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2016 OAK RIDGE RESERVATION ANNUAL SITE ENVIRONMENTAL REPORT

Oak Ridge Reservation

Annual Site Environmental Report 2016

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Acronyms and Abbreviations

A	AAS	ambient air (monitoring) station
	ABC	aluminum beverage can (recycling)
	ACHP	Advisory Council on Historic Preservation
	ACO	Analytical Chemistry Organization (Y-12 Complex)
	ACM	asbestos-containing material
	AFV	alternative fuel vehicle
	AGL	above ground level
	ALARA	as low as reasonably achievable
	AMP	asset management program
	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 Assessment Package (software)
	CAS	condition assessment survey
	CCA	chromated copper arsenate (as in CCA Type C pressure-treated wood)
	CCR	climate change resiliency
	CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
	CEUSP	Consolidated Edison Uranium Solidification Project
	CFL	Computers for Learning
	CFR	*Code of Federal Regulations*
	CFTF	Carbon Fiber Technology Facility

	CH	contact-handled
	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
	CRT	cathode ray tube (also display devices, especially computers incorporating cathode ray tubes)
	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
E	EA	environmental assessment
	EC&P	environmental compliance and protection
	ECD	Environmental Compliance Department (Y-12)
	ECM	energy conservation measure
	ED	effective dose
	EFK	East Fork Poplar Creek kilometer
	EFPC	East Fork Poplar Creek
	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
	EPT	ephemeroptera, plecoptera, and trichoptera (taxa)
	EPSD	Environmental Protection Services Division (UT-Battelle)
	ES&H	environment, safety, and health
	ESPC	Energy Savings Performance Contract
	ESS	Environmental Surveillance System (ORNL)
	ETTP	East Tennessee Technology Park
	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	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*
	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
	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	ODS	ozone-depleting substance
	O&M	operations and maintenance
	OMP	operational monitoring plan
	ORAU	Oak Ridge Associated Universities
	OREIS	Oak Ridge Environmental Information System
	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
	ORSSAB	Oak Ridge Site Specific Advisory Board
	ORWMA	Oak Ridge Wildlife Management Area
	OS	Office of Science (DOE)
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
	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
	RA	remedial action
	R&D	research and development
	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)
	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
	SPCC	spill prevention, control, and countermeasures (plan)
	SPMD	semipermeable membrane device
	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-Battelle	UT-Battelle, LLC (partnership between University of Tennessee and Battelle Memorial Institute formed to manage ORNL for DOE)
V	VOC	volatile organic compound

W	WCK	White Oak Creek kilometer
	WEMA	west end mercury-use area (Y-12)
	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
Y	Y-12/Y-12 Complex	Y-12 National Security Complex

Units of Measure and Conversion Factors*

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

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 Oak Ridge Reservation (ORR), managed by the US Department of Energy (DOE), is located in Roane and Anderson counties in east Tennessee about 40 km (25 mi) from Knoxville. The ORR is one of DOE's most unusual and complex sites. It encompasses three major facilities and thousands of employees who perform 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. The ORR was established in 1942 as part of the Manhattan Project for the purposes of enriching uranium and pioneering methods for producing and separating plutonium. Today scientists at the Oak Ridge National Laboratory (ORNL), DOE's largest multipurpose national laboratory, conduct leading-edge research in advanced materials, alternative fuels, climate change, and supercomputing. 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.

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 (i.e., radiation protection, fire protection, nuclear safety, environmental protection, waste management, and environmental management).

The ORR is managed by three DOE Program Secretarial Offices and their management and operating contractors and support contractors. This 2016 *Oak Ridge Reservation Annual Site Environmental Report* (ASER) contains detailed and complex information provided to the DOE ORR integrating contractor by contractors including UT-Battelle, LLC; Consolidated Nuclear Security, LLC; URS | CH2M Oak Ridge LLC; North Wind Solutions (NWSol) ; Oak Ridge Associated Universities; and Isotek Systems LLC. Five key chapters were prepared as follows: Chapter 3 by URS | CH2M Oak Ridge LLC (UCOR), the lead environmental management contractor for ETTP; Chapter 4 by Consolidated Nuclear Security, LLC, which manages and operates the Y-12 National Security Complex; and Chapter 5 by UT-Battelle, LLC, which manages the Oak Ridge National Laboratory; Chapter 6 ORR Environmental Monitoring Program; and Chapter 7 Dose. In addition, the aforementioned contractors are responsible for independently carrying out the various DOE missions at the three major ORR facilities. These contractors manage and implement environmental protection programs through environmental management systems that adhere to International Organization for Standardization standard 14001:2004, *Environmental Management Systems*, and are integrated with ISMS to provide unified strategies for managing resources. Detailed information on contractors' environmental management systems is provided in Chapters 3, 4, and 5.

DOE operations on the ORR have the potential to release a variety of constituents into 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 the 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 community and the environment, and it encourages the public to participate in matters to the ORR's environmental impact on the

community by soliciting citizens' input on matters of significant public interest and through various communications. DOE also provides 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 O 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 serve to reduce all types of waste and pollutant releases to the environment. An environmental report for the ORR that provides consolidated data on overall reservation performance and status has been published annually since the mid-1970s. The ASER continues to be a key component of the DOE 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.

2016 Impacts

DOE ORR operations in 2016 continued to result 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 O 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 the ORR in 2016 was estimated to be 0.2 mrem from air pathways, 1.3 mrem from water pathways (drinking water, fish consumption, swimming, recreation, and other uses), and 1 mrem from consumption of wildlife harvested on the ORR. This is about 3% 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 2016 maximum hypothetical dose is consistent with those calculated for the previous 6 years (2010–2015).

Environmental Monitoring

Extensive environmental monitoring is conducted across the ORR each year. Site-specific environmental protection programs are carried out at ORNL, the Y-12 Complex, and ETTP. The ORR-wide environmental surveillance programs, which include locations and media both on and off the reservation, are conducted to enhance and supplement data from site-specific efforts. In 2016 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, permits and standards, public and environmental exposure pathways, public concerns, and measurement capabilities. Chapters 2 through 7 of this report provide detailed summaries of the environmental protection and surveillance programs on the 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 the ORR for compliance with applicable environmental regulations and permits. These agencies issue permits, review

compliance reports, participate in joint monitoring programs, inspect facilities and operations, and/or oversee compliance with regulations. Continued compliance with environmental regulations and DOE orders assures on-site processes do not adversely impact the public or the environment.

During 2016 there were only a few instances of noncompliance with regulations, permits, and DOE orders. These were promptly addressed to ensure minimal adverse environmental or public health effects resulted. Noncompliances and notifications made to regulatory agencies during the year are summarized below, and detailed information is provided in Chapters 2 through 5 of this report.

- On December 8, 2016, UCOR D&D personnel were downsizing an exterior tank on the north side of Bldg. K-131, the former function and original location of which are unknown. Heavy machinery was used to cut the tank into smaller pieces for disposal. During this operation, an unknown white solid material was released onto the paved area where the tank was located. This release occurred immediately before a rainfall event, and D&D personnel were not able to clean up the material before the rain began. Despite efforts to prevent the material from entering a nearby storm drain inlet, some of it entered an inlet connected to Outfall 382, which discharges to Poplar Creek. Because this material could have posed safety and health hazards, sampling of it was delayed until additional information could be gathered on the potential source of the released material and the tank.

- On December 1, 2016, a significant fire-water line break occurred near the M&EC Process/Storage Area at Bldg. K-1052. Chlorinated fire water, discharged as part of this event, flowed into a radiologically contaminated portion of Bldg. K-1052, as well as a radiologically contaminated portion of Bldg. K-1010 (M&EC Process Area). The K-1010 Process Area had been recently contaminated during the processing of a waste stream containing a significant amount of strontium-90 (90Sr) and was being cleaned. Even though elevated levels of gross beta radiation and 90Sr were detected after the initial spill, the levels of these contaminates had dissipated by the time the follow-up sampling was performed. Therefore, it is believed that no threat to the environment occurred as a result of this spill. No impact to aquatic biota in the K-1007-P1 pond was observed.

- Personnel from EPA Region 4 and the TDEC Knoxville Field Office conducted a RCRA hazardous waste compliance inspection of the Y-12 Complex August 15–17, 2016. The inspections covered 48 waste storage areas and record reviews. The report identified two findings involving a single container of used lamps (light bulbs). The lamps were not dated and labeled as required. These issues were immediately corrected.

- TDEC performed a UST compliance inspection at ORNL in November 2016, and two findings were cited by TDEC as a result of the inspection. Both findings were resolved within 60 days, as required by TDEC.

Pollution Prevention and Site Sustainability

Numerous pollution prevention and sustainability programs across the 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 reduce life-cycle costs of programs and projects and reduce risks to the environment. In 2016, ORR contractors were recognized for excellence in pollution prevention and sustainability programs with multiple awards, which are described in Chapters 3, 4, and 5.

Cleanup Operations in 2016

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

Chapter 1 - Introduction to the Oak Ridge Reservation

The Oak Ridge Reservation (ORR) is a Federally owned 13,547 Hectare (ha) (32,671-acre) site located in Anderson and Roane counties in eastern Tennessee. The 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). A number of other facilities are located on ORR, including the East Tennessee Technology Park (ETTP), site of a former gaseous diffusion plant that is undergoing 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 of the National Nuclear Security Administration (NNSA) Office of Secure Transportation.

The ORR was established in 1942 as part of the Manhattan Project for the purposes of enriching uranium, pioneering methods for producing and separating plutonium, and administering the nationwide World War II effort. ORR missions are continuing 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 xxxi and xxxii is intended to help readers convert numeric values presented here as needed for specific calculations and comparisons. Appendix A contains a glossary of technical terms that may be useful for understanding the terminology used in this report.

1.1 Background

The Oak Ridge Reservation Annual Site Environmental Report (ASER) is prepared annually and presents environmental data to (1) characterize environmental performance, (2) summarize environmental occurrences reported during the year, (3) confirm compliance with environmental standards and requirements, and (4) highlight significant program activities. The report fulfills the requirement contained in DOE O 231.1B, Environment, Safety, and Health Reporting (DOE 2012) that an integrated annual site environmental report be prepared.

The results summarized in this report are based on data collected before and continuing through calendar year 2016. This report is not intended to, nor does it, present the results of all environmental monitoring associated with the ORR. Data collected for other sites 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/or guidance and are referenced here, as appropriate. Environmental monitoring on the ORR consists primarily of two major activities effluent monitoring and environmental surveillance. Effluent monitoring involves the collection and analysis of samples or measurements of solids, 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 and chemicals, and demonstration of compliance with applicable standards and permit requirements. Environmental surveillance consists of direct measurements and collection and analysis of samples taken from the site and its environs exclusive

of effluents; these activities provide information on contaminant concentrations in air, water, groundwater, soil, foods, biota, and other media. Environmental surveillance data support determinations regarding environmental compliance and, when combined with data from effluent monitoring, 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

The ORR area was first occupied by Native Americans more than 10,000 years ago, and members of the Overhill Cherokee tribe still lived in the East Tennessee region when European settlers arrived in the late 1700s. These settlers lived on farms or in four small communities called Elza, Robertsville, Scarborough, and Wheat. All but Elza were founded shortly after the Revolutionary War. In the early 1940s about 1,000 families inhabited the area.

In 1942, the area that was to become the ORR was selected for use in 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. About 3,000 residents received orders to vacate within weeks the homes and farms that their families had occupied for generations. The site's wartime name was "Clinton Engineering Works."

The workers' city, named Oak Ridge, was established on the reservation's northern edge. The city grew to a population of 75,000 and was the fifth largest in Tennessee; however, it was not shown on any map. At the Y-12 Complex south of the residential area, an electromagnetic separation method was used to separate uranium-235 (^{235}U) from natural uranium. A gaseous diffusion plant, later known as 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, was a third facility known as X-10 or Clinton Laboratories where the Graphite Reactor was built. The X-10 facility was a pilot scale facility for the larger plutonium production facilities built at Hanford, Washington. Two years after World War II ended, Oak Ridge was shifted to civilian control under the authority of the US Atomic Energy Commission. In 1959, the city was incorporated and a city manager and city council form of government was adopted by the community.

Since that time, the missions of the three major ORR installations have continued to evolve and operations have adapted to meet the changing defense, energy, and research needs of the United States. Their current missions, as well as the missions of several smaller DOE facilities and activities on the ORR, are described in Section 1.4 of this document.

1.3 Site Description

1.3.1 Location and Population

The ORR lies within the Great Valley of East Tennessee between the Cumberland and Great Smoky Mountains and is bordered by the Clinch River (Fig. 1.1). The Cumberland Mountains are 16 km (10 mi) to the northwest; the Great Smoky Mountains are 51 km (31.6 mi) to the southeast. The ORR encompasses about 13,221 ha (32,671 acres) of mostly contiguous land in Anderson and Roane counties that is owned by the federal government and under the management of DOE (Fig. 1.2). The population of the 10-county region surrounding the ORR is about 1,096,961, and about 2% of its labor force is employed on the ORR. The 2016 US Census population estimate for the official nine-county Knoxville metropolitan statistical area is 857,585. 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 located about 40 km (25 mi) to the east and, as of 2016, had a population of about 186,239. Except for the city of Oak Ridge, the land within 8 km (5 mi) of the 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.

Fig. 1.1. Location of the Oak Ridge Reservation.

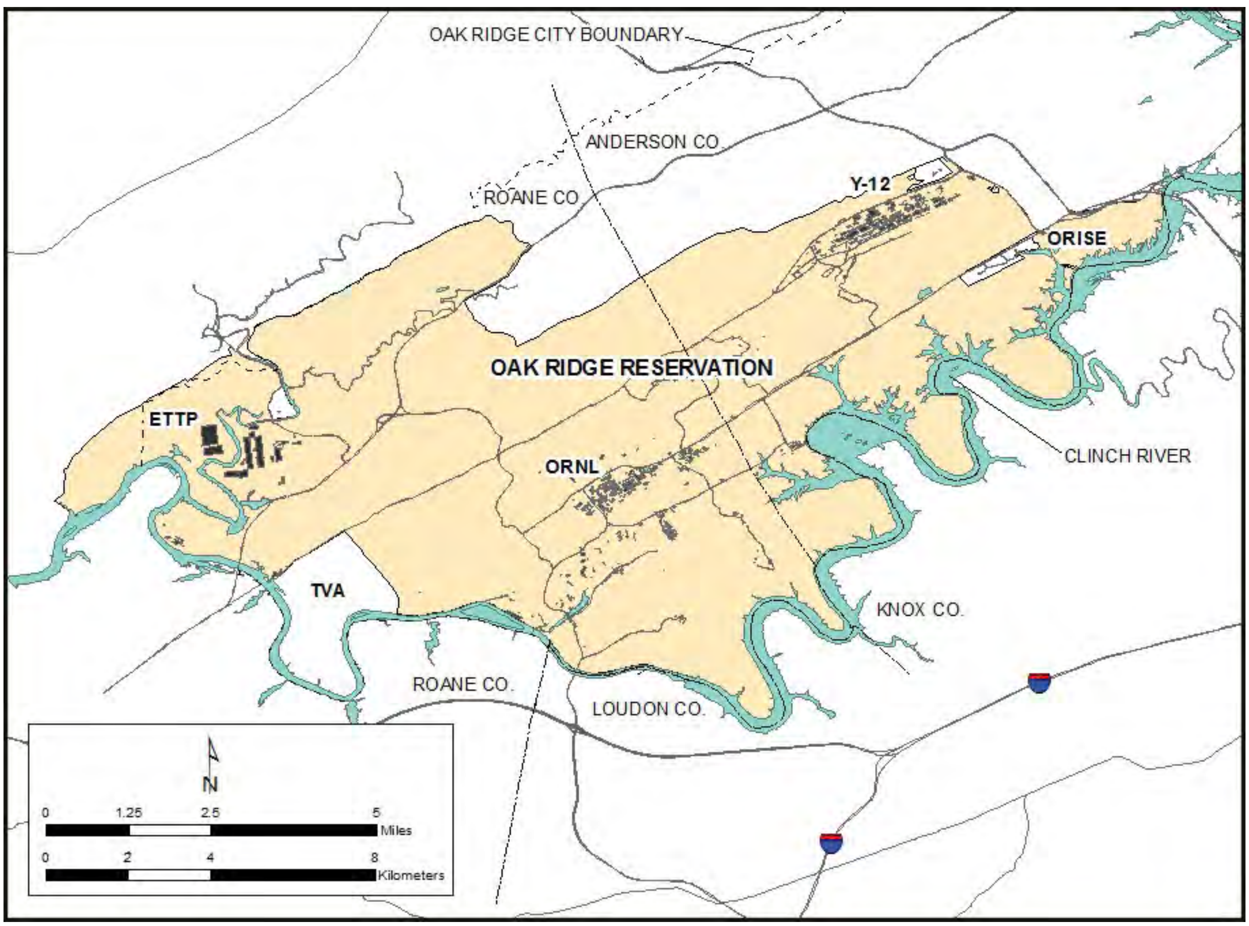

Fig. 1.2. The Oak Ridge Reservation.

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 1986-2016 was 14.7°C (58.5°F). The average temperature for the Oak Ridge area in 2016 was 15.2°C (59.3°F). The coldest month is usually January, when temperatures average about 3.1°C (37.5°F). During 2016, January temperatures were the coldest, averaging 1.3°C (34.4°F). August was the warmest month, with average temperatures of 25.6°C (78.0°F). Monthly summaries of temperature averages, extremes, and 2016 values are provided in Appendix B, Table B.1.

Average annual precipitation in the Oak Ridge area for the 30-year period from 1986 to 2016 was 1,337.5 mm (52.64 in.), including about 21.3 cm (8.4 in.) of snowfall annually (NOAA 2011). Total precipitation during 2016 as measured at meteorological tower (MT)2 was 1075 mm (42.31 in.). Monthly summaries of precipitation averages, extremes, and 2016 values are provided in Appendix B, Table B.1.

In 2016 wind speeds at ORNL Tower C/D (MT2), measured at 15 m (49 ft) above ground level (AGL), averaged 0.94 m/s (2.2 mph). This value remained unchanged for winds at 60 m (198 ft) AGL. 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 2016 precipitation hours for the ORR towers may be reviewed at http://metweb.ornl.gov/page7.htm under the header "2016 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 the 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 at https://www.ornl.gov/content/wind-regimes-complex-terrain-great-valley-eastern-tennessee.

1.3.3 Regional Air Quality

The US Environmental Protection Agency (EPA) Office of Air Quality Planning and Standards has set National Ambient Air Quality Standards (NAAQS) for key principal pollutants, which are called "criteria" pollutants. These pollutants are sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), lead (Pb), ozone (O_3), particulate matter (PM) with an aerodynamic diameter less than or equal to 10 µm (PM_{10}), and fine PM 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, whereas areas that exceed NAAQS for a particular pollutant are classified as nonattainment areas for that pollutant.

The ORR is in Anderson and Roane counties. EPA has designated Anderson, Knox, and Blount counties as a nonattainment area for the $PM_{2.5}$ air quality standard. EPA also designated the portion of Roane County surrounding the Kingston Steam Plant as a nonattainment area for $PM_{2.5}$. 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

The ORR lies within the Valley and Ridge Physiographic Province, which is composed of a series of drainage basins or troughs containing many small streams feeding the Clinch River. Surface water on the ORR drains into a tributary or series of tributaries, streams, or creeks within 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 the ORR. It flows from northeast to southwest, roughly through the center of ETTP, and discharges directly into the Clinch River.

East Fork Poplar Creek (EFPC), which discharges into Poplar Creek east of ETTP, originates within the Y-12 Complex and flows northeast along the south side of the Y-12 Complex. Bear Creek also originates within the Y-12 Complex but 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 (WOC) drainage basin, which has an area of 16.5 km^2 (6.4 mi^2). WOC headwaters originate on Chestnut Ridge, north of ORNL and near the Spallation Neutron Source (SNS) 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, where it forms a confluence with Melton Branch. The headwaters of Melton Branch originate in Melton Valley east of the High Flux Isotope Reactor (HFIR) complex. It has a drainage basin area of about 3.8 km^2 (1.47 mi^2). The waters of WOC enter White Oak Lake, which is an impoundment formed by White Oak Dam (WOD). Water flowing over WOD enters the Clinch River after passing through the WOC embayment area.

1.3.5 Geological Setting

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

Two geologic units on the 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 the 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 form caverns and extensive solution conduit networks under some circumstances. 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 the 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 the 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 those bedrock units. Groundwater availability in such settings is dependent 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

The ORR contains a unique variety of natural, cultural, and historic resources. Ongoing efforts continue to focus on preserving the rich diversity of these resources.

1.3.7 Wetlands

About 243 ha (600 acres) of wetlands have been identified on the ORR; most are classified as forested palustrine, scrub/shrub, and emergent wetlands. Wetlands occur across the ORR at low elevations, primarily in riparian zones of headwater streams and receiving streams and in the Clinch River embayments (Fig. 1.3). Wetlands identified to date range in size from several square meters at small seeps and springs to about 10 ha (25 acres) at White Oak Lake.

In 2016, the fifth and final year of postmitigation monitoring and reporting was completed on compensatory mitigation sites for the ORNL Parking Structure, which was constructed in 2011.The percentage of cover by species was measured for each plot. Information was also taken on any fauna present at the time of the survey. Five years of data, including the data collected during the year of mitigation, have shown excellent overall vegetationcoverage providing good quality habitat. Vegetation growing in the wetland in 2016 included both planted and volunteer plant species. There was a noted increase in black willow, sycamore, and green ash saplings. Climbing hempweed, an invasive species, continues to infiltrate the west end of the wetland; however, the spread is being controlled by the UT-Battelle grounds crew. A good variety of fauna was noted in and around the wetland including birds, frogs, and benthic macroinvertebrates.

Surveys of wetland resources presented in *Identification and Characterization of Wetlands in the Bear Creek Watershed* (Rosensteel and Trettin 1993), *Wetland Survey of the X-10 Bethel Valley and Melton Valley Groundwater Operable Units at Oak Ridge National Laboratory, Oak Ridge, Tennessee* (Rosensteel 1996), and *Wetland Survey of Selected Areas in the Oak Ridge Y-12 Plant Area of Responsibility, Oak Ridge, Tennessee* (Rosensteel 1997) serve as references to support wetland assessments for upcoming projects and activities. In addition, wetland maps have been developed for selected areas of the ORR in response to project-specific requirements. These are also consulted and verified by site inspections when appropriate. See Chapter 5, Section 5.3.12 for additional details.

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 (CWA).

In 2014, as part of the Uranium Processing Facility (UPF) project at the Y-12 Complex, construction was completed on the Bear Creek Road bypass Phase II and a haul road extension modified wetlands on the north side of Bear Creek Road. 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 in 2015 revealed that, in general, the wetlands are responding as intended and have shown remarkable wetland plant coverage in the first year.

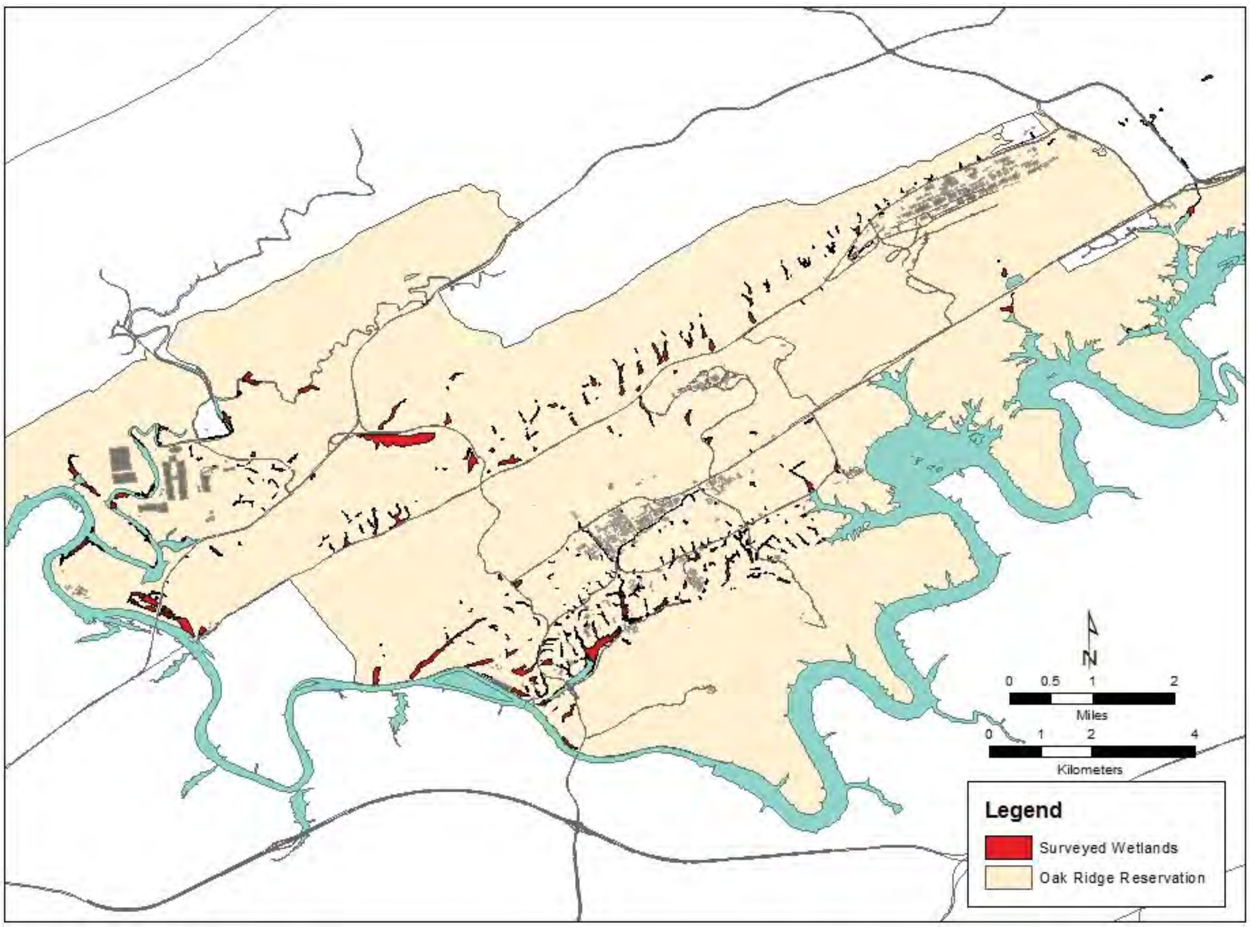

Fig. 1.3. Oak Ridge Reservation wetlands.

1.3.8 Wildlife/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 (e.g., anhinga) have been seen only once or a few times; others (e.g., sharp-shinned hawk and southeastern shrew) are comparatively common and widespread on the reservation.

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		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	
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

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]
	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	Bank swallow			RI
Hirundo rustica	Barn swallow			RI
	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

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 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
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]			
Myotis septentrionalis	Northern long-eared bat	T		
Sorex longirostris	Southeastern shrew		NM	
Sorex cinereus	Masked shrew		NM	
Zapus hudsonius	Meadow jumping mouse		NM	

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

[a] Land and surface waters of the Oak Ridge Reservation (ORR) exclusive of the Clinch River, which borders the ORR.
[b] Status codes
E = endangered
T = threatened
MC = of management concern
NM = in need of management
ORR = Oak Ridge Reservation
RI = regional importance
[c] Partners in Flight (PIF)-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 the ORR. Nevertheless, the only federally listed animal species that have been observed on the ORR in recent years have been mammals. Gray bats were observed over the Clinch River bordering the ORR in 2003 and over a pond on the ORR in 2004. Three gray bats were mist-netted outside a cave on the ORR in 2006. Several gray bats and one Indiana bat were also captured in mist nets bordering the Clinch River in June-July 2013. Northern long-eared bats, recently federally listed as threatened, are known to be present on the 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 the ORR and its boundary waters. These are 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 (EO) 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) strengthens migratory bird conservation on the ORR through enhanced collaboration between DOE and FWS (DOE-FWS 2013). Breeding bird surveys were conducted at 79 points along nine routes on the ORR in 2014 for the Partners in Flight Program. Multiple public nature walks were held on the ORR in 2016, including a bird-specific American Woodcock and Falconry walk. ORR work on early succession habitat was selected to represent DOE in the 2015 Presidential Migratory Bird Federal Stewardship Award nominations. All known ORR bird records since 1950, as well as population trends for 32 species of birds, were documented in the technical manuscript *Oak Ridge Reservation Bird Records and Population Trends* (Roy et al. 2014).

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 the ORR but is currently listed as a potential breeding bird on the ORR (Roy et al. 2014) as its actual breeding status is still uncertain. The bald eagle (Fig. 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 2016. 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.

ORNL 2012-P01070

Fig. 1.4. Bald eagle nest on the Oak Ridge Reservation.
[Source: Jason Richards, ORNL photographer.]

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 only recorded locally on boundary waters of the reservation. Other uncommon birds for the ORR have been recorded in recent years, including several species associated with wetland habitats. The sora, least bittern, and Virginia rail (Fig. 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 a fairly common migrant throughout Tennessee but it is seldom seen on the 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 the 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 (Table 1.1).

ORNL 2015-G00408/chj

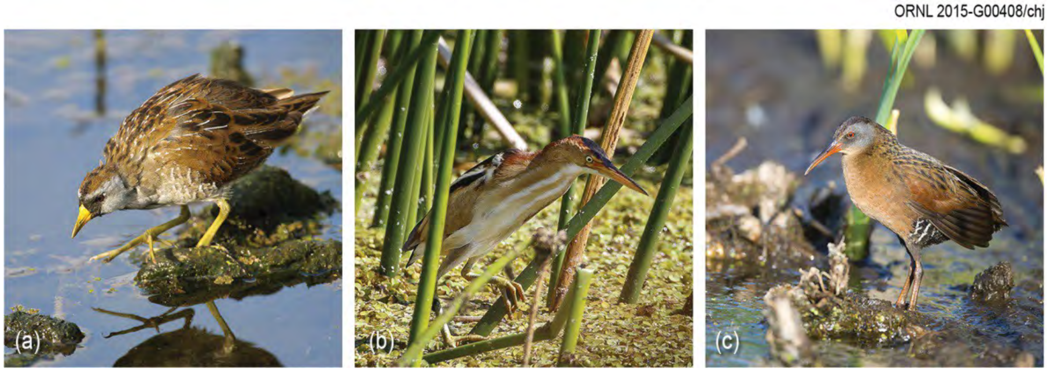

Fig. 1.5. Interesting bird species sighted on the Oak Ridge Reservation in recent years: (a) sora, (b) least bittern, and (c) Virginia rail.
[Source: Stock images courtesy of iStock.]

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 the 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 the 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).

1.3.9 Threatened and Endangered Plants

Four plant species currently known to be on the 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 as "special concern" species by the US Fish and Wildlife Service. (Note Appalachian bugbane is no longer listed by Tennessee and does not have official federal status; therefore, it does not appear in Table 1.2.)

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

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 the ORR by six. The protection of these six species on the 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, 2016

Species	Common name	Habitat on the ORR	Status code[a]
	Currently known to be or previously reported on the 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 the 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 the 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

1.3.10 Historical and Cultural Resources

Efforts continue to preserve the ORR's rich prehistoric and historic cultural resources. Compliance with the National Historic Preservation Act (NHPA) on the ORR is maintained in conjunction with National Environmental Policy Act (NEPA) and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) compliance. Pursuant to the *Programmatic Agreement Among the Department of Energy Oak Ridge Office, The Tennessee State Historic Preservation Officer, and the Advisory Council on Historic Preservation Concerning Management of Historical and Cultural Properties at the Oak Ridge Reservation* a Cultural Resource Management Plan was prepared. The DOE ORR Cultural Resource Management Plan provides a mechanism by which the DOE ORR will comply with cultural resource statutes, address cultural resources in the early process of its undertakings, and implement necessary protective measures for its cultural resources prior to initiating undertakings on the evaluated 254 structures of which forty-one are National Register of Historic Places (NRHP) Eligible Properties and six are included in the NRHP. Please keep the verbiage that state the reservation contains more than 45 known prehistoric sites. ETTP has 135 facilities that were 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 US, as well as numerous facilities that were not eligible for inclusion on the 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. 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. On the Oak Ridge Reservation, the boundaries of the National Park include the X-10 Graphite Reactor, buildings 9731 and 9204-3 at the Y-12 National Security Complex, and the K-25 Building Site at the East Tennessee Technology Park. The Park also includes facilities and lands in Los Alamos, New Mexico and Hanford, Washington.

- X-10 Graphite Reactor - The building has been registered with the National Register of Historic Places since 1966, and has been open for public access in varying fashions since that time. Enhancing access and the visitor experience are part of DOE's objectives moving forward in implementing the National Park.

- Y-12 National Security Complex - Buildings 9731 and 9204-3 were eligible for listing on the National Register of Historic Places, and both are currently unavailable for regular public access. Irregular public access to both facilities has occurred as recently as Nov. 12, 2015, when DOE facilitated public tours to both buildings in celebration of the establishment of the National Park. Enhancing safe access while protecting DOE's mission capabilities is part of DOE's objectives moving forward in implementing the National Park.

- K-25 Building Site - 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 part of 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 at http //www.k-25virtualmuseum.org/.

In addition, 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 (MOA) for the interpretation of historical properties at ETTP was signed in 2012 by DOE Oak Ridge Office (ORO), the State Historic Preservation Officer (SHPO), the Advisory Council on Historic Preservation (ACHP), the City of Oak Ridge, and the East Tennessee Preservation Alliance. The MOA 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. Details are provided in Chapter 3, Sections 3.3.4 and 3.8.2. 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 award 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. An MOA was signed by the US Department of Interior and DOE on November 10, 2016 creating the new Manhattan Project Historic National Park. The K-25 Virtual Museum website (K-25 Virtual Museum 2016) was launched in conjunction with the signing of the MOA.

Two site-wide programmatic agreements among DOE ORO, SHPO, and ACHP 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

1.4.1 Oak Ridge National Laboratory

ORNL, managed for DOE by UT-Battelle, LLC, a partnership of the University of Tennessee and Battelle Memorial Institute, is the largest science and energy national laboratory in the DOE system (Fig. 1.6), 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 SNS and HFIR. ORNL hosts a DOE leadership computing facility, home of the Titan supercomputer; one of DOE's nanoscience centers, the Center for Nanophase Materials Sciences; one of DOE's energy research centers, the BioEnergy Science Center; and a DOE innovation hub, the Consortium for Advanced Simulation of Light-Water Reactors. UT-Battelle also manages the US ITER project for DOE.

ORNL 2011-P02352

Fig. 1.6. The Oak Ridge National Laboratory.

ORNL, formerly called X-10, was established in 1943 to support the Manhattan Project. From an early focus on chemical technology and reactor development, ORNL's research and development (R&D) portfolio broadened to include programs supporting DOE missions in scientific discovery and innovation, clean energy, and nuclear security. Today, the laboratory's extensive capabilities for scientific discovery and innovation are applied to the delivery of mission outcomes for DOE and other sponsors.

The Transuranic Waste Processing Center (TWPC) is located on a tract of land about 10.5 ha (26 acres) in size in the Melton Valley area of ORNL about 120 ft west of the existing Melton Valley Storage Tanks. TWPC is managed by North Wind Solutions, LLC (NWSol) for DOE. TWPC's mission is to receive transuranic (TRU) waste for processing, treatment, repackaging, and shipment to designated facilities for final disposal. Waste that is determined to be non-TRU (e.g., low-level radioactive waste, mixed low-

level waste) is shipped to the Nevada National Security Site (NNSS) or other approved facilities.

DOE remains focused on disposing of a significant inventory of uranium-233 (^{233}U) stored in Building 3019 at ORNL. This special nuclear material requires strict safeguards and security controls to protect against access. The ^{233}U Project's objective is 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 (CEUSP) material. CEUSP 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 (Isotek) 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.

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, TRU waste storage, and operation of the liquid low-level and process waste systems and the off-gas collection and treatment system.

1.4.2 The Y-12 National Security Complex

The original Y-12 Complex was 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 site.

Today, as part of the NNSA Nuclear Security Enterprise, the Y-12 Complex (Fig. 1.7) 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 2015, DOE headquarters approved the Outfall 200 Mercury Treatment Facility (MTF) Conceptual Design Report, as well as plans to proceed with MTF design. The goal of the MTF 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. Mercury from historical operations is present in the Outfall 200 storm water entering Poplar Creek. Also in 2015, eight pre-design studies to evaluate storm water chemistry, optimal treatment parameters, potential water diversion strategies, storm impacts on mercury levels, and other parameters were completed to provide information to support MTF siting and design.

In support of mercury clean-up efforts, research and technology development activities focused on the major factors influencing the accumulation of mercury in fish (fish are the major route of both human and wildlife exposure). Three lines of investigation for East Fork Poplar Creek were developed to (1) examine potential downstream sources, such as bank soil and sediment control, (2) study the ecology and how differences in food chain processes may influence the uptake of mercury in fish, and (3) investigate the water chemistry and flow characteristics of the creek and its influence.

The MTF is being designed to treat up to 3,000 gallons of storm water per minute and 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 Outfall 200 MTF design incorporates flexibility and expandability of treatment processes for mercury if required in the future.

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. In March 2015, scientists issued a report titled *Mercury Remediation Technology Development for Lower East Fork Poplar Creek* (ORNL/SPR-2014/645). This report offers science-based approaches and ideas for research and technology development activities that may lead to new mercury remediation projects.

Fig. 1.7. Y-12 National Security Complex.

1.4.3 East Tennessee Technology Park

What is now known as ETTP (Fig. 1.8) was originally named the K-25 Site, where the nation's first gaseous diffusion plant for enriching uranium as part of the Manhattan Project was located.

During the Cold War additional uranium enrichment facilities were built adjacent to K-25, 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 (D&D) 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. Restoration of the environment, D&D of facilities, disposition of wastes, and reindustrialization are the major activities at the site. During 2016, ETTP landlord contractor functions and the majority of the ETTP cleanup program actions were managed by UCOR.

During CY 2016, ETTP private initiative projects continue to utilize solar power to generate electricity that is provided to TVA through the City of Oak Ridge. Powerhouse Six is a 1-megawatt solar array on 5 acres of

former DOE land and Brightfield 1 is a 200-kW array located on a 1-acre tract purchased from CROET.

Fig. 1.8. East Tennessee Technology Park.

1.4.4 Environmental Management Waste Management Facility

EMWMF is 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 the 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 (ROD). The facility currently consists of six disposal cells.

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. The leachate is treated at the ORNL Liquids and Gaseous Treatment Facility, which is operated by UCOR.

1.4.5 Oak Ridge Environmental Research Park

In 1980, DOE established the Oak Ridge Environmental Research Park (Fig. 1.9). The research park 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.

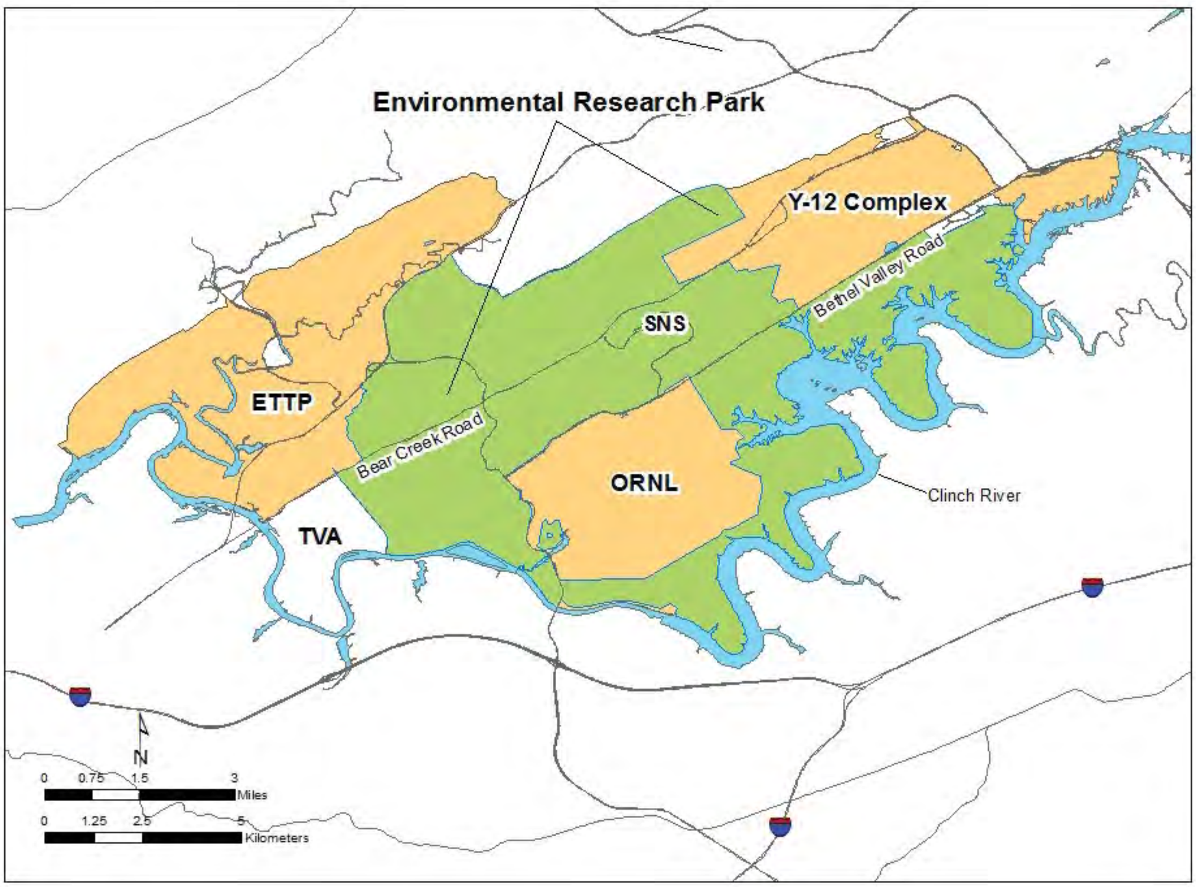

Fig. 1.9. The Oak Ridge Environmental Research Park.

1.4.6 Oak Ridge Institute for Science and Education

ORISE is managed by Oak Ridge Associated Universities (ORAU). ORISE addresses national needs in assessing and analyzing environmental and health effects of radiation, beryllium, and other hazardous

materials; developing and operating medical and national security radiation emergency management and response capabilities; and managing education programs to help ensure a robust supply of scientists, engineers, and technicians to meet future science and technology needs. ORISE creates opportunities for collaboration through partnerships with other DOE facilities, federal agencies, academia, and industry in a manner consistent with DOE objectives and the ORISE mission.

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

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

Since 1947, DOE and its predecessor agencies have moved nuclear weapons, weapons components, special nuclear materials, and other important national security assets by commercial and government transportation modes. 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. Thus, 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 within DOE NNSA responsible for this mission is the Office of Secure Transportation (OST).

The NNSA OST Agent Operations Eastern Command (AOEC) Secure Transportation Center and Training Facility is located on the ORR. NNSA OST AOEC is situated on about 723 ha (1,786 acres) of the ORR and operates under a user permit agreement with DOE ORO. NNSA OST AOEC implements its assigned mission transportation operations, maintains applicable fleet and escort vehicles, and continues extensive training activities for its federal agents.

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Chapter 2 - Compliance Summary and Community Involvement

DOE operations on the ORR are required to be in conformance with environmental standards established by a number of federal and state statutes and regulations, EOs, DOE orders, contract-based standards, and compliance and settlement agreements. Principal among the regulating agencies are EPA and TDEC. These agencies issue permits, review compliance reports, participate in joint monitoring programs, inspect facilities and operations, and oversee compliance with applicable regulations.

When environmental concerns or problems are identified during routine operations or during ongoing self-assessments of compliance status, the issues are discussed with the respective regulatory agencies. The following sections summarize the major environmental statutes and 2016 status for DOE operations on the ORR. Several facilities at ETTP and the Oak Ridge Science and Technology Park sites have been leased to private entities over the past several years through the DOE Reindustrialization Program. 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 xxiv and xxv is intended to help readers convert numeric values presented in this document as needed for specific calculations and comparisons.

2.1 Laws and Regulations

Table 2.1 summarizes the principal environmental standards applicable to DOE activities on the reservation, the 2016 status, and references to the report sections that provide more detailed information.

2.2 External Oversight and Assessments

Inspections of ORR environmental activities conducted by regulatory agencies during 2016 are summarized in Table 2.2. This table does not include internal DOE or DOE contractor assessments, audits, or evaluations.

The State of Tennessee also conducts a program of independent monitoring and oversight of DOE activities on the ORR through the Tennessee Oversight Agreement (TOA). 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 at http://www.tennessee.gov/environment/topic/rem-oak-ridge-reservation-clean-up

Table 2.1 Applicable Environmental Laws/Regulations and 2016 Status		
Regulatory Program Description	**2016 Status**	**Report Section**
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 rad-NESHAPs authorization. Greenhouse gas emissions inventory tracking and reporting are regulated by EPA and DOE internal oversight.	ETTP was in full compliance with CAA regulations and permit conditions in 2016. One CAA regulatory inspection of the asbestos compliance program was performed by TDEC in 2016 at ETTP and no regulatory violations or concerns were noted by TDEC during the inspection. State permit to operate an air contaminant source—internal combustion engine–powered emergency generators and fire water pump amended 11-22-2016. ORNL had no UT-Battelle CAA violations and no Isotek, UCOR, or NWSol CAA violations or exceedances in 2016. All CAA reporting requirements were met at Y-12 during CY 2016, and there were no permit violations or exceedances during the report period.	3.3.5 4.3.3 5.3.3
CERCLA provides a regulatory framework for remediation of the release or threat of release of hazardous substances from past practices on the ORR.	The ORR has been on the EPA NPL since 1989. The ORR FFA, initiated in 1992 among EPA, TDEC, and DOE, establishes the framework and schedule for developing, implementing, and monitoring remedial actions on the 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 the ORR, including ORNL. EMWMF is an engineered landfill that accepts low-level radioactive, hazardous, asbestos, and PCB wastes and combinations of the aforementioned wastes in accordance with specific waste acceptance criteria under an agreement with state and federal regulators. No NOVs were issued for CERCLA- related ORR actions during 2016.	3.3.11 4.3.7 5.3.8

Table 2.1 Applicable Environmental Laws/Regulations and 2016 Status		
Regulatory Program Description	**2016 Status**	**Report Section**
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 NPDES permits issued by TDEC.	During 2016, ORR operations were conducted in compliance with contractual and regulatory environmental requirements, and there were no National Pollutant Discharge Elimination System (NPDES) notice of violations. In 2016, 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 2016 was 100%. In 2016, 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 2016 was greater than 99%. During 2016, the Y-12 Complex continued its excellent record for compliance with the NPDES water discharge permit.	3.3.6 4.3.4 5.3.4
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 GI or LID practices have been implemented on the ORR. The ORNL, Y-12 and ETTP sites sustainability plans, documentation and goals for sustainability projects and indicate the ORR is in compliance with EISA § 438.	4.2.6.8 5.2.1.5
EPCRA, also referred to as SARA Title III, requires reporting emergency planning information, hazardous chemical inventories, and environmental releases of certain toxic chemicals to federal, state, and local authorities.	ETTP had no reportable releases of hazardous substances or extremely hazardous substances, as defined by EPCRA, in 2016. The Y-12 Complex submitted reports in 2016 in accordance with requirements under EPCRA Sections 302, 303, 311, 312, and 313. For 2016, ORNL exceeded the reporting threshold and reported on the otherwise use of nitric acid and the manufacture of nitrate compounds.	3.3.14 4.3.9 5.3.10

Table 2.1 Applicable Environmental Laws/Regulations and 2016 Status		
Regulatory Program Description	**2016 Status**	**Report Section**
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 2016, DOE planning and decision-making activities on the ORR were conducted in accordance with NEPA requirements.	3.3.4 4.3.2 5.3.2
NHPA provides protection for the nation's historic resources by establishing a comprehensive national historic preservation policy.	The ORR has several facilities eligible for inclusion in the NRHP. Proposed activities are reviewed to determine potential adverse effects on these properties, and methods to avoid or minimize harm are identified. During 2016, activities on the ORR were in compliance with NHPA requirements.	1.3.10 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 the ORR is conducted in accordance with 10 CFR 1022 and EO 11990, Protection of Wetlands. About 243 ha (600 acres) of wetlands have been identified on the ORR; most are classified as forested palustrine, scrub/shrub, and emergent wetlands.	1.3.6 4.2.6 5.3.12
RCRA governs the generation, storage, handling, and disposal of hazardous wastes. RCRA also regulates USTs containing petroleum and hazardous substances, universal waste, and recyclable used oil.	The Y-12 Complex, 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. TDEC made a total of four regulatory oversight, assessments, inspections, and site visits at East Tennessee Technology Park, 2016 and no issues or violations were discovered. EPA Region 4 and TDEC conducted inspections of the Y-12 facility and discovered two issues with a container of light bulbs. The container was not labelled or dated and these issues were corrected immediately. TDEC performed a UST compliance inspection at ORNL in November 2016, and two findings were cited by TDEC as a result of the inspection. Both findings were resolved within 60 days, as required by TDEC.	3.3.9 4.3.6 5.3.6

Table 2.1 Applicable Environmental Laws/Regulations and 2016 Status		
Regulatory Program Description	**2016 Status**	**Report Section**
SDWA establishes minimum drinking water standards and monitoring requirements.	The City of Oak Ridge supplies potable water to the facilities on the ORR and is responsible for all SDWA requirements. In 2016, ORNL's water system residual chlorine levels, bacterial constituents, and disinfectant by-products were all within acceptable limits. In 2016, the Y-12 Complex potable water system received a sanitary survey score of 98 out of a possible 100 points and retained its approved status for potable water with TDEC.	3.3.8 4.3.5 5.3.5
TSCA regulates the manufacture, use, and distribution of a number of toxic chemicals.	PCB waste generation, transportation, disposal, and storage at ETTP is regulated under EPA ID number TN0890090004. In 2016, ETTP operated eight 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. Y-12 Complex operations involving TSCA-regulated materials were conducted in accordance with TSCA regulations and ORR PCB FFCA. PCB waste generation, transportation, and storage at ORNL are reported under EPA ID TN1890090003. In 2016, UT-Battelle operated 12 PCB waste storage areas.	3.3.13 4.3.8 5.3.9
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 the ORR year-round.	1.3.6
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.	The ORR is host to several plant and animal species that are categorized as endangered, threatened, or of special concern and that are protected in accordance with this act.	1.3.6
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.	The ORR hosts numerous migratory birds that are protected under this act.	1.3.6

Table 2.1 Applicable Environmental Laws/Regulations and 2016 Status		
Regulatory Program Description	**2016 Status**	**Report Section**
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 2016* summarizes ORR environmental activities during 2016 and characterizes environmental performance.	All Chapters 5.3.9
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 the ORR to ensure compliance with this DOE order.	
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 the ORR have developed SSPs and have implemented EMSs that are incorporated with the contractors' ISMSs to promote sound stewardship practices and to ensure compliance with this DOE order. In 2016, ORR contractors were recognized for excellence in pollution prevention and sustainability programs with multiple awards, which are described in Chapters 3, 4, and 5.	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.	There are no known significant doses from discharges of radioactive constituents from the 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 the ORR during 1 year to no more than 100 mrem. The 2016 maximum ED 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	Chapter 7

Table 2.1 Applicable Environmental Laws/Regulations and 2016 Status		
Regulatory Program Description	**2016 Status**	**Report Section**
EO 13186, Responsibilities of Federal Agencies to Protect Migratory Birds, identifies the responsibilities of federal agencies to promote the conservation of migratory bird populations.	An MOU was entered into by DOE and FWS that meets the requirements under Section 3 of EO 13186. The ORR hosts numerous migratory birds that are present either seasonally or year-round. This MOU, which was updated in September 2013, strengthens migratory bird conservation on the ORR through enhanced collaboration between DOE and FWS.	1.3.8
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.	In 2015, EO 13693, Planning for Federal Sustainability in the Next Decade, superseded EO 13514 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. ORR activities complied with the planning and reporting requirements of these executive orders in 2016.	3.2.4 4.2.3 5.2.1

Acronyms:
ARAR = applicable, relevant, and appropriate requirement
CAA = Clean Air Act
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
CNS = Consolidated Nuclear Security, LLC
CWA = Clean Water Act
DOE = US Department of Energy
EISA = Energy Independence and Security Act
EMS = environmental management system
EMWMF = Environmental Management Waste Management Facility
EO = executive order
EPA = US Environmental Protection Agency
EPCRA = Emergency Planning and Community Right-to-Know Act
ETTP = East Tennessee Technology Park
FFA = Federal Facility Agreement
FFCA = Federal Facilities Compliance Agreement
FWS = US Fish and Wildlife Service
GI = green infrastructure
ISMS = integrated safety management system
LID = low impact development
MOU = memorandum of understanding
NEPA = National Environmental Policy Act
NESHAPs = National Emission Standards for Hazardous Air Pollutants
NHPA = National Historic Preservation Act
NOV = notice of violation
NPDES = National Pollutant Discharge Elimination System
NPL = National Priorities List
NRHP = National Register of Historic Places
ORNL = Oak Ridge National Laboratory
ORR = Oak Ridge Reservation
rad-NESHAPs = National Emission Standards for Hazardous Air Pollutants for radionuclides
RCRA = Resource Conservation and Recovery Act
SARA = Superfund Amendments and Reauthorization Act
SDWA = Safe Drinking Water Act
SP = site sustainability plan
STP = sewage treatment plant
TDEC = Tennessee Department of Environment and Conservation
TSCA = Toxic Substances Control Act
UCOR = URS CH2M Oak Ridge LLC
UST = underground storage tank
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, 2016			
Date	**Reviewer**	**Subject**	**Issues**
ORNL (including UT-Battelle, LLC; UCOR; Isotek; and NWSol activities)			
March 7	COR	CFTF Wastewater Inspection	0
April 12-13	TDEC	Annual RCRA Inspection for ORNL (including TWPC)	0
April 12	COR	CFTF Wastewater Monitoring	0
September 7	COR	CFTF Wastewater Inspection	0
October 24	TDEC	Annual CAA Inspection for ORNL and CFTF	0
November 17	TDEC	UST Compliance Inspection	2
ETTP			
March 7	TDEC	Annual RCRA Compliance Inspection	0
August 2	TDEC	RCRA Facility Closure Inspection	0
August 24-25	TDEC	Asbestos Accreditation Inspection	0
December 7	TDEC	RCRA Facility Closure Inspection	0
December 14	TDEC	Underground Storage Tank Inspection	0

Table 2.2. Summary of regulatory environmental evaluations, audits, inspections, and assessments conducted at Oak Ridge Reservation, 2016

Date	Reviewer	Subject	Issues
Y-12 Complex			
February 23	TDEC	Biennial Survey of Potable Water System	1
March 29	COR	Semiannual Industrial Pretreatment Compliance Inspection	0
August 15-17	EPA/TDECCOR	Annual RCRA Hazardous Waste Compliance Inspection	2
August 30	COR	Semiannual Industrial Pretreatment Compliance Inspection	0

Acronyms:
CAA = Clean Air Act
CFTF = Carbon Fiber Technology Facility
COR = City of Oak Ridge
D&D = decontamination and decommissioning
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
TNHW = Tennessee Hazardous Waste Permit
TWPC = Transuranic Waste Processing Center
UCOR = URS CH2M Oak Ridge LLC
NWSol = North Wind Solutions, 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 (RQ) for hazardous substance releases. Any hazardous substance release exceeding an RQ 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]).

2.4 Notices of Violations and Penalties

Environmental NOVs, penalties, or consent orders were not reported on the reservation during 2016 except the NOVs for USTs listed in Table 2.1

2.5 Community Involvement

Many community involvement activities were provided by and/or supported by the DOE and its contractors in 2016 across a diverse range of subjects and activities. These included, but were not limited to, ETTP historic interpretation efforts, Manhattan Project National Historical Park public meetings and engagement, 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 2016 organizations such as Great Smoky Mountains National Park, the East Tennessee Foundation, Oak Ridge Associated Universities Science Bowl, America Recycles Day activities, and local charities benefited from DOE and its contractors' efforts.

2.5.1 Public Comments Solicited

To keep the public informed of comment periods and other matters related to cleanup activities on the ORR, DOE publishes online notices (http://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 (EM) Program. The board was formed in 1995 and is composed of up to 22 members chosen to reflect the diversity of gender, race, occupation, views, and interests of persons living near the DOE ORR. Members are appointed by DOE and serve on a voluntary basis without compensation.

Information on recommendations the board has made since its establishment, minutes of board and committee meetings, and other information are available on the ORSSAB website at http://www.energy.gov/ORSSAB.

Videos of the first hour of recent board meetings are posted on YouTube at http://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, 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
- DOE ORO Public Information Line: 1-800-382-6938
- 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.ettpreuse.com/default.htm
- ORNL: https://www.ornl.gov/
- ORSSAB: http://www.energy.gov/ORSSAB
- TDEC: http://www.tennessee.gov/environment/
- TDEC, DOE Oversight Division: http://www.tn.gov/environment/section/rem-remediation/energy-oversight.shtml
- Y-12 National Security Complex: http://www.y12.doe.gov/

2.6 References

DOE 2016. *2016 Strategic Sustainability Performance Plan*. US Department of Energy, Washington, DC

Chapter 3 - East Tennessee Technology Park

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 and restoration operations, and the name was changed to the "East Tennessee Technology Park."

Environmental management and remediation operations consist of operations such as waste management, the cleanup of outdoor storage and disposal areas, the demolition and/or 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 underused 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 2016, there was 100% compliance with permit standards for emissions/discharges from ETTP operations.

On November 10, 2015, the US Department of Energy (DOE) and the US Department of Interior signed a memorandum of agreement (MOA) establishing the Manhattan Project National Historic 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 Building 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 through narrative and photographs and can be found at http://www.k-25virtualmuseum.org/.

3.1 Description of Site and Operations

Construction of the K-25 Site (Fig. 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.

Fig. 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 East Tennessee Technology Park (ETTP) site areas before the start of decontamination and decommissioning (D&D) activities. In 1996, the K-25 Site was renamed the "East Tennessee Technology Park" to reflect its new mission. Figure 3.3 shows the ETTP areas designated for D&D activities through 2016.

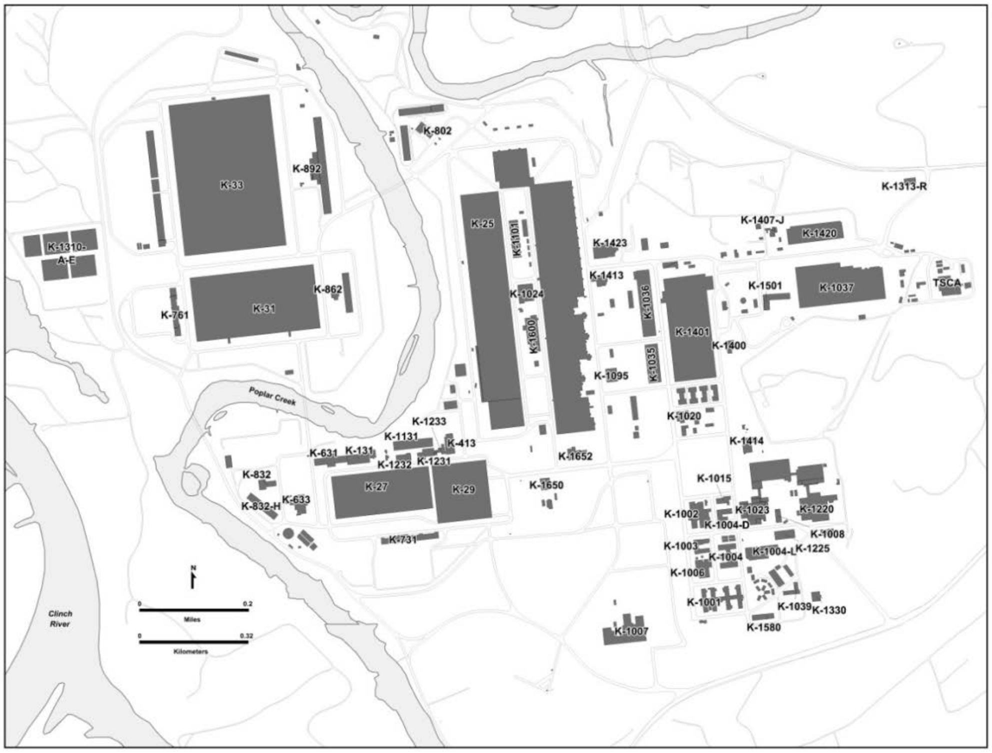


Fig. 3.2. East Tennessee Technology Park before the start of decontamination and decommissioning activities in 1991.

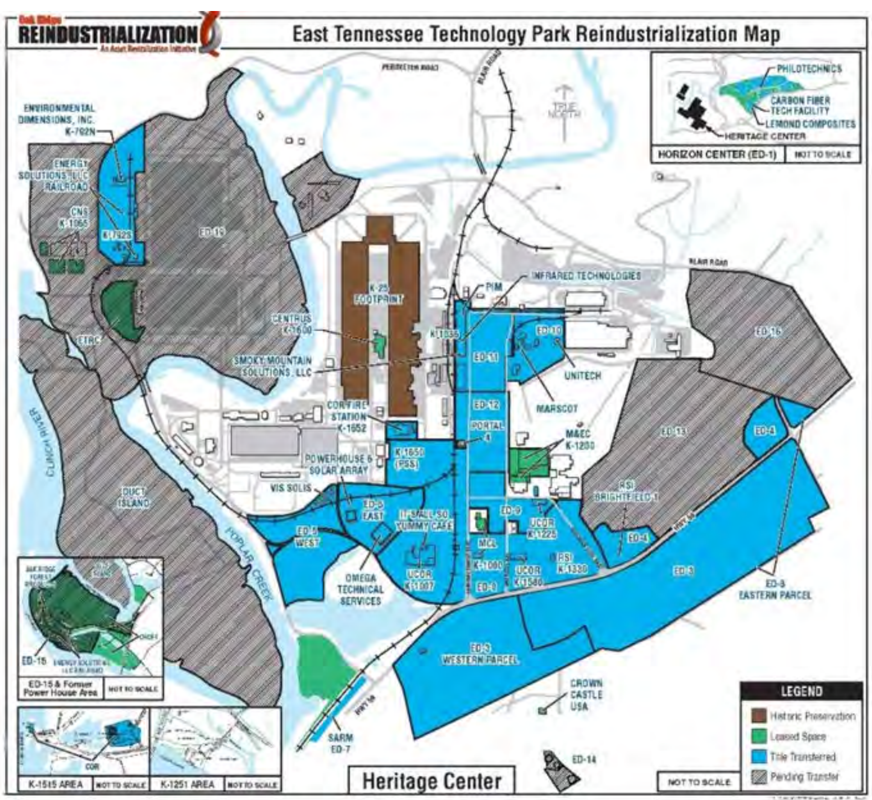


Fig. 3.3. East Tennessee Technology Park in 2016, showing progress in reindustrialization.

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 private 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.

URS | CH2M Oak Ridge LLC (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 Environmental Management (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 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 2016, UCOR received "green scores" for EMS performance. As an example, Fig. 3.4 presents information on UCOR's 2016 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 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 (CRTs and 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 2016 from the Green Electronics Council for its use of Electronic Product Environmental Assessment Tool (EPEAT) methods. 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.

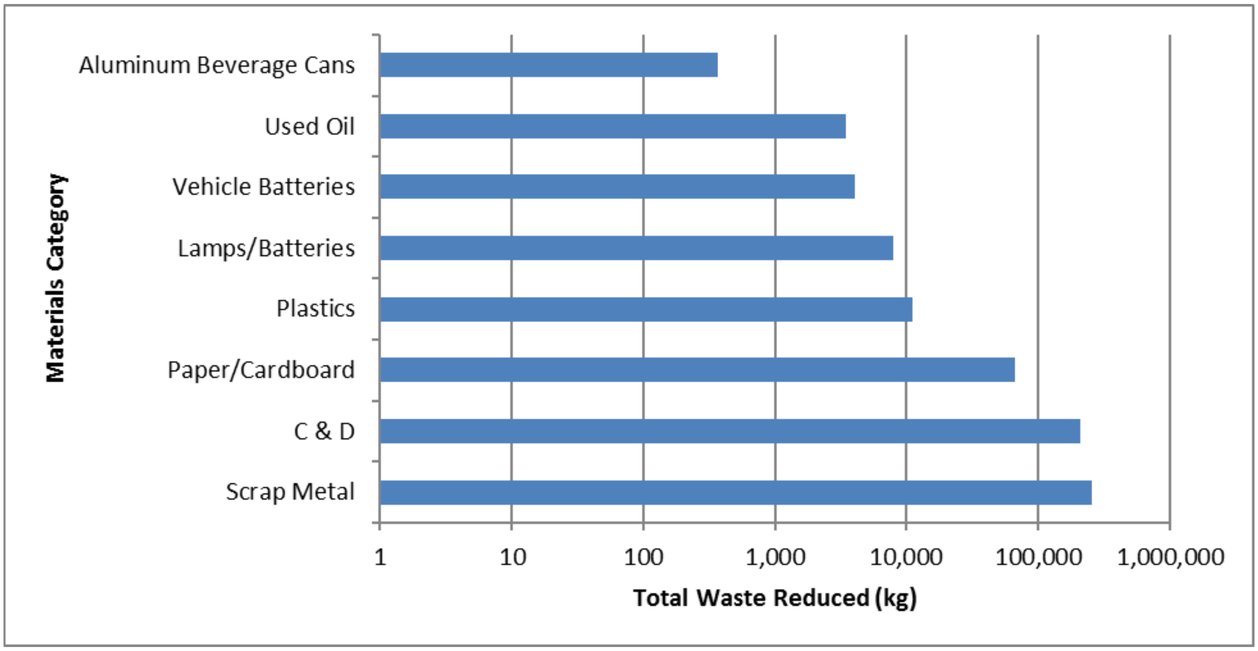


Fig. 3.4. Pollution prevention recycling activities related to solid waste reduction at East Tennessee Technology Park in Calendar Year 2016.

Additionally, UCOR internally recognized six projects for their pollution prevention/waste minimization (P2/WMin) accomplishments in 2016. ETTP also strives to continually 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 US Environmental Protection Agency (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 2016, UCOR worked with EPA and the Tennessee Department of Environment and Conservation (TDEC) to develop a 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 361,776 lb [164 metric tons [MT]) of scrap metal to be recycled in fiscal year (FY) 2016 in lieu of land disposal and provides a path forward for additional waste diversion for the duration of the contract.

Some of the scrap metal that has been screened for recycling is listed below:

- The ETTP power transmission and distribution systems and associated equipment/components, including electrical wire, cable, conductors, service equipment, lighting housing, metal conduit, switches, grounding equipment and associated bolts, nuts, clamps, etc. Legacy, nonenergized electrical power transmission and distribution system and associated equipment and components are considered industrial process equipment and constitute bulk metal that is ubiquitous at the site. This resulted in approximately 43,000 lb (19.5 MT) of scrap metal that was recycled.
- The K-1234 propane storage tank, a 30,000-gal metal storage tank, was purged with nitrogen, disconnected from the distribution lines, and taken out of service. A total of 51,750 lb (23.47 MT) was recycled by an offsite vendor as scrap metal.
- Numerous items at the Molten Salt Reactor Experiment (MSRE) Building 7505 at ORNL, consisting of large salt transfer casks, salt transfer cans, salt can transportation cages and heat exchanger covers deemed excess, and unused equipment with an estimated weight of 250,000 lb (114 MT). The material is stainless steel, lead, and carbon steel. The material, which consisted of equipment that was never used or placed in a radiological area, was recycled.
- Approximately 7,500 lb (3.4 MT) of scrap metal from the 6556 Trailer Complex at ORNL consisting of piping, conduit and sheet metal from roofing over walkways and utility disconnects to the trailers. The material, which had never been in a radiological area, was screened and recycled.
- A total of 9,526 lb (4.32 MT) of scrap metal located in Building 7503 at ORNL. It consisted of a stainless steel tool pig that was built for use during the uranium deposit removal project at the MSRE but never used and never put into a radiological area of any kind. It was recycled.

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

- Provides funds from the recycling payments that can support the Oak Ridge cleanup program. Receipts from these shipments resulted in approximately $18,000 that was available to go back into the program.
- Conserves valuable landfill space. In total, the scrap metal recycled from these five shipments saved over 200 yd^3 of valuable landfill space at an estimated cost savings of approximately $43,000, which takes into consideration capital cost, landfill capacity, historical operating costs, packing, and transportation.
- Supports EPA, TDEC, and DOE programmatic environmental stewardship goals for waste diversion.

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

In the area of alternative energy, Restoration Services, Inc. (RSI), in concert with UCOR, continued operation of ETTP's first solar farm on the east end of the plant property. Brightfield 1 (Fig. 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.

Fig. 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 (CORED) 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% more than projected, with no downtime due to maintenance issues. In Calendar Year (CY) 2016, Brightfield 1 produced 256,060 kWh of energy.

In addition, through the cooperative efforts of DOE, UCOR, RSI, Vis Solis, Inc., CROET, and the 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 the 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 14001:2004, Section 4.5.3, "Nonconformity, Corrective Action, and Preventive Action" (ISO 2004).

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 incorporating environmental protection and the elements of an enabling EMS into the daily conduct of business; fostering a spirit of cooperation with federal, state, and local regulatory agencies; and 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 biobased 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 of 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 into 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 more 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. Some recent examples include:

- The UCOR IT organization implemented:
  - A Xerox contract that increased EPEAT-certified imaging equipment from 10% to 100%, reduced the number of onsite devices from 180 to 140 machines, and resulted in $130,000 of savings and $556,000 over the term of the contract.
  - A digital signature program for all UCOR documents using the Homeland Security Presidential Directive-12 (HSPD-12) badges that meets standards for authentication and can save thousands of dollars in paper savings.
- The UCOR CERCLA Decision Document Group and EC&P negotiating with regulators a screening process that allowed 361,776 lb of uncontaminated scrap metal to be recycled, with more expected.
- The UCOR Finance and Accounting organization migrated transactions from paper to electronic, saving 100,000 sheets of paper and $1,500 in expenses per year.
- The UCOR D&D organization along with the Power Integration Group, Supply Chain Management, and Reindustrialization:
  - Rerouted K-27 roof drains during D&D activities that avoided treating 5 million gallons of water and saved $203,000.
  - Transferred five racks of Dielecktrol® capacitor units to a local municipality for reuse, saving landfill space and $4,200 in avoided disposal costs.

- The Nuclear and High Hazard Organization (N&HHO):
  - Excessed $459,000 of unneeded materials.
  - Disposed of contaminated B-25 boxes as waste containers, saving $12,000.
  - Transitioned paper logs to electronic logbooks, saving $8,900 over the next 5 years.
- The UCOR Property Management and Shipping and Receiving organizations:
  - Recycled 400 ink cartridges and 90 new ink cartridges, saving valuable landfill space and $400 in cost avoidance.

Total savings associated with these projects were in excess of $1.2M and in many cases, valuable landfill space and virgin materials were conserved. The internal awards will be evaluated for possible 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, 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., ASER and the annual cleanup progress report (UCOR 2015a)]. 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, permit review public meetings, and CERCLA decision document public meetings]. 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 2017, UCOR-4127/R5). The EMS program is audited by a third party triennially by EO 13423, *Strengthening Federal Environmental, Energy, and Transportation Management* (CEQ 2007), for conformance to the ISO 14001:2004 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 2016, ETTP operations were conducted in compliance with contractual and regulatory environmental requirements, and there were no National Pollutant Discharge Elimination System (NPDES) permits or 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 (ER)-related activities in 2016.

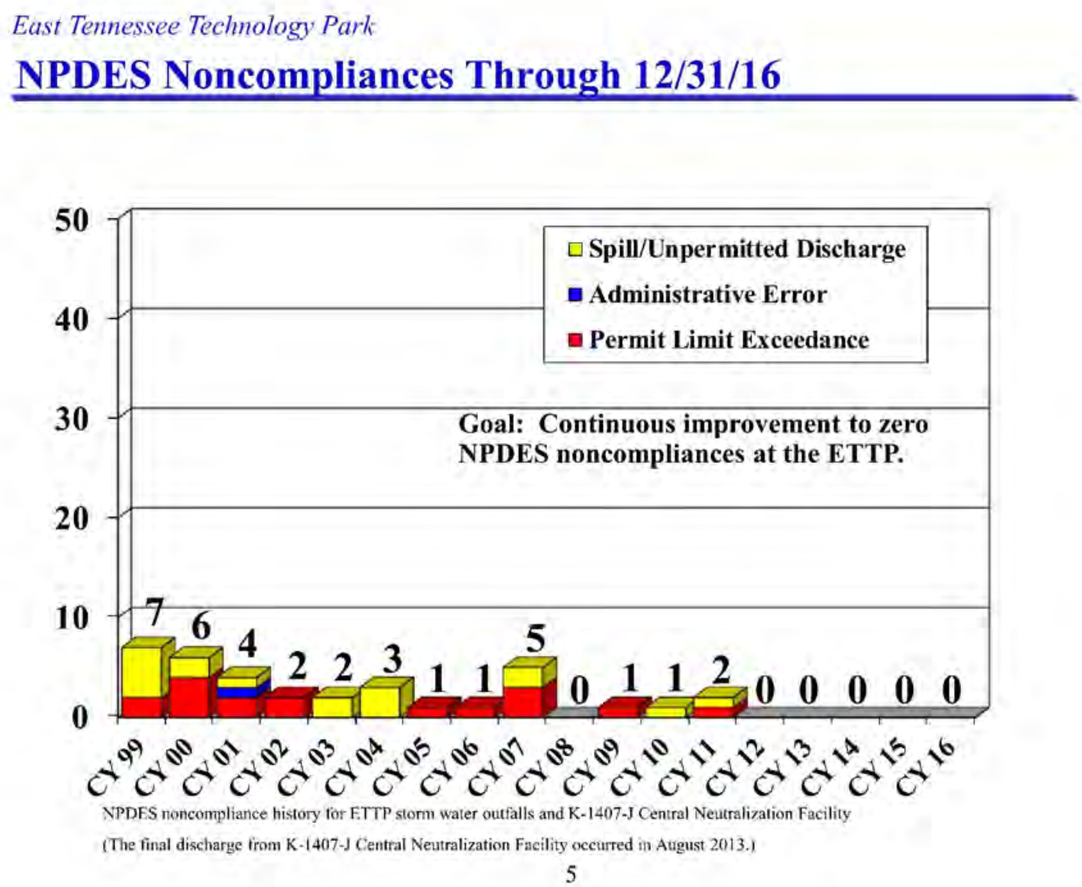


Fig. 3.6. East Tennessee Technology Park (ETTP) National Pollutant Discharge Elimination System (NPDES) permit compliance since 1999.

3.3.1 Environmental Permits

Table 3.1 contains a list of environmental permits that were in effect at ETTP in 2016.

3.3.2 Notices of Violation and Penalties

ETTP received no environmental violations in 2016.

3.3.3 Audits and Oversight

Table 3.2 presents a summary of environmental audits and oversight visits conducted at ETTP in 2016.

One CAA regulatory inspection was performed in 2016. An unannounced inspection of the UCOR asbestos compliance program was performed by TDEC Division of Solid Waste Management on August 24 and 25, 2016. The focus of the inspection was compliance with the applicable recordkeeping requirements. No regulatory violations or concerns were noted by TDEC during the inspection.

Table 3.1. East Tennessee Technology Park environmental permits, 2016

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	2-01-15	3-31-2020	DOE	UCOR	UCOR
CWA	State operating permit—waste transportation project; Blair Road and Portal 6 sewage pump and haul permit	SOP-05068	07-01-14	02-28-2019	DOE	TFE	TFE
CWA	State operating permit—ETTP holding tank/haul system for domestic wastewater	SOP-99033	07-01-15	06-30-2020	UCOR	UCOR	UCOR
UST	Authorized/certified USTs at K-1414 Garage	Customer ID 30166 Facility ID 073008	03-20-89	Ongoing	DOE	UCOR	UCOR
RCRA	ETTP container storage and treatment units	TNHW-165	09-15-15	09-15-2025	DOE	UCOR	UCOR
RCRA	Hazardous waste corrective action document (encompasses entire ORR)	TNHW-164	09-15-15	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, 2016

Date	Reviewer	Subject	Issues
March 7	TDEC	Annual RCRA Compliance Inspection	0
August 2	TDEC	RCRA Facility Closure Inspection	0
August 24-25	TDEC	Asbestos Accreditation Inspection	0
December 7	TDEC	RCRA Facility Closure Inspection	0
December 14	TDEC	Underground Storage Tank Inspection	0

RCRA = Resource Conservation and Recovery Act
TDEC = Tennessee Department of Environment & 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 2016, 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 to 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, facilities 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 Oak Ridge Reservation (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 2016, 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 US, 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 a Memorandum of Agreement (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 Historical Park to commemorate the history of the Manhattan Project. 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 Historic National Park* was signed by the US Department of Interior and DOE on November 10, 2015 (DOE 2015d,), creating the new Manhattan Project Historic National 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 will be completed and sent to the consulting parties for review in 2017.

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 2016. The ETTP ambient air monitoring program, permitted source operations tracking, and record keeping provided documentation fully supporting a 100% 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 2016, ETTP discharged to the waters of the state of Tennessee under the individual NPDES permit TN0002950, which regulates storm water discharges.

3.3.7 National Pollutant Discharge Elimination System Permit Noncompliances

In 2016, 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 2016 was 100%.

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 DOE 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 2016, 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 Resource Conservation and Recovery Act (RCRA) Part B Permit TNHW-165. Hazardous waste may be treated and stored at permitted locations in Building K-1423 and 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 CERCLA areas of concern and solid waste management units was also reissued on September 15, 2015, as a replacement for TNHW-121.

In CY 2016, ETTP prepared and submitted to the TDEC Division of Solid Waste Management the CY 2015 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 Part 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 2016, operations of 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.

3.3.12 East Tennessee Technology Park RCRA-CERCLA Coordination

The *Federal Facility Agreement for the Oak Ridge Reservation* (FFA, DOE 2015a, 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 Part 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 2016, ETTP operated eight 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 2016, 3 of the 8 PCB waste storage areas went through RCRA closure and were closed in September 2016, with 5 remaining open at the end of the year. 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 nonelectrical 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 remain 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 calendar year. The PCBADL documents such things as container inventory, shipments, and PCB spills at the facility. Authorized representatives of EPA may inspect the PCBADL at the facility where they are maintained during normal business hours. The PCBADL must be maintained 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 require 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, and the state emergency response commission, and the local fire department. ETTP complied with these requirements in 2016 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 2016.

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 2016, 12 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, 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)

Section 313 requires facilities to complete and submit a toxic chemical release inventory (TRI) form (Form R) annually. Form R must be submitted for each TRI chemical that is manufactured, processed, or otherwise used in quantities above the applicable threshold quantity. The reports address releases of certain toxic chemicals to air, water, land, and waste management, recycling, and P2 activities. Threshold determinations and reports for each of the ORR facilities are made separately. Operations involving TRI chemicals were compared with regulatory thresholds to determine which chemicals exceeded the reporting thresholds based on amounts manufactured, processed, or otherwise used at each facility. After threshold determinations were made, releases and off-site transfers were calculated for each chemical that exceeded the threshold quantity. In 2016, 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 2016, 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 issued an operating permit (069346P) covering six RICE units on March 3, 2015. The permit covered four RICE emergency generators and two RICE emergency firewater booster pumps. Three generators are diesel fueled and one is natural gas fueled. The two booster pumps are diesel fueled. During this reporting period one of the booster pumps was permanently removed from service. A request for an administrative amendment of the operating permit was submitted to TDEC. The operating permit as amended on November 22, 2016, covers the five remaining RICE through October 1, 2024.

Compliance for all units is demonstrated by following specified maintenance schedules, limiting hours of operations for non-emergencies 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 (ACMs) are fully compliant with 40 CFR 61, Subpart M. This includes using approved engineering controls and work practices, inspections, and monitoring for proper removal and waste disposal of ACMs. ETTP has numerous buildings and equipment that contain ACMs. Major demolition activities during 2016 involved the abatement of significant quantities of ACMs that were subject to the requirements of 40 CFR 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 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 2016, four Notification of Demolition and/or Asbestos Renovation submittals to TDEC were submitted for non-CERCLA ETTP activities. Three notices involved both asbestos abatement and demolition, and the fourth was for demolition only. 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 2016, 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 ACMs occurred at ETTP during 2016.

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.

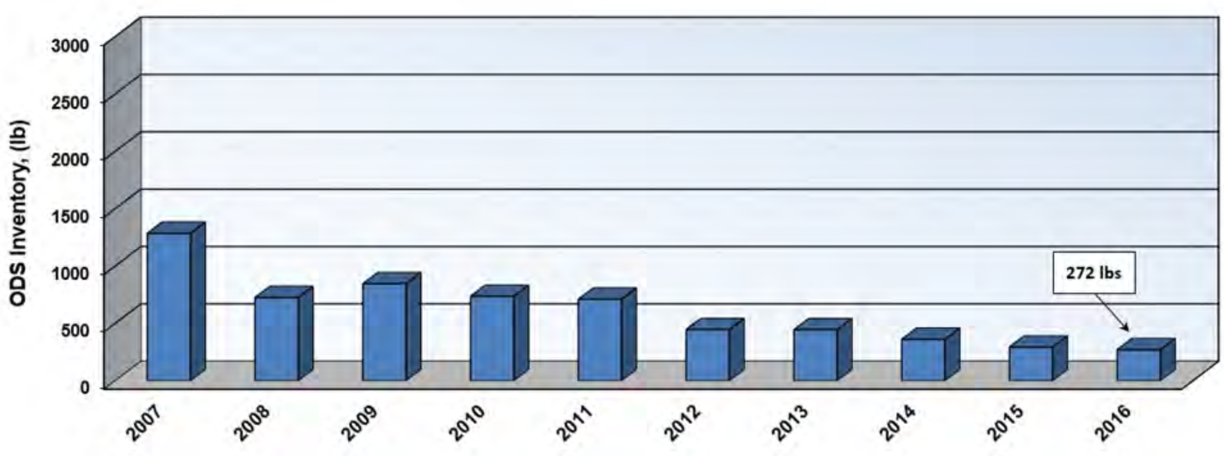


Fig. 3.7. East Tennessee Technology Park total on-site ozone-depleting substances inventory, 10-year history.

3.5.1.2 Fugitive Particulate Emissions

ETTP has been the location of major building demolition activities 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, 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 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 2016—the K-1407 Chromium Water Treatment System (CWTS) Volatile Organic Compound (VOC) Air Stripper and K-2500-H Segmentation Shops B, C, and D—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. Figure 3.8 provides a historical dose trend for the most impacted onsite member of the public if they were located at the sampling locations. During 2016, there was a small dose increase that was coincidental to the demolition and debris removal of the last gaseous diffusion building. The highest annual dose impact as measured at the ambient air station K12 was only 0.07 mrem. The major dose contributor at K12 was ^{99}Tc. The results are based on actual ambient air sampling in a location conservatively representative of the onsite location.

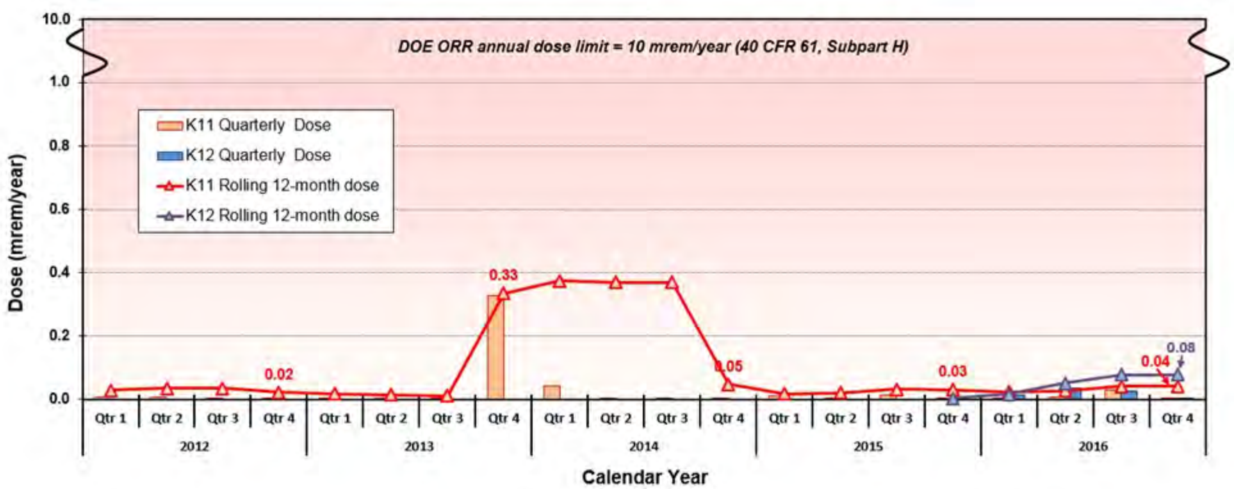


Fig. 3.8. East Tennessee Technology Park Ambient Air stations K11 and K12 radionuclide monitoring results: 5-year rolling 12-month dose history up through 2016. *(DOE = US Department of Energy and ORR = Oak Ridge Reservation)*

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 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 2005a).

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 or more of GHGs per year, reported as metric tons of CO_2 equivalent (CO_2e) 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 2016 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 2016, 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 2016 of ETTP total GHG stationary emissions. For the 2016 CY, GHG emissions totaled only 107 MT, which is less than 1% of the 25,000 MT per year threshold for reporting.

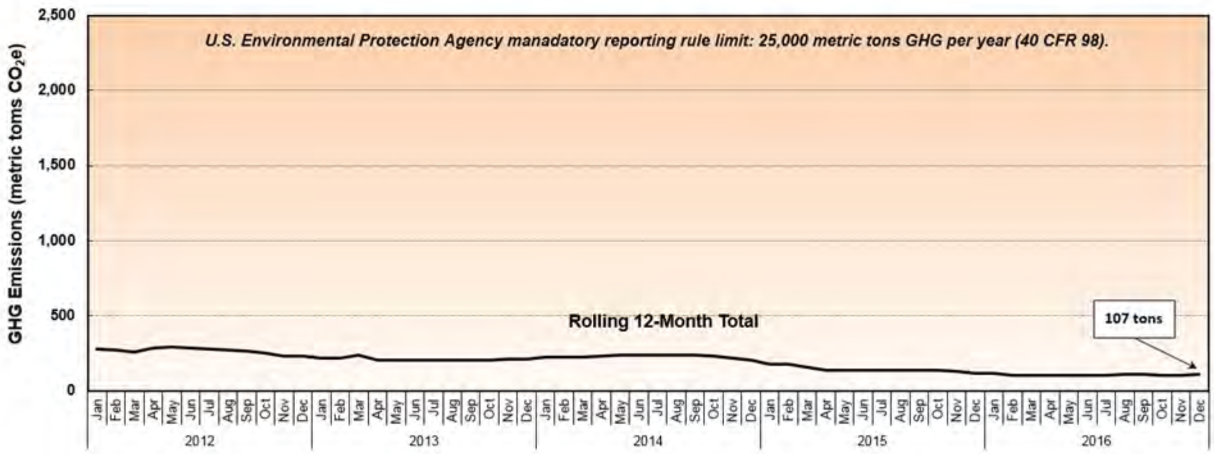


Fig. 3.9. East Tennessee Technology Park stationary source greenhouse gas (GHG) emissions tracking history. *(in carbon dioxide equivalent [CO2e]; CFR = Code of Federal Regulations)*

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%, 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% 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 by UCOR. The landfills are not part of the contiguous ETTP site; however, DOE requested that UCOR 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 28% total Scope 1 and 2 GHG emissions reduction target by FY 2020 and the 40% goal by FY 2025.

With respect to EO 13514, emissions for FY 2016 Scope 1 and 2 including the landfills totaled 19,138 MT CO_2e, roughly 49% below the FY 2020 target level of 37,478 MT CO_2e and a 63% reduction to date compared to the FY 2008 baseline year level of 52,053 MT. When compared to the EO 13693 target, FY 2016 data show that the targeted 40% reduction has already been achieved by comparing the FY 2016 total of 19,138 MT to the 40% target level of 31,232 MT.

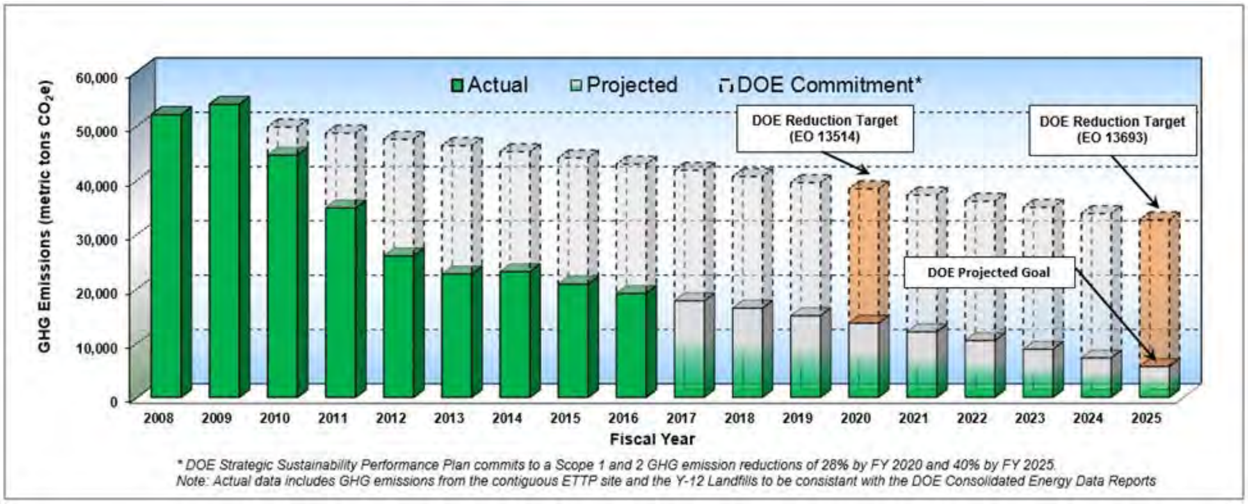


Fig. 3.10. East Tennessee Technology Park (ETTP) greenhouse gas (GHG) emissions trend and targeted reduction commitment. *(in metric tons carbon dioxide equivalent [CO2e])*

Figure 3.11 shows the relative distribution and amounts of all ETTP FY 2016 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 2016 was 24,252 tons, as compared to the 25,884 tons (originally reported as 25,867 tons, but revised after publication to 25,884 tons when additional data became available) for FY 2015.

