	$\mu Ci/cm^3$	$\times 2.22 \times 10^{9}$	dpm/L
pCi/L	$\times 10^{-9}$	µCi/mL	µCi/mL	$\times 10^{9}$	pCi/L
pCi/m^3	$\times 10^{12}$	$\mu Ci/cm^3$	$\mu Ci/cm^3$	$\times 10^{12}$	pCi/m^3

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Executive Summary

Overview

The US Department of Energy (DOE) manages the Oak Ridge Reservation (ORR), which is located in Roane and Anderson Counties in East Tennessee about 40 km (25 mi) northwest of Knoxville. DOE's signature integrated safety management system (ISMS) integrates safety in all aspects of work at its 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.

ORR is one of DOE's most unusual and complex sites. It was established in the early 1940s as part of the Manhattan Project to enrich uranium and pioneer methods for producing and separating plutonium. Today it comprises three major facilities and 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 2017 *Oak Ridge Reservation Annual Site Environmental Report* (ASER) contains detailed and complex information furnished to the DOE ORR integrating contractor by contractors including UT-Battelle, LLC; Consolidated Nuclear Security, LLC; URS | CH2M Oak Ridge LLC; North Wind Solutions, LLC.; Oak Ridge Associated Universities; and Isotek Systems, LLC.

Three key chapters were prepared for DOE in strict accordance with applicable federal, state, and local regulations. Chapter 3 was written by URS | CH2M Oak Ridge LLC, the lead environmental management contractor for ETTP; Chapter 4 was developed by Consolidated Nuclear Security, LLC, which manages and operates the Y-12 Complex; and Chapter 5 was written by UT-Battelle, LLC, which manages 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 the contractors' environmental management systems.

DOE operations on ORR have the potential to release a variety of 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. Any releases are highly regulated and carefully monitored. 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 and through various communications. DOE also offers 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 all types of waste and pollutant releases to the environment. An environmental report that provides consolidated data on overall ORR performance and status has been published annually 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 prepared for readability, and frequent references to other sections, chapters, and reports are made throughout to avoid redundancy.

2017 Impacts

DOE ORR operations in 2017 resulted in minimal impact to the public and the environment. Permitted discharges to air and water were well below regulatory standards, and potential radiation doses to the public from activities on the reservation were significantly 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 2017 was estimated to be 0.3 mrem from air pathways, 1 mrem from water pathways (drinking water, fish consumption, swimming, recreation, and other uses), and 2 mrem from consumption of wildlife harvested on ORR. This is about 3 percent of the DOE 100 mrem standard for all pathways and is significantly less than the 300 mrem annual average dose to people in the United States from natural or background radiation. The 2017 maximum hypothetical dose is consistent with those calculated for the previous 5 years (2012–2016).

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 2017 thousands of samples and measurements of air, water, direct radiation, vegetation, fish, and wildlife collected from across the reservation were analyzed for both radioactive and nonradioactive contaminants. Sample media, locations, frequencies, and parameters were selected based on environmental regulations and standards, public and environmental exposure pathways, public concerns, 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 (EPA) 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 joint monitoring programs, and inspect facilities and operations. Continued compliance with environmental regulations and DOE orders assures on-site processes do not adversely impact the public or the environment.

Compliance with applicable regulations during 2017 for the three major ORR sites is summarized as follows:

- Y-12 experienced two notices of violation in 2017 in reference to the Resource Conservation and Recovery Act.
- ETTP had no environmental violations, issues, or findings in 2017.
- ORNL achieved 99 percent compliance with permit limits and conditions during 2017.

Chapter 2 provides a detailed summary of ORR environmental compliance during 2017. Chapters 3, 4, and 5 discuss each site's compliance status for the year.

Pollution Prevention and Site Sustainability

Numerous pollution prevention and sustainability programs across ORR embody efforts to achieve enduring sustainability in facilities, operations, and organizational culture. These programs promote energy and water conservation, building efficiency, sustainable landscaping, green transportation, sustainable acquisition, and waste minimization, which in turn decrease the life-cycle costs of programs and projects and reduce risks to the environment. While implementing their work in 2017, ORR contractors achieved a high level of excellence in operations, pollution prevention, and sustainability programs as described in Chapters 3, 4, and 5.

Cleanup Operations in 2017

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 have left 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.

A notable ETTP accomplishment in 2017 was completion of the design for the K-25 History Center, which will ensure the national historical significance of this crucial site is preserved. The History Center will feature a theater experience, period artifacts, equipment replicas, and workers' oral histories to explain K-25's historical context in World War II and the Cold War. Other significant accomplishments at ETTP included completion of characterization for the disposal of demolition debris at the Central Neutralization Facility, the beginning of demolition at the Poplar Creek facilities, and continued deactivation of Building K-1037 to prepare for its demolition in 2018.

Y-12 achievements included characterization of the eight remaining buildings at the Y-12 Biology Complex and completion of preparations for demolition of the complex, which is scheduled to begin in 2018. Also, the design was completed for the Outfall 200 Mercury Treatment Facility, which 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. A construction contract is to be awarded in 2018.

ORNL achievements included implementation of 24 new pollution prevention projects and ongoing reuse and recycling projects that eliminate more than 6.5 million kg of waste annually.

Sustainability accomplishments in 2017 included the following:

- Y-12 achieved an 8.0 percent reduction in energy use intensity from the fiscal year 2015 baseline, in line with meeting the DOE site sustainability plan reduction goal of 25 percent by fiscal year 2025, and a 65 percent reduction in water use.
- ORNL achieved a 24 percent reduction in water use intensity through fiscal year 2017, in compliance with the Executive Order 13693 reduction goal of 36 percent by 2025; a 32 percent decrease in petroleum consumption; and an increase, to 47, in the number of electric vehicle charging stations available for both personal and government fleet vehicles.
- ETTP carbon dioxide emissions have exceeded the targeted 40 percent reduction outlined in Executive Order 13693.

The Office of Environmental Management also continued planning for capital asset projects that will further advance ORR cleanup objectives. In addition to the aforementioned mercury treatment facility at Y-12, such projects include a new disposal facility that will accept debris from future cleanup at Y-12 and ORNL, and a new sludge treatment facility at the Transuranic Waste Processing Center.

1. Introduction to the Oak Ridge Reservation

The Oak Ridge Reservation (ORR) is a federally owned site in Anderson and Roane Counties in eastern Tennessee. The ORR site covers 52.3 square miles of land used for commercial and industrial activities as well as streams, lakes, and woodlands teeming with deer, wild turkey, raccoon, birds of prey (eagles, osprey, great horned owls, red tail and sparrow hawks), squirrels, and rabbits as well as wildlife predators such as coyotes and bobcats. ORR 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 facilities on ORR include the East Tennessee Technology Park (ETTP), site of a former gaseous diffusion plant that has undergone significant environmental cleanup and transition 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; a variety of smaller government-owned, contractor-operated facilities 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). Personnel entering ORR must be badged in accordance with current access security requirements.

Originally established in the early 1940s as part of the Manhattan Project to enrich uranium and pioneer methods for producing and separating plutonium, 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 differing permit reporting requirements and instrument capabilities, various units of measurement are used in this report. The list of units of measure and conversion factors provided on pages xxix and xxx is intended 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) presents summary environmental data that characterizes environmental performance, summarizes environmental occurrences reported during the year, confirms compliance with environmental standards and requirements, and highlights significant environmental program activities. The report fulfills the requirement in DOE Order 231.1B, *Environment, Safety, and Health Reporting*, Attachments 1, 2, 3, 4, and 5 (DOE 2012) requiring the preparation of an integrated annual site environmental report.

Summary results presented in this report are based on data collected before and continuing through 2017. Not all results of the environmental monitoring associated with ORR are reported here, and this report is not intended for that purpose. 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 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 release to the environment. These measurements allow the 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 measurements, collection, and analysis of samples taken from the site and its environs, exclusive of effluents. Activities such as these 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 Oak Ridge Reservation

Historically the ORR area was occupied by Native Americans. Tribes such as the Cherokee, which are descendants of Neolithic and Stone Age people, still lived in the East Tennessee region when European settlers arrived in the late 1700s. These early settlers to the ORR area lived on farms or in four small communities named Elza, Robertsville, Scarboro, and Wheat. All but Elza were founded shortly after the Revolutionary War. In the early 1940s about a thousand families inhabited the area.

The area that became ORR was selected in 1942 for the Manhattan Project, in part, because the Clinch River provided ample supplies of water, the terrain featured linear and partitioned ridges, nearby Knoxville was a good source of labor, and the Tennessee Valley Authority (TVA) could supply ample amounts of needed electricity. Families that had occupied the area's homes and farms for generations received orders to vacate within just a few weeks. More than three thousand individuals were immediately affected by the federal government's acquisition of their property. 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; others were paid less. Many felt they were poorly paid, especially for their homes.

The site's wartime name was Clinton Engineering Works. Although it was not shown on any map, the workers' city, named Oak Ridge, was established on the reservation's northern edge and grew to a population of 75,000, becoming the fifth largest city in Tennessee. To the south of the residential area, an electromagnetic separation method at the Y-12 Complex separated uranium-235 (^{235}U) from natural uranium. A gaseous diffusion plant, K-25, 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—called 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.

Since that time, 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. Their current missions, as well as the missions of several smaller DOE facilities and activities on ORR, are described in Section 1.4.

1.3 Site Description

1.3.1 Location and Population

As shown in Figure 1.1, ORR is situated in the Great Valley of East Tennessee between the Cumberland and Great Smoky Mountains and is bordered by 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 13,547 ha (33,476 acres) of mostly contiguous land in Anderson and

Roane Counties that is owned by the federal government, and is under the management of DOE. According to the U.S. Census Bureau, the estimated population of the 10-county region surrounding ORR is 1,180,996 and, as reported in *US Department of Energy FY2017 | Economic Impact in Tennessee*, about 3 percent of the region's labor force is employed on ORR. The 2017 US census population estimate for the official nine-county Knoxville metropolitan statistical area is 967,262. Other municipalities within about 30 km (18.6 mi) of the reservation include Oliver Springs, Clinton, Rocky Top, Lenoir City, Farragut, Kingston, and Harriman.

Knoxville, the major metropolitan area nearest Oak Ridge, is about 40 km (25 mi) to the east and had a population of about 187,347 according to the 2017 US census population estimate. 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.

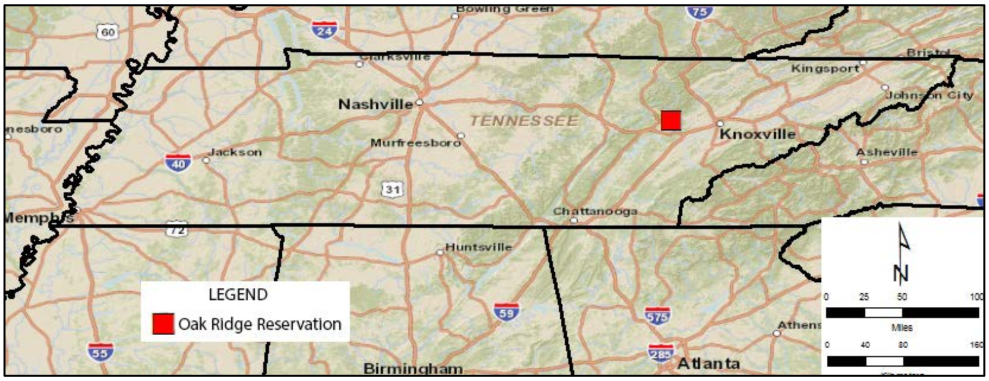

Figure 1.1. Location of the Oak Ridge Reservation in Tennessee

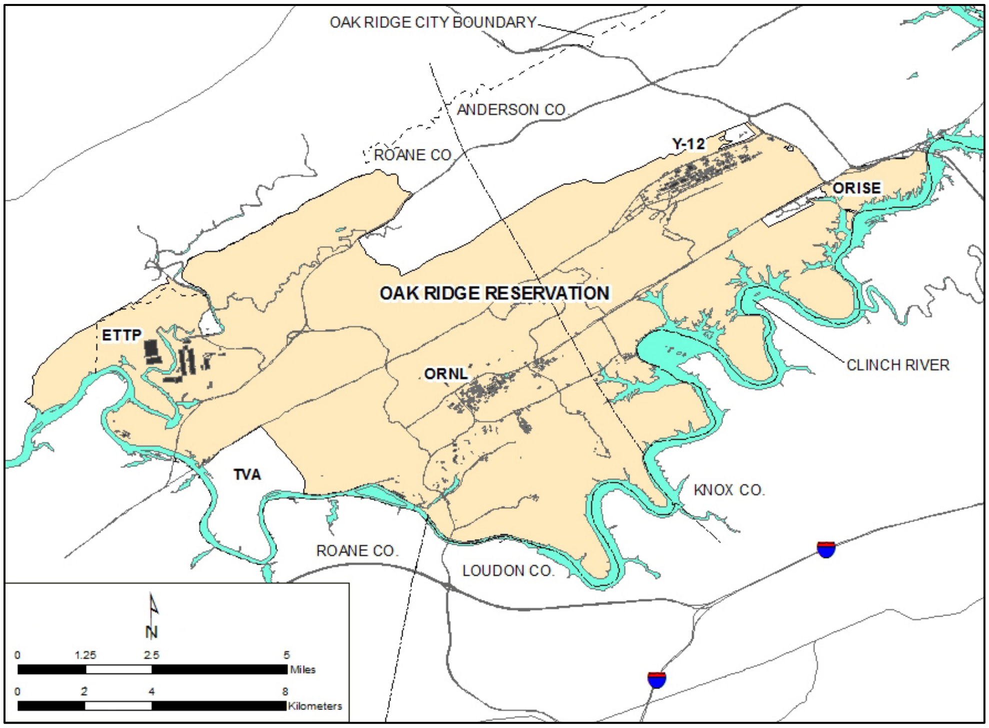

Figure 1.2. Map of the Oak Ridge Reservation

1.3.2 Climate

The climate of the Oak Ridge region may be broadly classified as humid subtropical and is characterized by significant temperature changes between summer and winter. The 30-year mean temperature for 1981–2010 was 14.7°C (58.5°F). The average high temperature for the Oak Ridge area in 2017 was 21.3°C (70.3°F). During 2017, December temperatures were coldest, averaging 9.1°C (48.4°F). July was the warmest month, with average temperatures of 30.9°C (87.6°F). Monthly summaries of temperature averages, extremes, and 2017 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 annually (NOAA 2011). Total precipitation during 2017 as measured at meteorological tower (MT)2 was 1,485.9 mm (58.48 in.), which is 10 percent above the 30-year average. Monthly summaries of precipitation averages, extremes, and 2017 values are also presented in Appendix B, Table B.1.

The average annual wind data recovery rates (a measure of acceptable data) across locations used for modeling during 2017 stood at 99.2 percent for wind sensors at the ORNL sites (towers MT2, MT3, MT4, and MT10). All other MT2, MT3, and MT4 instrument recoveries were well above 90 percent for both quarterly and annual values.

In 2017 wind speeds at ORNL Tower C/D (MT2), measured at 15 m (49 ft) above ground level, averaged 0.94 m/s (2.2 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 2017 Annual Precipitation Wind Roses−Oak Ridge Reservation.

More 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 document. A detailed analysis of wind patterns for ORR was conducted from 2009 to 2011 and is documented in Wind Regimes in Complex Terrain in the Great Valley of Eastern Tennessee (Birdwell 2011), which may be reviewed online **here**.

1.3.3 Regional Air Quality

National Ambient Air Quality Standards (NAAQS) for key principal pollutants, also known as criteria pollutants, are set by the US Environmental Protection Agency (EPA) Office of Air Quality Planning and Standards. 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 (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 classified as non-attainment areas for that pollutant.

ORR is located in Anderson and Roane Counties, as previously noted. 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 classified as a NAAQS attainment area for all other criteria pollutants for which EPA has made attainment designations.

1.3.4 Surface Water

ORR is situated in the Valley and Ridge Physiographic Province, which is composed of a series of drainage basins or troughs containing many small streams that feed the Clinch River. Surface water on ORR drains into a tributary or series of tributaries, streams, or creeks in different watersheds. Each of these watersheds drains into the Clinch River which, in turn, flows into the Tennessee River.

The largest of the 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 mostly 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 has an area of 16.5 km^2 (6.4 mi^2). White Oak Creek headwaters originate on Chestnut Ridge, north of ORNL and near the Spallation Neutron Source site. At the ORNL site, the creek flows west along the southern boundary of the developed area and 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, designated as the Knox Group and the Maynardville Limestone of the Upper Conasauga Group and consisting of dolostone and limestone, respectively, make up the most significant water-bearing hydrostratigraphic units in the Valley and Ridge Province (Zurawski 1978) and on ORR. Composed of fairly 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 referred to locally 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 for many streams (base flow), and most large springs on ORR receive discharge from the Knox Aquifer. Yields of some wells penetrating larger solution conduits are reported to exceed 3,785.4 L/min (1,000 gal/min). The high productivity of the Knox Aquifer is attributed to 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 predominantly 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, that 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

A unique variety of natural, cultural, and historic resources can be found on ORR. 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.

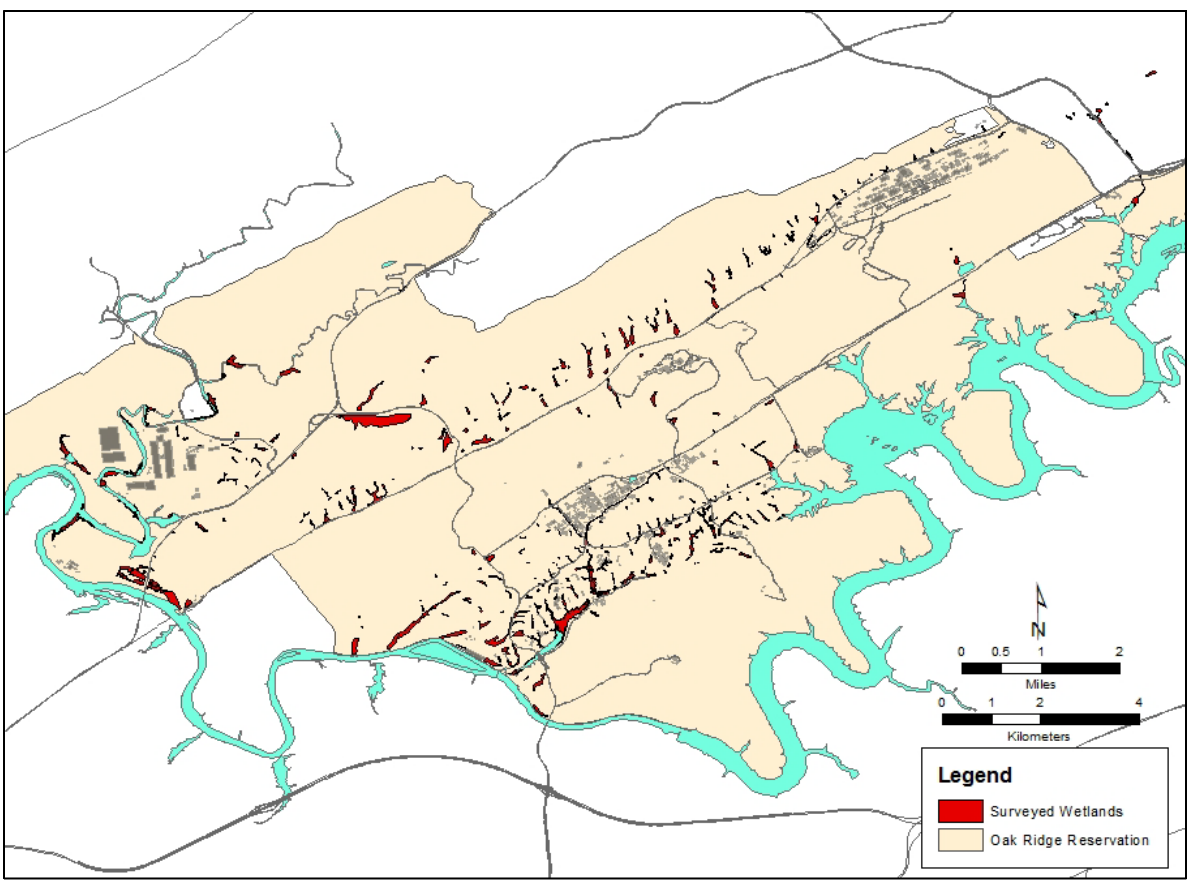

Figure 1.3. Location of Oak Ridge Reservation wetlands

About 243 ha (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 ha (25 acres) at White Oak Lake. Monitoring restored or created mitigation sites for five years is a standard requirement of the Tennessee Department of Environment and Conservation's (TDEC's) wetland mitigation Aquatic Resource Alteration Permits (ARAPs) required by Section 401 of the Clean Water Act.

Activities and conditions in and around ORNL wetlands are verified by site inspections when appropriate; see Chapter 5, Section 5.3.12. In 2017 wetlands were delineated in the Copper Ridge Borrow Area and 294 Power Line Area.

In another wetland mitigation effort that began in 2014 as part of the Uranium Processing Facility project at the Y-12 Complex, construction was completed on the Bear Creek Road Bypass Phase II and a haul road extension that modified wetlands on the north side of Bear Creek Road. 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 ARAP issued by TDEC. The wetland mitigation work performed under these permits will result in a more than 3:1 net increase in total wetland area when the multiyear project is complete. Monitoring mitigation in accordance with the permits has been initiated. Annual monitoring of wetland sites through 2017 revealed that, in general, the wetlands continue to respond as intended and have shown remarkable wetland plant coverage.

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 anhinga, have been seen only once or a few times; others, including sharp-shinned hawk and southeastern shrew, are comparatively common and widespread on the reservation. 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 can be 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	MC	NM	
Hemidactylium scutatum	Four-toed salamander		NM	
	BIRDS			
	Darters			
Anhinga anhinga	Anhinga		NM	
	Bitterns and Herons			
Ixobrychus exilis	Least bittern	MC	NM	
Ardea alba	Great egret		NM	
Egretta caerulea	Little blue heron	MC	NM	
Egretta thula	Snowy egret	MC	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]
	Kites, Hawks, Eagles, and Allies			
Haliaeetus leucocephalus	Bald eagle	MC[d]	NM	
Circus cyaneus	Northern harrier		NM	
Accipiter striatus	Sharp-shinned hawk	MC	NM	
Buteo lineatus	Red-shouldered hawk			RI
Buteo platypterus	Broad-winged hawk			RI
	Falcons			
Falco peregrinus	Peregrine falcon	MC[e]	E	RI
Falco sparverius	American kestrel	MC		RI
	Grouse, Turkey, and Quail			
Bonasa umbellus	Ruffed grouse			RI
Colinus virginianus	Northern bobwhite			RI
	Rails, Gallinules, and Coots			
Rallus limicola	Virginia rail	MC		
Porzana Carolina	Sora	MC		
Gallinula galeata	Common gallinule		NM	
	Owls			
Aegolius acadicus	Northern saw-whet owl	MC	T	RI
Tyto alba	Barn owl		NM	
	Goatsuckers			
Caprimulgus carolinensis	Chuck-will's-widow	MC		RI
Caprimulgus vociferus	Eastern whip-poor-will			RI
	Swifts			
Chaetura pelagica	Chimney swift			RI
	Kingfishers			
Megaceryle alcyon	Belted kingfisher			RI
	Woodpeckers			
Melanerpes erythrocephalus	Red-headed woodpecker	MC		RI
Sphyrapicus varius	Yellow-bellied sapsucker	MC	NM	
Picoides pubescens	Downy woodpecker			RI
Colaptes auratus	Northern flicker			RI
	Tyrant Flycatchers			
Contopus cooperi	Olive-sided flycatcher	MC	NM	RI
Contopus virens	Eastern wood-pewee			RI
Empidonax virescens	Acadian flycatcher			RI
Empidonax trailii	Willow flycatcher			RI
	Swallows			
Progne subis	Purple martin			RI
Riparia riparia	Bank swallow			RI
Hirundo rustica	Barn swallow			RI

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]
	Titmice and Chickadees			
Poecile atricapillus	Black-capped chickadee	MC	NM	
Poecile carolinensis	Carolina chickadee			RI
	Nuthatches			
Sitta pusilla	Brown-headed nuthatch	MC		RI
	Wrens			
Troglodytes	Winter wren			RI
Thryothorus ludovicianus	Carolina wren			RI
	Kinglets, Gnatcatchers, and Thrushes			
Hylocichla mustelina	Wood thrush	MC		RI
	Thrashers and Mockingbirds			
Toxostoma rufum	Brown thrasher			RI
	Waxwings			
Bombycilla cedrorum	Cedar waxwing			RI
	Shrikes			
Lanius ludovicianus	Loggerhead shrike	MC	NM	RI
	Vireos			
Vireo flavifrons	Yellow-throated vireo			RI
Vireo solitaries	Blue-headed vireo			RI
Vireo griseus	White-eyed vireo			RI
	Wood Warblers			
Vermivora chrysoptera	Golden-winged warbler	MC	NM	RI
Vermivora cyanoptera	Blue-winged warbler	MC		RI
Setophaga cerulea	Cerulean warbler	MC	NM	RI
Setophaga discolor	Prairie warbler	MC		RI
Setophaga dominica	Yellow-throated warbler			RI
Mniotilta varia	Black-and-white warbler			RI
Helmitheros vermivorum	Worm-eating warbler	MC		RI
Parkesia motacilla	Louisiana waterthrush	MC		RI
Protonotaria citrea	Prothonotary warbler	MC		RI
Geothlypis formosa	Kentucky warbler	MC		RI
Cardellina canadensis	Canada warbler	MC		RI
Setophaga citrina	Hooded warbler			RI
Icteria virens	Yellow-breasted chat			RI
Setophaga pinus	Pine warbler			RI
Cardellina pusilla	Wilson’s warbler			RI
Setophaga magnolia	Magnolia warbler			RI
Setophaga fusca	Blackburnian warbler			RI
Setophaga pennsylvanica	Chestnut-sided warbler			RI

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]
Setophaga virens	Black-throated green warbler			RI
	Tanagers			
Piranga olivacea	Scarlet tanager			RI
Piranga rubra	Summer tanager			RI
	Cardinals, Grosbeaks, and Allies			
Passerina cyanea	Indigo bunting			RI
	Towhees, Sparrows, and Allies			
Pipilo erythrophthalmus	Eastern towhee			RI
Spizella pusilla	Field sparrow			RI
Ammodramus savannarum	Grasshopper sparrow			RI
Pooecetes gramineus	Vesper sparrow		NM	
Ammodramus henslowii	Henslow's sparrow	MC	NM	RI
Melospiza Georgiana	Swamp sparrow			RI
	Blackbirds and Allies			
Dolichonyx oryzivorus	Bobolink			RI
Sturnella magna	Eastern meadowlark			RI
	Finches and Allies			
Spinus tristis	American goldfinch			RI
	MAMMALS			
Myotis grisescens	Gray bat	E	E	
Myotis sodalist	Indiana bat[f]	E	E	
Myotis septentrionalis	Northern long-eared bat	T		
Sorex longirostris	Southeastern shrew		NM	
Sorex cinereus	Masked shrew		NM	
Zapus hudsonius	Meadow jumping mouse		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
T = threatened
MC = of management concern
NM = in need of management
RI = regional importance
[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 8, 2007.
[e]The peregrine falcon was federally delisted effective August 25, 1999.
[f]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 that have been observed on ORR in recent years are mammals. Gray bats were observed 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 also captured 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).

Two-hundred twenty-nine species of birds have been recorded on ORR and its boundary waters: the 228 species documented by Roy et al. (2014) and the cackling goose (*Branta hutchinsii*), which was recorded in eBird (Sullivan et al. 2009) at the ORNL Swan Pond in November 2014. Most of these species are afforded protection under the Migratory Bird Treaty Act and Executive Order 13186, Responsibilities of Federal Agencies to Protect Migratory Birds. DOE's 2013 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 were conducted at 79 points along nine routes on ORR in 2014 for the Partners in Flight Program. Five public nature walks were held on ORR in 2017, including a bird walk, frog calls, bat monitoring, and a wildflower walk. In previous years ORR has been nominated for the Presidential Migratory Bird Federal Stewardship Award, but ORR did not receive a nomination in 2017. 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 anhinga, olive-sided flycatcher, and little blue heron are uncommon migrants or visitors to the reservation. The cerulean warbler, listed by the state as in need of management, has been recorded during the breeding season on ORR but is currently listed as a potential breeding bird on ORR (Roy et al. 2014) as its actual breeding status is still uncertain. The bald eagle (shown in Figure 1.4), also listed by the state as in need of management, 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 2011, and this pair nested again in 2012, 2013, and 2014. A second bald eagle nest, with an eaglet, was discovered in 2013. Adult eagles were observed at this nest in 2014 and eaglets were successfully fledged from the Poplar Creek nesting location in 2015. More than two dozen eaglets were fledged in East Tennessee during 2017, according to bald eagle information published by the East Tennessee State University College of Arts and Sciences, Biological Sciences department.

Other species such as the northern harrier, great egret, and yellow-bellied sapsucker are migrants, winter residents, or casual visitors and are not known to nest on the reservation. The golden-winged warbler, listed by the state as in need of management, was sighted once (in May 1998) on the reservation, as was the Lincoln's sparrow (*Melospiza lincolnii*, in May 2014, no listed status). Barn owls have been known to nest on the reservation in the past and are still occasionally seen on the reservation.

Source: Jason Richards, ORNL photographer

Figure 1.4. Bald eagle nest on the Oak Ridge Reservation

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 have been recorded in recent years, including several species associated with wetland habitats. The sora, least bittern, and Virginia rail (Figure 1.5) were all observed at the K1007 P1 pond at ETTP in 2013, where high quality wildlife habitat has been established as a result of recent restoration efforts. The sora, seen as recently as December 2013, is considered to be a fairly common migrant throughout Tennessee but it is seldom seen on ORR. The least bittern, heard in July 2012 and then again in May and July of 2013, is an uncommon migrant and summer resident in Tennessee. The Virginia rail, most recently observed in October 2013, was previously known only from historic (early 1950s) records on ORR (Roy et al. 2014). All three species have been listed by FWS as of management concern, and the least bittern is also deemed in need of management by the State of Tennessee as shown in Table 1.1.

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

One species of fish, 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 being in need of management, has been found in the Bear Creek watershed, tributaries to the lower East Fork watershed, and Ish Creek and may occur in some sections of Grassy Creek upstream of Scientific Ecology Group, Inc., and International Technology Corporation at Clinch River kilometer 23 (e.g., south of west Bear Creek Road near Grassy Creek sampling point 1.9).

1.3.6.3 Threatened and Endangered Plants

Four plant species currently 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 listed under the formerly used C2 candidate designation. These species are now informally referred to by FWS as special concern species.

Seventeen plant species occurring on ORR are listed by the state as endangered, threatened, or of special concern; these are listed in Table 1.2. (Note that 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 are known to occur in the area and, although currently unconfirmed on ORR, have the potential to be present; these are also included in Table 1.2. Other plant populations are currently under study on ORR, which may lead to future additions to the table.

The Tennessee Heritage Program scientific advisory committee met in 2012 to revise the state's Rare Plant List. Those changes are now official. This has reduced the number of state-protected species on ORR by six. The protection of these six species on ORR was a factor in their delisting.

Table 1.2. Vascular plant species listed by state or federal agencies and sighted/reported on or near the Oak Ridge Reservation, 2017

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
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.

Acronyms: ORR = Oak Ridge Reservation

1.3.6.4 Historical and Cultural Resources

Efforts continue to preserve ORR's rich prehistoric and historic cultural resources. Compliance with the National Historic Preservation Act at ETTP is achieved and maintained in conjunction with National Environmental Policy Act (NEPA) compliance. The scope of proposed actions is reviewed in accordance with the ORR cultural resource management plan (Souza et al. 2001). ETTP has 135 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 inclusion on the NRHP. More than 800 facilities have been demolished to date. Artifacts of historical or cultural significance are identified before demolition and are catalogued in a database to aid in the historic interpretation of ETTP. The reservation contains more than 45 known prehistoric sites (primarily burial mounds and archeological evidence of former structures), more than 250 historic pre-World War II structures, 32 cemeteries, and several historically significant Manhattan Project-era structures.

The National Defense Authorization Act of 2015, passed by Congress and signed into law December 19, 2014, included provisions authorizing the Manhattan Project National Historical Park. On November 10, 2015, the Manhattan Project National Historical Park was established with the execution of an agreement by the Secretaries of Energy and Interior. 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 registered with the NRHP since 1966, and has been open for public access in various ways since that time. Enhancing access and improving the visitor experience are two of DOE's objectives moving forward in implementing the National Park.

Although Buildings 9731 and 9204-3 at the Y-12 National Security Complex were eligible for listing on the NRHP in 2017, at present neither is available for regular public access. Irregular public access to both facilities occurred as recently as Nov. 12, 2015, when DOE facilitated public tours to both buildings to celebrate the establishment of the National Park. Enhancing safe access to these buildings while protecting DOE's mission capabilities is a DOE objective in implementing the National Park.

The K-25 Building site is already undergoing extensive historic interpretation activities implemented separately and independently of the National Park. Enabling safe access to the former site of the K-25 Building is among DOE's objectives in moving forward with the implementation of the National Park. As part of the activities to establish the Park, DOE released the K-25 Virtual Museum, which details the history of the K-25 Gaseous Diffusion Plant through narrative and photographs and can be found **here**.

Seven historic ORR properties are individually listed in the NRHP:

- Freels Bend Cabin
- Graphite Reactor
- 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 listed in 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 for the interpretation of historic properties at ETTP was signed in 2012 by 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. The memorandum of agreement is being implemented through planning for a museum that will highlight the historic aspects of ETTP and of the communities that were displaced during the construction of the site. During 2017, ETTP continued to operate under site-level, site-specific procedures that include 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 to the environment. To streamline the NEPA review and documentation process, DOE Oak Ridge Office has approved generic categorical exclusion determinations that cover certain proposed activities (i.e., maintenance activities, facility upgrades, and personnel safety enhancements). A categorical exclusion is one of a category of actions defined in 40 Code of Federal Regulations (CFR) Part 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.

URS | CH2M Oak Ridge, LLC (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 environmental management system requirements has been developed to aid project planners. DOE generic categorical exclusion determinations are used for routine, recurring activities. Details are provided in Chapter 3, Sections 3.3.4 and 3.8.2.

The final memorandum of agreement signed in November 2012 finalized the aspects set forth in the mitigation plan. During 2013, a request for proposals was issued for a professional design team and a museum professional as specified in the memorandum of agreement. Nine firms were prequalified, and the selection and award were executed on April 1, 2014. The procurement process for the K-25 Virtual Museum web design firm was also begun in 2013 and a contract was awarded on September 2, 2014. The K-25 Virtual Museum website referenced on the previous page was launched in conjunction with the signing of the memorandum of agreement. No new categorical exclusion determinations for activities at ETTP were issued by DOE in 2017.

The Historic American Engineering Record documentation for the K-1037 Barrier Plant was completed and approved by the National Park Service in May 2017. The Historic American Engineering Record documentation for the K-25 Building is being prepared for transmittal to the National Park Service.

Two 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 at ORNL and at Y-12 have been enforced since their respective approvals.

1.4 Oak Ridge Sites

The Oak Ridge Reservation includes a number of sites critical to the mission of DOE. Eight of these sites, including the Oak Ridge National Laboratory, the Y-12 National Security Complex, the East Tennessee Technology Park, the Environmental Management Waste Management Facility, the Oak Ridge Environmental Research Park, the Oak Ridge Institute for Science and Education, the National Nuclear Security Administration Office of Secure Transportation Agent Operations Eastern Command, and the Transuranic Waste Processing Center Sludge Buildout Facility, are described in the following sections.

1.4.1 Oak Ridge National Laboratory

ORNL (shown in Figure 1.6) is managed for DOE by UT-Battelle, LLC, a partnership of the University of Tennessee and Battelle Memorial Institute. It is the largest science and energy national laboratory in the DOE system, conducting 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 also manages the US 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 there are about 4,400 workers at ORNL, and the laboratory's extensive capabilities for scientific discovery and innovation are applied to the delivery of mission outcomes for DOE and other sponsors.

Figure 1.6. Aerial view of the Oak Ridge National Laboratory

During fiscal year 2017, DOE remained focused on disposing of a significant inventory of ^{233}U stored in Building 3019 at ORNL. This special nuclear material requires strict safeguards and security controls to protect against access. The objectives of the ^{233}U Project are to address safeguards and security requirements, eliminate safety and nuclear criticality concerns, and safely dispose of the material. In 2015 DOE 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 ^{233}U stored in the complex. As of November 2017, all shipments of ^{233}U stored in Building 3019 had been shipped to the National Nuclear Security Site.

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 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.

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 ^{235}U from natural uranium by an electromagnetic separation process. At its peak in 1945, more than 22,000 workers were employed at the Y-12 site.

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

Today, as part of the NNSA Nuclear Security Enterprise, the Y-12 Complex serves as the nation's only source of enriched uranium nuclear weapons components and provides enriched uranium for the US Navy. The Y-12 Complex 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.

UCOR is the DOE ORR cleanup contractor responsible for mercury remediation at the Y-12 Complex. In December 2017, UCOR issued the *Construction Execution and Management Plan for the Outfall 200 Mercury Treatment Facility at the Y-12 Nuclear Security Complex, Oak Ridge, Tennessee*. The goal of the Mercury Treatment Facility is to reduce the mercury concentration in water exiting the Y-12 Complex. Outfall 200 is the point at which the west end Y-12 storm drain system discharges to Upper East Fork Poplar Creek, and mercury from historical operations is present in the Outfall 200 storm water entering Poplar Creek. 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. Three lines of investigation for East Fork Poplar Creek were developed: 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. Also in 2017, UCOR awarded a contract to GEM Technologies to perform work for the new Outfall 200 Mercury Treatment Facility at Y-12.

At the end of fiscal year 2017, the Y-12 Complex had achieved seven of its 14 established targets; the remaining targets were carried into future years. Overall, 17 actions were completed through September 2017. Highlights include the following; additional details and successes are presented in other sections of this report.

- **Clean Air:** The Y-12 Complex finalized the evaluation of its uranium monitored-stack infrastructure to identify refurbishment needs for continued safe and compliant operations. Significant progress was made in obtaining a new Title V air permit.
- **Energy Efficiency:** Implementation of five Energy Savings Performance Contract energy conservation measures began in fiscal year 2014 for projects to improve lighting, chilled water, air compressors, and the Y-12 Complex steam system. All five projects were completed in 2017. Significant progress was made on the effort to obtain Leadership in Energy and Environmental Design (LEED) certification on the Uranium Processing Facility Construction Support Building. A Silver Certification was awarded, with the additional credit points required for obtaining a Gold Certification pending occupancy.
- **Hazardous Materials:** A project to improve controls for intermodal storage containers was substantially implemented in 2017, and the contents of more than half of the 128 excess intermodal containers were disposed of or dispositioned. A project to disposition and ship nine items of legacy mixed waste per Site Treatment Plan milestones was completed in 2017.
- **Reduce/Reuse/Recycle/Buy Green:** The Y-12 Complex completed a project to strengthen the site-wide procedure for handling universal waste in 2017, and began a project to install a drum crusher in one facility to greatly reduce the quantity of empty drum waste.

The Mercury Treatment Facility is being 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, and then treat the stored water 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. The design of the Outfall 200 Mercury Treatment Facility incorporates flexibility, and treatment processes for mercury can be expanded if required in the future. Y-12 treated 115 million gallons of wastewater during fiscal year 2017.

Understanding the movement of mercury in the East Fork Poplar Creek system was deemed essential to the development of new technologies and ultimately to the development of remedial options and strategies for the creek. Early studies have pointed to the importance of bank soils and sediments as a source of mercury to the creek, especially during high-flow events. Research is under way to examine potential technologies that may limit mercury erosion. Stream management changes—such as controlling nutrients or algae growth or managing fish populations—are also under investigation. A March 2015 report titled *Mercury Remediation Technology Development for Lower East Fork Poplar Creek* (ORNL 2014) offered science-based approaches and ideas for research and technology development activities that may lead to new mercury remediation projects.

1.4.3 East Tennessee Technology Park

What is now known as ETTP (see Figure 1.8), and was originally named K-25, is the site of the nation's first gaseous diffusion plant for enriching uranium as part of the Manhattan Project. Additional uranium enrichment facilities K-29, K-31, and K-33 were built adjacent to K-25 during the Cold War, forming a complex officially known as the Oak Ridge Gaseous Diffusion Plant. Uranium enrichment operations at the site ceased in 1987, 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

During 2017, ETTP landlord contractor functions and the majority of the ETTP cleanup program actions were managed by UCOR. ETTP had no reportable releases of hazardous substances or extremely hazardous substances, as defined by the Emergency Planning and Community Right-to-Know Act of 1986, in 2017. As of the end of 2017 all debris and the concrete pad of the final demolished gaseous diffusion building had been removed. The annualized levels of chromium and lead during 2017 were below the indicated annual standards. The K-1423 Repacking Facility, which was once used to store polychlorinated biphenyls (PCBs) and was in standby status, was officially closed in 2017. One noncompliance occurred in 2017 when an unknown volume of sanitary wastewater was potentially discharged to Mitchell Branch via Outfall 210. However, no regulatory issues were encountered in fiscal year 2017 during two separate TDEC site visits, and no regulatory issues were identified during two separate Contracting Officer's Representative assessments and inspections.

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.

1.4.4 Environmental Management Waste Management Facility

The Environmental Waste Management Facility, or 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 (CERCLA) cleanup actions on ORR. The original design was for the construction, operation, and closure of a projected 1.3 million m^3 (1.7 million yd^3) disposal facility. The approved capacity was subsequently increased to 1.8 million m^3 (2.4 million yd^3) to maximize use of the footprint designated in a 1999 record of decision. The facility currently consists of six disposal cells. EMWMF will reach its capacity before the Oak Ridge Office of Environmental Management completes its cleanup at Y-12 and ORNL. Planning continued throughout fiscal year 2017 for a new facility, the Environmental Management Disposal Facility, that will provide the additional disposal capacity needed to complete the cleanup at Oak Ridge.

During fiscal year 2017 the EMWMF received 5,309 waste shipments, accounting for 71,534 tons, from cleanup projects at ETTP, ORNL, and Y-12.

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 the DOE 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 fiscal year 2017 the facility collected, analyzed, and disposed of approximately 4.46 million gallons of leachate. The leachate is treated at the ORNL Liquids and Gaseous Treatment Facility, which is also operated by UCOR.

1.4.5 Oak Ridge Environmental Research Park

In 1980 DOE established the Oak Ridge Environmental Research Park (see Figure 1.10) managed for DOE by UT-Battelle, which serves as an outdoor laboratory to evaluate the environmental consequences of energy use and development and the strategies to mitigate those effects. It contains large blocks of forest and diverse communities of vegetation that 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 of time. 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.

National recognition of the value of the research park has led to its use as a component of both regional- and continental-scale research projects. Various 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.

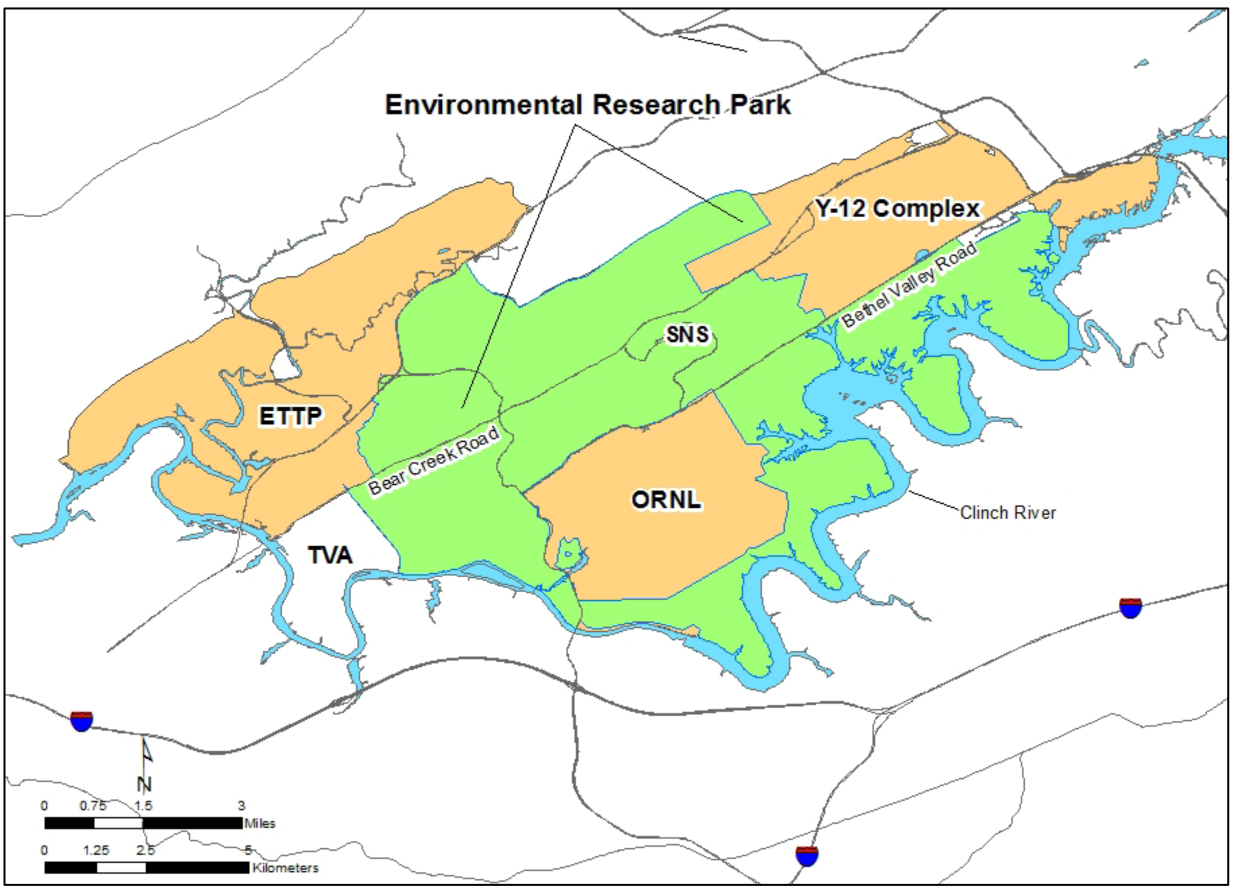

Figure 1.10. Location of the Oak Ridge Environmental Research Park

1.4.6 Oak Ridge Institute for Science and Education

The 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 their 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 (OST).

The NNSA OST Agent Operations Eastern Command (AOEC) Secure Transportation Center and Training Facility is located on ORR. NNSA OST AOEC is situated on about 723 ha (1,786 acres) and 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 TWPC Sludge Buildout Facility

The Transuranic Waste Processing Center (TWPC) is located on an approximately 10.5 ha (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 the 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.

Key progress for the project during fiscal year 2017 included the following actions:

- Released a request for information to potential vendors for the sludge mobilization system.
- Completed initial development of a design package for the Sludge Test Area, design of the density test element skid, and the specification package for offsite vendor testing of the slurry mixing and characterization tanks and measurement system. These were issued to the Oak Ridge Office of Environmental Management for review.
- Completed process chemistry modeling and issued a Chemistry Modeling Report (calculation) to support an update of the Integrated Systems Test Plan.
- Conducted quarterly Safety Design Integration Team meetings.

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2. Compliance Summary and Community Involvement

Environmental standards established by federal and state statutes and regulations including Executive Orders, DOE orders, contract-based standards, and compliance and settlement agreements require conformance by DOE operations on ORR. EPA and TDEC are the principal regulating agencies that issue permits, review compliance reports, participate in joint monitoring programs, inspect facilities and operations, and oversee compliance with applicable regulations.

Environmental concerns or problems identified during routine operations or during ongoing self-assessments of compliance status require discussions with the respective regulatory agencies. The major environmental statutes and their 2017 status for DOE operations on ORR are summarized in the following sections. The DOE Reindustrialization Program has provided several facilities at ETTP and the Oak Ridge Science and Technology Park sites for lease to private entities over the past several years. The compliance status of these lessee operations is not discussed in this report.

Because of different permit reporting requirements and instrument capabilities, various units of measure are used in this report. The list of units of measure and conversion factors provided on pages xxix and xxx is intended to help readers convert numeric values presented in this document as needed for specific calculations and comparisons.

2.1 Laws and Regulations

The principal environmental standards applicable to DOE activities on ORR, the 2017 status, and references to the report sections that provide more detailed information are summarized in Table 2.1.

2.2 External Oversight and Assessments

Inspections of ORR environmental activities conducted by regulatory agencies during 2017 are summarized in Table 2.2. This table does not include internal DOE or DOE contractor assessments, audits, or evaluations.

The Tennessee Oversight Agreement (TOA) allows a program of independent monitoring and oversight of DOE activities on ORR. The TOA is a voluntary agreement between DOE and the State of Tennessee and is designed to assure the citizens of Tennessee that their health, safety, and environment are being protected through existing programs and substantial new commitments by DOE. More information on TOA and reporting of monitoring conducted under TOA is available **here**.

Table 2.1. Applicable environmental laws and regulations and 2017 status

Regulatory program description	2017 status	Report sections
The Clean Air Act (CAA) 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 DOE internal oversight.	In 2017, all activities on ORR were conducted in accordance with CAA requirements.	3.3.5 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 the aforementioned 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 2017.	3.3.11 4.3.7 5.3.7 5.3.8 3.3.2
The Clean Water Act (CWA) 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. A compliance rate of greater than 99% was achieved by all three major ORR sites in 2017. One carbonaceous biological oxygen demand event, five ammonia, and three *E. coli* noncompliances occurred at the ORNL sewage treatment plant in May 2017 due to heavy rains in April 2017. Corrective actions were immediately put in place, and operations were fully restored before the end of July 2017. There was one noncompliance in 2017 when a bathroom and shower facility (K-2527-T) overflowed a storage tank into the secondary containment dike. See Appendix D for more information.	3.3.6 4.3.4 5.3.4 3.3.7

Table 2.1. Applicable environmental laws and regulations and 2017 status (continued)

Regulatory program description	2017 status	Report sections
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.	To comply with EISA, a variety of storm water management techniques referred to as green infrastructure or low impact design practices have been implemented on ORR. The site sustainability plans and associated reporting provide data on sustainability projects and support EISA § 438 compliance.	4.2.6.3 5.2.1.5
The Emergency Planning and Community Right-to-Know Act (EPCRA), also referred to as the Superfund Amendments and Reauthorization Act (SARA) Title III, requires reporting emergency planning information, hazardous chemical inventories, and environmental releases of certain toxic chemicals to federal, state, and local authorities.	In 2017 DOE facilities on ORR were operated in accordance with emergency planning and reporting requirements. ETTP had no reportable releases of hazardous substances or extremely hazardous substances, as defined by EPCRA, in 2017.	3.3.14 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 2017 DOE planning and decision-making activities at ETTP and ORNL were conducted via site-level procedures that provide requirements for project reviews and NEPA compliance. At Y-12 environmental evaluations were completed for 48 proposed actions during 2017.	3.3.4 4.3.2 5.3.2
The National Historic Preservation Act (NHPA) provides protection for the nation's historic resources by establishing a comprehensive national historic preservation policy.	ORR has several facilities eligible for inclusion in the National Register of Historic Places. Proposed activities are reviewed to determine potential adverse effects on these properties, and methods to avoid or minimize harm are identified. During 2017 activities on ORR were in compliance with NHPA requirements.	3.3.4 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 for the presence of wetlands are conducted on a project or program as-needed basis through NEPA and other reviews. Wetland protection on ORR is conducted in accordance with 10 CFR 1022 and EO 11990, *Protection of Wetlands*. Annual monitoring of remediated wetland sites through 2017 revealed that the wetlands are responding as intended. In 2017 wetlands were delineated in the Copper Ridge Borrow Area and 294 Power Line Area.	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.	3.3.9 4.3.6 5.3.6

Table 2.1. Applicable environmental laws and regulations and 2017 status (continued)

Regulatory program description	2017 status	Report sections
The Safe Drinking Water Act (SDWA) 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. In 2017 sampling results for ORNL's water system residual chlorine levels, bacterial constituents, and disinfectant by-products were all within acceptable limits.	3.3.8 4.3.5 5.3.5
The Toxic Substances Control Act (TSCA) regulates the manufacture, use, and distribution of a number of toxic chemicals.	PCB waste generation, transportation, disposal, and storage at ETTP are regulated under EPA ID number TN0890090004. In 2017 ETTP operated five PCB waste storage areas in ETTP generator buildings, and when longer-term storage of PCB and radioactive wastes was necessary, RCRA permitted storage buildings were used. A single PCB waste storage area in Building K-1423 is not part of the RCRA permitted storage buildings. 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.	3.3.13 4.3.8 5.3.9
The Bald and Golden Eagle Protection Act (16 U.S.C. 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. Currently two active bald eagle nests on ORR are protected in accordance with this act. Eaglets were successfully fledged from a Poplar Creek nesting location in 2015.	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 2017 status (continued)

Regulatory program description	2017 status	Report sections
DOE O 231.1B, *Environment, Safety, and Health Reporting,* ensures timely collection, reporting, analysis, and dissemination of information on environment, safety, and health issues.	The *Oak Ridge Reservation Annual Site Environmental Report for 2017* summarizes ORR environmental activities during 2017 and characterizes environmental performance.	All chapters
DOE O 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.	3.8.1 4.2.3.4 5.8
DOE O 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 to ensure compliance with this DOE order.	3.2 4.2 5.2
DOE O 458.1, ***Radiation Protection of the Public and the Environment,*** issued in June 2011, canceled DOE O 5400.5 and 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.	In 2017, DOE O 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 O 5400.5 requirements. A dose assessment, 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, estimated the maximum 2017 dose to a hypothetically exposed member of the public from all ORR potential exposure pathways combined would be about 0.3 mrem. The 2017 maximum effective dose was about 3% of the limit given in DOE O 458.1. Clearance of property from ORNL, ETTP, and the Y-12 Complex was conducted in accordance with approved procedures that comply with DOE O 458.1. During 2017, there were no unplanned radiological air emission releases from the three major ORR sites.	4.3.13 Chapter 7 4.3.11

Table 2.1. Applicable environmental laws and regulations and 2017 status (continued)

Regulatory program description	2017 status	Report sections
DOE O 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 O 5400.5 is the primary environmental surveillance radiological applicable, relevant, and appropriate requirement for most CERCLA activities across ORR, and it will remain in force until the individual CERCLA decision documents are reissued or revised to incorporate DOE O 458.1. A dose assessment, 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, estimated the maximum 2017 dose to a hypothetically exposed member of the public from all ORR potential exposure pathways combined would be about 0.3 mrem.	Chapter 7
EO 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
EO 13693, *Executive Order -- Planning for Federal Sustainability in the Next Decade,* instructs federal agencies to increase efficiency and improve their environmental performance, which will protect our planet for future generations and save taxpayer dollars through avoided energy costs.	EO 13693, *Planning for Federal Sustainability in the Next Decade*, superseded EO 13514 in fiscal year 2015 and established a new Scope 1 and Scope 2 total reduction target of 40% by 2025. Progress toward achieving DOE sustainability goals is summarized in this report. ORNL, Y-12, and ETTP activities complied with and exceeded the planning and reporting requirements of these executive orders in 2017. Comparing the ETTP fiscal year 2017 total of 17,894 metric tons to the 40% target level of 31,232 metric tons shows that the targeted 40% reduction in greenhouse gas emissions has already been achieved .	3.2.4 3.5.1.5 4.2.6.8 5.2.1.4

[a]DOE. 2015. *2015 Strategic Sustainability Performance Plan*. US Department of Energy, Washington, DC.

Acronyms:
CAA = Clean Air Act
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
CWA = Clean Water 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
EPCRA = Emergency Planning and Community Right-to-Know Act
ETTP = East Tennessee Technology Park
NEPA = National Environmental Policy Act
NHPA = National Historic Preservation Act
NPDES = National Pollutant Discharge Elimination System
NRHP = National Register of Historic Places
ORNL = Oak Ridge National Laboratory
ORR = Oak Ridge Reservation
PCB = polychlorinated biphenyl
RCRA = Resource Conservation and Recovery Act
SDWA = Safe Drinking Water Act
TDEC = Tennessee Department of Environment and Conservation
TSCA = Toxic Substances Control Act
UCOR = URS | CH2M Oak Ridge LLC
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, 2017

Date	Reviewer	Subject	Issues
		ORNL **(including UT-Battelle, LLC; UCOR; Isotek; and NorthWind Solutions, LLC activities)**	
January 9	City of Oak Ridge	Carbon Fiber Technology Facility (CFTF)Wastewater Inspection	0
March	TDEC	Inspection of Underground Injection Control Program	0
April 11–12	TDEC	Annual RCRA Inspection for ORNL (including Transuranic Waste Processing Center)	0
May 25–26	TDEC	NPDES Permit Inspection	0
July 27	TDEC	National Transportation Research Center RCRA Inspection	0
September 28	City of Oak Ridge	CFTF Wastewater Inspection	0
October 17	City of Oak Ridge	CFTF Wastewater Inspection	0
October 26–27	TDEC	Annual CAA Inspection for ORNL and CFTF	0
		ETTP	
February 27	TDEC	Annual RCRA Compliance Inspection	0
October	City of Oak Ridge	Sewage Manhole Radiologic Inspection	0
November	City of Oak Ridge	Visit to discuss radiologic discharges to the Rarity Ridge Collection System	0
		Y-12 Complex	
February 21	City of Oak Ridge	Semiannual Industrial Pretreatment Compliance Inspection	0
April 25, 27	TDEC	Annual CAA Inspection	0
June 20–21	TDEC	Underground Injection Control Program Compliance Inspection	0
July 19-24	TDEC	Annual RCRA Hazardous Waste Compliance Inspection	2
September 26–27	TDEC	NPDES Compliance Evaluation Inspection	0
October 3	City of Oak Ridge	Semiannual Industrial Pretreatment Compliance Inspection	0
November 16, 30	TDEC	Annual CAA Inspection	0

Acronyms:
CAA = Clean Air Act
CFTF = Carbon Fiber Technology Facility
ETTP = East Tennessee Technology Park
Isotek = Isotek Systems LLC
NPDES = National Pollutant Discharge Elimination System
ORNL = Oak Ridge National Laboratory
RCRA = Resource Conservation and Recovery Act
TDEC = Tennessee Department of Environment and Conservation
UCOR = URS | CH2M Oak Ridge LLC
Y-12 Complex = Y-12 National Security Complex

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 CFR 110.3[b]).

ORNL, ETTP and Y-12 had no reportable releases of extremely hazardous substances, as defined by EPCRA, in 2017.

See Sections 3.6.4.7, 4.3.11, and 5.3.10 for more information.

2.4 Notices of Violations and Penalties

ETTP: No issues, findings or violations during fiscal year 2017

ORNL: No Issues, findings or violations during fiscal year 2017

Y-12: Two notices of violation during fiscal year 2017

2.5 Community Involvement

Many community involvement activities were provided by or supported by DOE and its contractors in 2017 across a diverse range of subjects and activities. These included ETTP historic interpretation efforts, Manhattan Project National Historical Park public meetings and public engagement, 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 comment periods for draft environmental assessments, and Community Relations Council meetings.

During 2017 organizations such as Great Smoky Mountains National Park, the East Tennessee Foundation, Girls, Inc., as well as America Recycles Day and Earth Day activities and 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 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 www.energy.gov/ORSSAB.

Videos of the first hour of recent board meetings are posted at www.youtube.com/user/ORSSAB.

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 http://doeic.science.energy.gov.

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: http://doeic.science.energy.gov
- EPA Region 4: http://www.epa.gov/region4
- ETTP: http://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 2017. *2017 Remediation Effectiveness Report for the U.S. Department of Energy Oak Ridge Reservation, Oak Ridge, Tennessee, Data and Evaluations*. DOE/OR/01-2731&D2. US Department of Energy, Oak Ridge, Tennessee.

3. East Tennessee Technology Park

ETTP was originally 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, and 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 vegetation from ETTP and the surrounding area. Monitoring results are used to assess exposures to members of the public and the environment, to assess the performance of treatment systems, to help identify areas of concern, to plan remediation efforts, and to evaluate the efficacy of remediation efforts. In 2017, there was better than 99 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. 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. The K-25 Site, formerly the K-25 Gaseous Diffusion Building, is within the boundary of the newly established National Park. 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 (now renamed the K-25 Building Footprint) through narrative and photographs, and can be found **here**.

3.1 Description of Site and Operations

Construction of the K-25 Site (Figure 3.1) began in 1943 as part of the World War II Manhattan Project. The plant’s original mission was the production of enriched uranium for nuclear weapons. Enrichment was initially carried out in the S-50 thermal diffusion process facility, which operated for 1 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 the Oak Ridge Gaseous Diffusion Plant (ORGDP).

After military production of highly enriched uranium (HEU) was concluded in 1964, the two original process buildings were shut down. For the next 20 years, the plant’s primary missions were 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.

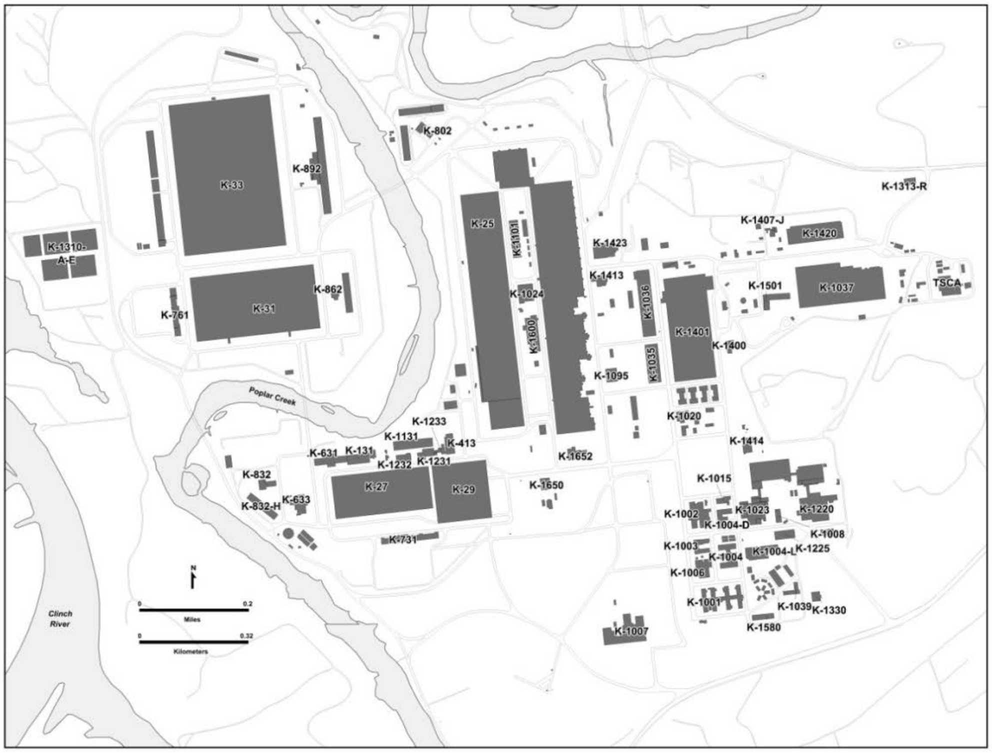


Figure 3.2. East Tennessee Technology Park before the start of decontamination and decommissioning activities in 1991

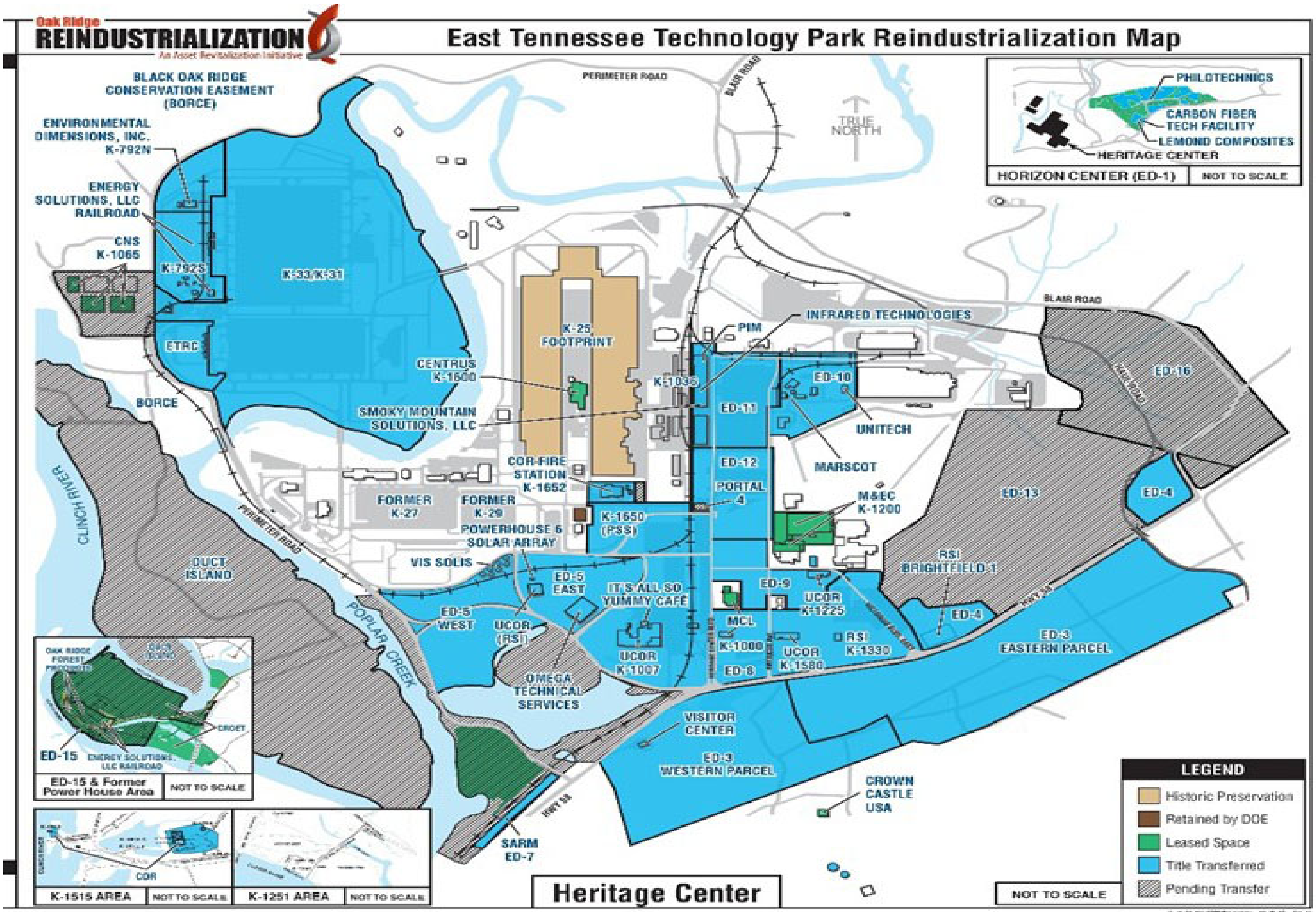


Figure 3.3. East Tennessee Technology Park in 2017, showing progress in reindustrialization

Figure 3.3 shows the ETTP areas designated for D&D activities through 2017. The ETTP mission is to reindustrialize and reuse site assets through leasing and/or transferring excess or underutilized land and facilities and through incorporating commercial industrial organizations as partners in the ongoing environmental restoration, D&D, and waste treatment and disposal.

The site is undergoing environmental cleanup of its land, as well as D&D of most of its buildings. The cleanup approach makes land and various types of buildings (e.g., office, manufacturing) suitable for private industrial use and for title transfer to the Community Reuse Organization of East Tennessee (CROET) or other entities such as the City of Oak Ridge (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, 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:

- **Management 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 Environmental Stewardship Scorecard

The Environmental Stewardship Scorecard is used to track and measure site-level EMS performance. During 2017 UCOR received "green scores" for EMS performance. As an example, Figure 3.4 presents information on UCOR's 2017 P2 recycling activities related to solid waste reduction at ETTP. UCOR recycles office and mixed paper, cardboard, phone books, newspapers, magazines, aluminum cans, antifreeze, engine oils, batteries (lead [Pb] acid, universal waste, and alkaline), universal waste bulbs, plastic bottles, all types of #1 and #2 plastics, and surplus electronic assets, such as computers (CPUs and laptops) and monitors (cathode ray tubes [CRTs] and liquid crystal displays [LCDs]). Other recycling opportunities include unique structural steel, stainless-steel structural members, transformers, and electrical breakers.

UCOR's exceptional electronics stewardship earned it an award in 2017 from the Green Electronics Council for its use of Electronic Product Environmental Assessment Tool (EPEAT) methods. There are two categories at the two-star level—one for computers and displays, and one for imaging equipment. EPEAT purchasers earn a star for each product category for which they have a policy in place and purchase EPEAT-registered electronics. EPEAT is a free and trusted source of environmental product ratings that help purchasers select high-performance electronics that meet their organizations' IT and sustainability goals. Manufacturers register products based on the devices' ability to meet various criteria developed and agreed upon by diverse stakeholders to address the full life cycle of an electronic product.

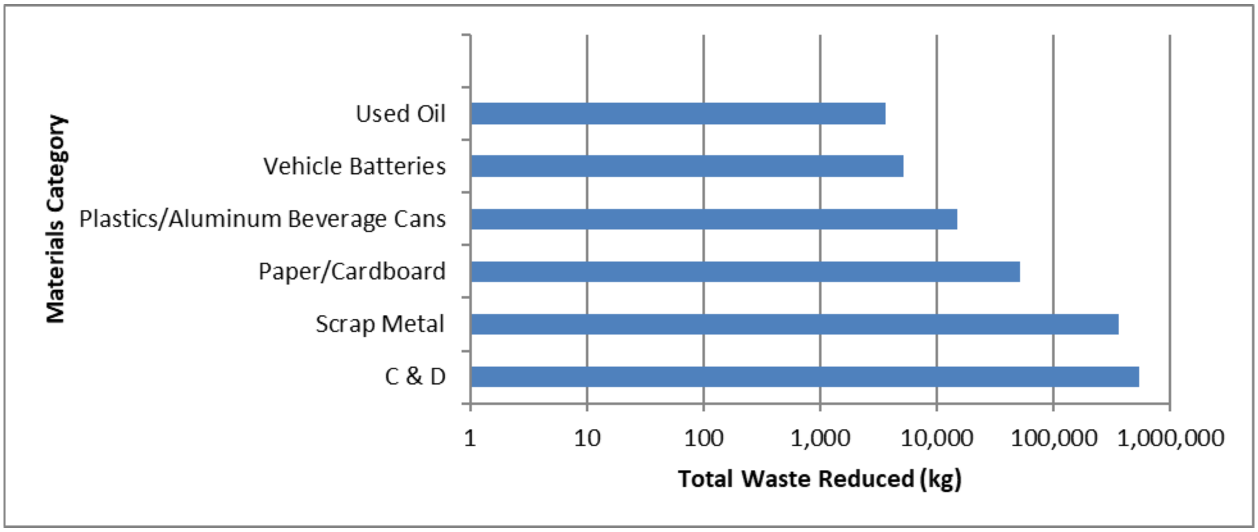


Figure 3.4. Pollution prevention recycling activities related to solid waste reduction at East Tennessee Technology Park in Calendar Year 2017

Additionally, UCOR internally recognized six projects for their P2/waste minimization (P2/WMin) accomplishments in 2017, which are summarized below.

- The EMWMF team was recognized for implementing a berm in Cell 6 covering part of the cell that is clean, to divert water from a portion of the waste cell when it opens in 2018. This action will avoid the creation of millions of gallons of projected leachate water that would have to be managed, mitigating adverse impacts on the environment, avoiding treatment and its associated transportation, and will provide $745,000 in savings annually.
- The ETTP Fleet Management and Operations and Real Estate Services organizations were recognized for the first addition of hybrid vehicles to its fleet. The increased mileage of the sedans is estimated to save 160 gal of fuel in the first year, avoiding 1,606 lb of CO^2 emissions. There are plans to procure more such vehicles.
- The ORNL Nuclear and High Hazard Operations (NHHO) project identified and recycled 5,000 lb of lead that would otherwise have gone to a landfill. In addition, it saved $5,000 in disposal costs.
- The UCOR ETTP Reindustrialization, Business Assurance and Compliance, Decontamination & Demolition, and Environmental Remediation and Closure organizations and the K-1007 Local Site

Improvement Team Preparation, Institution, Listening and Learning Leads to Safety groups together harnessed a number of programs, to identify valuable glass cases for use, conserving landfill space, avoiding carpentry and virgin materials to build them and increasing work efficiencies by providing central locations for communications.

- The ORNL NHHO project worked with the Environmental Compliance Group to negotiate with regulators an alternate calculation that would avoid continually adding costly fans to increase stack flow to the 3039 Stack, as buildings continually go offline in 2018. This avoided $1.4 million in the first year alone.
- The UCOR ETTP Personal Property Management and Receiving and Disposition organizations recycled 600,690 lb of metal in FY 2017, saving landfill space, conserving virgin material, and generating $41,000 in revenues to go back into projects.

ETTP also continually strives to find new avenues for waste diversion. In 2016, a significant improvement in the diversion of scrap metal was made. In the course of demolition and environmental cleanup, one challenge has been the ability to divert large volumes of construction and demolition debris from disposal in landfills due to radiological contamination. However, despite the radiological challenge, a substantial amount of scrap metal located inside of Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)-designated areas is still eligible for recycling because it is not radiologically contaminated. For the nonradiological areas, a second challenge was identified due to the CERCLA Offsite Rule that requires all disposal and recycle facilities receiving CERCLA waste be reviewed and approved by the EPA for acceptability. UCOR conducted a nationwide search for scrap metal recyclers that EPA had determined to be acceptable with the CERCLA Offsite Rule requirements all the way through the required smelter/foundry process step; however, none were located. Therefore, the only available option for disposal of the noncontaminated CERCLA scrap metal was land disposal.

In 2017 UCOR continued to work with EPA and the Tennessee Department of Environment and Conservation (TDEC) to apply the CERCLA screening process that allows noncontaminated scrap metal from CERCLA areas to be 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 unprecedented agreement allowed approximately an additional 181,200 lb (82 metric tons [MT] of scrap metal to be recycled in FY 2017 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 216 yd^3 of valuable landfill space at an estimated cost savings of approximately $46,200, 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, ORNL, and Y-12.

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

Figure 3.5. Brightfield 1 Solar Farm

RSI self-financed the project, using solar panels manufactured in Tennessee, and partnering with other local small businesses for the installation. Power generated from Brightfield 1 is being sold to the Tennessee Valley Authority (TVA) through the City of Oak Ridge Electric Department using a TVA Generation Partners contract. The completed project was commissioned in April 2012 and is part of RSI's Brownfields to Brightfields (B2B) 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) 2017, Brightfield 1 produced approximately 250,000 kWh of energy.

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 boosters development at ETTP. This project provides numerous benefits to the environment and the community at large, and includes 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 carbon dioxide).
- Provides brownfield reuse/redevelopment at ETTP.
- Supports the COR renewable energy goals.
- Supports the TVA renewable energy initiative.
- 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 continued to use green products whenever possible and evaluated large quantity purchases for less toxic alternatives. In addition, UCOR maintained its extensive recycling program, which helps provide employment to beneficiaries of local charities who are employed by the local recycling facility for the county.

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 assessments conducted by functional or project organizations, and routine field walkdowns conducted by a variety of functional and project personnel. Management and independent assessments are performed in accordance with *Management Assessment*, PROC-PQ-1420, and *Independent Assessment*, PROC-PQ-1401. Assessments are scheduled on the UCOR Quality Assurance System (QAS) in accordance with PROC-PQ-1420. Records are maintained for all formal assessments and audits. Issues identified in assessments are handled, as required, by ISO 14001:2015, Section 4.5.3, “Nonconformity, Corrective Action, and Preventive Action” (ISO 2015).

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 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.

The environmental performance objectives are to achieve zero unpermitted discharges to the environment; comply with all conditions of environmental permits, laws, regulations, and DOE orders; integrate EMS and environmental considerations as part of ISMS; and, to the extent practicable, reduce waste generation, prevent pollution, maximize recycle and reuse potential, and encourage environmentally preferable procurement of materials with recycled and bio-based content.

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.

3.2.5 Implementation and Operations

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 management assessments also provide a measure of how well EMS attributes are integrated into work activities through ISMS. UCOR has embodied its program for EC&P 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

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 or other wastes generated 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.

Total cost savings and avoidance associated with these projects were in excess of $2.1 million and resulted in conserving valuable landfill space, and resources, as well as mitigating water contamination, and greenhouse gas emissions. The internal awards will be evaluated for nomination in national-level awards (e.g., DOE Headquarters annual award program).

3.2.7 Competence, Training, and Awareness

The UCOR training and qualification process ensures that needed skills for the workforce are identified and developed. The process also documents knowledge, experience, abilities, and competencies of the workforce for key positions requiring qualification. This process is described in PROC-TC-0702, *Training Program*. Completion and documentation of training, including required reading, are managed by the Local Education Administration Requirements Network (LEARN).

3.2.8 Communication

UCOR communicates externally regarding environmental aspects through the UCOR public website, which includes a link to its environmental policy statement in *Environmental Management and Protection,* POL-UCOR-007; a list of environmental aspects; and a link to the *Integrated Safety Management System Description*, PPD-EH-1400.

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 2016, DOE/ORO-251] and the annual cleanup progress report [UCOR 2017b, *2017 Cleanup Progress—Annual Report to the Oak Ridge Regional Community*, OREM-17-2530]).

UCOR participates in a number of public meetings related to environmental activities at the site (e.g., Oak Ridge Site Specific Advisory Board [ORSSAB] 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 Do-Act-Check, it provides a framework by which work incorporates 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 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 2018, UCOR-4127/R6). The EMS program is audited by a third party triennially by EO 13423, *Strengthening Federal Environmental, Energy, and Transportation Management* (EO 13423), for conformance to the ISO 14001:2015 standard, with the most recent having been conducted in 2015. The results of the audit were zero Findings, two Observations, and four Proficiencies.

3.2.10 Management Review

Senior management review of EMS is performed at several layers and frequencies. A formal review/presentation with UCOR senior management that addresses the requirement elements contained in this section is conducted at least once per year. At least two of the senior managers are present for management reviews. The ISMS description is updated annually to address improvements and lessons learned and to update objectives and targets as necessary and signed by the UCOR president and project manager. The environmental policy is also reviewed during the management review annually and revised as necessary.

3.3 Compliance Programs and Status

During 2017, ETTP operations were conducted in compliance with contractual and regulatory environmental requirements. There was one National Pollutant Discharge Elimination System (NPDES) permit noncompliance and no Clean Air Act (CAA) noncompliances. Figure 3.6 shows the trend of NPDES compliance at ETTP since 1999. The following sections provide more detail on each compliance program and the environmental remediation-related activities in 2017.

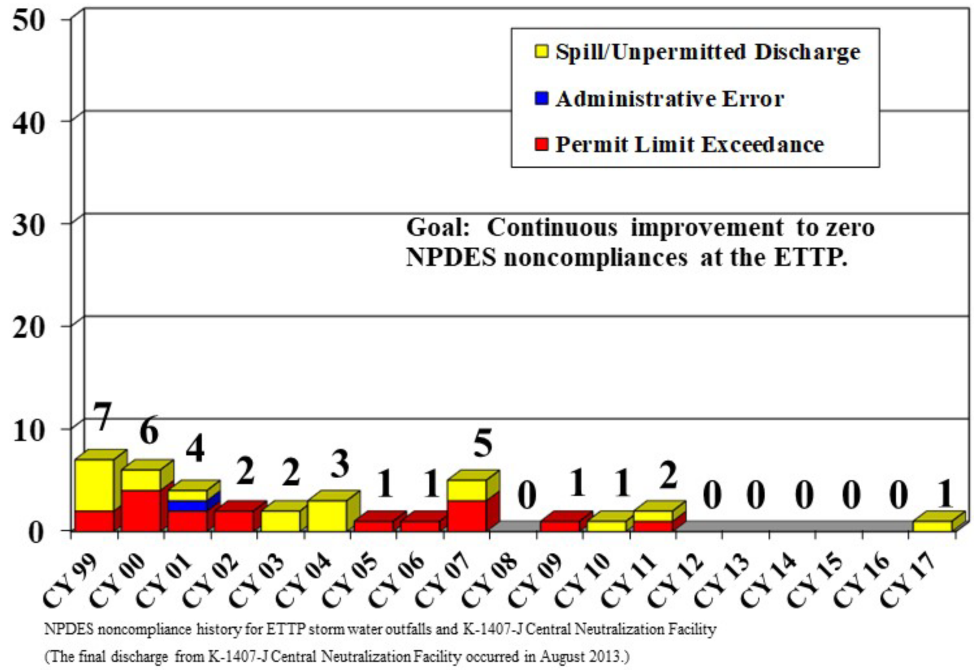


Figure 3.6. East Tennessee Technology Park National Pollutant Discharge Elimination System permit noncompliances since 1999

3.3.1 Environmental Permits

Table 3.1 contains a list of environmental permits that were in effect at ETTP in 2017.

3.3.2 Notices of Violation and Penalties

ETTP received no notices of environmental violations or penalties in 2017.

3.3.3 Audits and Oversight

Table 3.2 presents a summary of environmental audits and oversight visits conducted at ETTP in 2017.

Table 3.1. East Tennessee Technology Park environmental permits, 2017

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	069346P	03-03-2015 Amended 11-22-2016	10-01-2024	DOE[a]	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	DOE	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)
NPDES = National Pollutant Discharge Elimination System
ORR = Oak Ridge Reservation
RCRA = Resource Conservation and Recovery Act
SOP = state operating permit
TFE = Technical and Field Engineering, Inc.
UCOR = URS | CH2M Oak Ridge LLC
UST = underground storage tank

Table 3.2. Regulatory oversight, assessments, inspections, and site visits at East Tennessee Technology Park, 2017

Date	Reviewer	Subject	Issues
February 27	TDEC	Annual RCRA Compliance Inspection	0
October	COR	Sewage Manhole Radiologic Inspection	0
November	COR	Visit to discuss radiologic discharges to the Rarity Ridge Collection System	0

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

3.3.4 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.

During 2017, 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 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 the 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 2017, no new CX determinations for activities at ETTP were issued by DOE.

Compliance with the National Historic Preservation Act (NHPA) 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 National Park Service (NPS) 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.

Consultation for the development of an 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 (SHPO), and the Advisory Council on Historic Preservation (ACHP) entered into an MOA that included the retention of the north end tower (also known as north wing and 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. Another series of consultation meetings ensued in 2009 and DOE advised that prohibitive costs and safety considerations precluded fulfillment of three stipulations in the 2005 MOA, including the preservation of the north end tower. The parties offered a wide array of potential mitigation measures and, in the absence of consensus on how best to commemorate Building K-25, DOE, SHPO, and ACHP entered into a bridge MOA until the parties could reach a final agreement. After completing an evaluation of the structural integrity of the K-25 building and interpretative approaches for the site, DOE distributed a preferred mitigation plan to the consulting parties in October 2011. The DOE final mitigation plan, which addressed comments submitted by consulting parties in November 2011, 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. A final MOA was signed in August 2012, finalizing the aspects set forth in the mitigation plan. During 2013, a request for proposal was issued for a “Professional Design Team and Museum Professional,” as specified in the MOA. Nine firms were prequalified, and the selection and awards were executed April 1, 2014. The procurement process for the K-25 “virtual museum” web design firm was also begun in 2013 and awarded September 2, 2014.

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.

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. The K-25 Virtual Museum website (K-25 Virtual Museum) was launched in conjunction with the signing of the MOA.

The Museum Preliminary Design Report was completed and provided to the Consulting Parties in July 2016. The Consulting Parties reviewed the report and plans and provided comments. The Final Design Plan was completed and sent to the consulting parties for review in January 2017. Comments from the consulting parties were received and incorporated into the Certified for Construction design package and a request for proposal was issued for construction, exhibit fabrication, and installation activities for the K-25 History Center.

At the heart of the gaseous diffusion process is a porous, metallic membrane called the barrier. In December 1947, when barrier construction was transferred to the K-25 Site, the 662 warehouse was converted into the barrier manufacturing facility and designated K-1037. Beginning in 1947, K-1037 was the only facility in the United States capable of producing barrier material. The Historic American Engineering Record (HAER) documentation for K-1037 Barrier Plant was completed and approved by the NPS in May 2017. The HAER documentation for the K-25 building is being prepared for transmittal to the NPS.

3.3.5 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 2017. The ETTP ambient air-monitoring program, permitted source operations tracking, and record keeping provided documentation fully supporting a 100 percent compliance rate.

3.3.6 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 2017, ETTP discharged storm water to the waters of the state of Tennessee under the individual NPDES permit TN0002950, which regulates storm water discharges.

In 2017, 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.

3.3.7 National Pollutant Discharge Elimination System Permit Noncompliances

In 2017, 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 2017 was greater than 99 percent. There was one noncompliance in 2017. Sanitary wastewater from a bathroom and shower facility (K-2527-T) is routed to a 1,100-gal capacity aboveground poly tank for storage until it is pumped out by a sewage pumping subcontractor. On June 12, 2017, the sanitary wastewater was discovered to have overtopped this storage tank and filled the associated secondary containment dike. The water then flowed over a concrete surface into a storm drain catch basin. This catch basin is connected to the Storm Water Outfall 210 drainage system, which discharges into Mitchell Branch. The volume of sanitary wastewater that entered the storm drain inlet could not be accurately determined. The contents of the tank had been pumped out on June 9, 2017. Since a limited staff was working during the period from June 9, 2017, through the morning of June 12, 2017, it is likely that the vast majority of the water released was chlorinated potable water. Visual observation of Outfall 210 conducted on June 12, 2017, showed that the outfall was dry. Therefore, it is likely that no wastewater from the overflow reached Mitchell Branch. This event was determined to be a noncompliance with the ETTP NPDES permit (permit no. TN0002950) due to an unpermitted discharge of wastewater to the storm drain system. It is also considered to be a violation of State Operating Permit (SOP) SOP-99033, and was reported to TDEC in the quarterly operations report. No adverse impact on fish or other aquatic life occurred as a result of this event.

3.3.8 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.

3.3.9 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. This amount includes hazardous waste generated under permitted activities (including repackaging or treatment residuals). At the end of 2017, ETTP had three 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 the ORR areas of concern and solid waste management units, was also reissued on September 15, 2015, as a replacement for TNHW-121.

In CY 2017, ETTP prepared and submitted to the TDEC Division of Solid Waste Management the CY 2016 annual report of hazardous waste activities. This report identifies the type and amount of hazardous waste that was generated, shipped offsite, or is currently in storage.

3.3.10 Resource Conservation and Recovery Act Underground Storage Tanks

Underground storage tanks (USTs) containing petroleum and hazardous substances are regulated under RCRA Subtitle I (40 CFR 280). EPA granted TDEC authority to regulate USTs containing petroleum under TDEC Rule 0400-18-01, *Underground Storage Tank Program*; however, EPA still regulates hazardous substance USTs. During 2017, operations of the two USTs at ETTP were in complete regulatory compliance.

3.3.11 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.

3.3.12 East Tennessee Technology Park RCRA-CERCLA Coordination

The *Federal Facility Agreement for the Oak Ridge Reservation* (FFA, DOE 2017, 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.

3.3.13 Toxic Substances Control Act Compliance Status—Polychlorinated Biphenyls

On April 3, 1990, DOE notified EPA headquarters (as required by 40 CFR 761.205) that ETTP is a generator with onsite storage, a transporter, and an approved disposer of polychlorinated biphenyl (PCB) wastes. ETTP is no longer a disposer of PCBs since the Toxic Substances Control Act (TSCA) Incinerator's hazardous waste management permit TNHW-015 was terminated on September 21, 2012.

PCB waste generation, transportation, disposal, and storage at ETTP is regulated under EPA ID number TN0890090004. In 2017, ETTP operated five PCB waste storage areas in ETTP generator buildings, and when longer term storage of PCB/radioactive wastes were necessary, RCRA-permitted storage buildings were used. These facilities were operated under 40 CFR 761.65(b)(2)(iii), 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. During 2017, the K-1423 Repacking Facility, which was once used for PCB storage and was in standby status, was officially closed. ETTP operated one long-term PCB waste storage area at ETTP 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. Most TSCA-regulated equipment at ETTP has been disposed of. However, some ETTP facilities continue to use or store non-electrical PCB-contaminated equipment for future reuse.

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 2012, ORR-PCB-FFCA), which became effective December 16, 1996, and was last revised on May 23, 2012, to Revision 5. The modification in 2012 incorporated institutional controls at the TSCA Incinerator where limited areas of contamination remained in place at the facility after the facility closure actions were completed. The institutional controls will remain in place until future PCB cleanup actions, which will be addressed during CERCLA demolition actions.

The 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) each year per 40 CFR 761.180(a). The written PCBADL is prepared by July 1 of each year and covers the previous CY. 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 onsite for a minimum of 3 years.

3.3.14 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 inventories 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 2017 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 2017.

3.3.14.1 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 2017, 13 were located at ETTP. These chemicals were nickel metal, lead metal (including large lead acid batteries), sodium metal, diesel fuel, sulfuric acid (including large lead acid batteries), Chemical Specialties Ultrapoles, creosote-treated wood, unleaded gasoline, Sakrete Type S or N mortar mix, Portland cement, CCA Type C pressure-treated wood, Flexterra FGM erosion control agent, and sodium chloride.

3.3.14.2 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 offsite transfers were calculated for each chemical that exceeded the threshold quantity. In 2017, the only chemicals that met the reporting requirements were diisocyanates associated with foaming activity to stabilize deposits in pipes undergoing remediation actions.

3.4 Quality Assurance Program

3.4.1 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 independently of 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 2017, 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 RICE units on March 3, 2015. An amended permit was issued on November 22, 2016, that removed one permanently shut down unit. The current operating permit was amended on November 22, 2016, and covers four RICE emergency generators and one RICE emergency 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.

Compliance for all units is demonstrated by following specified maintenance schedules, limiting hours of operations for nonemergencies to 100 h 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 impacting asbestos-containing materials (ACM) are fully compliant with 40 CFR 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 2017 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 2017, only one Notification of Demolition and/or Asbestos Renovation submittals to TDEC was submitted for non-CERCLA ETTP activities. That notice involved 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 2017, 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 2017.

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 onsite ODS inventory at ETTP.

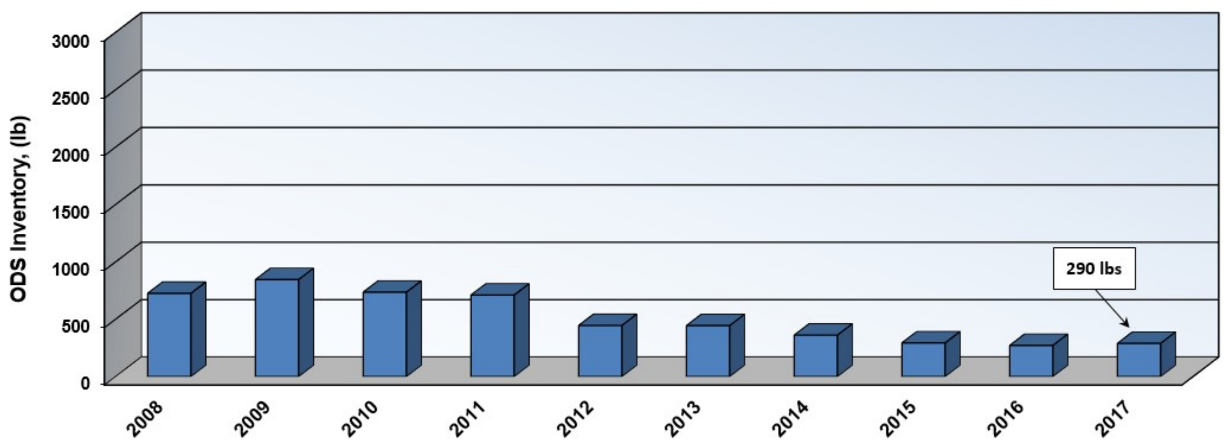


Figure 3.7. East Tennessee Technology Park total onsite ozone-depleting substances inventory, 10-year history

3.5.1.2 Fugitive Particulate Emissions

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

3.5.1.3 Radionuclide National Emission Standards for Hazardous Air Pollutants

Radionuclide airborne emissions from ETTP are regulated under 40 CFR Part 61, *National Emission Standards for Hazardous Air Pollutants (Rad-NESHAP)*. 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 (ED) 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 2017—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 described in Section 3.5.2.

Quarterly radiochemical analyses are performed on composited samples collected at all ETTP ambient air sampling stations. The selected isotopes of interest were ^{234}U, ^{235}U, and ^{238}U with the ^{99}Tc inorganic analysis results included as a dose contributor. The concentration and dose results for each of the nuclides are presented in Table 3.3 for the 2017 reporting period.

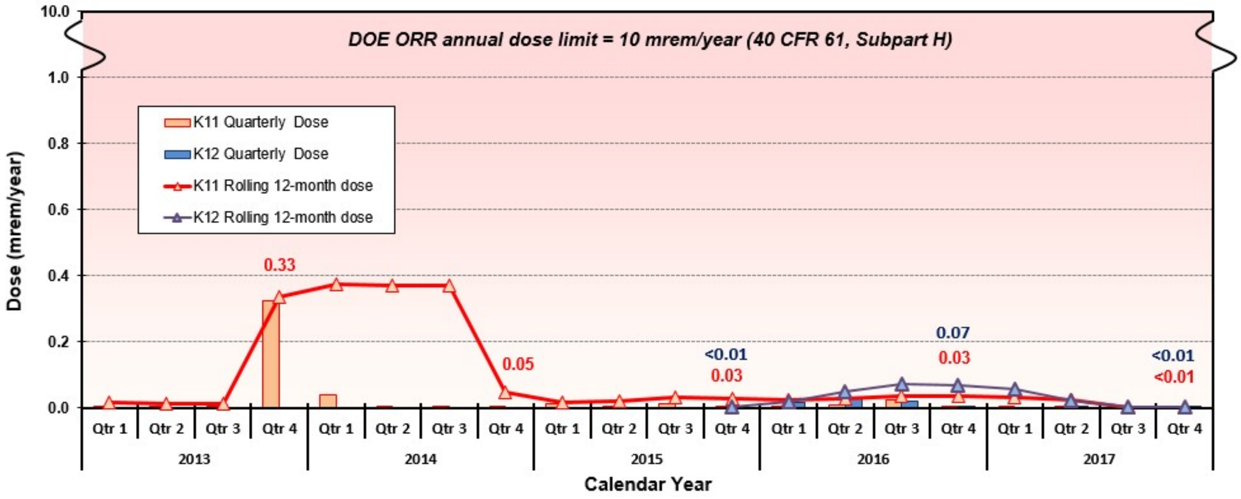
Table 3.3. Radionuclides in ambient air at East Tennessee Technology Park, January 2017 through December 2017

Station	Concentration (μCi/mL)				
	^{99}Tc	^{234}U	^{235}U	^{238}U	
K2[a]	ND[b]	1.12E-18	7.55E-19	1.68E-18	
K6[ac]	ND	ND	ND	1.03E-17	
K11[d]	2.66E-17	1.24E-18	6.95E-19	8.20E-18	
K12[d]	6.20E-17	5.84E-18	1.32E-18	1.39E-17	
	40 CFR 61, Effective Dose (mrem/year)				**Total Dose**
K2	ND	< 0.001	< 0.001	< 0.001	< 0.001
K6	ND	ND	ND	< 0.001	< 0.001
K11	< 0.001	< 0.001	< 0.001	< 0.001	0.001
K12	0.001	< 0.001	< 0.001	0.001	0.002

[a] K2 and K6 results represent a residential exposure.
[b] ND = not detectable.
[c] K6 was permanently shut down at the end of June 2017.
[d] K11 and K12 represent an onsite business exposure equivalent to half of a yearly exposure at this location.

Figure 3.8 provides a historical dose trend for the most impacted onsite member of the public if they were located at any of the three sampling locations. Each data point represents the accumulated dose over the previous four quarterly sampling periods. Stations K11 and K12 are near onsite businesses, therefore the estimated doses based upon residential exposures were divided by 2 to account for occupational exposures following approved procedures. This conservatively assumes that the onsite member of the public is at his or her workstation for half of the year.

During 2017, the onsite dose decreased as major demolition and debris removal activities were completed. The highest annual dose impact as measured at the ambient air station K12 was only 0.002 mrem as compared to the annual limit of 10 mrem. The onsite location of K12 was in close proximity to major demolition and debris removal activities that impacted radiologically contaminated materials. The major dose contributors at K12 were ^{99}Tc (46.1 percent) and ^{238}U (33.6 percent). The results are based on actual ambient air sampling in a location conservatively representative of onsite business locations. All data continue to show potential exposures are all well below the 10 mrem annual dose limit.



DOE = US Department of Energy and ORR = Oak Ridge Reservation

Figure 3.8. East Tennessee Technology Park ambient air stations K11 and K12 radionuclide monitoring results: 5-year rolling 12-month dose history up through 2017

3.5.1.4 Quality Assurance

QA activities for the Rad-NESHAP program are documented in the *Quality Assurance Program Plan for Compliance with Radionuclide National Emission Standards for Hazardous Air Pollutants, East Tennessee Technology Park, Oak Ridge Tennessee* (UCOR 2015b, UCOR-4257). 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).

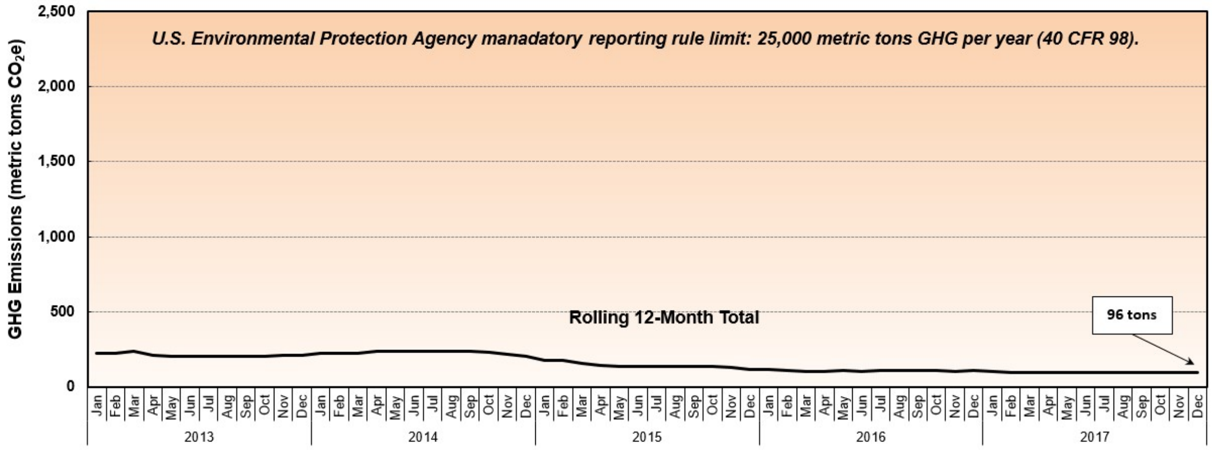
3.5.1.5 Greenhouse Gas Emissions

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 2017 review was performed of ETTP processes and equipment categorically identified under 40 CFR 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 2017, 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 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 3.9 shows the 5-year trend up through 2017 of ETTP total GHG stationary emissions. For the 2017 CY, GHG emissions totaled only 96 MT, which is less than 1 percent of the 25,000 MT per year threshold for reporting.



in carbon dioxide equivalent [CO2e]; CFR = Code of Federal Regulations; GHG = greenhouse gas

Figure 3.9. East Tennessee Technology Park stationary source greenhouse gas emissions tracking history

Executive Order (EO) 13514, *Federal Leadership in Environmental, Energy, and Economic Performance*, was signed by President Barak Obama on October 5, 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:

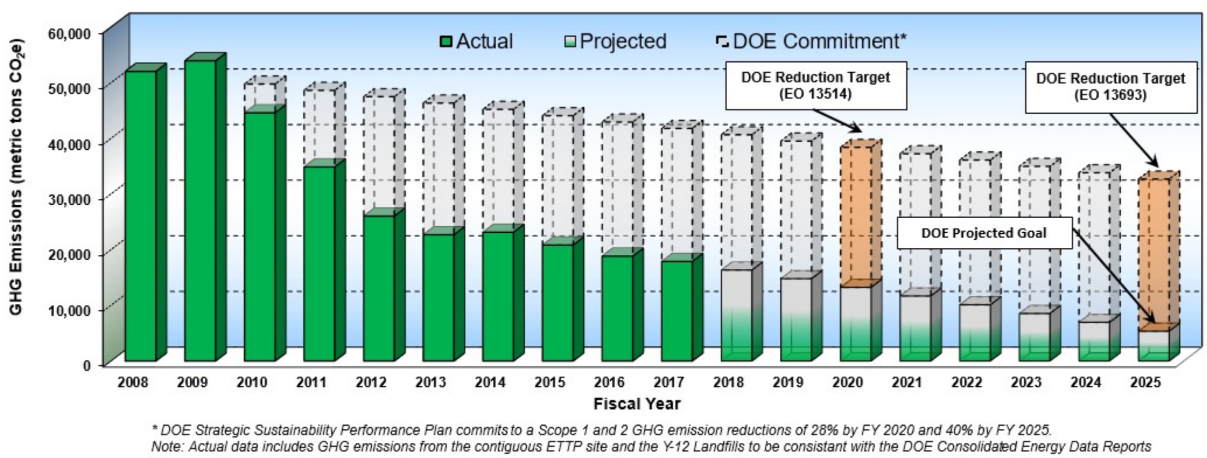
1. Scope 1 is essentially direct GHG emissions from sources that are owned or controlled by a federal agency.
2. Scope 2 encompasses GHG emissions resulting from the generation of electricity, heat, or steam purchased by a federal agency.
3. Scope 3 involves GHG emissions from sources not owned or directly 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 signed and issued on March 25, 2015. This order supersedes EO 13514 and established a new Scope 1 and Scope 2 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.

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 3.10 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 current EO 13693 40 percent goal by FY 2025.

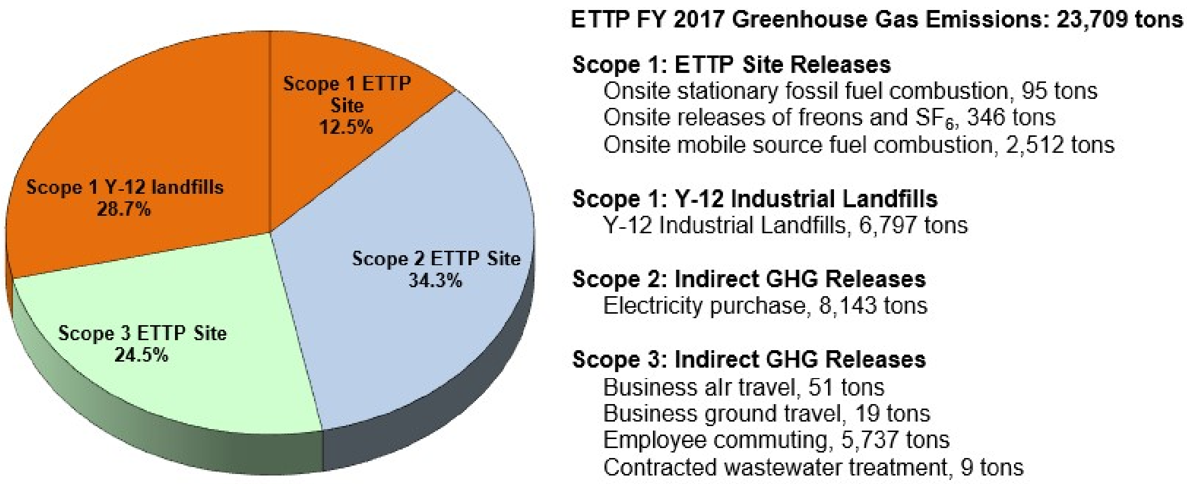
With respect to EO 13514, emissions for FY 2017 Scope 1 and 2 including the landfills totaled 17,894 MT CO_2e, roughly 52 percent below the FY 2020 target level of 37,478 MT CO_2e and a 66 percent reduction to date compared to the FY 2008 baseline year level of 52,053 MT. When compared to the EO 13693 target, FY 2017 data show that the targeted 40 percent reduction has already been achieved by comparing the FY 2017 total of 17,894 MT to the 40 percent target level of 31,232 MT.



in metric tons carbon dioxide equivalent [CO2e]; ETTP = East Tennessee Technology Park; GHG = greenhouse gas emissions

Figure 3.10. East Tennessee Technology Park greenhouse gas emissions trend and targeted reduction commitment

Figure 3.11 shows the relative distribution and amounts of all ETTP FY 2017 GHG emissions for Scopes 1, 2, and 3 including the landfills. 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 onsite combustion of fuels (stationary and mobile sources), lower consumption of electricity, and a smaller workforce. The total amount of GHG emissions for FY 2017 was 23,709 tons, as compared to the 24,252 tons for FY 2016. Total reduction to date starting with the 2008 baseline year of 61,453 tons of GHG emissions is 61.4 percent.



ETTP = East Tennessee Technology Park; GHG = greenhouse gas; Y-12 = Y-12 National Security Complex; and SF_6 = sulfur hexafluoride

Figure 3.11. FY 2017 East Tennessee Technology Park greenhouse gas emissions by scope, as defined in Executive Order 13514

3.5.1.6 Source-Specific Criteria Pollutants

ETTP operations included one functioning minor stationary source, the CWTS, with a potential to emit any form of criteria air pollutant. This unit is equipped with an air stripper to remove VOCs from the 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 2017 for CWTS were only 0.012 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 of 2013 require TDEC permitting for existing and new stationary RICE-powered emergency generators and firewater booster pumps (i.e., emergency or e-RICE). 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. 2017 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). During 2016 the K-802 e-RICE powered firewater booster pump was permanently removed from service. TDEC issued an amended permit with an effective date of November 22, 2016. The expiration date of the amended permit is October 1, 2024.

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. The current permit specifies conditions that must be met to demonstrate compliance. These requirements include performing scheduled maintenance, record keeping, and tracking the run times of each of the five permitted units. Copies of all maintenance activities are provided for permit compliance review, and the runtimes are entered into spreadsheets to track against annual limits. Table 3.4 provides the number of hours of operations for each unit, up through December 31, 2017.

Table 3.4. East Tennessee Technology Park UCOR emergency reciprocating internal combustion engine air permit compliance demonstration, 2017

e-RICE Unit	Permit limits: Total hours/year = 100		Nonemergency hours/year = 50	
	PM Testing (hours/year)	Nonemergency (hours/year)	Total (hours/year)	Emergency (hours/year)
K-1007	5.9	11.8	17.7	56.6
K-1039	5.9	14.6	20.5	61.7
K-1095	6.0	6.8	12.8	20.9
K-1310-RW	4.5	27.8	32.3	1.5
K-1407[a]	4.8	14.4	19.2	44.0
K-1652	6.0	13.1	19.1	17.3

[a]K-1407 e-RICE operating under CERCLA and exempt from TDEC air emission permitting.

Acronyms
e-RICE = emergency reciprocating internal combustion engine
PM = particulate matter
TDEC = Tennessee Department of Environment and Conservation
UCOR = URS | CH2M Oak Ridge LLC

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.

3.5.1.7 Hazardous Air Pollutants (Nonradionuclide)

Unplanned releases of hazardous air pollutants (HAPs) 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 (RMP) threshold quantities listed in 40 CFR 68.130 was conducted. This is an ongoing action that documents the potential applicability for maintaining and distributing an RMP and to ensure threshold quantities are not exceeded.