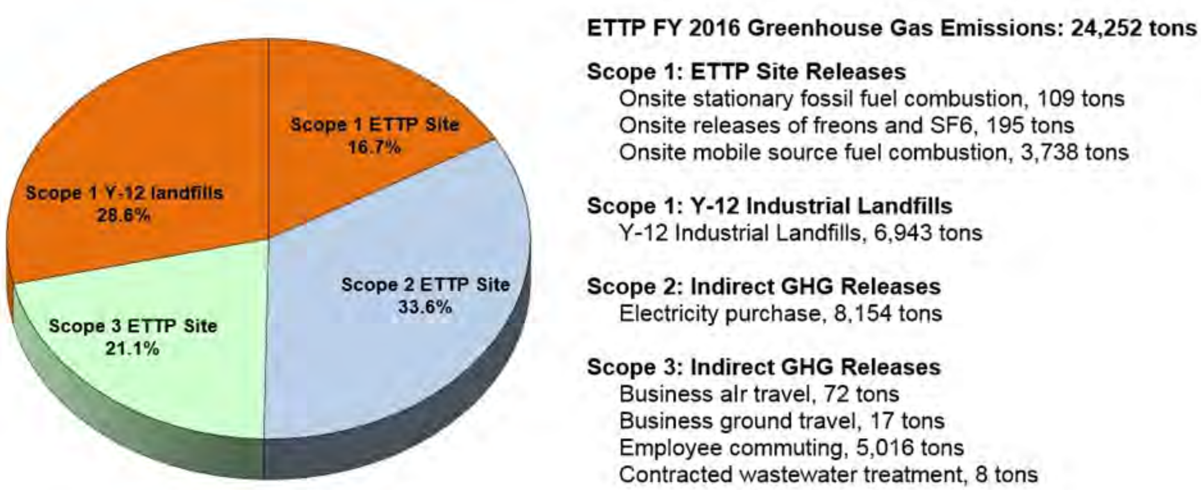


Fig. 3.11. FY 2016 East Tennessee Technology Park (ETTP) greenhouse gas (GHG) emissions by scope, as defined in Executive Order 13514. (Y-12 = Y-12 National Security Complex and SF6 = sulfur hexafluoride)

3.5.1.6 Source-Specific Criteria Pollutants

ETTP operations included one functioning minor stationary source with a potential to emit any form of criteria air pollutant in the CWTS. 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 2016 for CWTS were only 0.011 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 permitting for existing and new stationary emergency generators powered by reciprocating internal combustion engines (i.e., emergency or e-RICE). Compliance actions specified by these amendments do not apply to e-RICE covered under CERCLA projects. TDEC originally issued an amended construction permit for six onsite units with an effective date of August 22, 2013. TDEC issued an operating permit for the six e-RICE units with an effective date of March 3, 2015. 2016 operations included four emergency generator engines (K-1007, K-1039, K-1095, and K-1652), and the remaining two units were fire water booster pump engines (K-802 and K-1310-RW). K-802 was permanently removed from service during 2016. A request to amend the operating permit was submitted to TDEC that requested removing the K-802 unit. 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 runtimes 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 3.3 provides the number of hours of operations for each unit, up through December 31, 2016.

Table 3.3. East Tennessee Technology Park UCOR emergency reciprocating internal combustion engine air permit compliance demonstration, 2016

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-802[a]	1.5	2.1	3.6	0.0
K-1007	6.4	17.2	23.6	11.5
K-1039	5.5	11.8	17.3	14.8
K-1095	6.9	0.1	7.0	1.4
K-1310-RW	4.0	20.8	24.8	0.9
K-1407[b]	3.5	9.6	13.1	12.0
K-1652	6.5	0.7	7.2	5.6

[a]K-802 fire water booster pump unit permanently removed from service on April 15, 2016. Removed from permit effective November 22, 2016.

[b]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, Sect. 112(r), "Prevention of Accidental Releases." The results of this review indicated that all RMP-listed chemicals were less than 1% 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 of air contaminant emissions from ETTP operations on ambient air quality.

The sampling stations in the ETTP area are designated as base, supplemental, or ORR perimeter air monitoring (PAM) stations. Figure 3.12 shows the locations of all ambient air sampling stations in and around ETTP that were active during the 2016 reporting period. Figure 3.13 shows an example of a typical ETTP air monitoring station.

The base program consists of two locations using high-volume, ambient air samplers. Supplemental locations are typically temporary, project-specific stations. Historically, the project-specific samplers are the same high-volume systems used for the base program. All base, supplemental, and PAM samplers operate continuously with exposed filters collected weekly. The radiological monitoring results for samples collected at the two ETTP area PAM stations were provided by UT-Battelle, LLC (UT-Battelle) staff and are included in the ETTP network for comparative purposes.

The analytical parameters were chosen with regard to existing and proposed regulations and with respect to activities at ETTP. A principle reason for supplemental stations K11 and K12 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 onsite members of the public. K12 remained a key sampling location regarding the potential dose impact on the most exposed individual (MEI), who is a member of the public during the demolition of K-27, which was 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.

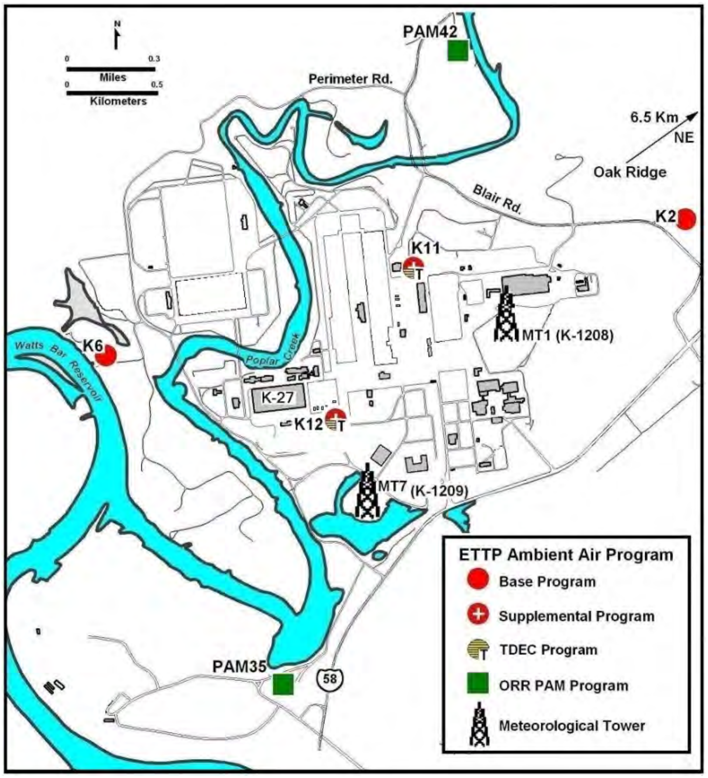


Fig. 3.12. East Tennessee Technology Park ambient air monitoring station locations.
(ETTP = East Tennessee Technology Park, MT = meteorological tower, ORR = Oak Ridge Reservation, PAM = perimeter air monitoring, TDEC = Tennessee Department of Environment & Conservation, and TSCAI = Toxic Substances Control Act Incinerator)

Fig. 3.13. East Tennessee Technology Park ambient air monitoring station.

All base and supplemental stations collected continuous samples for radiological and selected metals analyses during 2016. Inorganic analytical techniques were used to test samples for chromium (Cr) and lead (Pb). Radiological analyses of samples from the ETTP stations test for the isotopes ^{99}technetium (^{99}Tc), ^{234}uranium (^{234}U), ^{235}uranium (^{235}U), and ^{238}uranium (^{238}U); ORR station sampling results for ^{234}U, ^{235}U, and ^{238}U provided by UT-Battelle are included with the ETTP results.

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 2016 were well below the indicated annual standards. Stations K2 and K6 are in the prevailing topography of influenced upwind and 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.

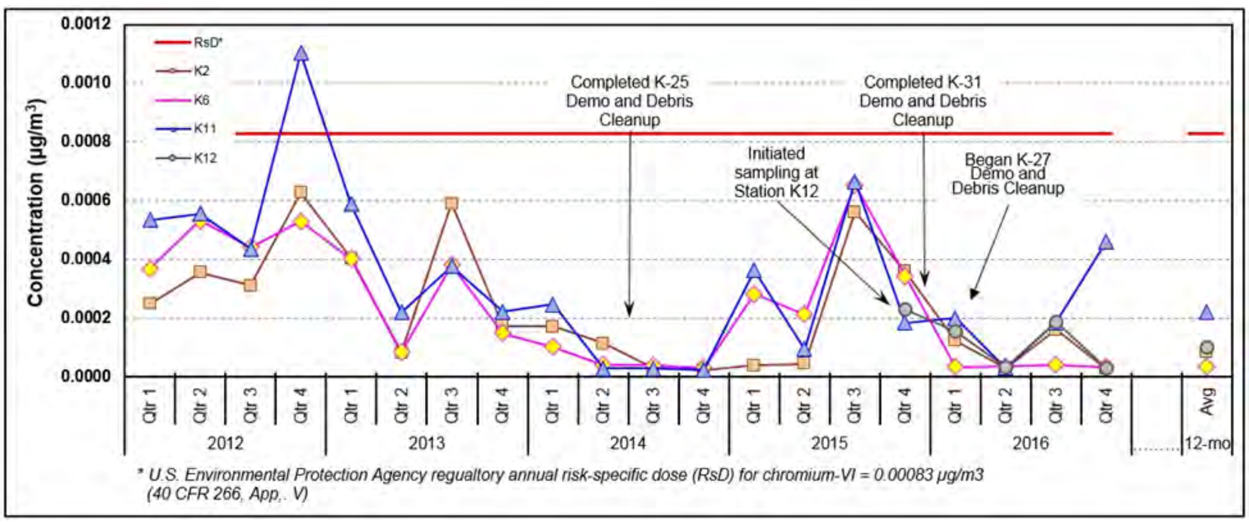


Fig. 3.14. Chromium monitoring results: 5-year history through December 2016. *(Demo = demolition)*

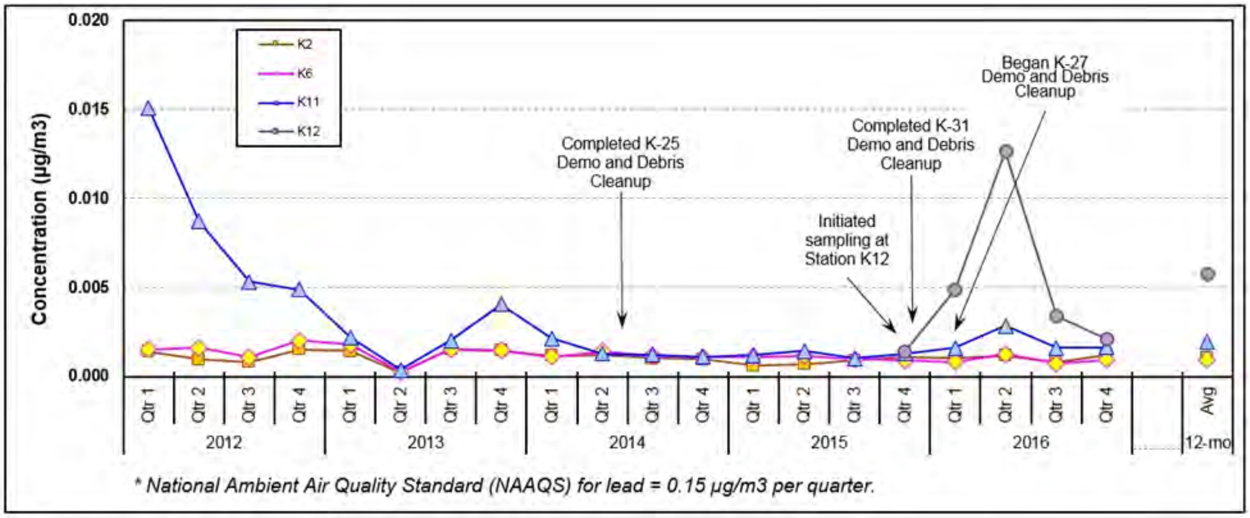


Fig. 3.15. Lead monitoring results: 5-year history through December 2016. *(Demo = demolition)*

Quarterly radiochemical analyses are performed on composite samples collected at all stations. The selected isotopes of interest were ^{99}Tc, ^{234}U, ^{235}U, and ^{238}U. The concentration and dose results for each of the nuclides are presented in Table 3.4 for the 2016 reporting period.

Table 3.4. Radionuclides in ambient air at East Tennessee Technology Park, January 2016 through December 2016

Station	Concentration (µCi/mL)				
	^{99}Tc	^{234}U	^{235}U	^{238}U	
K2[a]	1.78E-15	4.11E-18	6.92E-19	4.59E-20	
K6[a]	1.53E-15	4.22E-17	2.35E-18	3.46E-18	
K11[b]	2.27E-15	5.42E-17	4.93E-18	8.49E-18	
K12[b]	4.19E-15	1.55E-16	1.10E-17	2.76E-17	
	40 CFR 61, Effective Dose (mrem/year)				Total Dose
K2[a]	0.05	<0.001	<0.001	<0.001	0.05
K6[a]	0.04	0.005	<0.001	<0.001	0.05
K11[b]	0.03	0.003	<0.001	<0.001	0.03
K12[b]	0.05	0.009	0.001	0.001	0.07

[a]K2 and K6 results represent a residential exposure,

[b]K11 and K12 represent an onsite business exposure equivalent to ½ of a yearly exposure at this location.

The 2016 annual dose impact as listed in Table 3.4 show that Stations K2, K6, K11, and K12 have equivalent results. The doses associated with air monitoring stations K2 and K6 were approximately 0.05 mrem, and for air monitoring stations K11 and K12 the estimated doses were 0.03 mrem and 0.07 mrem, respectively. 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. The isotopic details that were measured at the ambient air monitoring stations show that the most significant dose contributor was ^{99}Tc with the percent contribution ranging between 75.2% (K12) to 98.1% (K2). The remainder of the dose contribution was attributed to ^{234}U, ^{235}U, and ^{238}U. Data show that all measurements were well below the 10 mrem annual dose limit.

Figure 3.16 is a historical summary chart of dose calculation results. Each data point represents the accumulated dose over the previous four quarterly sampling periods. The highest potential dose impact over a 12-month rolling period for an individual over the most recent 5-year period and working in the vicinity of Station K11 would only be 0.37 mrem as compared to the annual limit of 10 mrem. For calendar year 2016, the dose impact was only 0.03 mrem. The onsite location of Station K12 was in close proximity to major demolition and debris removal activities that impacted radiologically contaminated materials. The dose at K12 was only 0.07 mrem. All data continue to show potential exposures are all well below the 10 mrem annual dose limit.

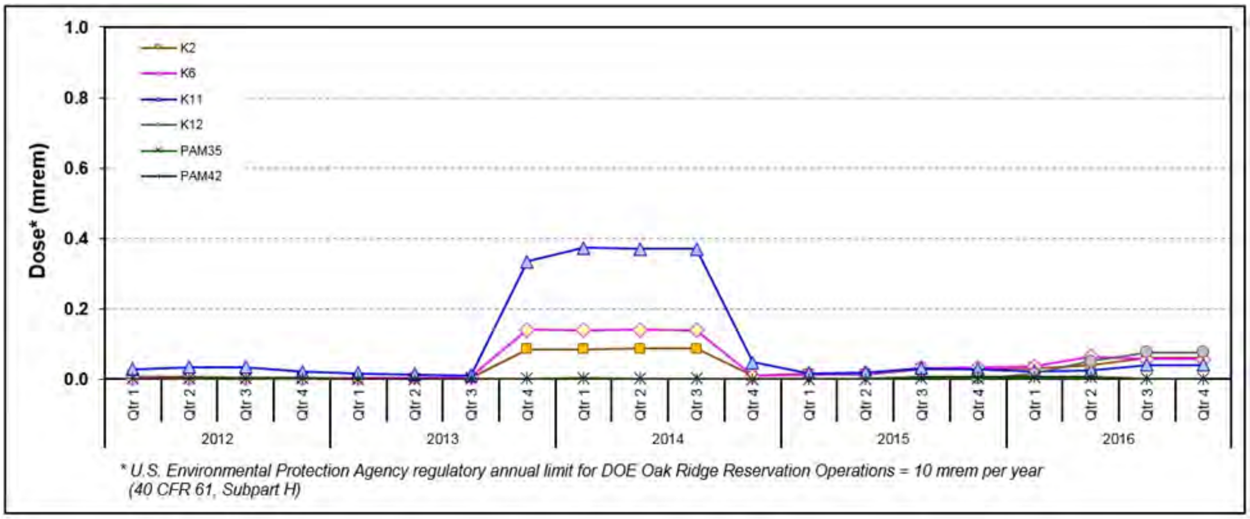


Fig. 3.16. Dose impact results: 5-year history through December 2016.

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. As part of the requirements of the current ETTP NPDES permit, storm water outfalls will no longer be divided into two groups based on the types of flows being discharged through the outfalls. All outfalls will now be combined into a single group. A total of 27 representative outfalls will be monitored on an annual basis for oil and grease, total suspended solids (TSS), pH, and flow. Outfall 170 will be 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 have been 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 shall include the following:

   - Flow Monitoring

   Selected outfalls will include Outfalls 100, 170, 180, and 190, using field-installed flow meters 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), 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 shall 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 will be collected at locations that will be 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, will be 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 fiscal year (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 will be 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 will be conducted to ensure all required samples are 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 will be conducted:
     - Representative outfalls meeting the requirements to complete an EPA Form 2E will be sampled. Parameters that must be collected by grab sample, per analytical method or regulatory guidance will be collected as a grab sample only. All other required parameters will be collected as time-weighted composites only.
     - Representative outfalls will be sampled to ensure completion of EPA Form 2F, Sect. VII, Discharge Information, Parts A, B, and C, as follows:
       - Part A—Required parameters will be collected as required. Oil and grease, total nitrogen, total phosphorus, and pH will collected as grab samples per EPA guidance. Biochemical oxygen demand, chemical oxygen demand, and TSS will be 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 will be 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 will be collected from all representative outfalls. In addition, each representative outfall will be evaluated, and VOCs, radionuclides, and other selected parameters will be collected from the representative outfalls as required. Part C parameters that must be collected by grab sample, per analytical method or regulatory guidance, will be collected as grab samples only. All other Part C parameters will be 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-4028/R5, *East Tennessee Technology Park Storm Water Pollution Prevention Program Sampling and Analysis Plan).*
   - 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 3 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 information on the outfalls that were sampled for radiological discharges. Table 3.8 contains the results of this sampling effort. No radiological screening criteria were exceeded at these outfalls. Screening levels for individual radionuclides are established at 4% of the DCS values listed in DOE Standard 1196 (DOE 2011). Table 3.9 lists the cumulative activity levels of each of the major isotopes that were discharged from the overall ETTP water system in 2016.

Table 3.7. Storm water composite sampling for radiological discharges

Storm water outfall	Gross alpha/ gross beta (composite sample)	U isotopic (composite sample)	^{99}Tc (composite sample)
200	X	X	X
240	X	X	X

Table 3.8. Analytical results for radiological monitoring at ETTP storm water outfalls in 2016

Parameter	Screening Level	Outfall 200	Outfall 240
Alpha activity (pCi/L)	10	1.15 U	3.57 U
Beta activity (pCi/L)	30	2.49 U	4.77
^{99}Tc (pCi/L)	1760	3.31 U	3.89 U
$^{233/234}$U (pCi/L)	28	0.598	3.32
$^{235/236}$U (pCi/L)	29	–0.0191 U	0.162 U
^{238}U (pCi/L)	30	0.243 U	0.684

Table 3.9. Radionuclides released to offsite waters from the ETTP storm water system in 2016 (Ci)

Isotope	^{234}U	^{235}U	^{238}U	^{99}Tc
Activity level	0.0033	0.00034	0.0018	0.21

3.6.2.2 Post-Demolition Monitoring for the K-731 Switch House D&D

The K-732 Switchyard is a level, gravel-covered yard approximately four acres in size that is fenced on three sides. The K-732 Switchyard is bounded by the K-731 Switchhouse area to the north. The gravel layer covering the switchyard is approximately 18 in. thick. It was put into place as a containment measure for any spills. The switchyard was originally constructed in 1944 to provide electrical power to the K-27 Process Building. It later became the receiving point for TVA power at 161 kV and supplying 13.8 kV power to the ETTP site. The adjacent K-731 Switchhouse received power from the K-732 Switchyard via underground conduits. The switchyard contains a number of below-grade vaults and pits with conduits for electrical and communication cables. Use of the switchyard was phased out over the years and the yard was completely shut down in 2011. Electricity to ETTP is now provided by COR.

UCOR conducted the demolition of the K-731 Switchhouse, and the demolition of the K-732 Switchyard structures and equipment was contracted by DOE to CTI and Associates of Kansas City, Missouri. The projects included the recovery and recycling of metals and material assets.

Two sumps are located in the basement of the K-731 Switchhouse.

- Sump S-053 discharges to Sump S-054.
- Sump S-054 discharges to storm water Outfall 430.

An additional five sumps (Sumps S-055, S-056, S-057, S-058, and S-059) are located in the K-732 Switchyard.

- Sump S-055 collects water from Valve Vault 2 in the K-731 Switchyard.
- Sump S-056 collects water from Valve Vault 3 in the K-731 Switchyard.
- Sump S-057 collects water from Synchronous Condenser 101.
- Sump S-058 collects water from Synchronous Condenser 102.
- Sump S-059 collects water from Synchronous Condenser 103.

Five of these sumps discharge to Outfall 440. A portion of the south side of the switchyard discharges to storm water Outfall 440, as well. This discharge to Outfall 440 includes surface runoff from paved sections of the switchyard area as well as infiltration through the gravel portion of the switchyard area. The K-731/K-732 sumps and the drainage system from this area to Outfalls 430 and 440 are shown in Fig. 3.17.

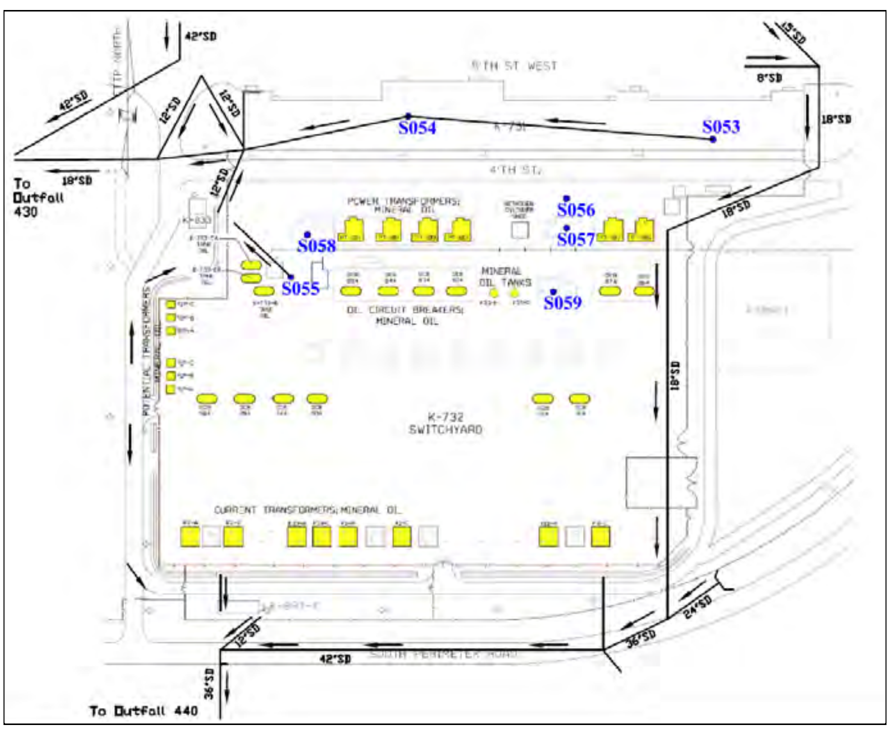


Fig. 3.17. K-731 Switchhouse and K-732 Switchyard draining system.

Outfall 430 was sampled on several occasions as part of the D&D of the K-27 building and the K-731 Switchhouse, since storm water runoff from both of these locations discharges through this outfall and portions of the D&D activities were being performed concurrently. Analytical data from samples of storm water from Outfall 430 are shown in Table 3.10.

On November 30, samples were collected from Outfall 440 to determine if water from Sumps S-055, S-056, S-057, S-058, and S-059, or from other portions of the K-732 Switchyard area, could be adversely affecting the discharge from the outfall. PCBs, metals, radiological parameters, and mercury were sampled in each of these sampling events. No results over screening levels were detected in samples collected from Outfall 440.

The K-732 Switchyard D&D required the electrical cables located in the basement of Building K-731 Switchhouse to be disconnected. Historically, the basement of Building K-731 has experienced water infiltration issues, and two sump pumps located in the east and west ends of the basement have transferred the water to the storm water system. In 2014, the sump pumps stopped operating, and the water accumulated in the basement at levels of up to 8 ft. In order to support the K-732 D&D efforts, and allow characterization of the basement under the *Record of Decision for Soil, Buried Waste, and Subsurface Structure Actions in Zone 2, East Tennessee Technology Park, Oak Ridge, Tennessee,* DOE/OR/01-2161&D2 [Zone 2 Record of Decision (ROD)], and to repair the sump pumps, approximately 1 million gallons of water were pumped from the basement and discharged to the Outfall 430 drainage network.

The water in the Building K-731 basement was sampled, and the results showed low levels of metals and radionuclides. However, the basement water was allowed to be pretreated and discharged to the storm drain system based on the following criteria:

- The water was below the sum of fractions (SOF) of the Derived Concentration Guide (DCG) listed in DOE Order 5400.5, *Radiation Protection of the Public and the Environment.*
- The water is not a listed or characteristic hazardous waste.
- The untreated water met all TDEC ambient water quality criteria except for PCB-1260.
- The water met the TSCA concentrations for the unrestricted use of water, which allows discharge to the storm drain system.

The water from the basement of Building K-731 was discharged to Poplar Creek, an impaired stream for PCBs and mercury, via the ETTP storm water network at Outfall 430. Prior to discharge, the water was treated for PCBs and mercury to meet the TDEC ambient water quality criteria (AWQC) and antidegradation requirements as follows:

- The water was filtered using 25, 10, and 5 μm filters to remove suspended solids.
- The water was treated for PCBs and mercury using activated carbon columns (accepted Best Available Technology for PCB and mercury removal).
- The water was treated with a polishing filter using a 5 μm filter to capture fines from the carbon treatment unit.
- The effluent was treated to a level that will result in the surface water not exceeding 0.00064 ng/L for PCBs and 0.51 ng/L mercury.

Discharge of the water from the basement of K-731 was conducted in May and June 2016. None of the water that was discharged as part of this activity exceeded the stated discharge criteria.

Demolition of the K-731 Switchhouse was completed in the fourth quarter of CY 2016. Samples were collected from Outfalls 430 and 440 on December 12, 2016, as part of the ETTP SWPP Program sampling effort. These samples were collected after D&D activities at K-731were completed. No results over screening levels were detected in samples collected from either outfall.

3.6.2.3 D&D of the K-27 Building

Initial sampling was performed in CY 2015 at Outfalls 380 and 430 and in Poplar Creek near Outfall 460 to provide baseline data for conditions before demolition of the K-27 Building began in February 2016. During demolition activities, samples were collected at Outfalls 380 and 430 and at Poplar Creek near Outfall 460 after each rain event of 1 in. or more. The outfall sampling was weather dependent, and samples were collected any time storm water runoff was observable in the area where D&D activities were being conducted. The criteria for storm event sampling utilized for other SWPP Program sampling did not have to be met for this sampling effort.

Table 3.10 contains information on the locations and parameters that were sampled as part of the K-27 D&D monitoring effort.

Table 3.10. Storm water sampling to support D&D of the K-27 Building

Sampling location	Sampling frequency	pH	Gross alpha/beta	U Isotopic, ^{99}Tc	PCBs[a] (individual Aroclors® and total PCBs)	Metals[b]/ Mercury	Hexavalent chromium
Outfall 380	Prior to initiation of building demolition activities After each rain event of 1 in. or more in a 24-h period. Upon completion of D&D activities	X	X	X	X	X	X
Outfall 430	Prior to initiation of building demolition activities After each rain event of 1 in. or more in a 24-h period. Upon completion of D&D activities	X	X	X	X	X	X
Poplar Creek instream @ Outfall 460	Prior to initiation of building demolition activities After each rain event of 1 in. or more in a 24-h period. Upon completion of D&D activities	X	X	X	X	X	X

[a] PCB analysis includes: Aroclors 1016, 1221, 1232, 1242, 1248, 1254, 1260, 1262, and 1268. Total PCBs will also be reported as part of the analytical data package.

[b]Metals analysis includes: Al, Ag, As, Ba, Be, B, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Pb, Sb, Se, Tl, V, and Zn.

Samples were collected on February 16, 2016, at Outfalls 380 and 430; and in Poplar Creek near Outfall 460, after a rain event of approximately 2.1 in. had occurred. Table 3.11 shows the parameters that exceeded screening criteria as part of this sampling event.

Samples were collected on April 1, 2016, at Outfalls 380 and 430 and in Poplar Creek near Outfall 460 after a rain event of approximately 1.55 in. had occurred. Table 3.11 shows the parameters that exceeded screening criteria as part of this sampling event.

Samples were collected on July 6, 2016, at Outfall 430 and in Poplar Creek near Outfall 460 after a rain event of approximately 1.12 in. had occurred. Outfall 380 did not flow during this storm event and could

not be sampled. Table 3.11 shows the parameters that exceeded screening criteria as part of this sampling event.

Samples were collected on August 19, 2016, at Outfalls 380 and 430, and in Polar Creek near Outfall 460, after a rainfall of approximately 0.95 in. Table 3.11 shows the parameters that exceeded screening criteria as part of this sampling event.

Table 3.11. Results over screening levels for Building K-27 D&D monitoring

Sampling Location	Gross Alpha (pCi/L)	Thallium (µg/L)	Lead (µg/L)	Cadmium (µg/L)	PCB-1260 (µg/L)	Mercury (µg /L)	Hexavalent chromium (µg/L)	Selenium (µg/L)
Screening Level	10	7.5	1.8	Detectable	Detectable	25	8	3.8
OUTFALL 380								
2/16/16	36.9	0.457	11.2	0.169				
4/1/16	41.4	1.55	7.87					
7/6/16								
8/19/16	18.7		17.4					
11/30/16								
OUTFALL 430								
2/16/16			4.43					
4/1/16		0.463	3.88		0.0581			
7/6/16							12	
8/19/16							12	
11/30/16			5.09					
12/12/16								
INSTREAM POPLAR CREEK @ OUTFALL 460								
2/16/16			5.37	7.55		1120		
4/1/16			2.8	1.09		273		
7/6/16				6.4		72		
8/19/16				0.225		84.6		
11/30/16						244		9.05
12/12/16						335		

On November 30, 2016, and December 12, 2016, sampling was conducted after rainfalls of 4.4 in. and 0.96 in., respectively. Samples were collected at Outfalls 380 and 430, and in Poplar Creek near Outfall 460. However, due to low flows at Outfall 380, only samples for ^{99}Tc were collected at this location. Table 3.11 shows the results that exceeded screening criteria at the other two locations. While it is

possible that the lead, thallium, gross alpha, and PCB-1260 screening level exceedances at Outfalls 380 and 430 may be related to the D&D of the K-27 Building, the mercury detected in instream samples collected in Poplar Creek may likely be more due to historical releases of mercury from upstream operations into East Fork Poplar Creek, which discharges into Poplar Creek north of ETTP.

3.6.2.4 D&D of the K-25 Building

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. Table 3.12 contains information on ^{99}Tc levels detected in discharges from Outfall 190 since the first quarter of CY 2015.

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

Sampling location	^{99}Tc (pCi/L)* 3/19/15	^{99}Tc (pCi/L)* 5/11/15	^{99}Tc (pCi/L)* 8/3/15	^{99}Tc (pCi/L)* 11/2/15	^{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
Outfall 190	33.1	27.7	14.4	15.9	13.4	6.37 U	4.21 U	3.26 U

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

From this data, it does not appear that ^{99}Tc contaminated groundwater is discharging at significant levels to Mitchell Branch via Outfall 190.

3.6.2.5 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 (GD) plant operations and support buildings, Oak Ridge National Laboratory (ORNL), and Y-12. Mercury from soils and spill cleanups was processed on site 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 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 remedial action 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 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 time period of 24 h or less and which 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

Sects. 3.1.2 and 3.3.1 of EPA 833-B-92-001, *NPDES Storm Water Sampling Guidance Document,* and applicable procedures that have been developed by the sampling subcontractor, Restoration Services Inc (RSI).

ETTP Monitoring Programs

Several monitoring programs collected mercury data across ETTP at various locations during CY 2016. 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.

As part of the previous NPDES permit compliance program, 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 NPDES permit that took effect on April 1, 2015, 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 has not been detected at Outfall 170 at levels over the AWQC of 51 ng/L for several years, Outfall 170 will not be sampled as part of this SWPP Program effort. 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. Mercury sampling at storm water outfalls sampled under previous NPDES permit

Sampling Location	Parameter	Measurement frequency	Sample type
Outfall 05A	Mercury	1/quarter	Grab
Outfall 180	Mercury	1/quarter	Grab
Outfall 190	Mercury	1/quarter	Grab

Table 3.14 contains analytical data from mercury sampling performed at Outfalls 170, 180, 190, and 05A during CYs 2015 and 2016. Samples collected during the first and second quarters of CY 2015 were collected as part of the requirements of the ETTP NPDES permit that was in effect at that time. Mercury samples collected since that time were taken as part of the requirements of the ETTP SWPP Program.

Table 3.14. Quarterly NPDES/SWPP Program mercury monitoring results—CY 2015 and 2016

Sampling location	1st Quarter CY 2015 (ng/L)	2nd Quarter CY 2015 (ng/L)	3rd Quarter CY 2015 (ng/L)	4th Quarter CY 2015 (ng/L)	1st Quarter CY 2016 (ng/L)	2nd Quarter CY 2016 (ng/L)	3rd Quarter CY 2016 (ngL)	4th Quarter CY 2016 (ng/L)
Outfall 170**	4.1	25.6	-----	-----	-----	-----	-----	-----
Outfall 180	**219**	**53.1**	50.8	**99.3**	27.1	31.3	**123**	**177**
Outfall 190	20.3	11.1	16.7	**55.6**	12.9 **(96.5)*****	35	16.4	17.6
Outfall 05A	**67.4**	**132**	**148**	**185**	**86.4**	**105**	**126**	**459**

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

**Quarterly mercury samples were not collected at Outfall 170 after March 2015.

***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 3.18 through 3.21 represent the mercury levels at the surface water K-1700 Weir and at storm water Outfalls 170, 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.

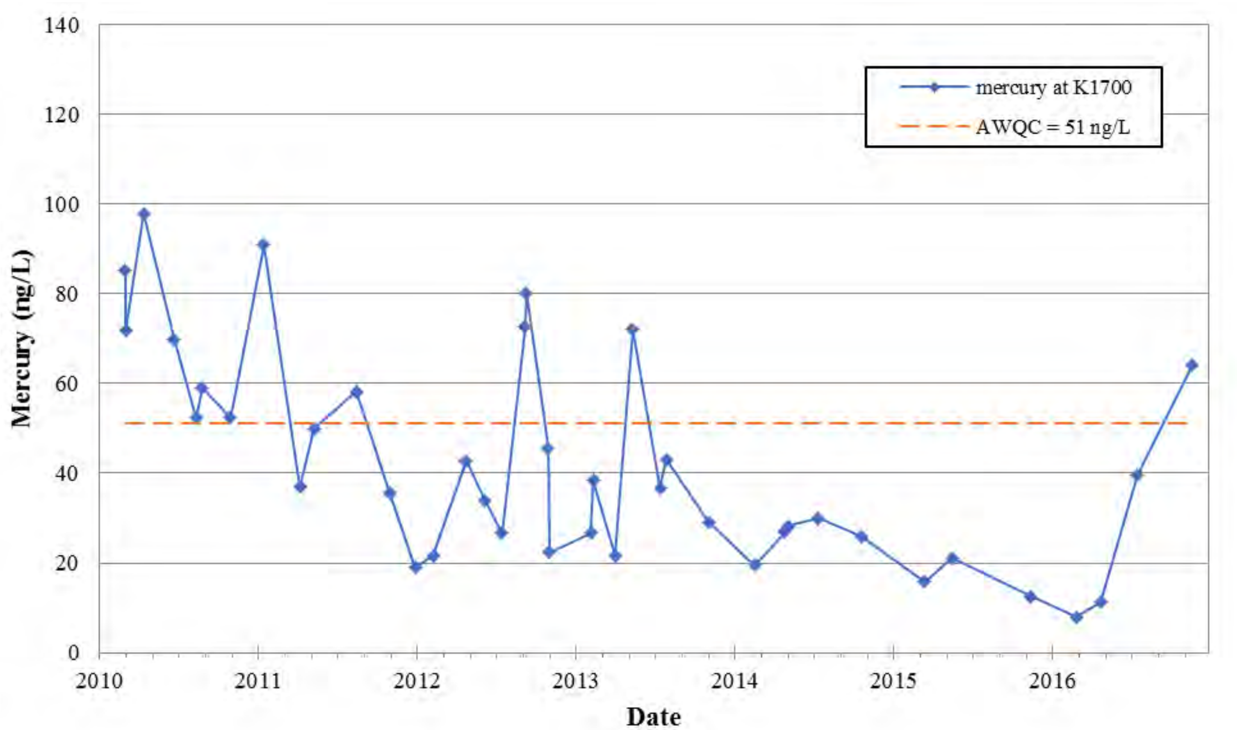


Fig. 3.18. Mercury concentrations at Surface Water Location K-1700

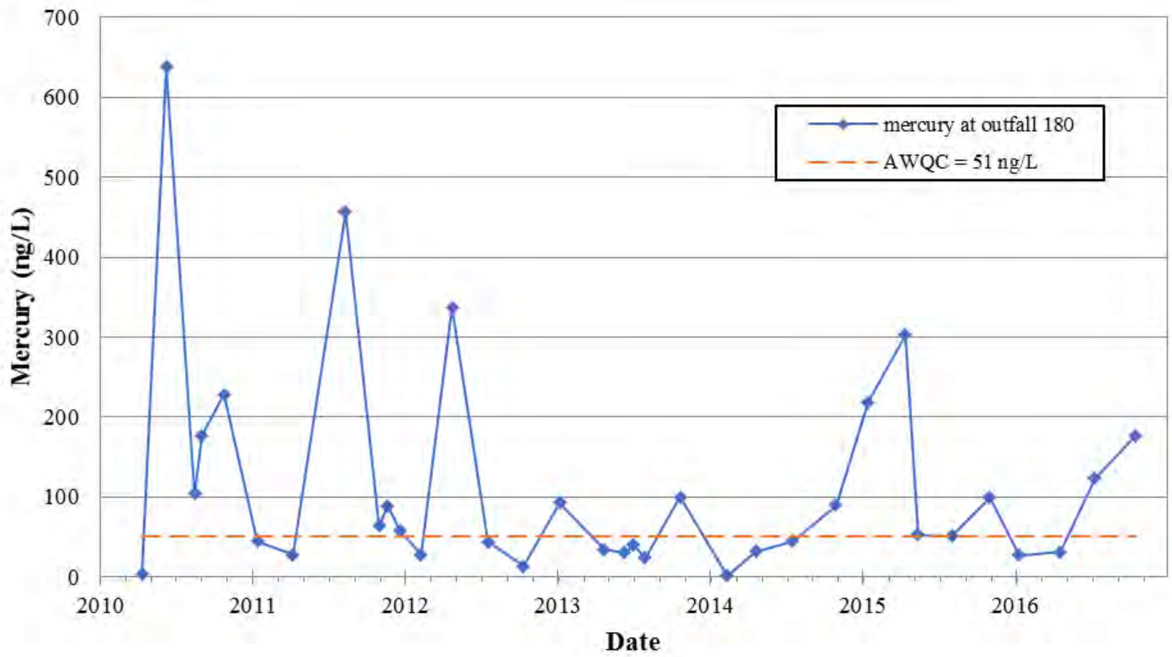


Fig. 3.19. Mercury concentrations at Outfall 180.

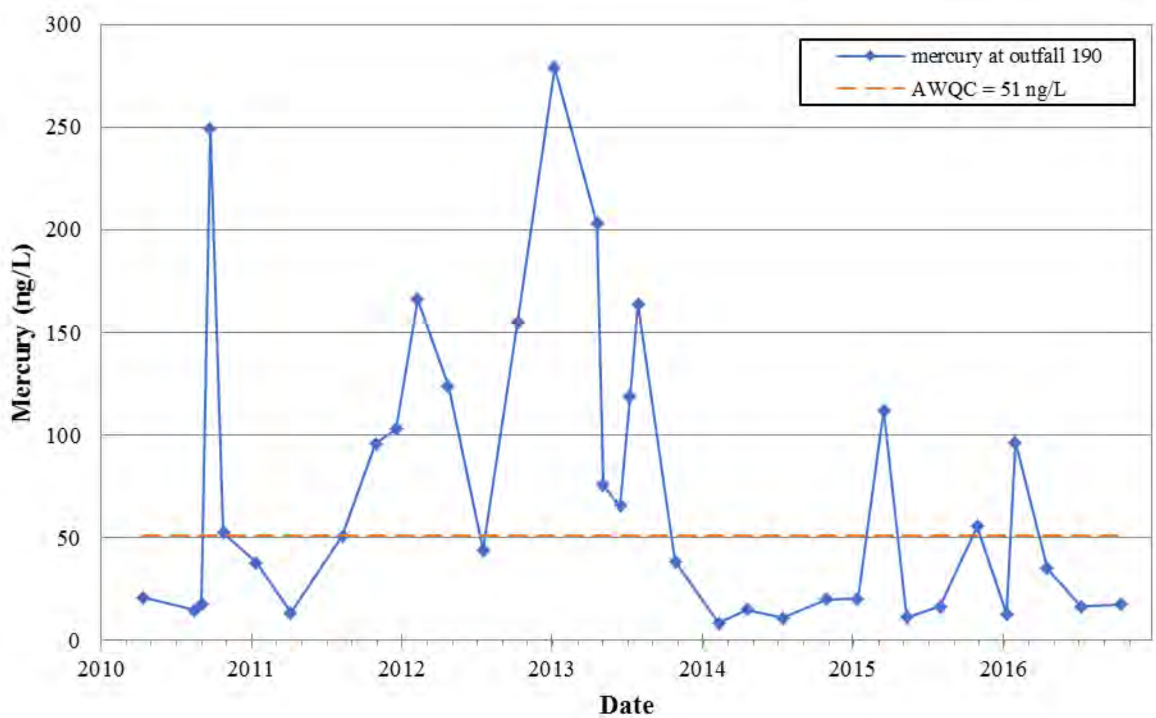


Fig. 3.20. Mercury concentrations at Outfall 190.

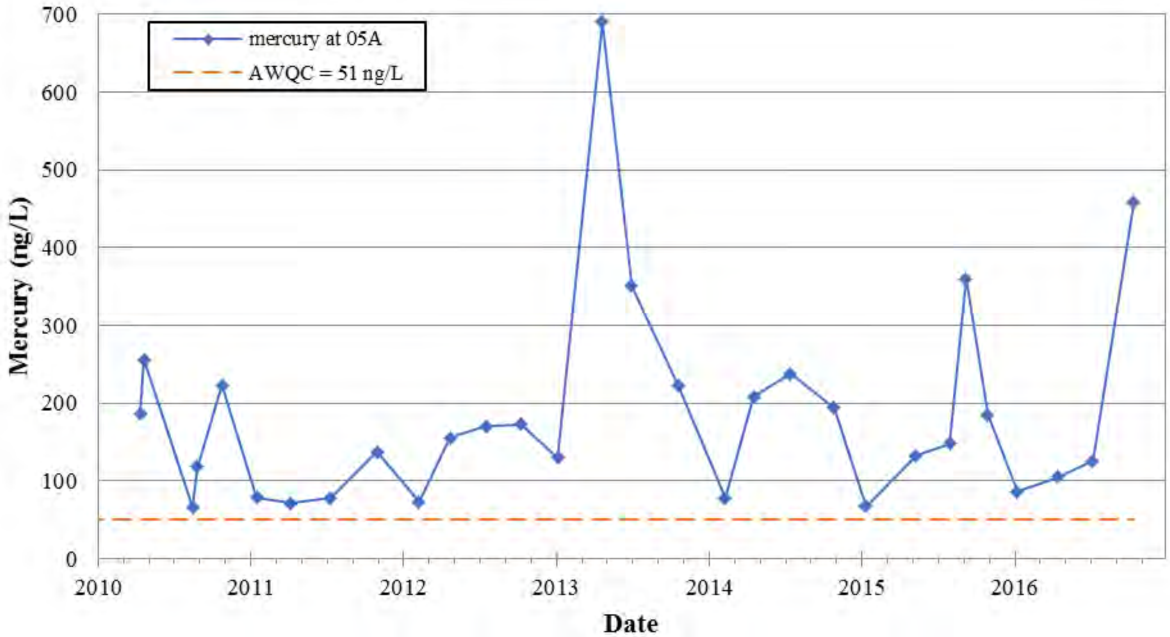


Fig. 3.21. Mercury concentrations at Outfall 05A.

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 230, which had a mercury level of 129 ng/L. The results of the NPDES permit renewal mercury sampling are in Table 3.15.

Table 3.15. NPDES permit renewal sampling-mercury results

Sampling location	Mercury (ng/L)
Outfall 230	**129**
Outfall 430	16.8
Outfall 490	14.9
Outfall 560	20
Outfall 724	7.27

3.6.2.6 PCB Monitoring at ETTP Storm Water Outfalls

An evaluation of PCB data collected as part of the ETTP SWPP Program from CY 2000 to CY 2015 was performed to identify locations where PCBs have been detected at ETTP storm water outfall locations. Several of the locations where PCBs were identified were sampled as part of the FY 2016 SWPP Program, as shown in Table 3.16. Table 3.17 indicates the analytical results from storm water outfall samples for PCBs collected as part of this sampling program.

Table 3.16. PCB samples collected as part of the FY 2016 SWPP Program

Location	Parameter[a]	Sample type
Outfall 150	Total PCBs and individual PCB Aroclors	Grab
Outfall 170	Total PCBs and individual PCB Aroclors	Grab
Outfall 180	Total PCBs and individual PCB Aroclors	Grab
Outfall 280	Total PCBs and individual PCB Aroclors	Grab
Outfall 510	Total PCBs and individual PCB Aroclors	Grab
Outfall 690	Total PCBs and individual PCB Aroclors	Grab

[a] PCB analysis includes: Aroclors 1016, 1221, 1232, 1242, 1248, 1254, 1260, 1262, and 1268. Total PCBs will also be reported as part of the analytical data package.

Table 3.17. Analytical results from CY 2016 SWPP Program PCB sampling

Location	Parameter[a]	Date Sampled	Results Above Detection Limit
Outfall 150	Total PCBs and individual PCB Aroclors	2/23/2016	No PCBs detected
Outfall 170	Total PCBs and individual PCB Aroclors	2/23/2016	No PCBs detected
Outfall 180	Total PCBs and individual PCB Aroclors	2/23/2016	No PCBs detected
Outfall 280	Total PCBs and individual PCB Aroclors	11/30/2016	No PCBs detected
Outfall 510	Total PCBs and individual PCB Aroclors	2/23/2016	No PCBs detected
Outfall 690	Total PCBs and individual PCB Aroclors	2/23/2016	PCB-1254-0.0518 µg/L

As shown in Table 3.17, detectable quantities of PCBs were found in samples collected at Outfall 690. Additional sampling of the discharges from this outfall may be conducted as part of upcoming SWPP Program. Analytical data collected as part of the storm water monitoring effort will be utilized to provide information for evaluating cleanup decisions and to measure the effectiveness of RAs.

3.6.2.7 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 0.78 mg/L, which exceeded the State of Tennessee hexavalent chromium water quality chronic criterion of 0.011 mg/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 0.78 mg/L to levels consistently below the AWQC value of 0.011 mg/L. The time-critical removal action is

documented in (DOE/OR/01-2598&D2), *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 2016, 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. Requirements for this sampling effort are listed in Table 3.18.

These locations are manually grab-sampled quarterly during alternating wet-and-dry weather conditions according to the guidelines specified in Sects. 3.1.2 and 3.3.1 of EPA 833-B-92-001 and applicable procedures developed by the sampling subcontractor. All guidelines in UCOR-4028/R5, *East Tennessee Technology Park Storm Water Pollution Prevention Program Sampling and Analysis Plan,* were also followed as part of this sampling effort. Figures 3.22 and 3.23 show the results of this monitoring.

Table 3.18. Monitoring requirements–Mitchell Branch subwatershed total and hexavalent chromium sampling locations

Sampling Location	Parameter	Measurement frequency	Sample type
MIK 0.79	Total chromium	1/quarter	Grab
MIK 0.79	Hexavalent chromium	1/quarter	Grab
Outfall 170	Total chromium	1/quarter	Grab
Outfall 170	Hexavalent chromium	1/quarter	Grab
Monitoring Well-289 (TP-289)	Total chromium	1/quarter	Grab
Monitoring Well-289 (TP-289)	Hexavalent chromium	1/quarter	Grab
Cr collection system wells (CWTS-INF)	Total chromium	1/quarter	Grab
Cr collection system wells (CWTS-INF)	Hexavalent chromium	1/quarter	Grab

NOTE: Total chromium and hexavalent chromium will be collected during varying weather conditions (for example, samples will be collected during wet weather conditions one quarter and during dry weather conditions the following quarter.)

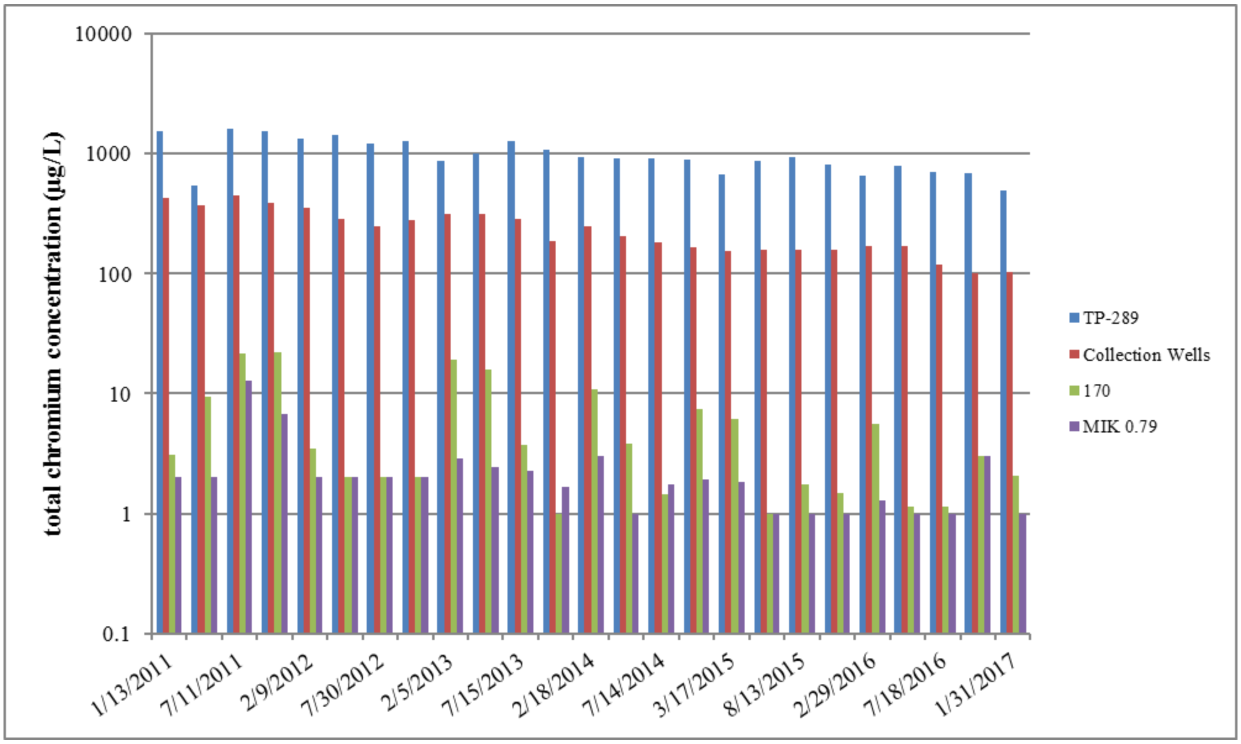


Fig. 3.22. Total chromium sample results for the chromium collection system.

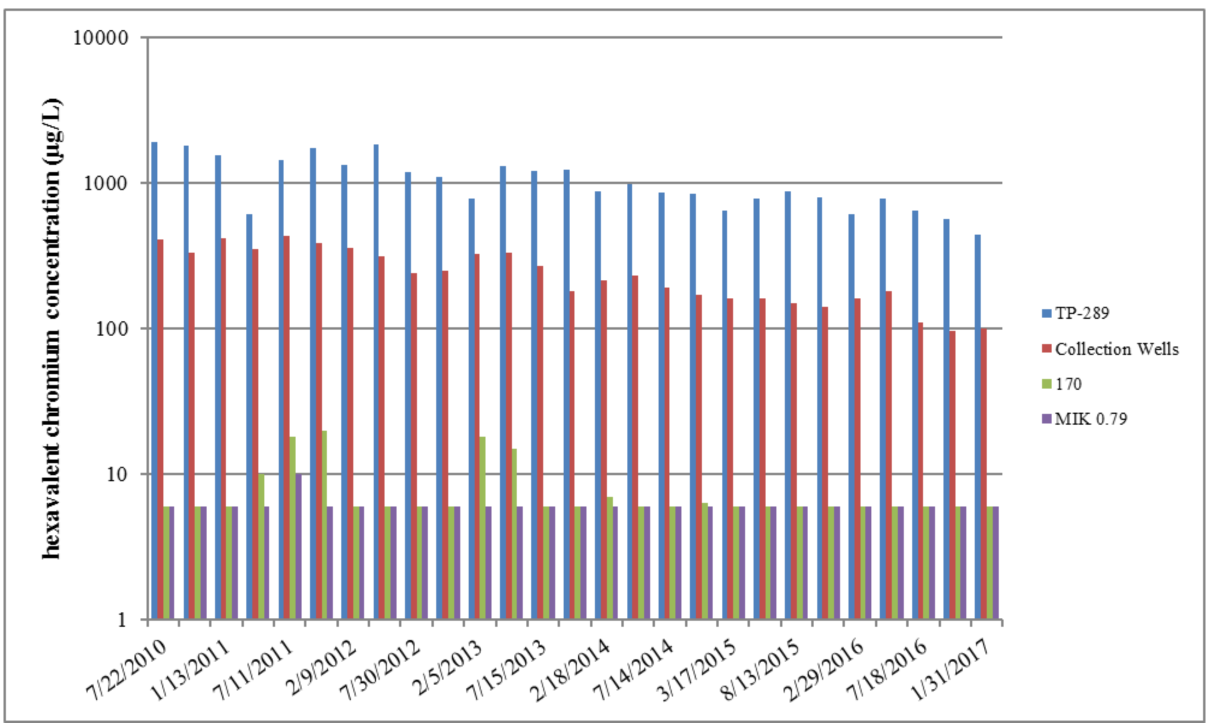


Fig. 3.23. Hexavalent chromium sample results for the chromium collection system.

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 in Fig. 3.23.

In October 2016, during a CERCLA project test of the CWTS, the pumps at the collection wells were turned off for a period of 48 hours. Samples were collected from several locations, including Outfall 170 and MIK 0.79, before and during the time the pumps were off. Samples were then collected 6 hours after the pumps were returned to service. The samples were analyzed for total and hexavalent chromium. Figures 3.24 and 3.25 show the results for hexavalent chromium at Outfall 170 and MIK 0.79 respectively. Prior to the test, hexavalent chromium levels were below the detection limit. When the pumps were turned off, levels of hexavalent chromium rose to 34 µg/L at storm water Outfall 170, and 29 µg/L at MIK 0.79. Six hours after the pumps were returned to service, levels of hexavalent chromium had returned to below the AWQC at Outfall 170. After 6 hours, the instream levels of hexavalent chromium at MIK 0.79 had dropped to approximately 15 µg/L. Additional sampling conducted four days after the test showed hexavalent chromium at MIK 0.79 had dropped to below detection levels. Levels of total chromium followed the same pattern.

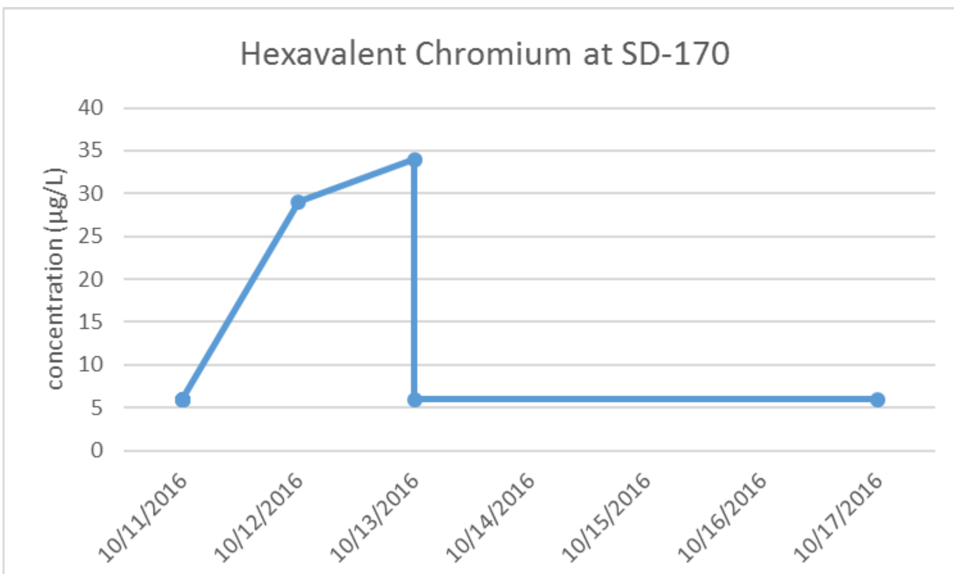


Fig. 3.24. Hexavalent chromium results at storm water Outfall 170 during the CERCLA Project test of CWTS.

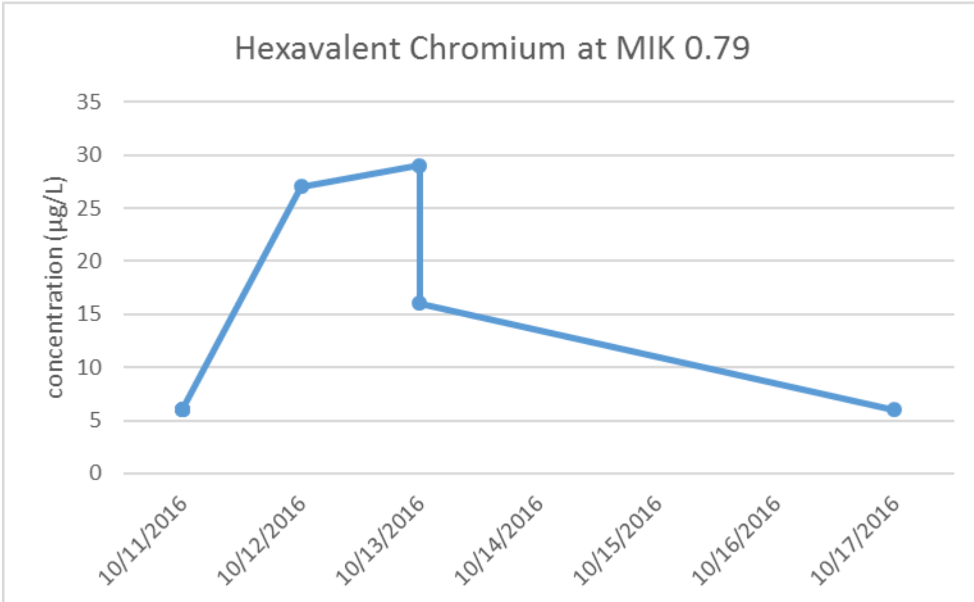


Fig. 3.25. Hexavalent chromium results at MIK 0.79 during the CERCLA Project test of CWTS.

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*. 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% over the last several monitoring periods.

3.6.2.8 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 2016 SWPP Program SAP. Table 3.19 indicates the dates when samples were collected at representative outfalls during CY 2016.

Table 3.19. NPDES permit renewal sampling conducted in CY 2016

Outfall	Manual Grab Samples—Date Collected	Manual Grab or Grab-by-Compositor Samples—Date Collected	Composite Samples—Date Collected
230			5/11/2016
430			1/26/2016
490	2/1/2016	2/1/2016	2/1/2016
560		12/1/2016	8/18/2016
724	1/26/2016	1/26/2016	1/26/2016

Table 3.20 indicates results from these NPDES permit renewal sampling efforts performed in CY 2016 that exceeded screening levels.

Table 3.20. Analytical results exceeding screening levels for NPDES permit renewal sampling—CY 2016

Outfall	Copper	Lead	Zinc	Mercury	Gross Beta Activity
	Screening level 7 µg/L	Screening level 1.8 µg/L	Screening level 75 µg/L	Screening level 51 ng/L	Screening level 50 pCi/L
230	8.75	23.3	102	129	
430	12.6	33	130		
490					276
560	7.47	9.78	106		

When screening levels are exceeded, any of several actions may be implemented, including:

- An investigation is undertaken by EC&P personnel to determine the cause of the exceedance.
- Personnel from the EC&P Organization observe the storm water outfall(s) and drainage basins where the screening levels were exceeded to determine if best management practices (BMPs) or other corrective measures may be required.
- Corrective actions are implemented to ensure that an NPDES permit limit or other reference standard is not exceeded during subsequent sampling events.
- Additional monitoring is performed to determine if the release is ongoing.
- Evaluations through sampling at instream locations are conducted to confirm that no impacts are occurring in instream mixing zones.

Exceedance of screening levels at Outfalls 230 and 490 are likely related to D&D actions that were performed for the K-25 building. Exceedance of screening levels at Outfall 430 is likely related to D&D actions that were performed for the K-731 Switchhouse and/or the K-732 Switchyard. Exceedance of screening levels at Outfall 560 is likely related to D&D actions that were performed for the K-31 building. Additional best management practices (BMPs) were not determined to be necessary since D&D actions at the facilities listed have been completed and no instream mixing zone impacts were identified. Additional monitoring will be performed as part of future ETTP SWPP Program sampling efforts to determine if additional corrective actions may be required at these outfalls.

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

Flux monitoring was conducted as part of the mercury investigation at ETTP. To properly monitor mercury flux, accurate flow estimates and mercury concentrations measured during storm events were needed. Flow monitoring was conducted at Outfalls 100, 170, 180, and 190 as part of the requirements of the ETTP NPDES permit. Outfall 170 was monitored first.

At each of these four storm drain locations, the ETTP NPDES permit required 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 was 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 were utilized to compare against modeled flows generated using the Natural Resources Conservation Service Technical Report 55 (TR-55), which was the model used at ETTP to estimate storm water discharge flows. These compared values were used to increase the accuracy of the TR-55 flow modeling process. Given that the flow monitoring occurred over a variety of rain events and multiple field variables could pose problems in collecting usable data, this monitoring was completed during the permit period.

3.6.2.10 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 consistent 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% 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.

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

As part of the requirements of the ETTP NPDES permit that became effective in April 2015, flow monitoring will also be conducted at Outfalls 100, 180, and 190. An H-type flume was purchased and installed at Outfall 190 in late 2015. Flow data have been collected from the monitoring equipment at

the Outfall 190 flume since December 2015. During much of this time period, a small oily sheen has been discharged from the Outfall 190 piping system, necessitating the use of an oil-absorbent boom at the end of the Outfall 190 pipe. It is possible that the boom may have disrupted the flow measurement equipment here; a data analysis will be conducted to determine if this has happened. In the meantime, collection of flow data at Outfall 190 will continue.

In addition, flow-paced composite mercury samples required by the ETTP NPDES permit have been collected at Outfall 190 for the 0.1–0.5 in. rain event and the 0.5–1.5 in. rain event, as specified in the ETTP NPDES permit. The results from these samples are shown in Table 3.21.

Table 3.21. Analytical results from flow-proportional composite sampling

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	1/12/2017	0.5–1.5 in.	162

3.6.2.12 Significant Spill Events

Release of Unknown Material into Catch Basin Located Near Building K-131
On December 8, 2016, UCOR D&D personnel were downsizing an exterior tank on the north side of Bldg. K-131, the former function and original location of which are unknown. Heavy machinery was used to cut the tank into smaller pieces for disposal. During this operation, an unknown white solid material was released onto the paved area where the tank was located. This release occurred immediately before a rainfall event, and D&D personnel were not able to clean up the material before the rain began. Despite efforts to prevent the material from entering a nearby storm drain inlet, some of it entered an inlet connected to Outfall 382, which discharges to Poplar Creek. Because this material could have posed safety and health hazards, sampling of it was delayed until additional information could be gathered on the potential source of the released material and the tank.

On December 12, 2016, samples of the discharge from Outfall 382 were collected and analyzed for radiological parameters, metals, total ammonia nitrogen, semivolatile organic compounds (SVOCs), mercury, and total residual chlorine. No analytical results exceeded screening criteria. Further analysis indicated that the unknown material was most likely sodium sulfate. No threat to the environment occurred as a result of this spill, no impact to aquatic biota was observed, and discharge of this material from the tank appeared to be unrelated to mercury found in the discharge from Outfall 382.

Fire Water Line Break at Building K-1052
On December 1, 2016, a significant fire-water line break occurred near the M&EC Process/Storage Area at Bldg. K-1052. Chlorinated fire water, discharged as part of this event, flowed into a radiologically contaminated portion of Bldg. K-1052, as well as a radiologically contaminated portion of Bldg. K-1010 (M&EC Process Area). The K-1010 Process Area had been recently contaminated during the processing of a waste stream containing a significant amount of strontium-90 (^{90}Sr) and was being cleaned.

The water flowed back out of these buildings and into a nearby storm drain inlet that is connected to the storm water Outfall 100 drainage system. In addition, a substantial quantity of sediment was transported to the Outfall 100 drainage system as part of the line break. UCOR personnel valved off the leak shortly after it was noted. The area was stabilized until the line could be repaired. On December 7, 2016, UCOR personnel repaired the break and backfilled the affected area with gravel.

Due to the potential for transport of radiological contamination to the Outfall 100 drainage system and into the K-1007-P1 pond, sampling was conducted at Outfall 100 and the K-1007-B weir on December 2, 2016, for gross alpha/gross beta activity, isotopic uranium, ^{90}Sr, and gamma activity. The results from this sampling effort are shown in Table 3.22.

Table 3.22. Analytical results for Outfall 100 and K-1007-B Weir sampling conducted on December 2, 2016

Location	Gross Alpha Activity	Gross Beta Activity	^{137}Cs	^{90}Sr	$^{233/234}$U	$^{235/236}$U	^{238}U
	Screening level 10 pCi/L	Screening level 30 pCi/L	Screening level 120 pCi/L	Screening level 44 pCi/L	Screening level 28 pCi/L	Screening level 29 pCi/L	Screening level 30pCi/L
Outfall 100	7.41	**591**	2.4 U	**275**	1.39	0.217 U	0.879
K-1007-B Weir	-0.488 U	7.44	-0.228 U	0.059 U	0.642 U	0.0235 U	0.045 U

Results in **BOLD** indicate exceedance of screening criteria.

Water samples taken by UCOR personnel on December 2, 2016, at Outfall 100 did indicate increased levels of ^{90}Sr (275 pCi/L) as well as total beta (591 pCi/L). However, all other nuclides showed no significant increase in activity levels. The activity levels of ^{90}Sr were below the levels given in DOE Standard 1196. Gross alpha radiation activity levels in samples collected at the K-1007-B Weir were below the analytical detection limit, and gross beta radiation levels were below the internal screening levels established based upon the National Primary Drinking Water standards listed in 40 CFR 141.

On December 13, 2016, follow-up sampling for gross alpha/gross beta contamination was performed at Outfall 100 to determine if radiological contamination might still be present at the outfall as a result of this fire-water break. The results from this sampling event are shown in Table 3.23.

Table 3.23. Analytical results for Outfall 100 and K-1007-B Weir sampling conducted on December 13, 2016

Location	Gross Alpha Activity	Gross Beta Activity
	Screening level 10 pCi/L	Screening level 30 pCi/L
Outfall 100	4.22	7.49

Even though elevated levels of gross beta radiation and ^{90}Sr were detected after the initial spill, the levels of these contaminates had dissipated by the time the follow-up sampling was performed. Therefore, it is believed that no threat to the environment occurred as a result of this spill. No impact to aquatic biota in the K-1007-P1 pond was observed.

3.6.3 Surface Water Monitoring

During 2016, the ETTP EMP personnel conducted environmental surveillance activities at 12 surface water locations (Fig. 3.26) 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 and analyzed quarterly for radionuclides; 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 2011). Radiological data are reported as fractions of DCSs for reported radionuclides, and the fractions for all of the isotopes are added together to produce the SOF and averaged to produce a rolling 12-month average. The average SOF is recalculated whenever new data become available. If the average SOF for a location exceeds the DCS requirement of remaining below 1.0 (100%) 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%). In 2016, the monitoring results yielded SOF values of less than 0.01 (1% of the allowable DCS) at all surface water surveillance locations at ETTP (Fig. 3.27).

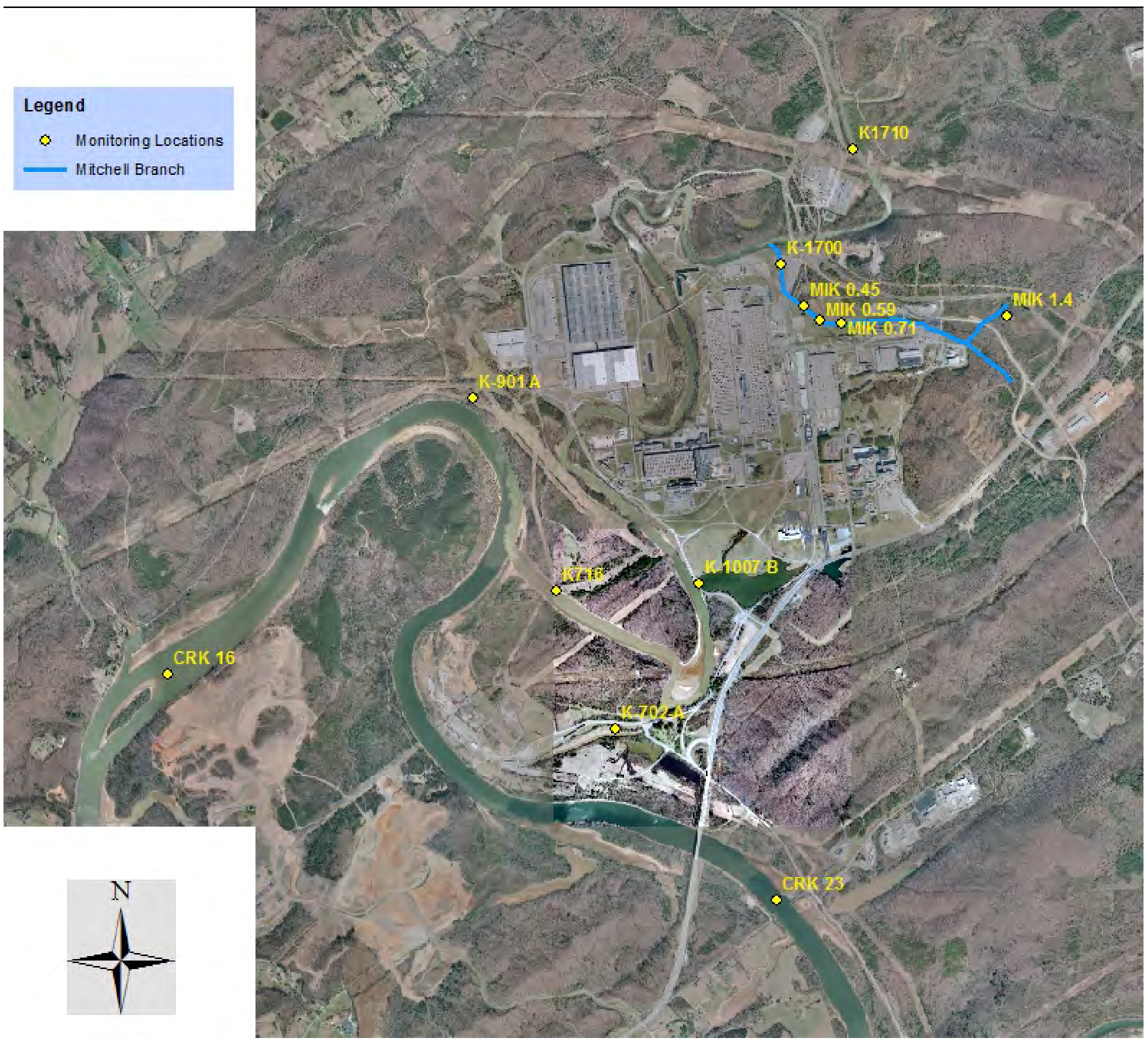


Fig. 3.26. East Tennessee Technology Park Environmental Monitoring Program surface water monitoring locations. *(CRK = Clinch River kilometer and MIK = Mitchell Branch kilometer)*

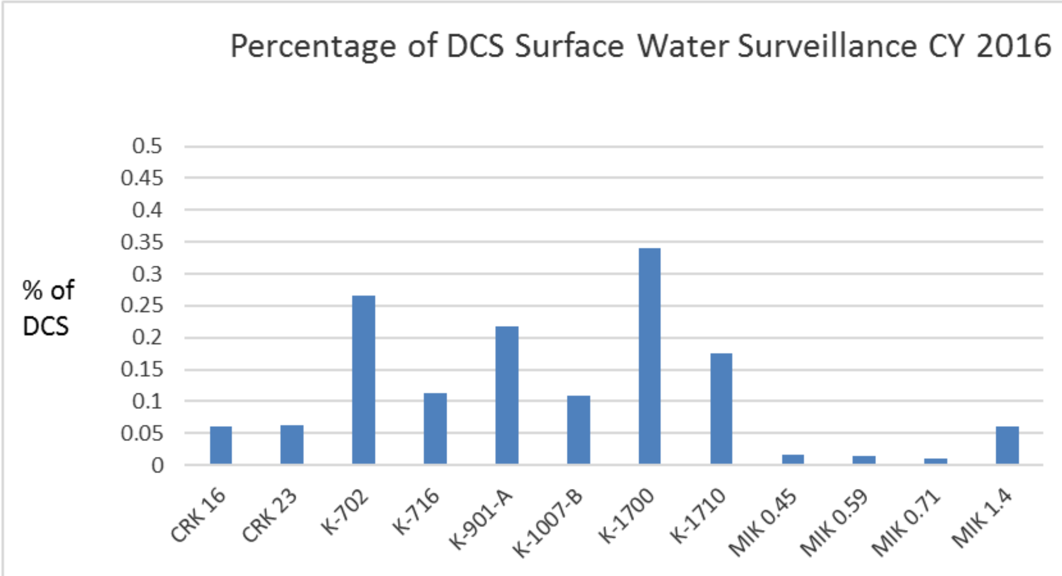


Fig. 3.27. Annual average percentage of derived concentration standards (DCSs) at surface water monitoring locations, 2016. *(CRK = Clinch River kilometer and MIK = Mitchell Branch kilometer)*

Depending on the monitoring location, water samples may be analyzed for pH, selected metals, and VOCs. In 2016, results for most of these parameters were well within the appropriate AWQC. There were nine exceptions in 2016. During the second quarter of 2016, there were 3 exceedances of the AWQC. At K-716, mercury was measured at 0.0534 µg/L, which exceeded the AWQC of 0.051 µg/L. K-716 monitors Poplar Creek, which typically contains elevated levels of mercury as a result of past discharges from Y-12, which is situated upstream from ETTP. At K-1700, zinc was measured at 380 µg/L, which exceeded the hardness-dependent AWQC of 203 µg/L. K-1700 monitors Mitchell Branch, which drains areas of naturally high levels of zinc in the soil. At MIK 1.4, lead was measured at 3.4 µg/L, which exceeded the AWQC of 2.1 µg/L. This level of lead is not typical at this location, and no operations were ongoing in the vicinity that might have caused the exceedance, so the cause of this exceedance remains unknown. During the third quarter, there were two failures to meet the minimum level of dissolved oxygen (5.0 mg/L). Dissolved oxygen levels were measured at 3.4 mg/L at K-901-A and at 4.1 mg/L at K-1007-B. Both of these readings were collected at times of elevated temperatures and very low flow due to the drought, conditions which favor high biological activity and the consequent depletion of dissolved oxygen. In the fourth quarter, elevated levels of mercury were detected at both K-1700 (0.0642 µg/L) and K-1710 (0.0561 µg/L). The drainage area monitored by K-1700 supported some minor mercury operations in the past, and such levels are not unprecedented here. K-1710 monitors Poplar Creek, which typically contains elevated levels of mercury as a result of past discharges from Y-12, which is situated upstream from ETTP. Elevated levels of zinc were also seen at K-1710 (680 µg/L). Soils in the northern portion of ETTP contain relatively high levels of naturally occurring zinc. The result reported for carbon tetrachloride at K-1700, 19 µg/L, exceeds the AWQC of 16 µg/L. This result is atypical for this location, where the concentrations of carbon tetrachloride are usually below the detection limit, and to date no cause of the exceedance has been identified. No obvious signs of distress (e.g., dead fish) were observed to be associated with any of these exceedances in 2016.

Figures 3.28 and 3.29 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 has reviewed these data points and they did not discover any indication of a laboratory error. At this time the reason for these increases is unknown. 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 (Fig. 3.30). 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 (Fig. 3.31). In 2016, hexavalent chromium levels in Mitchell Branch were all below the detection limit of 6 µg/L.

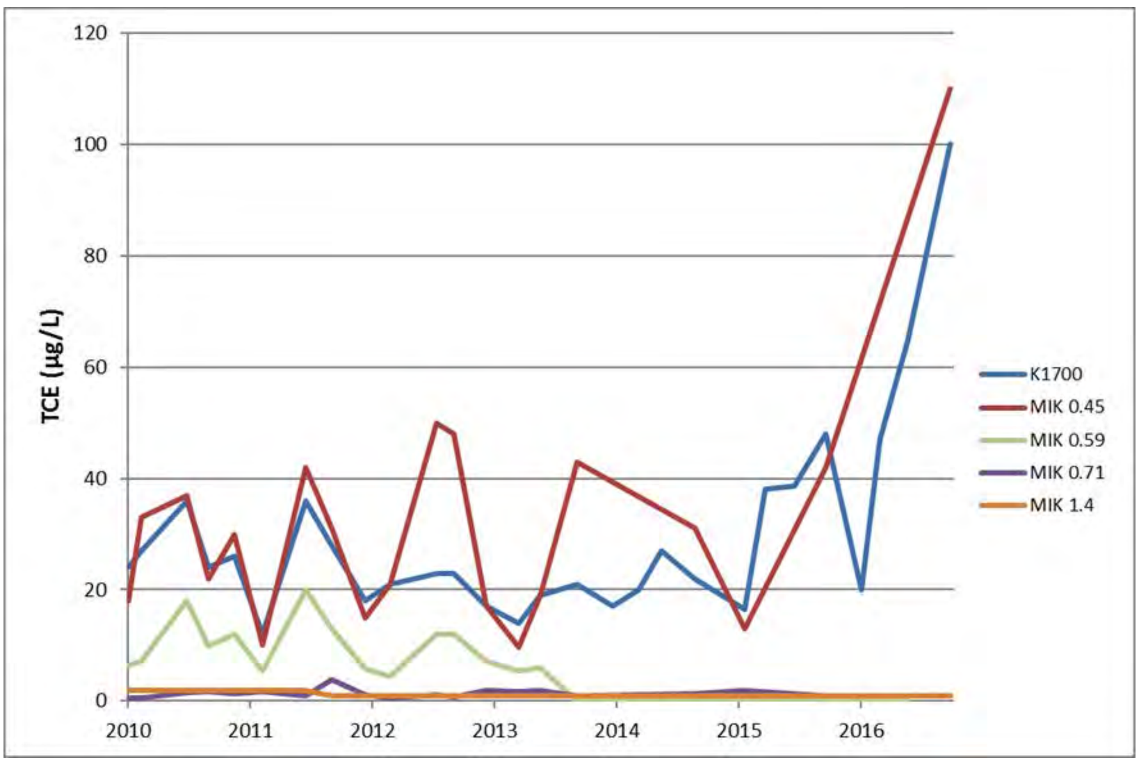


Fig. 3.28. Trichloroethene concentrations in Mitchell Branch. *(MIK = Mitchell Branch kilometer)*

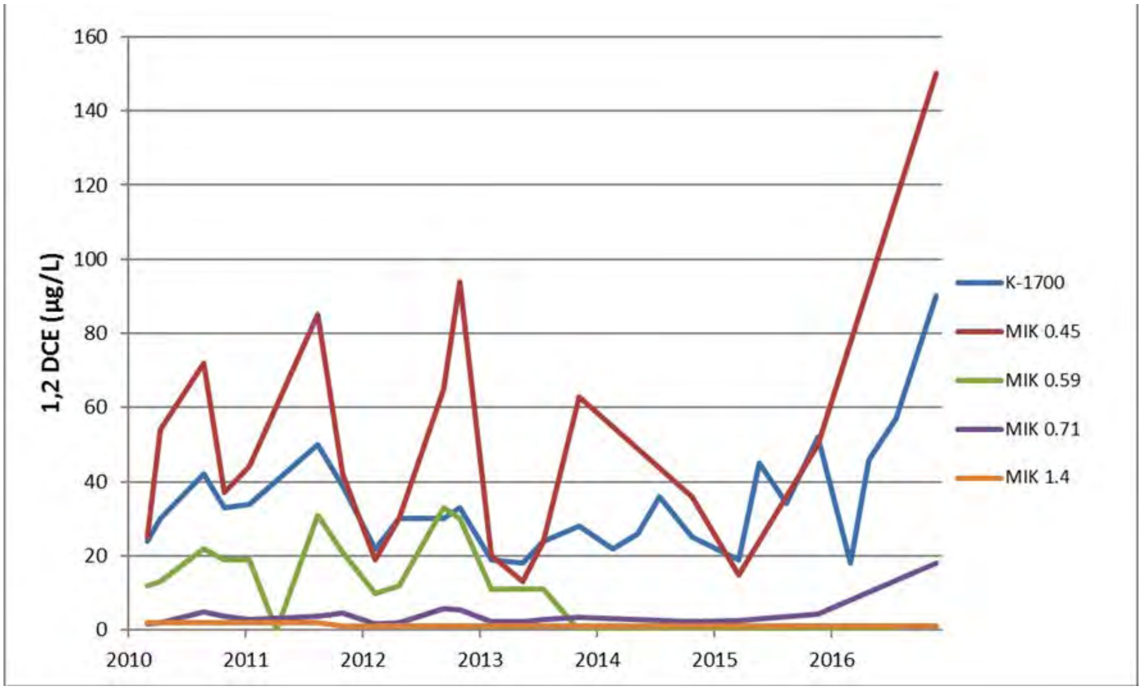


Fig. 3.29. Concentrations of cis-1,2-dichloroethene in Mitchell Branch. *(MlK = Mitchell Branch kilometer)*

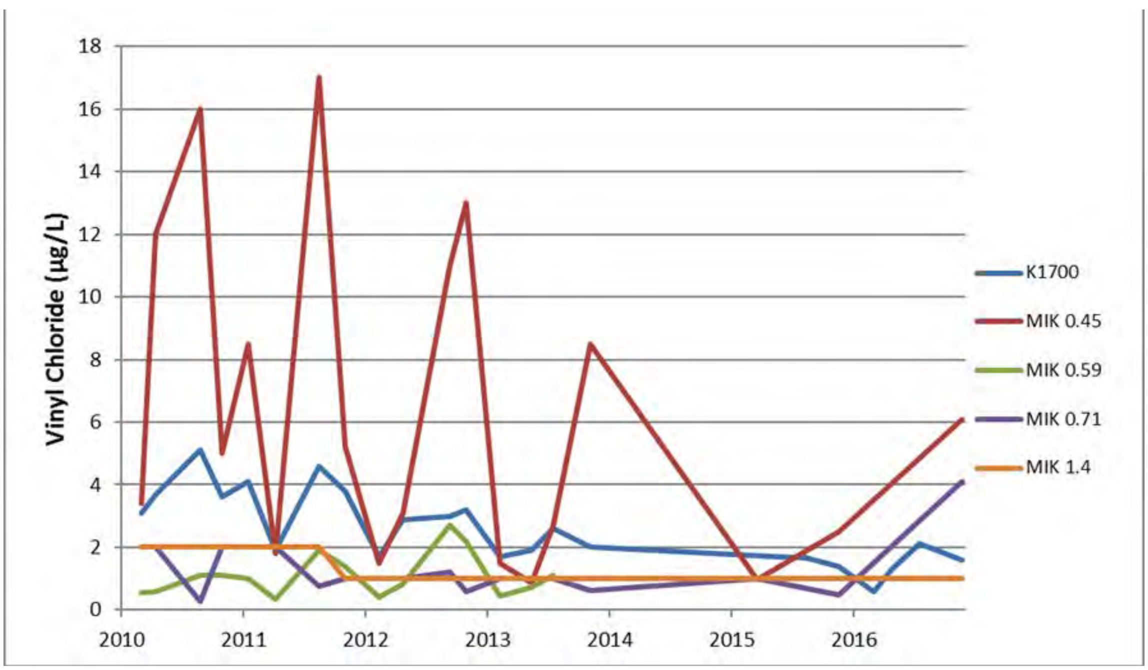


Fig. 3.30. Vinyl chloride concentrations in Mitchell Branch. *(MlK = Mitchell Branch kilometer)*

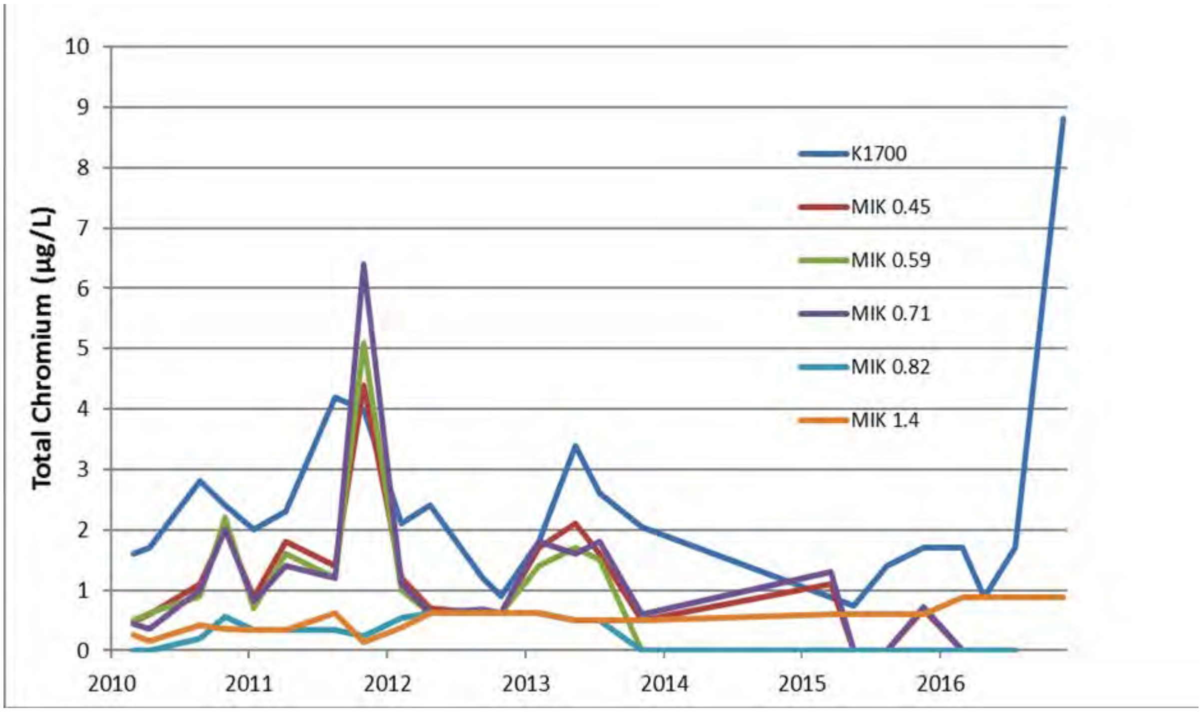


Fig. 3.31. Total chromium concentrations at K-1700. *(The AWQC for Cr(III), which is hardness-dependent, is 74 µg/L, based on a hardness of 100 mg/L. The AWQC for Cr(IV) is 11 µg/L. (AWQC = ambient water quality criterion, MIK = Mitchell Branch kilometer)*

3.6.4 Groundwater Monitoring

3.6.4.1 Groundwater Exit Pathways

Groundwater exit pathway monitoring sites are shown in Fig. 3.32. Groundwater monitoring results for the exit pathways are discussed below:

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. Section 3.6.3 includes discussion of the detected concentrations of VOCs in Mitchell Branch.

Wells BRW-083 and UNW-107, located near the mouth of Mitchell Branch, have been monitored since 1994. Table 3.24 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 2016, no chlorinated VOCs were detected in either 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 and arsenic. Antimony was detected at very low, estimated concentration in both wells. Well BRW-003 had an antimony detection of 0.11 µg/L (J) in the September sample and well BRW-017 had 0.1 µg/L in the March sample with a nondetect result in September. Arsenic

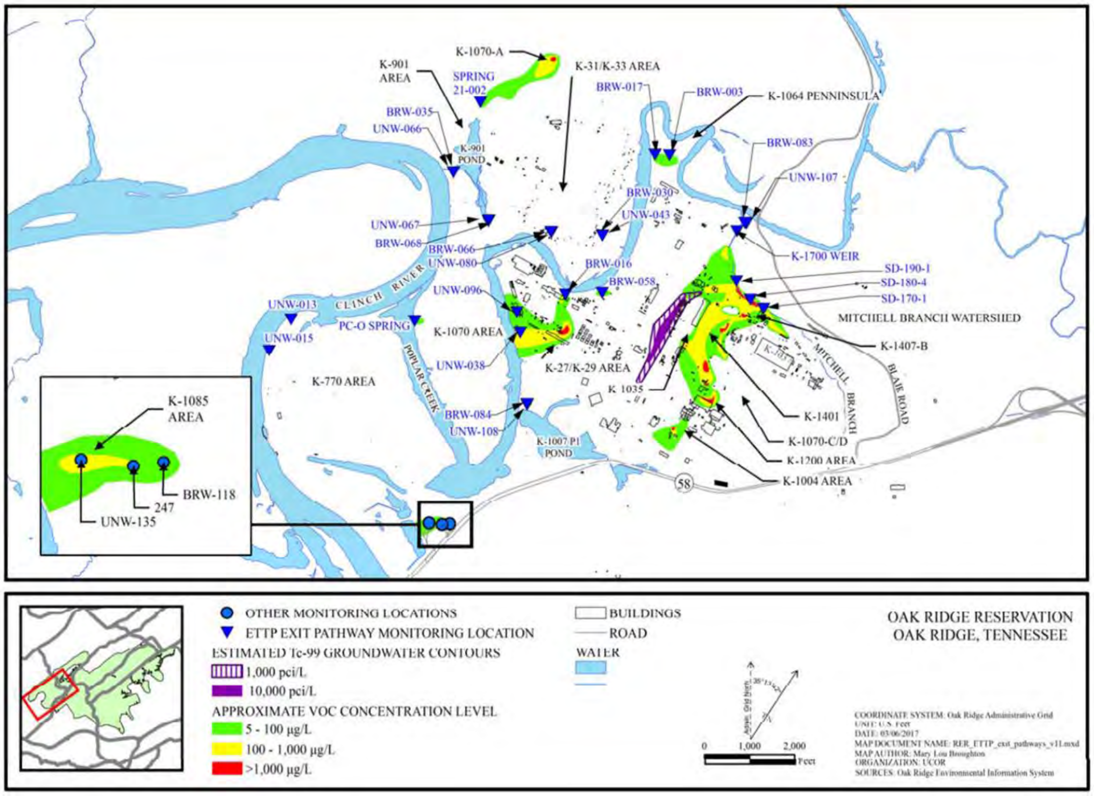


Fig. 3.32. ETTP exit pathways monitoring locations.

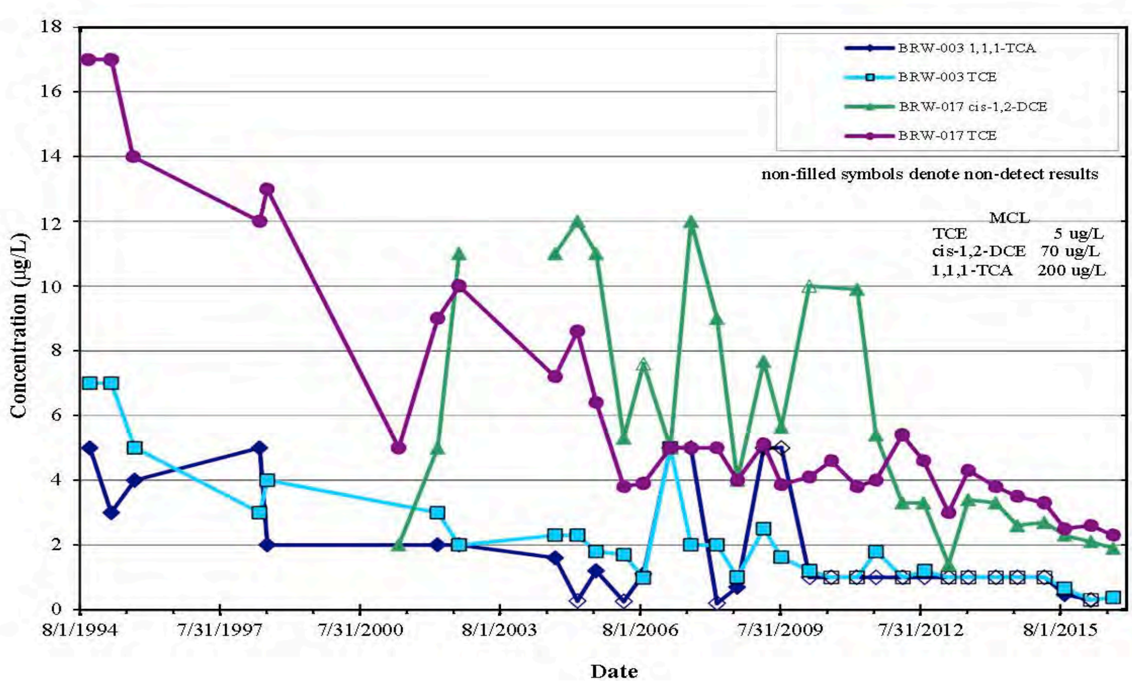


Fig. 3.33. VOC concentrations in groundwater at K-1064 Peninsula area.

was also detected in both wells with maximum concentrations of 0.015 mg/L in well BRW-003 in September and 0.016 mg/L in well BRW-017 in March. Figure 3.33 shows the history of significant VOC

detections in groundwater from FY 1994 through FY 2016. 1,1,1-TCA was detected at 0.65 µg/L (J) in well BRW-003 in the September sample and was not detected in the March sample. Cis-1,2-DCE was detected in well BRW-017 at 2.1 and 1.9 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 2016 at both wells. In well BRW-017, TCE was detected at concentrations of 2.6 and 2.3 µg/L in March and September, respectively. At well BRW-003, TCE was detected at 0.38 µg/L (J) in the September sample and was not detected in the March sample.

K-31/K-33 area—Groundwater is monitored in 4 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 recirculated cooling water in the past have left residual subsurface chromium contamination. Chromium concentrations in the unconsolidated zone wells (UNW-043 and UNW-080) have exceeded the 1 mg/L MCL screening concentration in the past while levels have been much lower in the bedrock wells. Figure 3.34 shows the history of chromium detection in wells UNW-043 and UNW-080. Groundwater at well UNW-043 exhibits 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 recirculated cooling water leaks. The data indicated the chromium in groundwater near the leak sites was essentially all the less toxic trivalent species. During FY 2008 through FY 2016, field-filtered (i.e., dissolved) and unfiltered samples were collected from UNW-043. Chromium concentrations in the field-filtered samples are consistently much less than the MCL and during FY 2016 the chromium concentration in filtered aliquots were 0.017 mg/L and 0.0056 mg/L in March and August, respectively. During FY 2016, both field-filtered and unfiltered samples were collected for chromium analysis from wells BRW-066, UNW-030 and UNW-080. All results in samples from UNW-030 and UNW-080 were less than the MCL. Chromium was below the detection limit in all samples from well BRW-066 during FY 2016.

K-27/K-29 area—Several exit pathway wells are monitored in the K-27/K-29 area. Figure 3.35 provides concentrations of detected VOCs in wells both north and south of K-27 and K-29 through FY 2016. 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 while cis-1,2-DCE remains at concentrations slightly lower than 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 continue to gradually decrease and cis-1,2-DCE, which does not exceed its MCL, is the only detectable VOC in the well. At BRW-016, cis-1,2-DCE levels show a decreasing trend and VC has decreased to < 1 µg/L which is less than the MCL. 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 10–20 times the MCL.

Table 3.24. VOCs detected in groundwater in the Mitchell Branch Exit Pathway

Well	Date	cis-1,2-DCE	PCE	TCE	VC
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
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
	9/12/2012	ND	ND	ND	ND
	8/8/2013	ND	ND	ND	ND
	3/20/2013	ND	ND	ND	ND

Table 3.24. VOCs detected in groundwater in the Mitchell Branch Exit Pathway (cont.)

Well	Date	cis-1,2-DCE	PCE	TCE	VC
UNW-107	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

[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.
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

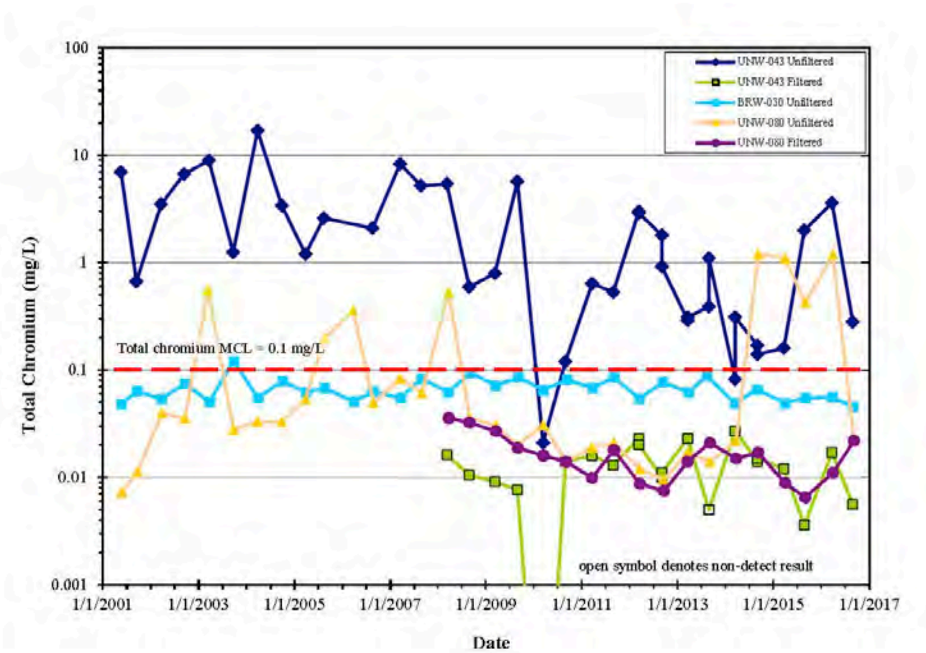


Fig. 3.34. Chromium concentrations in groundwater in the K-31/K-33 area.

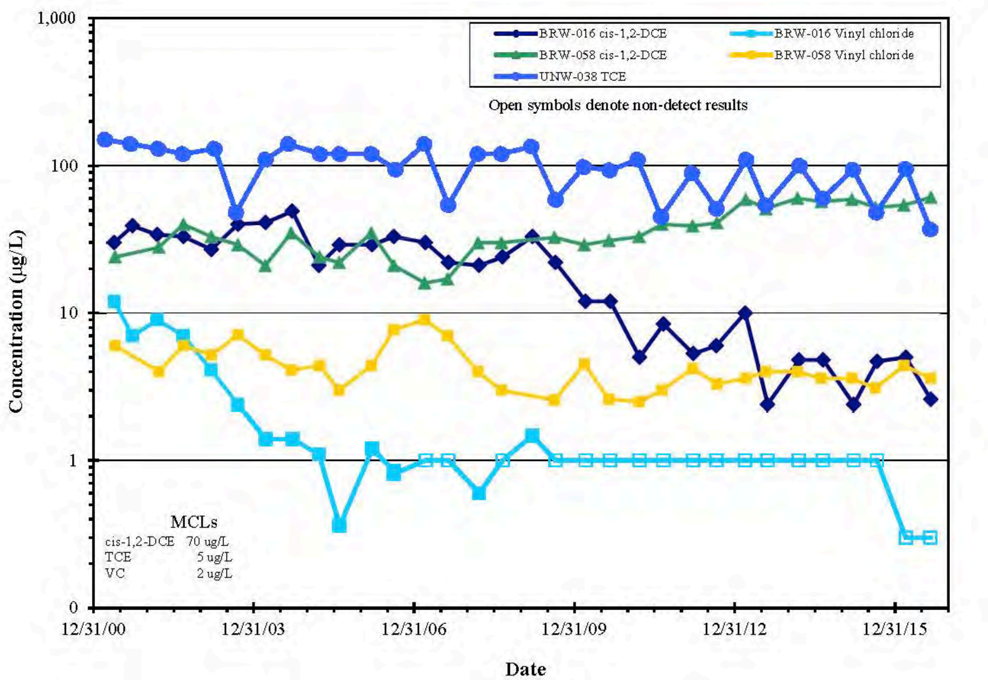


Fig. 3.35. Detected VOC concentrations in groundwater exit pathway wells near K-27 and K-29.

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 (Fig. 3.32). These wells were monitored intermittently from 1994 through 1998 and semiannually from FY 2001 through FY 2016. 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 2016, no VOCs were detected in either well. Metals continue to be detected and are associated with the presence of turbidity in the samples. Data from filtered samples indicate very low, apparently dissolved concentrations of antimony (0.22 µg/L (J) in well BRW-084 in August, and 0.11 µg/L (J) in well UNW-108 in August) and selenium (1.2 µg/L [J] in BRW-084 in March) were detected in FY 2016. Potential sources of these metals in this area are unknown and the detected concentrations are far below any criterion level.

K-901-A Holding Pond area—Exit pathway groundwater in the K-901-A Holding Pond area (Fig. 3.36) is monitored by four wells (BRW-035, BRW-068, UNW-066, and UNW-067) and two springs (21-002 and PC-0). 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. VOCs detected in the K-901-A Holding Pond exit pathway wells during FY 2016 include cis-1,2-DCE at 0.46 µg/L (J) and TCE at 0.31 µg/L (J) in the March sample from well BRW-035, and TCE at 0.48 J µg/L in the March sample from well UNW-066. At well BRW-035 alpha and beta activity levels have remained fairly consistent over the past several years with nondetect concentrations of alpha and beta levels between 10–15 pCi/L. Similarly, well BRW-068 has experienced fairly stable, low-to-nondetect concentrations of alpha and < 10 pCi/L of beta activity. In the past 2 years at well UNW-066, the alpha activity has exceeded the 15 pCi/L screening level in three of four samples, with a value of 62.5 pCi/L in August 2016. Likewise, the beta activity levels in well UNW-066 have exceeded the 50-pCi/L

screening level in three of four samples collected during FY 2015–2016. During August 2016, the beta activity was 79.9 pCi/L. In well UNW-067, the alpha and beta activity screening levels were not exceeded during FY 2016. Technetium-99 was analyzed in samples from wells UNW-066 and UNW-067 during FY 2016. Low concentrations of ^{99}Tc were detected in samples from both wells. In well UNW-066, the ^{99}Tc level was 8.81 pCi/L in March and, in well UNW-067, the level was 6.03 pCi/L in September.

TCE is the most significant groundwater contaminant detected in the springs, and the historic TCE concentrations are shown in Fig. 3.52. 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) located on Duct Island. The TCE concentrations in PC-0 spring have varied between nondetectable levels and 26 µg/L and have decreased from their highest measured value in 2006 to concentrations less than or several times the drinking water standard. During FY 2016, cis-1,2-DCE was detected at estimated low concentrations < 1 µg/L in PC-0 samples collected in November 2015 and in March and September 2016.

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 > 5 µg/L and 25 µg/L, and this variation appears to be related to variability in rainfall which affects groundwater discharge from the K-1070-A VOC plume. During FY 2016, the TCE detected concentrations ranged from a high of 24 µg/L in November 2015, to a low of 5.4 µg/L in March 2016. Alpha activity was detected at 3.13 pCi/L and 4.09 pCi/L in November and March samples, respectively; and detected beta activities were 20.8 pCi/L and 9.08 pCi/L in November and May samples, respectively. Technetium-99 detections ranged from 2.71 pCi/L to 19.9 pCi/L, much lower than the 900-pCi/L MCL-DC. Uranium-234, ^{235}U, and ^{238}U were detected at < 1 pCi/L.

The 10-895 spring discharges groundwater from beneath Black Oak Ridge along Poplar Creek, near Blair Road. Black Oak Ridge is located behind the ETTP site. The source of TCE has not been confirmed. Although the Contractors 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. TCE concentrations measured in samples from spring 10-895 are shown on Fig. 3.36. The highest TCE concentration measured was 5.6 µg/L. Cis-1,2-DCE was detected at 0.34 µg/L (J) in the September sample.

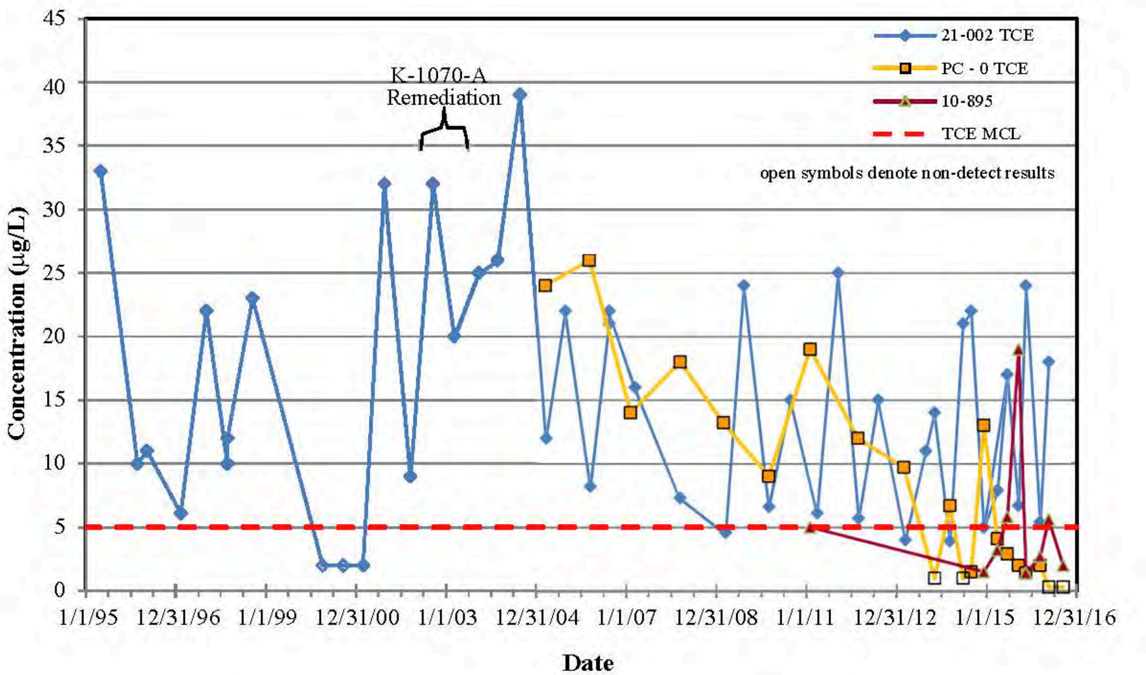


Fig. 3.36. TCE concentrations in selected ETTP area springs.

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 (Fig. 3.32). Measured alpha and beta activity levels were below screening levels during FY 2016, with the exception that beta activity in the September 2016 sample from well UNW-013 had 50.8 pCi/L (50 pCi/L is the beta activity screening level). Figure 3. 37 shows the history of measured alpha and beta activity in this area. Historic analytical results indicate that the alpha activity is largely attributable to uranium isotopes, and well UNW-013 historically contained ^{99}Tc that is a strong beta-emitting radionuclide responsible for the elevated beta activity in that well. Much lower alpha and beta activity levels have been measured in well UNW-015 since sampling was resumed in FY 2013 following an interruption in sampling during site remediation activities.

K-1085 Drum Burial/Old Firehouse Burn area—In October 2000, the TDOT encountered three buried drums adjacent to State Route 58 (locally known as Highway 58) during a road-widening project. This discovery triggered a CERCLA Removal Action to identify buried waste at the site and to excavate and dispose of the waste at the Environmental Management Waste Management Facility (EMWMF). Approximately 77 m^3 of mixed RCRA, TSCA, and low-level waste (LLW) was excavated from five separate locations at the 12,000 ft^2 site. In 2005, the area was further characterized, and in 2008, an additional 300 yd^3 of soil were removed for disposal. During 2010−2011, four groundwater monitoring wells were installed at the site. One bedrock well (BRW-118) was installed at the downslope edge of the excavation area to monitor contaminants in the bedrock groundwater zone, which might indicate the presence of DNAPLs beneath the site. Three unconsolidated zone wells were installed radial to the excavation site in directions of potential groundwater movement. Initial sampling of all four wells showed the presence of VOC contamination in two of the wells, BRW-118 and UNW-135, and in a surface seep location (247). Wells BRW-118 and UNW-135 are sampled semiannually to provide contaminant trend data. Figure 3.38 shows the VOC monitoring results from BRW-118 and UNW-135. In well BRW-118 PCE and TCE both exceed their 5 µg/L MCL screening levels and both exhibit seasonal

fluctuations. The detected concentrations of cis-1,2-DCE, carbon tetrachloride, and chloroform in well BRW-118, are all less than MCL screening levels. At well UNW-135, TCE continually exceeds its 5 mg/L MCL screening level, although cis-1,2-DCE concentrations dipped below its 70 µg/L MCL screening level between March 2014 and March 2016, with the most recent point reaching 85 µg/L. The measured VOC concentrations at the site are indicative of dissolved phase contamination in the groundwater. Concentration trends at the K-1085 site are generally decreasing although concentrations fluctuate based on seasonal influences.

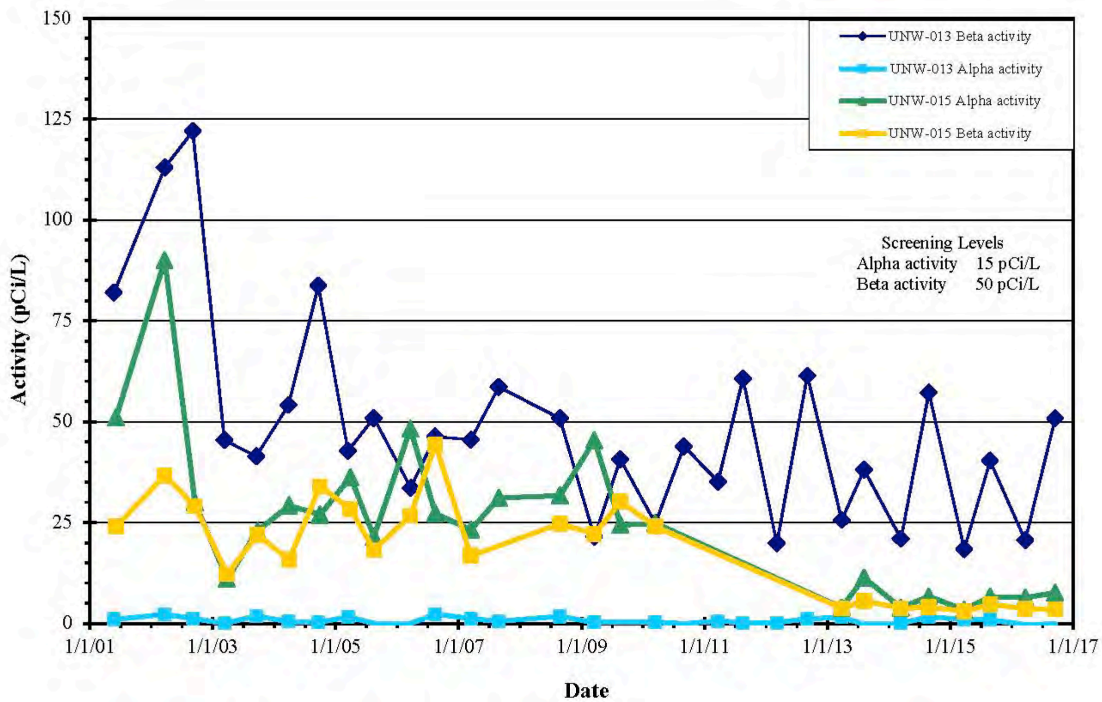


Fig. 3.37. History of measured alpha and beta activity in the K-770 area.

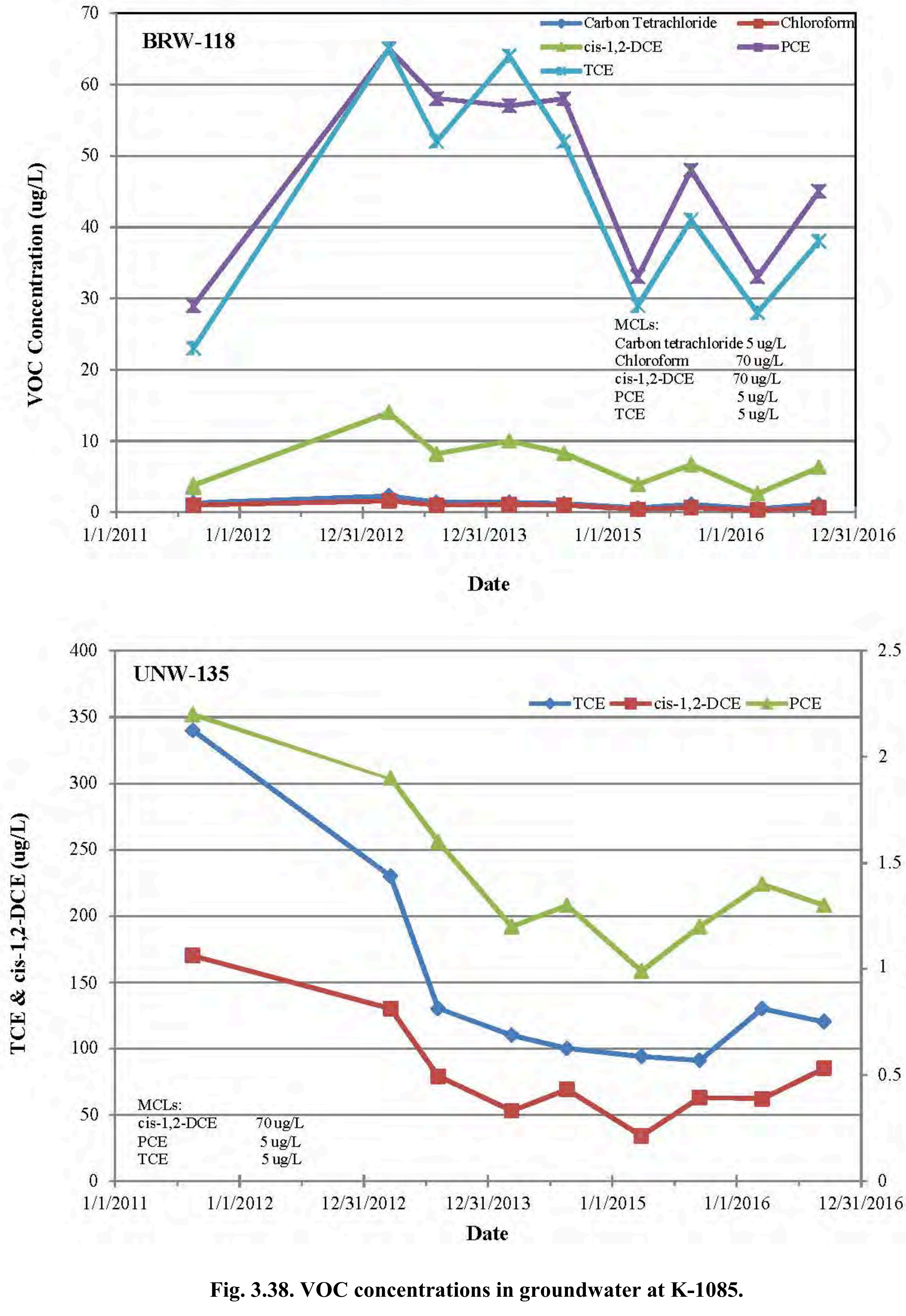


Fig. 3.38. VOC concentrations in groundwater at K-1085.

3.6.4.2 ^{99}Tc 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 environmental fate of some metal contaminants in groundwater is strongly dependent on the pH and redox 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 the Hanford Site in the state of Washington. 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.

During demolition of the K-25 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. During FY 2016, the third and final phase of subsurface investigation work was completed. The investigation included additional shallow piezometer installation and sampling along the abandoned electrical duct bank to the north of the ^{99}Tc source area and installation of two bedrock wells and one additional unconsolidated well in locations downgradient from the source area.

The scope of investigations focused on understanding the role of site subsurface infrastructure in migration of ^{99}Tc away from the K-25 east wing source area and the involvement of groundwater. The investigations primarily used push technology to sample soil along and beneath portions of SDs, sanitary sewer pipes, and the abandoned electrical ductbank that formerly carried electrical cables along the east side of the K-25 building. Temporary polyvinyl chloride (PVC) piezometers were installed in each of the Phase 1 and 2 boreholes to allow observation of groundwater levels and to provide groundwater samples for ^{99}Tc and/or VOC analyses. The Phase 3 investigation included seven push probe sample locations and installation of two permanent bedrock monitoring wells and one unconsolidated zone well.

The investigations determined that although ^{99}Tc entered and traveled through the sanitary sewer and the SD that discharges to the K-1007-P1 Holding Pond, the amount of ^{99}Tc transport in backfill outside those pipes was minimal. The investigation 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. Twenty-one of the groundwater investigation locations installed in the RmSE are retained for long term monitoring and to support future CERCLA groundwater decisions at ETTP. During FY 2016, groundwater was analyzed for ^{99}Tc in samples from 68 wells across the ETTP area. The highest concentrations remain centered along the eastern side of the K-25 Building. An *Addendum to the Technetium-99 Removal Site Evaluation at the East Tennessee Technology Park, Oak Ridge, Tennessee* (DOE/OR/01-2663&D1/A2) was issued in August 2016, providing documentation of the investigation and results.

3.6.4.3 Technetium-99 sampling investigation

The conclusion of the *Technetium-99 Removal Site Evaluation at the East Tennessee Technology Park, Oak Ridge, Tennessee* (DOE/OR/01-2663&D1) indicated the measured levels of Tc-99 in site surface water releases were in compliance with applicable regulatory requirements and DOE Orders in prior years and do not pose a threat to human health and the environment. The discussion that follows describes the sewage sampling that continued in FY 2016.

3.6.4.4 Sanitary sewer

The Tc-99 sampling for FY 2016 continued to show declining trends:

- Concentrations at the Rarity Ridge Lift Station #1 ranged from a high of 85 pCi/L to a low of 6 pCi/L.
- Concentrations at the Rarity Ridge Effluent Weir ranged from a high of 90 pCi/L to a low of 25 pCi/L.
- Concentrations at the Rarity Ridge Biological Treatment Aeration Basins ranged from a high of 7,690 pCi/L to a low of 3,350 pCi/L.
- Concentrations at the Rarity Ridge Digester ranged from a high of 171,000 pCi/L to a low of 68,200 pCi/L.

- During FY 2016, five tanker shipments of approximately 5,000 gal per tanker of digester sludge were pumped and shipped off-site for treatment as LLW.

The ^{99}Tc sewage treatment network influent concentrations and STP effluent discharges in FY 2016 were both in compliance with DOE Order 458.1 and state of Tennessee annual SOF criteria.

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 3.39 shows the major water bodies at ETTP and Fig. 3.40 shows the BMAP monitoring locations along Mitchell Branch.

3.7.1 Bioaccumulation Studies

The bioaccumulation task includes monitoring of caged Asiatic clams (*Corbicula fluminea*; Fig. 3.41) 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 contaminant of concern (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 2016, the clams were deployed for four weeks. They were then analyzed for PCBs (as Aroclors; Fig. 3.42) and, at all but one of the sites, for total and methylmercury (Fig. 3.43). In general, there is significant variability in PCB concentrations in the clams from year to year, although there are some overall trends of note. In 2016, the greatest concentrations of PCBs were found in the clams from storm water Outfall 190 and downstream of that location in Mitchell Branch, as has been seen in recent years. The concentrations of PCBs in the clams from the K-1007-P1 pond were significantly lower in the 2015 and 2016 samples than in the 2013 and 2014 samples.

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 2016. The highest mean total mercury concentrations were found in the clams from storm water Outfall 180 (0.136 µg/g). Clams from the section of Mitchell Branch between K-1700 and Outfall 190 also had elevated concentrations, ranging from a low of 0.03 µg/g to a high of 0.08 µg/g. At other sites, mercury concentrations in clams ranged from at or near reference values to fourfold higher (e.g., from 0.019 µg/g to 0.078 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 2016 ranged from a low of 0.005 µg/g in the clams from K-897-K to a high of 0.020 µg/g in the clams from MIK 0.2. 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 0.011 µg/g).

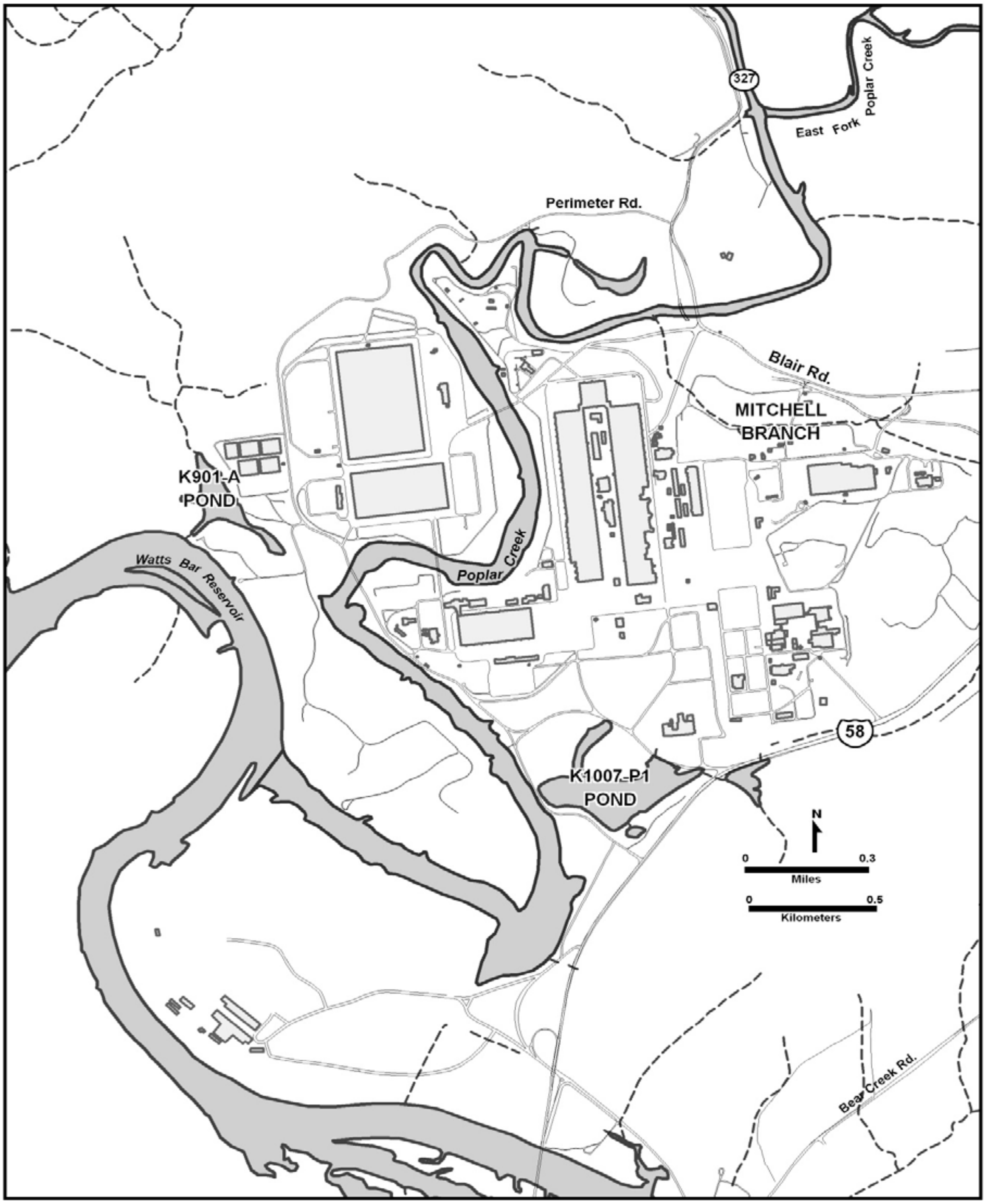


Fig. 3.39. Water bodies at the East Tennessee Technology Park.

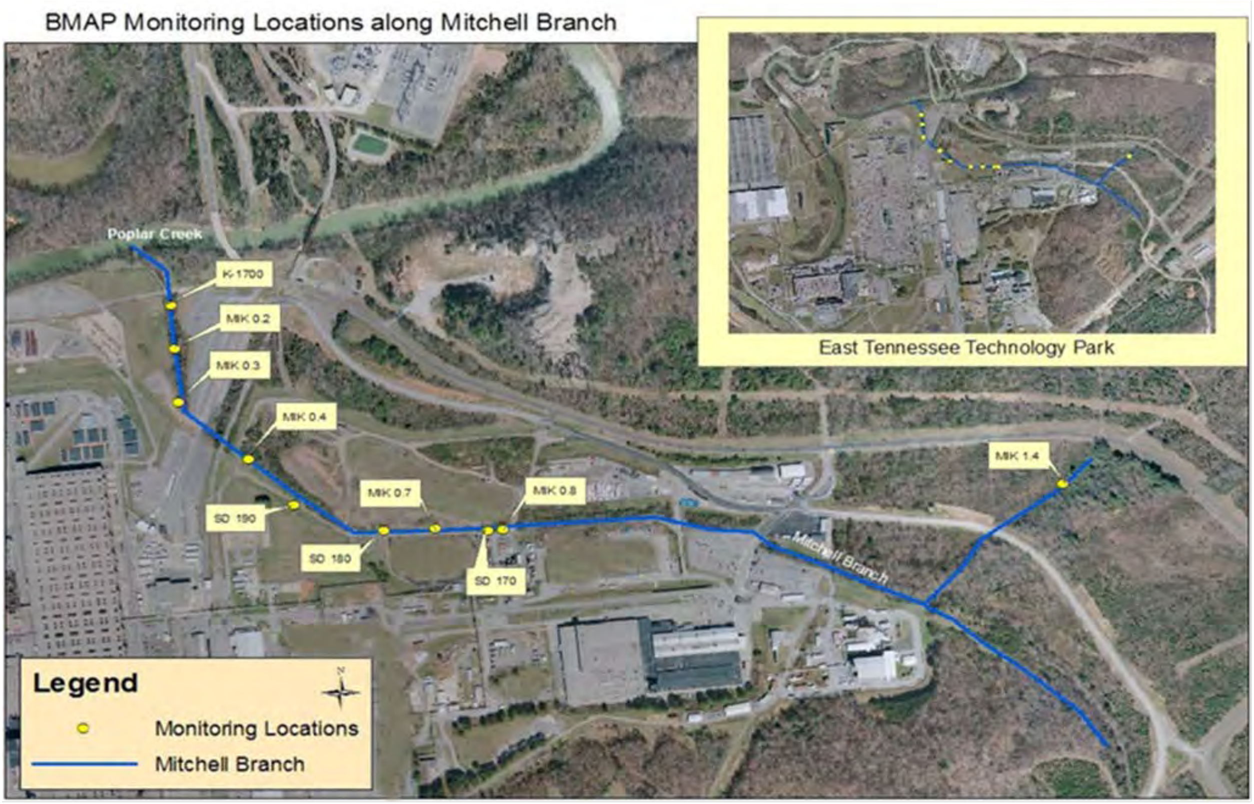


Fig. 3.40. Major storm water outfalls and biological monitoring locations on Mitchell Branch.
(BMAP = Biological Monitoring and Abatement Program, MIK = Mitchell Branch kilometer, and SD = storm water outfall/storm drain)

Bioaccumulation monitoring in the K-1007-P1 pond, K-901-A pond, K-720 slough, and Mitchell Branch involves sampling fish (Fig 3.44) and analyzing the tissues for PCB concentrations (Fig. 3.45). 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 2016 in the K-1007-P1 pond was bluegill sunfish (*Lepomis macrochirus*) (Fig. 3.46). 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 (six composites of 10 bluegill) 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 1.91 µg/g total PCBs, down slightly from 2.03 µg/g in 2015. Fillets averaged 1.06 µg/g total PCBs, slightly higher than concentrations seen in 2015 (0.45 µg/g). Average PCB concentrations in sunfish fillets collected in Mitchell Branch were 1.95 µg/g, slightly lower than the levels seen in 2015 (2.71 µg/g). The concentrations observed in fillets of largemouth bass from the K-901-A pond (0.90 µg/g) increased slightly from the concentrations seen in the 2015 monitoring, 0.66 µg/g. Fillets of carp from the K-901-A pond averaged 1.43 µg/g. Gizzard shad whole body composite samples from K-901-A pond (4.52 µg/g) decreased slightly from the concentrations seen in the 2015 monitoring (5.41 µg/g). Levels of PCBs in

bass, gizzard shad, and carp from the K-720 slough (0.07 µg/g, 0.40 µg/g, and 0.31 µg/g, respectively) were considerably lower than for the same species from the K-901-A pond.

ORNL 2010-G00934/chj

Fig. 3.41. Asiatic clam (*Corbicula fluminea*).

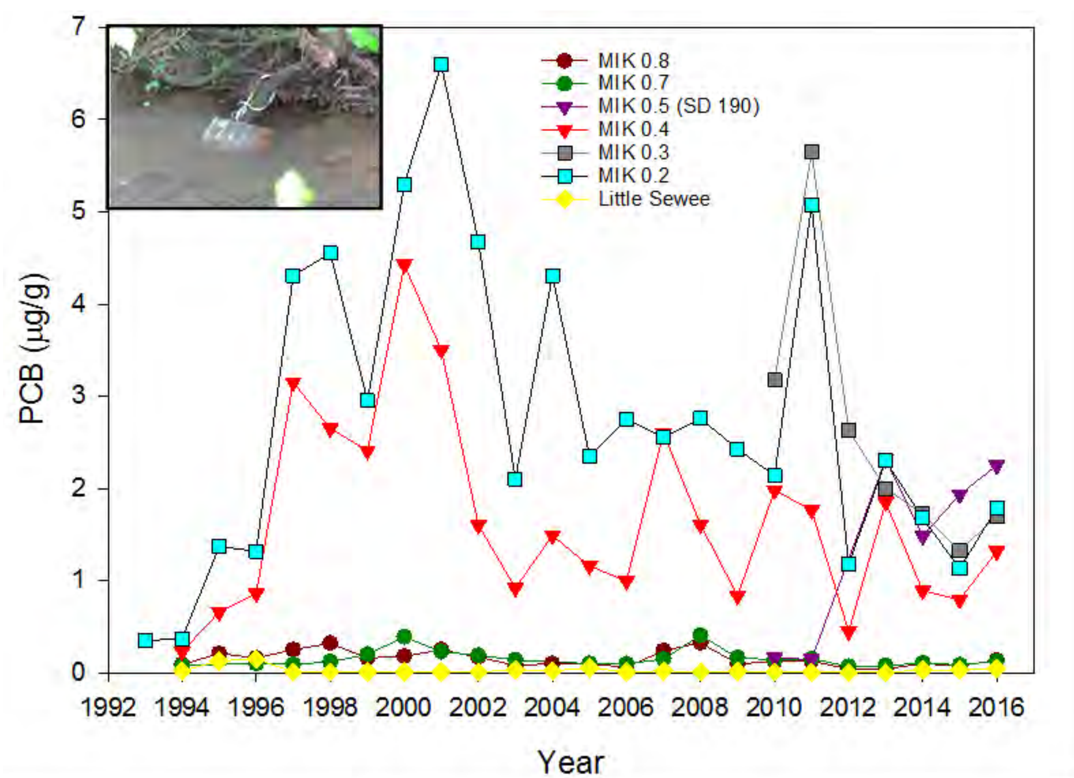


Fig. 3.42. Mean total polychlorinated biphenyl (PCB) (µg/g, wet wt; 1993–2016) concentrations in the soft tissues of caged Asiatic clams deployed in Mitchell Branch. *N = 2 composites of 10 clams each per year. Shown in yellow are data for clams collected from the reference site, Little Sewee Creek (Sweetwater, Tennessee). Total PCBs defined as the sum of Aroclors 1248, 1254, and 1260. (MIK = Mitchell Branch kilometer)*

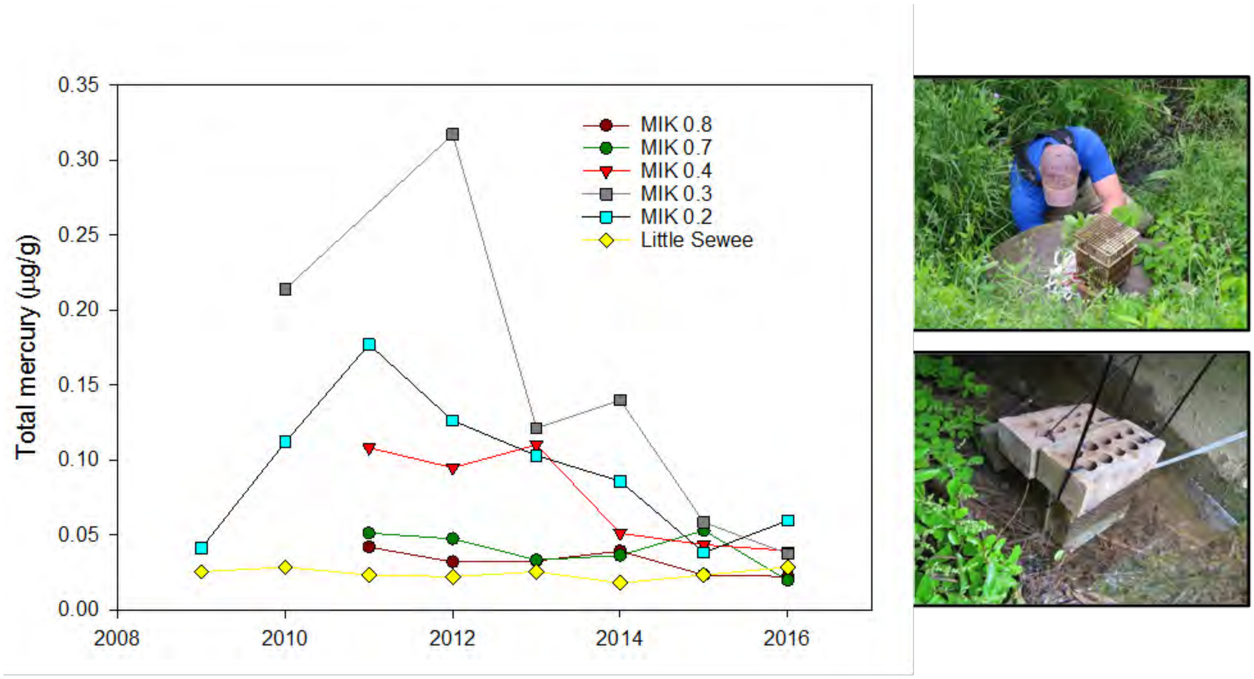


Fig. 3.43. Mean total mercury (µg/g wet wt; 2009–2016) concentrations in the soft tissues of caged Asiatic clams deployed in Mitchell Branch. *N = 2 composites of 10 clams each per year. Shown in yellow are data for clams collected from the reference site, Little Sewee Creek (Sweetwater, Tennessee). (MIK = Mitchell Branch kilometer)*

Fig. 3.44. Fish bioaccumulation sampling at K-1007-P1 pond.

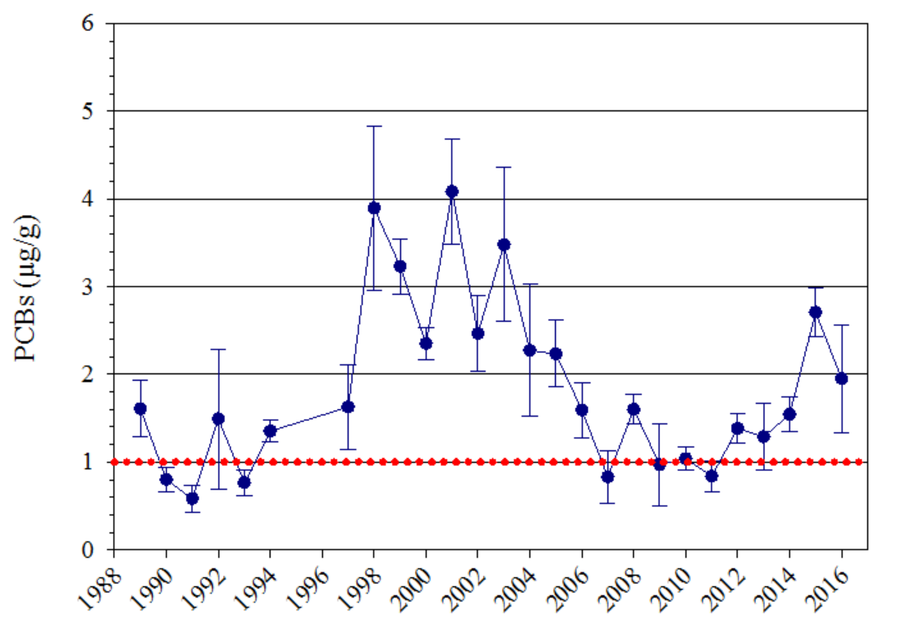


Fig. 3.45. Mean (+/- standard error) polychlorinated biphenyl (PCB) concentrations (µg/g, wet wt) in redbreast sunfish fillets in Mitchell Branch (MIK 0.2).

1989–2016, N = 6 fish per year. Shown in red is the fish advisory level for PCBs (1 µg/g).

ORNL 2011-G00782/chj

Fig. 3.46. Bluegill sunfish (Lepomis macrochirus).

In addition to being analyzed for PCBs, selected species collected from several locations were analyzed for total mercury (Fig. 3.47). Previous studies have shown that methylmercury accounts for more than 95% 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 0.41 µg/g in 2016, the same as in 2015. 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% variability within the annual collection. Fillets of sunfish from the reference site, Hinds Creek, averaged 0.07 µg/g of mercury in 2016.

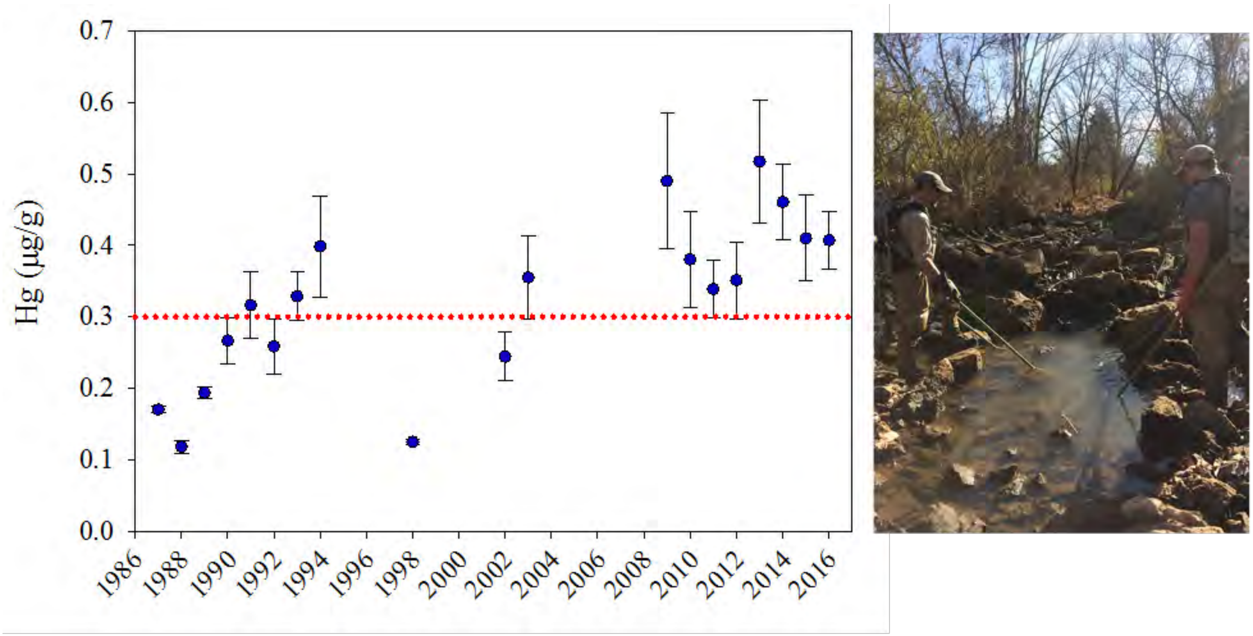


Fig. 3.47. Mean total mercury (Hg) concentrations (µg/g, wet wt) in redbreast sunfish fillets in Mitchell Branch (MIK 0.2). *1989–2016, N = 6 fish per year. Shown in red is the fish advisory level mercury (0.3 µg/g). The photograph shows fish electrofishing activities in lower Mitchell Branch.*

3.7.2 Instream Monitoring of Biological Communities

In April 2016, 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 (Fig. 3.48). MIK 1.4 was the reference location. Results of monitoring in 2016 using the ORNL protocols show little change at the three uppermost locations (MIKs 1.4, 0.8, and 0.7). The number of pollution-intolerant species is highest at MIK 1.4 (Fig. 3.49). Pollution-tolerant species make up a higher percentage of the total number of individuals at MIK 0.7. Otherwise, except for the period from 2010–2012, trends in change at MIK 0.4 have generally mirrored those at MIKs 0.7 and 0.8. In recent years, the benthic macroinvertebrate community at MIK 0.7 and MIK 0.8 has shown no major persistent change in trends of either the mean number of taxa (taxonomic richness of all taxa) or the mean number of pollution-intolerant taxa (i.e., the taxonomic richness of the *Ephemeroptera*, *Plecoptera*, and *Trichoptera* [EPT]— mayflies, stoneflies, and caddisflies). These results show that the benthic community at MIK 0.4 continues to be negatively impacted while the results for MIKs 0.7 and 0.8 suggest that the macroinvertebrate community at those sites is affected to a lesser degree.

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 (Fig. 3.50). The 2016 biotic index indicated that the communities at MIKs 0.7, 0.8, and 1.4 were nonimpaired, and the community at MIK 0.4 was slightly impaired. The habitat assessment (which primarily considers the physical aspects of the stream to determine its suitability to support biological communities) in 2016 indicated habitat impairment at MIKs 0.4, 0.7, and 1.4, while the habitat at MIK 0.8 was rated as unimpaired. 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. Habitat assessments show evidence of some impairment at all sites.

Fig. 3.48. Benthic macroinvertebrate sampling in Mitchell Branch.

Fish communities in MIKs 0.4 and 0.7 and at local reference sites were sampled in 2016. In Mitchell Branch, species richness (number of species; Fig. 3.54), density (fish/m²; Fig. 3.52), and biomass were assessed for comparison with area reference streams. Results for 2016 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 (Fig. 3.54) increased from 2015, with a slight decrease in both density and biomass. MIK 0.7 had an increase in species richness and biomass, and a decrease in density. Overall, variations in these three parameters 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 2016, the fish community was comprised primarily of sunfish (> 65%) and gizzard shad (22.4%), with largemouth bass and other species comprising small percentages. These numbers continue to vary from year to year, indicating that the population has not reached a state of balance yet, but they do continue to indicate a movement towards the goal of a sunfish-dominated community.

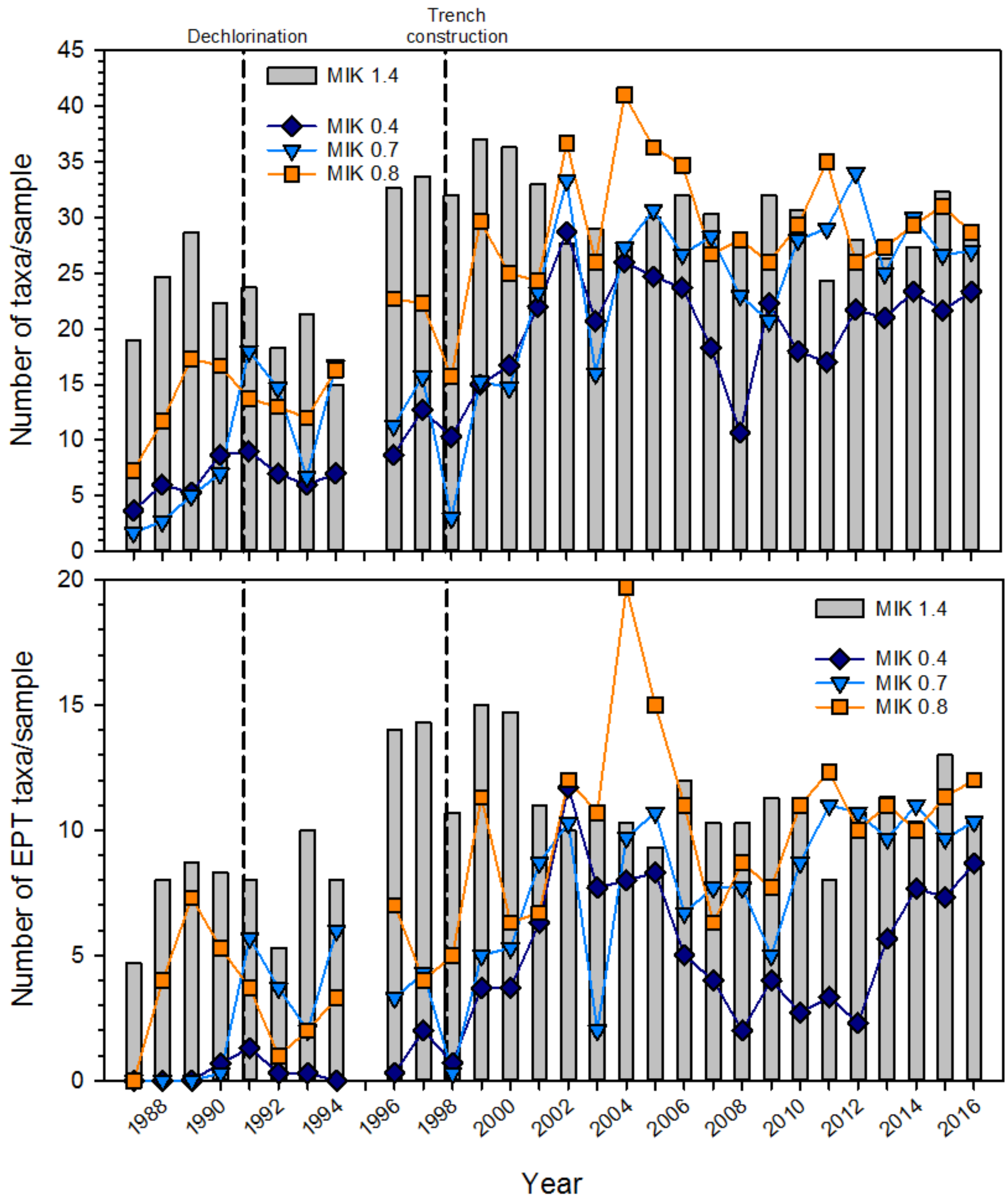
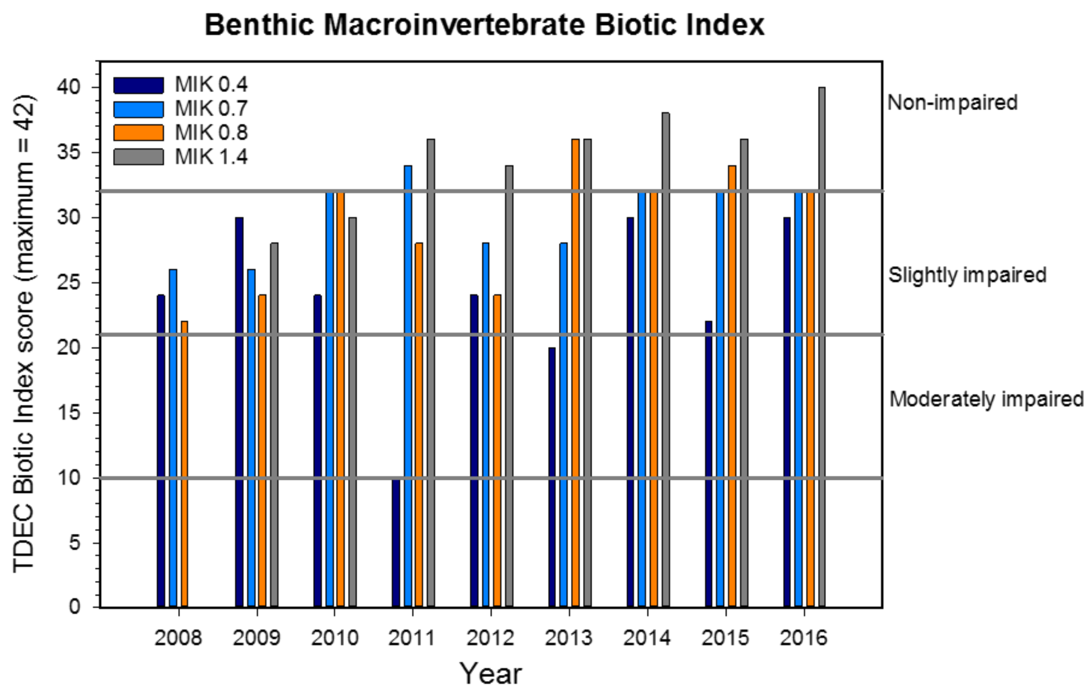


Fig. 3.49. Mean taxonomic richness in Mitchell Branch, 1987–2016 *(a) number of all taxa, and (b) number of pollution-intolerant Ephemeroptera, Plecoptera, and Trichoptera (mayflies, stoneflies, and caddisflies, or EPT) taxa per sample. Samples were not collected in April 1995, as indicated by the gap in the lines. (MIK = Mitchell Branch kilometer)*



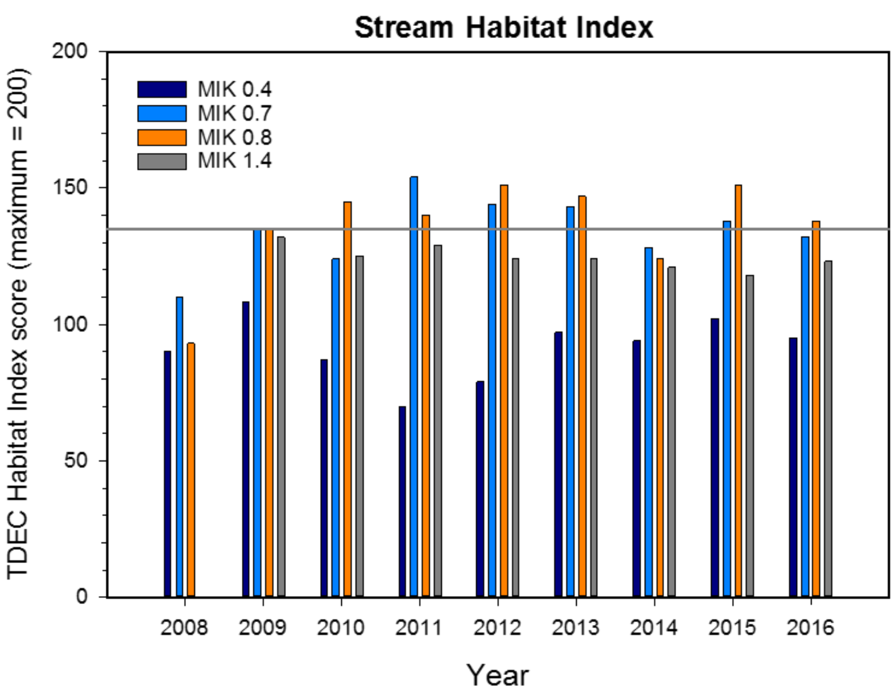


Fig. 3.50. Temporal trends in Tennessee Department of Environment and Conservation (TDEC) Benthic Macroinvertebrate Biotic Index (a) and Stream Habitat Index (b) scores for Mitchell Branch, August 2008–2016. *Horizontal lines in both graphs show the lower thresholds for narrative index ratings; respective narrative ratings for each threshold are shown on the right side of each graph. (MIK = Mitchell Branch kilometer)*

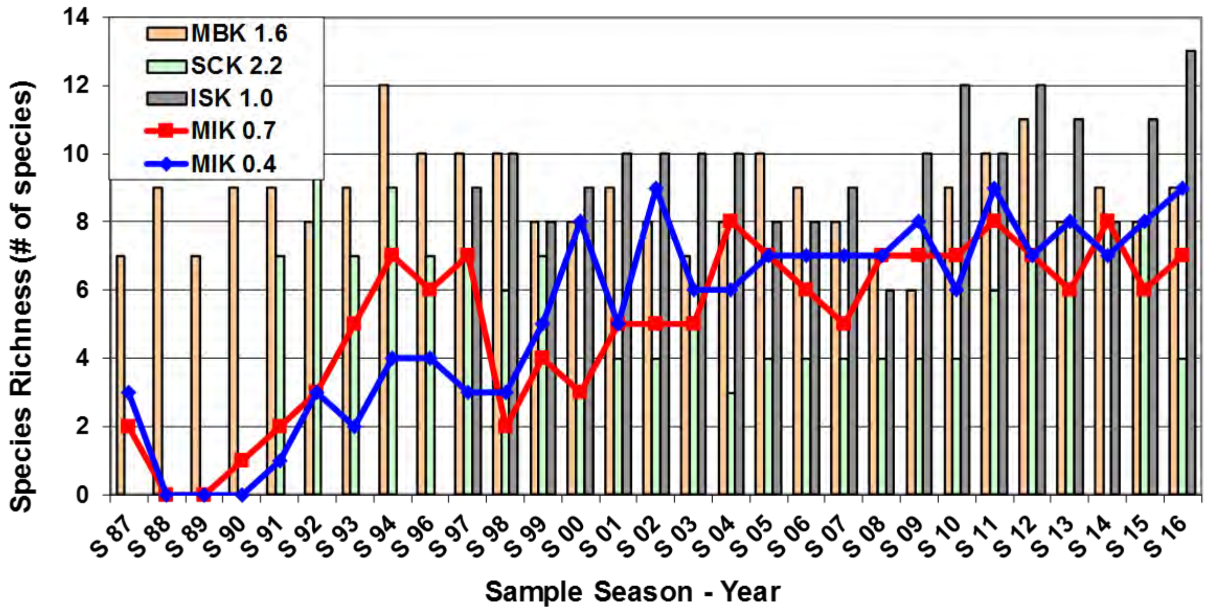


Fig. 3.51. Species richness for fish communities at sites in Mitchell Branch and in reference streams.
(ISK = Ish Creek kilometer, MBK = Mill Branch kilometer, MIK = Mitchell Branch kilometer, SCK = Scarboro Creek kilometer)

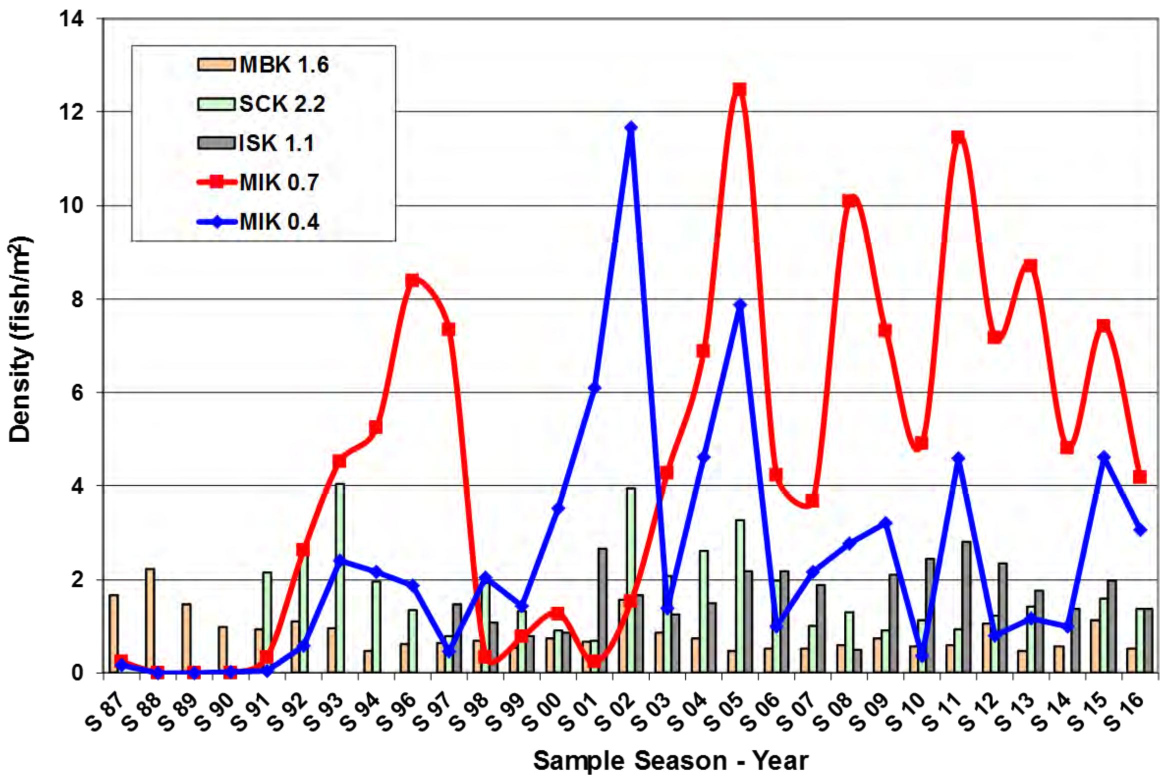


Fig. 3.52. Density for fish communities at sites in Mitchell Branch, and in reference streams.
(ISK = Ish Creek kilometer, MBK = Mill Branch kilometer, MIK = Mitchell Branch kilometer, SCK = Scarboro Creek kilometer)

3.8 Environmental Management and Waste Management Activities

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 3.6.2.7 provides a more detailed discussion of CWTS operations.

3.8.1 Environmental Remediation Activities

EM continued remediation activities to reduce ETTP soil contamination in 2016. In FY 2016 the groundwater treatability study that will help determine the effectiveness of different treatment technologies that will assist in identifying and selecting the ETTP's final groundwater remedy continued. The 2016 effort included characterization to support the design of a pilot scale *in situ* thermal treatment study in the K-1401 area. The work plan was updated and approved by regulators and planning was initiated. Sitewide groundwater and surface water data are being evaluated in conjunction with the treatability study activities that support the preparation of CERCLA documentation leading to a final sitewide ROD.

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.

3.8.1.1 Zone 1

The interim Zone 1 ROD, which documents the cleanup method for the site, required EM to remediate soil to a depth of 10 ft (suitable for the protection of an industrial work force) and remove sources of groundwater contamination. As part of this interim ROD, an evaluation of the K-1065 former waste storage area was conducted and the determination was made that no further cleanup is required in this area. This outcome makes the area available for industrial use.

3.8.1.2 Zone 2

The Zone 2 ROD divides the zone into seven geographic areas and 44 EUs that range in size from 6 to 38 acres.

In FY 2016, UCOR completed remediation of EU Zone 2-28 and the confirmation sampling. EPA and TDEC approved concurrence forms documenting the completion. The area is in the former administrative section of ETTP and generally housed offices and laboratories. The area has now been recommended for unrestricted industrial use.

The Building K-25 and K-31 footprint areas were also characterized. It was determined that the K-25 footprint will require remediation, but that the K-31 footprint will require no further action. The K-25 footprint has been dedicated for historical commemoration and interpretation activities. The characterization data are being used to evaluate potential end states that can preserve the building slab.

The remainder of Zone 2 is still being characterized. EU Zones 2-28 and 2-41 were remediated. This remediation action resulted in the disposal of 5,850 yds^3 of soil and debris at EMWMF and the Nevada National Security Site. No further remedial actions will be required at these two areas.

3.8.1.3 Technetium-99 GW Investigation

Elevated levels of ^{99}Tc, a slowly decaying isotope, were observed in groundwater, storm water, and sanitary sewage during the demolition of the K-25 building. In 2016, the shallow groundwater investigation near the K-25 Building slab was completed. It was determined that the migration of ^{99}Tc outside of sanitary sewer and storm drain lines in subsurface utility corridors has been limited. However, 21 locations will be retained for future groundwater monitoring.

3.8.1.4 Building K-27 Demolition

Demolition of the K-27 building in 2016 marked the first time in the world that all of a former enrichment complex's process buildings were successfully removed. UCOR completed the demolition nine months ahead of schedule and $2.8 million under budget.

3.8.1.5 Building K-731 Demolition

In addition to completing the Bldg. K-27 demolition, demolition of buildings that supported the gaseous diffusion operations also were conducted in 2016.

Demolition began on the K-731 Switch House. The three-floor building was built in 1944 to provide electrical power to the K-27 process building, and was later enlarged to also provide electrical power to the K-29 process building.

3.8.1.6 Building K-1037 Deactivation Begins

The deactivation of K-1037 began in 2016. Deactivation is the initial step that prepares the facility for eventual demolition. The facility is one of the highest remaining cleanup priorities at ETTP.

K-1037 was originally a warehouse that was later converted into a facility that produced the porous barrier material used in the gaseous diffusion process to separate the ^{235}U from the ^{238}U isotopes. Currently, the facility contains the barrier material from the sites former enrichment operations.

Work conducted in 2016 included asbestos abatement, universal hazardous waste disposal, chemical removal, and radiologic surveys. All electrical and mechanical hazardous energy sources were also removed. Temporary power to support facility deactivation activities was installed. Demolition is expected to begin in 2018.

3.8.1.7 Poplar Creek Deactivation Underway

The deactivation of the 27 Poplar Creek facilities was underway in 2016, with approximately 40% of the deactivation completed by the end of FY 2016. These facilities provided a variety of supporting operations at the site and include storage buildings, water pumping houses, and sandblasting and painting activities. The deactivation process includes disconnecting utilities to these facilities, removing certain components, and performing other steps necessary to prepare the buildings for demolition.

Deactivation and demolition of the tie lines in the Poplar Creek area was also well underway and was approximately 45% complete by the end of FY 2016. The 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 inject foam into these lines to stabilize any remaining contaminants so they will meet the criteria necessary for disposal at EMWMF.

3.8.1.8 Converters Removed

The last of approximately 5,000 converters were removed from the ETTP and shipped to the Nevada National Security Site for disposition in 2016. The converters were part of the gaseous diffusion process used to enrich uranium.

3.8.1.9 Commemoration of the K-25 Site

Historic preservation of the K-25 Site continued in FY 2016 with the launch of the K-25 Virtual Museum, which is now available online at www.K-25virtualmuseum.org. The virtual museum shares oral histories from the site's former workers, and it recounts the history of the world's first gaseous diffusion plant and the hundreds of facilities and structures at ETTP.

Congress appropriated approximately $6 million for K-25 historic preservation activities. This funding is being used for the conceptual design of the Equipment Building, Viewing Tower, K-25 History Center, Wayside Exhibits, and K-25 slab delineation.

3.8.2 Reindustrialization

As cleanup has progressed extensively at ETTP, more large parcels are becoming available for transfer (Fig. 3.53). The completion of K-31 demolition allows for the first parcel of over 200 contiguous acres that can be developed for a large-scale, industrial project at Heritage Center Industrial Park. This area has been approved for transfer by the EPA and TDEC. Transfer of the land is expected to take place in 2017. This will be the second largest transfer in the history of the program. 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 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 2016, DOE received EPA and TDEC approval on documentation for future property transfers of large industrial parcels at the former Powerhouse area and Duct Island, both located at the western end of the site. DOE also submitted documentation to EPA and TDEC for their approval for transfer of three large warehouse facilities at K-1065.

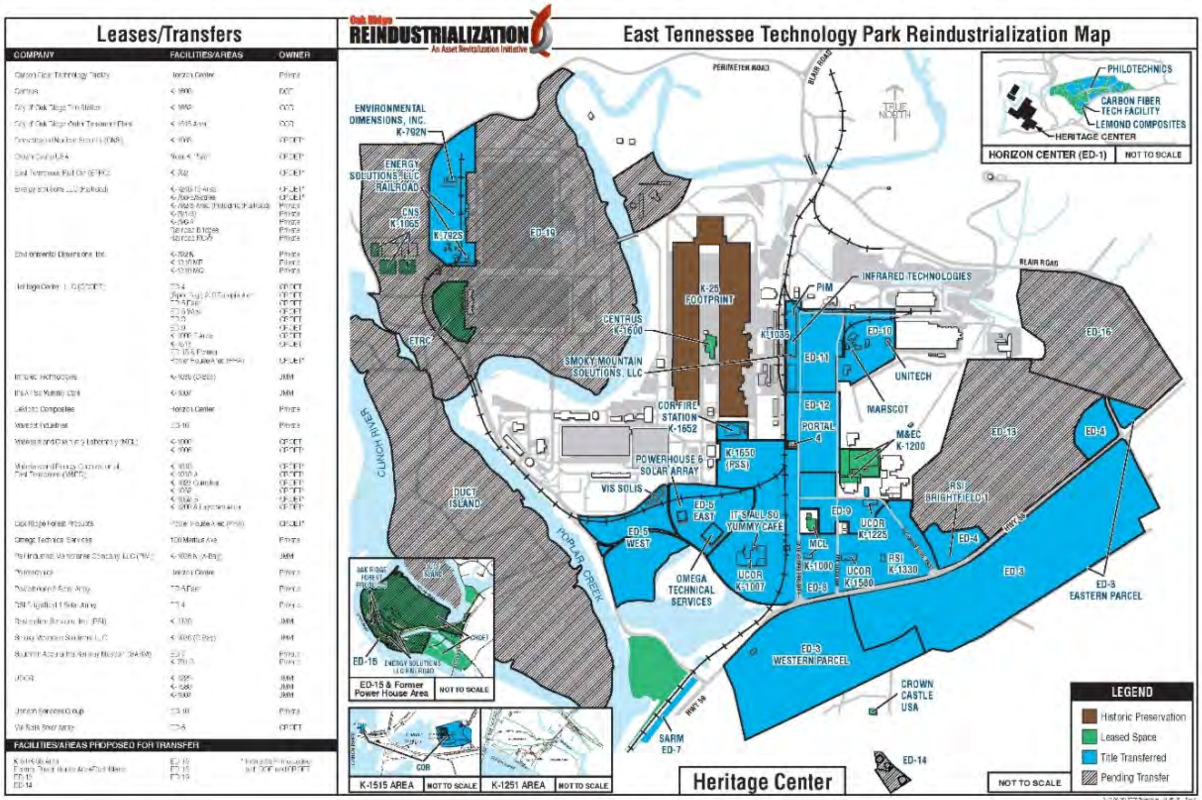


Fig. 3.53. East Tennessee Technology Park reindustrialization status, 2016.

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4. The Y-12 National Security Complex

The Y-12 National Security Complex, a premier manufacturing facility operated by Consolidated Nuclear Security, LLC, for the National Nuclear Security Administration, plays a vital role in the US Department of Energy Nuclear Security Enterprise. Drawing on more than 60 years of manufacturing excellence, the Y-12 Complex helps ensure a safe and reliable US 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 have 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 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.

4.1 Description of Site and Operations

4.1.1 Mission

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

Located within the city limits of Oak Ridge, the Y-12 Complex covers more than 328 ha (810 acres) in the Bear Creek Valley, stretching 4.0 km (2.5 miles) in length down the valley and nearly 2.4 km (1.5 miles) in width across it. NNSA-related facilities located off the Y-12 Complex site but in Oak Ridge include the Central Training Facility, Uranium Processing Facility (UPF) project offices, a records storage facility, Y-12 Shipping and Receiving, and an analytical laboratory.

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 mission-critical facilities are over 70 years old (Figure 4.1). To address this situation, Y-12 has been consolidating operations, modernizing facilities and infrastructure, and reducing the legacy footprint for more than a decade. These actions are consistent with and supportive of NNSA enterprise transformation planning. Through continued infrastructure projects, new construction, and the disposition of excess facilities, 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, Y-12 continues to meet the challenges of declining budgets through enhanced security measures, enhanced technology, and innovative business practices.

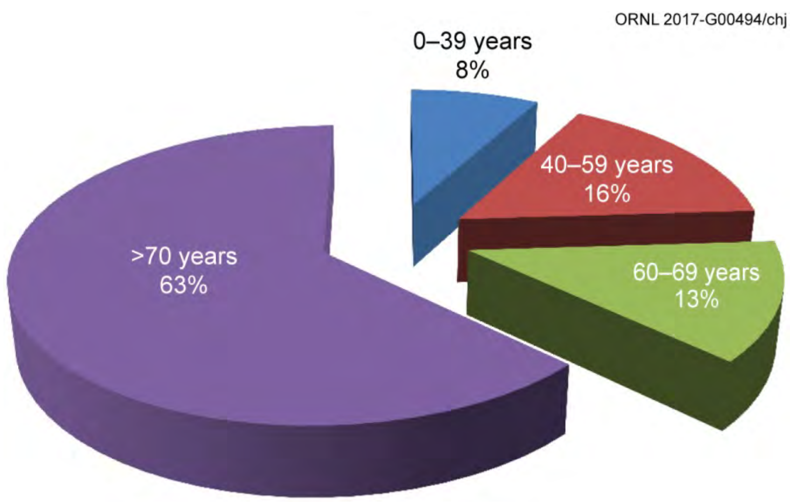

Figure 4.1. Age of mission-critical facilities at the Y-12 National Security Complex.

Replacement and revitalization are key elements of the modernization strategy at Y-12. A significant number of facilities at Y-12 are at or beyond design life. At present, several facilities are in the early construction or critical design process.

4.1.2.1 Enriched Uranium Operations

Y-12'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 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. Efforts are under way to implement the revised strategy and to

incorporate bridging plans to maintain the integrity of the aged infrastructure. These efforts are vital to the long-term mission of Y-12.

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

- accelerating transition out of Building 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 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.

4.1.2.2 Lithium Production Capability

The lithium production equipment and facilities at Y-12 have degraded to the point that repair is no longer an option. Thus, to ensure continued mission availability and to reduce annual operating costs, the lithium capability must be replaced. Production work for lithium and related nonnuclear special material vital to production of canned subassemblies is performed in Building 9204-2, built in 1944. The facility, at approximately 325,000 ft^2, is oversized for today's mission and for decades concrete on the inside and outside of the building has deteriorated. The roof, walls, and ceilings have been exposed to corrosive liquids and processing fumes, requiring restricted access and protective equipment in many areas. The facility, currently carrying approximately $22.5M 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 Y-12. Critical process equipment (hydraulic press) failures caused "code blue", or immediate, repair efforts to minimize the negative impact on delivery schedules of directed stockpile work (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. An analysis of alternatives has been completed, and CNS is evaluating options for a path forward for replacement of the HVAC equipment.

4.1.2.3 Support Facilities

Emergency response capabilities at Y-12 reside in four primary facilities: three located on site (Buildings 9706-2, 9105, and 9710-2) and one (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 9105 due to a flood event in Building 9706-02 in 2014. Building 9710-2 is the principal facility housing Fire Protection Operations (FPO). 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, the TSC, and the Emergency Response Center. The proposed EOC will more effectively and efficiently support the Y-12 missions by consolidating emergency-response capabilities into a habitable, survivable facility that also provides space for a technical support team.

Built in 1948, Building 9710-2 houses the Fire Station and the Fire Department Alarm Room. The overflow station for the fire department is located in Building 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 Y-12's most hazardous operations. Seismic, tornado, hazardous material release, and security events could render the fire station inaccessible. Off-duty personnel augment the duty staff, and thus their access to the facility is critical. Although upgrades have been performed over the years, the FPO 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 hazardous material facilities is necessary to ensure that the fire department can respond safely and effectively to all emergencies at Y-12. A proposed new fire station would be located on the east end of the plant and would be designed to meet current codes and functional requirements.

Over the next 10 years and beyond, Y-12 will continue to consolidate personnel and processes in support of the vision for long-range footprint reduction and modernization. The planned renovations at Y-12 would eliminate many of the World War II–vintage buildings that currently house the nuclear operations. The plan envisions a smaller site and the following capable, responsive, and sustainable facilities on. The following projects are currently under construction or are being initiated during the Future Year Nuclear Security Plan (FYNSP) period:

- Uranium Processing Facility
- New 13.8kV Substation
- Emergency Operations Center
- Protected Area Reduction
- Fire Station
- Lithium Production Capability
- Bridging Strategy for 9215 and 9204-02E

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

- West End Change House
- Applied Technologies Laboratory
- Security Support Complex
- Consolidated Manufacturing Capability
- Maintenance Complex
- Material Storage and Staging Facility
- Waste Management Complex

4.1.2.4 Excess Facility Disposition

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

EM, through its contractors is responsible for decommissioning and demolishing the facilities. Nonprocess 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 biphenyl [PCB]). The nonprocess-contaminated excess facilities will be deactivated by NNSA and decommissioned by NNSA or EM, depending on the cost and complexity.

The NNSA Facilities Disposition Program 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, Y-12 will continue to use limited resources to safely maintain those facilities that no longer have a mission 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 ISO 14001 (ISO 2004) standard to plan, implement, control, and continually improve environmental performance at Y-12.

DOE O 436.1, *Departmental Sustainability* (DOE 2011), provides requirements and responsibilities for managing sustainability within DOE in accordance with applicable executive orders. The order further requires implementation of an EMS that is either certified 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. Y-12 has maintained an EMS with self-declared conformance to the 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 Contract Requirements Assurance System.

4.2.1 Integration with Integrated Safety Management System

The Y-12 Integrated Safety Management System (ISMS) is the basis for planning and implementing environment, safety, and health (ES&H) programs and systems that provide the necessary structure for any work activity that could affect the public, a worker, or the environment. At Y-12, the elements of the ISO 14001 EMS are incorporated in and are consistent with the ISMS to achieve environmental compliance, pollution prevention, waste minimization, resource conservation, and sustainability. Both the ISMS and the 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. The figure shows the relationship between the ISMS (blue arrows) and the integrated EMS (green boxes).

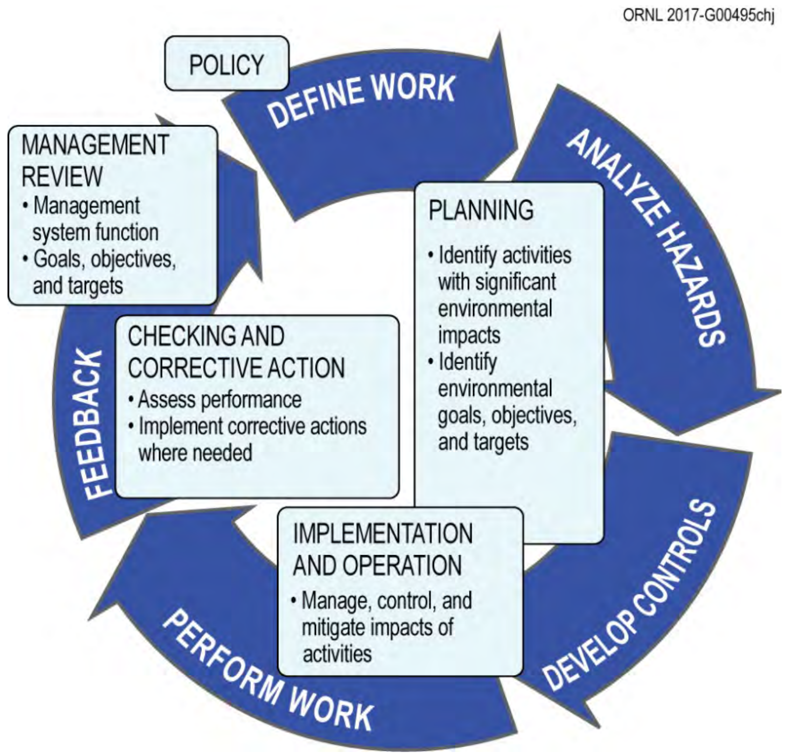

Figure 4.2. The relationship between the Y-12 Environmental Management System and the Integrated Safety Management System depicted in a "plan-do-check-act" cycle.

4.2.2 Policy

The Y-12 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 ES&H policy is presented in Figure 4-3.

ORNL 2010-G00475/chj

Y-12 Environment, Safety, and Health Policy

Policy: 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: We protect the environment, prevent pollution, comply with applicable requirements, and continually improve our environment.
- Safety and Health Policy: 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 this policy, we are committed to:

- Integration of Environment, Safety and Health (ES&H) into our business processes for w ork planning, budgeting, authorization, execution, and change control in accordance with our Integrated Safety Management System.
- Continuously improving our processes and systems by establishing, tracking, and achieving goals that drive performance excellence.
- Direct, open, and truthful communication of this policy and our ES&H performance to our employees, contractors, customers, and stakeholders.
- Strive to minimize the impact of our operations on the environment in a safe, compliant, and cost-effective manner using sustainable practices for energy efficiency, fleet management, water consumption, pollution prevention, recycling/reuse, source reduction, resource conservation, and environmentally preferable purchasing.
- Incorporate sustainable design principles into the design and construction of facility upgrades, new facilities, and infrastructure considering life-cycle costs and savings.
- Incorporate the use of engineering controls to reduce or eliminate hazards whenever possible into the design and construction of facility upgrades, new facilities, and infrastructure.
- Strive to provide a clean and efficient workplace free of occupational injuries and illnesses (Target Zero).
- Foster and maintain 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 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 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 Environmental Aspects

Environmental aspects may be thought of as potential environmental hazards associated with a facility operation, maintenance job, or work activity. The environmental aspects and their impacts (potential effects on the environment) are evaluated to ensure that the significant aspects of Y-12 activities that are identified continue to reflect stakeholder concerns and changes in regulatory requirements. The EMS provides the system to ensure that environmental aspects are systematically identified, monitored, and controlled to mitigate or eliminate potential impacts to the environment.
The FY 2016 analysis identified the following as significant environmental aspects:

- 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)
- clearing, grading, or excavation (nonquarantined 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 Y-12 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, *Site Sustainability Plan* (SSP) (CNS 2016) and other 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 2016 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.

4.2.3.4.1 Environmental Compliance

The Y-12 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 site procedures. ECD serves as the Y-12 interpretive authority for environmental compliance requirements and as the primary point of contact between Y-12 and external environmental compliance regulatory agencies such as the City of Oak Ridge, the Tennessee Department of Environment and Conservation (TDEC), and the US 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.

4.2.3.4.2 Waste Management

The Y-12 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 operations for waste planning, characterization, packaging, tracking, reporting, and managing waste treatment/disposal subcontracts.

4.2.3.4.3 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. Y-12 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 executive orders, 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.

4.2.3.4.4 Energy Management

The mission of the Y-12 Energy Management program is to incorporate energy-efficient technologies site wide and to position Y-12 to meet NNSA energy requirement needs. The program identifies improvements in energy efficiency in facilities, coordinates energy-related efforts across the site, and promotes employee awareness of energy conservation programs and opportunities. Y-12 is committed to achieving the sustainable energy and transportation goals established in Executive Order 13693. Sustainability goals, goal performance, and goal achievement are defined in the CNS SSP (CNS 2016).

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 Y-12 and the community. The council provides feedback to Y-12 regarding its operations and ways to enhance community and public communications. Y-12 sponsored the Great Smoky Mountains National Park, the East Tennessee Foundation, and expansion of the 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.

Y-12 continues to promote sustainable behaviors for environmental improvements at the site and within the community. As a part of Earth Day activities, LiveWise personnel again collected gently used athletic shoes to support the Modular Organic Regenerative Environments Foundation Group. Personal 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 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 National Security 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 National Security Complex emergency response exercises.

Five exercises and seventeen drills were conducted at the Y-12 Complex during FY 2016. The drills and exercises focused on topics such as responding to a hazardous chemical release, natural disaster, radiological release, active shooter event, security condition change, and severe event (multiple hazards, multiple buildings). Seven building evacuation and accountability drills were also conducted.

Y-12 National Security 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 Leesburg, Virginia, in May 2016. The Y-12 National Security Complex staff made presentations, participated in steering committee meetings, and distributed Y-12 National Security Complex Emergency Management Program information to other DOE facility emergency management professionals. Additionally, three members of the Emergency Management Program Office were part of a team that revised DOE O 151.1C for reissuance as DOE 151.1D *Comprehensive Emergency Management System* in August, 2016.

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 2016 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 National Nuclear Security Administration 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 the ISO 14001 in accordance with instructions issued by the Federal Environmental Executive and adhere to DOE O 436.1 (DOE 2011) 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 EMS May 11–14, 2015. The Y-12 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.

- Pollution Prevention Tracking and Reporting System, which collects environmental, sustainable acquisition and product purchases, and best practices data.

- 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.

- SSP Performance Reporting, which collects data on site-identified sustainability projects and supports Energy Independence and Security Act (EISA) Section 432 compliance.

The DOE Office of Health, Safety, and Security annual environmental progress reports on implementation of EMS requirements and sustainability goals driven by executive orders and the Office of Management and Budget's Environmental Stewardship Scorecard gave the Y-12 Complex an EMS scorecard rating for FY 2016 of green, indicating full implementation of EMS requirements.

4.2.6.1 Environmental Management System Objectives and Targets

At the end of FY 2016 Y-12 had achieved 6 of 10 targets that had been established; the 4 remaining targets were carried into future years. Overall, 25 actions were completed through September. Highlights include the following, with additional details and successes presented in other sections of this report.

- Clean Air—Y-12 completed an evaluation of uranium monitored-stack infrastructure to identify refurbishment needs for continued safe and compliant operations.

- 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 steam. Significant progress was made in many areas, and the ECM for air compressor upgrades was substantially completed by the end of FY 2016.

- Hazardous Materials—Projects for legacy and excess unneeded material/equipment removal in several facilities were developed and implemented. A project to improve controls for Sealand storage containers was substantially implemented in FY 2016. A project to disposition 57 containers of Ash residue per Site Treatment Plan milestones was completed in July 2016, more than two years ahead of schedule.

- Land/Water—In FY 2016, a project to reduce inflow and infiltration into the sanitary sewer system wase completed with the installation of fiberglass liner in 1000 feet of sanitary sewer, the repair of eleven manholes, and an expansion of stream restoration and wetlands efforts.