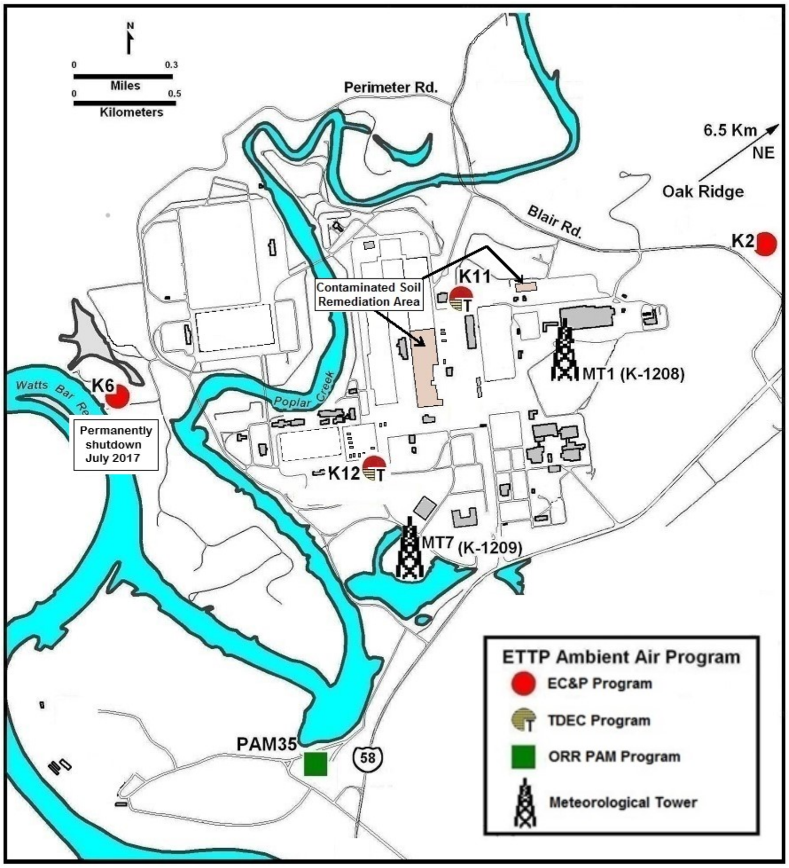
ETTP personnel have determined that there are no processes or facilities containing inventories of chemicals in quantities exceeding thresholds specified in rules pursuant to CAA, Title III, Section 112(r), "Prevention of Accidental Releases." The results of this review indicated that all RMP-listed chemicals were less than 1 percent of their specific trigger thresholds. Therefore, activities at ETTP are not subject to the rule. Procedures are in place 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 3.12 shows the locations of all ambient air sampling stations in and around ETTP that were active during the 2017 reporting period. Figure 3.13 shows an example of a typical EC&P program air monitoring station.



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

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

The EC&P program consisted of four sampling locations at the beginning of 2017. Due to the shrinking footprint of DOE ETTP operations, station K6 was permanently shut down at the end of June. 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 (UT-Battelle). TDEC is responsible for the data collected from their two samplers. UT-Battelle 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 onsite (on the ORR) or offsite. K12 remained a key sampling location regarding the potential dose impact on the most exposed member of the public at an onsite business location during the demolition and debris removal of the last gaseous diffusion building on the ETTP site.

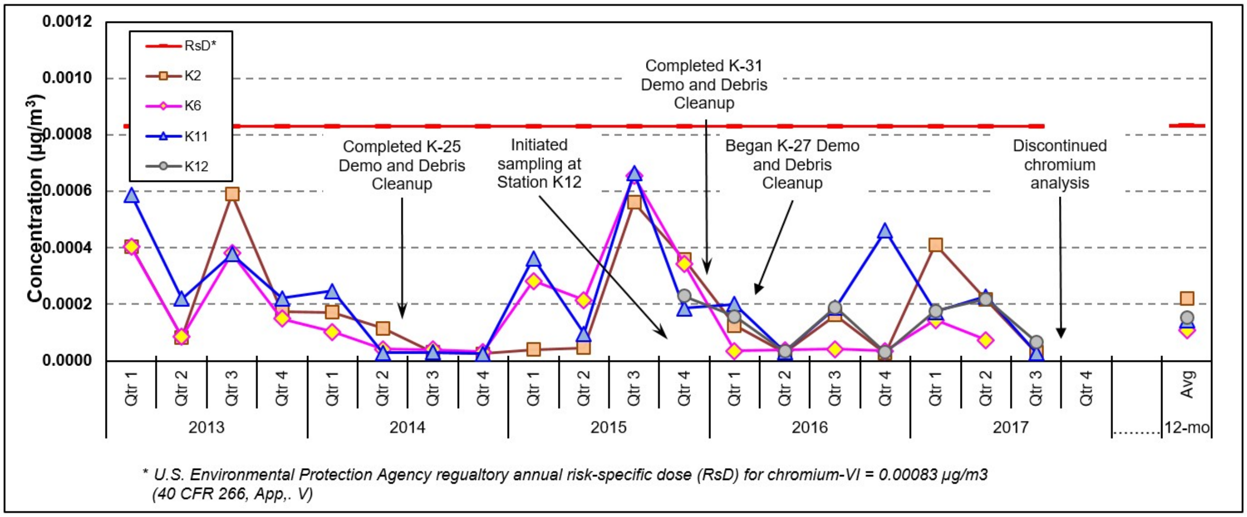
Changes of emissions from ETTP will warrant periodic reevaluation of the parameters being sampled. Ongoing ETTP reindustrialization efforts will also introduce new locations for members of the public that may require adding or relocating monitoring site locations. To ensure understanding of the potential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

Figure 3.13. East Tennessee Technology Park ambient air monitoring station

All EC&P program stations collected continuous samples for radiological and selected metals analyses during 2017. Inorganic analytical techniques were used to test samples for chromium (Cr), Pb, and ^{99}technetium (^{99}Tc). Radiological analyses of samples from the EC&P stations test for the isotopes ^{234}uranium (^{234}U), ^{235}uranium (^{235}U), and ^{238}uranium (^{238}U).

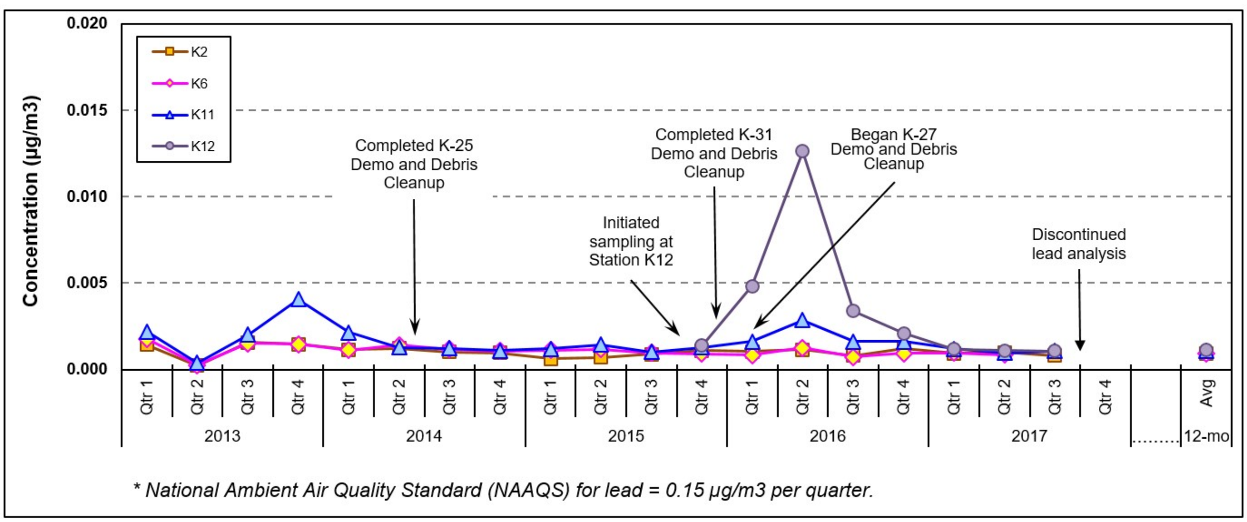
Figures 3.14 and 3.15 illustrate the ambient air concentrations of chromium and lead for the past 5 years, based on quarterly composites of weekly continuous samples. All samples were analyzed by the inductively coupled plasma-mass spectrometer (ICP-MS) analytical technique. The results are compared with applicable air quality standards for each pollutant. The annualized levels of Cr and Pb during 2017 were well below the indicated annual standards. Station K2 is in the prevailing topography of influenced downwind directions that are for identifying the impact to offsite members of the public. Stations K11 and K12 are located to provide a conservative measurement of the impact to onsite members of the public. Sampling results for Cr and Pb have periodically trended higher due to the proximity to major demolition sites, service roads for transporting debris, other demolition machinery, and railroad operations. Cr variations have been coincidental to activities associated with the removal of the gaseous diffusion building concrete pads. Pb variations are most likely due to the close proximity of the exhaust of diesel-burning equipment and vehicles.

Near the end of 2017, all debris and the concrete pad of the last gaseous diffusion building to be demolished had been removed. The completion of this effort removed a major potential source of fugitive emissions that could include Cr and Pb. Future activities are not expected to contain Cr and Pb levels that would be distinguishable from background levels that were recorded prior to the start of the demolition campaign at ETTP. Based on this information, Cr and Pb were dropped from the analytical matrix after the third quarter of 2017. However, analyzing for ^{99}Tc as an inorganic metal continued.



Demo = demolition

Figure 3.14. Chromium monitoring results: 5-year history through December 2017



Demo = demolition

Figure 3.15. Lead monitoring results: 5-year history through December 2017

3.6 Water Quality Program

3.6.1 NPDES Permit Description

The latest ETTP NPDES permit became effective on April 1, 2015. It is scheduled to expire on March 31, 2020. 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 monitored quarterly for total chromium and hexavalent chromium. ETTP NPDES permit monitoring requirements for storm water outfalls are shown in Tables 3.5 and 3.6.

Table 3.5. Representative outfalls

(Outfalls 05A, 100, 142, 150, 170, 180, 190, 195, 198, 230, 280, 294, 334, 350, 430, 490, 510, 560, 660, 690, 694, 700, 710, 724, 890, 930, and 992)

Parameter	Qualifier	Value	Unit	Sample Type	Frequency	Statistical Base
Flow	Report	-	million gallons per day (MGD)	Estimate	Annual	Daily Maximum
Oil & Grease	Report	-	mg/L	Grab	Annual	Daily Maximum
Total Suspended Solids (TSS)	Report	-	mg/L	Grab	Annual	Daily Maximum
pH	≥ 6.0 and ≤ 9.0	-	SU	Grab	Annual	Daily Minimum and Daily Maximum

Table 3.6. Storm Water Outfall 170 for chromium monitoring

Parameter	Qualifier	Unit	Sample Type	Frequency	Report
Chromium, hexavalent (as Cr)	Report	mg/L	Grab	Quarterly	Daily Maximum
Chromium, total (as Cr)	Report	mg/L	Grab	Quarterly	Daily Maximum

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

1. Flux Monitoring

   For bioaccumulative pollutants such as mercury, a long-term monitoring of pollutant loadings (known as flux) will be conducted. This flux monitoring will include the following:

   - Flow Monitoring

     For Outfalls 100, 170, 180, and 190, field-installed flow meters will be used to gauge flows for the following ranges of rain events at least once during the permit term at each outfall:

- 0.1–0.5 in. rain event
- 0.5–1.5 in. rain event
- 1.5 in. or greater rain event

These flows will be used to compare against flows generated using the Natural Resources Conservation Service (NRCS) Technical Report-55 (TR-55, NRCS 1986), the current flow modeling technique used at ETTP, to increase the accuracy of the TR-55 flow modeling process. Given that the flow monitoring will occur over a variety of rain events, and multiple field variables can pose problems in collecting usable data, this monitoring will be completed any time during the permit period.

- Mercury Monitoring

  Mercury will be sampled at Outfalls 180 and 190 using the flow-weighted sampling technique. Specific sample collection guidelines will be included as part of upcoming SWPP Program Sampling and Analysis Plans (SAPs).

- Flux Calculation

  Flow monitoring results will be used to calibrate the variable inputs to the TR-55 flow model, which will then be used with the flow-paced mercury sampling results to determine mercury flux at the respective outfalls.

2. Remedial Activities, CERCLA, and Legacy Pollutant Monitoring

   - Storm water samples have been collected at locations that are affected by RA activities prior to the initiation of these activities in order to determine the conditions present before remediation begins. In addition, storm water samples will be collected at potentially affected outfalls and storm water catch basins after remedial activities have been undertaken, and after they have been completed, to help gauge the effectiveness of the remediation efforts.
   - The results of the monitoring effort at the D&D sites, which are a subset of remedial activities, are utilized in determining the effectiveness of BMPs in controlling offsite releases of legacy pollutants.
   - Periodic monitoring will be performed as part of the ETTP SWPP Program to monitor the continued effectiveness of the chromium collection system.

3. Permit Renewal Sampling

   - Sampling required for the completion of the NPDES permit application was initiated in FY 2015 as part of the ETTP SWPP Program. The application for this permit renewal is required to be submitted to TDEC by October 1, 2019, to allow TDEC 180 days to review it prior to permit expiration on March 31, 2020. Additionally, DOE will require time to review the permit application before it is submitted to TDEC. 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 the EPA Form 2E, Application Form 2E—*Facilities Which Do Not Discharge Process Wastewater*; and EPA Form 2F, *Application for Permit to Discharge Storm Water Discharges Associated with Industrial Activity*.
   - The following sampling was conducted:

     Representative outfalls meeting the requirements to complete an EPA Form 2E were sampled. Parameters that must be collected by grab sample, per analytical method or regulatory guidance were collected as a grab sample only. All other required parameters will be collected as time-weighted composites only.

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

– 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 as either 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. Based upon historical site knowledge and analytical monitoring results, metals, mercury, and PCBs were collected from all representative outfalls. In addition, each representative outfall were evaluated, and VOCs, radionuclides, and other selected parameters were collected from the representative outfalls 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.

4. Investigative Sampling

- Investigative sampling will be performed as part of the ETTP SWPP Program. This will include sampling of storm drain networks for bioaccumulative parameters and investigations triggered by analytical results, CERCLA requirements, changes in site conditions, etc. (UCOR 2015, UCOR-4028/R5, *East Tennessee Technology Park Storm Water Pollution Prevention Program Sampling and Analysis Plan, Oak Ridge, Tennessee).*
- Storm water sampling results will be 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 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.

As part of the ETTP SWPP SAP, storm water samples were collected from discharges that occurred after a storm event that (1) was greater than 0.1 in. in 24 h, and (2) occurred at least 72 h after a rain event greater than 0.1 in. in 24 h. No specified dry period was required before the samples were taken. A series of at least three manual grab samples of equal volume were collected during the first 60 min of a storm event discharge, and combined into a composite sample.

Table 3.7 contains the results of this sampling effort. Screening levels for individual radionuclides are established at 4 percent of the DCS values listed in DOE Standard 1196 (DOE 2011b, DOE-STD-1196). At Outfall 240, results for alpha activity and $^{233/234}U$ exceeded the screening criteria. Table 3.8 lists the cumulative activity levels of each of the major isotopes that were discharged from the overall ETTP storm water system in 2017.

Table 3.7. Analytical results for radiological monitoring at ETTP storm water outfalls, 2017

Parameter	Screening Level	Outfall 100	Outfall 142	Outfall 170	Outfall 210	Outfall 240	Outfall 694	Outfall 700	Outfall 890	Outfall 992
Alpha activity (pCi/L)	10	2.69 U	0.315 U	0.952 U	6.16	**47.6**	4.29 U	2.61 U	3.05 U	1.33 U
Beta activity (pCi/L)	30	18.1	1.91 U	1.46 U	10.1	6.04	5.93	0.606 U	3.13 U	0.987 U
^{99}Tc (pCi/L)	1760	4.85 U	0.84 U	2.7 U	9.74 U	2.94 U	-0.74 U	0.585 U	4.1 U	6.41 U
$^{233/234}U$ (pCi/L)	28	0.934	0.46 U	1.08	2.14	**34.3**	0.37 U	0.821	1.31	0.31 U
$^{235/236}U$ (pCi/L)	29	0.137 U	0.179 U	0.201 U	0.255 U	1.43	0.124 U	0.152 U	0.201 U	0.143 U
^{238}U (pCi/L)	30	0.0808	0.385 U	0.432	0.476 U	3.06	0.132 U	0.608	0.912	0.122 U

*Results in **bold** exceed the screening level.

Screening criteria for gross alpha radiation and $^{233/234}U$ were exceeded at Outfall 240. Outfall 240 receives storm water runoff from a portion of the Building K-25 pad. Operations conducted in this building included the isotopic enrichment of uranium by gaseous diffusion. Discharges from this outfall have historically contained radiological contaminants at levels above screening criteria due to past operations at the K-25 building.

No screening criteria were exceeded at Outfalls 100, 142, 170, 210, 694, 700, 890, or 992.

Table 3.8. Radionuclides released to offsite waters from the ETTP storm water system in 2017 (Ci)

Isotope	^{234}U	^{235}U	^{238}U	^{99}Tc
Activity level	4.5 E-3	4.4 E-4	3.0 E-3	2.4 E-1

3.6.2.2 D&D of the K-27 Building

Initial sampling was performed at several outfall locations that drain the K-27 D&D area to provide baseline data for conditions present before demolition began. Additional monitoring has been and will continue to be performed as D&D activities are concluded. The building pad will be removed as the final part of the K-27 D&D activities. The K-27 slab removal work was completed in CY 2017.

Samples were collected at Outfalls 380 and 430 on March 2, 2017, and April 3, 2017. Table 3.9 contains information on the analytical results from the K-27 D&D monitoring effort that were over screening levels.

Table 3.9. Analytical results over screening levels for sampling during removal of the K-27 building slab

Location	$^{233/234}U$ Screening level 28 pCi/L
Outfall 380	32.7

No analytical results from Outfall 430 exceeded screening levels.

3.6.3 D&D of the K-1203 Sewage Treatment Plant

The K-1203 STP was previously used to treat and process all sanitary sewage waste from the ETTP. The plant was shut down on May 29, 2008, as a result of the transition of sewage treatment for ETTP to COR. COR expanded the Rarity Ridge Wastewater Treatment Plant to include capacity to treat the waste from ETTP, and the Community Reuse Organization of East Tennessee (CROET) constructed a new ETTP lift station and force main to the plant.

All samples collected as part of this effort were taken using the manual grab sampling method. Manual grab samples were collected according to the guidelines specified in Sections 3.1.2 and 3.3.1 of the EPA's *NPDES Storm Water Sampling Guidance Document* (EPA 1992, EPA 833-B-92-001) and applicable procedures that have been developed by the sampling subcontractor. For collection of storm water samples at the K-1203 D&D project, a qualifying rain event was defined as a rain event that (1) produced 1 in. or greater measured rainfall within a 24-h period; (2) caused runoff to be present at the outfall; and (3) occurred after a dry period of at least 72 h. A dry period means no measurable rainfall (0.1 in. or greater) occurs within a 72-h period.

D&D activities began at the K-1230 STP facility in October 2017. As part of the ETTP SWPP Program SAP for FY 2018, Outfall 05A was monitored for contamination associated with the K-1203 facility demolition and storm water runoff. Initial sampling was performed at Outfall 05A on October 23, 2017, to provide baseline data for conditions present before demolition begins. Sampling was conducted while D&D activities were being conducted on November 7, 2017, and December 6, 2017, following rainfall events of 2.42 in. and 0.93 in., respectively. A final monitoring event occurred after a rainfall event of 1.56 in. on December 20, 2017, at the conclusion of demolition and waste handling actions. Analytical results that exceeded screening criteria as part of these sampling events are shown in Table 3.10. Of particular note are the mercury results that exceeded the screening levels before, during, and after the demolition activities. The legacy mercury discharges will be addressed in future CERCLA Remedial Actions.

Table 3.10. Results over screening levels for K-1203 Sewage Treatment Plant monitoring

Sampling Location	Copper	Lead	PCB-1254	PCB-1260	Mercury	Zinc	Selenium
	(ug/L)	(μg/L)	(μg/L)	(μg/L)	(μg /L)	(μg/L)	(μg/L)
Screening Level	7	1.8	Detectable	Detectable	25	75	3.8
Outfall 05A							
10/23/17	7.78				418		10.2
11/7/17	25.6		0.082	0.0392	1620	93.7	6.1
12/6/17					306		
12/20/17	7.45	3.91			240		

3.6.3.1 D&D of the K-25 Building

Final D&D activities were completed for the K-25 building in July 2014. In order to assess any ongoing impacts, the remaining K-25 building slab has on the quality of the storm water runoff, monitoring of runoff from the slab will be performed on an annual basis. As shown in Table 3.11, runoff samples were collected at Outfall 490 to monitor east wing slab runoff, runoff from Outfall 334 was sampled to monitor west wing slab runoff, and Outfall 230 was sampled to monitor north end slab runoff.

Because sampling of the K-25 building slab runoff required a fairly heavy and intense rain event, samples were collected when runoff was sufficient to allow all of the samples for the given analytical parameters to be collected, regardless of the amount or intensity of the rainfall event. All samples collected as part of this effort were taken using the manual grab sampling method. Manual grab samples were collected according to the guidelines specified in Sections 3.1.2 and 3.3.1 of the EPA's *NPDES Storm Water Sampling Guidance Document* (EPA 1992) and applicable procedures that have been developed by the sampling subcontractor. Samples were collected at Outfalls 230, 334, and 490 in July 2017. Results over screening levels are shown in Table 3.11.

Table 3.11. Analytical results over screening levels for K-25 building D&D annual slab runoff monitoring

Location	Selenium	Gross Beta Radiation
	Screening level 3.8 μg/L	Screening level 50 pCi/L
Outfall 230	6 U	
Outfall 334	6.23	
Outfall 490	6.51	145

To collect data for trend graphs in the Remediation Effectiveness Report (RER) and ASER, and to collect data that can be compared with information gathered by TDEC on an ongoing basis, a sample for ^{99}Tc will be collected at Outfall 190 each time a quarterly mercury sample is collected. The analytical data from this sample will assist in determining if ^{99}Tc-contaminated groundwater from the K-25 D&D project could be migrating to the Outfall 190 drainage area and then discharging into Mitchell Branch. As shown in Table 3.12 the storm water results for the Mitchell Branch watershed area indicate that ^{99}Tc was not detected in samples collected at Outfall 190 during FY 2017 except in July 2017. Additional outfall sampling for ^{99}Tc conducted in February 2017 indicates levels at Outfall 210 were also below detection (9.74 U pCi/L). From 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 or Outfall 210.

Table 3.12. Quarterly ^{99}Tc sampling at Outfall 190

Sampling location	^{99}Tc (pCi/L)* 1/12/16	^{99}Tc (pCi/L)* 4/19/16	^{99}Tc (pCi/L)* 7/11/16	^{99}Tc (pCi/L)* 10/17/16	^{99}Tc (pCi/L)* 1/9/17	^{99}Tc (pCi/L)* 4/18/17	^{99}Tc (pCi/L)* 7/13/17	^{99}Tc (pCi/L)* 10/12/17
Outfall 190	13.4	6.37 U	4.21 U	3.26 U	4.38 U	-3.27 U	6.71	2.96 U

*Tc-99 results are provided as a reference. They do not exceed screening criteria.

As shown in Figure 3.16, the activity levels of ^{99}Tc at the Mitchell Branch exit weir K-1700 location were below the established standards. The maximum ^{99}Tc measurement at K-1700 in 2017 was 18.7 pCi/L, which is orders of magnitude below the ^{99}Tc DCS value of 44,000 pCi/L and the drinking water maximum contaminant level (MCL)-DC of 900 pCi/L.

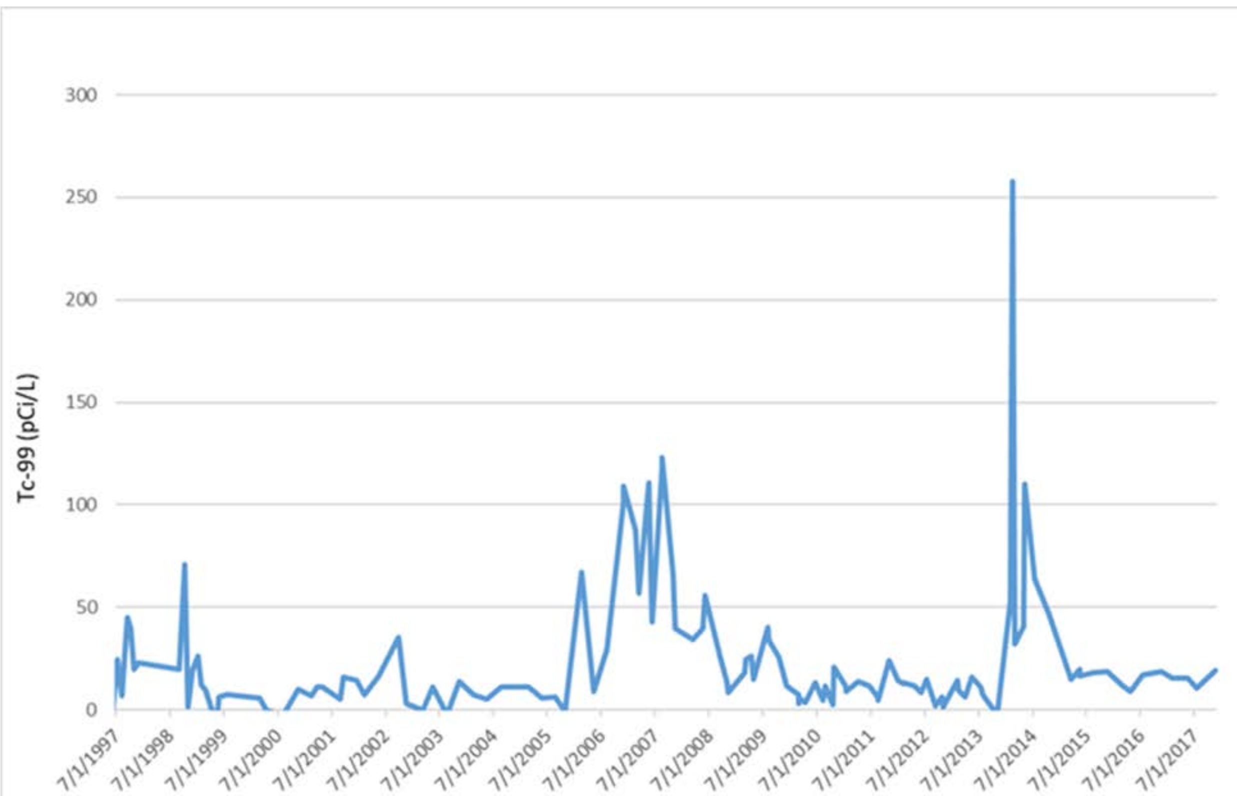


Figure 3.16. Tc-99 levels at K-1700 weir

3.6.3.2 Mercury Investigation Monitoring

ETTP conducted activities involving mercury, including use and handling of manometers, switches, mass spectrometers, mercury diffusion pumps, mercury traps, and laboratory operations. ETTP also processed and stored large quantities of mercury-bearing wastes from the onsite gaseous diffusion plant operations and support buildings, Oak Ridge National Laboratory (ORNL), and Y-12. Mercury from soils and spill cleanups was processed onsite as well. Mercury recovery operations were conducted in a number of buildings, many of which were located in watersheds that discharged primarily to Mitchell Branch.

It was subsequently found that mercury levels exceeding the 51 ng/L ambient water quality criterion (AWQC) at ETTP were identified in the Mitchell Branch watershed, as well as in a number of storm water outfalls, surface water locations, and groundwater monitoring wells at ETTP. Knowledge of known historical mercury processes at the facility has increased substantially during RA investigations. This has led to an ongoing storm water network investigation to more precisely detect and quantify the extent of any mercury contamination that may exist.

Factors considered as part of the mercury investigation include weather conditions (wet vs. dry), RA activities (before, during, and after demolition of ETTP facilities), and types of monitoring locations chosen for sampling (in-stream, outfall, ambient, catch basin). For the purpose of the investigation activities, a dry-weather period was defined as being at least 72 h after a storm event of 0.1 in. or more. Wet weather conditions were defined as a storm event greater than 0.1 in. that occurs within a period of 24 h or less and that occurs at least 72 h after any previous rainfall greater than 0.1 in. in 24 h. In addition, manual grab samples were defined as samples collected according to the guidelines specified in Sections 3.1.2 and 3.3.1 of EPA 833-B-92-001 and applicable procedures that have been developed by the sampling subcontractor, RSI.

ETTP Monitoring Programs

Several monitoring programs collected mercury data across ETTP at various locations during CY 2017. Samples were collected as specifically defined in the NPDES permit and as part of the SWPP Program. In addition, samples were also collected as part of the Environmental Monitoring Program (EMP) and in support of D&D activities.

There are numerous legacy mercury historical operations within the Outfall 180 and 190 network areas and overall Mitchell Branch watershed. Collectively, these are potential contributors to the continuing legacy mercury discharges to Mitchell Branch due to contaminated sediment within storm water networks and potential infiltration sources into the piping. These include mercury recovery operations at the K-1401 and K-1420 buildings that led to downstream waste disposal areas such as the K-1407 ponds and K-1070-B Burial Ground. Additionally, the K-1035 building instrument shop with associated mercury activities discharged liquids through building acid pits to the storm drain network. In addition to the continuing contributions from the storm drain outfalls, the instream sediments within Mitchell Branch are a potential contributor to water column measurements and fish bioaccumulation. Storm water Outfall 05A drains portions of the inactive K-1203 STP that discharge into the K-1203-10 sump. Soils and facility components from the K-1203 STP, including inactive piping, facilities, basins, etc., are contaminated with mercury from historical treatment operations from sources such as the plant laboratory discharges.

As part of previous NPDES permit compliance program monitoring activities, mercury was sampled on a quarterly basis at Outfalls 05A, 170, 180, and 190. These four locations were selected because information gathered as part of the permit application process indicated that mercury levels at these sites occasionally exceeded the AWQC level of 51 ng/L. Outfalls 170, 180, and 190 collect storm water from large areas on the north side of ETTP and discharge to Mitchell Branch. Outfall 05A is the discharge point for the former sewage treatment plant drainage basin into Poplar Creek on the east side of ETTP.

The current ETTP 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 sampling will be conducted as part of the ETTP SWPP Program, as indicated in Table 3.13. Because mercury was not detected at Outfall 170 at levels over the AWQC of 51 ng/L for several years, routine sampling of Outfall 170 was discontinued.

Data from this sampling effort will be used as part of the RER, and may provide information that can be used in upcoming CERCLA cleanup decisions.

Table 3.13 contains analytical data from mercury sampling performed at Outfalls 180, 190, and 05A during CYs 2016 and 2017.

Table 3.13. Quarterly NPDES/SWPP Program mercury monitoring results CYs 2016–2017

Sampling location	1st Qt CY 2016 (ng/L)	2nd Qt CY 2016 (ng/L)	3rd Qt CY 2016 (ng/L)	4th Qt CY 2016 (ng/L)	1st Qt CY 2017 (ng/L)	2nd Qt CY 2017 (ng/L)	3rd Qt CY 2017 (ngL)	4th Qt CY 2017 (ng/L)
Outfall 180	27.1	31.3	**123**	**177**	44.3	**117**	**93.5**	**63.7**
Outfall 190	12.9 **(96.5)****	35	16.4	17.6	16.1	**74.5**	15.2	16.6
Outfall 05A	**86.4**	**105**	**126**	**459**	**75.2**	**186**	**127**	**427**

*Results in **bold** exceed the AWQC for mercury (51 ng/L).
**Sample result was from a special flow-proportional sample collected as part of the mercury flux study.

Mercury levels at Outfalls 180, 190, and 05A continue to fluctuate over time, but frequently remain above the AWQC. This is likely due to the transport of mercury-contaminated sediments in these drainage networks by storm water flow. Data from this sampling effort will be used as part of the RER, and may provide information for upcoming CERCLA cleanup decisions.

Figures 3.17 through 3.20 represent the mercury levels at the surface water K-1700 weir and at Storm Water Outfalls 180, 190, and 05A from CY 2010–present. The outfall sampling results are from quarterly sampling performed as part of the quarterly NPDES permit compliance/quarterly SWPP Program sampling, NPDES permit renewal sampling, D&D sampling, and other mercury sampling performed at these outfalls.

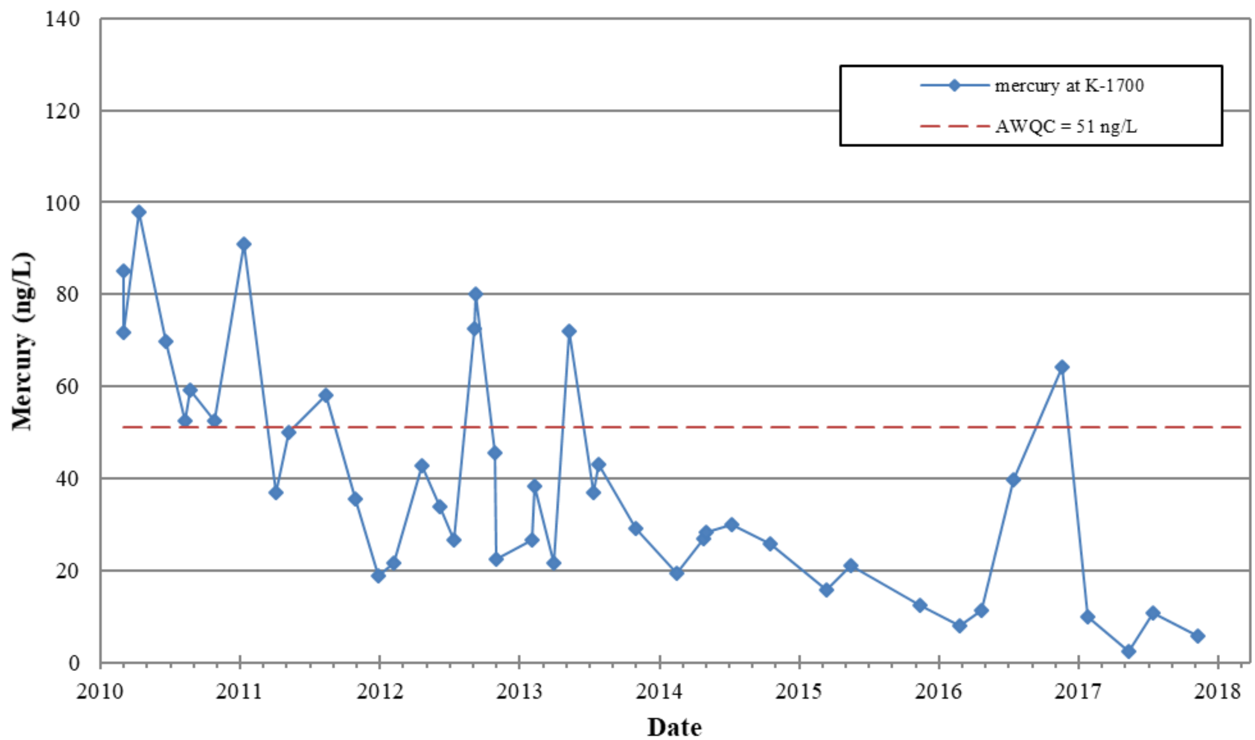


Figure 3.17. Mercury concentrations at surface water location K-1700

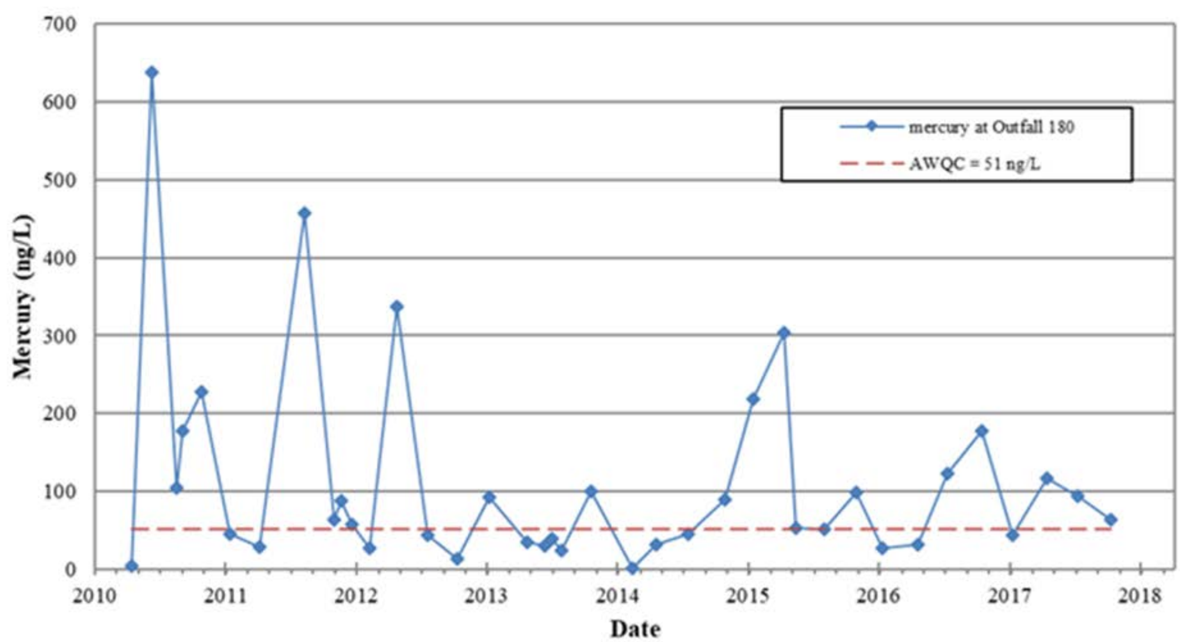


Figure 3.18. Mercury concentrations at Outfall 180

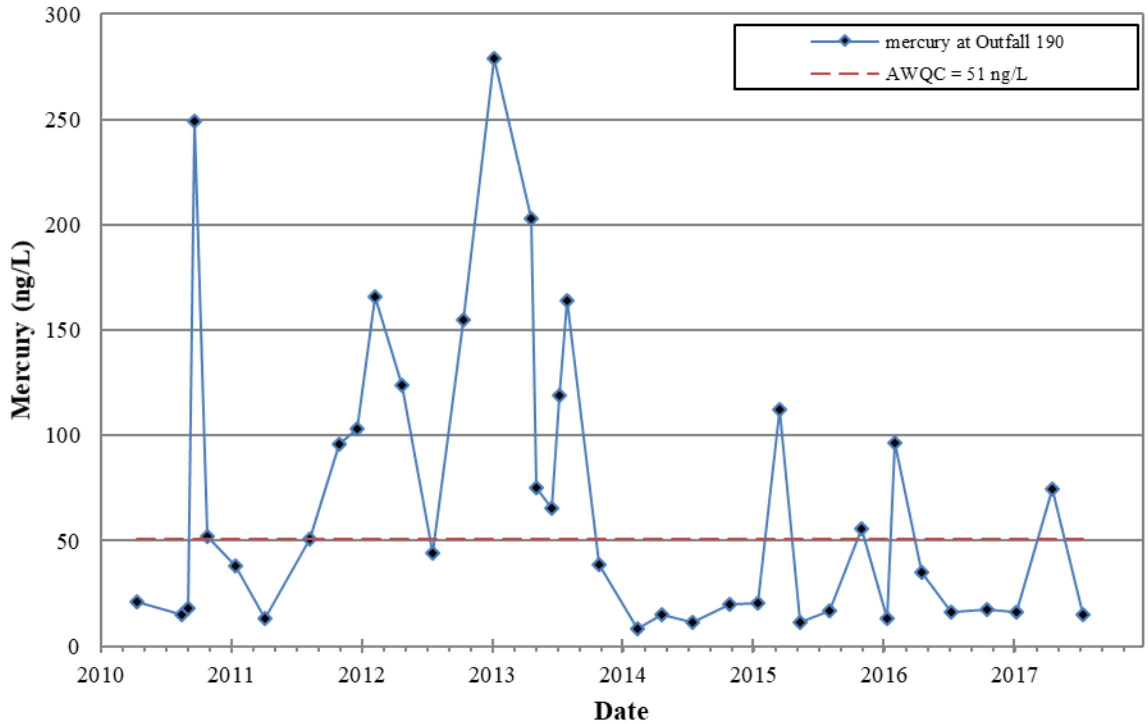


Figure 3.19. Mercury concentrations at Outfall 190

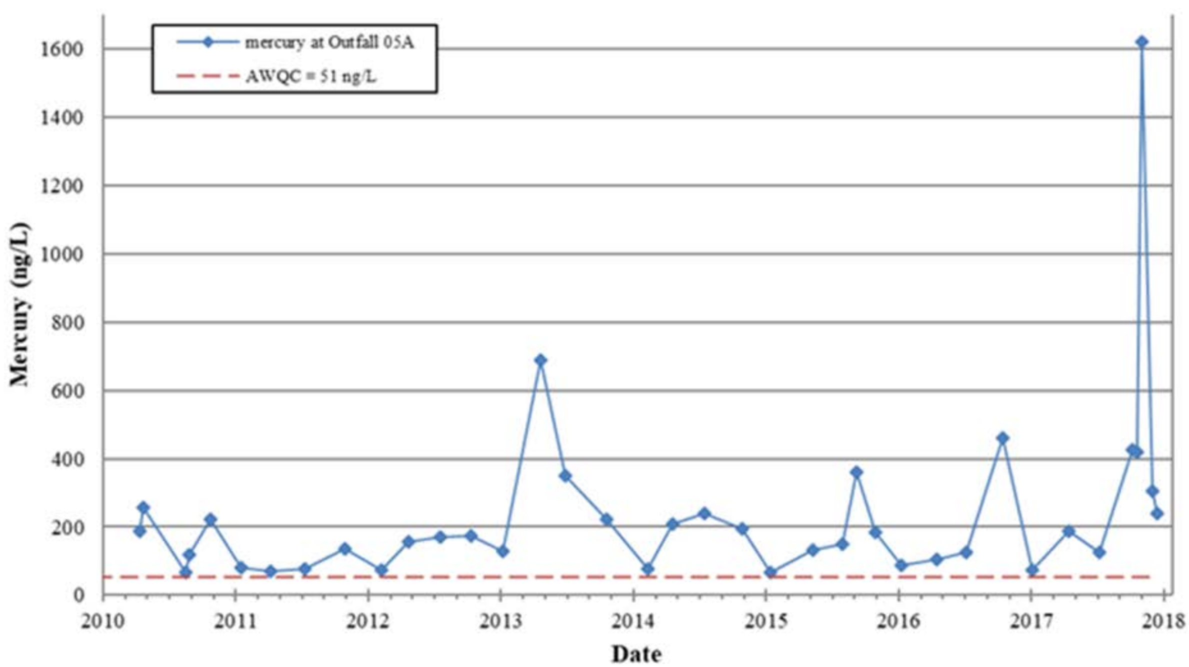


Figure 3.20. Mercury concentrations at Outfall 05A

NPDES Permit Renewal Sampling

Mercury has been sampled at several outfalls as part of the NPDES permit renewal process. None of the mercury results for these samples exceeded the AWQC of 51 ng/L with the exception of Outfall 694, which had a mercury level of 52.8 ng/L. The results of the NPDES permit renewal mercury sampling are in Table 3.14.

Table 3.14. NPDES permit renewal sampling - mercury results

Sampling location	Mercury (ng/L)
Outfall 280	15.3
Outfall 294	32/12.3
Outfall 334	32.6
Outfall 350	45.7
Outfall 660	13.4
Outfall 690	12.7
Outfall 694	**52.8**
Outfall 700	11
Outfall 890	1.55
Outfall 930	4.22
Outfall 992	7.86

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

3.6.4 Additional Mercury Sampling at Selected Storm Water Outfalls

An evaluation of mercury data collected as part of the ETTP SWPP Program was performed to identify locations where mercury has been detected at storm water outfall locations. Mercury has been detected at numerous outfalls across ETTP at levels exceeding water quality criteria. Mercury samples were collected at each of these outfalls as part of the SWPP sampling program. This sampling was performed to determine if mercury levels at these outfalls are decreasing, increasing or stable.

Manual grab samples were collected for low-level mercury analysis at each of the outfalls shown in Table 3.15. Manual grab samples were collected according to the guidelines specified in Sections 3.1.2 and 3.3.1 of EPA 833-B-92-001 and applicable procedures that have been developed by the sampling subcontractor. All mercury samples collected as part of this effort were analyzed using the low-level mercury method, *Method 1631, Revision E: Mercury in Water by Oxidation, Purge and Trap, and Cold Vapor Atomic Fluorescence Spectrometry* (EPA 2002, EPA-1631). Results from this mercury monitoring effort are presented in Table 3.15.

Table 3.15. SWPP mercury sampling results

Sampling location	Mercury (ng/L)
Outfall 100	6.4
Outfall 195	8.77
Outfall 210	0.612
Outfall 230	31.7
Outfall 240	**67.6**
Outfall 250	45.7
Outfall 280	19
Outfall 350	11.9
Outfall 694	23.2

*Results in **bold** exceed the AWQC for mercury (51 ng/L)

Storm Water Outfall 240 drains the area of the former K-1024 building. Historically, Building K-1024 housed instrument shop operations. Mercury was commonly used in instruments, switches, and other equipment that may have been serviced in this shop. Discharges from K-1024 went to building storm water neutralization pits, which were connected to the storm drain system. Therefore, elevated mercury at Outfall 240 may be related to the K-1024 instrument shop operations. Figure 3.21 shows mercury concentrations at Outfall 240 from CY 2010 through CY 2017.

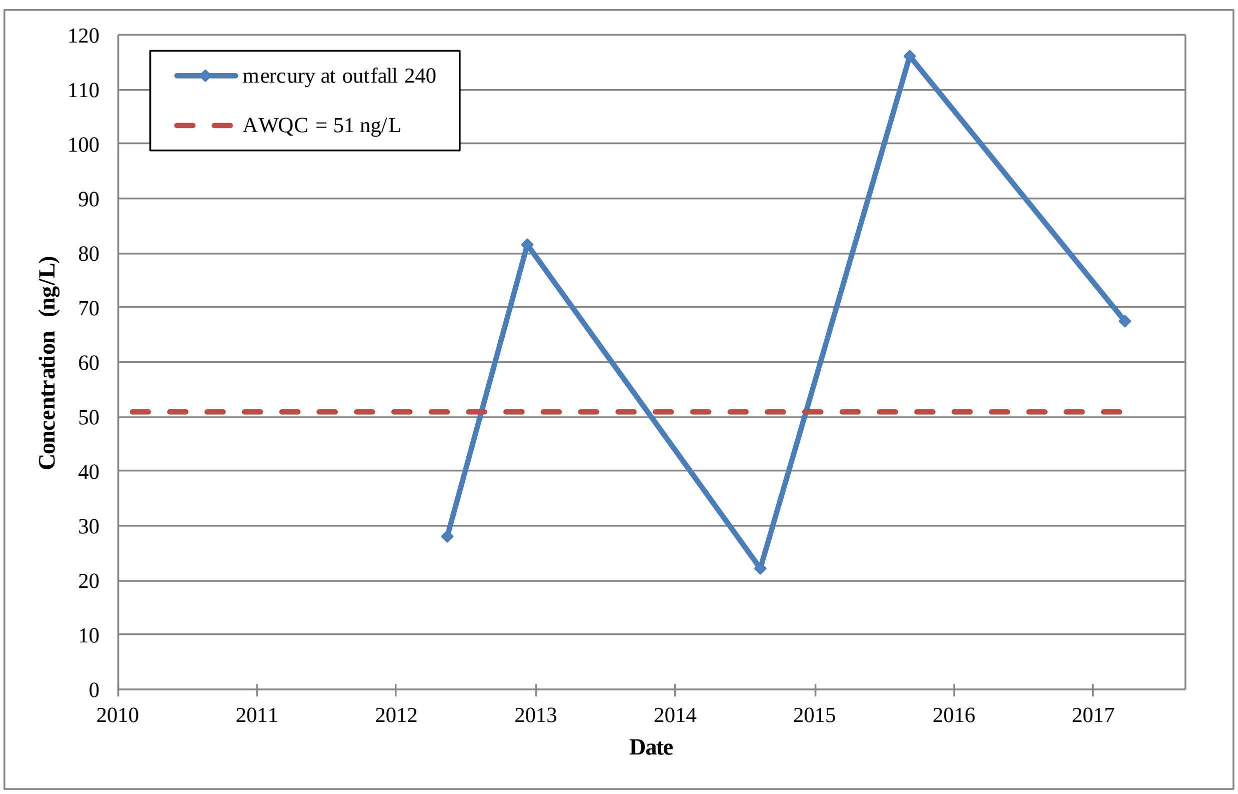


Figure 3.21. Mercury concentrations at Outfall 240

3.6.4.1 Chromium Water Treatment System and Plume Monitoring

In 2007, the release of hexavalent chromium into Mitchell Branch from Storm Water Outfall 170 and from seeps at the headwall of Outfall 170 resulted in levels of hexavalent chromium that exceeded state of Tennessee AWQC. Immediately below Outfall 170, hexavalent chromium levels were measured at levels as high as 780 µg/L, which exceeded the state of Tennessee hexavalent chromium water quality chronic criterion of 11 µg/L for the protection of fish and aquatic life. The levels of total chromium were at approximately the same value, indicating that the bulk of the release was almost entirely hexavalent chromium at the release point. The reason that the chromium was still in a hexavalent state is unknown, considering that hexavalent chromium has not been used in ETTP operations in over 30 years. On November 5, 2007, DOE notified EPA and TDEC of their intent to conduct a CERCLA time-critical removal action to install a grout barrier wall and groundwater collection system to intercept this discharge. This action reduced the level of hexavalent chromium in Mitchell Branch from 780 µg/L to levels consistently below the AWQC value of 11 µg/L. The time-critical removal action is documented in DOE/OR/01-2598&D2 (DOE 2013), *Removal Action Report for the Long-Term Reduction of Hexavalent Chromium Releases into Mitchell Branch at the East Tennessee Technology Park, Oak Ridge, Tennessee*.

In 2012, the treatment of the chromium collection system water was transitioned from the Central Neutralization Facility (CNF) to the CWTS. To monitor both the continued effectiveness of the collection system as well as the effectiveness of the new CWTS, periodic monitoring is performed as part of the ETTP SWPP Program. In CY 2017, samples were collected 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. Samples are collected at MIK 0.79 to monitor chromium and hexavalent chromium concentrations in Mitchell Branch. Figures 3.22 and 3.23 show the results for the analyses for total chromium and hexavalent chromium, respectively.

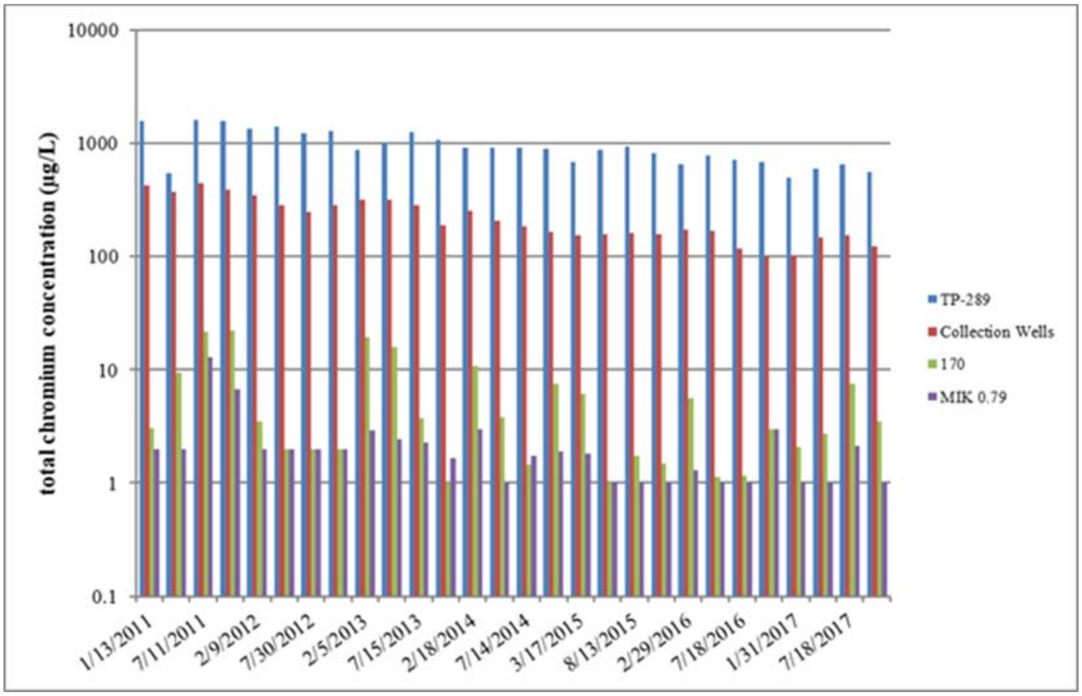


Figure 3.22. Total chromium sample results for the chromium collection system

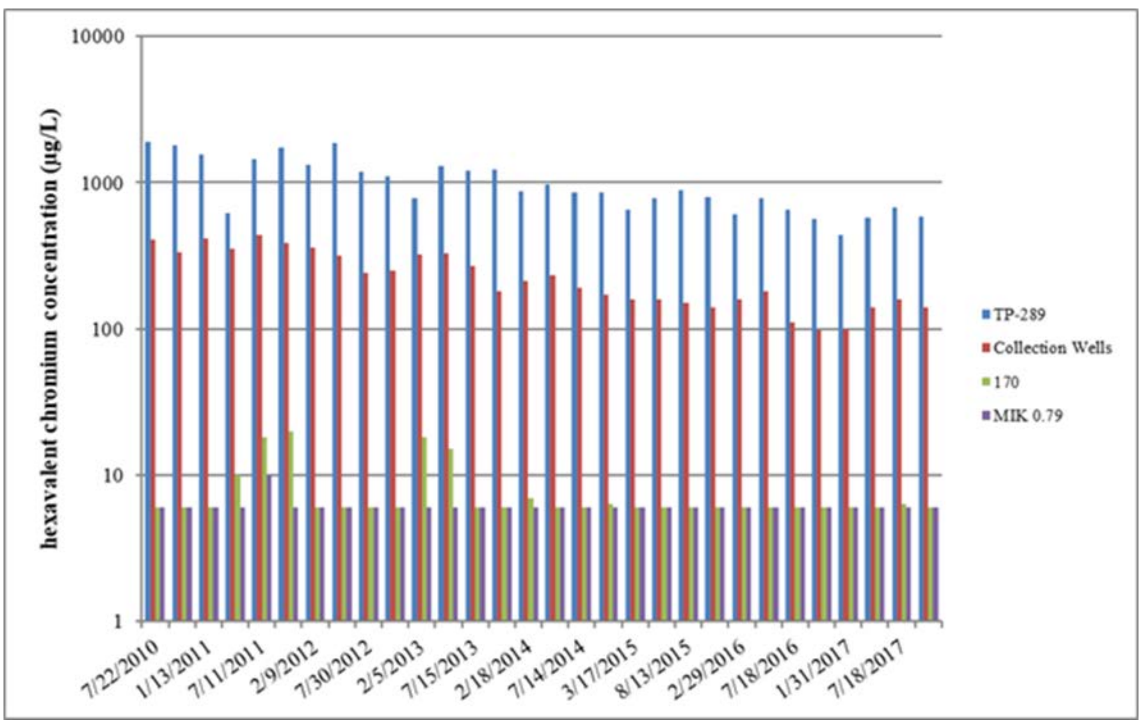


Figure 3.23. Hexavalent chromium sample results for the chromium collection system

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. Hexavalent chromium levels at Outfall 170 and MIK 0.79 have remained remarkably consistent since 2010, as shown earlier in Figure 3.24.

Additional monitoring of the CWTS will be performed as indicated in UCOR-4259, *East Tennessee Technology Park Chromium Water Treatment System Sampling and Analysis Plan, Oak Ridge, Tennessee* (UCOR 2017a). In addition to chromium treatment, the upgraded CWTS also has provisions for air stripping of the VOCs that are also found in the groundwater. The air stripper has demonstrated a removal efficiency of greater than 98 percent over the last several monitoring periods.

3.6.4.2 NPDES Permit Renewal Monitoring

Preparations are being made for the NPDES permit application that will be submitted to TDEC in CY 2019. The submittal schedule will include time for DOE to review the application before it is submitted to TDEC. Sampling required to complete the permit application continued as part of the CY 2017 SWPP Program SAP. Table 3.16 indicates the dates when samples were collected at representative outfalls during CY 2017.

Table 3.16. NPDES permit renewal sampling conducted in CY 2017

Outfall	Manual Grab Samples—Date Collected	Manual Grab or Grab-by-Compositor Samples—Date Collected	Composite Samples—Date Collected
280	2/7/17	2/7/17	1/11/17
294	10/23/17	10/24/17	10/23/17
334	10/23/17	10/23/17	9/5/17
350	10/23/17	10/23/17	10/24/17
560	4/3/17	---	---
660	4/3/17	4/3/17	1/11/17
690	4/3/17	3/14/17	3/8/17
694	4/3/17	3/8/17	1/11/17
700	12/5/17	12/5/17	12/6/17
710	---	12/21/17	1/23/17
890	2/22/17	2/22/17	2/23/17
930	12/21/17	---	12/21/17
992	3/7/17	3/7/17	3/17/17

Table 3.17 indicates results from these NPDES permit renewal sampling efforts performed in CY 2017 that exceeded screening levels.

Table 3.17. Analytical results exceeding screening levels for NPDES permit renewal sampling, CY 2017

Outfall	Copper	Lead	Gross Alpha Activity	$^{233/234}U$	^{238}U	Mercury	PCB-1254	PCB-1260
	Screening level 7 µg/L	Screening level 1.8 µg/L	Screening level 15 pCi/L	Screening level 28 pCi/L	Screening level 30 pCi/L	Screening level 51 ng/L	Screening level Detectable	Screening level Detectable
280	8.97						0.0845	0.0488
294	11.3							
334	12.7	8.09						
350			151	61.6	46.1			
380				32.7				
690							0.0386	
694						52.8		

Screening criteria for copper, PCB-1254, and PCB-1260 were exceeded at Outfall 280, which receives storm water runoff from a portion of the K-1064 peninsula. Past activities conducted at the K-1064 area include incineration of waste paints, organics, and waste oils in a tepee incinerator. In addition, the area was also used for the storage of drums of PCB-contaminated materials, solvents, and waste oils. PCBs identified in the storm water samples from Outfall 280 may be related to these past activities, when scrap metal and electrical equipment had been stored. The presence of copper in the storm water runoff from Outfall 280 may also be linked to these past uses of portions of the K-1064 peninsula area.

Screening criteria for copper were exceeded at Outfall 294, which receives storm water runoff from a radiologically contaminated area on the K-1064 peninsula where uranium hexafluoride (UF_6) converter shells were once stored. The converter shells were removed several years ago as part of the K-1064 peninsula D&D program. Discharges from this outfall have historically contained metals and radiological contaminants at levels above screening criteria due to these converter shells.

Screening criteria for copper and lead were exceeded at Outfall 334. Outfall 334 receives runoff from a portion of the west wing of the K-25 building slab. The former K-25 building was utilized in the isotopic enrichment of uranium by gaseous diffusion. As part of this process, large quantities of copper piping, lead solder, and other metals were utilized. D&D activities at the K-25 building slab likely led to the presence of lead and copper in quantities above screening criteria in the discharge from Outfall 334.

Screening criteria for gross alpha radiation, $^{233/234}U$, and ^{238}U were exceeded at Outfall 350. Outfall 350 receives storm water runoff from the former K-1066-D cylinder yard area. Even though this area has not been utilized for uranium operations for many years, the presence of elevated gross alpha radiation and isotopic uranium in storm water runoff from Outfall 350 was likely since K-1066-D was historically utilized in the handling of UF_6.

Screening criteria for $^{233/234}U$ were exceeded at Outfall 380, which receives storm water runoff from the K-27 and K-29 building slabs, as well as Building K-1131. The former K-27 and K-29 buildings were utilized in the isotopic enrichment of uranium by gaseous diffusion. Building K-1131 was utilized in the production of UF_6 as well as withdrawal of UF_6 tails. D&D activities at K-27 and K-1131 likely led to the presence of $^{233/234}U$ in quantities above screening criteria in the discharge from Outfall 380.

Screening criteria for PCB-1254 were exceeded at Outfall 690. Outfall 690 receives storm water runoff from a portion of the former K-33 building area. K-33 was used in the isotopic enrichment of uranium. A variety of oils, lubricants, and solvents were in use in the K-33 building as part of the enrichment process. Some of these materials are believed to have been contaminated with PCBs. The presence of PCBs in the storm water runoff from Outfall 690 may be related to past activities conducted in the K-33 building or with the D&D of the K-33 building.

Screening criteria for mercury were exceeded at Outfall 694. Storm Water Outfall 694 receives storm water runoff from the area near the former K-891 pump house. The pump house may have pumped mercury-contaminated water and sediments from Poplar Creek to the K-892 water treatment facility. Some of the water and sediments may have been discharged back into the creek through Outfall 694. D&D activity in early 2015 removed the K-892 building, which is located immediately to the south of the Outfall 694 drainage area. The recent increase in the mercury levels measure at Outfall 694 may be attributable to the recent D&D activities of the K-892 building.

3.6.4.3 Investigative Sampling at Storm Water Outfalls

Storm Water Outfall 195 receives storm water runoff from an area that has been utilized for several years by the UCOR Power Integration Group for the storage of new power poles. Because of the potential for wood preservatives to be washed from the power poles by storm water flow, an investigation was conducted to determine if the flow from Outfall 195 contained any chemicals that might be traceable to the use of wood preservatives. In March 2017, discharge from Outfall 195 was sampled for VOCs, semivolatile organic compounds (SVOCs), metals, and other chemicals commonly utilized in the production of wood preservatives. No exceedances of screening levels were noted in the samples collected from Outfall 195. Therefore, it is likely that none of the chemical components of wood preservatives utilized in wood preservatives are being washed from power poles being stored in the Outfall 195 drainage area.

3.6.4.4 Flow Monitoring at Storm Water Outfalls Associated with NPDES Permit Requirements

Flux monitoring at selected outfalls is a part of the mercury investigation at ETTP. To properly monitor mercury flux, accurate flow estimates and mercury concentrations measured during storm events are needed. Flow monitoring was conducted or is planned at Outfalls 100, 170, 180, and 190 as part of the requirements of the ETTP NPDES permit.

At each of these four storm drain locations, the ETTP NPDES permit requires that flows for three ranges of rainfall events be monitored at least once during the permit term at each outfall. The rainfall events for which flow-monitoring data were collected and evaluated are defined as follows:

- 0.1–0.5 in. rain event
- 0.5–1.5 in. rain event
- 1.5 in. or greater rain event

These measured flows are being utilized to compare against modeled flows generated using TR-55, which is the model at ETTP for estimating storm water discharge flows. These compared values will be used to increase the accuracy of the TR-55 flow modeling process, if possible. Given that the flow monitoring occurs over a variety of rain events and multiple field variables could pose problems in collecting usable data, this monitoring will be completed during the permit period.

3.6.4.5 Results of Flow Monitoring at Outfall 170

The calculated flows obtained at Outfall 170 with the TR-55 model do not appear to correspond well with the measured flows obtained by direct measurement using a rain gauge and flow meter. In many instances, the flow values calculated using TR-55 are a fraction of the flows measured by monitoring equipment. The only situations where the calculated flows and the measured flows were reasonably close occurred when there had been a long span of time between rain events and the baseflow had returned to a minimum level. It appears the TR-55 model does not consider that a rain event may affect the amount of discharge from an outfall for several days after an event. It may be that the model treats the rain event as discrete and short term, without considering longer-term effects. This could explain the consistently low estimates of flow compared to the flow measurements collected by the automatic water sampling equipment (ISCO), which operates and records on a continuous basis. It would also explain why the TR-55 calculated flow and the measured flow are closest for a rain event that occurs after an extended dry period.

Flow data collected by the ISCO monitoring equipment indicate that rain events of as little as 0.2 in. may cause the discharge from Outfall 170 to overtop the V-notch weir if they occur over a short period of time. The Outfall 170 drainage system responds rather quickly to short-term, high-intensity rain events. Because of the size of the drainage area and due to the fact that approximately 30 percent of the area is impervious to storm water infiltration, even smaller rain events generate large quantities of runoff. It is believed that the V-notch weir at Outfall 170 can be utilized for flow measurement in storm events of up to approximately 0.5 in., as long as the rain event occurs over a long enough time period that the weir is not overtopped.

In the ETTP NPDES permit, TDEC states that only an annual estimate of the daily maximum flow is required at regulated outfalls. There is no accompanying description in the ETTP NPDES permit concerning the accuracy of the measurement. Therefore, flow measurements obtained at Outfall 170 using the TR-55 model meet the requirements of the NPDES permit as being a flow estimate. Additionally, no flux monitoring was required at Outfall 170 by the ETTP NPDES permit due to the historically low concentrations of bioaccumulative pollutants, such as mercury and PCBs that are discharged from this outfall. Therefore, it is not believed at this time that additional flow monitoring capabilities are required at Outfall 170. In the future, if more accurate flow measurement is required, an H-flume or similar flow measurement device, may be required at this outfall.

3.6.4.6 Status of Additional Flow Monitoring Activities Associated with NPDES Permit Requirements

As part of the requirements of the ETTP NPDES storm water permit that became effective on April 1, 2015, continuous flow monitoring was conducted at Outfall 190 using an H-type flume and flow meter with recorder. Flow data were collected from the monitoring equipment at the Outfall 190 flume from December 2015 through March 2017. Base flow for Outfall 190 was determined by utilizing the lowest 24-h average flow that was measured during the December 2015 through March 2017 time period. The base flow for Outfall 190 was calculated to be approximately 8500 gal/min. The measured flow data at Outfall 190 will be compared to calculated flows for Outfall 190 that will be generated using the NRCS TR-55 model. The flow comparisons are being made for three ranges of rainfall events: a 0.1–0.5 in. rain event, a 0.5–1.5 in. rain event, and a 1.5 in. or greater rain event. These compared values will be utilized to increase the accuracy of the TR-55 flow modeling process.

In addition, flow-weighted composite sampling for mercury was conducted using the flume and flow monitoring equipment installed at Outfall 190. Mercury samples were collected for each of the three ranges of rainfall events, and the results are shown in Table 3.18. The mercury sampling results will be used along with the recalibrated TR-55 flow model to determine mercury flux for Outfall 190.

Table 3.18. Analytical results from flow-proportional composite sampling at Outfall 190

Location	Parameter	Date Sampled	Rain Event Sampled	Results (ng/L)
Outfall 190	Mercury	2/2/16	0.1–0.5 in.	96.5
Outfall 190	Mercury	1/12/17	0.5–1.5 in.	162
Outfall 190	Mercury	9/7/17	1.5 in. or greater	566

An H-type flume was also purchased for installation at Outfall 100. Installation of the flume was completed in late CY 2017. Collection of flow data began in early CY 2018. A flume was also purchased for Outfall 180 in CY 2017. It is expected that the flume will be installed at Outfall 180 in early CY 2018.

3.6.4.7 Significant Spill Events

Sanitary wastewater from a bathroom and shower facility (K-2527-T) is routed to a 1,100-gal capacity, aboveground tank for storage until it is pumped out by a sewage pumping subcontractor. On June 12, 2017, the sanitary wastewater was discovered to have overtopped this storage tank and filled the associated secondary containment dike. The water then flowed over a concrete surface into storm drain catch basin 8060, which is located approximately 15 to 20 ft to the west of the tank and dike. Flow that enters catch basin 8060 travels, through a subsurface storm water drainage piping system to Storm Water Outfall 210, which discharges into Mitchell Branch. The volume of sanitary wastewater that entered the storm drain inlet could not be accurately determined.

Corrective actions were taken immediately upon discovery of this overflow. The sewage pumping contractor pumped the contents of the tank and the secondary containment dike for treatment at a permitted sewage treatment facility. UCOR Maintenance personnel identified the causes of this incident and began taking actions to correct them. It was determined that the cause of this overflow was a shut-off valve in the change house that had failed. In addition, a urinal flap had also stuck in the open position. This allowed sanitary water to flow into the tank on a continuous basis for an unknown amount of time over the weekend.

ACs had previously been put in place in an effort to prevent overflows of this type from occurring. These ACs included shutting off the water supply to the restrooms during offshift periods, and placement of signs in the bathroom facility connected to this tank reminding employees to be sure the bathroom fixtures have stopped running before leaving the facility. However, in this instance the shut-off valve proved to be faulty. In addition, a flapper valve in one of the urinals stuck in the open position and went un-noticed by the last users.

The contents of the tank had been pumped out on June 9, 2017. Since a limited staff was working during the period of June 9, 2017, through the morning of June 12, 2017, it is likely that the vast majority of the water released was chlorinated, potable water.

Visual observation of Outfall 210 conducted on June 12, 2017, showed that the outfall was dry. Therefore, it is likely that no wastewater from the overflow reached Mitchell Branch. No adverse impact to fish or other aquatic life was observed.

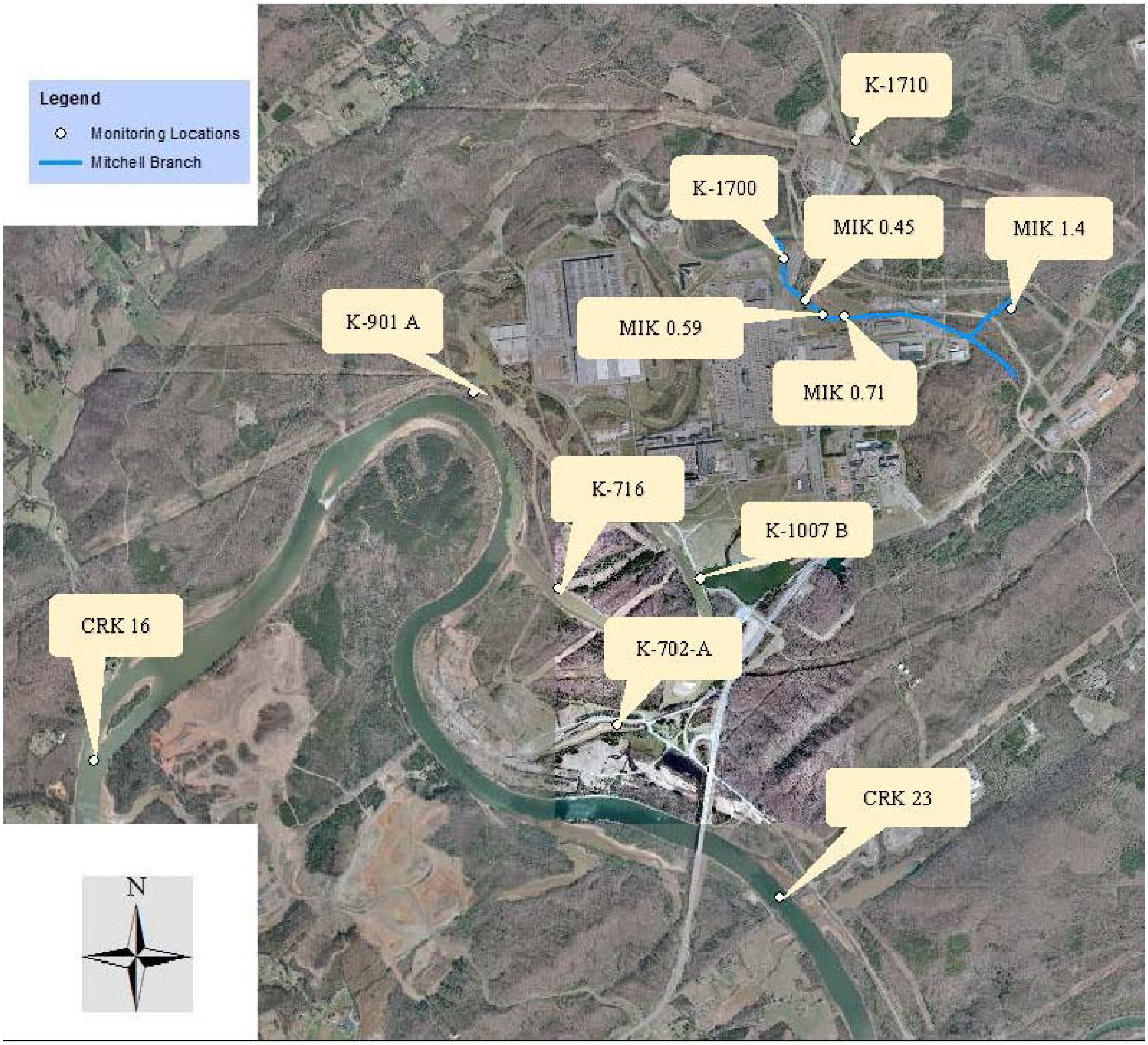
This event is considered to be a noncompliance with the ETTP NPDES permit (permit no. TN0002950) due to an unpermitted discharge of wastewater to the storm drain system. An NPDES permit noncompliance report was sent to TDEC as part of the Discharge Monitoring Report submitted in April 2018. The incident was also considered to be a violation of SOP-99033 and was reported to TDEC in the July 2017 quarterly report.

No impact to the fish and aquatic life in Mitchell Branch was noted immediately after this incident occurred or during subsequent inspections of the Mitchell Branch and Storm Water Outfall 210 areas. No threat to human health or the environment is believed to have occurred as a result of this incident.

3.6.5 Surface Water Monitoring

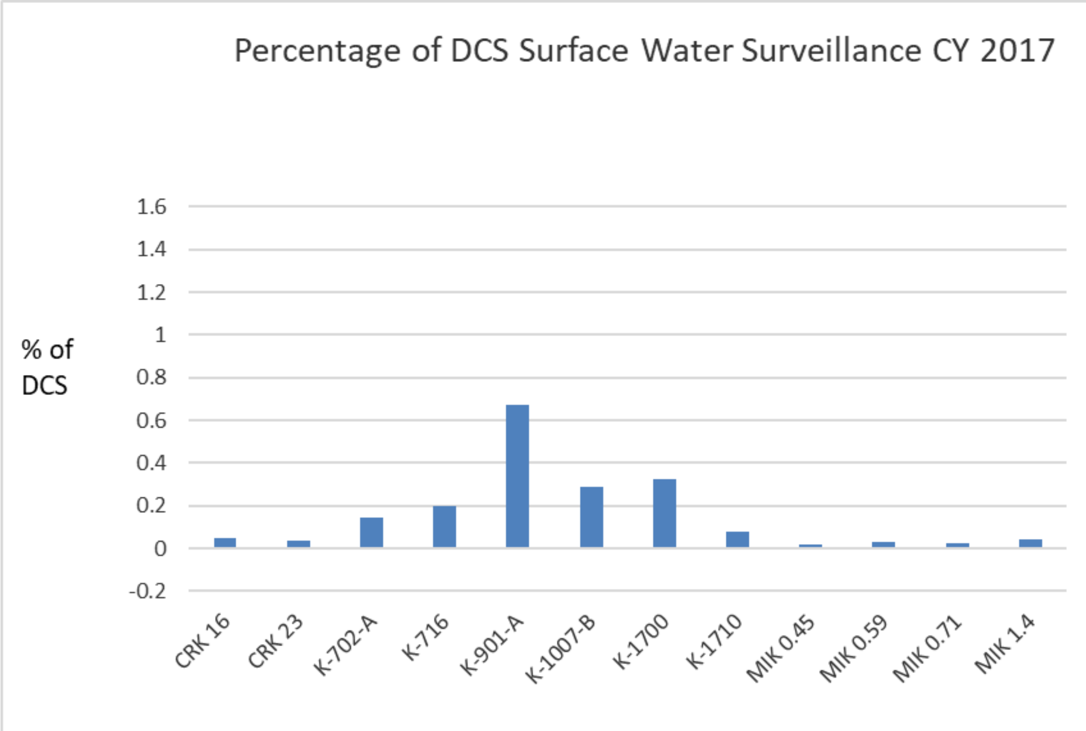
During 2017, the ETTP EMP personnel conducted environmental surveillance activities at 12 surface water locations (Figure 3.24) to monitor groundwater and storm water runoff at watershed exit pathway locations (K-1700, K-1007-B, and K-901-A) or ambient stream conditions (Clinch River kilometers [CRKs] 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.

At MIKs 0.45, 0.59, and 0.71, quarterly monitoring is conducted for ^{99}Tc only. 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 sum of fractions (SOF) and averaged to produce a rolling 12-month average. The average SOF is recalculated whenever new data become available. If the average SOF for a location exceeds the DCS requirement of remaining below 1.0 (100 percent) for the year, a formal source investigation is required. Sources exceeding DCS requirements would need an analysis of the best available technology to reduce the SOF of the radionuclide concentrations to less than 1.0 (100 percent). In 2017, the monitoring results yielded SOF values of less than 0.01 (1 percent of the allowable DCS) at all surface water surveillance locations at ETTP (Figure 3.25).



CRK = Clinch River kilometer and MIK = Mitchell Branch kilometer

Figure 3.24. East Tennessee Technology Park Environmental Monitoring Program surface water monitoring locations



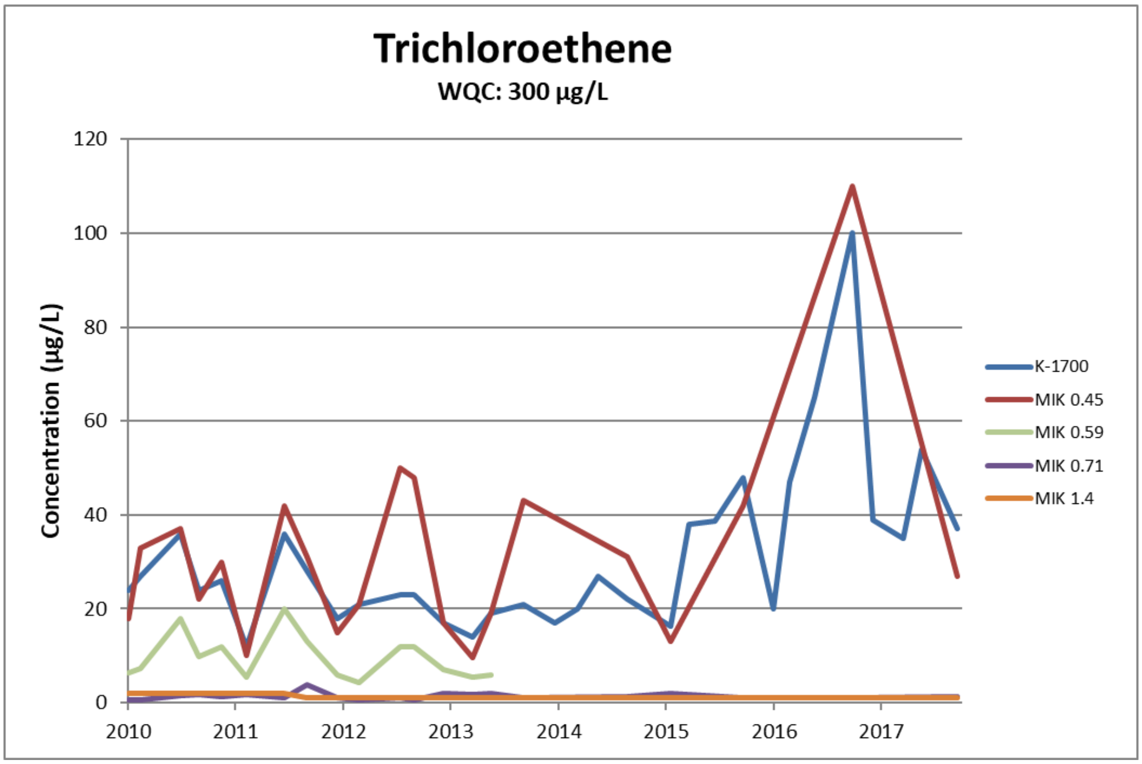
CRK = Clinch River kilometer and MIK = Mitchell Branch kilometer

Figure 3.25. Annual average percentage of derived concentration standards (DCSs) at surface water monitoring locations, 2017

Depending on the monitoring location, water samples may be analyzed for pH, selected metals, and VOCs. In 2017, results for most of these parameters were well within the appropriate AWQC. There were five exceptions in 2017. During the second quarter of 2017, there were two exceedances of the AWQC for cadmium. At CRK-16, cadmium was measured at 0.39 µg/L, and at K-1700, cadmium was measured at 0.6 µg/L. Cadmium has a hardness-dependent AWQC of 0.28 µg/L and 0.43 µg/L for the Clinch River and Mitchell Branch, respectively. 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 4.9 mg/L at K-901-A. This reading was collected at a time of elevated temperatures and very low flow due to the drought conditions, which favor high biological activity and the resulting depletion of dissolved oxygen. In addition, due to a laboratory reporting error, the results for cadmium at K-901-A, K-1007-B, and K-1700 were reported at 0.6 µg/L, which is above the AWQC. However, in all three instances the results were reported as non-detectable. In the fourth quarter, elevated levels of zinc were detected at both CRK-23 (360 µg/L) and MIK 1.4 (1,200 µg/L). Soils in the northern portion of ETTP contain relatively high levels of naturally occurring zinc. No obvious signs of distress (e.g., dead fish) were observed to be associated with any of these exceedances in 2017.

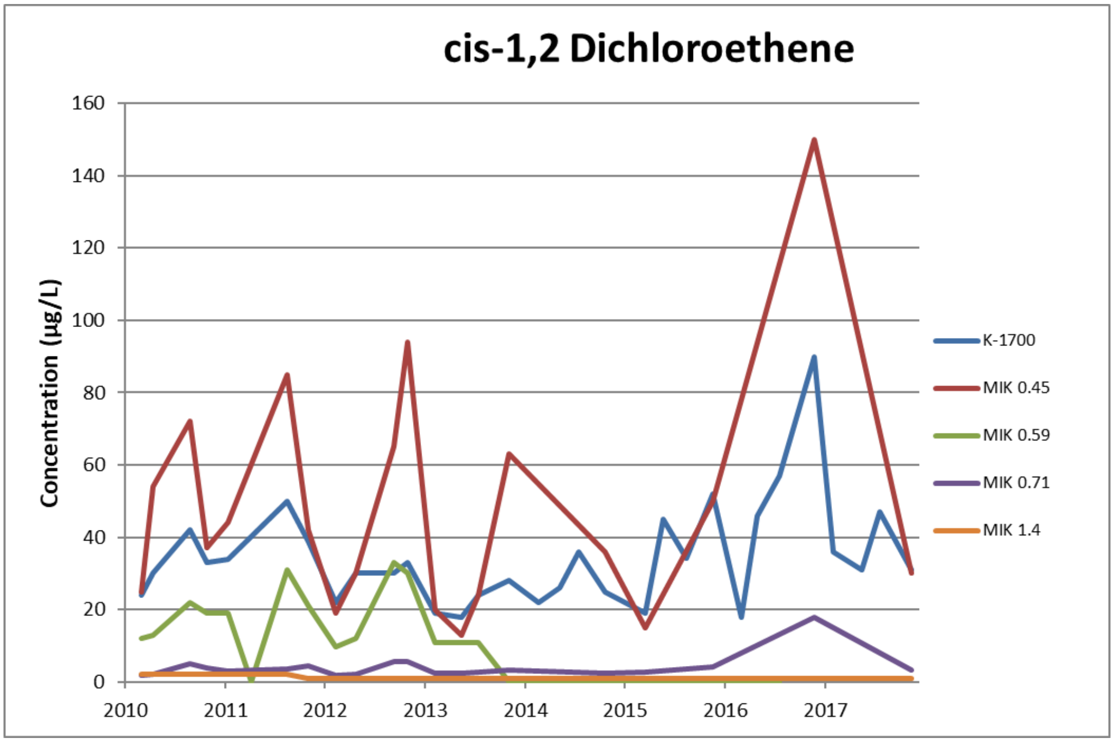
Figures 3.26 and 3.27 illustrate the concentrations of TCE (trichloroethene) and cis-1,2-dichloroethene (cis-1,2-DCE) from the K-1700 weir (which is used to monitor Mitchell Branch), the only surface water monitoring location where VOCs are regularly detected. In the samples collected on November 22, 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. Although there had been a test of the CWTS in October 2016, in which the collection well pumps had been intentionally stopped, the test had been completed and the pumps restarted over a month before these samples were collected. The Sample Management Office (SMO) has reviewed these data points and they did not discover any indication of a laboratory error, and all other sources of error have been ruled out, leaving the investigation 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. Moreover, the standards for 1,2-DCE apply only to the “trans” form of 1,2-DCE; almost all of the 1,2-DCE is in the cis- isomer. In addition, vinyl chloride has sometimes been detected in Mitchell Branch water (Figure 3.28). 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, storm drain network monitoring generally has not detected these compounds in the storm water discharges. When detected, the concentrations are lower than in the stream. Therefore, it appears that the primary source of these compounds is contaminated groundwater.

Since CWTS was installed, chromium levels in Mitchell Branch have dropped dramatically, with levels of total chromium being routinely measured at less than 6 µg/L (Figure 3.29). In 2017, hexavalent chromium levels in Mitchell Branch were all below the detection limit of 6 µg/L.



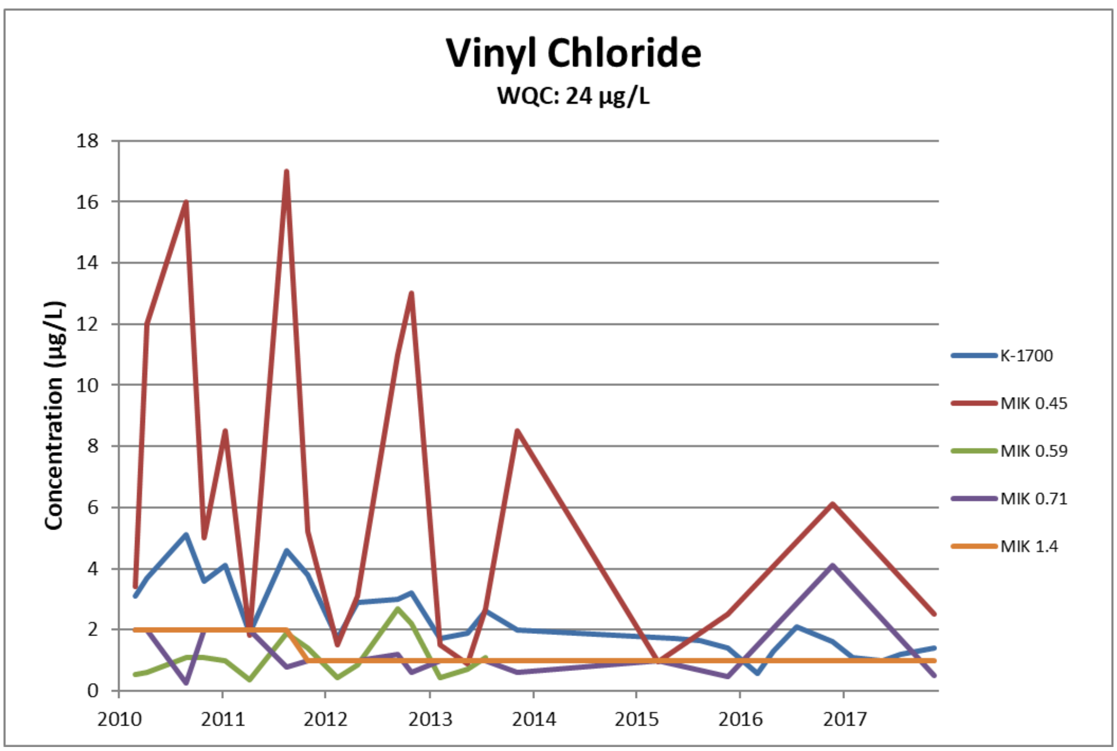
MIK = Mitchell Branch kilometer

Figure 3.26. Trichloroethene concentrations in Mitchell Branch.



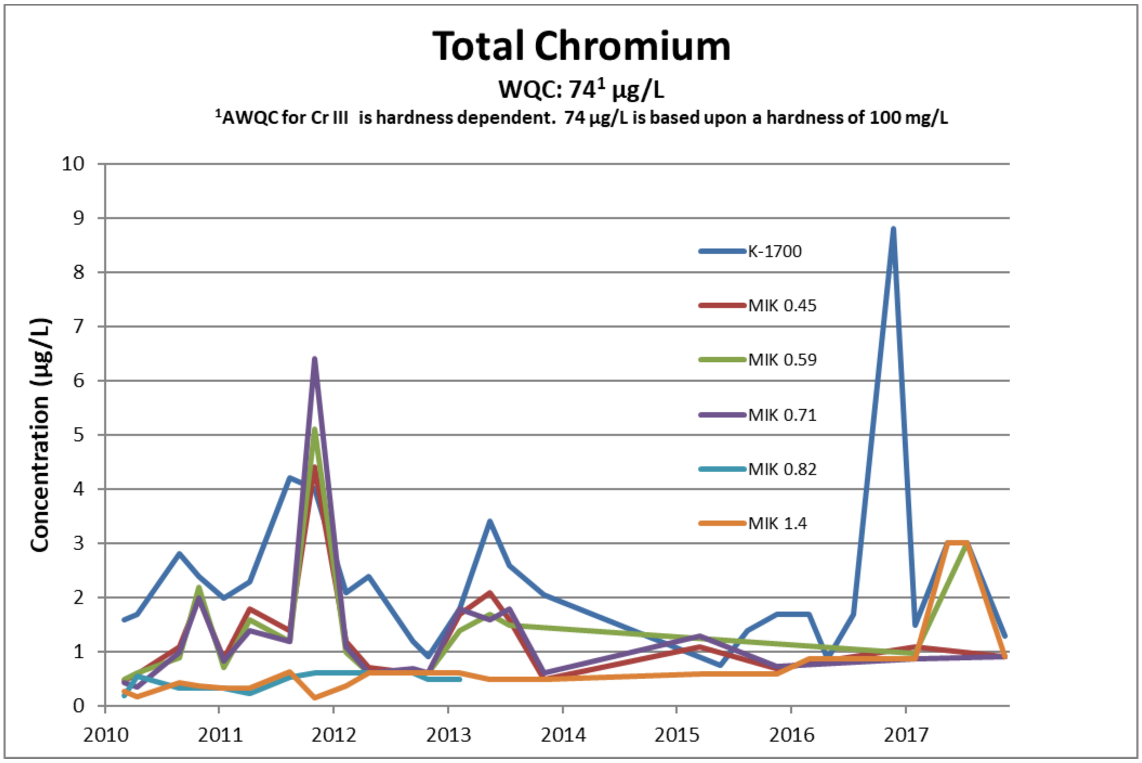
MIK = Mitchell Branch kilometer

Figure 3.27. Concentrations of cis-1,2-dichloroethene in Mitchell Branch



MIK = Mitchell Branch kilometer

Figure 3.28. Vinyl chloride concentrations in Mitchell Branch



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. AWQC = ambient water quality criterion, MIK = Mitchell Branch kilometer

Figure 3.29. Total chromium concentrations in Mitchell Branch

3.6.6 Groundwater Monitoring

3.6.6.1 General Groundwater Monitoring at ETTP

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 associated with wells UNW-114 and UNW-064 continue to decrease, there remains a known area with very high concentrations that affect wells DPT-K1070-5 and DPT-K1070-6. The persistent, very high concentrations of these VOCs suggest an ongoing contaminant source release, possibly a DNAPL.

Contaminant conditions in the groundwater exit pathway areas are generally stable and similar to conditions in recent years. Results are compared to MCL values for comparative purposes only because MCLs are not a record of decision (ROD)-specified goal. Chromium continues to be measured at levels near or slightly above MCLs at the K-31/K-33 area. A slight increase in arsenic concentrations was observed at the K-1064 peninsula that may be related to RA work in the area. At the K-27/K-29 area, TCE continues a gradual decrease in well UNW-038, while cis-1,2-DCE continues a gradual increasing trend in well BRW-058. Samples from springs 10-895 and PC-0, which discharge groundwater into Poplar Creek, had TCE concentrations greater than the 5 µg/L MCL during FY 2017, similar to levels measured in recent years. Low concentrations of metals (less than MCL concentrations) are detected in wells near the K-1007-P1 Holding Pond, and at the K-770 area, alpha and beta activity levels are near or below the MCL screening concentrations. At the K-1085 Drum Burial/Old Firehouse Burn area, TCE, and PCE continue to be present at concentrations greater than the MCL.

Monitoring results at the wells in the K-1407-B and -C ponds area are generally consistent with results from previous years and show several fold concentration fluctuations in seasonal and longer-term periods. The detection of VOCs at concentrations well above 1,000 µg/L and the steady concentrations over recent years suggest the presence of DNAPL in the vicinity of well UNW-003. The Sitewide ROD will address groundwater contamination present in the area of the former ponds.

Monitoring locations, analytical parameters, and cleanup levels were not specified for groundwater monitoring at the K-1070-C/D Burial Ground (Figure 3.30), although the primary contaminants of concern (COCs) in that area are VOCs. Semiannual samples collected at wells and surface water locations outside the perimeter of the K-1070-C/D Burial Ground are analyzed for VOCs and general water quality parameters. Monitoring at the site is focused on providing data for evaluating changes in contaminant concentrations near the source units or potentially discharging to surface water within the boundaries of the ETTP. Approximately 9,100 gal of mixed volatile organic liquids were disposed of in G-Pit during its period of use between 1977 and 1979. Site characterization data collected at G-Pit in the mid-1990s showed the presence of 1,1,1-TCA (840 mg/L); 1,1-DCA (43 mg/L); toluene (74 mg/L); and TCE (220 mg/L). The 1,1,1-TCA is amenable to biodegradation to 1,1-DCA by microbes in the *Dehalobacter* genus. Although 1,1-DCA is also amenable to degradation by some species of *Dehalobacter*, the presence of cis-1,2-DCE and vinyl chloride (VC) tend to inhibit the biodegradation of 1,1-DCA. Cis-1,2-DCE and VC are common biodegradation products of PCE and TCE, which are also present in groundwater at the site along with 1,1-DCE, another biodegradation product of PCE and TCE.

Following remediation of G-Pit in December 1999 through January 2000, monitoring wells UNW-114, TMW-011, and UNW-064 (Figure 3.31) were selected to monitor the VOC plume leaving the K-1070-C/D Burial Ground because they were located in the principal known downgradient groundwater pathway. Results of monitoring at these wells show elevated VOC concentrations. VOC concentrations at these three wells were decreasing prior to the excavation of the G-Pit contents (during FY 2000) and continue to decrease. Although 1,1,1-TCA was formerly present at concentrations far greater than its 200 µg/L MCL, natural biodegradation has reduced 1,1,1-TCA concentrations to less than the drinking water standard. Several direct push monitoring points were installed to the west of UNW-114 during investigations conducted in support of a Sitewide Groundwater RI in 2005. The purpose of these monitoring points was to investigate groundwater contamination in an area along potential geologically controlled seepage pathways that may have connected the G-Pit contaminant source to the former SW-31 spring. DOE continues to monitor two of these points (DPT-K1070-5 and DPT-K1070-6) to measure VOC concentrations and their fluctuations.

Of the three wells monitored at this site, well UNW-114 is closest to the source area and with a well screen interval elevation of 774.95–784.95 ft above mean sea level (aMSL). Monitoring data for well UNW-114 (Figure 3.31) show that concentrations of most VOCs have been variable since 2005, although with the addition of the FY 2017 data, an increase in concentration is noted in VC and 1,1-DCE, along with a slight increase in cis-1,2-DCE and TCE levels. PCE has remained in a gradual decline throughout the sampling period. Concentrations of 1,1-DCA have gradually increased from a minimum of about 140 µg/L in 2007 to a recent concentration of 1,200 µg/L. Since 2010, 1,1,1-TCA has remained at 1 µg/L or below. The September 2017 sample yielded a very low concentration of 0.59 J µg/L. The lingering 1,1-DCA, which exhibits an increasing concentration trend, is inferred evidence of residual contamination migrating from degrading DNAPLs in the source area beneath the former G-Pit disposal site. Recent concentrations of most chlorinated VOCs in well UNW-114 are within factors of about 2 to 5 times their MCLs.

Well UNW-064 (well screen elevation 783.87–788.87 ft aMSL) is located slightly further downgradient from the contaminant source area than UNW-114 and its monitoring data exhibit a slightly different behavior. Similar to the overall trend observed at UNW-114, the majority of VOC concentrations at

UNW-064 (Figure 3.32) decreased from about 2002 through 2005. Concentrations remained relatively low through the drought years of 2006 into 2008, and increased between 2008 and 2010. Since 2010, VOCs in well UNW-064 have exhibited stable to gradually decreasing concentrations with seasonal fluctuations. At UNW-064, the 1,1-DCA, 1,1-DCE, cis-1,2-DCE, and TCE show rather stable concentration ranges and exhibit seasonal concentration fluctuations with higher concentrations during winter than during summer. This seasonal fluctuation suggests that contaminant mass transport responds to increased groundwater recharge and seepage through the plume. DOE suspects that increased seasonal recharge drives mass transfer in the plume through two combined mechanisms. One mechanism is a rise in groundwater elevation in the source area (residuals from liquid waste beneath G-Pit) which allows groundwater seepage through fractures of higher permeability at a somewhat shallower depth. The second mechanism is simply a higher flow volume through the source area and downgradient fractures caused by the higher head imposed on the whole saturated zone. Cis-1,2-DCE, PCE, and VC have decreased to concentrations less than their respective MCLs in well UNW-064 (Figure 3.32). TCE continues to fluctuate at concentrations approximately 2 to 5 times the MCL and 1,1-DCE concentrations are about 2 to 10 times the MCL.

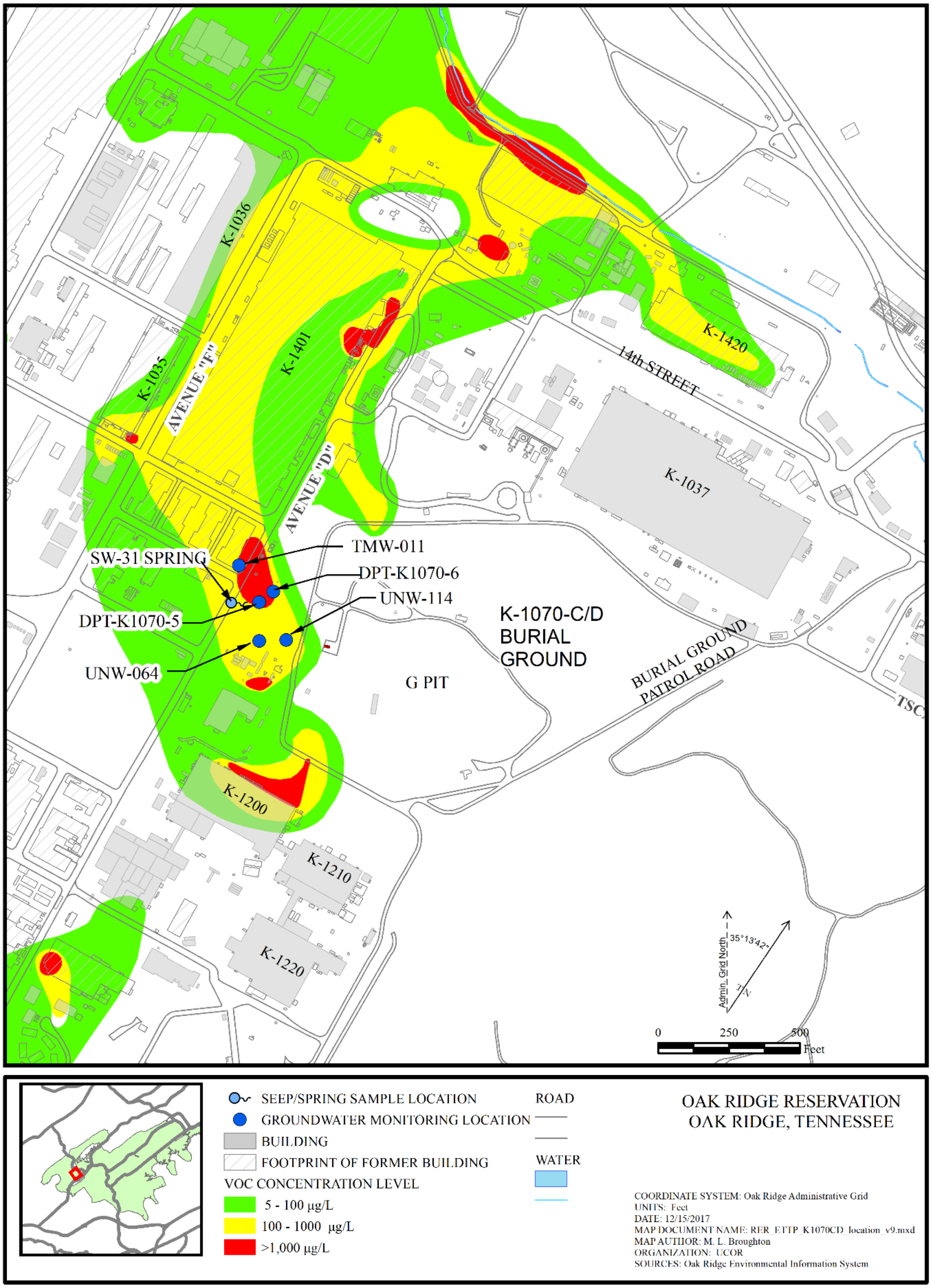


Figure 3.30. Location map for K-1070-C/D Burial Ground

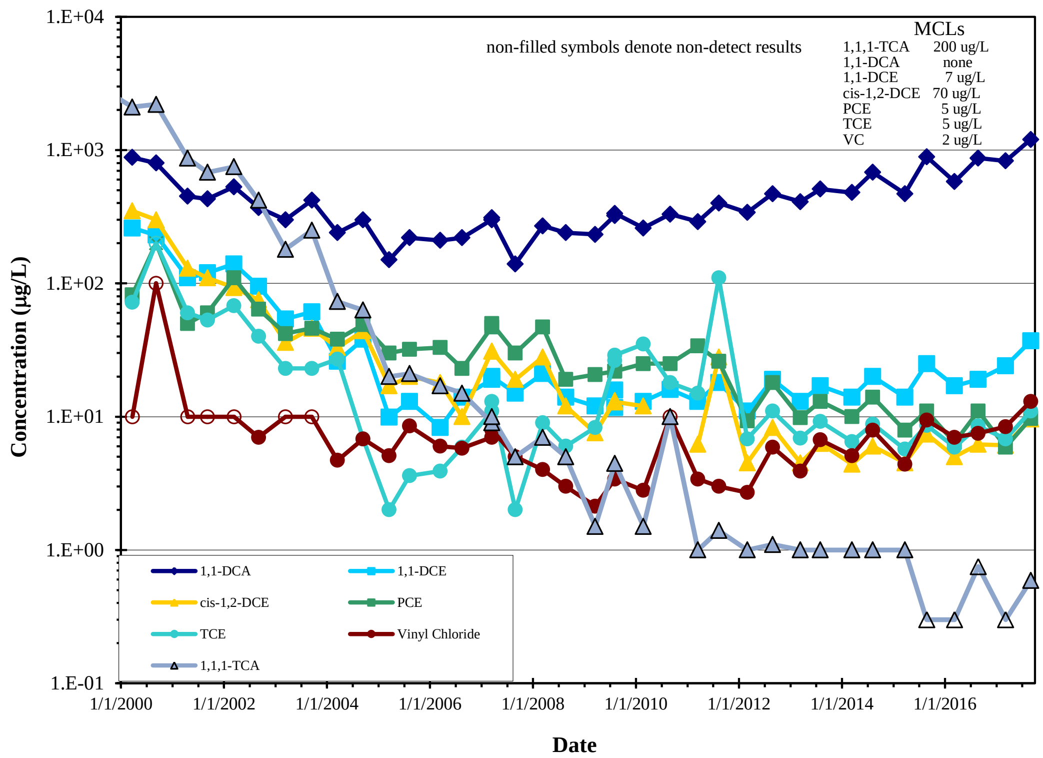


Figure 3.31. VOC concentrations in well UNW-114, FY 2002–FY 2017

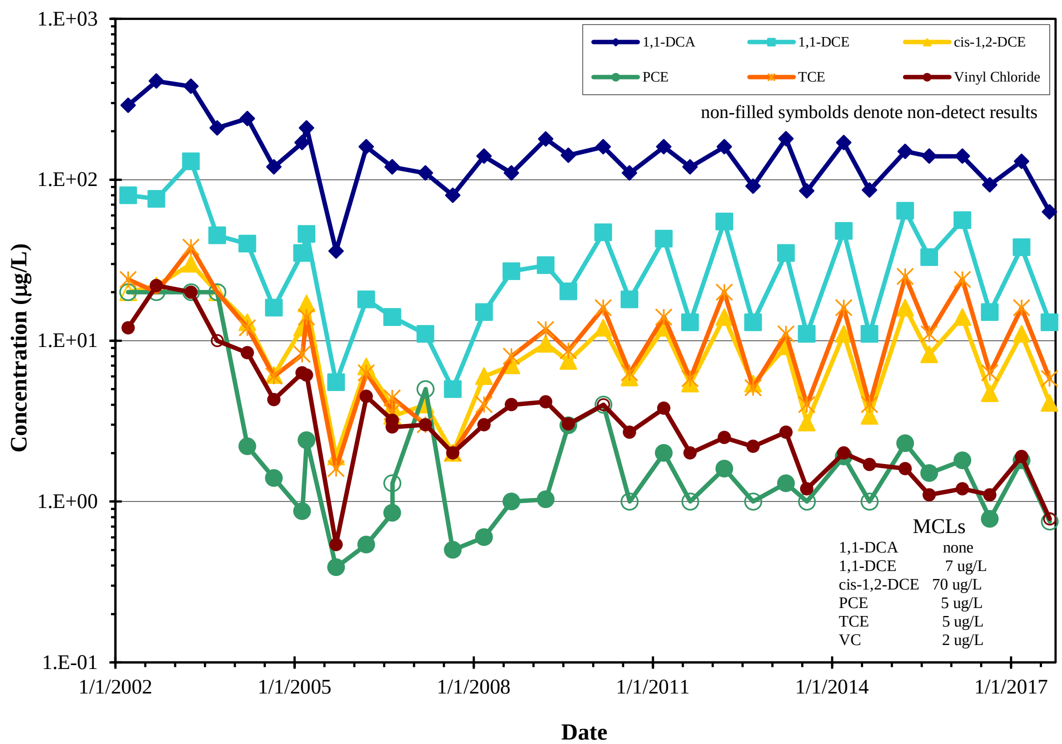


Figure 3.32. VOC concentrations in well UNW-064, FY 2002–FY 2017

Well TMW-011 (screen just above bedrock at elevation 762.8 ft aMSL) is located furthest from the contaminant source area near the base of the hill below K-1070-C/D. VOC concentrations at TMW-011 tend to fluctuate in a fashion similar to those at UNW-064, except that the seasonal signature is reversed, with higher concentrations in summer than during winter. This relationship suggests that groundwater recharge during winter tends to dilute the VOCs near TMW-011 rather than cause a pulse of higher concentration groundwater as was observed at the mid-slope location near UNW-064. Like the other two wells, VOC concentrations (Figure 3.33) have gradually decreased since FY 2000, although levels appear to have leveled off since 2013. Cis-1,2-DCE and PCE have remained below their respective MCLs since the winter of 2012. TCE and 1,1-DCE concentrations fluctuate at concentrations about 5 to 15 times their respective MCLs. Since 2012, VC has fluctuated, with wet season concentrations below the MCL and dry season concentrations exceeding the MCL.

Monitoring locations DPT-K1070-5 and DPT-K1070-6 (Figure 3.34) (screened intervals 776.93–781.93 and 777.48–782.48 ft aMSL, respectively) were installed using direct push technology (DPT) and therefore they sample groundwater just at, and somewhat above, the top of bedrock downgradient of the G-Pit VOC source. Both sample locations exhibit a fairly wide range of VOC contaminants, with DPT-K1070-5 being more highly contaminated than DPT-K1070-6. In DPT-K1070-5, VOCs that exceed the MCL screening concentrations include 1,1,1-TCA, 1,1,2-TCA, 1,1-DCE, 1,2-DCA, benzene, cis-1,2-DCE, methylene chloride, PCE, TCE, and VC. At DPT-K1070-6, the VOCs with MCL exceedances include 1,1,1-TCA, 1,1-DCA, 1,1-DCE, PCE, TCE, and VC. Figure 3.34 shows the concentration history for those constituents with the highest concentrations.