- Reduce/Reuse/Recycle/Buy Green—Y-12 continued efforts to increase use of remanufactured toner cartridges, completed revisions to applicable procedures, identified suitable vendors, and automated catalogs so that remanufactured toner cartridges would be preferentially procured.

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).

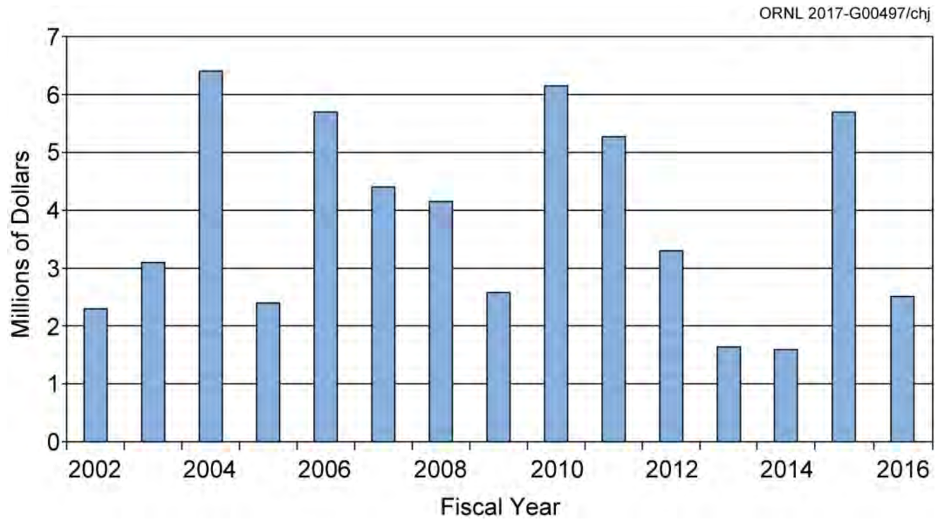

Figure 4.4. Cost efficiencies from Y-12 National Security Complex pollution prevention activities.

In FY 2016, the Y-12 Complex implemented 95 pollution prevention initiatives (Figure 4.5), with a reduction of more than 77 million lb. of waste and cost efficiencies of more than $2.5 million. The completed projects include the activities described below.

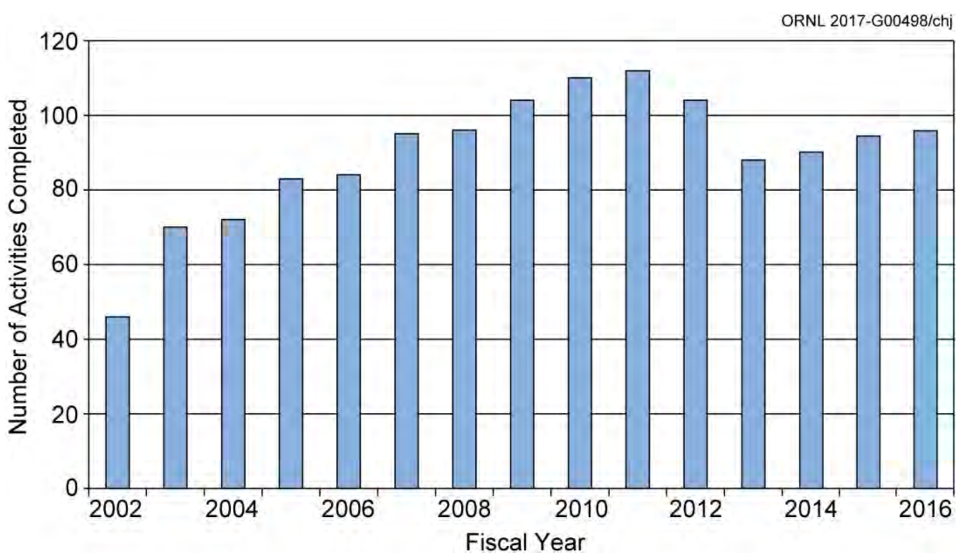

Figure 4.5. Y-12 National Security Complex pollution prevention initiatives.

4.2.6.2.1 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 2016 activities highlighted in this section.

4.2.6.2.2 Sustainable Acquisition—Environmentally Preferable Purchasing

Sustainable products, including recycled-content materials, are procured for use across the Y-12 Complex. In 2016, Y-12 procured recycled-content materials valued at more than $1.78 million for use at the site.

4.2.6.2.3 Solid Waste Reduction

In 2016, Y-12 diverted 60.9% of municipal and 94.7% of construction and demolition waste from landfill disposal through reuse and recycle. The Clean Sweep Program provides turnkey services to material generators, including segregation, staging and pickup of materials for excess, recycle, and disposal. Clean Sweep specialists ensure that materials are reused or recycled to the maximum extent possible. In FY 2016 Clean Sweep dispositioned over 200,000 ft^3 of materials with approximately 76% of the materials being reused or recycled in support of landfill diversion goals.

In FY 2016, Protective Force had excess security jackets from a uniform changeover. To prevent the jackets from going to the landfill, the site obtained permission from NNSA to donate the jackets to the Volunteer Ministry Center. Radiological Control employees donated their time to survey the jackets for release, and other employees donated their time to remove the sewn-on company patches. The jackets were then cleaned and sorted by a local organization, and more than 100 obsolete security jackets were donated. The United Way Committee worked with the Volunteer Ministry Center to ensure that the jackets would go to homeless veterans (Figure 4.6). This activity reflects Y-12 employees' commitment to reduce landfill waste and to support community outreach.

4.2.6.2.4 Hazardous Chemical Minimization

The Y-12 Complex is committed to reducing the use of toxic and hazardous chemicals and minimizing the volume of hazardous waste generated by site operations. Y-12 has established mechanisms for internal and external transfers of chemicals for reuse in order to minimize the quantity of chemicals being acquired, used, and disposed of. In FY 2016, Utilities transferred more than 3,000 gal of excess brine off site for reuse to prevent the brine from being disposed of as waste. The Generator Services group provides material disposition management service for generators at Y-12, which includes technical support to assist generators with determining whether or not the materials can be recycled, excessed, or reused. Generator Services can be used by any Y-12 department or generator. During FY 2016, Generator Services personnel reused or disseminated to other Y-12 organizations for reuse various excess materials and chemicals, preventing the generation of more than 1,200 lb of waste.

4.2.6.2.5 Recycling

Y-12 has a well-established recycling program and continues to identify new material streams and expand the types of materials that can be recycled by finding new markets and outlets for the materials. As shown in Figure 4.7, more than 3.1 million lb of materials was diverted from landfills and into viable recycle processes during 2016. Currently recycled materials range from office-related materials to operations-related materials such as scrap metal, tires, and batteries. Y-12 adds at least one new recycle stream to the Recycle Program each year to continue to increase the waste diversion rate. Chain link fencing was added in FY 2016 to broaden waste diversion efforts.

Figure 4.6. Y-12 donated obsolete security jackets to homeless veterans. *[Source: Lance King, Y-12 photographer.]*

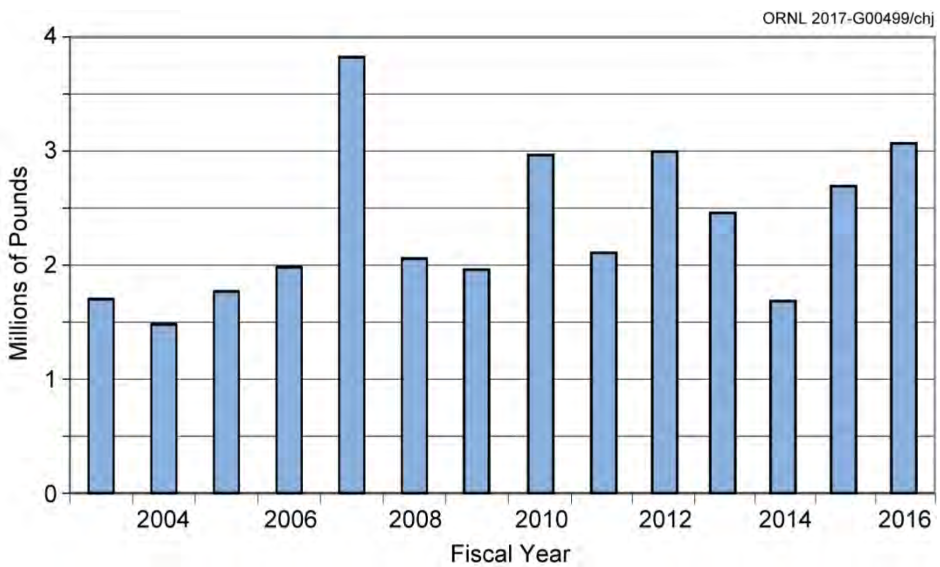

Figure 4.7. Y-12 National Security Complex recycling results.

4.2.6.3 Energy Management

The mission of the Y-12 Energy Management program is to incorporate energy-efficient technologies site wide and to position Y-12 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. Y-12 is committed to achieving the sustainable energy and transportation goals established in Executive Order 13693, *Planning for Federal Sustainability in the Next Decade*.

Executive Order 13693 established a goal of reducing building energy intensity by 25% by 2025 from a FY 2015 baseline. Y-12 exceeded the FY 2016 goal by achieving a 10% reduction in energy intensity (Figure 4.8).

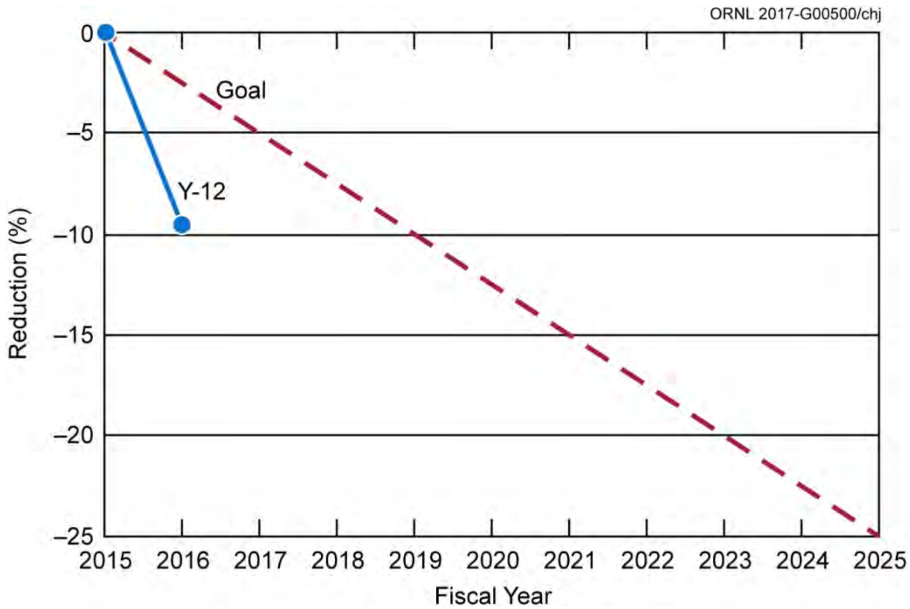

Figure 4.8. Y-12 has achieved a 10% reduction in energy intensity from the FY2015 baseline.

The following specific initiatives aided in the reduction of electricity consumption at Y-12 during FY 2016:

- Installed light-emitting diode (LED) and T-8 fluorescent lighting,
- Replaced steam with natural gas in nine buildings,
- Replaced chillers and cooling towers,
- Retrofitted three existing chillers with energy efficient controls,
- Installed condensate return unit replacements,
- Repaired steam and condensate distribution system leaks,
- Replaced steam pressure reducing stations, and
- Installed a new compressed air facility to save electricity and maintenance by better matching the demand load for instrument air with the amount of air being produced.

Additional energy reductions will be required in numerous areas to fully reduce energy use across the plant. Both facility management and utilities management are diligently 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 thermostat setbacks as well as 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 and additional modifications (lighting, chilled water, steam, natural gas, and compressed air);
- Consolidate data centers, per Office of Management and Budget definition, and install electric meters;
- Continue installation of advanced metering;
- 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.

4.2.6.3.1 Energy Monitoring

Comprehensive water and energy audits at Y-12 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.

Y-12 currently has numerous standard and advanced electrical meters located on various facilities throughout the plant. Y-12 began entering facilities into the EPA Portfolio Manager in FY 2011. Y-12 enters and tracks data for both covered and noncovered facilities. Data from the Portfolio Manager is shared with NNSA sustainability contacts and is automatically migrated to DOE's web-based EISA Section 432 Compliance Tracking System for annual reporting in June. Meter data are also entered into Portfolio Manager for benchmarking and reporting purposes. The actual electricity costs for the plant are based on total energy consumption as defined by the Tennessee Valley Authority (TVA) revenue meters in the Elza 1 substation. Y-12 does not use a space chargeback system, and individual building metering is not currently used for such purposes. The Elza 1 substation electricity use is monitored to ensure accurate billing from TVA and to develop the annual utilities budget.

Minimal funding was available for dedicated metering during FY 2016. Efforts will continue on establishing communications with the Utilities Management System. Metering for HPSB candidates is still a concern for the plant. This issue prevents adequate monitoring of energy for the required 25% reduction. It is also impacting required reporting of power usage effectiveness at the plant data centers. Efforts will continue to identify funding to install meters for HPSB candidates as well as for the data centers.

4.2.6.3.2 Energy Savings Performance Contracts

Dedicated funding for energy and water projects is provided via the ESPC mechanism. Y-12 has taken advantage of the energy-saving opportunities provided by the ESPCs. ESPC delivery order 2 is in the fourth period of performance at Y-12. ESPC delivery order 2 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.

Y-12 entered into its third ESPC in September 2013. Delivery order 3 is in the construction phase, which will continue through FY 2017. Delivery order 3 will result in an estimated annual energy and water cost savings of $2.9 million and estimated energy-related operations and maintenance (O&M) annual energy and water cost savings of $2.4 million. The site will continue to work with NNSA for successful accomplishment of these efforts. Delivery order 3 includes the following ECMs:

- steam system decentralization,
- chiller plant upgrades,
- energy efficient lighting upgrades,
- steam and condensate system improvements,
- compressed air system upgrades.

Y-12 entered into its first modification to delivery order 3 in September 2014. Delivery order 3, modification 1, was in the construction phase throughout FY 2016, and will result in an estimated annual energy and water cost savings of $240K and an estimated energy-related O&M annual energy and water cost savings of $100K. Delivery order 3, Modification 1, includes chiller plant upgrades and energy-efficient lighting upgrades.

Y-12 entered into its second modification to delivery order 3 in September 2015. Modification 2 adds 160 buildings to the lighting scope, 9 buildings to the steam decentralization scope, and replaces 1 more cooling tower. Modification 2 is in the construction phase through FY 2017 and will result in an estimated annual energy and water cost savings of $240K with no other energy-related O&M annual energy and water cost savings. Delivery order 3, modification 2, includes the following ECMs:

- chiller plant upgrades,
- energy-efficient lighting upgrades, and
- steam system decentralization

4.2.6.3.3 The CNS Site Sustainability Plan

The DOE SSPs are an annual reporting requirement and are prepared in accordance with DOE Guidance for the Site Sustainability Plans (SSP) (CNS2016) and supplemental NNSA guidance from the Associate Administrator for Infrastructure and Operations, and supports the requirements of DOE O 436.1 (DOE 2011). The Y-12 and Pantex SSPs were combined into a single CNS SSP to fulfill the planning and reporting requirements for FY 2016. The DOE sustainability goals, Y-12 status, and plans for these goals are summarized in Table 4.1.

Table 4.1. FY 2016 sustainability goals and status

SSPP goal No.	DOE goal	Performance status through FY 2016	Planned actions and contribution
		Goal 1: Greenhouse Gas (GHG) Reduction	
1.1	50% Scope 1 & 2 GHG reduction by FY 2025 from an FY 2008 baseline (2016 target: 22%)	**Goal Met for 2016**—Scope 1 & 2 emissions have decreased by 45% (-184,849 MTCO2e / 337,628.4 MTCO2e). Surpassed FY 2016 interim goal of 22%. **At Risk**—It is uncertain if the 2025 goal can be met due to construction of the Uranium Processing Facility (UPF).	Y-12 will continue to identify methods for reduction of GHG and further emphasize energy reductions.
1.2	25% Scope 3 GHG reduction by FY 2025 from a FY 2008 baseline (2016 target: 7%)	**At Risk** —Site Scope 3 emissions have increased by 9.4% (+3,004.1 $MTCO_2e$ /31,894.5 $MTCO_2e$), which did not meet the FY 2016 interim goal of 7%. It is uncertain if this goal will be achievable due to increased travel between Pantex and Y-12, increased commuting due to the UPF 9/80 work schedule, and increased site population.	Y-12 will continue to promote alternative commuting methods and research other means of reducing Scope 3 emissions.
		Goal 2: Sustainable Buildings	
2.1	25% energy intensity (Btu per gross square foot) reduction in goal-subject buildings, achieving 2.5% reductions annually, by FY 2025 from a FY 2015 baseline	**Goal Met—**Y-12 has met the 2016 goal by achieving a 10% (-2,603/251,472 Btu) reduction from the 2015 baseline. Y-12 is on the path to achieve the goal of a 25% energy intensity reduction by FY 2025.	Y-12 will continue implementation of planned energy reduction initiatives through ESPCs and further emphasize energy reductions
2.2	EISA Section 432 energy and water evaluations	**Goal Met** –Y-12 completed all required EISA-covered assessments during FY 2016	Assessments will continue to meet a 4 year cycle.
2.3	Meter all individual buildings for electricity, natural gas, steam, and water, where cost-effective and appropriate	**On Track—**Currently 93% of electricity is metered; 100% of natural gas, 100% of steam, and 100% of potable water are metered.	Y-12 will continue procurement and installation of metering at the individual building level as funding is allocated where cost-effective and appropriate.

Table 4.1 (continued)

SSPP Goal #	DOE Goal	Performance Status through FY 2016	Planned Actions and Contribution
2.4	At least 17% (by building count) of existing buildings greater than 5,000 gross square feet (GSF) to be compliant with the *revised* Guiding Principles for high-performance sustainable buildings (HPSBs) by FY 2025, with progress to 100% thereafter.	**At Risk**—Y-12 previously achieved, for GSF, an 11% (549,595/4,969,621) compliance based on gross square with HPSB Guiding Principles. Based on building count Y-12 has only met 2% compliance.	Y-12 will continue to implement initiatives to meet HPSB compliance as funding and resources allow.
2.5	Efforts to increase regional and local planning coordination and involvement	**Goal Me**—Y-12 is actively involved in local and regional efforts on transportation planning, ecosystem, watershed, and environmental management.	Y-12 will continue to participate in existing activities and look for new opportunities to leverage regional and local resources.
2.6a	Net Zero Buildings: 1% of the site's existing buildings above 5,000 gross square feet intended to be energy, waste, or water net-zero buildings by FY 2025.	**At Risk**—An assessment for the installation of renewable energy projects for both solar and wind technologies found neither to be feasible for Y-12.	Y-12 will continue to evaluate opportunities as market advances bring payback within reasonable time frames.
2.6b	Net Zero Buildings: All new buildings (> 5,000 GSF) entering the planning process designed to achieve energy net-zero beginning in FY 2020.	**On Track—**At Y-12, the UPF project is currently seeking a waiver for Leadership in Energy and Environmental Design (LEED) Gold certification.	If Y-12 is granted the waiver, the UPF project will review and implement LEED scorecard credit and Guiding Principles by building, where feasible-now six buildings.
		Goal 3: Clean & Renewable Energy	
3.1	"Clean Energy" requires that the percentage of an agency's total electric and thermal energy accounted for by renewable and alternative energy shall be not less than: 10% in FY 2016–2017, working towards 25% by FY 2025.	**On Track—**Due to sharing the Wind Renewable Energy Certificates with Pantex, Y-12 achieved 10% clean energy consumption.	Both Pantex and Y-12 plan to renew the shared credits for FY 2017 and beyond. To continue to allow both sites to achieve future "clean" and "renewable electric energy goals.
3.2	"Renewable Electric Energy" requires that renewable electric energy account for not less than 10% of a total agency electric consumption in FY 2016–2017, working towards 30% of total agency electric consumption by FY 2025.	**On Track**—Due to sharing the Wind RECs with Pantex, Y-12 achieved 10% renewable energy consumption.	Both Pantex and Y-12 plan to renew the shared credits for FY 2017 and beyond. To continue to allow both sites to achieve future "clean" and "renewable electric energy goals.

Table 4.1 (continued)

SSPP Goal #	DOE Goal	Performance Status through FY 2016	Planned Actions and Contribution
		Goal 4: Water Use Efficiency and Management	
4.1	36% potable water intensity (gal per gross square foot) reduction by FY 2025 from a FY 2007 baseline. (2016 target: 18%)	**Goal Met**—Y-12 achieved a 65% (-137/210.8) reduction from the baseline, surpassing, not only the interim goal of 18%, but the 2025 goal of 36%.	Y-12, water conservation measures will continue to be implemented as practicable in support of the HPSB initiative.
4.2	30% water consumption (Gal) reduction of industrial, landscaping, and agricultural (ILA) water by FY 2025 from a FY 2010 baseline. (2016 target: 12%)	**Not Applicable—**Y-12 no longer consumes ILA and baseline ILA water is accounted for in Goal 4.1.	All water used at Y-12 is potable water and included in the potable water category.
		Goal 5: Fleet Management	
5.1	30% reduction in fleet-wide per-mile greenhouse gas emissions reduction by FY 2025 from a FY 2014 baseline. (2016 target: 3%; 2017 target: 4%)	**Goal Met** –40 of the light duty and medium duty vehicles were replaced during FY 2016. These replacements had much higher GHG ratings then the former fleet vehicles.	Future vehicle purchases and leases will include alternative fuel vehicles (AFVs), including E85, hybrid, and electric vehicles where possible
5.2	20% reduction in annual petroleum consumption by FY 2015 relative to a FY 2005 baseline; maintain 20% reduction thereafter. (2016 target: 20%)	**Goal Met—**Petroleum fuel consumption was reduced by 26% for FY 2016.	Heavy duty vehicles will be assessed in FY 2017 to better determine a replacement strategy for those vehicles.
5.3	10% increase in annual alternative fuel consumption by FY 2015 relative to a FY 2005 baseline; maintain 10% increase thereafter. (2016 target: 10%)	**Goal Was Not Met** —The Y-12 site does not currently have a method for dispensing E85 fuel and is operating under an exemption from the Department of Energy for using alternative fuels.	Y-12 needs additional funding in order to install a new pumping facility on-site.
5.4	75% of light duty vehicle acquisitions must consist of AFVs. (2016 target: 75%)	**Goal Was Not Met**—At Y-12, 58.5% of the light vehicle purchases during FY 2016 were AFVs, this was due to the limited availability of AFVs through GSA.	AFVs will continue to be ordered as replacement vehicles when AFVs are listed as an option in GSA.
5.5	50% of passenger vehicle acquisitions consist of zero emission or plug-in hybrid electric vehicles by FY 2025. (2016 target: 4%)	**Goal Was Not Met** —Y-12 does not have the necessary infrastructure to support these types of vehicles. Additionally, GSA did not have zero emission or plug-in hybrid electrical vehicles available when the site was acquiring vehicles.	Future vehicle purchases and leases will include hybrid and electric vehicles where possible.

Table 4.1 (continued)

SSPP Goal #	DOE Goal	Performance Status through FY 2016	Planned Actions and Contribution
		Goal 6: Sustainable Acquisition	
6.1	Promote sustainable acquisition and procurement to the maximum extent practicable, ensuring Bio-Preferred and bio based provisions and clauses are included in 95% of applicable contracts.	**Goal Met**—Sustainable acquisition clauses have been incorporated into standard contract terms and conditions.	Y-12 will incorporate additional clauses as requested and will continue to evaluate sustainable products for use at the sites.
		Goal 7: Pollution Prevention & Waste Reduction	
7.1	Divert at least 50% of non-hazardous solid waste, excluding construction and demolition debris.	**Goal Met**—60.9% (1,383.7 metric tons/2,273.5 metric tons) of nonhazardous waste diverted from landfill.	At least one new recycle material stream is added to the recycling program each fiscal year to further increase the diversion rate.
7.2	Divert at least 50% of construction and demolition materials and debris.	**Goal Met**—At Y-12, 94.7% (29,438.6 metric tons/ 31,104 metric tons) of construction and demolition (C&D) waste diverted from landfill.	A systematic disposition evaluation method will continue to be used for C&D materials to ensure maximum waste diversion is achieved.
		Goal 8: Energy Performance Contracts	
8.1	Annual targets for performance contracting to be implemented in FY 2017 and annually thereafter as part of the planning of section 14 of E.O. 13693.	**Goal Met**—Y-12 has taken advantage of the energy saving opportunities provided by the ESPCs. ESPC Delivery Order #2 is in the fourth period of performance at Y-12. Delivery Order #3 is in the construction phase which will continue through FY 2017.	Y-12 will continue to leverage ESPCs to help achieve sustainability goals.
		Goal 9: Electronic Stewardship	
9.1	Purchases—95% of eligible acquisitions each year are Electronic Product Environmental Assessment Tool (EPEAT)-registered products.	**Goal Was Not Met**—Approximately 93% (2,340/2,520) of all eligible electronic acquisitions during FY 2016 were EPEAT-registered. However, more than 98% (2,473/2,520) were either EPEAT-registered or Energy Star-qualified products and more than 97% (1959/2002) of all computer desktops, laptops, tablets, workstations, monitors, and thin clients purchased were EPEAT Gold registered.	Y-12 will continue to promote the acquisition of EPEAT-registered and Energy Star-qualified products. Y-12 has a standard desktop configuration that specifies the procurement of EPEAT-registered and Energy Star-qualified products.
9.2	Power management—100% of eligible PCs, laptops, and monitors have power management enabled.	**At Risk**—Y-12 has implemented power management to feasible CPUs and laptops; power management features are enabled on all monitors not deemed mission critical.	100% implementation of PCs and laptops at Y-12 is not currently feasible with existing network security features. However the site will continue active implementation of power management requirements where feasible when acquiring new products.

Table 4.1 (continued)

SSPP Goal #	DOE Goal	Performance Status through FY 2016	Planned Actions and Contribution
9.3	Automatic duplexing—100% of eligible computers and imaging equipment have automatic duplexing enabled.	**At Risk**—During FY 2016, more than 21.4% of the printers, copiers, and multifunction devices were set to automatically duplex.	The recommended default for all networked printers with duplexers was "duplex" instead of "simplex." The number of non-networked printers that either don't have duplex capability or can be changed by the user to a simplex default will make this goal difficult to achieve.
9.4	End of Life—100% of used electronics are reused or recycled using environmentally sound disposition options each year.	Go**al Met –**Y-12's approved electronics recycling vendor achieved R2 certification in May 2015; therefore, all FY 2016 shipments were made to an R2 certified recycler. The only electronics that were not either recycled by the R2 vendor or donated for reuse were electronics that could not be radiologically cleared for release.	With the certification of Y-12's approved electronics recycling vendor as an R2 certified recycler, all used electronics were recycled using environmentally sound disposition options in FY 2016 and beyond.
9.5	Data Center Efficiency. Establish a power usage effectiveness target in the range of 1.2-1.4 for new data centers and less than 1.5 for existing data centers	**At Risk**—The PUE is currently estimated at lower then 1.4, since the current PUE rating for Y-12 data centers is unknown. However, this value is based solely on electricity usage and does not account for energy intensity	At Y-12 projects for chilled water and electrical metering are planned for Building 9117 when funding becomes available. This data will allow the measurement of the PUE.
		Goal 10: Climate Change Resilience	
10.1	Update policies to incentivize planning for, and addressing the impacts of climate change.	**On Track**—Policies for planning and addressing climate change impacts are reviewed and updated as needed, particularly with regard to severe winter weather and heat stress	Y-12 will continue to track trends and information on climate change and remain engaged with organizations dedicated to future planning and impacts.
10.2	Update emergency response procedures and protocols to account for projected climate change, including extreme weather events.	**On Track** –The *Y-12 National Security Complex Severe Event Emergency Response Plan* addresses severe natural phenomena events such as tornadoes, earthquakes, snow and ice, extended loss of power events and events that result in the loss of mutual aid.	Continue to review and update Emergency Response procedures as needed.
10.3	Ensure workforce protocols and policies reflect projected human health and safety impacts of climate change.	**On Track** –Y-12 has a robust Building/Facility Emergency Program to protect personnel during severe weather emergencies, including earthquakes, tornados, and floods. Procedures contained with the Plan are designed to protect personnel during such emergencies as winter weather events and both extreme cold and hot events.	Protocols, processes and procedures will continue to be reviewed and revised as needed based on improved understanding/lessons learned regarding climate change impact.

Table 4.1 (continued)

SSPP Goal #	DOE Goal	Performance Status through FY 2016	Planned Actions and Contribution
10.4	Ensure site/lab management demonstrates commitment to adaptation efforts through internal communications and policies.	**On Track**—Management communications protocols at both sites include procedures, texts/pages, emergency call-in number, and safety messages as applicable.	Communications will continue to be evaluated to ensure a good understanding by plant personnel of climate adaptation policies at both sites.
10.5	Ensure that site/lab climate adaptation and resilience policies and programs reflect best available current climate change science, updated as necessary.	**On track**—The current climate change discussion does not present any new scenarios at either Pantex or Y-12 that have not been planned for already therefore no changes to policies or programs were needed based on advancements in climate change science or on-site analysis.	Y-12 will continue to partner with Oak Ridge National Laboratory (ORNL), TVA, and others to remain current on climate change science and will update on-site policies and programs as needed.

4.2.6.4 Water Conservation

In FY 2016, Y-12 achieved a 65% (-137/210.8 MGal) water intensity reduction from the baseline, surpassing not only the interim goal of 18% but the 2025 goal of 36%. Y-12 is currently meeting the water intensity reduction goals and storm water initiatives (Figure 4.9). Actions that have contributed to the overall reduction in potable water use include the following:

- 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.

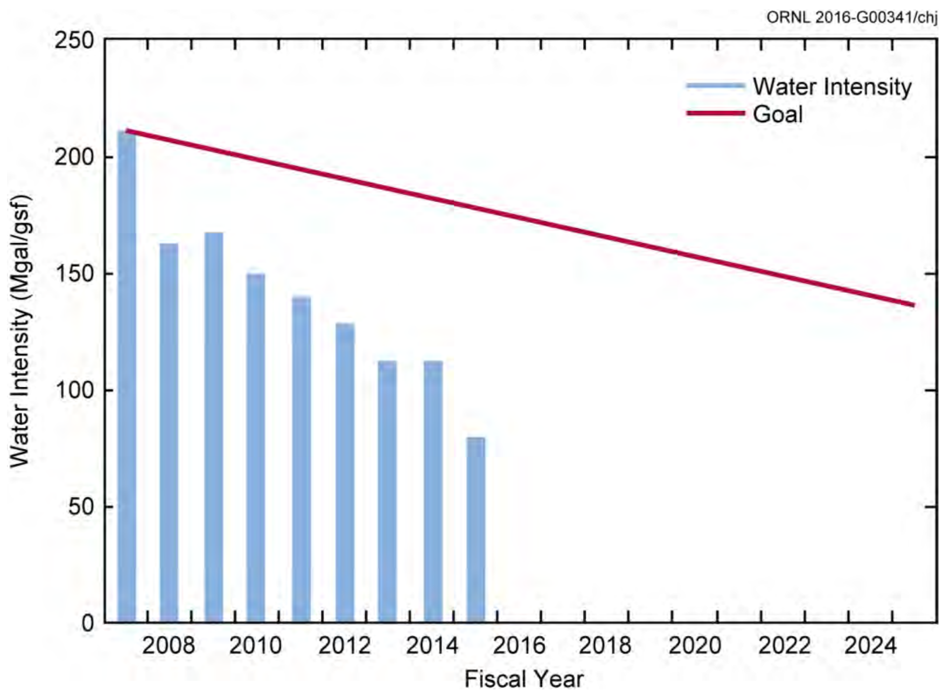

Figure 4.9. Y-12 National Security Complex water intensity goals. *(Mgal = millions of gallons, gsf = gross square foot)*

Meters are installed on the potable water tanks and on various facilities within the plant. Future metering will include advanced meter installations for all enduring facilities, as applicable, to comply with the 2025 goal.

Although the site has met this goal, significant reductions in water consumption can still be achieved through continued improvements in facilities, metering, and replacement of inefficient HVAC units. Additionally, water use per square foot is expected to increase in the coming years. Even though it is believed existing buildings will continue to reduce consumption, UPF construction will use a large amount of water. A concrete batch plant has been constructed to supply concrete to the construction site. During the construction period water use will increase but the square footage will not, skewing the

calculation. The water is not metered separately. Therefore, there is no way to distinguish the quantity of water used for construction from the quantity of water used in buildings.

Internal EISA audits are conducted on covered facilities on a three-year rotating schedule. Additionally, in FY 2016 Pacific Northwest National Laboratory conducted a water assessment of the Y-12 Site through the Federal Energy Management Program. Both of these assessments have identified a number of water conservation projects that could be implemented if funding were allocated. These projects include domestic plumbing retrofits, kitchen equipment upgrades, process system upgrades, cooling tower upgrades, and steam plant upgrades. The site expects to participate in the NNSA Water Asset Management Program to accomplish these water-saving projects.

Continued reductions in water use will be incorporated into the following ongoing facility repairs and renovations as funding becomes available:

- 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; and
- Repairing system to allow 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

4.2.6.5 Fleet Management

The Y-12 fleet is comprised of DOE-owned and Government Services Administration (GSA) sedans, light-duty trucks/vans, medium-duty trucks/vans, and heavy-duty trucks. During the last quarter of FY 2015, 240 sedans, light-duty, and medium-duty vehicles from the Y-12 DOE-owned fleet were transferred to the GSA. During FY 2016, the GSA replaced all those vehicles and 177 of the replacements were alternative fuel (E85) vehicles. This consolidation has decreased the average age of Y-12's vehicle fleet from 15 years to 1 year for light-duty and medium-duty vehicles. By replacing the older, less-fuel-efficient vehicles with newer, alternative fuel vehicles, Y-12 will greatly reduce its consumption of petroleum fuels and its GHG emissions and will increase its use of alternative fuels. Y-12 continues to operate a taxi service as one of the strategies for fleet optimization.

Y-12 had surpassed both FY 2015 goals regarding alternative fuel use and petroleum use at the end of FY 2014 with a 40% reduction in petroleum use and a 77.7% increase in alternative fuel use compared to the FY 2005 baseline. The rupture of an on-site fuel tank at the subcontractor-operated fuel station, and subsequent concerns that surfaced during the investigation resulted in the fuel station being placed out of service, effectively eliminating availability of E85 fuel for Y-12 vehicles. Therefore, Y-12 was not able to meet the goal for FY 2016 of decreasing alternative fuel use by 10%. The site reduced petroleum use by 26%, which exceeded the 2016 goal of a 20% reduction.

Y-12 anticipates having E85 fuel available by the end of FY 2017. Y-12 is currently operating under an exception granted by DOE due to its current inability to store fuel on site. Areas where electric vehicles

could meet mission requirements will be evaluated in FY 2017 along with the infrastructure that will be required to meet the new telematics requirements. Y-12 will continue to monitor vehicle use and will redistribute or remove vehicles from the fleet as needed (see Figure 4.10).

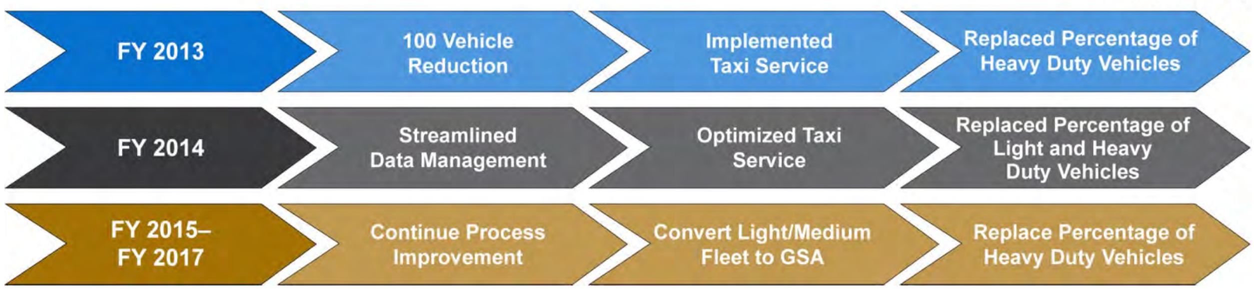

Figure 4.10. Fleet management roadmap.

4.2.6.6 Electronic Stewardship

Y-12 has implemented a variety of electronic stewardship activities, including server virtualization, virtual desktop infrastructure, procurement of energy-efficient computing equipment, reuse and recycle of computing equipment, replacement of aging computing equipment with more energy-efficient equipment, and reconfiguration of data centers to achieve more energy-efficient operations. Approximately 93% of desktop computers, laptops, monitors, and thin clients purchased or leased during FY 2016 were registered Electronic Product Environmental Assessment Tool (EPEAT) products. Y-12's standard desktop configuration specifies the procurement of EPEAT-registered and Energy Star–qualified products.

4.2.6.7 Greenhouse Gases

Table 4.2 provides a summary of Y-12 Complex GHG emissions for FY 2008 (the baseline year as required by EO 13693) and FY 2016. The Y-12 Complex has reduced Scopes 1 and 2 GHG emissions by 45.3% 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 increased by 9.4% since the 2008 baseline year. This increase is due primarily to rising employee commuting emissions due to site population growth. (Any increase in on-site personnel directly affects employee commuting.)

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

GHG emission source	FY 2008 baseline (metric ton CO_2e/year)	FY 2016 (metric ton CO_2e/year)
	Scope 1[a]	
Steam (coal, natural gas, fuel oil)	129,021	51,064
Industrial fugitive emissions	22,542	8,089
On-site wastewater treatment	6.9	9.5
Fleet fuels (Gas, E85, Diesel)	1,063	-
	Scope 2 [a]	
Renewable energy certificates		(16,290)[b]
Purchased electricity	184,995	141,977
Total Scopes 1 and 2	**337,627.9**	**184,849**
	Scope 3 [a]	
T&D losses	12,185.8	9,352.2
Off-site municipal wastewater treatment	25.3	13.4
Employee commuting	17,447	24,587.3
Business ground and air travel	2,251	2,018.4
Renewable energy certificates	N/A	(1,072.7)
Total Scope 3	**31,909.1**	**34,898.6**
TOTAL GHG emissions	**369,537**	**219,747.6**

[a] Greenhouse gas (GHG) emissions are classified as Scope 1, 2, or 3. Scope 1 includes GHG emissions occurring directly on site, 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.
[b] With the agreement of the NPO for the Y-12 and Pantex sites, the Y-12 Complex GHG inventory was credited with renewable energy produced by the Pantex Renewable Energy Project as part of the Pantex–Y-12 integration effort. This renewable energy strategy was supported by the fact that CNS Pantex meets the DOE renewable energy goal requirement through purchase of renewable energy credits.

Acronyms

CNS = Consolidated Nuclear Security, LLC
CO_2e = CO_2 equivalent
FY = fiscal year
GHG = greenhouse gas
NPO = National Nuclear Security Administration Production Office
T&D = transmission and distribution

4.2.6.8 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 2016 include the following.

- UPF continued transferring portions of soil; there has not been a significant change (up or down) in green space during FY 2016 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) as final grade is achieved at excess soil placement areas such as West Borrow Area and Wet Spoils Area consistent with the storm water control plan.

- Y-12 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 136 external environmental awards from local, state, and national agencies. The awards received in 2016 are summarized in the following sections.

4.2.7.1 Tennessee Chamber of Commerce and Industry Award

Y-12 was recognized at the 34th Annual Tennessee Chamber of Commerce and Industry Environment and Energy Conference in an awards ceremony on October 26, 2016, at Montgomery Bell State Park. Y-12 received the Energy Excellence Award for "Y-12 ESPCs Building a Sustainable Future in Energy Conservation." (See Figure 4.11.)

4.2.7.2 Electronic Product Environmental Assessment Tool Award

Y-12 received an EPEAT Purchaser 2 Star Level Award for Excellence in Green Procurement of Electronics in a ceremony in Washington, DC, on May 23, 2016. Y-12 was recognized by the Green Electronics Council at the 2 Star Level for purchasing EPEAT electronics in the following categories: PCs and Displays; Imaging Equipment (e.g., copiers, scanners, multifunction devices); and Televisions. (See Figure 4.12.)

4.2.7.3 DOE Sustainability Awards

Y-12 received two DOE Sustainability Awards in 2016. "Terry Cothron Builds Bridges to a Brighter Future at Y-12" was recognized in the Change Agent category and "Y-12 Reduced Water Usage and Improved Water Quality" was recognized in the Water category.

4.2.7.4 NNSA Sustainability Awards

Y-12 received four NNSA Sustainability Best In Class Awards in 2016: "Terry Cothron Builds Bridges to a Bright Future at Y-12" in the Change Agent category, "Y-12 Reduced Water Usage and Improved Water Quality" in the Water category, "Y-12 Perseveres to Prevent Pollution in Wastewater Treatment Operations" in the Waste Reduction and Pollution Prevention category, and "Y-12 Energy Savings Performance Contracts Investing in a Sustainable Future" in the Performance Based Contracts category. Y-12 also received two NNSA Environmental Stewardship Award Certificates: "Y-12 Steams Ahead—Wise Utilities Management" in the Greenhouse Gas Scope 1 and 2 category and "Y-12 Uranium Processing Facility Sustainable Practices" in the Waste Reduction and Pollution Prevention category.

Figure 4.11. Tennessee Chamber of Commerce and Industry awards ceremony for Y-12, Montgomery Bell State Park, October 26, 2016.

Figure 4.12. In a ceremony in Washington, DC, on May 23, 2016, Y-12 received the Electronic Product Environmental Assessment Tool Award Purchaser 2 Star Level Award for Excellence in Green Procurement of Electronics.

4.3 Compliance Status

4.3.1 Environmental Permits

Table 4.3 lists environmental permits in force at the Y-12 Complex during 2016. More detailed information can be found in the following sections.

Table 4.3. Y-12 National Security Complex environmental permits, CY 2016

Regulatory driver	Title/description	Permit number	Issue date	Expiration date	Owner	Operator	Responsible contractor
CAA	Title V Major Source Operating Permit	562767	1/8/2012	1/8/2017	DOE	DOE	CNS
CAA	UPF Construction Permit	967550P	3/01/2014	3/01/2017	DOE	DOE	CNS
CWA	Industrial & Commercial User Wastewater Discharge (Sanitary Sewer) Permit	1-91	4/1/2010	3/30/2015[a]	DOE	DOE	CNS
CWA	NPDES Permit	TN0002968	10/31/2011	11/30/2016[b]	DOE	DOE	CNS
CWA	UPF 401 Water Quality Certification/ ARAP Access/Haul Road	NRS10.083	6/10/2010	6/09/2015[c]	DOE	DOE	CNS
CWA	UPF Department of Army Section 404 Clean Water Act Permit	2010-00366	9/02/2010	9/02/2020	DOE	DOE	CNS
CWA	UPF General Storm Water Permit Y-12 Complex (41.7 hectares/103 acres)	TNR 134022	10/27/2011	9/30/2021	DOE	CNS	CNS
RCRA	Hazardous Waste Transporter Permit	TN3890090001	12/22/2016	1/31/2018	DOE	DOE	CNS
RCRA	Hazardous Waste Corrective Action Permit	TNHW-164	9/15/2015	9/15/2025	DOE	DOE, NNSA, and all ORR co-operators of hazardous waste permits	UCOR
RCRA	Hazardous Waste Container Storage Units	TNHW-122	8/31/2005	8/31/2015[b]	DOE	DOE/CNS	CNS/ Navarro co-operator
RCRA	Hazardous Waste Container Storage and Treatment Units	TNHW-127	10/06/2005	10/06/2015[b]	DOE	DOE/CNS	CNS co-operator

Table 4.3 (continued)

Regulatory driver	Title/description	Permit number	Issue date	Expiration date	Owner	Operator	Responsible contractor
RCRA	RCRA Post closure Permit for the Chestnut Ridge Hydrogeologic Regime	TNHW-128	9/29/2006	9/29/2016 [b]	DOE	DOE/UCOR	UCOR
RCRA	RCRA Postclosure Permit for the Bear Creek Hydrogeologic Regime	TNHW-116	12/10/2003 Permit reapplication submitted to TDEC on 1/31/13	12/10/2013[b]	DOE	DOE/UCOR	UCOR
RCRA	RCRA Postclosure Permit for the Upper East Fork Poplar Creek Hydrogeologic Regime	TNHW-113	9/23/2003 Permit reapplication submitted to TDEC on 1/31/13	9/23/2013[b]	DOE	DOE/UCOR	UCOR
Solid Waste	Industrial Landfill IV (Operating, Class II)	IDL-01-103-0075	Permitted in 1988—most recent modification approved 1/13/1994	N/A	DOE	DOE/UCOR	UCOR
Solid Waste	Industrial Landfill V (Operating, Class II)	IDL-01-103-0083	Initial permit 4/26/1993	N/A	DOE	DOE/UCOR	UCOR
Solid Waste	Construction and Demolition Landfill (Overfilled, Class IV subject to CERCLA ROD)	DML-01-103-0012	Initial permit 1/15/1986	N/A	DOE	DOE/UCOR	UCOR
Solid Waste	Construction and Demolition Landfill VI (Postclosure care and maintenance)	DML-01-103-0036	Permit terminated by TDEC 3/15/2007	N/A	DOE	DOE/UCOR	UCOR
Solid Waste	Construction and Demolition Landfill VII (Operating, Class IV)	DML-01-103-0045	Initial permit 12/13/1993	N/A	DOE	DOE/UCOR	UCOR
Solid Waste	Centralized Industrial Landfill II (Postclosure care and maintenance)	IDL-01-103-0189	Most recent modification approved 5/8/1992	N/A	DOE	DOE/UCOR	UCOR

Table 4.3 (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	3/12/2002	None	DOE	DOE	CNS

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

Acronyms

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 = US Department of Energy
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
TDEC = Tennessee Department of Environment and Conservation
UCOR = URS | CH2M Oak Ridge LLC
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 the National Environmental Policy Act (NEPA) requirements (procedural provisions, 40 CFR 1500 thru 1508), as outlined in the DOE's Implementing Procedures for NEPA (Title 10 CFR 1021). CNS fully supports NNSA's commitment to NEPA by evaluating proposed federal actions for potential impacts that affect the quality of the environment at Y-12. 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 the 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.

Environmental evaluations were completed for 72 proposed actions during CY 2016, and 67 proposed actions were determined to be covered by a categorical exclusion (CX), as listed in Appendix B for facility operations to Subpart D of Part 1021, in National Environmental Policy Act General Categorical Exclusion (Y/TS-2312). The majority of proposed actions involved the sustainment of enduring facilities and bridging strategies for facilities identified with an out-year replacement. Since many facilities are approaching 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 9215 and 9204-2E), Fire Suppression upgrades (wet pipe sprinkler head replacements), Building 9995 Air Handling Unit Project, other humidity control improvements, and multiple machining tool and controller equipment upgrades or replacements. The following projects continue in 2016: the Energy Conservation Measure project—with the Chiller Plant upgrade as the last project, the Roof Asset Management Project, the Emergency Operations Center, the Y-12 Fire Station Construction project, and the bridging and sustainment of lithium production capabilities (equipment and facilities). NNSA has performed an analysis of alternative for constructing a new Lithium Production Capability facility.

During CY 2016, the following CXs were signed by NNSA Production Office and posted on the Y-12 public website:

- NEPA #4201.16, Easement to Tennessee Valley Authority (TVA) for the new Pine Ridge Substation and Associated Transmission Line Feeds for the Uranium Processing Facility (UPF) at the Y-12 National Security Complex;
- NEPA #4752, Depleted Uranium Technology Testing for the Uranium Processing Facility (UPF);
- NEPA #4201.17, UPF, Multi-Purpose Fabrication Facility; and
- NEPA #4779, Building 9204-2 Annex Demolition Project at the Y-12 National Security Complex.

The *Final Site-Wide Environmental Impact Statement for the Y-12 National Security Complex* (DOE 2011a) was issued in March, 2011. The Site-Wide Environmental Impact Statement – (SWEIS) and the notice of availability were published March 4, 2011, and are available on the Internet at http://nnsa.energy.gov/content/y12sweis2011. NNSA issued a ROD in July 2011 for the Continued Operation of the Y-12 National Security Complex, based on the SWEIS. Since the ROD, NNSA has updated the strategy and design approach for UPF. NNSA would use a hybrid approach of upgrading existing Y-12 facilities and building multiple UPF facilities, which was consistent with recommendations from a project peer review of the UPF, Final Report of the Committee to Recommend Alternatives to the

Uranium Processing Facility Plan in Meeting the Nation's Enriched Uranium Strategy (the Red Team Report, issued April 2014). The updated UPF strategy was addressed in detail in a Supplement Analysis Final Site-Wide Environmental Impact Statement (EIS-0387-SA-01) and the ROD was amended July 22, 2016. Please see http://energy.gov/nepa/downloads/eis-0387-sa-01-supplement-analysis. As required by DOE's NEPA implementing procedures, 10 CFR 1021, a 5-year evaluation of the 2011 SWEIS is currently in process for the continued operations of Y-12.

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 2016 included completing Section 106 reviews of ongoing and new projects, collecting and storing historic artifacts, conducting tours, maintaining the Y-12 History Center, and participating in various outreach projects with local organizations and schools.

Seventy-two 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 72 projects would have an adverse effect on historic properties eligible for listing in the *National Register* and that no further Section 106 documentation was required. The Y-12 Oral History Program continues efforts to identify leads to conduct oral interviews and to document the knowledge and experience of those who worked at 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 the interviews will be available in various media, including DVDs shown in the Y-12 History Center.

The Y-12 History Center, located in The New Hope Center, continues to be a work in progress. The Y-12 History Center features many historical photographs and artifacts, a history library, and a video viewing area. More interactive and video-based exhibits are planned for the future. The Y-12 History Center is open to the public Monday through Thursday from 8:00 a.m. to 5:00 p.m. and on Fridays by special request. A selection of materials, including documentary DVDs, books, pamphlets, postcards, and fact sheets are available free to the public.

Y-12 partnered with The National Park Service during the annual Earth Day events on April 19, 2016. These events were held in the Y-12's Jack Case Center cafeteria lobby area. The DOE Earth Day Theme was "Earth Day—Everyday." 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 2016 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, The Secret City Festival promoted the history of the Manhattan Project by providing information to visitors regarding the history of Y-12 and directions for them to visit the Y-12 History Center.

Y-12 also continues to partner with the American Museum of Science and Energy by providing guided public tours of the Y-12 History Center from March through November. Other outreach activities to local and visiting schools, agencies, and organizations included tours and presentations on the 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 562767.

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 CY 2016, and there were no permit violations or exceedances during the report period.

The TDEC–Knoxville Office, Clean Air Compliance, did not complete the Y-12 annual Clean Air Compliance inspection for CY 2016. They plan to perform an inspection in CY 2017.

Ambient air monitoring, while not specifically required by any permit condition, is conducted at the Y-12 Complex to satisfy DOE Order 458.1, *Radiation Protection of the Public and the Environment* (DOE 2011c) 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 the ORR and by both on-site and off-site monitoring conducted by TDEC.

Section 4.4 provides detailed information on 2016 activities conducted at Y-12 in support of CAA.

4.3.4 Clean Water Act Compliance Status

During 2016, the Y-12 Complex continued its excellent record for compliance with the 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 2016 was almost 100%.

About 2,300 data points were obtained from sampling required by the NPDES permit; no noncompliances were reported. The Y-12 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 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.

Tennessee Regulations for Public Water Systems and Drinking Water Quality, Chap. 0400-45-01, set limits for biological contaminants, chemical activities, and chemical contaminants. Sampling for total coliform, chlorine residuals, lead, copper, and disinfectant by-product is conducted by the Y-12 Environmental Compliance Department.

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 for potable water with TDEC. All total coliform samples collected during 2016 were analyzed by the State of Tennessee laboratory, and the results were negative. Analytical results for disinfectant by-products (total trihalomethanes and haloacetic acids) for Y-12 Complex water systems were below TDEC and Safe Drinking Water Act (SDWA) limits. The Y-12 Complex potable water system is currently sampled triennially for lead and copper, and the system sampling was last completed in 2014. These results were below TDEC and SDWA limits and met the established requirements. Lead and copper samples will be taken in June 2017.

In 2016, the potable water compliance moved from Y-12 Infrastructure to Environmental Compliance. Y-12 Infrastructure remains responsible for maintenance to the distribution system; Environmental Compliance is now responsible for potable water monitoring and oversight of the cross-connection control program.

4.3.6 Resource Conservation and Recovery Act Compliance Status

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 off the site 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 (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 2016) 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 in fiscal years from 2013 through 2018 (see Figure 4.13). In 2016, the Y-12 Complex staff completed disposition of 100% of the inventory of legacy mixed waste listed on the ORR site treatment plan 2 years ahead of the 2018 completion milestone. Additional future milestones have been developed for newly identified legacy mixed waste identified in 2016.

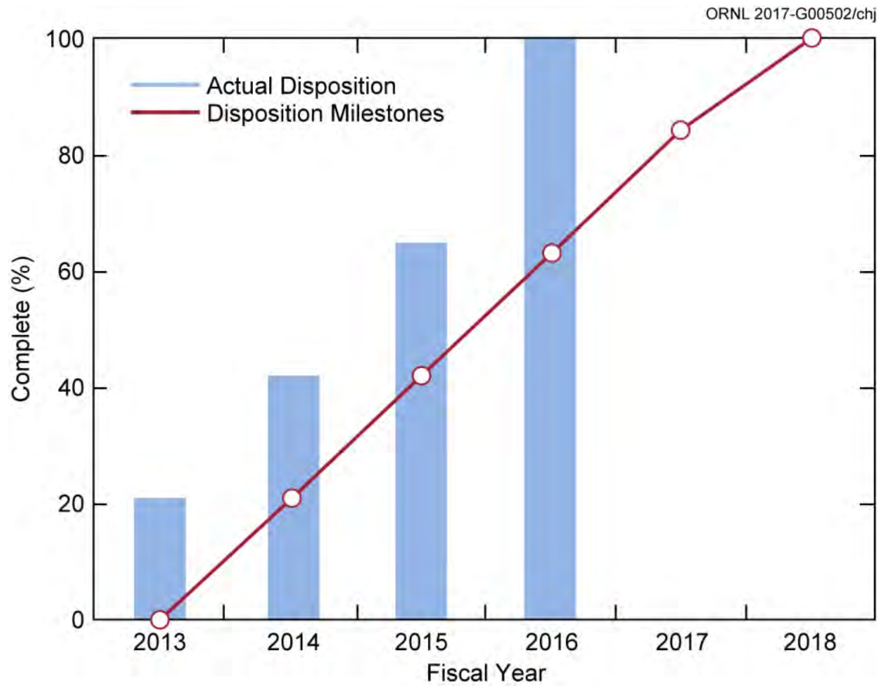

Figure 4.13. Y-12 National Security Complex path to elimination of its inventory of legacy mixed waste as part of the Oak Ridge Reservation site treatment plan.

The quantity of hazardous and mixed wastes generated by the Y-12 Complex decreased in 2016 (Figure 4.14). The decrease was primarily due to a decrease in contaminated leachate from legacy operations, which made up 97% of the total hazardous and mixed waste generated in 2016. The Y-12 Complex currently reports waste on 77 active waste streams. The Y-12 Complex is a state-permitted treatment, storage, and disposal facility. Under its permits, the Y-12 Complex received 1,770 kg of hazardous and mixed waste from the off-site Union Valley analytical chemistry laboratory and the Central Training Facility in 2016. In addition, 116,879 kg of hazardous and mixed waste was shipped to DOE-owned and commercial treatment, storage, and disposal facilities. More than 7 million kg of hazardous and mixed wastewater was treated at on-site wastewater treatment facilities.

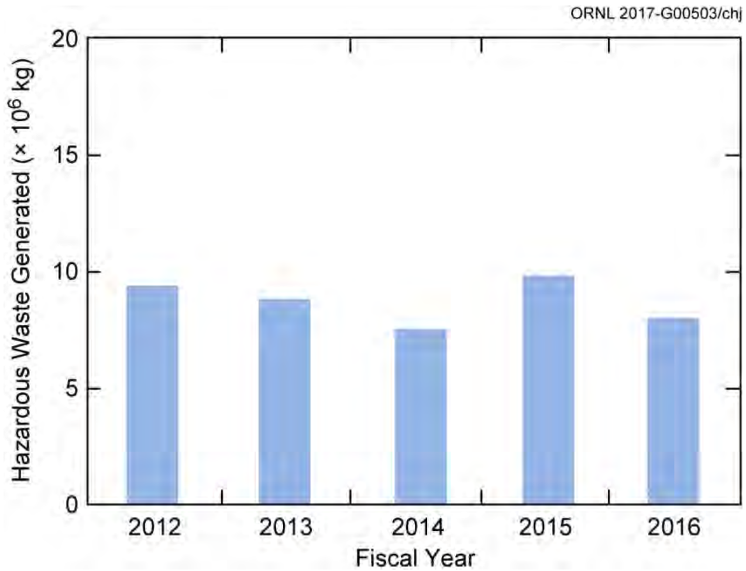

Figure 4.14. Hazardous waste generation, 2012–2016.

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 was completed in August 2012. There are no petroleum USTs remaining at Y-12.

4.3.6.2 Resource Conservation and Recovery Act Subtitle D Solid Waste

The ORR landfills operated by the DOE EM 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 CERCLA remedial investigation/feasibility study. 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 4.8.2, "Waste Management."

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

The ORR Federal Facility Agreement (DOE 2014b) 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 the Oak Ridge Reservation Corrective Action document TNHW-164 was issued for the 10-year period from September 15, 2015, through September 15, 2025. During CY 2016, the annual update of Solid Waste Management Units and Areas of Concern was submitted to TDEC in January 2016.

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). In March 2016, an application was submitted to TDEC to renew the post-closure permit for the Chestnut Ridge Hydrogeologic Regime. Groundwater corrective actions required under the post-closure permits have been deferred to CERCLA. RCRA groundwater-monitoring data were reported to TDEC and EPA in the annual groundwater monitoring report for the Y-12 Complex (UCOR 2016).

Periodic updates of proposed construction and demolition (C&D) activities at the Y-12 Complex (including alternative financing projects) have been provided to managers and project personnel from the TDEC DOE Oversight Division and from EPA Region 4. A CERCLA screening process is used to identify proposed C&D projects that warrant CERCLA oversight. The goal is to ensure that modernization efforts do not diminish the effectiveness of previously completed CERCLA environmental remediation actions and that they do not adversely affect future CERCLA environmental remediation actions.

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 East Fork Poplar Creek Hydrogeologic Regime (RCRA Post-closure Permit TNHW-113)	
New Hope Pond	Engineered cap, upper East Fork Poplar Creek distribution channel	Cap inspection and maintenance. No current groundwater monitoring requirements in lieu of ongoing CERCLA actions in the eastern portion of 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 (continued)

Unit	Major components of closure	Major post-closure requirements
	Bear Creek Hydrogeologic Regime (RCRA Post-closure Permit TNHW-116)	
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

Acronyms
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
RCRA = Resource Conservation and Recovery Act
Y-12 Complex = Y-12 National Security Complex

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 June 9, 2016.

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 ORR PCB FFCA.

The removal of legacy PCB waste, some of which had been stored since 1997, in accordance with the terms of 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 2016 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 which required notification of the regulatory agencies. See Section 4.3.11 for more information. Section 311 notifications were sent to TEMA and local emergency responders in 2016 because chemicals newly exceeded the reporting

thresholds or new information was identified about previously reported chemicals. Those chemicals included HFC-134a (CAS No. 811-97-2) used in upgraded chiller systems; asphalt (CAS No. 8052-42-4) from roofing projects; fly ash (mixture), Portland cement (CAS No. 65597-15-1) and slag (mixture) used in a new concrete batch plant; and propane (CAS No. 74-98-6) used in various facility and 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. Y-12 reported 48 chemicals that were over Section 312 inventory thresholds in 2016.

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 TRI-ME (Toxics Release Inventory-Made Easy) web-based reporting system operated by EPA. Total 2016 reportable toxic releases to air, water, and land and waste transferred off-site for treatment, disposal, and recycling were 32,967 kg (72,679 lb). Table 4.5 lists the reported chemicals for the Y-12 Complex for 2015 and 2016 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, 2015 and 2016

Chemical	Year	Quantity[a] (lb)[b]
Chromium	2015	3,474
	2016	7,006
Copper	2015	3,605
	2016	2,747
Diisocyanate compounds	2015	---[c]
	2016	568
Lead compounds	2015	14,914
	2016	10,013
Manganese	2015	3,763
	2016	6,038
Mercury	2015	179
	2016	25
Methanol	2015	16,350
	2016	37,554
Nickel	2015	3,622
	2016	8,728
Silver	2015	Form A[d]
	2016	Form A[d]
Total	2015	45,907
	2016	72,679

[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 lbs. released.

4.3.10 Spill Prevention, Control, and Countermeasures

The Clean Water Act (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. 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 (B&W Y-12 2010) 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 Y-12 by reducing the amount of oil stored on site, particularly electrical transformer oil. The revised Y-12 SPCC Plan (CNS Y-12 2015) 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 (RQ) 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 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 (ORPS). ORPS provides NNSA and the DOE community with a readily accessible database of information about occurrences at DOE facilities, causes of those occurrences, and corrective actions to prevent recurrence of the events. DOE analyzes aggregate occurrence information for generic implications and operational improvements.

During CY 2016 there was one reportable release. On December 28, 2016, there was a slight oil sheen observed at Outfall 200 of East Fork Poplar Creek. The oil sheen was no longer present on December 29, 2016, and there were no observed impacts to aquatic life. The source of the oily substance could not be determined. The appropriate authorities were notified of the oil sheen.

During 2016, 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 2016, the Y-12 Complex was inspected by federal, state, or local regulators on three occasions. Table 4.6 summarizes the results, and additional details follow.

As part of the City of Oak Ridge's pretreatment program, city personnel collect samples from the Y-12 monitoring station to conduct compliance monitoring as required by the pretreatment regulations. City personnel also conduct compliance inspections twice yearly. No issues were identified in 2016.

Personnel from EPA Region 4 and the TDEC Knoxville Field Office conducted a RCRA hazardous waste compliance inspection August 15–17, 2016. The inspections covered 48 waste storage areas and records

reviews. The report identified two findings involving a single container of used lamps (light bulbs). The lamps were not dated and labeled as required. These issues were immediately corrected.

Table 4.6. Summary of external regulatory audits and reviews, 2016

Date	Reviewer	Subject	Issues
February 23	TDEC	Biennial Survey of Potable Water Distribution System	1
March 29	COR	Semiannual Industrial Pretreatment Compliance Inspection	0
August 15–17	EPA/TDEC	Annual RCRA Hazardous Waste Compliance Inspection	2
August 30	COR	Semiannual Industrial Pretreatment Compliance Inspection	0

Acronyms
COR = City of Oak Ridge
EPA = U.S. Environmental Protection Agency
RCRA = Resource Conservation and Recovery Act
TDEC = Tennessee Department of Environment and Conservation

4.3.13 Radiological Release of Property

Clearance of property from the Y-12 National Security Complex is conducted in accordance with approved procedures that comply with DOE O 458.1, *Radiation Protection of the Public and the Environment* (DOE 2011c). Property consists of real property (i.e., land and structures), personal property, and material and equipment (M&E). At the Y-12 National Security 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 preapproved 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, and
- 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 2016. During FY 2016, Y-12 recycled more than 3.10 million lb of materials off the site 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 2016

Category	Amount released
Real property (land and structures)	None
Computer equipment recycle	134,471 lb
– Computers, monitors, printers, and mainframes	
Recycling examples	
– Used oils	4,730 gal
– Used tires	15,760 lb

– Scrap metal	1,767,446 lb
– Lead acid batteries	77,303 lb
Public/negotiated sales[a]	
– Copper	11,836 lb
– Miscellaneous furniture	240,044 lb
– Vehicles and miscellaneous equipment	177,754 lb
External transfers[b]	191,826 lb

[a] Sales during FY 2015.
[b] Vehicles; miscellaneous equipment; and materials transferred to various federal, state, and local agencies for reuse during FY 2016.

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 *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM) (NRC 2000) and *Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual* (MARSAME) (NRC 2009) .[1] The surface contamination limits used at the Y-12 National Security Complex to determine whether M&E are suitable for release to the public are provided in Table 4.7.

Y-12 uses an administrative limit for total activity of 2,400 dpm/100 cm² for radionuclides in groups 3 and 4 (see Table 4.7). The use of the more restrictive administrative limits ensures that M&E do not enter into commerce exceeding the definition of contamination found in 49 CFR 173, "Shippers—General Requirements for Shipments and Packagings."

Table 4.8. DOE O 458.1 preapproved 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]	Not applicable	Not applicable	10,000

[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.

[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-emitting and beta-gamma-emitting radionuclides exists, the limits established for alpha-emitting 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 nonremovable fractions and residual tritium in mass will not cause exposures that exceed US Department of Energy dose limits and constraints.

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 National Security 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 National Security 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 National Security 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 nonradiological 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 nonradiological areas.
- Subcontractor/vendor/privately owned vehicles, tools, and equipment used in nonradiological 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 National Security Complex locations.
- New computer equipment distributed from Building 9103, subcontractor/vendor/privately owned vehicles, tools, and equipment that has not been used in contaminated areas or for excavation activities.

4.4 Air Quality Program

Sections of the Y-12 Complex Title V permit 562767 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, nonradiological 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 2016, the Y-12 Complex received an extension to the construction air permit for UPF, amended by TDEC on February 9, 2016. The Y-12's Title V (Major Source) Operating Air Permit was revised/updated in CY 2016. The air permit is due to expire on January 8, 2017. The terms of the air permit require that a complete and timely permit renewal application be submitted no later than 180 days prior to expiration. The permit renewal application was delivered to TDEC, Division of Air Pollution Control (DAPC), on July 11, 2016, for review and approval in accordance with Condition A-12 of the Y-12 Major Source (Title V) Operating Air Permit 562767. The complete permit renewal application consists of Volumes 1, 2, 3, and 4. The edited, unclassified nonsensitive versions being provided to the TDEC to enable application processing are Volumes 1, 2, 3.1, and 4.1. Also provided are the unclassified sensitive Volumes 3.2 and 4.2, which are edited for classification reasons. Due to its classified nature, Volume 4.3 is held on site at the Y-12 Complex for appropriately Q-cleared TDEC personnel to review as needed. An operational flexibility request to add a new machine to the Graphite Carbon Machine Shop, located in Building 9201-1, was submitted to TDEC DAPC on April 25, 2016, for review and approval. TDEC approved the request on April 26, 2016. Another operational flexibility request change to the ventilation system for the Purification Facility located in Building 9225-3 was submitted to TDEC DAPC on June 23, 2016, for review and approval. TDEC approved the request on June 30, 2016.

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

CNS Y-12 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 2016, emissions categorized as actual emissions totaled 32,160 kg, and emissions calculated by the allowable method totaled 590,342 kg. The total emissions fee paid was $22,697.23.

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 consists of tasks such as 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 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; the second is an annual Title V compliance certification report indicating compliance status with all conditions of the permit. The third is a Title V semiannual report, which covers a 6-month period for some specific emission sources. It 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, 2016

Pollutant	Emissions (tons/year)[a]		Percentage of allowable
	Actual	Allowable	
Particulate	3.34	41	8.1
Sulfur dioxide	0.26	39	0.7
Nitrogen oxides[b]	14.07	81	17.4
Volatile organic compounds[b]	3.25	9.4	34.6
Carbon monoxide[b]	36.94	139	26.6

NOTE: The emissions are based on fuel usage data for January through December 2016. The volatile organic compound emissions include volatile organic compound 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 h/year). Both actual and allowable emissions were calculated based on the latest US 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.

4.4.1.1.1 Control of Asbestos

The Y-12 Complex has numerous buildings and equipment that contain asbestos-containing materials. The compliance program for management of removal and disposal of asbestos-containing materials 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 2016. There were three notifications of asbestos demolition or renovation, one revision of notification of asbestos demolition or renovation, one annual estimate for CY 2017, one revised annual estimate for CY 2016.

An internal surveillance of the asbestos NESHAP reporting process was conducted on November 28, 2016. 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.

4.4.1.1.2 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 (SNAP). Y-12 Complex personnel are notified as EPA issues regulations detailing SNAP replacement chemicals that may be applicable to Y-12 Complex operations. To prevent ODSs from coming on site, procurement documents are written to ensure that no additional equipment or processes using Class I ODSs are brought on site, 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 in 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 on site are first made available to the Defense Logistics Agency. Remaining refrigerants, including Class I and Class II ODSs, are sold to refrigerant reclamation facilities or properly disposed of.

4.4.1.1.3 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 C&D 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 4.15). The particle size and solubility class of the emissions are determined based on review of the operations and processes served by the exhaust systems to determine the quantity of uranium handled in the operation or process, the physical form of the uranium, and the nature of the operation or process. The four categories of processes or operations that are considered when calculating the total uranium emissions are:

- those that exhaust through monitored stacks;
- unmonitored processes for which calculations are performed per Appendix D of 40 CFR 61;
- processes or operations exhausting through laboratory hoods, also involving 40 CFR 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 2016, 32 process exhaust stacks were continuously monitored, 24 of which were major sources; the remaining 8 were minor sources. The sampling systems on the stacks have been approved by EPA Region 4.

During 2016, unmonitored uranium emissions at the Y-12 Complex occurred from 31 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 operates out of two main laboratories. One is located on the site in Building 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 2016, 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 (DAC) 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. Five emission points from room ventilation exhausts were identified in 2016 where emissions exceeded 10% of DAC. 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 per 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 0.0052 Ci (1.5 kg) of uranium was released into the atmosphere in 2016 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 issued a Construction Air Permit, 967550P. The current strategy, with concurrence from the TDEC Air Division, is to include the UPF in the 2017 update of the Y-12 Site Title V Operating Permit and to maintain the facility on the permit as inactive until operations commence in about 2025.

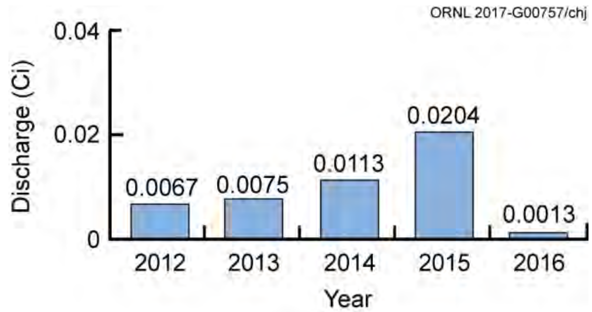

Figure 4.15. Total curies of uranium discharged from the Y-12 National Security Complex to the atmosphere, 2012–2016.

The calculated radiation dose to the maximally exposed off-site individual from airborne radiological release points at the Y-12 Complex during 2016 was 0.04 mrem. This dose is well below the NESHAP standard of 10 mrem and is less than 0.02% 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 *Y-12 National Security Complex Quality Assurance Project Plan for National Emission Standards for Hazardous Air Pollutants (NESHAP) 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 management of 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 4.8.

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 2016 are 102.06 lb (0.05 tons) and 39,204 lb (19.60 tons), respectively. The highest calculated

amount of acetonitrile emitted to the atmosphere for CY 2016 was 5.5 tons, which was less than the permitted value of 9 tons/year.

4.4.1.5 Mandatory Reporting of Greenhouse Gas Emissions under 40 CFR 98

Title 40 of the Code of Federal Regulations Part 98, *Mandatory Greenhouse Gas Reporting*, 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 (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), 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 Btu/h. Natural gas is the primary fuel source for the boilers; Number 2 fuel oil as a backup source of fuel. Other limited stationary combustion sources are metal-forming operations and production furnaces that use natural gas. In Building 9212, a gas-fired furnace used for drying wet residues and burning solids in a recovery process has a maximum heat input of 700,000 Btu/h. In Building 9215, 10 natural gas torches, each at 300 standard ft^3/h, are used to preheat tooling associated with a forging and forming press. In Building 9204-2, natural gas is used to heat two electrolytic cells. The maximum rated heat input to the burners on each cell is 550,000 Btu/h.

All of the combustion units burning natural gas are served through the fuel supply and distribution system and are reported as combined emissions consistent with the provisions of 40 CFR 98.36(c)(3). The Tier 1 Calculation Method was used to calculate GHGs from 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 emission 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 2016 is associated with the fact that coal is no longer burned since the natural-gas-fired steam plant came on line.

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

Acronyms
CO_{2e} = CO_2 equivalent GHG = greenhouse gas

4.4.1.6 Hazardous Air Pollutants (Nonradiological)

Beryllium emissions from machine shops are regulated under a state-issued permit and are subject to a limit of 10 g/24 h. Compliance is demonstrated through a 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.

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, “Ambient Air.”

In 2007, EPA vacated a proposed Maximum Achievable Control Technology (MACT) standard that was intended to minimize hazardous air pollution 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. To comply with that requirement, an energy assessment for the Y-12 Steam Plant, performed by a qualified energy assessor, was completed in July 2013. Tune-ups for boilers were completed on January 13 and 14, 2016.

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.

4.4.1.7 Reciprocating Internal Combustion Engines: New Source Performance Standards and National Emission Standards for Hazardous Air Pollutants

Reciprocating internal-combustion engines (RICEs) use reciprocating motion to convert heat energy into mechanical work. A number of stationary emergency-use RICEs (which power generators) are located throughout the Y-12 Complex. The emergency engines/generators are used to provide power for critical systems in the event of electrical power failures/outages at the Y-12 Complex. Emergency RICEs are defined as stationary RICEs whose operations are limited to emergency situations and require testing and maintenance activities to ensure operation during emergencies. A stationary RICE used for peak shaving is not considered an emergency stationary RICE, although such a RICE may be used for periods of emergency demand response, subject to restriction.

EPA has created multiple national air pollution regulations to reduce air emissions from 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 (Title 40 CFR Part 63, Subpart ZZZZ). The compression ignition engines/generators located at Y-12 are subject to these rules. EPA is concerned about how RICEs are used and the emissions generated from these engines in the form of both HAPs and criteria pollutants.

All previous stationary emergency engines/generators were listed in the Y-12 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 Major Source (Title V) 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 Major Source (Title V) 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 Y-12 a minor permit modification to the Title V air permit on March 3, 2014, for the emergency engines/generators. Compliance for the engines/generators is determined through monthly records of the operation of the engines/generators that are recorded through a nonresettable 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) nonemergency operation. Each engine/generator must use only diesel fuel with low sulfur content (15 ppm) 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. Originally four monitoring stations were operated at the Y-12 Complex, including two within the west end mercury-use area (WEMA). The two atmospheric mercury monitoring stations, ambient air monitoring station (AAS) 2 and AAS8, located near the east and west boundaries of the Y-12 Complex, respectively, are currently operating (Figure 4.16). 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: (1) 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 (2) a site was operated at New Hope Pond for a 25 month period from August 1987 to September 1989.

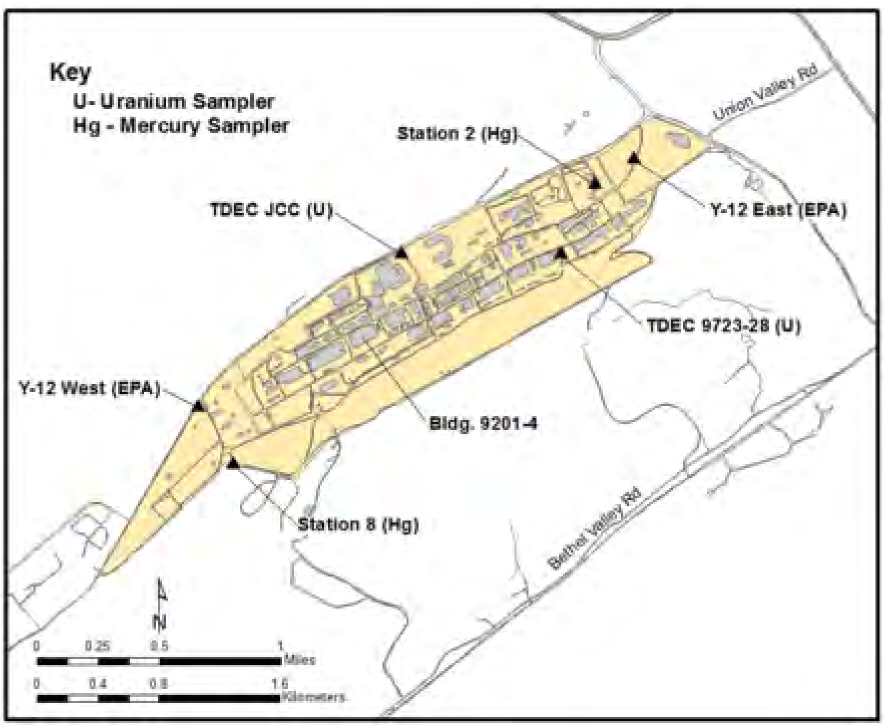

Figure 4.16. Locations of ambient air monitoring stations at the Y-12 Complex. *[EPA = US Environmental Protection Agency (sampler) TDEC = Tennessee Department of Environment and Conservation, and JCC = Jack Case Center.]*

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 ~1 L/min. Actual flows are measured biweekly with a calibrated Gilmont flowmeter in conjunction with the biweekly change-out of the sampling trap. The charcoal in each trap is analyzed for total mercury using cold vapor atomic fluorescence spectrometry after acid digestion. The average concentration of mercury vapor in ambient air for each 14 day sampling period is then calculated by dividing the total mercury per trap by the volume of air pulled through the trap during the corresponding 14 day sampling period.

As reported previously, average mercury concentration at the ambient air monitoring sites has declined significantly since the late 1980s. Recent average annual concentrations at the two boundary stations are comparable to concentrations measured in 1988 and 1989 at the Chestnut Ridge reference site (Table 4.10). Average mercury concentration at the AAS2 site for 2016 is 0.0028 μg/m^3 (N = 24), comparable to averages measured since 2003. After an increase in average concentration at AAS8 for the period 2005 through 2007, thought to be possibly due to increased decontamination and decommissioning work on the west end, the average concentration at AAS8 for 2016 was 0.0037 μg/m^3 (N = 23), similar to levels reported for 2008 and for the early 2000s.

Table 4.11 summarizes the 2016 mercury results; results from the 1986 through 1988 period are included for comparison. Figure 4.18 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 2016 [parts (a) and (b)] and seasonal trends at AAS8 from 1994 through 2016 [part (c)]. The dashed line superimposed on the plots in Figures 4.18(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 within WEMA. In Figure 4.18(c), a monthly moving average has been superimposed over the AAS8 data to highlight seasonal trends in mercury at AAS8 from January 1994 through 2016.

Table 4.11. Summary of data for the Y-12 National Security Complex ambient air monitoring program for mercury for CY 2016

Ambient air monitoring stations	Mercury vapor concentration (μg/m^3)			
	2016 minimum	2016 maximum	2016 average	1986–1988[a] average
AAS2 (east end of the Y-12 Complex)	0.0016	0.0044	0.0028	0.010
AAS8 (west end of the Y-12 Complex)	0.0004	0.0075	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 ’80s with elevated ambient air mercury levels; shown for comparison.
[b]Data for period from February 9 through December 31, 1988.
[c]Data for period from January 1 through October 31, 1989.

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

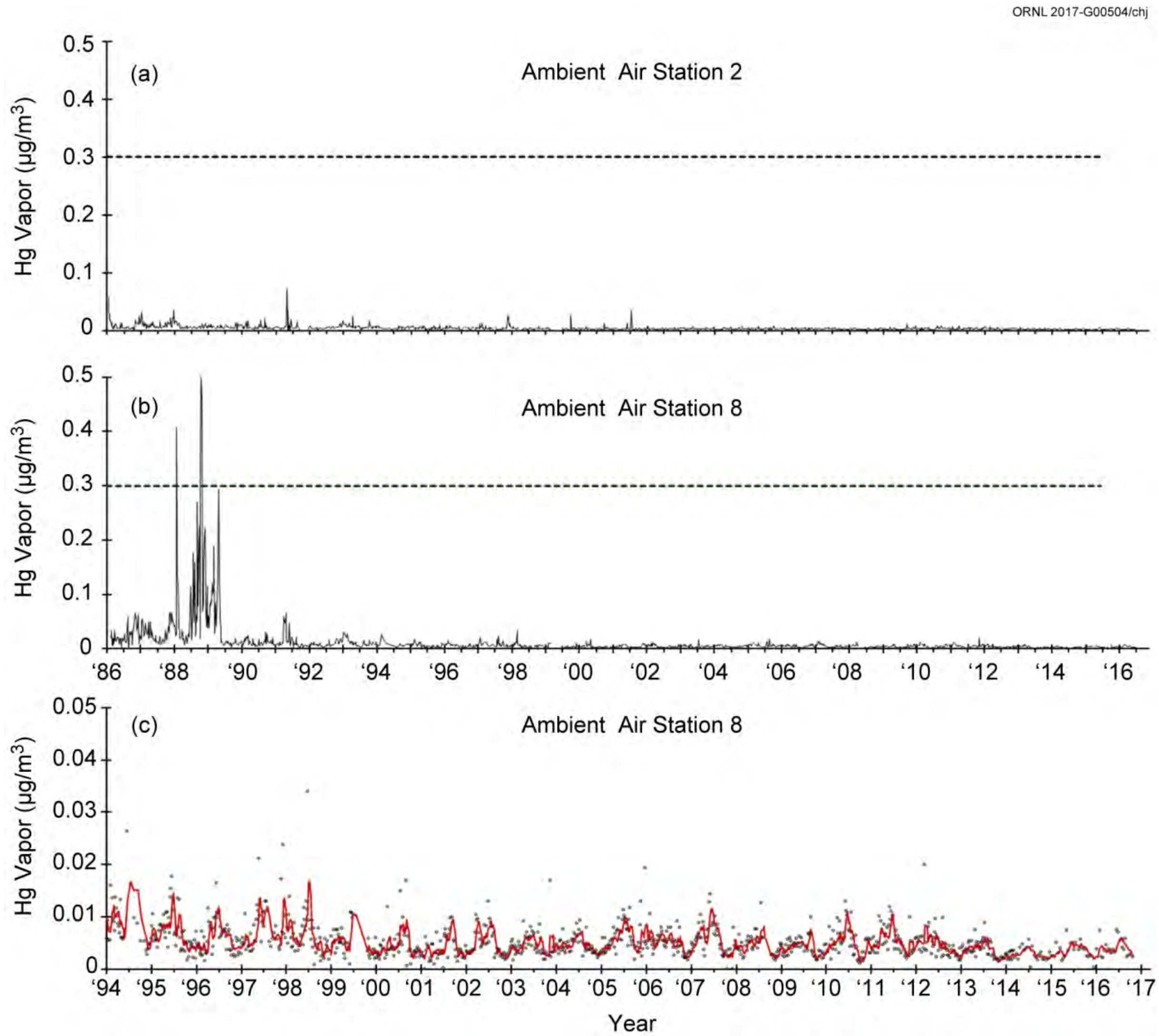

Figure 4.17. Temporal trends in mercury vapor concentration for the boundary monitoring stations at the Y-12 Complex, July 1986 to January 2017 [(a) and (b)] and January 1994 to January 2017 for ambient air station 8 [(c)]. Note the different concentration scale in (c).

The dashed lines superimposed on (a) and (b) represent the EPA reference concentration of 0.3 µg/m^3 for chronic inhalation exposure. In (c) (note different concentration scale), a monthly moving average has been superimposed over the data to highlight seasonal trends in mercury at ambient air station 8 from January 1993 to January 2017, with higher concentrations generally measured during the warm weather months.

In conclusion, 2016 average mercury concentrations at the two mercury monitoring sites were comparable to reference levels measured for the Chestnut Ridge reference site in 1988 and 1989. More importantly, measured concentrations continue to be well below current environmental and occupational health standards for inhalation exposure to mercury vapor (i.e., the National Institute for Occupational Safety and Health recommended exposure limit of 50 µg/m^3, time-weighted average for up to a 10 h workday, 40 h workweek; the American Conference of Governmental Industrial Hygienists workplace threshold limit value of 25 µg/m^3 as a time-weighted average for a normal 8 h workday and 40 h workweek; and the

current EPA reference concentration of 0.3 μg/m^3 for elemental mercury for a continuous inhalation exposure to the human population without appreciable risk of harmful effects during a lifetime).

4.4.2.2 Quality Control

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

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

The Gilmont correlated flowmeter, used for measuring flows through the sampling train, is either purchased annually or, if not new, is shipped back to the manufacturer annually for calibration in accordance with standards set by the National Institute of Standards and Technology.

A minimum of 5% 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, August 4, 2016.

Analytical QA/QC requirements include the following:

- use of prescreened and/or laboratory-purified reagents,
- analysis of at least two method blanks per batch,
- analysis of standard reference materials,
- analysis of laboratory duplicates (one per 10 samples; if any laboratory duplicates differ by more than 10% at five or more times the detection limit a third aliquot (identical to the duplicates) is analyzed 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 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. The 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, the uranium monitors at stations 4, 5, and 8 were phased out of service, and two additional high-volume samplers (Figure 4.17) are now being used by TDEC to provide isotopic uranium monitoring capability. These are located on the east side of the Jack Case Center and on the south side of the Building 9723-28 change house. EPA performs ambient air monitoring on the east end of the plant near the intersection of Scarboro Road and Bear Creek Road and on the west end of the plant near the intersection of Bear Creek Road and Old Bear Creek Road.

In addition, TDEC Division of Remediation Oak Ridge Office conducts several other air quality monitoring programs on the ORR including:

- sample collection in support of EPA’s nationwide RadNet air monitoring system,
- 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 4.18. 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.

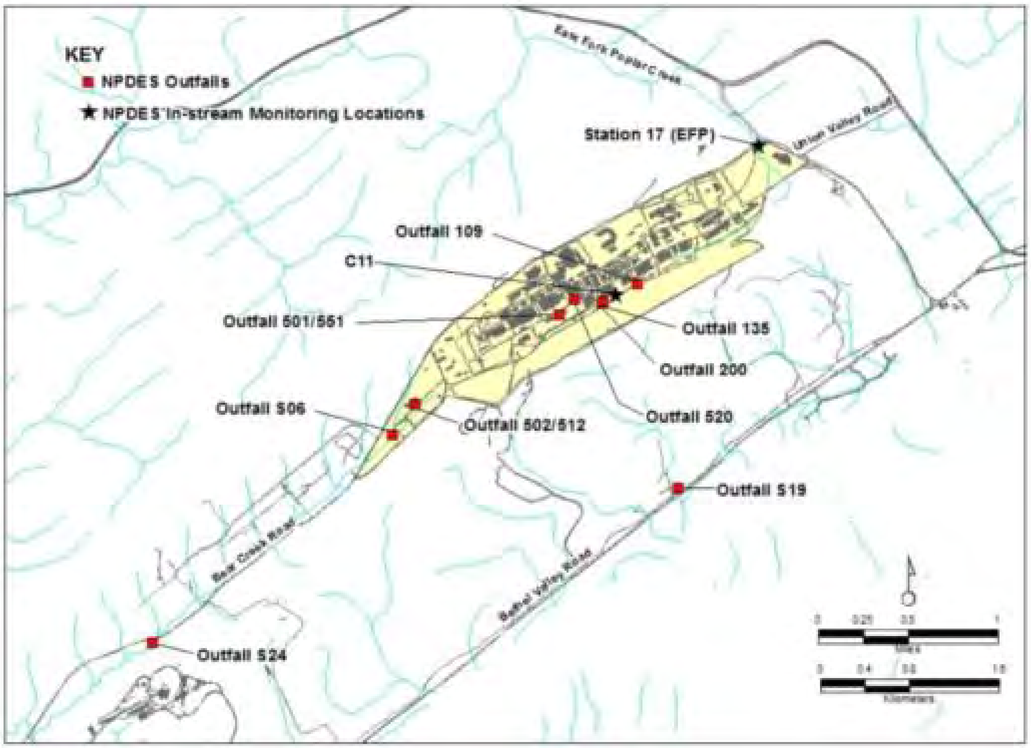

Figure 4.18. Major Y-12 National Security Complex National Pollutant Discharge Elimination System (NPDES) outfalls and monitoring locations . *EFP = East Fork Poplar*

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 2016 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 2016 was almost 100% (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 2016

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
	Polychlorinated biphenyl (PCB)				0.001	*b*	0
Outfall 502 (West End Treatment Facility)	pH, standard units			*a*	9.0	100	3
	Total suspended solids		31		40	100	3
	Total toxic organic				2.13	100	3
	Hexane extractables			10	15	100	3
	Cadmium		0.4		0.15	100	3
	Chromium		1.7		1.0	100	3
	Copper		2.0		1.0	100	3
	Lead		0.4		0.2	100	3
	Nickel		2.4		3.98	100	3
	Nitrate/Nitrite				100	100	3
	Silver		0.26		0.05	100	3
	Zinc		0.9		1.48	100	3
	Cyanide		0.72		1.20	100	3
	PCB				0.001	100	3
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	16
	IC_{25} *Ceriodaphnia*			37% Minimum		100	1
	IC_{25} *Pimephales*			37% Minimum		100	1
	Total residual chlorine			0.024	0.042	100	13

Table 4.12 (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 551	pH, standard units			*a*	9.0	100	53
	Mercury			0.002	0.004	100	52
Outfall C11	pH, standard units			*a*	9.0	100	14
Outfall 135	pH, standard units			*a*	9.0	100	12
	IC_{25} *Ceriodaphnia*			9% Minimum		100	1
	IC_{25} *Pimephales*			9% Minimum		100	1
Outfall 109	pH, standard units			*a*	9.0	60	5
	Total residual chlorine			0.010	0.017	100	5
Outfall S19	pH, standard units			*a*	9.0	100	2
Outfall S06	pH, standard units			*a*	9.0	100	2
Outfall S24	pH, standard units			*a*	9.0	100	2
Outfall EFP	pH, standard units			*a*	9.0	100	12
Category I outfalls	pH, standard units			*a*	9.0	100	52
Category II outfalls	pH, standard units			*a*	9.0	100	21
	Total residual chlorine				0.5	100	25
Category III outfalls	pH, standard units			*a*	9.0	100	8
	Total residual chlorine			*a*	0.5	100	10

[a]Not applicable.
[b]No discharge.

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.

Table 4.13. Radiological parameters monitored at the Y-12 National Security Complex, 2016

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

Acronyms
Y-12 Complex = Y-12 National Security Complex

Radiological monitoring during storm water events is accomplished as part of the storm water monitoring program. Uranium is monitored at three major EFPC storm water outfalls, two instream monitoring locations, and an outfall on Bear Creek. In addition, the monthly 7-day composite sample for radiological parameters taken at Station 17 on EFPC likely includes rain events.

Radiological monitoring plan locations sampled in 2016 are noted on Figure 4.19. Table 4.14 identifies the monitored locations, the frequency of monitoring, and the sum of the percentages of the derived concentration standards (DCSs) for radionuclides measured in 2016. Radiological data were well below the allowable DCSs.