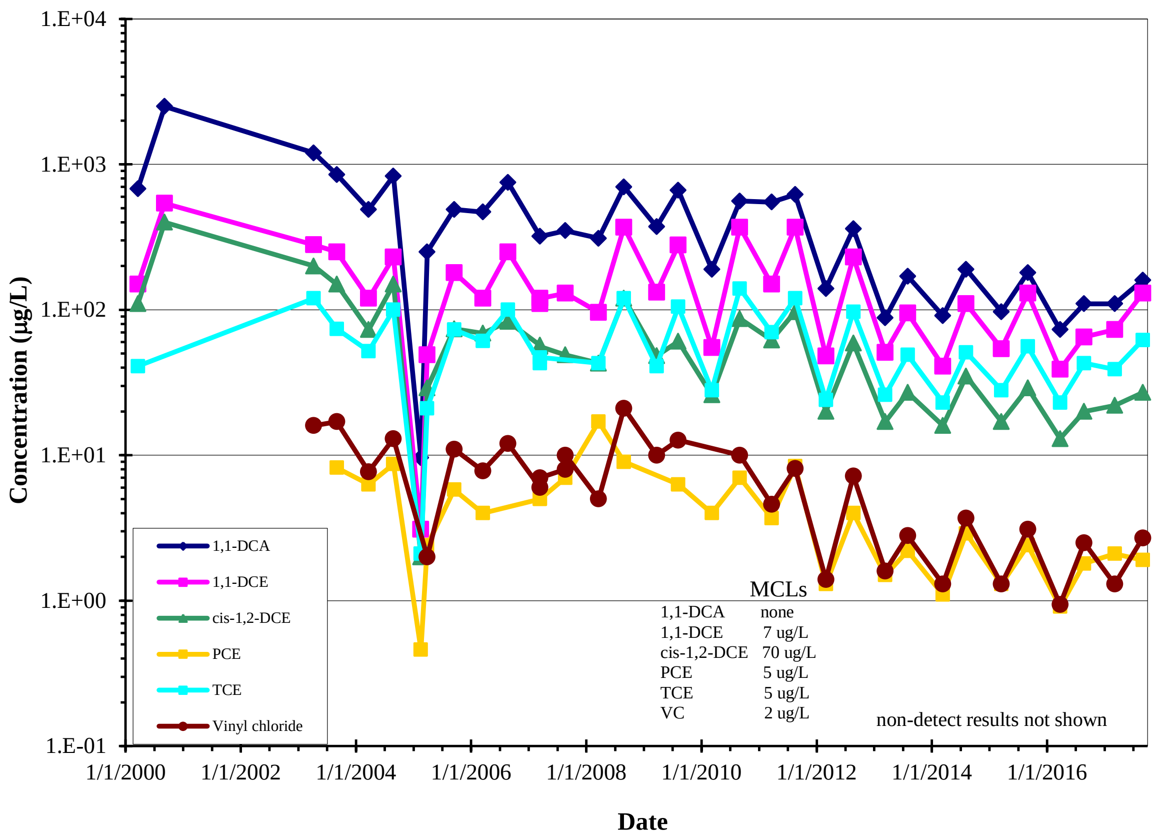


Figure 3.33. VOC concentrations in well TMW-011, FY 2001–FY 2017

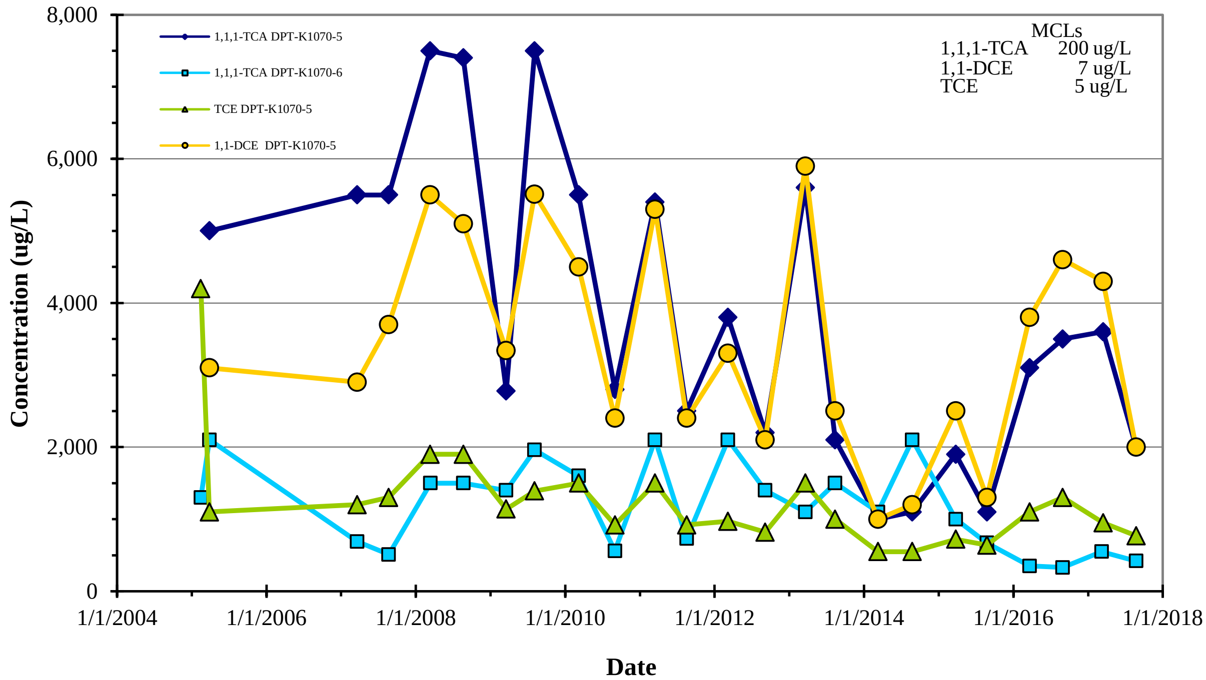


Figure 3.34. Concentrations of selected VOCs in DPT-K1070-5 and DPT-K1070-6

The elevation and VOC concentration relationships among the monitoring wells demonstrate that the G-Pit plume is a heterogeneous flow system and that wells DPT-K1070-5 and DPT-K1070-6 lie in a different flowpath from the area monitored by UNW-064 and UNW-114. Although the screen elevations of the two DPT wells and well UNW-114 are essentially the same, the VOC concentrations in the DPT samples are much higher than those in well UNW-114. Bedrock wells have not been installed in the area to date to evaluate deeper groundwater conditions.

Extensive groundwater monitoring at the ETTP site, using Safe Drinking Water Act (SDWA) MCLs as groundwater screening values, has identified VOCs as the most significant groundwater contaminant on site. The principal chlorinated hydrocarbon chemicals that were used at ETTP were PCE, TCE, and 1,1,1-TCA. During preparation of a Remedial Investigation/Feasibility Study (RI/FS) in 2007 in support of CERCLA decision-making for the ETTP site, the human health risk assessment summarized "*priority COCs in groundwater . . . for the industrial worker, which is the most likely of the future scenarios assessed for exposure to groundwater*." The evaluation of priority groundwater COCs identified the major groundwater contaminant source areas and associated plumes as listed in Table 3.19.

Two new groundwater COCs have been identified in recent years as site conditions change through the site closure program: hexavalent chromium in the Mitchell Branch area and ^{99}Tc in the vicinity of the K-25 building east slab. To date, neither of these contaminants has been subjected to the formal risk assessment process, although that will occur during the ETTP Sitewide ROD project, which is currently in the planning phase. Both of these COCs are discussed in this RER. The hexavalent chromium collection and treatment is addressed in Section 3.6.4.1 and ^{99}Tc is discussed in Section 3.6.6.2.

Table 3.19. Principal groundwater contaminant source areas and associated priority groundwater COCs

Source area/plume	1,1-DCE	Carbon tetrachloride	PCE	TCE	Cis-1,2-DCE	Manganese	VC
K-1070-C/D	X	X		X	X	X	
K-1035	X		X	X	X		
K-1401	X			X	X		X
K-1407-B	X		X	X	X		X
K-27/K-29				X			
K-1200			X				
K-1070-A	X	X		X			

Source: Table 7.12 of the *Final Sitewide Remedial Investigation and Feasibility Study for East Tennessee Technology Park, Oak Ridge, Tennessee* (DOE 2007, DOE/OR/01-2279&D3, Volume 1).

Acronyms
COC = contaminant of concern
DCE = dichloroethene
PCE = perchloroethene
TCE = trichloroethen
VC = vinyl chloride

Figure 3.35 shows the distribution and generalized concentrations of the sum of the primary chlorinated hydrocarbon chemicals and their transformation products, respectively, at ETTP. Specific compounds included in the summation of chlorinated VOCs include chloroethenes (PCE, TCE, cis-1,2-DCE, trans-1,2-DCE, and VC), chloroethanes (1,1,1-TCA, 1,1,2-TCA, 1,2-DCA, 1,1-DCA, and chloroethane), and chloromethanes (carbon tetrachloride, chloroform, and methylene chloride). Several plume source areas are identified within the regions of the highest VOC concentrations. In these areas, the primary chlorinated hydrocarbons have been present for decades and mature contaminant plumes have evolved. The degree of transformation, or degradation, of the primary chlorinated hydrocarbon compounds is highly variable across the site. In the vicinity of the K-1070-C/D source a high degree of degradation has occurred, although a strong source of contamination still remains in the vicinity of the G-Pit, where approximately 9,000 gal of chlorinated hydrocarbon liquids were disposed of in an unlined pit. Other areas where transformation is significant include the K-1401 Acid Line leak site, and the K-1407-B Pond area. Transformation processes are weak or inconsistent at the K-1004 and K-1200 area, K-1035, K-1413, and K-1070-A Burial Ground, and little transformation of TCE is observed in the K-27/K-29 source and plume area.

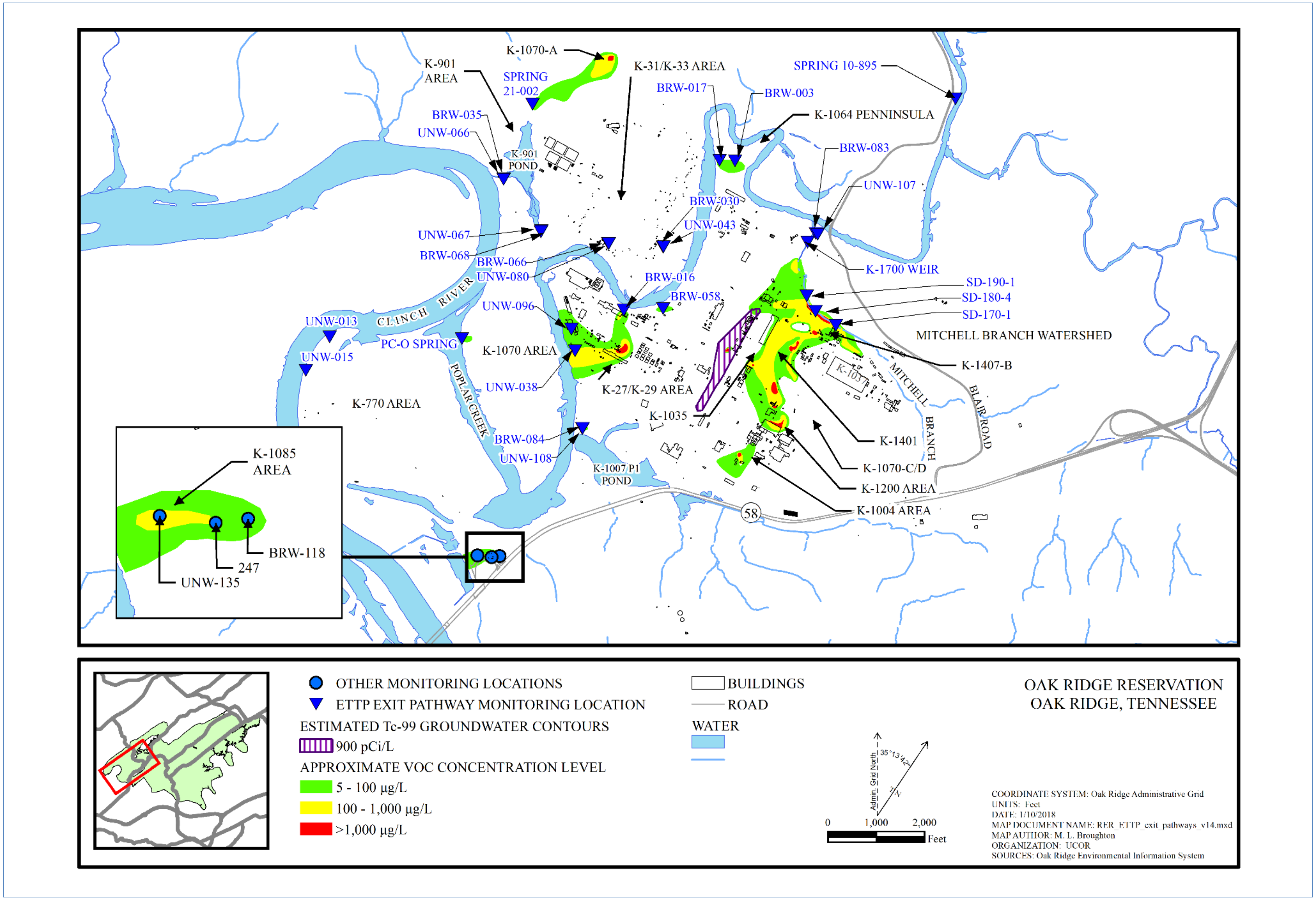


Figure 3.35. ETTP exit pathways monitoring locations

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

Wells BRW-083 and UNW-107, located near the mouth of Mitchell Branch, have been monitored since 1994. Table 3.20 shows the history and concentrations of detected VOCs in groundwater. Detection of VOCs in groundwater near the mouth of Mitchell Branch is considered an indication of the migration of the Mitchell Branch VOC plume complex. The intermittent detection of VOCs in this exit pathway is thought to be a reflection of variations in groundwater flowpaths that can fluctuate with seasonal hydraulic head conditions, which are strongly affected by rainfall. During FY 2017, cis-1,2-DCE was detected at 0.61 J µg/L, at well BRW-083 in March. No other chlorinated VOCs were detected in wells BRW-083 or UNW-107.

K-1064 peninsula area – Wells BRW-003 and BRW-017 monitor groundwater at the K-1064 peninsula burn area. Metals and VOCs are monitored at the site. Metals detected in groundwater at the site include antimony, zinc, chromium, and arsenic. Antimony was detected at very low, estimated concentration in both wells. Well BRW-003 had an antimony detection of 0.4 J and 0.3 J µg/L in the March filtered and unfiltered samples, respectively, with non-detect results in September. Well BRW-017 had 0.32 J and 0.24 J µg/L in the unfiltered and filtered March samples, respectively, with non-detect results in September. Chromium was detected in the March unfiltered and filtered BRW-017 samples at 2.0 J and 1.6 J µg/L, respectively. Zinc was detected at 4.4 J µg/L in the unfiltered BRW-017 March sample. Arsenic was detected in both wells with maximum concentrations of 20 µg/L in well BRW-003 in the unfiltered sample in March and 11 µg/L in the unfiltered sample from well BRW-017 in September.

Figure 3.36 shows arsenic concentration histories in samples from wells BRW-003 and BRW-017. Arsenic concentrations in both unfiltered and filtered samples from well BRW-003 have shown long-term decreases during the period between 2004 and 2017. At well BRW-017, a period of arsenic non-detection in unfiltered samples ended in the summer of 2015 and since then the samples have shown arsenic detections with MCL exceedances in March 2016 and September 2017.

Figure 3.37 shows the history of significant VOC detections in groundwater from FY 1994 through FY 2017. In the September sample, 1,1,1-TCA was detected at 0.4 J µg/L in well BRW-003 and was not detected in the March sample. In September, Cis-1,2-DCE was detected in well BRW-003 at 0.96 J µg/L and at BRW-017 at 1.2 and 0.94 J µg/L in March and September, respectively. TCE concentrations have declined in both wells over the monitoring period. TCE was present at concentrations less than the MCL during FY 2017 at both wells. In well BRW-017, TCE was detected at concentrations of 2.3 and 2 µg/L in March and September, respectively. At well BRW-003, TCE was detected at 3.2 µg/L in the September sample and was not detected in the March sample. The recent increase in TCE concentration at BRW-003 and variability of arsenic concentrations in both wells may be related to area RA activities.

K-31/K-33 area – Groundwater is monitored in four wells (BRW-066, BRW-030, UNW-080, and UNW-043) that lie between the K-31/K-33 area and Poplar Creek. VOCs are not COCs in this area; however, leaks of recirculating cooling water (RCW) in the past have left residual subsurface chromium contamination. Chromium concentrations in the unconsolidated zone wells (UNW-043 and UNW-080) have exceeded the 0.1 mg/L MCL screening concentration in the past, while levels have been much lower in the bedrock wells.

Figure 3.38 shows the history of chromium detection in wells BRW-030, UNW-043, and UNW-080. Groundwater at well UNW-043 has exhibited the highest residual chromium concentrations of any in the area. Chromium concentrations in well UNW-043 correlate with the turbidity of samples. The acidification of unfiltered samples that contain suspended solids often causes detection of high metals content because the addition of acid preservative releases metals that are adsorbed to the solid particles at the normal groundwater pH.

During FY 2006, an investigation was conducted to determine if groundwater in the vicinity of the K-31/K-33 buildings contained residual hexavalent chromium from RCW leaks. The data indicated the chromium in groundwater near the leak sites was essentially all the less toxic trivalent species. Starting in FY 2008, field-filtered (i.e., dissolved) and unfiltered samples have been collected from the wells sampled in the K-31/K-33 area. Chromium concentrations in the field-filtered samples are consistently much less than the 0.2 mg/L MCL. During FY 2017, the only samples that were equal to or greater than the chromium MCL were the unfiltered samples from UNW-030 in March and September, and the unfiltered sample collected from UNW-043 in March. Chromium was non-detect in all samples from well BRW-066 during FY 2017.

K-27/K-29 area – Several exit pathway wells are monitored in the K-27/K-29 area, as shown on Figure 3.35. Figure 3.39 provides concentrations of detected VOCs in wells both north and south of K-27 and K-29 through FY 2017. The source of VOC contamination in well BRW-058 is not suspected to be from K-27/K-29 area operations, but is more likely associated with groundwater contamination that originates in the K-25 area. At well BRW-058, VC continues to slightly exceed the MCL and showed a slight increase in the September 2017 sample. Cis-1,2-DCE also showed an increase in concentrations during FY 2017 and both measured results exceeded the MCL. The presence of cis-1,2-DCE and VC in well BRW-058 is an indication that some natural attenuation is occurring in the source area. The VOC concentrations in well BRW-016 showed a slight increase in the September 2017 sampling event, but remain well below the MCL concentrations. This increase is thought to be related to demolition of the K-27 building and slab. Increases in groundwater TCE and ^{99}Tc concentrations in the vicinity of the K-27 building have been noted during the D&D period. TCE levels in well UNW-038 exhibit a long-term decreasing trend, with seasonal fluctuations (higher during the wet season and lower during the dry season) between about 10 to 20 times the MCL.

Table 3.20. VOCs detected in groundwater in the Mitchell Branch Exit Pathway

Well	Date	cis-1,2-DCE (μg/L)	PCE (μg/L)	TCE (μg/L)	VC (μg/L)
BRW-083	8/29/2002	ND	**5**	**28**	ND
	3/16/2004	0.69	2.2	**9.9**	ND
	8/26/2004	2	4.7	**20**	ND
	3/14/2007	5	**9**	**28**	ND
	3/20/2008	ND	ND	ND	ND
	8/21/2008	ND	ND	ND	ND
	3/12/2009	ND	ND	1.31 J	ND
	8/3/2009	ND	2.66	**14.2**	ND
	3/3/2010	ND	ND	ND	ND
	8/30/2010	3.6	**5.1**	**18**	ND
	3/15/2011	2.8	**6.7**	**22**	ND
	8/10/2011	ND	ND	ND	ND
	3/1/2012	ND	ND	ND	ND
	8/16/2012	ND	ND	ND	ND
	8/6/2013	ND	ND	ND	ND
	3/13/2013	ND	ND	ND	ND
	3/13/2014	ND	ND	ND	ND
	8/7/2014	ND	ND	ND	ND
	3/30/2015	ND	ND	ND	ND
	8/20/2015	ND	ND	ND	ND
	3/8/2016	ND	ND	ND	ND
	8/31/2016	ND	ND	ND	ND
	3/6/2017	0.61 J	ND	ND	ND
	8/23/2017	ND	ND	ND	ND
UNW-107	8/3/1998	ND	ND	3	ND
	8/26/2004	4.7	ND	3.6	ND
	8/21/2006	3.4	**14**	2	1.2
	3/13/2007	25	2 J	**23**	2[a]
	8/21/2007	17	ND	**30**	0.3 J
	3/5/2008	ND	ND	ND	ND
	8/18/2008	ND	ND	ND	ND
	3/12/2009	ND	ND	ND	ND
	7/30/2009	ND	ND	ND	ND
	3/4/2010	ND	ND	ND	ND
	7/28/2010	ND	ND	ND	ND
	3/16/2011	ND	ND	ND	ND
	8/11/2011	ND	ND	ND	ND
	3/20/2012	ND	ND	ND	ND

Table 3.20. VOCs detected in groundwater in the Mitchell Branch Exit Pathway (continued)

Well	Date	cis-1,2-DCE (µg/L)	PCE (µg/L)	TCE (µg/L)	VC (µg/L)
	9/12/2012	ND	ND	ND	ND
	8/8/2013	ND	ND	ND	ND
	3/20/2013	ND	ND	ND	ND
	3/18/2014	ND	ND	ND	ND
	8/20/2014	ND	ND	ND	ND
	3/16/2015	ND	ND	ND	ND
	8/25/2015	ND	ND	0.53 J	ND
	3/9/2016	ND	ND	ND	ND
	8/30/2016	ND	ND	ND	ND
	3/9/2017	ND	ND	ND	ND
	8/23/2017	ND	ND	ND	ND

[a]Detection occurred in a field replicate. Constituent not detected in regular sample.
Bold table entries exceed SDWA MCL screening values (PCE, TCE = 5 µg/L, cis-1,2-DCE = 70 µg/L, VC = 2 µg/L).
All concentrations µg/L.

Acronyms
DCE = dichloroethene
J = estimated value
MCL = maximum contaminant level
ND = not detected
PCE = tetrachloroethene
SDWA = Safe Drinking Water Act
TCE = trichloroethene
VC = vinyl chloride
VOC = volatile organic compound

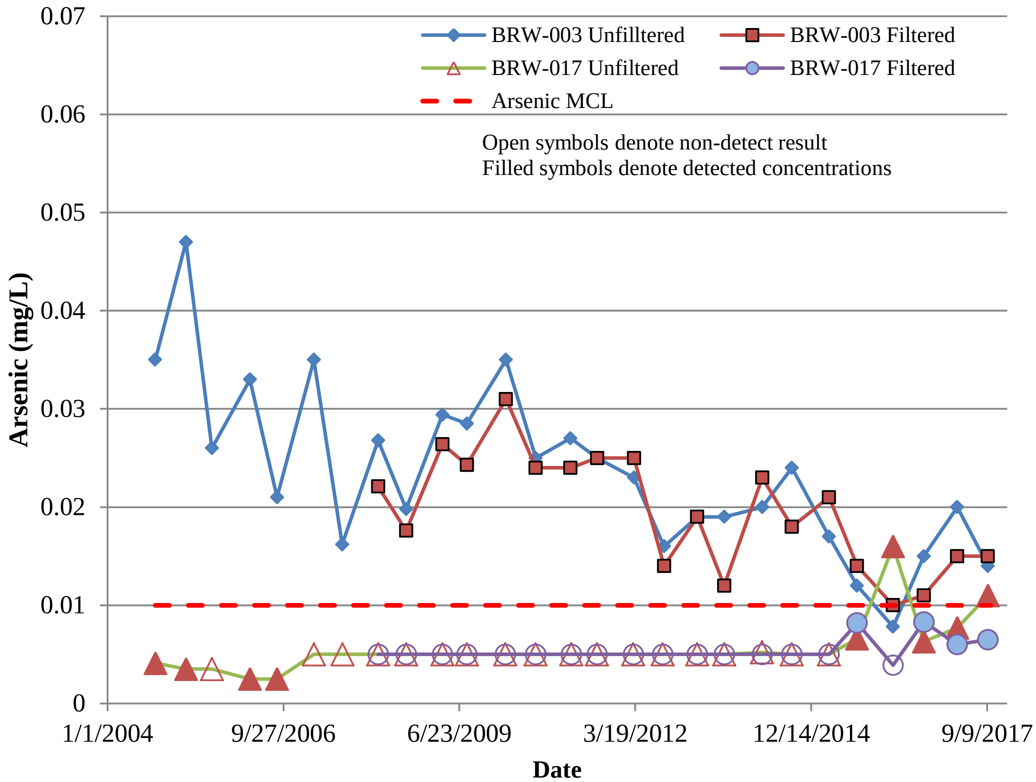


Figure 3.36. Arsenic concentrations in groundwater in the K-1064 peninsula area

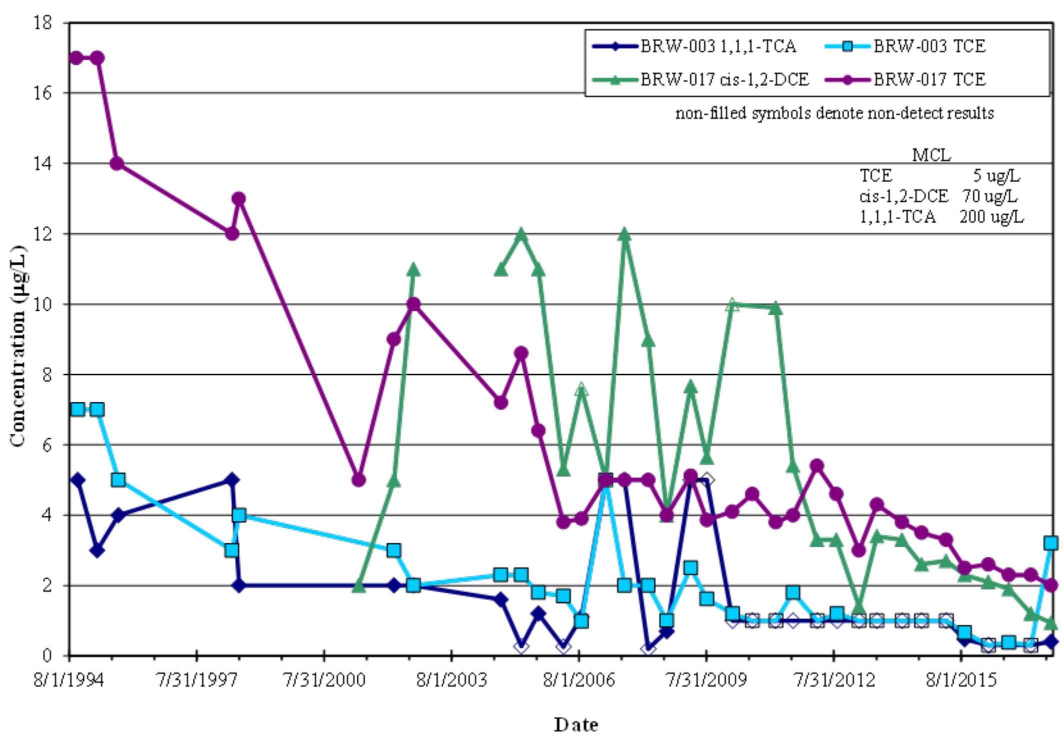


Figure 3.37. VOC concentrations in groundwater in the K-1064 peninsula area

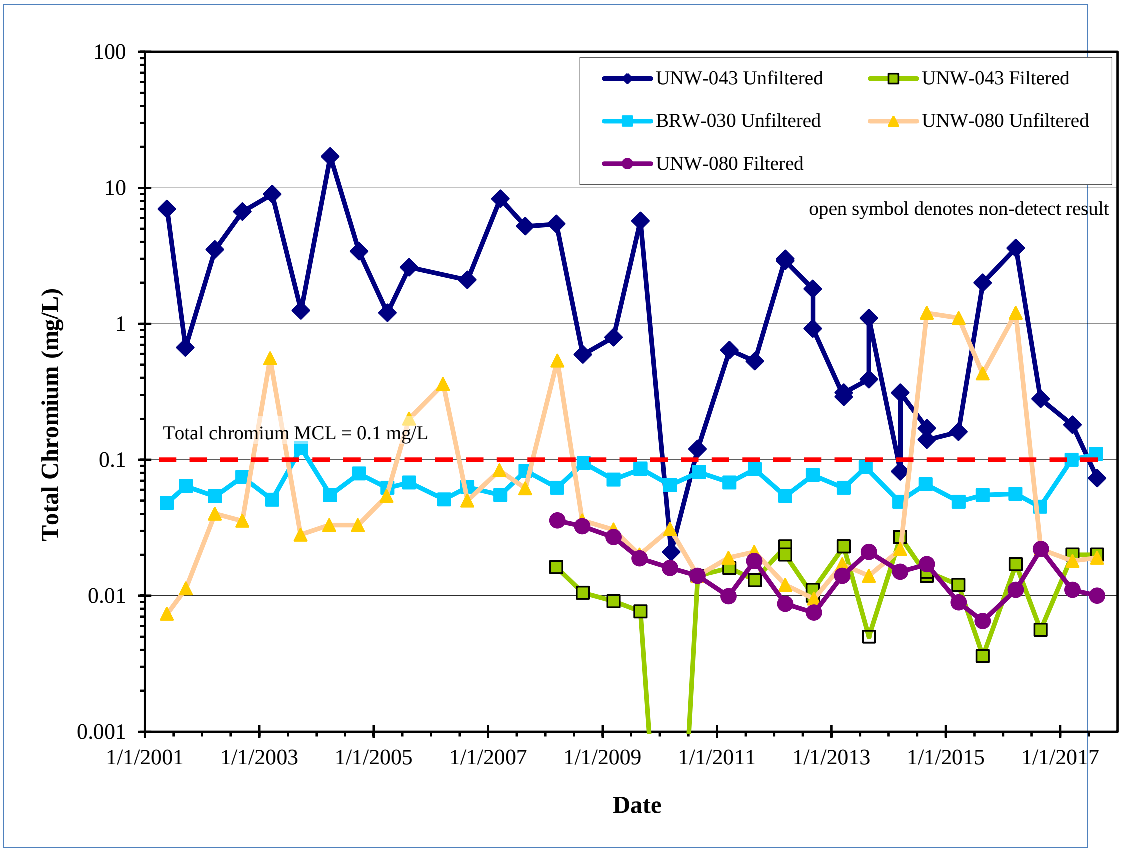


Figure 3.38. Chromium concentrations in groundwater in the K-31/K-33 area

K-1007-P1 Holding Pond area – Wells BRW-084 and UNW-108 are exit pathway monitoring locations at the northern edge of the K-1007-P1 Holding Pond (Figure 3.35). These wells were monitored intermittently from 1994 through 1998 and semiannually from FY 2001 through FY 2017. The first detections of VOCs in these wells occurred during FY 2006, with detection of low (approximately 10 µg/L or less) concentrations of TCE and cis-1,2-DCE. The source area for these VOCs is not known. During FY 2017, no VOCs were detected in either well. Metals continue to be detected and are associated with the presence of turbidity in the samples.

At well BRW-084, antimony was detected in both the filtered and unfiltered samples collected in March (0.48 µg/L in unfiltered and 0.33 µg/L in filtered). Antimony was also detected in samples collected at BRW-084 in August (0.2 J µg/L in unfiltered and 0.06 J µg/L in filtered). At well UNW-108, antimony was present at 2.8 J µg/L and 0.13 J µg/L in the unfiltered and filtered samples collected in March, respectively. Antimony was detected in the August sample from UNW-108 at 0.05 J µg/L. Cadmium was detected in the March unfiltered samples from both BRW-084 and UNW-108 (0.1 J µg/L and 0.2 µg/L, respectively). Cadmium was detected in the UNW-108 August unfiltered sample at 0.11 J µg/L.

Chromium was detected in the BRW-084 unfiltered samples collected in March and August (6.1 and 5.6 µg/L, respectively) with no detection in the filtered samples. At well UNW-108, chromium was detected at 4.9 J µg/L in the unfiltered sample collected in March, with no other detections during the year. The only detection of lead from these two wells was from the unfiltered sample collected from UNW-108 in March, which had a concentration of 3.6 µg/L. Selenium was detected in both the filtered and unfiltered samples collected in August from well BRW-084 (0.65 J µg/L and 0.45 J µg/L, respectively). In addition, selenium was detected in both the filtered and unfiltered samples collected in

March from well BRW-084 (1.2 J µg/L and 1.0 J µg/L, respectively). Thallium was detected in both August and March filtered and unfiltered samples from well UNW-108 (maximum of 0.08 J µg/L and a minimum of 0.02 J µg/L). Uranium concentrations in both wells were quite low with a maximum measured value of 0.64 J µg/L. Potential sources of these metals in this area are unknown and the detected concentrations are far below any criterion level.

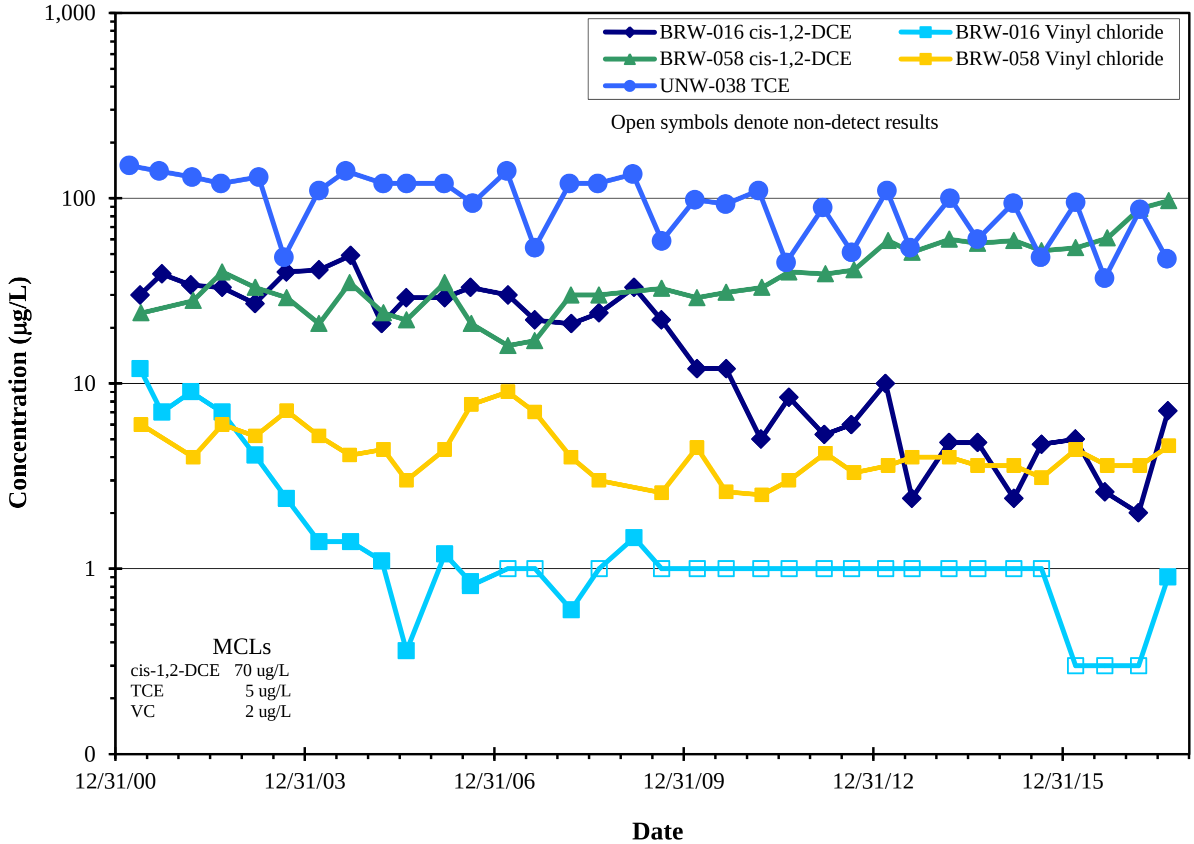


Figure 3.39. Detected VOC concentrations in groundwater exit pathway wells near Buildings K-27 and K-29

K-901-A Holding Pond area – Exit pathway groundwater in the K-901-A Holding Pond area (see earlier Figure 3.35) is monitored by four wells (BRW-035, BRW-068, UNW-066, and UNW-067) and one spring (21-002). Very low concentrations (< 5 µg/L) of VOCs are occasionally detected in wells adjacent to the K-901-A Holding Pond. However, these contaminants are not persistent in groundwater west and south of the pond. No VOCs were detected in the K-901-A Holding Pond exit pathway wells during FY 2017. At well BRW-035, alpha- and beta-activity levels have remained fairly consistent over the past several years, with non-detect concentrations of alpha and beta levels between about 10–15 pCi/L. Similarly, well BRW-068 has experienced fairly stable, low to non-detect concentrations of alpha (none detected in FY 2017) and less than 10 pCi/L of beta activity. Although UNW-066 has experienced alpha and beta MCL exceedances in the past, measured concentrations of these parameters did not exceed MCL screening criteria during FY 2017. In well UNW-067, the alpha- and beta-activity screening levels were not exceeded during FY 2017. Technetium-99 was analyzed in samples from wells UNW-066 and UNW-067 during FY 2017. The only ^{99}Tc detection from these wells during FY 2017 was a result of 12.8 pCi/L in the February sample.

TCE is the most significant groundwater contaminant detected in the springs, and the historic TCE concentrations are shown in Figure 3.40. Spring PC-0 was added to the sampling program in 2004. During April through October each year, spring PC-0 is submerged beneath the Watts Bar Lake level. In the late winter of 2012, DOE installed a sampling pump in the spring mouth to allow year-round sampling. The contaminant source for the PC-0 spring is presumed to be disposed waste at the former Construction Spoil Area (K-1070-F) on Duct Island. The TCE concentrations in PC-0 spring have varied between non-detectable levels and 26 µg/L; they have decreased from their highest measured value in 2006 to concentrations that are a small fraction of the drinking water standard. During FY 2017, cis-1,2-DCE was detected at estimated low concentrations <1 µg/L in PC-0 samples collected in June and August.

Although TCE is the principal contaminant detected at spring 21-002, 1,1-DCE, carbon tetrachloride, chloroform, and PCE were present at concentrations less than 5 µg/L. The TCE concentration at spring 21-002 tends to vary between less than 5 and 25 µg/L and this variation appears to be related to variability in rainfall that affects groundwater discharge from the K-1070-A VOC plume. During FY 2017, the TCE detected concentrations ranged from a high of 25 µg/L detected in January to a low of 19 µg/L measured in both December 2016 and August 2017. Alpha activity was detected < 5 pCi/L in December, January, and August samples, and detected beta activities ranged from 4.27 to 20.2 pCi/L. Technetium-99 detections ranged from 12.8 to 22.6 pCi/L, which are much lower than the 900 pCi/L MCL-DC. Uranium-234, ^{235}U, and ^{238}U were detected at less than 1 pCi/L.

The 10-895 spring discharges groundwater from beneath Black Oak Ridge along Poplar Creek near Blair Road (Figure 3.35). Black Oak Ridge is located behind the ETTP site. The source of TCE has not been confirmed. Although the Contractor's Spoil Area is the closest upgradient waste disposal site, it is possible that contaminants from the more distant K-1070-A site could migrate via karst groundwater flow pathways to the spring, which is suggested based on the presence of carbon tetrachloride along with the other VOCs. TCE concentrations measured in samples from spring 10-895 are shown on Figure 3.40. The highest TCE concentration measured was 8.8 µg/L.

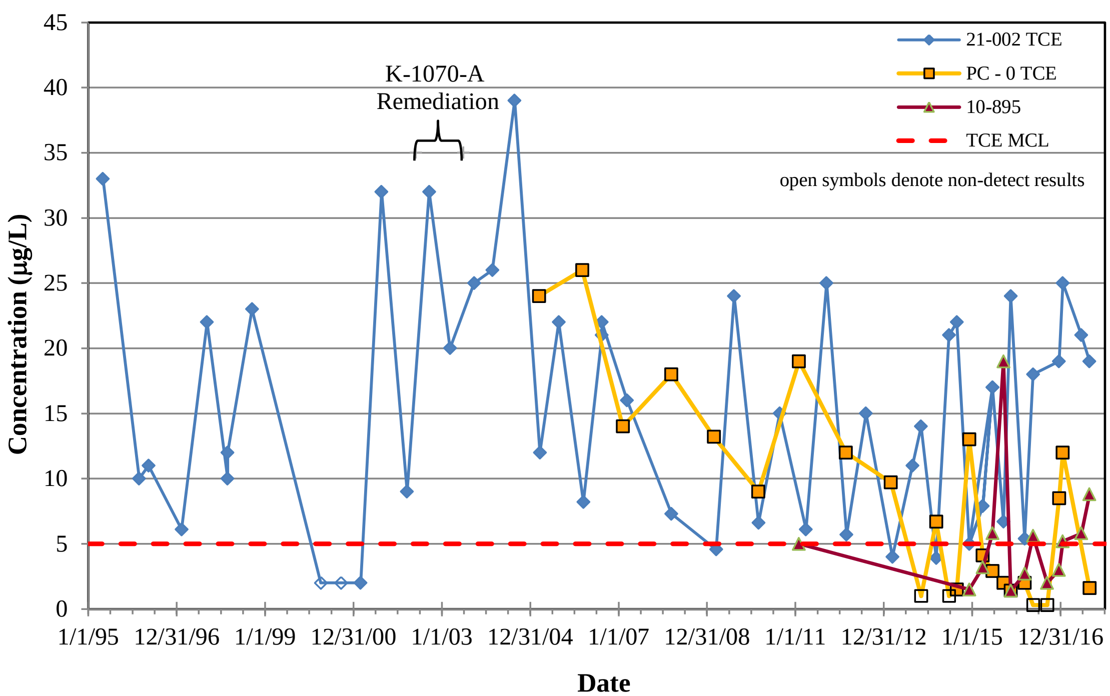


Figure 3.40. TCE concentrations in selected East Tennessee Technology Park area springs

K-770 area – Exit pathway groundwater monitoring is also conducted at the K-770 area, where wells UNW-013 and UNW-015 are used to assess radiological groundwater contamination along the Clinch River (Figure 3.35). Measured alpha- and beta-activity levels were below screening levels during FY 2017. Figure 3.41 shows the history of measured alpha and beta activity in this area. Analytical results show that alpha activity was not detected in samples from well UNW-013 during FY 2017, although beta activity was present with a maximum detected value of 37.9 pCi/L. Trace levels of ^{90}Sr (0.371 J pCi/L) and ^{238}Pu (0.178 pCi/L) and 53.7 pCi/L of ^{99}Tc were detected in UNW-013 during FY 2017. Results from well UNW-015 showed alpha activity (maximum of 12.7 pCi/L), beta activity (single detection of 2.8 J pCi/L), trace levels of ^{90}Sr (0.471 J pCi/L), ^{232}Th (0.0684 pCi/L) and ^{234}U, ^{235}U, and ^{238}U (7.74, 0.456, and 5.29 pCi/L, respectively). All of the detected radionuclides occur at concentrations much less than water quality criteria.

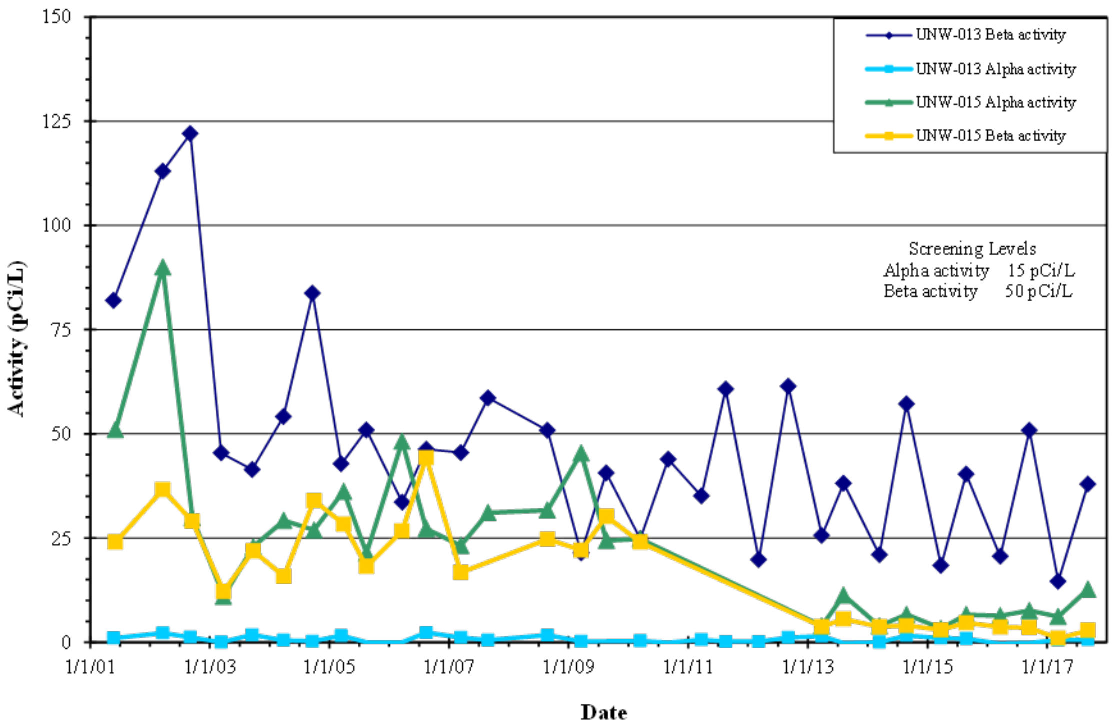


Figure 3.41. History of measured alpha and beta activity in the K-770 area

3.6.6.2 Tc-99 in ETTP site groundwater

Technetium-99 is a beta particle-emitting radionuclide. There is not a specific drinking water MCL for ^{99}Tc, but its MCL-DC concentration is 900 pCi/L. Technetium-99 has been a known groundwater contaminant at the ETTP site for many years. Past CERCLA investigations have sampled and analyzed for ^{99}Tc in groundwater. In the past, the highest ^{99}Tc activity levels (as high as 6,000+ pCi/L) have been observed beneath the K-1070-A Burial Ground, where concentrations at a couple of wells remain in the 200–500 pCi/L range. The area along Mitchell Branch near the former K-1407 Ponds has residual ^{99}Tc-contaminated groundwater from the operational era of the ponds, and possibly from K-1420, with much lower activity levels (< 100 pCi/L). The K-25 building also contained some areas with elevated levels of ^{99}Tc. These areas were exposed to the environment during the demolition of the building.

Background

The environmental fate of some metal contaminants in groundwater is strongly dependent on the pH and oxidation-reduction potential state of the water. A summary review of the environmental behavior of ^{99}Tc in the environment was published by Pacific Northwest National Laboratory (PNNL; PNNL-15372) related to tank wastes at Hanford. Background information from that report is used in preparation of the following interpretation of potential ^{99}Tc mobility in groundwater at the ETTP site.

Under electrochemically oxidizing conditions, technetium forms the negatively charged pertechnetate ion (TcO_4^-) with technetium assuming a valence of 7^+. The pertechnetate ion is quite mobile in aqueous settings since negatively charged ions do not tend to adsorb to mineral surfaces in soil or rock, which inherently tend to have negatively charged to neutrally charged surfaces. Under electrochemically reducing conditions, the pertechnetate ion is not stable and technetium may assume a 4^+ valence. In the 4^+ valence state, technetium may form ionic combinations with oxygen and hydroxyl groups, which may be amorphous solids with lower solubilities than the pertechnetate ion. In the 4^+ valence, in the absence of complexing ligands, technetium may adsorb to mineral and organic matter surfaces, and may become bound in low solubility technetium oxyhydroxides. In the 4^+ valence, technetium may also form soluble complexes with carbonate/bicarbonate ions as well as sulfate. Thermodynamic and directly measured speciation and solubility relationships for technetium carbonate and sulfate complexes have not been established, although these complexes may be important to technetium mobility in reducing electrochemical environments.

In addition to standard physical chemical conditions, microbial processes are important as potential mediators that can lead to reduction of technetium from the highly soluble and mobile 7^+ valence in the pertechnetate ion to the 4^+ valence in the lower solubility forms. Microbial processes often occur in very localized regions in the subsurface where chemical conditions are favorable. This fact is evident in groundwater at the ETTP site where intrinsic microbial communities are known to slowly degrade chlorinated organic compounds in some areas but not in other areas. Factors that may favor microbial reduction of dissolved compounds include relatively slow groundwater movement, which limits influx of dissolved oxygen via groundwater recharge; presence of organic carbon that can serve as electron donor material; and presence of microbes capable of affecting the required molecular transformations.

FY 2017 distribution of ^{99}Tc in ETTP site groundwater

During demolition of the K-25 building east wing in the winter of 2013, fugitive dust suppression misting and rainfall carried ^{99}Tc off the work area. Contaminated runoff apparently percolated through soil and into subsurface utility lines and probably into backfill surrounding the buried utilities. Groundwater sampling for ^{99}Tc was increased in wells in the general vicinity of the east wing and where wells were available along potential groundwater transport pathways.

Investigations conducted to understand the movement of ^{99}Tc away from the K-25 building east wing area documented that contamination entered and traveled through the sanitary sewer and the storm water outfall that discharges to the K-1007-P1 Holding Pond and that the amount of ^{99}Tc transport in backfill outside those pipes was minimal. The investigation also found that ^{99}Tc transport through the abandoned underground electrical ductbank was an important transport pathway along the east side of the K-25 building as far south as ductbank manhole row 21. RAs conducted in Zone 1 included plugging the ductbank manholes with cement grout from row 21 to the south and west to the former steam plant located near the Clinch River in the K-770 Area. To minimize the remaining available transport flow path, 38 additional manholes in Zone 2 were grouted starting with manhole row 22, moving northward all the way through the demolition area and beyond. Since chlorinated VOCs are the most common groundwater contaminant at ETTP, groundwater at all locations was sampled and analyzed for these contaminants. VOCs were found to not be significant contaminants in any of the groundwater.

During FY 2017, groundwater was analyzed for ^{99}Tc in samples from 80 wells and two springs across the ETTP area. The highest concentrations remain centered along the eastern side of the former K-25 building. Concentrations of ^{99}Tc have decreased significantly in the area east of K-25. Monitoring in the vicinity of the K-27 D&D project has shown an increase in ^{99}Tc concentrations in area groundwater, although levels are currently well below the MCL-DC.

3.7 Biological Monitoring

The ETTP BMAP consists of two tasks designed to evaluate the effects of ETTP historical 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 3.42 shows the major water bodies at ETTP and Figure 3.43 shows the BMAP monitoring locations along Mitchell Branch.

3.7.1 Bioaccumulation Studies

The bioaccumulation task includes monitoring of caged Asiatic clams (*Corbicula fluminea*) (Figure 3.44) placed at selected locations around ETTP, and the collection and analysis of fish from Mitchell Branch and three major ponds on the site. Both clams and fish from uncontaminated offsite locations are also analyzed as points of reference. While historically, the primary COC for the bioaccumulation task at ETTP has been PCBs, in recent years mercury has been added to the list of legacy COCs at selected locations.

In 2017, the clams were deployed for 4 weeks. They were then retrieved and soft tissues were extracted and analyzed for PCBs (as Aroclors; Figure 3.45) and, at all but one of the sites, for total and methylmercury (Figure 3.46). In general, there is significant variability in PCB concentrations in the clams from year to year. In 2017, the highest concentrations of PCBs were found in the clams from Storm Water Outfall 100 (1.99 µg/g and 4.61 µg/g in upper and lower Outfall 100, respectively) and in the K-1007-P1 Holding Pond. These concentrations were significantly higher than in 2016 and in recent years, as concentrations in the clams from these locations had been decreasing since 2009. The concentrations of PCBs in the clams from the Mitchell Branch sites saw a slight increase in the 2016 monitoring, but concentrations seen in 2017 were back to levels comparable to those seen in 2015.

Clams from the Mitchell Branch watershed, the K-901-A and K-1007-P1 ponds, and two oil separators (K-897-J and K-897-K) were analyzed for mercury (both total mercury and methylmercury) in 2017. The highest mean total mercury concentrations were found in the clams from storm water Outfall 180 (0.105 µg/g) which was similar to the results from the 2016 monitoring. Clams from the section of Mitchell Branch between K-1700 and Outfall 190 also had elevated concentrations, ranging from a low of 0.027 µg/g to a high of 0.043 µg/g. At other sites, mercury concentrations in clams were comparable to, or lower than, reference site values (e.g., from 0.013 µg/g to 0.021 µg/g). Clams were also analyzed for methylmercury, which typically makes up a small fraction of the total mercury in clams. Methylmercury concentrations in clams deployed in 2017 ranged from a low of 0.003 µg/g in the clams from K-897-K, to a high of 0.011 µg/g in the clams from MIKs 0.3 and 0.4. In most instances, the methylmercury concentrations were only slightly elevated with respect to concentrations seen in the clams from the reference locations (an average of 0.0045 µg/g).

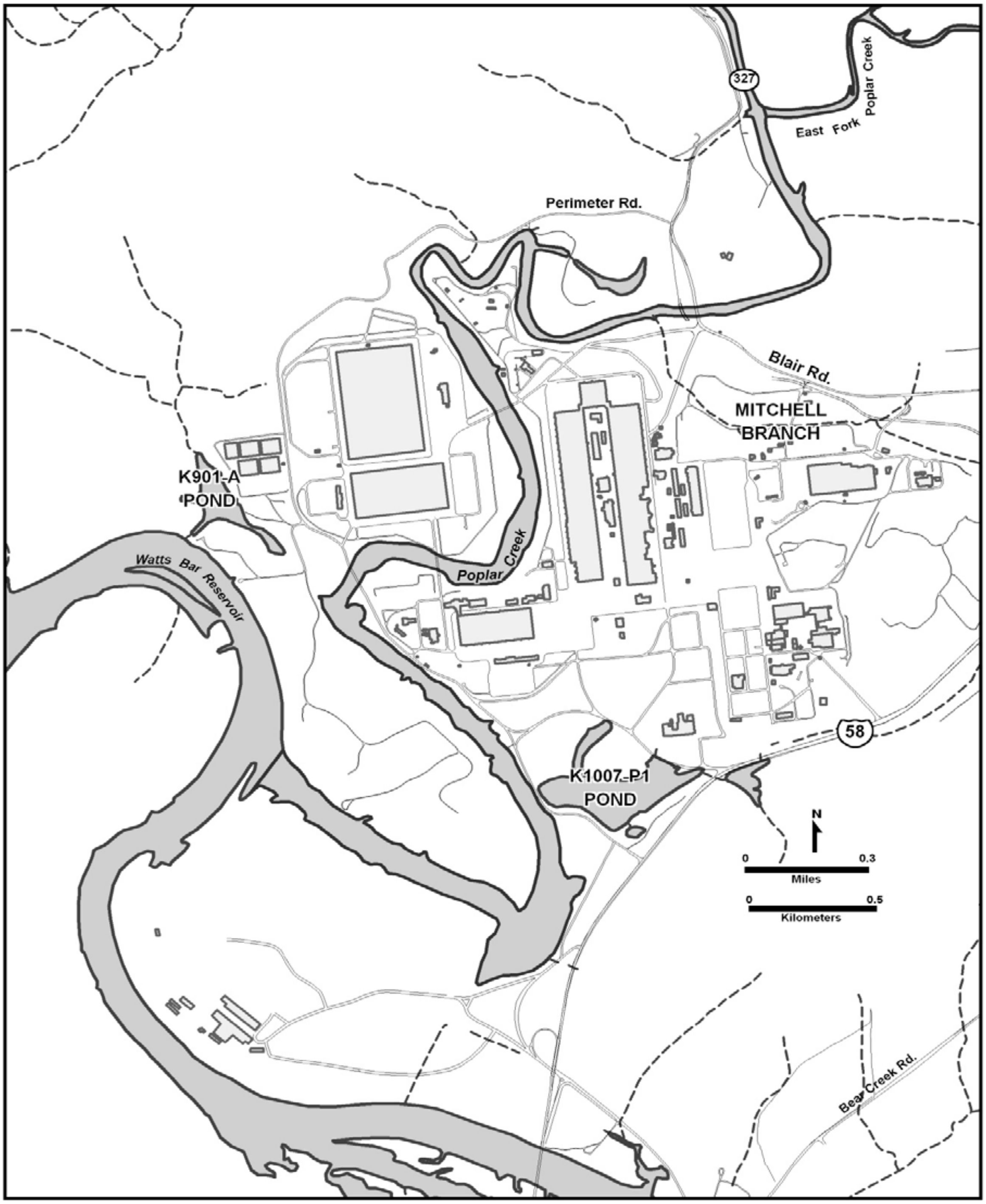
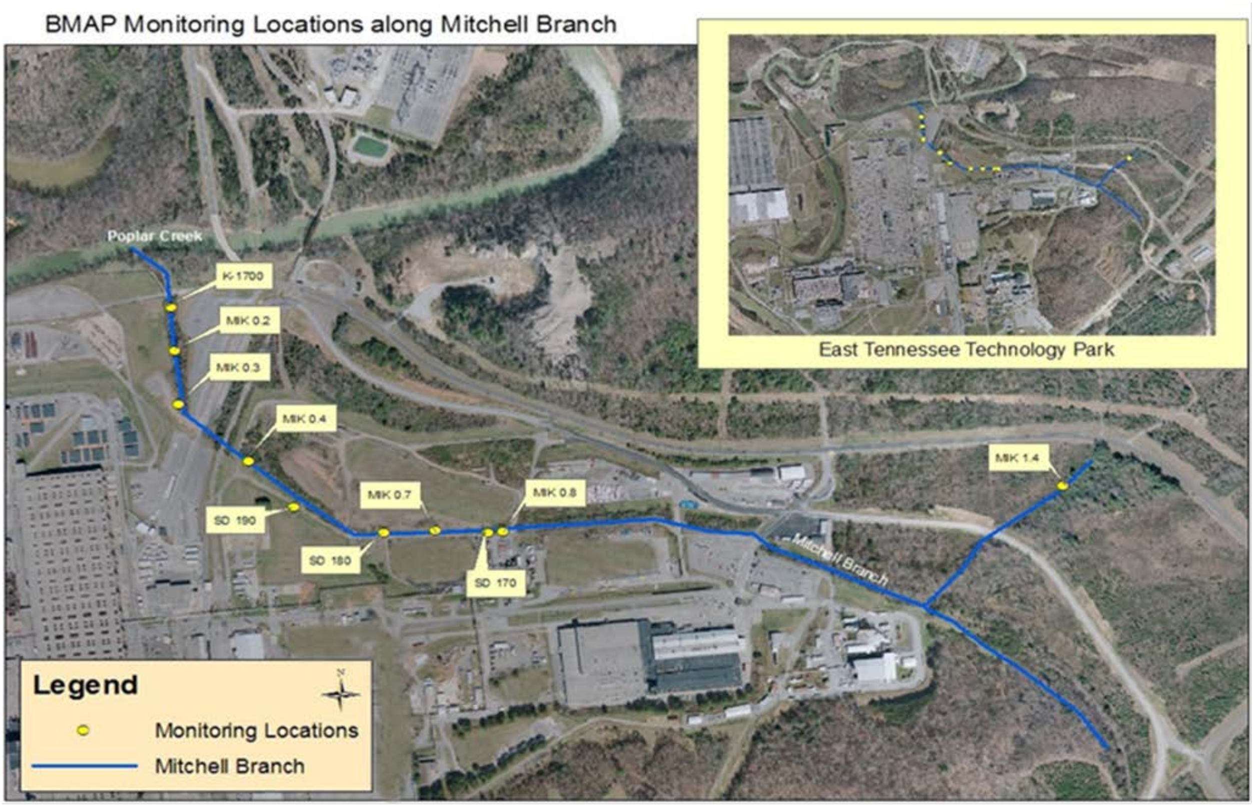


Figure 3.42. Water bodies at the East Tennessee Technology Park



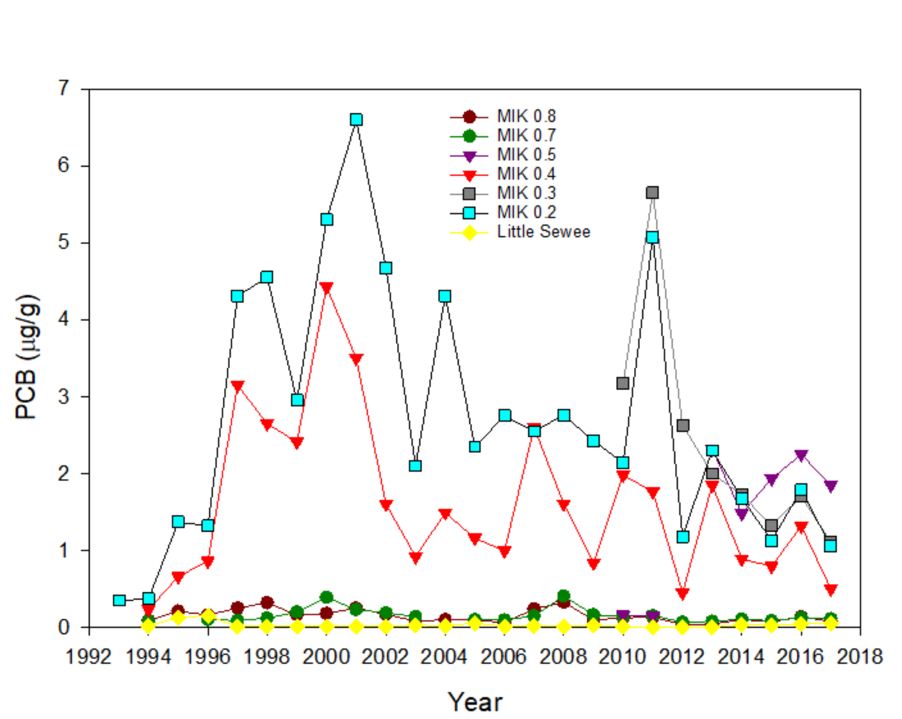
BMAP = Biological Monitoring and Abatement Program, MIK = Mitchell Branch kilometer, and SD = storm drain/storm water outfall

Figure 3.43. Major storm water outfalls and biological monitoring locations on Mitchell Branch

Bioaccumulation monitoring in the K-1007-P1 pond, K-901-A pond, K-720 slough, and Mitchell Branch involves sampling fish (Figure 3.47) and analyzing the tissues for PCB concentrations (Figure 3.48). Typically, fillets of game fish are used as a monitoring tool to assess human health risks, while whole-body composites of forage fish are used to assess ecological risks associated with exposure to PCBs. Target species vary from site to site, depending upon the habitat. The target species for bioaccumulation monitoring in 2017 in the K-1007-P1 pond was bluegill sunfish (*Lepomis macrochirus*) (Figure 3.49). In Mitchell Branch, the target species was the redbreast sunfish (*Lepomis auritus*). In the K-901-A pond and the K-720 slough, the target species were the gizzard shad (Dorosoma cepedianum) and largemouth bass (*Micropterus salmoides*). As there were not enough largemouth bass, carp (*Cyprinus carpio*) were also collected.

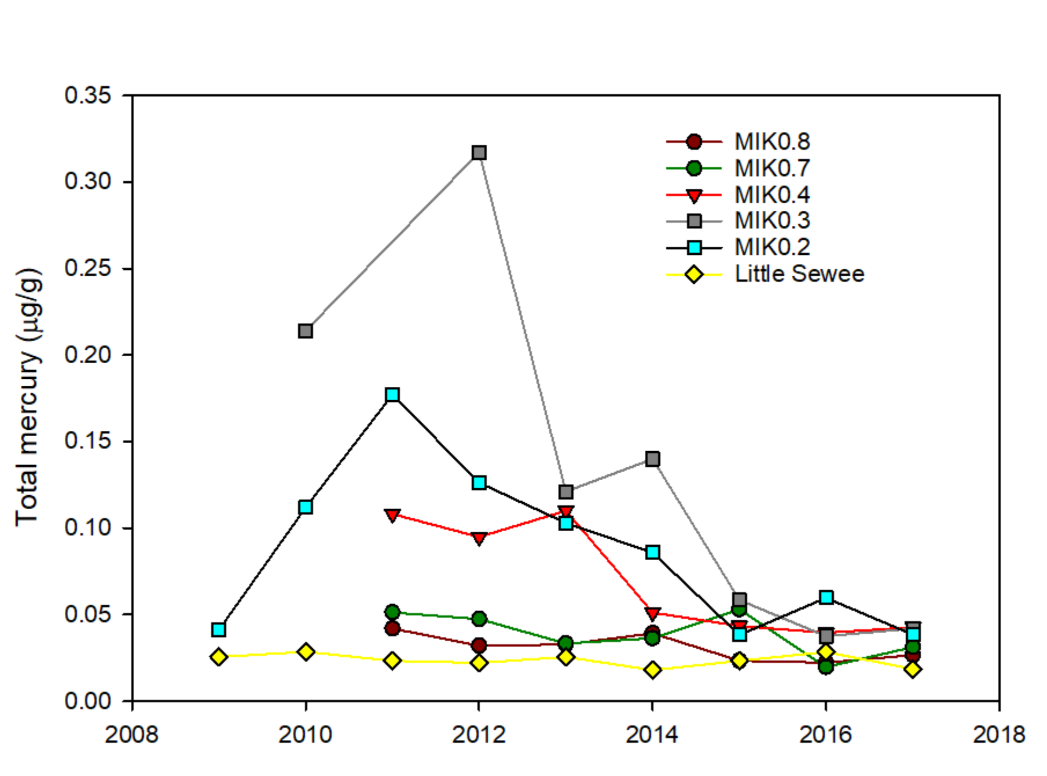
Whole body samples (6 composites of 10 bluegill each) and fillets from 20 individual bluegills were analyzed for PCBs to assess the ecological and human health risks associated with PCB contamination in the K-1007-P1 pond. Whole body bluegill composites from the K-1007-P1 pond averaged 2.58 µg/g total PCBs, a slight increase from the 1.91 µg/g seen in 2016. Fillets averaged 0.95 µg/g total PCBs, slightly lower than concentrations seen in 2016 (1.06 µg/g). Average PCB concentrations in sunfish fillets collected in Mitchell Branch were 2.17 µg/g, slightly higher than the levels seen in 2016 (1.95 µg/g). The concentrations observed in fillets of largemouth bass from the K-901-A pond (1.26 µg/g) increased slightly from the concentrations seen in the 2016 monitoring, 0.90 µg/g. Fillets of carp from the K-901-A pond averaged 1.28 µg/g, essentially unchanged from last year. Gizzard shad whole body composite samples from K-901-A pond (3.77 µg/g) decreased slightly from the concentrations seen in the 2016 monitoring (4.52 µg/g). Levels of PCBs in bass, gizzard shad, and carp from the K-720 slough (0.10 µg/g, 0.40 µg/g, and 0.46 µg/g, respectively) were considerably lower than for the same species from the K-901-A pond, and except for a slight increase in the concentrations in carp were little changed from 2016.

Figure 3.44. Asiatic clam (*Corbicula fluminea*)



N = 2 composites of 10 clams each per year. Shown in yellow are data for clams collected from the reference site, Little Sewee Creek (Sweetwater, Tennessee). Total PCBs defined as the sum of Aroclors 1248, 1254, and 1260.
MIK = Mitchell Branch kilometer

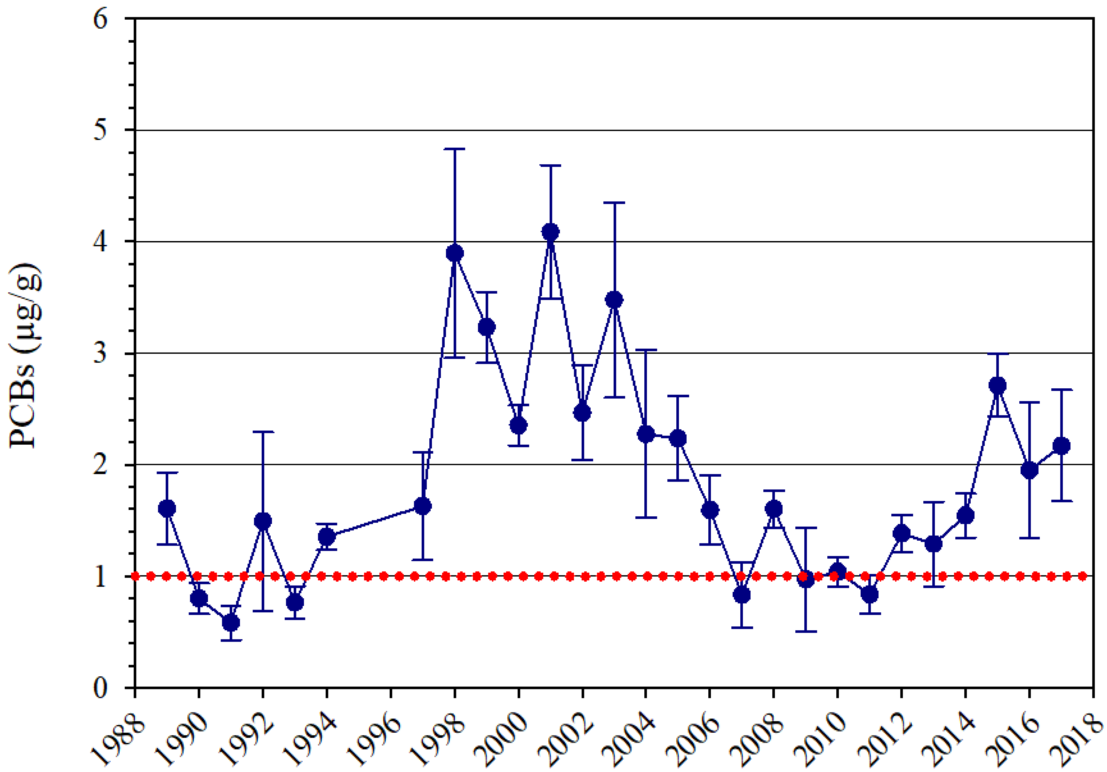
Figure 3.45. Mean total polychlorinated biphenyl (PCB) (µg/g, wet wt; 1993–2017) concentrations in the soft tissues of caged Asiatic clams deployed in Mitchell Branch



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

Figure 3.46. Mean total mercury (µg/g wet wt; 2009–2017) concentrations in the soft tissues of caged Asiatic clams deployed in Mitchell Branch

Figure 3.47. Fish bioaccumulation sampling at K-1007-P1 pond



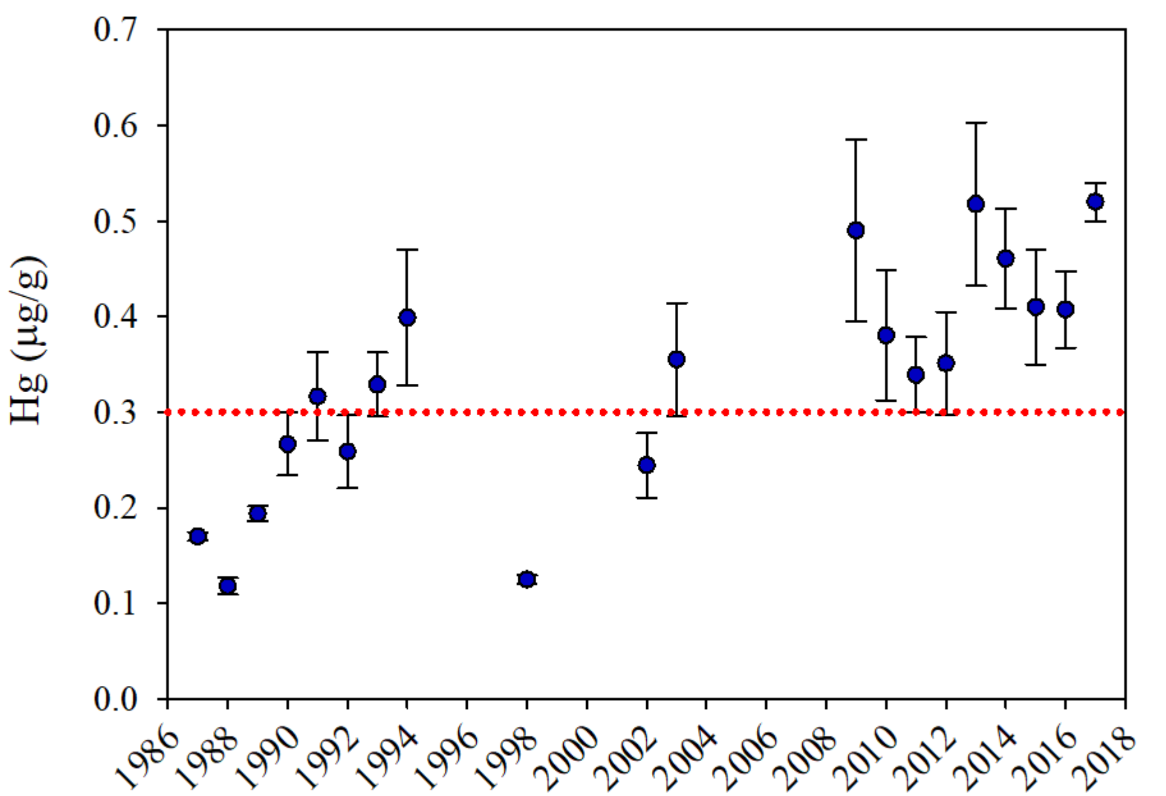
1989–2017, N = 6 fish per year. Shown in red is the fish advisory level for PCBs (1 µg/g).

Figure 3.48. Mean (+/- standard error) polychlorinated biphenyl (PCB) concentrations (µg/g, wet wt) in redbreast sunfish fillets in Mitchell Branch (MIK 0.2)

ORNL 2011-G00782/chj

Figure 3.49. Bluegill sunfish (Lepomis macrochirus)

In addition to being analyzed for PCBs, select species collected from several locations were analyzed for total mercury (Figure 3.50). Previous studies have shown that methylmercury accounts for more than 95 percent of the total mercury in fish, so a separate analysis for methylmercury was not conducted. The EPA's recommended limit for mercury in fish fillets is 0.3 µg/g. The mean mercury concentration in sunfish fillets collected at MIK 0.2 was 0.52 µg/g in 2017, an increase from 0.41µg/g in 2016. Average mercury concentrations in fish in Mitchell Branch in recent years have ranged between 0.3 µg/g and 0.5 µg/g, with about 10–20 percent variability within the annual collection. Fillets of sunfish from the reference site, Hinds Creek, averaged 0.08 µg/g of mercury in 2017, essentially unchanged from 2016.



1989–2017, N = 6 fish per year. Shown in red is the fish advisory level mercury (0.3 µg/g).

Figure 3.50. Mean total mercury (Hg) concentrations (µg/g, wet wt) in redbreast sunfish fillets in Mitchell Branch (MIK 0.2)

3.7.2 Instream Monitoring of Biological Communities

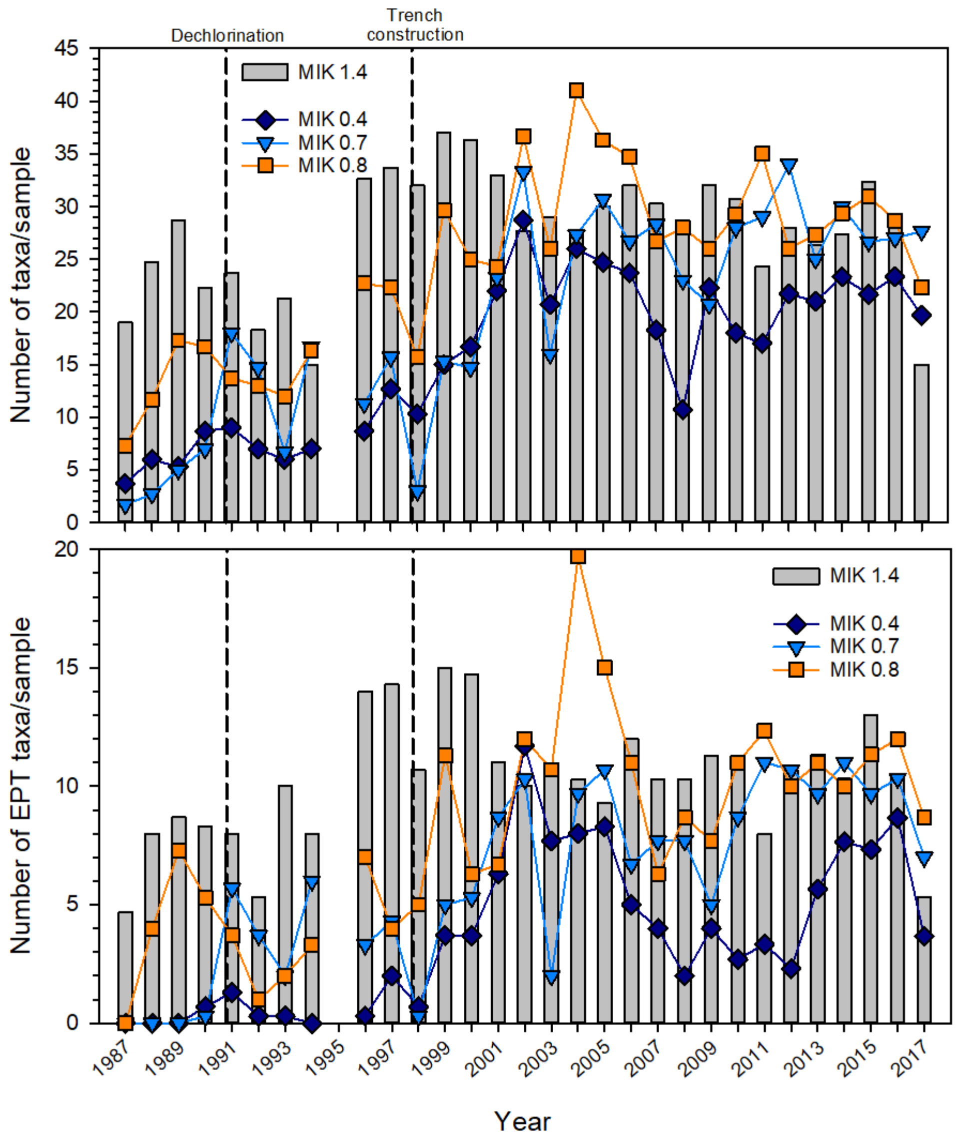
In May 2017, the benthic macroinvertebrate community at four Mitchell Branch locations (MIKs 0.4, 0.7, 0.8, and 1.4) was sampled using standard quantitative techniques (Figure 3.51). MIK 1.4 was the reference location. Results of monitoring in 2017 using the ORNL protocols show that the taxa richness and Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa richness were more variable than what has typically been seen at the same locations. At all four locations, taxa richness, EPT richness, total density, and taxa-specific densities all decreased to some degree from 2016 to 2017. The reference location, MIK 1.4, had the lowest total richness of the four Mitchell Branch locations, and the EPT richness was considerably lower at MIK 1.4 than at MIK 0.7 and MIK 0.8. This is a change from the previous years of monitoring results, which typically have shown similar values for taxa richness, EPT richness, and EPT density at MIK 1.4, MIK 0.7, and MIK 0.8. In particular, total taxa richness at MIK1.4 has never dropped below values at MIK 0.4 during the period of sampling. Furthermore, values of taxa richness at MIK1.4 in 2017 have not been observed at the site since the mid-1990s. The total density at MIK 1.4 showed a marked decrease from 2016 to 2017. The physical condition of MIK 1.4 (very shallow with low flow, fine sediments, and unstable stream banks) coupled with the drought of 2016 followed by the higher than normal precipitation of early 2017 is thought to be the cause of many of these changes. The number of pollution-intolerant species is highest at MIK 1.4 (Figure 3.52), as has been the case for some time. Pollution-tolerant species make up a higher percentage of the total number of individuals at MIK 0.4, MIK 0.7, and MIK 0.8. However, at MIK 0.7 and MIK 0.8 the percent abundance of pollution-tolerant taxa decreased approximately 50 percent from 2016 to 2017.

Since August 2008, TDEC protocols, which assess both community and habitat characteristics, have also been used at the MIK 0.4, 0.7, and 0.8 monitoring locations. Beginning in August 2009, the use of TDEC protocols was expanded to include MIK 1.4 as well (Figure 3.53). The 2017 biotic index indicated that the communities at MIKs 0.4 and 0.7 were nonimpaired, the community at MIK 0.8 was slightly impaired, and the community at MIK 1.4 was moderately impaired. The habitat assessment (which primarily considers the physical aspects of the stream to determine its suitability to support biological communities) in 2017 indicated habitat impairment at all four Mitchell Branch locations. Overall, results using TDEC's semiquantitative protocols and ORNL's quantitative protocols since 2008 have been in general agreement that the macroinvertebrate community at MIK 0.4 scores from slightly to moderately impaired, and the communities at MIKs 0.7 and 0.8 score from slightly impaired to unimpaired.

Figure 3.51. Benthic macroinvertebrate sampling in Mitchell Branch

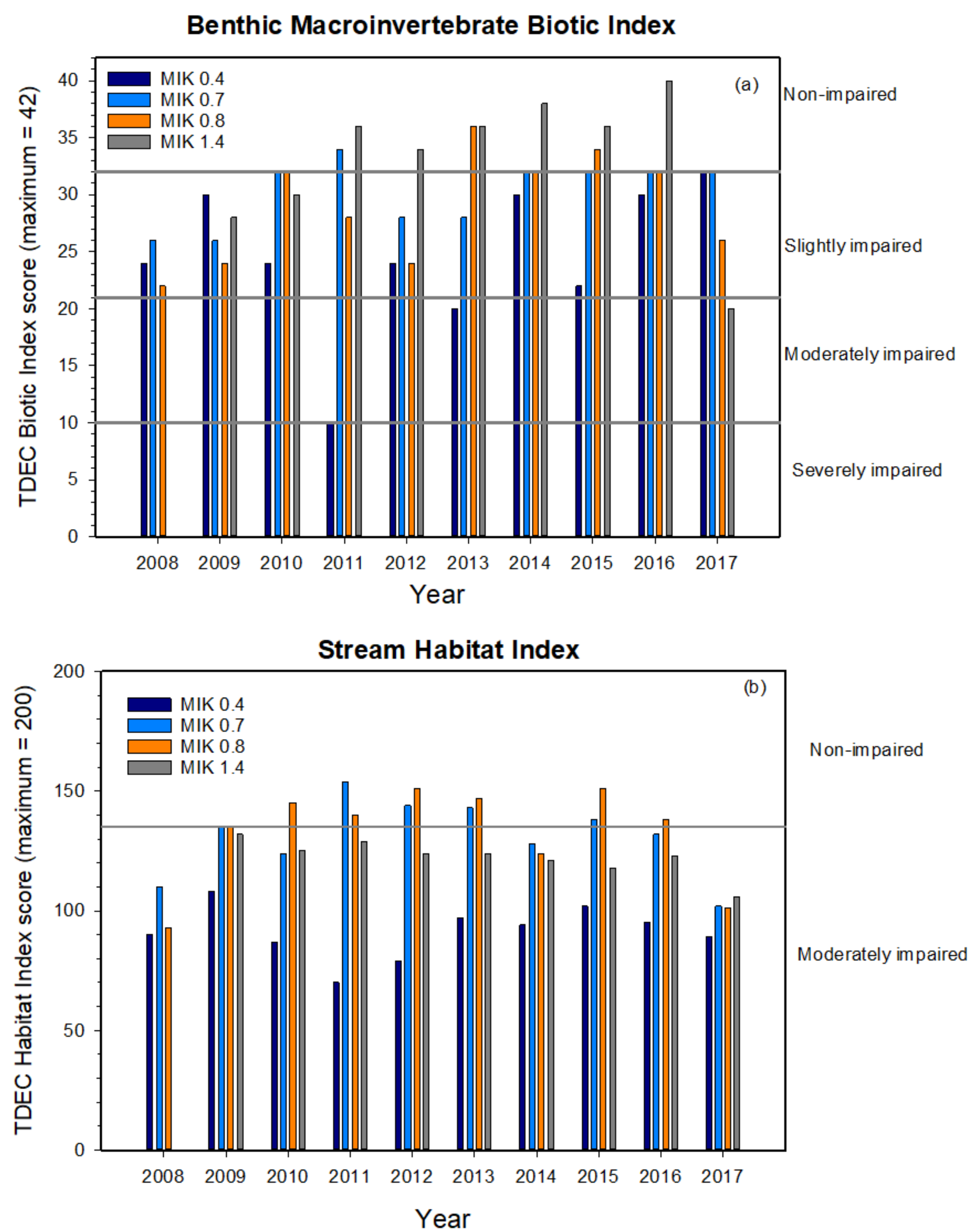
Fish communities in MIKs 0.4 and 0.7 and at local reference sites were sampled in 2017. In Mitchell Branch, species richness (number of species; Figure 3.54), density (fish/m²; Figure 3.55), and biomass were assessed for comparison with area reference streams. Results for 2017 showed changes within the normal range of variation for species richness. However, most of the species found during the community studies sampling tend to be more tolerant of less than optimal conditions. At the most downstream site (MIK 0.4), species richness decreased by one species from 2016, with a slight decrease in both density and biomass, compared with the results from 2016. Species richness at MIK 0.7 was unchanged from 2016, but density and biomass saw a significant decrease. As was the case with the benthic macroinvertebrate communities, the drought of 2016 followed by the increased precipitation of early 2017 would have stressed the fish communities. Overall, variations in species richness, density, and biomass are typical of streams that have been severely impacted and are still recovering. While the condition of the fish communities over the last several years has been relatively stable, they have yet to reach conditions typical of less impacted streams in the area; and the stream is still dominated by more tolerant fish species.

Similar to stream sampling, the K-1007-P1 pond is sampled annually to assess the diversity and density of resident fish populations. The pond is isolated from Poplar Creek by a weir grate at the outfall, preventing migration of fish into or out of the pond. Remediation efforts in 2007 focused on creating a fish community dominated by short-lived sunfish. Before remediation activities, the fish community contained high densities of predatory fish, as well as grazers, which fed on phytoplankton. In 2017, the fish community was comprised primarily of sunfish (> 83 percent) and gizzard shad (7.2 percent), with largemouth bass and other species comprising smaller percentages. While these numbers continue to vary from year to year, indicating that the population has not yet reached a state of balance, they continue to indicate a movement toward the goal of a sunfish-dominated community.



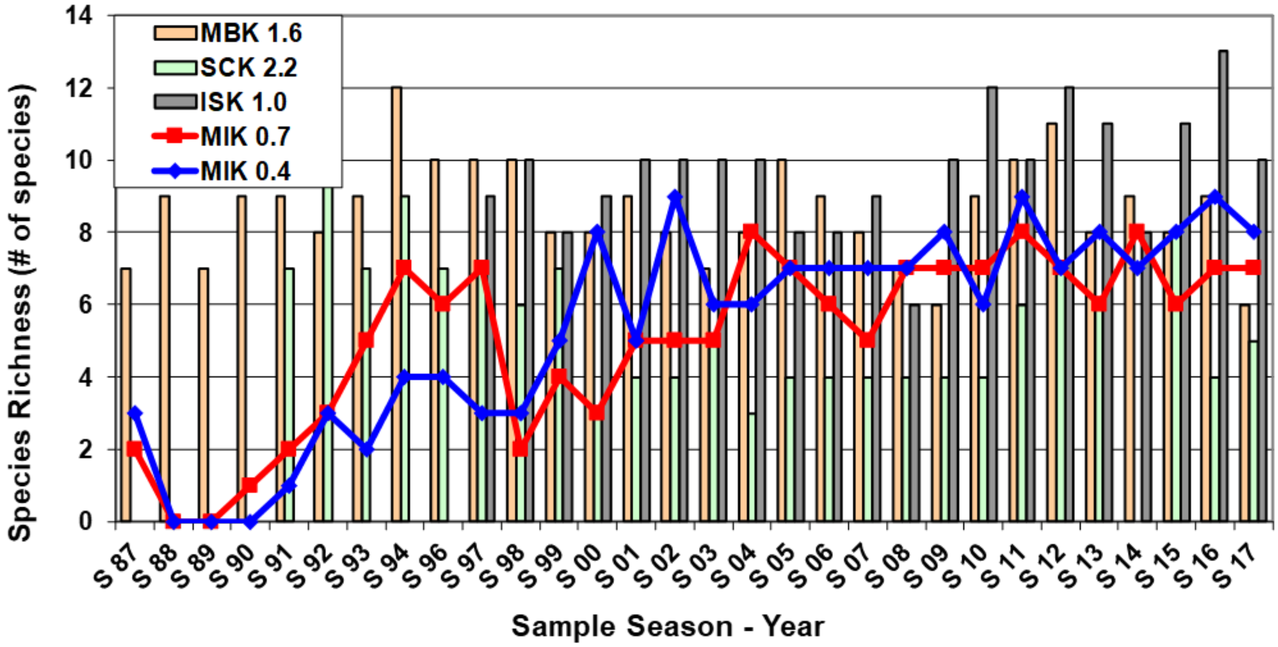
(a) number of all taxa, and (b) number of pollution-intolerant Ephemeroptera, Plecoptera, and Trichoptera (mayflies, stoneflies, and caddisflies, or EPT) taxa per sample. Samples were not collected in April 1995, as indicated by the gap in the lines. (MIK = Mitchell Branch kilometer)

Figure 3.52. Mean taxonomic richness in Mitchell Branch, 1987–2017



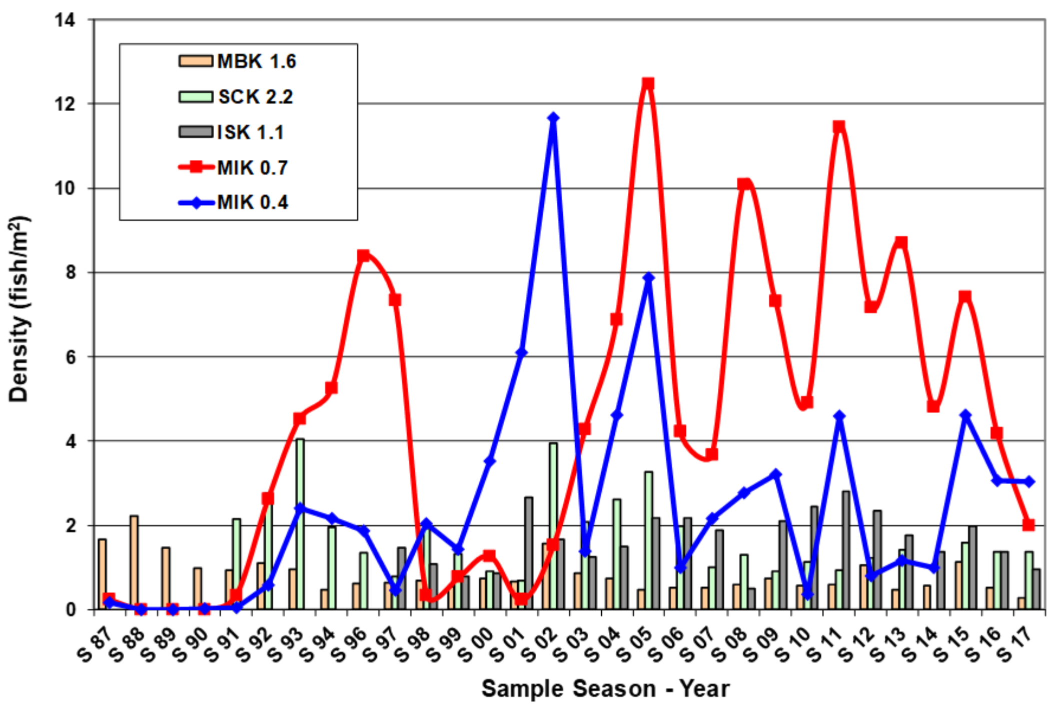
Horizontal lines in both graphs show the lower thresholds for narrative index ratings; respective narrative ratings for each threshold are shown on the right side of each graph. MIK = Mitchell Branch kilometer

Figure 3.53. Temporal trends in Tennessee Department of Environment and Conservation (TDEC) Benthic Macroinvertebrate Biotic Index (a) and Stream Habitat Index (b) scores for Mitchell Branch, August 2008–2017



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

Figure 3.54. Species richness for fish communities at sites in Mitchell Branch and in reference streams



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

Figure 3.55. Density for fish communities at sites in Mitchell Branch, and in reference streams

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 CNF 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 CNF discharge line. Section 3.6.4.1 provides a more detailed discussion of CWTS operations.

3.8.2 Environmental Remediation Activities

The Oak Ridge Office of Environmental Management (OREM) is performing a groundwater treatability study that will help determine the effectiveness of different *in situ* groundwater treatment technologies that will assist in identifying and selecting ETTP's final groundwater remedy. Phase 1 of the study, which included the characterization of a groundwater contamination source in the K-1401 area, was completed in FY 2010. The study resumed in FY 2016 and involved characterization to support the design of a pilot scale *in situ* thermal treatment study in the K-1401 area. In 2017, 18 investigative groundwater boreholes were installed and 14 existing Phase 1 boreholes reconfigured to allow monitoring of discrete levels. Seven pump test/observation wells were also installed in preparation for hydraulic testing. Innovative technologies—including Rotosonic drilling, rock core dye testing, flexible underground liner technology, and real time analysis—were used to determine the extent of contamination and to confirm the presence of DNAPLs in the K-1401 area.

Upcoming work includes the hydraulic testing, data evaluation, and planning for the pilot scale thermal demonstration.

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 exposure units (EUs) that vary in size.

3.8.2.1 Zone 1

The Interim ROD, which documents the cleanup method for Zone 1, requires OREM to remediate soil for the protection of groundwater and a future industrial workforce, and to maintain land use controls. In FY 2017, remediation was completed in EU Z1-50, where the K-1066-K Cylinder Storage Yard is located, opening its 4.8 acres for industrial use. During 2016, OREM prepared the Zone 1 Final Soils Proposed Plan, and EPA and TDEC approved it. In FYs 2017 and 2018, OREM prepared the Final Soil ROD to finalize the remediation of soil for recreational use, industrial use, and ecological protection, and provided it to EPA and TDEC for review and approval.

3.8.2.2 Zone 2

The Zone 2 ROD requires OREM to remediate soil for the protection of an industrial workforce and groundwater and divides the zone into 44 EUs that range in size from 6 to 38 acres. In FY 2017, characterization of EUs Z2-12, -14, and -19 was completed, and remediation of EUs Z2-17, -20, -22, -28, -29, and -41 was completed. Following remediation, these two EUs were recommended for unrestricted industrial use. The Building K-27 slab is in EU Z2-14.

3.8.2.3 Support Facilities Demolition

UCOR completed demolition of Buildings K-731, the K-832 complex, K-833, K-1028-81 and K-1028-64 following demolition of Building K-27. These mark the first post-Vision 2016 demolition projects that significantly move OREM closer to its Vision 2020: the goal to complete cleanup of ETTP by the end of CY 2020.

Constructed in 1944, Building K-731 Electrical Switch House provided electrical power to the K-27 process building. The building was extended east in 1949 to provide electricity to the K-29 process building. Building K-731 was a brick and concrete structure with two main floors, three 3rd floor penthouses, and a below-grade basement each measured 31,000 ft^2. The building was demolished to grade, the floor removed, and the basement area backfilled. The demolition area was then graded, topsoil added and the grounds reseeded.

Shortly after the demolition of Building K-731, crews mobilized to Building K-1028-64, Portal 9 to demolish this structure. Portal 9 was a permanent guardhouse located southwest of the K-27 Process Building. The guardhouse was built in 1973 and was 160 ft^2. Building K-1028-81, Portal 19, and Building K-833, and the Cooling Water Return Pump House also were demolished in 2017, which concluded the removal of ancillary buildings associated with the K-27 process building.

The K-832 RWC complex was built in 1945-1946 to provide recirculating cooling water to the enrichment cascades. The K-832 RCW complex included Building K-832, 11,000 ft^2 Recirculating Water Pump House, K-832-B, Sprinkler Valve House, K-832-H, 5,500 ft^2 Cooling Tower Superstructure, and K-832-S, Acid Tank. The complex was shut down in 1985 when Building K-25 ceased operations. The K-832 facilities were demolished in 2017.

3.8.2.4 Building K-1037 Deactivation Continues

UCOR continued deactivation work in Building K-1037 in FY 2017. Deactivation is the initial step that prepares the facility for eventual demolition. The facility 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 when workers separated the ^{235}U and ^{238}U isotopes.

K-1037 was once a warehouse, which was later converted into a facility that produced the porous barrier material used in the separation process.

Crews completed asbestos-abatement activities identified in the original scope; however, as items such as loose equipment were removed throughout the building, additional asbestos was uncovered, so abatement work and loose equipment removal activities continued into 2018. In addition, a tremendous amount of effort was dedicated to the removal of excess chemicals throughout the facility. Over 1400 chemicals have been collected, sampled, and prepared for disposal. Demolition is scheduled to begin in 2018.

3.8.2.5 Poplar Creek Deactivation Continues

At the end of FY 2017, OREM had completed 67 percent of the deactivation and continued characterization for the Poplar Creek facilities of ETTP. Deactivation involves disconnecting utilities to the facilities, removing certain components, and performing other steps necessary to prepare the buildings for demolition. The 52 Poplar Creek facilities supported operations at the site and included storage buildings that housed process equipment, water pump houses, and sandblasting/painting buildings.

Demolition of the tie lines in the Poplar Creek area continued in 2017, with approximately 31,000 linear feet (LF) removed, with the remaining 12,000 ft to be demolished in FY 2018. These tie lines connected the K-27 and K-31 gaseous diffusion buildings and carried enriched uranium from one building to another as the uranium moved through the enrichment process. Workers have been injecting foam into these lines to stabilize the contaminants so they will meet the criteria necessary for disposal in the onsite EMWMF and installing contamination liners and pads to prevent contamination of surrounding soil during demolition.

3.8.2.6 Central Neutralization Facility Deactivation Continues

CNF was a wastewater treatment facility for industrial wastewater generated at ETTP. CNF was constructed in stages from 1945 to 2000. In 2013, CNF was decommissioned and the NPDES-permitted facility water treatment equipment was cleaned of all hazardous waste contamination.

In 2017, characterization of CNF for the disposal of demolition debris was completed and removal of legacy waste, universal waste, and fixed equipment was nearly complete in preparation for the demolition of CNF.

3.8.2.7 Commemoration of the K-25 Site

National historic preservation initiatives at ETTP reached a milestone in FY 2017 with completion of design activities. Following classification and non-proliferation reviews, final design documents were released to the Historic Preservation Consulting Parties in January 2017 for review and comment. Issued for Construction design packages for historic preservation facilities and exhibits were finalized in April 2017.

Consulting Parties to K-25 historic preservation activities participated in a meeting on July 27, 2017, to review the current condition of the K-25 building footprint. The highlight of the meeting was an opportunity to tour the building footprint and walk on portions of the original concrete slab. Following the tour, NPS staff facilitated discussions on plans for preservation and public use of the K-25 building footprint.

At the close of the FY, activities were underway to procure the services of construction and exhibit fabrication support subcontractors for the History Center work. Construction of the Equipment Building and Viewing Tower is planned for FY 2018.

Visitors to the K-25 History Center will be invited to explore the rich history of this Manhattan Project site. This facility will feature 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 to make it a reality, will be highlighted. The 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 2017, DOE completed transfer of 185 acres in the former K-33/K-31 Area to CROET. This transfer is the second largest transfer in the history of the program, and the largest at ETTP Heritage Center. Because of the ample utility infrastructure at the K-33/K-31 Area, this area could potentially host a large-scale industrial project, which makes it the most desirable for redevelopment at the site. 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 will accommodate small corporate jets, private airplanes, and EMS aircraft. DOE completed an Environmental Assessment to support the property transfer and potential construction and operation of the airport. In 2017, DOE completed all of the approval requirements for the 200-acre Duct Island, which is now ready for transfer. 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.

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4. The Y-12 National Security Complex

The Y-12 National Security Complex (Y-12 Complex), 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 70 years of manufacturing excellence, the Y-12 Complex helps ensure a safe and reliable United States nuclear weapons deterrent.

The Y-12 Complex also retrieves and stores nuclear materials, fuels the nation's naval reactors, and performs complementary work for other government and private-sector entities.

Today's environment requires that the Y-12 Complex has a new level of flexibility and versatility, so while continuing its key role, the Y-12 Complex 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.

Because of differing permit-reporting requirements and instrument capabilities, various units of measurement are used in this chapter. The information found in "Units of Measure and Conversion Factors" is intended to help readers convert numeric values presented here as needed for specific calculations and comparisons.

4.1 Description of Site and Operations

4.1.1 Mission

CNS manages and operates the Pantex Plant and the Y-12 Complex on behalf of NNSA. Together, these two sites are a core element of a sustainable and robust national nuclear deterrent.

Charged with maintaining the safety, security, and effectiveness of the United States nuclear weapons stockpile, the Y-12 Complex is a one-of-a-kind manufacturing facility that plays an important role in United States national security. The Y-12 Complex'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 the Y-12 Complex. Through life extension program activities, the Y-12 Complex produces refurbished, replaced, and/or upgraded weapons components to modernize the enduring stockpile. As the nation reduces the size of its arsenal, the Y-12 Complex has a central role in decommissioning weapons systems and providing weapons material for non-explosive, peaceful uses. The Y-12 Complex 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). The Y-12 Complex 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 Complex 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. NNSA-related facilities located offsite from the Y-12 Complex include the Central Training Facility, Uranium Processing Facility (UPF) project offices, Y-12 Complex Shipping and Receiving, and the Union Valley Sample Prep 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 the Y-12 Complex.

More than 60% of the Y-12 Complex mission-critical facilities are over 70 years old (Figure 4.1). To address this situation, the Y-12 Complex 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, the Y-12 Complex will continue to strive toward becoming a more responsive, sustainable enterprise. As evidenced by the performance achievements presented in this chapter, the Y-12 Complex continues to meet the challenges of declining budgets through enhanced security measures, enhanced technology, and innovative business practices.

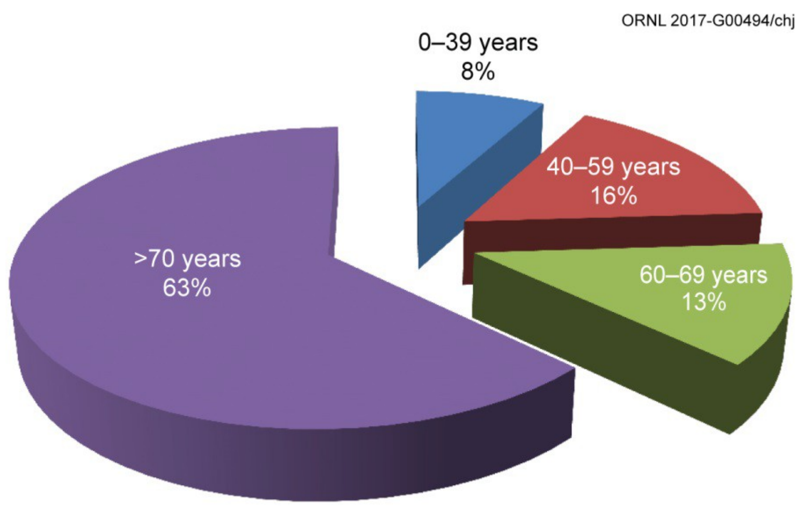


Figure 4.1. Age of mission-critical facilities at the Y-12 National Security Complex

Replacement and revitalization are key elements of the modernization strategy at the Y-12 Complex. A significant number of facilities at the Y-12 Complex 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

The Y-12 Complex's 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 the Y-12 Complex 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 HEU production functions. The remaining HEU production capability will be transitioned to Bldgs. 9215 and 9204-02E, which must be sustained to achieve the HEU mission strategy. The strategy includes the following:

- accelerating transition out of Bldg. 9212 by 2025 to reduce nuclear safety and operational risk while maintaining enriched uranium capabilities;
- integrating evaluation of alternatives for delivery of UPF that prioritizes replacement capabilities according to risk to nuclear safety, security, and mission continuity;
- substantially improving the needed Y-12 Complex infrastructure over the next decade at a risk-based annual funding level that supports safe and secure operations; and
- prioritizing replacement capabilities by risk-to-mission continuity, nuclear safety, and security.

4.1.4 Lithium Production Capability

The lithium production equipment and facilities at the Y-12 Complex 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 Bldg. 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 to 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. The facility, currently carrying approximately $31million (M) in deferred maintenance, could be replaced by a new facility less than one fourth its size. Site production risk assessments rate two of the lithium processes as the highest equipment risks at the Y-12 Complex. 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 (DSW) components. The inability to control humidity due to aged and inoperable heating, ventilating, and air-conditioning (HVAC) equipment has caused recurrent lost work days, negatively affecting DSW costs and life extension program schedules. Construction and replacement activities are underway for the HVAC equipment.

4.1.5 Support Facilities

Emergency response capabilities at the Y-12 Complex reside in five primary facilities: four located onsite (Bldgs. 9706-2, 9105, 2005, and 9710-2), and one (Bldg. K-1650) located at the East Tennessee Technology Park (ETTP). Building 9706-2 houses the Plant Shift Superintendent (PSS) and the Emergency Control Center. The Technical Support Center (TSC) was relocated to Bldg. 9105 due to a flood event in Bldg. 9706-02 in 2014. Building 9710-2 is the principal facility housing Fire Protection Operations, with a back-up facility (2005) located on the west end. Building K-1650 houses the Command Center/alternate Emergency Operations Center (EOC). A line-item project for construction of a new EOC, scheduled to begin in 2018, includes the replacement of the PSS, TSC, and Emergency Response Center. The proposed EOC will more effectively and efficiently support the Y-12 Complex missions by consolidating emergency-response capabilities into a habitable, survivable facility that also provides space for a technical support team.

Built in 1948, Bldg. 9710-2 houses the Fire Station and the Fire Department Alarm Room. The overflow station for the fire department is located in Bldg. 2005, at the far west end of the plant.

Building 9710-02 is located within the most highly protected area of the plant and close to the Y-12 Complex'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 the 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 Complex hazardous material facilities is necessary to ensure that the fire department can respond safely and effectively to all emergencies at the Y-12 Complex. A proposed new fire station is planned for construction beginning in 2019. The new facility will be located on the east end of the plant and is designed to meet current codes and functional requirements.

Over the next 20-year horizon, the Y-12 Complex will continue to consolidate personnel and processes in support of the vision for long-range footprint reduction and modernization. The planned construction at the Y-12 Complex would eliminate many of the World War II-vintage buildings that currently house the nuclear operations. The following projects are currently under construction or are being initiated during the Future Year Nuclear Security Plan period:

- UPF,
- New 13.8kV Substation,
- EOC,
- West End Protected Area Reduction,
- Fire Station,
- Lithium Production Capability,
- Bridging Strategy for Bldgs. 9215 and 9204-02E, and
- West End Change House.

The following projects are planned for completion beyond the Future Year Nuclear Security Plan period:

- Applied Technologies Laboratory,
- Security Support Complex,
- Consolidated Manufacturing Capability,
- Maintenance Complex,
- Non-Special Nuclear Material Storage and Staging Facility,
- Waste Management Complex,
- Bldg. 9215 Replacement Capability, and
- Bldg. 9204-02E Replacement Capability.

4.1.6 Excess Facility Disposition

Since 2002, the Y-12 Complex has demolished more than 1.4M ft^2 of excess facilities. Currently, more than 80 excess DOE facilities are located on the Y-12 Complex site. The excess facilities are owned by NNSA and the DOE Office of Environmental Management (OREM), Office of Science, and Office of Nuclear Energy. Process-contaminated excess facilities contain radiological or chemical contamination resulting from their mission operations during the Manhattan Project or the Cold War.

OREM, through its contractors, is responsible for decommissioning and demolishing the legacy contaminated facilities.

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 OREM, depending on the cost and complexity.

The NNSA Facilities Disposition Program will continue to evaluate facilities, prioritize their disposition, develop cost and schedule, and communicate requirements for disposal of excess facilities. Without a defined program to eliminate excess facilities, the Y-12 Complex will continue to use limited resources to safely maintain those facilities that no longer have a mission or enduring use.

4.2 Environmental Management System

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

DOE Order (O) 436.1, *Departmental Sustainability* (DOE 2011a), provides requirements and responsibilities for managing sustainability within DOE in accordance with applicable Executive Orders (EOs). DOE O 436.1 further requires implementation of an EMS that is either registered to the requirements of ISO 14001 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. The Y-12 Complex has maintained an EMS with self-declared conformance to ISO 14001 since 2006.

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

4.2.1 Integration with Integrated Safety Management System

The Y-12 Complex 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 the Y-12 Complex, 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.

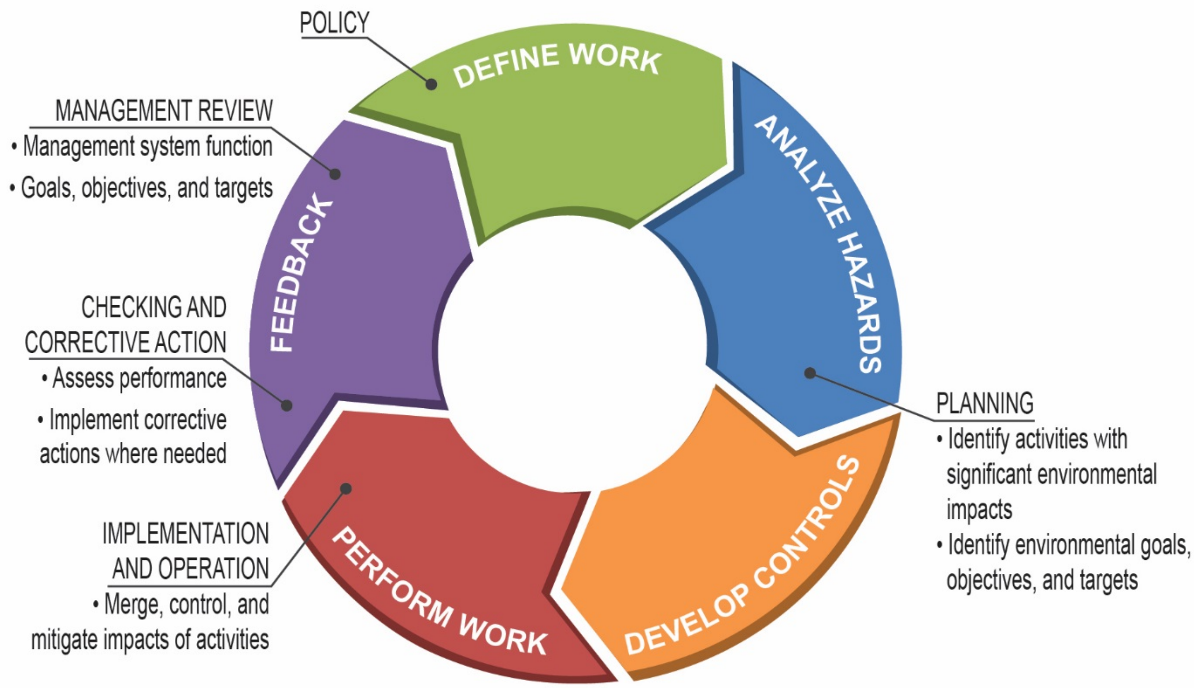


Figure 4.2. Relationship between the Y-12 National Security Complex Environmental Management System and the Integrated Safety Management System depicted in a "plan-do-check-act" cycle

4.2.2 Policy

The Y-12 Complex 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. The Y-12 Complex 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 environment, safety, and health policy

The Y-12 Complex ES&H policy has been communicated to all employees and is incorporated into mandatory training for every employee; it is available for viewing on the Y-12 Complex external website and on the internal Y-12 Complex website. Y-12 Complex personnel are made aware of the commitments stated in the policies and how the commitments relate to Y-12 Complex 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 Complex 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 2017:

- air emissions;
- greenhouse gas (GHG) emissions (scopes 1 and 3);
- wastewater/groundwater;
- excess facilities and unneeded materials and chemicals;
- hazardous or mixed wastes;
- radiological waste;
- potable water use;
- surface water and storm water;
- aging infrastructure and equipment;
- legacy contamination and disturbance;
- universal waste and other recycled streams;
- energy consumption (Scope 2 GHGs); and
- clearing, grading, or excavation (non-quarantined soil).

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 the Y-12 Complex by establishing and maintaining environmental objectives, targets (goals), and action plans. Goals and commitments are established annually. They are consistent with the Y-12 Complex's mission, budget guidance, ES&H work scope, DOE sustainability goals, site incentive plans, and continuous improvement 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 2017 environmental targets achieved at the Y-12 Complex 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 Complex 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

The Y-12 Complex Environmental Compliance Department (ECD) provides environmental technical support services and oversight for Y-12 Complex 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 Complex site procedures. ECD serves as the Y-12 Complex interpretive authority for environmental compliance requirements and as the primary point of contact between the Y-12 Complex 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 Complex 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 the Y-12 Complex EMS and spearheads initiatives to proactively address environmental concerns, to continually improve environmental performance, and to exceed compliance requirements.

Waste Management

The Y-12 Complex Waste Management Program supports the full life cycle of all waste streams within the Y-12 Complex. While ensuring compliance with Federal and State regulations, DOE Orders, waste acceptance criteria, and Y-12 Complex 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 Complex operations for waste planning, characterization, 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 companywide programs and services to support sustainable material management operations. These sustainable operations include pollution prevention and recycling programs, excess materials programs, generator services programs, and facility destruction and recycling operations. The Y-12 Complex has implemented continuous improvement activities, such as a "Stuff I Want to Get Rid of" 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 and Unneeded Materials and Chemicals (UMC). 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.

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

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 biobased products, including alternative fuels such as E85), meet sustainable design requirements, and adhere to pollution prevention reporting requirements.

Energy Management

The mission of the Y-12 Complex Energy Management Program is to incorporate energy-efficient technologies site-wide and to position the Y-12 Complex 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. The Y-12 Complex is committed to achieving the sustainable energy and transportation goals established in EO 13693.

Sustainability goals, goal performance, and goal achievement are defined and tracked within the DOE Sustainability Dashboard.

4.2.4 Implementation and Operation

4.2.4.1 Roles, Responsibility, and Authority

The safe, secure, efficient, and environmentally responsible operation of the Y-12 Complex 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 the Y-12 Complex.

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 the Y-12 Complex. 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

The Y-12 Complex is committed to keeping the community informed on operations, environmental concerns, safety, and emergency preparedness. The Community Relations Council, composed of 20 members from a cross-section of the community, including environmental advocates, neighborhood residents, Y-12 Complex retirees, and business and government leaders, serves to facilitate communication between the Y-12 Complex and the community. The council provides feedback to the Y-12 Complex regarding its operations and ways to enhance community and public communications. The Y-12 Complex sponsored the Great Smoky Mountains National Park and the East Tennessee Foundation, and supported the expansion of a Girls, Inc., program that promotes science, technology, engineering, and mathematics.

As part of the Y-12 Complex America Recycles Day activities, four local charities received $200 donations from funds raised by the Y-12 Complex employee aluminum beverage can recycling efforts. Since the program began in 1994, more than $86,400 raised by the collection of aluminum beverage cans has been donated to various local charities.

The Y-12 Complex 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 eye glasses 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 Complex 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 the Y-12 Complex 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 Complex emergency response exercises.

Three exercises, 1 performance drill, and 17 training drills were conducted at the Y-12 Complex during FY 2017. The drills and exercises focused on topics such as responding to a hazardous chemical release, natural disaster, radiological fire and release, active shooter event, and a criticality event. Seven building evacuation and accountability drills were also conducted.

Y-12 Complex expertise in emergency management continues to be recognized within DOE. Members of the Emergency Management Program Office staff participated in the DOE Emergency Management Issues Special Interest Group Conference, held in Las Vegas, Nevada, in May 2016. The Y-12 Complex staff made presentations, participated in steering committee meetings, and distributed Y-12 Complex Emergency Management Program information to other DOE facility's emergency management professionals.

4.2.5 Checking

4.2.5.1 Monitoring and Measurement

The Y-12 Complex 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 2017 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 Complex 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 Complex 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 adhere to DOE O 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 the Y-12 Complex EMS during May 11 through 14, 2015. The Y-12 Complex EMS was found to fully conform, and no issues were identified. The next external verification audit is scheduled for spring 2018.

4.2.6 Performance

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

- 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, 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 (OMB's) Environmental Stewardship Scorecard gave the Y-12 Complex an EMS scorecard rating for FY 2017 of green, indicating full implementation of EMS requirements.

4.2.6.1 Environmental Management System Objectives and Targets

At the end of FY 2017, the Y-12 Complex had achieved 7 of 14 targets that had been established; the remaining targets were carried into future years. Overall, 17 actions were completed through September 2017. Highlights include the following, with additional details and successes presented in other sections of this report:

- Clean Air—The Y-12 Complex finalized the evaluation of its uranium monitored-stack infrastructure to identify refurbishment needs for continued safe and compliant operations. Significant progress in obtaining a new Title V air permit was made.
- Energy Efficiency—Implementation of five Energy Savings Performance Contract (ESPC) energy conservation measures (ECMs) began in FY 2014 for projects to improve lighting, chilled water, air compressors, and the Y-12 Complex steam system. The five projects were completed in 2017. Significant progress was made on the effort to obtain Leadership in Energy and Environmental Design (LEED) certification on the UPF Construction Support Building. LEED awarded a Silver Certification, with the additional credit points required for obtaining a Gold Certification pending occupancy.
- Hazardous Materials—A project to improve controls for SeaLand storage containers was substantially implemented in 2017, with the contents of more than one-half of the 128 excess Sealand containers dispositioned or disposed. A project to disposition and ship nine items of legacy mixed waste per Site Treatment Plan milestones was completed in 2017.
- Reduce/Reuse/Recycle/Buy Green—The Y-12 Complex completed a project to strengthen the site-wide procedure for handling of universal waste in 2017 and began a project to install a drum crusher in one facility to greatly reduce the quantity of empty drum waste.

4.2.6.2 Sustainability and Stewardship

Numerous efforts at the Y-12 Complex 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 the Y-12 Complex have not only benefited the environment but have also resulted in cost efficiencies (Figure 4.4).

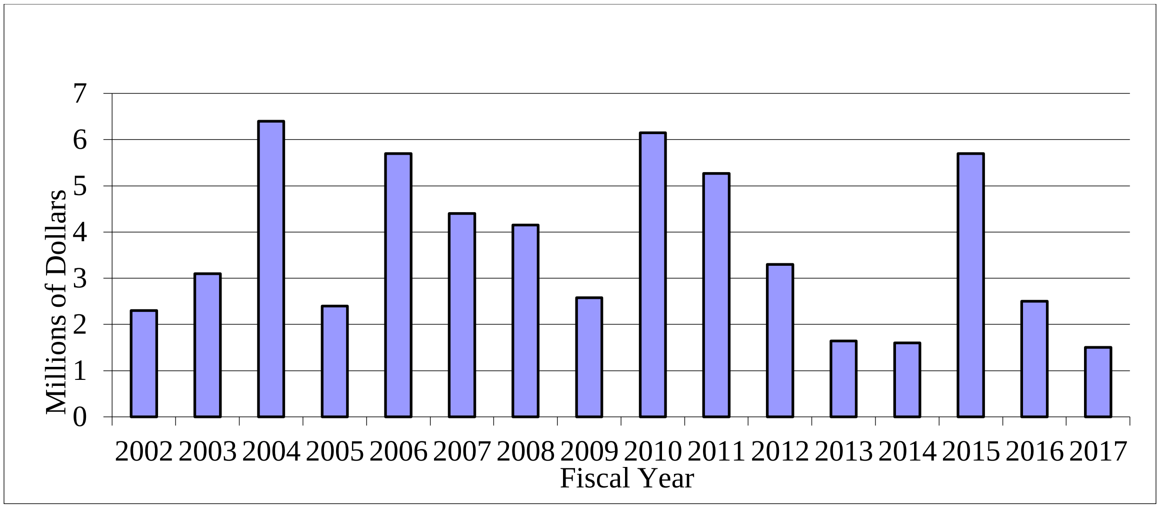


Figure 4.4. Cost efficiencies from Y-12 National Security Complex pollution prevention activities

In FY 2017, the Y-12 Complex implemented 101 pollution prevention initiatives (Figure 4.5), with a reduction of more than 32.8M lb of waste and cost efficiencies of more than $1.5M. The completed projects include the activities described below.

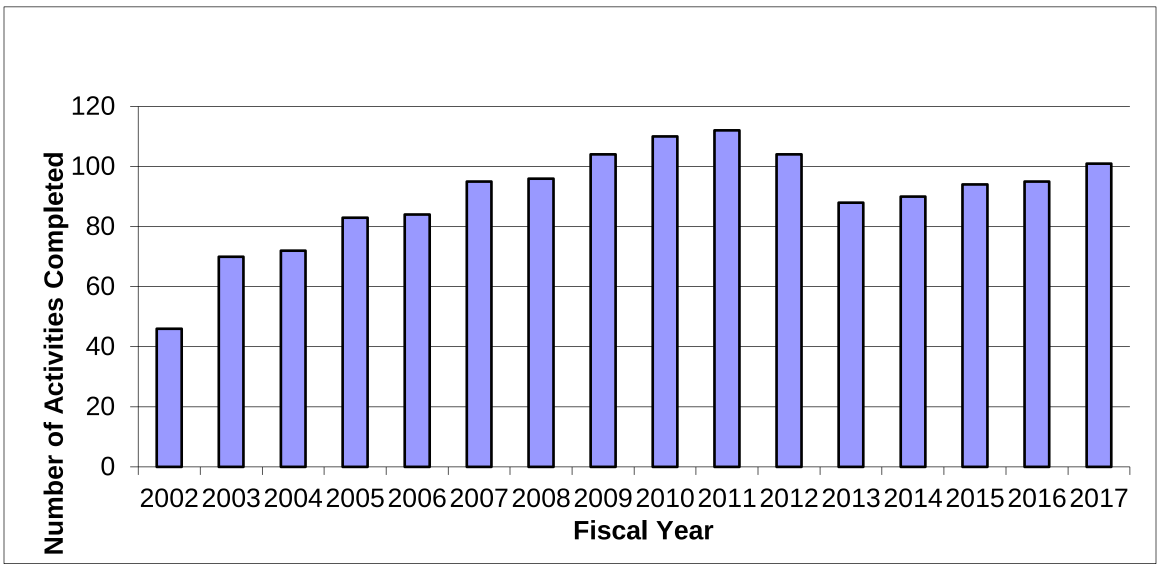


Figure 4.5. Y-12 National Security Complex pollution prevention initiatives

Pollution Prevention/Source Reduction

Sustainable initiatives have been embraced across the Y-12 Complex to reduce the impact of pollution on the environment and to increase operational efficiency. Many of the Y-12 Complex sustainable initiatives have pollution prevention benefits or targets eliminating the source of pollution, including the 2017 activities highlighted in this section.

Sustainable Acquisition—Environmentally Preferable Purchasing

Sustainable products, including recycled-content materials, are procured for use across the Y-12 Complex. In 2017, the Y-12 Complex procured recycled-content materials valued at more than $14.2M for use at the site.

Solid Waste Reduction

At the Y-12 Complex, unneeded materials are not automatically assumed to be wastes requiring disposal. The Y-12 Complex uses a systematic disposition evaluation process. The first step in the disposition process is to determine if the items can be reused at the Y-12 Complex. Items that cannot be reused at the Y-12 Complex 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 2017, the Y-12 Complex diverted 47.6% of municipal and 89.5% of construction and demolition waste from landfill disposal through reuse and recycle. The Y-12 Complex diverted more than 1.9M lb of municipal materials from landfill disposal through source reduction, reuse, and recycling in FY 2017. More than 29.4M lb of construction and demolition materials were diverted from landfill disposal in FY 2017. UPF added concrete as a new recycle stream for the site in FY 2017 to further waste diversion efforts.

Hazardous Chemical Minimization

The Generator Services Group provides a material disposition management service for generators at the Y-12 Complex, 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 the Y-12 Complex. During FY 2017, Generator Services Group personnel, rather than declaring materials as waste, reused or disseminated to other Y-12 Complex organizations for reuse, various excess materials and chemicals. In FY 2017, Generator Services Group prevented the generation of more than 1,800 lb of waste by transferring materials for on-site reuse.

Recycling

The Y-12 Complex 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 2.65M lb of materials was diverted from landfills and into viable recycle processes during 2017. Currently, recycled materials range from office-related materials to operations-related materials, such as scrap metal, tires, and batteries. The Y-12 Complex adds at least one new recycle stream to the Recycle Program each year to continue to increase the waste diversion rate. Three-dimensional printer cartridges were added in FY 2017 to broaden waste diversion efforts.

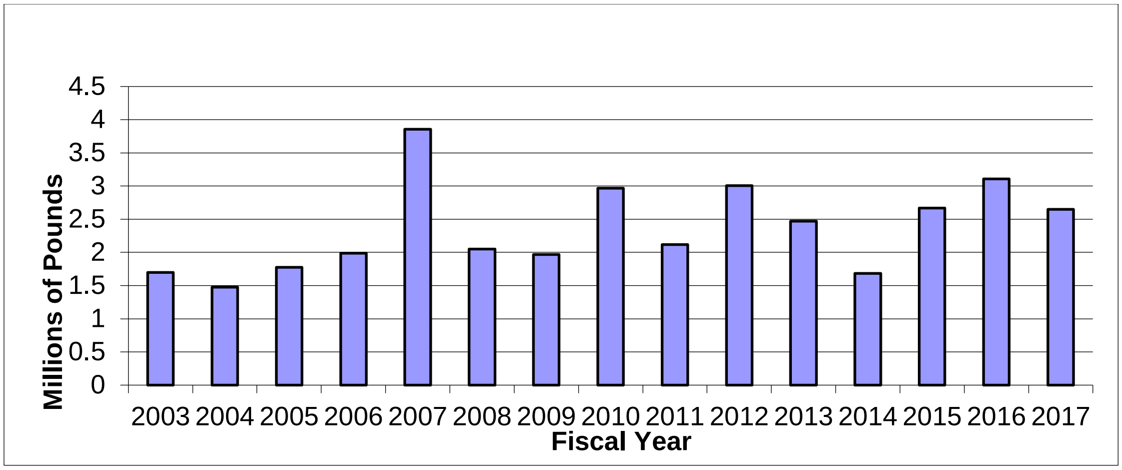


Figure 4.6. Y-12 National Security Complex recycling results

4.2.6.3 Energy Management

The mission of the Y-12 Complex Energy Management Program is to incorporate energy-efficient technologies site-wide and to position the Y-12 Complex to meet NNSA energy requirement needs through 2025 and beyond. 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. The Y-12 Complex is committed to achieving the sustainable energy and transportation goals established in EO 13693, *Planning for Federal Sustainability in the Next Decade*.

EO 13693 established a goal of reducing building energy intensity by 25% by 2025 from a FY 2015 baseline. The Y-12 Complex exceeded the FY 2017 goal by achieving an 8% reduction in energy intensity (Figure 4.7).

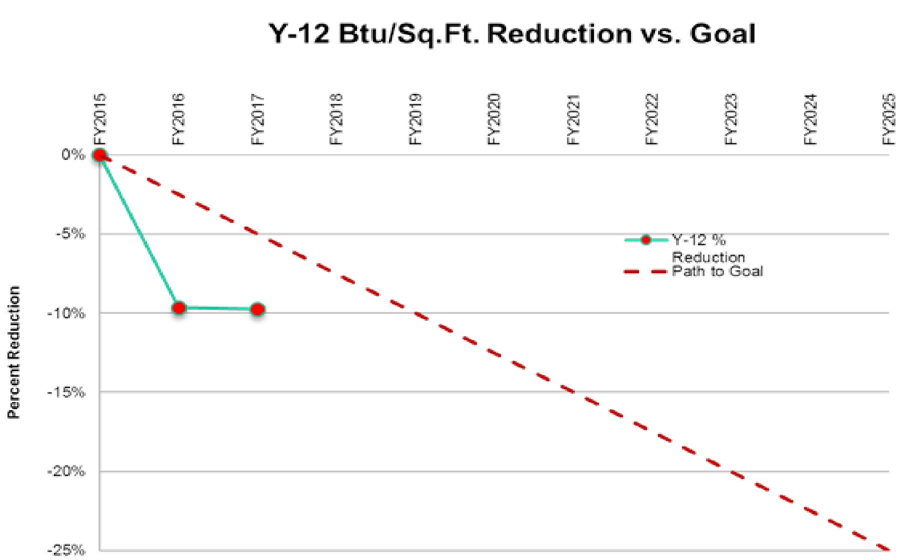


Figure 4.7. Y-12 National Security Complex has achieved an 8% reduction in energy intensity from the Fiscal Year 2015 baseline

Significant reductions have been noted with the implementation of ESPCs at the Y-12 Complex. Specific ESPC initiatives that aided in the reduction of energy consumption at the Y-12 Complex during FY 2017 included:

- Completing the new Air Compressor Plant at the end of FY 2016. This plant saves electricity and maintenance by better matching the demand load for instrument air with the amount of air being produced.
- Continuing to upgrade light fixtures with light-emitting diode and T-8 fluorescent lighting.
- 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, replacing tower pumps, steam controls, and control valves.
- Replacing Cooling Towers.

Additional energy reductions will be required in numerous areas to fully reduce energy use across the plant. Both facility management and utilities management are focusing on improvements to achieve the goal. Efforts that are fully incorporated into planning activities for facilities include the following:

- Energy Independence and Securities Act (EISA) assessments are included in annual reporting;
- ECMs from both EISA and the ESPC process are included in budgeting reviews; and
- Low-cost/no-cost efforts, including component replacements, are incorporated into routine activities. These include upgrades such as new control valves, leak repairs, and new faucets.

Future reductions may be challenging due to a projected increase in the site’s energy intensity. Current projections indicate increases once UPF goes on line, but they may be partially offset by an accelerated demolition program.

The following efforts are planned to ensure continued site success for energy reduction:

- Complete implementation of ESPC Delivery Order 3 (construction phase of ESPC throughout FY 2017), including lighting upgrades.
- Consolidate data centers, per OMB’s definition, and install electric meters.
- Continue installation of advanced metering as funding becomes available.
- Continue facility upgrades for high-performance sustainable building (HPSB) compliance and implement building retro-commissioning.
- Continue implementation of cool roof applications.
- Encourage energy reduction through tenant awareness, including training and monthly meter reporting.

Energy Monitoring

Comprehensive water and energy audits at the Y-12 Complex are performed to meet EISA Section 432. The audits evaluate energy and water use and identify opportunities to reduce use. The audits are performed by a certified energy auditor. The implementation costs for the ECMs are developed using the Condition Assessment Information System database. Energy projects are included in out-year planning for the site, and with adequate return on investment, will be funded. Specific examples include HVAC replacements and lighting upgrades in HPSB candidate facilities.

The Y-12 Complex currently has numerous standard and advanced electrical meters located on various facilities throughout the site. The actual electricity costs for the Y-12 Complex are based on total energy consumption, as defined by the Tennessee Valley Authority (TVA) revenue meters in the ELZA 1 substation. The Y-12 Complex does not use a space chargeback system, and individual building metering is not currently used for such purposes. Monitoring of the ELZA 1 substation electricity usage is used to ensure accurate billing from TVA and to develop the annual utilities budget.

Efforts to read meters and monitor commodity information have been hindered during FY 2017 by communication issues with the Utilities Management System. Additionally, approximately 20 meters have been identified as needing maintenance. Where meter data are available, it is entered into the Portfolio Manager for benchmarking and reporting purposes. The Y-12 Complex began entering facilities into the EPA Portfolio Manager in FY 2011. During FY 2017, metering data continued to be included in the Portfolio Manager as new meter data became available. At present, 114 facilities have been entered and are being tracked for compliance. Data from the Portfolio Manager are shared with NNSA sustainability contacts and are migrated to the Compliance Tracking System annually. These data are also published in metrics and shared with the infrastructure organization on a monthly basis.

In FY 2017, Johnson Controls, Inc., completed installation of electric and gas meters on approximately 17 buildings. These meters were installed with the completion of ESPC projects. In addition to the new meters, work has been performed on the energy management system for it to work properly. As these connections have progressed, data are being migrated to the energy management module for eventual use in site metrics, data reporting, and energy conservation measures.

Energy Savings Performance Contracts

The Y-12 Complex utilizes several mechanisms to integrate long-term sustainability goals into the budget planning process. The Y-12 Site Modernization Plan includes many elements that will reduce the number of operating facilities and utility infrastructure which will, in turn, reduce the electricity demand and GHG emissions. Both the Utilities Migration Plan and the Balance of Plant Facilities Plan include initiatives to improve the overall energy posture of the site. Accomplishment of smaller-scale energy reduction projects is included within internal baseline budgets. Although funding for specific projects is limited, the site recognizes that significant contributions to the goals can be achieved by including energy, water, and sustainability efficiencies within ongoing maintenance work. When appropriate and feasible, modifications to facilities include both energy and sustainable elements. Specific examples of this integration include HVAC replacements, lighting replacements, and energy-efficient utility modifications.

Dedicated funding for large-scale energy and water projects is provided via the ESPC mechanism. The Y-12 Complex has taken advantage of the energy saving opportunities provided by the ESPCs. ESPC Delivery Order 2 is in the sixth period of performance at the Y-12 Complex. This contract included chiller plant improvements, steam condensate return system modifications, steam trap improvements, and demineralized water production facility replacement. Efforts from Delivery Order 2 have greatly contributed toward both energy reduction and efficiency gains for the projects implemented. All guaranteed savings for ESPC Delivery Order 2 have been realized up to the present time. The Y-12 Complex entered into its third ESPC contract in September 2013. Delivery Order 3 was in the construction phase throughout FY 2017. Delivery Order 3 will result in an estimated annual energy and water cost savings of $2,874,696 and an estimated energy-related operations and maintenance (O&M) annual energy and water cost savings of $2,381,304. ECMs included in Delivery Order 3 include the following:

- Steam System Decentralization,
- Chiller Plant Upgrades,

- Energy Efficient Lighting Upgrades,
- Steam and Condensate System Improvements, and
- Compressed Air System Upgrades.

The Y-12 Complex entered into its first modification to Delivery Order 3 in September 2014. Delivery Order 3, Modification #1 was also in the construction phase throughout FY 2017. It will result in an estimated annual energy and water cost savings of $243,443 and an estimated energy-related O&M annual energy and water cost savings of $100,000. ECMs included in Delivery Order 3, Modification #1 consist of Chiller Plant Upgrades and Energy Efficient Lighting Upgrades. The Y-12 Complex entered into its second modification to Delivery Order 3 in September 2015. Modification #2 added additional scope to existing lighting, steam decentralization, and cooling tower replacement projects. This modification added 160 buildings to the lighting scope, added 9 additional buildings to the steam decentralization scope, and replaced an additional cooling tower. Delivery Order 3, Modification #2 was also in the construction phase throughout FY 2017 and will result in an estimated annual energy and water cost savings of $242,800 with no other energy-related O&M annual energy and water cost savings.

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. Each year, DOE tracks performance and reports progress towards these goals by providing the annual GHG Inventory, Annual Energy Report, Strategic Sustainability Performance Plan, and related reports to OMB, the White House Council for Environmental Quality, and Congress. Since 2009, the Sustainability Performance Office (SPO) has utilized the Consolidated Energy Data Report (CEDR) in Microsoft Excel to collect DOE site-level sustainability data and consolidate these data sets on behalf of the Department. In October 2014, the SPO launched the web-based DOE Sustainability Dashboard to serve the same functions as the CEDR and to add analysis capabilities for DOE sustainability data reporting. Beginning in FY 2016, CNS has completed required sustainability reporting through the DOE Sustainability Dashboard, the Department's official sustainability reporting tool.

In FY 2017, DOE modified the Sustainability Dashboard to focus on specific sustainability goals and to facilitate completion of the Site Sustainability Plans within the Dashboard. These goals, along with the current Y-12 Complex performance ratings, are found in Table 4.1.

Table 4.1. FY 2017 Sustainability Goals and Performance

Category	Goal	Current Performance
	GHG Inventory	
Scope 1 and 2 GHG Emissions	Reduce direct GHG emissions by 50% by FY 2025 relative to a FY 2008 baseline. Interim Target (FY 2017): -5%	Goal Met: -48%
Scope 3 GHG Emissions	Reduce indirect GHG emissions by 25% by FY 2025 relative to a FY 2008 baseline. Interim Target (FY 2017): -9%	Goal at Risk: -8%
	Facilities	
Energy Intensity	Reduction in energy intensity for goal subject facilities by 25% by FY 2025 relative to FY 2015 baseline. Interim Target (FY 2017): -5%	Goal Met: -8%

Table 4.1. FY 2017 Sustainability Goals and Performance (continued)

Category	Goal	Current Performance
Clean Energy	By FY 2025, use 25% renewable energy as a percentage of overall facility electric and thermal energy use. Interim Target (FY 2017): 10%	Goal Met: 10%
Renewable Electricity	By FY 2025, use 30% renewable energy as a percentage of overall facility electricity use. Interim Target (FY 2017): 10%	Goal Met: 22.7%
Potable Water Intensity	Reduce potable water intensity by 36% by FY 2025 relative to FY 2007 baseline. Interim Target (FY 2017): -20%	Goal Met: -65%
Industrial, Landscaping, Agricultural Water	Reduce industrial, landscaping, and agricultural water use by 30% by FY 2025 relative to FY 2010 baseline. Interim Target (FY 2017): -14.0%	Not Applicable for Y-12
HPSBs	Ensure 17% by building count comply with the Guiding Principles for sustainable buildings by FY 2025. Interim Target (FY 2017): 15.0%	Goal at Risk: 0%
	Fleet	
Fleet GHG Emissions/Mile	Reduce per-mile GHG emissions by 30% by FY 2025 relative to FY 2014 baseline. Interim Target (FY 2017): -4%	Goal at Risk: 96%
Fleet Petroleum	Reduce fleet petroleum use by 20% by FY 2015 and thereafter relative to FY 2005 baseline. Interim Target (FY 2017): -20%	Goal Met: -26%
Fleet Alternative Fuel	Increase fleet alternative fuel use by 10% by FY 2015 and thereafter relative to FY 2005 baseline. Interim Target (FY 2017): 10%	Goal Not Met: 99%
	Waste	
Municipal Solid Waste Diversion	Divert at least 50% of non-hazardous solid waste (excluding construction and demolition debris). Interim Target (FY 2017): 50%	Goal Not Met: 48%
Construction and Demolition Diversion	Divert at least 50% of construction and demolition materials and debris. Interim Target (FY 2017): 50%	Goal Met: 90%
	Electronics	
Electronics Acquisition	100% of eligible electronics procurements must be environmentally sustainable (e.g., EPEAT). Interim Target (FY 2017): 95%	Goal Met: 96%
Electronics Recycling	Dispose of 100% of electronics through government programs and certified recyclers. Interim Target (FY 2017): 100%	Goal Not Met: 96%
Power Management	Implement and actively use power management features on 100% of eligible computers (personal computers and laptops) and monitors. Interim Target (FY 2017): 100%	Goal Met: 100%
Duplex Printing	Implement and actively use duplex printing features of 100% of eligible printers. Interim Target (FY 2017): 100%	Goal Not Met: 22%

Table 4.1. FY 2017 Sustainability Goals and Performance (continued)

Category	Goal	Current Performance
	Acquisition	
Sustainable Acquisition	Ensure 95% of new contract actions for products and services meet sustainable acquisition requirements. Interim Target (FY 2017): 95%	Goal Met: 100%

EPEAT = Electronic Product Environmental Assessment Tool
FY = Fiscal Year
GHG = greenhouse gas
HPSB = high performance sustainable building

4.2.6.5 Water Conservation

In FY 2017, the Y-12 Complex achieved a 65% water intensity reduction from the baseline, surpassing the 2025 goal of 36% (Figure 4.8). The Y-12 Complex is currently meeting the water intensity reduction goals and storm water initiatives. All potable water consumed at the Y-12 Complex 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 Complex boundary. The Y-12 Complex purchases potable water from the city for all domestic and industrial applications. Raw water purchased for creek augmentation was discontinued in FY 2014. 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; and
- replacing steam with natural gas in buildings.

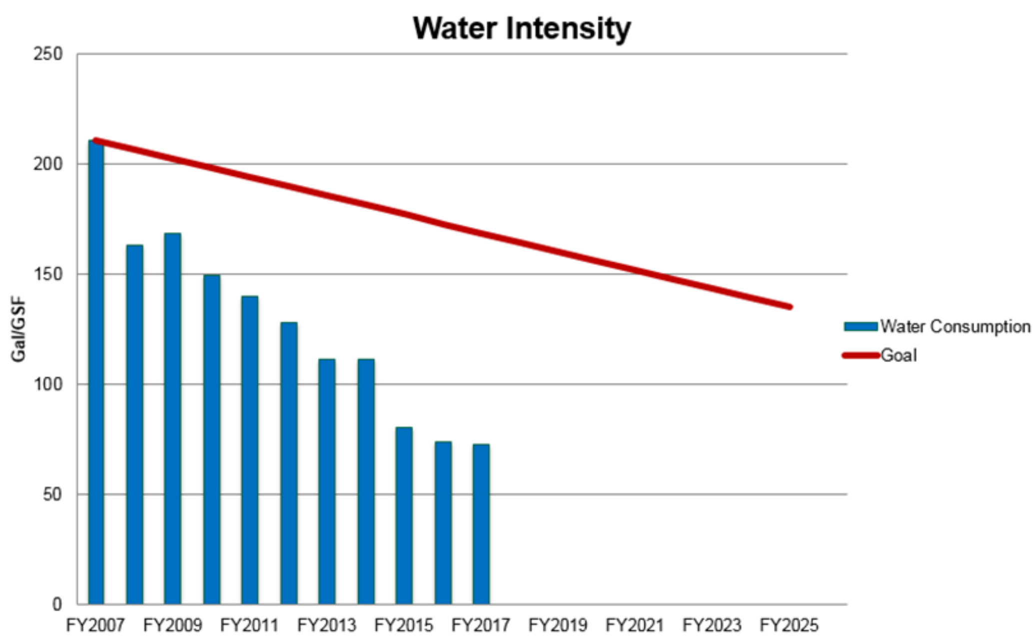


Figure 4.8. Y-12 National Security Complex water intensity goals
(gal = gallons, gsf = gross square foot)

Most potable water is not metered at the point of use at the Y-12 Complex, 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 Complex site. Through the various ESPC and utility efficiency improvement initiatives, the site is seeing significant improvement in most of these areas. As future projects are implemented, additional savings will be realized. In FY 2017, the Steam Decentralization ESPC, a project that replaced steam with point of use natural gas in 17 buildings, was completed. These buildings previously used steam for space heating and domestic water heating. The steam condensate is then dumped into the storm drain instead of being returned to the steam plant. By switching from steam to natural gas in these situations, it saves energy and water. This replacement of worn-out steam equipment reduces the risk of failure and eliminates deferred maintenance.

In FY 2018, the Y-12 Complex expects an increase in water use attributed to construction projects. The UPF, EOC, and Mercury Treatment facility are all expected to have increasing water needs in FY 2018.

Internal EISA audits are conducted on covered facilities on a 4-year rotating schedule. Additionally, in FY 2016, Pacific Northwest National Laboratory conducted a water assessment of the Y-12 Complex site through the Federal Energy Management Program. These assessments have identified a number of water conservation projects that could be implemented should funding be allocated. These projects include domestic plumbing retrofits, kitchen equipment upgrades, process system upgrades, cooling tower upgrades, and steam plant upgrades. Continued reductions in water usage will be incorporated into ongoing facility repairs and renovations as funding becomes available. These efforts will include the following:

- Upgrading toilets and urinals to low-flow, hands-free units.
- Installing flow restrictors on faucets and shower heads.
- Repairing condenser loop connections so all condenser water is returned to the cooling towers.
- Replacing existing once-through, water-cooled air conditioning system with air-cooled equivalents.
- Installing advanced potable water meters.
- Repairing systems to allow Bldg. 9212 condensate to be returned to the steam plant. The condensate return was repaired in October 2014, but several additional repairs are needed to the system. When the system is fully repaired, an estimated return of 16,848,000 gal of condensate per year back to the steam plant will be realized.

Many of the domestic upgrades are identified in the Balance of Plant Facilities Plan for implementation on a building-by-building basis as funding allows. Similarly, many of the cooling tower upgrades are prioritized in the Utilities Migration Plan and will be evaluated accordingly for implementation as funding permits. Specific goals include the following:

- There are several HVAC units in Bldg. 9201-3 that require once-through cooling water to cool the condenser. These units are old, and the controls do not work properly. These were submitted as a project to the Asset Management Program. Goal one is to replace these units.
- There are several very old, underground laterals that go from the water main to the building that need to be replaced. Because these are very old, they are suspected to leak water. Replacement of these laterals is a goal.
- There are several vacuum pumps in the Y-12 Complex that require once-through cooling water. It is a goal to replace these with air-cooled pumps or to cool them with a circulating tower water; therefore, omitting wasting the cooling water required for this equipment and increasing efficiency.

4.2.6.6 Fleet Management

The Y-12 Complex fleet is comprised of agency- and Government Services Administration (GSA)-owned sedans, light-duty trucks/vans, medium-duty trucks/vans, and heavy-duty trucks. During the last quarter of FY 2015, 240 sedans and light- and medium-duty vehicles from the Y-12 Complex agency-owned fleet were transferred to GSA. Throughout FY 2016, GSA replaced 240 of those vehicles, with 177 of the replacements being alternative fuel (E85) vehicles. The Y-12 Complex additionally acquired 31 Flex Fuel vehicles during FY 2017 and completed an assessment of the heavy-duty vehicle inventory. As a result of the assessment, multiple heavy-duty vehicle reassignments were made to better utilize the heavy-duty fleet. This revitalization of the existing fleet has decreased the average age of the Y-12 Complex's vehicles from 15 years to 2 years of age for light- and medium-duty vehicles. By replacing the older, less fuel efficient vehicles with newer, alternative fuel vehicles, the Y-12 Complex will reduce its consumption of petroleum fuels and its GHG emissions and increase its potential capacity for the use of alternative fuels. The Y-12 Complex continues to operate a taxi service as one of the strategies for fleet optimization.

The Y-12 Complex currently does not utilize alternative fuel and continues to operate under an exception from DOE. The only available on-site fuel station was placed out of service in 2015 after the rupture of an on-site fuel tank. In FY 2017, the Y-12 Complex continued to implement an interim refueling process using mobile tanker trucks to perform all vehicle and equipment refueling operations until a new fueling capability can be established. The mobile tanker trucks have only enough capacity to provide diesel and gasoline.

The Y-12 Complex anticipates having E-85 fuel available by the end of FY 2018. The Y-12 Complex is actively pursuing the restoration of the dismantled fueling station on the west end of the plant and the transfer of the ownership of that facility from the Office of Science to NNSA. This fueling station will include E-85 fueling capabilities and is slated for operation during FY 2018.

The Y-12 Complex has ordered one new heavy-duty vehicle, which will replace two of the older units. Two other older, heavy-duty vehicles will be replaced during FY 2018 as well. The Y-12 Complex will be planning and ordering new replacement vehicles for approximately 26 of our older passenger-carrying vehicles, along with consolidating 22 of older government-owned vehicles into GSA-owned units, and then ordering new replacements for them as well. The vast majority of those 22 older vehicles that will be dispositioned are not Flex Fuel vehicles, but will be replaced with new vehicles, thus increasing the potential capacity for using alternative fuel once it becomes available.

4.2.6.7 Electronic Stewardship

The Y-12 Complex 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. More than 98% of desktop computers, laptops, monitors, and thin clients purchased or leased during FY 2017 were registered Electronic Product Environmental Assessment Tool (EPEAT) products. The Y-12 Complex's standard desktop configuration specifies the procurement of EPEAT-registered and Energy Star-qualified products.

4.2.6.8 Greenhouse Gases

Table 4.2 summarizes the Y-12 Complex GHG emissions for FY 2008 (the baseline year as required by EO 13693) and FY 2017. The Y-12 Complex has reduced Scopes 1 and 2 GHG emissions by 48% since the 2008 baseline year, primarily due to decreased Scope 1 emissions from steam generation and decreased Scope 2 emissions from energy efficiency projects. Scope 3 GHG emissions have decreased by 7.5% since the 2008 baseline year.

Table 4.2. Y-12 National Security Complex greenhouse gas emissions summary

Greenhouse Gas Inventory

Scope 1 & 2 Greenhouse Gas Emissions

Goal: Reduce direct GHG emissions by 50 percent by FY 2025 relative to FY 2008 baseline.
Interim target (FY 2017): -25.0%

Current Performance: -48%

	FY 2008	FY 2017	% Change
Facility Energy	313,648.8	185,359.8	-40.9%
Non-Fleet V&E Fuel	367.3	286.2	-22.1%
Fleet Fuel	1,063.1	1,183.2	11.3%
Fugitive Emission	22,542.4	7,289.6	-67.7%
On-site Landfills	0.0	0.00	N/A
On-site WWT	6.9	9.1	31.9%
Renewables	0.0	0.00	N/A
RECs	0.0	-16,206.4	N/A
Total (MtCO2e)	**337,628.4**	**175,919.6**	**-47.9%**

Scope 3 Greenhouse Gas Emissions

Goal: Reduce indirect GHG emissions by 25 percent by FY 2025 relative to FY 2008 baseline.
Interim target (FY 2017): -9.0%

Current Performance: -8%

	FY 2008	FY 2017	% Change
T&D Losses*	12,185.8	7,658.4	-37.2%
Air travel	1,919.7	1,906.7	-0.6%
Ground Travel	331.0	344.0	4.2%
Commute	17,446.8	19,564.5	12.1%
On-site MSW	0.0	0.00	N/A
On-site WWT	11.2	12.1	6.0%
Total (MtCO2e)	**31,894.5**	**29,488.6**	**-7.5%**

GHG emissions are classified as Scope 1, 2, or 3. Scope 1 includes GHG emissions occurring directly onsite, such as heating or air conditioning in DOE buildings or the combustion of fuel in vehicles owned or operated by DOE. Scope 2 includes indirect emissions that are produced by an outside source as part of the productions process, such as electricity consumed in DOE buildings. Scope 3 includes air and ground business travel, commuting, municipal solid waste, and electricity transmission and distribution losses.

CO2e = CO_2 (carbon dioxide) equivalent
DOE = U.S. Department of Energy
FY = Fiscal Year
GHG = greenhouse gas
N/A = not applicable
Non-Fleet V&E Fuel = non-fleet vehicle and equipment fuel
Off-Site MSW = Off-site municipal solid waste
Off-Site WWT = Off-site waste water treatment
REC = renewable energy credit
T&D = transmission and distribution

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

EISA Section 438 requires Federal agencies to reduce storm water runoff from development and redevelopment projects to protect water resources. The Y-12 Complex 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 FY 2017 include the following.

- UPF continued transferring portions of soil; there has not been a significant change (up or down) in green space during FY 2017 due to UPF site readiness activities. The new paved areas for UPF should be offset by the constructed sediment ponds with the Faircloth skimmers that mitigate the rate of the storm water leaving the area.
- UPF establishes vegetative cover (grass) at excess soil placement areas, such as the West Borrow Area and Wet Spoils Area, consistent with the Storm Water Control Plan.
- The Y-12 Complex evaluates and incorporates, as feasible, the principles of low-impact development in the design of new construction projects, such as the EOC project, which will replace the existing PSS facility. The use of low-impact development techniques, such as landscape rock gardens and permeable pavers to reduce storm water runoff, are being incorporated in the design of the project.

In all, about 3.5 acres have been added to the green bank to offset future projects within the Y-12 Complex.

4.2.7 Awards and Recognition

Since November 2000, the commitment to environmentally responsible operations at the Y-12 Complex has been recognized with more than 138 external environmental awards from local, state, and national agencies. The awards received in 2017 are summarized in the following sections.

4.2.7.1 Federal Energy and Water Management Award

The Y-12 Complex received a Federal Energy and Water Management Award for "Y-12 Lights up to Lock-In Savings."

4.2.7.2 Federal Green Challenge Award

The Y-12 Complex received a 2017 EPA Federal Green Challenge (FGC) Regional Award – Southeast (Region 4) for Electronics. The Y-12 Complex was selected from the 264 Federal agencies that took steps to improve efficiency, save resources, and reduce costs as part of the FGC. This is the first time that the Y-12 Complex has received an FGC award. The Y-12 Complex was recognized for sending 67.24 tons (134,470 lb) of electronics (i.e., central processing units, printers, scanners, fax machines, monitors, servers, etc.) to a Responsible Recycling© certified recycler during FY 2016.

4.3 Compliance Status

4.3.1 Environmental Permits

Table 4.3 lists environmental permits in force at the Y-12 Complex during 2017. More detailed information can be found in the following sections.

Table 4.3. Y-12 National Security Complex environmental permits, Calendar Year 2017

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
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/ ARAP Access/Haul Road	NRS10.083	06/10/10	06/09/15[c]	DOE	DOE	CNS
CWA	UPF Department of Army Sect. 404 CWA Permit	2010-00366	09/02/10	09/02/20	DOE	DOE	CNS
CWA	UPF General Storm Water Permit Y-12 Complex (41.7 ha/ 103 acres)	TNR 134022	10/27/11	09/30/21	DOE	CNS	CNS
CWA	No Discharge Portal 20 Pump and Haul Permit	SOP-170-14	07/08/17	07/01/22	DOE	DOE	CNS
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	05/31/14	05/30/18	DOE	DOE	CNS
RCRA	Hazardous Waste Transporter Permit	TN3890090001	12/14/17	01/31/19	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

Table 4.3. Y-12 National Security Complex environmental permits, Calendar Year 2017 (continued)

Regulatory driver	Title/description	Permit number	Issue date	Expiration date	Owner	Operator	Responsible contractor
RCRA	Hazardous Waste Container Storage and Treatment Units	TNHW-127	10/06/05	10/06/15 [a]	DOE	DOE/CNS	CNS co-operator
RCRA	RCRA Post-closure Permit for the Chestnut Ridge Hydrogeologic Regime	TNHW-128	09/29/06 Permit reapplication submitted to TDEC on 03/02/16	09/29/16 [b]	DOE	DOE/UCOR	UCOR
RCRA	RCRA Post-closure Permit for the Bear Creek Hydrogeologic Regime	TNHW-116	12/10/03 Permit reapplication submitted to TDEC on 01/31/13	12/10/13[b]	DOE	DOE/UCOR	UCOR
RCRA	RCRA Post-closure Permit for the Upper East Fork Poplar Creek Hydrogeologic Regime	TNHW-113	09/23/03 Permit reapplication submitted to TDEC on 01/31/13	09/23/13[b]	DOE	DOE/UCOR	UCOR
Solid waste	Industrial Landfill IV (Operating, Class II)	L-01-103- 0075	Permitted in 1988—most recent modification approved 01/13/94	N/A	DOE	DOE/UCOR	UCOR
Solid waste	Industrial Landfill V (Operating, Class II)	L-01-103- 0083	Initial permit 04/26/93	N/A	DOE	DOE/UCOR	UCOR
Solid waste	Construction and Demolition Landfill (Overfilled, Class IV subject to CERCLA ROD)	L-01-103- 0012	Initial permit 01/15/86	N/A	DOE	DOE/UCOR	UCOR
Solid waste	Construction and Demolition Landfill VI (Post-closure care and maintenance)	L-01-103- 0036	Permit terminated by TDEC 03/15/07	N/A	DOE	DOE/UCOR	UCOR
Solid waste	Construction and Demolition Landfill VII (Operating, Class IV)	L-01-103- 0045	Initial permit 12/13/93	N/A	DOE	DOE/UCOR	UCOR
Solid waste	Centralized Industrial Landfill II (Post-closure care and maintenance)	L-01-103- 0189	Most recent modification approved 05/08/92	N/A	DOE	DOE/UCOR	UCOR

Table 4.3. Y-12 National Security Complex environmental permits, Calendar Year 2017 (continued)

Regulatory driver	Title/description	Permit number	Issue date	Expiration date	Owner	Operator	Responsible contractor
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] Continue to operate in compliance pending TDEC action. A public notice to deny the renewal of the three post-closure permits and provide post-closure care under CERCLA was published on 12/27/17.
[c] Monitoring and maintenance phase.

ARAP = Aquatic Resource Alteration Permit
CAA = Clean Air Act
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
CNS = Consolidated Nuclear Security, LLC
CWA = Clean Water Act
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
UCOR = URS | CH2M Oak Ridge, LLC
UPF = Uranium Processing Facility
Y-12 Complex = Y-12 National Security Complex

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). CNS fully supports NNSA's commitment to NEPA through evaluating the potential impacts of proposed Federal actions that affect the quality of the environment at the Y-12 Complex. CNS 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 is performed before an irreversible commitment of resources is made.

The *Final Site-Wide Environmental Impact Statement for the Y-12 National Security Complex* (DOE 2011b) was issued in March 2011. The Site-Wide Environmental Impact Statement (SWEIS) and the Notice of Availability were published on March 4, 2011, and are available **here**. NNSA issued a Record of Decision (ROD) in July 2011 for the continued operation of the Y-12 Complex, based on the SWEIS. 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 Complex 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) Final SWEIS (DOE 2016a; EIS-0387-SA-01), and NNSA amended the ROD (DOE 2016b) on July 22, 2017 as shown **here**.

In accordance with 10 CFR 1021.330, DOE/NNSA shall evaluate site-wide environmental impact statements (EISs) by means of an SA at least every 5 years. The SA determines if there are substantial changes to the SWEIS, if there are significant new circumstances at the site, or if there is information that is relevant to environmental concerns as discussed in 40 CFR 1502.9(c)(1). The SA determines whether: (1) the SWEIS is sufficient, (2) a supplement EIS is required, or (3) if a new SWEIS document is required. The SA discussed above (EIS-0387-SA-01) addressed UPF's change in strategy and did not address or evaluate the remainder of operations and activities at the Y-12 Complex since the 2011 document. Starting in 2016, CNS began the development of a second SA (EIS-0387-SA-02) for the continued operations of the Y-12 Complex. This document is currently in draft.

During 2017, CNS completed environmental evaluations for 48 proposed actions at the Y-12 Complex, and 45 such actions were categorically excluded, as allowed by Y/TS-2312, *National Environmental Policy Act General Categorical Exclusion, Appendix B to Subpart D of Part 1021* (March 2012). The majority of the proposed actions involved the sustainment of enduring facilities and bridging strategies for facilities identified with an out-year replacement. 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. The following projects were evaluated for the Extended Life Program (for existing enriched uranium facilities): the Nuclear Facility Electrical Maintenance Project (electrical improvements to Bldgs. 9215 and 9204-2E), the Fire Suppression Upgrade Project (wet pipe sprinkler head replacements), milling and lathe machine replacement, removal of five legacy machine tooling equipment, and a new chip melt furnace. The following projects were evaluated for enduring facilities: (1) the bridging and sustainment of lithium production capabilities (equipment and facilities)—replacement and refurbishment of the humidity control system, the Material Conversion Equipment Project, and Lithium Purification – parts cleaning station, upgrades to Bldg. 9204-2, and the Lithium Salvage Reclamation Project; (2) the replacement of elevator hydraulic jacks for two buildings; (3) multiple machining tool and controller equipment upgrades; and (4) upgrades to sensor systems of the Perimeter Intrusion Detection Alarm System. Other projects include the closure of two sulfuric acid tanks, the isolation of utilities to the three

Biology Complex buildings (preparation for demolition), and the replacement of the Bldg. 9202 mop water tank. The Roof Asset Management Project and planning and design of the Y-12 Complex EOC and the Y-12 Complex Fire Station continued this year.

During 2017, the following categorically excluded determination forms were approved by the NPO and posted on the public website:

- NEPA #4782 and #4783 revision 1, Demolition of Bldgs. 9111, 9112 and 9616-10; and
- NEPA #4822, Demolition of Bldg. 9201-05 Annex.

An environmental assessment determination for the Lithium Production Capability (LPC; NEPA #4810) was sent to NNSA for review and approval. A new LPC facility will provide administrative and manufacturing space for the production of lithium components. The new facility will ensure the Y-12 Complex maintains the required lithium production capabilities, reduces the annual operating cost, and increases processing efficiencies—using safer, more-modern, -agile, and -responsive processes. The construction footprint is located within the Biology Complex, located on the east end of the Y-12 Complex. This facility is anticipated to be a non-nuclear, hazardous material facility.

The LPC project will encompass site preparations; building design and construction; and design, installation, and testing of lithium capability processes and systems. The new LPC building will be approximately 75,000 ft^2 in size with 10,000 ft^2 of outside storage. DOE OREM has committed to the demolition of several of the Biology Complex buildings, removing slabs and/or footings, and the remediation 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. NNSA will conduct a geotechnical investigation in addition to DOE OREM's characterization of possible soil contamination. The *Geotechnical Report* will describe the soil, rock, and groundwater conditions and make appropriate recommendations so that a satisfactory and economical foundation may be designed. Re-routing of utilities will be required, including re-routing or abandoning storm, sanitary sewer, and water lines and re-routing the steam lines as required.

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 2017 included completing Sect. 106 reviews of ongoing and new projects, collecting and storing historic artifacts, conducting tours, maintaining the Y-12 Complex History Center, and participating in various outreach projects with local organizations and schools.

Forty-eight 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 none of the 48 projects would have an adverse effect on historic properties eligible for listing in the National Register and that no further Sect. 106 documentation was required. The Y-12 Complex Oral History Program continues efforts to identify leads to conduct oral interviews and to document the knowledge and experience of those who worked at the Y-12 Complex during World War II and the Cold War era. The interviews also provide information on day-to-day operations of the Y-12 Complex, 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 DVDs shown in the Y-12 Complex History Center.

The Y-12 Complex History Center, located in The New Hope Center, continues to be a work in progress. The Y-12 Complex 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 Complex 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 documentary DVDs, books, pamphlets, postcards, and fact sheets, is available free to the public.

The Y-12 Complex partnered with the National Park Service during the annual Earth Day events on April 18, 2017. These events were held in the Y-12 Complex'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.

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. This document will establish a baseline for park planning and interpretive activities and provide 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 2017 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 2017, the Secret City Festival promoted the history of the Manhattan Project by providing information to visitors regarding the history of the Y-12 Complex and directions for them to visit the Y-12 Complex History Center. The Y-12 Complex provided visitors with windshield tours of the perimeter of the Y-12 Complex and a more in-depth tour inside Bldg. 9731, also known as the "Pilot Plant."

The Y-12 Complex also continues to partner with the American Museum of Science and Energy by providing guided public tours of the Y-12 Complex History Center from March through November. Other outreach activities to local and visiting schools, agencies, and organizations included tours and presentations on the rich and significant history of the Y- 12 Complex 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 the Y-12 Complex. New projects are governed by construction permits and modifications to the Title V operating air permit, and eventually the requirements are incorporated into the site-wide Title V operating permit. The Y-12 Complex is currently governed by Title V Major Source Operating Permit 571832.

The permit requires annual and semiannual reports. More than 2,000 data points are obtained and reported each year. All reporting requirements were met during Calendar Year (CY) 2017, and there were no permit violations or exceedances during the report period.

The TDEC–Knoxville Office, Clean Air Compliance, completed two Clean Air Compliance inspections for CY 2017. Compliance inspections on April 25 and 27, 2017, and November 16 and 30, 2017, resulted in no findings or deficiencies.

Ambient air monitoring, while not specifically required by any permit condition, is conducted at the Y-12 Complex to satisfy DOE O 458.1, *Radiation Protection of the Public and the Environment*

(DOE 2011d) requirements, as a best management practice and/or to provide evidence of sufficient programmatic control of certain emissions. Ambient air monitoring conducted specifically for the Y-12 Complex (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 2017 activities conducted at the Y-12 Complex in support of the Clean Air Act (CAA).

4.3.4 Clean Water Act Compliance Status

During 2017, the Y-12 Complex 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. The percentage of compliance with permit discharge limits for 2017 was 100%.

Approximately 2,300 data points were obtained from sampling required by the NPDES permit; no non-compliances were reported. The Y-12 Complex NPDES permit in effect during 2015 (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.

4.3.5 Safe Drinking Water Act Compliance Status

The City of Oak Ridge supplies potable water to the Y-12 Complex and meets all Federal, State, and local standards for drinking water. The water treatment plant, located north of the Y-12 Complex, is operated by the City of Oak Ridge. The Y-12 Complex 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, Chap. 0400-45-01, sets limits for biological contaminants, chemical activities, and chemical contaminants. Sampling for total coliform, chlorine residuals, lead, copper, and disinfectant byproducts are conducted by the Y-12 Complex ECD, with oversite by a State-certified operator.

In 2016, the Y-12 Complex potable water system received a sanitary survey score of 98 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 2018. All total coliform samples collected during 2017 were analyzed by the State of Tennessee laboratory, and all results were negative. Analytical results for disinfectant byproducts (total trihalomethanes and haloacetic acids) for the Y-12 Complex water distribution system were within allowable TDEC and Safe Drinking Water Act (SDWA) limits for the yearly average. The Y-12 Complex 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 SDWA 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. The Y-12 Complex 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. The Y-12 Complex 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. The Y-12 Complex has developed new disposition milestones to address its remaining inventory of legacy mixed waste. Disposition milestones for the final inventory are FYs from 2013 through 2018 (see Figure 4.9). In 2017, Y-12 Complex staff completed disposition of 36% of the inventory of legacy mixed waste listed on the ORR Site Treatment Plan.

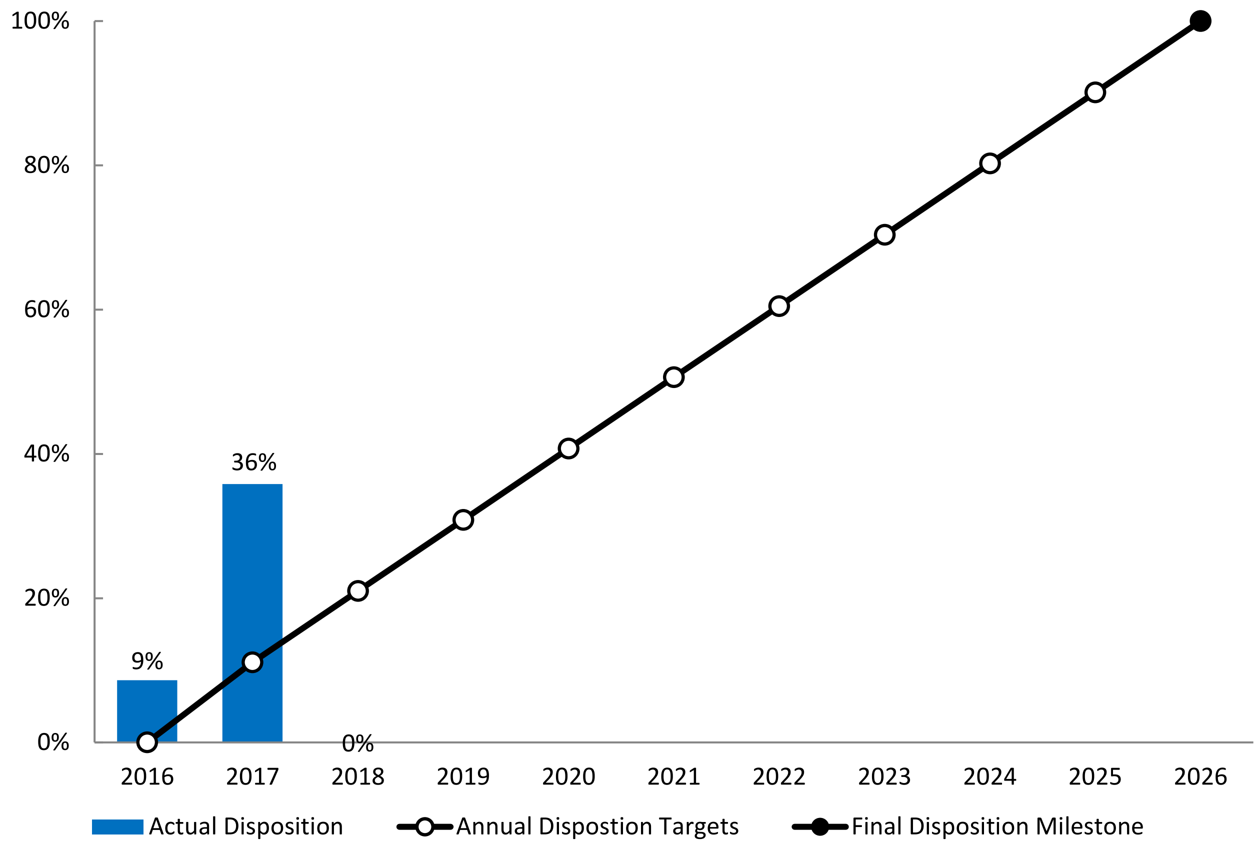


Figure 4.9. Y-12 National Security Complex path to elimination of its inventory of legacy mixed waste as part of the Oak Ridge Reservation Site Treatment Plan

The quantity of hazardous and mixed wastes generated by the Y-12 Complex increased in 2017 (Figure 4.10). The increase was primarily due to an increase in contaminated leachate from legacy operations, which made up 95% of the total hazardous and mixed waste generated in 2017. The Y-12 Complex currently reports waste on 74 active waste streams. The Y-12 Complex is a State-permitted treatment, storage, and disposal facility. Under its permits, the Y-12 Complex received 871 kg of hazardous and mixed waste from the off-site Union Valley analytical chemistry laboratory and the Central Training Facility in 2017.

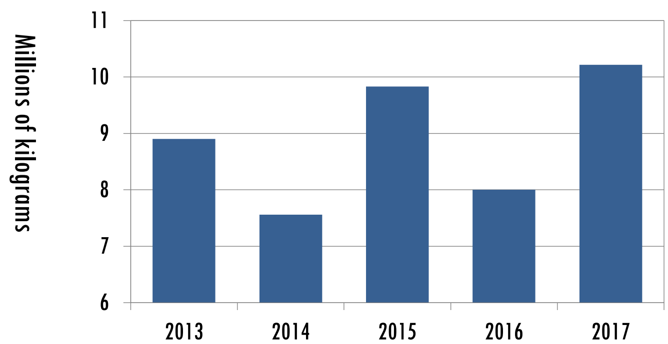


Figure 4.10. Hazardous waste generation, 2013–2017

In addition, 249,086 kg of hazardous and mixed waste was shipped to DOE-owned and commercial treatment, storage, and disposal facilities. More than 9M kg of hazardous and mixed wastewater was treated at on-site wastewater treatment facilities.

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 the Y-12 Complex.

4.3.6.2 Resource Conservation and Recovery Act Subtitle D Solid Waste

The ORR landfills operated by the DOE environmental management program are located within the boundary of the Y-12 Complex. The facilities include two Class II operating industrial solid waste disposal landfills and one operating Class IV construction demolition landfill. The facilities are permitted by TDEC and accept solid waste from DOE operations on the 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 (RI). A CERCLA ROD for Spoil Area 1 was signed in 1997. One Class II facility (Landfill II) has been closed and is subject to post-closure care and maintenance. Associated TDEC permit numbers are noted in Table 4.3. Additional information about the operation of these landfills is addressed in Section 4.8.4, "Waste Management."

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

The ORR Federal Facility Agreement (FFA) (DOE 2017a) 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 2017 as an update of the previous CY 2016 activities.

Three RCRA post-closure permits, one for each of the three hydrogeologic regimes at the Y-12 Complex, have been issued to address the eight major closed waste disposal areas at the Y-12 Complex. Because it falls under the jurisdiction of two post-closure permits, the S-3 Pond site is described as having two parts, eastern and former S-3 (Table 4.4). RCRA groundwater monitoring data were reported to TDEC and EPA in the Annual Groundwater Monitoring Report for the Y-12 Complex (UCOR 2017a).

Table 4.4. Y-12 National Security Complex Resource Conservation and Recovery Act post-closure status for former treatment, storage, and disposal units on the Oak Ridge Reservation

Unit	Major components of closure	Major post-closure requirements
Upper EFPC Hydrogeologic Regime (RCRA Post-closure Permit TNHW-113)		
New Hope Pond	Engineered cap, upper EFPC distribution channel	Cap inspection and maintenance. No current groundwater monitoring requirements in lieu of ongoing CERCLA actions in the eastern portion of the Y-12 Complex
Eastern S-3 Ponds groundwater plume	None for groundwater plume; see former S-3 Ponds (S-3 Site) for source area closure	Post-closure corrective action monitoring. Inspection and maintenance of monitoring network
Chestnut Ridge Hydrogeologic Regime (RCRA Post-closure Permit TNHW-128)		
Chestnut Ridge security pits	Engineered cap	Cap inspection and maintenance. Post-closure corrective action monitoring. Inspection and maintenance of monitoring network and survey benchmarks
Kerr Hollow Quarry	Waste removal, access controls	Access controls inspection and maintenance. Post-closure detection monitoring. Inspection and maintenance of monitoring network and survey benchmarks
Chestnut Ridge sediment disposal basin	Engineered cap	Cap inspection and maintenance. Post-closure detection monitoring. Inspection and maintenance of monitoring network and survey benchmarks
East Chestnut Ridge Waste Pile	Engineered cap	Cap inspection and maintenance. Post-closure detection monitoring. Inspection and maintenance of monitoring network, leachate collection sump, and survey benchmarks. Management of leachate

Table 4.4. Y-12 National Security Complex Resource Conservation and Recovery Act post-closure status for former treatment, storage, and disposal units on the Oak Ridge Reservation (continued)

Unit	Major components of closure	Major post-closure requirements
Chestnut Ridge Hydrogeologic Regime (RCRA Post-closure Permit TNHW-128)		
Former S-3 Ponds (S-3 pond site)	Neutralization and stabilization of wastes, engineered cap, asphalt cover	Cap inspection and maintenance. Post-closure corrective action monitoring. Inspection and maintenance of monitoring network and survey benchmarks
Oil landfarm	Engineered cap	Cap inspection and maintenance. Post-closure corrective action monitoring. Inspection and maintenance of monitoring network and survey benchmarks
Bear Creek Burial Grounds: A-North, A-South, and C-West and the walk-in pits	Engineered cap, seep collection system specific to the burial grounds	Cap inspection and maintenance. Post-closure corrective action monitoring. Inspection and maintenance of monitoring network and survey benchmarks

CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
EFPC = East Fork Poplar Creek
RCRA = Resource Conservation and Recovery Act
Y-12 Complex = Y-12 National Security Complex

Permit renewal applications had been previously submitted to TDEC, Division of Solid Waste Management for the three RCRA post-closure permits. On December 27, 2017, TDEC issued a Public Notice of their intent to deny the renewal of the three permits. The proposed denial was initiated by DOE’s request to withdraw the permit renewal applications in coordination in advance with TDEC. Pursuant to the ORR FFA, this denial allows DOE to provide post-closure care for the permitted hazardous waste management units under the existing CERCLA remedial program. The public comment period for this notice ends on February 12, 2018.

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 7, 2017.

Given the widespread historical uses of PCBs at the Y-12 Complex 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 Complex 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. The Y-12 Complex submitted reports in 2017 in accordance with requirements under EPCRA Sections 302, 303, 311, 312, and 313.

The Y-12 Complex had no unplanned release of a hazardous substance that required notification of the regulatory agencies (see **Sect. 4.3.11** for more information). Section 311 notifications were sent to TEMA and local emergency responders in 2017 because chemicals newly exceeded the reporting thresholds or new information was identified about previously reported chemicals. Those chemicals included bromo-chloro 5,5-dimethyl hydantoin (Chemical Abstract Service [CAS] No. 32718-18-6) and sodium bisulfite (CAS No. 7631-90-5) used in water treatment; Stoddard solvent (CAS No. 8052-41-3) from roofing projects; and Pine Bluff Natural Sand from construction activities. 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. The Y-12 Complex reported 48 chemicals that were over Section 312 inventory thresholds in 2017.

Y-12 Complex 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 (i.e., TRI-ME) web-based reporting system operated by EPA. Total 2017 reportable toxic releases to air, water, and land and waste transferred offsite for treatment, disposal, and recycling were 27666 kg (60,994 lb). Table 4.5 lists the reported chemicals for the Y-12 Complex for 2016 and 2017 and summarizes releases and off-site waste transfers for those chemicals.

Table 4.5. Emergency Planning and Community Right-to-Know Act Section 313 toxic chemical release and off-site transfer summary for the Y-12 National Security Complex, 2016 and 2017

Chemical	Year	Quantity[a] (lb)[b]
Chromium	2016	7,006
	2017	5,853
Copper	2016	2,747
	2017	2,809
Diisocyanate compounds	[c]	568
	2017	---
Lead compounds	2016	10,013
	2017	9,948
Manganese	2016	6,038
	2017	---
Mercury	2016	25
	2017	5,263
Methanol	2016	37,554
Methanol	2017	29,207

Table 4.5. Emergency Planning and Community Right-to-Know Act Section 313 toxic chemical release and off-site transfer summary for the Y-12 National Security Complex, 2016 and 2017 (continued)

Chemical	Year	Quantity[a] (lb)[b]
Nickel	2016	8,728
	2017	7,914
Silver	2016	Form A[d]
	2017	---
Total	2016	72,679
	2017	60,994

[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.
[d]Form A - less than 500 lb released.

4.3.10 Spill Prevention, Control, and Countermeasures

The Clean Water Act, Sect. 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.

The Y-12 Complex SPCC Plan (CNS 2015b) was revised in September 2015 to update general Y-12 Complex changing site infrastructure. This plan presents the SPCC to be implemented by the Y-12 Complex 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 PSS. Spill response materials and equipment are stored near tanks and drum storage areas and other strategic areas of the Y-12 Complex to facilitate spill response. All Y-12 Complex personnel and subcontractors are required to have initial spill and emergency response training before they can work on the site.

SPCC-related improvements have been made at the Y-12 Complex by reducing the amount of oil stored onsite, particularly electrical transformer oil. The revised Y-12 Complex SPCC Plan (CNS 2015b) was completed in September 2015, meeting the regulatory requirement to review and update the SPCC Plan every 5 years.

4.3.11 Unplanned Releases

The Y-12 Complex has procedures for notifying off-site authorities for categorized events at the Y-12 Complex. 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 East Fork Poplar Creek (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, the Y-12 Complex occurrence reporting program provides timely notification to the DOE community of Y-12 Complex 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 Complex 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 2017. During 2017, there were no unplanned radiological air emission releases for the Y-12 Complex.

4.3.12 Audits and Oversight

A number of Federal, State, and local agencies oversee Y-12 Complex activities. In 2017, the Y-12 Complex was inspected by Federal, State, or local regulators on seven occasions. Table 4.6 summarizes the results, and additional details follow.

Table 4.6. Summary of external regulatory audits and reviews, 2017

Date	Reviewer	Subject	Issues
February 21	COR	Semiannual Industrial Pretreatment Compliance Inspection	0
April 25, 27	TDEC	Annual CAA Inspection	0
June 20-21	TDEC	Underground Injection Control Program Compliance Inspection	0
July 19-24	TDEC	Annual RCRA Hazardous Waste Compliance Inspection	2
September 26-27	TDEC	NPDES Compliance Evaluation Inspection	0
November 16, 30	TDEC	Annual CAA Inspection	0
October 3	COR	Semiannual Industrial Pretreatment Compliance Inspection	0

CAA = Clean Air Act
COR = City of Oak Ridge
NPDES = national pollutant discharge elimination system
RCRA = Resource Conservation and Recovery Act
TDEC = Tennessee Department of Environment and Conservation

As part of the City of Oak Ridge’s pretreatment program, City personnel collect samples from the Y-12 Complex 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 2017.

The TDEC Underground Injection Control Coordinator visited the Y-12 Complex and the Central Training Facility in June 2017 to review Class V injection wells. The inspection covered 156 steam condensate discharge French drains and a large-capacity septic system that meets the definition of an injection well. There were no findings identified.

Personnel from the TDEC–Knoxville Office conducted two CAA compliance inspections in 2017. The inspections covered 25 emissions sources and records reviews. No issues were identified.

Personnel from the TDEC–Knoxville Office conducted an NPDES compliance evaluation inspection on September 26 and 27, 2017. The inspection included 4 wastewater treatment facilities, 6 outdoor storage areas, and 15 outfalls. No violations were identified.

Personnel from the TDEC–Knoxville Office conducted a RCRA hazardous waste compliance inspection July 19–24, 2017. The inspections covered 45 waste storage areas and records reviews. The report identified two findings involving a container of used batteries (universal waste) and two containers of hazardous waste. The containers were not dated and labeled as required. These issues were immediately corrected.

4.3.13 Radiological Release of Property

Clearance of property from the Y-12 Complex is conducted in accordance with approved procedures that comply with DOE O 458.1, *Radiation Protection of the Public and the Environment* (DOE 2011d). Property consists of real property (i.e., land and structures), personal property, and material and equipment (M&E). At the Y-12 Complex, 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) to ensure that no radioactivity has been added.
- Evaluation using process knowledge (surface and volumetric).

These three release paths are discussed in the following sections. Table 4.7 summarizes some examples of the quantities of property released in 2017. During FY 2017, the Y-12 Complex recycled more than 2.65M 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 4.7. Summary of materials released in 2017

Category	Amount released
Real property (land and structures)	None
Computer equipment recycle –Computers, monitors, printers, and mainframes	69,078 lb
Recycling examples	
–Used oils	4,855 gal
–Used tires	11,840 lb
–Scrap metal	1,196,265 lb
–Lead acid batteries	31,622 lb
Public/negotiated sales[a]	
–Copper and brass	17,165 lb
–Miscellaneous furniture	230,810 lb
–Vehicles and miscellaneous equipment	209,154 lb
External transfers[b]	50,786 lb

[a] Sales during Fiscal Year 2017.

[b] Vehicles; miscellaneous equipment; and materials transferred to various Federal, State, and local agencies for reuse during Fiscal Year 2017.

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* (MARSSIM) (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 the Y-12 Complex to determine whether M&E are suitable for release to the public are provided in Table 4.8.

Table 4.8. U.S. Department of Energy 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.

N/A = not applicable.

The Y-12 Complex uses an administrative limit for total activity of 2,400 dpm/100 cm^2 for radionuclides in groups 3 and 4 (see Table 4.8). The use of the more-restrictive administrative limits ensures that M&E

[1] The *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM) provides guidance on how to demonstrate that a site is in compliance 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* annual is a supplement to MARSSIM that provides technical information on approaches for determining proper disposition of materials and equipment.
Source: Vázquez 2011

do not enter into commerce exceeding the definition of contamination 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. No authorized volumetric contamination limits have been approved for material released from the Y-12 Complex. Materials that are subject to volumetric contamination are evaluated for release by 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 this is documented and used to justify release; then the basis for release is documented. 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 Complex activities. If the results meet defined criteria, then they are documented and the material is released.

4.3.13.3 Process Knowledge

Process knowledge is used to release property from the Y-12 Complex without monitoring or analytical data and to implement a graded approach (less than 100% monitoring) for monitoring of some M&E (MARSAME Classes II and III) (NRC 2009). A conservative approach (nearly 100% 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 Complex 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 Complex locations.
- New computer equipment distributed from Bldg. 9103.
- Subcontractor/vendor/privately owned vehicles, tools, and equipment that have not been used in contaminated areas or for excavation activities.

4.4 Air Quality Program

Sections of the Y-12 Complex'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 the Y-12 Complex. 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 State of Tennessee.

4.4.1 Construction and Operating Permits

In 2017, the Y-12 Complex received an extension to the construction air permit for UPF, amended by TDEC on February 14, 2017. The UPF permit application was included in the Y-12 Complex's Title V (Major Source) Operating Air Permit Renewal Application in CY 2016. TDEC issued the Y-12 Complex their Title V (Major Source) renewal air permit on December 1, 2017, which included the UPF emission sources. The new Title V air permit expires on November 30, 2022. The Clean Air Program met with the owners and/or operators of their respective emission sources and discussed and explained each source's conditions and its compliance method. An operational flexibility request to replace five old, existing swaging machines and associated components with one new, similar machine located in the Foundry Operations in Bldg. 9998 was submitted on May 4, 2017, to TDEC, Division of Air Pollution Control for their review and approval. TDEC approved the request on June 1, 2017.

Permit administration fees are paid to TDEC annually in support of the Title V program.

CNS has chosen to pay the fees based on a combination of actual emissions (steam plant, methanol, solvent 140/142, volatile organic compounds [VOCs]) and allowable emissions (balance of plant). In 2017, emissions categorized as actual emissions totaled 37,032 kg, and emissions calculated by the allowable method totaled 590,342 kg. The total emissions fee paid was $22,994.84.

Demonstrating compliance with the conditions of air permits is a significant effort at the Y-12 Complex. 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 the Y-12 Complex. 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 the Y-12 Complex.

The Y-12 Complex site-wide permit requires annual and semiannual reports. One report is the overall Annual ORR Rad-NESHAPs Report, which includes specific information regarding Y-12 Complex 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. Table 4.9 gives the actual emissions versus allowable emissions for the Y-12 Complex steam plant.

Table 4.9. Actual versus allowable air emissions from the Y-12 National Security Complex steam plant, 2017

Pollutant	Emissions (tons/year)[a]		Percentage of allowable
	Actual	Allowable	
Particulate	3.32	41	8.1
Sulfur dioxide	0.26	39	0.7
Nitrogen oxides[b]	13.97	81	17.2
VOCs[b]	2.40	9.4	25.5
Carbon monoxide[b]	36.67	139	26.4

NOTE: The emissions are based on fuel usage data for January through December 2017. The volatile organic compound (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 and 1998).

4.4.1.1 Generally Applicable Permit Requirements

The Y-12 Complex, like many industrial sites, has a number of generally applicable requirements that require management and control. Asbestos, ozone-depleting substances (ODSs), and fugitive particulate emissions are notable examples.

Control of Asbestos

The Y-12 Complex has numerous buildings and equipment that contain asbestos-containing materials (ACMs). The compliance program for management of removal and disposal of ACMs includes demolition and renovation notifications to TDEC and inspections, monitoring, and prescribed work practices for abatement and disposal of asbestos materials. There was no reportable release of asbestos in 2017. There were three notifications of asbestos demolition or renovation, one revision of notification of asbestos demolition or renovation, and one annual estimate for CY 2017. There was one notification sent to TDEC in March 2017 by URS|CH2M Oak Ridge LLC (UCOR). The 2018 annual estimates of friable asbestos were also submitted to TDEC in November 2017 for their records.

An internal surveillance of the asbestos National Emission Standards for Hazardous Air Pollutant (NESHAP) reporting process was conducted on December 6, 2017. The scope of the surveillance was focused on compliance with applicable State and Federal environmental regulations, specifically reporting and record-keeping requirements for on-site demolition and renovation activities for buildings. There were no findings or deficiencies identified as a result of this surveillance.

Stratospheric Ozone Protection

The *Y-12 Complex Ozone Depleting Substances (ODS) Phase-Out and Management Plan* (B&W Y-12 2014) provides a complete discussion of requirements and compliance activities at the Y-12 Complex. Past ODS-reduction initiatives that began in the early 1980s focused on elimination of Class I ODS use in refrigerants and in cleaning operations involving solvents. In 2012, the last remaining chiller system at the Y-12 Complex with Class I ODSs was taken out of service. The refrigerant from that system was sent to the Defense Logistics Agency.

Y-12 Complex initiatives have also involved elimination of ODS solvents in cleaning processes. Operations personnel developed and implemented changes in one process that eliminated ODS solvents from that process. Evaluation of ODS reduction opportunities continue for another solvent-based cleaning operation. Future actions related to this process will be dependent on ongoing efforts to identify a safe and viable replacement chemical or to identify practical and cost-effective modifications to process equipment.

All Class I and Class II substitutions are made in accordance with EPA's Significant New Alternatives Program. Y-12 Complex personnel are notified as EPA issues regulations detailing Significant New Alternatives Program replacement chemicals that may be applicable to Y-12 Complex operations. To prevent ODSs from coming onsite, procurement documents are written to ensure that no additional equipment or processes using Class I ODSs are brought onsite, and Class II ODS use is limited wherever possible.

Site procedures are in place for disposition of excess refrigerant or refrigerant-containing equipment. Recovered refrigerant is recycled/reused in equipment at the Y-12 Complex whenever feasible.

Refrigerant is recovered from refrigerant-containing equipment before disposal of the equipment. Class I ODSs that cannot be used onsite are first made available to Defense Logistics Agency. Remaining refrigerants, including Class I and Class II ODSs, are sold to refrigerant reclamation facilities or properly disposed of.

Fugitive Particulate Emissions

As modernization and infrastructure reduction efforts increase at the Y-12 Complex, the need also increases for good work practices and controls to minimize fugitive dust emissions from construction and demolition activities. Y-12 Complex 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 be limited to: (1) use, where possible, of water or chemicals for control of dust in demolition of existing buildings or structures, construction operations, grading of roads, or the clearing of land; (2) application of asphalt, water, or suitable chemicals on dirt roads, material stockpiles, and other surfaces that can create airborne dusts; and (3) 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 the Y-12 Complex occurs almost exclusively as a result of plant production, maintenance, and waste management activities. The major radionuclide emissions contributing to the dose from the Y-12 Complex are ^{234}U, ^{235}U, ^{236}U, and ^{238}U, which are emitted as particulates (Figure 4.11). The particle size and solubility class of the emissions are determined based on review of the operations and processes served by the exhaust systems

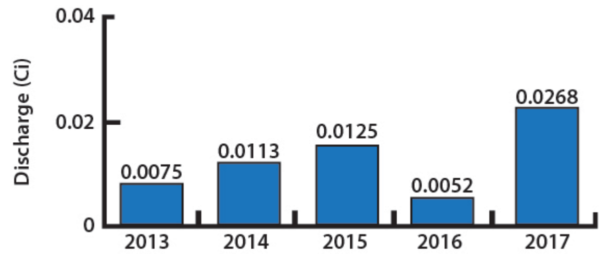


Figure 4.11. Total curies of uranium discharged from the Y-12 National Security Complex to the atmosphere, 2013 through 2017

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 61Appendix D calculations; and
- emissions from room ventilation exhausts (calculated using radiological control monitoring data from the work area).

Continuous sampling systems are used to monitor emissions from a number of process exhaust stacks at the Y-12 Complex. 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 2017, 32 process exhaust stacks were continuously monitored, 25 of which were major sources; the remaining 7 were minor sources. The sampling systems on the stacks have been approved by EPA Region 4.

During 2017, unmonitored uranium emissions at the Y-12 Complex occurred from 38 emission 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 Complex source term includes an estimate of these emissions.

The Y-12 Analytical Chemistry Organization (ACO) operates out of two main laboratories. One is located onsite in Bldg. 9995. The other is located in a leased facility on Union Valley Road, about 0.3 miles east of the Y-12 Complex, and is not within the ORR boundary. In 2017, 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% 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. Three emission points from room ventilation exhausts were identified in 2017 where emissions exceeded 10% of derived air concentration. These emission points feed to monitored stacks, and any radionuclide emissions are accounted for as noted for monitored emission points.

The Y-12 Complex Title V (Major Source) Operating Permits contain a site-wide, 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 0.0268 Ci (3.43 kg) of uranium was released into the atmosphere in 2017 as a result of Y-12 Complex process and operational activities.

A UPF, presently being designed, is intended to house some of the processes that are currently in existing production buildings. The UPF project was initially issued Construction Air Permit 967550P. In 2017, the UPF was included in Y-12 Complex's Title V Operating Permit 571832. The facility will be maintained on the permit as inactive until operations commence in about 2025.

The calculated radiation dose to the maximally exposed off-site individual from airborne radiological release points at the Y-12 Complex during 2017 was 0.24 millirem (mrem). This dose is well below the NESHAP standard of 10 mrem and is less than 0.08% 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.

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 the Y-12 Complex 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 the Y-12 Complex radionuclide emission measurements data from the continuous samplers, breakthrough monitors, 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 the Y-12 Complex 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 4.9.

Particulate emissions from point sources result from many operations throughout the Y-12 Complex. Compliance demonstration is achieved via several activities, including monitoring the operations of control devices, limiting process input materials, and using certified readers to conduct stack-visible emission evaluations.

Use of solvent 140/142 and methanol throughout the complex and use of acetonitrile at a single source are primary sources of VOC emissions. Material mass balances and engineering calculations are used to determine annual emissions. The calculated amounts of solvent 140/142 and methanol emitted for CY 2017 are 1,149.98 lb (0.575 tons) and 27,225 lb (13.61 tons), respectively. The highest calculated amount of acetonitrile and isopropyl alcohol (VOCs) emitted to the atmosphere for CY 2017 was 5.239 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).

The Y-12 Complex is subject only to the Subpart A general provisions and reporting from stationary fuel combustion sources covered in 40 CFR 98, Subpart C, *General Stationary Fuel Combustion*. Currently, the rule does not require control of GHGs; rather, it requires only that sources emitting above the 25,000-CO_2e threshold level monitor and report emissions.

The Y-12 Complex steam plant is subjected 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 per hour (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 Bldg. 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 Bldg. 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 Bldg. 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 the Y-12 Complex. The amount of natural gas supplied to the site, along with the fuel use logs, provides the basic information 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 the Y-12 Complex is shown in Table 4.10. The decrease in emissions from 2010 to 2017 is associated with the fact that coal is no longer burned since the natural-gas-fired steam plant came on line.

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 2016 and were found to be operating properly.

Table 4.10. Greenhouse gas emissions from Y-12 National Security Complex stationary fuel combustion sources

Year	GHG emissions (metric tons CO_2e)
2010	97,610
2011	70,187
2012	63,177
2013	61,650
2014	58,509
2015	51,706.9
2016	50,671.6
2017	50,292.7

CO_2e = CO_2 equivalent GHG = greenhouse gas

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 the Y-12 Complex, 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.

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 Complex replacement steam plant. The new natural-gas-fired steam plant came on line 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 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 Complex steam plant, performed by a qualified energy assessor, was completed in July 2013. The tune-ups for boilers were completed on December 21, 2016, and again on January 8 and 9, 2018.

Unplanned releases of HAPs are regulated through the Risk Management Planning regulations. Y-12 Complex personnel have determined no processes or facilities contain inventories of chemicals in quantities exceeding thresholds specified in rules pursuant to CAA, Title III, Sect.112(r), *Prevention of Accidental Releases*. Therefore, the Y-12 Complex 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: (1) new source performance standards (Title 40 CFR Part 60, Subpart IIII), and (2) NESHAPs (EPA 2013; Title 40 CFR Part 63, Subpart DDDDD). The compression ignition engines/generators located at the Y-12 Complex 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 the Y-12 Complex 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, the Y-12 Complex prepared a significant permit modification to the Y-12 Complex Title V (Major Source) Operating Air Permit to add numerous stationary, emergency-use engines/generators located throughout the Y-12 Complex. 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 the Y-12 Complex Title V (Major Source) Operating Air Permit dated March 9, 2011, Y-12 Complex 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 the Y-12 Complex. TDEC issued the Y-12 Complex 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: (1) emergency operation, (2) maintenance checks and readiness testing, and (3) non-emergency operation. Each engine/generator must use only diesel fuel with low sulfur content (15 parts per million) and a cetane index of 40.

4.4.2 Ambient Air

To understand the complete picture of ambient air monitoring in and around the Y-12 Complex, data from on- and off-site monitoring conducted specifically for the Y-12 Complex, reservation-wide surveillance 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 Complex 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 NESHAP regulations.

4.4.2.1 Mercury

The Y-12 Complex 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 the Y-12 Complex. The two atmospheric mercury monitoring stations currently operating at the Y-12 Complex, ambient air (monitoring) station (AAS)2 and AAS8, are located near the east and west boundaries of the Y-12 Complex, respectively (Figure 4.12). Since their establishment in 1986, AAS2 and AAS8 have monitored mercury in ambient air continuously, with the exception of short intervals of downtime because of electrical or equipment outages. In addition to the monitoring stations located at the Y-12 Complex, 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.

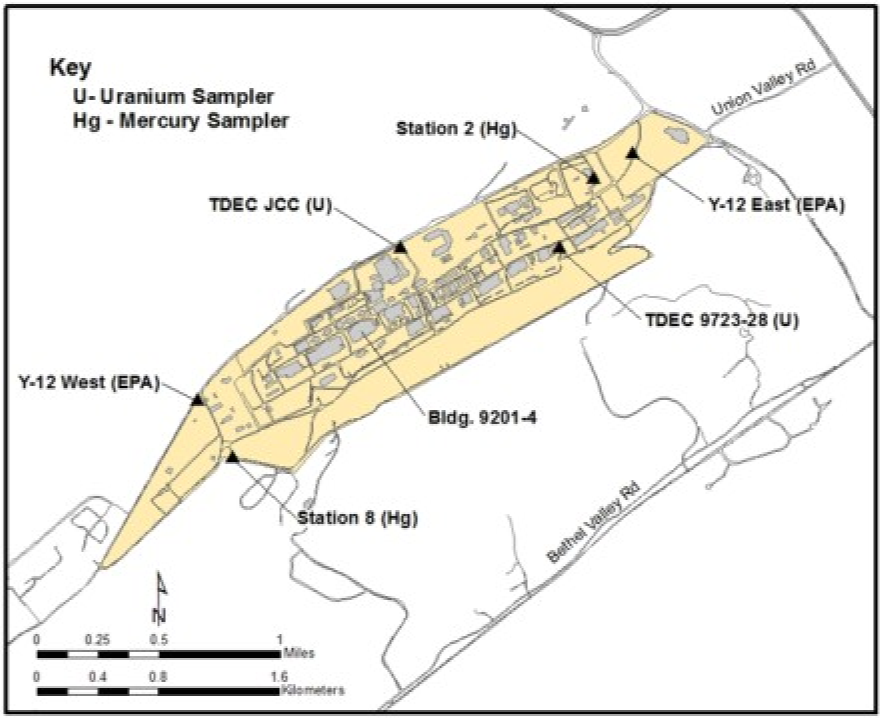


Figure 4.12. Locations of ambient air monitoring stations at the Y-12 National Security Complex

EPA = U.S. Environmental Protection Agency (sampler)
TDEC = Tennessee Department of Environment and Conservation
JCC = Jack Case Center

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 flow meter 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 4.11). Average mercury concentration at the AAS2 site for 2017 is 0.0030 μg/m^3 (N = 24), comparable to averages measured since 2003. After an increase in average concentration at the AAS8 site 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 2017 was 0.0037 μg/m^3 (N = 24), similar to levels reported for 2008 and the early 2000s.

Table 4.11. Summary of data for the Y-12 National Security Complex ambient air monitoring program for mercury for Calendar Year 2017

Ambient air monitoring stations	Mercury vapor concentration (μg/m^3) 2017 Minimum	2017 Maximum	2017 Average	1986–1988[a] Average
AAS2 (east end of the Y-12 Complex)	0.0017	0.0054	0.0030	0.010
AAS8 (west end of the Y-12 Complex)	0.0021	0.0071	0.0037	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.

AAS = ambient air (monitoring) station
CY = Calendar Year
N/A = not applicable
Y-12 Complex = Y-12 National Security Complex

Table 4.11 summarizes the 2017 mercury results, with results from the 1986 through 1988 period included for comparison. Figure 4.13 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 2017 (parts [a] and [b]) and seasonal trends at AAS8 from 1994 through 2017 (part [c]). The dashed line superimposed on the plots in Figures 4.13(a) and (b) is the EPA reference concentration of 0.3 μg/m^3 for chronic inhalation exposure. The large increase in mercury concentration at AAS8 observed in the late 1980s (part [b]) was thought to be related to disturbances of mercury-contaminated soils and sediments during the Perimeter Intrusion Detection Assessment System installation and storm drain restoration projects under way at that time. In Figure 4.13(c), a monthly moving average has been superimposed over the AAS8 data to highlight seasonal trends in mercury at AAS8 from January 1994 through 2017.

The dashed lines superimposed on parts (a) and (b) represent the EPA reference concentration of 0.3 μg/m^3 for chronic inhalation exposure. In part (c) (note the different concentration scale), a monthly moving average has been superimposed over the data to highlight seasonal trends in mercury at AAS8 from January 1993 to December 2017, with higher concentrations generally measured during the warm weather months.

In conclusion, 2017 average mercury concentrations at the two mercury monitoring sites were comparable to reference levels measured for the Chestnut Ridge reference site in 1988 and 1989. More importantly, measured concentrations continue to be well below current environmental and occupational health standards for inhalation exposure to mercury vapor (i.e., the National Institute for Occupational Safety and Health-recommended exposure limit of 50 μg/m^3, time-weighted average for up to a 10-hr workday, 40-hr workweek; the American Conference of Governmental Industrial Hygienists workplace threshold limit value of 25 μg/m^3 as a time-weighted average for a normal 8-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).

4.4.2.2 Quality Control

A number of QA/quality control (QC) steps are taken to ensure the quality of the data for Y-12 Complex mercury in the ambient air monitoring program.

An hour meter records the actual operating hours between sample changes. This allows for correction of total flow in the event of power outages during the weekly sampling interval.

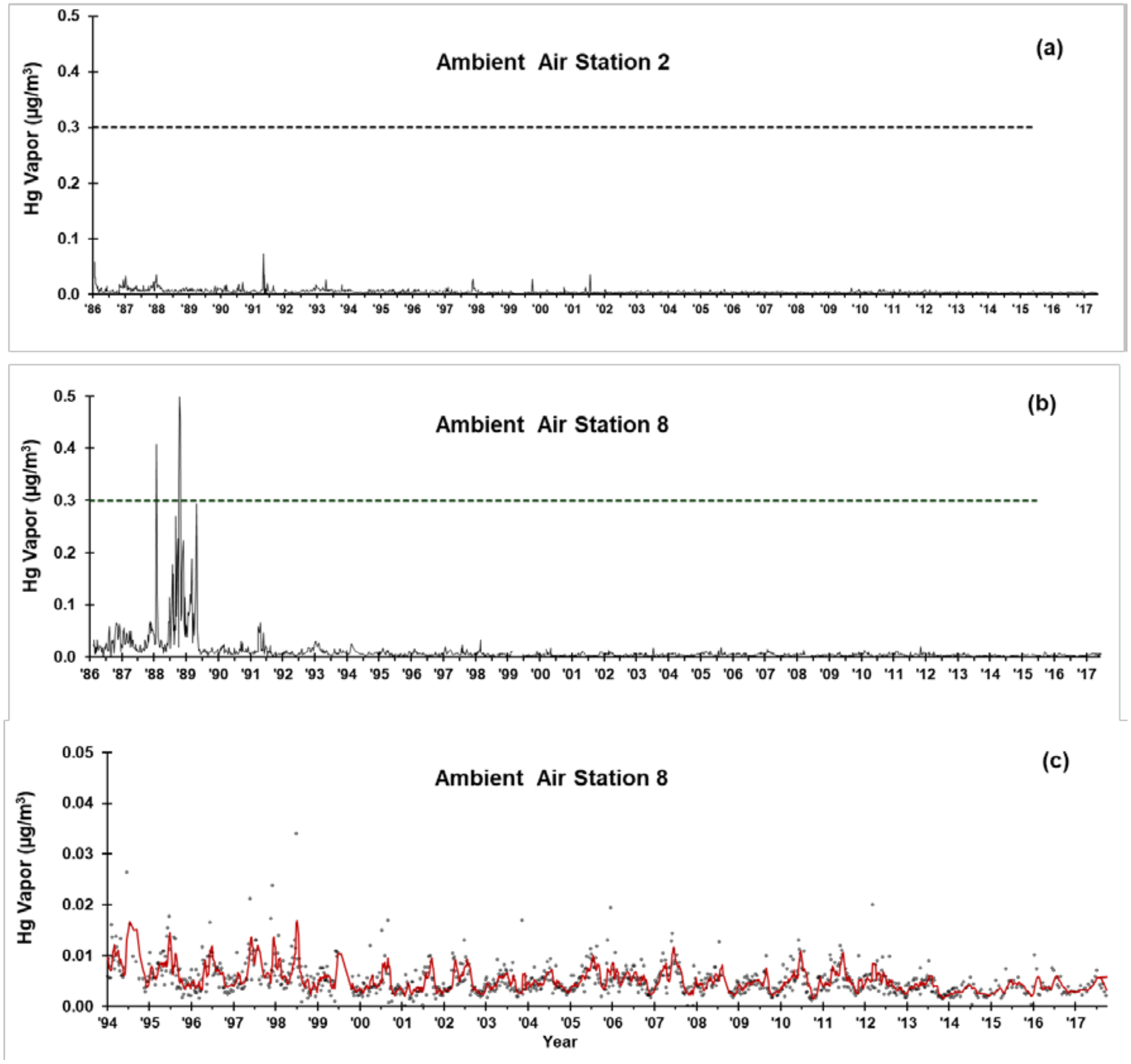


Figure 4.13. Temporal trends in mercury vapor concentration for the boundary monitoring stations at the Y-12 National Security Complex, July 1986 to January 2017 *([a] and [b]) and January 1994 to January 2017 for ambient air station 8 ([c])*

The Gilmont correlated flow meter, 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 (NIST).

A minimum of 5% 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% of the field samples have the front (upstream) and back segments of the charcoal sample trap analyzed separately. The absence of mercury above blank values on the back segment confirms the absence of breakthrough.

Chain-of-custody forms track the transfer of sample traps from the field technicians all the way to the analytical laboratory.

A field performance evaluation is conducted annually by the project manager to ensure that proper procedures are followed by the sampling technicians. No issues were identified in the last evaluation conducted on August 10, 2017.

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% at 5 or more times the detection limit are to be rerun [third duplicate] to resolve the discrepancy), and
- archiving all primary laboratory records for at least 1 year.

4.4.2.3 Ambient Air Monitoring Complementary to the 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 Complex 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 the Y-12 Complex (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 Complex operations, there are three uranium ambient air monitors within the Y-12 Complex 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 4.14) 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 Bldg. 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.

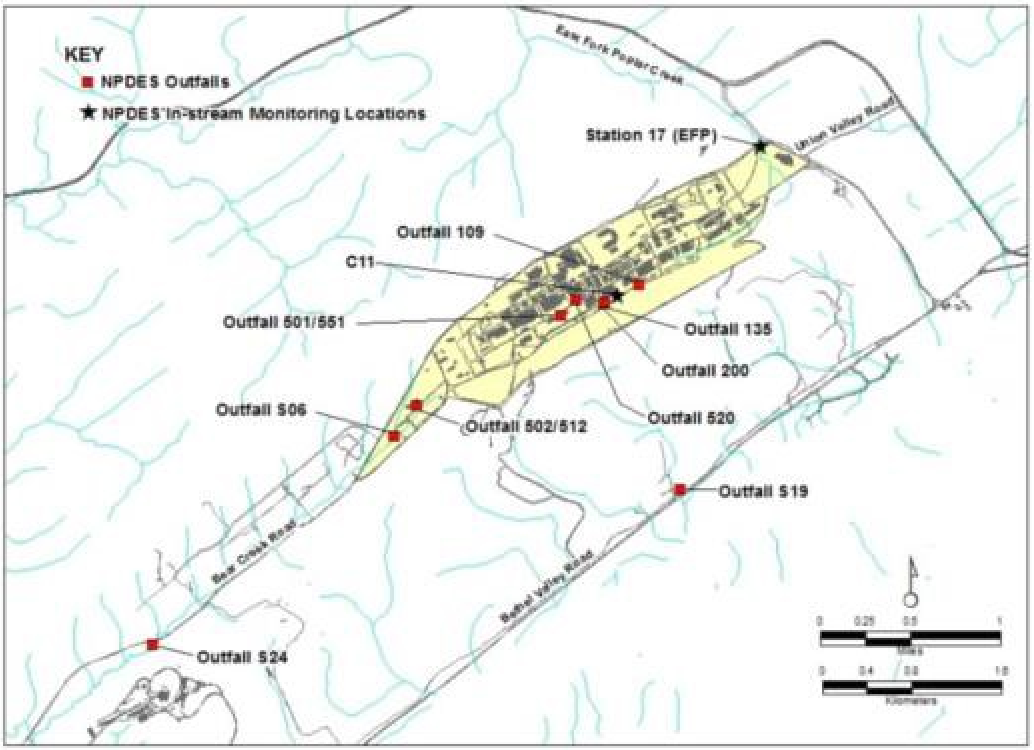


Figure 4.14. Major Y-12 National Security Complex national pollutant discharge elimination system (NPDES) outfalls and monitoring locations *(EFP = East Fork Poplar)*

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, and
- program-specific monitoring associated with infrastructure-reduction activities.

Results of these activities are summarized in Annual Status Reports, which are issued by the TDEC DOE Oversight Division.

The State of Tennessee also operates a number of regional monitors to assess ambient concentrations of criteria pollutants such as sulfur dioxide, particulate (various forms), and ozone for comparison against ambient standards. The results are summarized and available through EPA and State reporting mechanisms.

4.5 Water Quality Program

4.5.1 National Pollutant Discharge Elimination System Permit and Compliance Monitoring

The current Y-12 Complex NPDES permit (TN0002968) requires sampling, analysis, and reporting for about 56 outfalls. Major outfalls are depicted in Figure 4.14. The number is subject to change as outfalls are eliminated or consolidated or if permitted discharges are added. Currently, the Y-12 Complex 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 the Y-12 Complex is affected by current and legacy operations. Discharges from Y-12 Complex processes flow into EFPC before the water exits the Y-12 Complex. 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.

Requirements of the NPDES permit for 2017 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 2017 was 100% (see Table 4.12).

Table 4.12. National Pollutant Discharge Elimination System compliance monitoring requirements and record for the Y-12 National Security Complex, January through December 2017

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 4.12. National pollutant discharge elimination system compliance monitoring requirements and record for the Y-12 National Security Complex, January through December 2017 (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	4
	Total suspended solids		31		40	100	4
	Total toxic organic				2.13	100	4
	Hexane extractables			10	15	100	4
	Cadmium		0.4		0.15	100	4
	Chromium		1.7		1.0	100	4
	Copper		2.0		1.0	100	4
	Lead		0.4		0.2	100	4
	Nickel		2.4		3.98	100	4
	Nitrate/Nitrite				100	100	4
	Silver		0.26		0.05	100	4
	Zinc		0.9		1.48	100	4
	Cyanide		0.72		1.20	100	4
	PCB				0.001	100	4
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	53
	Hexane extractables			10	15	100	13
	Cadmium			0.001	0.023	100	15
	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	52
	Mercury			0.002	0.004	100	52
Outfall C11	pH, standard units			*a*	9.0	100	13
Outfall 135	pH, standard units			*a*	9.0	100	13
	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

Table 4.12. National pollutant discharge elimination system compliance monitoring requirements and record for the Y-12 National Security Complex, January through December 2017 (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
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.

IC_{25} = 25% inhibition concentration
PCB = polychlorinated biphenyl

4.5.2 Radiological Monitoring Plan and Results

A radiological monitoring plan is in place at the Y-12 Complex to address compliance with DOE Orders and NPDES permit TN0002968. The permit requires the Y-12 Complex 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: (1) treatment facilities, (2) other point-source and area-source discharges, and (3) instream locations. Operational history and past monitoring results provide a basis for parameters routinely monitored under the plan (Table 4.13). The current Radiological Monitoring Plan for the Y-12 Complex (B&W Y-12 2012) was last revised and reissued in January 2012.

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.

Table 4.13. Radiological parameters monitored at the Y-12 National Security Complex, 2017

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 the Y-12 Complex and are the dominant detectable radiological parameters in surface water
Fission and activation products	^{90}Sr, ^{3}H, ^{99}Tc, ^{137}Cs	These parameters reflect a minor activity at the Y-12 Complex, 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

Y-12 Complex = Y-12 National Security Complex

Radiological monitoring plan locations sampled in 2017 are noted on Figure 4.15. Table 4.14 identifies the monitored locations, the frequency of monitoring, and the sum of the percentages of the derived concentration standards for radionuclides measured in 2017. Radiological data were well below the allowable derived concentration standards.

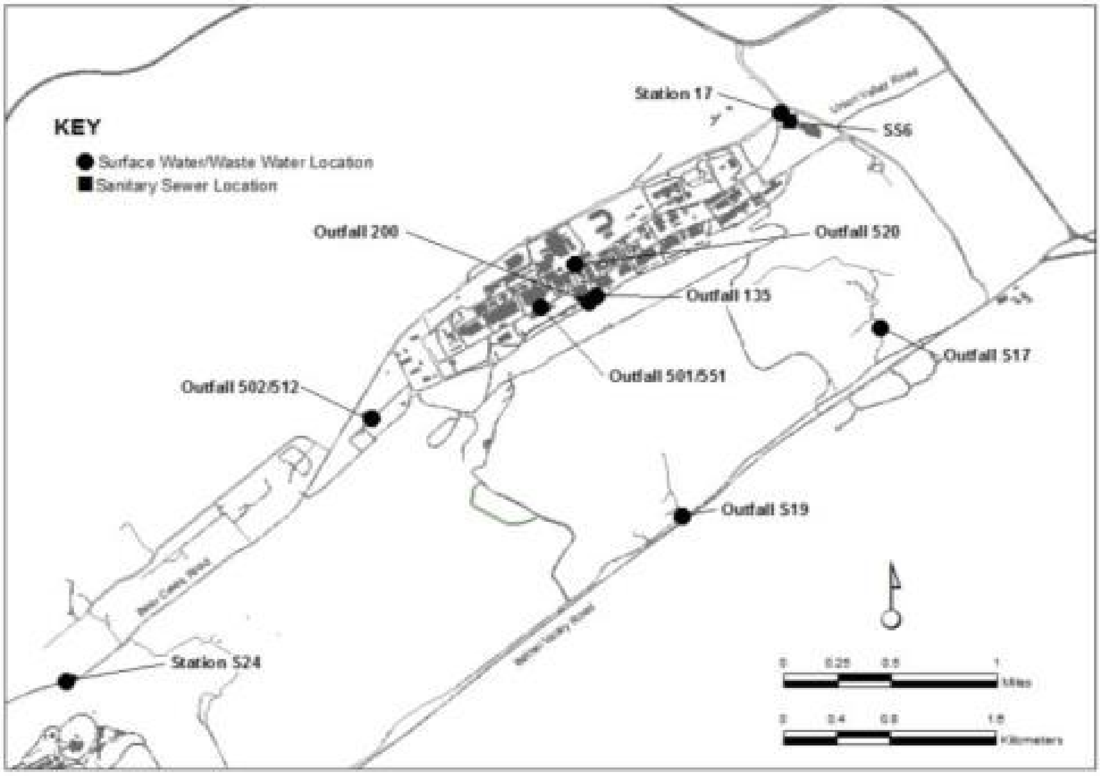


Figure 4.15. Surface water and sanitary sewer radiological sampling locations at the Y-12 National Security Complex

Table 4.14. Summary of Y-12 National Security Complex radiological monitoring plan sample requirements and 2017 results

Location	Sample frequency	Sample type	Sum of DCS percentages
		Y-12 Complex wastewater treatment facilities	
Central Pollution Control Facility	1/batch	Composite during batch operation	No flow
West End Treatment Facility	1/batch	24-hr composite	2.6
Groundwater Treatment Facility	4/year	24-hr composite	3.3
Steam condensate	1/year	Grab	No flow
Central Mercury Treatment Facility	4/year	24-hr composite	0.8
		Other Y-12 Complex point- and area-source discharges	
Outfall 135	4/year	24-hr composite	0.99
Kerr Hollow Quarry	1/year	24-hr composite	0.82
Rogers Quarry	1/year	24-hr composite	4.2
		Y-12 Complex instream locations	
Outfall S24	1/year	7-day composite	6.4
East Fork Poplar Creek, complex exit (east)	1/month	7-day composite	1.9
North/south pipes	1/month	24-hr composite	5.2
		Y-12 Complex Sanitary Sewer	
East End Sanitary Sewer Monitoring Station	1/year	7-day composite	28

DCS = derived concentration standard Y-12 Complex = Y-12 National Security Complex

In 2017, the total mass of uranium and associated curies released from the Y-12 Complex at the easternmost monitoring station, station 17 on upper EFPC, was 154 kg or 0.080 Ci (Table 4.15).

Table 4.15. Release of uranium from the Y-12 National Security Complex to the off-site environment as a liquid effluent, 2011–2017

Year	Quantity released	
	Ci[a]	**kg**
	Station 17	
2013	0.055	140
2014	0.061	90
2015	0.068	116
2016	0.045	88
2017	0.080	154

[a]1 Ci = 3.7E+10 Bq.

Figure 4.16 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 [mgd]). Converting units and multiplying by 365 days per year yields the calculated discharge.

The Y-12 Complex 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 the Y-12 Complex 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 2017 quarterly monitoring reports.

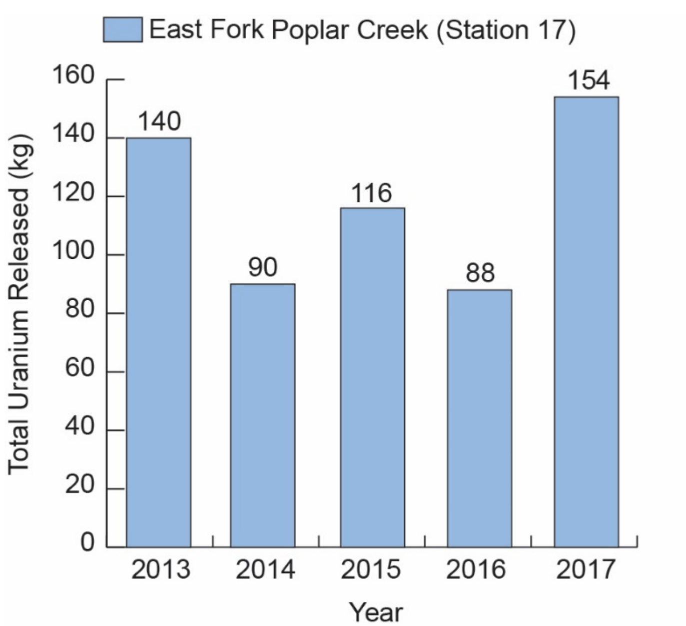


Figure 4.16. Five-year trend of Y-12 National Security Complex releases of uranium to East Fork Poplar Creek

4.5.3 Storm Water Pollution Prevention

The Storm Water Pollution Prevention Plan (SWPPP) at the Y-12 Complex 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: (1) characterization of storm water by sampling during storm events, (2) implementation of measures to reduce storm water pollution, (3) facility inspections, and (4) employee training.