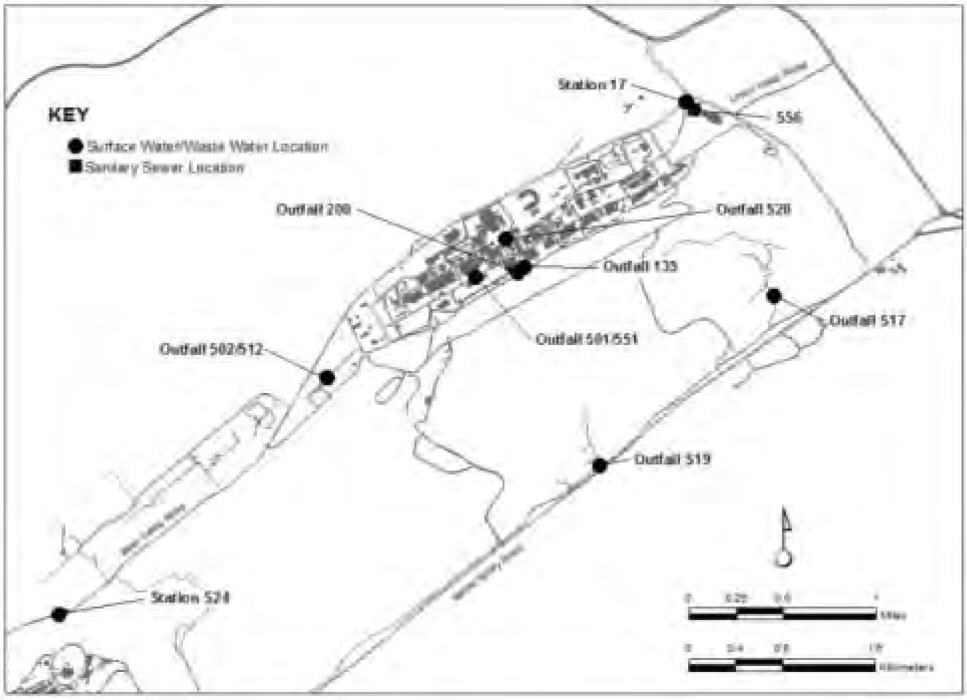

Figure 4.19. Surface water and sanitary sewer radiological sampling locations at the Y-12 National Security Complex.

Table 4.14. Summary of Y-12 National Security Complex radiological monitoring plan sample requirements and 2016 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 h composite	13
Groundwater Treatment Facility	4/year	24 h composite	8.8
Steam condensate	1/year	Grab	No flow
Central Mercury Treatment Facility	4/year	24 h composite	0
Other Y-12 Complex point and area source discharges			
Outfall 135	4/year	24 h composite	3.1
Kerr Hollow Quarry	1/year	24 h composite	4.1
Rogers Quarry	1/year	24 h composite	0
Y-12 Complex instream locations			
Outfall S24	1/year	7-day composite	9.5
East Fork Poplar Creek, complex exit (east)	1/month	7-day composite	0
North/south pipes	1/month	24 h composite	2.4
Y-12 Complex Sanitary Sewer			
East End Sanitary Sewer Monitoring Station	1/year	7-day composite	0

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

In 2016, 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 88 kg or 0.045 Ci (Table 4.15).

Figure 4.20 illustrates a 5-year trend of these releases. The total release is calculated by multiplying the average concentration (grams per liter) by the average flow (million gallons per day). 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 2016 quarterly monitoring reports.

Table 4.15. Release of uranium from the Y-12 National Security Complex to the off-site environment as a liquid effluent, 2011–2016

Year	Quantity released	
	Ci[a]	Kg
	Station 17	
2011	0.104	124
2012	0.039	121
2013	0.055	140
2014	0.061	90
2015	0.068	116
2016	0.045	88

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

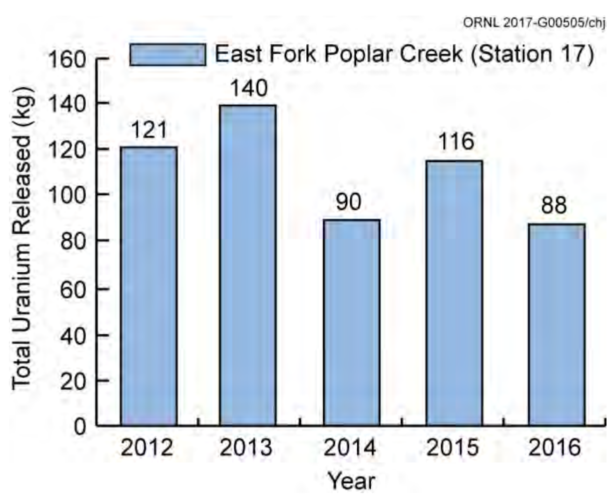

Figure 4.20. Five-year trend of Y-12 National Security Complex releases of uranium to East Fork Poplar Creek.

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 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 2016 during rain events that occurred on February 1, November 19, and November 29. Results were published in the annual storm water report (CNS 2016b), which was submitted to the TDEC Division of Water Pollution Control in January 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 4.21). 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 million gal per day, or about 60%).

In general, the quality of storm water exiting the Y-12 Complex via EFPC remained relatively stable from 2015 to 2016. The one area of concern is 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. The result in 2014 (0.892 µg/L) showed some improvement. However, in 2015, the result was 9.11 µg/L. In 2016, the concentration was measured to be 0.49 µg/L. These elevated and sporadic changes in mercury concentrations at this location have garnered the attention of TDEC Division of Water Resources personnel and has resulted in some discussion of including discharges from this outfall to be routed to the planned mercury treatment system, which is to be located nearby. A final decision on this issue is still pending.

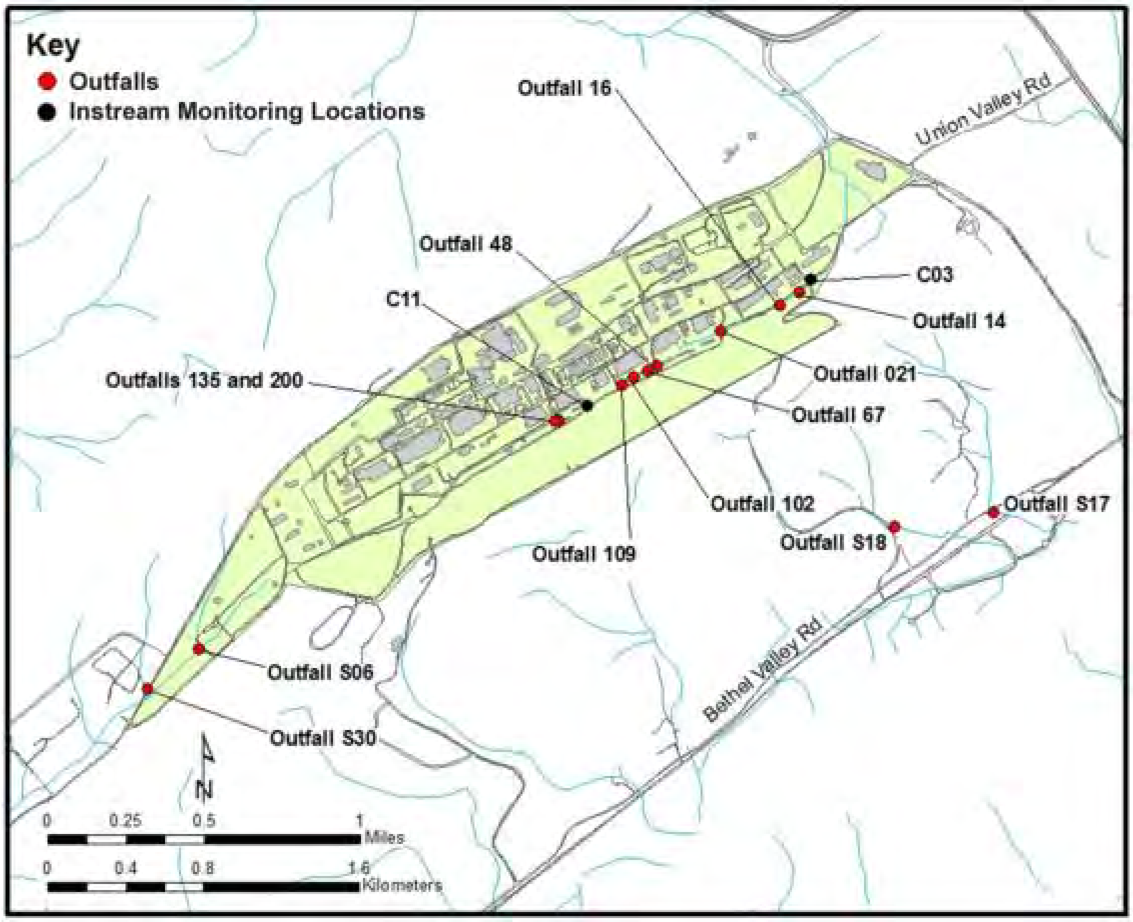

Figure 4.21. Y-12 National Security Complex storm water monitoring locations. East Fork Poplar Creek.

4.5.4 Y-12 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 4.23. The primary function of SWHISS is to provide an indication of 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 Groundwater Protection Program (GWPP) to monitor trends throughout the three hydrogeologic regimes (see Section 4.6).

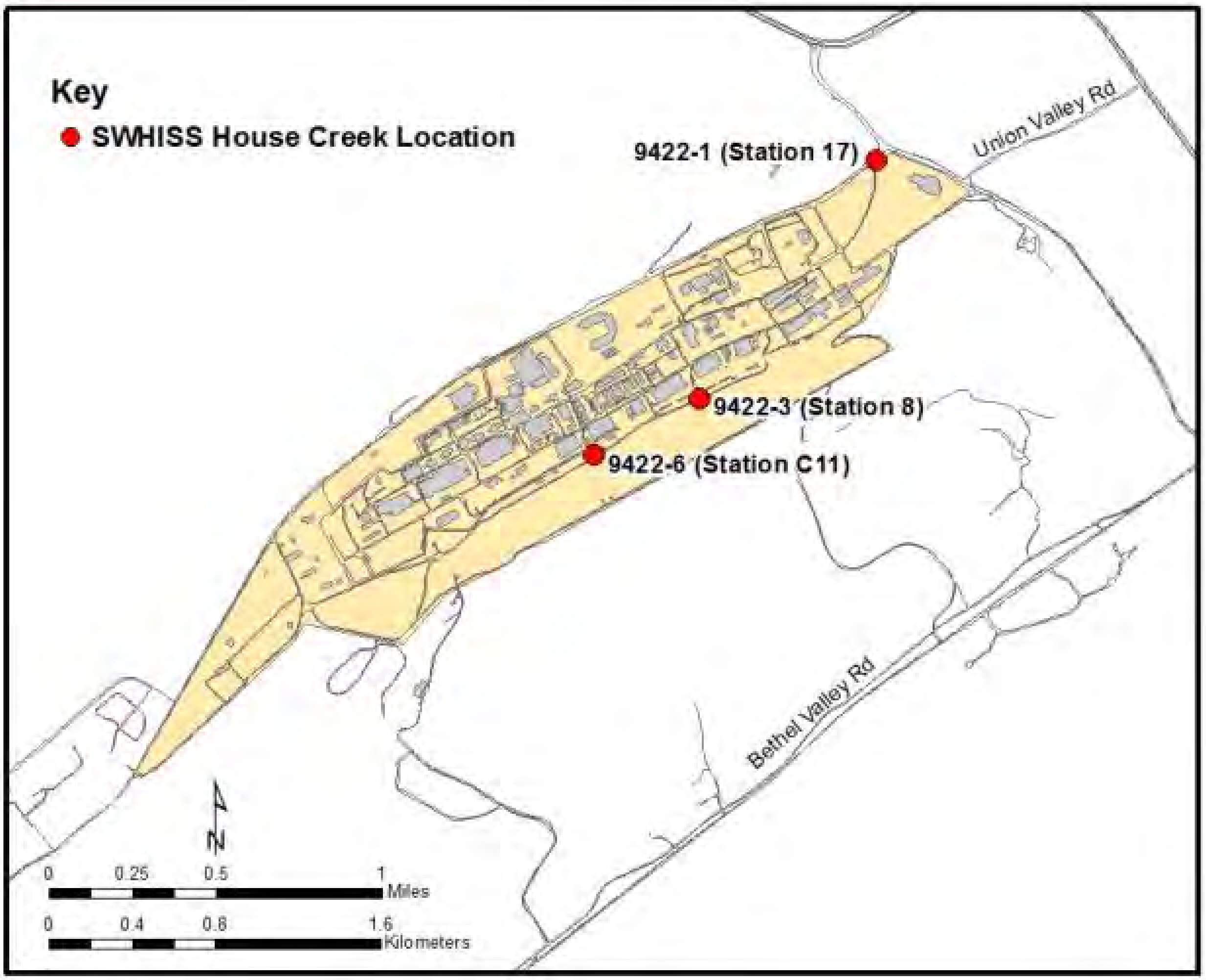

Figure 4.22. Surface Water Hydrological Information Support System (SWHISS) monitoring locations.

4.5.5 Industrial Wastewater Discharge Permit

The 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 hour 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 4.22) to conduct compliance monitoring as required by the pretreatment regulations. City personnel also conduct twice-yearly compliance inspections. Monitoring results during 2016 (Table 4.16) indicate three exceedances of permit limits. Two were for exceedances of the daily flow limit and the third was for an exceedance of the oil and grease limit.

In January 2016, the City of Oak Ridge issued a new Industrial and Commercial Users Wastewater Discharge Permit 1-91 to the Y-12 Complex. Due to numerous changes in parameter limits and allowable flow rates, an appeal was filed with the City of Oak Ridge within thirty days of the issuance of the new permit. Negotiations between the two parties then ensued, and a resolution is still pending. The monitoring requirements and limits of the previous permit remained in effect during the period of appeal.

Table 4.16. Y-12 National Security Complex discharge point SS6, Sanitary Sewer Station 6, January through December 2016 (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)	365	355	1,400	N/A	2
pH (standard units)	14	N/A	9/6[b]	9/6[b]	0
Biochemical oxygen demand	14	84.7	300	200	0
Kjeldahl nitrogen	14	20.0	90	45	0
Phenols—total recoverable	14	<0.002	0.3	0.15	0
Oil and grease	14	<9.5	50	25	1
Suspended solids	23	99.7	300	200	0
Cyanide	14	<0.006	0.062	0.041	0
Arsenic	14	<0.004	0.025	0.010	0
Cadmium	14	<0.0003	0.005	0.0033	0
Chromium	14	<0.0032	0.075	0.05	0
Copper	14	0.0211	0.21	0.14	0
Iron	14	0.423	30	10	0
Lead	14	<0.002	0.074	0.049	0
Mercury	23	0.001	0.035	0.023	0
Nickel	14	<0.004	0.032	0.021	0
Silver	14	0.003	0.10	0.05	0
Zinc	14	0.0961	0.75	0.35	0
Molybdenum	14	0.0545	0.05[c]	0.05[c]	Not applicable
Selenium	14	<0.01	0.01[c]	0.01[c]	Not applicable
Toluene	4	0.005U	0.005[c]	0.005[c]	Not applicable
Benzene	4	0.005U	0.005[c]	0.005[c]	Not applicable
1,1,1-trichloroethane	4	0.005U	0.005[c]	0.005[c]	Not applicable
Ethylbenzene	4	0.005U	0.005[c]	0.005[c]	Not applicable
Carbon tetrachloride	4	0.005U	0.005[c]	0.005[c]	Not applicable
Chloroform	4	0.006J	0.005[c]	0.005[c]	Not applicable
Tetrachloroethylene	4	0.003J	0.005[c]	0.005[c]	Not applicable
Trichloroethene	4	0.005U	0.005[c]	0.005[c]	Not applicable
Trans-1,2-dichloroethylene	4	0.005	0.005[c]	0.005[c]	Not applicable
Methylene chloride	4	0.005JU	0.005[c]	0.005[c]	Not applicable

[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.

4.5.6 Quality Assurance/Quality Control

The Environmental Monitoring Management Information System (EMMIS) is used to manage surface water monitoring data at Y-12. EMMIS uses standard sample definitions to ensure that samples are taken at the correct location at a specified frequency using the correct sampling protocol.

Field sampling QA encompasses many practices that minimize error and evaluate sampling performance. Some key quality practices include the following:

- use of standard operating procedures for sample collection and analysis;
- use of chain-of-custody and sample identification, customized chain-of-custody documents, and sample labels provided by EMMIS;
- instrument standardization, calibration, and verification;
- sample technician training;
- sample preservation, handling, and decontamination; 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 standards, 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 2016 using fathead minnow (*Pimephales promelas*) larvae and water fleas (*Ceriodaphnia dubia)*. A third discharge, Outfall 125, no longer has sufficient base flows for toxicity to be evaluated. Table 4.17 summarizes the results of the 2016 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 *C. dubia* survival or reproduction or fathead minnow survival or growth. The lower the value of the IC_{25}, the more toxic the effluent.

Table 4.17. Y-12 National Security Complex Biomonitoring Program summary information for outfalls 200 and 135 in 2016[a]

Site	Test start date	Species	IC_{25}[b] (%)
Outfall 200	7/06/16	*Ceriodaphnia dubia*	>100
Outfall 200	7/06/16	*Pimephales promelas*	>100
Outfall 135	7/06/16	*Ceriodaphnia dubia*	>36
Outfall 135	7/06/16	*Pimephales promelas*	>36

[a]Inhibition concentration (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 *C. dubia* survival or reproduction or fathead minnow survival or growth; 36% is the highest concentration of Outfall 135 tested.

Effluent from Outfall 135 did not reduce fathead minnow survival or growth or *C. 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 therefore >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 survival or growth or *C. 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 Programs

The NPDES permit issued for the Y-12 National Security 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 2016 BMAP sampling efforts reported in this chapter follow the NPDES-required Y-12 National Security Complex BMAP plan (Peterson et al. 2013). The Y-12 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 the 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 4.23). Brushy Fork at Brushy Fork kilometer 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 4.24).

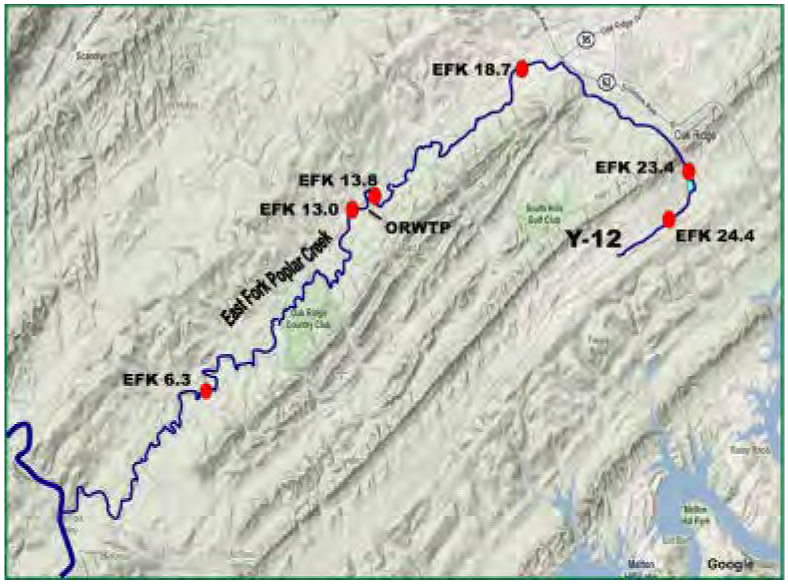

Figure 4.23. Locations of biological monitoring sites on East Fork Poplar Creek in relation to the Y-12 National Security Complex. *(EFK = East Fork Poplar Creek kilometer and ORWTP = Oak Ridge Water Treatment Plant.)*

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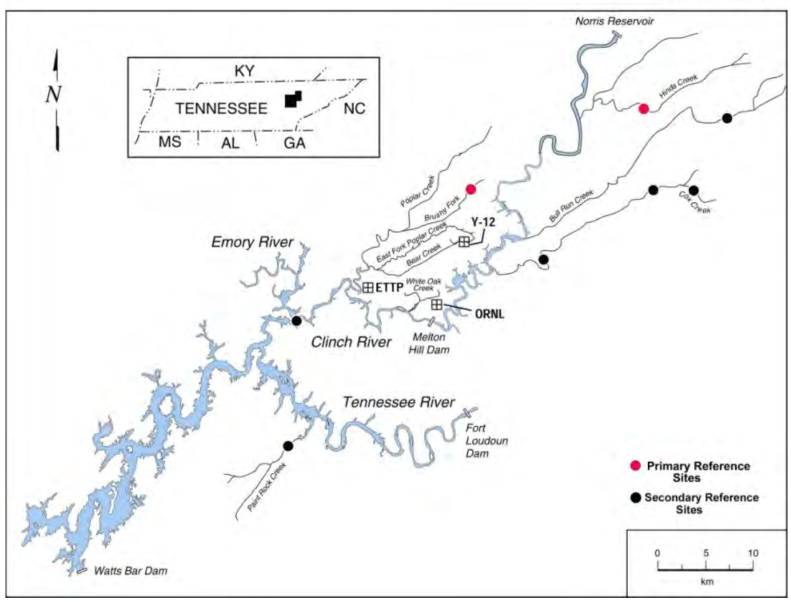

Figure 4.24. Locations of biological monitoring reference sites in relation to the Y-12 National Security Complex. *(ETTP = East Tennessee Technology Park, ORNL = Oak Ridge National Laboratory, and Y-12 = Y-12 National Security Complex.*

Significant increases in the number of invertebrate and fish species in EFPC over the last two 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 National Security Complex has slowed in recent years, and

fish and invertebrate communities continue to have fewer species than the corresponding communities in reference streams. The impacts on stream ecology of recent remedial and abatement actions to address mercury releases at Y-12, including a major storm drain cleanout in WEMA (2011) and flow augmentation cessation (April 30, 2014), are still uncertain and, along with additional anticipated changes in stream conditions in upper EFPC with a planned mercury treatment facility in the EFPC headwaters, will continue to be a focus of future monitoring and investigation.

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 4.25). Mercury concentrations remained higher in fish from EFPC in 2016 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 4.25 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 4.26). 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 ~0.6 µg/g in 2011 to above 1 µg/g in 2012 and dropped back down in 2013–2016 (~0.7 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.

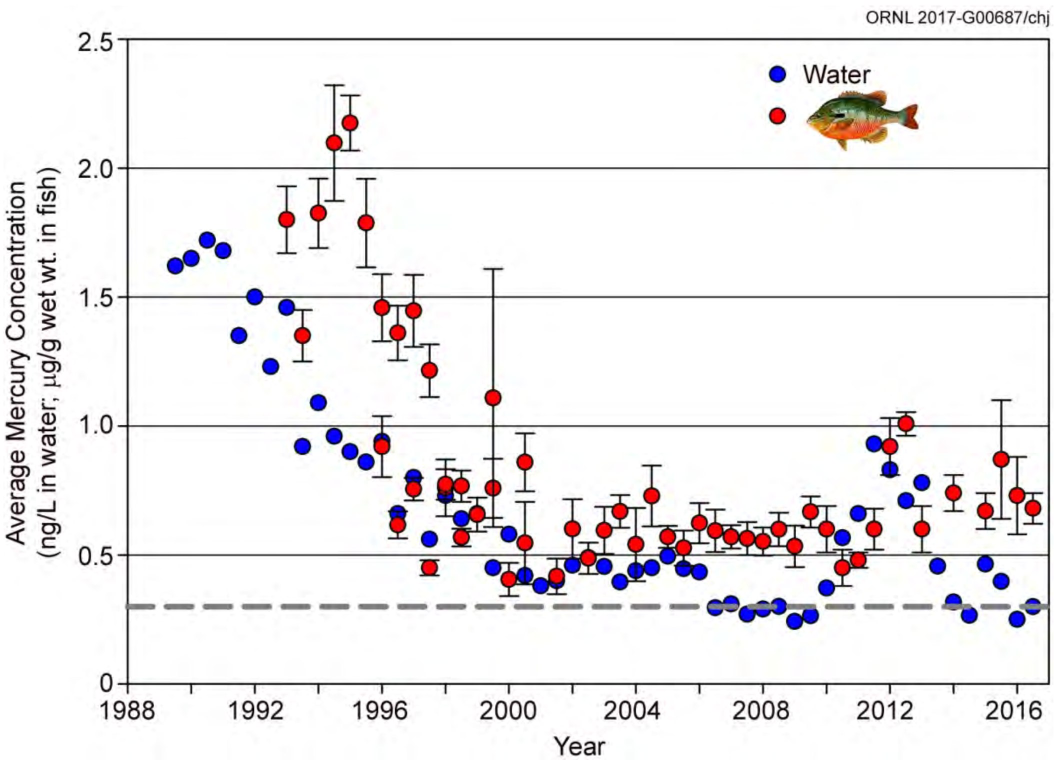

Figure 4.25. Semiannual average mercury concentration in muscle fillets of redbreast sunfish and water from East Fork Poplar Creek (EFPC) at EFPC kilometers 23.4 (water) and 24.4 (fish), FY 2016. *Dashed grey line represents the ambient water quality criterion for methylmercury in fish fillets (0.3 mg/kg).*

The mean total PCB concentration in sunfish fillets at EFK 23.4 was 0.60 µg/g in FY 2016, which was comparable to the concentration in FY 2015 (0.56 µg/g) (Figure 4.26). 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 (TMDLs), including for local reservoirs (Melton Hill, Watts Bar, and Fort Loudoun; TDEC 2010a, b, c). In the state of Tennessee, assessments of impairment for water body segments as well as public fishing advisories are based on fish tissue concentrations. Historically, the US Food and Drug Administration threshold limit of 2 µ g/g PCBs in fish fillets was used for advisories, and then for many years an approximate range of 0.8 to 1 µ g/g was used, depending on the data available and factors such as the fish species and size. The remediation goal for fish fillets at the 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 TMDL (TDEC 2007). This concentration is 0.02 mg/kg PCBs in fish fillets (TDEC 2010a, b, and c). The mean fish PCB concentration in upper EFPC, 0.60 µg/g in fish fillets, is well above this concentration.

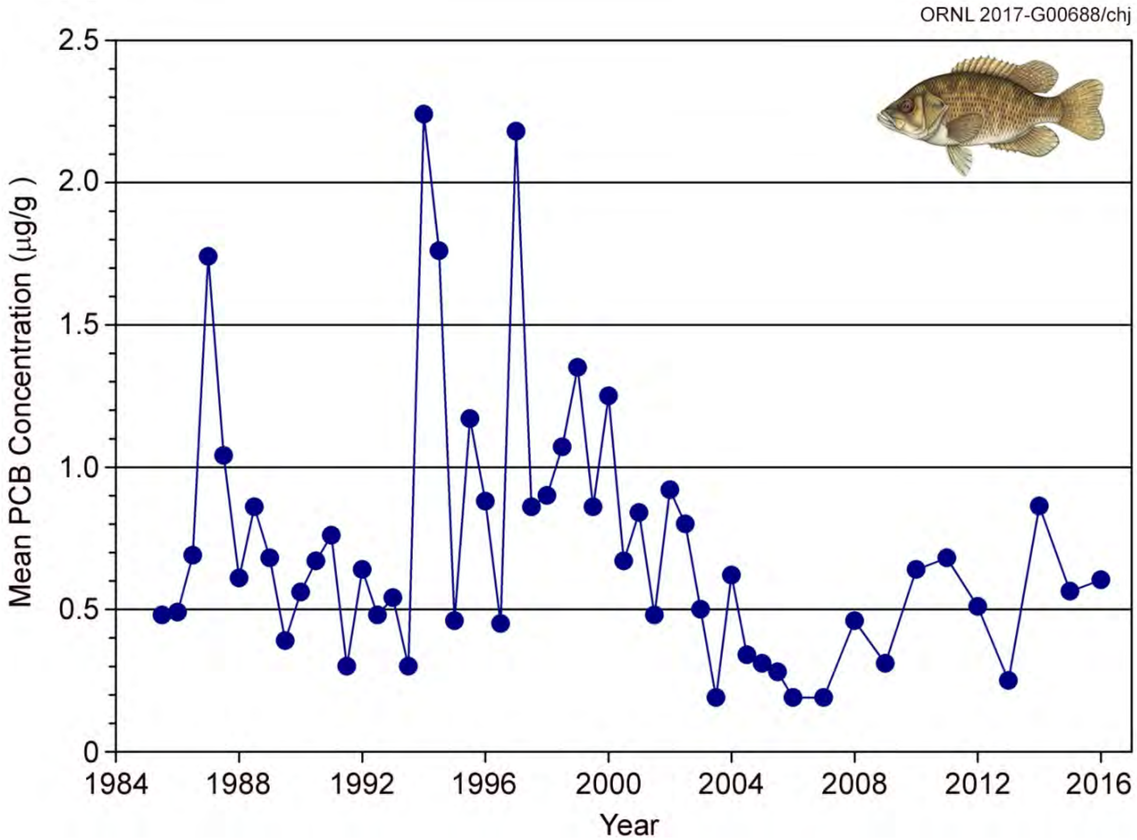

Figure 4.26. Annual mean concentrations of polychlorinated biphenyls (PCBs) in rock bass muscle fillets at East Fork Poplar Creek kilometer 23.4., FY 2016.

4.5.8.2 Benthic Invertebrate Surveys

Monitoring of the benthic macroinvertebrate community continued in the spring of 2016 at three sites in EFPC and at two reference streams. The numbers of pollution-intolerant taxa (Ephemeroptera, Plecoptera, and Tricoptera, or EPT taxa) increased in 2016 at all monitored sites with the exception of EFK 23.4 (Figure 4.27a). The densities of these pollution-intolerant taxa increased in 2016 at the reference sites and at EFK 13.8, but decreased at the two sites nearest the Y-12 Complex (EFK 23.4 and EFK 24.4) (Figure 4.28b). 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, where mean densities for pollution-intolerant taxa exceeded that of reference sites in 2015 for the first time since monitoring began in 1985, densities returned in 2016 to typical low levels indicative of mildly degraded conditions. 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.

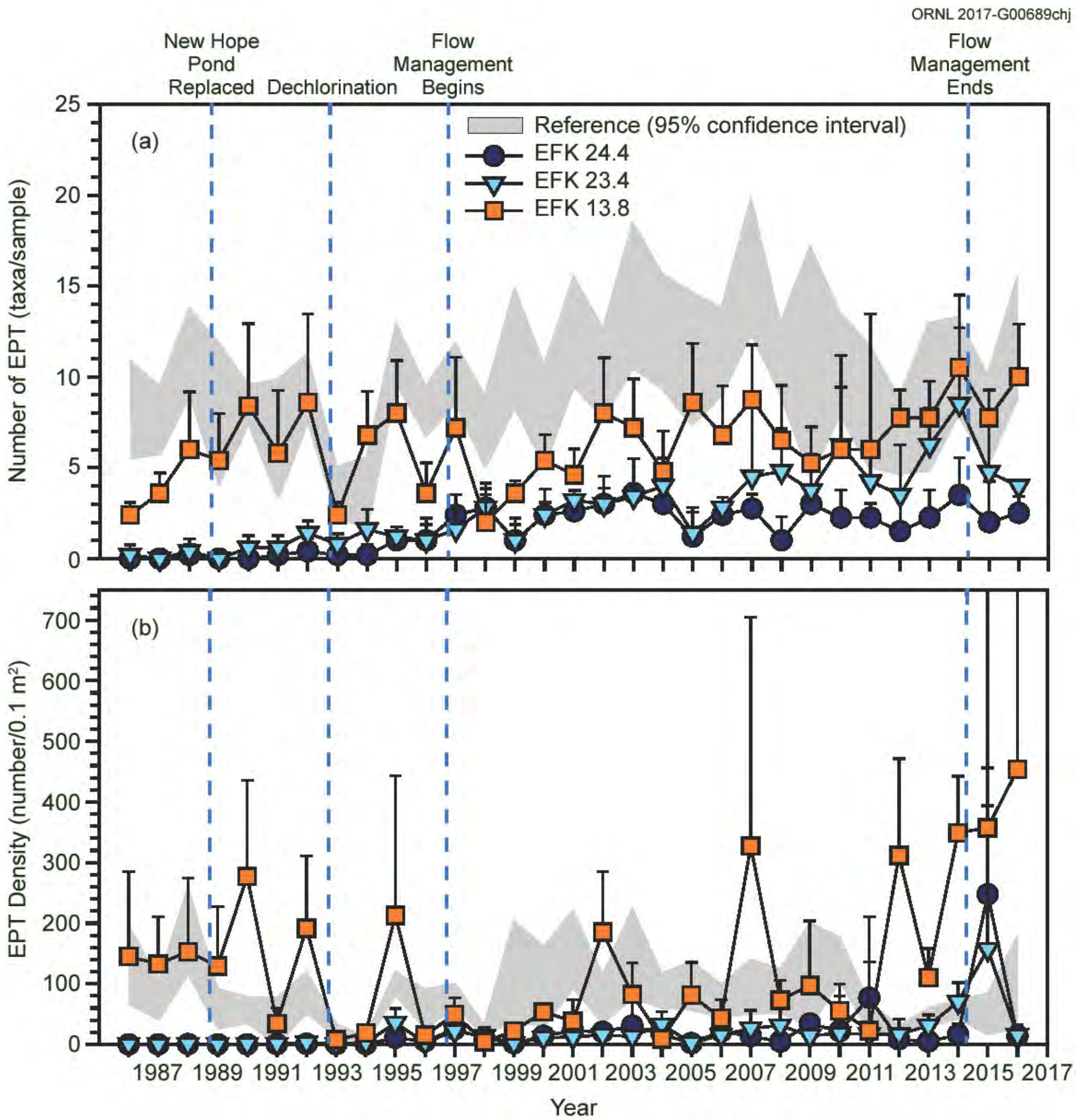

Figure 4.27. (a) Taxonomic richness (mean number of taxa per sample) and (b) density (mean number of taxa per square meter) of the Ephemeroptera, Plecoptera, and Trichoptera (EPT) in the benthic macroinvertebrate communities sampled in the spring from East Fork Poplar Creek and two nearby reference streams (Brushy Fork and Hinds Creek), 1986–2016. *(EFK = East Fork Poplar Creek kilometer.)*

4.5.8.3 Fish Community Monitoring

Fish communities were monitored in the spring and fall of 2016 at five sites along EFPC and at a comparable local reference stream (Brushy Fork). In the past two 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 4.28, dramatically highlighting major improvements in the fish community in the middle to lower sections of the stream. However, the

EFPC fish community continues to lag behind the reference stream community in most important metrics of fish diversity and community structure, especially at the monitoring sites closest to the Y-12 Complex.

Fish communities appeared to be stable in upper EFPC in 2016, even under the reduced stream flows associated with the termination of flow augmentation from Melton Hill in April 2014. No fish kills were observed in 2016 in upper EFPC, and in contrast fish densities were considerably higher at the uppermost sampling location (Figure 4.29). Very high densities are not always a positive indicator of fish health however, and the most abundant species within these sites are considered tolerant species. Continued monitoring will provide additional insight into these variabilities.

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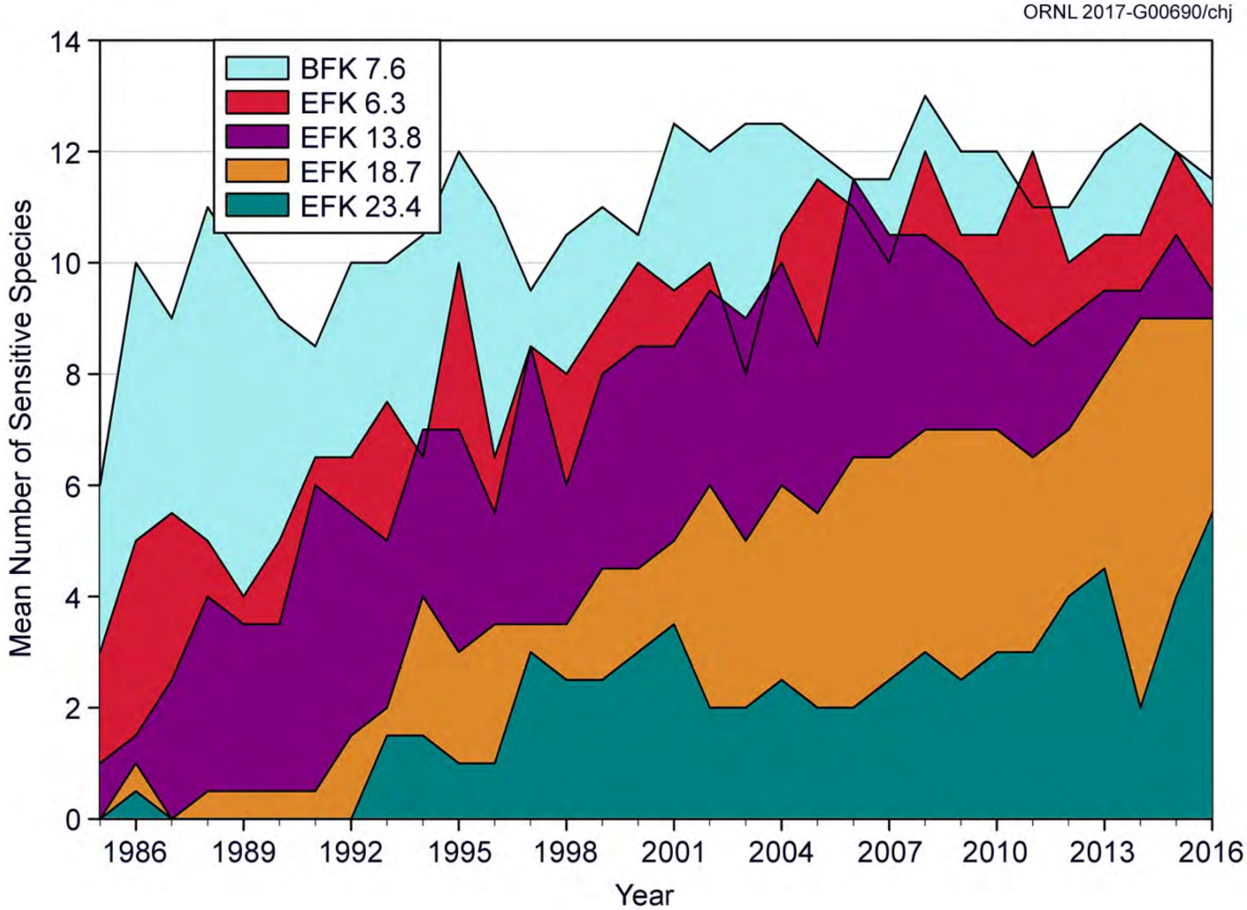

Figure 4.28. Comparison of mean sensitive species richness (number of species) collected each year from 1985 to 2016 from four sites in East Fork Poplar Creek and a reference site (Brushy Fork). *(BFK = Brushy Fork kilometer and EFK = East Fork Poplar Creek kilometer.)*

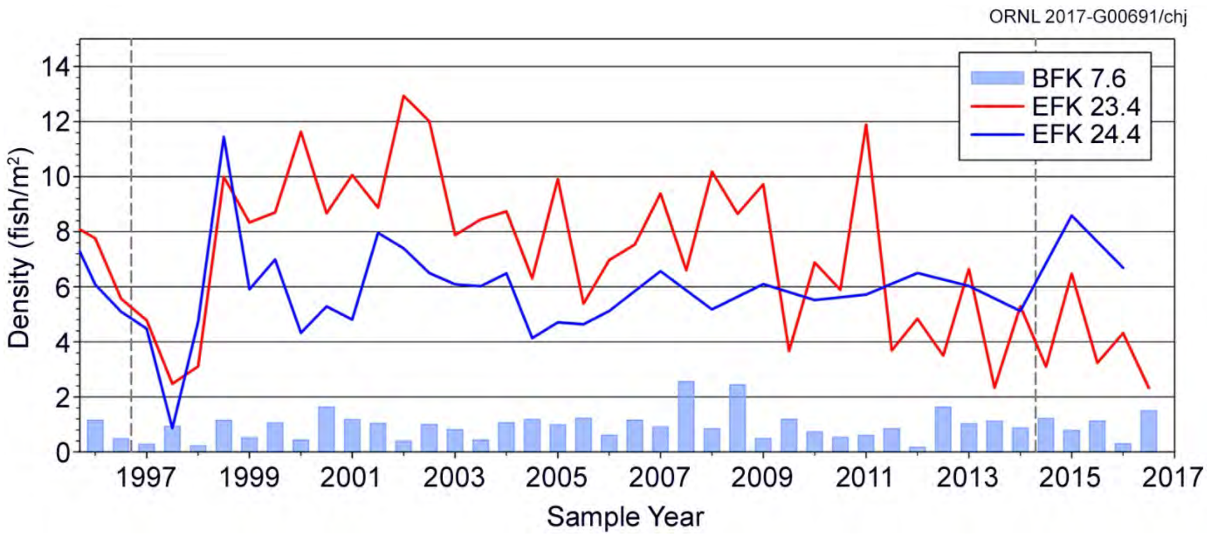

Figure 4.29. Fish density (number of fish per square meter) for two sites in upper East Fork Poplar Creek and a reference site (Brushy Fork) from 1996 to 2016. *(BFK = Brushy Fork kilometer and EFK = East Fork Poplar Creek kilometer).* The interval of time between the dashed lines represents the period 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 Y-12, Haul Road was expanded in 2013–2014, and several wetlands were 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 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 reestablish the stream's riparian zone following the construction.

Annual monitoring of the remediated wetland sites through 2016 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.

Similarly, there have been positive developments associated with the stream mitigation site, in that the stream channel has a more natural meander and habitat appears to be much improved. Follow-up engineering actions have been applied to address some earlier challenges associated with several leaks in the weir separating the two channels. Additional plantings were also needed to supplement the riparian plantings, which experienced some plant mortality. Future monitoring will help determine whether the restoration and follow-up actions have been successful.

4.6 Groundwater at the Y-12 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 2017). 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 4.30 depicts the major facilities or areas of the Y-12 Complex and known and potential groundwater contaminant sources for which groundwater monitoring is performed.

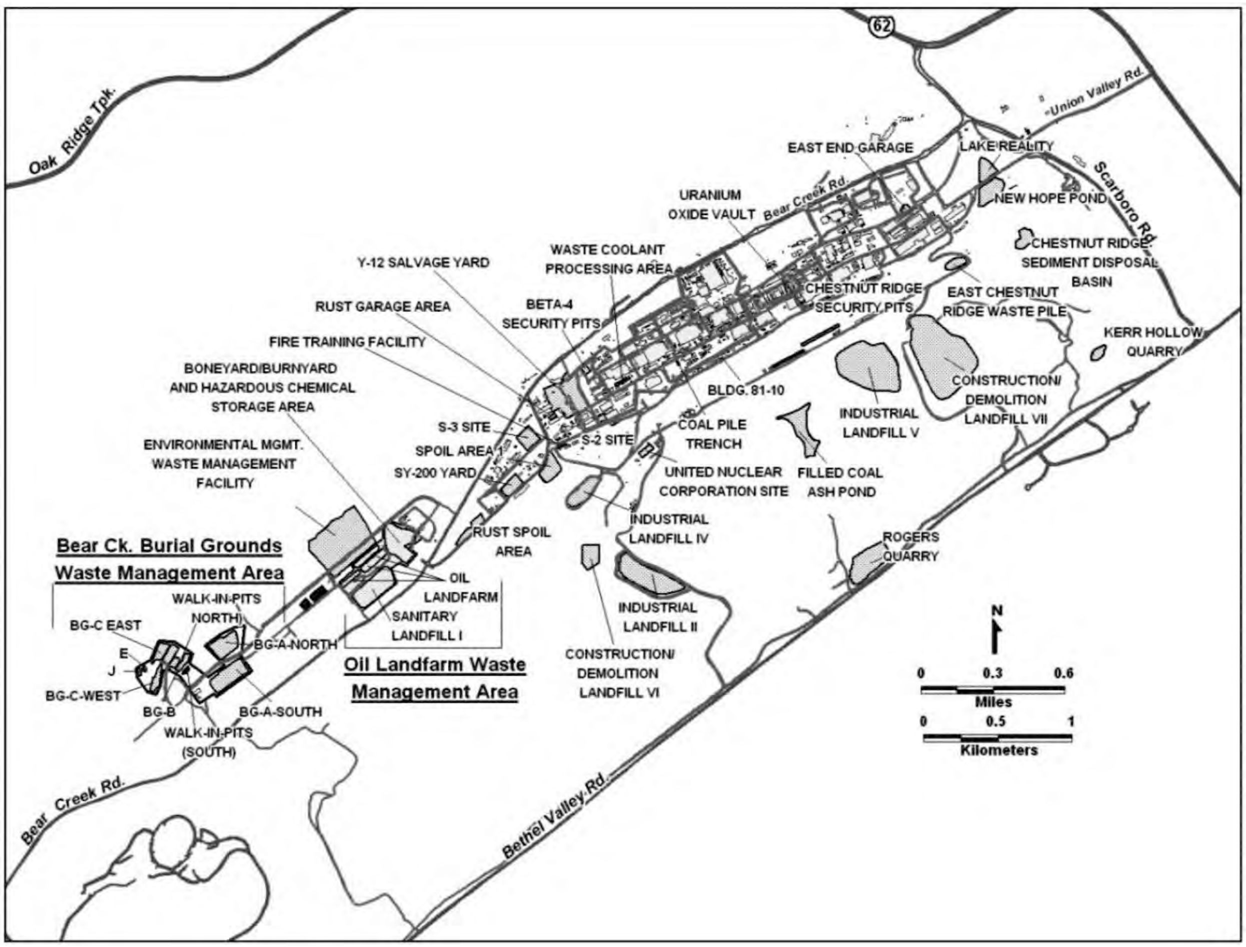

Figure 4.30. Known or potential contaminant sources for which groundwater monitoring is performed at the Y-12 National Security Complex.

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 4.31). 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 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 4.32). 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.

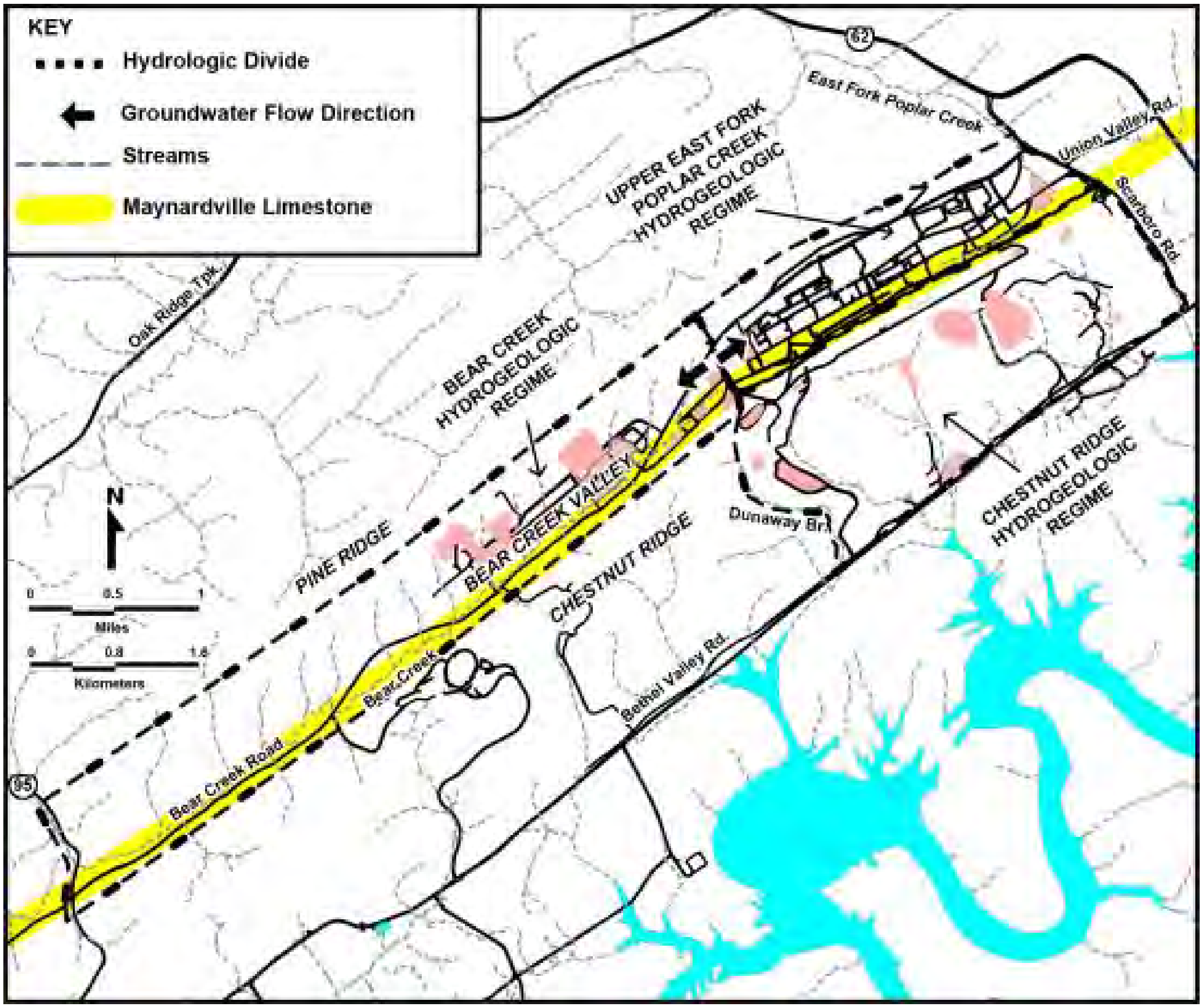

Figure 4.31. Hydrogeologic regimes at the Y-12 National Security Complex and the position of the Maynardville Limestone in Bear Creek Valley.

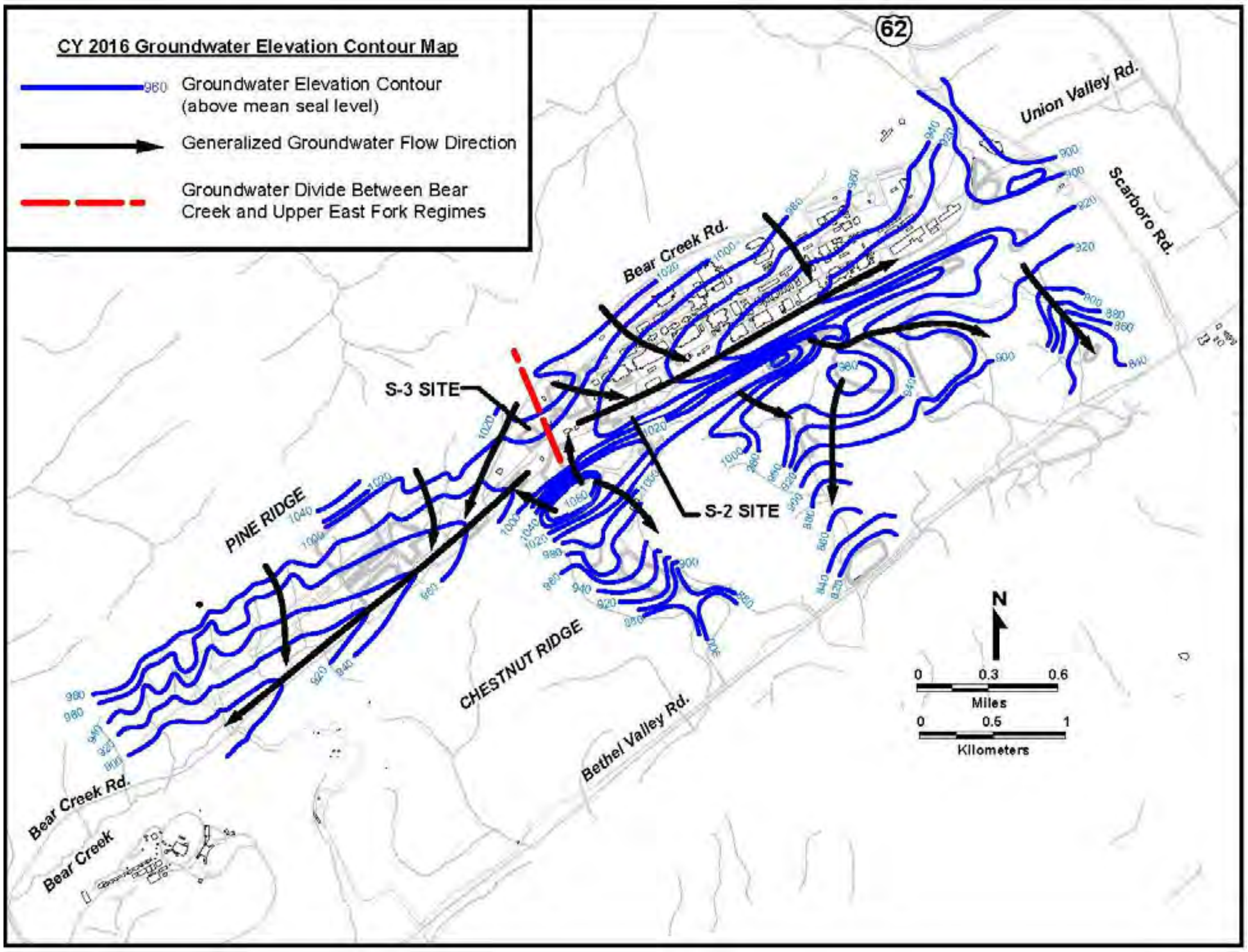

Figure 4.32. Groundwater elevation contours and flow directions at the Y-12 National Security Complex.

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 4.31). 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 noncarbonate rock (less than 10 ft/year) but can be quite rapid within solution conduits in the Maynardville Limestone (10–500 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 also very slow below the water table interval.

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 4.32). 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 4.33 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.

No wells were installed or plugged and abandoned in CY 2016.

4.6.3 CY 2016 Groundwater Monitoring

Groundwater monitoring in CY 2016 was performed to comply with DOE orders and regulations as part of the Y-12 (GWPP, DOE EM programs such as the Water Resources Restoration Program (WRRP), and other projects. Compliance requirements were met by monitoring 201 wells and 50 surface water locations and springs (Table 4.18). Figure 4.34 shows the locations of Y-12 Complex perimeter/exit pathway groundwater monitoring stations.

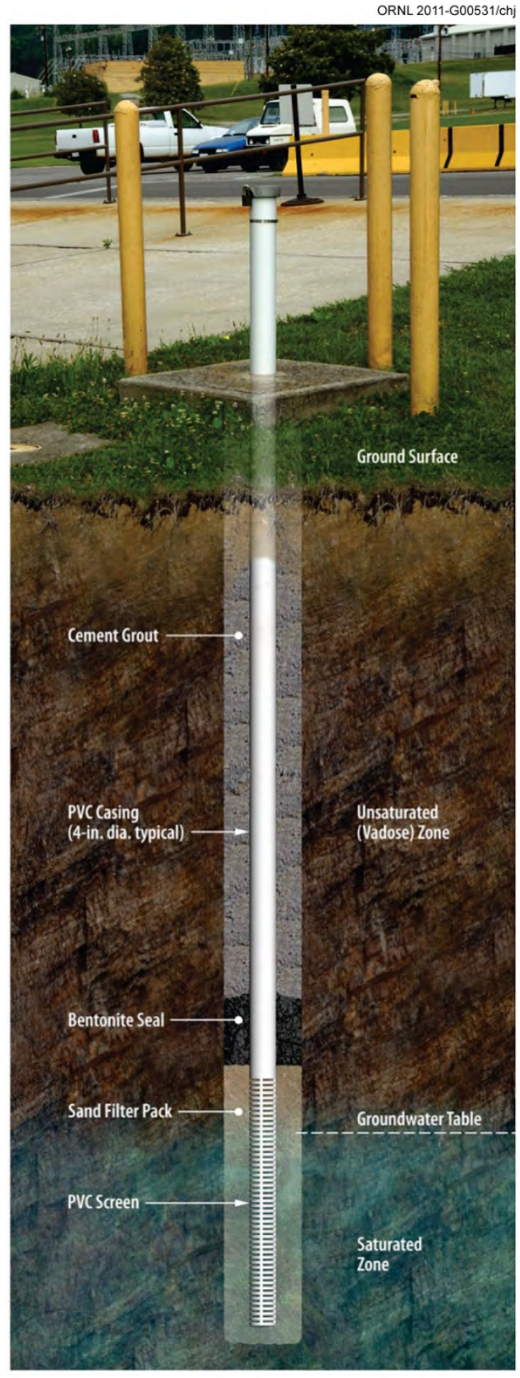

Figure 4.33. Cross section of a typical groundwater monitoring well.

Table 4.18. Summary of groundwater monitoring at the Y-12 Complex, 2016

	Purpose for which monitoring was performed				
	Restoration[a]	Waste management[b]	Surveillance[c]	Other[d]	Total
Number of active wells	63	33	105	27	228
Number of other monitoring stations (e.g., springs, seeps, surface water)	30	6	14	0	50
Number of samples taken[e]	182	69	121	663	1,035
Number of analyses performed	9,466	9,203	10,739	5,869	35,277
Percentage of analyses that are non-detects	68.5	91.4	81.0	10.5	68.6
Ranges of results for positive detections, VOCs (µg/L)[f]					
Chloroethenes	0.25–2,600	5.74–8.37	1–48,000	NA[g]	
Chloroethanes	0.35–550	7.72–75	2–1,300	NA	
Chloromethanes	0.33–950	ND[h]	2–1,500	NA	
Petroleum hydrocarbons	0.31–1,200	ND	1–2,500	NA	
Uranium (mg/L)	0.0042–0.55	ND	0.00051–0.283	NA	
Nitrates (mg/L)	0.0033–5,700	0.594–2.26	0.0429–9,600	0.2–22.8	
Ranges of results for positive detections, radiological parameters (pCi/L)[i]					
Gross alpha activity	2.55–249	1.4–7.71	4.6–340	NA	
Gross beta activity	2.94–11,200	3.45–12.3	7.8–15,000	NA	

[a] Monitoring to comply with Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requirements and with Resource Conservation and Recovery Act post closure detection and corrective action monitoring.
[b] Solid waste landfill detection monitoring and CERCLA landfill detection monitoring
[c] DOE Order surveillance monitoring
[d] Research-related groundwater monitoring associated with activities of the DOE Oak Ridge Field Research Center and Enigma.
[e] The number of unfiltered samples, excluding duplicates, determined for unique location/date combinations.
[f] These ranges reflect concentrations of individual contaminants (not summed volatile organic compound 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] NA—not analyzed.
[h] ND—not detected.
[i] pCi = 3.7×10^2 Bq.

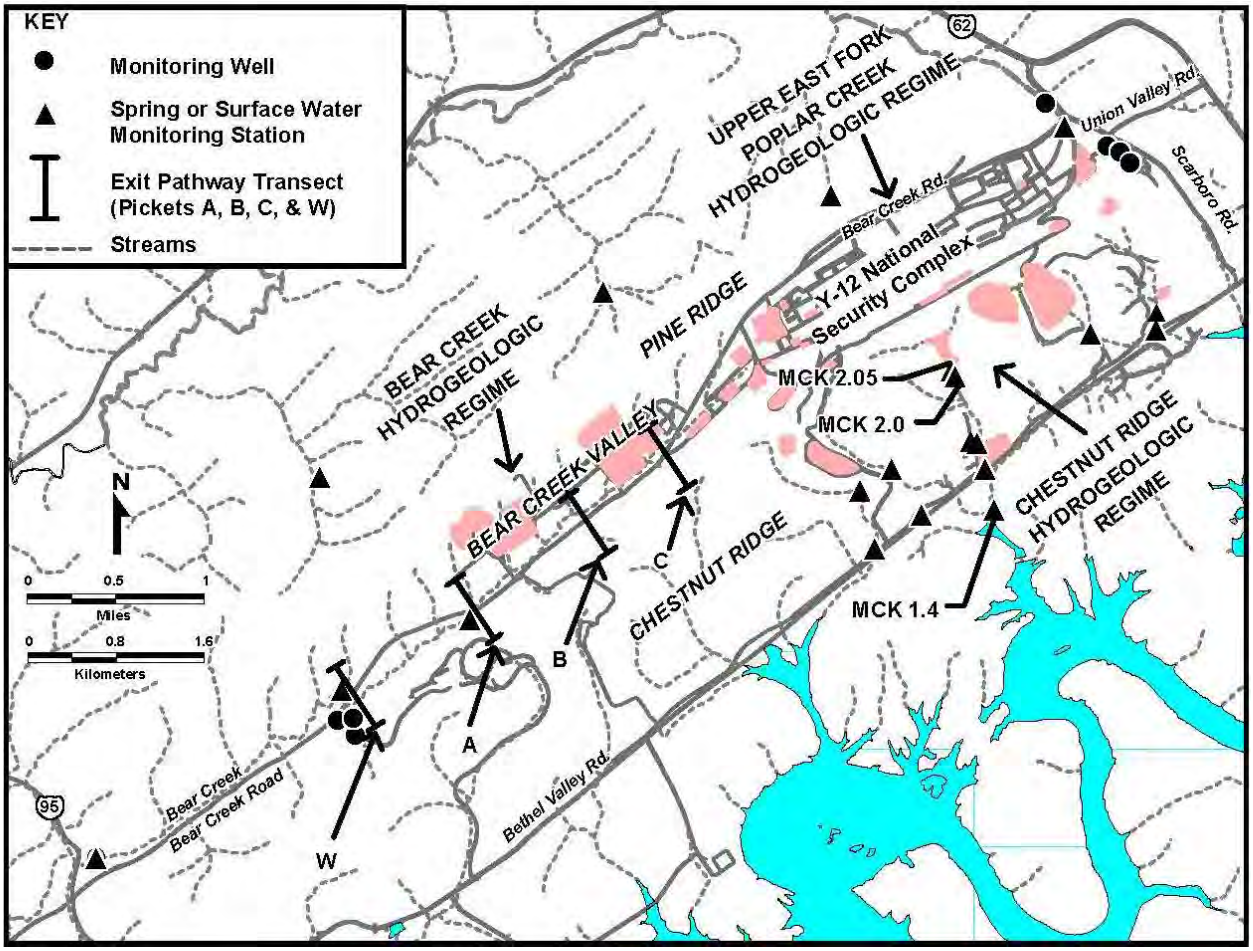

Figure 4.34. Location of Y-12 National Security Complex perimeter/exit pathway well, spring, and surface water monitoring stations. *(MCK = McCoy Branch kilometer.)*

Most of the conventional monitoring wells at the Y-12 Complex were sampled using industry standard methods approved by TDEC and EPA (Figure 4.35).

Figure 4.35. Groundwater monitoring well sampling at the Y-12 National Security Complex.
[Source: Kathryn Fahey, Y-12 photographer.]

Comprehensive water quality results of groundwater monitoring activities at the Y-12 Complex in CY 2016 are presented in the *Calendar Year 2016 Groundwater Monitoring Report* (CNS 2017).

Details of monitoring efforts performed specifically for CERCLA baseline and remediation evaluation are published in the FY 2016 and FY 2017 WRRP sampling and analysis plans (UCOR 2015 2016a) and the annual CERCLA remediation effectiveness report (DOE 2017a).

Groundwater monitoring compliance reporting to meet RCRA postclosure permit requirements can be found in the annual RCRA groundwater monitoring report (UCOR 2017).

4.6.4 Y-12 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 ^{99}Tc are the radionuclides of greatest concern. Trace metals (e.g., arsenic, barium, cadmium, chromium, 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 4.19. 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 4.19. Description of waste management units and underground storage tanks included in groundwater monitoring activities, upper East Fork Poplar Creek hydrogeologic regime, 2016

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 discharge 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 nonenriched 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.

Table 4.19 (continued)

Site	Description
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.
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.

Acronyms
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

4.6.4.1.1 Plume Delineation

Sources of groundwater contaminants monitored during CY 2016 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 4.37–4.40) represent CY 2016 monitoring results.

In CY 2013, the Y-12 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 Y-12 2013). Plume maps in previous ASERs were developed from those presented in CERCLA remedial investigations (RIs) that took place in the late 1990s (DOE 1997, 1998). The RI plume maps were determined to be representative of groundwater contamination at Y-12 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, Section 4.7.4.1.4).

4.6.4.1.2 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 2016, groundwater concentrations of nitrate as high as 9,600 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 4.36). These results are consistent with results from previous years.

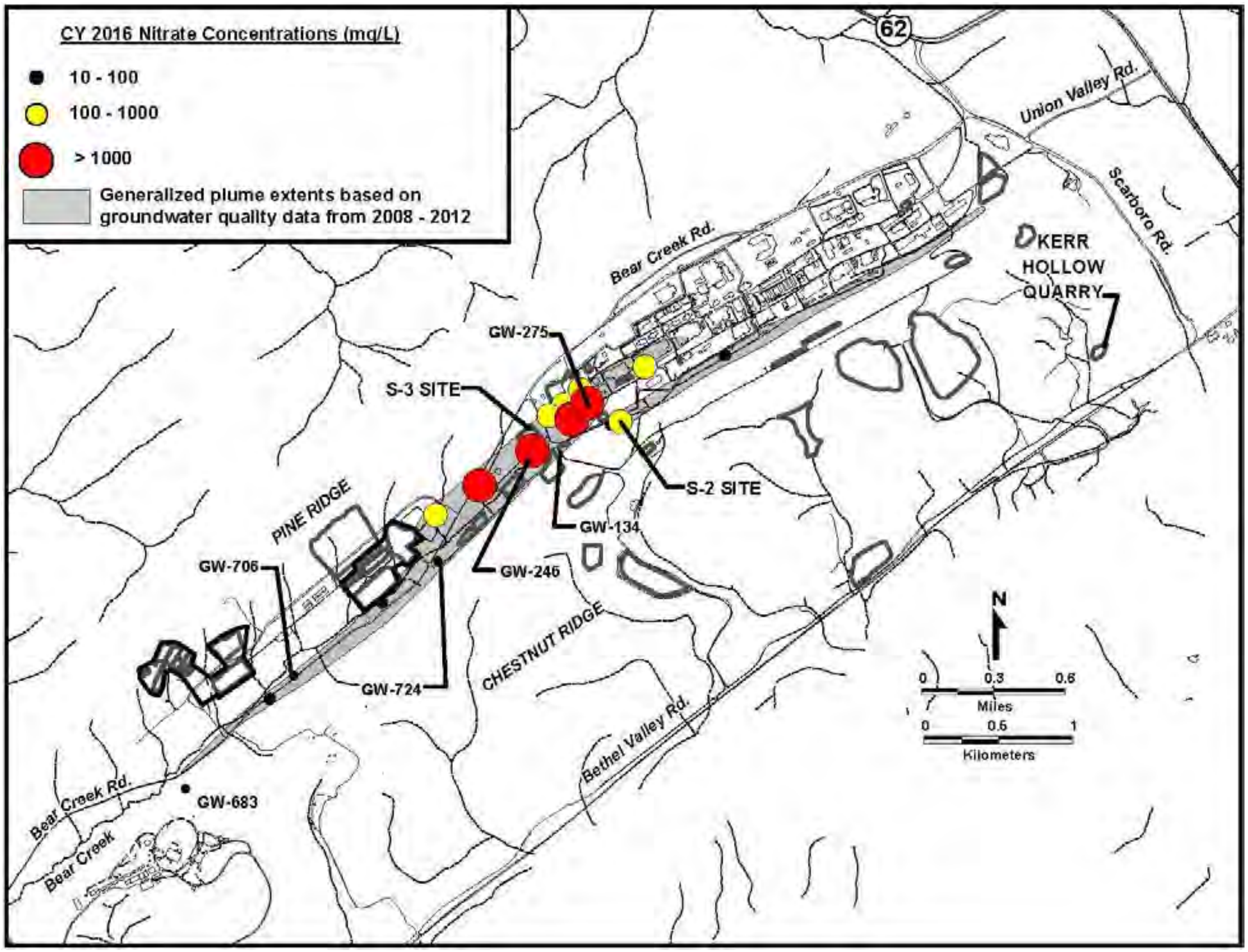

Figure 4.36. Nitrate observed in groundwater at the Y-12 National Security Complex, 2016.

4.6.4.1.3 Trace Metals

Concentrations of barium, beryllium, cadmium, chromium, copper, lead, nickel, thallium, and uranium exceeded drinking water standards during CY 2016 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 upper EFPC.

4.6.4.1.4 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 2016, the highest summed concentration of dissolved chlorinated hydrocarbons (55,843 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 (10,452 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 4.37). 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, Trichloroethene, Dichloroethene, 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) 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.

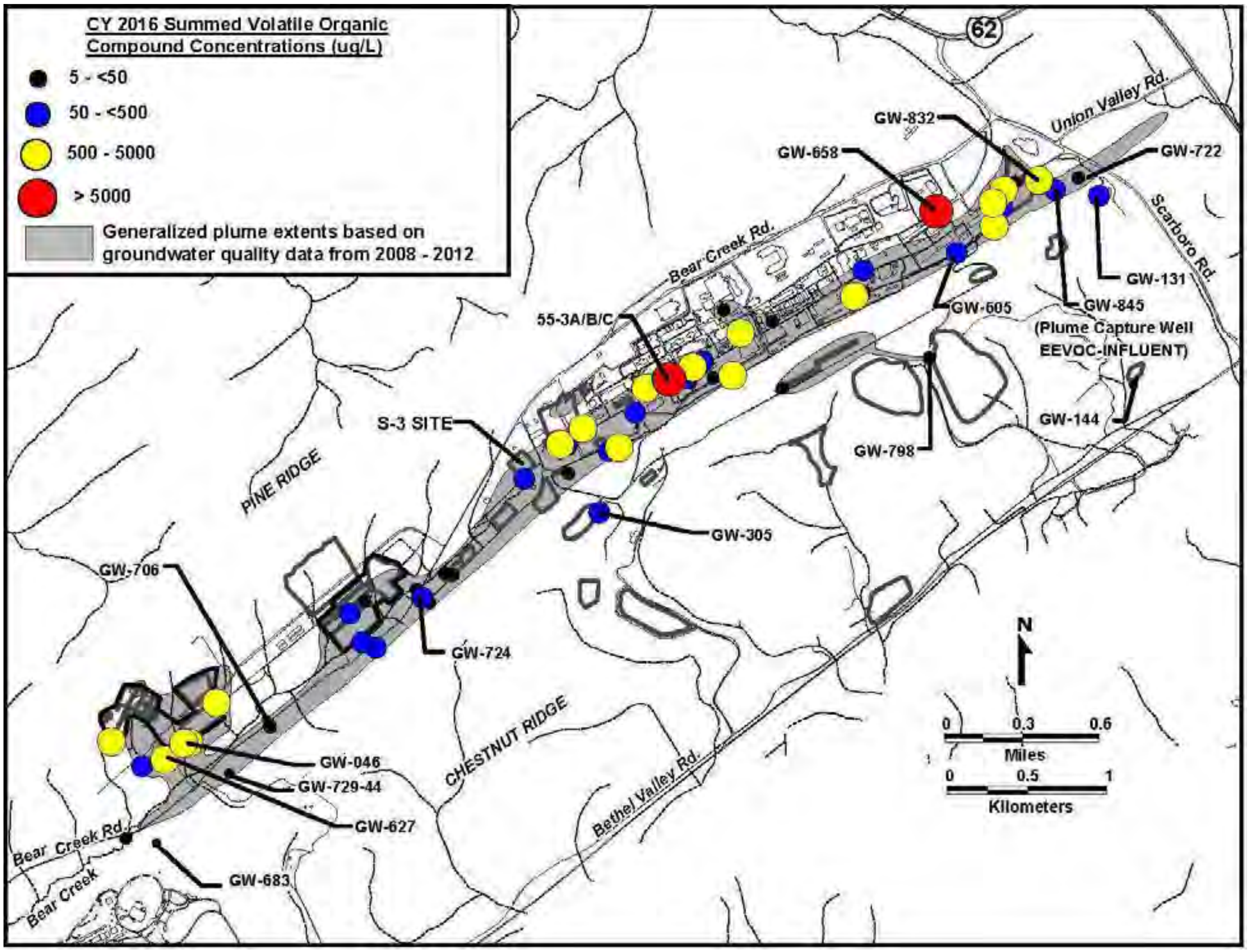

Figure 4.37. Summed volatile organic compounds observed in groundwater at the Y-12 National Security Complex, 2016. *(EEVOC = east end volatile organic compound.)*

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 the 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, so either migration is limited or some downgradient across-strike influence by the plume capture system is occurring.

4.6.4.1.5 Radionuclides

The primary alpha-emitting radionuclides found in the upper EFPC regime during CY 2016 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 and Salvage Yard source areas and also in the east end near the former oil skimmer basin at the former inlet to the New Hope Pond, which is now capped. In CY 2016, the maximum occurrence of gross alpha activity in groundwater in the upper EFPC regime was 249 pCi/L at well GW-154 on the east end (Figure 4.38).

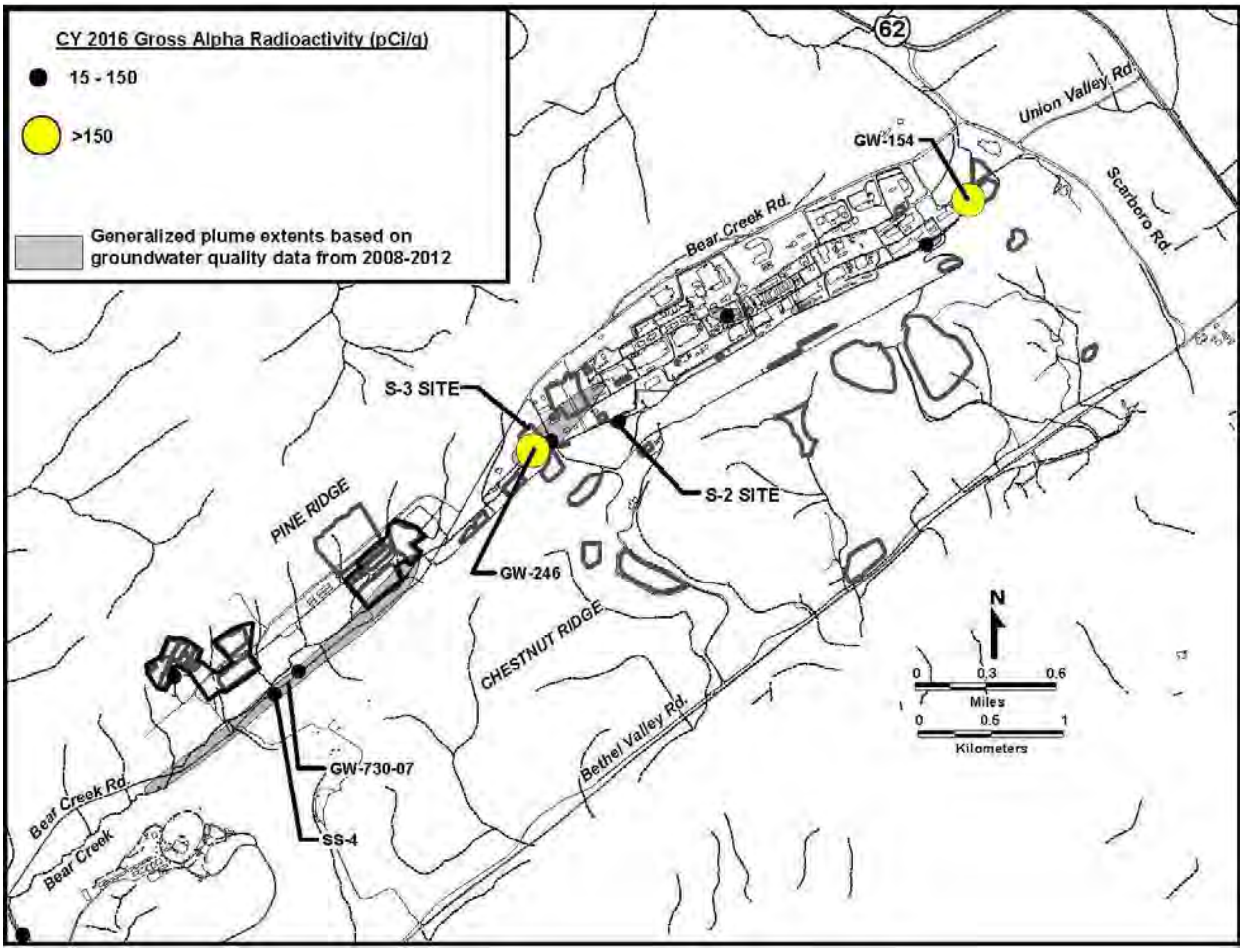

Figure 4.38. Gross alpha activity observed in groundwater at the Y-12 National Security Complex, 2016.

The primary beta-emitting radionuclides observed in the upper EFPC regime are technetium-99 (^{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 4.39). The highest gross beta activity in groundwater was observed during CY 2016 from well GW-108 (11,200 pCi/L), east of the S-3 site.

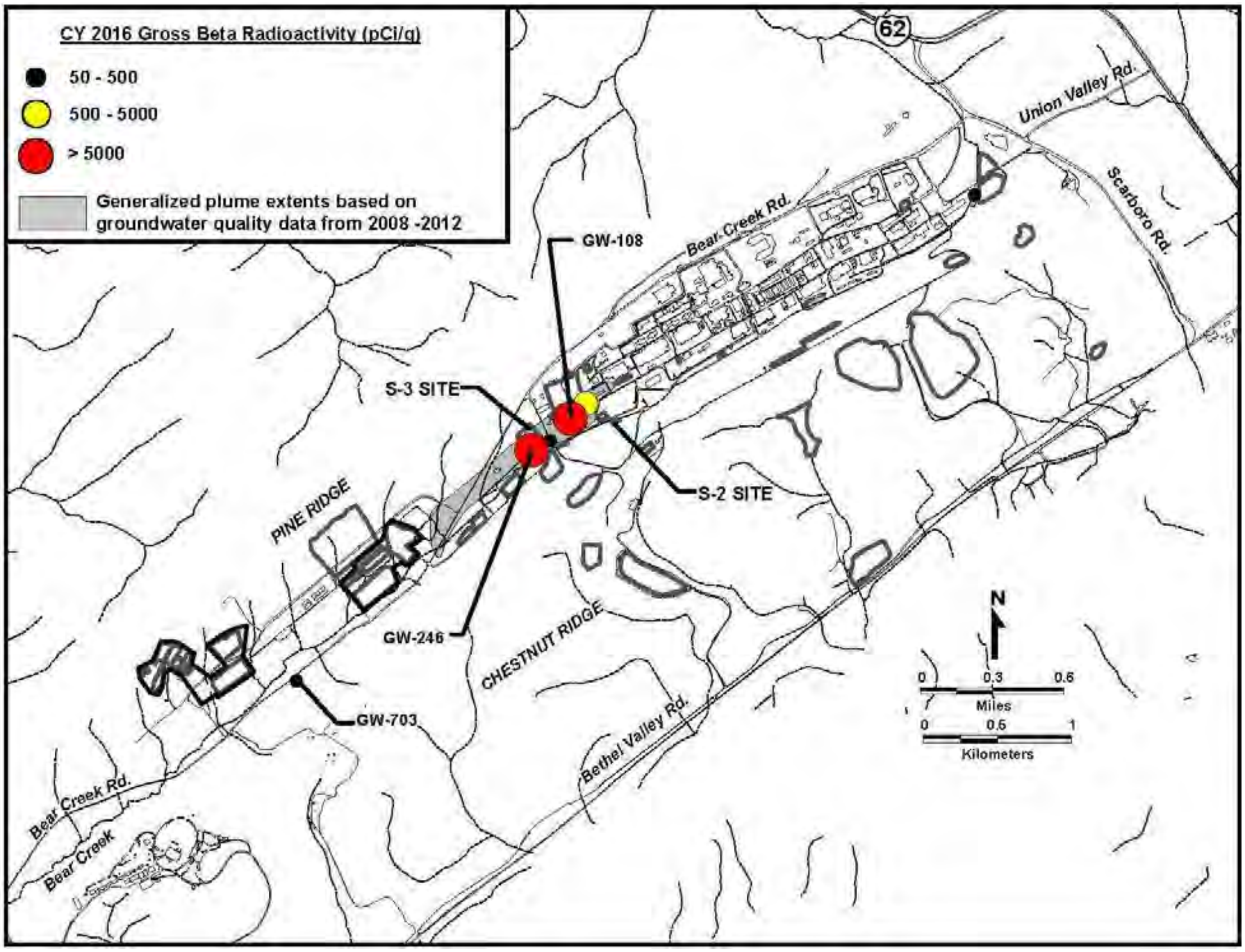

Figure 4.39 Gross beta activity observed in groundwater at the Y-12 National Security Complex, 2016.

4.6.4.1.6 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 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 are 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 2016, the observed concentrations of VOCs at the New Hope Pond distribution channel underdrain remained low (23.3 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 Volatile Organic Compound 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 multiport system installed in well GW-722, 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 4.38). 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 4.41. 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.

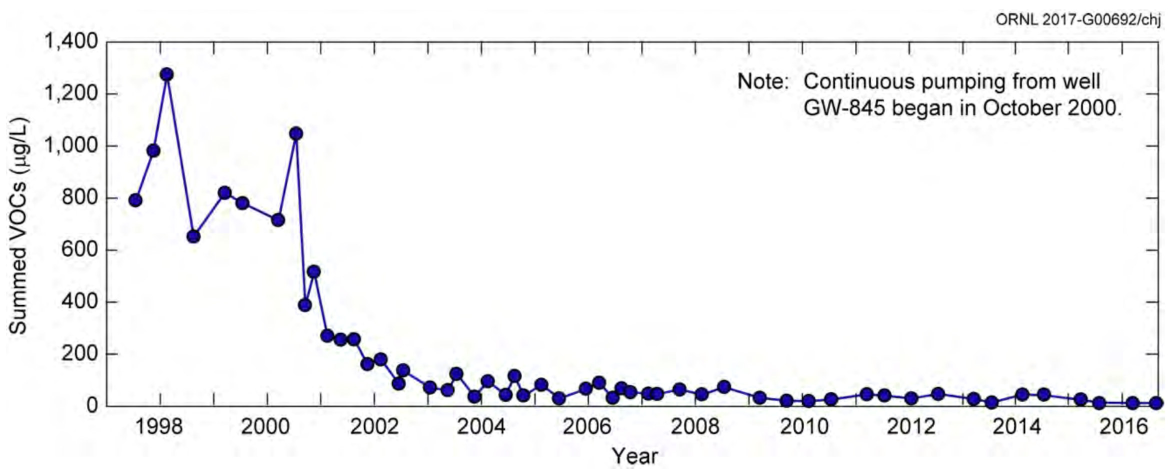

Figure 4.40. Decreasing summed volatile organic compounds (VOCs) observed in exit pathway well GW-722-17 near the New Hope Pond, 2016.

Ten zones of the Westbay™ multiport monitoring well GW-131, located on the east end of the upper EFPC regime (Figure 4.40), were sampling in CY 2016 with 6 of the 10 zones showing summed VOCs greater than 5 µg/L. However, the VOCs observed in these zones did not include the typical components of the East End VOC Plume (i.e., carbon tetrachloride, PCE, TCE) and none of them exceeded drinking water standards.

Traces of petroleum hydrocarbons (benzene, ethylbenzene, toluene, and xylene) were detected in 5 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.

Other non-EEVOC plume characteristic compounds (acrylonitrile, styrene) were detected in seven of Well GW-131’s 10 zones. According to the manufacturer, the Westbay™ sampling system contains several components made with acrylonitrile and styrene, and detection of those compounds is often an

artifact from sampling ports in low-permeability zones. Two zone samples yielded chloroform results at very low levels (2 µg/L).

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 4.34.) One shallow well was monitored in CY 2016, and no groundwater contaminants were observed.

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; however, monitoring continues to be performed to assess potential health impacts from Y-12 Complex operations to nearby residences. 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.

4.6.4.1.7 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) provided a discussion of the nature and extent of the VOCs.

In CY 2016, 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 2015b).

In July 2006, the Agency for Toxic Substances and Diseases Registry (ATSDR), 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 4.20 describes each of the waste management sites within the Bear Creek regime.

Table 4.20. Description of waste management units included in 2016 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 2002–2003 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 2002–2003 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 2002–2003 as part of Boneyard-Burnyard remedial activities.
Sanitary Landfill I	Used from 1968 to 1982. Nonhazardous 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.
Spoil Area I	Used from 1980 to 1988 for disposal of construction debris and other stable, nonradioactive 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.

Table 4.20 (continued)

Site	Description
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 2020.

Acronyms
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
ETTP = East Tennessee Technology Park
ORNL = Oak Ridge National Laboratory
ORR = Department of Energy Oak Ridge Reservation
PCB = polychlorinated biphenyl
RCRA = Resource Conservation and Recovery Act
ROD = record of decision
TDEC = Tennessee Department of Environment and Conservation
VOC = volatile organic compound
Y-12 Complex = Y-12 National Security Complex

4.6.4.2.1 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 and 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 in 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 4.37–4.40) represent CY 2016 monitoring results. (See Section 4.7.4.1.1 for more details.)

4.6.4.2.2 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 essentially defined in groundwater in the upper to intermediate bedrock intervals of the aquitard units and Knox aquifer (less than 92 m [300 ft] below the ground surface).

Data obtained during CY 2016 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 (2,329 mg/L) was observed at well GW-246 adjacent to the S-3 site at a depth of 23 m (76 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 source area. Concentrations exceeding the drinking water standard in CY 2016 were observed in groundwater as far as 2,438 m (8,000 ft) west of the S-3 site.

4.6.4.2.3 Trace Metals

During CY 2016, barium, beryllium, cadmium, lead, manganese, 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 (see Section 4.7.4.2.3). 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, indicating that geochemical conditions are favorable for its migration. 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 all 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 was excavated and was placed in the Environmental Management Waste Management Facility (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 4.21); 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 4.21. 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	2015–2016
BCK[b]-11.84 to 11.97	Nitrate	116	65.7	89.5	43.3	53.3	27
(~0.5 miles downstream)	Uranium	0.203	0.112	0.129	0.112	0.172	0.199
BCK-09.20 to 09.47	Nitrate	16.1	7.8	12.1	8.4	4.4	4.2
(~2 miles downstream)	Uranium	0.098	0.093	0.135	0.060	0.051	0.059
BCK-04.55	Nitrate	4.7	2.3	3.5	1.1	0.8	0.9
(~5 miles downstream)	Uranium	0.034	0.030	0.033	0.020	0.016	0.021

[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 observed in the groundwater of Bear Creek regime are arsenic, boron, chromium, copper, mercury, selenium, strontium, thallium, and zinc. Concentrations have commonly exceeded background values in groundwater near

contaminant source areas. One exception to this is the detection of mercury in the bottom zone (1,026 ft below ground surface) of Westbay™ well GW-790 in CY 2015. Due to the depth of the location and the hydrologic and geochemical characteristics of the groundwater from this zone (total dissolved solids analysis from this sample was 179,000 mg/L), it is unlikely that the detected result indicates a Y-12 source. This was confirmed with follow-up monitoring (GW-790-02) in CY 2016, which did not reveal mercury above detection limits.

4.6.4.2.4 Volatile Organic Compounds

VOCs are widespread in groundwater in the Bear Creek regime. The primary compounds are PCE, TCE, 1,2-1,2-dichloroethene 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 2016 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 4,293 µg/L in well GW-046 (Figure 4.38).

High concentrations of VOCs like this and in other near source wells, coupled with increasing and elevated stable trends (the latter are increasing trends that have plateaued, having become stable at the high concentrations) observed downgradient of the Bear Creek Burial Ground waste management area in the clastic (noncarbonated) dominated fractured bedrock of the aquitard units (Well GW-627, Figure 4.41), indicate that a considerable mass of dense nonaqueous-phase organic compounds is still present at a depth below the Bear Creek Burial Grounds, providing a source for dissolved-phase migration of VOCs. This migration parallel to the valley axis and toward the exit pathway (Maynardville Limestone) is occurring in both the unconsolidated and bedrock intervals.

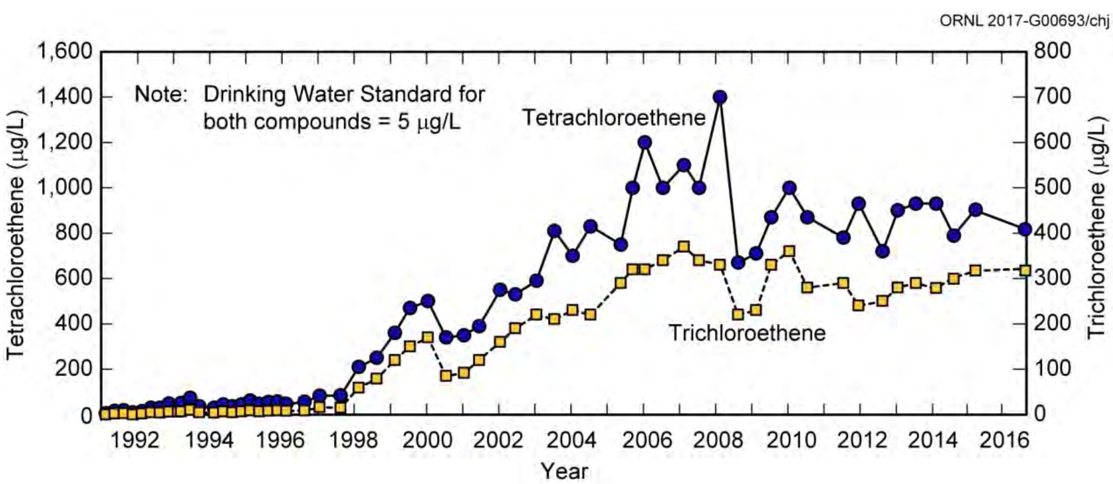

Figure 4.41. Increasing volatile organic compounds observed in groundwater at well GW-627 west and downgradient of the Bear Creek Burial Grounds, 2016.

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 the 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.

4.6.4.2.5 Radionuclides

The primary radionuclides identified in the Bear Creek regime are isotopes of uranium and ^{99}Tc. 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 2016 were based primarily on measurements of gross alpha activity 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 4.39). However, in CY 2015 in a deep zone of GW-730, an anomalous gross alpha activity of 1,600 pCi/L was observed. Monitoring well GW-730 is a multiport Westbay™ well located downgradient of the Oil Landfarm waste management area. This sample is considered anomalous because (1) uranium, the primary alpha-emitting radionuclide in the Bear Creek regime, was not detected in this sample; (2) the zone (GW-730-07) is more than 1,200 ft deep and is unlikely to be hydrologically active; and (3) the sample had an extremely high concentration of total dissolved solids, which can have a significant deleterious effect on the analytical determination of both gross alpha and gross beta activity. The zone was resampled in CY 2016 with no detectable gross alpha activity, confirming that the CY 2015 gross alpha result was anomalous.

Data obtained from exit pathway monitoring stations during CY 2016 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 2,438 m (8,000 ft) west of the S-3 site (SS-4, 30 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 2016 (pCi/L in well GW-340).

In CY 2016, the highest gross beta activity in groundwater in the Bear Creek regime was also observed at well GW-246 (15,000 pCi/L) indicating that this site continues to be a significant source of radionuclide contamination. One well located at transect B (Figure 4.35) about 2,195 m (7,200 ft) west of the S-3 Site, Well GW-703, presented a gross beta activity (82 pCi/L) in CY 2016 above the drinking water standard. Well GW-703 has historically had elevated activities, but this is the first exceedance since CY 2005.

4.6.4.2.6 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. The Maynardville Limestone is the primary exit pathway for groundwater. Bear Creek, which flows across the Maynardville Limestone 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 4.35).

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 2016 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 4.42).

Surface water samples collected during CY 2016 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 4.20; see Section 4.7.4.2.3).

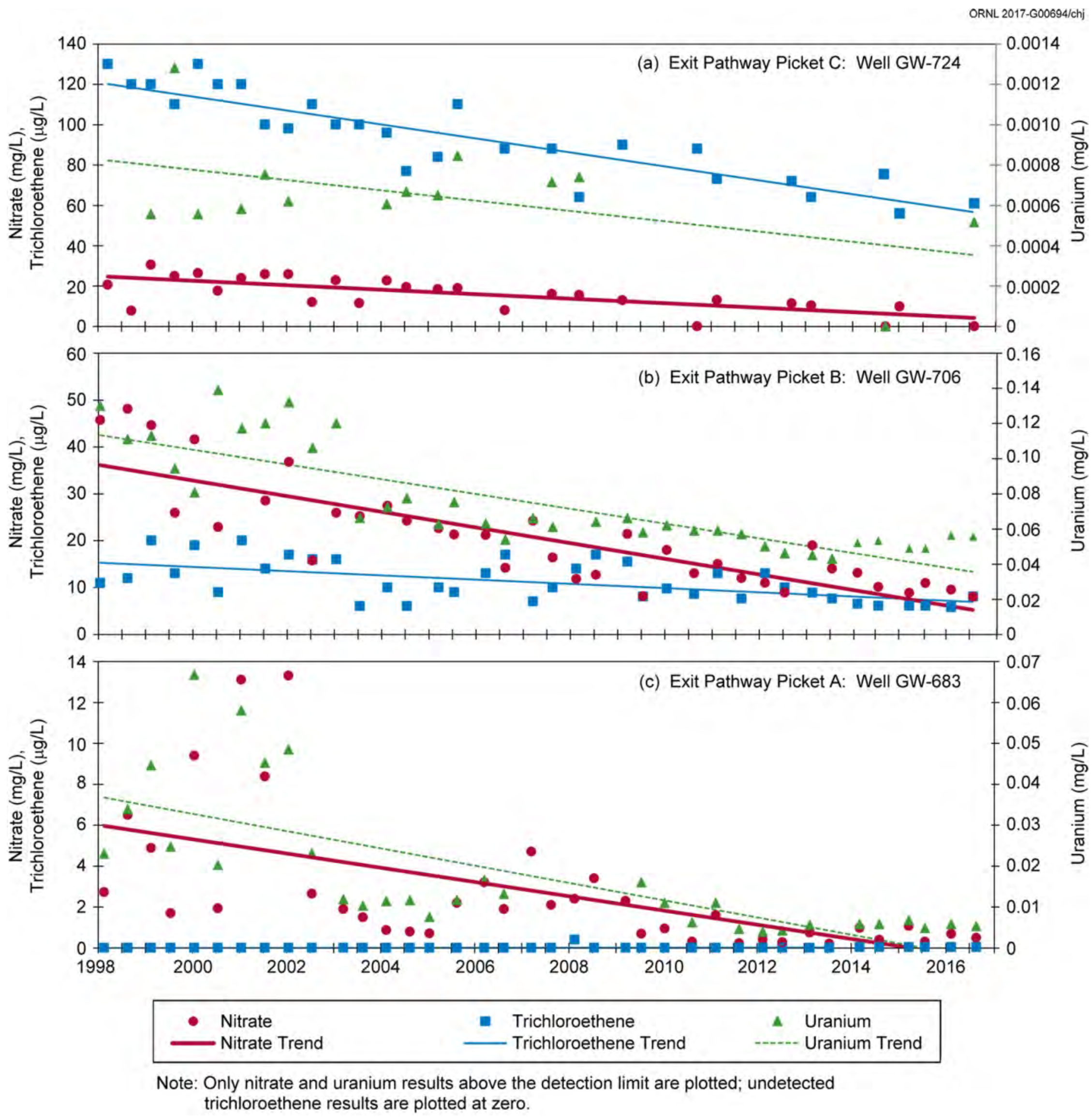

Figure 4.42. CY 2016 concentrations of selected contaminants in exit pathway monitoring wells in the Bear Creek hydrogeologic regime.

4.6.4.3 Chestnut Ridge Hydrogeologic Regime

The Chestnut Ridge hydrogeologic regime is flanked to the north by Bear Creek Valley and to the south by Bethel Valley Road (Figure 4.35). 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 4.22 summarizes the operational history of waste management units in the regime.

Table 4.22. Description of waste management units included in groundwater monitoring activities, Chestnut Ridge hydrogeologic regime, 2016

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 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 1983–1995. During operations this was the central sanitary landfill for ORR. Detection monitoring under postclosure plan has been ongoing since 1996.
Industrial Landfill IV	Opened for operations in 1989. Permitted to receive only nonhazardous 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 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 postclosure period ended, and the permit was terminated March 2007.
Construction/Demolition Landfill VII	Facility construction completed in December 1994. TDEC granted approval to operate January 1995. Permit-required detection monitoring per TDEC was temporarily suspended 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 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 postclosure permit issued by TDEC in 2006.

Acronyms

CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
ORR = Department of Energy 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

4.6.4.3.1 Plume Delineation

Through extensive monitoring of the wells on Chestnut Ridge, the horizontal extent of the VOC plume at the Chestnut Ridge Security Pits 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 Chestnut Ridge Security Pits has not migrated very far in any direction (< 305 m [< 1,000 ft]). Groundwater quality data obtained during CY 2016 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 Chestnut Ridge Security Pits (well GW-798; Figure 4.38) 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 Chestnut Ridge Security Pits) at a natural spring about 2,745 m (9,000 ft) to the east and along geologic strike may suggest that Chestnut Ridge Security Pits 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 4.37–4.40) represent CY 2016 monitoring results. (See Section 4.7.4.1.1 for more details.)

4.6.4.3.2 Nitrate

Nitrate concentrations were below the drinking water standard at all monitoring stations in the Chestnut Ridge hydrogeologic regime.

4.6.4.3.3 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 2016). Under the ROD, migration of contaminated effluent from the Filled Coal Ash Pond is being reduced by a constructed wetland area. During CY 2016, elevated arsenic levels were detected both upgradient (McCoy Branch kilometer [MCK] 2.05) and downgradient (MCK 2.0) of this wetland area (Figure 4.35). Even though both MCK 2.05 and MCK 2.0 monitoring station concentrations were higher than the drinking water standard for arsenic (0.01 mg/L), the passive wetland treatment area reduces total arsenic concentrations by about 46% with associated reductions of dissolved arsenic of about 75% (based on sampling results obtained between 2011 and 2016)(DOE 2017). 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 2016; no arsenic was detected.

4.6.4.3.4 Volatile Organic Compounds

Monitoring VOCs in groundwater attributable to the Chestnut Ridge Security Pits 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 4.38) have been developing since CY 2000. The maximum summed VOC concentration observed at well GW-798 during CY 2016 was 23.77 µg/L. The VOCs detected in well GW-798 continue to be characteristic of the Chestnut Ridge Security Pits plume.

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 2016 this well had the highest summed VOC concentration (90.3 µg/L) observed in the Chestnut Ridge Hydrogeologic Regime. 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.

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 4.38). This well is sampled as part of a RCRA postclosure permit with TDEC managed by UCOR, a DOE EM 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 GW-144 (1.1 µg/L). In CY 2016, carbon tetrachloride was not detected at either location.

4.6.4.3.5 Radionuclides

In CY 2016, no gross alpha or gross beta activity above the drinking water standard of 15 pCi/L and 50 pCi/L, respectively, was observed in any groundwater samples collected in the Chestnut Ridge hydrogeologic regime.

4.6.4.3.6 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 Chestnut Ridge Security Pits; 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 2016. No contaminants at any of these monitoring stations were detected at levels above primary drinking water standards. However, A gross beta activity above the drinking water standard of 50 pCi/L was observed at surface water location MCK 2.05 (113 pCi/L) in February. This result is unusual; historical activities are typically at background levels. The sample taken the following August was back within the historical range of gross beta activity and was below the drinking water standard.

4.6.5 Quality Assurance

All groundwater monitoring is performed under QCs to ensure that representative samples and analytical results are obtained. Because there are a number of organizations responsible for performing groundwater sampling and analysis activities to meet separate requirements, there may be some minor differences in sampling and analysis procedures and methods, but the final results are comparable and are therefore

useful for all projects and programs. This permits the integrated use of all groundwater quality data obtained at the Y-12 Complex.

A number of QA measures are performed to ensure accurate, consistent, and comparable groundwater results. These measures are described in sampling and analysis plans and include the following:

- Groundwater sampling is performed across the Y-12 Complex using a number of sampling methods and procedures. The predominant method of sampling monitoring wells is using a low-flow minimum drawdown method. Using this method, a sample is obtained from a discrete depth interval within the monitoring interval (screened or open borehole) without introducing stagnant water from the well casing. Groundwater is pumped from the well at a flow rate low enough to minimize drawdown of the water level in the well; field readings are also taken to ensure that the sample is representative of the groundwater system and not the water column inside the well casing itself. All sampling methods follow industry/regulator–recognized protocols to ensure that consistent and repeatable samples are obtained.

- QC samples such as field blank, trip blank, duplicate, and equipment rinsate samples are collected.

- All groundwater samples are controlled under chain of custody from their collection in the field to the analytical laboratory that performs the analyses.

- Laboratory analyses are performed using standard methods and protocols within established holding times.

During 2016 all groundwater monitoring and related analytical activities were performed in accordance with the established protocols.

4.7 Quality Assurance Program

The Y-12 Complex Quality Assurance Program establishes a quality policy and requirements for the overall QA program for the Y-12 site. Management requirement Y60-101PD, *Quality Assurance Program Description*, details the methods used to carry out work processes safely and securely and in accordance with established procedures. 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.

Y-12 Environmental Sampling Services performs field sampling, sample preservation and handling, and chain-of-custody and takes field control (QC) samples in accordance with Y-12 Environmental Compliance's internal procedures. Environmental Sampling Services developed a standards and calibration program (SCP) that conforms to ISO/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). SCP 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 Analytical Chemistry Organization (ACO) Quality Assurance manual describes QA program elements that are based on the Y-12 Complex Quality Assurance 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 2011b).

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 the using technically validated and properly documented methods.

The Y-12 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 Y-12, East Fork Poplar Creek

Mercury remediation in the Oak Ridge area is a high priority for DOE. Releases of mercury during Y-12 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.

In FY 2016, a major focus has been 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. Once researchers have a better understanding of key mercury sources areas and processes, targeted technologies can be developed. 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.

Technology development activities have focused on developing strategies 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 the development of sorbents that might be effective in sequestering mercury, the use of alternative treatment chemicals at Y-12 that might help reduce mercury flux, and the addition of filtering organisms such as mussels that might help change instream chemistry to limit mercury transport on particles or algae.

The multiyear 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 Designing the Mercury Treatment Facility

The Oak Ridge Office of Environmental Management (OREM) is working to plan, design, and construct the Outfall 200 Mercury Treatment Facility to reduce mercury concentrations in water exiting the Y-12

Complex. The facility opens the door for large-scale demolition to begin at Y-12 by providing a mechanism to limit and control potential mercury releases caused from disturbing the western portion of the site. It will also help the cleanup program make progress toward achieving compliance with regulatory criteria.

Outfall 200 is the point where the west end Y-12 storm drain system discharges to upper EFPC. Mercury from historical operations is present in the Outfall 200 storm water entering upper EFPC.

In FY 2016, OREM prepared the Preliminary Design Report UCOR-4784*, Preliminary Design Report for the Outfall 200 Mercury Treatment Facility, Y-12 National Security Complex, Oak Ridge, Tennessee* (UCOR 2016) and completed independent design, cost, and constructability reviews. OREM also completed a site geotechnical investigation to support the final design of the facility.

Final design efforts began in early 2016, with completion scheduled for FY 2017. OREM is designing the mercury treatment facility with the capability to treat 3,000 gpm, and the designs also include a 2-million-gal storage tank to collect storm water during peak flow conditions. The facility will treat mercury using chemical precipitation, clarification, and media filtration. The treated water will then be discharged back into upper EFPC.

Employees working on the design are incorporating a modular design that enables future modifications as needed, such as adding additional storm water storage or unit operations to achieve greater mercury reductions based on performance monitoring data.

4.8.3 Waste Management

4.8.3.1 CERCLA Waste Disposal

During FY 2016, EMWMF received 10,668 waste shipments, accounting for 100,208 tons, from K-27's demolition and several smaller cleanup projects at ETTP, ORNL, and Y-12. 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 2016, EMWMF operations collected, analyzed, and dispositioned approximately 3.6 million gal of leachate at the ORNL Liquid and Gaseous Waste Operations (LGWO) facility. No contact water (water that comes in contact with waste but does not enter the leachate collection system) required treatment at ORNL. However, 7.6 million gal of contact water was collected, analyzed, and released to the storm water retention basin after laboratory analyses verified the water met all discharge standards.

4.8.3.2 Solid Waste Disposal

DOE operates and maintains solid waste disposal facilities called the Oak Ridge Reservation Landfills, three of which are active. In FY 2016, approximately 33,632 cubic yards of waste were disposed in the landfills, which marks a 13% decrease from FY 2015 volumes. However, the clean spoils receipts increased 81% over FY 2015. Clean spoils have the potential for being reused and are segregated to avoid taking up valuable landfill space. Construction of phase two of three phases of the classified landfill was also initiated.

Operation of the ORR landfills generated approximately 2.1 million gal of leachate that was collected, monitored, and discharged into the Y-12 Complex sanitary sewer system.

4.8.3.3 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 112 million 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 1.1 million gal of wastewater, primarily in support of NNSA operational activities.
- Big Springs Water Treatment System treated more than 94 million gal of mercury-contaminated groundwater. The East End Volatile Organic Compounds Treatment System treated 12.8 million gal of VOC-contaminated groundwater.
- The Liquid Storage Facility and Groundwater Treatment Facility treated more than 2.3 million gal of leachate from burial grounds and well purge waters from remediation areas.
- The Central Mercury Treatment System treated approximately 2.1 million gal of mercury-contaminated sump waters from the Alpha 4 building.

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Chapter 5 - Oak Ridge National Laboratory

Oak Ridge National Laboratory (ORNL) is the largest US Department of Energy (DOE) science and energy laboratory, conducting basic and applied research to deliver 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 2016 included North Wind Solutions, LLC; URS | CH2M Oak Ridge LLC; and Isotek Systems LLC. During 2016 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) (Fig. 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.

Fig. 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. *[ETTP: East Tennessee Technology Park; ORISE: Oak Ridge Institute for Science and Education; Y-12: Y-12 National Security Complex.]*

In March 2007, Isotek Systems LLC 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 2011) 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 continued through 2016. Plans and preparations for the disposition of the remaining ^{233}U inventory are under way.

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 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. Research achievements in 2016 included (1) collaboration with Boeing to print the 777-X drill and trim tool (Fig. 5.2); (2) collaboration in developing the first 100% digitally manufactured autoclaveable tool for vacuum-assisted-transfer manufacturing; (3) production of a mold with built-in convection heat for a 13 m wind turbine blade; and (4) partnership with teams from the Office of Naval Research to design, 3D-print, and assemble a SEAL delivery vehicle.

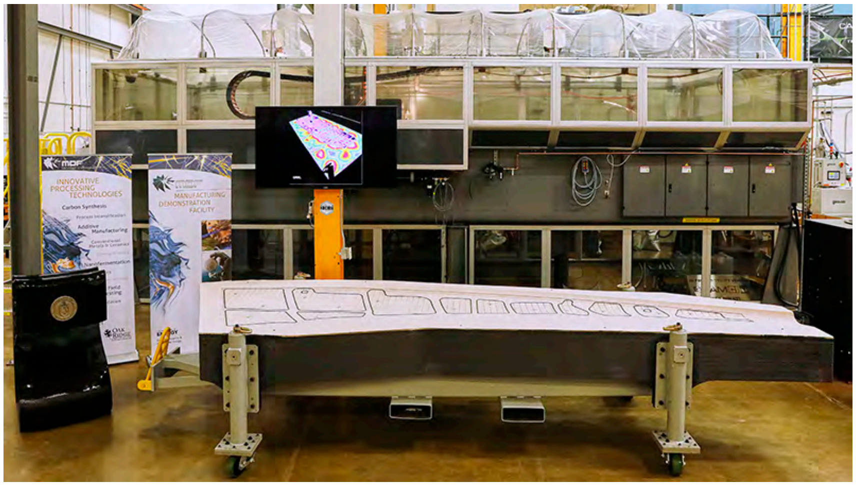

Fig. 5.2. Boeing 777-X drill and trim tool at the *Guinness World Records* ceremony.

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 (Fig. 5.3). 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.

Fig. 5.3. Production of lower-cost carbon fiber at the Carbon Fiber Technology Facility.
[Photo by Jason Richards.]

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.

5.2 Environmental Management Systems

Demonstration of environmental excellence through high-level policies that clearly state expectations for continual improvement, pollution prevention, and compliance with regulations and other requirements is a priority at ORNL. In accordance with DOE Order 436.1, *Departmental Sustainability* (DOE 2011a), UT-Battelle, NWSol, UCOR, and Isotek have implemented environmental management systems (EMSs), modeled after International Organization for Standardization (ISO) 14001, 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. UT-Battelle's EMS was first registered in July 2013 and was successfully registered, by National Quality Assurance, U.S.A., in July 2016 to the new ISO 14001:2015 standard.

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 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 environmental safety and health (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 5.4 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.

Fig. 5.4. The relationship between the UT-Battelle Environmental Management System and the Integrated Safety Management System.

5.2.1.2 UT-Battelle 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 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 has established and implemented objectives and performance indicators for appropriate functions and activities. In all cases, the objectives and performance indicators are consistent with the UT-Battelle Policy for ORNL and are supportive of the laboratory mission, and where practical, they are measurable. The objectives are entered into a commitment tracking system and are tracked to completion.

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 2016 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, and 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 is a holistic approach to sustainability based on DOE guidance and on Executive Order (EO) 13693 (2015). In 2016 the SCI addressed a number of sustainability issues at ORNL, such as water and energy use, waste management, and greenhouse gas emissions.

Avoided Costs: Energy, Water, and Waste

SCI 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 resulted in an accumulated cost (Fig. 5.5).

Energy Use Intensity Reduction. UT-Battelle reduced EUI by 5.4% in FY 2016, exceeding the 2.5% annual goal established in EO 13693 (Fig. 5.6).

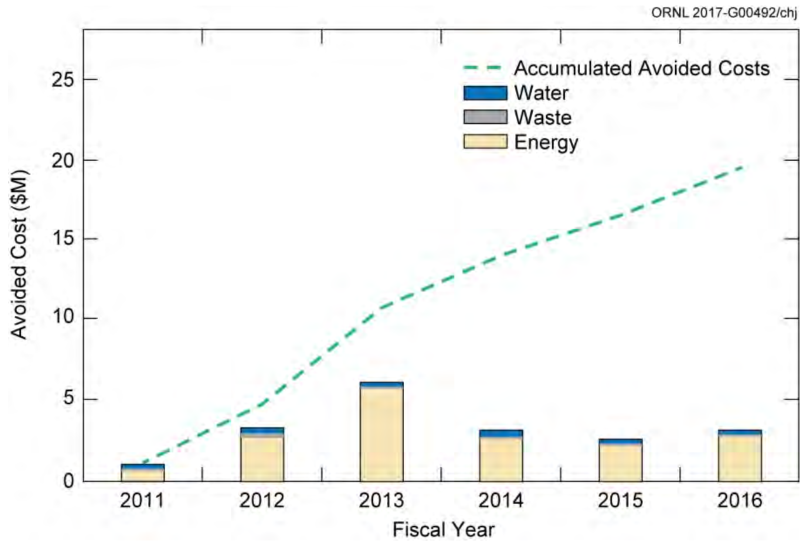

Fig. 5.5. Avoided costs.

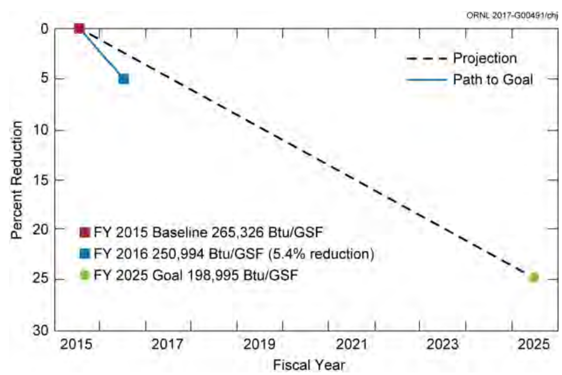

Fig. 5.6. ORNL energy use intensity reduction summary.

Water Use Intensity Reduction. EO 13693 established a potable water consumption reduction goal of 36% by 2025 through reductions of 2% annually relative to baseline consumption in 2007, and DOE O 230.2B established a reduction goal of 15% between 2007 and 2015. A cumulative reduction in WUI of 21.8% has been realized at ORNL between 2007 and 2016 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 has exceeded both of these goals (Fig. 5.7).

Waste Diversion. The diversion rate for municipal solid waste at ORNL was 46% in FY 2016, slightly less than the DOE goal of 50%. The diversion rate for C&D materials and debris (66%) exceeded the DOE goal of 50%.

Pollution Prevention. UT-Battelle implemented 38 new pollution prevention projects at ORNL during 2016, eliminating more than 3.7 million kg of waste. In total, these projects and ongoing reuse/recycle projects led to cost savings/avoidance of more than $2.5 million. Source reduction actions pursued in 2016 included moving toward paperless work processes; resource-efficient computing; and recycling efforts for paper, scrap metal, pallets, carpet, drums, electronics, and C&D debris (Fig. 5.8).

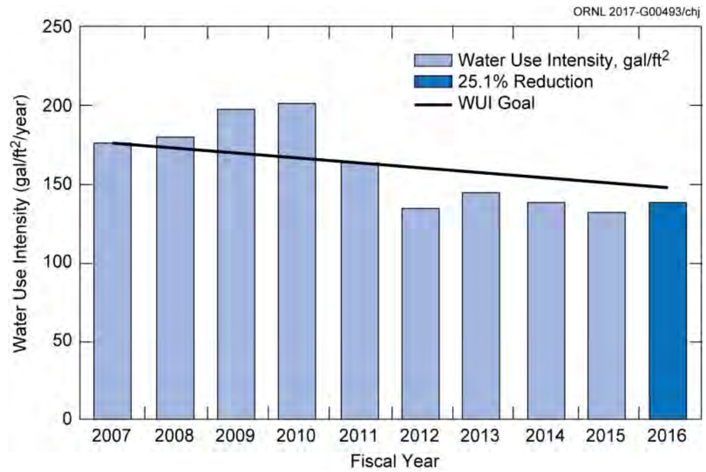

Fig. 5.7. ORNL water use intensity reduction summary.
(EO 13693 reduction goal between 2007 and 2025: 36%.
DOE O 430.2B reduction goal between 2007 and 2016: 15%.)

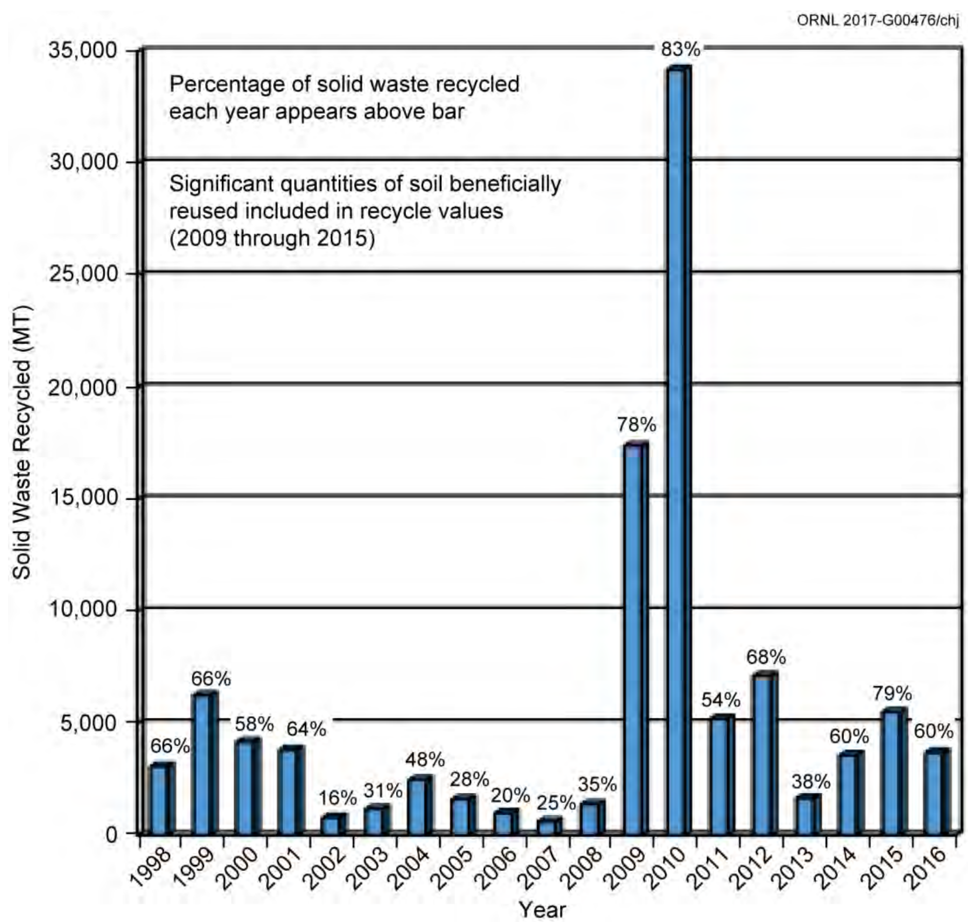

Fig. 5.8. Solid waste recycled at Oak Ridge National Laboratory as a result of recycling programs through 2016.

Sustainable Vehicle Fleet

Fleet Fuel Savings. The vehicle fleet at ORNL includes 63 flexible fuel vehicles and 5 plug-in hybrid sedans, which also use alternative fuels. Fuel data for FY 2016 show a 54.6% decrease in petroleum consumption at ORNL since the 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 331%, far exceeding the 160% target.

Electric Vehicle Drivers Club. 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. Most of the EV chargers were installed under the EV Research Project, which bore the associated costs until the end of FY 2016. An EV Owners Club was formed at ORNL to continue operating the non-fleet EV charging stations; annual club dues cover the costs of charging personal vehicles.

Sustainable Buildings: Battle of the Buildings

The Battle of the Buildings, a competition started at ORNL to encourage the reduction of electricity use in buildings, was held between July and September 2016. Electricity use in 2016 at eight buildings with similar missions and similar square footage was compared to use for the previous year. The occupants of the winning building achieved accumulated energy savings of 23%; savings for the second- and third-place buildings were 14% and 8%, respectively.

Regional and Local Planning: The Shuttle Bus System

A bus route between ORNL, the University of Tennessee, and Pellissippi State Community College continued operations for a second year in 2016. The average daily ridership was 27 people. (Fig. 5.9)

Fig. 5.9. ORNL-UT-Pellissippi shuttle bus.

Employee, Family, and Community Engagement: The Science of Earth Day

ORNL's Earth Day celebration spanned 1 week in 2016. Activities included a tour of the Additive Manufacturing Integrated Energy demonstration project, where a natural-gas-powered hybrid electric vehicle was on display; multiple seminars; a bike ride and a 5k walk; and the opportunity to speak to SCI representatives about various projects and displays.

Awards for Sustainability Efforts

Efforts at ORNL that are related to sustainability were recognized with the following awards in 2016.

- DOE Presidential Migratory Bird Federal Stewardship Award, honorable mention for four species of warblers benefitting from wetlands on the ORR

- DOE Sustainability Award for Green IT Stewardship for team efforts related to "Programming Future Sustainability"

- DOE Sustainability Award for ORNL's Green Transportation Team efforts related to "Driving Future Sustainability"

- *Facility Maintenance Decisions Magazine* Achievement in Sustainability Award for recognizing "the essential role maintenance and engineering departments play in the safe, sustainable and efficient operation of the nation's institutional and commercial facilities"

- *R&D Magazine* R&D 100 Awards:

  - The Roof Savings Calculator Suite, a Web-based tool for simulating energy flow and loss developed by a team from ORNL, Jacksonville State University, and White Box Technologies

  - The U-Grabber, an adsorbent material designed to extract uranium and other metals from water inexpensively and efficiently

  - Waste Tire Derived Carbon technology, which enables the economic use of waste tires in a green, value-added product and results in lower-cost, higher-performance lithium-ion batteries and a significant reduction in carbon emissions, awarded to ORNL and RJ Lee Group Inc.

  - Wireless Power Transfer Based Electric and Plug-In Vehicle Charging System, awarded to Toyota Engineering and Manufacturing North America with co-developers at ORNL and the Cisco Systems International Transportation Innovation Center

  - Open Port Sampling Interfaces for Mass Spectrometry, which solved a major bottleneck in the expansion of mass spectrometry, an important measurement technique for chemically characterizing materials (Fig. 5.10)

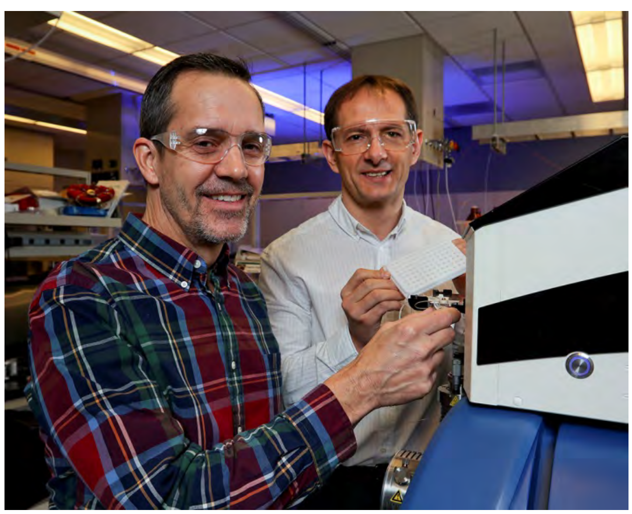

Fig. 5.10. The Open Port Sampling Interfaces for Mass Spectrometry, invented by Gary Van Berkel (left) and Vilmos Kertes, ORNL. *(ORNL photo by Carlos Jones.)*

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, a three-step approach is used to evaluate and satisfy the requirements of EISA Section 438. Evaluation occurs

1. within the project boundaries. If the necessary volume of runoff cannot be infiltrated or retained on site, then

2. on land immediately adjacent to the project boundaries. If the necessary volume of runoff cannot be infiltrated or retained on land immediately adjacent to the project boundaries, then

3. within the same valley or ridge area (e.g., within Bethel Valley if the project is within Bethel Valley; within Melton Valley if the project is within Melton Valley).

In addition to GI/LID practices, the projects may remove impervious areas and reestablish pervious areas to allow infiltration or evapotranspiration to occur.

5.2.1.6 Emergency Preparedness and Response

The UT-Battelle Emergency Management Program supplies the resources and capabilities to provide emergency preparedness services and, in the event of an accident, emergency response services. Emergency preparedness personnel perform hazard surveys and hazard assessments to identify potential emergency situations. Procedures and plans have been developed to prepare for and respond to a wide variety of potential emergency situations. Training is provided to ensure appropriate response and performance during emergency events. Frequent exercises and drills are scheduled to ensure the effective performance of the procedures and plans. An environmental subject matter expert is a member of the emergency response team and participates in drills and exercises to ensure that environmental requirements are met and that environmental impacts from an event and the response are mitigated.

5.2.1.7 Checking

Monitoring and Measurement

UT-Battelle has developed monitoring and measurement processes for each operation or activity that can have a significant adverse effect on the environment. Several SBMS subject areas include requirements for managers to establish performance objectives and indicators, conduct performance assessments to collect data and monitor progress, and evaluate the data to identify strengths and weaknesses in performance and areas for improvement.

UT-Battelle Environmental Management System Assessments

UT-Battelle uses several methods to evaluate compliance with legal and other environmental requirements. Most of the compliance evaluation activities are implemented through the EMS or 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 registration audit conducted in 2016 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 14001:2004 standard (ISO 2004) in May 2008. 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.

The NSF-ISR registered the TWPC EMS for activities to the ISO 14001:2004 standard in May 2008. NSF-ISR conducted a recertification audit in April 2014 and a surveillance audit in April 2016. 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. NWSol has established a "single stream" recycling program that allows the mixing of multiple types of recyclables that increases the amount of recyclable items and improves compliance. A construction debris recycling program began in September 2011 and has resulted in about 172 tons being diverted from the landfill to date.

"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.

Several methods are used by NWSol 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 and that satisfies the applicable requirements of DOE O 450.1A, *Environmental Protection Program* (DOE 2008). The scope of the Isotek EMS is to achieve and demonstrate environmental excellence by identifying, assessing, and controlling the impact of Isotek activities and facilities on the environment. The EMS is designed to ensure compliance with environmental laws, regulations, and other applicable requirements and to improve effectiveness and efficiency, reduce costs, and earn and retain regulator and community trust. The Isotek EMS and ISMS are fully integrated.

Project procedures provide a systematic approach to integrating environmental considerations into all aspects of Isotek's activities at ORNL. The Isotek EMS includes a procedure for identifying environmental aspects associated with the U-233 Disposition Project and for determining whether those aspects can have significant environmental impacts. Isotek has identified radiological air emissions as the only environmental aspect of its operations that has potentially significant environmental impacts and has developed an environmental management plan with measurable objectives and targets to address that aspect. Isotek reviews environmental aspects, potential impacts, objectives, targets, and its environmental management plan at least annually and updates them as necessary.

The U-233 Disposition Project has a well-established recycling program that is implemented at all Isotek facilities and includes Buildings 3017 and 3019 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 2016 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 2016.

The following discussions summarize the major environmental programs and activities carried out at ORNL during 2016 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, 2016

Date	Reviewer	Subject	Issues
March 7	City of Oak Ridge	CFTF Wastewater Inspection	0
April 12–13	TDEC	Annual RCRA Inspection for ORNL (including TWPC)	0
April 12	City of Oak Ridge	CFTF Wastewater Monitoring	0
September 7	City of Oak Ridge	CFTF Wastewater Inspection	0
October 24	TDEC	Annual CAA Inspection for ORNL and CFTF	0
November 17	TDEC	UST Compliance Inspection	2[a]

[a] Three active tanks were identified as not being registered correctly (one violation, rescinded), and two electronic line leak detectors had not been third-party tested in the preceding 12 months.

Acronyms
CAA = Clean Air Act
CFTF = Carbon Fiber Technology Facility
ORNL = Oak Ridge National Laboratory
RCRA = Resource Conservation and Recovery Act
TDEC = Tennessee Department of Environment and Conservation
TWPC = Transuranic Waste Processing Center
UST = Underground storage tank

5.3.1 Environmental Permits

Table 5.2 contains a list of environmental permits that were in effect in 2016 at ORNL.

Table 5.2. Environmental permits in effect at ORNL in 2016

Regulatory driver	Permit title/description	Permit number	Owner	Operator	Responsible contractor
CAA	Title V Major Source Operating Permit, ORNL	562765	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, Steam Plant boilers 7–9	969317F	DOE	UT-B	UT-B
CAA	Construction Permit, 4501/4505 Area Off Gas System	971441P	DOE	UT-B	UT-B
CAA	Operating Permit, NTRC	0941-05	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	Tennessee General NPDES Permit TNR10-0000, Storm Water Discharges from Construction Activities—Spallation Neutron Source	TNR139975	DOE	DOE	UT-B
CWA	Tennessee General NPDES Permit TNR10-0000, Storm Water Discharges from Construction Activities—7018 Renovations/Additions (2.81 acres)	TNR134552	DOE	DOE	UT-B
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

Table 5.2 (continued)

Regulatory driver	Permit title/description	Permit number	Owner	Operator	Responsible contractor
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
CWA	ARAP for ORNL East Campus Pond Replacement	ARAP NR1403.060	DOE	UT-B	UT-B
RCRA	Hazardous Waste Transporter Permit	TN1890090003	DOE	DOE	UT-B, UCOR
RCRA	Hazardous Waste Corrective Action Permit	TNHW-164	DOE	DOE/all	DOE/all
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

ARAP = Aquatic Resource Alteration Permit
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 2016.

Table 5.3. National Environmental Policy Act activities, 2016

Types of NEPA documentation	Number of instances
Oak Ridge National Laboratory	
Approved under general actions or generic CX determinations[a]	103
Project-specific CX determinations[b]	3
North Wind Solutions	
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 2016, 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 sitewide UT-Battelle Title V Major Source Operating Permit, which was issued in 2011, was sent in for renewal in February 2016. Three minor modification requests were submitted to TDEC in 2016 and will likely be finalized in a minor modification in 2017. TDEC issued two additional construction permits, one for the new off-gas system radionuclide emission source at Building 3525 and one for the new off-gas system radionuclide emission source at Buildings 4501 and 4505.

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 April 2016. 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 2016.

In summary, there were no UT-Battelle CAA violations and no Isotek, UCOR, or NWSol CAA violations or exceedances in 2016. Section 5.4 provides detailed information on 2016 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 CAA 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 2016, 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 2016 was greater than 99%, with no measurements exceeding numeric NPDES permit limits. One laboratory sampling error occurred during February 2016 when the contents of the sample bottle containing the composited effluent from the week of February 8–12, 2016, was mistakenly discarded before being

analyzed for the total suspended solids (TSS). A replacement sample was unable to be obtained, and so the required analysis for the weekly TSS concentration could not be measured or reported.

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 2016, 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 2016, 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 2016. 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 2016, 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 42 active waste streams at ORNL, some of which are mixed wastes. The quantity of hazardous/mixed waste generated at ORNL in 2016 was 540,600 kg, with mixed wastewater accounting for 387,637 kg. ORNL generators treated 5,773 kg of hazardous/mixed waste by elementary neutralization, silver recovery, and deactivation. Four hundred forty-seven kg of hazardous waste from ETTP was treated at Process Waste Treatment Complex (PWTC). The quantity of hazardous/mixed waste treated in RCRA-permitted treatment facilities at ORNL in 2016 was 6,191 kg. This included waste treated by macroencapsulation, size reduction, stabilization/solidification, and wastewater treatment at the PWTC. In addition, 387,637 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 118,186 kg in 2016.

Table 5.4. Oak Ridge National Laboratory Resource Conservation and Recovery Act operating permits, 2016

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-121[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

In April 2016, TDEC conducted an annual RCRA inspection of ORNL generator areas; battery collection areas; RCRA-permitted treatment, storage, and disposal facilities; 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; and DOT training records. All records and areas were found to be in compliance with RCRA regulations and the RCRA permits.

DOE and UT-Battelle operations at NTRC and CFTF were regulated as "conditionally exempt small-quantity generators" in 2016, meaning that less than 100 kg of hazardous waste per month was generated.

In 2016, 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. The 0800 Area is a location on ORR adjacent to ORNL that has been assigned EPA identification number TNR000019760.

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 2015 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 2016.

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 three USTs registered with TDEC under Facility ID 0-730089. Two are in service (petroleum) and meet the current UST standards. One (formerly storing petroleum) is undergoing permanent closure activities and is expected to be closed in the first quarter of 2017.

TDEC performed a compliance inspection in November 2016, and two findings were cited by TDEC as a result of the inspection. Both findings were resolved within 60 days, as required by TDEC.

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 among EPA, TDEC, and DOE became effective 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 2016, UT-Battelle operated 12 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.

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 report is submitted to the University of Texas at Dallas (UT-Dallas) Emergency Response Information System (E-Plan) E-Plan 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 2016 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.

ORNL had no releases of extremely hazardous substances, as defined by EPCRA, in 2016. Releases of toxic chemicals that were greater than the Section 313 designated reportable threshold quantities are discussed in Section 5.3.10.2.

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

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 2016, there were 25 hazardous and/or extremely hazardous substances at ORNL that met EPCRA reporting criteria.

Private-sector lessees were not included in the 2016 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 2016, 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 2016, UT-Battelle personnel had 39 permits and agreements for the receipt, movement, or controlled release of regulated articles.

5.3.12 Wetlands

In 2016, the fifth and final year of postmitigation monitoring and reporting was completed on compensatory mitigation sites for the ORNL Parking Structure, which was constructed in 2011. The monitored mitigation sites included the expansion of Wetland P2 and the enhanced sections of White Oak Creek and First Creek riparian zones. All requirements of TDEC's wetland-mitigation Aquatic Resource Alteration Permits stipulated by Section 401 of the CWA are fulfilled. Wetland monitoring included surveys of vegetation and fauna. Creek monitoring included riparian-zone vegetation surveys, fish and benthic community surveys, and stream habitat assessments (Fig. 5.11).

Fig. 5.11. Creek monitoring of wetland mitigation site.
(ORNL photo by Neil Giffen, Facilities and Operations Directorate.)

5.3.12.1 Wetland P2

Baseline data collected in 2011 showed sparse vegetation with limited habitat and lack of fauna prior to mitigation. Five years later, the wetland has good overall vegetative cover from a mix of planted and volunteer species. The plant community has shifted from herbaceous growth (e.g., rushes and sedges) to woody species (e.g., willows) over time. The improved wildlife habitat is evident by the increased presence of birds, frogs, and benthic macroinvertebrates in and around the wetland.

5.3.12.2 First Creek

Riparian zone planting was conducted prior to the completion of the ORNL Parking Structure, resulting in more than the required 5 years of monitoring. Plantings on the east side of the creek have improved habitat quality in that area over original habitat conditions, which included large mowed turf grass areas and a high number of invasive plant species. Results of habitat measurements conducted in 2016 along this reach of First Creek showed that the creek provided good overall habitat and was in a nonimpaired state. Fish community monitoring showed fish population densities similar to certain reference streams, although the number of fish species was generally lower than the numbers found in reference streams.

5.3.12.3 White Oak Creek

Vegetation surveys have shown improved riparian buffer habitat quality compared to the premitigation mowed turf. Although there have been records of dying shrubs over the years, plant cover remains good due to replacement shrub plantings and volunteer plants. Results of habitat measurements conducted in 2016 along the mitigated section of White Oak Creek showed that the creek provided average overall habitat and was in a nonimpaired state. A moderately diverse benthic macroinvertebrate population was recorded at the site in 2016. Fish population density and biomass were lower in this reach of White Oak Creek than were found in certain reference streams on the ORR. The number of fish species was comparable to or lower than the numbers found in the reference streams.

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 2011b), 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 the site'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 2011b) 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.

UT-Battelle continues to use the preapproved authorized limits for surface contamination 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 2016, 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 (including donations, transfers, landfill, reutilization, and sales) is shown in Table 5.6.

Table 5.6. Excess items requested for release and/or recycling, 2016

Item	Process knowledge	Radiologically surveyed
Release request totals for 2016		
Computers-for-Learning	0	0
DOE donations	0	0
Other donations	613	129
LEDP (donations to colleges/universities)	77	0
DOE transfers	524	100
Other federal agency transfers	159	61
Landfill	67	12
Reuse at ORNL	390	29
Sales	12,477	2,522
Totals	14,307	2,853
Recycling request totals for 2016		
Cardboard (tons)	125.45	
Scrap metal (nonradiological areas) (tons)	583.32	
Pallets (each)	4,000	

Acronyms
DOE = US Department of Energy
LEDP = Laboratory Equipment Donation Program
ORNL = Oak Ridge National Laboratory

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 2011b) 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., 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.

The approved revised process for notification was continued in 2016. In 2016 ORNL cleared 184 samples from neutron scattering experiments using the SNS and HFIR sample authorized limits process.

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 September 2011, the State of Tennessee issued Title V Major Source Operating Permit 562765 to DOE and UT-Battelle operations at ORNL. This permit was renewed in 2016 and was issued on August 2, 2017. 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 UT-Battelle applied for and received construction permit number 965103P 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 2017.

DOE /NWSol has two 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 2016 no permit limits were exceeded. UCOR has a Title V Major Source Operating Permit for the 3039 stack. No permit limits were exceeded for these sources in 2016.

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 2016 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 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 (Fig. 5.12).

- 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 2016 there were 14 minor point/group sources, and emission calculations/estimates were made for each of them.

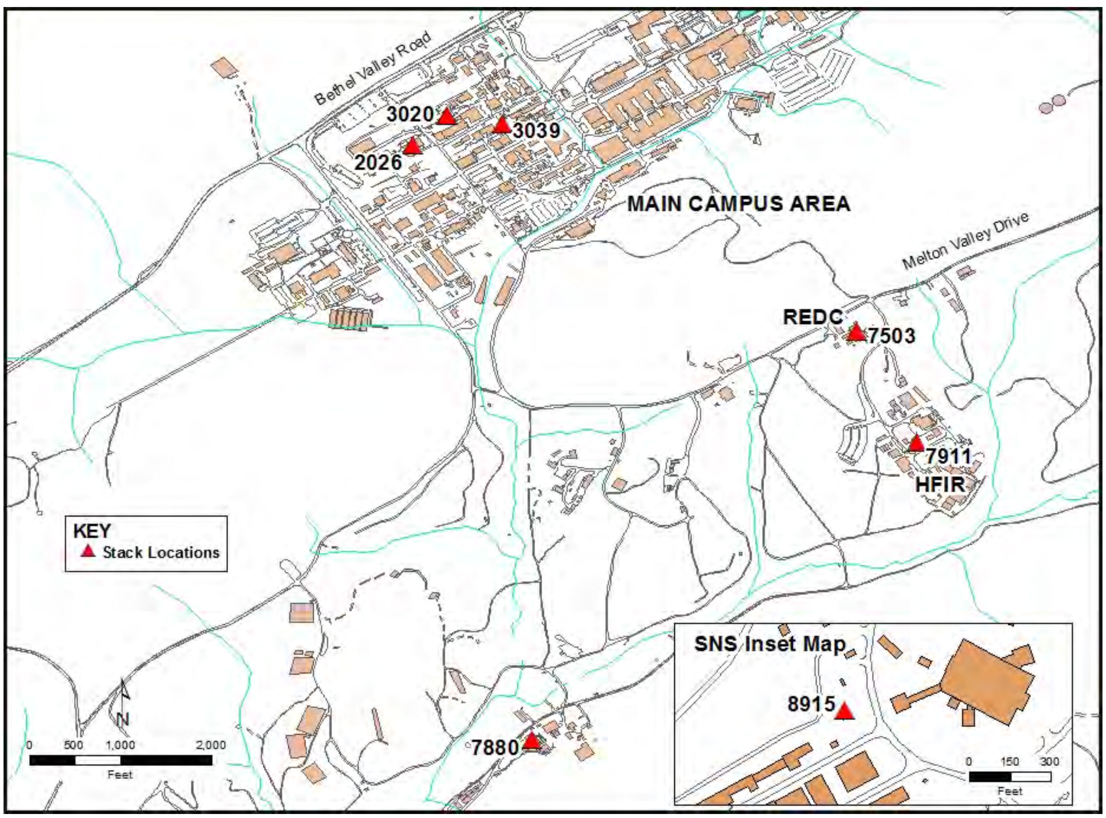

Fig. 5.12. Locations of major radiological emission points at Oak Ridge National Laboratory. *(HFIR = High Flux Isotope Reactor, REDC = Radiochemical Engineering Development Center, and SNS = Spallation Neutron Source.)*

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. 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 and 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.

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 2016 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 Figs. 5.13 and 5.14. For 2016, tritium emissions totaled about 1,086.9 Ci (Fig. 5.13), over twice the emissions seen in 2015; ^{131}I emissions totaled 0.03 Ci (Fig. 5.11), a 65% reduction from 2015. For 2016, of the 278 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 ^{11}C, ^{234}U, and ^{212}Pb, with dose contributions of about 34%, 21%, and 18%, respectively. The increase in tritium and ^{11}C emissions results from SNS operations and research activities (Fig. 5.15). Emissions of ^{234}U are associated with a number of sources at ORNL, including 1000, 3000, 4000 and 7000 area laboratory hoods. 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, 7935 Glove Box, the STP Sludge Drier and the 4000 area laboratory hoods. For 2016, ^{11}C emissions totaled 40,000 Ci, double that of 2015; ^{234}U emissions totaled 0.0243 Ci; and ^{212}Pb emissions totaled 2.02 Ci.

The calculated radiation dose to the maximally exposed individual (MEI) from all radiological airborne release points at ORR during 2016 was 0.2 mrem. The dose contribution to the MEI from all ORNL radiological airborne release points was 97.8% of the ORR dose. This dose is well below the NESHAPs standard of 10 mrem and is less than 0.07% 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, 2016 (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								3.04E-04	3.04E-04
^{226}Ac	M	Particulate								5.63E-08	5.63E-08
^{227}Ac	M	Particulate								6.48E-09	6.48E-09
^{228}Ac	M	Particulate								2.34E-05	2.34E-05
^{109m}Ag	B	Unspecified								1.25E-14	1.25E-14
^{110m}Ag	M	Particulate								1.15E-09	1.15E-09
^{111}Ag	M	Particulate								8.52E-06	8.52E-06
^{112}Ag	M	Particulate								2.45E-08	2.45E-08
^{26}Al	M	Particulate								6.85E-14	6.85E-14
^{241}Am	M	Particulate	4.78E-08	3.01E-07				3.06E-08		9.76E-06	1.01E-05
^{241}Am	F	Particulate			1.23E-07	1.08E-08	1.02E-06			1.69E-08	1.17E-06
^{243}Am	M	Particulate								8.74E-09	8.74E-09
^{37}Ar	B	Unspecified								9.75E-11	9.75E-11
^{39}Ar	B	Unspecified								7.25E-10	7.25E-10
^{41}Ar	B	Unspecified						4.44E+02	7.80E+01		5.22E+02
^{42}Ar	B	Unspecified								2.04E-14	2.04E-14
^{133}Ba	M	Particulate								2.14E-09	2.14E-09
^{137m}Ba	B	Unspecified								3.13E-11	3.13E-11
^{139}Ba	M	Particulate						1.99E-01			1.99E-01
^{140}Ba	M	Particulate						3.80E-04		3.80E-06	3.84E-04
^{7}Be	M[b]	Particulate	1.99E-07							7.74E-06	7.94E-06
^{7}Be	S	Particulate			6.56E-06	3.47E-07				5.19E-07	7.43E-06
^{206}Bi	M	Particulate								3.80E-07	3.80E-07
^{211}Bi	B	Unspecified								5.82E-11	5.82E-11
^{212}Bi	M	Particulate								1.70E-07	1.70E-07
^{213}Bi	M	Particulate								2.76E-04	2.76E-04

Table 5.7 (continued)

Isotope	Inhalation form	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total minor Source	ORNL total
^{249}Bk	M	Particulate								7.00E-11	7.00E-11
^{82}Br	M	Particulate								8.99E-08	8.99E-08
^{11}C	G	Dioxide							4.00E+04		4.00E+04
^{14}C	M	Particulate								7.11E-08	7.11E-08
^{14}C	G	Dioxide								3.00E-02	3.00E-02
^{41}Ca	M	Particulate								1.13E-10	1.13E-10
^{45}Ca	M	Particulate								9.70E-08	9.70E-08
^{47}Ca	M	Particulate								1.10E-10	1.10E-10
^{109}Cd	M	Particulate								1.25E-14	1.25E-14
^{113m}Cd	M	Particulate								2.66E-14	2.66E-14
^{115}Cd	M	Particulate								3.55E-06	3.55E-06
^{139}Ce	M	Particulate								3.69E-08	3.69E-08
^{141}Ce	M	Particulate						8.18E-07		1.24E-06	2.06E-06
^{143}Ce	M	Particulate								4.36E-07	4.36E-07
^{144}Ce	M	Particulate								5.17E-07	5.17E-07
^{249}Cf	M	Particulate								1.06E-08	1.06E-08
^{250}Cf	M	Particulate								2.91E-07	2.91E-07
^{251}Cf	M	Particulate								2.50E-09	2.50E-09
^{252}Cf	M	Particulate						1.56E-08		2.31E-06	2.33E-06
^{36}Cl	M	Particulate								3.90E-10	3.90E-10
^{242}Cm	F	Particulate					6.61E-07				6.61E-07
^{242}Cm	M	Particulate								4.32E-13	4.32E-13
^{243}Cm	M	Particulate	1.19E-07							7.66E-09	1.26E-07
^{243}Cm	F	Particulate			1.01E-08	2.04E-08	4.29E-07			2.81E-09	4.62E-07
^{244}Cm	M	Particulate	1.19E-07	2.93E-08						3.56E-06	3.71E-06
^{244}Cm	F	Particulate			1.01E-08	2.04E-08	4.29E-07			2.81E-09	4.62E-07
^{245}Cm	M	Particulate								3.74E-10	3.74E-10

Table 5.7 (continued)

Isotope	Inhalation form	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total minor Source	ORNL total
^{246}Cm	M	Particulate								2.26E-14	2.26E-14
^{248}Cm	M	Particulate								6.80E-14	6.80E-14
^{56}Co	M	Particulate								1.58E-13	1.58E-13
^{57}Co	M	Particulate								4.13E-09	4.13E-09
^{57}Co	S	Particulate			1.79E-07		6.06E-07				7.85E-07
^{58}Co	M	Particulate								9.91E-09	9.91E-09
^{60}Co	M	Particulate								2.79E-05	2.79E-05
^{60}Co	S	Particulate			1.04E-07		1.96E-06				2.06E-06
^{60m}Co	M	Particulate								1.05E-13	1.05E-13
^{51}Cr	S	Particulate								1.99E-05	1.99E-05
^{51}Cr	M	Particulate								2.18E-04	2.18E-04
^{134}Cs	F	Particulate								3.61E-07	3.61E-07
^{136}Cs	F	Particulate								1.02E-06	1.02E-06
^{137}Cs	F	Particulate	2.45E-06	1.59E-06				4.02E-06		4.85E-04	4.93E-04
^{137}Cs	S	Particulate			5.72E-05	4.58E-07	1.79E-06			5.30E-05	1.12E-04
^{138}Cs	F	Particulate						2.05E+02			2.05E+02
^{64}Cu	M	Particulate								3.70E-07	3.70E-07
^{66}Cu	B	Unspecified								1.93E-13	1.93E-13
^{67}Cu	M	Particulate								4.35E-09	4.35E-09
^{169}Er	M	Particulate								2.41E-19	2.41E-19
^{152}Eu	M	Particulate			4.34E-07					2.57E-04	2.58E-04
^{154}Eu	M	Particulate								4.86E-05	4.86E-05
^{155}Eu	M	Particulate								5.09E-06	5.09E-06
^{156}Eu	M	Particulate								6.58E-15	6.58E-15
^{55}Fe	M	Particulate								1.91E-05	1.91E-05
^{59}Fe	M	Particulate								1.93E-06	1.93E-06
^{60}Fe	M	Particulate								1.05E-13	1.05E-13

Table 5.7 (continued)

Isotope	Inhalation form	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total minor Source	ORNL total
^{221}Fr	B	Unspecified								3.00E-04	3.00E-04
^{72}Ga	M	Particulate								4.69E-12	4.69E-12
^{151}Gd	M	Particulate								2.64E-14	2.64E-14
^{153}Gd	M	Particulate								2.19E-08	2.19E-08
^{71}Ge	M	Particulate								6.53E-09	6.53E-09
^{3}H	V	Vapor	1.94E-02		4.77E+00	6.77E-01		1.21E+02	9.60E+02	3.98E-01	1.09E+03
^{175}Hf	M	Particulate								1.45E-08	1.45E-08
^{178m}Hf	M	Particulate								4.01E-11	4.01E-11
^{181}Hf	M	Particulate								3.23E-07	3.23E-07
^{203}Hg	M	Inorganic								3.66E-11	3.66E-11
^{166m}Ho	M	Particulate								1.90E-12	1.90E-12
^{124}I	F	Particulate								2.73E-07	2.73E-07
^{124}I	V	Vapor								5.08E-16	5.08E-16
^{125}I	V	Vapor								7.96E-10	7.96E-10
^{126}I	F	Particulate								2.48E-07	2.48E-07
^{126}I	V	Vapor								5.82E-10	5.82E-10
^{129}I	F	Particulate								1.86E-05	1.86E-05
^{129}I	V	Vapor					1.94E-06			1.27E-12	1.94E-06
^{131}I	F	Particulate			1.31E-05			3.24E-02		2.72E-06	3.24E-02
^{131}I	V	Vapor					8.41E-06			4.48E-07	8.86E-06
^{132}I	F	Particulate						4.09E-01			4.09E-01
^{133}I	F	Particulate			9.39E-06			1.82E-01		1.53E-08	1.82E-01
^{134}I	F	Particulate						8.25E-01			8.25E-01
^{135}I	F	Particulate						6.18E-01			6.18E-01
^{113m}In	M	Particulate								7.11E-10	7.11E-10
^{114}In	B	Unspecified								8.67E-12	8.67E-12
^{114m}In	M	Particulate								1.37E-10	1.37E-10

Table 5.7 (continued)

Isotope	Inhalation form	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total minor Source	ORNL total
^{192}Ir	M	Particulate								1.82E-13	1.82E-13
^{40}K	M	Particulate								7.99E-05	7.99E-05
^{42}K	M	Particulate								2.04E-14	2.04E-14
^{81}Kr	B	Unspecified								5.82E-12	5.82E-12
^{85}Kr	B	Unspecified						6.63E+02		2.74E-01	6.63E+02
^{85m}Kr	B	Unspecified						5.06E+00			5.06E+00
^{87}Kr	B	Unspecified						3.21E+01			3.21E+01
^{88}Kr	B	Unspecified						4.45E+01	4.10E+01		8.55E+01
^{89}Kr	B	Unspecified						2.91E+01			2.91E+01
^{140}La	M	Particulate						3.61E-04		1.22E-06	3.62E-04
^{177}Lu	M	Particulate								9.28E-11	9.28E-11
^{177m}Lu	M	Particulate								2.20E-12	2.20E-12
^{54}Mn	M	Particulate								4.23E-07	4.23E-07
^{56}Mn	M	Particulate								2.04E-21	2.04E-21
^{93}Mo	M	Particulate								2.96E-12	2.96E-12
^{99}Mo	M	Particulate								3.97E-06	3.97E-06
^{13}N	B	Unspecified							8.80E+02		8.80E+02
^{22}Na	M	Particulate								4.27E-11	4.27E-11
^{24}Na	M	Particulate								9.52E-08	9.52E-08
^{91m}Nb	B	Unspecified								1.62E-11	1.62E-11
^{92m}Nb	B	Unspecified								1.83E-17	1.83E-17
^{93m}Nb	M	Particulate								1.63E-13	1.63E-13
^{94}Nb	M	Particulate								1.37E-12	1.37E-12
^{95}Nb	M	Particulate								4.20E-07	4.20E-07
^{95m}Nb	M	Particulate								1.76E-13	1.76E-13
^{96}Nb	M	Particulate								4.59E-09	4.59E-09
^{97}Nb	M	Particulate								2.15E-09	2.15E-09

Table 5.7 (continued)

Isotope	Inhalation form	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total minor Source	ORNL total
^{147}Nd	M	Particulate								6.37E-07	6.37E-07
^{59}Ni	M	Particulate								4.94E-09	4.94E-09
^{63}Ni	M	Particulate								6.58E-03	6.58E-03
^{65}Ni	M	Particulate								2.81E-24	2.81E-24
^{66}Ni	M	Particulate								1.92E-13	1.92E-13
^{237}Np	M	Particulate								8.94E-08	8.94E-08
^{239}Np	M	Particulate								1.90E-09	1.90E-09
^{191}Os	M	Particulate								7.03E-10	7.03E-10
^{32}P	M	Particulate								6.38E-09	6.38E-09
^{33}P	M	Particulate								3.85E-12	3.85E-12
^{228}Pa	M	Particulate								2.48E-09	2.48E-09
^{230}Pa	M	Particulate								6.62E-07	6.62E-07
^{232}Pa	M	Particulate								8.44E-09	8.44E-09
^{233}Pa	M	Particulate								1.53E-07	1.53E-07
^{234m}Pa	B	Unspecified								2.11E-09	2.11E-09
^{210}Pb	M	Particulate								4.06E-12	4.06E-12
^{212}Pb	M	Particulate	3.80E-01	3.86E-01				1.95E-02		1.08E-05	7.86E-01
^{212}Pb	S	Particulate			1.10E+00	1.15E-01				2.12E-02	1.24E+00
^{214}Pb	M	Particulate								6.08E-14	6.08E-14
^{147}Pm	M	Particulate								7.80E-11	7.80E-11
^{148m}Pm	M	Particulate								1.53E-07	1.53E-07
^{210}Po	B	Inorganic								5.17E-12	5.17E-12
^{143}Pr	M	Particulate								2.86E-15	2.86E-15
^{144}Pr	M	Particulate								6.32E-11	6.32E-11
^{193}Pt	M	Particulate								5.40E-10	5.40E-10
^{238}Pu	M	Particulate	2.88E-08	6.68E-08				8.02E-08		2.32E-05	2.33E-05
^{238}Pu	F	Particulate			3.18E-08	7.58E-09	9.81E-07			1.00E-08	1.03E-06

Table 5.7 (continued)

Isotope	Inhalation form	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total minor Source	ORNL total
^{239}Pu	M	Particulate	3.95E-08	3.38E-07				3.36E-08		1.97E-07	6.08E-07
^{239}Pu	F	Particulate			2.84E-07	5.30E-09	4.48E-07			3.13E-09	7.40E-07
^{240}Pu	M	Particulate	3.95E-08					3.36E-08		8.94E-08	1.62E-07
^{240}Pu	F	Particulate			2.84E-07	5.30E-09	4.48E-07			3.13E-09	7.40E-07
^{241}Pu	M	Particulate								2.16E-06	2.16E-06
^{242}Pu	M	Particulate								3.96E-09	3.96E-09
^{223}Ra	M	Particulate								3.17E-06	3.17E-06
^{224}Ra	M	Particulate								9.54E-07	9.54E-07
^{225}Ra	M	Particulate								2.34E-12	2.34E-12
^{226}Ra	M	Particulate								1.20E-07	1.20E-07
^{228}Ra	M	Particulate								2.34E-05	2.34E-05
^{88}Rb	M	Particulate								2.56E-15	2.56E-15
^{186}Re	M	Particulate								3.58E-10	3.58E-10
^{188}Re	M	Particulate								6.21E+01	6.21E+01
^{189}Re	M	Particulate								3.04E-11	3.04E-11
^{105}Rh	M	Particulate								2.17E-06	2.17E-06
^{106}Rh	B	Unspecified								1.09E-11	1.09E-11
^{219}Rn	B	Unspecified								3.80E-11	3.80E-11
^{220}Rn	B	Unspecified								1.70E-07	1.70E-07
^{103}Ru	M	Particulate						4.78E-08		3.12E-06	3.17E-06
^{106}Ru	M	Particulate								1.20E-06	1.20E-06
^{35}S	M	Particulate								1.21E-07	1.21E-07
^{120m}Sb	M	Particulate								1.50E-07	1.50E-07
^{122}Sb	M	Particulate								5.59E-07	5.59E-07
^{124}Sb	M	Particulate								4.94E-07	4.94E-07
^{125}Sb	M	Particulate								1.26E-07	1.26E-07
^{126}Sb	M	Particulate								1.19E-06	1.19E-06

Table 5.7 (continued)

Isotope	Inhalation form	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total minor Source	ORNL total
^{127}Sb	M	Particulate								4.14E-07	4.14E-07
^{44}Sc	M	Particulate								3.75E-22	3.75E-22
^{46}Sc	M	Particulate								3.46E-08	3.46E-08
^{47}Sc	M	Particulate								5.01E-08	5.01E-08
^{48}Sc	M	Particulate								2.93E-08	2.93E-08
^{75}Se	S	Particulate			3.75E-03					5.83E-09	3.75E-03
^{75}Se	F	Particulate								1.39E-11	1.39E-11
^{31}Si	M	Particulate								1.51E-23	1.51E-23
^{32}Si	M	Particulate								1.17E-13	1.17E-13
^{145}Sm	M	Particulate								2.91E-10	2.91E-10
^{151}Sm	M	Particulate								2.54E-12	2.54E-12
^{113}Sn	M	Particulate								1.60E-09	1.60E-09
^{117m}Sn	M	Particulate								1.44E-07	1.44E-07
^{119m}Sn	M	Particulate								4.58E-10	4.58E-10
^{121}Sn	M	Particulate								3.42E-10	3.42E-10
^{121m}Sn	M	Particulate								7.24E-12	7.24E-12
^{123}Sn	M	Particulate								5.94E-12	5.94E-12
^{125}Sn	M	Particulate								1.08E-06	1.08E-06
^{85}Sr	M	Particulate								5.17E-11	5.17E-11
^{89}Sr	M	Particulate	1.72E-07	1.01E-06				5.90E-06		3.14E-04	3.21E-04
^{89}Sr	S	Particulate			1.06E-05	3.43E-08				1.77E-05	2.83E-05
^{90}Sr	M	Particulate	1.72E-07	1.01E-06				5.90E-06		4.16E-04	4.23E-04
^{90}Sr	S	Particulate			1.06E-05	3.43E-08	5.97E-06			1.77E-05	3.43E-05
^{182}Ta	M	Particulate								2.49E-08	2.49E-08
^{183}Ta	M	Particulate								2.96E-06	2.96E-06
^{184}Ta	M	Particulate								4.08E-14	4.08E-14
^{160}Tb	M	Particulate								1.06E-10	1.06E-10

Table 5.7 (continued)

Isotope	Inhalation form	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total minor Source	ORNL total
^{161}Tb	M	Particulate								9.36E-22	9.36E-22
^{96}Tc	M	Particulate								1.84E-08	1.84E-08
^{99}Tc	M	Particulate								3.47E-06	3.47E-06
^{99}Tc	S	Particulate					6.88E-06				6.88E-06
^{121}Te	M	Particulate						1.17E-07		7.84E-08	1.95E-07
^{121m}Te	M	Particulate								7.64E-09	7.64E-09
^{123m}Te	M	Particulate								4.90E-09	4.90E-09
^{125m}Te	M	Particulate								2.12E-08	2.12E-08
^{127}Te	M	Particulate								3.60E-13	3.60E-13
^{127m}Te	M	Particulate								3.68E-13	3.68E-13
^{131m}Te	M	Particulate								2.74E-07	2.74E-07
^{132}Te	M	Particulate								1.24E-06	1.24E-06
^{227}Th	S	Particulate								4.03E-06	4.03E-06
^{228}Th	S	Particulate	8.72E-09	7.85E-09	1.34E-08	2.37E-09		7.97E-09		4.16E-07	4.56E-07
^{229}Th	S	Particulate								7.61E-09	7.61E-09
^{230}Th	S	Particulate	1.43E-09	4.80E-09				7.37E-09		7.06E-08	8.42E-08
^{230}Th	F	Particulate			1.39E-08	1.25E-09				2.94E-09	1.81E-08
^{232}Th	S	Particulate	1.72E-09	2.90E-09				4.52E-09		8.48E-06	8.49E-06
^{232}Th	F	Particulate			8.31E-09	9.52E-10				1.74E-09	1.10E-08
^{45}Ti	M	Particulate								2.06E-24	2.06E-24
^{202}Tl	M	Particulate								3.98E-12	3.98E-12
^{204}Tl	M	Particulate								3.46E-13	3.46E-13
^{208}Tl	B	Unspecified								3.17E-06	3.17E-06
^{170}Tm	M	Particulate								1.25E-09	1.25E-09
^{171}Tm	M	Particulate								5.66E-10	5.66E-10
^{232}U	M	Particulate								1.70E-07	1.70E-07
^{233}U	M	Particulate	5.40E-08					2.29E-08		1.78E-04	1.78E-04

Table 5.7 (continued)

Isotope	Inhalation form	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total minor Source	ORNL total
^{233}U	S	Particulate			1.07E-07	1.52E-08	1.53E-06			2.16E-06	3.81E-06
^{234}U	M	Particulate	5.40E-08	1.57E-07				2.29E-08		2.43E-02	2.43E-02
^{234}U	S	Particulate			1.07E-07	1.52E-08	1.53E-06			2.16E-06	3.81E-06
^{235}U	M	Particulate	1.54E-08	1.40E-08				1.54E-08		1.20E-03	1.20E-03
^{235}U	S	Particulate			6.08E-08	6.59E-09	1.36E-06			1.29E-07	1.56E-06
^{236}U	S	Particulate								2.37E-07	2.37E-07
^{236}U	M	Particulate								8.17E-05	8.17E-05
^{238}U	M	Particulate	7.11E-09	1.45E-08				1.35E-08		4.89E-03	4.89E-03
^{238}U	S	Particulate			5.69E-08	4.78E-09	1.83E-06			1.66E-07	2.06E-06
^{49}V	M	Particulate								2.08E-09	2.08E-09
^{181}W	M	Particulate								1.27E-11	1.27E-11
^{185}W	M	Particulate								6.06E-09	6.06E-09
^{187}W	M	Particulate								5.29E-03	5.29E-03
^{188}W	M	Particulate								6.18E-04	6.18E-04
^{127}Xe	B	Unspecified							8.11E+02	6.18E-11	8.11E+02
^{129m}Xe	B	Unspecified								1.31E-10	1.31E-10
^{131m}Xe	B	Unspecified						1.46E+02		8.52E-08	1.46E+02
^{133}Xe	B	Unspecified						5.13E+00		8.02E-09	5.13E+00
^{133m}Xe	B	Unspecified						2.13E+01		4.88E-16	2.13E+01
^{135}Xe	B	Unspecified						1.53E+01			1.53E+01
^{135m} Xe	B	Unspecified						6.73E+00			6.73E+00
^{137}Xe	B	Unspecified						3.16E+01			3.16E+01
^{138}Xe	B	Unspecified						4.31E+01			4.31E+01
^{87}Y	M	Particulate								1.18E-08	1.18E-08
^{88}Y	M	Particulate								6.23E-11	6.23E-11
^{88}Y	F	Particulate					1.35E-06				1.35E-06
^{90}Y	M	Particulate								1.36E-10	1.36E-10

Table 5.7 (continued)

Isotope	Inhalation form	Chemical Form	Stack								
			X-2026	X-3020	X-3039	X-7503	X-7880	X-7911	X-8915	Total minor Source	ORNL total
^{91}Y	M	Particulate								4.00E-11	4.00E-11
^{65}Zn	M	Particulate								1.96E-05	1.96E-05
^{69}Zn	M	Particulate								2.76E-09	2.76E-09
^{69m}Zn	M	Particulate								1.84E-09	1.84E-09
^{95}Zr	M	Particulate								1.00E-06	1.00E-06
^{97}Zr	M	Particulate								1.14E-07	1.14E-07
Totals			**3.99E-01**	**3.86E-01**	**5.87E+00**	**7.92E-01**	**3.96E-05**	**1.82E+03**	**4.28E+04**	**6.29E+01**	**4.47E+04**

[a]Emissions given in curies (Ci). 1 Ci = 3.7E+10 Bq
[b]The designations of F, M, and S refer 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.

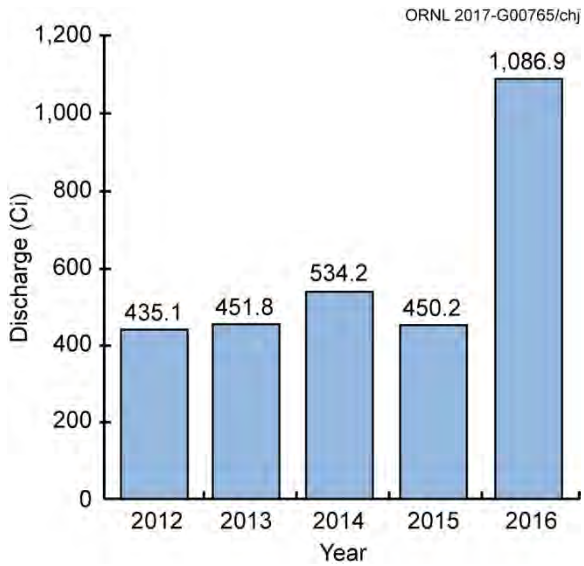

Fig. 5.13. Total curies of tritium discharged from Oak Ridge National Laboratory to the atmosphere, 2012–2016.

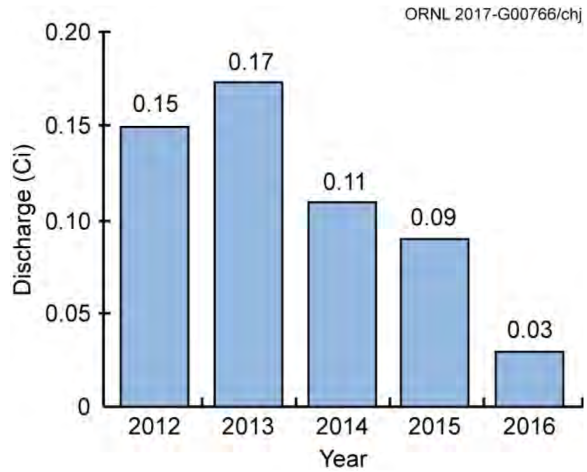

Fig. 5.14. Total curies of ^{131}I discharged from Oak Ridge National Laboratory to the atmosphere, 2012–2016.

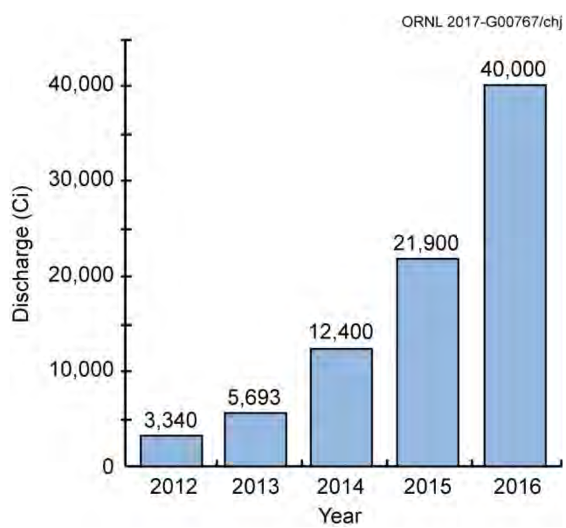

Fig. 5.15. Total curies of ^{11}C discharged from Oak Ridge National Laboratory to the atmosphere, 2012–2016.

5.4.4 Stratospheric Ozone Protection

As required by the CAA Title VI Amendments of 1990, actions have been implemented to comply with the prohibition against intentionally releasing ozone-depleting substances (ODSs) during maintenance activities performed on refrigeration equipment. In addition, service requirements for refrigeration systems (including motor vehicle air conditioners), technician certification requirements, and labeling requirements have been implemented. ORNL has implemented a plan to phase out the use of all Class I

ODSs. (Class I includes the fully halogenated chlorofluorocarbons, halons, and the ODSs that are the most threatening to the ozone layer.) All critical applications of Class I ODSs have been eliminated, replaced, or retrofitted with other materials. Work is progressing as funding becomes available for noncritical applications.

5.4.5 Ambient Air

During 2016 two of the three ORNL perimeter air monitoring stations were upgraded and incorporated into the ORR perimeter monitoring network, leaving Station 7 in the ORNL 7000 maintenance area as the only site-specific ambient air monitoring location. (Monitoring results from Stations 2 and 3, which have previously been included as part of ORNL site-monitoring activities, are now discussed in Chapter 6.) 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) were compared with derived concentration standards (DCSs) for air established by DOE as guidelines for controlling exposure to members of the public. During 2016 average radionuclide concentrations at Station 7 were less than 1% of the applicable DCS in all cases.

Table 5.8. Radionuclide concentrations (pCi/mL)[a] measured at Oak Ridge National Laboratory air monitoring Station 7, 2016

Parameter	Concentration
Alpha	7.33E-09
Be-7	2.29E-08
Beta	1.57E-08
K-40	−1.8E-09[b]
U-234	5.93E-12
U-235	1.04E-12
U-238	4.23E-12
U-TOT	1.12E-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.

5.4.5.1 Results

Station 7 sampling data (Table 5.8) are compared with DCSs for air established by DOE as guidelines for controlling exposure to members of the public. During 2016 average radionuclide concentrations at Station 7 were less than1% of the applicable DCS in all cases.

5.5 Oak Ridge National Laboratory Water Quality Program

NPDES permit TN 0002941, issued to DOE for the ORNL site, was renewed by the State of Tennessee in 2014 and includes requirements for discharging wastewaters from the two ORNL on-site wastewater treatment facilities 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, allows an annual assessment of all outfalls, and focuses on significant findings. The WQPP goals 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. 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. The WQPP has been reviewed and revised annually and submitted to TDEC for review and comment.

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 5.16 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 (Fig. 5.17) and then on PCBs 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.

At the end of each year, monitoring and investigation data collected under the ORNL WQPP are analyzed, interpreted, reported, and compared with past results in the WQPP annual report. 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.

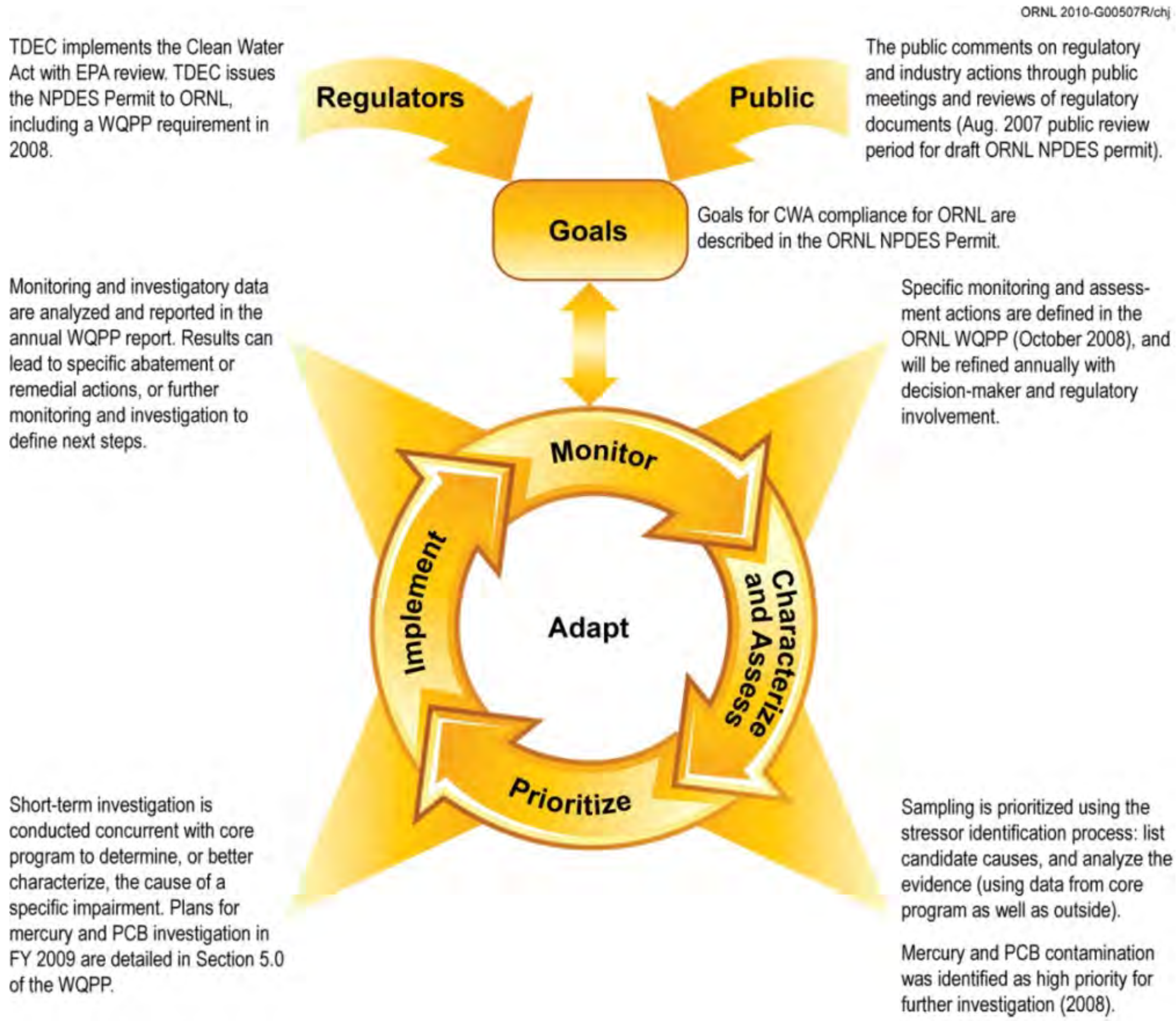

Fig. 5.16. Diagram of the adaptive management framework with step-wise planning specific to the Oak Ridge National Laboratory Water Quality Protection Plan (WQPP). *[Adapted from the US Environmental Protection Agency (EPA) stressor guidance document (EPA 2000). CWA = Clean Water Act, NPDES = National Pollutant Discharge Elimination System, ORNL = Oak Ridge National Laboratory, PCB = polychlorinated biphenyl, TDEC = Tennessee Department of Environment and Conservation.]*

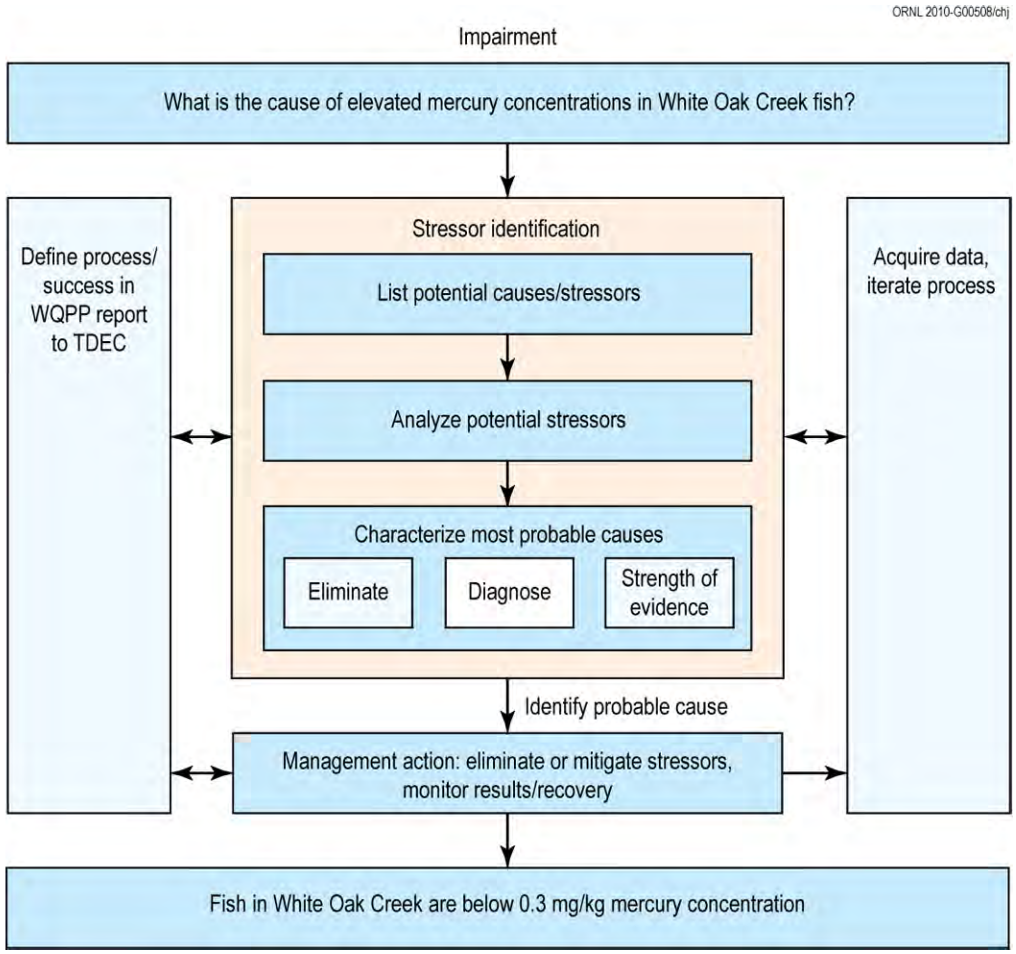

Fig. 5.17. Application of stressor identification guidance to address mercury impairment in the White Oak Creek watershed. *[Modified from Fig. 1-1 in the US Environmental Protection Agency stressor guidance document (EPA 2000). TDEC = Tennessee Department of Environment and Conservation, WQPP = water quality protection plan.]*

5.5.1 Treatment Facility Discharges

Two on-site wastewater treatment systems were operated at ORNL in 2016 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 2016. 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 is in design, including increased influent-handling capacity. The project is planned to be completed in 2017.

Table 5.9. National Pollutant Discharge Elimination System compliance at Oak Ridge National Laboratory, January through December 2016

Effluent parameters	Permit limits: Monthly average (lb/day)	Daily max. (lb/day)	Monthly average (mg/L)	Daily max. (mg/L)	Daily min. (mg/L)	Permit compliance: Number of noncompliances	Number of samples	Percentage of compliance[a]
X01 (ORNL Sewage Treatment Plant)								
LC_{50} for *Ceriodaphnia* (%)					100	0	4	100
LC_{50} for fathead minnows (%)					100	0	4	100
Ammonia, as N (summer)	6.26	9.39	2.5	3.75		0	26	100
Ammonia, as N (winter)	13.14	19.78	5.25	7.9		0	26	100
Carbonaceous biological oxygen demand	19.2	28.8	10	15		0	52	100
Dissolved oxygen					6	0	52	100
Escherichia coliform (col/100 mL)			941	126		0	52	100
Oil and grease				15		0	1	100
pH (standard units)				9	6	0	52	100
Total suspended solids	57.5	86.3	30	45		1	51[b]	98
X12 (Process Waste Treatment Complex)								
LC_{50} for *Ceriodaphnia* (%)					100	0	4	100
LC_{50} for fathead minnows (%)					100	0	4	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	52	100
Temperature (°C)				30.5		0	52	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] The suspended solids sample taken February 16, 2016, was mistakenly disposed of by the lab before the analysis was performed. By the time of disposal, the weekly period in which a replacement sample could be collected had passed.

Abbreviated terms

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 of four effluent samples each from the ORNL STP and PWTC collected at 6 h intervals over a 24 h period, using both test species. In 2016, 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

Chlorine is added to drinking water as a disinfectant prior to consumption. Chlorine and bromine are added to cooling system water to prevent bacterial growth in the system. 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. When the permit action level of 1.2 g/day TRO is exceeded at an outfall, the staff investigate and implement treatment and reduction measures. NPDES permit outfalls that contain TRO are monitored and are dechlorinated until chlorine sources are removed or until the data show that the source is gone. The most frequent monitoring, which is performed to check the effectiveness of the dechlorination systems, takes place twice a month at outfalls where dechlorination of cooling tower blowdown or large cooling water discharges occur. TRO is also monitored at instream points twice per month to verify that releases are not creating adverse conditions for fish and other aquatic life.

In 2016, TRO measurements were required at 27 outfalls on a semiannual, quarterly, monthly, or semimonthly basis if flow was present. A total of 245 TRO measurements were made at the 27 outfalls during 2016. Table 5.10 summarizes those that exceeded the TRO permit action level. The action level was exceeded twice in 2015 at Outfall 267 because a carbon filter had been valved off, but 2016 semimonthly monitoring showed no recurring problems.

During 2016 TRO from outfall 231 exceeded the permit action level of 1.2 g/day in one monitoring event. The outfall receives cooling tower blowdown from Building 5800 that is dechlorinated inside the building using a sodium sulfite tablet feeder; the cause of this exceedance is not known.

Outfall 082 receives discharge from an old hose-fed once-through air-conditioning unit in Building 7509, which is dechlorinated using a tablet feeder. Operational problems such as old and stuck tablets accounted for its ineffectiveness. Outfall 082 was removed from the NPDES permit when the permit was reissued in 2008 because the area is associated with CERCLA activities. However, it continues to be monitored because there is a preexisting source of TRO.

Table 5.10. Outfalls exceeding total residual oxidant NPDES permit action level in 2016

Sample date	Outfall	TRO[a] concentration (mg/L)	Flow (gpm)	Load (g/day)	Receiving stream	Downstream integration point	Instream TRO point
9/23/2016	231	1.68	30	274.7	White Oak Creek	WCK 4.4	X25
5/16/2016	082[b]	0.7	1.5	5.7	Melton Branch	MEK 0.6	X27
7/11/2016	082[b]	0.82	12	53.6	Melton Branch	MEK 0.6	X27
8/15/2016	082[b]	1.1	5	30	Melton Branch	MEK 0.6	X27

[a] The NPDES action level is 1.2 g/day.
[b] Outfall 082 was removed from ORNL's NPDES Permit when it was reissued in 2008 and was not included in the 2014 NPDES Permit or the 2015 modification because all effluents discharged were associated with CERCLA activities.

Acronyms

CERCLA= Comprehensive Environmental Response Compensation & Liability Act
MEK = Melton Valley Creek kilometer
NPDES = National Pollutant Discharge Elimination System
ORNL = Oak Ridge National Laboratory
TRO = total residual oxidant
WCK = White Oak Creek kilometer

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 2016 at 2 treatment facility outfalls, 3 instream monitoring locations, and 20 category outfalls (outfalls that are categorized into groups with similar effluent characteristics for the purposes of setting monitoring and reporting requirements in the site NPDES permit). Dry-weather discharges from category outfalls are primarily cooling water, groundwater, and condensate. Low levels of radioactivity can be discharged from category outfalls in areas where groundwater contamination exists and where contaminated groundwater enters category outfall collection systems from building and facility sumps, building footer drains, and direct infiltration. In 2016, dry-weather grab samples were collected at 16 of the 20 category outfalls targeted for sampling. Four category outfalls (205, 241, 265, and 368) were not sampled because there was no discharge present during sampling attempts.

The two ORNL treatment facility outfalls that were monitored for radioactivity in 2016 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) (Fig. 5.18). 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. 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, 204, 207, 302, 304, X01, and X12 and at instream sampling locations on WOC (X14) and at WOD (X15) (Fig. 5.19).

Table 5.11. Radiological monitoring conducted under the Oak Ridge National Laboratory Water Quality Protection Plan, 2016

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]	X[a]		
Outfall 203	Annual	X	X			X				
Outfall 204	Semiannual	X	X			X				
Outfall 205 [b]	Annual									
Outfall 207	Quarterly	X	X[a]			X[a]	X[a]			
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	Annual	X								
Outfall 302	Monthly	X	X	X		X	X[a]	X[a]	X[a]	X[a]
Outfall 304	Monthly	X	X	X		X	X[a]	X[a]	X[a]	X[a]
Outfall 365	Semiannual	X								
Outfall 368 [b]	Annual									
Outfall 383	Annual	X		X						
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 criteria (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

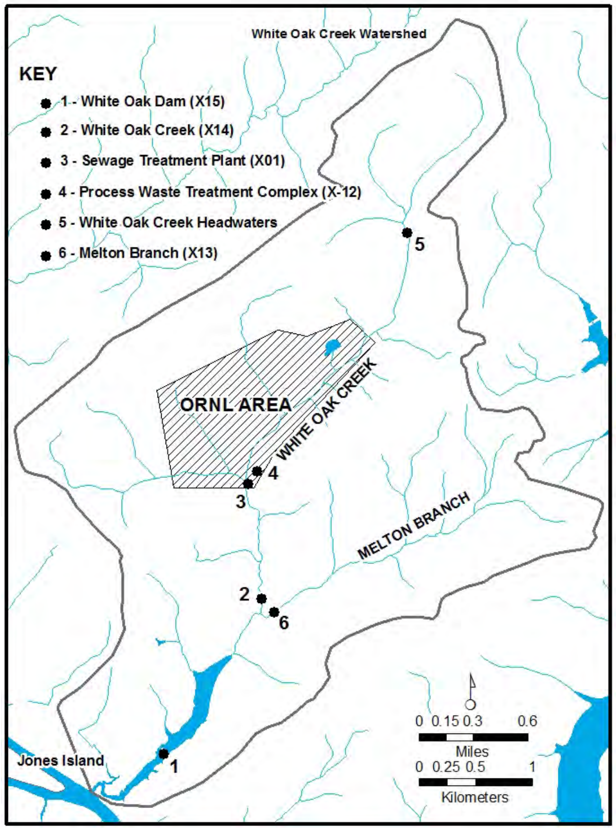

Fig. 5.18. Selected surface water, National Pollutant Discharge Elimination System, and reference sampling locations at Oak Ridge National Laboratory.