The Y-12 Complex 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 the Y-12 Complex 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 the Y-12 Complex 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 2017 during rain events that occurred on April 3, May 4, July 27, and September 5. Results were published in the Annual Storm Water Report (CNS 2017a), which was submitted to the TDEC, Division of Water Pollution Control in December 2017. Consistent with permit requirements, storm water monitoring is performed each year for sector outfalls, three major outfalls that drain large areas of the Y-12 Complex, and two instream monitoring locations on EFPC (Figure 4.17).

The permit no longer calls for sampling of stream base-load sediment that is being transported as a result of the heavy flow.

A significant change from 2013 to 2014 was the elimination of flow augmentation in EFPC. This discharge of raw water into EFPC was discontinued on April 30, 2014; thus, raw water is no longer required to be sampled. The discontinuation of flow augmentation has reduced the flow in EFPC by a significant amount (about 3.3 mgd, or about 60%).

In general, the quality of storm water exiting the Y-12 Complex via EFPC remained relatively stable from 2016 to 2017. One 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. Subsequent concentrations are listed in Table 4.16. These elevated and sporadic changes in mercury concentrations at this location have garnered the attention of TDEC, Division of Water Resources personnel. Some discussion was given to routing the discharge from this outfall through the new mercury treatment facility. However, at this time, there are no plans to implement this change.

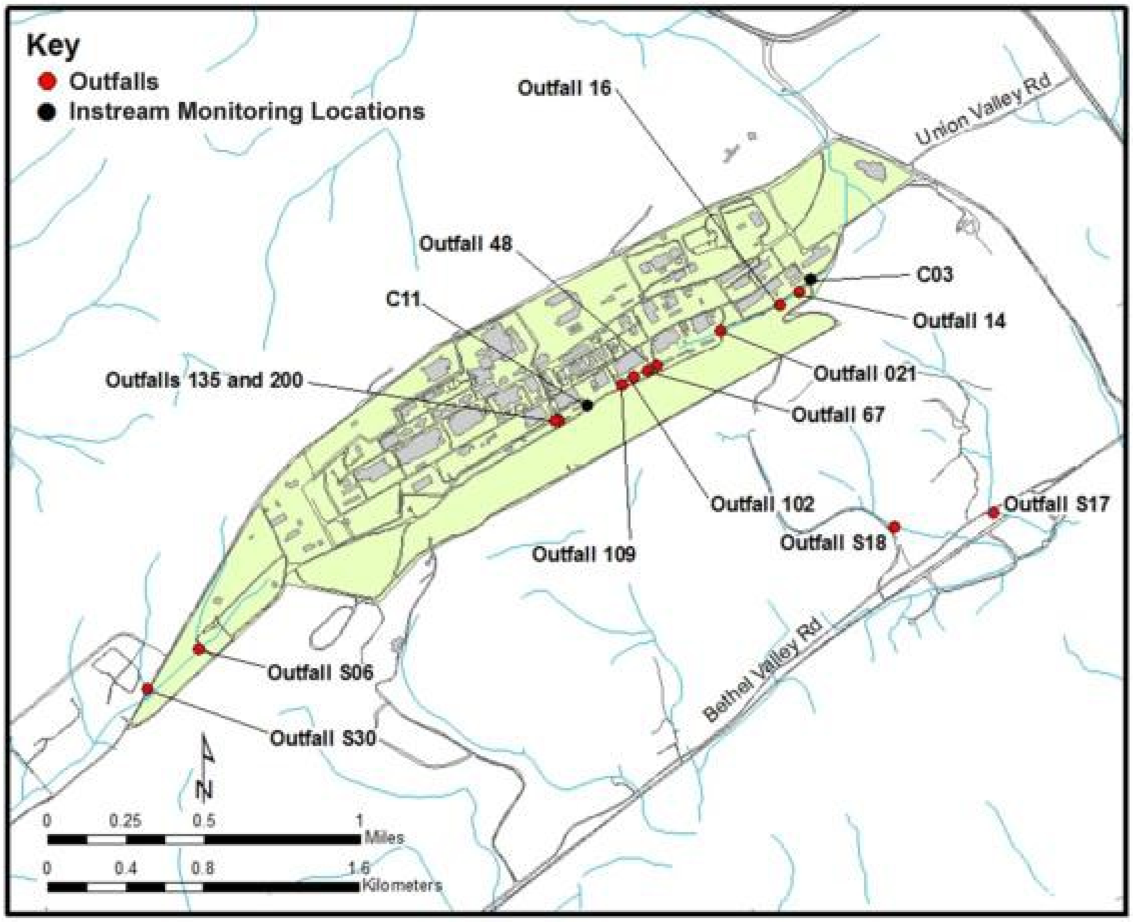


Figure 4.17. Y-12 National Security Complex storm water monitoring locations, East Fork Poplar Creek

Table 4.16. Mercury concentrations at Outfall 014

Calendar year	2013	2014	2015	2016	2017
Mercury concentration (µg/L)	7.12	0.892	9.11	0.49	0.237

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 4.18. 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 the Y-12 Complex Groundwater Protection Program (GWPP) to monitor trends throughout the three hydrogeologic regimes (see Section 4.6).

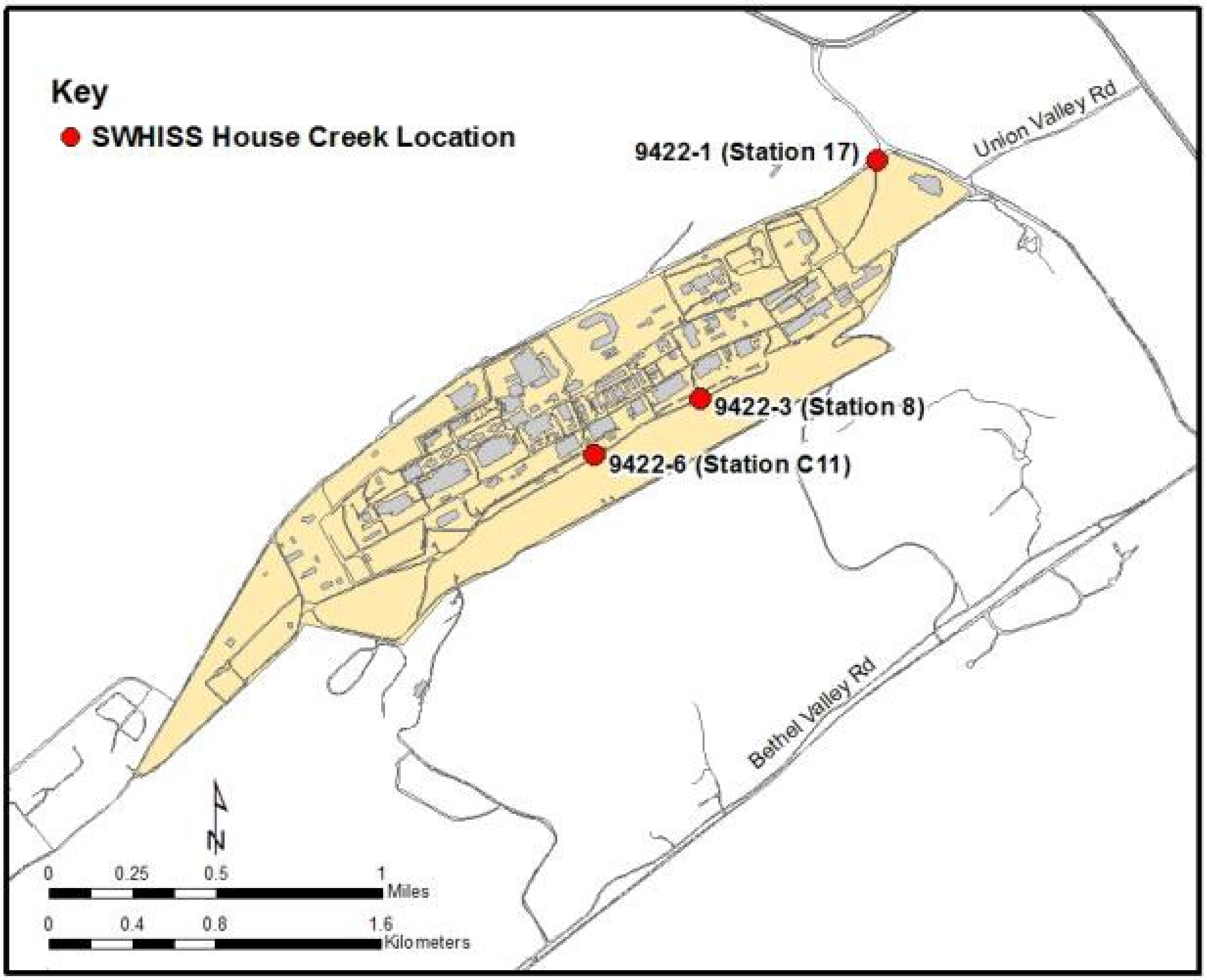


Figure 4.18. Surface Water Hydrological Information Support System (SWHISS) monitoring locations

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 4.18) to conduct compliance monitoring as required by the pretreatment regulations. City personnel also conduct twice-yearly compliance inspections.

During 2016 and the first part of 2017, the City of Oak Ridge and Y-12 Complex personnel negotiated a new permit for the Y-12 Complex. This new permit became effective July 1, 2017. Significant changes between the two permits are as follows:

- The previous permit contained a flow limit of 1.4M mgd. The revised permit contains two flow limits; a maximum instantaneous flow rate of 2,100 gallons per minute (gpm) and a maximum average total daily flow of 500,000 gal (computed on a quarterly basis).
- The revised permit eliminated daily maximum permit limits for metals and other parameters.
- The revised limit for cyanide is significantly lower than that stated in the previous permit.
- The revised permit contains a requirement to sample for hexavalent chromium, ammonia, and methanol. Only hexavalent chromium has a permit limit and the other two parameters only have required detection limits.

Monitoring results from 2017 are contained in Table 4.17 (January through June 2017) and Table 4.18 (July through December 2017). There were five exceedances of permit limits in 2017; two exceedances of the 1.4-mgd limit under the previous permit and three exceedances of the 2,100-gpm limit under the revised permit.

Table 4.17. Y-12 National Security Complex Plant discharge point SS6, Sanitary Sewer Station 6, January through June 2017 *(all units are mg/L unless noted otherwise)*

Effluent parameter	Number of samples	Average value	Daily maximum (effluent limit)[a]	Monthly average (effluent limit)[a]	Number of limit exceedances
Flow (kgal/day)	181	412	1,400	N/A	2
pH (standard units)	7	N/A	9/6[b]	9/6[b]	0
Biochemical oxygen demand	7	70.4	300	200	0
Kjeldhal nitrogen	7	21.3	90	45	0
Phenols—total recoverable	7	<0.039	0.3	0.15	0
Oil and grease	7	<7.6	50	25	0
Suspended solids	7	114	300	200	0
Cyanide	7	<0.0041	0.062	0.041	0
Arsenic	7	<0.003	0.025	0.010	0
Cadmium	7	<0.0003	0.005	0.0033	0
Chromium	7	<0.003	0.075	0.05	0
Copper	7	0.0257	0.21	0.14	0
Iron	7	0.52	30	10	0
Lead	7	<0.002	0.074	0.049	0
Mercury	11	0.002	0.035	0.023	0
Nickel	7	<0.003	0.032	0.021	0
Silver	7	<0.002	0.10	0.05	0
Zinc	7	0.110	0.75	0.35	0
Molybdenum	7	0.0423	0.05[c]	0.05[c]	N/A
Selenium	7	<0.007	0.01[c]	0.01[c]	N/A
Toluene	2	0.005U	0.005[c]	0.005[c]	N/A
Benzene	2	0.005U	0.005[c]	0.005[c]	N/A
1,1,1-trichloroethane	2	0.005U	0.005[c]	0.005[c]	N/A
Ethylbenzene	2	0.005U	0.005[c]	0.005[c]	N/A

Table 4.17. Y-12 National Security Complex Plant discharge point SS6, Sanitary Sewer Station 6, January through June 2017 (all units are mg/L unless noted otherwise) (continued)

Effluent parameter	Number of samples	Average value	Daily maximum (effluent limit)[a]	Monthly average (effluent limit)[a]	Number of limit exceedances
Carbon tetrachloride	2	0.005U	0.005[c]	0.005[c]	N/A
Chloroform	2	0.006	0.005[c]	0.005[c]	N/A
Tetrachloroethylene	2	0.003J	0.005[c]	0.005[c]	N/A
Trichloroethene	2	0.005U	0.005[c]	0.005[c]	N/A
Trans-1,2-dichloroethylene	2	0.005U	0.005[c]	0.005[c]	N/A
Methylene chloride	4	0.003JU	0.005[c]	0.005[c]	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.

N/A = not applicable

Table 4.18. Y-12 National Security Complex Plant discharge point SS6, Sanitary Sewer Station 6, July through December 2017 *(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)	184	435	2,100	N/A	3
Flow (average kgpd) July through September	92	377	N/A	500	0
Flow (average kgpd) October through December	92	321	N/A	500	0
pH (standard units)	7	N/A	N/A	9/6[b]	0
Biochemical oxygen demand	7	83.4	N/A	200	0
Kjeldhal nitrogen	7	23.7	N/A	45	0
Phenols—total recoverable	7	<0.028	N/A	0.15	0
Oil and grease	7	<6.97	N/A	25	0
Suspended solids	7	105	N/A	200	0
Cyanide	7	<0.0033	N/A	0.005	0
Arsenic	7	<0.005	N/A	0.010	0
Cadmium	7	<0.0005	N/A	0.0033	0
Chromium, hexavalent	7	0.005U	N/A	0.053	0
Copper	7	0.033	N/A	0.14	0
Iron	7	0.619	N/A	10	0
Lead	7	<0.002	N/A	0.049	0
Mercury (lb/day)	7	0.00281	N/A	0.035	0
Nickel	7	<0.005	N/A	0.021	0
Silver	7	<0.0008	N/A	0.05	0
Zinc	7	0.13	N/A	0.35	0
Molybdenum	7	0.047	N/A	0.05[c]	N/A
Selenium	7	<0.009	N/A	0.01[c]	N/A
Toluene	2	0.005U	N/A	0.005[c]	N/A

Table 4.18. Y-12 National Security Complex Plant discharge point SS6, Sanitary Sewer Station 6, July through December 2017 *(all units are mg/L unless noted otherwise)* (continued)

Effluent parameter	Number of samples	Average value	Daily maximum (gpm)[a]	Monthly average (effluent limit)[a]	Number of limit exceedances
Benzene	2	0.005U	N/A	0.005[c]	N/A
1,1,1-trichloroethane	2	0.005U	N/A	0.005[c]	N/A
Ethylbenzene	2	0.005U	N/A	0.005[c]	N/A
Carbon tetrachloride	2	0.005U	N/A	0.005[c]	N/A
Chloroform	2	0.0105	N/A	0.005[c]	N/A
Tetrachloroethene	2	0.006	N/A	0.005[c]	N/A
Trichloroethene	2	0.005U	N/A	0.005[c]	N/A
Trans-1,2-dichloroethylene	2	0.005U	N/A	0.005[c]	N/A
Methylene chloride	2	0.005U	N/A	0.005[c]	N/A
Ammonia	2	17.4	N/A	0.10[c]	N/A
Methanol	2	0.745	N/A	1.0[c]	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.

gpm = gallons per minute
N/A = not applicable

4.5.6 Quality Assurance/Quality Control

The Environmental Monitoring Management Information System (EMMIS) is used to manage surface water monitoring data at the Y-12 Complex. 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; and
- 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 the 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

In accordance with the requirements of the NPDES permit effective December 1, 2011, Part III-E, p. 31, two outfalls that discharge to the headwaters of EFPC (Outfalls 200 and 135) were evaluated for toxicity during 2017 using fathead minnow (*Pimephales promelas*) larvae and water fleas (*Ceriodaphnia dubia)*. A third discharge once evaluated for toxicity, Outfall 125, no longer has sufficient base flows for toxicity to be evaluated. Table 4.19 summarizes the results of the 2017 outfall biomonitoring tests in terms of the 25% inhibition concentration (IC_{25}), the concentration (i.e., a percentage of full-strength effluent diluted with laboratory control water) of each outfall effluent that causes a 25% reduction in water fleas (*Ceriodaphnia dubia*) survival or reproduction or fathead minnow (*Pimephales promelas*) survival or growth. The lower the value of the IC_{25}, the more toxic the effluent.

Table 4.19. Y-12 National Security Complex Biomonitoring Program summary information for Outfalls 200 and 135 in 2017[a]

Site	Test start date	Species	IC_{25}[b] (%)
Outfall 200	07/19/17	*Ceriodaphnia dubia*	>100
Outfall 200	07/19/17	*Pimephales promelas*	>100
Outfall 135	07/19/17	*Ceriodaphnia dubia*	>36
Outfall 135	07/19/17	*Pimephales promelas*	>36

[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.

IC_{25} = 25% inhibition concentration (IC_{25})

Effluent from Outfall 135 did not reduce fathead minnow (*Pimephales promelas*) survival or growth or water fleas (*Ceriodaphnia dubia*) survival or reproduction by 25% or more at any of the tested concentrations. For both species, the IC_{25} for survival, growth, or reproduction was >36% (the highest concentration of this effluent that was tested). Toxicity is demonstrated according to the NPDES permit if the IC_{25} is less than or equal to the permit limit (9% whole effluent for Outfall 135).

Effluent from Outfall 200 also did not reduce fathead minnow (*Pimephales promelas*) survival or growth or water fleas (*Ceriodaphnia dubia*) survival or reproduction by 25% or more at any of the tested concentrations. Therefore, the fathead minnow IC_{25} for survival, growth, or reproduction was >100% (the highest concentration of this effluent that was tested). For this outfall, toxicity is demonstrated according to the NPDES permit if the IC_{25} is less than or equal to the permit limit (37% whole effluent for Outfall 200).

4.5.8 Biological Monitoring and Abatement Program

The NPDES permit issued for the Y-12 Complex 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 2017 BMAP sampling efforts reported in this chapter follow the NPDES-required Y-12 Complex BMAP Plan (Peterson et al. 2013). The Y-12 Complex 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 the Y-12 Complex 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; and EFK 6.3, located about 1.4 km downstream of the ORR boundary (Figure 4.19). 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 4.20).

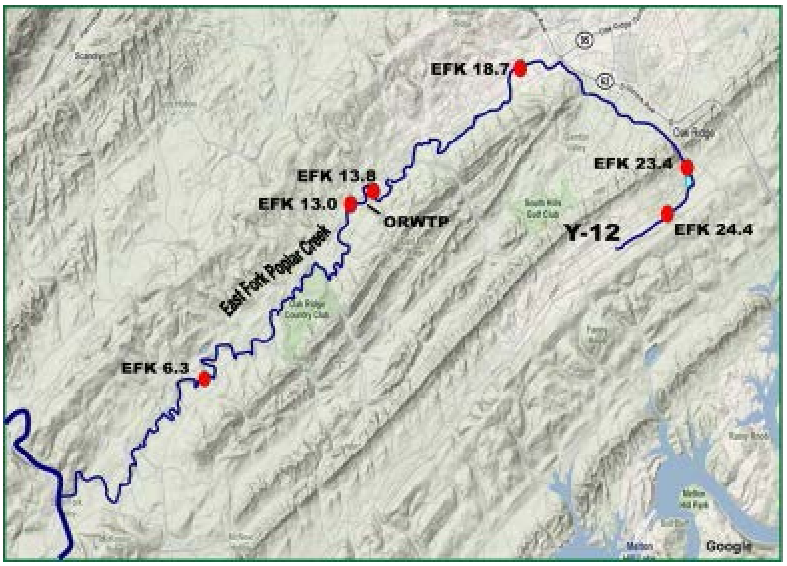


Figure 4.19. Locations of biological monitoring sites on East Fork Poplar Creek in relation to the Y-12 National Security Complex *(EFK = East Fork Poplar Creek kilometer and ORWTP = Oak Ridge Water Treatment Plant)*

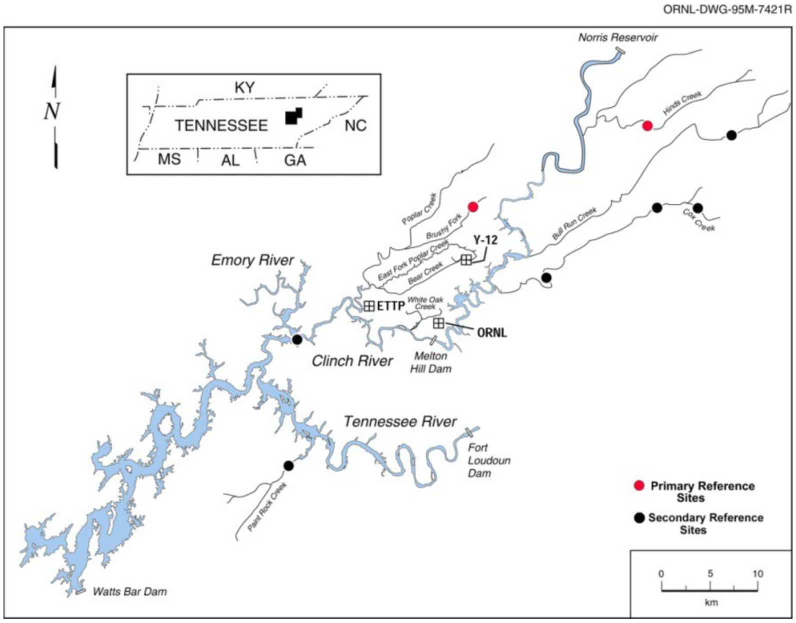


Figure 4.20. Locations of biological monitoring reference sites in relation to the Y-12 National Security Complex *(ETTP = East Tennessee Technology Park, ORNL = Oak Ridge National Laboratory, and Y-12 = Y-12 National Security Complex)*

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 the Y-12 Complex has slowed in recent years, and fish and invertebrate communities continue to have fewer species than the corresponding communities in reference streams.

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 Complex 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 4.21). Mercury concentrations remained higher in fish from EFPC in 2017 than in fish from reference streams. Elevated mercury concentrations in fish from the upper reach of EFPC indicate that the Y-12 Complex remains a continuing source of mercury to fish in the stream.

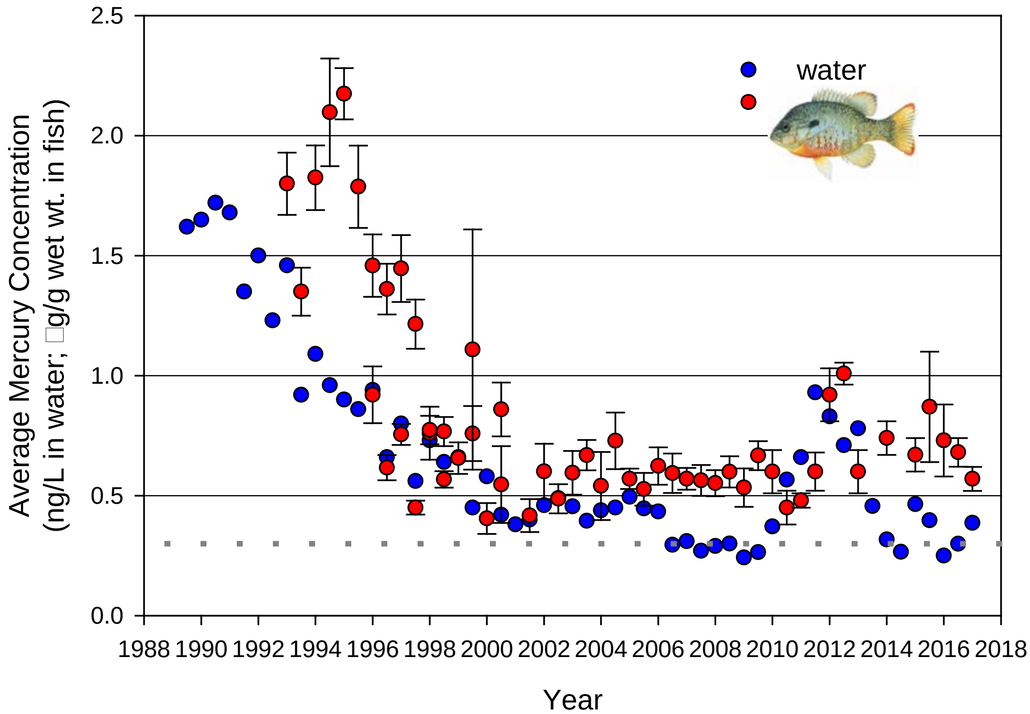


Figure 4.21. Semiannual average mercury concentration in muscle fillets of redbreast sunfish and water from East Fork Poplar Creek (EFPC) at EFPC km 23.4 (water) and 24.4 (fish), Fiscal Year 2017 ***(Dashed grey line represents the ambient water quality criterion for methylmercury in fish fillets [0.3 mg/kg])***

Figure 4.21 shows temporal trends for mercury concentrations in water collected from EFK 23.4 (Station 17) and in fish collected just upstream of this monitoring station at EFK 24.4. Waterborne mercury concentrations in the upper reach of EFPC have decreased substantially over the years in response to various remedial actions, first over the 1990s time period and then again in response to the Big Springs Treatment System in 2006. 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 4.21). 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 2017 (approximately 0.6 µg/g). These concentrations are above the EPA ambient water quality criterion for mercury (0.3 µg/g mercury as methylmercury in fish fillet). 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 0.58 µg/g in FY 2017, which was comparable to the concentration in FY 2016 (0.60 µg/g) (Figure 4.22). 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).

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, and 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 2017 at three sites in EFPC and at two reference streams. The numbers of pollution-intolerant taxa (Ephemeroptera, Plecoptera, and Tricoptera, or EPT taxa) increased at EFK 23.4, remained the same at EFK 24.4, and decreased at EFK 13.8 (Figure 4.23a). The densities of these pollution-intolerant taxa increased at the two sites nearest the Y-12 Complex (EFK 23.4 and EFK 24.4), but decreased at the reference sites and at EFK 13.8 (Figure 4.23b). Of particular significance, the mean densities of the pollution-intolerant taxa at EFK 13.8 have continued to exceed the upper bound of the reference site confidence limits since 2012. However, at EFK 23.4 and EFK 24.4, mean densities for pollution-intolerant taxa remain at typical low levels, indicative of degraded conditions after exceeding densities at reference sites in 2015 for the first time since monitoring began in 1985. Considered together, these results suggest that the actual long-term effects on the invertebrate community of ending flow management in EFPC will only become evident as conditions stabilize and additional data become available.

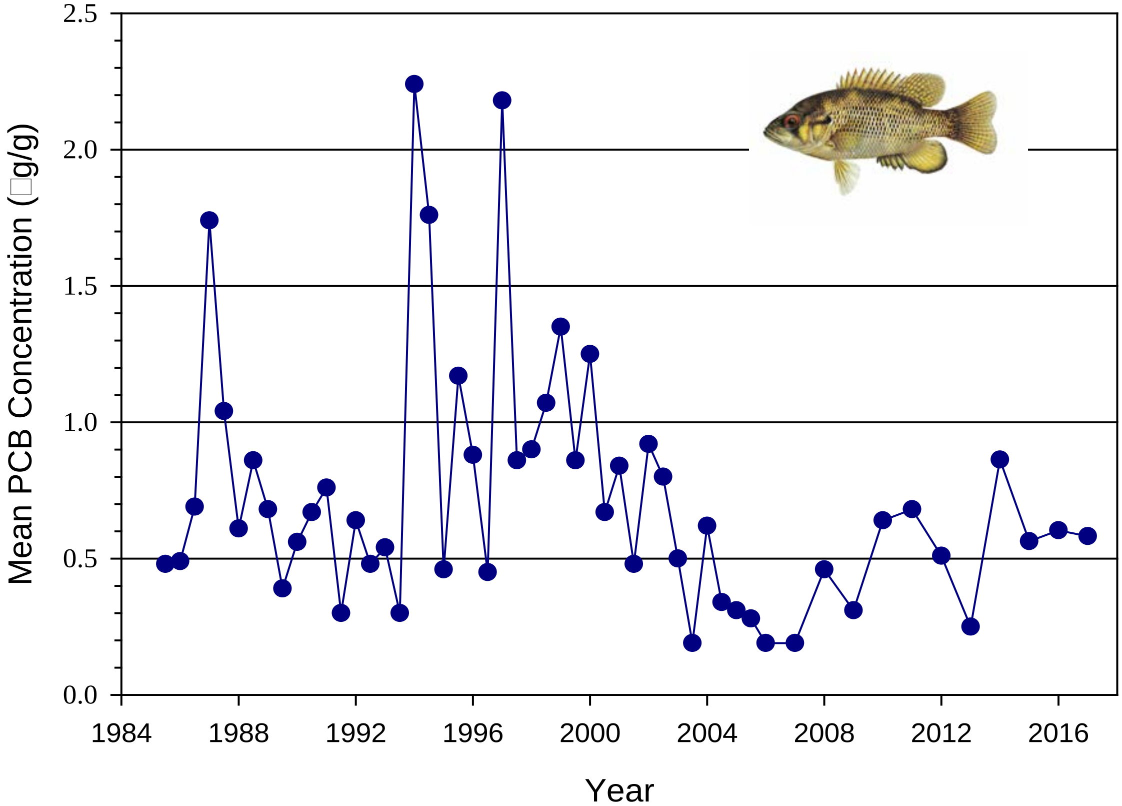


Figure 4.22. Annual mean concentrations of polychlorinated biphenyls (PCBs) in rock bass muscle fillets at East Fork Poplar Creek kilometer 23.4, Fiscal Year 2017

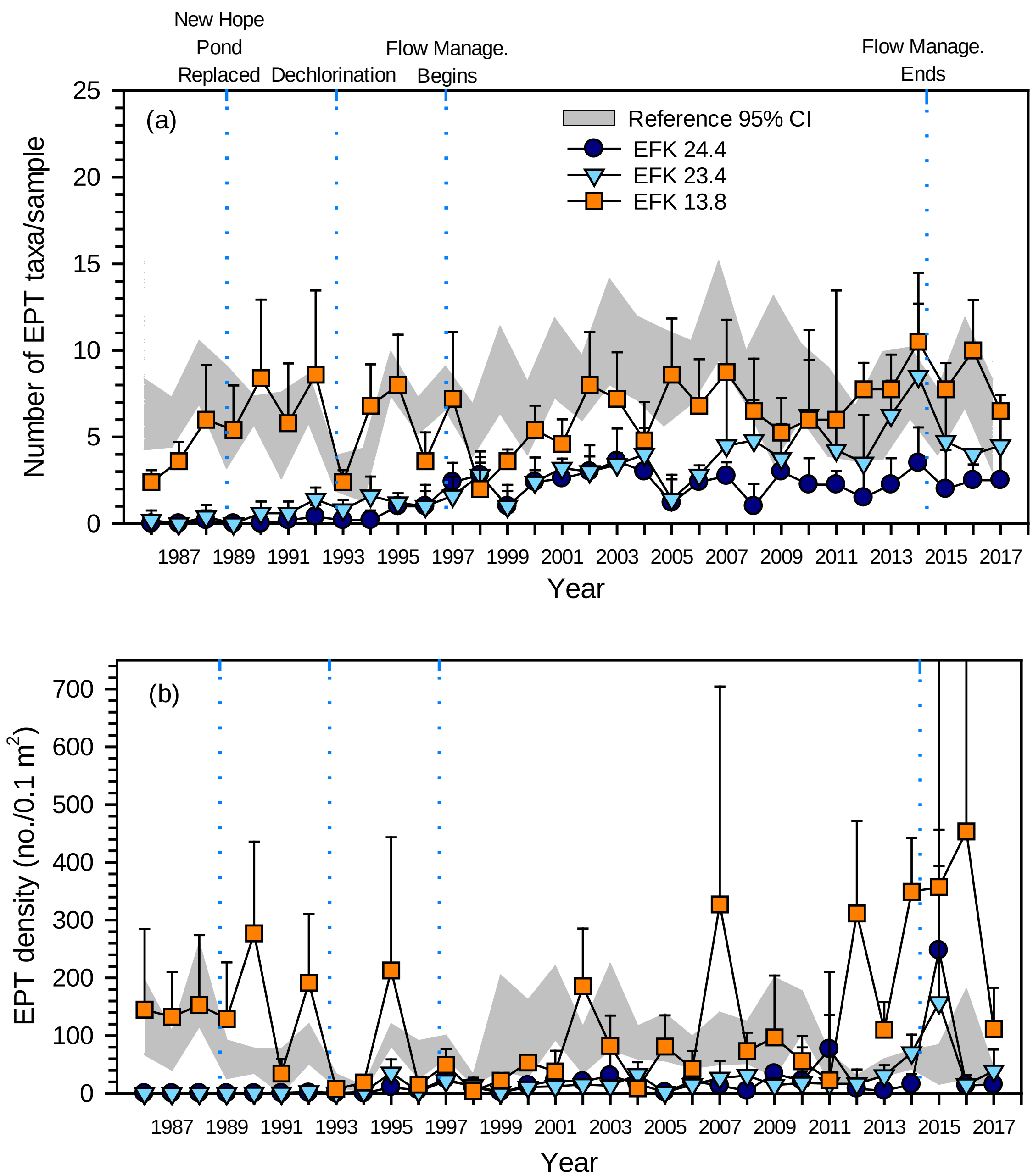


Figure 4.23. (a) Taxonomic richness (mean number of taxa per sample), and (b) density (mean number of taxa per square meter) of the Ephemeroptera, Plecoptera, and Tricoptera (EPT) in the benthic macroinvertebrate communities sampled in the spring from East Fork Poplar Creek and two nearby reference streams (Brushy Fork and Hinds Creek), 1986 through 2017 *(EFK = East Fork Poplar Creek kilometer)*

4.5.8.3 Fish Community Monitoring

Fish communities were monitored in the spring and fall of 2017 at five sites along EFPC and at a comparable local reference stream (Brushy Fork). In the past three decades, overall species richness, density, biomass, and number of pollution-sensitive fish species improved at all sampling locations below Lake Reality. Some 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 4.24, 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 the Y-12 Complex (EFK 23.4 and EFK 24.4).

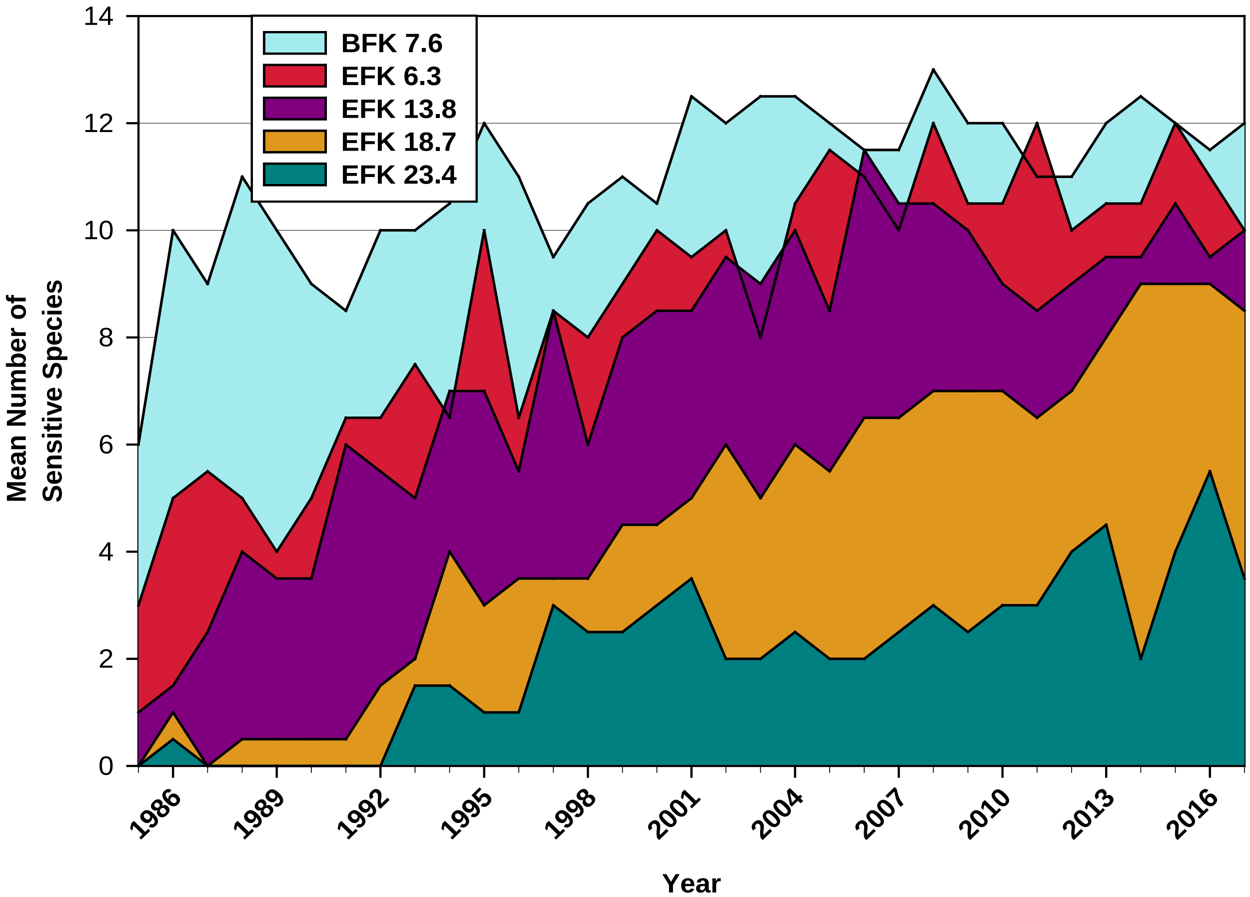


Figure 4.24. Comparison of mean sensitive species richness (number of species) collected each year from 1985 to 2017 from four sites in East Fork Poplar Creek and a reference site (Brushy Fork) *(BFK = Brushy Fork kilometer and EFK = East Fork Poplar Creek kilometer)*

Fish communities in upper EFPC in 2017 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 4.25). 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. No fish kills were observed in 2017 in upper EFPC.

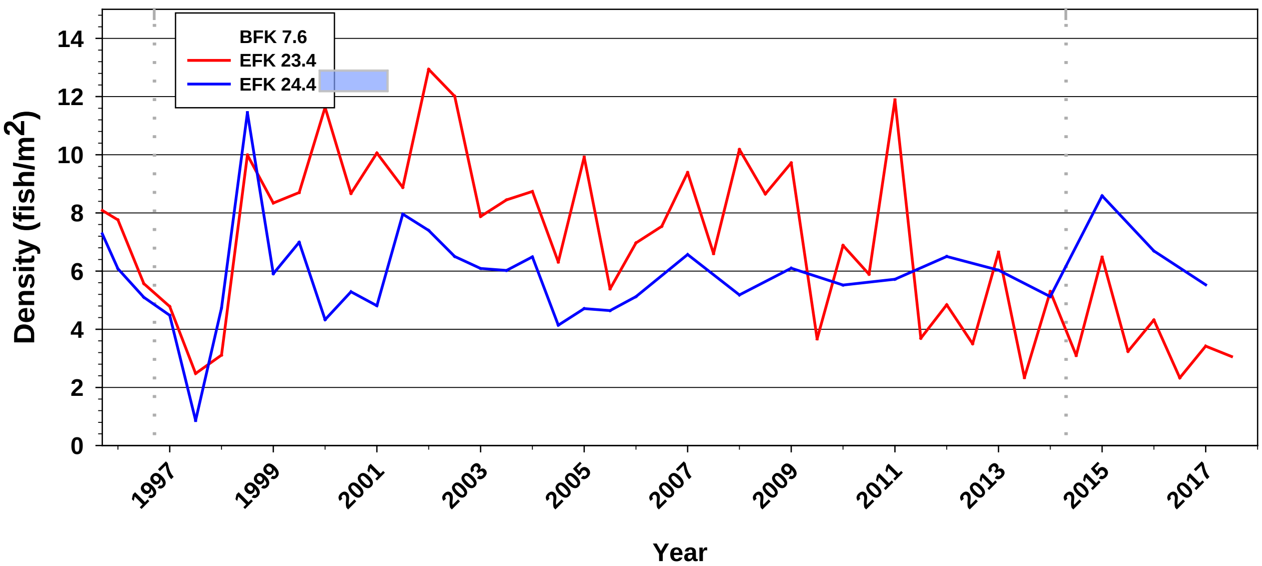


Figure 4.25. Fish density (number of fish per square meter) for two sites in upper East Fork Poplar Creek and a reference site (Brushy Fork) from 1996 to 2017. ***(BFK = Brushy Fork kilometer and EFK = East Fork Poplar Creek kilometer) (The interval of time between the dashed lines represents the period of flow management in East Fork Poplar Creek.)***

4.5.8.4 Upper Bear Creek Remediation

As part of the construction of the UPF inside the Y-12 Complex, 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, was 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.

Annual monitoring of the remediated wetland sites through 2017 revealed that, in general, the wetlands are responding as intended and have shown remarkable wetland plant coverage over the past couple of years. The wetland soil bank was undoubtedly key to the restoration effort. There are some wetlands with extensive open water areas, and there are some areas with somewhat less wet conditions. However, this is not unusual at this stage of wetland restoration projects. It will be important to carefully monitor hydrologic conditions and wetland plant growth with time and to understand responses to annual precipitation patterns. Keeping invasive plants in check is also important because invasive species can be aggressive shortly after soil disturbance.

The stream remediation site in upper Bear Creek continues to show signs of stability as well. After some 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. The riparian plantings are establishing, and native flora is abundant in the area adjacent to the stream. The fish and aquatic invertebrate communities was slightly impacted by the drought in summer 2016 but appeared to be recovering in 2017 samples.

4.6 Groundwater at the Y-12 National Security Complex

Groundwater monitoring at the Y-12 Complex is performed to comply with Federal, State, and local requirements and DOE Orders to determine the degree of environmental impact from legacy and current operations. More than 150 known or potential sources of environmental contamination have been identified at the Y-12 Complex, some from plant operations and some from former waste management practices (DOE 2017b). Monitoring provides information on the nature and extent of contamination of groundwater, which is then used to determine what actions must be taken to protect the worker, public, and environment. Figure 4.26 depicts the major facilities or areas of the Y-12 Complex and known and potential groundwater contaminant sources for which groundwater monitoring is performed.

4.6.1 Hydrogeologic Setting

The Y-12 Complex is divided into three hydrogeologic regimes (Bear Creek, upper EFPC, and Chestnut Ridge), which are delineated by surface water drainage patterns, topography, and groundwater flow characteristics (Figure 4.27). Most of the Bear Creek and upper EFPC regimes are underlain by the shales, siltstones, and sandstones with a subordinate and locally variable amount of carbonate bedrock, mentioned in Section 1.3.5, and are hydrostratigraphically referred to as aquitards. Aquitards are rock units that contain water but do not readily yield significant water to pumping wells. However, geologic units that are considered aquitards can often yield water in quantities sufficient for domestic or small farm use (Domenico and Schwartz 1990). The southern portion of the two regimes is underlain by the Maynardville Limestone, which is part of the Knox aquifer. The Chestnut Ridge regime is almost entirely underlain by the Knox aquifer. The southernmost portion near Bethel Valley Road consists of the lowest members of the Chickamauga Group. In general, groundwater flow in the water table interval follows the topography (Figure 4.28). Shallow groundwater flow in the Bear Creek and upper EFPC regimes is divergent from the topographic and groundwater divide located near the western end of the Y-12 Complex that defines the boundary between the two. In addition, flow converges on the primary surface streams (Bear Creek and upper EFPC) from Pine Ridge and Chestnut Ridge. In the Chestnut Ridge regime, a groundwater divide exists that nearly coincides with the crest of the ridge. Shallow groundwater flow tends to be toward either flank of the ridge, with discharge primarily to surface streams and springs located in Bethel Valley to the south and Bear Creek Valley to the north.

In Bear Creek Valley, groundwater in the intermediate and deep intervals moves predominantly through fractures in the aquitard, converging on and then moving through fractures and solution conduits in the Maynardville Limestone (Figure 4.27). Karst development in the Maynardville Limestone has a significant impact on groundwater flow paths in the water table and intermediate intervals. In general, groundwater flow parallels the valley and geologic strike. Groundwater flow rates in Bear Creek Valley vary widely; they are very 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 5000 ft/day). The rate of groundwater flow perpendicular to geologic strike from the aquitard units of the lower Conasauga Group to the Maynardville Limestone is typically even slower below the water table interval.

Figure 4.26. Known or potential contaminant sources for which groundwater monitoring is performed at the Y-12 National Security Complex

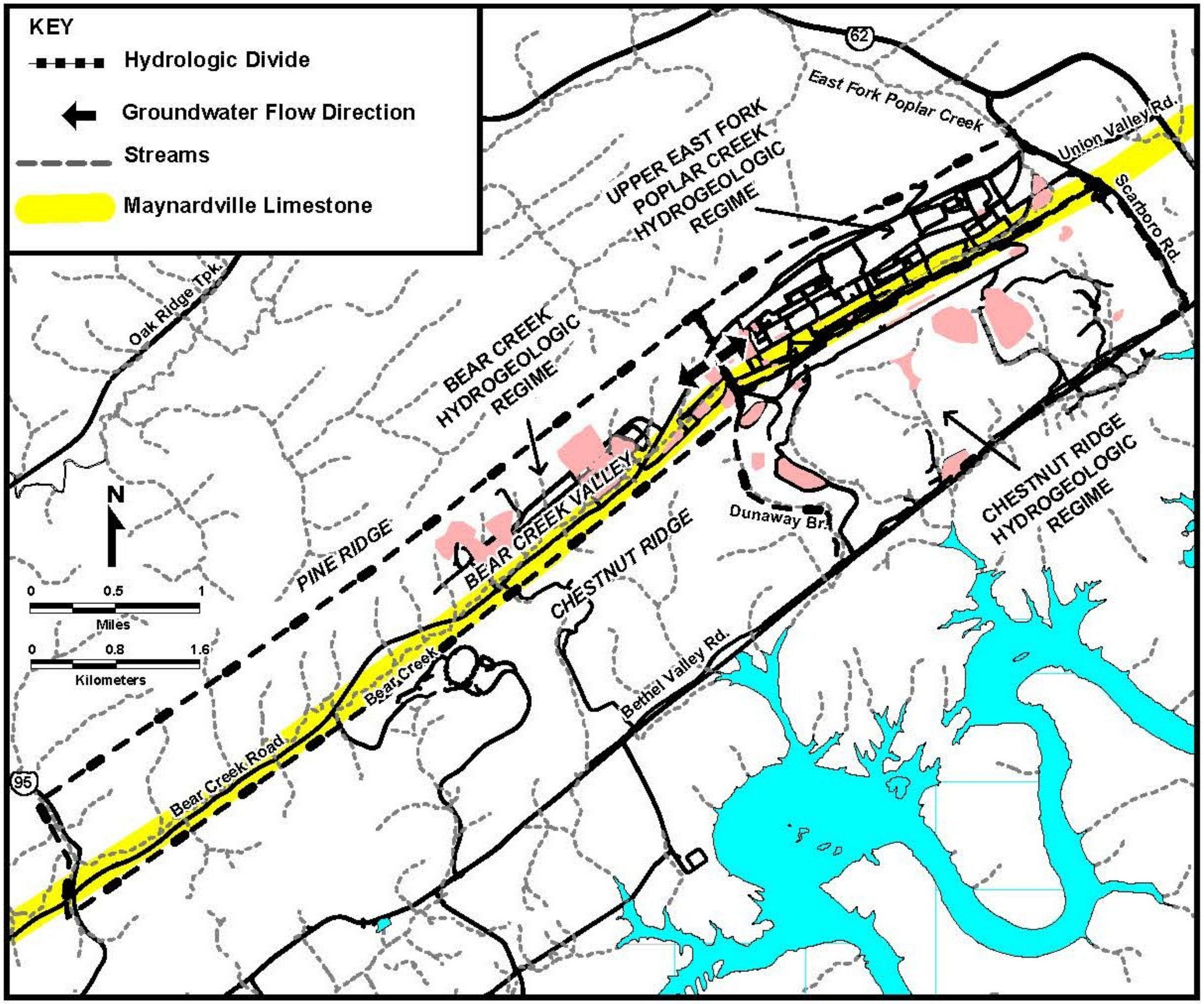


Figure 4.27. Hydrogeologic regimes at the Y-12 National Security Complex and the position of the Maynardville Limestone in Bear Creek Valley

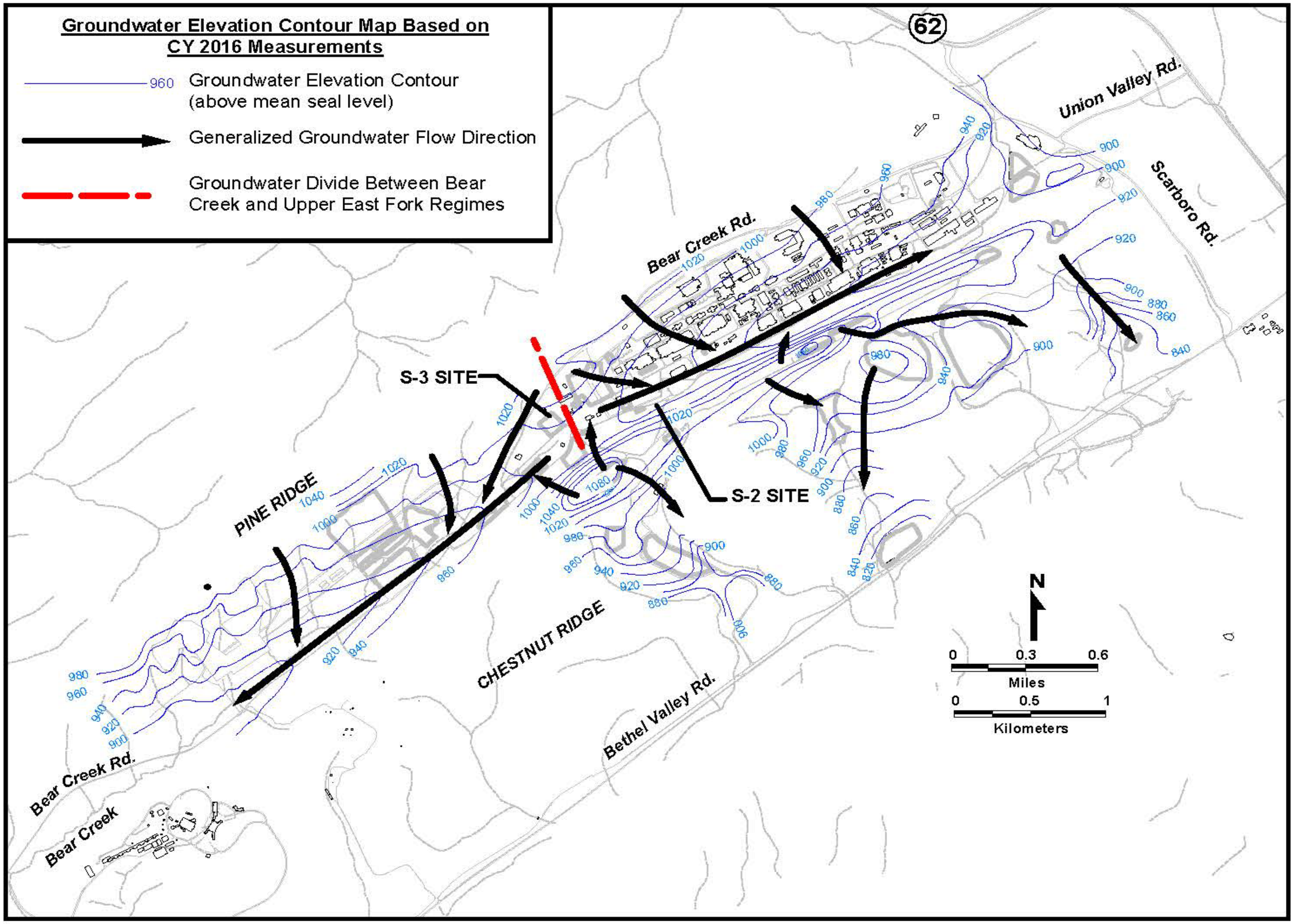


Figure 4.28. Groundwater elevation contours and flow directions at the Y-12 National Security Complex

Contaminant migration is primarily advective (contaminants are transported along with flowing groundwater through the pore spaces, fractures, or conduits of the hydrogeologic system). Strike-parallel transport of some contaminants can occur within the aquitard units for significant distances, where they discharge to surface water tributaries or underground utility and storm water distribution systems in industrial areas. Continuous elevated levels of nitrate (a groundwater contaminant from legacy waste disposals) within the fractured bedrock of the aquitards are known to extend east and west from the S-2 and S-3 sites for thousands of feet. VOCs (e.g., petroleum products, coolants, and solvents) at source units over or in the fractured clastic dominated bedrock 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. However, extensive VOC contamination from multiple sources is observable throughout the groundwater system in both the Bear Creek and upper EFPC regimes, and to a lesser extent in the Chestnut Ridge regime.

Groundwater flow in the Chestnut Ridge regime is through fractures and solution conduits in the Knox Group. Discharge points for intermediate and deep flow are not well known. Groundwater is currently presumed to flow toward Bear Creek Valley to the north and Bethel Valley to the south (Figure 4.28). Groundwater from intermediate and deep zones may discharge at certain spring locations along the flanks of Chestnut Ridge. Following the crest of the 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

A number of monitoring devices have been used for groundwater data collection at the Y-12 Complex. Monitoring wells are permanent devices used for the collection of groundwater samples; they are installed according to established regulatory and industry standards. Figure 4.29 shows a cross-section of a typical groundwater monitoring well. Other devices or techniques (e.g., drive points and direct-push installations) are sometimes used to gather groundwater data.

In CY 2017, at the Environmental Management Waste Management Facility (EMWMF) (see Figure 4.26), a total of nine wells (three clusters of three wells each in the shallow, intermediate, and deep intervals) were installed upgradient of waste cells 1, 2, and 3 (along the EMWMF North Perimeter Road). These wells were installed to support a hydrologic investigation.

No wells were plugged and abandoned in CY 2017.

4.6.3 Calendar Year 2017 Groundwater Monitoring

Groundwater monitoring in CY 2017 was performed to comply with DOE Orders and regulations as part of the Y-12 Complex GWPP, DOE Environmental Management programs such as the Water Resources Restoration Program, and other projects. Compliance requirements were met by monitoring 193 wells and 52 surface water locations and springs (Table 4.20). Figure 4.30 shows the locations of Y-12 Complex perimeter/exit pathway groundwater monitoring stations.

Most of the conventional monitoring wells at the Y-12 Complex were sampled using industry standard methods approved by TDEC and EPA (Figure 4.31).

Comprehensive water quality results of groundwater monitoring activities at the Y-12 Complex in CY 2017 are presented in the *Calendar Year 2017 Groundwater Monitoring Report* (CNS 2018).

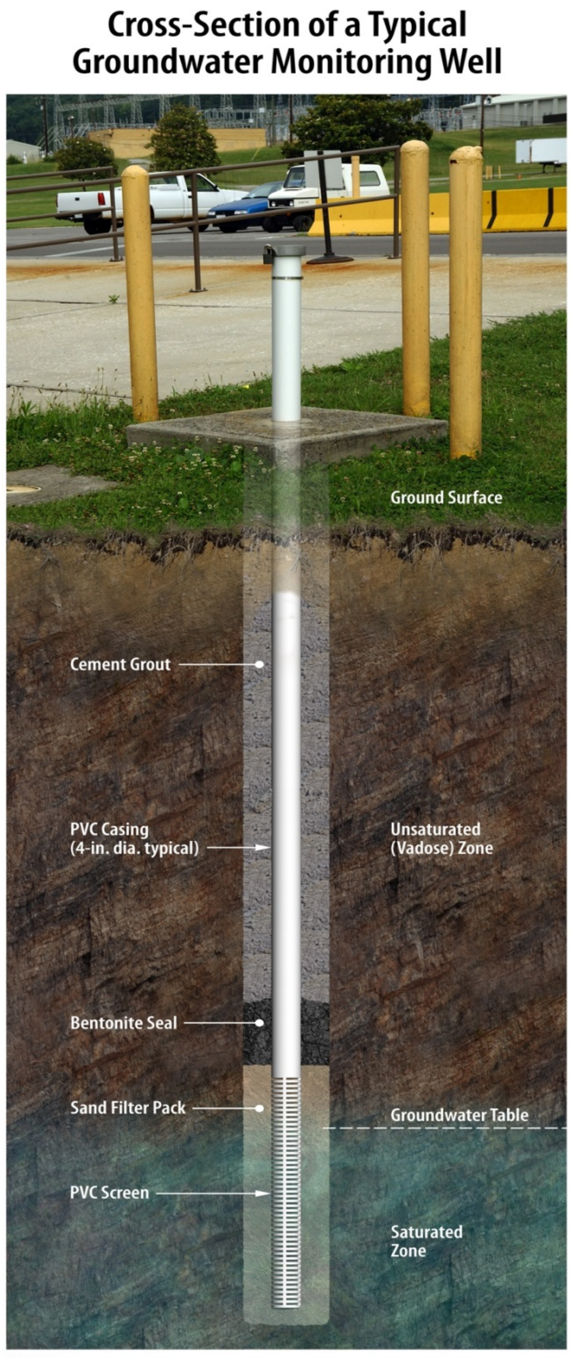


Figure 4.29. Cross-section of a typical groundwater monitoring well

Table 4.20. Summary of groundwater monitoring at the Y-12 National Security Complex, 2017

	Purpose for which monitoring was performed				
	Restoration[a]	Waste management[b]	Surveillance[c]	Other[d]	Total
Number of active wells	63	33	97	27	220
Number of other monitoring stations (e.g., springs, seeps, and surface water)	30	6	16	0	52
Number of samples taken[e]	185	115	119	266	685
Number of analyses performed	9,357	7,860	9,138	4,947	31,302
Percentage of analyses that are non- detects	67.2	90.4	82.9	13.0	69.0
Ranges of results for positive detections, VOCs (μg/L)[f]					
Chloroethenes	0.22-5,500	3.94-7.17	1-39,000	NA	
Chloroethanes	0.38-400	5.38-77.4	0.91-1,200	NA	
Chloromethanes	0.34-1,100	ND	1-870	NA	
Petroleum hydrocarbons	0.32-7,400	ND	1-2,200	NA	
Uranium (mg/L)	0.0005-0.49	0.0227-0.0227	0.0005-0.516	NA	
Nitrates (mg/L)	0.005-6,400	0.543-1.82	0.0554-36,100	0.19-25.13	
Ranges of results for positive detections, radiological parameters (pCi/L)[g]					
Gross-alpha activity	2.04-299	1.22-5.84	4.7-130	NA	
Gross-beta activity	3.53-10,200	2.88-16.6	8.8-940	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] U.S. 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

Bq = becquerel
NA = not analyzed
ND = not detected
pCi/L = picocuries per liter
VOC = volatile organic compound

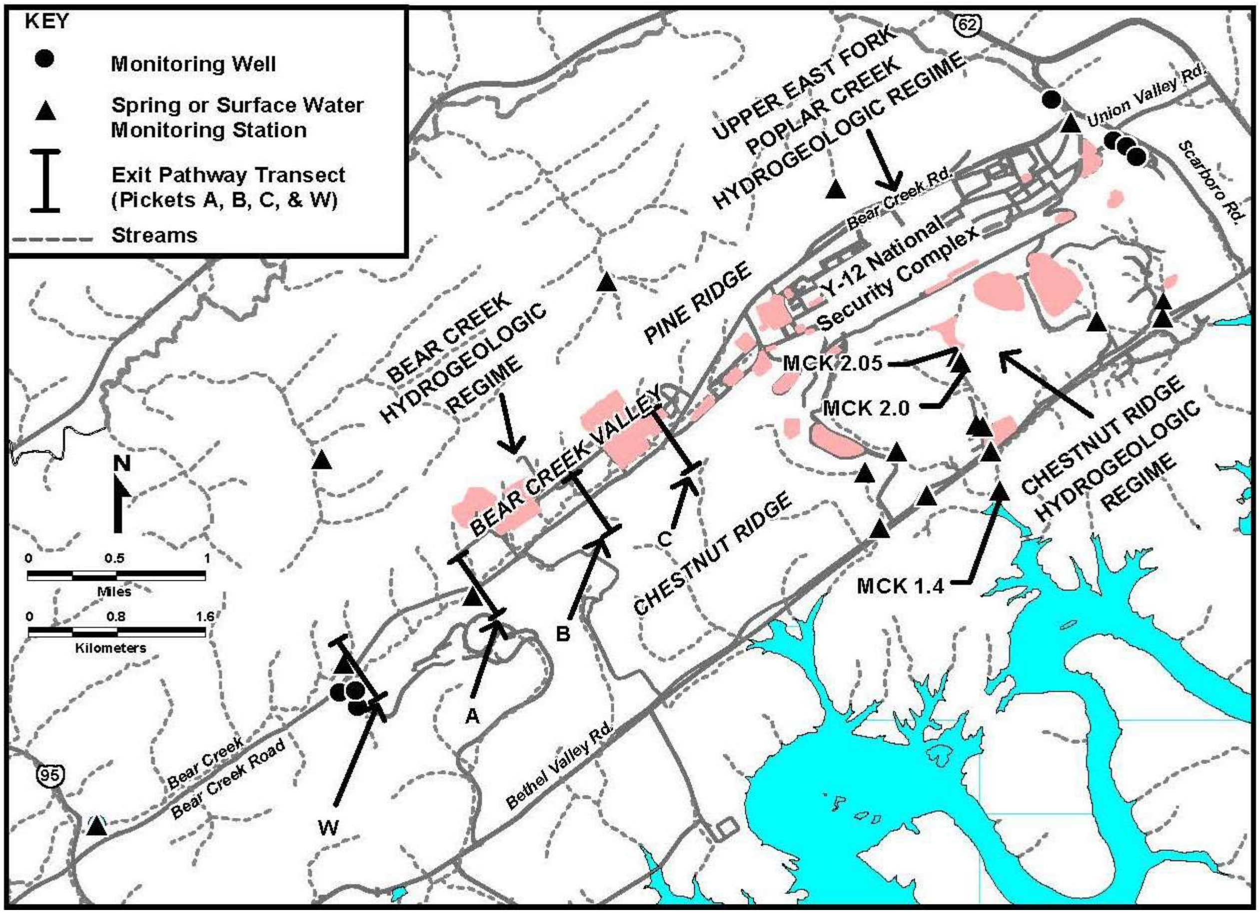


Figure 4.30. Location of Y-12 National Security Complex perimeter/exit pathway well, spring, and surface water monitoring stations *(MCK = McCoy Branch kilometer)*

Figure 4.31. Groundwater monitoring well sampling at the Y-12 National Security Complex *[Source: Kathryn Fahey, Y-12 National Security Complex photographer]*

Details of monitoring efforts performed specifically for CERCLA baseline and remediation evaluation are published in the FY 2017 and FY 2018 Water Resources Restoration Program Sampling and Analysis Plans (UCOR 2016b, 2017b, respectively) and the Annual CERCLA Remediation Effectiveness Report (DOE 2018).

Groundwater monitoring compliance reporting to meet RCRA post-closure permit requirements can be found in the Annual RCRA Groundwater Monitoring Report (UCOR 2018). The associated post-closure permits were terminated effective February 23, 2018, and future data will be reported in the annual CERCLA remediation effectiveness reports.

4.6.4 Y-12 National Security Complex Groundwater Quality

Historical monitoring efforts show that four primary contaminants impact groundwater quality at the Y-12 Complex: nitrate, VOCs, metals, and radionuclides. Of those, VOCs are the most widespread as a result of their common use and disposal at the site. 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 generally high adsorption characteristics. Historical 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 underlying the Y-12 Complex, the upper EFPC regime encompasses most of the known and potential sources of surface water and groundwater contamination. A brief description of waste management sites is given in Table 4.21. Chemical constituents from the S-3 site (primarily nitrate and ^{99}Tc) and VOCs from multiple source areas are observed in the groundwater in the western portion of the upper EFPC regime; groundwater in the eastern portion is predominantly contaminated with VOCs.

Table 4.21. Description of waste management units and underground storage tanks included in groundwater monitoring activities, upper East Fork Poplar Creek hydrogeologic regime, 2017

Site	Description
New Hope Pond	Built in 1963 and closed in 1988. Regulated flow of water in upper East Fork Poplar Creek before exiting the Y-12 Complex. Sediments include PCBs, mercury, and uranium. An oil skimmer basin was built as part of the pond when constructed. This basin collected oil and floating debris from upper East Fork Poplar Creek before discharging into the pond. A minor source of uranium in groundwater, the basin was closed under RCRA in 1990
Salvage Yard Scrap Metal Storage Area	Used from 1950 to 1999 for scrap metal storage. Some metals contaminated with low levels of uranium. In 2011, a CERCLA action to characterize and remove the scrap was completed. Soil characterization and analysis performed in 2010 and 2011 determined that this facility is not a significant risk to groundwater
Salvage Yard Oil/Solvent Drum Storage Area	Operated from 1976 to 1989. Primary wastes included waste oils, solvents, uranium, and beryllium. Closed under RCRA with all drums removed. Soil characterization and analysis performed in 2010 and 2011 determined that this facility is not a significant risk to groundwater
Salvage Yard Oil Storage Tanks	Used from 1978 to 1986. Two tanks used to store PCB-contaminated oil, both within a diked area. Tanks were removed after 1993. Soil characterization and analysis performed in 2010 and 2011 determined that this facility is not a significant risk to groundwater
Salvage Yard Drum Deheader	Used from 1959 to 1989. Sump tanks 2063-U, 2328-U, and 2329-U received residual drum contents. Tanks removed in 1989. Sump leakage was a likely release mechanism to groundwater. The facility was demolished and removed, and the soils beneath this facility were excavated and replaced with clean fill and gravel to remediate the site in 2011
Building 81-10 Area	Mercury recovery facility operated from 1957 to 1962. Historical releases to soil, groundwater, and surface water from leaks and spills of liquid wastes or mercury. The building structure was demolished in 1995
Rust Garage Area	Former vehicle and equipment maintenance area, including four former petroleum USTs. All tanks were removed by 1990. Petroleum product releases to groundwater are documented
Building 9418-3 Uranium Oxide Vault	Originally contained an oil storage tank. Used from 1960 to 1964 to dispose of non-enriched uranium oxide. Leakage from the vault to groundwater is the likely release mechanism
Fire Training Facility	Used for hands-on firefighting training. Sources of contamination to soil include flammable liquids and chlorinated solvents. Infiltration is the primary release mechanism to groundwater
Beta-4 Security Pits	Used from 1968 to 1972 for disposal of classified materials, scrap metals, and liquid wastes. Site is closed and capped. Primary release mechanism to groundwater is infiltration
S-2 site	Used from 1945 to 1951. An unlined reservoir received liquid wastes. Infiltration is the primary release mechanism to groundwater
Waste Coolant Processing Area	Used from 1977 to 1985. Former biodegradation facility used to treat waste coolants from various machining processes. Closed under RCRA in 1988
East End Garage	Used from 1945 to 1989 as a vehicle fueling station. Five USTs used for petroleum fuel storage were excavated, 1989 to 1993. Petroleum releases to the groundwater are documented. The Bldg. 9754 Fuel Station transfer lines and dispenser tanks were removed in October 1993

Table 4.21. Description of waste management units and underground storage tanks included in groundwater monitoring activities, upper East Fork Poplar Creek hydrogeologic regime, 2017 (continued)

Site	Description
Coal Pile Trench	Located beneath the former steam plant coal pile. Disposals included solid materials (primarily alloys). Trench leachate is a potential release mechanism to groundwater. In 2011, the coal pile overlying the coal pile trench was removed and the area resurfaced with gravel

CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
PCB = polychlorinated biphenyl
RCRA = Resource Conservation and Recovery Act
UST = underground storage tank
Y-12 Complex = Y-12 National Security Complex

Plume Delineation

Sources of groundwater contaminants monitored during CY 2017 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 the Y-12 Complex. Although the S-3 site, now closed under RCRA, is located west of the current hydrologic divide that separates the upper EFPC regime from the Bear Creek regime, it has contributed to groundwater contamination in the western part of the upper EFPC regime. Contaminant plumes in the upper EFPC regime are elongated in shape 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 units.

The plumes depicted in this section reflect the average concentrations and radioactivity in groundwater between CYs 2008 and 2012. The circular icons presented on the plume maps (Figures 4.32 through 4.35) represent CY 2017 monitoring results.

In CY 2013, the Y-12 Complex GWPP evaluated the extent of current groundwater contamination and updated the plume maps for a number of contaminants of concern, including the primary contaminants (B&W 2013). In CY 2015, the document was revised to graphically depict areas of increasing and decreasing trends based on statistical methods (CNS 2015). Plume maps in previous Annual Site Environmental Reports (ASERs) were developed from those presented in CERCLA RIs that took place in the late 1990s (DOE 1997, 1998). The RI plume maps were determined to be representative of groundwater contamination at the Y-12 Complex during the years subsequent to publication and were considered relevant for presentation in the ASERs. The updated maps are based on the more-extensive and more-recent sampling and analysis results, which include data not available for the RIs (e.g., existing or new wells being sampled subsequent to the RIs). These results were used to capture current groundwater conditions, and in some areas, reflect substantially different (higher or lower) contaminant concentrations than the data used during the RIs. These changes are due to improved data availability and/or changes within the hydrogeologic system (i.e., plume migration and/or degradation processes) either related to time and natural processes or as a result of actions taken to mitigate groundwater contamination (i.e., the east end VOC plume capture system, see VOCs discussion below).

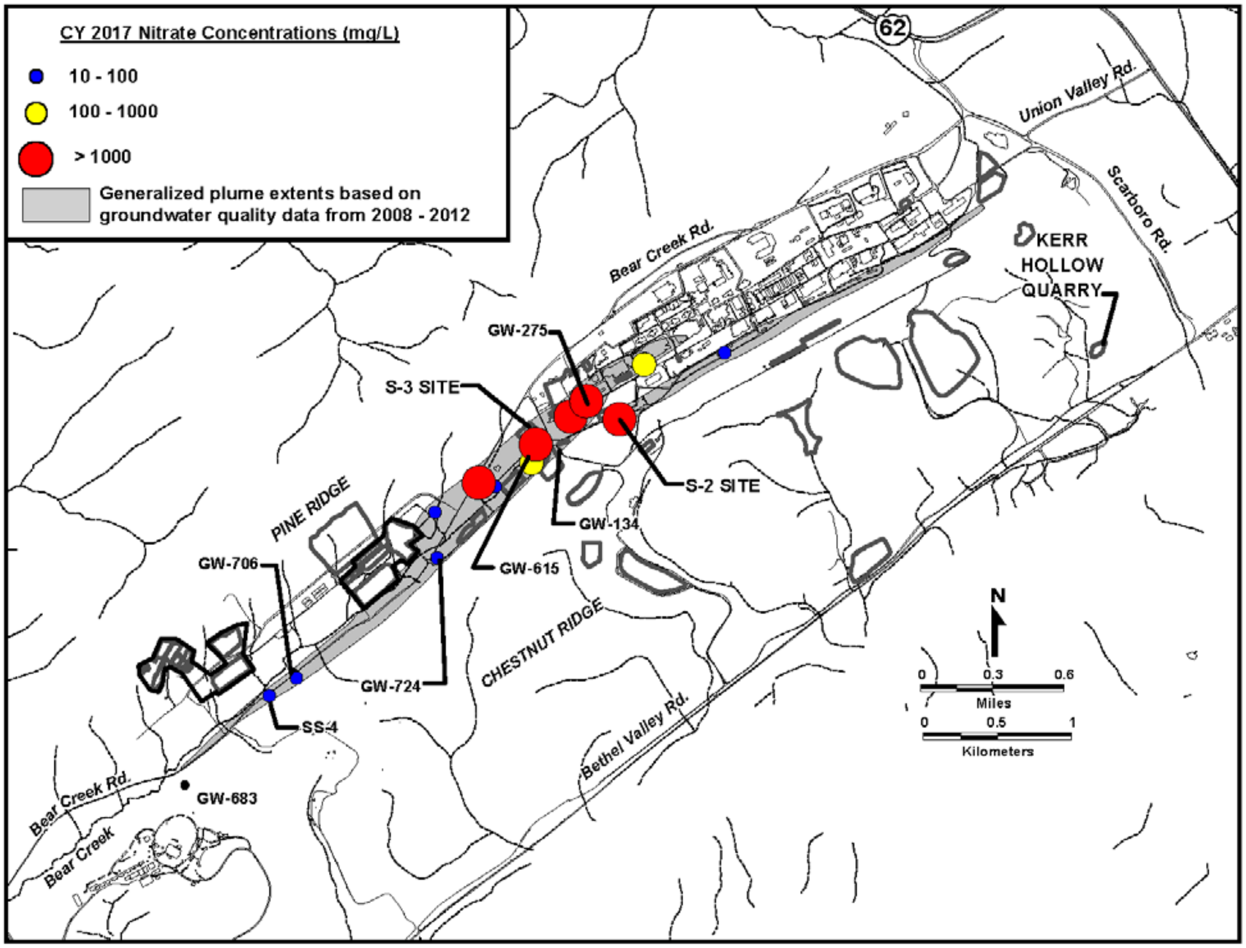


Figure 4.32. Nitrate observed in groundwater at the Y-12 National Security Complex, 2017

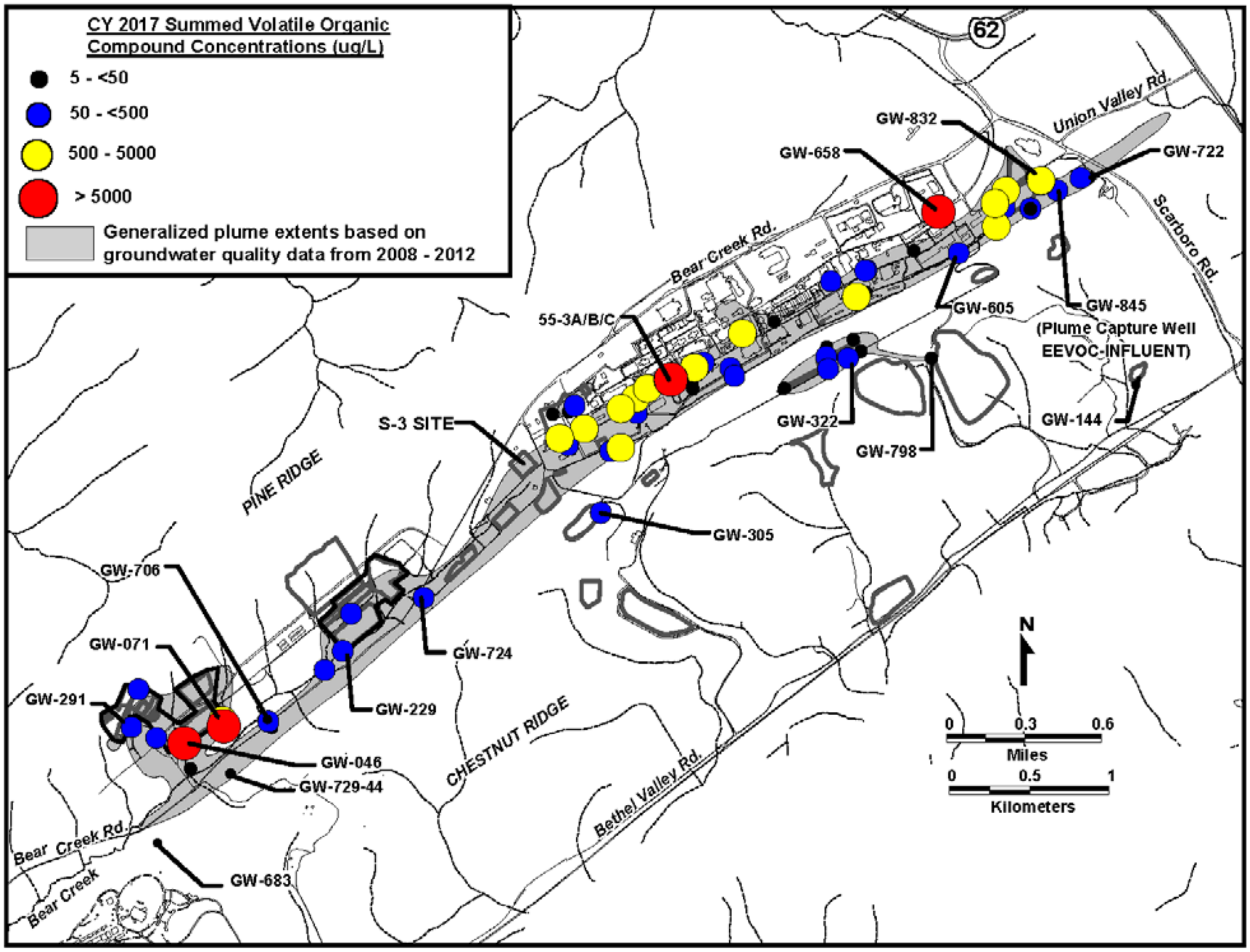


Figure 4.33. Summed volatile organic compounds observed in groundwater at the Y-12 National Security Complex, 2017 *(EEVOC = east end volatile organic compound.)*

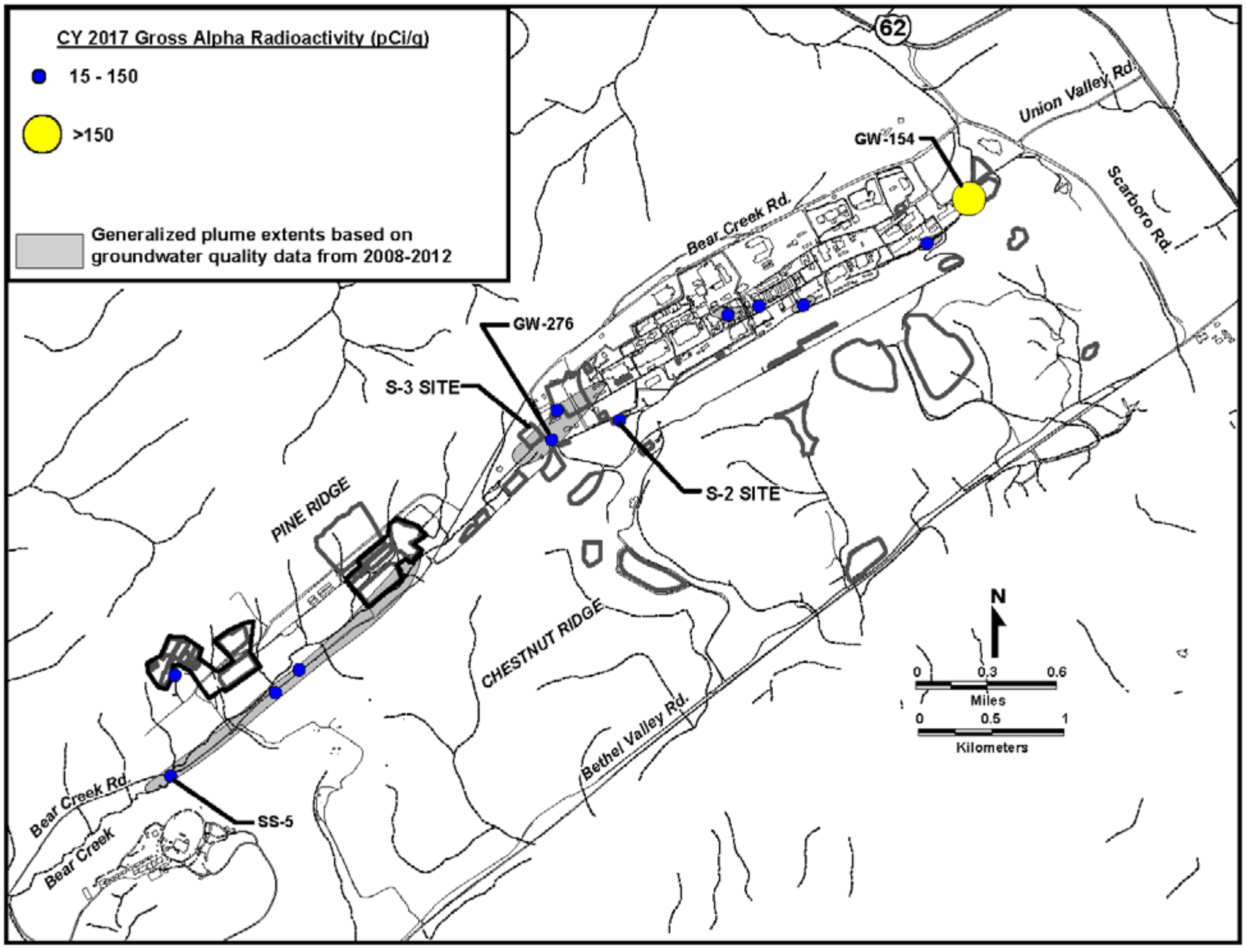


Figure 4.34. Gross-alpha activity observed in groundwater at the Y-12 National Security Complex, 2017

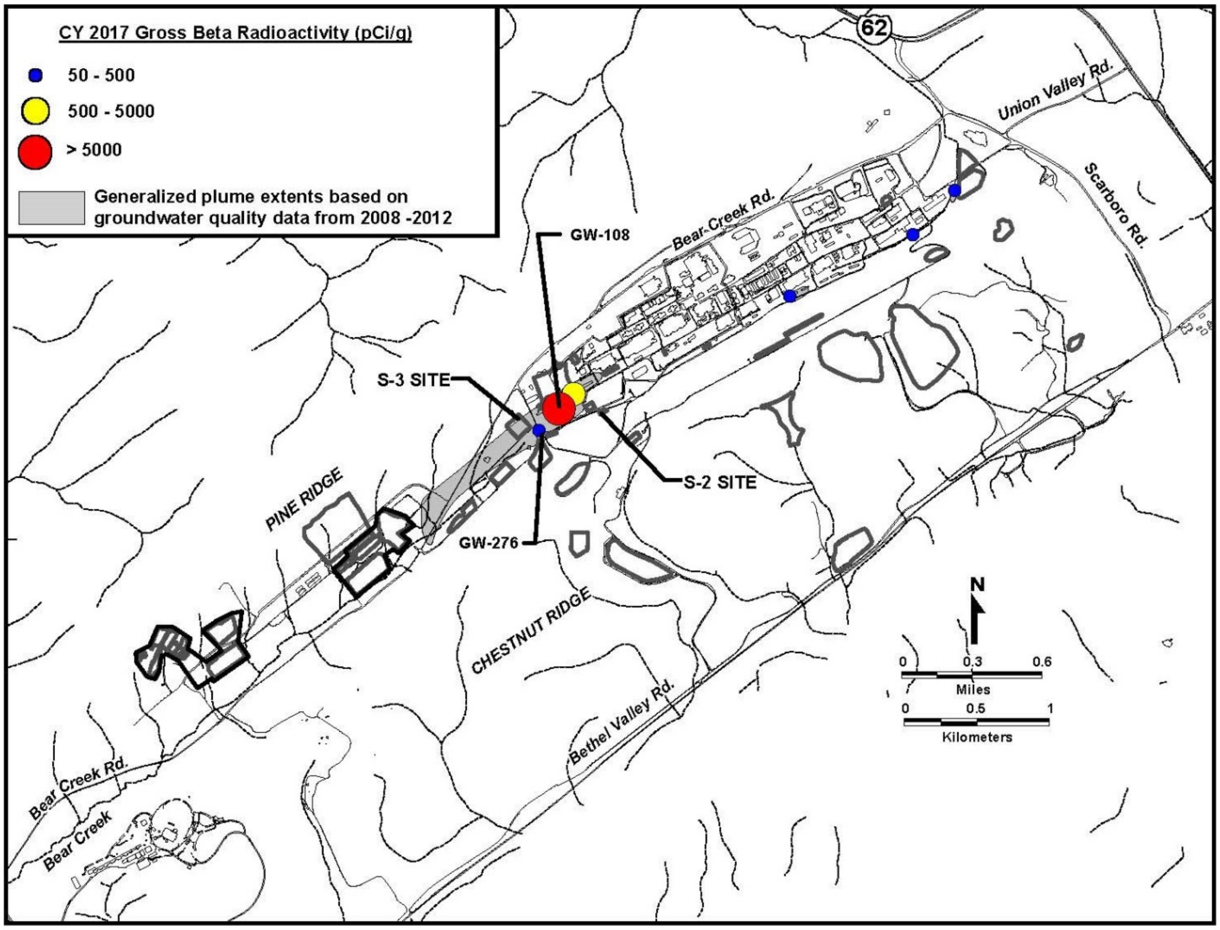


Figure 4.35. Gross-beta activity observed in groundwater at the Y-12 National Security Complex, 2017

Nitrate

Unlike many groundwater contaminants, nitrate is highly soluble and moves easily with groundwater. Nitrate concentrations in groundwater at the Y-12 Complex exceed the 10-mg/L drinking water standard (a complete list of national drinking water standards is presented in Appendix C) in part of the western portion of the upper EFPC regime in the aquitard units and in the Maynardville Limestone unit of the Knox aquifer. The two primary sources of nitrate contamination are the S-2 and S-3 sites. The extent of the nitrate plume is essentially defined in the unconsolidated and shallow bedrock zones. In CY 2017, groundwater concentrations of nitrate as high as 36,100 mg/L (well GW-275) were observed in the shallow–intermediate bedrock intervals about 20 m (65 ft) below ground surface and about 396 m (1,300 ft) east of the S-3 site (Figure 4.32). This result was anomalously high (even an historic high) compared with previous years. The laboratory QC batch file was reviewed, and nothing was noted to point to an analytical problem or a calculation error. Therefore, the well was resampled the following quarter with a result of 9,700 mg/L. This result is consistent with results from previous years. The spike is unexplained and is considered an outlier.

Trace Metals

Concentrations of barium, beryllium, cadmium, chromium, copper, lead, nickel, thallium, and uranium exceeded drinking water standards during CY 2017 in samples collected from various groundwater monitoring locations throughout the complex, specifically at and downgradient of the S-2 and S-3 sites. Trace metal concentrations above standards tend to occur only adjacent to source areas due to their low solubility in natural water systems and high adsorption to the clay-rich soils and bedrock underlying the Y-12 Complex.

Concentrations of uranium exceed the standard (0.03 mg/L) in a number of source areas (e.g., the S-3 site, the Uranium Oxide Vault, New Hope Pond, and the former oil skimmer basin) and contribute to the uranium concentration in the upper EFPC.

Volatile Organic Compounds

Because of the many legacy source areas, VOCs are the most widespread groundwater contaminants in the upper EFPC regime. VOC contaminants in the regime primarily consist of chlorinated and petroleum hydrocarbons. In CY 2017, the highest summed concentration of dissolved chlorinated hydrocarbons (46,268 µg/L) was again found in groundwater at well 55-3B in the western portion of the Y-12 Complex, adjacent to currently inactive manufacturing facilities. The highest dissolved concentration of petroleum hydrocarbons (16,380 µg/L) was obtained from well GW-658 at the closed East End Garage.

These monitoring results are consistent with data from the previous years of monitoring. A continuous dissolved plume of VOCs in groundwater in the bedrock zone extends eastward from the S-3 site over the entire length of the regime (Figure 4.33). The primary sources are the Waste Coolant Processing Facility, fuel facilities (Rust Garage and East End Garage), and other waste-disposal and production areas throughout the Y-12 Complex. Chloroethene compounds (tetrachloroethene [PCE], trichloroethene [TCE], dichloroethene [DCE], and vinyl chloride) tend to dominate the volatile organic plume composition in the western and central portions of the Y-12 Complex. However, PCE is almost ubiquitous throughout the extent of the plume, indicating many source areas. Chloromethane compounds (carbon tetrachloride, chloroform, and methylene chloride) are the predominant VOCs in the eastern portion of the Y-12 Complex.

Variability in concentration trends of chlorinated and petroleum VOCs near source areas is seen within the upper EFPC regime. As seen in previous years, data from most of the monitoring wells have remained relatively constant (i.e., stable concentration trends) or have decreased since 1988. However, increasing trends have been observed in monitoring wells associated with the Rust Garage, Old Salvage Yard, and

S-3 site in the western part of the Y-12 Complex; some legacy sources at production/process facilities in central areas; and the east end VOC plume, indicating that some portions of the plume are still showing activity.

Within the exit pathway (the Maynardville Limestone underlying EFPC), the general trends are also stable or decreasing. However, one shallow well (GW-605) exhibits an increasing trend in chloroethenes, indicating active transport in that region of the groundwater plume. The well is west and upgradient of the pumping well (GW-845) operated to capture the east end VOC plume before it migrates off ORR into Union Valley. The pumping well may be influencing plume stability, causing mobilization in the region of well GW-605. Other than well GW-605, the decreasing and stable trends west of New Hope Pond are indicators that the contaminants from source areas are attenuating due to factors such as: (1) dilution by surrounding uncontaminated groundwater, (2) dispersion through a complex network of fractures and conduits, (3) degradation by chemical or biological means, and/or (4) adsorption by surrounding bedrock and soil media. Wells to the southwest and southeast of New Hope Pond are displaying the effects of pumping well GW-845.

Wells east of New Hope Pond and north of well GW-845 exhibit stable to increasing trends in VOC concentrations, indicating that little impact or attenuation from the plume capture system is apparent across lithologic units (perpendicular to strike). However, no subsequent downgradient detection of these compounds is apparent; therefore, either migration is limited, or some downgradient across-strike influence by the plume capture system is occurring.

Radionuclides

The primary alpha-emitting radionuclides found in the upper EFPC regime during CY 2017 are isotopes of uranium. These radionuclides are not as widely occurring in groundwater as VOCs. Exceedances of the drinking water standard for gross alpha (15 pCi/L) have been observed in the western portion of the Y-12 Complex near the S-3 site, the Salvage Yard, and other 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 2017, the maximum occurrence of gross-alpha activity in groundwater in the upper EFPC regime was 299 pCi/L at well GW-154 on the east end (Figure 4.34).

The primary beta-emitting radionuclides observed in the upper EFPC regime are ^{99}Tc and isotopes of uranium. Elevated gross-beta activity in groundwater in the upper EFPC regime shows a pattern similar to that observed for historical gross-alpha activity on the west end of the Y-12 Complex.

Technetium-99 is the primary contaminant exceeding the screening level of 50 pCi/L; the source is the S-3 site (Figure 4.35). The highest gross-beta activity in groundwater was observed during CY 2017 from well GW-108 (10,200 pCi/L), east of the S-3 site.

Exit Pathway and Perimeter Monitoring

Data collected to date indicate that VOCs are the primary class of contaminants migrating through the exit pathways in the upper EFPC regime. Historically, the compounds have been observed at depths of up to 500 ft below ground surface in the Maynardville Limestone, the primary exit pathway for groundwater on the east end of the Y-12 Complex. The deep fractures and solution channels that constitute flow paths within the Maynardville Limestone appear to be well connected, resulting in contaminant migration for substantial distances off ORR into Union Valley to the east of the Y-12 Complex.

In addition to the intermediate-to-deep pathways within the Maynardville Limestone, shallow groundwater within the water table interval near New Hope Pond, Lake Reality, and upper EFPC is also monitored. Historically, VOCs have been observed near Lake Reality from monitoring wells, a dewatering sump, and the New Hope Pond distribution channel underdrain (GW-832). In that area, shallow groundwater flows north-northeast through the water table interval east of New Hope Pond and Lake Reality, following the path of the distribution channel for upper EFPC.

During CY 2017, the observed concentrations of VOCs at the New Hope Pond distribution channel underdrain remained low (28.6 µg/L). This may be because the continued operation of the groundwater plume capture system in well GW-845 southeast of New Hope Pond is effectively reducing the levels of VOCs in the area. The installation of the plume capture system (the East End VOC Treatment System [EEVOCTS]) was completed in June 2000. This system pumps groundwater from the intermediate bedrock 48 to 134 m (157 to 438 ft) below ground surface to mitigate off-site migration of VOCs. 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.

Monitoring wells near well GW-845 continue to show an encouraging response to the EEVOCTS operations. The Westbay™ multiport system installed in well GW-722 in 1991, about 153 m (500 ft) east and downgradient of well GW-845, permits sampling of vertically discrete zones within the Maynardville Limestone between 27 and 130 m (87 and 425 ft) below ground surface (Figure 4.33). This well has been instrumental in characterizing the vertical extent of the east-end plume of VOCs and is critical in the evaluation of the effectiveness of the plume capture system. Monitoring results from the sampled zones in well GW-722 indicate reductions in VOCs due to groundwater pumping upgradient at well GW-845, as shown in sample zone GW-722-17 (385 ft below ground surface) in Figure 4.36. Other wells also show decreases that may be attributable to the EEVOCTS operation. These indicators demonstrate that operation of the plume capture system is decreasing VOCs upgradient and downgradient of well GW-845, minimizing exposure to the public and the environment.

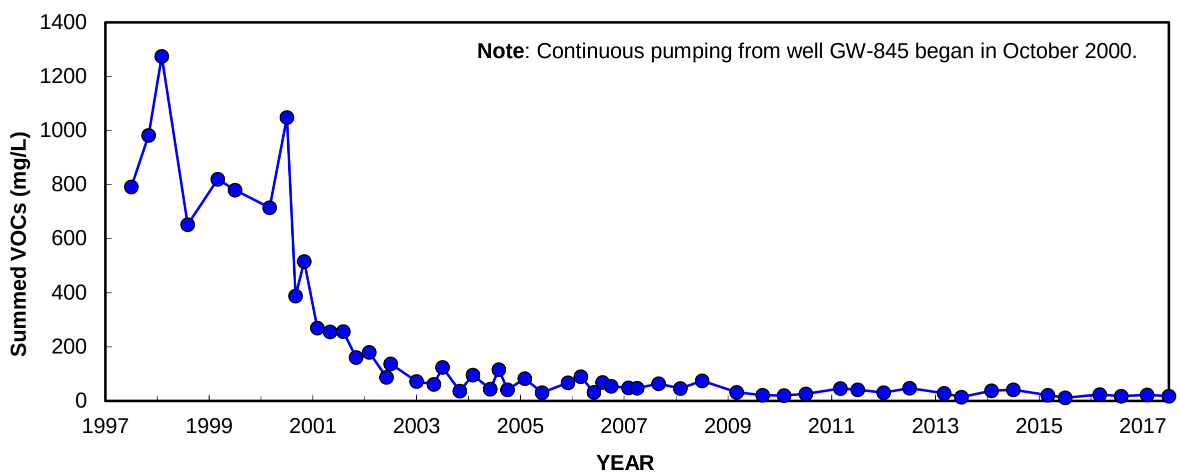


Figure 4.36. Decreasing summed volatile organic compounds observed in exit pathway well GW-722-17 near New Hope Pond, 2017

Ten zones of monitoring well GW-722 were sampled in CY 2017, with 8 of the 10 zones showing summed VOCs greater than 5 µg/L. Only four zones exceeded individual drinking standards (from elevated detections of carbon tetrachloride, PCE, and TCE, the highest of which was 24 µg/L of carbon tetrachloride). Other (atypical) VOCs observed in these zones were acetone; acrylonitrile; chloroform; cis-1,2-DCE; ethylbenzene; styrene; and toluene.

The atypical VOCs were present for four reasons: (1) acetone was detected in 8 of 10 zones sampled and is likely a sampling artifact and not from groundwater; (2) acrylonitrile and styrene were detected in 7 of the 10 zones (according to the manufacturer, older Westbay™ sampling systems contain components made with acrylonitrile and styrene, and detection of those compounds is often an artifact from sampling ports in low-permeability zones); (3) five zone samples yielded chloroform and cis-1,2-DCE results, common degradation product of carbon tetrachloride, PCE, and TCE; and (4) traces of petroleum hydrocarbons (ethylbenzene and toluene) were detected in 7 of the 10 zones (traces of petroleum hydrocarbons naturally present at depth in the low-permeability bedrock may explain the detection of those compounds). Natural hydrocarbons have been observed in groundwater samples from other deep wells installed in carbonate units (limestone and dolomite) on the ORR.

Upper EFPC flows north from the Y-12 Complex through a large gap in Pine Ridge. Shallow groundwater moves through that exit pathway, and very strong upward vertical flow gradients exist. Continued monitoring of the wells in this pathway gap since about 1990 has shown no indication of any contaminants moving via that exit pathway (Figure 4.30.) One shallow well was monitored in CY 2017, and no groundwater contaminants were observed above primary drinking water standards.

Sampling locations continue to be monitored north and northwest of the Y-12 Complex to evaluate possible contaminant transport from the ORR. Those locations are considered unlikely groundwater or surface water contaminant exit pathways. Monitoring continues to be performed to demonstrate no impact from Y-12 Complex activities. One of the stations monitored is a tributary that drains the north slope of Pine Ridge on the perimeter of the ORR 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 discharges from the perimeter of the ORR and flows adjacent to the Country Club Estates community. Samples were obtained and analyzed for metals, inorganic parameters, VOCs, and gross-alpha and gross-beta activities. No results exceeded a primary drinking water standard, and there were no indications that contaminants were being discharged from the ORR into those communities.

Union Valley Monitoring

Groundwater monitoring data obtained during the early 1990s provided the first strong indication that VOCs were being transported off ORR through the deep Maynardville Limestone exit pathway. The upper EFPC RI (DOE 1998) discussed the nature and extent of the VOCs.

In CY 2017, monitoring of locations in Union Valley continued, showing overall decreasing or very low concentration stable trends (less than primary drinking water standards) in the individual concentrations of contaminants forming the groundwater contaminant plume in Union Valley.

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 EEVOCTS (well GW-845) was installed, and operations were initiated to mitigate the migration of groundwater contaminated with VOCs into Union Valley (DOE 2018).

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 the ORR was evaluated (ATSDR 2006). In the report, it was acknowledged that extensive groundwater contamination exists throughout the ORR, but the authors concluded that there is no public health hazard from exposure to contaminated groundwater originating on the ORR. The Y-12 Complex 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 the Y-12 Complex 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 the Y-12 Complex to State Highway 95. **Table 4.22** describes each of the waste management sites within the Bear Creek regime.

Table 4.22. Description of waste management units included in 2017 groundwater monitoring activities, Bear Creek hydrogeologic regime

Site	Description
S-3 site	Four unlined surface impoundments constructed in 1951. Received liquid nitric acid/uranium-bearing wastes via the nitric acid pipeline until 1983. Other disposals included ^{99}Tc. Closed and capped under RCRA in 1988. Infiltration was the primary release mechanism to groundwater
Oil Landfarm	Operated from 1973 to 1982. Received waste oils and coolants tainted with metals and PCBs. Closed and capped under RCRA in 1989. Infiltration was the primary release mechanism to groundwater
Boneyard	Used from 1943 to 1970. Unlined shallow trenches used to dispose of construction debris and to burn magnesium chips and wood. Excavated and restored in 2002 and 2003 as part of Boneyard-Burnyard remedial activities
Burnyard	Used from 1943 to 1968. Wastes, metal shavings, solvents, oils, and laboratory chemicals were burned in two unlined trenches. Excavated and restored in 2002 and 2003 as part of the Boneyard-Burnyard remedial activities
Hazardous Chemical Disposal Area	Used from 1975 to 1981. Built over the Burnyard. Handled compressed gas cylinders and reactive chemicals. Residues placed in a small, unlined pit. The northwest portion was excavated and restored in 2002 and 2003 as part of Boneyard-Burnyard remedial activities
Sanitary Landfill I	Used from 1968 to 1982. Non-hazardous industrial landfill. May be a source of certain contaminants to groundwater. Closed and capped under TDEC requirements in 1985. Evaluation under CERCLA determined that no further action was need
Bear Creek Burial Grounds A and C and Walk-In Pits	Burial grounds A and C received waste oils, coolants, beryllium, uranium, various metallic wastes, and asbestos into unlined trenches and standpipes. The walk-in pits received chemical wastes, shock-sensitive reagents, and uranium saw fines. Activities ceased in 1981. Final closure was certified for A (1989), C (1993), and the walk-in pits (1995). Infiltration is the primary release mechanism to groundwater
Bear Creek Burial Grounds B, D, E, and J and Oil Retention Ponds 1 and 2	Burial grounds B, D, E, and J consisted of unlined trenches. These burial grounds received uranium chip, metal, and oxide wastes and uranium-contaminated debris. Ponds 1 and 2, built in 1971 and 1972, respectively, captured waste oils seeping into two Bear Creek tributaries. The ponds were closed and capped under RCRA in 1989. Certification of closure and capping of Burial Ground B and part of C was granted in February 1995
Rust Spoil Area	Used from 1975 to 1983 for disposal of construction debris but may have included materials bearing solvents, asbestos, mercury, and uranium. Closed under RCRA in 1984. Site is a source of VOCs to shallow groundwater according to CERCLA remedial investigation and current surveillance monitoring

Table 4.22. Description of waste management units included in 2017 groundwater monitoring activities, Bear Creek hydrogeologic regime (continued)

Site	Description
Spoil Area I	Used from 1980 to 1988 for disposal of construction debris and other stable, non-radioactive wastes. Permitted under TDEC solid waste management regulations in 1986; closure began shortly thereafter. Soil contamination is of primary concern. CERCLA ROD issued in 1997
SY-200 Yard	Used from 1950 to 1986 for equipment and materials storage. No documented waste disposal at the site occurred. Leaks, spills, and soil contamination are concerns. CERCLA ROD issued in 1996
Environmental Management Waste Management Facility	A CERCLA ROD defines the construction, operation, and closure of this on-site facility for disposal of radioactive, hazardous, and mixed wastes generated from CERCLA cleanup projects conducted on the ORR and associated sites. The facility began accepting wastes in 2002 with full capacity estimated to be reached in FY 2023

CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
FY = Fiscal Year
ORR = Oak Ridge Reservation
PCB = polychlorinated biphenyl
RCRA = Resource Conservation and Recovery Act
ROD = Record of Decision
99TC = technetium-99
TDEC = Tennessee Department of Environment and Conservation
VOC = volatile organic compound

Plume Delineation

The primary groundwater 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 significant sources of uranium, other trace metals, and VOCs. High concentrations of chlorinated hydrocarbons and PCBs have been observed as deep as 82 m (270 ft) below the Bear Creek Burial Grounds (MMES 1990).

Contaminant plume boundaries are essentially defined by the bedrock formations that directly underlie many waste disposal areas in the Bear Creek regime, particularly the Nolichucky Shale. This fractured aquitard unit is positioned north of and adjacent to the exit pathway unit, the Maynardville Limestone. The elongated shape of the contaminant plumes in the Bear Creek regime is the result of preferential transport of the contaminants parallel to strike (parallel to the valley axis) in the Maynardville Limestone and the aquitard units.

The plumes depicted in this section reflect the average concentrations and radioactivity in groundwater between CYs 2008 and 2012. The circular icons presented on the plume maps (Figures 4.32 through 4.35) represent CY 2017 monitoring results. (See Section 4.6.4.1 for more details.)

Nitrate

The limits of the nitrate plume probably define the maximum extent of groundwater contamination in the Bear Creek regime. The horizontal extent of the nitrate plume is defined in groundwater in the upper to intermediate bedrock intervals of the aquitard units and Knox aquifer (less than 92 m [300 ft] below ground surface).

Data obtained during CY 2017 indicate that nitrate concentrations in groundwater continue to exceed the drinking water standard (10 mg/L) in an area that extends west from the source area at the S-3 site. The highest nitrate concentration (12,400 mg/L) was observed at well GW-615 adjacent to the S-3 site at a depth of 75 m (247 ft) below ground surface (Figure 4.37). Samples drawn from multiport monitoring well GW-134 in CY 2011 showed elevated concentrations of nitrate (1,420 mg/L) as deep as 226 m (740 ft) below ground surface near the S-3 site source area. Concentrations exceeding the drinking water standard in CY 2017 were observed in groundwater as far as 2,438 m (8,000 ft) west of the S-3 site, discharging natural spring SS-4.

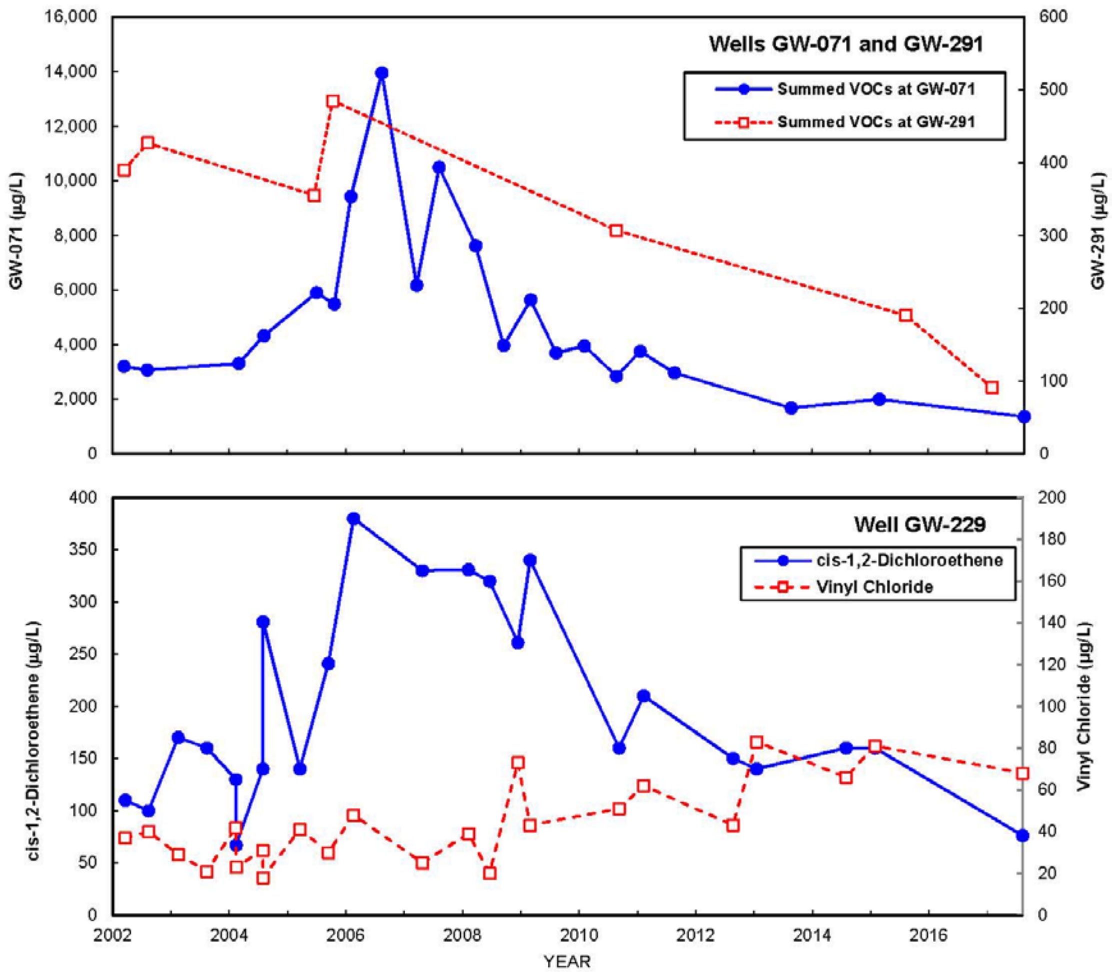


Figure 4.37. Volatile organic compounds observed in groundwater at wells GW-071 and GW-291 at the Bear Creek Burial Grounds and GW-229 at the Oil Landfarm, 2017

Trace Metals

During CY 2017, barium, cadmium, nickel, and uranium were identified from groundwater monitoring as the trace metal contaminants in the Bear Creek regime that exceeded drinking water standards. Historically, elevated concentrations of many of the trace metals were observed at shallow depths near the S-3 site. In 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. 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.

The most prevalent trace metal contaminant observed within the Bear Creek regime is uranium. Early characterization indicated that the Boneyard-Burnyard site was the primary source of uranium contamination of surface water and groundwater. Historically, uranium has been observed at concentrations exceeding the drinking water standard of 0.03 mg/L in shallow monitoring wells, springs, and surface water locations downgradient from many of the waste areas. In 2003, the final remedial actions at the Boneyard-Burnyard were performed with the objective of removing materials contributing to surface water and groundwater contamination to meet existing ROD goals. About 65,752 m^3 (86,000 yd^3) of waste materials were excavated and placed in the EMWMF (DOE 2007). There were significant decreases in uranium concentration and flux in the surface water tributary immediately downstream of the Boneyard-Burnyard (NT-3), which indicate that remedial actions performed from 2002 to 2003 were successful in removing much of a primary source of uranium in Bear Creek Valley. There has been an overall decrease in uranium concentrations in Bear Creek since 1990 (Table 4.23); however, concentrations of uranium in the upper reaches of Bear Creek have been fairly stable, indicating that this contaminant still presents a significant impact in surface water and groundwater.

Table 4.23. 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	2015–2017
BCK[b]-11.84 to 11.97	Nitrate	116	65.7	89.5	43.3	53.3	28.2
(approximately 0.5 miles downstream)	Uranium	0.203	0.112	0.129	0.112	0.172	0.214
BCK-09.20 to 09.47	Nitrate	16.1	7.8	12.1	8.4	4.4	4.7
(approximately 2 miles downstream)	Uranium	0.098	0.093	0.135	0.060	0.051	0.063
BCK-04.55	Nitrate	4.7	2.3	3.5	1.1	0.8	0.7
(approximately 5 miles downstream)	Uranium	0.034	0.030	0.033	0.020	0.016	0.018

[a]Excludes results that do not meet data quality objectives.
[b]BCK = Bear Creek kilometer.

Additional monitoring is ongoing in an attempt to determine uranium inputs to the stream from source areas and the karst groundwater system underlying Bear Creek. Other trace metals historically observed in the groundwater of the Bear Creek regime are arsenic, beryllium, boron, chromium, copper, lead, mercury, selenium, strontium, thallium, and zinc. Concentrations have commonly exceeded background values in groundwater near contaminant source areas.

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. Groundwater in the fractured bedrock of the aquitard units that contain detectable levels of VOCs occurs within about 305 m (1,000 ft) laterally of the source areas. The highest concentrations observed in CY 2017 in the Bear Creek regime occurred in the Nolichucky shale bedrock unit (an aquitard) at the Bear Creek Burial Ground waste management area, with a maximum summed VOC concentration of 8,484 µg/L in well GW-046 (Figure 4.33).

Near contaminant source areas, such as the Bear Creek Burial Grounds and the Oil Landfarm waste management areas, a variety of elevated concentration trends is observed. These trends are dependent upon proximity to sources and hydrogeologic conditions. Decreasing and stable VOC trends dominate, as observed in wells GW-071 and GW-291, but there are observable increasing trends, such as vinyl chloride in well GW-229 (Figure 4.37). In well GW-229, the VOCs cis-1,2-DCE and vinyl chloride are likely degradation products of TCE (not shown on the figure).

Significant transport of VOCs has occurred in the Maynardville Limestone. Historical data obtained from monitoring well GW-729-44 shows that, in the intermediate-deep groundwater interval (98 m [320 ft] below ground surface), an apparently continuous dissolved plume extends at least 2,591 m (8,500 ft) westward from the S-3 site to just south of the Bear Creek Burial Ground waste management area. CY 2017 samples obtained from wells at exit pathway transect W (Figure 4.30) showed qualitatively detectable trace concentrations of VOCs (below drinking water standards), thus indicating migration (periodic or sporadic extensions) of contaminants through the Maynardville Limestones a distance of 4,785 m (15,700 ft) from the S-3 Ponds (DOE 2018).

Radionuclides

As in the East Fork Regime, the primary radionuclides identified in the Bear Creek regime are isotopes of uranium and 99Tc. Neptunium, americium, radium, strontium, thorium, plutonium, and tritium are secondary and less-widespread radionuclides that historically have been observed in groundwater near the S-3 site.

Evaluations of the extents of radionuclides in groundwater in the Bear Creek regime during CY 2017 were based primarily on measurements of gross-alpha and gross-beta activity. If the annual average gross-alpha activity in groundwater samples from 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 at elevated levels in the groundwater monitored by the well and, at certain monitoring locations, is evaluated isotopically. A similar rationale is used for annual average 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 levels of gross-alpha activity occurs near the S-3 site and the Oil Landfarm waste management area. In the bedrock interval, gross-alpha activity has historically exceeded 15 pCi/L in groundwater in the fractured bedrock of the aquitard units only near source areas (Figure 4.34).

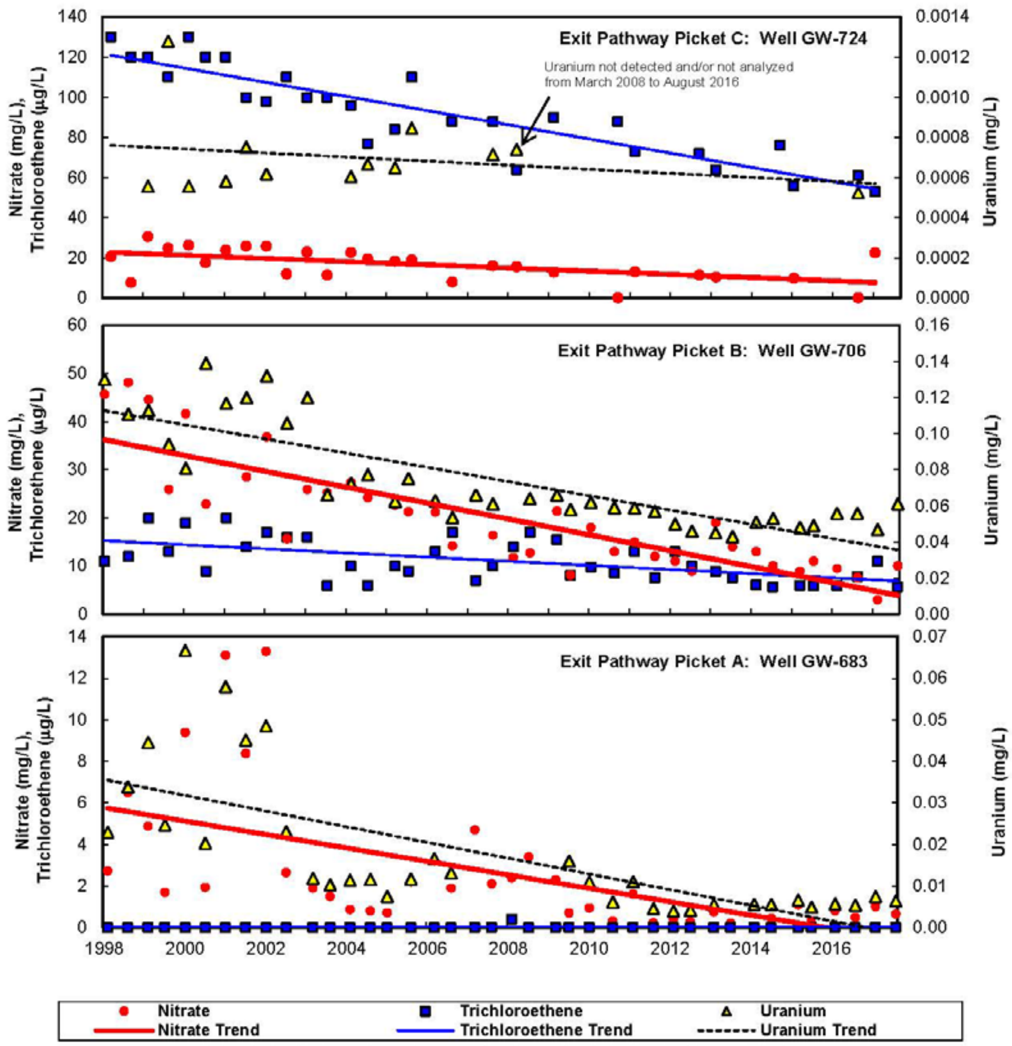
Data obtained from exit pathway monitoring stations during CY 2017 show that gross-alpha activity in groundwater in the Maynardville Limestone and in the surface waters of Bear Creek exceeds the drinking water standard for over 3,353 m (11,000 ft) west of the S-3 site (SS-5, 31 pCi/L). The highest gross-alpha activity observed in the Bear Creek regime in groundwater was located adjacent to the S-3 site in CY 2017 (121 pCi/L in well GW-276, Figure 4.34).

In CY 2017, the highest gross-beta activity in groundwater in the Bear Creek regime was also observed at well GW-276 (150 pCi/L, Figure 4.35).

Exit Pathway and Perimeter Monitoring

Exit pathway monitoring began in 1990 to provide data on the quality of groundwater and surface water exiting the Bear Creek regime. Bear Creek, which flows across the Maynardville Limestone (the primary exit pathway for groundwater) in much of the Bear Creek regime, is the principal exit pathway for surface water. Various 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 well location for the Bear Creek regime (Figure 4.30).

Exit pathway monitoring consists of continued monitoring at four well transects (pickets) and selected springs and surface water stations. Groundwater quality data obtained during CY 2017 from the exit pathway monitoring wells indicate that groundwater is contaminated above drinking water standards in the Maynardville Limestone between Pickets A and C. Trends continue to be generally stable to decreasing (Figure 4.38).



Note: Only nitrate and uranium results above the detection limit are plotted; non-detected trichloroethene results are plotted at zero.

Figure 4.38. Calendar Year 2017 concentrations of selected contaminants in exit pathway monitoring wells in the Bear Creek hydrogeologic regime

Surface water samples collected during CY 2017 indicate that water in Bear Creek contains many of the 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 4.23; see Section 4.6.4.2).

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 4.27). 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.

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. Table 4.24 summarizes the operational history of waste management units in the regime.

Table 4.24. Description of waste management units included in groundwater monitoring activities, Chestnut Ridge hydrogeologic regime, 2017

Site	Description
Chestnut Ridge Sediment Disposal Basin	Operated from 1973 to 1989. Received soil and sediment from New Hope Pond and mercury-contaminated soils from the Y-12 Complex. Site was closed under RCRA in 1989. Not a documented source of groundwater contamination
Kerr Hollow Quarry	Operated from 1940s to 1988. Used for the disposal of reactive materials, compressed gas cylinders, and various debris. RCRA closure (waste removal) was conducted between 1990 and 1993. Certification of closure with some wastes remaining in place was approved by TDEC in February 1995
Chestnut Ridge Security Pits	Operated from 1973 to 1988. Series of trenches for disposal of classified materials, liquid wastes, thorium, uranium, heavy metals, and various debris. Closed under RCRA in 1989. Infiltration is the primary release mechanism to groundwater
United Nuclear Corporation Site	Received about 29,000 drums of cement-fixed sludges and soils, demolition materials, and low-level radioactive contaminated soils. CERCLA ROD issued in 1991.
Industrial Landfill II	Operated from 1983 to 1995. During operations, this was the central sanitary landfill for ORR. Detection monitoring under post-closure plan has been ongoing since 1996
Industrial Landfill IV	Opened for operations in 1989. Permitted to receive only non-hazardous industrial solid wastes. Detection monitoring under TDEC solid waste management regulations has been ongoing since 1988. Assessment monitoring began in 2008 because of consistent exceedance of the TDEC groundwater protection standard for 1,1-dichloroethene
Industrial Landfill V	Initiated operations in April 1994, replacing Industrial Landfill II. Currently under TDEC solid waste management detection monitoring
Construction/Demolition Landfill VI	Operated from December 1993 to November 2003. The post-closure period ended, and the permit was terminated in March 2007
Construction/Demolition Landfill VII	Facility construction completed in December 1994. TDEC granted approval to operate in January 1995. Permit-required detection monitoring per TDEC was temporarily suspended in October 1997 pending closure of construction/demolition Landfill VI. Reopened and began waste disposal operations in April 2001
Filled Coal Ash Pond	Site received Y-12 Complex Steam Plant coal ash slurries from 1955 to 1968. A CERCLA ROD was issued in 1996. Remedial action complete. Monitoring under the ROD is ongoing
East Chestnut Ridge Waste Pile	Operated from 1987 to 1989 to store contaminated soil and spoil material generated from environmental restoration activities at the Y-12 Complex. Closed under RCRA in 2005 and incorporated into RCRA post-closure permit issued by TDEC in 2006

CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
ORR = Oak Ridge Reservation
RCRA = Resource Conservation and Recovery Act
ROD = Record of Decision
TDEC = Tennessee Department of Environment and Conservation
Y-12 Complex = Y-12 National Security Complex

Plume Delineation

Through extensive monitoring of the wells on Chestnut Ridge, the horizontal extent of the VOC plume at the Chestnut Ridge Security Pits (CRSP) seems to be reasonably well defined in the water table and shallow bedrock zones. With two possible exceptions, historical monitoring indicates that the VOC plume from the CRSP has not migrated very far in any direction (<305 m [<1,000 ft]).

Groundwater quality data obtained during CY 2017 indicate that the western lateral extent of the plume of VOCs at the site has not changed significantly from previous years. However, the continued observation of VOC contaminants over the past several years at a well about 458 m (1,500 ft) southeast and downgradient of the CRSP (well GW-798; Figure 4.33) shows that some migration of the eastern plume has occurred. Additionally, dye tracer test results and the intermittent detection of trace concentrations of VOCs (similar to those found in wells adjacent to the CRSP) at a natural spring about 2,745 m (9,000 ft) to the east and along geologic strike may suggest that CRSP groundwater contaminants have migrated much further than the monitoring well network indicates.

The plumes depicted in this section reflect the average concentrations and radioactivity in groundwater between CYs 2008 and 2012. The circular icons presented on the plume maps (Figures 4.32 through 4.35) represent CY 2017 monitoring results. (See Section 4.6.4.1 for more details.)

Nitrate

Nitrate concentrations were below the drinking water standard at all monitoring stations in the Chestnut Ridge hydrogeologic regime.

Trace Metals

Elevated concentrations of arsenic were observed in two surface water monitoring locations downstream from the Filled Coal Ash Pond, which is monitored under a CERCLA ROD (DOE 2018). Under the ROD, migration of contaminated effluent from the Filled Coal Ash Pond is being reduced by a constructed wetland area. During CY 2017, elevated arsenic levels were detected both upgradient (McCoy Branch kilometer [MCK] 2.05) and downgradient (MCK 2.0) of this wetland area (Figure 4.30). The passive wetland treatment area reduces total arsenic concentrations by about 59%, with associated reductions of dissolved arsenic of about 45% in the wet-season sample and about 73% for total arsenic and 64% for dissolved arsenic during the dry-season sample (DOE 2018). 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 2017; arsenic was detected below drinking water standards.

Volatile Organic Compounds

Monitoring VOCs in groundwater attributable to the CRSP has been in progress since 1987. A review of historical data indicates that concentrations of VOCs in groundwater at the site have generally decreased since 1988. However, stable to very shallow increasing trends in VOCs in groundwater samples from monitoring well GW-798 (Figure 4.33) have been developing since CY 2000. The maximum summed VOC concentration observed at well GW-798 during CY 2017 was 10.36 µg/L. The VOCs detected in well GW-798 continue to be characteristic of the CRSP plume. However, in CY 2017, the highest summed VOC in the Chestnut Ridge regime was in another well at the CRSP, GW-322 with 159 µg/L (Figure 4.33).

At Industrial Landfill IV, a number of VOCs have been observed since 1992. Monitoring well GW-305, located immediately to the southeast of the facility, has historically displayed concentrations of compounds below applicable drinking water standards, but the concentrations have exhibited shallow increasing trends; and in CY 2017 this well had a summed VOC concentration of (90.49 µg/L). In

CY 2015, samples from this well continued to exceed the drinking water standard for 1,1-DCE (7 µg/L). That finding led to quarterly monitoring to further evaluate the trend. The CY 2015 samples had concentrations of 5.8 to 9.8 µg/L, but in CY 2016, only one quarterly sample exceed the drinking water standard for 1,1-DCE at a concentration of 7.43 µg/L. And again in CY 2017, only one quarterly sample exceeded the drinking water standard for 1,1-DCE at a concentration of 7.17 µg/L.

In CY 2014, a VOC, carbon tetrachloride, was consistently detected at low concentrations in groundwater samples from well GW-144 at Kerr Hollow Quarry (Figure 4.33). This well is sampled as part of a RCRA post-closure permit with TDEC managed by UCOR, a DOE environmental manager contractor. Three consecutive samples (all below 4 µg/L) confirmed the presence of carbon tetrachloride. Additional sampling at this well and at a downgradient surface water location was implemented in CY 2015 to more-closely monitor this VOC. The CY 2015 samples yielded only one detection of carbon tetrachloride at well GW-144 (1.1 µg/L). In CYs 2016 and 2017, carbon tetrachloride was not detected at either location.

Radionuclides

In CY 2017, no gross-alpha or gross-beta activity above the drinking water standard of 15 and 50 pCi/L, respectively, was observed in any groundwater samples collected 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 by conventional monitoring techniques. A number of 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 the Y-12 Complex that is a known or potential groundwater contaminant source. Water quality from springs along Scarboro Creek are monitored, and trace concentrations of VOCs are intermittently detected. The detected VOCs are suspected to originate from the CRSP; however, this has not been confirmed.

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 2017. No contaminants at any of these monitoring stations were detected at levels above primary drinking water standards.

4.7 Quality Assurance Program

The Y-12 Complex QA Program establishes a quality policy and requirements for the overall QA Program for the Y-12 Complex 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. 2017c). 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; and
- use of QC samples, such as field and trip blanks, duplicates, and equipment rinses.

The Y-12 Complex Environmental Sampling Services performs field sampling, sample preservation and handling, and chain-of-custody and takes field control (QC) samples in accordance with the Y-12 Complex 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 (M&TE). The standards and calibration program ensures measurements are made using appropriate, documented methods; traceable standards; appropriate M&TE 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 the Y-12 Complex 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, frequent use of check sources and background counts, replicate and spiked sample analyses, matrix and reagent blanks, and 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 NIST, DOE sources, or EPA are used (when available) for such work.

The Y-12 Complex ACO QA Manual describes QA program elements that are based on the Y-12 Complex 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; and waste acceptance criteria. As a government-owned, contractor-operated laboratory that performs work for DOE, the ACO laboratory operates in accordance with DOE O 414.1D, *Quality Assurance* (DOE 2011c).

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.

The Y-12 Complex ACO participated in both Mixed Analyte Performance Evaluation Program studies conducted in 2016 for water, soil, and air filter matrices for metals, organics, and radionuclides. The overall acceptability rating from both studies was greater than 96%.

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 (1) data have been accurately transcribed and recorded, (2) appropriate procedures have been followed, (3) electronic and hard-copy data show one-to-one correspondence, and (4) 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 an RI 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 Mercury Technology Development Activities for the Y-12 National Security Complex, East Fork Poplar Creek

Mercury remediation in the Oak Ridge, Tennessee, area is a high priority for DOE. Releases of mercury during Y-12 Complex operations during the 1950s and early 1960s resulted in contamination of surrounding soil, groundwater, and biota. Subsequent transport from the facility resulted in off-site contamination of the lower EFPC. Starting in late 2014, mercury research and technology development activities have been conducted in an effort to develop potential remedial alternatives for lower EFPC.

Research and technology development activities to date have focused on understanding mercury transport and fate in the EFPC system. Monitoring sites from upstream to downstream EFPC were established to measure flow, water chemistry, groundwater, and biota. Field studies have pointed to the importance of bank soil erosion as a source of mercury to the creek, especially in the upstream section. Instream factors such as water chemistry and flow characteristics also influence mercury concentration, including the production of methylmercury. Research studies have also highlighted the importance of methylmercury and its bioaccumulation in the food chain. The early efforts to understand the watershed have added significantly to our understanding of key mercury sources areas and mercury transformations and processes. The watershed-scale mercury information is informing conceptual and dynamic models that can be used for future technology development and remedial decision-making in lower EFPC.

In FY 2017, technology development activities centered on developing strategies and technologies that may influence the major factors controlling mercury bioaccumulation in fish—the amount of mercury to the system, the conversion of inorganic mercury to methylmercury, and the uptake of mercury in the food chain. Field and laboratory studies have focused on developing sorbents that might be effective in sequestering mercury, using alternative dechlorination chemicals at the Y-12 Complex that might help reduce mercury flux, and adding filtering organisms such as mussels that might help change instream chemistry to limit mercury transport on particles or algae.

The multi-year research and technology development effort in Lower EFPC is providing detailed and valuable information that will inform remedial alternatives evaluation currently scheduled for the mid-2020s.

4.8.2 Excess Facilities

In 2017, the Oak Ridge Office of Environmental Management's (OREM's) Excess Contaminated Facilities initiative continued to remove risks by stabilizing excess facilities, performing characterization, removing mercury from deteriorating equipment, and developing required plans for future cleanup and demolition activities.

OREM efforts on the column exchange system located outside the Alpha-4 building at the Y-12 Complex resulted in recovery of a significant quantity of mercury at risk of release from the deteriorating equipment, supporting equipment removal in 2018.

Characterization of nine facilities, comprising the Y-12 Biology Complex, was completed in accordance with the regulator-approved Waste Handling Plan to support future demolition waste disposal. The characterization effort, which included collection of more than 300 samples from various structural components and equipment, required special attention to personnel protection due to deteriorated conditions in and around the facilities. Critical decision documentation was prepared to support planning for future demolition. Preparations began for demolition in 2018 of two of the nine facilities (9743-2 and 9770-2), as well as more extensive planning for deactivation of the 9207 and ancillary facilities.

4.8.3 Mercury Treatment Facility

OREM continued progress on the Outfall 200 Mercury Treatment Facility to reduce mercury concentrations in water exiting the Y-12 Complex and to support future large-scale demolition of mercury-contaminated facilities. Outfall 200 is the point where the west end Y-12 Complex storm drain system discharges to upper EFPC and is a documented source of mercury discharge to the creek.

Water will be collected at the Outfall 200 discharge point (headworks site) and transferred by pipeline to the treatment plant located at the eastern end of the Y-12 Complex. The water will be treated to reduce mercury using chemical precipitation, clarification, and media filtration and discharged back into upper EFPC (UCOR.2016a).

In 2017, OREM completed design of the facility, with the capability to treat 3,000 gpm and including a 2M-gal storage tank to collect storm water during peak flow conditions. Responsibility for the headworks and treatment plant site footprints was transferred from NNSA to OREM. Early site preparation was initiated at the headworks and treatment plant sites. Procurement of a construction contract for the balance of construction was initiated to support award of the contract in 2018.

4.8.4 Waste Management

4.8.4.1 Comprehensive Environmental Response, Compensation, and Liability Act Waste Disposal

During FY 2017, the EMWMF received 5,309 waste shipments, accounting for 34,757 tons, primarily from soil remediation activities and several smaller cleanup projects at ETTP and the Y-12 Complex. The EMWMF, an engineered landfill, consists of six disposal cells that only accept low-level radioactive and hazardous CERCLA waste that meets specific waste acceptance criteria. Waste types that qualify for disposal include soil, dried sludge and sediment, solidified waste, stabilized waste, building debris, scrap equipment, personal protective equipment, and classified waste.

In FY 2017, EMWMF operations collected, analyzed, and dispositioned approximately 4.5M gal of leachate at the Oak Ridge National Laboratory (ORNL) Liquid and Gaseous Waste Operations facility. No contact water (water that comes in contact with waste but does not enter the leachate collection system) required treatment at ORNL. However, 9.3M gal of contact water were collected, analyzed, and released to the storm water retention basin after laboratory analyses verified the water met all discharge standards.

4.8.4.2 Solid Waste Disposal

DOE operates and maintains solid waste disposal facilities called the ORR Landfills, three of which are active. In FY 2017, approximately 54,771 yd^3 of waste were disposed in the landfills, which marks a 62% increase from FY 2016 volumes. Clean spoils receipts in FY 2017 were approximately 424 yd^3. Clean spoils have the potential for being reused and are segregated to avoid taking up valuable landfill space. Several projects are planning large spoils campaigns for FY 2018 construction of phase two of three phases of the classified landfill.

Operation of the ORR Landfills generated approximately 2.5M gal of leachate that was collected, monitored, and discharged into the Y-12 Complex sanitary sewer system.

4.8.4.3 Wastewater Treatment

NNSA at the Y-12 Complex treats wastewater generated from both production activities and environmental cleanup activities. Safe and compliant treatment of more than 119M gal of wastewater was provided at various facilities during the year:

- The West End Treatment Facility and the Central Pollution Control Facility at the Y-12 Complex processed more than 1.1M gal of wastewater, primarily in support of NNSA operational activities.
- The Big Springs Water Treatment System treated more than 102M gal of mercury-contaminated groundwater. The EEVOCTS treated 11.8M gal of VOC-contaminated groundwater.
- The Liquid Storage Facility and Groundwater Treatment Facility treated more than 2.5M gal of leachate from burial grounds and well purge waters from remediation areas.
- The Central Mercury Treatment System treated approximately 1.8M gal of mercury-contaminated sump waters from the Alpha-4 building.

5. Oak Ridge National Laboratory

Oak Ridge National Laboratory (ORNL) is the largest US Department of Energy (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 2017 included North Wind Solutions, LLC; URS | CH2M Oak Ridge LLC; and Isotek Systems LLC. During 2017 activities of these contractors were conducted to comply with contractual and regulatory environmental requirements.

Because of differing permit-reporting requirements and instrument capabilities, various units of measurement are used in this report. The information found in "Units of Measure and Conversion Factors" is intended to help readers convert numeric values presented here as needed for specific calculations and comparisons.

5.1 Description of Site, Missions, and Operations

Oak Ridge National Laboratory (ORNL), which is managed for the US Department of Energy (DOE) by UT-Battelle, LLC, a partnership of the University of Tennessee and Battelle Memorial Institute, lies in the southwest corner of the DOE Oak Ridge Reservation (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.

ETTP: East Tennessee Technology Park; ORISE: Oak Ridge Institute for Science and Education; Y-12: Y-12 National Security Complex

Figure 5.1. Location of Oak Ridge National Laboratory (ORNL) within the Oak Ridge Reservation and its relationship to other local US Department of Energy 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% of the inventory. The transfer of the ZPR plate canisters was completed in 2012. Disposal of the CEUSP material canisters began in 2015 and completed in 2017. Plans and preparations for the disposition of the remaining ^{233}U inventory are under way. Building 2026 was transferred from UT-Battelle to Isotek in May of 2017. Preparations are under way for start-up for processing in Building 2026.

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.

URS | CH2M Oak Ridge LLC (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 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) and the Manufacturing Demonstration Facility (MDF). 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). 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 the Y-12 National Security Complex (Y-12) and in the city of Oak Ridge.

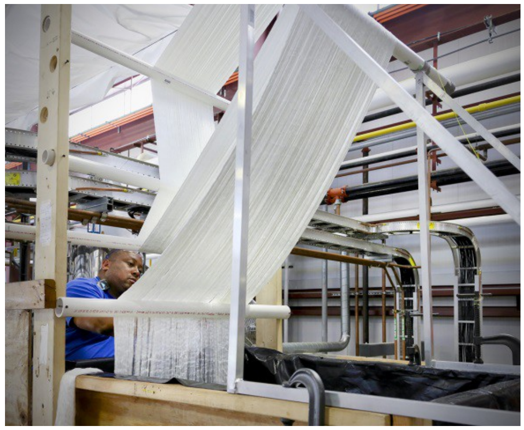


Photo by Jason Richards.

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) 14001 (ISO 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. Throughout 2017, UT-Battelle was registered to the ISO 14001:2015 standard and had maintained ISO 14001 registration since 2004.

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 subject area documents (procedures and guidelines). Through environmental protection officers, environmental compliance representatives, and waste services representatives (WSRs), the UT-Battelle EMS assists the line organizations in identifying and addressing environmental issues in accordance with SBMS 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. Figure 5.3 depicts the relationship between the EMS and the ISMS. The UT-Battelle EMS is consistent with the ISMS and includes all the elements in the ISO 14001:2015 standard.

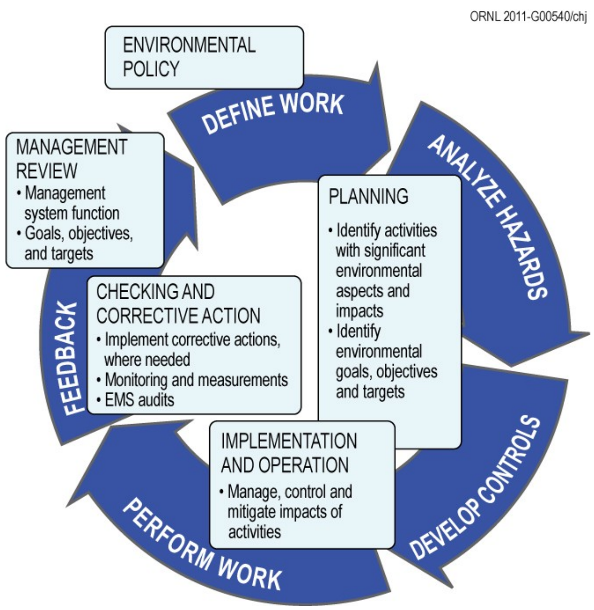


Figure 5.3. The relationship between the UT-Battelle Environmental Management System and the Integrated Safety Management System

5.2.1.2 UT-Battelle Environmental Policy for Oak Ridge National Laboratory

UT-Battelle’s Environmental Policy for ORNL 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 project and activity level. Activities that are relative to any of the aspects are carefully controlled to minimize or eliminate impacts to the environment. Nine environmental aspects 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 performance indicators for appropriate functions and activities. Laboratory-level environmental objectives are documented in the annual Site Sustainability Plan. Line organization objectives are developed annually, entered into a commitment tracking system, and tracked to completion. In all cases, the objectives and performance indicators are consistent with the UT-Battelle Policy for ORNL, are supportive of the laboratory mission, and where practical, they 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 2017 compliance status, activities, and accomplishments is presented in Section 5.3.

The environmental protection staff provide critical support services in the following areas:

- waste management;
- National Environmental Policy Act (NEPA) compliance;
- air quality compliance;
- water quality compliance;
- US Department of Agriculture (USDA) compliance;
- transportation safety;
- environmental sampling and data evaluation; and
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) interface.

UT-Battelle's staff also include subject matter experts who provide critical waste management, transportation, and disposition support services to research, operations, and support divisions:

- pollution prevention staff, who manage recycling programs, work with staff to reduce waste generation and to promote sustainable acquisition;
- radiological engineering staff, who provide radiological characterization support to generators and WSRs, develop tools to help ensure compliance with facility safety and transportation, and provide packaging support;
- waste acceptance and disposition staff, who 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;
- WSRs, who 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, which performs waste-packing operations and conducts inspections of waste items, areas, and containers;
- the transportation management team, which ensures that both the on-site and off-site packaging and transportation activities are performed in an efficient and compliant manner; and

- the hazardous material spill response team, which 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 UT-Battelle Sustainable Campus Initiative

The UT-Battelle Sustainable Campus Initiative (SCI) for ORNL was launched in 2008 and has a 10 year history of promoting a proven holistic approach to the support of sustainable operations and employee engagement. Many of the SCI Roadmaps were revised in fiscal year (FY) 2015 to address Executive Order (EO) 13693 (EO 2015). The DOE annual Site Sustainability Plan (SSP) guidance reevaluated target dates and reduction goals to align with current federal and agency directives, including EO 13693. The DOE Headquarters Sustainability Performance Office (SPO) and the Office of Science (SC) work together to update SSP goals and to provide guidance to ensure that each DOE location reports annual performance data in a consistent manner through the web-based SPO Dashboard Reporting System. ORNL maintains a website where current and past SSPs can be found. Most SSP goals are now oriented toward a 2025 target date. In 2017 the SCI (through the SPO Dashboard and other reporting mechanisms) provided performance updates on a broad range of sustainability topics at ORNL, such as water and energy use, waste management, and the reduction of greenhouse gas (GHG) emissions.

FY 2017 SSP Performance Summary Data for Energy, Water, and Waste

In FY 2017 ORNL was again resolute in its commitment to sustainable operations and the reduction of GHG emissions wherever possible while remaining diligent in pursuing its mission to provide valuable solutions to the nation’s energy and security challenges. ORNL efforts to reduce energy use intensity (EUI) and water use intensity (WUI) and to divert municipal solid waste and construction and demolition (C&D) debris have remained on track with SSP target dates and reduction percentage goals.

In FY 2017 ORNL installed 18 new advanced utility meters across all utilities, including electrical, steam, chilled water, natural gas, and potable water. The meters were connected to a central energy data system that enables meter data trend analysis, report generation, data export for other analyses, and data archival. Better energy and water data will develop as more ORNL buildings deploy advanced meter technologies.

Energy Use Intensity

Based on FY 2017 performance data, ORNL achieved an EUI reduction of 7.4% from the FY 2015 baseline and is on target to meet the DOE/SSP reduction goal of 25% by FY 2025 (Figure 5.4). To maintain steady progress toward this goal, ORNL focuses on energy-efficient and sustainable design in new construction projects as well as smart repurposing of existing facilities and a drive for continuous improvement in facility and utility operations. Initiatives in FY 2017 included new approaches to energy consumption awareness using data visualization and reporting. Building data analytics, including fault detection and diagnostics, are also being added to ORNL’s energy conservation tools.

Water Use Intensity

EO 13693 established a potable water consumption reduction goal of 36% by 2025 through reductions of 2% annually relative to baseline consumption in 2007. A cumulative reduction in WUI of 24% was realized at ORNL between 2007 and 2017 by means of an aggressive approach that includes repairing leaks and replacing old lines in the site water distribution system and eliminating once-through cooling where possible. Water reduction at ORNL is on target to meet or exceed the 2025 goal (Figure 5.5).

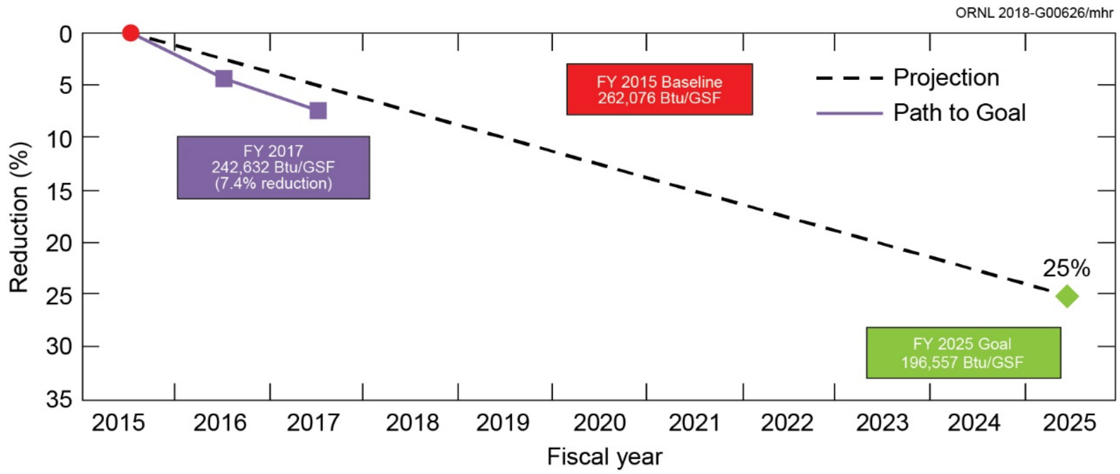


Image adapted from DOE 2017a. *Oak Ridge National Laboratory FY 2018 Site Sustainability Plan with FY 2017 Performance Data*. US Department of Energy Sustainability Performance Office, Washington, DC.

Figure 5.4. ORNL energy use intensity reduction compared with the target goal per Executive Order 13693, "Planning for Federal Sustainability in the Next Decade," March 25, 2015

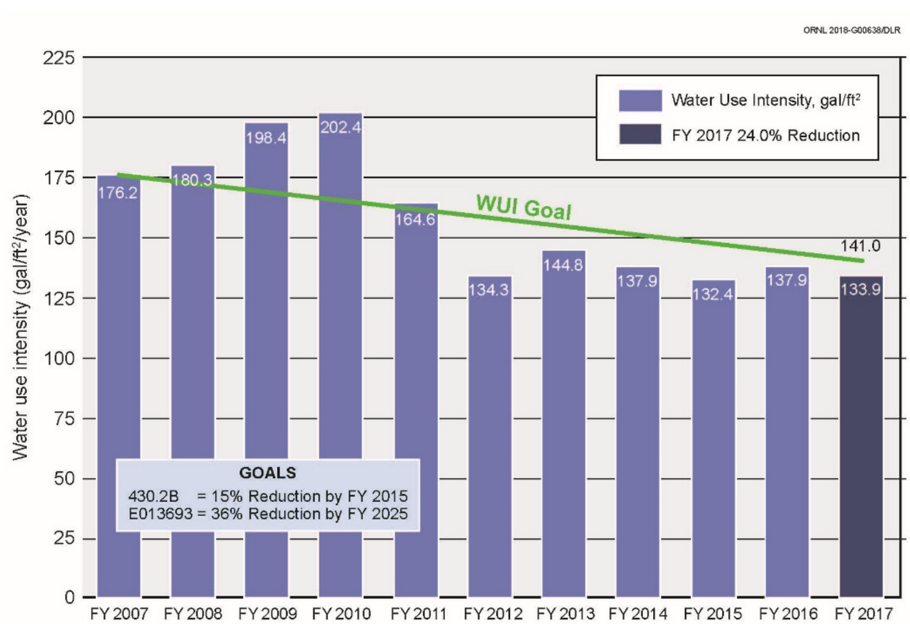


Image adapted from DOE 2017a. *Oak Ridge National Laboratory FY 2018 Site Sustainability Plan with FY 2017 Performance Data*. US Department of Energy Sustainability Performance Office, Washington, DC.

Figure 5.5. ORNL water use intensity reduction compared with the target goal per Executive Order 13693, "Planning for Federal Sustainability in the Next Decade," and DOE Order 430.2B, *Departmental Energy, Renewable Energy, and Transportation Management*

Waste Diversion. The diversion rate for municipal solid waste at ORNL was 44% in FY 2017, slightly less than the DOE goal of 50%. The diversion rate for C&D materials and debris (76%) exceeded the DOE goal of 50%.

Pollution Prevention. UT-Battelle implemented 24 new pollution prevention projects and ongoing reuse/recycle projects at ORNL during 2017, eliminating more than 6.5 million kg of waste. Source reduction actions pursued in 2017 included continued deployment of paperless work processes and resource-efficient computing. Recycling efforts included paper, scrap metal, wood pallets, carpet, drums, electronics, and C&D debris.

Sustainable Vehicle Fleet

The vehicle fleet at ORNL includes 63 flexible fuel vehicles and 5 plug-in hybrid sedans, which also use alternative fuels.

Fleet Fuel Savings. Fuel data for FY 2017 show a 32% decrease in petroleum consumption at ORNL since 2005, the baseline year established by DOE. This decrease exceeds the DOE cumulative target of a 20% reduction. In addition, ORNL alternative fuel use has increased from the 2005 baseline by 70%, exceeding the target. Overall, 72% of the fleet can use alternative fuel.

Electric Vehicles. Over the past 5 years, 47 electric vehicle (EV) charging stations have been installed on the ORNL campus. The stations are available for charging of both personal and government fleet vehicles. ORNL began purchasing plug-in hybrid electric vehicles (PHEVs) in FY 2013 and now has a total of five PHEVs in the fleet. Due to lack of funding, no PHEVs were purchased in FY 2017.

Sustainable Buildings

In FY 2017, ORNL's high-performance sustainable building (HPSB) inventory included a total of 20 buildings, or 15% (which meets the 2017 interim target) of the total applicable site buildings according to the *Guiding Principles for Sustainable Federal Buildings and Associated Instructions* (CEQ 2016).

Employing a systematic approach to identifying HPSB candidates and applying the guiding principles has been an effective way to ensure continued progress. HPSB candidates have been identified based on building space use, existing metering infrastructure, and known energy-conservation opportunities. Action plans for achieving building-specific guiding principles are developed and executed while laboratory-wide standards are used to fulfill HPSB applicable policies and procedures. Engagement of facility managers, facility engineers, and other technical personnel has been essential to acquiring quality benchmarking data, performing commissioning activities, and implementing energy conservation measures.

Regional and Local Planning: Commuting Options

A bus route between ORNL, the University of Tennessee, and Pellissippi State Community College continued operations for a second year in 2017. The average daily ridership during the academic year was 30 people. The average daily ridership during the summer months (May–August) was 48. One hundred seventy employees participated in carpools and vanpools, 140 employees completed a formal telework agreement (an increase of more than 300% from the prior year), and 114 employees participated in alternative work schedules via 9/80 and 4/10 shift designs. A commuter survey was distributed to all staff in June 2017 and received a 33% response rate. Analysis and further focus on some key areas are scheduled for FY 2018.

Employee and Community Engagement: Earth Day 2017

ORNL's Earth Day, "Seeds of Progress," celebration was held in April 2017. Activities included the featured presentation, "The Gatlinburg Firestorm—Can It Happen Here?" Employees and guests had the opportunity to participate in Earth Day events such seed planting and recycling relays. "Ask the Experts" activities included presentations and displays promoting energy efficiency and sustainable practices at home and at work.

SCI Achievements

The following achievements were highlighted in the ORNL SSP report submitted to the DOE SPO in December 2017:

- Teresa Nichols, co-lead of the ORNL SCI, led a DOE SPO project to create a telework guide for distribution to DOE facilities. The project involved working with five partner SC labs, with ORNL as project lead. The guide was completed in May 2017, and the final report (ORNL 2017) was distributed by the SPO through its June SPOtlight newsletter and was posted on the SPO homepage.
- ORNL SCI compiled the Oak Ridge National Laboratory Annual Sustainability Report for FY 2017 (ORNL 2017a), which was electronically distributed to all ORNL staff and guests. The report was also distributed to 104 recipients in cities, counties, municipalities, chambers, colleges, and high schools in the counties neighboring ORNL. By distributing the report, ORNL informed its neighbors of its sustainable best practices.
- ORNL distributed a commuter survey in June 2017 to all ORNL staff and received a 33% response rate. Analysis and further focus on some key areas are scheduled for FY 2018.
- ORNL applied new approaches to energy consumption awareness using data visualization and reporting during FY 2017. One such approach was the development of utility consumption dashboards and reports populated with interval data, which helped to identify energy conservation opportunities in FY 2017. Building data analytics, including fault detection and diagnostics, are also being added to ORNL's energy conservation tools. To bolster this effort, ORNL has elected to participate in the Better Buildings Smart Energy Analytics Campaign. Going forward, ORNL will implement a new energy data analytics module for more robust dashboard development and sharing. Implementation of fault detection and diagnostics will also be scaled up to include additional buildings, and a work flow will be established to successfully address faults and to achieve energy and operational improvements.
- The 2017 Government Green Fleet awards were presented at the Sustainable Fleet Technology Conference, held in Raleigh, North Carolina. ORNL's fleet received a 2017 Government Green Fleet Award. There are 38,000 government fleets in North America. The annual award honors the top 50 federal, state and local government fleets in North America that have achieved success in "greening" their fleets by using alternative fuel and hybrid vehicles, emissions reduction, long-range planning, and staff education and involvement. This year, ORNL was ranked 29th on the list. It was the only DOE facility to be recognized, and its fleet was the only one from the State of Tennessee to win the award.

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.

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). GI/LID practices that have been incorporated at ORNL include

- 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, and
- water reuse (e.g., tanks in restrooms to collect water for reuse in irrigation).

At ORNL, evaluation occurs to meet the requirements of EISA Section 438. A three-step approach is applied as needed:

- Within the project boundaries if the necessary volume of runoff can be infiltrated or retained on site.
- On land immediately adjacent to the project boundaries if the necessary volume of runoff cannot be infiltrated or retained on site.
- 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) if the necessary volume of runoff cannot be infiltrated or retained on land immediately adjacent to the project boundaries.

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 are a part of 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 internal audit and an external surveillance audit conducted in 2017 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) through NWSol’s *Regulatory Management Plan* (NWSol 2015), which dictates 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 NWSol 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, construction debris, 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 O 450.1A, Environmental Protection Program (DOE 2008a). 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 an off-site administrative office 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 2017 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 2017. The following discussions summarize the major environmental programs and activities carried out at ORNL during 2017 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, 2017

Date	Reviewer	Subject	Issues
January 9	City of Oak Ridge	CFTF Wastewater Inspection	0
March	TDEC	Inspection of Underground Injection Control Program	0
April 11–12	TDEC	Annual RCRA Inspection for ORNL (including TWPC)	0
May 25–26	TDEC	NPDES Permit Inspection	0
July 27	TDEC	NTRC RCRA Inspection	0
September 28	City of Oak Ridge	CFTF Wastewater Inspection	0
October 17	City of Oak Ridge	CFTF Waste Water Inspection	0
October 26–27	TDEC	Annual CAA Inspection for ORNL and CFTF	

Acronyms
CAA = Clean Air Act
CFTF = Carbon Fiber Technology Facility
NPDES = National Pollutant Discharge Elimination System
NTRC = National Transportation Research Center
ORNL = Oak Ridge National Laboratory
RCRA = Resource Conservation and Recovery Act
TDEC = Tennessee Department of Environment and Conservation
TWPC = Transuranic Waste Processing Center

5.3.1 Environmental Permits

Table 5.2 contains a list of environmental permits that were in effect in 2017 at ORNL.

Table 5.2. Environmental permits in effect at ORNL in 2017

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	Construction Permit, CFTF facility (located near ETTP)	965013P	DOE	UT-B	UT-B
CAA	Construction Permit, CFTF emergency generator	967180P	DOE	UT-B	UT-B
CAA	Construction Permit, 4501/4505 Area Off Gas System	971441P	DOE	UT-B	UT-B
CAA	Operating Permit, NTRC	17-0941-01	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
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 General NPDES Permit TNR10-0000, Storm Water Discharges from Construction Activities—Pro2Serve National Security Engineering Center		DOE	DOE	CROET
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	Tennessee General NPDES Permit TNR10-0000, Storm Water Discharges from Construction Activity—Site Expansion Project	TNR 133560	DOE	NWSol	NWSol
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 2017 (continued)

Regulatory driver	Permit title/description	Permit number	Owner	Operator	Responsible contractor
RCRA	Hazardous Waste Container Storage and Treatment Units	TNHW-134	DOE	DOE/UT-B	UT-B
RCRA	Hazardous Waste Container Storage and Treatment Units	TNHW-145	DOE	DOE/ UCOR/ NWSol	UCOR/ NWSol

Acronyms
CAA = Clean Air Act
CFTF = Carbon Fiber Technology Facility
CROET = Community Reuse Organization of East Tennessee
CWA = Clean Water Act
DOE = US Department of Energy
ETTP = East Tennessee Technology Park
Isotek = Isotek Systems LLC
NPDES = National Pollutant Discharge Elimination System
NTRC = National Transportation Research Center
NWSol = North Wind Solutions, LLC
ORNL = Oak Ridge National Laboratory
RCRA = Resource Conservation and Recovery Act
UCOR = URS | CH2M Oak Ridge LLC
UT-B = UT-Battelle

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 2017.

Table 5.3. National Environmental Policy Act activities, 2017

Types of NEPA documentation	Number of instances
Oak Ridge National Laboratory	
Approved under general actions or generic CX determinations[a]	75
Project-specific CX determinations[b]	0
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 2017, 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 Oak Ridge Office has approved generic categorical exclusion (CX) determinations that cover proposed bench- 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 Protection Act at ORNL 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).

5.3.3 Clean Air Act Compliance Status

The Clean Air Act (CAA), passed in 1970 and amended in 1977 and 1990, forms the basis for the national air pollution control effort. This legislation 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 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 August 2017. One administrative amendment request was submitted to TDEC in October 2017. The Title V Major Source Operating Permit for the 3039 stack, operated by UCOR, was renewed in 2015. 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 9 major radionuclide sources and periodically from 15 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. A permit was issued by Knox County for an emergency generator located at NTRC in June 2017. The CFTF operates under two construction permits issued by TDEC. A permit application to convert them to a true minor operating air permit was submitted in 2015 and was still pending issuance at the end of 2017.

In summary, there were no UT-Battelle CAA violations and no Isotek, UCOR, or NWSol CAA violations or exceedances in 2017. Section 5.4 provides detailed information on 2017 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) 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 2017, compliance with the ORNL NPDES permit was determined by about 2,300 laboratory analyses and field measurements. The NPDES permit limit compliance rate for all discharge points for 2017 was greater than 99%. Heavy rains in April 2017 caused heavy influent flows to the STP. Operations were adjusted to prevent washout of the treatment plant. These operational disruptions caused a carbonaceous biological oxygen demand and five ammonia noncompliances during the next several months that it took to investigate, adjust, and fully restore equalized STP operations. In addition, malfunctioning equipment in the STP ozone disinfection system caused three E. coli noncompliances during May–July 2017. No adverse impacts to the creek aquatic life or environs were identified in the aftermath of these noncompliances. Operational response resulted in timely restoration of normal functional STP status following these irregularities.

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 2012), 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), and
- 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 2017, sampling results for ORNL's water system residual chlorine levels, bacterial constituents, and disinfectant by-products were all within acceptable limits. Sampling for lead and copper will not be required again until 2018.

5.3.6 Resource Conservation and Recovery Act Compliance Status

The Hazardous Waste Program under the Resource Conservation and Recovery Act (RCRA) 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 2017, 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 2017.

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 2017, UT-Battelle and UCOR were permitted to transport hazardous wastes under an 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 34 active waste streams at ORNL, some of which are mixed wastes. The quantity of hazardous/mixed waste generated at ORNL in 2017 was 564,434 kg, with mixed wastewater accounting for 357,429 kg. ORNL generators treated 9,410 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 2017 was 2,761 kg. This included waste treated by macroencapsulation, size reduction, stabilization/solidification, and wastewater treatment at the Process Waste Treatment Complex (PWTC). In addition, 357,429 kg of liquid mixed waste was treated at the Liquid Low-Level Waste Treatment Facility. The amount of hazardous/mixed waste shipped off site to commercial treatment, storage, and disposal facilities was 177,040 kg in 2017.

In April 2017, TDEC Division of Solid Waste Management conducted a Hazardous Waste Compliance Evaluation inspection of ORNL generator areas; battery 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; US Department of Transportation (DOT) inspection records for tractors, trailers, and tankers; commercial driver's licenses; hazardous waste manifests; and DOT training records. All records and areas were found to be in compliance with RCRA regulations and the RCRA permits.

Table 5.4. Oak Ridge National Laboratory Resource Conservation and Recovery Act operating permits, 2017

Permit number	Storage and treatment units/description
	Oak Ridge National Laboratory
TNHW-134	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 Storage Unit and Treatment Unit Building 7572 Container Storage Unit Building 7574 Container Storage Unit Building 7823 Container Storage Unit Building 7855 Container Storage Unit Building 7860A Container Storage Unit Building 7879 Container Storage Unit Building 7883 Container Storage Unit TWPC-1 (Contact-Handled Storage Area) Container Storage Unit TWPC-2 (Second Floor WPB) Container Storage Unit TWPC-3 (Drum Aging Criteria) Container Storage Unit TWPC-4 (First Floor WPB) Container Storage Unit TWPC-5 (Container Storage Area) Container Storage Unit TWPC-6 (Contact-Handled Marshaling Building) Container Storage Unit, Building 7880BB TWPC-7 (Drum-Venting Building) Container Storage Unit, Building 7880AA TWPC-8 (Multipurpose Building) Container Storage Unit, Building 7880QQ T-1[a] Macroencapsulation Treatment T-2[a] Amalgamation Treatment T-3[a] Solidification/Stabilization Treatment T-4[a] Groundwater Absorption Treatment T-5[a] Size Reduction T-5a Treatment T-6[a] Groundwater Filtration Treatment
	Oak Ridge Reservation
TNHW-164[b]	Hazardous Waste Corrective Action Permit

[a] Treatment operating units within TWPC facilities.
[b] On September 15, 2015, the ORR Hazardous Waste Corrective Action Permit TNHW-121 was reissued as TNHW-164.

Acronyms
TWPC = Transuranic Waste Processing Center
WPB = Waste Processing Building

DOE and UT-Battelle operations at NTRC and CFTF were regulated as "conditionally exempt small-quantity generators" in 2017, meaning that less than 100 kg of hazardous waste was generated per month.

In 2017, no hazardous/mixed wastes were generated, accumulated, or shipped by DOE or UT-Battelle at the DOE Office of Scientific and Technical Information, the 1916-T2 warehouse, or the 0800 Area.

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 2016 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 2017.

Periodic updates of proposed C&D activities and 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 Resource Conservation and Recovery Act 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. One UST was removed in late 2016 and received noncontaminated closure approval from TDEC in March 2017.

5.3.8 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.

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 2017, UT-Battelle operated seven PCB waste storage areas. When longer-term storage was necessary, PCB/radioactive wastes were stored in RCRA-permitted storage buildings at ORNL. One PCB waste storage area 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 disposed of. 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) 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 2017.

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

The Emergency Planning and Community Right-to-Know Act (EPCRA) 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 U.S. 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 2017 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 2017. 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 Material 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 2017, there were 36 hazardous and/or extremely hazardous substances at ORNL that met EPCRA reporting criteria.

Private-sector lessees were not included in the 2017 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 2017, 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 2017, UT-Battelle personnel had 36 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. Delineation information assists project planners avoiding or mitigating negative impacts to wetlands. In 2017, wetlands were delineated in the Copper Ridge Borrow Area and 294 Power Line Area.

5.3.13 Radiological Clearance of Property at Oak Ridge National Laboratory

DOE O 458.1, Radiation Protection of the Public and the Environment (DOE 2011d), established standards and requirements for operations of DOE and its contractors with respect to protection of members of the public and the environment against undue risk from radiation. In addition to discharges to the environment, the release of property containing residual radioactive material is a potential contributor to the dose received by the public, and DOE O 458.1 established requirements for clearance of property from DOE control and for public notification of clearance of property.

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; and
- 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 O 458.1 (DOE 2011d) in that ORNL requires an individual to take personal responsibility and accountability for knowing the complete history of an item before it can be cleared using process knowledge alone. DOE O 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 2017, UT-Battelle cleared more than 17,000 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, 2017

Item	Process knowledge	Radiologically surveyed
Release request totals for 2017		
Totals	15,862	2,688
Recycling request totals for 2017		
Cardboard (tons)	147	
Scrap metal (nonradiological areas) (tons)	731.72	
Pallets (each)	~3,200	

5.3.13.1 Authorized Limits Clearance Process for Spallation Neutron Source and High Flux Isotope Reactor Neutron Scattering Experiment Samples

The Spallation Neutron Source (SNS) and High Flux Isotope Reactor (HFIR) facilities provide unique neutron scattering experiment capabilities that allow researchers to explore the properties of various materials by exposing samples to well-characterized neutron beams. Because materials exposed to neutrons can become radioactive, a process has been developed to evaluate and clear samples for release to off-site facilities. DOE regulations and orders governing radiological release of material do not specifically cover items that may have radioactivity distributed throughout the volume of the material. To address sample clearance, activity-based limits were established using the authorized limits process defined in DOE O 458.1 (DOE 2011d) and associated guidance. The sample clearance limits are based on an assessment of potential doses against a threshold of 1 mrem/year to an individual and evaluation of other potentially applicable requirements (e.g., Nuclear Regulatory Commission [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 2017 ORNL cleared a total of 94 samples from neutron scattering experiments using the sample authorized limits process. Of these, 74 samples were from SNS and 20 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 ambient air criteria 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 operations at ORNL. In January 2015, TDEC also issued two construction permits for the Building 3525 and the 4501/4505 Off Gas System new radionuclide emission sources. DOE and UT-Battelle also maintained a valid minor source operating permit with the Knox County Air Quality Management Division for NTRC facilities located in Knox County.

In 2012 and in 2014 UT-Battelle applied for and received, construction permit numbers 965013P and 967180P, respectively, for the construction of CFTF, located off site at the Horizon Center Business Park in Oak Ridge, Tennessee. The initial start-up of CFTF occurred in March 2013. A True Minor Source Operating Permit for the facility and its emergency generator is anticipated to be issued in 2018.

DOE/NWSol has two non-Title V Major Source Operating Permits for one emission source and two emergency generators at TWPC. Isotek has a Title V Major Source Operating Permit for the Radiochemical Development Facility (Building 3019 complex). During 2017 no permit limits were exceeded. UCOR was issued a Title V Major Source Operating Permit 569768 on September 18, 2015, for the 3039 stack. No permit limits were exceeded for these sources in 2017.

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 2017 there were no deviations or releases of reportable quantities of ACM.

5.4.3 Oak Ridge National Laboratory Radiological Airborne Effluent Monitoring

Radioactive airborne discharges at ORNL are subject to Rad-NESHAP 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).

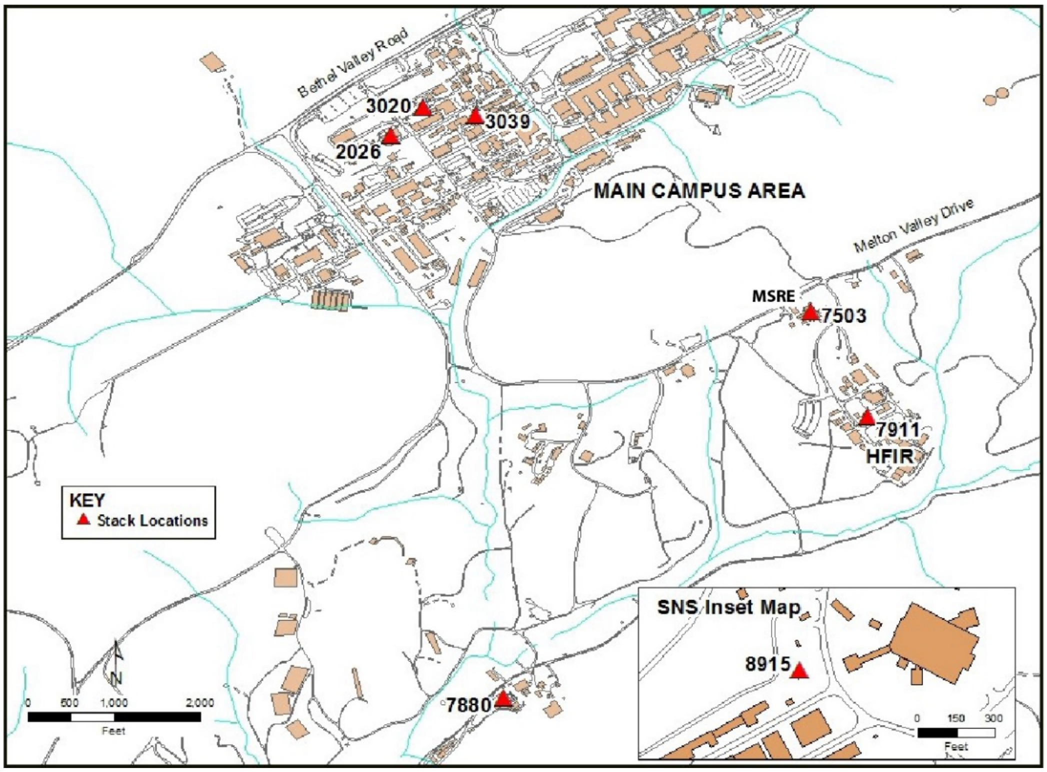
The major radiological emission point sources for ORNL consist of the following seven stacks. Six are located in Bethel and Melton Valleys, and one, the SNS Central Exhaust Facility stack, is located on Chestnut Ridge (Figure 5.6):

- 2026 Radioactive Materials Analytical Laboratory
- 3020 Radiochemical Development Facility
- 3039 central off-gas and scrubber system, which includes the 3500 cell ventilation system, isotope solid-state ventilation system, 3025 area cell ventilation system, 3042 ventilation system, and 3092 central off-gas system
- 7503 Molten Salt Reactor Experiment Facility

- 7880 TWPC
- 7911 Melton Valley complex, which includes HFIR and the Radiochemical Engineering Development Center
- 8915 SNS Central Exhaust Facility stack

In 2017 there were 12 minor point/group sources, and emission calculations/estimates were made for each of them.

ORNL 2018-G00383/mhr



HFIR = High Flux Isotope Reactor, MSRE = Molten Salt Reactor Experiment, and SNS = Spallation Neutron Source

Figure 5.6. Locations of major radiological emission points at Oak Ridge National Laboratory, 2017

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, a silica gel cartridge (if required), flow-measurement and totalizing instruments, a sampling pump, and a return line to the stack. The 7911 (Melton Valley complex) and 7880 (TWPC) stacks are equipped with in-stack source-sampling systems that comply with criteria in the ANSI–Health Physics Society standard ANSI/HPS N13.1-1999 (ANSI 1999).

The 7911 sampling system has the same components as the ANSI 1969 sampling systems but uses a stainless-steel-shrouded probe instead of a multipoint in-stack sampling probe. The 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 a number of 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, particulate filters, and silica-gel traps are collected weekly to biweekly. The use of charcoal cartridges 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, 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 2017 are presented in Table 5.7. All data presented were determined to be statistically different from zero at the 95% 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% confidence level means that there is a 5% chance that the results could be erroneous.

Historical trends for tritium (^{3}H) and ^{131}I are presented in Figures 5.7 and 5.8. For 2017, tritium emissions totaled about 897 Ci (Figure 5.7), a decrease in the emissions seen in 2016; ^{131}I emissions totaled 0.39 Ci (Figure 5.8), a tenfold increase from 2016 due to REDC target research. For 2017, of the 324 radionuclides released from ORNL operations and evaluated (see Table 5.7), the isotopes that contributed 10% or more to the off-site dose from ORNL were ^{212}Pb and ^{11}C, contributing about 30% and 17%, respectively. Emissions of ^{212}Pb result 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, 7503, 7856, 7911, the STP Sludge Drier, and the 3000 and 4000 area laboratory hoods. Carbon-11 emissions result from SNS operations and research activities. For 2017, ^{212}Pb emissions totaled 3.94 Ci and ^{11}C emissions totaled 16,510 Ci, over half that of 2016 (see Figure 5.9).

The calculated radiation dose to the maximally exposed individual (MEI) from all radiological airborne release points at ORR during 2017 was 0.3 mrem. The dose contribution to the MEI from all ORNL radiological airborne release points was 23.4% of the ORR dose. This dose is well below the NESHAPs standard of 10 mrem and is equal to approximately 0.1% 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 ORNL, 2017 (Ci)[a]

Isotope	Inhalation Form[b]	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total Minor Source	ORNL Total
^{225}Ac	M	particulate								1.91E-06	1.91E-06
^{226}Ac	M	particulate								5.02E-08	5.02E-08
^{227}Ac	M	particulate								3.90E-09	3.90E-09
^{228}Ac	M	particulate								2.34E-05	2.34E-05
^{108}Ag	B	unspecified								1.37E-14	1.37E-14
^{108m}Ag	M	particulate								1.56E-13	1.56E-13
^{109m}Ag	B	unspecified								1.25E-14	1.25E-14
^{110}Ag	B	unspecified								3.72E-12	3.72E-12
^{110m}Ag	M	particulate								9.38E-09	9.38E-09
^{111}Ag	M	particulate								3.70E-06	3.70E-06
^{112}Ag	M	particulate								3.43E-08	3.43E-08
^{26}Al	M	particulate								6.85E-14	6.85E-14
^{241}Am	F	particulate			5.32E-08	1.10E-09	4.26E-06			2.65E-09	4.32E-06
^{241}Am	M	particulate	1.64E-08	2.74E-07				1.44E-08		2.34E-05	2.37E-05
^{242}Am	M	particulate								2.57E-08	2.57E-08
^{242m}Am	M	particulate								2.58E-08	2.58E-08
^{243}Am	M	particulate								5.99E-07	5.99E-07
^{37}Ar	B	unspecified								2.36E-05	2.36E-05
^{39}Ar	B	unspecified								7.25E-10	7.25E-10
^{41}Ar	B	unspecified						5.78E+02	2.40E+01		6.02E+02
^{42}Ar	B	unspecified								2.04E-14	2.04E-14
^{73}As	M	particulate								3.88E-18	3.88E-18
^{131}Ba	M	particulate								5.51E-08	5.51E-08
^{133}Ba	M	particulate								8.60E-08	8.60E-08
^{137m}Ba	B	unspecified								2.39E-04	2.39E-04

Table 5.7 Radiological airborne emissions from all sources at ORNL, 2017 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total Minor Source	ORNL Total
^{139}Ba	M	particulate						2.11E-01			2.11E-01
^{140}Ba	M	particulate						3.46E-04		3.22E-06	3.49E-04
^{7}Be	S	particulate			6.96E-06	3.39E-08				6.88E-07	7.68E-06
^{7}Be	M	particulate	8.35E-08					2.52E-06		3.07E-06	5.68E-06
^{10}Be	M	particulate								7.65E-13	7.65E-13
^{206}Bi	M	particulate								1.68E-07	1.68E-07
^{211}Bi	B	unspecified								5.82E-11	5.82E-11
^{212}Bi	M	particulate								1.70E-07	1.70E-07
^{214}Bi	M	particulate								4.71E-20	4.71E-20
^{249}Bk	M	particulate								6.15E-10	6.15E-10
^{82}Br	M	particulate								2.78E-08	2.78E-08
^{11}C	G	dioxide							1.65E+04		1.65E+04
^{14}C	M	particulate								2.50E-03	2.50E-03
^{41}Ca	M	particulate								1.13E-10	1.13E-10
^{45}Ca	M	particulate								1.18E-07	1.18E-07
^{47}Ca	M	particulate								3.02E-11	3.02E-11
^{109}Cd	M	particulate								6.54E-12	6.54E-12
^{113m}Cd	M	particulate								7.30E-10	7.30E-10
^{115}Cd	M	particulate								8.53E-07	8.53E-07
^{115m}Cd	M	particulate								2.66E-18	2.66E-18
^{139}Ce	M	particulate								4.36E-05	4.36E-05
^{141}Ce	M	particulate						4.19E-07		2.95E-07	7.14E-07
^{143}Ce	M	particulate								6.06E-08	6.06E-08
^{144}Ce	M	particulate								4.07E-06	4.07E-06
^{249}Cf	M	particulate								1.66E-11	1.66E-11
^{250}Cf	M	particulate								6.12E-12	6.12E-12
^{251}Cf	M	particulate								1.58E-13	1.58E-13
^{252}Cf	M	particulate	3.96E-10	1.85E-09	7.20E-09	3.92E-10		3.98E-09		2.70E-08	4.09E-08

Table 5.7 Radiological airborne emissions from all sources at ORNL, 2017 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total Minor Source	ORNL Total
^{36}Cl	M	particulate								3.90E-10	3.90E-10
^{242}Cm	M	particulate								7.52E-08	7.52E-08
^{243}Cm	F	particulate			1.07E-08	5.55E-09	2.16E-07			6.98E-10	2.33E-07
^{243}Cm	M	particulate	2.80E-08					1.05E-08		9.38E-08	1.32E-07
^{244}Cm	F	particulate			1.07E-08	5.55E-09	2.16E-07			6.98E-10	2.33E-07
^{244}Cm	M	particulate	2.80E-08	2.56E-08				1.05E-08		3.47E-05	3.47E-05
^{245}Cm	M	particulate								8.15E-09	8.15E-09
^{246}Cm	M	particulate								3.63E-09	3.63E-09
^{247}Cm	M	particulate								7.02E-09	7.02E-09
^{248}Cm	M	particulate								4.78E-09	4.78E-09
^{56}Co	M	particulate								1.80E-13	1.80E-13
^{57}Co	M	particulate								1.20E-08	1.20E-08
^{58}Co	M	particulate								3.06E-08	3.06E-08
^{60}Co	M	particulate								1.26E-04	1.26E-04
^{60}Co	S	particulate			4.75E-07						4.75E-07
^{60m}Co	M	particulate								1.05E-13	1.05E-13
^{51}Cr	M	particulate								5.20E-05	5.20E-05
^{131}Cs	F	particulate								4.01E-10	4.01E-10
^{132}Cs	F	particulate								8.87E-09	8.87E-09
^{134}Cs	F	particulate								7.50E-06	7.50E-06
^{135}Cs	F	particulate								1.60E-09	1.60E-09
^{136}Cs	F	particulate								4.12E-07	4.12E-07
^{137}Cs	F	particulate	1.02E-06	3.98E-06				2.46E-02		7.53E-04	2.54E-02
^{137}Cs	S	particulate			5.17E-05	1.21E-07				1.01E-07	5.19E-05
^{138}Cs	F	particulate						2.36E+02			2.36E+02
^{64}Cu	M	particulate								1.07E-07	1.07E-07
^{66}Cu	B	unspecified								1.93E-13	1.93E-13
^{67}Cu	M	particulate								1.25E-09	1.25E-09

Table 5.7 Radiological airborne emissions from all sources at ORNL, 2017 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total Minor Source	ORNL Total
^{159}Dy	M	particulate								2.86E-16	2.86E-16
^{152}Eu	M	particulate								3.47E-04	3.47E-04
^{154}Eu	M	particulate								5.88E-05	5.88E-05
^{155}Eu	M	particulate								6.69E-06	6.69E-06
^{156}Eu	M	particulate								3.30E-06	3.30E-06
^{55}Fe	M	particulate								3.32E-05	3.32E-05
^{59}Fe	M	particulate								3.91E-07	3.91E-07
^{60}Fe	M	particulate								1.05E-13	1.05E-13
^{72}Ga	M	particulate								7.71E-13	7.71E-13
^{151}Gd	M	particulate								1.88E-12	1.88E-12
^{153}Gd	M	particulate								4.38E-06	4.38E-06
^{71}Ge	M	particulate								4.16E-10	4.16E-10
^{3}H	V	vapor	9.19E-03		3.11E+00	6.38E-01		2.51E+02	6.42E+02	2.79E-01	8.97E+02
^{175}Hf	M	particulate								1.42E-08	1.42E-08
^{178m}Hf	M	particulate								4.01E-11	4.01E-11
^{181}Hf	M	particulate								3.22E-07	3.22E-07
^{203}Hg	M	inorganic								5.75E-13	5.75E-13
^{166m}Ho	M	particulate								1.94E-12	1.94E-12
^{124}I	F	particulate								1.22E-07	1.22E-07
^{126}I	F	particulate								1.22E-07	1.22E-07
^{129}I	F	particulate					1.49E-06			1.22E-04	1.23E-04
^{131}I	F	particulate						3.89E-01		6.21E-06	3.89E-01
^{132}I	F	particulate						5.50E-01			5.50E-01
^{133}I	F	particulate						3.88E-01		4.00E-10	3.88E-01
^{134}I	F	particulate						8.48E-01			8.48E-01
^{135}I	F	particulate						1.09E+00			1.09E+00
^{113m}In	M	particulate								7.11E-10	7.11E-10
^{114}In	B	unspecified								8.67E-12	8.67E-12

Table 5.7 Radiological airborne emissions from all sources at ORNL, 2017 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total Minor Source	ORNL Total
^{114m}In	M	particulate								4.35E-10	4.35E-10
^{192}Ir	M	particulate								1.73E-13	1.73E-13
^{40}K	M	particulate								7.99E-05	7.99E-05
^{42}K	M	particulate								2.04E-14	2.04E-14
^{85}Kr	B	unspecified						1.37E+03		3.36E-01	1.37E+03
^{85m}Kr	B	unspecified						6.73E+00			6.73E+00
^{87}Kr	B	unspecified						4.12E+01	3.50E+01		7.62E+01
^{88}Kr	B	unspecified						5.32E+01	1.90E+01		7.22E+01
^{89}Kr	B	unspecified						3.30E+01			3.3E+01
^{137}La	M	particulate								1.80E-14	1.80E-14
^{140}La	M	particulate								7.85E-07	7.85E-07
^{173}Lu	M	particulate								3.32E-13	3.32E-13
^{174}Lu	M	particulate								1.31E-13	1.31E-13
^{174m}Lu	M	particulate								1.24E-14	1.24E-14
^{177}Lu	M	particulate								9.28E-11	9.28E-11
^{177m}Lu	M	particulate								2.20E-12	2.20E-12
^{53}Mn	M	particulate								6.94E-19	6.94E-19
^{54}Mn	M	particulate								1.86E-06	1.86E-06
^{56}Mn	M	particulate								6.08E-22	6.08E-22
^{93}Mo	M	particulate								1.24E-04	1.24E-04
^{99}Mo	M	particulate								1.56E-06	1.56E-06
^{13}N	B	unspecified							3.63E+02		3.63E+02
^{22}Na	M	particulate								2.71E-11	2.71E-11
^{24}Na	M	particulate								2.72E-08	2.72E-08
^{91m}Nb	B	unspecified								2.75E-13	2.75E-13
^{92}Nb	B	unspecified								3.23E-18	3.23E-18
^{93m}Nb	M	particulate								3.78E-09	3.78E-09
^{94}Nb	M	particulate								3.57E-08	3.57E-08

Table 5.7 Radiological airborne emissions from all sources at ORNL, 2017 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total Minor Source	ORNL Total
^{95}Nb	M	particulate								6.31E-07	6.31E-07
^{95m}Nb	M	particulate								1.78E-13	1.78E-13
^{96}Nb	M	particulate								5.41E-09	5.41E-09
^{97}Nb	M	particulate								3.30E-09	3.30E-09
^{147}Nd	M	particulate								2.58E-07	2.58E-07
^{59}Ni	M	particulate								1.12E-07	1.12E-07
^{63}Ni	M	particulate								6.60E-03	6.60E-03
^{65}Ni	M	particulate								4.69E-25	4.69E-25
^{66}Ni	M	particulate								1.92E-13	1.92E-13
^{235}Np	M	particulate								2.24E-14	2.24E-14
^{237}Np	M	particulate								1.18E-07	1.18E-07
^{238}Np	M	particulate								1.23E-10	1.23E-10
^{239}Np	M	particulate								2.14E-07	2.14E-07
^{185}Os	M	particulate								2.15E-14	2.15E-14
^{191}Os	M	particulate								7.03E-10	7.03E-10
^{32}P	M	particulate								7.97E-10	7.97E-10
^{33}P	M	particulate								1.67E-12	1.67E-12
^{228}Pa	M	particulate								3.30E-09	3.30E-09
^{230}Pa	M	particulate								3.80E-07	3.80E-07
^{231}Pa	M	particulate								4.24E-13	4.24E-13
^{232}Pa	M	particulate								1.09E-08	1.09E-08
^{233}Pa	M	particulate								1.51E-06	1.51E-06
^{234}Pa	M	particulate								1.84E-12	1.84E-12
^{234m}Pa	B	unspecified								1.13E-09	1.13E-09
^{212}Pb	M	particulate	5.08E-01	3.72E-01				4.15E-02		1.08E-05	9.22E-01
^{212}Pb	S	particulate			2.89E+00	9.68E-02				3.07E-02	3.02E+00
^{214}Pb	M	particulate								4.71E-20	4.71E-20
^{214}Pb	S	particulate			4.83E-02						4.83E-02

Table 5.7 Radiological airborne emissions from all sources at ORNL, 2017 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total Minor Source	ORNL Total
^{107}Pd	M	particulate								5.55E-10	5.55E-10
^{145}Pm	M	particulate								6.94E-12	6.94E-12
^{146}Pm	M	particulate								1.04E-10	1.04E-10
^{147}Pm	M	particulate								7.13E-06	7.13E-06
^{148m}Pm	M	particulate								5.82E-08	5.82E-08
^{209}Po	B	unspecified								1.09E-09	1.09E-09
^{210}Po	B	inorganic								3.89E-12	3.89E-12
^{212}Po	B	unspecified								7.41E-11	7.41E-11
^{213}Po	B	unspecified								2.58E-13	2.58E-13
^{214}Po	B	unspecified								4.71E-20	4.71E-20
^{215}Po	B	unspecified								2.05E-15	2.05E-15
^{216}Po	B	unspecified								1.15E-10	1.15E-10
^{218}Po	B	unspecified								4.71E-20	4.71E-20
^{144}Pr	M	particulate						4.20E-01		2.60E-06	4.20E-01
^{144m}Pr	B	unspecified								6.82E-10	6.82E-10
^{193}Pt	M	particulate								5.40E-10	5.40E-10
^{236}Pu	M	particulate								6.37E-11	6.37E-11
^{237}Pu	M	particulate								5.28E-22	5.28E-22
^{238}Pu	F	particulate			3.82E-08	1.40E-08	4.20E-07			8.86E-09	4.81E-07
^{238}Pu	M	particulate		4.34E-08				1.64E-08		4.47E-05	4.48E-05
^{239}Pu	F	particulate			1.31E-07	4.03E-09	2.00E-07			2.10E-09	3.37E-07
^{239}Pu	M	particulate	3.88E-09	2.87E-07				7.50E-09		9.43E-07	1.24E-06
^{240}Pu	F	particulate			1.31E-07	4.03E-09	2.00E-07			2.10E-09	3.37E-07
^{240}Pu	M	particulate	3.88E-09					7.50E-09		2.02E-06	2.04E-06
^{241}Pu	M	particulate								1.76E-04	1.76E-04
^{242}Pu	M	particulate								5.05E-08	5.05E-08
^{243}Pu	M	particulate								1.50E-14	1.50E-14
^{244}Pu	M	particulate								4.91E-09	4.91E-09

Table 5.7 Radiological airborne emissions from all sources at ORNL, 2017 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total Minor Source	ORNL Total
^{223}Ra	M	particulate								1.25E-06	1.25E-06
^{224}Ra	M	particulate								9.64E-07	9.64E-07
^{225}Ra	M	particulate								7.82E-08	7.82E-08
^{226}Ra	M	particulate								5.12E-07	5.12E-07
^{228}Ra	M	particulate								2.34E-05	2.34E-05
^{83}Rb	M	particulate								1.17E-19	1.17E-19
^{84}Rb	M	particulate								1.94E-25	1.94E-25
^{87}Rb	M	particulate								6.39E-14	6.39E-14
^{183}Re	B	unspecified								2.22E-18	2.22E-18
^{184}Re	M	particulate								5.59E-14	5.59E-14
^{184m}Re	M	particulate								2.87E-13	2.87E-13
^{186}Re	M	particulate								3.58E-10	3.58E-10
^{188}Re	M	particulate								3.67E+00	3.67E+00
^{189}Re	M	particulate								3.04E-11	3.04E-11
^{101}Rh	M	particulate								3.51E-15	3.51E-15
^{102}Rh	M	particulate								8.61E-14	8.61E-14
^{102m}Rh	M	particulate								1.26E-11	1.26E-11
^{103m}Rh	M	particulate								1.83E-14	1.83E-14
^{105}Rh	M	particulate								4.05E-07	4.05E-07
^{106}Rh	B	unspecified								3.31E-07	3.31E-07
^{219}Rn	B	unspecified								3.80E-11	3.80E-11
^{220}Rn	B	unspecified								1.70E-07	1.70E-07
^{222}Rn	B	unspecified								4.71E-20	4.71E-20
^{103}Ru	M	particulate								1.36E-06	1.36E-06
^{106}Ru	M	particulate								2.62E-06	2.62E-06
^{35}S	M	particulate								7.02E-08	7.02E-08
^{120m}Sb	M	particulate								9.50E-08	9.50E-08
^{122}Sb	M	particulate								1.92E-07	1.92E-07

Table 5.7 Radiological airborne emissions from all sources at ORNL, 2017 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total Minor Source	ORNL Total
^{124}Sb	M	particulate								7.28E-07	7.28E-07
^{125}Sb	M	particulate						6.49E-07		8.03E-07	1.45E-06
^{126}Sb	M	particulate								4.76E-07	4.76E-07
^{126m}Sb	M	particulate								2.17E-09	2.17E-09
^{127}Sb	M	particulate								3.73E-07	3.73E-07
^{44}Sc	M	particulate								1.07E-22	1.07E-22
^{46}Sc	M	particulate								2.44E-04	2.44E-04
^{47}Sc	M	particulate								1.66E-08	1.66E-08
^{48}Sc	M	particulate								2.70E-08	2.70E-08
^{75}Se	F	particulate								4.24E-06	4.24E-06
^{75}Se	S	particulate			5.95E-05						5.95E-05
^{79}Se	F	particulate								2.41E-10	2.41E-10
^{31}Si	M	particulate								4.30E-24	4.30E-24
^{32}Si	M	particulate								8.73E-15	8.73E-15
^{145}Sm	M	particulate								2.91E-10	2.91E-10
^{147}Sm	M	particulate								1.98E-16	1.98E-16
^{151}Sm	M	particulate								9.06E-07	9.06E-07
^{113}Sn	M	particulate								8.96E-07	8.96E-07
^{117m}Sn	M	particulate								3.22E-08	3.22E-08
^{119m}Sn	M	particulate								4.88E-10	4.88E-10
^{121}Sn	M	particulate								3.33E-08	3.33E-08
^{121m}Sn	M	particulate								4.25E-08	4.25E-08
^{123}Sn	M	particulate								2.64E-04	2.64E-04
^{125}Sn	M	particulate								4.91E-07	4.91E-07
^{126}Sn	M	particulate								2.17E-09	2.17E-09
^{85}Sr	M	particulate								7.29E-08	7.29E-08
^{89}Sr	M	particulate	4.00E-08	3.46E-06				7.30E-06		3.91E-04	4.01E-04
^{89}Sr	S	particulate			1.25E-05	1.53E-08				9.82E-08	1.26E-05

Table 5.7 Radiological airborne emissions from all sources at ORNL, 2017 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total Minor Source	ORNL Total
^{90}Sr	S	particulate			1.25E-05	1.53E-08	3.98E-06			9.82E-08	1.66E-05
^{90}Sr	M	particulate	4.00E-08	3.46E-06				7.30E-06		5.69E-04	5.80E-04
^{91}Sr	M	particulate								1.78E-12	1.78E-12
^{179}Ta	M	particulate								1.87E-12	1.87E-12
^{182}Ta	M	particulate								7.08E-07	7.08E-07
^{183}Ta	M	particulate								4.86E-06	4.86E-06
^{184}Ta	M	particulate								4.08E-14	4.08E-14
^{157}Tb	M	particulate								4.99E-16	4.99E-16
^{158}Tb	M	particulate								7.50E-13	7.50E-13
^{160}Tb	M	particulate								5.55E-11	5.55E-11
^{95m}Tc	M	particulate								2.50E-14	2.50E-14
^{96}Tc	M	particulate								1.99E-08	1.99E-08
^{98}Tc	M	particulate								2.08E-14	2.08E-14
^{99}Tc	S	particulate					3.95E-06				3.95E-06
^{99}Tc	M	particulate								2.88E-04	2.88E-04
^{121}Te	M	particulate								4.54E-08	4.54E-08
^{121m}Te	M	particulate								4.01E-09	4.01E-09
^{123m}Te	M	particulate								4.90E-09	4.90E-09
^{125m}Te	M	particulate								1.82E-07	1.82E-07
^{127}Te	M	particulate								4.01E-13	4.01E-13
^{127m}Te	M	particulate								2.31E-12	2.31E-12
^{129m}Te	M	particulate								3.45E-19	3.45E-19
^{131m}Te	M	particulate								4.71E-08	4.71E-08
^{132}Te	M	particulate								3.92E-07	3.92E-07
^{227}Th	S	particulate								1.66E-06	1.66E-06
^{228}Th	S	particulate	3.64E-09	7.14E-09	1.74E-08	8.38E-09		7.71E-09		4.15E-07	4.59E-07
^{229}Th	S	particulate								4.19E-08	4.19E-08
^{230}Th	S	particulate	1.42E-09	3.35E-09				5.62E-09		4.16E-07	4.26E-07

Table 5.7 Radiological airborne emissions from all sources at ORNL, 2017 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total Minor Source	ORNL Total
^{230}Th	F	particulate			2.10E-08	1.57E-09				2.68E-09	2.53E-08
^{231}Th	S	particulate								1.20E-10	1.20E-10
^{232}Th	S	particulate	1.38E-09	3.07E-09				5.72E-09		8.48E-06	8.49E-06
^{232}Th	F	particulate			1.2E-08	1.74E-09				1.06E-09	1.48E-08
^{234}Th	S	particulate								2.86E-09	2.86E-09
^{44}Ti	M	particulate								1.29E-14	1.29E-14
^{45}Ti	M	particulate								5.91E-25	5.91E-25
^{201}Tl	M	particulate								3.48E-09	3.48E-09
^{202}Tl	M	particulate								8.91E-10	8.91E-10
^{204}Tl	M	particulate								3.46E-13	3.46E-13
^{208}Tl	B	unspecified								3.17E-06	3.17E-06
^{170}Tm	M	particulate								3.04E-04	3.04E-04
^{171}Tm	M	particulate								2.54E-12	2.54E-12
^{232}U	M	particulate								1.78E-07	1.78E-07
^{233}U	S	particulate			4.54E-08	4.10E-09	4.12E-07			7.03E-09	4.68E-07
^{233}U	M	particulate	1.80E-08					2.06E-08		1.30E-04	1.30E-04
^{234}U	S	particulate			4.54E-08	4.10E-09	4.12E-07			7.03E-09	4.68E-07
^{234}U	M	particulate	1.80E-08	3.43E-07				2.06E-08		1.45E-04	1.45E-04
^{235}U	M	particulate	2.05E-09	1.88E-08				9.51E-09		1.55E-04	1.55E-04
^{235}U	S	particulate			2.24E-08	8.88E-10				1.58E-09	2.49E-08
^{236}U	M	particulate								3.69E-06	3.69E-06
^{237}U	M	particulate								4.04E-09	4.04E-09
^{238}U	M	particulate	5.89E-09	2.73E-08				2.43E-08		5.06E-03	5.06E-03
^{238}U	S	particulate			4.52E-08	3.23E-09				8.28E-09	5.67E-08
^{48}V	M	particulate								8.58E-18	8.58E-18
^{49}V	M	particulate								1.06E-09	1.06E-09
^{181}W	M	particulate								7.52E-09	7.52E-09
^{185}W	M	particulate								1.66E-07	1.66E-07

Table 5.7 Radiological airborne emissions from all sources at ORNL, 2017 (Ci)[a] (continued)

Isotope	Inhalation Form[b]	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total Minor Source	ORNL Total
^{187}W	M	particulate								3.13E-03	3.13E-03
^{188}W	M	particulate								3.26E-04	3.26E-04
^{127}Xe	B	unspecified							3.05E+02		3.05E+02
^{131m}Xe	B	unspecified						1.38E+02			1.38E+02
^{133}Xe	B	unspecified			9.70E-05			1.47E+01			1.47E+01
^{133m}Xe	B	unspecified						2.62E+01			2.62E+01
^{135}Xe	B	unspecified						2.68E+01			2.68E+01
^{135m}Xe	B	unspecified						1.06E+01			1.06E+01
^{137}Xe	B	unspecified						4.80E+01			4.80E+01
^{138}Xe	B	unspecified						7.73E+01			7.73E+01
^{88}Y	M	particulate								3.70E-09	3.70E-09
^{90}Y	M	particulate								1.47E-04	1.47E-04
^{91}Y	M	particulate								6.33E-10	6.33E-10
^{65}Zn	M	particulate								9.89E-06	9.89E-06
^{69}Zn	M	particulate								7.88E-10	7.88E-10
^{88}Zr	M	particulate								6.99E-20	6.99E-20
^{93}Zr	M	particulate								5.66E-09	5.66E-09
^{95}Zr	M	particulate								7.32E-07	7.32E-07
^{97}Zr	M	particulate								2.30E-09	2.30E-09
Totals			**5.17E-01**	**3.72E-01**	**6.05E+00**	**7.35E-01**	**1.58E-05**	**2.91E+03**	**1.79E+04**	**4.34E+00**	**2.08E+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.

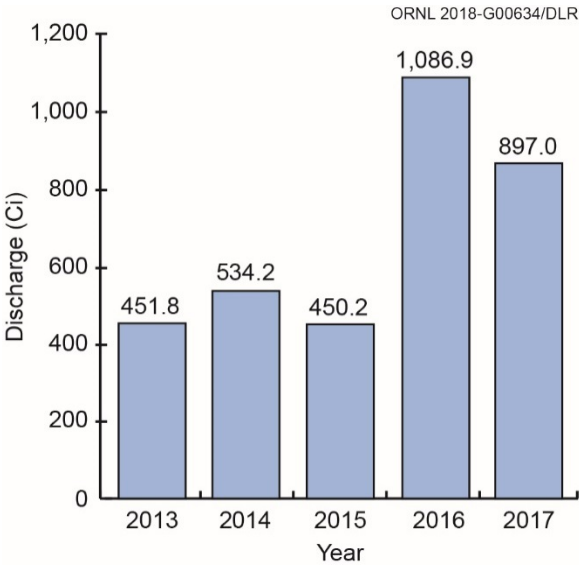


Figure 5.7. Total curies of tritium discharged from Oak Ridge National Laboratory to the atmosphere, 2013–2017

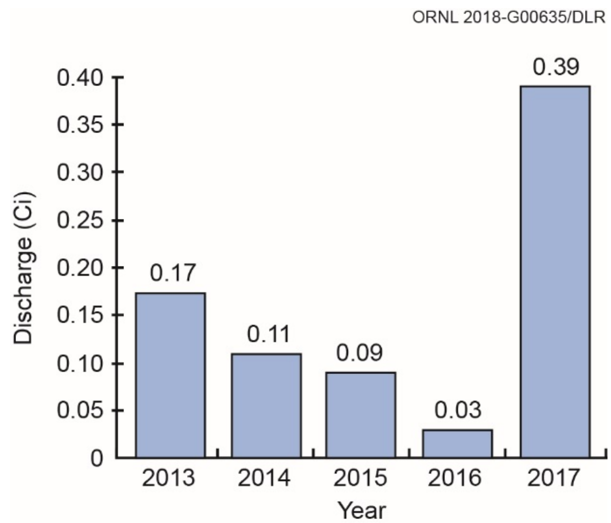


Figure 5.8. Total curies of ^{131}I discharged from Oak Ridge National Laboratory to the atmosphere, 2013–2017

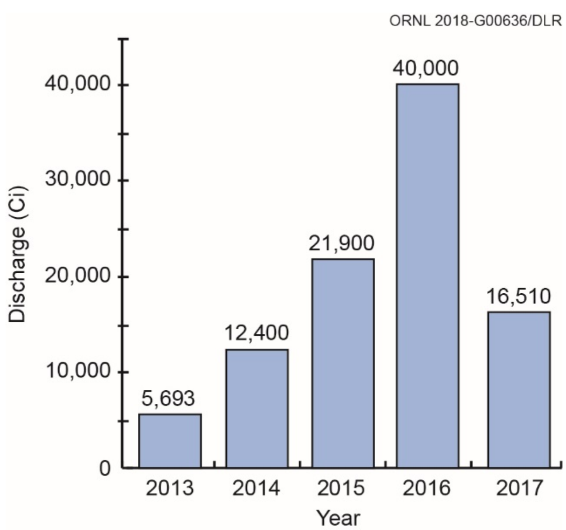


Figure 5.9. Total curies of ^{11}C discharged from Oak Ridge National Laboratory to the atmosphere, 2013–2017

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. 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 are effective January 1, 2018, for disposal of small appliances and January 1, 2019, for the leak rate provisions for large appliances. Assessments were conducted in 2017 to identify necessary changes to the Stratospheric Ozone Protection compliance program and were being 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 have already been implemented.

5.4.5 Ambient Air

Station 7 in the ORNL 7000 maintenance area is the site-specific ambient air monitoring location. During 2017, 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 2017 average radionuclide concentrations at Station 7 were less than 1% of the applicable DCS in all cases.

Table 5.8. Radionuclide concentrations measured at Oak Ridge National Laboratory air monitoring Station 7, 2017

Parameter	Concentration (pCi/mL)[a]
Alpha	4.14E-08
^{7}Be	9.37E-08
Beta	6.75E-08
^{40}K	−6.13E-09[b]
^{234}U	4.84E-11
^{235}U	1.53E-12
^{235}U	3.81E-11
Total U	8.80E-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 2014, 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 “establish better linkages between water quality monitoring and detecting and abating water quality and ecological impact.” 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 5.10) 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.

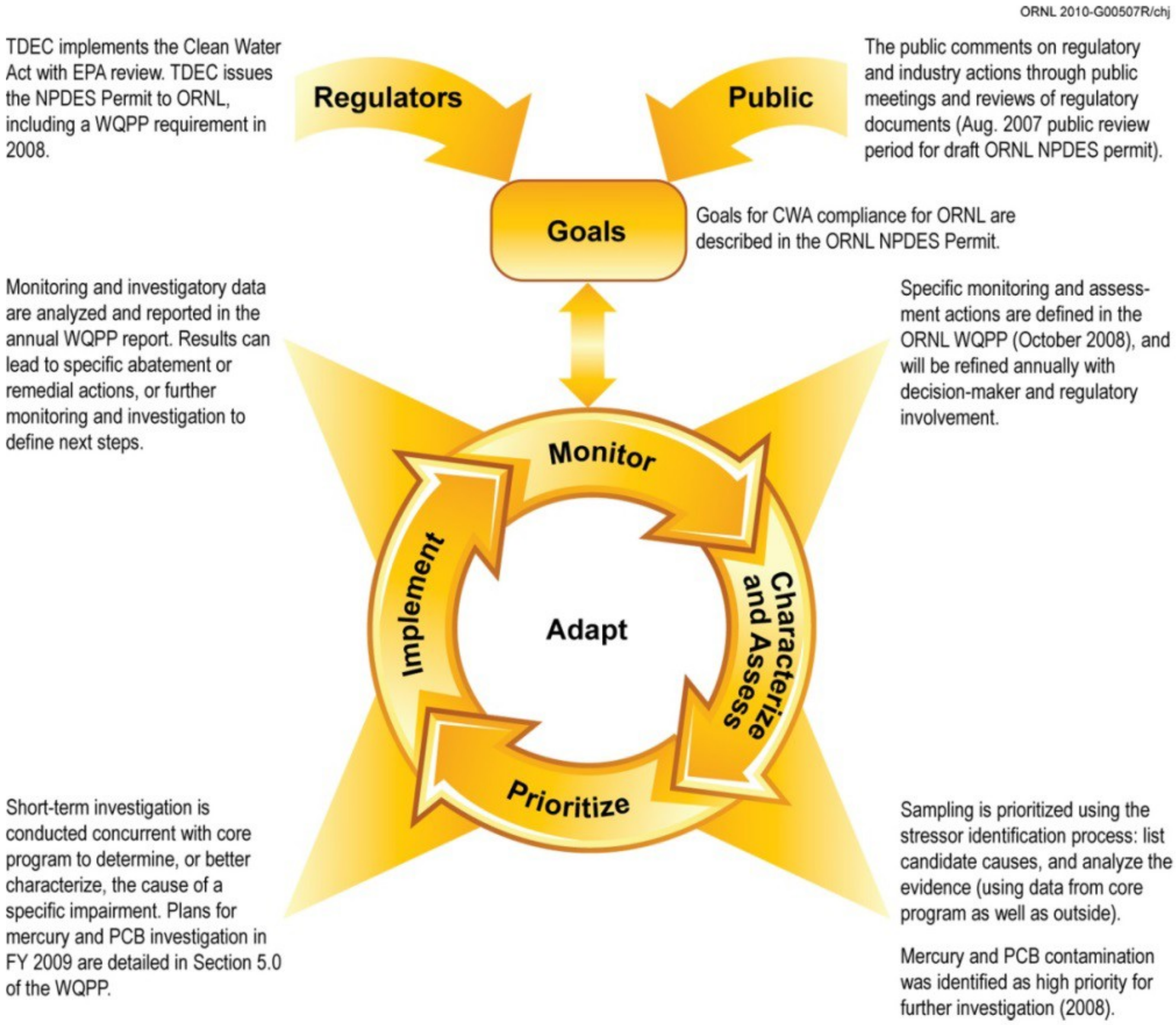
To prioritize the stressors and/or contaminant sources that may be of greatest concern to water quality and to define conceptual models that would guide any special investigations, the WQPP strategy was defined using EPA's Stressor Identification Guidance Document (EPA 2000). Figure 5.11 summarizes that 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), and
3. characterize the causes.

The first two steps of the stressor identification process were initiated in 2009, focusing first on mercury impairment (Figure 5.11) 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.

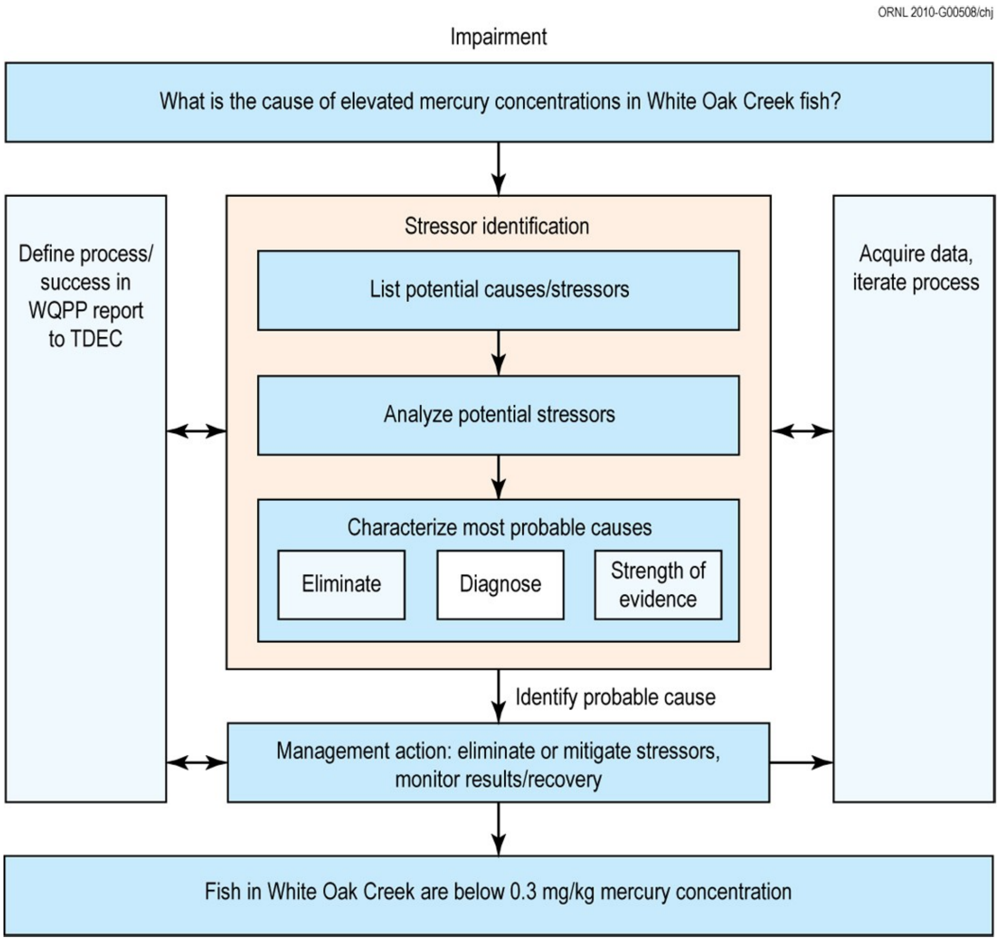
After potential causes were listed and the available evidence of mercury and PCB contamination in the WOC watershed was analyzed, it was clear that additional investigation was needed to characterize the causes. Special investigations were designed to identify specific source areas and to revise the 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 2000).
CWA = Clean Water Act, NPDES = National Pollutant Discharge Elimination System, ORNL = Oak Ridge National Laboratory, PCB = polychlorinated biphenyl, TDEC = Tennessee Department of Environment and Conservation

Figure 5.10. Diagram of the adaptive management framework with step-wise planning specific to the Oak Ridge National Laboratory Water Quality Protection Plan (WQPP)



Modified from Figure 1-1 in the US Environmental Protection Agency stressor guidance document (EPA 2000).
TDEC = Tennessee Department of Environment and Conservation, WQPP = water quality protection plan

Figure 5.11. 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 2017 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 March 2014. 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 99% compliance with permit limits and conditions in 2017. On infrequent occasions, the plant has gone into partial-treatment mode (disinfection) when the influent-handling capacity was exceeded due to heavy rain storms. A project to upgrade the ORNL STP, including increased influent-handling capacity, was completed in 2017.

Table 5.9. National Pollutant Discharge Elimination System compliance at Oak Ridge National Laboratory, January through December 2017

Effluent parameters	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 noncompliances	Number of samples	Percentage of compliance[a]
				X01 (ORNL Sewage Treatment Plant)				
LC_{50} for *Ceriodaphnia* (%)					100	0	1	100
LC_{50} for fathead minnows (%)					100	0	1	100
Ammonia, as N (summer)	6.26	9.39	2.5	3.75		5[b]	25	80
Ammonia, as N (winter)	13.14	19.78	5.25	7.9		0	29	100
Carbonaceous biological oxygen demand	19.2	28.8	10	15		1[b]	53	98
Dissolved oxygen					6	0	53	100
Escherichia coliform (col/100 mL)			941	126		3[c]	52	94
Oil and grease				15		0	1	100
pH (standard units)				9	6	0	53	100
Total suspended solids	57.5	86.3	30	45		0	53	100
				X12 (Process Waste Treatment Complex)				
LC_{50} for *Ceriodaphnia* (%)					100	0	1	100
LC_{50} for fathead minnows (%)					100	0	1	100
Arsenic, total				0.014		0	4	100
Chromium, total				0.44		0	4	100
Copper, total				0.11		0	4	100
Cyanide, total				0.046		0	2	100
Lead, total				0.69		0	4	100
Oil and grease				15		0	12	100
pH (standard units)				9.0	6.0	0	53	100
Temperature (ºC)				30.5		0	53	100
				Instream chlorine monitoring points				
Total residual oxidant			0.011	0.019		0	288	100

[a] Percentage compliance = 100 – [(number of noncompliances/number of samples) × 100].
[b] Heavy rains in April 2017 caused heavy influent flows to the Sewage Treatment Plant (STP). Operations were adjusted to prevent washout of the STP. The operational disruption caused a carbonaceous biological oxygen demand and five ammonia noncompliances during the next several months it took to fully restore STP operations.
[c] Malfunctioning equipment in the STP ozone disinfection system caused three *E. coli* noncompliances during May–July 2017.

Acronyms

LC_{50} = lethal concentration; the concentration (as a percentage of full-strength wastewater) that kills 50% of the test species in 48 h.
ORNL = Oak Ridge National Laboratory

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* (*C. 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. Test results have been excellent. PWTC effluent has always been shown to be nontoxic. The STP has shown isolated indications of effluent toxicity, none recent, 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 acute 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. In 2017, toxicity test results for the ORNL wastewater treatment facilities were once again favorable, with no indication of toxicity in any of the tests that were conducted (Table 5.9).

5.5.2 Residual Bromine and Chlorine Monitoring

At ORNL, chlorine is added to drinking water as a disinfectant prior to consumption. Additional chlorine and bromine are also added for maintenance of cooling system infrastructure to prevent bacterial growth. When waters are discharged to streams, residual chlorine and bromine can be toxic to fish and other aquatic life. The ORNL NPDES permit controls the discharge of chlorinated and brominated waters, reported as “total residual oxidant” (TRO), by limiting the TRO mass loading from outfalls. TRO is monitored to ensure effective dechlorination of cooling tower blowdown systems, once-through cooling water systems, and any infrastructure leaks from water lines. The NPDES permit action level is 1.2 g/day TRO at any outfall. NPDES permit outfalls that may contain TRO are dechlorinated and monitored to ensure that TRO is < 0.05 mg/L, which is the field detection level. Cooling tower blowdown and large cooling water discharges are monitored most frequently (twice a month) to check the effectiveness of dechlorination systems. Other outfalls that have been affected in the past by infrastructure leaks or other temporary incidents are monitored at regular, less-frequent intervals.

In 2017, TRO measurements were performed at 26 outfalls on a semiannual, quarterly, monthly, or semimonthly basis if flow was present. A total of 240 TRO measurements were taken. Table 5.10 shows that in 2017 there was just one instance of an outfall (Outfall 231) discharge that exceeded the TRO permit action level.

In 2016, Outfall 231 also had one incident of a TRO exceedance. Outfall 231 receives cooling tower blowdown from Building 5800 that is dechlorinated inside the building using a sodium sulfite tablet feeder. ORNL staff investigated the exceedance and implemented treatment and reduction measures. All of the tablet dechlorination boxes were inspected. It was determined that eight of the boxes associated with cooling tower discharges needed repair or replacement to keep tablets dry between flows, and to improve flow through the boxes and contact with the sodium sulfite tablets. All eight boxes were replaced in 2017. The tablet feeder at Outfall 231 had already been replaced when TRO was found again in December 2017. It is not known why excess oxidant was found at that time. Prior to the tablet feeder upgrade, backup secondary dichlorination had been utilized for discharges from the two largest cooling tower complexes that discharge to Outfalls 227 and 363. The secondary dichlorination at the larger towers has been retained until the inconsistencies are better understood. As ORNL tries to minimize water use and to replace once-through noncontact cooling water with recirculating systems, troubleshooting and improvements also continue to be made at the two sodium bisulfite liquid feed systems used in the main plant area.

Table 5.10. Outfalls exceeding total residual oxidant NPDES permit action level in 2017

Sample date	Outfall	TRO[a] concentration (mg/L)	Flow (gpm)	Load (g/day)	Receiving stream	Downstream integration point	Instream TRO point
12/18/2017	231	0.7	8	30.52	WOC	WCK 4.4	X25

[a] The NPDES action level is 1.2 g/day.

Acronyms
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 5.11 details the analyses performed on samples collected in 2017 at two treatment facility outfalls, three instream monitoring locations, and 21 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 2017, dry-weather grab samples were collected at 17 of the 21 category outfalls targeted for sampling. Four category outfalls (205, 241, 265, and 284) were not sampled because there was no discharge present during sampling attempts.

The two ORNL treatment facility outfalls that were monitored for radioactivity in 2017 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 5.12). 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 roughly equivalent to the 4 mrem dose limit on which the EPA radionuclide drinking water standards are based and is a convenient 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% of the relevant DCS concentration in dry-weather discharges from NPDES Outfalls 085, 203, 204, 302, 304, X01, and X12 and at instream sampling locations on WOC (X14) and at WOD (X15) (Figure 5.13).

Table 5.11. Radiological monitoring conducted under the Oak Ridge National Laboratory Water Quality Protection Plan, 2017

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	X[a]			
Outfall 203	Semiannual	X	X			X				
Outfall 204	Semiannual	X	X			X				
Outfall 205 [b]	Annual									
Outfall 207	Quarterly	X								
Outfall 211	Annual	X								
Outfall 234	Annual	X								
Outfall 241 [b]	Quarterly									
Outfall 265 [b]	Annual									
Outfall 281	Quarterly	X		X						
Outfall 282	Quarterly	X								
Outfall 284 [b]	Annual									
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	Annual	X								
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

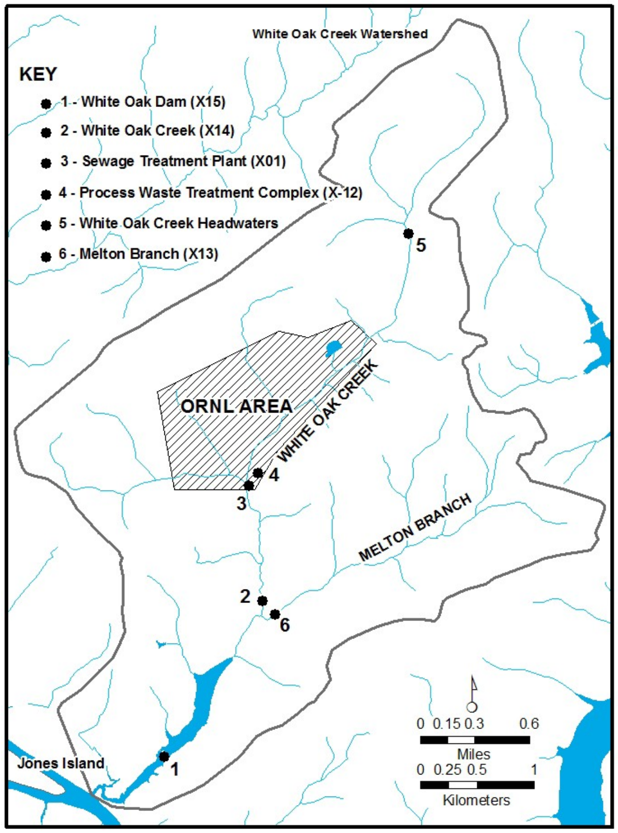


Figure 5.12. Selected surface water, National Pollutant Discharge Elimination System, and reference sampling locations at Oak Ridge National Laboratory, 2017

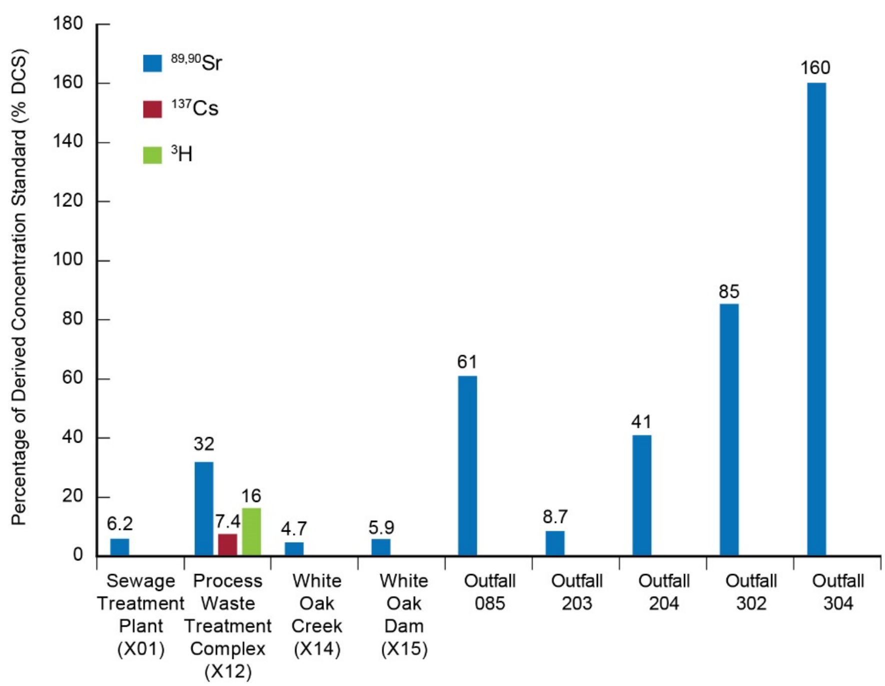


Figure 5.13. Outfalls and instream locations at Oak Ridge National Laboratory with average radionuclide concentrations greater than 4% of the relevant derived concentration standards in 2017

In 2017, one outfall (304) had an annual mean radioactivity concentration greater than 100% of a DCS. Outfall 304 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 160% of the DCS at Outfall 304. Consequently, concentrations of radioactivity in the discharge from Outfall 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); the sum of the fractions was 170%.