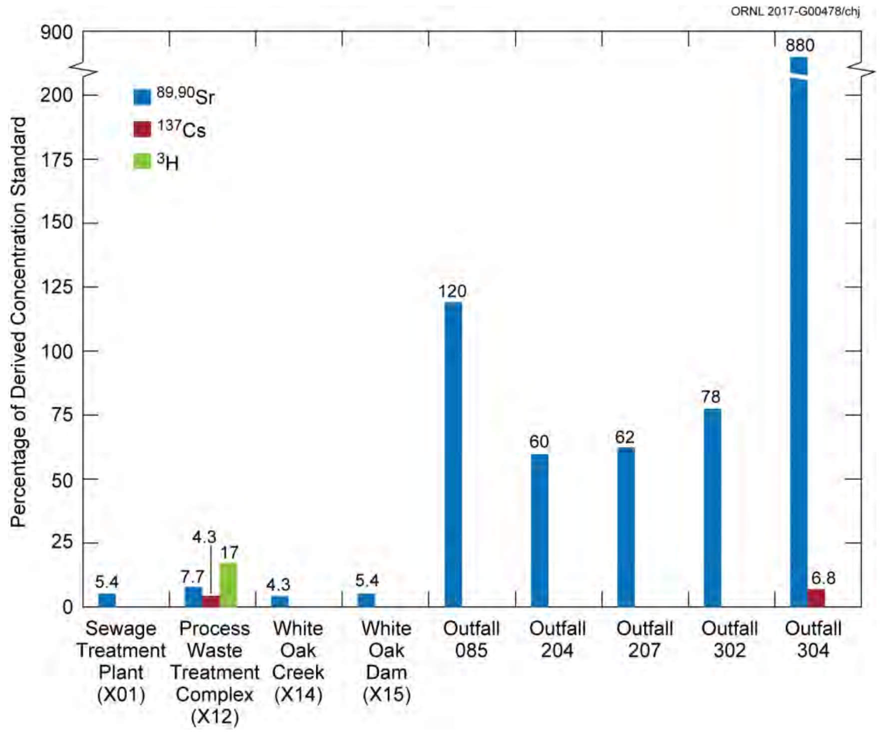

Fig. 5.19. Outfalls and instream locations at Oak Ridge National Laboratory with average radionuclide concentrations greater than 4% of the relevant derived concentration standards in 2016.

In 2016, two outfalls had an annual mean radioactivity concentration greater than 100% of a DCS. Outfalls 085 and 304 had average total radioactive strontium ($^{89,90}Sr$) concentrations 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 concentrations of $^{89,90}Sr$ were 120% and 880% of the DCS at outfalls 085 and 304, respectively. Consequently, concentrations of radioactivity in discharges from both outfalls were also greater than DCS levels on a sum-of-fractions basis (i.e., the summation of DCS percentages of multiple radiological parameters); the sums of the fractions were 124% and 896%, respectively.

Concentrations of radioactivity at outfall 085 have been elevated since early 2015, when a water leak occurred in Building 7830A. The foundation drain for that building is connected to Outfall 085. The leak resulted from a ruptured pipe in the building's fire suppression system that occurred when the pipe froze in the early morning hours of February 23, 2015. It is believed that leaked water mobilized existing underground contamination to a location where it could enter the building foundation drain. Concentrations have been declining since April 2015, although the rate of decline slowed in the latter part of 2016 and concentrations have not yet returned to levels that existed prior to 2015.

Levels of radioactivity in discharges from Outfall 304 have been elevated since 2014 because of two unrelated infrastructure issues. In 2014, a pump failed in a groundwater suppression sump at the EM 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 have remained above DCS levels in 2016. 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 Figs. 5.20 through 5.24. Because discharges of radioactivity are somewhat correlated to stream flow, annual flow volumes measured at the WOD monitoring station are given in Fig. 5.25. Discharges of radioactivity at WOD in 2016 are 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 2016 also included monitoring during storm runoff conditions. Three storm water outfalls were monitored. Storm water samples were analyzed for gross alpha, gross beta, Sr-89/90, 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 2016 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 2016, none of the outfalls had a radionuclide concentration in storm water that was greater than 4% of a DCS level.

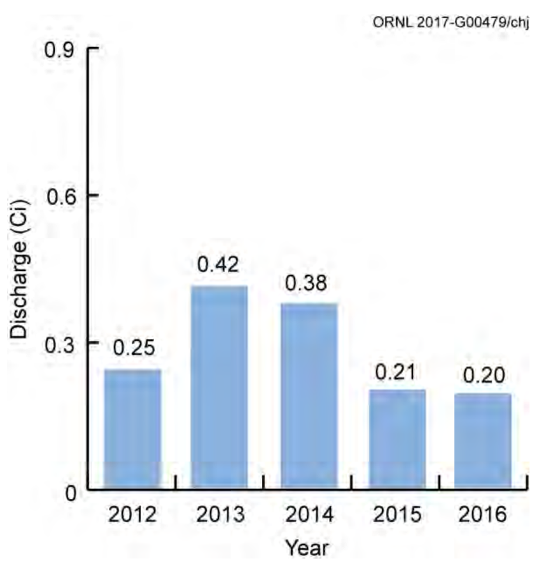

Fig. 5.20. Cesium-137 discharges at White Oak Dam, 2012–2016.

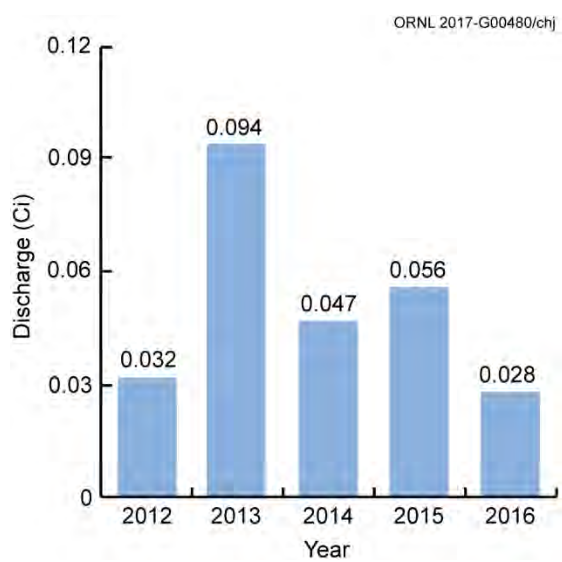

Fig. 5.21. Gross alpha discharges at White Oak Dam, 2012–2016.

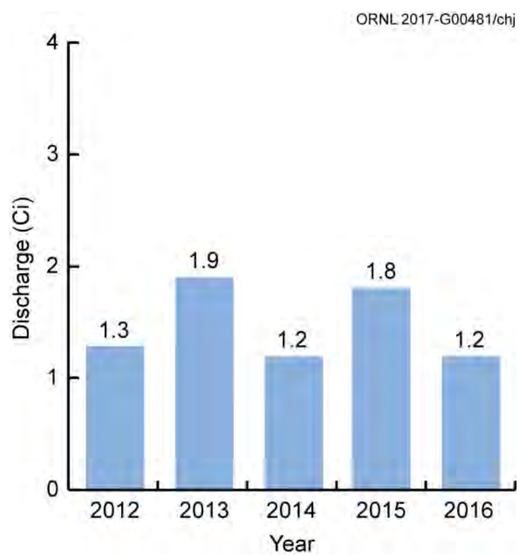

Fig. 5.22. Gross beta discharges at White Oak Dam, 2012–2016.

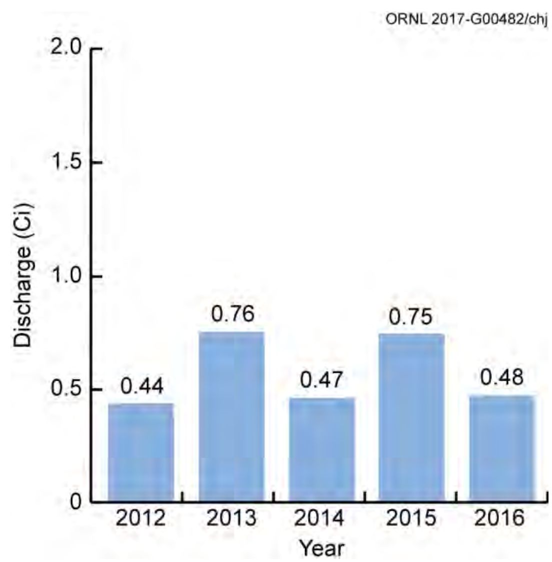

Fig. 5.23. Total radioactive strontium discharges at White Oak Dam, 2012–2016.

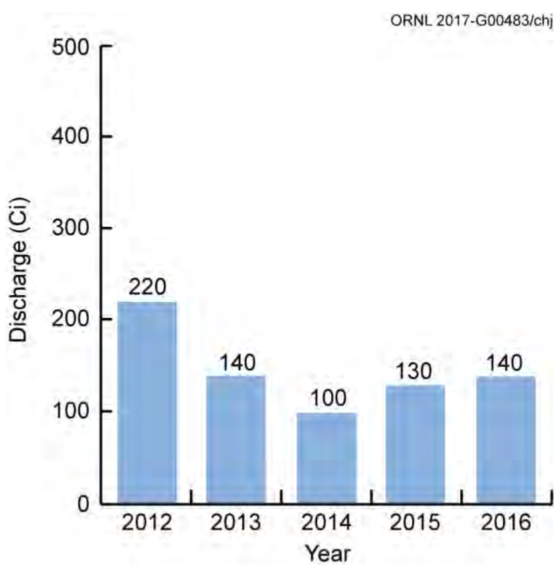

Fig. 5.24. Tritium discharges at White Oak Dam, 2012–2016.

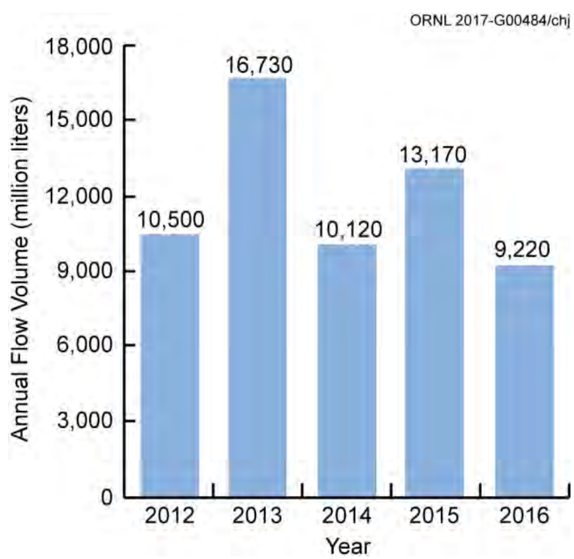

Fig. 5.25. Annual flow volume at White Oak Dam, 2012–2016.

5.5.4 Mercury in the White Oak Creek Watershed

Legacy mercury environmental contamination exists at ORNL, largely as a result of spills and releases that occurred in the 1950s during pilot-scale isotope separation work in Buildings 3503, 3592, 4501, and 4505. As a result, the mercury that is present in piping and soil can also be found in groundwater and storm water runoff in and around the four facilities. Buildings 4501 and 4505 are located adjacent to Fifth Creek, but most of the storm water from that area is routed to Outfall 211. Buildings 3592 and 3503 were

removed under the CERCLA remedial process in 2011 and 2012; their footprints are in the Outfall 207 storm water drainage area.

Process wastewater drains and building sumps from Buildings 4501 and 4505 are routed via underground collection system piping to the ORNL PWTC for treatment to remove constituents, including mercury, before discharge to WOC. Between 2007 and 2011, three sumps that receive foundation groundwater from around 4501/4505 and the area between 4501 and 4500N were redirected to PWTC treatment for mercury removal, and in 2009 a mercury pretreatment system was installed on the main sump in Building 4501. The PWTC treatment units include granular activated carbon filter columns, one of which was upgraded in 2014 to a sulfur-impregnated carbon that is optimized for mercury removal. These actions have significantly diminished the release of legacy mercury (Fig. 5.26) by redirecting foundation water away from the storm drain system and by improving treatment plant removal capabilities.

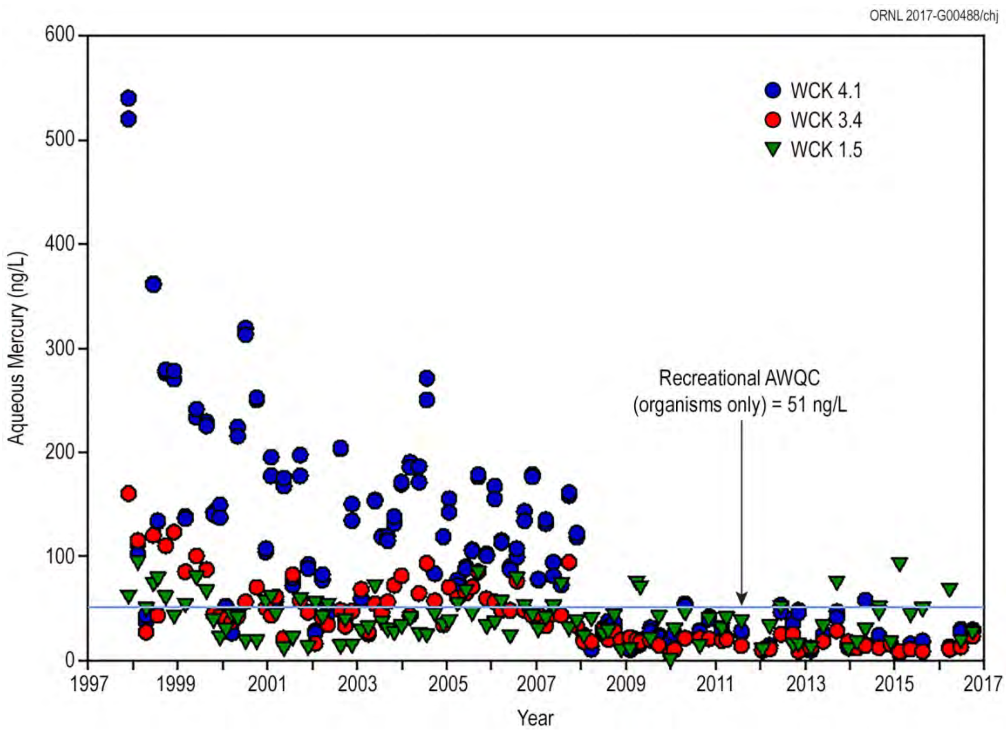

Fig. 5.26. Total aqueous mercury concentrations at sites in White Oak Creek downstream from Oak Ridge National Laboratory, 1998–2016. *(AWQC = ambient water quality criterion; WCK = White Oak Creek kilometer.)*

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 2016. 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 (see Fig. 5.27) upstream from ORNL [White Oak Creek kilometer (WCK) 6.8] was less than 5 ng/L in 2016. Long-term trends in waterborne mercury in the WOC system downstream of ORNL are shown in Fig. 5.26. Waterborne mercury downstream of ORNL declined abruptly in 2008 and remained low through 2016 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

22.76 ± 6.7 ng/L in 2016 compared with 108 ± 33 ng/L in 2007. The decrease was also apparent but less pronounced at WCK 3.4, with mercury averaging 15.46 ± 6.6 ng/L in 2016 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 of 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 30.66 ± 27.7 ng/L in 2016, higher than concentrations at other sites.

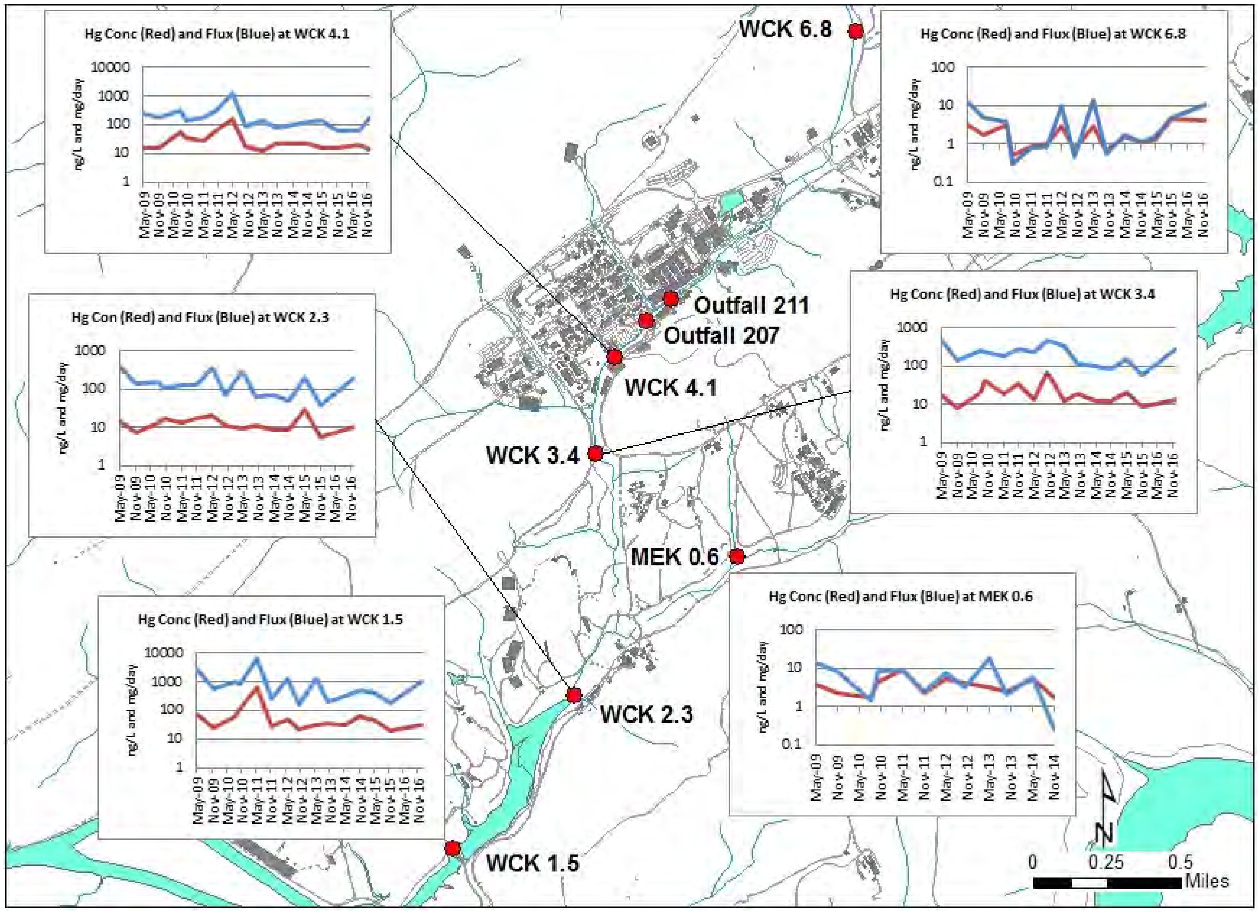

Fig. 5.27. Total mercury concentration and flux at selected Oak Ridge National Laboratory instream locations, 2009 through 2016.

Water Quality Protection Plan Mercury Investigation

The mercury-investigation component of the WQPP includes outfalls that are key mercury contributors to help delineate mercury sources and prioritize future abatement actions. In addition to the bimonthly instream samples taken in 2016, a dry-weather sample was taken at the five WOC instream points shown in Fig. 5.27; no samples were collected in May. The additional monitoring at Melton Branch kilometer (MEK) 0.6 was discontinued in 2015 due to the consistently low mercury levels found there from 2009 to 2014. Mercury concentration and flow measurements were used to calculate flux (the amount of a substance detected per unit time in flowing water). Results indicated that Tennessee mercury water-quality criteria (WQCs) were met at these instream locations. 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).

Monitoring in 2016 included dry-weather monitoring of Outfalls 211, 207, 304, and 302; wet-weather monitoring of Outfalls 211 and 207; and a study that targeted the WOC reach below Fifth Creek starting above Outfall 207 downstream to the Third Street Bridge. Data collected in 2015 had shown mercury flux increases occurring in the lower (downstream) ends of both Fifth Creek and this section of WOC above the Third Street Bridge that were not completely explained by flux data from individual outfalls. The 2016 study was coordinated to occur while there was no discharge from the PWTC at Outfall X12. The 2016 dye-calibrated flow study implies that the instream concentration and flux varied more upstream of Outfall 207 than below; mercury concentrations at WCK 4.1 and the Third Street Bridge remaining relatively constant (below 20 ng/L).

Dry- and wet-weather sampling of Outfalls 211 and 207 during 2016 confirm these outfalls as significant sources of mercury. Dry-weather flows from Outfall 207 may contain elevated mercury (35 and 856 ng/L were measured), but the flows are very small (estimated at 0.1 gpm); the larger concentration generated a flux of only 0.467 mg/day. A storm concentration of 272 ng/L was estimated at a flow rate of 40 gpm in November 2016, yielding a flux of 59 mg/day.

In contrast, the 2016 measurements of Outfall 211 storm flows show the major importance of storm flows from that outfall. A February storm flow of 180 gpm had a concentration of 9,670 ng/L total mercury, delivering a total flux of 9,490 mg/day, and in July a 175 gpm flow had a concentration of 2,150 ng/L, delivering a flux of 2,050 mg/day to WOC. Outfall 211 remains the major contributor of mercury to WOC.

5.5.5 Storm Water Surveillances and Construction Activities

In 2016, two construction sites were inspected to evaluate the overall effectiveness of the best management practices in use. Sites are considered significant if they occupy an area of nearly 1 acre or more and/or because of the requirements of a Tennessee construction general permit. In general, while some short-term impacts to receiving streams, such as increased sedimentation in runoff, were noted, no long-term adverse impacts were observed.

Land use within drainage areas is typical of office/industrial settings with surface features that include laboratories, support facilities, paved areas, and grassy lawns. Outdoor material storage 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); other 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 include metal items (sheeting, pipes, and parts); equipment awaiting use, disposal, or repair; construction material; and deicer product.

Some construction activities are performed on third-party-funded construction projects on the ORR under agreements with federal agencies other than DOE and with local and state agencies. There are mechanisms in place for ensuring effective storm water controls at the third-party sites, one of which includes staff from UT-Battelle acting as points of contact for communication interface on environmental conditions, 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 (Fig. 5.28). Mean fillet concentrations increased slightly from 0.16 µg/g in 2015 to 0.21 µg/g in 2016 at WCK 3.9 and from 0.21 µg/g in 2015 to 0.24 µg/g in 2016 at WCK 2.9 (Fig. 5.28). 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 2016. Concentrations increased to 0.46 µg/g from 0.36 µg/g in 2015. Mercury concentrations in bluegill collected from WCK 1.5 showed the same increase as largemouth bass but remained below the recommended guideline. Mean PCB concentrations in redbreast sunfish at WCK 3.9 and WCK 2.9 (0.22 and 0.20 µg/g, respectively) were comparable to values recorded in recent years and are continuing their decreasing trend. Mean PCB concentrations in largemouth bass from WCK 1.5 have been increasing since 2012, with concentrations remaining above the TDEC fish advisory limit of 1 µg/g in 2016 (Fig. 5.29).

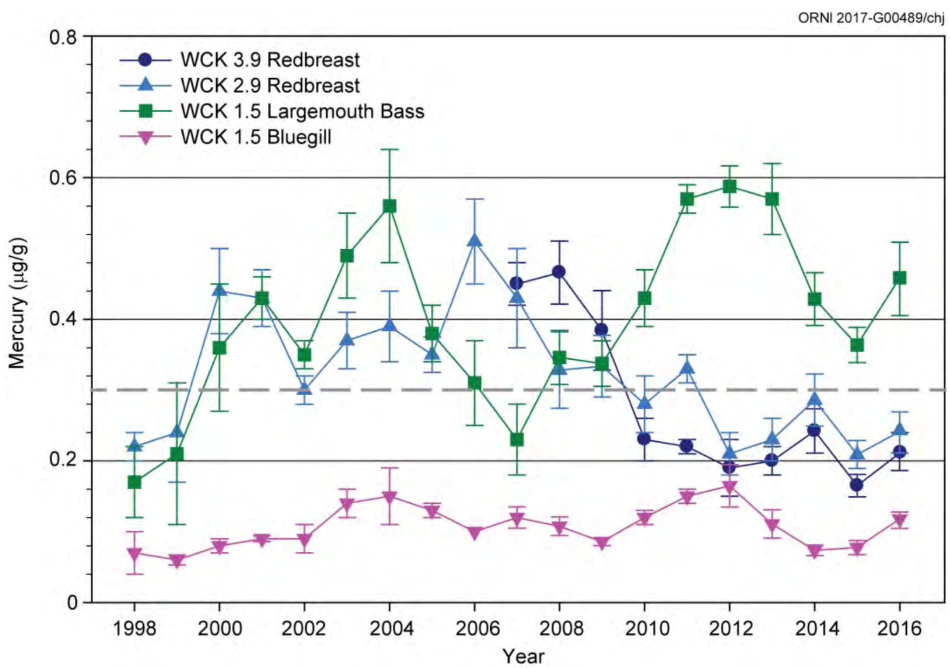

Fig. 5.28. Mean concentrations of mercury (± standard error, N = 6) in muscle tissue of sunfish and bass from White Oak Creek (White Oak Creek kilometers [WCKs] 3.9 and 2.9) and White Oak Lake (WCK 1.5), 1998–2016. *[Dashed grey line indicates the US Environmental Protection Agency ambient water quality criterion for mercury (0.3 µg/g in fish tissue).]*

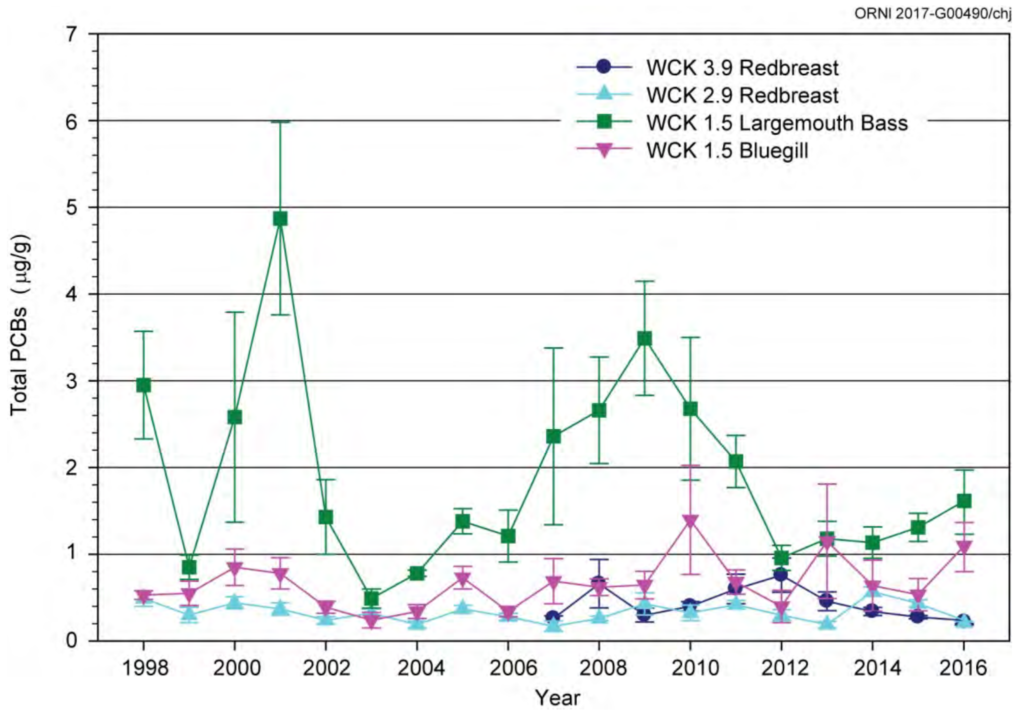

Fig. 5.29. Mean total polychlorinated biphenyl (PCB) concentrations (± standard error, N = 6) in fish fillets collected from the White Oak Creek watershed, 1998–2016. *(WCK = White Oak Creek kilometer.)*

5.5.6.2 Benthic Macroinvertebrate Communities

Monitoring of benthic macroinvertebrate communities in WOC, First Creek, and Fifth Creek continued in 2016. Additionally, monitoring of the macroinvertebrate community in lower Melton Branch (Melton Branch kilometer [MEK] 0.6) continued under the DOE Office of Environmental Management (EM) 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, 2016 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 2017 annual report. The 2015 results, which were not available in time for inclusion in the 2015 annual site environmental report (DOE 2016) are included in this report (see Fig. 5.30).

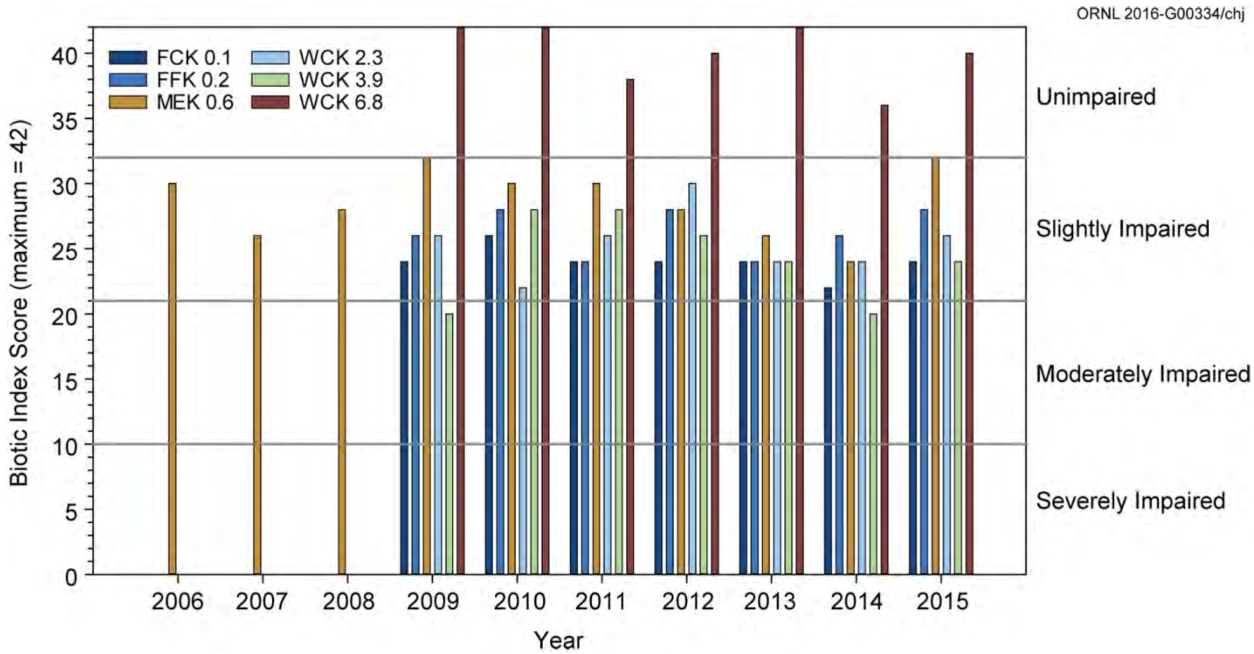

Fig. 5.30. Temporal trends in Tennessee Department of Environment and Conservation Biotic Index Scores for White Oak Creek watershed, August 2006–August 2015. *Results for 2016 were not available at the time of publication. Horizontal lines show the lower thresholds for biotic condition ratings for index scores; respective narrative ratings for each threshold are shown at right of graph. (FCK = First Creek kilometer, FFK = Fifth Creek kilometer, MEK = Melton Branch kilometer, and WCK = White Oak Creek kilometer.)*

The 2015 results indicated significant recovery in these communities since 1987, but community characteristics indicated that ecological impairment remains (Figs. 5.31–5.33). 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 First Creek kilometer (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 3 consecutive years, and in 2014 EPT taxa richness was the lowest it had been since the early 1990s. These results suggest a change may have occurred in conditions in lower First Creek. Total taxa richness remained low in 2015; however, a slight increase in EPT taxa richness was observed, although values remain low relative to the mid-1990s. 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.

Macroinvertebrate community metrics for lower Melton Branch (MEK 0.6, Fig. 5.34) suggested that in 2015 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.

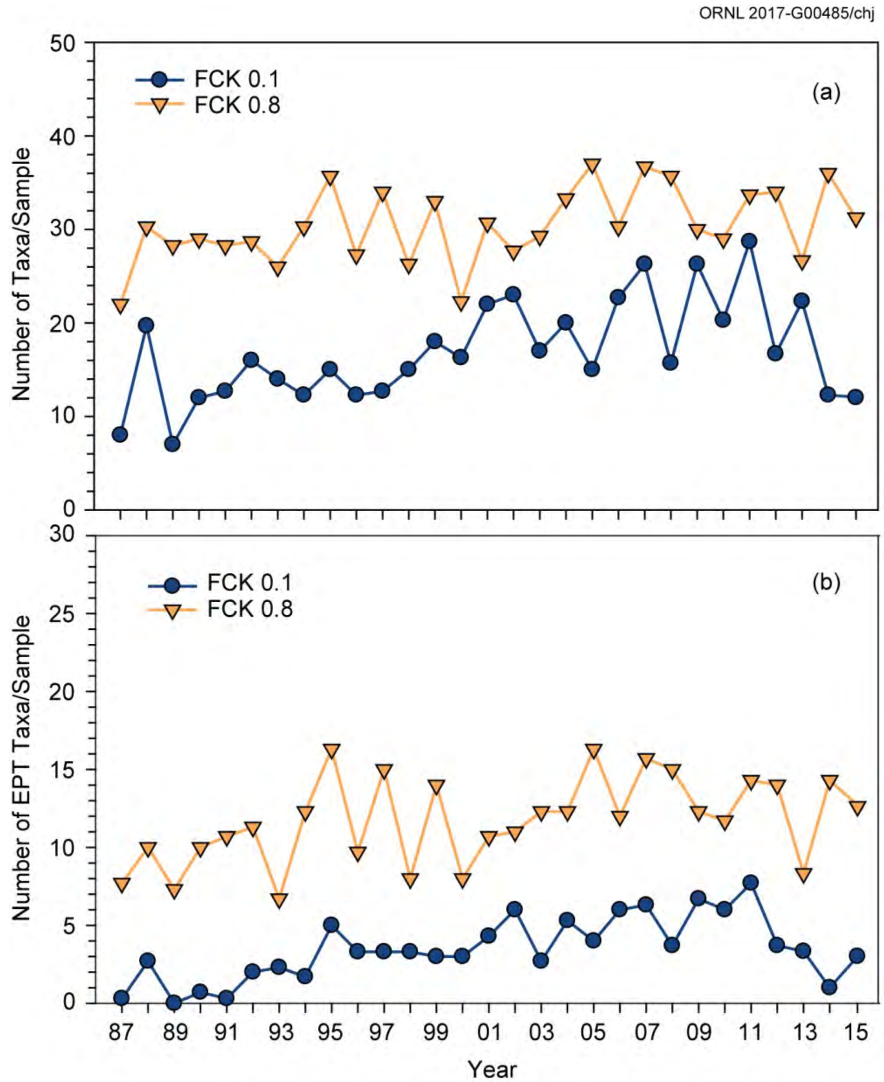

Fig. 5.31. Benthic macroinvertebrate communities in First Creek: (a) total taxonomic richness (mean number of all taxa/sample) and (b) taxonomic richness of the pollution-intolerant taxa, Ephemeroptera, Plecoptera, and Trichoptera (EPT); mean number of EPT taxa/sample, April sampling periods, 1987−2015. *Results for 2016 were not available at the time of publication. (FCK = First Creek kilometer; FCK 0.8 = reference site.)*

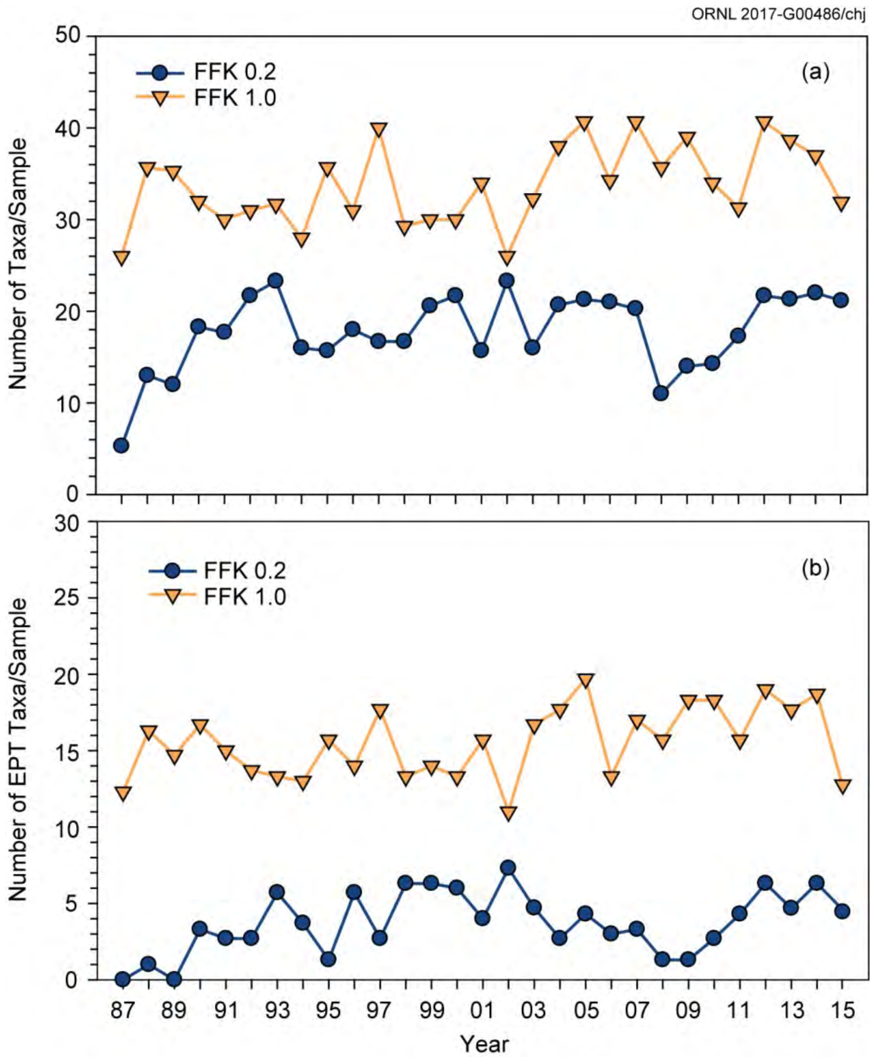

Fig. 5.32. Benthic macroinvertebrate communities in Fifth Creek: (a) total taxonomic richness (mean number of all taxa/sample) and (b) taxonomic richness of the pollution-intolerant taxa, Ephemeroptera, Plecoptera, and Trichoptera (EPT); mean number of EPT taxa/sample), April sampling periods, 1987−2015. *Results for 2016 were not available at the time of publication. (FFK = Fifth Creek kilometer; FFK 1. 0 = reference site.)*

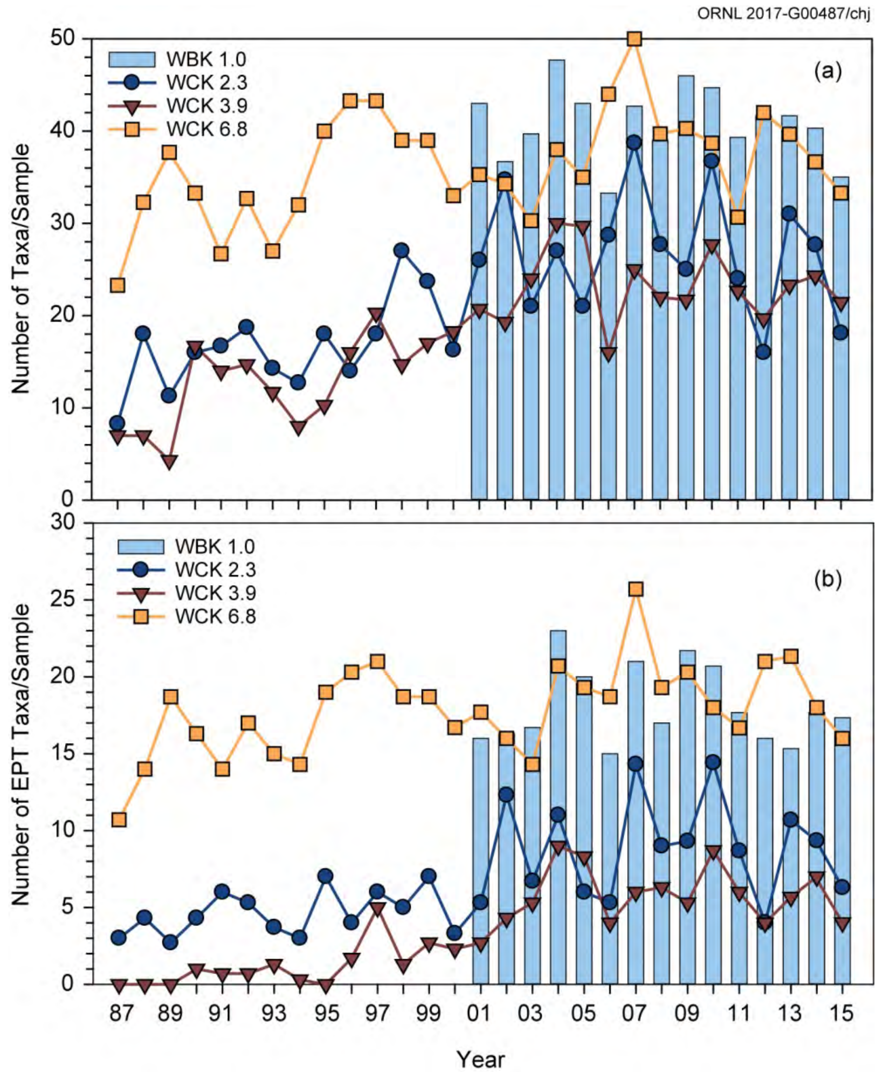

Fig. 5.33. Benthic macroinvertebrate communities in White Oak Creek: (a) total taxonomic richness (mean number of all taxa/ sample) and (b) taxonomic richness of the pollution-intolerant taxa, Ephemeroptera, Plecoptera, and Trichoptera (EPT); mean number of EPT taxa/sample), April sampling periods, 1987−2015. *Results for 2016 were not available at the time of publication. (WCK = White Oak Creek kilometer and WBK = Walker Branch kilometer; WBK 1.0 = reference site.)*

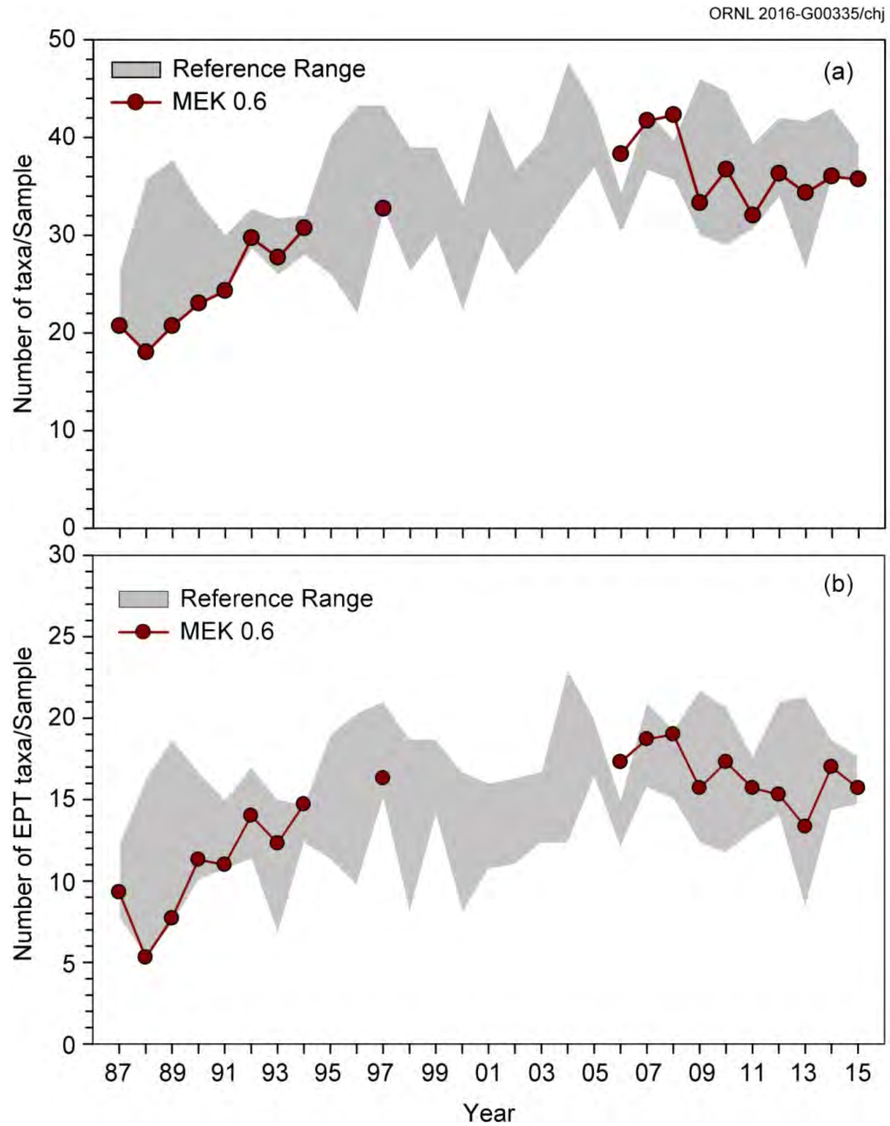

Fig. 5.34. Benthic macroinvertebrate communities in lower Melton Branch: (a) total taxonomic richness (mean number of all taxa/sample) and (b) taxonomic richness of the pollution-intolerant taxa, Ephemeroptera, Plecoptera, and Trichoptera (EPT); mean number of EPT taxa/sample, April sampling periods, 1987−2015. *Results for 2016 were not available at the time of publication. (MEK = Melton Branch kilometer; reference range = minimum and maximum values for Oak Ridge National Laboratory Biological Monitoring and Abatement Program reference sites on upper Melton Branch [1987–1997], First Creek and Fifth Creek [1987–2014], Walker Branch [2001–2014], and White Oak Creek [1987–2000, 2007–2014], and other Oak Ridge Reservation reference sites.)*

5.5.6.3 Fish Communities

Monitoring fish communities in WOC and major tributaries continued in 2016. 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 2016 compared with communities in reference streams. Sites closest to outfalls within the ORNL campus had lower species richness (number of species) (Fig. 5.35), fewer pollution-sensitive species, more pollution-tolerant species, and elevated density (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 explain some of the variability seen at these sites as well as recent fish introduction work. Overall, the fish communities in tributary sites adjacent to and downstream of ORNL outfalls also remained negatively affected by ORNL effluent in 2016 relative to reference streams and upstream sites.

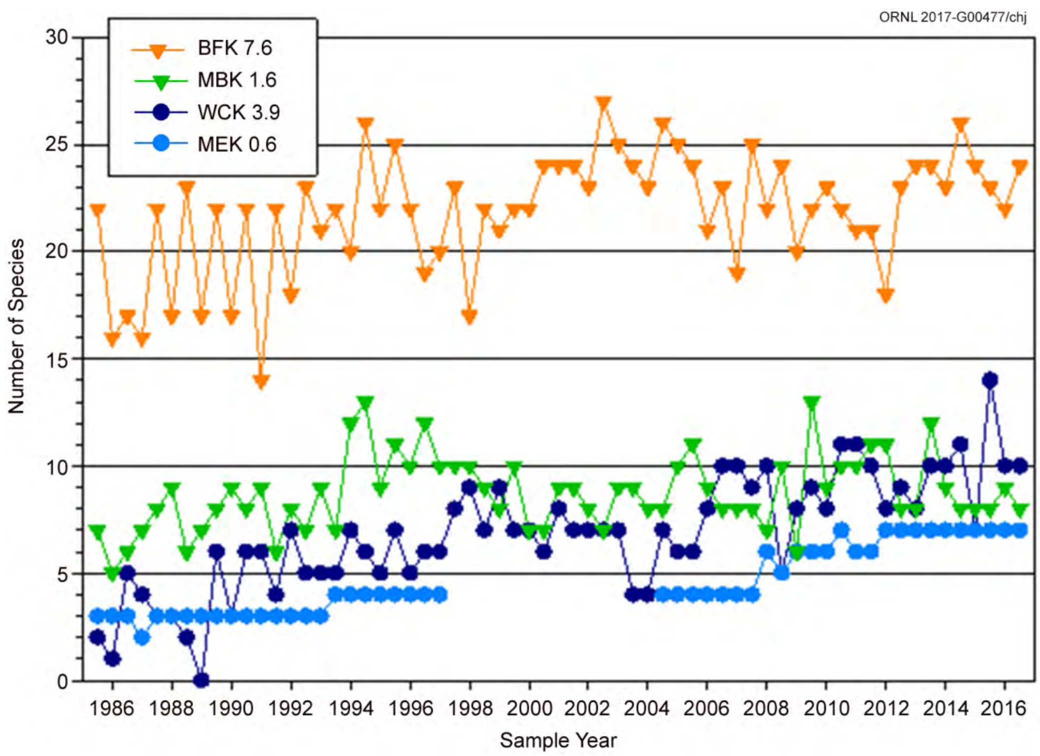

Fig. 5.35. Fish species richness (number of species) in upper White Oak Creek and lower Melton Branch compared with two reference streams (Brushy Fork and Mill Branch) 1985–2016 *(BFK = Brushy Fork kilometer; MBK = Mill Branch kilometer; MEK = Melton Branch kilometer; and WCK = White Oak Creek kilometer.)*

A project to introduce fish species that were not found in the WOC watershed but that exist in similar systems on the 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.

5.5.7 Polychlorinated Biphenyls in the White Oak Creek Watershed

The initial objective of the source identification task in the WOC watershed was to identify the stream reaches, outfalls, or sediment areas that are contributing to elevated PCB levels in the watershed. 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 5.29), 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.

While past monitoring efforts were instrumental in establishing a baseline for PCBs, the focus has historically been on relating PCB levels in fish to safe levels for consumption. These studies were not designed to identify specific stream reaches or sources contributing to PCB bioaccumulation.

In 2016, 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 3.4. SPMDs were also deployed on First Creek at outfalls 249, 250, 341, 341-1 (sampling port), and the piping network of outfall 250, which contributes to First Creek (Fig. 5.36). SPMDs deployed at manholes 250-19 and 341-1 were partially chewed/torn by an unidentified source, but some PCB data were recovered. The results are summarized in Table 5.12.

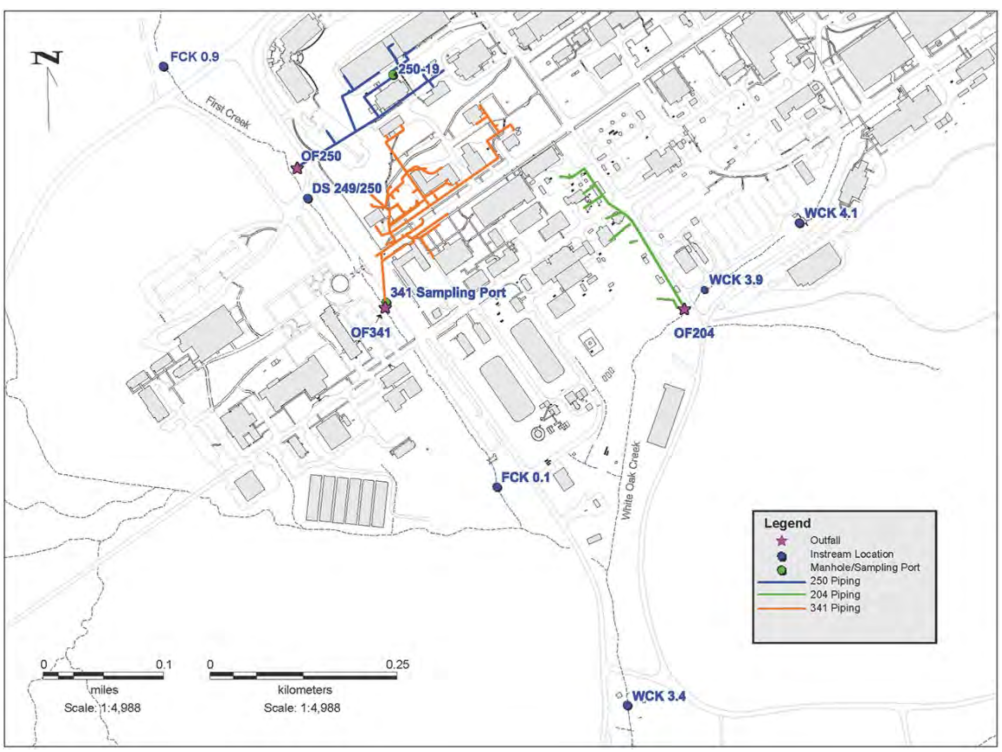

Fig. 5.36. Locations of monitoring points for First Creek source investigation.
(FCK = First Creek kilometer, WCK = White Oak Creek kilometer, OF = outfall.)

Table 5.12. First Creek and WOC PCB source assessment, September 2016 (Total PCBs [parts per billion])

Sample location	Location Type	SPMD (ppb)
OF 250	Outfall	1,000
250-19	Inlet/Outlet	12,077
FCK0.9	Instream	438
DS 249/250	Instream	4,804
OF 341 manhole/sampling port	Manhole/sampling port for outfall	400
OF 341	Outfall	767
FCK0.1	Instream	8,614
OF 204	Outfall	439
WCK3.9	Instream	863
WCK4.1	Instream	1,064
WCK3.4	Instream	2,405

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 2016 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 5.12) 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. In WOC, sample location 3.4, downstream of confluence with First Creek, contained the highest PCB concentration (Table 5.12). 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.

5.5.7.1 Biota sampling in First Creek

Over the past 8 years, the major sources of PCBs to the WOC watershed have been traced to two storm drains leading to First Creek (Outfalls 250 and 341). In 2016, fish and invertebrates were sampled at three sites that had not previously been monitored in First Creek to establish baseline PCB concentrations for biota in this stream. The sites included First Creek kilometer (FCK) 0.9 (above outfall 250), FCK 0.5 (below outfalls 250 and 341), and FCK 0.1 (just above the confluence with Northwest Tributary). Total PCB concentrations in both whole body black nose dace (*Rhinichthys obtusus*) and crayfish (*Cambarus sp.*) increased at each downstream location. At FCK 0.9, concentrations in fish were low, and concentrations in crayfish were below detection limits. At FCK 0.1, mean PCB concentrations in fish were higher (6.7 μg/g) than in crayfish (0.77 μg/g). Future monitoring will tell whether actions taken to clean out storm drains affect PCB bioaccumulation within the creek.

5.5.8 Oil Pollution Prevention

CWA Section 311 regulates the discharge of oils or petroleum products to waters of the United States and requires the development and implementation of spill prevention, control, and countermeasures (SPCC) plans to minimize the potential for oil discharges. These requirements are provided in 40 CFR 112, *Oil*

Pollution Prevention. Each ORR facility implements a site-specific SPCC plan. 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 an SPCC plan. There were no regulatory or permitting actions related to oil pollution prevention at ORNL or NTRC in 2016. An oil-handler training program exists to comply with training requirements in 40 CFR 112.

5.5.9 Surface Water Surveillance Monitoring

The ORNL surface water monitoring program is conducted in conjunction with the ORR surface water monitoring activities discussed in Section 6.4 to enable assessing the impacts of ongoing DOE operations on the quality of local surface water. The sampling locations (Fig. 5.37) 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 5.13. 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 and WCK 1.0 are classified by the State of Tennessee for freshwater fish and aquatic life. Tennessee WQCs associated with these classifications are used as references where applicable. 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.

There were no radionuclides reported above 4% of DCS at the Fifth Creek location (FFK 0.1). Also, no strontium-89/90 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 (immediately before WOC empties into the Clinch River) are discussed in Section 5.5.3.

Neither PCBs nor VOCs were detected during 2016 in WOC at WOD. Mercury was detected once in the September sample.

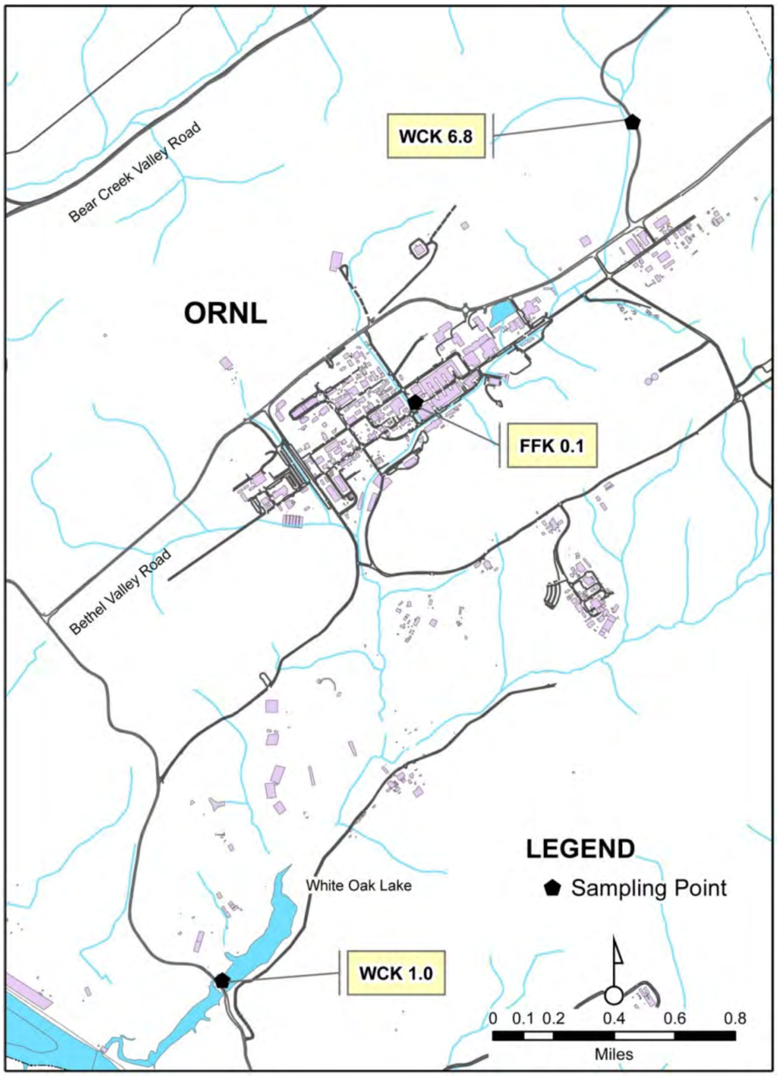

Fig. 5.37. Oak Ridge National Laboratory surface water sampling locations. *(FFK = Fifth Creek kilometer; WCK = White Oak Creek kilometer.)*

Table 5.13. Oak Ridge National Laboratory surface water sampling locations, frequencies, and parameters, 2016

Location[a]	Description	Frequency and type	Parameters[b]
WCK 1.0	White Oak Lake at WOD	Quarterly, grab	Volatiles, mercury, PCBs, field measurements
WCK 6.8	WOC upstream from ORNL	Quarterly, grab	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 Lake and the Clinch River).
[b]Field measurements consist of dissolved oxygen, pH, and temperature.

Acronyms
FFK = Fifth Creek kilometer
ORNL = Oak Ridge National Laboratory
PCB = polychlorinated biphenyl
WCK = WOC kilometer
WOC = White Oak Creek
WOD = White Oak Dam

5.5.10 Carbon Fiber Technology Facility Waste Water Monitoring

Facility and process waste water 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 2016 compliance status for this permit are summarized in Table 5.14.

Table 5.14. Industrial and Commercial User Waste Water Discharge Permit compliance at the Oak Ridge National Laboratory Carbon Fiber Technology Facility, 2016

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	1	100
pH (standard units)	9.0	6.0	0	1	100
Outfall 02 (Electrolytic Bath Tank)					
pH (standard units)	9.0	6.0	0	17	100
Outfall 03 (Sizing Bath Tank)					
Copper		0.87	0	5	100
Zinc		1.24	0	5	100
Total phenol		4.20	0	5	100
pH (standard units)	9.0	6.0	0	5	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 2016: DOE EM monitoring and DOE Office of Science (SC) surveillance monitoring. The DOE EM groundwater monitoring program was conducted by UCOR in 2016. 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 RAs is conducted as part of the WRRP. The WRRP is managed by UCOR for the DOE EM program. The results of CERCLA monitoring for ORR for FY 2016, including monitoring at ORNL, are evaluated and reported in the 2017 remediation effectiveness report (DOE 2017) 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 EM 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 2016 postremediation monitoring continued at Solid Waste Storage Area (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.

During FY 2016 EM 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 EM program, including sampling at six multiport monitoring wells in western Melton Valley (wells 4537, 4538, 4539, 4540, 4541, and 4542).

During FY 2014 the EM Groundwater Program staff conducted planning for an ORR off-site groundwater quality assessment and started development of an ORR regional groundwater flow model. The off-site groundwater assessment project is 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 to be assessed. The Offsite Groundwater Assessment project to evaluate off-site groundwater quality and movement continued in FY 2016. The project is a cooperative DOE, EPA, and TDEC effort. Two sampling events were completed in FY 2015 in accordance with an approved work plan. A confirmatory sampling event was completed in FY 2016, and a report of results was prepared and issued in November 2016 (DOE 2016a).

Construction and calibration of a regional-scale flow model was completed in FY 2016. The regional flow model will serve as an underlying framework to support future cleanup decisions and actions. A technical advisory group composed of members from DOE, EPA, TDEC, and industry has met several times annually since 2014. Members of the group reviewed progress and made recommendations for development and future use of the model.

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 2016 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 beta emitters, ^{90}Sr, and vinyl chloride. Benzene, potentially from natural sources, showed stable concentrations in one well with increasing concentrations at a second location.

During FY 2016, as part of the DOE EM program, three groundwater monitoring wells in Bethel Valley to the west of Tennessee Highway 95 were monitored to detect and track contamination from the SWSA 3 area. Data from those three wells supplement data being collected from a multiport well (4579) near SWSA 3 for exit pathway groundwater monitoring in western Bethel Valley. Groundwater monitoring near SWSA 3, along with the exit pathway, and groundwater and surface water monitoring at the northwest tributary of WOC and in the headwaters of Raccoon Creek allow integration of data concerning SWSA 3 contaminant releases. The data are presented in the 2016 remediation effectiveness report (DOE 2017).

Groundwater monitoring continued at the ORNL 7000 Area during FY 2016 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. A future full-scale bioremediation project will be designed to complete remediation of the plume.

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. The increase of contaminants feeding the plume was likely the result of leaking utility lines mobilizing contaminants near the source area. That has allowed increased contaminant flux to First Creek, a tributary of WOC. 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. Since FY 2013 the remedy has met its performance goal of reducing ^{90}Sr levels in WOC as measured at the 7500 bridge.

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 2016 was several inches below 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 ^{90}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 2016 an off-site groundwater monitoring well array west of the Clinch River and adjacent to Melton Valley was monitored as part of the EM 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. The maximum concentrations of ^{90}Sr and ^{3}H for the on-site exit pathway groundwater monitoring network during FY 2016 were estimated by the analytical laboratory. The estimated values were very low in comparison with the maximum contaminant levels (MCLs) specified in EPA regulations:

- Sr-90: 0.37 J pCi/L (8 pCi/L MCL-derived concentration)
- H-3: 209 J pCi/L (20,000 pCi/L MCL-derived concentration)

The “J” flags on the reported results indicate estimates of concentrations below contract required quantitation limits but greater than zero. Monitoring results are summarized in the 2017 remediation effectiveness report (DOE 2017).

Off-Site Groundwater Monitoring

During FY 2014 the EM Groundwater Program staff conducted planning for an ORR off-site groundwater quality assessment and started development of an ORR regional groundwater flow model. The off-site groundwater assessment project is 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 to be assessed. An off-site groundwater assessment project to evaluate off-site groundwater quality and movement continued in FY 2016. The project is a cooperative DOE, EPA, and TDEC effort. Two sampling events were completed in FY 2015 in accordance with an approved work plan. A confirmatory sampling event was completed in FY 2016, and a report of results was prepared and issued in November 2016 (DOE 2016a). Construction and calibration of a regional-scale flow model was completed in FY 2016. The regional flow model will serve as an underlying framework to support future cleanup decisions and actions. A technical advisory group composed of DOE, EPA, and TDEC members as well as industry experts has met several times annually since 2014. Members of the group reviewed progress and made recommendations for development and future use of the model.

5.6.2 DOE Office of Science Groundwater Monitoring

DOE O 458.1 (DOE 2011b) 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 2016 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 found in DOE O 458.1 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 2016, 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 5.38 shows the locations of the exit pathway monitoring points sampled in 2016.

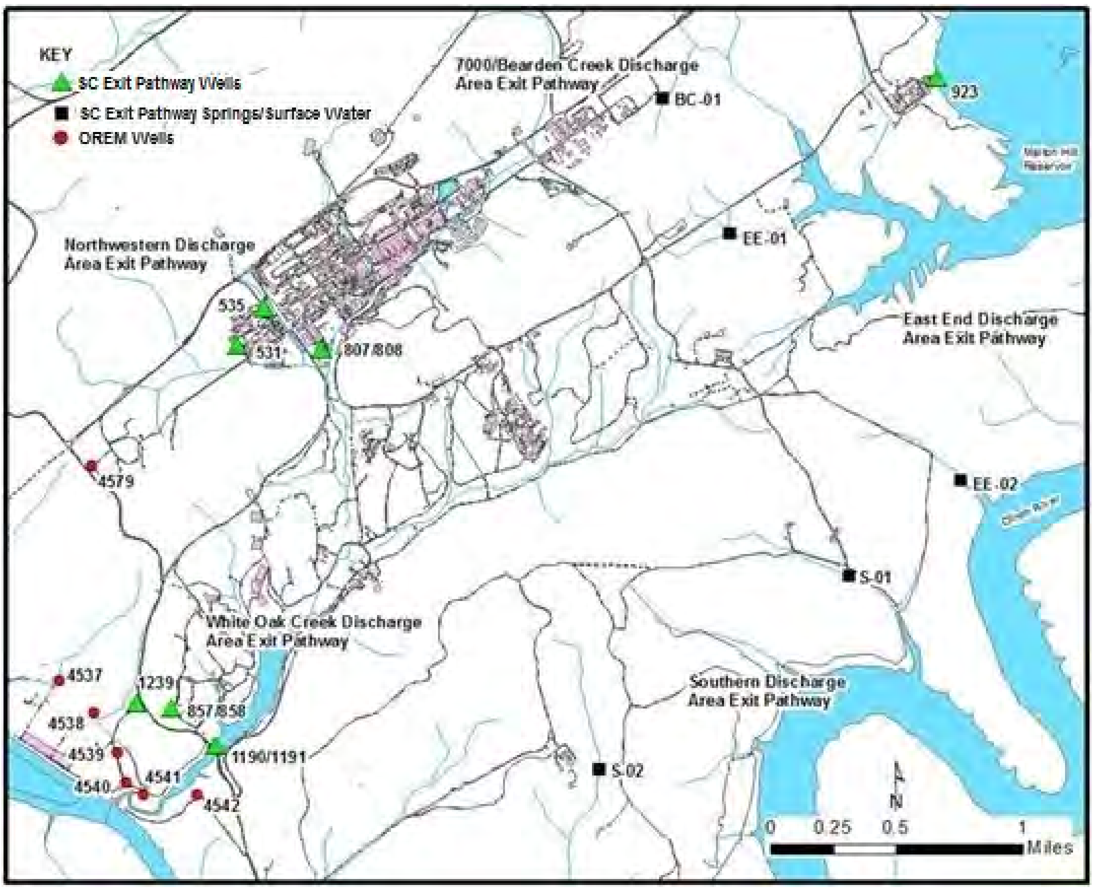

Fig. 5.38. UT-Battelle exit pathway groundwater monitoring locations at Oak Ridge National Laboratory, 2016. *(EM = DOE Environmental Management; OS = DOE Office of Science).*

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 2016 is outlined in Table 5.15.

Unfiltered samples were collected from the exit pathway groundwater surveillance monitoring points in 2016. 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, total radioactive strontium, 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/May) and dry (August/September/October) seasons.

Table 5.15. Scheduled 2016 exit pathway groundwater monitoring

Discharge area	Monitoring point	Wet season	Dry season
White Oak Creek	857	Radiological	Radiological
	858	Radiological	Radiological
	1190	Radiological, organic, and metals	Radiological, organic, and metals
	1191	Radiological, organic, and metals	Radiological, organic, and metals
	1239	Radiological, organic, and metals	Radiological
Northwestern	531	Radiological, organic, and metals	Radiological
	535	Radiological	Radiological
	807	Radiological	Radiological
	808	Radiological, organic, and metals	Radiological
7000–Bearden Creek	BC-01	Radiological	Radiological
East End	923	Radiological, organic, and metals	Radiological
	EE-01	Radiological, organic, and metals	Radiological
	EE-02	Radiological	Radiological
Southern	S-01	Radiological	Radiological
	S-02	Radiological	Radiological

Exit Pathway Monitoring Results

Statistical trend analyses were performed on 2016 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 5.16.

Samples were not collected at S-01during the wet season in 2016. Additionally, no samples were collected from BC-01, S-01, or EE-02 during the dry season. Samples were not collected due to a lack of water flow at the locations. Samples were collected at all other monitoring points during both the wet and dry seasons. Monitoring results are available in OREIS. Access to this system can be requested via email (oreis@ettp.doe.gov) or by telephone (865-574-3257).

Table 5.17 provides a summary of radiological parameters detected in samples collected from exit pathway monitoring points during 2016. Metals are ubiquitous in groundwater exit pathways and so are not summarized in the table.

Table 5.16. 2016 exit pathway groundwater monitoring—results of trend analyses for parameters exceeding reference standards

Discharge area	Monitoring point	Parameter	Trend
White Oak Creek	1190	H-3	Downward
		Fe	Downward
		Mn	Downward
	1191	H-3	Downward
		Sr-89/90	No trend
		Gross beta	Downward
		Fe	Downward
		Mn	No trend
	1239	Al	Downward
East End	EE-01	Al	Downward
		Mn	No trend
	923	Fe	No trend

Table 5.17. 2016 exit pathway groundwater monitoring results—detected radiological parameters

Discharge area	Monitoring location	Parameter	Result	Wet or dry season
Northwest	531	Beta	15	Wet
		Cs-137	4.4	Wet
		K-40	140	Wet
		Sr-89/90	4.9	Wet
		Beta	7	Dry
		K-40	150	Dry
	535	Cs-137	110	Wet
		K-40	110	Wet
		Sr-89/90	5	Wet
		Beta	24	Dry
		Cs-137	11	Dry
		K-40	190	Dry
		Sr-89/90	3.5	Dry
	807	Beta	12	Wet
		K-40	83	Wet
		Sr-89/90	6.5	Wet
		Tritium	490	Wet
		Alpha	4.5	Dry
		Beta	13	Dry
		Cs-137	53	Dry
		K-40	110	Dry
		Sr-89/90	5.1	Dry
	808	Beta	10	Wet
		Sr-89/90	3.1	Wet
		Beta	7.2	Dry
		K-40	170	Dry

Table 5.17 (continued)

Discharge area	Monitoring location	Parameter	Result	Wet or dry season
White Oak Creek	857	K-40	110	Wet
		Sr-89/90	4.3	Wet
		K-40	150	Dry
		Sr-89/90	11	Dry
	858	Cs-137	7.6	Wet
		Sr-89/90	3.7	Wet
		K-40	97	Dry
	1190	Alpha	11	Wet
		Beta	7.6	Wet
		Cs-137	79	Wet
		K-40	180	Wet
		Sr-89/90*	9.5	Wet
		Tritium	21,000	Wet
		Alpha	5.7	Dry
		Beta	8.9	Dry
		Tritium	26,000	Dry
	1191	Alpha	4.2	Wet
		Beta	200	Wet
		Cs-137	54	Wet
		K-40	120	Wet
		Sr-89/90	110	Wet
		Tritium	23,000	Wet
		Alpha	4.3	Dry
		Beta	260	Dry
		K-40	190	Dry
		Sr-89/90	140	Dry
		Tritium	29,000	Dry
	1239	Beta	6.6	Wet
		Cs-137	38	Wet
		K-40	150	Wet
		K-40	210	Dry
7000/Bearden Creek	BC-01	Alpha	2.5	Wet
		K-40	120	Wet
East End	EE-01	K-40	85	Wet
		Beta	6.4	Dry
		K-40	180	Dry
	EE-02	Sr-89/90	14	Dry
		Cs-137	8.2	Wet
		K-40	130	Wet
	923	K-40	120	Wet
		Sr-89/90	14	Dry
Southern	S-02	Alpha	2.9	Dry
		Beta	5.6	Dry
		K-40	130	Dry
		Sr-89/90	4.1	Dry

*The reported result is thought to be a laboratory error. The laboratory aliquot for the collected sample was discarded by the laboratory prior to a request for reanalysis to confirm the result.

Summary

The following bullets summarize the exit pathway groundwater surveillance program monitoring efforts for 2016 at ORNL:

- Seven radiological contaminants were detected in exit pathway groundwater samples collected in 2016. Tritium, total radioactive strontium, 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 2016. Statistical trend analyses show that the concentration trends for those parameters continue downward (no statistically significant trend was detected for $^{89/90}$Sr in Well 1191). No other radiological contaminants exceed reference standards at other discharge areas.

- Thirty-one metallic contaminants were detected in exit pathway groundwater samples collected in 2016; however, only three metals (iron, manganese, and aluminum) were detected at concentrations exceeding reference standards. These metals are commonly found in groundwater at ORNL

- Two VOCs (acetone and methylene chloride) were detected in exit pathway groundwater at ORNL during 2016. Both are common laboratory contaminants and are thought to be present due to contamination of the samples by the laboratory.

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 the ORR. Based on the results of the 2016 monitoring effort, there is no indication that current SC operations are significantly introducing contaminants to the groundwater at ORNL.

Active Sites Monitoring—High Flux Isotope Reactor

Outfall pipelines intercepting groundwater are routinely monitored under the ORNL NPDES permit. (See Section 5.5 for a discussion of results.)

Active Sites Monitoring—Spallation Neutron Source

Active sites groundwater surveillance monitoring was performed in 2016 at the SNS site under the SNS operational monitoring plan (OMP) (Bonine et al. 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 5.39 shows the locations of the specific monitoring points sampled during 2016.

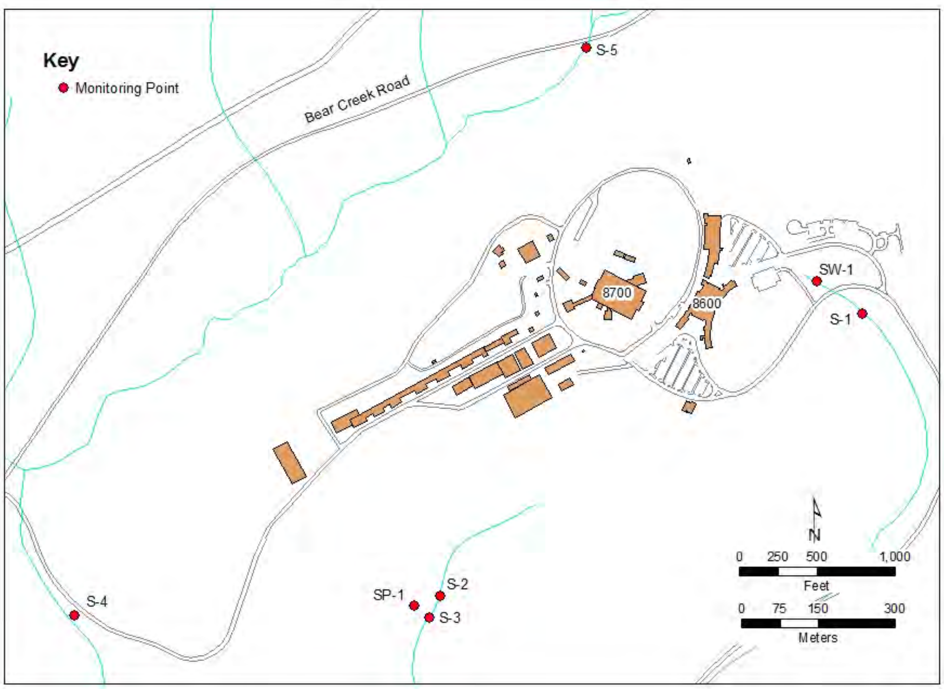

Fig. 5.39. Groundwater monitoring locations at the Spallation Neutron Source, 2016. *Springs are labeled with an S, seeps are labeled with SP, and surface water sampling areas are labeled with SW.*

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 2016.

Quarterly sampling at each monitoring point continued in 2016, allowing the opportunity for monitoring in wet and dry seasons. All sampling performed in 2016 was performed in conjunction with rainfall events, with samples being collected during rising or falling (recession) limb flow conditions (see Fig. 5.40). In Fig. 5.40, the curves represent spring or seep flow (base flow, through flow, overland flow, peak flow); the bars represent rainfall amounts. Table 5.18 shows the sampling and parameter analysis schedule followed in 2016.

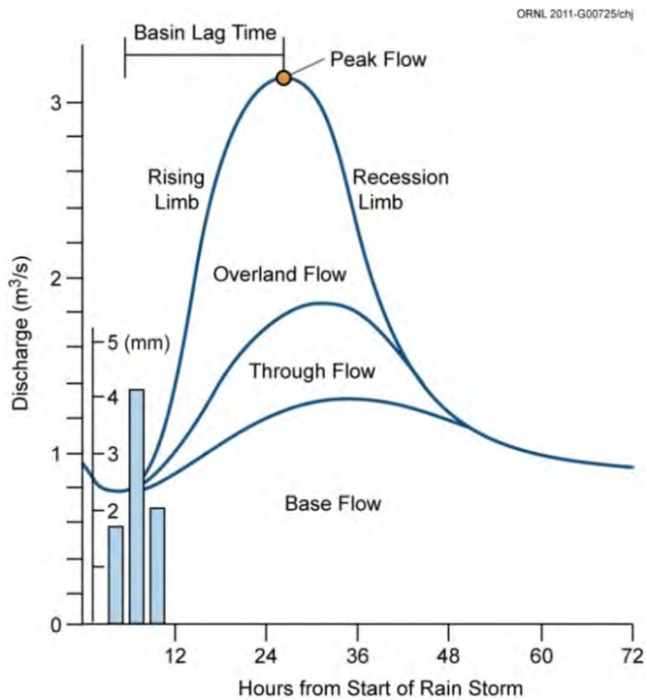

Fig. 5.40. Simple hydrograph of spring discharge vs. time after initiation of rainfall.

Spallation Neutron Source Site Results. In 2016 sampling at the SNS site occurred during March (quarter 1), May (quarter 2), August (quarter 3), and November (quarter 4). Low concentrations of several radionuclides were detected numerous times during 2016. Table 5.18 provides a summary of the locations for radionuclide detections observed during 2016.

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 Part 141). Gross alpha activity was detected in S-5 at a concentration exceeding its reference standard of 15 pCi/L during the fourth-quarter sampling event. Additionally, uranium isotopes were detected in samples collected from S-5 during the fourth-quarter event. 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 2016.

Table 5.18. Analytical results for parameters detected in samples collected at the Spallation Neutron Source during 2016 (pCi/L)

Quarter	Sampling station[a]	Parameter	Result	Reference standard
1	S-1	Tritium	452	20,000
	S-2	Tritium	418	20,000
	S-3	Tritium	311	20,000
	S-4	Tritium	570	20,000
	SP-1	Beta	4.29	50
	SW-1	Tritium	739	20,000
2	S-1	Alpha	4.67	15
	S-1	Tritium	4950	20,000
	S-2	Tritium	521	20,000
	S-4	Tritium	478	20,000
	SP-1	Tritium	334	20,000
	SW-1	Alpha	6.33	15
	SW-1	Beta	4.56	50
	SW-1	Bi-214	24.2	10,400
	SW-1	Tritium	2,350	20,000
3	S-1	Tritium	498	20,000
	S-2	Beta	5.01	50
	S-2	Bi-214	9.25	10,400
	S-2	Tl-208	4.27	No standard
	S-2	Tritium	564	20,000
	S-3	Bi-214	13.2	10,400
	SP-1	Tritium	304	20,000
	SW-1	Tritium	945	20,000
4	S-1	Tritium	261	20,000
	S-2	Tritium	263	20,000
	S-5	Alpha	19.7	15
	S-5	Beta	12	50
	S-5	Th-232	0.373	6
	S-5	U-233/234	5.31	No standard
	S-5	U-235/236	0.274	No standard
	S-5	U-238	9.18	30
	SP-1	Tritium	413	20,000
	SW-1	Tritium	204	20,000

[a]Springs are labeled with an S, seeps are labeled with SP, and surface water sampling areas are labeled with SW.

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/criterion 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. The accuracy of PEMS is determined three times per year by performing a RATA on a second, calibrated system. 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 2016 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 the 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 the 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 the ORR have been clearly defined, and EM is working to clean those areas under the Federal Facility Agreement with the EPA and TDEC. The *2016 Cleanup Progress Annual Report to the Oak Ridge Regional Community* (UCOR 2016) provides detailed information on DOE EM's 2016 cleanup activities.

5.8.1 Oak Ridge National Laboratory Wastewater Treatment

At ORNL, DOE EM operates PWTC and the Liquid Low-Level Waste Treatment Facility. In 2016 313 million L of wastewater was treated and released at PWTC. In addition, the liquid LLW evaporator at ORNL treated 388,360 L of waste. The waste treatment activities of these facilities support both DOE EM 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 EM 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 2016, ORNL performed 96 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 2016 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 2016. TRU waste disposal at the Waste Isolation Pilot Plant will resume once the facility is reopened to receive TRU waste.

During 2016, 26.21 m^3 of CH waste and 73.75 m^3 of RH waste were processed, and 11.96 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

Nine 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 nine meteorological towers on ORR are described in Table 6.1 and are depicted in Fig. 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. Additionally, data are collected at selected towers at the 30, 33, 35, and 60 m levels. At each measurement level except 2 m, temperature, wind speed, and wind direction are measured. 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. Barometric pressure is measured at one or more of the towers at each ORR plant (MT1, MT2, MT4, MT6, MT7, and MT9). Precipitation is measured at MT6 and MT9 at the Y-12 National Security Complex (the Y-12 Complex); at MT1 and MT7 at the East Tennessee Technology Park (ETTP); and at MT2, MT3, and MT4 at Oak Ridge National Laboratory (ORNL). Solar radiation is measured at MT6 and MT9 at the Y-12 Complex, at MT1 and MT7 at ETTP, and at MT2 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		
MT1	K, 1208	35.93317N, -84.38833W	263	10, 60
MT7	L, 1209	35.92522N, -84.39414W	233	10, 30
		ORNL		
MT2	D,[a] 1047	35.92559N, -84.32379W	261	2, 15, 35, 60
MT3	B, 6555	35.93273N, -84.30254W	256	15, 30
MT4	A, 7571	35.92185N, -84.30470W	266	10/15, 30
MT10	M, 208A	35.90947N, -84.38796W	244	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	35.98190 N,-84.25504W	352	25

Acronyms
ETTP = East Tennessee Technology Park
MSL = mean sea level
ORNL = Oak Ridge National Laboratory
PSS = plant shift superintendent
Y-12 Complex = Y-12 National Security Complex

[a]Tower "C" before May 2014 with measurement heights of 10, 30, and 100 m.

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 (60–900 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 nine ORR towers.

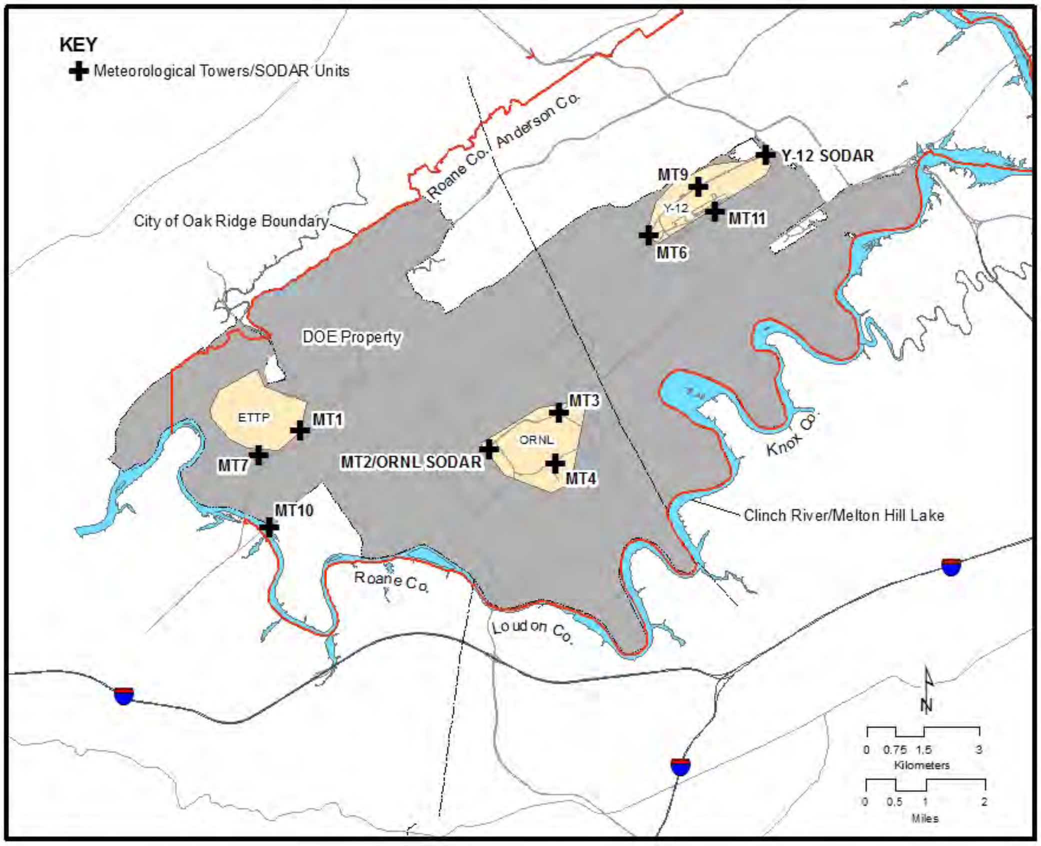

Fig. 6.1. The Oak Ridge Reservation meteorological monitoring network, including sonic detection and ranging (SODAR) devices.

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 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 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 2016 (1,084 mm or 42.68 in.) was almost 20% below 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 2016 were greater than 98% for wind sensors at the ORNL sites (towers MT2, MT3, MT4, and MT10). Annual wind data recovery from ETTP and Y-12 meteorological towers during 2016 exceeded 99% (towers MT1, MT6, MT7, MT9, and MT11).

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 2016 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 2016. During the year, as new stations came on line, others were discontinued, resulting in only partial data for several locations. Table 6.2 summarizes the data for each station.

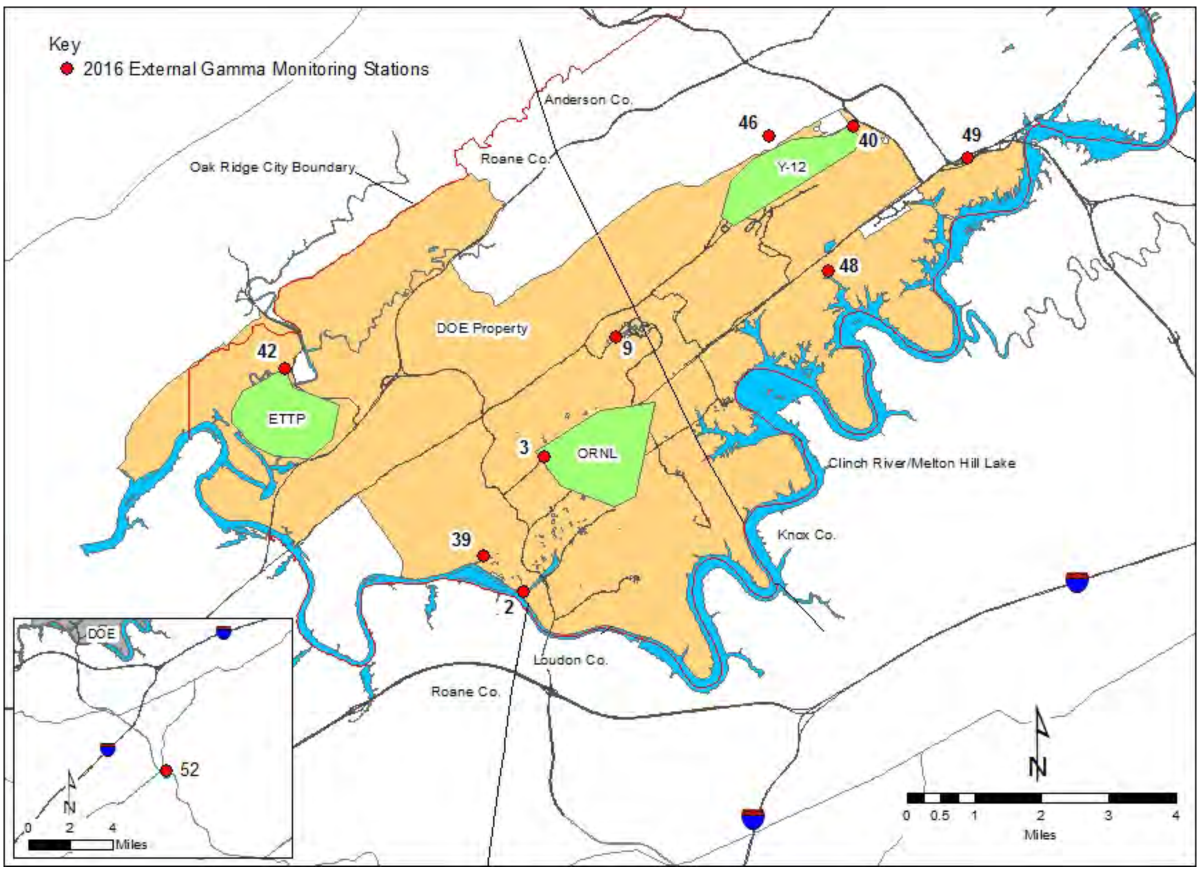

Fig. 6.2. External gamma radiation monitoring locations on the Oak Ridge Reservation.

6.2.2 Results

The mean exposure rate for the reservation network in 2016 was 10.5 µR/h, and the mean at the reference location was 9.7 µR/h. Exposure rates from background sources in Tennessee range from 2.9 to 11 µR/h.