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 at the DOE Office of Environmental Management (OREM) WOC-9 (WC-9) Low Level Liquid Waste Tank Farm, 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 $^{89/90}Sr$ concentration at Outfall 304 peaked at 29,000 pCi/L (August and September 2015). Since the bypass was implemented, $^{89/90}Sr$ levels in the outfall effluent have trended downward, but they remained above DCS levels in 2017. 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.

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 5.14 through 5.18. Because discharges of radioactivity are somewhat correlated to stream flow, annual flow volumes measured at the WOD monitoring station are given in Figure 5.19. Discharges of radioactivity at WOD in 2017 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 2017 also included monitoring during storm runoff conditions. Eight 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 2017 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 (there are no DCSs 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 2017, none of the outfalls had a radionuclide concentration in storm water that was greater than 4% of a DCS level.

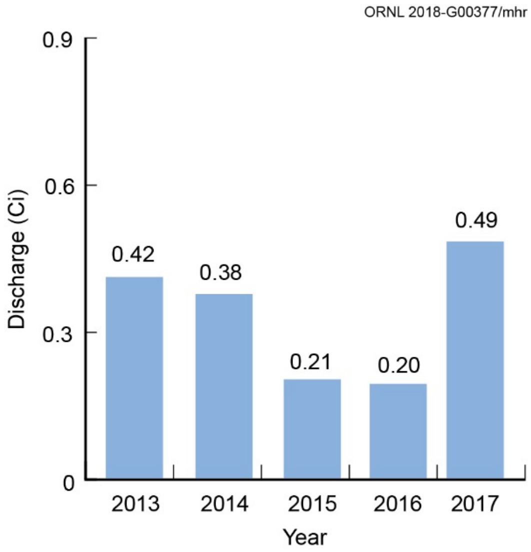


Figure 5.14. Cesium-137 discharges at White Oak Dam, 2013–2017

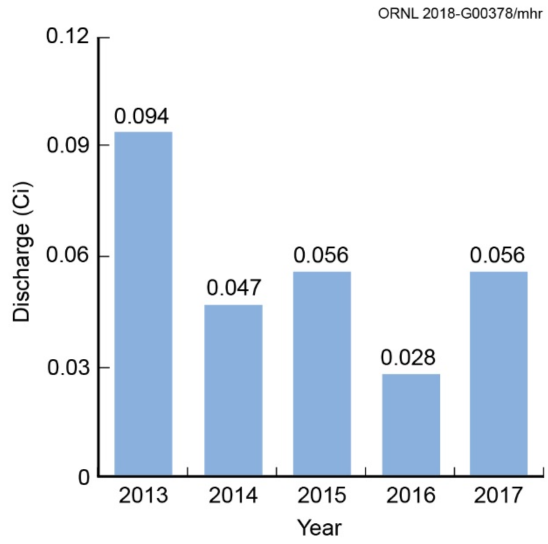


Figure 5.15. Gross alpha discharges at White Oak Dam, 2013–2017

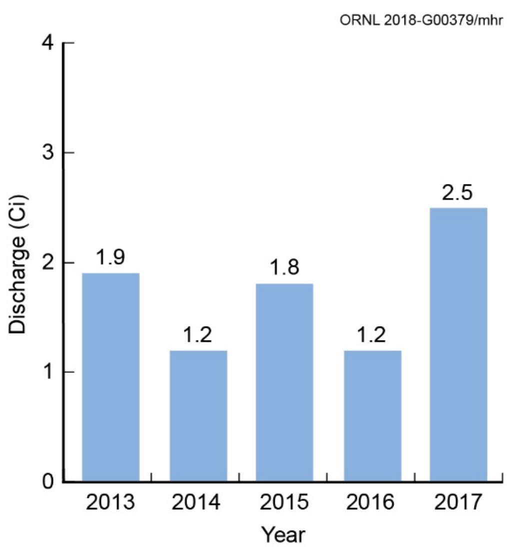


Figure 5.16. Gross beta discharges at White Oak Dam, 2013–2017

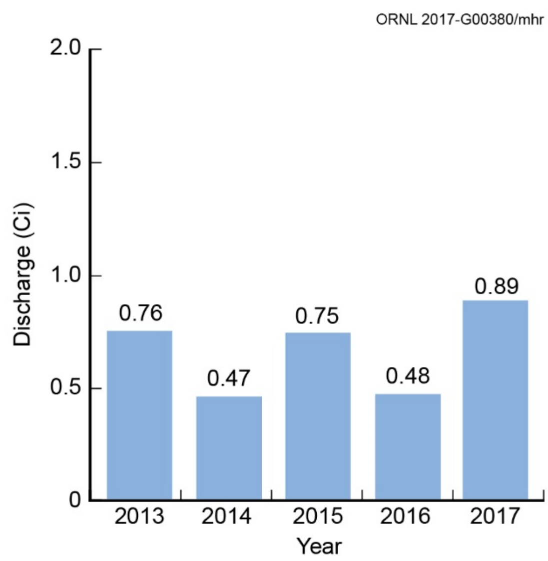


Figure 5.17. Total radioactive strontium discharges at White Oak Dam, 2013–2017

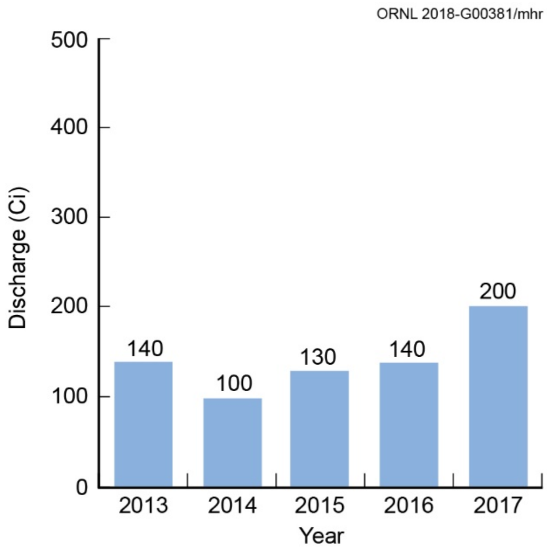


Figure 5.18. Tritium discharges at White Oak Dam, 2013–2017

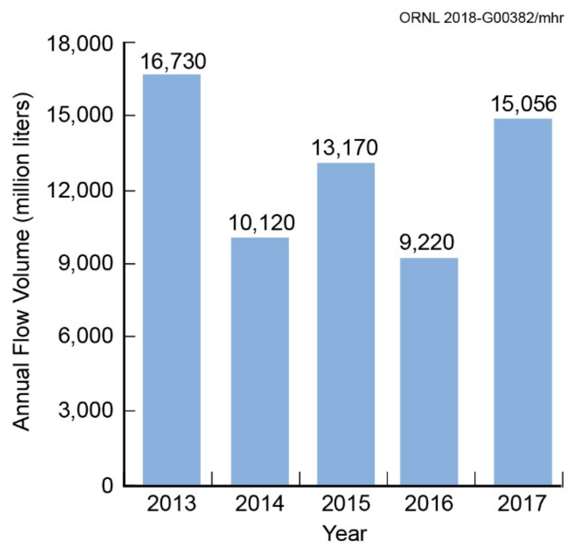


Figure 5.19. Annual flow volume at White Oak Dam, 2013–2017

5.5.4 Mercury in the White Oak Creek Watershed

Due to the persistence of elemental mercury, its volatility, and the complexity of its interactions in soil, mercury continues to be a contaminant associated with groundwater and storm water runoff in and around the facilities and associated piping where it was used. During the 1950s, mercury was used in a number of ORNL facilities (e.g., pilot-scale isotope separation work in Buildings 4501, 4505, and 3592 and in spent-fuel reprocessing in Building 3503). Legacy mercury contamination exists in those facilities and in infrastructure connected to them. Mercury is also present in process wastewater piping north of the intersection of Fifth Street and Central Avenue. The largest releases are known to be associated with Buildings 4501 and 4505, located east of Fifth Creek, where most of the building foundation sumps and storm drains were historically routed south to Outfall 211 on WOC (Figure 5.20). Buildings 3592 and 3503 were removed under the CERCLA remedial process in 2011 and 2012, respectively; however, their footprints and associated storm water drains remain in the Outfall 207 storm water drainage system.

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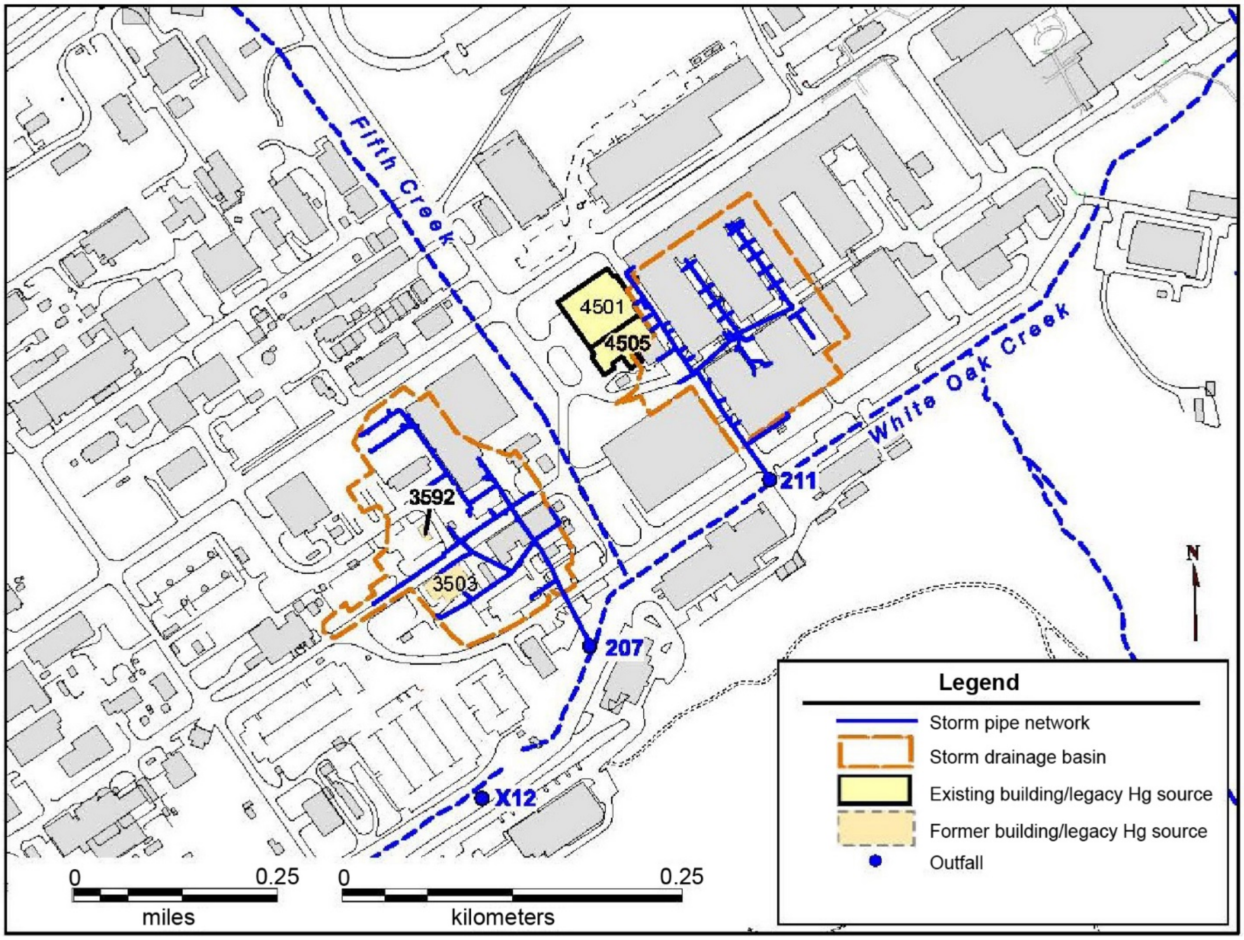


Figure 5.20. Outfalls with known historic mercury sources to White Oak Creek, 2017

5.5.4.1 Ambient Mercury in Water

In continuation of a monitoring effort initiated in 1997, bimonthly water samples were collected from WOC at four sites in 2017 (Figure 5.21). 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.

The concentration of mercury in WOC upstream from ORNL (White Oak Creek kilometer [WCK] 6.8) was less than 5 ng/L in 2017. Long-term trends in waterborne mercury in the WOC system downstream of ORNL are shown in Figure 5.22.

Waterborne mercury downstream of ORNL declined abruptly in 2008 and remained low through 2017 as a result of rerouting highly contaminated sump water in Building 4501 to PWTC in December 2007. The mean total mercury concentration at WCK 4.1 was 12.70 ± 8.19 ng/L in 2017 compared with 108 ± 33 ng/L in 2007. The decrease was also apparent at WCK 3.4, with mercury averaging 12.48 ± 7.33 ng/L in 2017 vs. 49 ± 23 ng/L in 2007. Mercury concentrations at these two sites were significantly lower than levels in 2007. A pretreatment system for the sump water, which started operation on October 22, 2009, removes almost all the mercury before sending the water to PWTC. The system reduces the mercury concentration in the PWTC influent and effluent. The average aqueous mercury concentration at WOD (WCK 1.5) was 36.38 ± 22.91 ng/L in 2017, higher than concentrations at other sites.

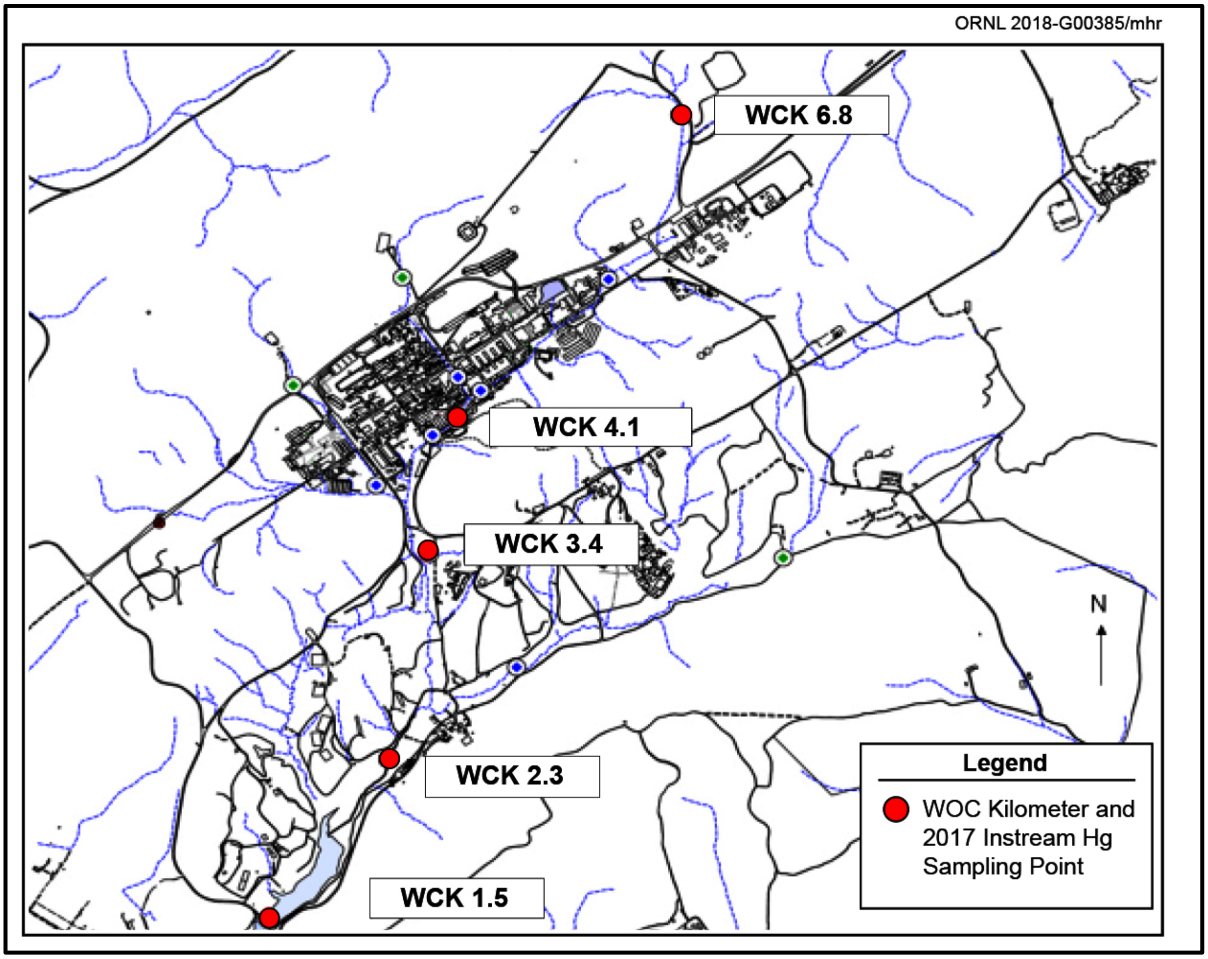
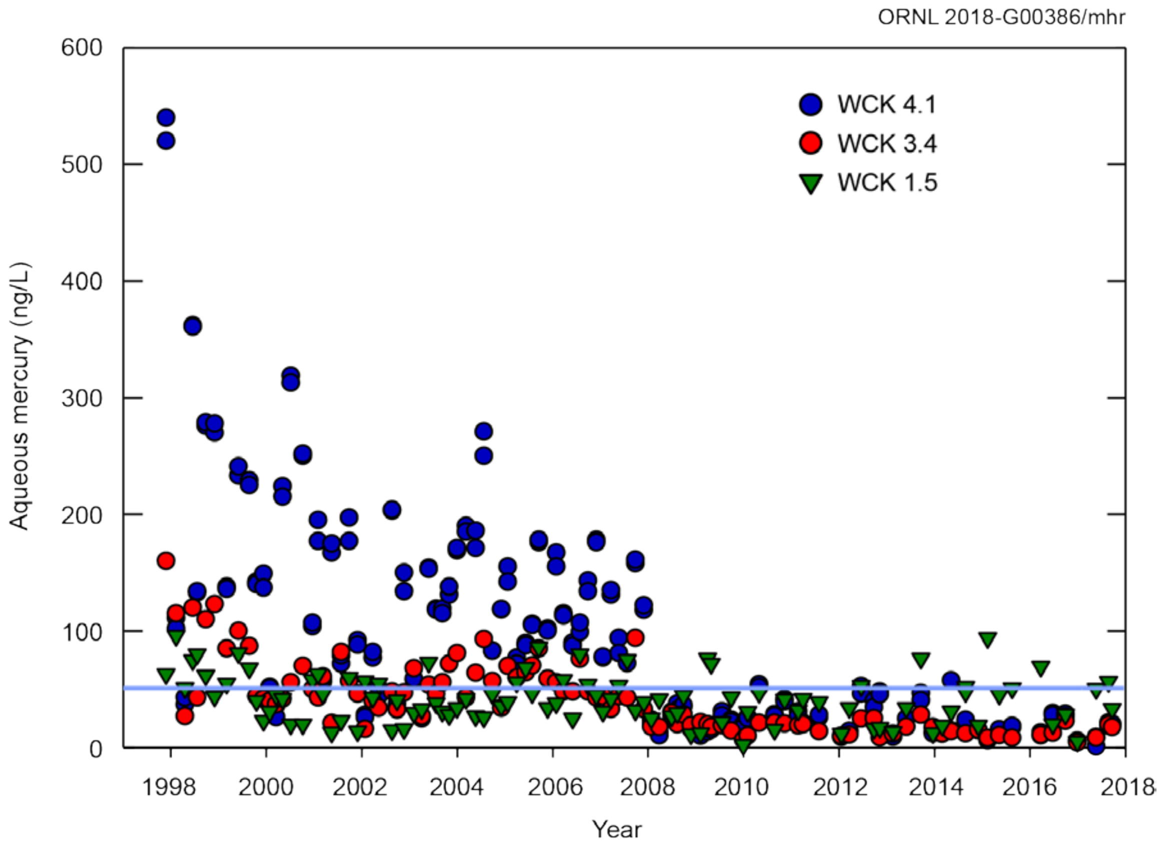


Figure 5.21. Instream monitoring and data locations, 2017

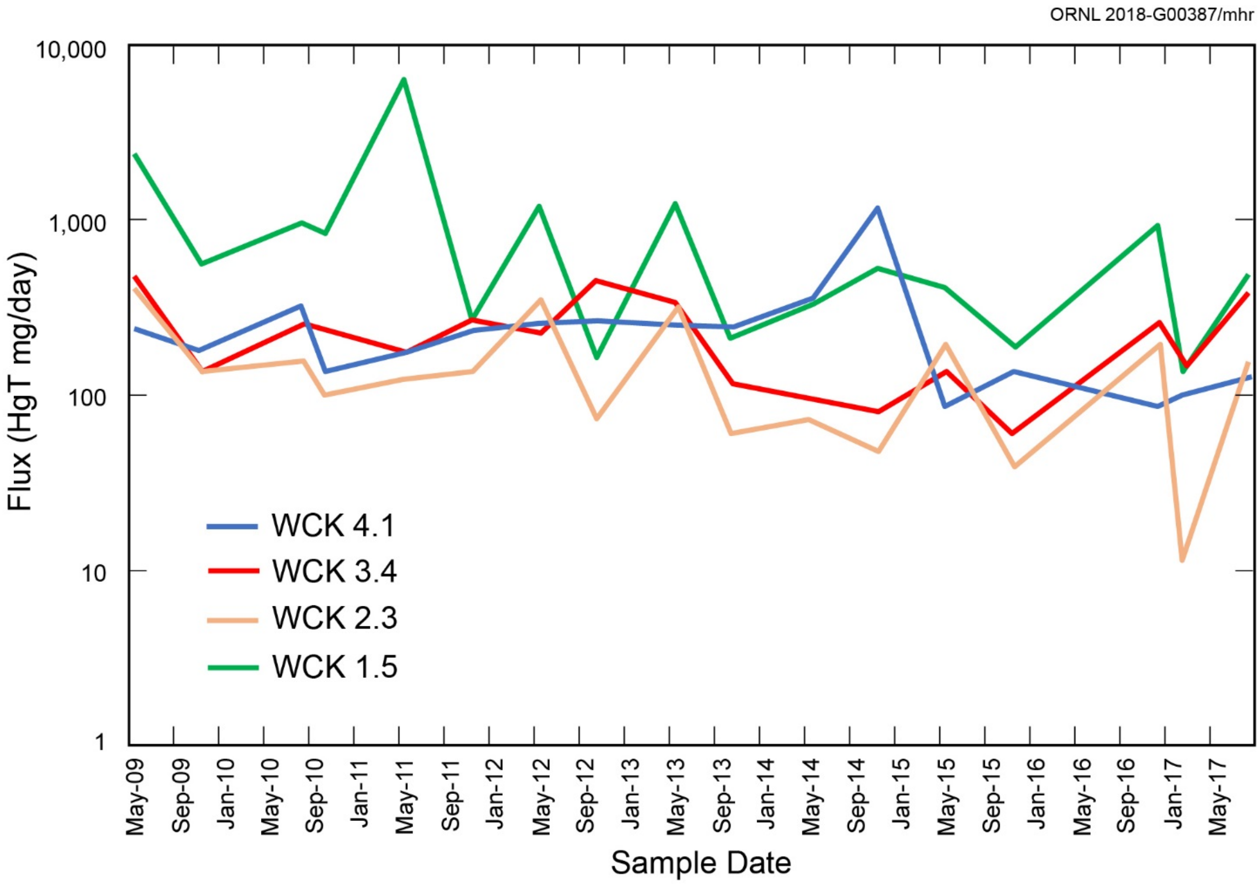


The blue line at 51 ng/L shows the Recreational Water Quality Criteria for Water and Organisms.
WCK = White Oak Creek kilometer

Figure 5.22. Total aqueous mercury concentrations at sites in White Oak Creek downstream from Oak Ridge National Laboratory, 1998–2017

Water Quality Protection Plan Mercury Investigation

In addition to the baseline bimonthly instream samples for mercury concentration, stream flow estimates and instream mercury concentrations are collected during dry weather in winter and summer at the WOC instream points shown in Figure 5.21. The mercury concentration data agree with the bimonthly data shown in Figure 5.22; total instream mercury concentrations are generally lower than the Tennessee AWQC. The exception has been at the WOD location (WCK 1.5). The August 2017 total mercury concentration at WCK 1.5 was just above the AWQC (51 ng/L). The collection of flow data allows for calculation of mercury flux (i.e., the amount of a substance detected per unit time in flowing water). Fluxes of mercury in milligrams per day since 2009 are shown in Figure 5.23. The figure compares trends at WCK 4.1 (mid-plant) downstream to WCK 1.5 at WOD and shows that there may be a downward trend in flux at WOD since 2009. Complete mercury monitoring results are available in the Oak Ridge Environmental Information System (OREIS). Access to OREIS can be requested via email (oreis@ettp.doe.gov) or by telephone (865-574-3257).



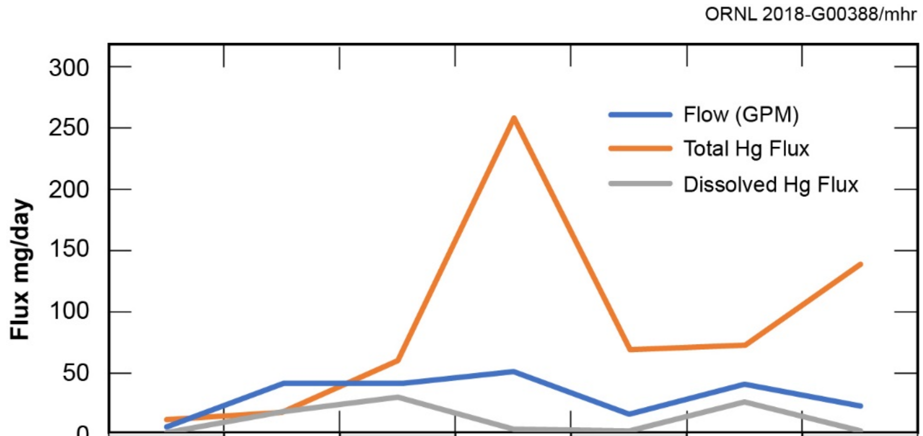
WCK = White Oak Creek kilometer

Figure 5.23. Historic (2009–2017) mercury flux (mg/day) at White Oak Creek instream monitoring locations WCK 1.5, 2.3, 3.4 and 4.1.

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. Between 2007 and 2011, three sumps that receive foundation groundwater from Buildings 4501 and 4500N were redirected to PWTC treatment for mercury removal; in addition, during 2009 a mercury pretreatment system was installed on the main sump in Building 4501. At the PWTC facility, one of the granular activated carbon filter columns was also upgraded in 2014 to a sulfur-impregnated carbon that is optimized for mercury removal. Figure 5.22 shows that after 2008, legacy mercury release was significantly reduced by these actions that directed foundation water away from the storm drain system and improved treatment plant removal capabilities.

Historically, dry- and wet-weather samples taken at storm Outfalls 211 and 207, have contained the highest concentrations of total mercury. At Outfall 207, the dry weather flows typically contain high concentrations of mercury, but the flows are very small. This trend continued in 2017, with the one monitored dry-weather flow of 0.1 gpm, having a high total mercury concentration of 1830 ng/L. During 2017, WQPP sampling of Outfall 207 focused on capturing data during storm flows in which larger mercury fluxes might be delivered to WOC. Figure 5.24 shows those results. During 2017 storms, the mercury flux at Outfall 207 was elevated by higher concentration but also limited by the relatively low volume of storm water flow entering and moving through the storm pipe network. The highest storm flow measured was estimated at 50 gpm. Although total mercury flux was as high as 260 mg/day, dissolved mercury flux was no more than 30 mg/day.



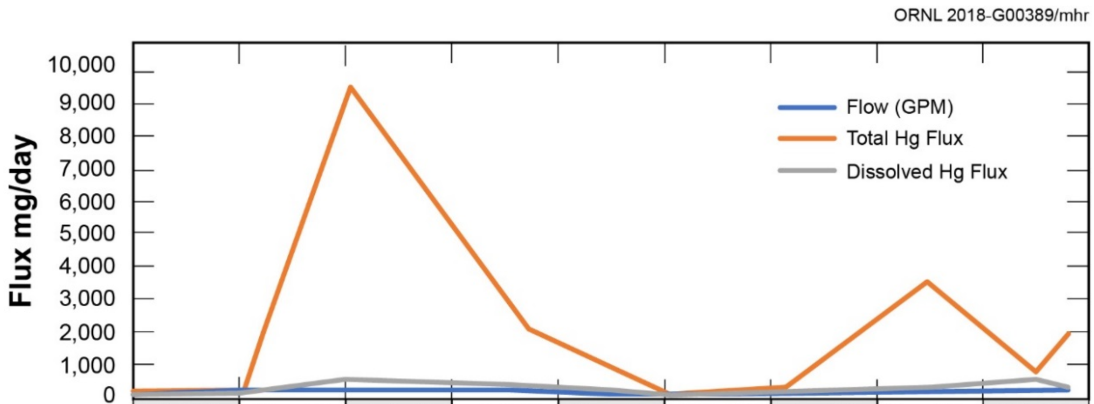
	Jul-15	Jul-16	Nov-16	Feb-17	Jun-17	Sep-17	Oct-17
Flow (GPM)	4.5	40	40	50	15	40	22
Total Hg Flux	12	16	59	261	68	71	138
Dissolved Hg Flux	1	17	30	3	2	25	1

Storm Date

Figure 5.24. Outfall 207 storm flow and flux of total and dissolved mercury, 2017

Storm data collected at Outfall 211 during 2016 through 2017 (Figure 5.25) show much higher fluxes of total mercury than seen at Outfall 207. Much bigger storm water flow rates occurred in the Outfall 211 piping system (estimated at 50 to 225 gpm). Even though the 2017 mercury fluxes were lower than the very high ones found in February of 2016, the 2017 total mercury flux values ranged from 202 to 3,532 mg/day. The storm water samples from Outfall 211 that measured the highest total mercury fluxes (>1,000 mg/day) also measured the highest percentage of total mercury flux composed of particulate (total minus dissolved) mercury.

At the terminus of the Outfall 211 pipe, sediment collects behind a weir plate to which two sodium sulfite tablet dechlorination boxes are attached to dechlorinate flows. Storm samples are taken from the area between the pipe terminus and this weir plate because the creek levels during storms are often above the level of the dechlorinator outlets on the creek side. During storms, accumulated sediment behind the Outfall 211 weir plate may be contributing to both nondissolved and dissolved mercury entering WOC via the Outfall 211 storm drain system.



	Jul-15	Nov-15	Feb-16	Jul-16	Nov-16	Feb-17	Jun-17	Sep-17	Oct-17
Flow (GPM)	50	225	180	175	70	175	180	170	170
Total Hg Flux	67	227	9490	2050	49	202	3532	731	1890
Dissolved Hg Flux	50	121	515	413	33	188	311	556	278

Storm Date

Figure 5.25. Outfall 211 storm flow and flux of total and dissolved mercury, 2016–2017

5.5.5 Storm Water Surveillances and Construction Activities

Storm water drainage areas at ORNL are inspected twice per year as stipulated 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 storage is dynamic in many places but is most prevalent in the 7000 area on the east end of the main ORNL facility, 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. A site visit to active construction sites also occurs twice per year to evaluate the overall effectiveness of the best management practices in use. In general, no long-term environmental impacts have been noted. 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 tORR 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 mg/g in fish fillets, a concentration considered to be 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 5.26). Mean fillet concentrations decreased from 0.21 µg/g in 2016 to 0.13 µg/g in 2017 at WCK 3.9, remained 0.21 µg/g at WCK 2.3, and decreased from 0.24 µg/g in 2016 to 0.17 µg/g in 2017 at WCK 2.9 (Figure 5.26). These concentrations are below the AWQC for mercury in fish. Mercury concentrations in largemouth bass collected from WCK 1.5 (White Oak Lake) had been decreasing in recent years but remained above the guideline in 2017. Concentrations decreased to 0.36 µg/g from 0.46 µg/g in 2016.Mercury concentrations in bluegill collected from WCK 1.5 showed the same decrease as largemouth bass but remained below the recommended guideline. Mean PCB concentrations in redbreast sunfish at WCK 3.9 and WCK 2.9 (0.32 and 0.46 µg/g, respectively) were higher than in 2016 but comparable to values recorded in recent years. PCB concentrations (defined as the sum of Aroclors 1248, 1254, and 1260) in redbreast sunfish from the WOC watershed remained within historical ranges despite slight increases at all stream sites in 2017, with mean concentrations of 0.32 ± 0.07 µg/g at WCK 3.9, 0.46 ± 0.09 µg/g at WCK 2.9, and 0.31 ± 0.05 µg/g at WCK 2.3 (compared to 0.23 µg/g at WCK 3.9, 0.20 µg/g at WCK 2.9, and 0.03 µg/g at WCK 2.3, respectively in 2016; Figure 5.26). In contrast, mean PCB concentrations in largemouth bass collected from WCK 1.5 (1.19 µg/g) decreased in 2017, as did mean concentrations in bluegill (0.93 µg/g; Figure 5.27).

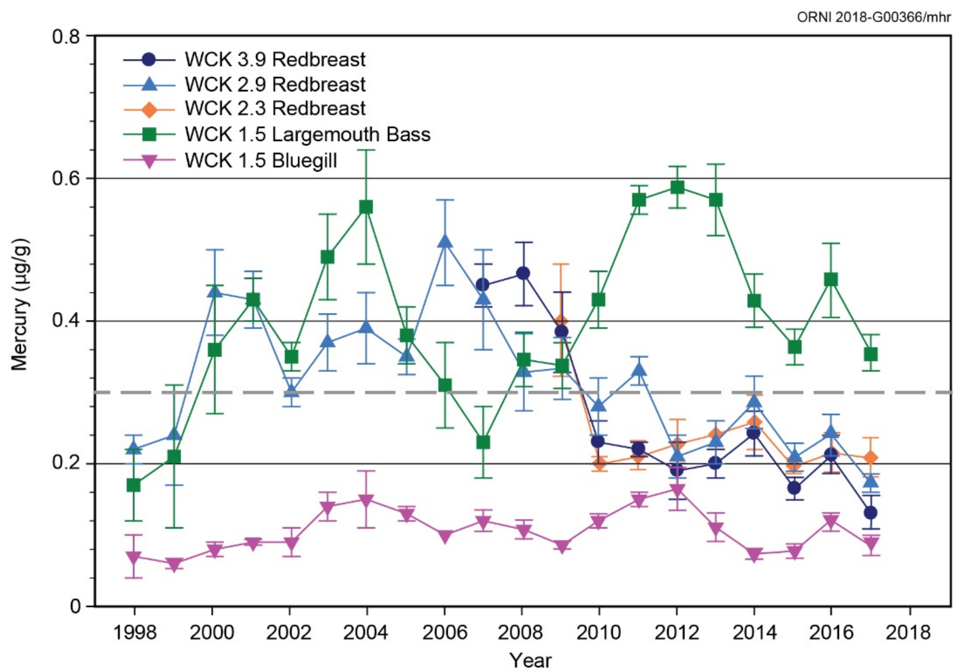


Figure 5.26. Mean concentrations of mercury (± standard error, N = 6) in muscle tissue of sunfish and bass from White Oak Creek kilometers (WCKs) 3.9, 2.9, and 2.3 and White Oak Lake (WCK 1.5), 1998–2017

Dashed grey line indicates the US Environmental Protection Agency ambient water quality criterion for mercury (0.3 µg/g in fish tissue).

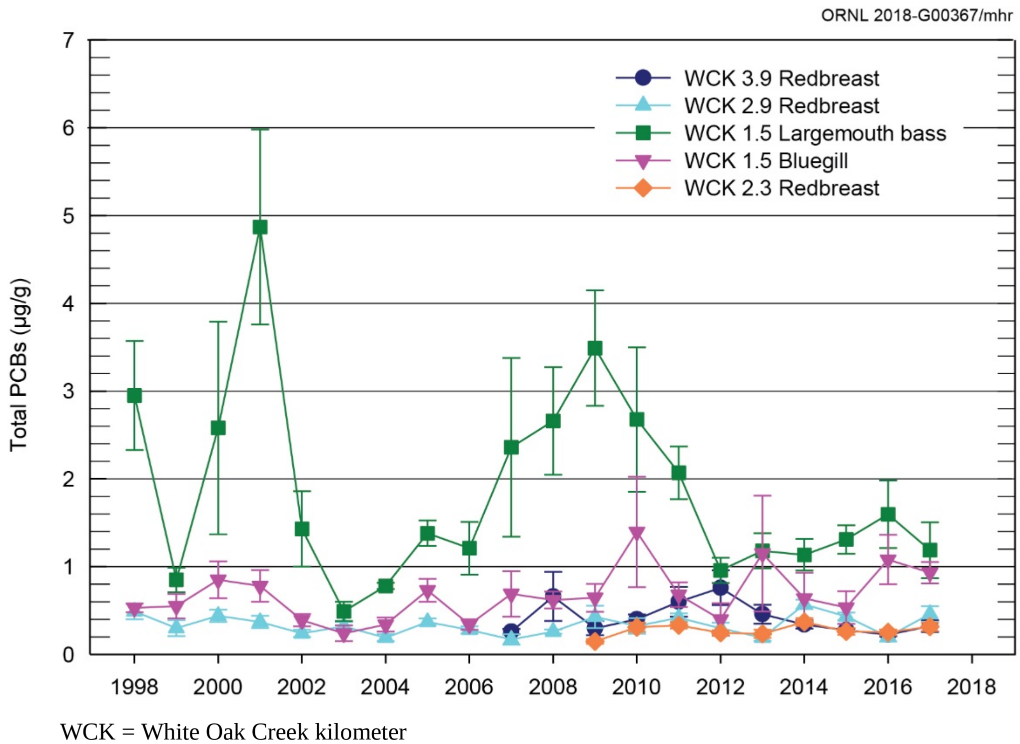


Figure 5.27. Mean total polychlorinated biphenyl (PCB) concentrations (± standard error, N = 6) in fish fillets collected from the White Oak Creek watershed (WCK 3.9, 2.9, 2.3, and 1.5), 1998–2017

5.5.6.2 Benthic Macroinvertebrate Communities

Monitoring of benthic macroinvertebrate communities in WOC, First Creek, and Fifth Creek continued in 2017. Additionally, monitoring of the macroinvertebrate community in lower Melton Branch (Melton Branch kilometer [MEK] 0.6) continued under the OREM Water Resources Restoration Program (WRRP). Benthic macroinvertebrate samples are collected annually following TDEC protocols and protocols developed by ORNL staff and used since 1986. The protocols developed by ORNL staff provide a continuous long-term record (29 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. At the time of publication, 2017 sample results for benthic macroinvertebrate communities in First Creek, Fifth Creek, and WOC downstream of effluent discharges were not available. These results will be reported in the 2018 annual report. The 2016 results, which were not available in time for inclusion in the 2016 annual site environmental report (DOE 2017) are included in this report (see Figure 5.28).

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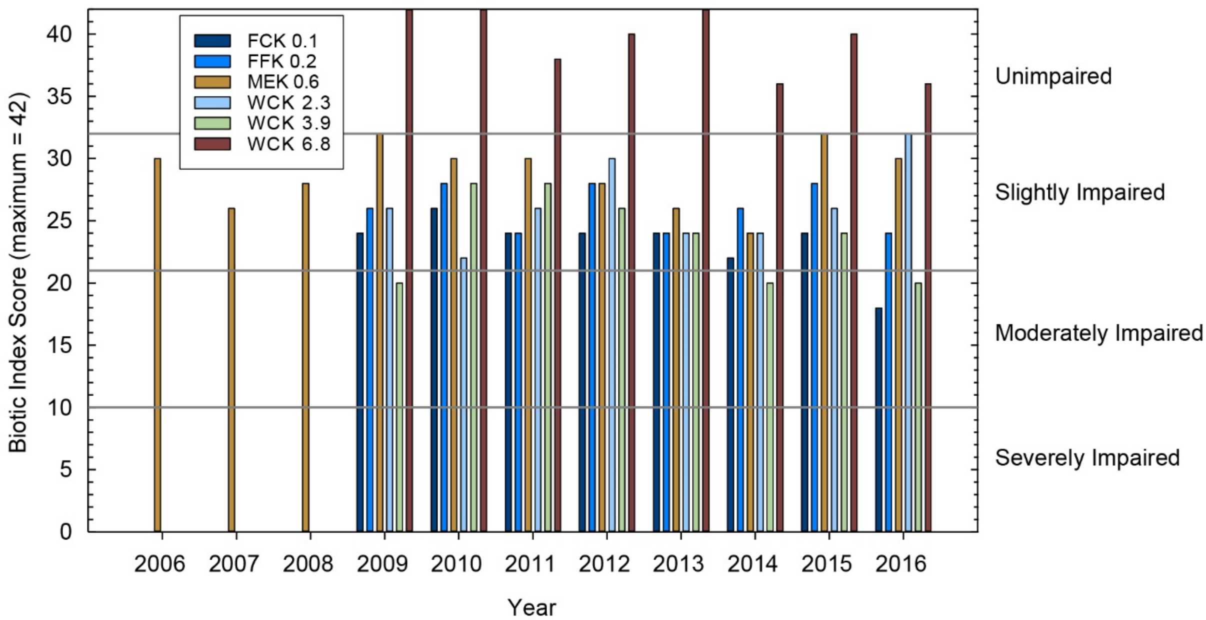


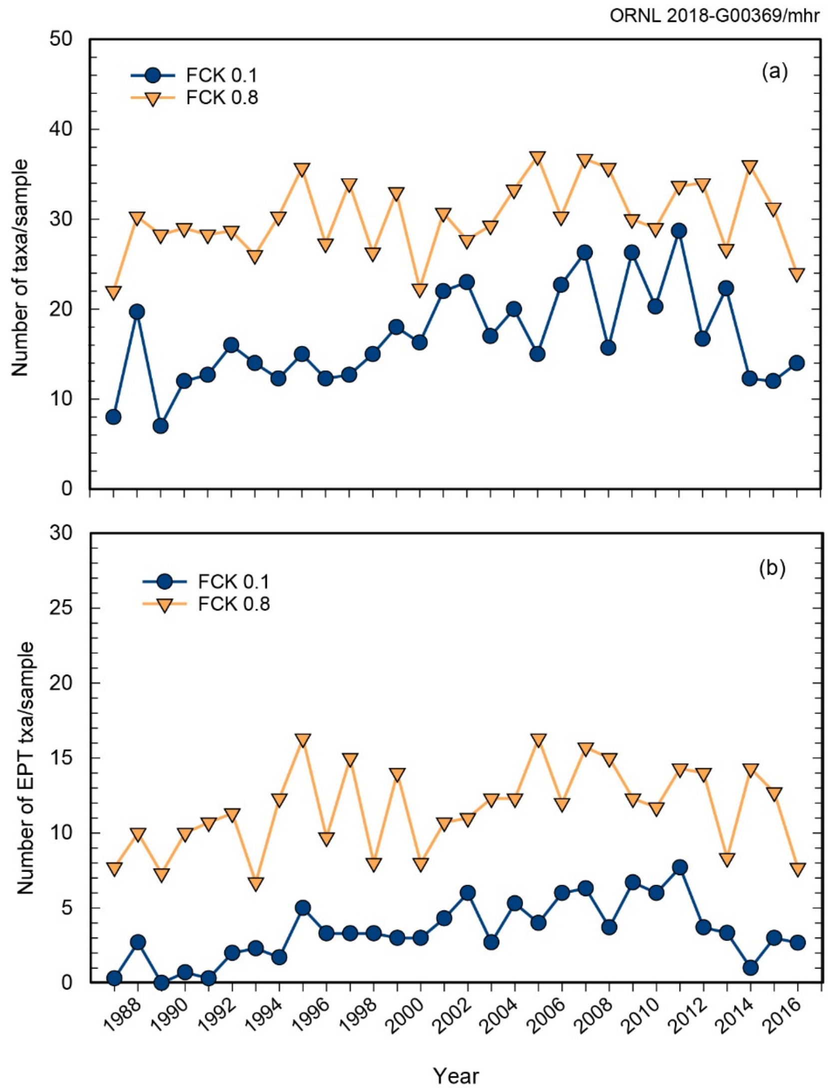
Results for 2017 were not available at the time of publication. Horizontal lines show the lower thresholds for biotic condition ratings for index scores; respective narrative ratings for each threshold are shown at right of graph.

Acronyms: FCK = First Creek kilometer, FFK = Fifth Creek kilometer, MEK = Melton Branch kilometer, and WCK = White Oak Creek kilometer

Figure 5.28. Temporal trends in Tennessee Department of Environment and Conservation Biotic Index Scores for White Oak Creek watershed (FCK 0.1; FFK 0.2; MEK 0.6; and WCK 6.8, 3.9, and 2.3), August 2006–August 2016

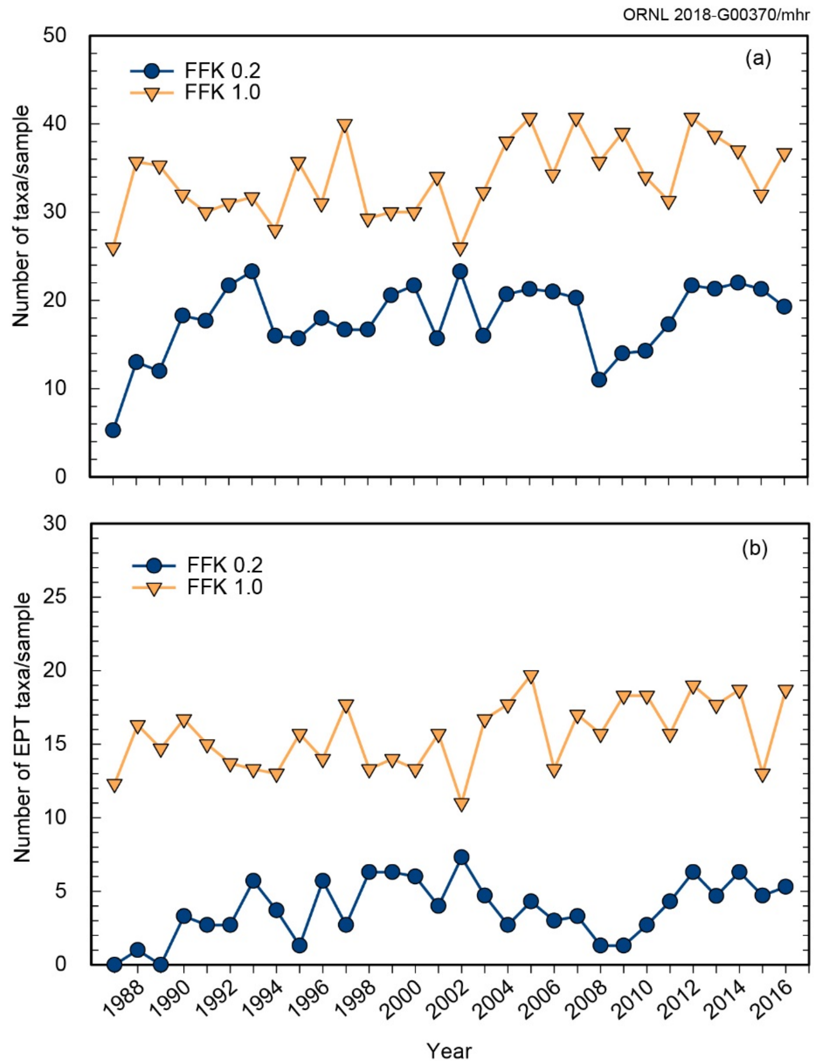
In 2016, results of TDEC protocols indicate that sites in First Creek and White Oak Creek immediately downstream of effluent discharges (First Creek kilometer [FCK 0.1] and WCK 3.9) were moderately impaired whereas these sites were rated as slightly impaired in previous years. Although Melton Branch Creek was rated as unimpaired in 2015, it was slightly impaired in 2016. The upper and most downstream White Oak Creek sites (WCK6.8 and WCK2.3, respectively) were rated as unimpaired in 2016. The 2016 ORNL protocols results indicated significant recovery in these communities since 1987, but community characteristics indicated that ecological impairment remains (Figures 5.29–5.31). 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. After modest increases in the mid-1990s, total taxa richness appeared to have generally decreased at FCK 0.1, and in 2014 the total number of taxa was the lowest it had been since 1989. 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. EPT taxa richness has remained low for 5 consecutive years, including 2016. These results suggest a change may have occurred in conditions 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. Trends in metrics at Fifth Creek kilometer (FFK) 0.2 since the mid-1990s suggest that a change in conditions at that site occurred between 2007 and 2008. More recent results, however, suggest that improvements have occurred, and the condition of the invertebrate community is now comparable to what it was from the late 1990s through the early 2000s. Metric values for WCK 2.3 and WCK 3.9 continued to remain within the ranges of values found since the early 2000s, although they also continued to be notably lower than those for the reference sites, suggesting that no additional major changes had occurred at those sites for roughly 13 years. Since 2001, Walker Branch has served as an additional reference site for WOC mainstem sites downstream of Bethel Valley Road (Figure 5.31). Comparisons of WCK6.8 to WBK1.0 show that communities in WCK 6.8 represent ideal reference conditions. Additionally, the comparison of Walker Branch to downstream sites in WOC show that these communities remain impaired.

Macroinvertebrate community metrics for lower Melton Branch (MEK 0.6, Figure 5.32) suggested that in 2016 taxa richness metrics continued to be similar to reference conditions. However, like the results from the TDEC protocols, other invertebrate community metrics potentially sensitive to more specific types of pollutants, such as the percent 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. Thus, while the condition of the invertebrate community at MEK 0.6 was generally at or near reference conditions, annual changes in some characteristics of the community suggested that annual fluctuations in environmental conditions at the site appear to have some minor negative influence on the condition of the community.



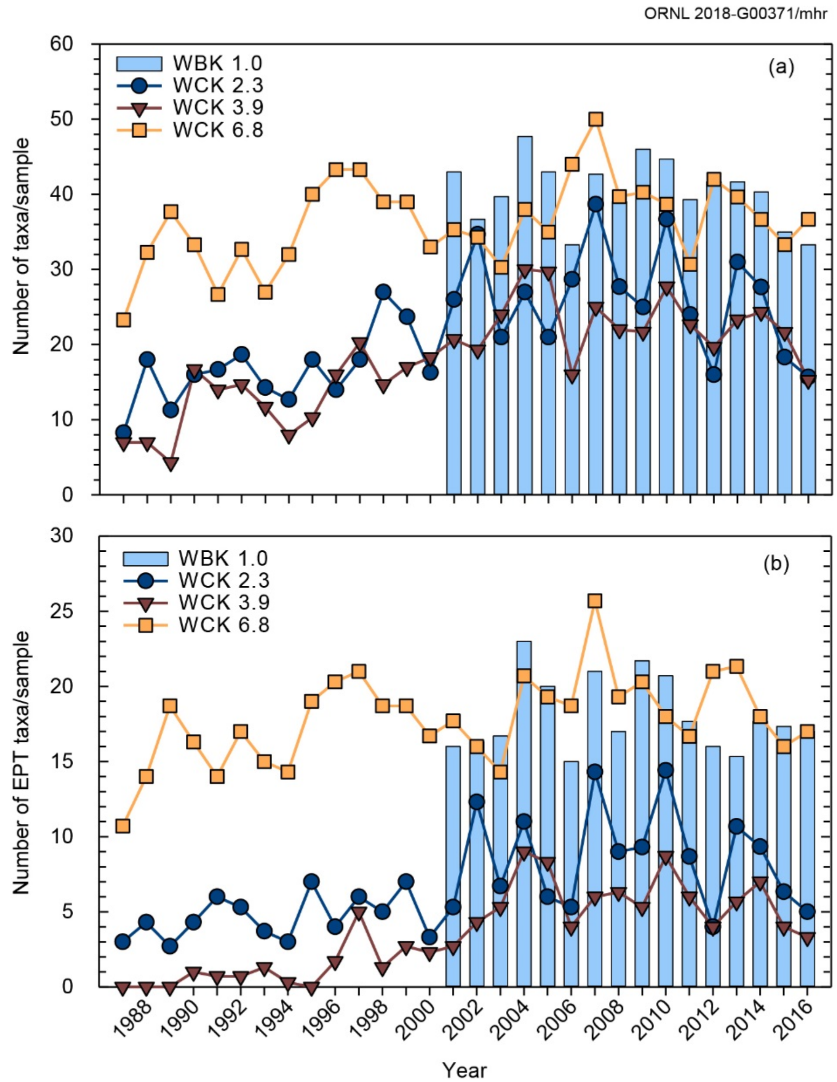
Results for 2017 were not available at the time of publication. FCK = Fifth Creek kilometer; FCK 1.0 = reference site

Figure 5.29. Benthic macroinvertebrate communities in First Creek (FCK 0.1 and 0.8): total taxonomic richness (mean number of all taxa/sample) and taxonomic richness of the pollution-intolerant taxa, Ephemeroptera, Plecoptera, and Trichoptera (EPT); mean number of EPT taxa/sample, April sampling periods, 1987−2016



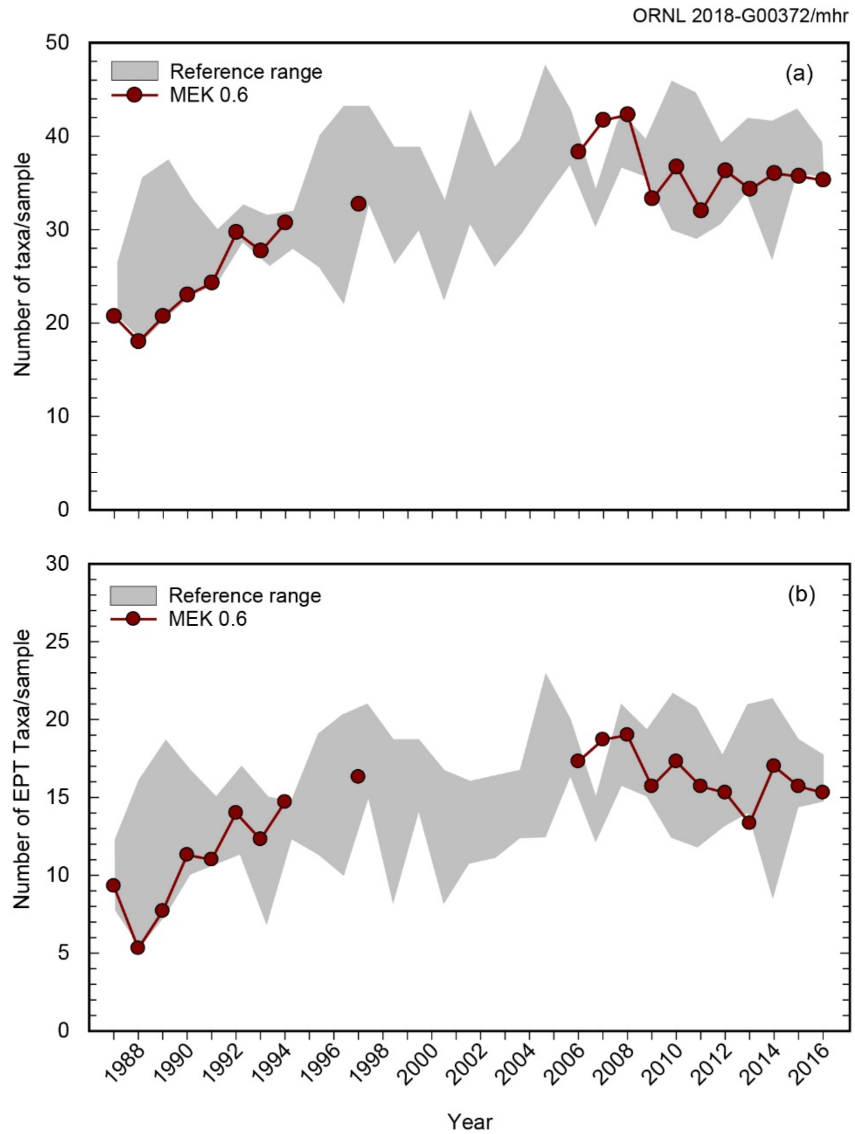
Results for 2017 were not available at the time of publication. FFK = Fifth Creek kilometer; FFK 1.0 = reference site

Figure 5.30. Benthic macroinvertebrate communities in Fifth Creek (FFK 0.2 and 1.0): total taxonomic richness (mean number of all taxa/sample) and taxonomic richness of the pollution-intolerant taxa, Ephemeroptera, Plecoptera, and Trichoptera (EPT); mean number of EPT taxa/sample), April sampling periods, 1987−2016



Results for 2017 were not available at the time of publication. WCK = White Oak Creek kilometer and WBK = Walker Branch kilometer; WBK 1.0 = reference site

Figure 5.31. Benthic macroinvertebrate communities in White Oak Creek (WBK 1.0 and WCK 6.8, 3.9, and 2.3): (a) total taxonomic richness (mean number of all taxa/ sample) and (b) taxonomic richness of the pollution-intolerant taxa, Ephemeroptera, Plecoptera, and Trichoptera (EPT); mean number of EPT taxa/sample), April sampling periods, 1987−2016



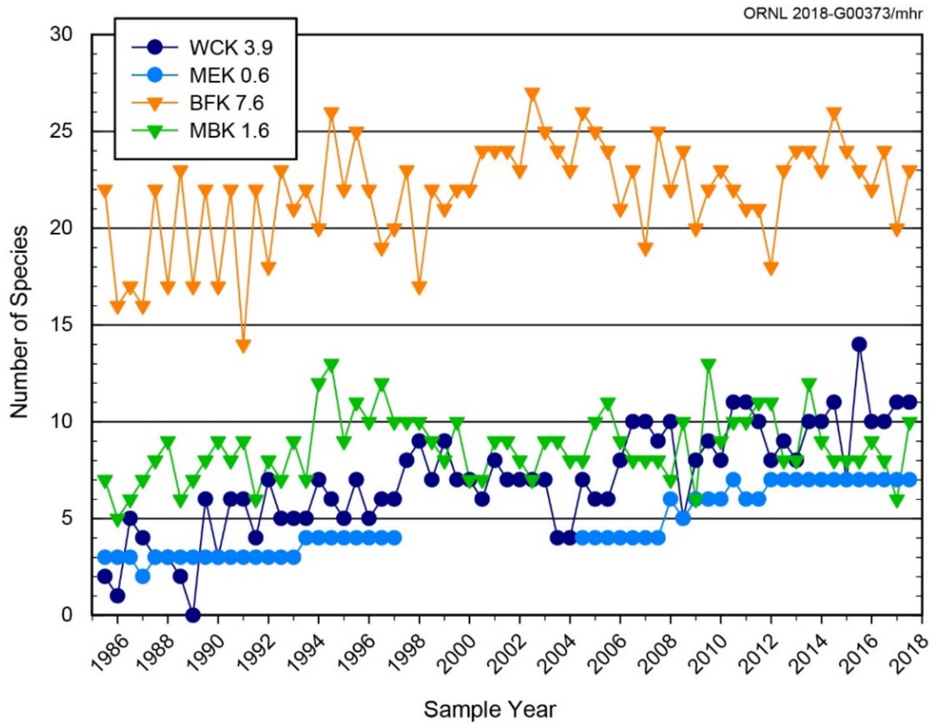
Results for 2017 were not available at the time of publication and maximum values for Oak Ridge National Laboratory Biological Monitoring and Abatement Program reference sites on First Creek and Fifth Creek (1987–2016), Walker Branch (2001–2016), and White Oak Creek (1987–2000, 2007–2016).

Figure 5.32. Benthic macroinvertebrate communities in lower Melton Branch (MEK 0.6): (a) total taxonomic richness (mean number of all taxa/sample) and (b) taxonomic richness of the pollution-intolerant taxa, Ephemeroptera, Plecoptera, and Trichoptera (EPT); mean number of EPT taxa/sample, April sampling periods, 1987−2016

5.5.6.3 Fish Communities

Monitoring of the fish communities in WOC and its major tributaries continued in 2017. 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 2017 compared with communities in reference streams. Sites closest to outfalls within the ORNL campus had lower species richness (number of species) (Figure 5.33), and fewer pollution-sensitive species. These sites also had more pollution-tolerant species, and elevated densities (number of fish per square meter) of pollution-tolerant species compared with similar-sized 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 remained negatively affected by ORNL effluent in 2017 relative to reference streams and upstream sites.



BFK = Brushy Fork kilometer; MBK = Mill Branch kilometer; MEK = Melton Branch kilometer; and WCK = White Oak Creek kilometer

Figure 5.33. Fish species richness (number of species) in upper White Oak Creek (WCK 3.9) and lower Melton Branch (MEK 0.6) compared with two reference streams, Brushy Fork (BFK 7.6) and Mill Branch (MBK 1.6), 1985–2017

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 six such native species. Reproduction has been noted for five 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, and as a result, introductions to supplement the small populations of these 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. 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.

5.5.7 Cooling Tower Blowdown Whole Effluent Toxicity Monitoring

As part of the WQPP at ORNL, samples of blowdown from cooling towers 7902 (the cooling tower for the HFIR facility) and 8913 (the cooling tower for the SNS facility) were tested for whole effluent toxicity (WET) in May 2017. This was done as part of an ongoing WQPP investigation to identify the causes of biological community impairments in the WOC watershed. Prior to 2017, the investigation was focused on the reach of WOC that encompasses stream kilometer 3.9 (WCK 3.9). Biological communities in that stream reach are moderately impaired relative to reference sites, and several large cooling tower systems discharge blowdown immediately upstream of, or within that stream reach. The cooling tower systems close to WCK 3.9 have been tested for WET on multiple occasions over several years. The 7902 cooling tower discharges blowdown to a small tributary to Melton Branch, which has no influence at all on WCK 3.9. The 8913 tower discharges blowdown to the headwaters of WOC, almost 3 km upstream of WCK 3.9. In addition, at a more distant location, blowdown from the 8913 tower flows through a large storm water detention pond prior to discharge, which is thought to mitigate most negative effects of blowdown from that tower. Although they have little or no effect on water quality at WCK 3.9, blowdown discharges from these two cooling towers were selected for testing in 2017 to determine how they compared to the other towers that had been tested previously. Those towers were of particular interest because the chemical maintenance protocols for the two towers are somewhat different from the towers that have a more direct influence on water quality at WCK 3.9; if blowdown from these towers were to be less toxic, it would provide some insight into potential mitigation options for the other towers.

In WET testing, standard test organisms are exposed to multiple concentrations of effluent under standard test conditions, and the responses of the organisms (e.g., survival, reproduction, and/or growth) are measured. The specific test conducted on 7902 and 8913 effluents was a *Ceriodaphnia dubia* (*C. dubia*) three-brood survival and reproduction test, a test designed to estimate chronic toxicity. Previous testing at other locations has demonstrated that *C. dubia* are more sensitive to cooling tower blowdown than are fathead minnow larvae, the other test species commonly used in testing ORNL effluents. Results of WET testing effluents from towers 7902 and 8913 are presented in Table 5.12.

Table 5.12. Results of chronic toxicity testing using *Ceriodaphnia dubia* conducted in May 2017 on blowdown

Blowdown concentration (%)	Survival (%)	Reproduction[a] (offspring/female)
	7902 cooling tower	
Control	100	33.4 ± 4.5
5	90	10.8 ± 5.4[b]
25	50[b]	5.4 ± 3.7[b]
50	80	6.0 ± 2.3[b]
100	60[b]	6.0 ± 3.0[b]
	8913 cooling tower	
Control	100	29.4 ± 5.6
5	80	12.8 ± 6.5[b]
25	70	7.0 ± 3.9[b]
50	80	7.6 ± 3.7[b]
100	70	8.2 ± 3.8[b]

[a] Mean ± standard deviation
[b] Significantly less than the control at alpha = 0.05

Cooling tower blowdown from 7902 and 8913 were found to have similar toxicity to other towers tested in previous years. In the 2017 tests, samples composed of 5% or greater tower blowdown (the rest being diluent, which in these tests were degassed mineral water) caused reductions in *C. dubia* fecundity. Although results varied temporally and from one tower to another in previous years' testing, *C. dubia* reproduction tended to be less than the control sample at blowdown concentrations of approximately 5% to 25%.

In addition to the measured effects on *C. dubia* reproduction, samples from the 7902 tower also caused reductions in *C. dubia* survival at blowdown concentrations of 25% or more. Although survival effects have been seen when testing blowdown from other towers, reductions in *C. dubia* survival have been observed less commonly.

In previous years, WET testing of other cooling tower blowdown discharges has included samples that were exposed in the laboratory to various forms of water treatment. Treatments have included metals chelation by addition of ethylenediaminetetraacetic acid (EDTA), particulate removal by filtration through a 1.2 μm filter, and activated carbon treatment. Treated samples were WET-tested in attempts to infer whether any chemical constituents of the blowdown might be causing toxicity, and to potentially identify processes that might be employed at cooling towers in the future to treat blowdown prior to discharge. In that previous testing, some success at removing toxicity was achieved through the addition of EDTA, with the degree of improvement related to the amount of EDTA added. In testing the 7902 and 8913 towers, samples of 100% blowdown were treated to three different sample EDTA concentrations: 3, 6, and 12 mg/L. Unlike other towers tested in previous years, none of the samples from 7902 or 8913 experienced a reduction in toxicity following the addition of EDTA, indicating that the toxicity in the blowdown discharges of those two towers is less likely to be caused by one of the common cationic metals that react readily with EDTA.

To support evaluation of the WET testing results, samples of cooling tower blowdown were collected for chemical analyses. For the WET tests, three effluent samples were collected at 2 or 3 day intervals to support daily test renewals (in the test protocol, the water to which the *C. dubia* are exposed in test chambers is changed daily; each of the three effluent samples support 2 or 3 days of water exchanges). At 8913 all three samples were 24 hour composite samples; at 7902, all samples were grab samples (due to limitations encountered with sampling with an automatic water sampler at that location). Analyses for total and dissolved metals were performed on each water sample that was collected for the WET test daily renewals. Field measurements (conductivity, dissolved oxygen, instantaneous flow rate, pH, and temperature) and samples for chemical oxygen demand and suspended-solids analyses were collected once, on the first day of sampling, at each location. Field measurements and analytical results for samples from 7902 and 8913 are shown in Tables 5.13 and 5.14, respectively.

In the tables, metals concentrations are compared to Tennessee AWQCs where one exists. AWQCs are not directly applicable to effluent concentrations; they are applicable to instream pollutant concentrations. They are compared to effluent concentrations here to provide a frame of reference and to indicate which metals in cooling tower blowdown are of most concern by showing which metals require the most dilution in order not to cause concentrations of that metal to exceed the applicable instream AWQC. The data show that at the time the samples were collected, copper in the 8913 tower was the metal that had that greatest potential to cause instream AWQC exceedances. However, the tower 8913 samples were collected for the study at the first accessible point near the tower, still a long distance from the receiving stream and before the effluent flows through a large storm water detention pond. The long travel distance and the effects of the retention pond are thought to do a great deal to mitigate potential negative effects of the tower 8913 blowdown. Three measurements of total Cu exist from previous monitoring at the location where this effluent eventually reaches the receiving stream (at Outfall 435). The maximum total Cu concentration at the outfall was 0.00272 mg/L, comfortably below the AWQC.

The dissolved Cu concentration in the May 16, 2017, sample from tower 7902, as reported by the analytical laboratory, was above the lowest applicable AWQC concentration. However, that result is expected to be an analytical anomaly because it is considerably higher than the total Cu concentration measured in the same sample. (Table 5.13). This is also supported by the fact that the 7902 cooling system includes very little copper in its construction (most metal components are constructed of stainless steel or aluminum).

Table 5.13. Field parameters and analytical results from laboratory analyses of blowdown from the 7902 cooling system, compared to Tennessee Ambient Water Quality Criteria (AWQC)

Parameter	5/16/2017	5/18/2017	5/21/2017	Lowest Applicable AWQC[a,b]
Chemical oxygen demand (mg/L)	45.6			
Conductivity (mS/cm)	1.55			
Dissolved oxygen (mg/L)	6.6			
Flow (gpm)	100			
pH (Standard units)	7.4			
Suspended solids (mg/L)	< 2			
Temperature (°C)	27.4			
Ag, dissolved (mg/L)	< 0.0000192	< 0.0000192	< 0.0000192	0.0032
Ag, total (mg/L)	< 0.0000192	< 0.0000192	< 0.0000192	
As, dissolved (mg/L)	< 0.001	< 0.001	< 0.001	0.150
As, total (mg/L)	< 0.001	< 0.001	< 0.001	0.010
Be, dissolved (mg/L)	< 0.0000359	< 0.0000359	< 0.0000359	
Be, total (mg/L)	< 0.0000359	< 0.0000359	< 0.0000359	
Ca, dissolved (mg/L)	194	220	267	
Ca, total (mg/L)	335	334	383	
Cd, dissolved (mg/L)	0.000204	0.000232[c]	0.000214	0.00033
Cd, total (mg/L)	0.000254	0.000222	0.000292	
Cr, dissolved (mg/L)	< 0.000115	< 0.000115	0.00014	0.074
Cr, total (mg/L)	0.000874	0.000838	0.000784	
Cu, dissolved (mg/L)	0.0316[c,d]	0.00273	0.00265	0.013
Cu, total (mg/L)	0.00332	0.00357	0.00333	
Fe, dissolved (mg/L)	< 0.0206	< 0.0206	< 0.0206	
Fe, total (mg/L)	< 0.0206	< 0.0206	< 0.0206	
K, dissolved (mg/L)	27.2	27.2[c]	27.1	
K, total (mg/L)	30.6	27.1	33.2	
Mg, dissolved (mg/L)	59.1	60	62.4	
Mg, total (mg/L)	66.5	60.3	76.9	
Mn, dissolved (mg/L)	0.0003	0.000582	0.000788	
Mn, total (mg/L)	0.00163	0.00256	0.00191	
Mo, dissolved (mg/L)	0.00191	0.00189	0.00196	
Mo, total (mg/L)	0.00224	0.00196	0.00244	

Table 5.13 Field parameters and analytical results from laboratory analyses of blowdown from the 7902 cooling system, compared to Tennessee AWQC (continued)

Parameter	5/16/2017	5/18/2017	5/21/2017	Lowest Applicable AWQC[a,b]
Na, dissolved (mg/L)	43.2	43.7[c]	45	
Na, total (mg/L)	48.6	43.6	55.4	
Ni, dissolved (mg/L)	0.00181	0.00254[c]	0.00281	0.073
Ni, total (mg/L)	0.00466	0.00233	0.00319	4.600
Pb, dissolved (mg/L)	0.000124	0.00025	< 0.0000951	0.0039
Pb, total (mg/L)	0.000252	0.000334	0.00028	
Sb, dissolved (mg/L)	0.00301	0.00285	0.00299	
Sb, total (mg/L)	0.00355	0.00301	0.00366	0.640
Se, dissolved (mg/L)	< 0.0025	< 0.0025	< 0.0025	
Se, total (mg/L)	< 0.0025	< 0.0025	< 0.0025	0.005
Tl, dissolved (mg/L)	< 0.00000379	< 0.00000379	< 0.00000379	
Tl, total (mg/L)	< 0.00000379	< 0.00000379	< 0.00000379	0.00047
Zn, dissolved (mg/L)	0.108	0.0956	0.0949	0.165
Zn, total (mg/L)	0.137	0.107	0.124	

[a] For metals that have an AWQC dependent on water hardness, criteria presented here are for a hardness of 150 mg/L ($CaCO_3$ equivalent) (with the exception of Cr which is based on a hardness of 100 mg/L [$CaCO_3$ equivalent] because published hardness correction factors could not be located).

[b] Some criteria for metals are based on the dissolved form of the metal and some are based on total (dissolved plus particulate) metal concentration; criteria based on dissolved concentration are shown in this table beside the dissolved result; criteria based on total metal are shown beside the total metal result.

[c] Physically, dissolved metals are a fraction of or are equal to total metals; analytically, dissolved metals can be reported at higher concentrations than total metals; this can occur for several reasons. Each concentration (total and dissolved) has an associated analytical uncertainty that is calculated and reported with the result. Other sources of uncertainty (not included in the reported analytical error) are associated with sample handling and preparation.

[d] The large difference between total and dissolved Cu on May 16 is too great to be explained by the reported analytical uncertainties. It is suspected that the May 16 filtered water sample was contaminated with Cu during the sample filtration process.

Table 5.14. Field parameters and analytical results from laboratory analyses of blowdown from the 8913 cooling system, compared to Tennessee Ambient Water Quality Criteria (AWQC)

Parameter	5/16/2017	5/18/2017	5/21/2017	Lowest Applicable AWQC[a,b]
Chemical oxygen demand (mg/L)	65.6			
Conductivity (mS/cm)	1.84			
Dissolved oxygen (mg/L)	7.4			
Flow (gpm)	45			
pH (Standard units)	7.5			
Suspended solids (mg/L)	< 2			
Temperature (°C)	25			
Ag, dissolved (mg/L)	< 0.0000192	< 0.0000192	< 0.0000192	0.0032
Ag, total (mg/L)	< 0.0000192	< 0.0000192	0.000032	
As, dissolved (mg/L)	< 0.001	< 0.001	< 0.001	0.150
As, total (mg/L)	< 0.001	< 0.001	< 0.001	0.010
Be, dissolved (mg/L)	< 0.0000359	< 0.0000359	< 0.0000359	
Be, total (mg/L)	< 0.0000359	< 0.0000359	< 0.0000359	
Ca, dissolved (mg/L)	261	262	290	
Ca, total (mg/L)	412	372	461	
Cd, dissolved (mg/L)	0.000248	0.00025	0.000306	0.00033
Cd, total (mg/L)	0.000256	0.000324	0.000358	
Cr, dissolved (mg/L)	0.00045	0.000776	0.000712	0.074
Cr, total (mg/L)	0.00131	0.00158	0.00182	
Cu, dissolved (mg/L)	0.017	0.0175	0.0149	0.013
Cu, total (mg/L)	0.0246	0.0238	0.031	
Fe, dissolved (mg/L)	< 0.0206	< 0.0206	< 0.0206	
Fe, total (mg/L)	0.0516	< 0.0206	0.524	
K, dissolved (mg/L)	10.1	10.4	11.6	
K, total (mg/L)	11.2	11	13.7	
Mg, dissolved (mg/L)	67.8	66.3	79.1	
Mg, total (mg/L)	76.7	71.1	94	
Mn, dissolved (mg/L)	0.00403	0.00508	0.00592	
Mn, total (mg/L)	0.00762	0.00743	0.0199	
Mo, dissolved (mg/L)	0.00224	0.00219	0.00265	
Mo, total (mg/L)	0.00259	0.00248	0.00328	
Na, dissolved (mg/L)	47.7	47.7	54.2	
Na, total (mg/L)	53.4	51.1	64.2	
Ni, dissolved (mg/L)	0.00344	0.00408	0.00507	0.073
Ni, total (mg/L)	0.00434	0.005	0.00604	4.600
Pb, dissolved (mg/L)	< 0.0000951	< 0.0000951	< 0.0000951	0.0039
Pb, total (mg/L)	0.000122	0.000368	0.00035	
Sb, dissolved (mg/L)	0.00645	0.0059	0.00551	

Table 5.14 Field parameters and analytical results from laboratory analyses of blowdown from the 8913 cooling system, compared to Tennessee AWQCs (continued)

Parameter	5/16/2017	5/18/2017	5/21/2017	Lowest Applicable AWQC[a,b]
Sb, total (mg/L)	0.00746	0.00663	0.00734	0.640
Se, dissolved (mg/L)	< 0.0025	< 0.0025	< 0.0025	
Se, total (mg/L)	< 0.0025	< 0.0025	< 0.0025	0.005
Tl, dissolved (mg/L)	< 0.00000379	< 0.00000379	0.000014[c]	
Tl, total (mg/L)	< 0.00000379	< 0.00000379	< 0.00000379	0.00047
Zn, dissolved (mg/L)	0.132	0.129	0.144	0.165
Zn, total (mg/L)	0.189	0.139	0.291	

[a] For metals that have an AWQC dependent on water hardness, criteria presented here are for a hardness of 150 mg/L ($CaCO_3$ equivalent) (with the exception of Cr which is based on a hardness of 100 mg/L [$CaCO_3$ equivalent] because published hardness correction factors could not be located).

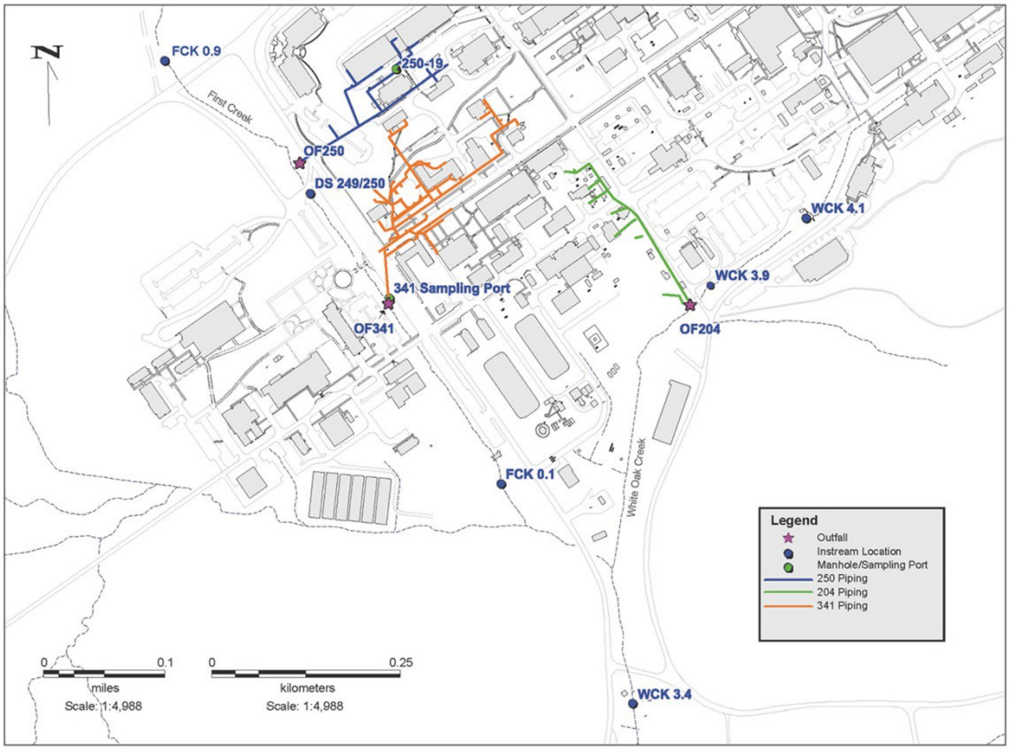
[b] Some criteria for metals are based on the dissolved form of the metal and some are based on total (dissolved plus particulate) metal concentration; criteria based on dissolved concentration are shown in this table beside the dissolved result; criteria based on total metal are shown beside the total metal result.

[c] Physically, dissolved metals are a fraction of, or are equal to total metals; analytically, dissolved metals can be reported at higher concentrations than total metals; this can occur for several reasons. Each concentration (total and dissolved) has an associated analytical uncertainty that is calculated and reported with the result. Other sources of uncertainty (not included in the reported analytical error) are associated with sample handling and preparation.

5.5.8 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. 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 (Figure 5.27), 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, 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 in contact with water at a given site for 4 weeks and have a high affinity for PCBs, a time-integrated semiquantitative index of the mean PCB concentration in the water column during the deployment period is obtained. SPMDs also have advantages over “snapshot” water concentration analyses. The long deployment period enables distinction between the relative PCB inputs at sites whose aqueous PCB concentrations are below detection limits in water.

In 2017, ORNL’s PCB monitoring efforts continued focusing on the First Creek watershed, which has been identified as a source of PCBs. Sampling sites on WOC included at kilometers 3.9, 4.1, and at Outfall 204. SPMDs were also deployed on First Creek at Outfalls 250, 341, 341-1 (sampling port), and the piping network of Outfall 250, which contributes to First Creek (Figure 5.34). SPMDs deployed in First Creek at FCK 0.9, downstream of Outfalls 249/250, and in the sampling port of Outfall 341 as well as that in WOC at WCK 3.4 were washed out during a storm event with heavy flows. The results for the remaining SPMDs are summarized in Table 5.15.



FCK = First Creek kilometer, WCK = White Oak Creek kilometer, OF = outfall

Figure 5.34. Locations of monitoring points for First Creek source investigation, 2017

Table 5.15. First Creek and WOC PCB source assessment, September 2017, total PCBs

Sample location	Location Type	SPMD (ppb)
OF 250	Outfall	7,634
250-19	Inlet/Outlet	15,161
OF 341	Outfall	2,021
FCK 0.1	Instream	5,360
OF 204	Outfall	321
WCK 3.9	Instream	1,057
WCK 4.1	Instream	1,057

Acronyms
FCK = First Creek kilometer
OF = outfall
PCB = polychlorinated biphenyl
SPMD = semipermeable membrane device
WCK = White Oak Creek kilometer
WOC = White Oak Creek

Results from the 2017 assessment confirm that upper parts of outfalls 249 and 250 pipe networks continue to be of primary interest for investigation of legacy PCB sources in the First Creek watershed. The results from sample location 250-19 (Table 5.15) indicate that PCBs remain available in that area despite recent actions to remove PCB-contaminated building materials from the upper part of the 250 watershed (Table 5.15). Therefore, First Creek remains the greatest area of concern for sources of PCBs and future remediation efforts. Results were within the ranges of past monitoring, giving no indication that the nature of PCB movement is significantly changing in those networks.

5.5.9 Oil Pollution Prevention

CWA Section 311 regulates the discharge of oils or petroleum products to waters of the United States and requires the development and implementation of spill prevention, control, and countermeasures (SPCC) plans to minimize the potential for oil discharges. These requirements are provided in 40 CFR 112, *Oil Pollution Prevention*. Each ORR facility implements a site-specific SPCC plan. NTRC, which is located off ORR, also has an SPCC plan covering the oil inventory at its location. CFTF is also located off ORR; however, that facility was evaluated, and a determination was made that it did not require a SPCC plan. The ORNL SPCC plan was revised in the later part of 2017. The major revision was the addition of an oil spill contingency plan in order to eliminate reliance on spill control gates at WOD for general spill containment requirements. The Oil Spill Contingency plan will be sent to local authorities in the first quarter of 2018. There were no regulatory actions related to oil pollution prevention at NTRC in 2017. An oil-handler training program exists to comply with training requirements in 40 CFR 112.

5.5.10 Surface Water Surveillance Monitoring

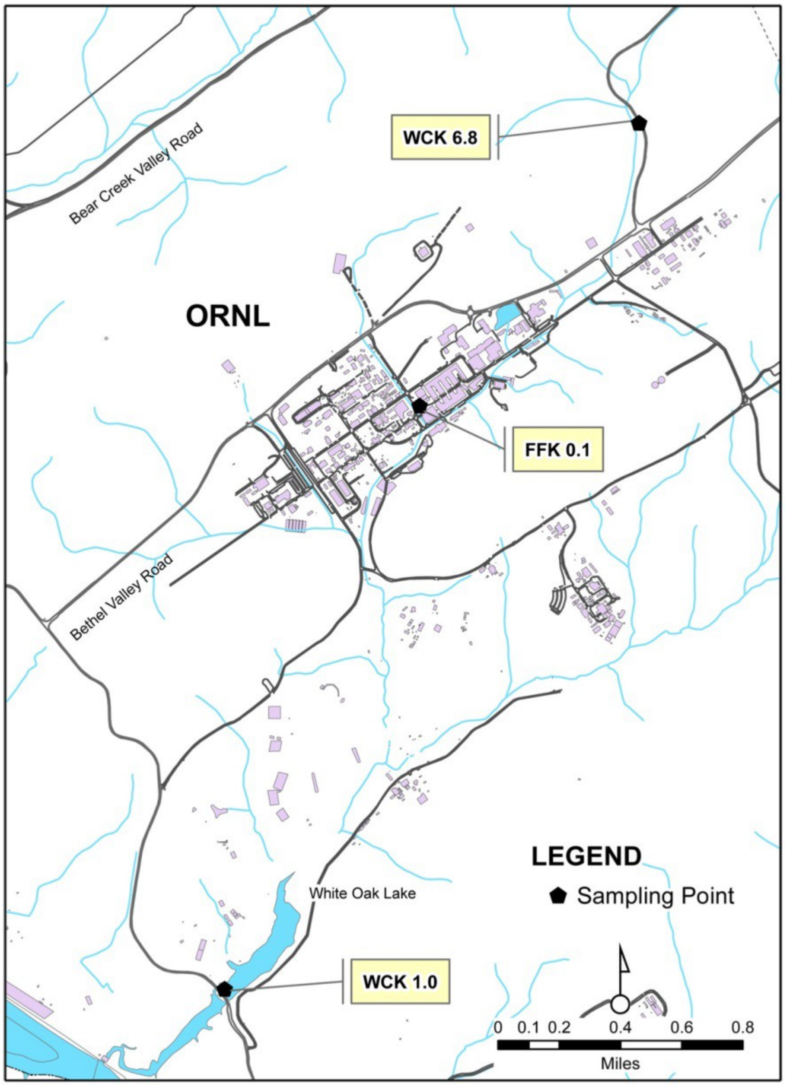
The ORNL surface water monitoring program is conducted in conjunction with the ORR surface water monitoring activities discussed in Section 6.4 to enable assessing the impacts of ongoing DOE operations on the quality of local surface water. The sampling locations (Figure 5.35) are used to monitor conditions 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 5.16. 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 (Section 5.5.3) 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 is used for radionuclide comparison because that value is roughly equivalent to the 4 mrem dose limit from ingestion of drinking water on which the EPA radionuclide drinking water standards are based (DOE 2011a).

There were no radionuclides reported above 4% of DCS at the Fifth Creek location (FFK 0.1). The beta activity and $^{89/90}$Sr concentrations are related to known sources in the middle of the ORNL main campus. No $^{89/90}$Sr results above 4% of DCS were reported for samples collected at the upstream White Oak Creek 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.

PCB-1254 and -1260 were detected at low, estimated concentrations in the June 2017 sample from WOC at WOD. PCBs have not been detected at WOC at WOD since 2012. Four VOC compounds were detected in samples from WOC at WOD during 2017 at low, estimated concentrations (below the method quantitation limit): acetone was detected in two samples, chloroform was detected in one sample, 4-Methyl-2-pentanone was detected in one sample, and toluene was detected in three samples. Each of these VOC compounds has occasionally been detected in at least one onsite groundwater well in past monitoring, including wells located in nearby Solid Waste Storage Area (SWSA) 6. Mercury was not detected in samples from WOC at WOD.



FFK = Fifth Creek kilometer; WCK = White Oak Creek kilometer

Figure 5.35. Oak Ridge National Laboratory surface water sampling locations, 2017

Table 5.16. Oak Ridge National Laboratory surface water sampling locations, frequencies, and parameters, 2017

Location[a]	Description	Frequency and type	Parameters[b]
WCK 1.0	White Oak Lake at WOD	Quarterly, grab	Volatiles, mercury, PCBs[c], field measurements
WCK 6.8	WOC upstream from ORNL	Quarterly, grab	PCBs, Total radioactive strontium, field measurements
FFK 0.1	Fifth Creek just upstream of WOC (ORNL)	Semiannually, grab	Gross alpha, gross beta, total radioactive strontium, gamma scan, tritium, field measurements

[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] Field measurements consist of dissolved oxygen, pH, and temperature.
[c] The September PCB sample was accidentally spiked during extraction by the lab. There was no sample left to re-extract and a replacement sample was not collected.

Acronyms
FFK = Fifth Creek kilometer
ORNL = Oak Ridge National Laboratory
PCB = polychlorinated biphenyl
WCK = WOC kilometer
WOC = White Oak Creek
WOD = White Oak Dam

5.5.11 Carbon Fiber Technology Facility Waste Water 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 Waste Water Discharge Permit 1-12. Permit limits, parameters, and 2017 compliance status for this permit are summarized in Table 5.17.

Table 5.17. Industrial and commercial user wastewater discharge permit compliance at the Oak Ridge National Laboratory Carbon Fiber Technology Facility, 2017

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		4.2	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 Groundwater Monitoring Program

Groundwater monitoring at ORNL was conducted under two sampling programs in 2017: DOE OREM monitoring and DOE SC surveillance monitoring. The DOE OREM groundwater monitoring program was conducted by UCOR in 2017. The SC groundwater monitoring surveillance program was conducted by UT-Battelle.

5.6.1 DOE 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 2017, including monitoring at ORNL, are evaluated and reported in the 2018 remediation effectiveness report (DOE 2018) as required by the ORR FFA. The monitoring results and remedial effectiveness evaluations for Bethel and Melton Valley 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 (TCE) 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 2017 postremediation monitoring continued at SWSA 3 following completion of hydrologic isolation of the area by construction of a multilayer cap and 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 Summary of DOE Office of Environmental Management Groundwater Monitoring

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 2017 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. Groundwater quality monitoring at SWSA 3 showed decreasing or stable concentrations of gross beta activity in two wells with beta activities greater than 50 pCi/L. Strontium-90, a signature contaminant at SWSA 3, showed decreasing trends for ^{90}Sr in two wells, a stable trend in one well, and an increasing trend in one well. Benzene, potentially from natural sources, showed a stable concentration trend in two wells where it is routinely detected.

During FY 2017, 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 (included in the preceding paragraph discussion) 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 2017 remediation effectiveness report (DOE 2018).

Groundwater monitoring continued at the ORNL 7000 Area during FY 2017 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 TCE 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. 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, which is a reduction of ^{90}Sr in WOC. 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. The ^{90}Sr concentrations in PWTC (X12) discharges were higher than normal during FY 2017 and contributed to Bethel Valley exceedances of the ROD goal for ^{90}Sr at the WOC Bridge Weir location.

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 during FY 2017 was about 4 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 substantively equivalent to the former RCRA monitoring continues at SWSA 6. Several VOC substances 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 Sr, 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 2017 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 2018 remediation effectiveness report (DOE 2018).

5.6.2 DOE Office of Science Groundwater Monitoring

DOE O 458.1 (DOE 2011d) 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 program are reported in the following sections.

Exit pathway and active-sites groundwater surveillance monitoring points sampled during 2017 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 monitoring performed under the exit pathway groundwater surveillance and active-sites monitoring programs are not regulated by federal or state rules. Consequently, no permit or standards exist for evaluating sampling results. To provide a basis for evaluating analytical results and to assess groundwater quality at locations monitored by UT-Battelle, current federal drinking water standards and/or Tennessee WQCs for radiological and nonradiological contaminants were used as reference standards. If no federal or state standard had been established for a particular radionuclide, 4% of the DCSs for radionuclides (DOE 2011a) were used to evaluate sampling results. Although drinking water standards and DOE DCSs were used for comparative purposes, 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.

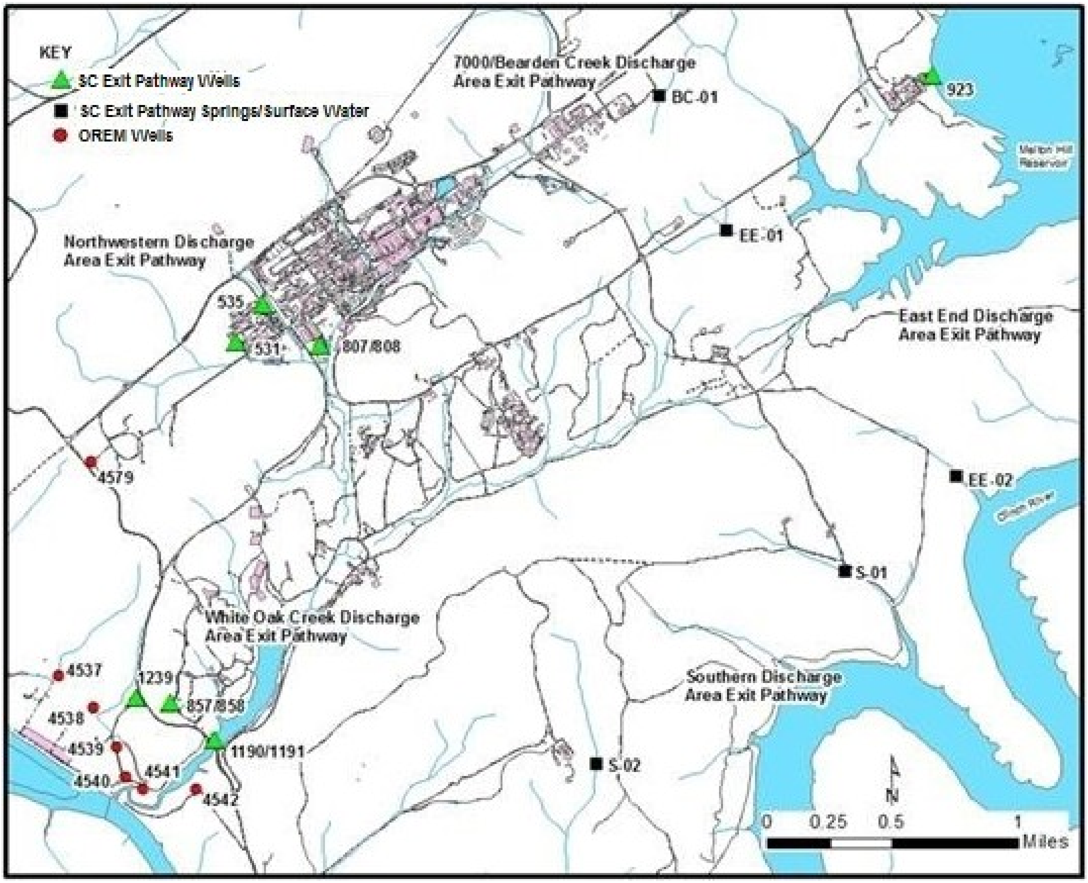
5.6.2.1 Exit Pathway Monitoring

During 2017, 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 as follows:

- the WOC Discharge Area Exit Pathway,
- the 7000–Bearden Creek Watershed Discharge Area Exit Pathway,
- the East End Discharge Area Exit Pathway,
- the Northwestern Discharge Area Exit Pathway, and
- the Southern Discharge Area Exit Pathway.

Figure 5.36 shows the locations of the exit pathway monitoring points sampled in 2017.



OREM = DOE Office of Environmental Management; SC = DOE Office of Science

Figure 5.36. UT-Battelle exit pathway groundwater monitoring locations at Oak Ridge National Laboratory, 2017

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 2017 is outlined in Table 5.18.

Unfiltered samples were collected from the exit pathway groundwater surveillance monitoring points in 2017. The organic suite was composed of VOCs and semivolatile organic compounds (SVOCs); 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 (April) and dry (July/August) seasons.

Table 5.18. 2017 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	Radiological
EE-01	Radiological	Radiological
EE-02	Radiological, organic, and metals	Radiological
	Northwestern Discharge Area	
531	Radiological	Radiological
535	Radiological	Radiological, organic, and metals
807	Radiological	Radiological
808	Radiological	Radiological
	Southern Discharge Area	
S-01	Radiological	Radiological
S-02	Radiological	Radiological
	White Oak Creek Discharge Area	
857	Radiological	Radiological, organic, and metals
858	Radiological	Radiological
1190	Radiological, organic, and metals	Radiological, organic, and metals
1191	Radiological, organic, and metals	Radiological, organic, and metals
1239	Radiological	Radiological

Exit Pathway Monitoring Results

Statistical trend analyses were performed on 2017 exit pathway monitoring data sets containing data exceeding reference standards. The bases used for the trend analyses were the historical data collected from the late 1980s through 2016. Trend analyses were not performed on data sets where minimum detection limits exceeded reference standards (i.e., the SVOCs atrazine, benzo(a)pyrene, hexachlorobenzene, and pentachlorophenol) and were not performed on parameters for which there are no reference standards or where data densities were insufficient. Parameters that exhibited statistically significant (80% to 99% confidence levels) upward or downward trends are reported. Trend analysis results are summarized in Table 5.19.

Table 5.20 provides a summary of radiological parameters detected in samples collected from exit pathway monitoring points during 2017. Metals are ubiquitous in groundwater exit pathways and so are not summarized in the table.

Table 5.19. 2017 exit pathway groundwater monitoring—results of trend analyses for parameters exceeding reference standards

Monitoring point	Parameter	Trend
East End Discharge Area		
EE-02	Al	No trend[a]
Northwestern Discharge Area		
535	Al	No trend
535	Fe	No trend
535	Mn	No trend
White Oak Creek Discharge Area		
857	Al	No trend
1190	Fe	Downward
1190	Mn	Downward
1190	Tritium	Downward
1191	Fe	No trend
1191	Mn	No trend
1191	Gross beta	Downward
1191	$^{89/90}Sr$	No trend
1191	Tritium	Downward

[a] Statistically insignificant trend upward or downward.

Table 5.20. Radiological concentrations detected in 2017 exit pathway groundwater monitoring

Parameter	Concentration[a] (pCi/L)		
	Season		Reference value[b]
	Wet	Dry	
Spring BC-01—7000 Area/Bearden Creek Watershed			
Beta activity	9.1	U0.22	50
^{214}Bi	38	nd	10,400
^{214}Pb	39	nd	8,000
Well 923—East End Discharge Point			
Beta activity	6.4	2.9	50
^{214}Bi	15	nd	10,400
^{214}Pb	20	nd	8,000
Spring/Surface Water Monitoring Point EE-01—East End Discharge Area Exit Pathway			
Beta activity	4.3	1.6	50
^{214}Bi	10	10	10,400
^{214}Pb	15	nd	8,000
^{40}K	26	U13	192
Spring/Surface Water Monitoring Point EE-02—East End Discharge Area Exit Pathway			
Beta activity	2.9	2.4	50
^{214}Bi	210	11	10,400
^{214}Pb	230	6.9	8,000
Well 531—Northwestern Discharge Area Exit Pathway			
Beta activity	3.0	1.2	50
^{40}K	U-18	47	192
Well 535—Northwestern Discharge Area Exit Pathway			
Beta activity	9.8	3.3	50
^{214}Bi	27	nd	10,400
^{214}Pb	29	nd	8,000
Well 807—Northwestern Discharge Area Exit Pathway			
Beta activity	9.2	14	50
^{214}Bi	110	nd	10,400
^{214}Pb	110	nd	8,000
$^{89/90}$Sr	3.1	2.3	44
Tritium	480	U150	20,000
Well 808—Northwestern Discharge Area Exit Pathway			
Beta activity	6.9	3.8	50
Spring/Surface Water Monitoring Point S-02—Southern Discharge Area Exit Pathway			
Alpha activity	2.7	U1.3	15
Beta activity	16	0.86	50
^{214}Bi	65	nd	10,400
^{214}Pb	66	nd	8,000

Table 5.20 Radiological concentrations detected in 2017 exit pathway groundwater monitoring (continued)

Parameter	Concentration[a] (pCi/L)		
	Season		Reference value[b]
	Wet	Dry	
Well 857—WOC Discharge Area Exit Pathway			
Beta activity	6.3	1.3	50
^{214}Bi	120	nd	10,400
^{214}Pb	130	nd	8,000
Well 858—WOC Discharge Area Exit Pathway			
Beta activity	5.4	U0.44	50
^{214}Bi	19	nd	10,400
^{214}Pb	19	nd	8,000
Well 1190—WOC Discharge Area Exit Pathway			
Beta activity	5.3	1.8	50
^{214}Bi	44	31	10,400
^{212}Pb	6.0	3.1	152
^{214}Pb	58	29	8,000
$^{89/90}$Sr	1.8	U-0.52	44
Tritium	24,000	24,000	20,000
Well 1191—WOC Discharge Area Exit Pathway			
Alpha activity	5.9	U2.6	15
Beta activity	270	220	50
^{214}Bi	32	12	10,400
^{214}Pb	35	13	8,000
$^{89/90}$Sr	130	120	44
Tritium	24,000	14,000	20,000
Well 1239—WOC Discharge Area Exit Pathway			
Alpha activity	4.8	U0.55	15
Beta activity	10	0.99	50

[a] ND: not detected. "U" means that the analyte was analyzed for but not detected above the PQL/CRDL.

[b] Current federal drinking water standards and/or Tennessee WQCs for radiological contaminants were used as reference standards. If no federal or state standard exists for a particular radionuclide, 4% of the DCS for a radionuclide is used.

Summary

The following bullets summarize the exit pathway groundwater surveillance program monitoring efforts for 2017 at ORNL:

- Eight radiological contaminants were detected in exit pathway groundwater samples collected in 2017. Tritium, $^{89/90}$Sr, and gross beta activity were the only radiological contaminants exceeding reference standards at any of the discharge areas, and, as in past years, those three contaminants were observed at the WOC discharge area in 2017. Statistical trend analyses show that the concentration trends for those parameters continue downward (or possess no statistically significant trend as was detected in the case of $^{89/90}$Sr in Well 1191). No other radiological contaminants exceed reference standards at other discharge areas.
- Twenty-four metallic contaminants were detected in exit pathway groundwater samples collected in 2017; however, only three metals (iron, manganese, and aluminum) were detected at concentrations

exceeding reference standards. Statistical trend analyses show that the concentration trends for these parameters continue downward or possess no statistically significant trend. These metals are commonly found in groundwater at ORNL

- No VOCs were detected in exit pathway groundwater at ORNL during 2017.

Radiological and metal contaminant concentrations observed in groundwater exit pathway discharge areas were generally consistent with observations reported in past annual site environmental reports for ORR. Based on the results of the 2017 monitoring effort, there is no indication that current SC operations are significantly introducing contaminants to the groundwater at ORNL.

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.)

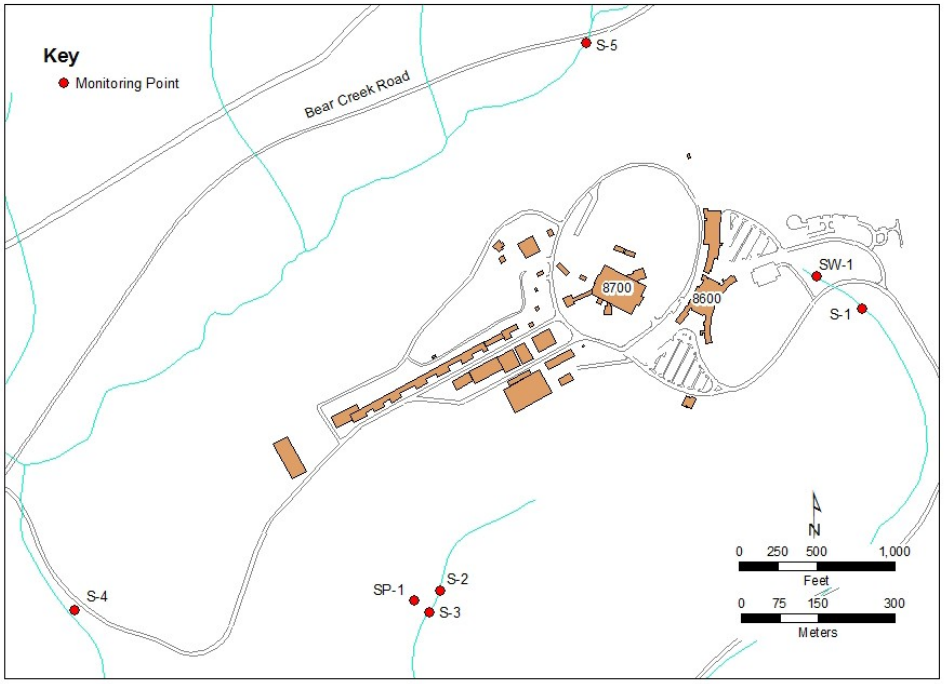
5.6.2.3 Active Sites Monitoring—Spallation Neutron Source

Active sites groundwater surveillance monitoring was performed in 2017 at the SNS site under the SNS operational monitoring plan (OMP) (Bonine, Kettelle, 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 5.37 shows the locations of the specific monitoring points sampled during 2017.



S = springs, SP = seeps, SW = surface water sampling areas

Figure 5.37. Groundwater monitoring locations at the Spallation Neutron Source, 2017

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 this 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 2017, allowing the opportunity for monitoring in wet and dry seasons. All sampling performed in 2017 was performed in conjunction with rainfall events, with samples being collected during rising or falling (recession) limb flow conditions (see Figure 5.38). In Fig. 5.38, the curves represent spring or seep flow (base flow, through flow, overland flow, peak flow); the bars represent rainfall amounts. Table 5.21 shows the sampling and parameter analysis schedule followed in 2017.

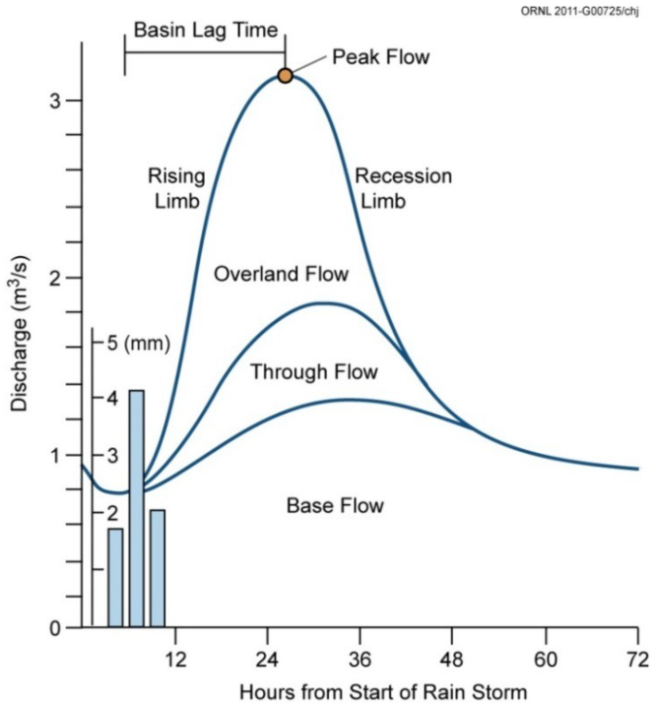


Figure 5.38. Simple hydrograph of spring discharge vs. time after initiation of rainfall

Table 5.21. 2017 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 and expanded suite[a]	Tritium	Tritium	Tritium
S-1	Tritium and expanded suite	Tritium	Tritium	Tritium
S-2	Tritium	Tritium and expanded suite	Tritium	Tritium
S-3	Tritium	Tritium and expanded suite	Tritium	Tritium
S-4	Tritium	Tritium	Tritium and expanded suite	Tritium
S-5	Tritium	Tritium	Tritium and expanded suite	Tritium and expanded suite
SP-1	Tritium	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 2017 sampling at the SNS site occurred during each quarter. Low concentrations of several radionuclides were detected numerous times during 2017. Table 5.22 provides a summary of the locations for radionuclide detections observed during 2017.

Table 5.22. Radiological concentrations detected in samples collected at the Spallation Neutron Source during 2017

Parameter	Concentrations[a] (pCi/L)				Reference Standard[b]
	March	May	August	November	
			SW-1		
	nd[c]				
^{214}Bi	20.4				10,400
^{214}Pb	16.4				8,000
Tritium	2690	1890	3440	2760	20,000
			S-1		
	nd[c]				
Beta	6.52				50
Tritium	2340	901	1600	968	20,000
			S-2		
		nd[d]			
Tritium	1080	625	1320	1680	20,000
			S-3		
		nd[c]			
^{214}Bi		18.9			10,400
Tritium	986	603	302	323	20,000
			S-4		
			nd[d]		
Tritium	1100	646	274	535	20,000
			S-5		
			nd[c]	nd[c]	
Alpha			19.6		15
Beta			22		50
Tritium	361	366	389	279	20,000
			SP-1		
Tritium	314	314	U81.7	U231	20,000

[a] ND: not detected. "U" means that the analyte was analyzed for but not detected above the PQL/CRDL.
[b] Current federal drinking water standards and/or Tennessee WQCs for radiological contaminants were used as reference standards. If no federal or state standard exists for a particular radionuclide, 4% of the DCS 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 were detected.

Sampling results were compared against reference standards. Reference standards used for comparison are either 4% of the DOE O 458.1 DCSs or the National Primary Drinking Water Standards (40 CRF 141). Gross alpha activity was detected in S-5 at a concentration exceeding its reference standard of 15 pCi/L during the third-quarter sampling event. However, Additional analysis was not done to identify the alpha activity because uranium isotopes were detected in samples collected from S-5 in 2013 and 2016. The source of these radionuclides is most likely the S-3 Ponds at Y-12. The S-3 Ponds are located up-gradient of S-5 and are interconnected via karst features to S-5. No other radionuclide exceeded its reference standard at SNS monitoring locations in 2017.

5.7 Quality Assurance Program

The UT-Battelle Quality Management System (QMS) has been developed to implement the requirements defined in DOE O 414.1D (DOE 2011c). 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; and
- 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; sample identification; sample collection and handling; sample preservation; equipment decontamination; and collection of 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 that are traceable to an authority standard. 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 EPA 40 CFR, Performance Specification 16 (PS-16). The accuracy of PEMS is also evaluated by performing relative accuracy audits in accordance with PS-16. The results of these 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 2017 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 2017 Cleanup Progress Annual Report to the Oak Ridge Regional Community (UCOR 2017) provides detailed information on DOE OREM's 2017 cleanup activities.

5.8.1 Oak Ridge National Laboratory Wastewater Treatment

At ORNL, DOE OREM operates PWTC and the Liquid Low-Level Waste Treatment Facility. In 2017 368 million L of wastewater was treated and released at PWTC. In addition, the liquid LLW evaporator at ORNL treated 162,680 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 Oak Ridge National Laboratory 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. UT-Battelle, as the prime contractor for the management of ORNL, is responsible for management of most of the wastes generated from R&D activities and wastes generated from operation of the R&D facilities. TRU wastes and 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 2017, ORNL performed 89 waste shipments to off-site hazardous/radiological/mixed waste treatment and/or disposal vendors with no shipment rejections or violations.

5.8.3 Transuranic Waste Processing Center

TRU waste-processing activities carried out for DOE in 2017 by NWSol addressed CH solids/debris and RH solids/debris, which involved processing, treating, and repackaging of waste. Off-site transportation and disposal of LLW at the Nevada National Security Site or other approved off-site facilities was also performed in 2017. TRU waste disposal at the Waste Isolation Pilot Plant resumed in 2017. TWPC made 17 CH TRU waste shipments in calendar year 2017 for a total of 459 containers or 96.4 m^3.

During 2017, 28.23 m^3 of CH waste and 57.52 m^3 of RH waste were processed, and 60.27 m^3 of mixed LLW (TRU waste that was recharacterized as low-level waste) was shipped off the site.

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6. Oak Ridge Reservation Environmental Monitoring Program

Environmental monitoring is performed on the Oak Ridge Reservation 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 US Department of Energy operations on the entire reservation and the surrounding area. Dose assessment information based on data from this program is presented in Chapter 7.

Because of differing permit-reporting requirements and instrument capabilities, various units of measurement are used in this report. The information found in "Units of Measure and Conversion Factors" is intended to help readers convert numeric values presented here 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 the Oak Ridge Reservation (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 Description

The 10 meteorological towers on the 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 the 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 lowest wind measurement height for MT11 is 25 m and 20 m for MT13. Additionally, data are collected at selected towers at the 30, 33, 35, and 60 m levels. Temperature, wind speed, and wind direction are measured at each measurement level except 2 m. Atmospheric stability (a measure of 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 towers that are 60 m in height (if using the Solar Radiation–Delta Temperature method). Stability is also calculated for sites MT2 and MT4; the Sigma Phi method is applied to the standard deviation of vertical wind speed. 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 National Security Complex (the Y-12 Complex); at MT7 and MT13 at the East Tennessee Technology Park (ETTP); and at MT2, MT3, MT4, and MT12 at Oak Ridge National Laboratory (ORNL). Solar radiation is measured at MT6 and MT9 at the Y-12 Complex, MT7 at ETTP, and at MT2 and MT12 at ORNL. Calibrations of the instruments 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[a]		
MT7	L, 1209	35.92522N, -84.39414W	233	15, 30
MT13	J, YEOC	35.93043N, -84.39346W	237	20
		ORNL		
MT2	D,[b] 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 MT1 (K1208) was retired August 1, 2017.
[b] Tower "C" before May 2014.

Acronyms
ETTP = East Tennessee Technology Park
ORNL = Oak Ridge National Laboratory
Y-12 Complex = Y-12 National Security Complex
MSL = mean sea level
PSS = plant shift superintendent
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 to 900 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.

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

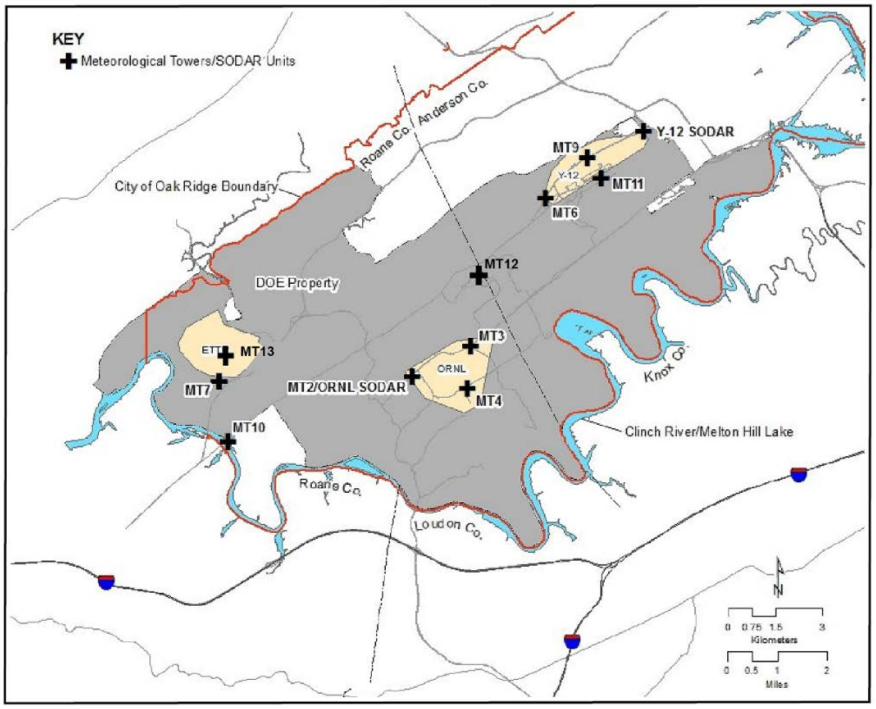

Figure 6.1. The Oak Ridge Reservation meteorological monitoring network, including sonic detection and ranging (SODAR) devices

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 the ORR sites. Winds in the valleys tend to follow the ridge axes, limiting cross-ridge flow within local valley bottoms. These conditions dominate over most of the ORR, but flow variation is greater at ETTP, which is located in a less-constrained open valley bottom.

On the 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 ridge-top level, particularly when flow is not parallel to the ridges (see Appendix B).

The atmosphere over the 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 emitted from the facilities. However, high roughness values (caused by terrain and obstructions such as trees and buildings) partially 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 thunderstorms. The total precipitation at ORNL during 2017 (1,454 mm or 57.26 in.) was about 10% 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 2017 were greater than 98% for wind sensors at the

ORNL sites MT2, MT4, and MT10. Site MT3 average annual wind data recovery was about 91% due to a major tower upgrade during August 2017. Site MT12 was brought online for the first time in October 2017. Annual wind data recovery from Y-12 meteorological towers during 2017 exceeded 98% (towers MT6, MT9, and MT11). At ETTP, significant lightning damage limited recovery at Site MT7 to about 71% at 15 m and 91% at 30 m. Site MT1 (K1208) was decommissioned in August 2017; Site MT13 (operated by Y-12) replaced it.

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 colocated with ORR ambient air stations. In 2017 several changes to station locations were made to reflect changes in activities on the ORR that have occurred since the original sites were established in the 1990s. Figure 6.2 shows locations that were monitored for all or part of 2017. During the year, as new stations came online, others were discontinued, resulting in only partial data for several locations.

Table 6.2 summarizes the data for each station.

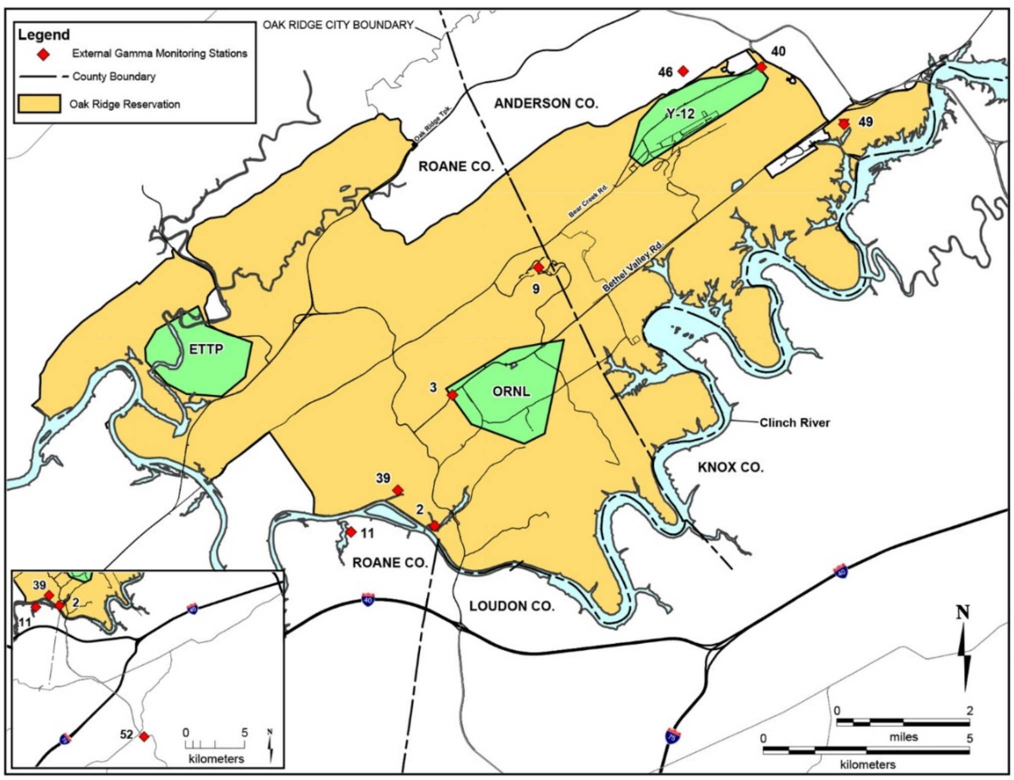

Figure 6.2. External gamma radiation monitoring locations on the Oak Ridge Reservation

6.2.2 Results

The mean exposure rate for the reservation network in 2017 was 10.5 µR/h, and the mean rate at the reference location was 9.5 µR/h. Background direct radiation exposure rates have been collected at an off-site location for many years. From 2007 through 2016 (the preceding 10 years), the exposure rates at the background off-site location ranged from 4.2 to 11.4 µR/h. The exposure rate at the off-site background location ranged from 5.6 to 11.4 µR/h from 2007 through 2017. The average exposure rate for those years was 7.6 µR/h (rounded to 8 µR/h).

Table 6.2. External gamma (exposure rate) averages for the Oak Ridge Reservation, 2017

Monitoring location	Number of data points (daily)	Measurement (µR/h)[a]		
		Min	Max	Mean
02	358	8.1	11	9.4
03	363	9.0	12	9.4
09	659	9.3	13	10
11	69	11	12	11
39	236	9.6	14	13
40	362	9.4	12	10
46	338	10	12	11
49	357	9.4	12	10
52	363	8.7	11	9.5

[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 the US Department of Energy (DOE) 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

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 the ORR operations to be assessed on an integrated basis. This program is discussed in detail in the following sections.

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 the ORR. The perimeter air monitoring network was established in the early 1990s. Since then there have been significant operational changes on the 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 2017 are shown in Figure 6.4. Reference samples are collected from Station 52 (Fort Loudoun Dam). Sampling was conducted at each ORR station during 2017 to quantify levels of alpha-, beta-, and gamma-emitting radionuclides. Upgrades were done sequentially throughout 2016 and 2017, so only partial data were available at several locations in 2017.

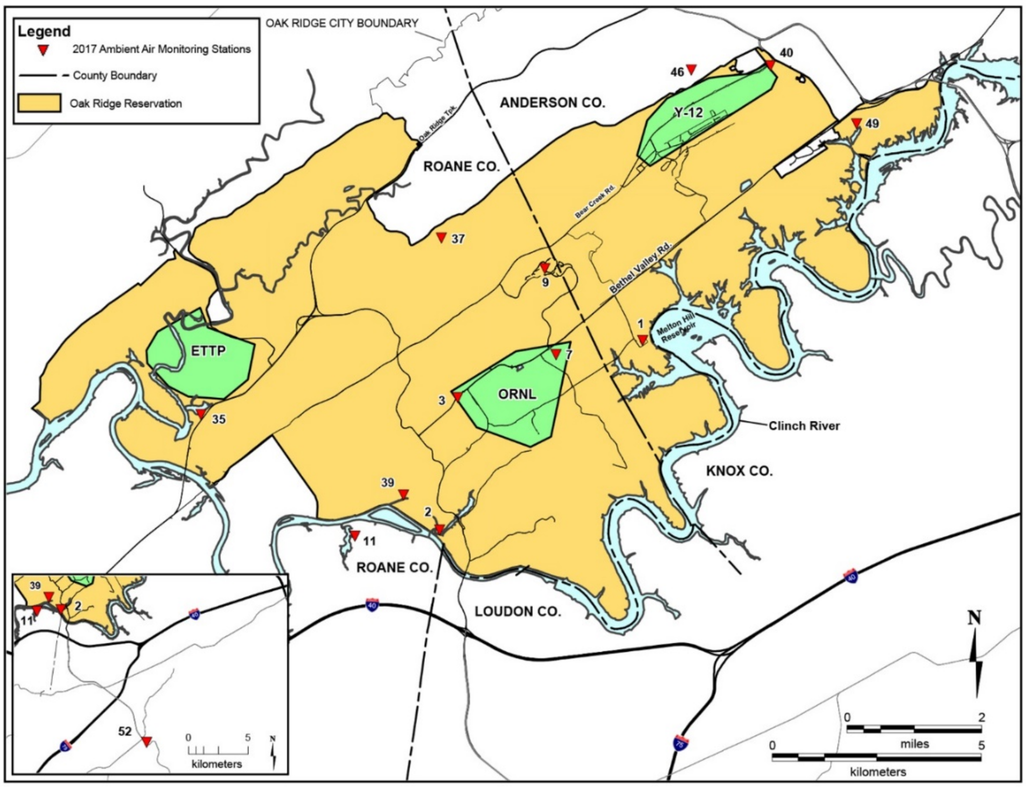

Figure 6.4. Locations of Oak Ridge Reservation perimeter air monitoring stations

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 the 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.

6.3.1 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 2017 were less than 1% of applicable DCSs, indicating that activities on the reservation are not adversely affecting local air quality.

Table 6.3. Radionuclide concentrations at Oak Ridge Reservation perimeter air monitoring stations, 2017

Parameter	N detected/N total	Concentration (pCi/mL)[a]		
		Average	Minimum	Maximum
		Station 1		
^{7}Be	4/4	4.02E-08	2.04E-08	5.76E-08
^{40}K	0/4	-2.80E-10	-5.70E-10	3.89E-11
Tritium	2/4	6.98E-06	-2.52E-09	1.58E-05
^{234}U	4/4	1.72E-12	1.01E-12	2.31E-12
^{235}U	1/4	2.36E-13	1.45E-14	4.95E-13
^{238}U	4/4	1.25E-12	3.81E-13	2.24E-12
		Station 2		
^{7}Be	4/4	3.68E-08	2.73E-08	4.88E-08
^{40}K	0/4	7.81E-11	-2.42E-10	3.05E-10
Tritium	2/4	2.87E-05	1.89E-09	1.03E-04
^{234}U	4/4	1.30E-12	6.83E-13	1.61E-12
^{235}U	1/4	1.46E-13	7.17E-14	2.48E-13
^{238}U	4/4	1.38E-12	6.94E-13	2.01E-12
		Station 3		
^{7}Be	4/4	4.01E-08	2.77E-08	5.56E-08
^{40}K	0/4	-1.35E-10	-2.96E-10	1.14E-10
Tritium	1/4	3.86E-06	3.63E-09	1.28E-05
^{234}U	4/4	2.56E-12	1.53E-12	5.39E-12
^{235}U	1/4	2.26E-13	-8.77E-14	6.56E-13
^{238}U	3/4	1.04E-12	6.35E-13	1.30E-12
		Station 9		
^{7}Be	4/4	4.14E-08	3.01E-08	5.65E-08
^{40}K	0/4	-9.82E-11	-3.75E-10	1.23E-10
Tritium	4/4	3.15E-05	1.14E-08	5.34E-05
^{234}U	4/4	2.78E-12	1.44E-12	3.81E-12
^{235}U	1/4	2.40E-13	6.21E-14	4.76E-13
^{238}U	4/4	1.90E-12	1.02E-12	2.99E-12
		Station 11[b]		
^{7}Be	1/1	5.51E-08	5.51E-08	5.51E-08
^{40}K	0/1	-3.26E-10	-3.26E-10	-3.26E-10
^{99}Tc	1/1	3.20E-10	3.20E-10	3.20E-10

Table 6.3 Radionuclide concentrations at Oak Ridge Reservation perimeter air monitoring stations, 2017 (continued)

Parameter	N detected/N total	Concentration (pCi/mL)[a]		
		Average	Minimum	Maximum
Tritium	0/1	9.17E-06	9.17E-06	9.17E-06
^{234}U	1/1	2.48E-12	2.48E-12	2.48E-12
^{235}U	0/1	2.39E-13	2.39E-13	2.39E-13
^{238}U	1/1	1.65E-12	1.65E-12	1.65E-12
Station 35				
^{7}Be	4/4	4.42E-08	3.73E-08	5.28E-08
^{40}K	0/4	-2.04E-10	-6.09E-10	1.40E-12
^{99}Tc	2/3	3.17E-10	-6.29E-11	5.74E-10
Tritium	0/4	3.97E-06	-1.26E-09	7.47E-06
^{234}U	4/4	3.02E-12	9.03E-13	6.12E-12
^{235}U	2/4	2.08E-13	-4.69E-14	5.40E-13
^{238}U	4/4	4.27E-12	1.85E-12	1.10E-11
Station 37				
^{7}Be	4/4	3.87E-08	2.72E-08	4.92E-08
^{40}K	0/4	-7.99E-11	-4.20E-10	2.42E-10
Tritium	2/4	2.99E-05	-3.84E-10	1.10E-04
^{234}U	4/4	2.02E-12	7.25E-13	3.07E-12
^{235}U	0/4	1.71E-13	9.45E-14	3.43E-13
^{238}U	4/4	1.32E-12	8.13E-13	2.63E-12
Station 39[c]				
^{7}Be	3/3	4.47E-08	3.02E-08	5.38E-08
^{40}K	0/3	-2.62E-10	-4.68E-10	-9.85E-11
Tritium	1/3	2.55E-06	-1.19E-09	4.14E-06
^{234}U	2/3	1.13E-12	1.84E-13	2.02E-12
^{235}U	0/3	2.00E-13	-1.45E-14	3.89E-13
^{238}U	3/3	1.18E-12	5.18E-13	1.66E-12
Station 40				
^{7}Be	4/4	3.96E-08	3.01E-08	5.21E-08
^{40}K	0/4	-2.90E-11	-2.06E-10	1.40E-10
Tritium	2/4	5.20E-06	4.76E-09	1.22E-05
^{234}U	4/4	8.45E-12	6.06E-12	1.21E-11
^{235}U	2/4	3.43E-13	6.18E-14	6.78E-13
^{238}U	4/4	3.04E-12	2.68E-12	3.38E-12
Station 46				
^{7}Be	4/4	3.89E-08	3.17E-08	5.12E-08
^{40}K	0/4	-2.95E-10	-5.53E-10	3.84E-12
Tritium	1/4	4.27E-06	1.95E-09	7.25E-06
^{234}U	4/4	3.66E-12	1.97E-12	5.39E-12
^{235}U	0/4	1.44E-13	2.72E-14	2.64E-13
^{238}U	4/4	1.52E-12	1.35E-12	1.78E-12

Table 6.3 Radionuclide concentrations at Oak Ridge Reservation perimeter air monitoring stations, 2017 (continued)

Parameter	N detected/N total	Concentration (pCi/mL)[a]		
		Average	Minimum	Maximum
		Station 49		
^{7}Be	4/4	3.99E-08	2.83E-08	5.63E-08
^{40}K	0/4	-3.70E-11	-2.97E-10	3.57E-10
Tritium	1/4	3.93E-06	-8.28E-10	7.53E-06
^{234}U	4/4	2.40E-12	1.06E-12	3.65E-12
^{235}U	¼	2.47E-13	-4.16E-14	5.48E-13
^{238}U	4/4	1.54E-12	8.72E-13	2.23E-12
		Station 52[d]		
	4/4	4.49E-08	3.76E-08	5.07E-08
^{40}K	0/4	-1.74E-10	-3.56E-10	1.02E-10
^{99}Tc	3/4	2.97E-10	-1.07E-10	5.77E-10
Tritium	1/4	2.51E-06	-1.54E-06	6.56E-06
^{234}U	4/4	2.14E-12	1.82E-12	2.48E-12
^{235}U	1/4	1.98E-13	3.09E-14	2.97E-13
^{238}U	4/4	2.00E-12	1.76E-12	2.46E-12

[a] 1 pCi = 3.7×10^{12} Bq.
[b] Station 11 became operational in Fall 2017; there are results from quarter 4 only.
[c] Station 39 was removed in Fall 2017; there are results from the first three quarters of 2017.
[d] Station 52 is the reference location.

6.4 Surface Water Monitoring

6.4.1 Oak Ridge Reservation 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.

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.

The sampling locations are classified by the State of Tennessee for recreation and domestic use. Tennessee Water Quality Criteria (WQCs) associated with these classifications 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 because this value is roughly equivalent to the 4 mrem dose limit from ingestion of drinking water on which the US Environmental Protection Agency (EPA) radionuclide drinking water standards are based.

6.4.2 Results

A comparison of radionuclide concentrations from 2017 sampling results for surface water collected upstream of DOE inputs with concentrations in surface water collected downstream of DOE inputs shows no statistically significant differences. No radionuclides were detected above 4% of the respective DCSs or the 4 mrem dose limit, which is the maximum contaminant level (MCL) for beta and photon emitters in community drinking water systems (EPA 2009).

Mercury was not detected above its MCL during 2017 at any of the sampling locations where mercury samples are collected.

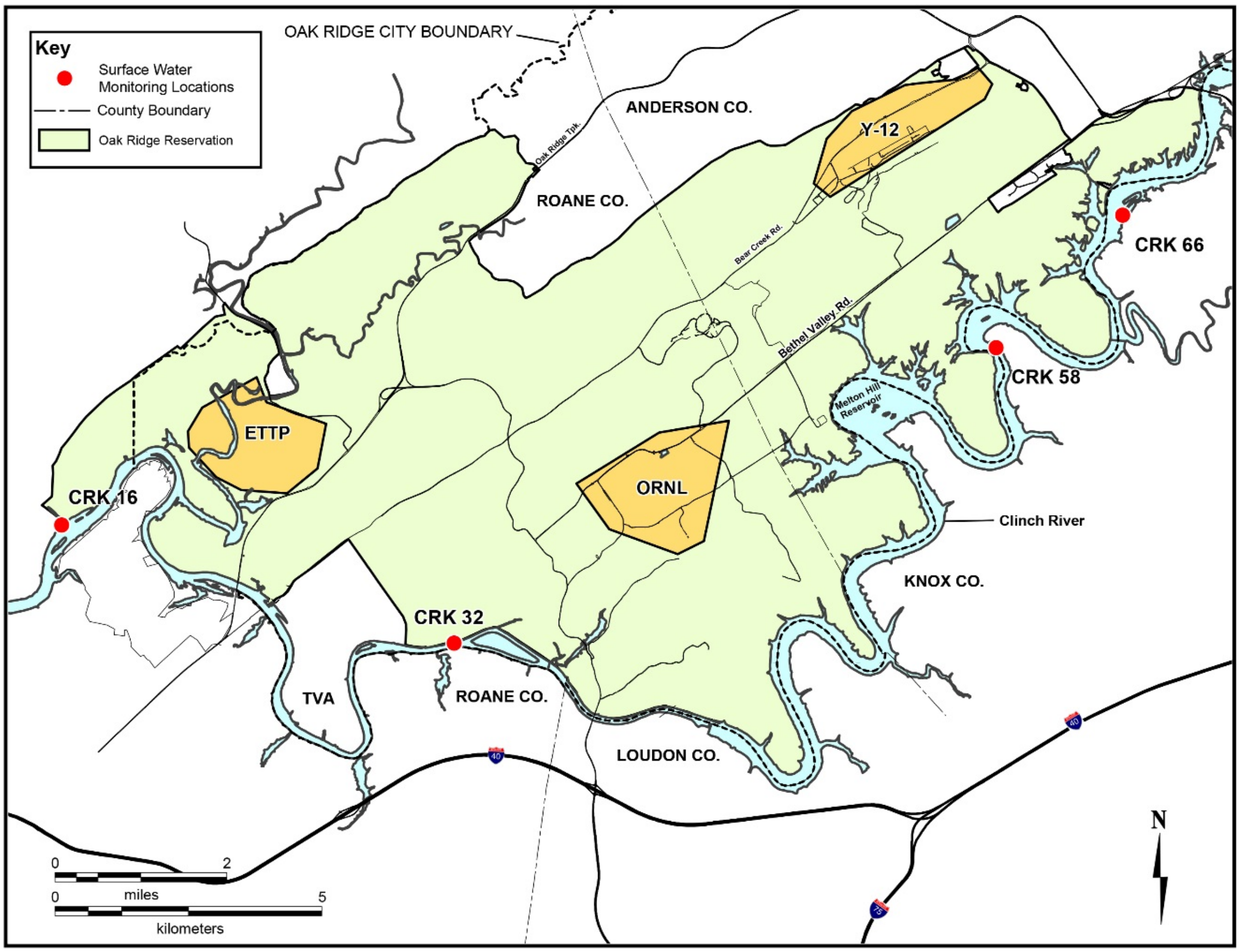

Figure 6.5. Oak Ridge Reservation surface water surveillance sampling locations

Table 6.4. Oak Ridge Reservation surface water sampling locations, frequencies, and parameters, 2017

Location[a]	Description	Frequency	Parameters
CRK 16	Clinch River downstream from all DOE ORR inputs	Quarterly	Mercury, gross alpha, gross beta, gamma scan, ^3H, field measurements[b]
CRK 32	Clinch River downstream from ORNL	Quarterly	Mercury, gross alpha, gross beta, gamma scan, total radioactive strontium, ^3H, field measurements[b]
CRK 58	Water supply intake for Knox County	Quarterly	Gross alpha, gross beta, gamma scan, ^3H, field measurements[b]
CRK 66	Melton Hill Reservoir above city of Oak Ridge water intake	Quarterly	Mercury, gross alpha, gross beta, gamma scan, total radioactive strontium, ^3H, field measurements[b]

[a] Locations indicate the water body and distances upstream of the confluence of the Clinch and Tennessee Rivers (e.g., CRK 16 is 16 km upstream from the confluence of the Clinch River with the Tennessee River, 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 2017 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 2017 the ORR Groundwater Program focused on activities in two tasks, an assessment of off-site groundwater and construction and calibration of a regional-scale flow model.

6.5.1 Offsite Groundwater Assessment

During FY 2017 OREM (the Oak Ridge Office of Environmental Management) 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).

The off-site groundwater assessment project was aimed at documenting water quality in selected residential water supply wells and at springs to the west and southwest of the ORR. General water chemistry, metals, organic compounds, and radionuclides are included in the suite of analytes that were assessed. The off-site groundwater assessment project was completed in FY 2017. DOE issued a final report on the off-site groundwater study in October 2017 (DOE 2017a). The project is a cooperative effort among the parties to the ORR Federal Facility Agreement to investigate off-site groundwater quality and potential movement. This report was approved by TDEC and EPA in November 2017 and December 2017, respectively. The report is available at the DOE Information Center.

Sampling was completed at a total of 49 locations (34 wells and 15 springs) in Roane County and compared to primary drinking water standards. There were primary drinking water exceedances at three locations during the first round of sampling. The exceedances were for lead, gross alpha activity, and combined Ra-226 and Ra-228, constituents that can be naturally-occurring. The exceedances corresponded with higher suspended solids and turbidity in the samples and were not repeated in the second and third rounds of samples.

6.5.2 Regional-Scale Flow Model

Construction and calibration of a regional-scale flow model was completed in FY 2017, and DOE issued a report on development of the regional groundwater flow model in July 2017 (DOE 2017b). The model will serve as an underlying framework to support future cleanup decisions and actions. A technical advisory group composed of experts from DOE, EPA, TDEC, and industry has met several times annually since 2014. Members of the advisory group reviewed progress and made recommendations for development and future use of the model.

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 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. Vegetables and milk were not collected in 2017 because they were not available. No vegetables were available in 2017 from local farmers, and the dairy that had supplied milk samples went out of business. The areas identified as potential areas of impact from DOE activities will be checked during 2018 for farming, vegetable production, and dairy operations.

The wildlife administrative release limits associated with deer, turkey, and geese harvested on the 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 Vegetables

Farms selling tomatoes, lettuce, and turnips near the ORR and from reference locations outside the potential DOE impact area were not identified in 2017. No vegetable samples were collected for analysis. When producers are identified, this program will resume.

6.6.2 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.

The one dairy that had been supplying milk samples to ORNL went out of business in 2016. During 2017, surveys to locate dairies in areas that could receive deposition from ORR activities were conducted and did not identify any dairies to replace the one that closed. When a dairy or dairies are located, this program will resume.

6.6.3 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 [Clinch River kilometer (CRK) 70],
- Clinch River downstream from ORNL (CRK 32), and
- Clinch River downstream from all DOE ORR inputs (CRK 16).

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 2017, 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.

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 2017). 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. See additional information **here**.

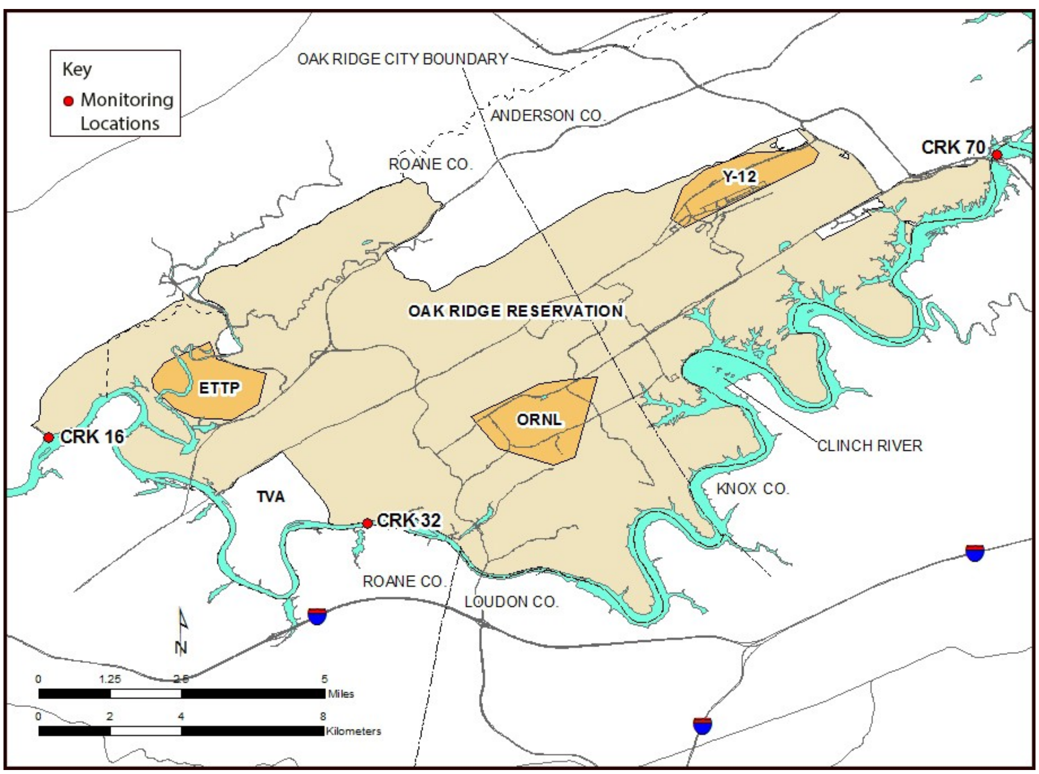

Figure 6.6. Fish-sampling locations for the Oak Ridge Reservation Surveillance Program

6.6.3.1 Results

PCBs, specifically Aroclor-1260, and mercury were detected in both sunfish and catfish at all three locations in 2017. These results are consistent with the TDEC advisories. Detected PCBs, mercury, and radionuclide concentrations are shown in Table 6.5.

Radiological analyses for fish tissues sampled in 2017 showed few statistical differences (at the 95% confidence level) between the upstream and downstream locations, indicating that DOE activities on the ORR are not significant contributors to the public radiological dose from fish consumption.

Table 6.5. Tissue concentrations in catfish and sunfish for detected mercury, PCBs, and radionuclides, 2017[a]

Parameter	Catfish[b]	Sunfish[b]
Clinch River downstream from all DOE ORR inputs (CRK 16)		
Metals (mg/kg)		
Hg	0.027	0.04
Pesticides and PCBs (µg/kg)		
PCB-1260	140	19
Radionuclides (pCi/g)[b]		
Beta activity	3.2[c]	3.7[c]
^{40}K	2.2[c]	3.8[c]
Clinch River downstream from ORNL (CRK 32)		
Metals (mg/kg)		
Hg	0.021	0.051
Pesticides and PCBs (µg/kg)		
PCB-1260	280	J18[d]
Radionuclides (pCi/g)[b]		
Alpha activity	-0.0032	0.056[c]
Beta activity	3.1[c]	3.8[c]
^{40}K	4.0[c]	2.2[c]
Clinch River (Solway Bridge) upstream from all DOE ORR inputs (CRK 70)		
Metals (mg/kg)		
Hg	0.074	0.018
Pesticides and PCBs (µg/kg)		
PCB-1260	61	18
Radionuclides (pCi/g)[b]		
Alpha activity	0.044[c]	-0.0015
Beta activity	3.5[c]	3.1[c]
^{40}K	3.2[c]	3.0[c]

[a] Only parameters that were detected for at least one species are listed in the table.
[b] Radiological results are reported after background activity has been subtracted. Negative values are reported when background activity exceeds sample activity.
[c] Radionuclide concentrations were significantly greater than zero. Detected radionuclides are at or above the minimum detectable activity.
[d] "J" indicates that the result is an estimated value.

Acronyms

CRK = Clinch River kilometer
ORNL = Oak Ridge National Laboratory
PCB = polychlorinated biphenyl
DOE = US Department of Energy
ORR = Oak Ridge Reservation

6.6.4 White-Tailed Deer

Three weekend quota deer hunts were held on the ORR during the final quarter of 2017. The hunts took place November 4–5, November 11–12, and December 9–10. 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.

Approximately 26,758 acres were available to deer hunters on the Oak Ridge Wildlife Management Area (ORWMA) in 2017 (15,723 acres for gun hunting and 11,035 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), and the UT Arboretum. The total harvest in 2017 was 137 deer, of which 59 (~43.1%) were bucks, and 78 (~56.9%) were does. The heaviest buck weighed 167 lb and had nine antler points. The greatest number of antler points found on one buck was 12. The heaviest doe weighed 117 lb. The most significant contributing factor to the notably low deer harvest was likely the outbreak of epizootic hemorrhagic disease (EHD) in the Tennessee deer herds during the summer of 2017. The outbreak of EHD appeared to impact east Tennessee more than the rest of the state, as evidenced by the number of dead deer reports and harvest decline. Warm weather experienced during the first weekend of hunts was likely another significant factor in the ORR harvest decline.

Since 1985, 12,979 deer have been harvested from the ORWMA, of which 218 (~1.7%) 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 the ORR hunt information website **here** for more information.

6.6.4.1 Results

None of the 137 deer harvested on the ORR during the 2017 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), nor for exceeding 5 pCi/g ^{137}Cs in edible tissue.

6.6.5 Canada Geese

On the Three Bends Area of the ORR, Canada goose hunting was allowed during the statewide season until noon on five days during September and four days during October. The consumption of Canada geese is a potential pathway for exposing members of the public to radionuclides released from ORR operations. To determine concentrations of gamma-emitting radionuclides accumulated by waterfowl that feed and live on the ORR, Canada geese are rounded up each summer for noninvasive gross radiological surveys.

6.6.5.1 Results

Sixteen geese (14 adults, 2 goslings) were captured during the June 15, 2017, roundup at the Solway Boat Ramp, Anderson County. All sixteen geese were subjected to live whole-body gamma scans. Gamma scan results for the 14 adult geese (all < 0.25 pCi/g ^{137}Cs) and 2 goslings (< 0.31 and < 0.34 pCi/g ^{137}Cs) showed that all were well below the administrative release limit of 5 pCi/g ^{137}Cs.

6.6.6 Turkey Monitoring

Two wild turkey hunts, managed by DOE and TWRA, were held on the reservation in 2017 (April 8–9 and April 22–23). Each hunt was limited to 225 hunters, preselected in a quota drawing. Approximately 22,134 acres were available to turkey hunters in 2017, of which 255 acres were available to archery-only hunters. Thirty-one male turkeys were harvested on the two hunts, of which six (~ 19.4%) were juveniles and 25 (~ 80.6%) were adults. The average weight of all turkeys harvested during spring 2017 hunts was ~18.5 lb, and the largest turkey weighed 23.7 lb. The average beard length was ~9.1 in., and the longest beard was 12.1 in. The average spur length was ~ 0.9 in., and the longest spur was 1.5 in.

In addition, two adult male turkeys (16 lb and 19 lb) were legally harvested by archery hunters on November 12 during the 2017 deer hunts. Both turkeys had 11 in. beards; one had 1 in. spurs; the other had 0.5 in. spurs. The largest turkey harvested to date on the ORR weighed 25.7 lb (harvested in 2009).

6.6.6.1 Results

None of the 31 turkeys harvested in 2017 exceeded the administrative release limits established for radiological contamination. Since 1997, 870 turkeys have been harvested on spring turkey hunts. Ten additional turkeys have been harvested (since 2012) by archery hunters during fall deer hunts. Of all turkeys harvested, only three (< 0.4%) 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 Quality Assurance

The activities associated with administration, sampling, data management, and reporting for the ORR environmental surveillance programs are performed by UT-Battelle. Project scope is established by a task team whose members represent DOE; UT-Battelle; Consolidated Nuclear Security, LLC; and URS | CH2M Oak Ridge LLC. UT-Battelle integrates quality assurance, environmental, and safety considerations into every aspect of ORR environmental monitoring. (See Chapter 5, Sect.ion. 5.7, for a detailed discussion of UT-Battelle quality assurance program elements for environmental monitoring and surveillance activities.)

6.8 References

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7. Dose

Activities on the Oak Ridge Reservation (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 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 2017, a hypothetical maximally exposed individual (MEI)could have received an effective dose (ED) of about 0.3 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 1 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 and boating.

In addition, if a hypothetical person consumed one 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 a MEI from all these potential exposure pathways combined was estimated to be about 3 mrem. There are no known significant doses from discharges of radioactive constituents from ORR other than those reported. U.S. Department of Energy (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 2017 maximum ED was about 3% of the limit given in DOE O 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 plants or animal populations.

Because of differing permit-reporting requirements and instrument capabilities, various units of measurement are used in this report. The information found in “Units of Measure and Conversion Factors” is intended to help readers convert numeric values presented here as needed for specific calculations and comparisons.

7.1 Radiation Dose

Small quantities of radionuclides were released to the environment from operations at Oak Ridge Reservation (ORR) facilities during 2017. 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. The 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 2017 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 US Department of Energy (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. These 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 24 emission points on ORR were modeled during 2017. The total includes 3 (two combined) points at Y-12 National Security Complex (Y-12), 19 points at Oak Ridge National Laboratory (ORNL), and 2 points at the East Tennessee Technology Park (ETTP). Table 7.1 lists the emission-point parameter values and receptor locations used in the dose calculations.

Table 7.1. Emission point parameters and receptor location used in the dose calculations, 2017

Source	Stack height (m)	Stack diameter (m)	Effective exit gas velocity (m/s)[a]	Maximum distance (m) and direction to the maximally exposed individual			
				At each site		On ORR	
Oak Ridge National Laboratory							
X-Laboratory Hoods							
X-1000 Lab Hoods	15	0.5	0	4,350	SW	11,260	NE
X-2000 Lab Hoods	15	0.5	0	4,770	SW	10,840	NE
X-3000 Lab Hoods	15	0.5	0	5,100	SW	10,510	NE
X-4000 Lab Hoods	15	0.5	0	5,270	SW	10,360	NE
X-5000 Lab Hoods	15	0.5	0	5,560	SW	10,110	NE
X-6000 Lab Hoods	15	0.5	0	5,850	SW	9,800	NE
X-7000 Lab Hoods	15	0.5	0	5,290	WSW	10,750	NNE
X-2026	22.9	1.05	8.62	4,820	SW	10,790	NE
X-2099	3.66	0.18	16.88	4,810	SW	10,800	NE
X-3018	61	1.75	0.95	5,030	SW	10,570	NE
X-3020	61	1.22	14.74	4,970	SW	10,630	NE
X-3039	76.2	2.44	6.56	5,060	SW	10,560	NE
X-3544	9.53	0.279	25.66	4,810	SW	10,820	NE
X-3608 Filter Press	8.99	0.36	9.27	4,930	SW	10,720	NE
X-7503	30.5	0.91	13.13	5,330	SW	10,590	NNE
X-7830 Group	4.6	0.25	7.23	3,920	WSW	12,130	NNE
X-7856-CIP	18.29	0.48	9.27	3,970	WSW	12,110	NNE
X-7877	13.9	0.41	13.56	3,890	WSW	12,180	NNE
X-7880	27.7	1.52	15.53	3,860	WSW	12,200	NNE
X-7911	76.2	1.52	13.84	5,240	WSW	10,820	NNE
X-7935							
X-7935 Building Stack	15.24	0.51	26.85	5,250	SW	10,740	NNE
X-7935 Glove Box	9.14	0.25	4.66	5,250	SW	10,740	NNE
X-7966	6.10	0.29	6.33	5,330	SW	10,620	NNE
X-8915	104.0	1.22	6.86	8,060	SW	7,580	NE
X-Decom Areas	15	0.5	0	5,310	SW	10,310	NE
X-STP	7.6	0.203	7.39	4,590	SW	11,050	NE
East Tennessee Technology Park							
K-1407-AL CWTS	2.74	0.15	0	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.

Acronyms

CIP = Capacity Increase Project
CWTS = Chromium Water Treatment System
Decom= Decommissioned
ORR = Oak Ridge Reservation
STP = Sewage Treatment Plant

Meteorological data used in the calculations for 2017 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 2017, rainfall, as averaged over the five rain gauges located on ORR, was about 150 cm (59 in.). The average air temperature was 15.2°C (59.2°F) at the 10 to 15 m levels, and the average mixing-layer height for ETTP and ORNL was 905.1 m (2,969 ft) and for Y-12 was 839.6 m (2,755 ft). The mixing height is the depth of the atmosphere adjacent to the surface within which air is mixed.

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% of the vegetables and produce, 44.2% of the meat, and 39.9% 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, 2017

Tower	Height (m)	Source
		Y-12 National Security Complex
MT6 (West Y-12)	30	All Y-12 sources
	60	X-8915 Spallation Neutron Source (ORNL)
		East Tennessee Technology Park
MT7 (K1209)	10	K-1407-AL CWTS, K-2500-H-C
		Oak Ridge National Laboratory
MT4 (Tow A)	15	X-7830, X-7877, X-7935 Glove Box, X-7935 Building, X 7966, and X-7000 Lab Hoods
	30	X-7503, X-7856-CIP, X-7880, and X-7911
MT3 (Tow B)	15	X-5000 and X-6000 Lab Hoods
MT2 (Tow D)	15	X-2099, X-3544, X-3608 FP, STP, X-Decom Hoods, X-1000, X-2000, X-3000, and X-4000 Lab Hoods
	35	X-2026
	60	X-3018, X-3020, and X-3039

Acronyms
CIP = Capacity Increase Project
CWTS = Chromium Water Treatment System
Decom= Decommissioned
FP = Filter Press
ORNL = Oak Ridge National Laboratory
STP = Sewage Treatment Plant

Results

Calculated EDs from radionuclides emitted to the atmosphere from ORR are listed in Table 7.3 (maximum individual) and Table 7.4 (collective). The hypothetical MEI for ORR was located about 2,270 m northeast of the main Y-12 release point, about 10,820 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 0.3 mrem, which is well below the National Emission Standards for Hazardous Air Pollutants for Radionuclides standard of 10 mrem and is about 0.1% of the roughly 300 mrem that the average individual receives from natural sources of radiation (40 CFR 61 Subpart H).

ORNL 2012-G00588/mhr

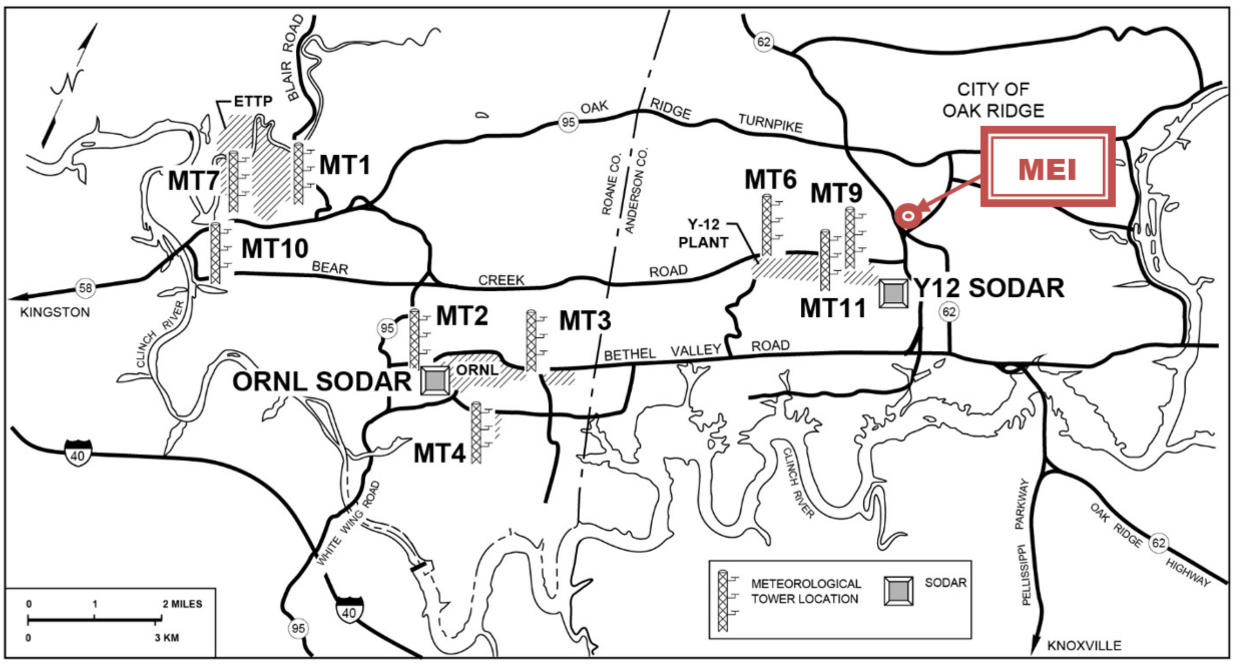

Figure 7.1. Location of the maximally exposed individual (MEI) for ORR

Based on the 2010 population census data, the calculated collective ED to the entire population within 80 km (50 miles) of ORR (about 1,172,530 persons) was about 10.1 person-rem, which is about 0.003% 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). CAP-88 PC Version 4 was used in 2017 to calculate both individual and collective doses.

Table 7.3. Calculated radiation doses to maximally exposed off-site individuals from airborne releases from ORR, 2017

Plant	Maximum effective dose, mrem (mSv)			
	At each site		On ORR	
	mrem	mSv	mrem	mSv
Oak Ridge National Laboratory	0.2[a]	0.002	0.07	0.0007
East Tennessee Technology Park	0.0005[b]	5×10^{-6}	7×10^{-6}	7×10^{-8}
Y-12 National Security Complex	0.2[c]	0.002	0.2	0.002
Entire Oak Ridge Reservation	*d*		0.3[e]	0.003

[a] The MEI was located 5,060 m SW of X-3039 and 5,240 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 National Security Complex MEI.

Acronyms
MEI = maximally exposed individual
ORR = Oak Ridge Reservation

Table 7.4. Calculated collective effective doses from airborne releases, 2017

Plant	Collective effective dose[a]	
	Person-rem	Person-Sv
Oak Ridge National Laboratory	7.3	0.073
East Tennessee Technology Park	0.0004	4×10^{-6}
Y-12 National Security Complex	2.9	0.029
Entire Oak Ridge Reservation	10.1	0.101

[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 Complex 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 0.2 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 99%, and ^{99}Tc accounted for about 0.3% 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 2.9 person-rem, which is about 28% of the collective ED for ORR.

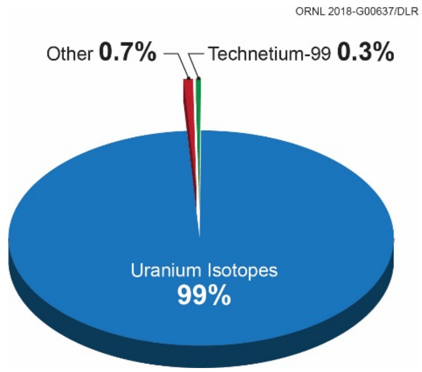

Figure 7.2. Nuclides contributing to the effective dose at Y-12 National Security Complex, 2017

The MEI for ORNL was located at a residence about 5,060 m (3.4 miles) southwest of the 3039 stack and 5,240 m (3.3 miles) west-southwest of the 7911 stack. This individual could have received an ED of about 0.2 mrem from ORNL airborne emissions. Radionuclides that contributed 10% or more to the dose were ^{212}Pb and ^{11}C, contributing about 30% and 17%, respectively (Figure 7.3). The total contribution from uranium radioisotopes (i.e., ^{232}U, ^{233}U, ^{234}U, ^{235}U, ^{236}U, and ^{238}U) accounted for about 4% of the dose, and ^{238}U contributed about 3% 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 72% of the collective ED for ORR.

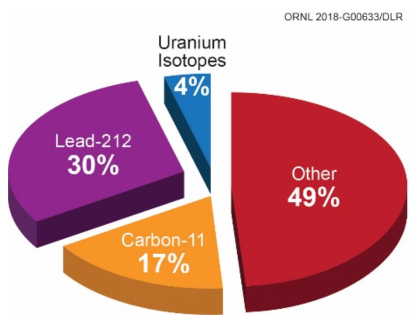

Figure 7.3. Nuclides contributing to effective dose at Oak Ridge National Laboratory, 2017

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 0.0005 mrem. About 91% of the dose is from uranium radioisotopes (^{234}U, ^{235}U, ^{236}U, and ^{238}U), and 6% 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 0.0004 person-rem, or about 0.004% of the collective ED for the reservation.

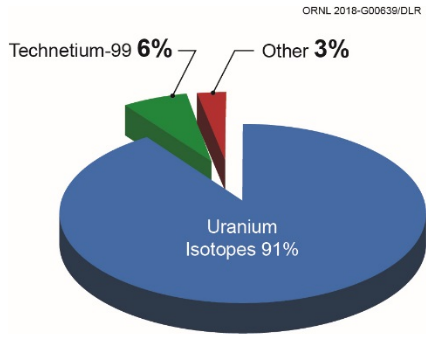

Figure 7.4. Nuclides contributing to effective dose at East Tennessee Technology Park, 2017

To evaluate the validity of the estimated doses calculated using CAP-88 PC Version 4 and emissions data (Table 7.5), the doses are compared to the EDs calculated using measured air concentrations of radionuclides (excluding naturally occurring ^{7}Be and ^{40}K) at ORR perimeter area monitoring (PAM) stations and at ORNL ambient air monitors 1 and 11 (AAM1 and AAM11). Based on measured air concentrations, hypothetical individuals assumed to reside at AAM1, AAM11, and PAM stations 35–49 could have received EDs between 0.007 and 0.08 mrem/year. Based on emissions data using CAP-88 PC Version 4, the above individuals could have received EDs between 0.05 and 0.4 mrem/year. As shown in Table 7.5, EDs calculated using CAP-88 PC Version 4 and emissions data tend to be greater than or equivalent to EDs calculated using measured air concentrations.

Table 7.5. Hypothetical effective doses from living near ORR, ORNL, and ETTP ambient air monitoring stations, 2017

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	0.02	0.0002	0.2	0.002
11	0.03	0.0003	0.2	0.002
35	0.009	0.00009	0.05	0.0005
37	0.08	0.0008	0.1	0.001
39	0.007	0.00007	0.2	0.002
40	0.02	0.0002	0.4	0.004
46	0.01	0.0001	0.1	0.001
49	0.01	0.0001	0.1	0.001
52	0.02	0.0002	0.02	0.0002
		ETTP		
K2	0.0006	0.000006	0.06	0.0006
K6	0.002	0.00002	0.05	0.0005
K11	0.001	0.00001	0.03	0.0003
K12	0.003	0.00003	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.

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. Based on measured air concentrations, the ED was estimated to be 0.02 mrem/year (the isotopes ^{7}Be and ^{40}K were not included in the background air monitoring station calculation); the estimated ED based on calculated air concentrations using CAP-88 PC Version 4 was also 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 0.001 mrem/year, which is lower than the ED of 0.03 mrem/year estimated using source emissions data. Ambient air station 11 is located near the off-site MEI for ORNL. The ED calculated with measured air concentrations was 0.03 mrem/year, which is lower than the ED of 0.2 mrem/year estimated using source emissions data. PAM station 40 is located near the off-site MEI for Y-12 Complex and ORR and the ED calculated with measured air concentrations was 0.02 mrem/year, which is also less than the ED of 0.4 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 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 330 L/year (87 gal/year). The average drinking water consumption rate is used to estimate the collective ED. At all locations in 2017, estimated maximum EDs to a person drinking water were calculated using both measured radionuclide concentrations in and measured radionuclide discharges to 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 CRK 66 near the City of Oak Ridge Water Intake Plant), a MEI drinking water at this location could have received an ED of about 0.02 mrem. The collective ED to the 47,933 persons who drink water from the City of Oak Ridge water plant would be 0.4 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. A MEI could have received an ED of about 0.02 mrem; the collective dose to the 63,779 persons who drink water from this plant could have been 0.5 person-rem.
- **Upper Clinch River.** 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. A MEI could have received an ED of about 0.01 mrem. The collective dose to the 30,895 persons who drink water from these plants could have been about 0.1 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 the 0.009 mrem. The collective dose to the 301,075 persons who drink water within the lower system could have been about 1.0 person-rem.
- **Poplar Creek/Lower EFPC.** No drinking water intakes are located on Poplar Creek or on lower EFPC.

Groundwater

A series of off-site monitoring wells were installed across the Clinch River from ORNL west of the Melton Valley waste management areas in 2010. Sampling of the off-site wells occurred semiannually, and results were compared to EPA MCLs. The analyses show that beta trends have remained stable over the past 5 years. For detailed information on results see 2017 Remediation Effectiveness Report for the U.S. Department of Energy (DOE 2017). 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 2017. For the average person used for collective dose calculations, it was assumed that 11 kg (24 lb) of fish was consumed in 2017. The estimated maximum ED will be 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 2017).

- **Upper Melton Hill Lake above All Possible ORR Inputs.** For reference purposes, a hypothetical avid fish consumer who ate fish caught at CRK 66, which is above all possible ORR inputs, could have received an ED of about 0.006 mrem. The collective ED to the nine persons who could have eaten such fish was about 2×10^{-5} person-rem.
- **Melton Hill Lake.** An avid fish consumer who ate fish from Melton Hill Lake could have received an ED of about 0.006 mrem. The collective ED to the 79 persons who could have eaten such fish could be about 2×10^{-4} person-rem.
- **Upper Clinch River.** An avid fish consumer who ate fish from the upper Clinch River could have received an ED of about 0.04 mrem. The collective ED to the 100 persons who could have eaten such fish could have been about 0.002 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 0.05 mrem. The collective ED to the 233 persons who could have eaten such fish could have been about 0.006 person-rem.
- **Upper Watts Bar Lake.** An avid fish consumer who ate fish from upper Watts Bar Lake could have received an ED of about 0.004 mrem. The collective ED to the 666 persons who could have eaten such fish could be about 0.001 person-rem.
- **Lower System.** An avid fish consumer who ate fish from the lower system could have received an ED of about 0.003 mrem. The collective ED to the about 9,825 persons who could have eaten such fish could have been about 0.01 person-rem.
- **Poplar Creek/Lower East Fork Poplar Creek.** An avid fish consumer who ate fish from Poplar Creek could have received an ED of about 1.0 mrem. Assuming 100 people could have eaten fish from lower EFPC and from Poplar Creek, the collective ED could have been about 0.05 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) and a recent survey was conducted regarding visitor and property owner activities for Chickamauga and Watts Bar Reservoir (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 1×10^{-6} mrem. The collective ED to the 14,483 other users could have been 5×10^{-7} person- rem.
- **Melton Hill Lake.** An individual other user of Melton Hill Lake could have received an ED of about 6×10^{-4} mrem. The collective ED to the 40,044 other users could have been about 0.003 person-rem.
- **Upper Clinch River.** An individual other user of the upper Clinch River could have received an ED of about 7×10^{-6} mrem. The collective ED to the 14,568 other users could have been about 6×10^{-6} person-rem.
- **Lower Clinch River.** An individual other user of the lower Clinch River could have received an ED of about 0.0004 mrem. The collective ED to the 33,992 other users could have been about 0.001 person-rem.
- **Upper Watts Bar Lake.** An individual other user of upper Watts Bar Lake could have received an ED of about 0.0001 mrem. The collective ED to the 97,119 other users could have been about 0.0009 person-rem.
- **Lower system (Watt Bar and Chickamauga Lakes).** An individual other user of the lower system could have received an ED of about 0.0001 mrem. The collective ED to the 3,401,402 other users could have been about 0.02 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 5×10^{-4} 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 2×10^{-7} to 0.03 mrem in 2017. The individual was assumed to consume 24 kg of leafy vegetables, 90 kg of produce, 321 L of milk and 671 kg of meat (beef) during the year.

Summary

Table 7.6 is a summary of potential EDs from identified waterborne radionuclides around ORR. Adding worst-case EDs for all pathways in a water-body segment gives a maximum individual ED of about 1 mrem to a person obtaining his or her full annual complement of fish from and participating in other water uses throughout these water systems. 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 0.05 mrem. The maximum collective ED to the 80 km (50 mile) population was estimated to be 2 person-rem. These are small percentages of individual and collective doses attributable to natural background radiation, about 0.3% of the average individual background dose of roughly 300 mrem/year and 0.0006% 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, 2017[a,b]

Effective dose	Source			Total[c]
	Drinking water	Eating fish	Other uses	
Upstream of all Oak Ridge Reservation discharge locations (CRK 66, City of Oak Ridge Water Plant)				
Individual	0.02	0.006	1×10^{-6}	0.02
Collective	0.4	2×10^{-5}	5×10^{-7}	0.4
Melton Hill Lake (CRK 58, Knox County Water Plant)				
Individual	0.02	0.006	0.0006	0.02
Collective	0.5	0.0002	0.003	0.5
Upper Clinch River (CRK 23, 32)				
Individual	NA[d]	0.04	7×10^{-6}	0.04
Collective	NA[d]	0.002	6×10^{-6}	0.002
Lower Clinch River (CRK 16)				
Individual	NA[d]	0.05	0.0004	0.05
Collective	NA[d]	0.006	0.001	0.007
Upper Watts Bar Lake, Kingston Municipal Water Plant				
Individual	0.01	0.004	0.0001	0.01
Collective	0.1	0.001	0.0009	0.2
Lower system (Lower Watts Bar Lake and Chickamauga Lake)				
Individual	0.009	0.003	0.0001	0.01
Collective	1	0.01	0.02	1
Lower East Fork Poplar Creek and Poplar Creek				
Individual	NA[d]	1.0	0.0005	1.0
Collective	NA[d]	0.05	2×10^{-5}	0.05

[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] Total doses and apparent sums over individual pathway doses may differ because of rounding.
[d] Not at or near drinking water supply locations.

Acronyms
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 ORR surveillance program. However, milk and vegetable samples were not available to be collected in 2017.

7.1.2.4 Food

Milk

During 2017, no milk samples were collected from a nearby dairy (in Claxton, Tennessee) because the dairy farm went out of business. Milk samples had been collected from that dairy for several years. Surveys to locate other dairies in areas that could receive deposition from ORR activities are conducted annually; however, the survey did not identify any dairies to replace the one that went out of business in 2016. The milk-sampling program will resume when a replacement for that dairy is identified.

Vegetables

Farms selling tomatoes, lettuce, and turnips near ORR and from reference locations outside the potential DOE impact area were not identified in 2017. No vegetable samples were collected for analysis. The vegetable-sampling program will resume when producers are identified.

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 June 2017 were analyzed for gross alpha, gross beta, gamma emitters, and uranium isotopes. Radionuclides detected in hay are shown in Table 7.7. Statistically significant concentrations of ^{7}Be, ^{40}K, ^{214}Pb, ^{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.

Table 7.7. Concentrations of radionuclides detected in hay, 2017 (pCi/kg)*[a]*

Gross alpha	Gross beta	^{7}Be	^{40}K	^{234}U	^{235}U	^{238}U	^{214}Pb
b	10.1	7.91	0.0125	0.00327	*b*	0.00282	0.525

*a*Detected radionuclides are those detected above the minimum detectable activity. 1 pCi = 3.7×10^{-2} Bq.
*b*Value was not detected above the minimum detectable activity.

White-Tailed Deer

TWRA conducted three 2-day deer hunts during 2017 on the Oak Ridge Wildlife Management Area, which is part of ORR (see Chapter 6). During the hunts, 137 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). No deer exceeded the wildlife release criteria.

The average ^{137}Cs concentration in muscle tissue of the 137 released deer, as determined by field counting, was 0.5 pCi/g; the maximum ^{137}Cs concentration in released deer was 0.8 pCi/g. Most of the ^{137}Cs concentrations were less than minimum detectable levels. The average weight of released deer was approximately 35 kg (77 lb); the maximum weight was 76 kg (167 lb). The EDs attributed to field-measured ^{137}Cs concentrations and actual field weights of the released deer ranged from about 0.02 to 1.1 mrem, with an average of about 0.4 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 (35 kg [77 lb], assuming that 55% of the field weight is edible meat) containing the 2017 average field-measured concentration of ^{137}Cs (0.5 pCi/g) could have received an ED of about 0.4 mrem. The maximum field-measured ^{137}Cs concentration was 0.8 pCi/g, and the maximum deer weight was 76 kg (167 lb). A hunter who consumed a hypothetical deer of maximum weight and ^{137}Cs content could have received an ED of about 2 mrem.

Muscle tissue samples collected in 2017 from six 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 either equal to or greater than the analytical results and that all were less than the administrative limit of 5 pCi/g (ORNL 2011). Using analytically measured ^{137}Cs and ^{90}Sr (excluding ^{40}K, a naturally occurring radionuclide) and actual deer weights, the estimated doses for the six released deer ranged from 0 to 0.2 mrem.

The maximum ED to an individual consuming venison from two or three deer was also evaluated. Seventeen 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 0.4 and 1.2 mrem.

The collective ED from eating all the harvested venison from ORR with a 2017 average field-derived ^{137}Cs concentration of 0.5 pCi/g and an average weight of 35 kg (77 lb) is estimated to be about 0.06 person-rem. The collective dose is based on number of hunters that harvested deer. It is possible that additional individuals may also consume the harvested venison; however, the collective dose would remain the same.

Canada Geese

Sixteen geese were captured during the 2017 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 (ORNL 2005). The average ^{137}Cs concentration was 0.2 pCi/g, with a maximum ^{137}Cs concentration in the released geese of 0.3 pCi/g. All of the ^{137}Cs concentrations were below minimum detectable activity levels. The average weight of the geese screened during the roundup was about 3.8 kg (8.3 lb), and the maximum weight was about 4.9 kg (10.7 lb).

The EDs attributed to field-measured ^{137}Cs concentrations of the geese ranged from 0.018 to 0.02 mrem. However, for bounding purposes, if a person consumed a released goose with an average weight of 3.8 kg (8.3 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 0.3 pCi/g and maximum weight of 4.9 kg (10.7 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 0.08 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

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. Two wild turkey hunts took place on the reservation in 2017: April 8–9 and April 22–23. Thirty-one turkeys were harvested during that time frame; no harvested turkeys were retained. The average ^{137}Cs concentration measured in the released turkeys was 0.1 pCi/g, and the maximum ^{137}Cs concentration was 0.3 pCi/g. All of the ^{137}Cs concentrations were below minimum detectable activity levels. The average weight of the released turkeys was about 8.4 kg (18.5 lb). The maximum turkey weight was about 10.8 kg (23.7 lb).

The EDs attributed to the field-measured ^{137}Cs concentrations of the released turkeys ranged from about 0.02 to 0.04 mrem with an average dose of 0.02 mrem. Potential doses were also evaluated for turkeys that might have moved off ORR and were then harvested elsewhere. In that scenario, if a person consumed a wild turkey with an average weight of 8.4 kg (18.5 lb) and an average ^{137}Cs concentration of 0.1 pCi/g, the estimated ED would be about 0.02 mrem. The maximum estimated ED to an individual who consumed a hypothetical released turkey with the maximum ^{137}Cs concentration of 0.3 pCi/g and the maximum weight of 10.8 kg (23.7 lb) was about 0.08 mrem. It is assumed that approximately half the weight of a wild turkey is edible. No tissue samples were analyzed in 2017.

The collective ED from consuming all the harvested wild turkey meat (31 birds) with an average field-derived ^{137}Cs concentration of 0.1 pCi/g and an average weight of 8.4 kg (18.5 lb) is estimated to be about 0.0007 person-rem. The collective dose is based on number of hunters who harvested turkeys. It is possible that additional individuals may also consume the harvested turkey meat; however, the collective dose would remain the same.

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 perimeter and on-site ambient air monitoring stations. External gamma exposure rates were continuously recorded by dual-range Geiger-Müller tube detectors co-located with ORR ambient air stations. In 2017, exposure rates averaged about 10.2 µR/h and ranged from 8.7 to 14.4 µR/h. These exposure rates correspond to an annual average dose of about 63 mrem with a range of 54 to 89 mrem. At the remote PAM station, the exposure rate averaged about 9.6 µR/h and ranged from 8.7 to 11.4 µR/h. The resulting average annual dose was about 59 mrem with a range of 54 to 71 mrem. The annual dose based on measured exposure rates at or near ORR boundaries were typically within the range of the doses measured at the remote location; slightly higher exposure rates were observed at PAM station 39.

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 2017, that person could have received a total ED of about 3 mrem. Of that total, 0.3 mrem would have come from airborne emissions, approximately 1 mrem from waterborne emissions (0.02 mrem from drinking water, 1 mrem from consuming fish, 0.0005 mrem from other water uses along the Clinch River, and 0.03 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.

Table 7.8. Summary of maximum estimated effective doses from ORR activities to an adult by exposure pathway, 2017

Pathway	Dose to maximally exposed individual		Percentage of DOE mrem/year limit (%)	Estimated collective radiation dose[a]		
				Pathway		Background (person-rem)
	mrem	mSv		person-rem	person-Sv	
			Airborne effluents			
All pathways	0.3	0.003	0.3	10.1	0.101	1,172,530[b]
			Liquid effluents			
Drinking water	0.02	0.0002	0.02	2.0	0.02	443,682[c]
Eating fish	1	0.001	0.1	0.07	0.0007	11,112[d]
Other activities	0.0005	5×10^{-6}	0.0005	0.02	0.0002	2,172,173[d]
Irrigation	0.03	0.003	0.03			
			Other pathways			
Eating deer	2[e]	0.02	2	0.06	0.0006	137
Eating geese	0.08[f]	0.0008	0.08	*g*	*g*	
Eating turkey	0.08[h]	0.0008	0.08	0.0007	7×10^{-6}	31
Direct radiation	NA[i]	NA				
			All pathways			
Total	**3**[j]	**0.003**	**3**	**13**	**0.13**	**363,484**

[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.
[b] Population based on 2010 census data.
[c] Population estimates based on community and non-community drinking water supply data from TDEC 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 TVA (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 consuming one hypothetical worst-case deer, a combination of the heaviest deer harvested and the highest measured concentrations of ^{137}Cs in released deer on the Oak Ridge Reservation; collective dose based on number of hunters that 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. The collective dose is based on the number of hunters who harvested turkey.
[I] Current exposure rate measurements at PAM stations are at or near background levels.
[j] Dose estimates have been rounded.

The dose of 3 mrem is about 1% of the annual dose (roughly 300 mrem) from background radiation. The ED of 3 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 1 mrem. DOE O 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 2017 maximum ED should not have exceeded about 3 mrem, or about 3% of the limit given in DOE O 458.1.

The total collective ED to the population living within an 80 km (50 mile) radius of ORR was estimated to be about 13 person-rem. This dose is about 0.004% of the 363,484 person-rem that this population received from natural sources during 2017.

7.1.4 Five-Year Trends

EDs associated with selected exposure pathways for years 2013 to 2017 are given in Table 7.9. In 2017, the air pathway dose is within the range of air pathway doses that have been estimated over the last 5 years; though 2014 air pathway dose was somewhat higher than the other 4 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. The 2017 dose from fish consumption is comparable to the doses estimated in 2015. 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 2014 fish consumption was due to a composite fish sample collected at CRK 16, in which ^{90}Sr was a primary dose contributor. In 2013, an increase in the dose from fish consumption was observed; this increase in dose was primarily due to a composite fish sample collected near CRK 32, in which ^{137}Cs was the primary dose contributor. There was a decrease in drinking water dose in 2014, but the doses in 2017 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 and slight increase in dose from consumption of venison and turkey in 2017.

Table 7.9. Trends in effective dose from ORR activities, 2013–2017 (mrem)[a]

Pathway	2013	2014	2015	2016	2017
Air					
All routes	0.4	0.6	0.4	0.2	0.3
Surface water					
Fish consumption (Clinch River)	1.5	1.2	0.03	1.3	0.05
Drinking water (Kingston)	0.01	0.003	0.02	0.03	0.01
Wildlife consumption					
Deer	2	2	1	1	2
Geese	0.1	0.1	0.08	0.2	0.08
Turkey	0.08	0.04	0.05	0.05	0.08

[a] 1 mrem = 0.01 mSv.

7.1.5 Potential Contributions from Non-DOE Sources

DOE O 458.1 (DOE 2011) requires that if DOE-related annual dose is greater than 25 mrem, the dose to members of the public must include major non-DOE sources of exposure as well as doses from DOE-related sources. In 2017, DOE-related source doses were considerably below the 25 mrem criterion. However, DOE requested information from non-DOE facilities pertaining to potential radiation doses to members of the public. There are several non-DOE facilities on or near ORR that could contribute radiation doses to the public. Fifteen facilities responded to DOE's request. Ten facilities had no radiological emissions. Three facilities reported doses from air emissions either using COMPLY, a computerized screening tool for evaluating radiation exposure from atmospheric releases of radionuclides (EPA 2016) or CAP-88 PC. One facility reported annual doses from airborne emissions of about 0.4 mrem 1 mile southwest of the facility, one facility reported an annual dose of 0.21 mrem at fence line, and the third facility reported an annual dose < 10 mrem (COMPLY, level 1). Doses from direct radiation ranged from none to an annual dose of 2 mrem, based on measurements at the facility and immediate surroundings. Therefore, annual doses from air and water emissions and external radiation from both non-DOE and DOE sources should be less than DOE O 458.1 annual public dose limit of 100 mrem.

7.1.6 Doses to Aquatic and Terrestrial Biota

7.1.6.1 Aquatic Biota

DOE O 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 2002). 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 (Melton Branch [X13])
- WOC headwaters, WOC (X14), and White Oak Dam (WOD) (X15)
- First Creek
- Fifth Creek
- Northwest Tributary
- Clinch River CRKs 16, 23, 32, 58, and 66

All locations, except WOC (X14) and WOD (X15) passed the general screening phase (comparison of maximum radionuclide water concentrations to default BCGs). White Oak Creek (X14) passed when average radionuclides were compared to default BCGs. WOD (X15) passed when average water concentrations and adjusted bioaccumulation factors for both ^{137}Cs and ^{90}Sr were used to reflect site-specific bioaccumulation of these radionuclides in fish. Riparian organisms are the limiting receptor for both ^{137}Cs and ^{90}Sr in surface water; however, the best available bioaccumulation data for WOC are for fish. Because fish are consumed by riparian organisms (e.g., raccoons), adjustment of the fish bioaccumulation factor modified the bioaccumulation of both ^{90}Sr and ^{137}Cs 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 of 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 DOE aquatic dose limit of 1 rad/day at the ETTP sampling locations.

7.1.6.2 Terrestrial Biota

A terrestrial organism assessment was conducted to evaluate impacts on biota in accordance with requirements in DOE O 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 2002) 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.

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. The next evaluation of exposure to terrestrial organisms would be within the next 5 years or if an abnormal event occurs that could have adverse effects on terrestrial organisms.

7.2 Chemical Dose

7.2.1 Drinking Water Consumption

7.2.1.1 Surface Water

To evaluate the drinking water pathway, hazard quotients (HQs) 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. 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 23 and CRK 16. The water intake for ETTP used to be located near CRK 23 but was deactivated in 2014. Therefore, it is not considered in this evaluation.

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 an indicator of the potential effect of drinking water from the Clinch River. As shown in Table 7.10, HQs were less than 1 for detected chemical analytes for which there are reference doses or a maximum contaminant level.

Acceptable risk levels for carcinogens typically range in magnitude from 10^{-4} to 10^{-6}. A risk value of 7×10^{-6} was calculated for the intake of arsenic in water collected at CRK 16.

Table 7.10. Chemical hazard quotients and estimated risks for drinking water from the Clinch River at CRK 16, 2017[a]

Chemical	Hazard quotient
Metals	
Antimony	0.004
Arsenic	0.04
Cadmium	0.02
Mercury	0.005
Nickel	0.002
Selenium	0.001
Uranium	0.03
Zinc	0.004
Risk for carcinogens	
Arsenic	7×10^{-6}

[a] Clinch River kilometer (CRK) 16, downstream of all US Department of Energy inputs.

7.2.1.2 Groundwater

Groundwater monitoring is conducted west of the Clinch River across from the Melton Valley waste management areas. These wells have been sampled semiannually from 2010 through 2017. Data are summarized in *2017 Remediation Effectiveness Report for the U.S. Department of Energy* (DOE 2017).

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 2017. This fish consumption rate of 74 g/day (27 kg/year) is assumed for both the noncarcinogenic and carcinogenic pollutants. 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 both sunfish and catfish at all three locations (CRKs 16, 32, and 70).

For carcinogens, risk values at or greater than 10^{-5} were calculated for the intake of chromium (as Cr^{+6}) for sunfish at all three locations and for Aroclor-1260 in sunfish and catfish collected at all three locations. The concentration for chromium was 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 2017). TDEC has issued a precautionary fish consumption advisory for catfish in the Clinch River arm of Watts Bar Reservoir (TWRA 2018).

Table 7.11. Chemical hazard quotients and estimated risks for carcinogens in fish caught and consumed from locations on ORR, 2017[a]

Carcinogen	Sunfish			Catfish		
	CRK 70[b]	CRK 32[c]	CRK 16[d]	CRK 70[b]	CRK 32[c]	CRK 16[d]
Hazard quotients for metals						
Aluminum		<0.001	<0.001		J0.001	J0.002
Antimony	J0.3		J0.3	<0.3		J0.4
Chromium	0.03	J0.04	J0.05	J0.02	J0.02	J0.02
Copper	0.008	0.009	0.008	0.008	0.009	0.009
Iron	0.006	0.004	0.009	0.01	0.009	0.01
Lead	J0.1	< 0.1	0.9	J 0.2	J 0.1	J0.2
Lithium	J0.03	J0.03	J0.03	J0.04	0.04	J0.04
Manganese	0.008	0.006	0.01	0.002	0.002	0.002
Mercury	0.05	0.2	0.1	0.2	0.06	0.08
Selenium	0.3	0.2	0.3	0.2	0.2	0.2
Strontium	0.003	0.004	0.005	< 0.00009	<0.00009	< 0.00008
Thallium	0.2	0.3	0.4	< 0.1	<0.1	J0.2
Uranium			J0.003			< 0.003
Zinc	0.05	0.04	0.05	0.03	0.02	0.02
Hazard quotients for pesticides and Aroclors						
Aroclor-1260	0.8	J0.8	0.8	3	12	6
Risks for carcinogens						
Chromium	J2E-5	J2E-5	J3E-5	J1E-5	J1E-5	J1E-5
Lead	J6E-8	<5E-8	5E-7	8E-8	J6E-8	J1E-7
Aroclor-1260	1E-5	J1E-5	1E-5	4E-5	2E-4	9E-5
PCBs (mixed)[e]	1E-5	J1E-5	1E-5	4E-5	2E-4	9E-5

[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 and “< “indicates that the concentration was not quantifiable at the analytical detection limit.
[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 that 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. The US Environmental Protection Agency (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-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.

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.

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."

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 are terms generally associated with freshwater systems; they 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.

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 generally 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 that is 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.

Oak Ridge winters are characterized by synoptic weather systems that produce significant precipitation events 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, occur most frequently during spring and rarely during winter. The Cumberland Mountains and Cumberland Plateau often 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 adequate precipitation usually occurs during the fall, the months of August through October often represent the driest period 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. During November, winter-type cyclones again begin to dominate the weather and may continue to do so until April or May.

Decadal-scale climate change has recently affected the East Tennessee region. Most of these changes appear to be related to the hemispheric 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 40 years, respectively, affect Pacific Ocean sea surface temperatures. The AMO, with a cycle of 30 to 70 years, affects Atlantic sea surface temperature. All of these patterns collectively modulate long-term regional temperature and precipitation trends in eastern Tennessee. The AMO shifted from a cold to a warm sea surface temperature phase (mid-1990s) and could continue in its present state for another decade or so. The PDO entered an either cool or transitional sea surface temperature state around 2000. Also, the ENSO pattern had frequently brought about warmer Eastern Pacific sea surface temperatures during the 1990s, but this phenomenon had subsided somewhat in the 2000s. A very strong El Niño occurred in 2015–2016, leading to above-normal temperatures, both locally and in much of the globe by 2016. Additionally, some evidence exists that human-induced climate change may be producing some effects (via an assembly 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, also play a role in inter-annual climate variability (Ineson et al. 2011). Perhaps partly due to the effects of the AMO and ENSO, the Oak Ridge climate warmed about 1.1°C from the 1980s to the 1990s but has stabilized just above the 1990s values during the 2000s (a further warming of 0.2°C was observed). The recent warming appears to have lengthened the growing season [i.e., the period with temperatures above 0°C (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 being 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 can 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. In 2017, the annual average temperature at ORNL returned almost to the 2014 level (14.9°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, and
- 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 on the Oak Ridge Reservation (ORR) (Birdwell 2011). Along-valley and mountain-valley circulations are thermally driven and occur within a large range of spatial scales. Thermally driven flows are more prevalent under conditions of clear skies and low humidity, favoring summer and 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 on ORR (Kossman and Sturman 2002).

Forced channeling within the Central Great Valley represents the dominant large-scale wind mechanism, influencing 50 to 60 percent of all winds observed in the area. For up-valley flow cases, these winds are frequently associated with large wind shifts when they initiate or terminate (45°–90°). At small scales, ridge-and-valley terrain usually produces forced-channeled local flow (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 (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. This results in downward air motion. Additionally, horizontal flow is reduced by the windward mountain range (Cumberland Mountains), which increases buoyancy and Coriolis effects (also known as Froude and Rossby ratios). Consequently, the leeward mountain range (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 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 present. 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).

Pressure-driven channeling, in essence, 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 flow shifts 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 (Monti et al. 2002).

Within the Central Great Valley, and especially 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 fall, when intense surface heating and/or low humidity help drive flow patterns (Birdwell 2011).

Annual wind roses have been compiled for 2017 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 (1948–2017) and their durations for the city of Oak Ridge and ORNL are summarized in Table B.1. Decadal temperature and precipitation averages for the four decades of the 1970s to 2000s, as well as the partial decade of the 2010s, are provided in Table B.2. Hourly freeze data (1985–March 2018) are given in Table B.3. Overall, at ORNL, 2017 was 0.2°C above normal with regard to temperatures compared to the 1981–2010 Oak Ridge base period, and precipitation was about 10 percent above normal compared to the 1981–2010 mean. ORNL became the official reporting site for climate purposes 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).

B.3.1 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 (to 2017). In general, temperatures in the Oak Ridge area rose until the 1990s but with a much slower rise since the 1990s. Based on these average decadal temperatures, temperatures have risen 1.4°C between the decades of the 1970s and the 2000s from 13.8°C to 15.2°C (56.8°F to 59.3°F). More detailed analysis reveals that these temperature increases have been neither linear nor equal throughout the months or seasons.

For the 1970s to the 2000s, January and February average temperatures have seen increases of 2.1°C and 1.9°C, respectively. This significant increase is probably dominated by 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 of anywhere in the Northern Hemisphere over the last 30 years, although the increase could also be associated with a variety of causes.

During the 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 from the 1970s and 1980s to the 2000s. However, this trend has noticeably stalled during the 2010s, with winter temperature averages remaining roughly steady or even slightly declining. From the 1980s to the 2010s, spring (March–May) temperatures rose by about 2°C. Summer and fall temperatures underwent lesser temperature rises, about 0.6°C, since the 1980s. Overall, temperatures remained approximately steady during the 2000s and 2010s. The only significant increases occurred in April and December. Most of the overall warming that has occurred over the last several decades has been driven by increases in minimum daily temperatures, a change likely resulting from the redistribution of heat in the boundary layer resulting from the increased presence of greenhouse gases and aerosols near the surface. An increase in greenhouse gases and aerosols acts to weaken the strength of nighttime surface temperature inversions. Specifically, overall annual minimum temperatures seem to have increased more dramatically (2.0°C from the 1980s to the 2010s) than maximum temperatures (0.9°C from the 1980s to the 2010s).

Table B.1. Climate normals (1981–2010) and extremes (1948–2017) 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)
2017 Average Max	12.1 (53.8)	14.9 (58.9)	17.1 (62.8)	24.2 (75.6)	25.0 (77.0)	28.1 (82.6)	30.9 (87.6)	29.2 (84.6)	26.2 (79.1)	22.5 (72.6)	15.9 (60.7)	9.1 (48.4)	21.3 (70.3)
70-Year Record Max	25 (77)	26 (79)	30 (86)	33 (92)	35 (95)	41 (105)	41 (105)	39 (103)	39 (102)	32 (90)	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)
2017 Average Min	2.9 (37.2)	2.0 (35.6)	3.9 (39.0)	11.1 (52.0)	12.5 (54.6)	16.8 (61.4)	19.6 (67.3)	18.4 (65.2)	14.6 (58.3)	14.6 (58.3)	3.8 (38.7)	-0.4 (31.3)	10.0 (49.9)
70-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)
2017 Average	7.5 (45.7)	8.5 (47.3)	10.3 (50.7)	17.3 (63.2)	18.6 (65.6)	21.9 (71.2)	24.5 (76.1)	23.0 (73.7)	19.4 (67.0)	14.9 (58.8)	8.6 (47.6)	4.1 (39.5)	14.9 (59.0)
2017 Departure from Average	4.4 (8.2)	3.2 (5.8)	0.5 (1.1)	2.7 (4.9)	-0.7 (-1.1)	-1.7 (-3.3)	-1.1 (-2.0)	-2.2 (-3.7)	-2.1 (-3.7)	-0.3 (-0.6)	-0.8 (-1.3)	-0.1 (-0.2)	0.2 (0.5)
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)
2017 Totals	101.9 (4.01)	67.8 (2.67)	122.5 (4.82)	244.4 (9.62)	114.6 (4.51)	106.5 (4.19)	159.1 (6.26)	140.3 (5.52)	112.3 (4.42)	140.3 (5.52)	77.7 (3.06)	98.6 (3.88)	1485.9 (58.48)
2017 Departure from Average	-20.0 (-0.75)	56.4 (2.22)	1.6 (0.06)	131.8 (5.19)	-2.0 (-0.08)	8.2 (0.32)	24.6 (0.97)	58.2 (2.29)	14.2 (0.56)	64.3 (2.53)	-44.5 (1.75)	32.5 (1.28)	148.4 (5.84)
70-Year Max Monthly	337.2 (13.27)	324.7 (12.78)	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)
70-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)
70-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)
2017 Totals	6.6 (2.6)	Trace	Trace	0	0	0	0	0	0	0	0	Trace	6.6 (2.6)
70-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)
70-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
2017 Max ≥ 32°C	0	0	0	0	0	1	11	3	0	0	0	0	15
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
2017 Min ≤ 0°C	12	11	11	0	0	0	0	0	0	1	11	19	65
30-Year Max ≤ °C	2.8	0.9	0.1	0	0	0	0	0	0	0	0	1.6	5.4
2017 Max ≤ 0°C	2	0	0	0	0	0	0	0	0	0	0	1	3
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
2017 Days ≥ 0.01 in.	15	12	14	14	14	12	12	11	7	6	9	8	134
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
2017 Days ≥ 1.00 in.	2	0	1	4	1	2	2	3	1	3	1	2	22

Table B.2. Decadal climate change (1970–2017) for City of Oak Ridge, Tennessee, with 2017 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)
2010–2017 Avg Max	8.0 (46.5)	11.4 (51.7)	16.4 (61.6)	23.0 (73.5)	26.3 (79.5)	30.4 (86.8)	31.3 (88.5)	30.9 (87.6)	28.4 (82.3)	22.2 (72.0)	15.8 (60.3)	11.2 (51.2)	21.2 (70.1)
1980s vs. 2010s	1.1 (2.0)	0.8 (1.4)	0.5 (1.0)	2.0 (3.6)	0.8 (1.4)	0.6 (1.1)	-0.2 (-0.3)	0.2 (0.3)	0.9 (1.6)	0.9 (1.7)	0.1 (0.2)	2.1 (3.7)	0.9 (1.5)
2000s vs. 2010s	-0.8 (-1.4)	-0.2 (-0.4)	-0.6 (-1.0)	1.6 (2.9)	0.6 (1.1)	0.6 (1.2)	0.6 (1.1)	-0.5 (-0.9)	0.3 (0.6)	0.4 (0.8)	-0.1 (-0.3)	0.9 (1.6)	0.2 (0.4)
2017 Avg Max	12.1 (53.8)	14.9 (58.9)	17.1 (62.8)	24.2 (75.6)	25.0 (77.0)	28.5 (82.6)	30.9 (87.6)	29.2 (84.6)	26.2 (79.1)	22.5 (72.6)	15.9 (60.7)	9.1 (48.4)	21.3 (70.3)
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)
2010–2017 Avg Min	-2.3 (27.9)	0.2 (32.4)	4.4 (39.9)	9.2 (48.6)	13.8 (56.8)	18.4 (65.2)	20.4 (68.8)	19.6 (67.3)	16.0 (60.6)	9.2 (48.6)	3.1 (37.5)	1.1 (34.0)	9.4 (49.0)
1980s vs. 2010s	1.8 (3.3)	2.3 (4.2)	2.7 (4.8)	3.2 (5.7)	2.4 (4.4)	2.3 (4.1)	1.5 (2.6)	1.2 (2.1)	1.5 (2.6)	1.7 (3.1)	0.0 (0.0)	3.4 (6.2)	2.0 (3.7)
2000s vs. 2010s	-0.8 (-1.5)	0.2 (0.4)	0.0 (0.0)	0.6 (1.1)	0.2 (0.4)	0.5 (0.9)	0.5 (0.9)	-0.4 (-0.8)	-0.2 (-0.4)	-0.3 (-0.5)	-0.8 (-1.5)	1.5 (2.6)	0.1 (0.1)
2017 Avg Min	-2.9 (37.2)	2.0 (35.6)	4.4 (39.0)	11.1 (52.0)	12.5 (54.6)	16.3 (61.4)	19.6 (67.3)	18.4 (65.2)	14.6 (58.3)	9.2 (48.7)	3.7 (38.7)	-0.4 (31.3)	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)
2010–2017 Avg	2.9 (37.1)	5.1 (42.1)	10.5 (50.9)	15.9 (60.9)	20.0 (68.0)	23.7 (75.6)	25.7 (78.1)	24.9 (76.9)	21.9 (70.9)	15.4 (59.7)	8.7 (48.6)	5.8 (42.4)	15.2 (59.3)
1980s vs. 2010s	1.4 (2.6)	1.5 (2.8)	1.7 (3.0)	2.5 (4.6)	1.5 (2.7)	1.2 (2.2)	0.3 (0.6)	0.4 (0.7)	0.8 (1.5)	1.0 (1.8)	-0.2 (-0.3)	2.7 (4.8)	1.3 (2.3)
2000s vs. 2010s	-0.8 (-1.5)	0.0 (0.0)	-0.2 (-0.4)	0.8 (1.4)	0.3 (0.5)	0.3 (0.6)	0.2 (0.4)	-0.8 (-1.4)	-0.3 (-0.5)	-0.3 (-0.5)	-0.7 (-1.3)	1.1 (2.0)	0.0 (0.0)
2017 Avg	7.5 (45.7)	8.5 (47.3)	10.4 (50.7)	17.3 (63.2)	18.6 (65.6)	21.8 (71.2)	24.5 (76.1)	23.1 (73.7)	19.4 (67.0)	14.9 (58.8)	9.2 (48.7)	4.1 (39.5)	15.0 (59.0)
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)
2010–2017 Avg	127.3 (5.01)	120.2 (4.73)	117.6 (4.63)	138.5 (5.45)	89.7 (3.53)	125.3 (4.93)	161.6 (6.36)	77.0 (3.35)	118.4 (4.66)	71.4 (3.15)	124.8 (4.91)	147.9 (5.82)	1421.8 (55.96)
1980s vs. 2010s	26.7 (1.05)	11.2 (0.44)	5.0 (0.20)	49.8 (1.96)	-20.8 (-0.82)	41.1 (1.62)	41.4 (1.62)	2.5 (0.10)	9.5 (0.38)	0.1 (0.01)	-3.2 (-0.13)	40.2 (1.58)	182.9 (7.20)
2000s vs. 2010s	10.4 (0.41)	-1.6 (-0.06)	2.1 (0.08)	13.5 (0.53)	-28.1 (-1.11)	30.0 (1.18)	23.1 (0.89)	6.6 (0.26)	9.6 (0.38)	5.9 (0.23)	3.4 (0.13)	23.3 (0.92)	90.4 (3.56)
2017 Totals	101.9 (4.01)	67.8 (2.67)	122.5 (4.82)	244.4 (9.62)	114.6 (4.51)	106.5 (4.19)	159.1 (6.26)	140.3 (5.52)	112.3 (4.42)	140.3 (5.52)	82.8 (3.06)	98.6 (3.88)	1485.9 (58.48)
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)
2010–2017 Avg	5.6 (2.2)	7.8 (3.1)	0.5 (0.2)	0.0 (0.0)	0	0	0	0	0	0	0.3 (0.1)	2.3 (0.9)	15.0 (5.9)
1980s vs. 2010s	-5.6 (-2.2)	-1.0 (-0.4)	-1.8 (-0.7)	-2.3 (-0.9)	0	0	0	0	0	0	0.3 (0.1)	-5.3 (-2.1)	-2.3 (-4.2)
2000s vs. 2010s	3.6 (1.4)	3.3 (1.3)	0.5 (0.2)	0.0 (0.0)	0	0	0	0	0	0	0.3 (0.1)	0.5 (0.2)	1.8 (3.3)
2017 Totals	6.6 (2.6)	Trace	Trace	0	0	0	0	0	0	0	0	Trace	6.6 (2.6)

Table B.3. Hourly subfreezing temperature data for Oak Ridge, Tennessee, January 1985–March 2018[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[b]	362	199	86	4	67	7	0	0	49	2	0	11	0															
Avg.	250	81	18	3	155	35	6	1	63	7	1	10	0	0	0	7	0	67	4	0	192	39	6	1	744	161	28	5

[a] Source: 1985–2015 National Oceanic and Atmospheric Administration, Atmospheric Turbulence and Diffusion Division, KOQT Station, Automated Surface Observing System; 2016–2018 Oak Ridge National Laboratory, Tower "D"

[b] 2018 values through March 31, 2018

Considering annual mean temperatures only, the mean annual temperature increased by 1.3°C between the 1980s and the 2010s. However, nearly all of that increase occurred between the 1980s and 1990s. Mean annual decadal-averaged temperatures have varied by 0.3°C or less since the 1990s.

Decadal precipitation averages suggest some important changes in precipitation patterns in Oak Ridge over the period of the 1980s to 2010s. Although overall precipitation has 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 or seasonal scale. During winter, precipitation declined only slightly in January and February but has seen a greater than 1 in. increase during December. During the remaining months of the year, a decline of more than 0.80 in. in May is notable with significant increases (greater than 0.80 in.) in June and July. Changes during the fall months have been minor. Annual precipitation during the 2010s is above the 30 year average [around 1422 mm (55.96 in.)]. The year 2007 was the driest year on record in Oak Ridge (91.1 cm or 35.87 in.), which represented the core of a 4 year period of below-average precipitation (2005–2008). The most recent calendar year (2017) yielded precipitation totals about 10 percent above the 30 year mean, with a total of 58.48 in. (1,486 mm). The statistics presented here encompass the period from 1948 to 2017.

The previously discussed increase in winter temperatures by the 2000s has affected monthly and annual snowfall amounts until recently. 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 full decade (2000s), snowfall has averaged only 6.6 cm (2.6 in) per year. This decrease seems to have occurred largely since the mid-1990s. The slight cooling of winter temperatures in the 2010s thus far has reversed the decrease in snowfall somewhat, with annual averages of 5.9 in. (15.0 cm). Concurrently with the overall decrease in snowfall, the annual number of hours of subfreezing weather has generally declined since the 1980s (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.

Select wind roses for ORR towers that show wind direction for hours with precipitation and other relevant meteorological parameters have been compiled for 2017 and may be reviewed **here**.

Hourly values of subfreezing temperatures in Oak Ridge are presented in Table B.3 for January 1985 through March 2018. During the middle to late 1980s, a typical year experienced about 900–1,000 h of subfreezing temperatures. In recent years, the value has fallen to about 600–800 h, though higher values have occurred recently (2010 at 1,123 h). 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 is 73.5 percent (1998–2013). In terms of absolute humidity (grams per cubic meter), the average annual humidity for ORR is 10.24 g/m^3. This value varies greatly throughout the annual cycle, ranging from a monthly minimum of about 4.9 g/m^3 during winter to a maximum of about 17.2 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 49 days/year, with a monthly maximum between 10 and 11 days occurring in July. About 42 of these thunderstorm days occur during a 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 was observed during 2012 (65); the lowest was observed during 2007 (34). Monthly and annual average numbers of thunderstorm days for ORNL and Knoxville McGhee-Tyson Airport, respectively, during 2001–2017 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 in association with 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 (having 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 tornadoes once every 3 to 6 years on average. They occur more frequently in Middle and West Tennessee. Tornado indices from the National Weather Service in Morristown 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 at distances within 20 km (12 miles) of ORNL, ranging in intensity from F0/EF0 (Enhanced Fujita Scale) to F2/EF2 in intensity. 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 with regard 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 a number of the above factors. The process results from "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 reintensifies the inversion and allows the process to start again. Tornadoes occur more frequently in Middle and West Tennessee than in East Tennessee; East Tennessee experiences tornadoes once every 3 to 6 years on average. 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 these oscillations.

Wind roses for stability and mixing depth have been compiled for all of the ORR tower sites for 2017. 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 can be accessed **here**.

B.7 References

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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	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 CFR 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.
[e]These values are not maximum contaminant levels but are concentrations that result in the effective dose equivalent of the maximum contaminant level for gross beta emissions, which is 4 mrem/year.
[f]Applies to combined ^{226}Ra and ^{228}Ra.
[g]Minimum of uranium isotopes.

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				8300, 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	2000 (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				1400, 65,000
Bis(2-ethylhexyl) phthalate (c)				12, 22
Bis (Chloromethyl) ether (c)				12, 22
Bromate	10 (E1)			
Bromoform (c)				43, 1400
Butylbenzyl phthalate				1500, 1900
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)	4000 (E1)	19	11	
Chlorite	1000 (E1)			
Chlorobenzene				130, 1600
Chlorodibromomethane (c)				4.0, 130
Chloroform (c)				57, 4700
Chloromines (as Cl2)	4000 (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				1000, 1600
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	1000 (E2) 1300 (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, 1300
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, 7100
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				2000, 4500
2,4-Dinitrophenol				69, 5300
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				1100, 5300
Fluoride	2000 (E2) 4000 (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, 1100
Hexachloroethane (c)				14, 33
Ideno(1,2,3-cd)pyrene (c)				0.038, 0.18
Iron	300 (E2)			
Isophorone (c)				350, 9600
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, 1500
2-Methyl-4,6-dinitrophenol				13, 280
Methylene chloride (Dichloromethane) (c)				46, 5900
Mirex (b)			0.001	
Monocholorobenzene	100 (E1, T)			
Nickel	100 (T)	470[d]	52[d]	610, 4600

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	1000 (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, 4000
Selenium	50 (E1, T)	20	5	170, 4200
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	1000 (E1, T)			1300, 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)			1800, 3600
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	5000 (E2)	120[d]	120[d]	7400, 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.

Abbreviations

TDEC = Tennessee Department of Environment and Conservation
EPA = US Environmental Protection Agency

Appendix D:
National Pollutant Discharge Elimination System Noncompliance Summaries for 2017

Appendix D. National Pollutant Discharge Elimination System Noncompliance Summaries for 2017

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 2017. Adequate data points were obtained from sampling required by the NPDES permit. Compliance with permit discharge limits for 2017 was 100 percent.

D.2 East Tennessee Technology Park

The East Tennessee Technology Park experienced one noncompliance with the NPDES permit in 2017. The program was 100 percent compliant with the numerical permit limits during this period, but there was one instance of an unpermitted discharge. Details of this discharge are provided in Section 3.6.4.7. The discharge did not result in any detectable impact to fish or aquatic organisms, and no notice of violation was associated with the event. The current ETTP NPDES permit was effective on April 1, 2015 and will remain in effect until March 31, 2020.

D.3 Oak Ridge National Laboratory

In 2017 compliance with the Oak Ridge National Laboratory NPDES permit was determined by laboratory analyses and field measurements. The NPDES permit limit compliance rate for all discharge points for 2017 was 99 percent.

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 (ORR), not as a comprehensive discussion of radiation and its effects on the environment and on biological systems.

Radiation comes from natural and human-made 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 (see Figure E.1).

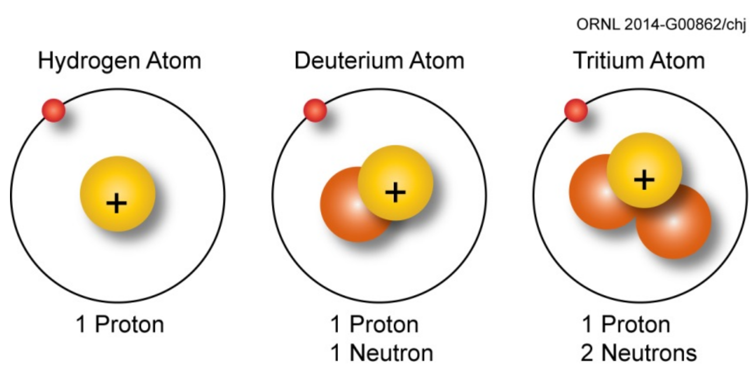

Figure E.1. The hydrogen atom and its isotopes

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; 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 (years unless otherwise noted)	Radionuclide	Symbol	Half-life (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. Examples include alpha and beta particles. Radiation also is characterized as ionizing or nonionizing because of the way in which it interacts with matter.

E.2.1 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.

E.2.2 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 (UV), visible light, infrared (IR), microwave, radio frequency (RF), and extremely low frequency. Lasers commonly operate in the UV, visible, and IR frequencies. Microwave radiation is absorbed near the skin, while RF 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, OSHA *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.

E.3.1 Activity

To determine radiation in the environment, the rate of radioactive decay or activity is measured. The rate of decay varies widely among various 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).

E.3.2 Absorbed Dose

The total amount of energy absorbed per unit mass of the 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).

E.3.3 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 gives 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.

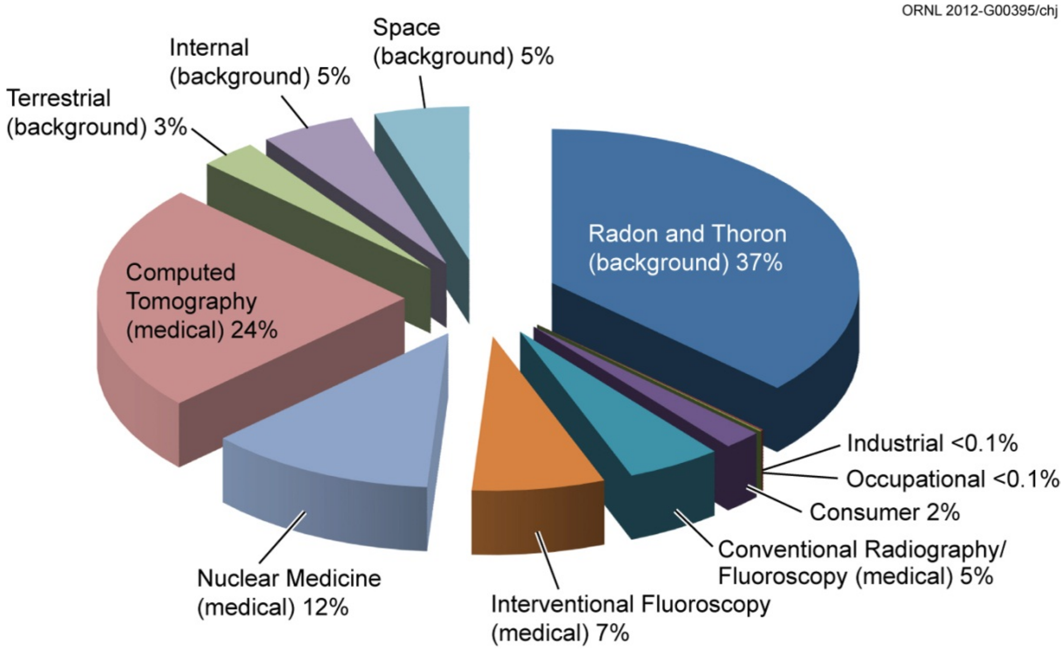

Figure E.3. All exposure categories for collective effective dose for 2006 (NCRP 2009)

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 its 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 and ^{232}Th and the ^{238}U series. The primary source of ^{40}K in body tissues is food, primarily fruits and vegetables. The sources of radionuclides from ^{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, there are human-made sources of radiation to which most people are exposed. Examples include 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).

E.5.2.1 Consumer Products

Some consumer products are sources of radiation. The radiation in these products, such as smoke detectors, radioluminous products (e.g., self-illuminating exit signs in commercial buildings), and airport x-ray baggage inspection systems, is essential to the performance of the device. In other products, such as tobacco products and building materials, the radiation occurs incidentally to the product's function (NCRP 1987, NCRP 2009).

The US average annual dose to an individual from consumer products and activities is 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 all contribute negligible doses (NCRP 2009).

E.5.2.2 Medical Sources

Radiation is an important tool of 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. Thus, not all body 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 involve internal administration of 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.

E.5.2.3 Other Sources

Other sources of radiation include emissions of radioactive materials from nuclear facilities such as uranium mines, fuel-processing plants, and nuclear power plants; transportation of radioactive materials; and emissions from mineral-extraction facilities. The dose to the general public from nuclear fuel cycle facilities, such as uranium mines, mills, fuel-processing plants, nuclear power plants, and transportation routes, has been estimated at less than 1 mrem (0.01 mSv) per year (NCRP 1987).

Small doses to individuals occur because of radioactive fallout from atmospheric atomic bomb tests, emissions of radioactive materials from nuclear facilities, emissions from certain mineral extraction facilities, and transportation of radioactive materials. The combination of these sources contributes less than 1 mrem (0.01 mSv) per year to an individual’s average dose (NCRP 1987).

E.6 References

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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 to the moon. At the same time, we must be cautious to ensure that our own existence is not endangered by uncontrolled and over-expanded use of chemicals (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 result from the direct or indirect actions of humans. Building materials used in the construction of homes may contain chemicals such as formaldehyde (in some insulation materials), asbestos (formerly used in insulations and ceiling tiles), and lead (formerly used in paints and gasoline). Some chemicals are present as a result of the application of pesticides and fertilizers to soil. Other chemicals may have been transported long distances through the atmosphere from industrial sources before being deposited on soil or water.

F.2 Pathways of Chemicals from Oak Ridge Reservation to the Public

"Pathways" refers to the route or way in which a person can come into 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 the 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 the 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

Chemicals have varying types of effects. Chemical health effects are divided into two broad categories: adverse or systemic effects (noncarcinogens) and cancer (carcinogens). Sometimes a chemical can have both noncarcinogenic and carcinogenic effects. The toxic effect can be acute (a short-term, 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 medications. Even those 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 are particularly sensitive to the chemical.

F.3.2 Dose Terms for Noncarcinogens

F.3.2.1 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 database deficiencies. The use of uncertainty factors in deriving reference doses is thought to 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.

F.3.2.2 Primary Maximum Contaminant Levels

For chemicals for which reference doses are not available in IRIS, Tennessee Water Quality Criteria, 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 L (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 milligrams per kilogram per day (mg/kg-day).

F.3.3 Dose Term for Carcinogens

F.3.3.1 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 (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 terms of milligrams or micrograms of chemical per liter of water; concentrations in solids (soil and fish tissue) are expressed in terms of 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 detected 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 was not quantifiable at the analytical detection limit.

F.5 Risk Assessment Methodology

F.5.1 Exposure Assessment

To evaluate an individual’s exposure by way of a specific exposure pathway, the intake amount of the chemical must be determined. For example, chemical exposure by 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 estimate chemical contaminant concentrations. It is assumed that individuals drink about 2 L (0.5 gal) of water per day directly from the river, which amounts to 730 L (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) concentrations in water by 2 L, or those in fish by 0.07 kg. This intake is first multiplied by the exposure duration (26 years) and exposure frequency (350 days/year) and then divided by an averaging time (26 years for noncarcinogens and 70 years for carcinogens) and 80 kg body weight. These assumptions are conservative, and in many cases they result in higher estimated intakes and doses than an individual would actually receive.

F.5.2 Dose Estimate

When the contaminant oral daily intake has been estimated, the dose is determined. For chemicals, the dose to humans is measured as milligrams per kilogram-day (mg/kg-day). In this case, the "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 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."

F.5.3 Calculation Method

Current risk assessment methodologies use the term "hazard quotient" to evaluate noncarcinogenic health effects. Because intakes are calculated in milligrams per kilogram per 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 health effects, whereas hazard quotient values greater than 1 indicate a concern for adverse health effects or the need for further study.

To evaluate carcinogenic risk, slope factors are used instead of reference doses.

To estimate the risk of inducing cancers 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).

F.6 References

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