Table 6.2. External gamma (exposure rate) averages for the Oak Ridge Reservation, 2016

Monitoring location	Number of data points (daily)	Measurement (μR/h)[a]		
		Min	Max	Mean
02	22	9.1	11.2	9.7
03	199	9.3	11.2	9.8
09	94	9.5	17.4	10.9
39	347	11.1	16.0	12.1
40	354	9.6	12.4	10.7
42	132	9.0	10.8	9.5
46	334	10.5	13.0	11.2
48	234	9.4	12.0	9.9
49	82	9.8	12.6	10.7
52	354	8.0	11.4	9.7

[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) Oak Ridge 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 (Fig. 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.

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 2016 are shown in Fig. 6.4. Reference samples are collected from Station 52 (Fort Loudoun Dam). Sampling was conducted at each ORR station during 2016 to quantify levels of alpha-, beta-, and gamma-emitting radionuclides. Upgrades were done sequentially throughout 2016, so only partial data were available at several locations.

Fig. 6.3. Oak Ridge Reservation ambient air station.

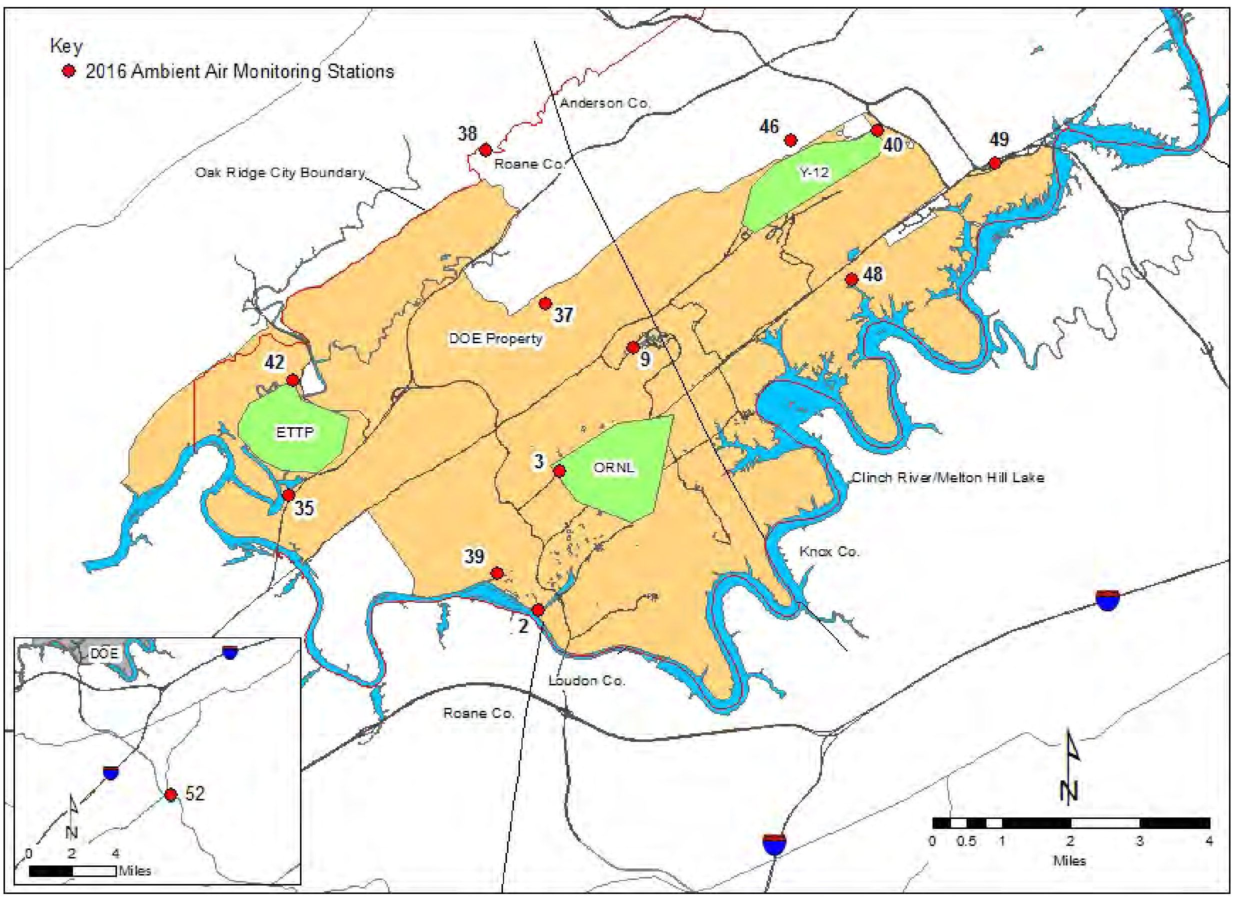

Fig. 6.4. Locations of Oak Ridge Reservation perimeter air monitoring stations.

Atmospheric dispersion modeling was used to select appropriate sampling locations. The locations selected are those likely to be affected most by releases from the Oak Ridge facilities. Therefore, in the event of a release, no residence or business near ORR should receive a radiation dose greater than doses calculated at the sampled locations.

The sampling system consists of two separate instruments. Particulates are captured by high-volume air samplers equipped with glass-fiber filters. The filters are collected weekly, composited quarterly, and then submitted to an analytical laboratory to quantify gross alpha and beta activity and to determine the concentrations of specific isotopes of interest on ORR. The second system is designed to collect tritiated water vapor. The sampler consists of a prefilter followed by an adsorbent trap that contains indicating silica gel. The samples are collected weekly or biweekly, composited quarterly, and then submitted to an analytical laboratory for tritium analysis.

6.3.1 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. All radionuclide concentrations measured at the ORR ambient air stations during 2016 were less than 1% of applicable DCSs, indicating that activities on the reservation are not adversely affecting local air quality.

Table 6.3. Average radionuclide concentrations at Oak Ridge Reservation perimeter air monitoring stations, 2016

Parameter	N detected/N total	Concentration (pCi/mL)[a]		
		Average	Minimum	Maximum
		Station 1		
Be-7	4/4	4.81E-08	3.62E-08	5.89E-08
K-40	0/4	-1.36E-10	-2.34E-10	-3.98E-11
Tc-99	2/3	3.20E-10	1.24E-10	4.43E-10
Tritium	1/4	3.89E-06	5.11E-07	7.17E-06
U-234	3/4	2.72E-12	1.37E-12	3.57E-12
U-235	1/4	1.98E-13	1.54E-13	2.80E-13
U-238	4/4	2.40E-12	1.28E-12	3.77E-12
		Station 2		
Be-7	3/3	5.98E-08	3.59E-08	7.51E-08
K-40	0/3	1.34E-10	-8.65E-10	1.52E-09
Tc-99	1/2	2.65E-10	3.11E-11	4.98E-10
Tritium	1/4	6.97E-06	2.69E-06	1.03E-05
U-234	3/3	2.73E-12	1.97E-12	3.35E-12
U-235	0/3	-5.31E-15	-7.47E-14	7.13E-14
U-238	3/3	2.04E-12	1.56E-12	2.76E-12

Table 6.3 (continued)

Parameter	N detected/N total	Concentration (pCi/mL)[a]		
		Average	Minimum	Maximum
		Station 3		
Be-7	3/3	8.28E-08	3.77E-08	1.45E-07
K-40	0/3	6.30E-10	9.27E-12	1.51E-09
Tc-99	0/2	3.48E-10	1.17E-11	6.84E-10
Tritium	1/4	4.71E-06	1.30E-06	9.36E-06
U-234	2/3	2.79E-12	2.36E-12	3.33E-12
U-235	2/3	7.38E-13	9.34E-14	1.82E-12
U-238	3/3	2.72E-12	2.57E-12	3.03E-12
		Station 35		
Be-7	4/4	4.27E-08	3.71E-08	5.49E-08
K-40	0/4	1.81E-10	-2.52E-10	9.32E-10
Tc-99	3/4	3.69E-10	6.97E-11	6.47E-10
Tritium	1/4	3.66E-06	-2.42E-07	8.81E-06
U-234	4/4	1.26E-11	2.11E-12	3.14E-11
U-235	2/4	1.12E-12	1.82E-13	2.40E-12
U-238	4/4	3.44E-12	1.76E-12	6.72E-12
		Station 37		
Be-7	4/4	3.81E-08	2.59E-08	5.55E-08
K-40	0/4	-8.56E-11	-1.98E-10	6.00E-12
Tc-99	2/3	2.50E-10	1.53E-10	3.45E-10
Tritium	0/4	1.14E-06	-1.39E-06	3.83E-06
U-234	4/4	2.82E-12	1.82E-12	4.60E-12
U-235	3/4	1.95E-13	0	2.85E-13
U-238	4/4	2.03E-12	1.60E-12	2.78E-12
		Station 38		
Be-7	3/3	4.95E-08	3.82E-08	6.86E-08
K-40	0/3	-2.25E-10	1.63237E+12	1.94E-11
Tc-99	2/3	3.02E-10	2.02E-10	4.03E-10
Tritium	0/3	1.73E-06	3.40E-08	4.94E-06
U-234	3/3	4.50E-12	3.28E-12	5.85E-12
U-235	1/3	2.57E-13	7.10E-14	3.67E-13
U-238	3/3	2.65E-12	1.88E-12	3.60E-12
		Station 39		
Be-7	4/4	4.26E-08	2.34E-08	6.17E-08
K-40	0/4	2.61E-10	-8.13E-11	6.38E-10
Tc-99	2/3	3.90E-10	1.59E-10	5.24E-10
Tritium	1/4	1.94E-06	2.10E-07	3.92E-06
U-234	4/4	2.90E-12	1.80E-12	5.22E-12
U-235	1/4	6.28E-14	-6.10E-14	2.11E-13
U-238	4/4	1.78E-12	1.68E-12	1.90E-12

Table 6.3 (continued)

Parameter	N detected/N total	Concentration (pCi/mL)[a]		
		Average	Minimum	Maximum
		Station 40		
Be-7	4/4	4.67E-08	3.45E-08	7.59E-08
K-40	1/4	3.35E-10	-1.38E-10	1.20E-09
Tc-99	2/3	3.73E-10	1.48E-10	5.04E-10
Tritium	0/4	3.59E-06	2.86E-06	4.55E-06
U-234	4/4	7.10E-12	4.72E-12	1.09E-11
U-235	3/4	5.40E-13	4.59E-13	6.59E-13
U-238	4/4	3.79E-12	3.07E-12	4.35E-12
		Station 42		
Be-7	2/2	6.36E-08	3.70E-08	9.02E-08
K-40	0/2	-4.00E-10	-5.56E-10	-2.43E-10
Tc-99	2/2	7.87E-10	4.58E-10	1.12E-09
Tritium	0/2	1.82E-07	-2.77E-07	6.42E-07
U-234	2/2	7.11E-11	1.26E-11	1.30E-10
U-235	2/2	5.48E-12	8.52E-13	1.01E-11
U-238	2/2	1.18E-11	4.33E-12	1.92E-11
		Station 46		
Be-7	4/4	4.50E-08	3.24E-08	7.17E-08
K-40	1/4	5.14E-10	-9.91E-11	1.86E-09
Tc-99	1/3	2.98E-10	1.48E-10	4.74E-10
Tritium	1/4	2.98E-06	1.48E-06	4.49E-06
U-234	4/4	4.21E-12	2.84E-12	7.01E-12
U-235	1/4	2.89E-13	2.18E-13	3.91E-13
U-238	4/4	2.54E-12	2.05E-12	3.15E-12
		Station 48		
Be-7	3/3	4.67E-08	2.95E-08	6.70E-08
K-40	0/3	-1.60E-10	-5.28E-10	1.66E-10
Tc-99	2/3	3.22E-10	1.97E-10	4.85E-10
Tritium	0/3	1.44E-06	-1.14E-07	3.58E-06
U-234	3/3	2.46E-12	1.82E-12	3.02E-12
U-235	1/3	3.03E-13	1.08E-13	4.72E-13
U-238	3/3	2.04E-12	1.56E-12	2.46E-12
		Station 49		
Be-7	1/1	4.44E-08	4.44E-08	4.44E-08
K-40	0/4	1.00E-10	1.00E-10	1.00E-10
Tritium	0/1	3.91E-06	3.91E-06	3.91E-06
U-234	1/1	3.56E-12	3.56E-12	3.56E-12
U-235	1/1	4.01E-13	4.01E-13	4.01E-13
U-238	1/1	3.54E-12	3.54E-12	3.54E-12

Table 6.3 (continued)

Parameter	N detected/N total	Concentration (pCi/mL)[a]		
		Average	Minimum	Maximum
		Station 52		
Be-7	4/4	5.07E-08	3.44E-08	7.32E-08
K-40	0/4	-2.13E-10	-4.24E-10	1.07E-10
Tc-99	3/4	3.05E-10	1.27E-10	5.39E-10
Tritium	0/4	3.73E-07	-8.50E-07	1.56E-06
U-234	4/4	2.53E-12	1.96E-12	3.29E-12
U-235	0/4	1.61E-13	3.08E-14	2.35E-13
U-238	4/4	2.11E-12	1.50E-12	2.71E-12
		Station 9		
Be-7	1/1	4.14E-08	4.14E-08	4.14E-08
K-40	0/1	-4.43E-11	-4.43E-11	-4.43E-11
Tritium	1/1	1.54E-4	1.54E-4	1.54E-4
U-234	1/1	3.21E-12	3.21E-12	3.21E-12
U-235	0/1	1.38E-13	1.38E-13	1.38E-13
U-238	1/1	2.44E-12	2.44E-12	2.44E-12

[a]1 pCi = 3.7×10^{12} Bq.

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 five locations on the Clinch River, including public water intakes (Fig. 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 five 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 2008). 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

In 2016, analyses of surface water samples collected for ORR-wide surveillance at Clinch River kilometers (CRKs) 66, 58, 32, 23, and 16 were transitioned from a commercial laboratory to the ORNL Radioactive Materials Analytical Laboratory (RMAL). Following the transition, analytical results for several radionuclides were higher than those previously reported by the commercial laboratory. The major reasons for the increases are thought to be the result of higher radiation background in the RMAL

counting laboratory, cross-contamination found in RMAL laboratory equipment, and the contributions of naturally occurring short-lived radionuclides that likely decayed significantly during transport to the commercial laboratory. Corrective actions have been identified and implemented to address these issues. During the year, surface water samples were also collected at CRKs 23 and 16 for ETTP site-specific monitoring. The results from the samples were used in dose calculations instead of those obtained via the ORR-wide program to eliminate the bias that was likely to be introduced by higher background and cross-contamination.

A comparison of radionuclide concentrations from 2016 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.

Mercury was detected above MCL once in the March sample from CRK 16; otherwise, mercury was not detected above MCL during the other three quarters at CRK 16 or at the other two sampling locations where mercury samples are collected.

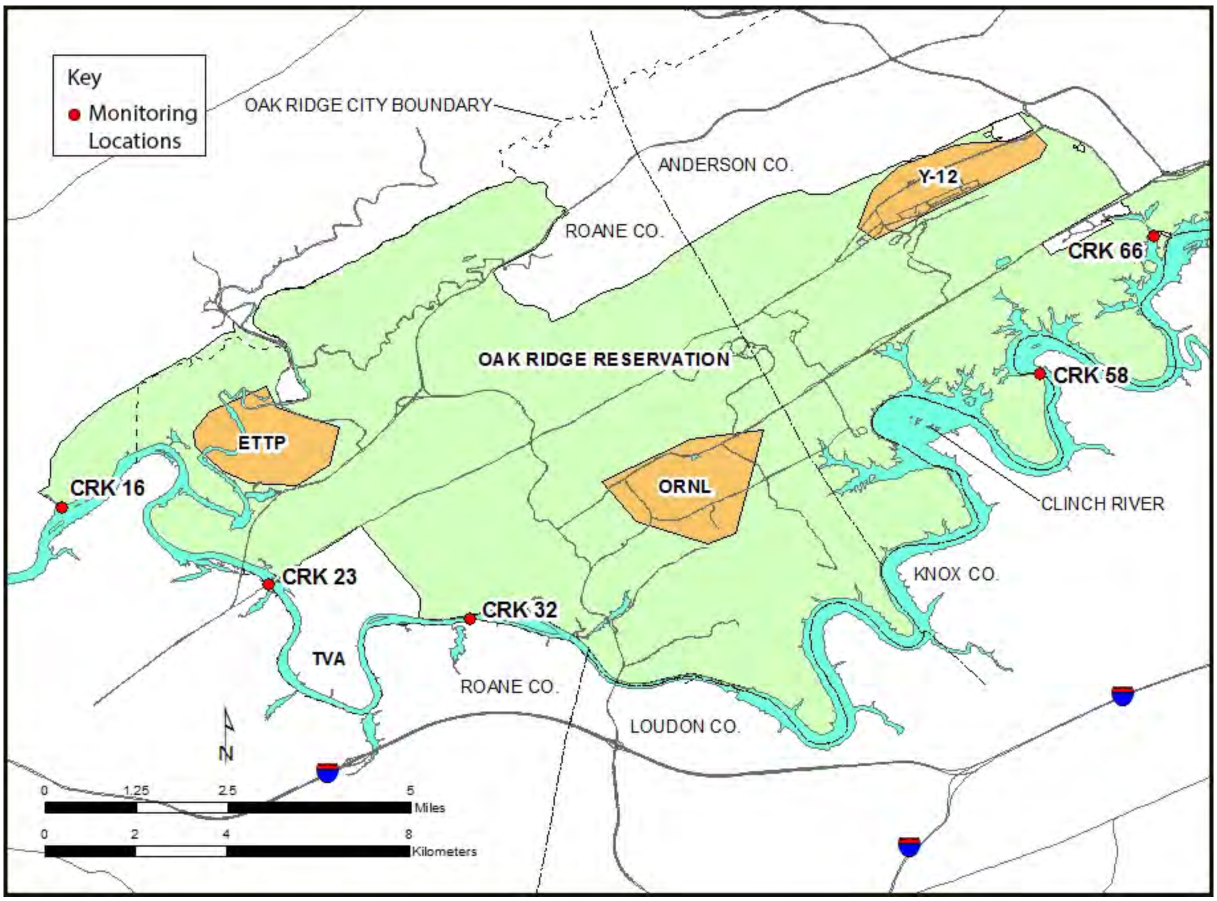

Fig. 6.5. Oak Ridge Reservation surface water surveillance sampling locations.

Table 6.4. Oak Ridge Reservation surface water sampling locations, frequencies, and parameters, 2016

Location[a]	Description	Frequency	Parameters
CRK 16	Clinch River downstream from all DOE ORR inputs	Quarterly	Mercury, gross alpha, gross beta, gamma scan, ^{3}H, field measurements[b]
CRK 23	Former water supply intake for ETTP	Quarterly	Mercury, gross alpha, gross beta, gamma scan, ^{3}H, field measurements[b]
CRK 32	Clinch River downstream from ORNL	Quarterly	Gross alpha, gross beta, gamma scan, total radioactive strontium, ^{3}H, field measurements[b]
CRK 58	Water supply intake for Knox County	Quarterly	Gross alpha, gross beta, gamma scan, ^{3}H, field measurements[b]
CRK 66	Melton Hill Reservoir above city of Oak Ridge water intake	Quarterly	Mercury, gross alpha, gross beta, gamma scan, total radioactive strontium, ^{3}H, field measurements[b]

[a]Locations indicate the water body and distances upstream of the confluence of the Clinch and Tennessee Rivers (e.g., CRK 16 is 16 km upstream from the confluence of the Clinch River with the Tennessee River, Watts Bar Reservoir).
[b]Field measurements consist of dissolved oxygen, pH, and temperature.

Acronyms
CRK = Clinch River kilometer
DOE = US Department of Energy
ETTP = East Tennessee Technology Park
ORNL = Oak Ridge National Laboratory
ORR = Oak Ridge Reservation

6.5 Groundwater Monitoring

Work continued in 2016 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 2016 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

An off-site groundwater assessment project to evaluate off-site groundwater quality and movement continued in FY 2016. The project is a cooperative effort by DOE, EPA, and TDEC. Two sampling events were completed in FY 2015 in accordance with an approved work plan. A confirmatory sampling event was completed in FY 2016, and a report of results was prepared and issued in November 2016 (DOE 2016).

6.5.2 Regional-Scale Flow Model

Construction and calibration of a regional-scale flow model was completed in FY 2016. 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 were 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 were collected from areas that could be affected by activities on the reservation and from off-site reference locations.

The wildlife administrative release limits associated with deer, turkey, and geese harvested on ORR are conservative and were established based on the "as low as reasonably achievable (ALARA)" principle to ensure that doses to consumers are managed at levels well below regulatory dose thresholds. The ALARA concept is not a dose limit but rather a philosophy that has the objective of maintaining exposures to workers, members of the public, and the environment below regulatory limits and as low as can be reasonably achieved. An administrative release limit of 5 pCi/g ^{137}Cs is based on the assumption that one person consumes all of the meat from a maximum-weight deer, goose, or turkey. This limit ensures that members of the public who harvest wildlife on the reservation will not receive significant radionuclide doses from that consumption pathway. In addition, a conservative administrative limit of 1.5 times background for gross beta activity has been established, a threshold that is near the detection limit for field measurements of $^{89/90}$Sr in deer leg bone.

6.6.1 Vegetables

Tomatoes, lettuce, and turnips were purchased from farms near ORR and from reference locations outside the potential DOE impact area. The locations were chosen based on availability and on the likelihood of effects from routine releases from the Oak Ridge facilities.

6.6.1.1 Results

Samples were analyzed for gross alpha, gross beta, gamma emitters, and uranium isotopes. No gamma-emitting radionuclides were detected above the minimum detectable activity (MDA), except for the naturally occurring radionuclides ^{7}Be and ^{40}K (Table 6.5).

Table 6.5. Concentrations of radionuclides detected in vegetables, 2016 (pCi/kg)[a]

Location	Gross alpha	Gross beta	^{7}Be	^{40}K	^{234}U	^{235}U	^{238}U
			Lettuce				
East of Y-12, Claxton vicinity	0.0000768	0.00419	0.000672	0.00539	0.00000379	*b*	*b*
West of ETTP	*b*	0.00537	*b*	0.00735	*b*	*b*	*b*
North of Y-12	*b*	0.00526	*b*	0.00664	*b*	*b*	0.00000275
South of ORNL	*b*	0.00423	*b*	0.0052	*b*	0.0000018	*b*
Southwest of ORNL, Lenoir City	*b*	0.00308	*b*	0.00229	0.00000396	*b*	*b*
Reference location	*b*	0.00139	*b*	0.00125	0.00000344	*b*	*b*
			Tomato				
East of Y-12, Claxton vicinity	*b*	0.00229	*b*	0.00159	*b*	*b*	*b*

Table 6.5 (continued)

Location	Gross alpha	Gross beta	^{7}Be	^{40}K	^{234}U	^{235}U	^{238}U
West of ETTP	*b*	0.0013	*b*	0.00178	*b*	*b*	*b*
North of Y-12	*b*	0.00216	*b*	0.00276	*b*	*b*	*b*
South of ORNL	*b*	0.00219	*b*	0.00203	*b*	*b*	*b*
Southwest of ORNL, Lenoir City	*b*	0.00144	*b*	0.00179	*b*	*b*	0.00000184
Reference location	*b*	0.0015	*b*	0.00153	0.00000281	0.0000022	*b*

[a]Detected radionuclides are those at or above minimum detectable activity. 1 pCi = 3.7×10^{-2} Bq.
[b]Value was less than or equal to minimum detectable activity.

Acronyms
ETTP = East Tennessee Technology Park
ORNL = Oak Ridge National Laboratory
Y-12 = Y-12 National Security Complex

6.6.2 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.

Surveys to locate dairies in areas that could receive deposition from ORR activities are conducted annually, and bimonthly grab samples are collected at those locations and at a reference location in an unimpacted area. For many years, the only known dairy with potential to be affected by DOE ORR activities was east of the ORR (Fig. 6.6) in the Claxton community. However, in April 2016 that dairy went out of business, and no further milk samples were collected during the year. The 2016 milk samples collected in February and April were analyzed for gamma emitters and for total radioactive strontium ($^{89}Sr + ^{90}Sr$).

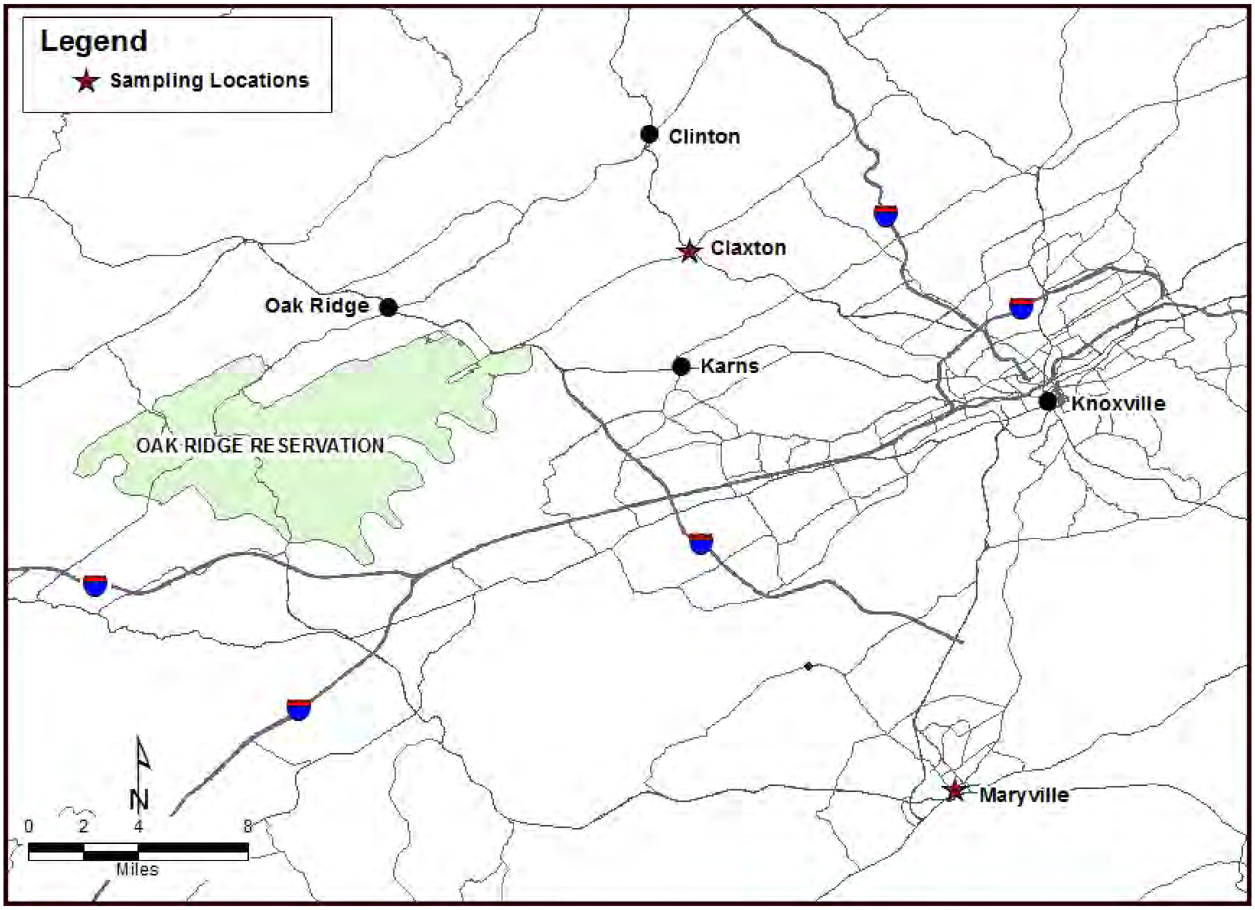

Fig. 6.6. Milk-sampling locations in the vicinity of the Oak Ridge Reservation.

6.6.2.1 Results

Concentrations of radionuclides detected above MDA in milk are presented in Table 6.6.

A comparison of results for milk collected from the Claxton dairy with those for milk collected from the reference dairy indicate that ORR activities are not significantly impacting radionuclide concentrations in milk.

Table 6.6. Concentrations of radionuclides detected in raw milk, 2016

Analysis	Number detected/ total number	Detected concentration (pCi/L)[a]			Standard error of mean
		Maximum	Minimum	Average	
		Claxton			
^{40}K	2/2	1,350[b]	1,310[b]	1,330[b]	20
		Reference location			
^{40}K	2/2	1,360[b]	1,290[b]	1,325[b]	35

[a]Detected radionuclides are those above minimum detectable activity. 1 pCi = 3.7 × 10^{12} Bq.
[b]Individual and average concentrations significantly greater than zero at the 95% confidence level.

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 (Fig. 6.7):

- Clinch River upstream from all DOE ORR inputs (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 2016, 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 impacted 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 2008).

6.6.3.1 Results

PCBs, specifically Aroclor-1260, and mercury were detected in both sunfish and catfish at all three locations in 2016. These results are consistent with the TDEC advisories. Detected PCBs, mercury, and radionuclide concentrations are shown in Table 6.7.

Radiological analyses for fish tissues sampled in 2016 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.

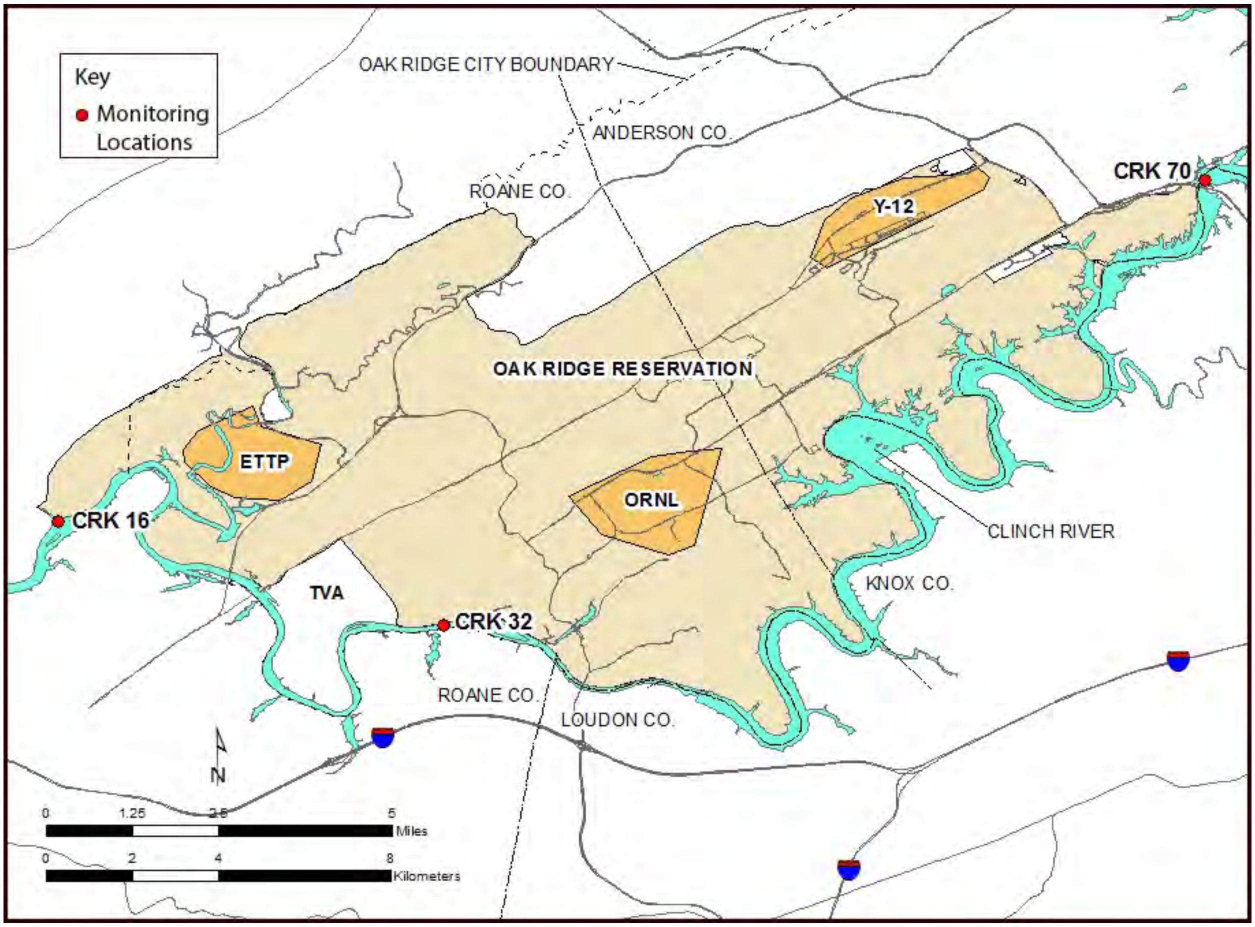

Fig. 6.7. Fish-sampling locations for the Oak Ridge Reservation Surveillance Program.

Table 6.7. Tissue concentrations in catfish and sunfish for detected mercury, PCBs, and radionuclides, 2016[a]

Parameter	Catfish[b]	Sunfish[b]
Clinch River downstream from all DOE ORR inputs (CRK 16)		
Metals (mg/kg)		
Hg	0.063	0.061
Pesticides and PCBs (µg/kg)		
PCB-1260	30	210
Radionuclides (pCi/g)[b]		
Beta activity	3.0[c]	2.6[c]
^{40}K	3.8[c]	2.9[c]
Clinch River downstream from ORNL (CRK 32)		
Metals (mg/kg)		
Hg	J0.026[d]	0.16
Pesticides and PCBs (µg/kg)		
PCB-1260	26	290

Table 6.7 (continued)

Parameter	Catfish[b]	Sunfish[b]
Radionuclides (pCi/g)[b]		
Beta activity	3.1[c]	2.5[c]
^{137}Cs	0.00016[c]	0.0000074
^{40}K	3.8[c]	3.6[c]
^{90}Sr	0.044[c]	−0.00073
Tritium	2.4[c]	0.098
Clinch River (Solway Bridge) upstream from all DOE ORR inputs (CRK 70)		
Metals (mg/kg)		
Hg	J0.0088[d]	J0.028[d]
Pesticides and PCBs (µg/kg)		
PCB-1260	160	48
Radionuclides (pCi/g)[b]		
Beta activity	3.0[c]	2.6[c]
^{40}K	3.1[c]	2.0[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
DOE = US Department of Energy
ORNL = Oak Ridge National Laboratory
ORR = Oak Ridge Reservation
PCB = polychlorinated biphenyl

6.6.4 White-Tailed Deer

Three weekend quota deer hunts were held on the ORR during the final quarter of 2016. The hunts took place October 29–30, November 12–13, and December 10–11. 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 27,107 acres were available to deer hunters on the Oak Ridge Wildlife Management Area (ORWMA) in 2016 (16,073 acres for gun hunting and 11,034 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 2016 was 361 deer, of which 209 (~57.9%) were bucks, and 152 (~42.1%) were does. The heaviest buck weighed 179 lb and had eight antler points. The greatest number of antler points found on one buck was 15. The heaviest doe weighed 115 lb.

Since 1985, 12,842 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 ~86.1 lb. The oldest deer harvested was a doe estimated to be 12 years old (1989), and the average age of all harvested deer is ~2 years. See the ORR hunt information website for more information (http://web.ornl.gov/sci/rmal/hunts/).

6.6.4.1 Results

Two of the 361 (~0.6%) deer harvested on ORR during the 2016 hunts were retained for exceeding the administrative release limit of 1.5 times background for beta activity in bone (~20 pCi/g $^{89/90}Sr$). None of the deer harvested in 2016 exceeded 5 pCi/g ^{137}Cs in edible tissue.

6.6.5 Canada Geese

Statewide, Canada goose hunting was allowed September 1–15, 2016, October 8–25, 2016, November 26–27, 2016, and December 3, 2016–January 29, 2017. On the Three Bends region of ORR, Canada goose hunting was allowed until noon on five days of the September season and four days of the October season. 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 ORR, Canada geese are rounded up each summer for noninvasive gross radiological surveys.

6.6.5.1 Results

Fifty geese (20 adults, 30 goslings) were captured during the June 30, 2016, roundup, including 43 from Clark Center Park (15 adults, 28 goslings) and seven from Solway Boat Ramp (5 adults, 2 goslings). Twenty-seven geese (20 adults, 7 goslings) were subjected to live whole-body gamma scans; 20 from Clark Park (15 adults, 5 goslings); and all seven that were captured at Solway Boat Ramp. Gamma scan results of the 27 geese (0.082–0.67 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 (April 9–10 and April 16–17, 2016). Each hunt was limited to 225 hunters, preselected in a quota drawing. Approximately 24,000 acres were available to turkey hunters in 2016, of which 255 acres were available to archery-only hunters. Twenty-seven male turkeys were harvested on the two hunts, of which four (~ 14.8%) were juveniles and 23 (~ 85.2%) were adults. The average weight of all turkeys harvested during spring 2016 hunts was ~18.1 lb, and the largest turkey weighed 23.6 lb. The average beard length was ~8.6 in., and the longest beard was 11.2 in. The average spur length was ~0.8 in., and the longest spur was 1.3 in.

In addition, two adult turkeys (an 8.0 lb female and a 17.0 lb male) were legally harvested by archery hunters on October 29 during the 2016 deer hunts. The male had a 7.0 in. beard and 0.8 in. spurs. The largest turkey harvested to date on ORR weighed 25.7 lb (harvested in 2009).

6.6.6.1 Results

None of the 29 turkeys harvested in 2016 exceeded the administrative release limits established for radiological contamination. Since 1997, 839 turkeys have been harvested on spring turkey hunts. Eight 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. For additional information, see http://web.ornl.gov/sci/rmal/hunts/.

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 Chap. 5, Sect. 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 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 2016, a hypothetical maximally exposed individual could have received an effective dose (ED) of about 0.2 mrem from radionuclides emitted to the atmosphere from all ORR sources; this is well below the National Emission Standards for Hazardous Air Pollutants for Radionuclides standard of 10 mrem/year for protection of the public.

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 the most contaminated fish accessible, drinking 680 L/year (180 gal/year) of the most contaminated drinking water, and using the shoreline near the most contaminated stretch of water for 60 h/year.

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 1 mrem. This calculation is conducted to provide an estimated upper-bound ED from consuming wildlife harvested from the ORR.

Therefore, the annual dose to a maximally exposed individual 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 the 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 the ORR during 1 year to no more than 100 mrem. The 2016 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 2016. 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. Thus 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 as long as 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 thus do not irradiate the body uniformly.

A number of the 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 2016 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 the 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 35 emission points on the ORR were modeled during 2016. The total includes 3 (two combined) points at the Y-12 National Security Complex (Y-12), 28 points at Oak Ridge National Laboratory (ORNL), and 4 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.

Meteorological data used in the calculations for 2016 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 2016, rainfall, as averaged over the six rain gauges located on the ORR, was 114.4 cm (45 in.). The average air temperature was 15.5°C (59.9°F) at the 10 to 15 m levels, and the average mixing-layer height for ETTP and ORNL was 919 m (3,016 ft) and for Y-12 was 899 m (2,956 ft). The mixing height is the depth of the atmosphere adjacent to the surface within which air is mixed.

Table 7.1. Emission point parameters and receptor locations used in the dose calculations

Source	Stack height (m)	Stack diameter (m)	Effective exit gas velocity (m/s) [a]	Distance (m) and direction to the maximally exposed individual			
				Plant maximum		Oak Ridge Reservation maximum	
Oak Ridge National Laboratory							
X-1000 Lab Hoods	15	0.5	0	4350	SW	4350	SW
X-2000 Lab Hoods	15	0.5	0	4770	SW	4770	SW
X-3000 Lab Hoods	15	0.5	0	5100	SW	5100	SW
X-4000 Lab Hoods	15	0.5	0	5270	SW	5270	SW
X-6000 Lab Hoods	15	0.5	0	5850	SW	5850	SW
X-7000 Lab Hoods	15	0.5	0	5290	WSW	5290	WSW
X-2026	22.9	1.05	7.42	4820	SW	4820	SW
X-2099	3.66	0.18	19.03	4810	SW	4810	SW
X-3018	61	1.75	0.95	5030	SW	5030	SW
X-3020	61	1.22	15.05	4970	SW	4970	SW
X-3039	76.2	2.44	6.39	5060	SW	5060	SW
X-3544	9.53	0.279	24.05	4810	SW	4810	SW
X-3608 Air Stripper	10.97	2.44	0.57	4930	SW	4930	SW
X-3608 Filter Press	8.99	0.36	9.27	4930	SW	4930	SW
X-5505M	11	0.305	2.54	5560	SW	5560	SW
X-5505NS	11	0.96	0	5560	SW	5560	SW
X-7503	30.5	0.91	12.85	5330	SW	5330	SW
X-7830 Group	4.6	0.25	7.67	3920	WSW	3920	WSW
X-7856-CIP	18.29	0.48	11.05	3970	WSW	3970	WSW
X-7877	13.9	0.41	13.56	3890	WSW	3890	WSW
X-7880	27.7	1.52	15.62	3860	WSW	3860	WSW
X-7911	76.2	1.52	14.38	5240	WSW	5240	WSW
X-7935 Building Stack	15.24	0.51	26.85	5250	SW	5250	SW
X-7935 Glove Box	9.14	0.25	0	5250	SW	5250	SW
X-7966	6.10	0.29	9.62	5330	SW	5330	SW
X-8915	104.0	1.22	6.68	8060	SW	8060	SW
X-Decon Areas	15	0.5	0	5310	SW	5310	SW
X-STP	7.6	0.203	7.39	4590	SW	4590	SW

Table 7.1 (continued)

Source ID	Stack height (m)	Stack diameter (m)	Effective exit gas velocity (m/s) [a]	Distance (m) and direction to the maximally exposed individual			
				Plant maximum		Oak Ridge Reservation maximum	
East Tennessee Technology Park							
K-1407-AL CWTS	2.74	0.15	0	460	WSW	5710	SSE
K-2500-H-B	8.23	0.61	12.9	550	SE	6350	SE
K-2500-H-C	8.23	0.61	12.9	550	SE	6340	SE
K-2500-H-D	8.23	0.91	12.9	520	SE	6320	SE
Y-12 National Security Complex							
Y-Monitored	20	0.5	0	2270	NE	13340	SW
Y-Unmonitored Processes	20	0.5	0	2270	NE	13340	SW
Y-Unmonitored Lab Hoods	20	0.5	0	2270	NE	13340	SW

[a] Exit gas temperatures are "ambient air" unless noted otherwise.

Acronyms

CIP = Capacity Increase Project
CWTS = Chromium Water Treatment System
STP = Sewage Treatment Plant

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 the 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

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- A, B, C, and D
		Oak Ridge National Laboratory
MT4 (Tow A)	15	X-7830, x-7935 Glove Box, X 7966,and X-7000 Lab Hoods
	30	X-7503, X-7856-CIP, X-7877, X-7880, X-7911, X-7935 Building
MT3 (Tow B)	15	X-5505, X-6000 Lab Hoods
MT2 (Tow D)	15	X-2099, X-3544, X-3608 FP, X-3608 AS, STP, X-Decon 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
ORNL = Oak Ridge National Laboratory
STP = Sewage Treatment Plant

7.1.2.1.1 Results

Calculated EDs from radionuclides emitted to the atmosphere from the ORR are listed in Table 7.3 (maximum individual) and Table 7.4 (collective). The hypothetical maximally exposed individual for the ORR was located about 13,340 m southwest of the main Y-12 release point, about 5,240 m west-southwest of the 7911 stack at ORNL, and about 5,710 m south-southeast of the K-1407-AL Chromium Water Treatment System (CWTS) at ETTP. This individual could have received an ED of about 0.2 mrem, which is well below the National Emission Standards for Hazardous Air Pollutants for Radionuclides standard of 10 mrem and is about 0.7% of the roughly 300 mrem that the average individual receives from natural sources of radiation. Based on the 2010 population census data, the calculated collective ED to the entire population within 80 km (50 miles) of the ORR (about 1,172,530 persons) was about 6.4 person-rem, which is about 0.002% 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 2016 to calculate both individual and collective doses. Due to improved time-in-flight calculations (implementation of full chain decay of isotopes in flight for each sector), collective doses associated with short-lived radionuclides are lower than would have been calculated using CAP-88 PC Version 3 (EPA 2015).

Table 7.3. Calculated radiation doses to maximally exposed off-site individuals from airborne releases, 2016

Plant	Effective dose, mrem (mSv)	
	At plant maximum	At Oak Ridge Reservation maximum
Oak Ridge National Laboratory	0.2 (0.002)[a]	0.2 (0.002)
East Tennessee Technology Park	0.004(0.00004)[b]	9×10^{-6} (9×10^{-8})
Y-12 National Security Complex	0.04 (0.0004)[c]	0.004 (0.00004)
Entire Oak Ridge Reservation	*d*	0.2 (0.002)[e]

[a]The maximally exposed individual was located 5,060 m SW of X-3039 and 5,240 m WSW of X-7911.
[b]The maximally exposed individual was located 460 m WSW of K-1407-AL Chromium Water Treatment System.
[c]The maximally exposed individual was located 2,270 m NE of the Y-12 National Security Complex release point.
[d]Not applicable.
[e]The maximally exposed individual for the entire Oak Ridge Reservation is also the Oak Ridge National Laboratory maximally exposed individual.

Table 7.4. Calculated collective effective doses from airborne releases, 2016

Plant	Collective effective dose[a]	
	Person-rem	Person-Sv
Oak Ridge National Laboratory	5.7	0.057
East Tennessee Technology Park	0.0003	3×10^{-6}
Y-12 National Security Complex	0.7	0.007
Entire Oak Ridge Reservation	6.4	0.064

[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 maximally exposed individual for the Y-12 Complex was located at a residence about 2,272 m (1.4 miles) northeast of the main Y-12 release point. This individual could have received an ED of about 0.04 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 97%, and technetium-99 (^{99}Tc) accounted for about 1.6% of the dose (Fig. 7.1). The contribution of Y-12 emissions to the 50-year committed collective ED to the population residing within 80 km (50 miles) of the ORR was calculated to be about 0.7 person-rem, which is about 11% of the collective ED for the ORR.

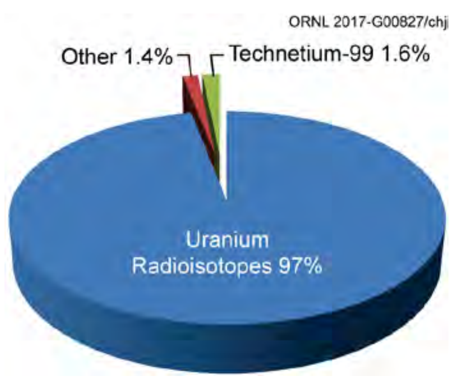

Fig. 7.1. Nuclides contributing to the effective dose at the Y-12 National Security Complex.

The maximally exposed individual 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 ^{11}C (34%), ^{234}U (21%), and ^{212}Pb (18%) (Fig. 7.2). The total contribution from uranium radioisotopes (i.e., ^{232}U, ^{233}U, ^{234}U, ^{235}U, ^{236}U, and ^{238}U) accounted for about 25% of the dose, and ^{234}U contributed about 21% of the dose. The contribution of ORNL emissions to the collective ED to the population residing within 80 km (50 miles) of the ORR was calculated to be about 5.7 person-rem or about 90% of the collective ED for the ORR.

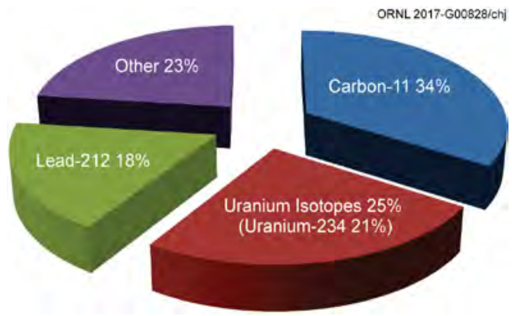

Fig. 7.2. Nuclides contributing to effective dose at Oak Ridge National Laboratory.

The maximally exposed individual for ETTP was located at a business about 460 m (0.3 miles) west southwest of the K-1407-AL CWTS. The ED received by this individual from airborne emissions was calculated to be about 0.0004 mrem. About 90% of the dose is from uranium radioisotopes (^{234}U, ^{235}U, ^{236}U, and ^{238}U), and 7% of the dose is from ^{99}Tc (Fig. 7.3). The contribution of ETTP emissions to the collective ED to the population residing within 80 km (50 miles) of the ORR was calculated to be about 0.0003 person-rem, or about 0.005% of the collective ED for the reservation.

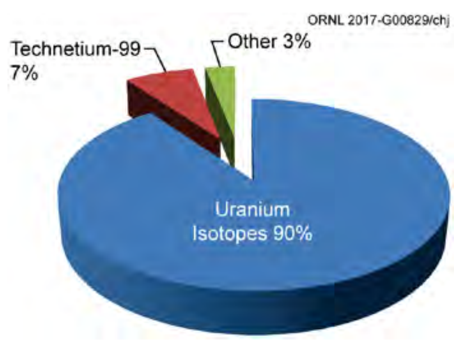

Fig. 7.3. Nuclides contributing to effective dose at East Tennessee Technology Park.

The reasonableness of the estimated doses can be inferred by comparing EDs calculated at the ORR perimeter area monitoring (PAM) stations from measured air concentrations of radionuclides, excluding naturally occurring ^{7}Be and ^{40}K, with air concentrations calculated using CAP-88 PC Version 4 and emissions data (Table 7.5). Based on measured air concentrations, hypothetical individuals assumed to reside at AAM1 and PAM stations 35–49 could have received EDs between 0.007 and 0.04 mrem/year. Based on emissions data using CAP-88 PC Version 4, the above individuals could have received EDs between 0.04 and 0.2 mrem/year. As shown in Table 7.5, EDs calculated using CAP-88 PC Version 4 and emissions data tend to be greater than or equivalent to EDs calculated using measured air concentrations.

Table 7.5. Hypothetical effective doses from living near the Oak Ridge Reservation, Oak Ridge National Laboratory, and the East Tennessee Technology Park ambient air monitoring stations, 2016

Station	Calculated effective doses			
	Using air monitor data		Using CAP-88[a] and emission data	
	mrem/year	mSv/year	mrem/year	mSv/year
1	0.02	0.0002	0.2	0.002
35	0.02	0.0002	0.04	0.0004
37	0.007	0.00007	0.08	0.0008
38	0.009	0.00009	0.02	0.0002
39	0.02	0.0004	0.2	0.002
40	0.01	0.0001	0.2	0.002
42	0.04	0.0002	0.02	0.0002
46	0.02	0.0002	0.1	0.001
48	0.009	0.00009	0.2	0.002
49	0.02	0.0002	0.09	0.0009
52	0.008	0.00008	0.009	0.00009
K2	0.05	0.0005	0.04	0.0004
K6	0.05	0.0005	0.02	0.0002
K11	0.03	0.0003	0.02	0.0002
K12	0.07	0.0007	0.02	0.0002

[a]CAP-88 PC Version 4 software, developed under US Environmental Protection Agency sponsorship to demonstrate compliance with 40 CFR 61, Subpart H.

Station 52, located remotely from the ORR, gives an indication of potential EDs from background sources. Based on measured air concentrations, the ED was estimated to be 0.008 mrem/year (the isotopes ^{7}Be and ^{40}K were not included in the background air monitoring station calculation), whereas the estimated ED based on calculated air concentrations using CAP-88 PC Version 4 was estimated to be 0.009 mrem/year. The measured air concentrations of ^{7}Be were similar at the PAM stations and at the background air monitoring station.

Of particular interest is a comparison of EDs calculated using measured air concentrations of radionuclides at PAM stations located near the maximally exposed individuals for each plant and EDs calculated for those individuals using source emissions data. K11 station is located near the on-site maximally exposed individual for ETTP. The ED calculated with measured air concentrations was 0.03 mrem/year, which is comparable to the ED of 0.02 mrem/year estimated using source emissions data. PAM station 46 is located near the off-site maximally exposed individual for the Y-12 Complex, and the ED calculated with measured air concentrations was 0.02 mrem/year, which is considerably less than the ED of 0.1 mrem/year estimated using source emissions data.

7.1.2.2 Waterborne Radionuclides

Radionuclides discharged to surface waters from the ORR enter the Tennessee River system by way of the Clinch River (see Section 1.3.4 for the surface water setting of the ORR). Discharges from Y-12 enter the Clinch River via Bear Creek and East Fork Poplar Creek (EFPC), both of which enter Poplar Creek

before it enters the Clinch River, and by 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 the ORR are divided into seven segments:

1. Melton Hill Lake above all possible ORR inputs,
2. Melton Hill Lake,
3. Upper Clinch River (from Melton Hill Dam to confluence with Poplar Creek),
4. Lower Clinch River (from confluence with Poplar Creek to confluence with the Tennessee River),
5. Upper Watts Bar Lake (from near the confluence of the Clinch and Tennessee Rivers to below Kingston),
6. the lower system (the remainder of Watts Bar Lake and Chickamauga Lake to Chattanooga), and
7. 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, 6.5, and 6.7). 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. 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 the 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 (1) that most radionuclides discharged from the ORR will be quantified and (2) 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.

In 2016, analyses of surface water samples collected for ORR-wide surveillance at Clinch River kilometers (CRKs) 66, 58, 32, 23, and 16 was transitioned from a commercial laboratory to the ORNL Radioactive Materials Analytical Laboratory (RMAL). Following the transition, reported concentrations radionuclides were higher than those typically reported by the commercial laboratory. The major reasons for the increases are thought to be the result of higher radiation background in the RMAL counting laboratory, cross-contamination found in RMAL laboratory equipment, and the contributions of naturally occurring short-lived radionuclides that likely decayed significantly during transport to commercial laboratories. Corrective actions have been identified and implemented to address these issues.

In 2016, surface water samples were also collected at CRKs 23 and 16 for ETTP site-specific monitoring. The results from these samples were used in dose calculations instead of those obtained via the ORR-wide program to reduce bias from the higher laboratory backgrounds and cross-contamination.

7.1.2.2.1 Drinking Water Consumption

Surface Water

Several 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; all of the dose estimates given below 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 maximally exposed individual is 680 L/year (180 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 2016, 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.

- **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 maximally exposed individual drinking water at this location could have received an ED of about 0.09 mrem. The collective ED to the 48,042 persons who drink water from the City of Oak Ridge water plant would be 2.0 person-rem.

- **Melton Hill Lake.** The only water treatment plant located on Melton Hill Lake that could be affected by discharges from the ORR is a Knox County plant. This plant is located near surface water sampling location CRK 58. A maximally exposed individual could have received an ED of about 0.09 mrem; the collective dose to the 63,779 persons who drink water from this plant could have been 2.7 person-rem.

- **Upper Clinch River.** The ETTP (Gallaher) water plant, which drew water from the Clinch River near CRK 23 was deactivated; 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 very far from its confluence with the Clinch River. A maximally exposed individual could have received an ED of about 0.03 mrem. The collective dose to the 30,355 persons who drink water from these plants could have been about 0.5 person-rem.

- **Lower system.** Several water treatment plants are located on tributaries of Watts Bar Lake and Chickamauga Lake. Persons drinking water from these plants could not have received EDs greater than the 0.03 mrem calculated for drinking water from the Kingston or Rockwood municipal water plants. The collective dose to the 311,223 persons who drink water within the lower system could have been about 3.4 person-rem.

- **Poplar Creek/Lower EFPC.** No drinking water intakes are located on Poplar Creek or 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 through FY 2016, 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 2016 Remediation Effectiveness Report for the U.S. Department of Energy (DOE 2016). Currently, no water is consumed from these off-site groundwater wells.

7.1.2.2.2 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 2016. For the average person used for collective dose calculations, it was assumed that 11 kg (24 lb) of fish was consumed in 2016. 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 EDs estimated by both methods, in each of the surface water segments, are provided in Appendix E. The number of individuals who could have eaten fish is based on lake creel surveys conducted annually by the Tennessee Wildlife Resources Agency (TWRA 2016).

- **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 0.04 mrem. This dose was estimated from a composite fish sample collected near CRK 70, and a major contributor to dose was ^{90}Sr. The collective ED to the 25 persons who could have eaten such fish was about 4×10^{-4} person-rem.

- **Melton Hill Lake.** An avid fish consumer who ate fish from Melton Hill Lake could have received an ED of about 1.3 mrem. The collective ED to the 222 persons who could have eaten such fish could be about 0.1 person-rem.

- **Upper Clinch River.** An avid fish consumer who ate fish from the upper Clinch River could have received an ED of about 1.3 mrem. The collective ED to the 365 persons who could have eaten such fish could have been about 0.2 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 1.3 mrem. The collective ED to the 853 persons who could have eaten such fish could have been about 0.4 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 0.2 mrem. The collective ED to the 2,436 persons who could have eaten such fish could be about 0.2 person-rem.

- **Lower System.** An avid fish consumer who ate fish from the lower system could have received an ED of about 0.2 mrem. The collective ED to the about 18,873 persons who could have eaten such fish could have been about 1.5 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 0.2 mrem. Assuming that 100 people could have eaten fish from lower EFPC and from Poplar Creek, the collective ED could have been about 0.01 person-rem.

7.1.2.2.3 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. At all locations in 2016, the estimated maximally exposed individual EDs were based on measured off-site surface water radionuclide concentrations and excluded naturally occurring radionuclides such as ^{7}Be and ^{40}K.

The number of individuals who could have been other users is different for each section of water because the data sources differ. For Watts Bar parts (upper Clinch River through lower Watts Bar), the assumption for other users is five times the number of people who harvest fish. For Chickamauga and Melton Hill, the number for other users is based on surveys conducted by the Tennessee Valley Authority.

- **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 7×10^{-7} mrem. The collective ED to the 19,643 other users could have been 2×10^{-6} person-rem.

- **Melton Hill Lake.** An individual other user of Melton Hill Lake could have received an ED of about 0.01 mrem. The collective ED to the 52,085 other users could have been about 0.06 person-rem.

- **Upper Clinch River.** An individual other user of the upper Clinch River could have received an ED of about 0.007 mrem. The collective ED to the 9,322 other users could have been about 0.01 person-rem.

- **Lower Clinch River.** An individual other user of the lower Clinch River could have received an ED of about 0.007 mrem. The collective ED to the 10,875 other users could have been about 0.02 person-rem.

- **Upper Watts Bar Lake.** An individual other user of upper Watts Bar Lake could have received an ED of about 0.002 mrem. The collective ED to the 31,072 other users could have been about 0.02 person-rem.

- **Lower system.** An individual other user of the lower system could have received an ED of about 0.002 mrem. The collective ED to the 693,978 other users could have been about 0.1 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 1×10^{-5} mrem. The collective ED to the 200 other users of Poplar Creek and Lower EFPC could have been about 4×10^{-8} person-rem.

7.1.2.2.4 Irrigation

Although there are no known locations that use water from water bodies around the ORR to irrigate food or feed crops, it was decided to determine whether irrigation could contribute to radiation doses to one or

more members of the public. To make this determination, the method described by the Nuclear Regulatory Commission (NRC 1977) was used. Cross-contamination in analytical equipment used to quantify radionuclides in ORR-wide surface water samples from CRKs 66, 58, 32,23, and 16 led to biased results for several 2016 sampling events. However, sampling was also performed at CRK 23 and CRK 16 for ETTP site-specific monitoring. To reduce bias in dose calculations, the results from the ETTP program sampling at CRKs 23 and 16 were used instead of those obtained via the ORR program. Based on measured and calculated concentrations of radionuclides at CRK 16, which is a location on the lower Clinch River and downstream of the ORR, the maximum potential dose (excluding the naturally occurring radionuclides ^{7}Be and ^{40}K) to an individual due to irrigation ranged from 7×10^{-10} to 0.05 mrem in 2016. 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.

7.1.2.2.5 Summary

Table 7.6 is a summary of potential EDs from identified waterborne radionuclides around the 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 on Melton Hill Reservoir/Clinch River. The maximum collective ED to the 80 km (50 mile) population could be as high as 11 person-rem. These are small percentages of individual and collective doses attributable to natural background radiation, about 0.4% of the average individual background dose of roughly 300 mrem/year and 0.003% 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 (EDs) from waterborne radionuclides, 2016[a,b]

	Drinking water	Eating fish	Other uses	Total[c]
Upstream of all Oak Ridge Reservation discharge locations (CRK 66, City of Oak Ridge Water Plant)				
Individual ED	0.09	0.04	7×10^{-7}	0.1
Collective ED	2.0	4×10^{-4}	2×10^{-6}	2.0
Melton Hill Lake (CRK 58, Knox County Water Plant)				
Individual ED	0.09	1.3	0.01	1.4
Collective ED	2.7	0.1	0.06	2.8
Upper Clinch River (CRK 23,32)				
Individual ED	NA[d]	1.3	0.007	1.3
Collective ED	NA[d]	0.2	0.01	0.2
Lower Clinch River (CRK 16)				
Individual ED	NA[d]	1.3	0.007	1.3
Collective ED	NA[d]	0.4	0.02	0.5
Upper Watts Bar Lake, Kingston Municipal Water Plant				
Individual ED	0.03	0.2	0.002	0.3
Collective ED	0.5	0.2	0.02	0.7
Lower system (Lower Watts Bar Lake and Chickamauga Lake)				
Individual ED	0.03	0.2	0.002	0.2
Collective ED	3.4	1.5	0.1	5

Table 7.6 (continued)

	Drinking water	Eating fish	Other uses	Total[c]
	Lower East Fork Poplar Creek and Poplar Creek			
Individual ED	NA[d]	0.2	1×10^{-5}	0.2
Collective ED	NA[d]	0.01	4×10^{-8}	0.01

[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. However, some environmental media, including milk and vegetables, are sampled as part of the surveillance program. The following dose estimates are based on environmental sampling results and may include contributions from radionuclides occurring in the natural environment, released from the ORR, or both.

7.1.2.4 Food

7.1.2.4.1 Milk

During 2016, milk samples were collected from a nearby dairy (in Claxton, Tennessee) and from a reference location in Maryville. Based on a nationwide food consumption survey (EPA 2011), a hypothetical person (weighted based on the combined population of Anderson, Knox, Loudon, and Roane counties) who drank milk was assumed to have consumed a maximum of about 321 L (85 gal) of milk annually. Statistically significant concentrations of ^{40}K were detected in all samples from the nearby dairy and reference location. Annual EDs attributable to ^{40}K found in dairy and composite samples were estimated to be about 13 mrem. The naturally occurring radionuclide ^{40}K was excluded. The doses associated with tritium and strontium were estimated to be 0.04 mrem for the Claxton dairy and 0 mrem for the reference location.

7.1.2.4.2 Vegetables

The food-crop sampling program is described in Chapter 6. Samples of tomatoes and lettuce were obtained from six gardens, five local and one distant. In 2016, turnip samples were not available from these gardens. These vegetables represent fruit-bearing and leafy vegetables. All radionuclides detected in the food crops can be found in the natural environment, and all but ^{7}Be and ^{40}K also may also have originated from activities or facilities on the ORR. Dose estimates are based on hypothetical consumption rates of vegetables that contain statistically significant amounts of detected radionuclides that could have come from the ORR. Based on a nationwide food consumption survey (EPA 2011), a hypothetical home gardener (weighted based on the combined population of Anderson, Knox, Loudon, and Roane counties) was assumed to have eaten a maximum of about 72 kg (158 lb) of homegrown tomatoes and 24 kg (53 lb) of homegrown lettuce. The hypothetical gardener could have received a 50-year committed ED of between 0.05 and 0.07 mrem, depending on garden location. Of this total, between 0.03 and 0.05 mrem could have come from eating tomatoes and between 0.01 and 0.02 mrem from eating lettuce. The highest

dose to a gardener could have been about 0.07 mrem from consuming both types of homegrown vegetables. A person eating food from the distant (background) garden could have received a committed ED of 0.1 mrem from consumption of both vegetables.

An example of a naturally occurring and fertilizer-introduced radionuclide is ^{40}K, which is specifically identified in the samples and accounts for most of the beta activity found in them. The presence of ^{40}K in the samples adds, on average, about 8 mrem to the hypothetical home gardener's ED. In 2016, the gardeners were asked about water sources and fertilizers used, and it was reported for tomatoes, none irrigated or used fertilizers. For lettuce, most did not irrigate and did not use fertilizers. One lettuce gardener irrigated with river water and also fertilized; another used mushroom dirt. It is believed ^{40}K and most of the excess unidentified alpha activities are due to naturally occurring radionuclides, not radionuclides discharged from the ORR.

7.1.2.4.3 Hay

Another environmental pathway that was evaluated was eating beef and drinking milk obtained from hypothetical cows that ate hay harvested from one location on the ORR. Statistically significant concentrations of ^{7}Be, ^{40}K, 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 0.0009 mrem.

7.1.2.4.4 White-Tailed Deer

TWRA conducted three 2-day deer hunts during 2016 on the Oak Ridge Wildlife Management Area, which is part of the ORR (see Chapter 6). During the hunts, 361 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 wildlife release criteria [less than net counts not greater than 1½ times background (~20 pCi/g $^{89/90}Sr$) of beta activity in bone or 5 pCi/g of ^{137}Cs in edible tissue]. Two deer exceeded the limit for beta-particle activity in bone and were retained. The remaining 359 deer were released to the hunters.

The average ^{137}Cs concentration in muscle tissue of the 359 released deer, as determined by field counting, was 0.4 pCi/g; the maximum ^{137}Cs concentration in released deer was 0.7 pCi/g. Most of the ^{137}Cs concentrations were less than minimum detectable levels. The average weight of released deer was approximately 40 kg (88 lb); the maximum weight was 81 kg (179 lb). The EDs attributed to field-measured ^{137}Cs concentrations and actual field weights of the released deer ranged from about 0.005 to 1.1 mrem, with an average of about 0.4 mrem.

Potential doses attributed to deer that might have moved off the ORR and been harvested elsewhere were also evaluated. In this scenario, an individual who consumed one hypothetical average-weight 40 kg (88 lb) deer (assuming 55% field weight is edible meat) containing the 2016 average field-measured concentration of ^{137}Cs (0.4 pCi/g) could have received an ED of about 0.5 mrem. The maximum field-measured ^{137}Cs concentration was 0.7 pCi/g, and the maximum deer weight was 81 kg (179 lb). A hunter who consumed a hypothetical deer of maximum weight and ^{137}Cs content could have received an ED of about 1 mrem.

Muscle tissue samples collected in 2016 from 10 deer (8 released and 2 retained) 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. In one case, the field concentration may have been slightly lower than the

analytical concentration; however, the analytical value was less than the minimum detectable activity. Using analytically measured ^{137}Cs and ^{90}Sr (excluding ^{40}K, a naturally occurring radionuclide) and actual deer weights, the estimated doses for the eight released deer ranged from 0 to 0.4 mrem. The highest estimated dose for a human consuming the retained deer would have been 0.5 mrem.

The maximum ED to an individual consuming venison from two or three deer was also evaluated. Twenty-eight hunters harvested either two or three deer from the 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 0.2 and 1.2 mrem.

The collective ED from eating all the harvested venison from the ORR with a 2016 average field-derived ^{137}Cs concentration of 0.4 pCi/g and an average weight of 40 kg (88 lb) is estimated to be about 0.2 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.

7.1.2.4.5 Canada Geese

Fifty geese (20 adults and 30 goslings) were captured during the 2016 goose roundup. Twenty-seven geese (20 adults, 7 goslings) were subjected to live whole-body gamma scans. The geese were field-counted for radioactivity to ensure that they met wildlife release criteria (< 5 pCi/g of ^{137}Cs in tissue). The average ^{137}Cs concentration was 0.24 pCi/g, with a maximum ^{137}Cs concentration in the released geese of 0.7 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 3.5 kg (7.7 lb), and the maximum weight was about 5.1 kg (11.3 lb).

The EDs attributed to field-measured ^{137}Cs concentrations and actual field weights of the geese ranged from 0.007 to 0.02 mrem. However, for bounding purposes, if a person consumed a released goose with an average weight of 3.5 kg (7.7 lb) and an average ^{137}Cs concentration of 0.24 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 0.7 pCi/g and maximum weight of 5.1 kg (11.3 lb) is about 0.08 mrem.

It is possible that a person could eat more than one goose that spent time on the 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). If one person consumed two hypothetical geese of maximum weight with the highest measured concentration of ^{137}Cs, that person could have received an ED of about 0.2 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).

7.1.2.4.6 Eastern Wild Turkey

Participating hunters are allowed to harvest one turkey from the reservation in a given season unless a harvested turkey is retained, in which case, the hunter is allowed to hunt for another turkey. Two wild turkey hunts took place on the reservation in 2016: April 9–10 and April 16–17. Twenty-seven male turkeys were harvested during that time frame; no harvested turkeys were retained. In addition, two

turkeys were harvested October 29 during the deer hunts, and neither was retained. The average ^{137}Cs concentration measured in the released turkeys was 0.1 pCi/g, and the maximum ^{137}Cs concentration was 0.2 pCi/g. All of the ^{137}Cs concentrations were below minimum detectable activity levels. The average weight of the released turkeys was about 8.1 kg (17.8 lb). The maximum turkey weight was about 10.7 kg (23.6 lb).

The EDs attributed to the field-measured ^{137}Cs concentrations and the actual field weights of the released turkeys ranged from about 0.02 to 0.03 mrem with an average dose of 0.02 mrem. Potential doses were also evaluated for turkeys that might have moved off the ORR and were then harvested elsewhere. In that scenario, if a person consumed a wild turkey with an average weight of 8.1 kg (17.8 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 0.2 pCi/g and the maximum weight of 10.7 kg (23.6 lb) was about 0.05 mrem. It is assumed that approximately half the weight of a wild turkey is edible. No tissue samples were analyzed in 2016.

The collective ED from consuming all the harvested wild turkey meat (29 birds) with an average field-derived ^{137}Cs concentration of 0.1 pCi/g and an average weight of 8.2 kg (18.1 lb) is estimated to be about 0.0006 person-rem. The collective dose is based on number of hunters that harvested turkey. 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).

7.1.2.5 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 the 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 colocated with ORR ambient air stations. In 2016, exposure rates averaged about 10.7 μR/h and ranged from 9.0 to 16 μR/h. These exposure rates correspond to an annual average dose of about 65 mrem with a range of 55 to 98 mrem. At the remote PAM station, the exposure rate averaged about 9.7 μR/h and ranged from 8 to 11 μR/h. The resulting average annual dose was about 59 mrem with a range of 49 to 70 mrem. The annual dose based on measured exposure rates at or near the 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 7.7. In the unlikely event that any person was irradiated by all of those sources and pathways for the duration of 2016, that person could have received a total ED of about 2 mrem. Of that total, 0.2 mrem would have come from airborne emissions and approximately 0.3 mrem from waterborne emissions (0.09 mrem from drinking water, 1 mrem from consuming fish, 0.01 mrem from other water uses along the Clinch River, and 0.05 mrem from irrigation at CRK16) and about 1 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 the ORR other than those reported.

Table 7.7. Summary of maximum estimated effective doses to an adult by exposure pathway

Pathway	Dose to maximally exposed individual		Percentage of DOE mrem/year limit (%)	Estimated collective dose		Population within 80 km	Estimated background radiation collective dose (person-rem)[a]
	mrem	mSv		person-rem	person-Sv		
				Airborne effluents			
All pathways	0.2	0.002	0.2	6.4	0.064	1,172,530[b]	
				Liquid effluents			
Drinking water	0.09	0.0009	0.09	8.5	0.085	453,399[c]	
Eating fish	1	0.01	1	2.4	0.024	22,974[d]	
Other activities	0.01	0.0001	0.001	0.2	0.002	816,975[d]	
Irrigation	0.05	0.005	0.05				
				Other Pathways			
Eating deer	1[e]	0.01	1	0.2	0.002	359	
Eating geese	0.2[f]	0.0008	0.08	*g*	*g*		
Eating turkey	0.05[h]	0.0005	0.05	0.0006	0.000006	29	
Direct radiation	NA[i]	NA					
All pathways	**3**	**0.003**	**3**	**18**	**0.18**	**1,172,530**	**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 the Tennessee Department of Environment and Conservation, Division of Water.
[d]Population estimates based on population within 80 km (50 miles) and fraction of fish harvested from Melton Hill, Watts Bar, and Chickamauga reservoirs. Melton Hill and Chickamauga recreational use information was obtained from the Tennessee Valley Authority (Stephens et al. 2006 and Stephens et al. 2007). These populations should not be added together since a member of the each population associated with one activity may also be included in the population of other activities (e.g, fishing and boating).
[e]From 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 ORR; collective dose based on number of hunters that harvested deer.
[f]From 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 since no geese were harvested for consumption during the goose roundup.
[h]From 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.

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 the ORR. If the maximally exposed individual did not consume wildlife harvested from the ORR, the estimated dose would be about 2 mrem. DOE O 458.1 limits the ED that an individual may receive from all exposure pathways from all radionuclides released from the ORR during 1 year to no more than 100 mrem. The 2016 maximum ED should not have exceeded about 3 mrem, or about 3% of the limit given in DOE O 458.1. (For further information, see Appendix E, which summarize dose levels associated with a wide range of activities.)

The total collective ED to the population living within an 80 km (50 mile) radius of the ORR was estimated to be about 18 person-rem. This dose is about 0.005% of the 363,484 person-rem that this population received from natural sources during 2016.

7.1.4 Five-Year Trends

EDs associated with selected exposure pathways for the years 2012 to 2016 are given in Table 7.8. In 2016, the air pathway dose decreased somewhat due to taking into account terrain height for SNS, since it is located on a ridge above most of the ORR. The 2016 dose from fish consumption is comparable to the doses estimated in 2013 and 2014. The primary contributor to dose from fish consumption was ^{137}Cs associated with samples collected at CRK 58, which is upstream from most ORR discharges. In 2016, there 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. 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. 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. There was a decrease in drinking water dose in 2014, but the doses in 2016 are comparable to earlier estimated doses. Recent direct radiation measurements along the Clinch River 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 decrease in dose from consumption of venison in 2015 and 2016.

Table 7.8. Trends in effective dose (mrem)[a]

Pathway	2012	2013	2014	2015	2016
Air pathway (all routes)	0.3	0.4	0.6	0.4	0.2
Surface water pathway					
Fish consumption (Clinch River)	0.08	1.5	1.2	0.03	1.3
Drinking water (Kingston)	0.02	0.01	0.003	0.02	0.03
Wildlife consumption					
Deer	2	2	2	1	1
Geese	0.1	0.1	0.1	0.08	0.2
Turkey	0.06	0.08	0.04	0.05	0.05

[a] 1 mrem = 0.01 mSv.

7.1.5 Potential Contributions from Non-DOE Sources

DOE O 458.1 (DOE 2011) requires that if the 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 2016, the 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 the ORR that could contribute radiation doses to the public. Eight facilities responded to the DOE request. Three facilities used COMPLY, a computerized screening tool for evaluating radiation exposure from atmospheric releases of radionuclides (EPA 2016). One facility reported annual doses from airborne emissions of 2.96×10^{-6} mrem at 30 m, one facility reported an annual dose of 0.26 mrem at fence line, and the other facility reported an annual dose < 10 mrem (COMPLY, level 1). Three non-DOE facilities reported liquid discharges that met license criteria. Doses from direct radiation ranged from none to an annual dose of

25 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 the 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 the 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 considered to 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 and sediment concentrations [Melton Branch, WOC, and White Oak Dam (WOD)] at the following instream sampling locations.

- Melton Branch [Melton Branch (X13)]
- WOC [WOC headwaters, WOC (X14), and WOD (X15)]
- First Creek
- Fifth Creek
- Northwest Tributary
- Clinch River CRKs 16 and 23

All locations, except WOD (X15) and CRK 23, passed the general screening phase (comparison of maximum radionuclide water concentrations to default BCGs). White Oak Dam (X15) and CRK 23 passed when average radionuclide water concentrations were compared to default BCGs. This resulted in absorbed dose rates to aquatic organisms below the DOE aquatic dose limit of 1 rad/day at all of 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 the DOE aquatic dose limit of 1 rad/day at all of 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 the DOE aquatic dose limit of 1 rad/day at all of 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 was 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 the ORR. 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 were collected in similar locations as in 2007. With the exception of samples collected on the WOC floodplain (collected on the WOC floodplain upstream from WOD), samples taken 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 7.9). 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 maximally exposed individual is 680 L/year (180 gal/year). 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 7.9, 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 slightly less than 10^{-5} was calculated for the intake of mercury in water collected at CRK 16.

Table 7.9. Chemical hazard quotients and estimated risks for drinking water, 2016

Chemical	Hazard quotient
	CRK 16[a]
Metals	
Antimony	0.01
Arsenic	0.05
Lead	0.1
Mercury	0.0006
Uranium	0.003
Zinc	0.0009
Risk for carcinogens	
Arsenic	9×10^{-6}

[a]Clinch River downstream of all US Department of Energy inputs.

Acronyms
CRK = Clinch River kilometer.

7.2.1.2 Groundwater

As discussed in Section 7.1.2.2.1, 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 2016. Data are summarized in *2016 Remediation Effectiveness Report for the U.S. Department of Energy* (DOE 2016).

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 the 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 2016. 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 7.10, 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 Aroclor-1260 in sunfish and catfish collected at all three locations. 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 has issued a precautionary fish consumption advisory for catfish in the Clinch River arm of Watts Bar Reservoir (TWRA 2012).

Table 7.10. Chemical hazard quotients and estimated risks for carcinogens in fish, 2016[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						
Antimony	0.3	0.2	0.5	0.2	0.4	0.3
Barium	0.0001	0.0001	0.0002	0.007	0.001	0.003
Cadmium	0.03			0.03		
Chromium	0.02	0.03	0.03	0.1	0.04	0.08
Manganese	0.003	0.002	0.003	0.07	0.01	0.03
Mercury	0.09	0.5	0.2	0.03	0.09	0.2
Nickel	0.002	0.002	0.002	0.001	0.001	0.002
Selenium	0.2	0.2	0.2	0.3	0.3	0.4
Strontium	0.0002	0.0002	0.00007	0.02	0.003	0.008
Thallium	0.05	0.06	0.02	0.08	0.1	0.09
Uranium	0.0002	0.0002	0.001	0.0007	0.0002	0.0004
Vanadium	0.003			0.004		
Zinc		0.03	0.02	0.06	0.06	0.06
Hazard quotients for pesticides and Aroclors						
Aroclor-1260	2	15	11	8	1	2
Risks for carcinogens						
Aroclor-1260	4E-5	3E-4	2E-4	1E-4	2E-5	3E-5
PCBs (mixed)[e]	4E-5	3E-4	2E-4	1E-4	2E-5	3E-5

[a]A blank space for a particular location indicates that the parameter was undetected.
[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

7.3 References

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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 O 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 of its sites (remediation) 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 and micrograms per kg.

parts per million (ppm)—A unit measure of concentration equivalent to the weight/volume ratio expressed as milligrams per liter or milligrams per kg.

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—**Stormwater runoff** is 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 government's program to clean up the nation's uncontrolled hazardous waste, is now commonly 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 ground water 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 in which statistical information concerning direction and speed of the wind at a location is summarized.

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 are most frequent during spring, very infrequent during winter, but can occur at any time of the year. 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.

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 the 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 the ORR (Kossman and Sturman 2002).

Forced channeling within the Central Great Valley represents the dominant large-scale wind mechanism, influencing 50% to 60% 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 (> 90% 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% 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 (> 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 the ORR, winds dominated by down-valley pressure-driven channeling range in frequency from 2% to 10%, 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% 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 the ORR when compared to other parts of the Great Valley (Birdwell 2011). Most pressure-driven channeled winds occurred in association with moderate synoptic pressure gradients (0.006–0.016 mb/km).

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, and/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% to 20% 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 2016 for each of the nine DOE-managed ORR meteorological towers (towers MT1, MT2, MT3, MT4, MT6, MT7, MT9, MT10, and MT11). These, along with other annual wind rose data may be viewed online at http://metweb.ornl.gov/page7.htm. 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 second wind gusts for various wind directions. All of these roses can be found at http://metweb.ornl.gov/page7.htm.

B.3 Temperature and Precipitation

Temperature and precipitation normals (1981–2010) and extremes (1948–2016) and their durations for the city of Oak Ridge and Oak Ridge National Laboratory (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 2017) are given in Table B.3. Overall, at ORNL, 2016 was 0.5°C above normal with regard to temperatures compared to the 1981–2010 Oak Ridge base period, and precipitation was over almost 20% below normal compared to the 1981–2010 mean. ORNL became the official reporting site for climate purposes in 2016 instead of the Oak Ridge townsite. This change was made in response to the implementation of climate-data-quality measurements initiated at ORNL in 2016 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 2016). 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, though this also could be associated with a variety of effects.

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. Spring temperatures (March–May) have risen by about 1.9°C for the 2010s vs. the 1980s. Summer and fall temperatures have exhibited lesser temperature rises of 0.9°C and 0.7°C, respectively, since the 1980s. Fall temperatures have fallen slightly between the 2000s and 2010s, dropping about 0.3°C. Most of the overall warming that has occurred 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. More greenhouse gases and aerosols act to weaken the strength of nighttime surface temperature inversions. Overall, annual minimum temperatures seem to have increased more dramatically (2.0°C from the 1980s to the 2010s) than maximum temperatures (0.8°C from the 1980s to the 2010s).

Table B.1. Climate normals (1981–2010) and extremes (1948–2016) 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)
2016 Average Max	7.1 (44.8)	10.1 (50.2)	18.9 (66.1)	22.3 (72.2)	24.7 (76.5)	31.1 (87.9)	32.5 (90.5)	32.2 (89.9)	31.1 (88.0)	26.1 (79.0)	18.7 (65.6)	10.0 (50.0)	22.1 (71.7)
66-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)
2016 Average Min	-3.8 (25.1)	0.5 (32.9)	5.6 (42.1)	8.0 (46.4)	12.3 (54.2)	17.7 (63.9)	20.5 (68.9)	20.7 (69.2)	16.1 (61.1)	10.0 (50.0)	3.2 (37.7)	-0.1 (31.9)	9.2 (48.6)
66-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)
2016 Average	1.3 (34.4)	5.3 (41.5)	12.3 (54.1)	15.2 (59.3)	18.1 (64.6)	23.7 (74.7)	25.5 (77.8)	25.6 (78.0)	22.9 (73.2)	17.0 (62.7)	10.3 (50.5)	4.8 (40.7)	15.2 (59.3)
2016 Departure from Average	-1.8 (-3.1)	0.0 (0.0)	2.5 (4.5)	0.6 (1.0)	-1.2 (-2.1)	0.1 (0.2)	-0.1 (-0.3)	0.4 (0.6)	1.4 (2.5)	1.8 (3.3)	0.9 (1.6)	0.5 (1.0)	0.5 (0.8)
30-year average heating degree days, °C (°F)[a]													
	471 (847)	365 (657)	264 (476)	126(226)	35(63)	2 (3)	0	0	13 (24)	111 (199)	266 (479)	432 (778)	2084 (3752)
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)
2016 Totals	89.9 (3.54)	148.9 (5.86)	76.2 (3.00)	75.5 (2.97)	71.4 (2.81)	117.1 (4.61)	92.7 (3.65)	60.7 (2.39)	35.1 (1.38)	1.3 (0.05)	120.9 (4.76)	195/2 (7.29)	1075.0 (42.31)
2016 Departure from Average	-31.0 (-1.22)	24.6 (0.97)	-44.7 (1.76)	-37.1 (-1.46)	-45.2 (-1.78)	18.8 (0.74)	-41.7 (-1.64)	-21.3 (-0.84)	-63.0 (-2.48)	-74.7 (-2.94)	-1.3 (-0.05)	54.1 (2.13)	-262.5(-10.33)
68-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)
68-Year Max 24-hr	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)
68-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)
2016 Totals	86.4 (3.4)	33.0 (1.3)	0.0 (0.0)	0	0	0	0	0	0	0	0	Trace	119.4 (4.7)
68-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)
68-Year Max 24-hr	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
2016 Max ≥ 32°C	0	0	0	0	0	11	18	21	14	0	0	0	64
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
2016 Min ≤ 0°C	26	18	7	2	0	0	0	0	0	0	9	16	78
30-Year Max ≤ °C	2.8	0.9	0.1	0	0	0	0	0	0	0	0	1.6	5.4
2016 Max ≤ 0°C	4	3	0	0	0	0	0	0	0	0	0	0	7
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
2016 Days ≥ 0.01 in.	10	12	13	10	11	7	12	11	4	3	6	15	114
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
2016 Days ≥ 1.00 in.	2	2	0	0	0	2	1	0	1	0	1	2	11

Table B.2. Decadal climate change (1970–2016) for City of Oak Ridge, Tennessee, with 2016 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)
2010–2016 Avg Max	7.7 (45.8)	10.4 (50.9)	16.7 (62.0)	22.8 (73.1)	26.6 (79.9)	30.8 (87.4)	31.5 (88.7)	31.1 (88.0)	28.2 (82.8)	22.1 (71.9)	15.8 (60.3)	10.9 (51.6)	22.0 (71.7)
1980s vs. 2010s	1.3 (2.4)	0.3 (0.6)	0.8 (1.4)	1.9 (3.3)	1.0 (1.8)	0.9 (1.7)	-0.0 (-0.1)	0.4 (0.7)	1.1 (2.0)	0.9 (1.6)	0.0 (0.1)	2.3 (4.1)	0.8 (1.5)
2000s vs. 2010s	-0.6 (-1.1)	-0.7 (-1.2)	-0.3 (-0.6)	1.5 (2.6)	0.8 (1.4)	1.0 (1.8)	0.7 (1.2)	-0.3 (-0.5)	0.6 (1.0)	0.4 (0.7)	-0.2 (-0.3)	1.1 (2.0)	0.2 (0.4)
2016 Avg Max	7.1 (44.8)	10.1 (50.2)	19.0 (66.1)	22.1 (72.2)	24.6 (76.5)	31.0 (87.9)	32.4 (90.5)	32.1 (89.9)	31.1 (88.0)	26.1 (79.0)	15.7 (60.2)	10.0 (50.0)	22.0 (71.7)
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)
2010–2016 Avg Min	-1.9 (28.6)	-0.3 (31.4)	4.6 (40.3)	9.0 (48.1)	14.0 (57.1)	18.8 (65.8)	20.7 (69.1)	19.7 (67.5)	16.0 (60.9)	9.2 (48.5)	3.0 (37.3)	1.3 (34.4)	9.4 49.0)
1980s vs. 2010s	2.2 (4.0)	1.8 (3.2)	2.9 (5.2)	2.9 (5.2)	2.6 (4.7)	2.6 (4.6)	1.6 (2.9)	1.3 (2.4)	1.7 (3.0)	1.7 (3.1)	-0.1 (-0.2)	3.7 (6.6)	2.0 (3.6)
2000s vs. 2010s	-0.4 (-0.8)	-0.3 (-0.6)	0.2 (0.4)	0.3 (0.6)	0.4 (0.7)	0.8 (1.5)	0.6 (1.1)	-0.3 (-0.5)	-0.0 (-0.1)	-0.2 (-0.4)	-0.9 (-1.7)	1.7 (3.0)	0.0 (0.1)
2016 Avg Min	-4.3 (25.1)	0.5 (32.9)	0.6 (42.1)	8.0 (46.4)	12.3 (54.2)	17.7 (63.9)	20.5 (68.9)	20.7 (69.2)	15.7 (61.1)	10.0 (50.0)	3.1 (37.7)	-0.1 (31.9)	8.7 (48.6)
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)
2010–2016 Avg	3.1 (37.7)	5.1 (41.2)	10.8 (51.4)	15.9 (60.6)	20.2 (68.3)	23.7 (74.7)	25.8 (78.4)	25.2 (77.4)	21.9 (71.4)	15.4 (59.8)	8.7 (48.6)	6.0 (42.9)	15.2 (59.3)
1980s vs. 2010s	1.7 (3.1)	1.1 (1.9)	1.9 (3.5)	2.3 (4.2)	1.7 (3.0)	1.6 (2.8)	0.5 (0.9)	0.6 (1.1)	1.2 (2.1)	1.1 (1.9)	-0.2 (-0.3)	2.9 (5.2)	1.3 (2.3)
2000s vs. 2010s	-0.6 (-1.0)	-0.5 (-0.9)	0.0 (0.1)	0.6 (1.0)	0.5 (0.9)	0.7 (1.2)	0.4 (0.7)	-0.5 (-0.9)	0.0 (0.0)	-0.2 (-0.3)	-0.7 (-1.3)	1.3 (2.4)	0.0 (0.0)
2016 Avg	1.3 (34.4)	5.3 (41.5)	12.3 (54.1)	15.2 (59.3)	18.1 (64.6)	24.6 (76.2)	25.4 (77.8)	25.6 (78.0)	22.9 (73.2)	17.1 (62.7)	10.3 (50.5)	4.7 (40.7)	15.2 (59.3)
Precipitation, mm (in.)													
1970–1979 Avg	143.4 (5.65)	94.6 (3.72)	169.4 (6.67)	118.3 (4.66)	149.8 (5.89)	120.5 (4.74)	130.4 (5.13)	109.8 (4.32)	107.2 (4.22)	99.8 (3.93)	129.6 (5.10)	145.3 (5.72)	1516.4 (59.68)
1980–1989 Avg	100.4 (3.95)	109.1 (4.29)	112.6 (4.43)	88.8 (3.49)	110.6 (4.35)	84.1 (3.31)	120.4 (4.74)	82.6 (3.25)	108.9 (4.29)	79.8 (3.14)	128.0 (5.04)	107.6 (4.23)	1236.2 (48.66)
1990–1999 Avg	141.4 (5.57)	136.5 (5.37)	149.0 (5.86)	126.3 (4.97)	113.4 (4.47)	110.0 (4.33)	134.8 (5.31)	83.6 (3.29)	71.9 (2.83)	67.3 (2.65)	109.8 (4.32)	161.0 (6.34)	1429.4 (56.26)
2000–2009 Avg	116.9 (4.60)	121.8 (4.80)	115.6 (4.55)	125.0 (4.92)	117.8 (4.64)	95.2 (3.75)	138.9 (5.47)	78.4 (3.09)	108.8 (4.28)	74.0 (2.91)	121.4 (4.78)	124.4 (4.90)	1333.4 (52.48)
2010–2016 Avg	147.6 (5.81)	104.9 (4.13)	122.2 (4.63)	123.4 (4.86)	86.1 (3.39)	127.8 (5.03)	161.8 (6.37)	77.0 (3.03)	119.2 (4.69)	71.4 (2.81)	131.4 (5.17)	154.7 (6.09)	1407.3 (55.59)
1980s vs. 2010s	47.3 (1.86)	-4.1 (-0.16)	5.1 (0.20)	34.5 (1.36)	-24.4 (-0.96)	43.7 (1.72)	41.4 (1.63)	-5.3 (-0.21)	10.4 (0.41)	-8.4 (-0.33)	3.6 (0.14)	47.3 (1.86)	176.2 (6.93)
2000s vs. 2010s	30.7 (1.21)	-16.8 (-0.66)	2.0 (.08)	-1.5 (-0.06)	-31.8 (-1.25)	32.8 (1.29)	23.1 (0.91)	-1.3 (-0.05)	10.4 (0.41)	-2.8 (-0.11)	10.6 (0.40)	30.2 (1.19)	79.0 (3.11)
2016 Totals	89.9 (3.54)	148.8 (5.86)	76.2 (3.00)	75.4 (2.97)	71.4 (2.81)	117.1 (4.61)	92.7 (3.65)	60.7 (2.39)	35.1 (1.38)	1.3 (0.05)	120.9 (4.76)	185.2 (7.29)	1075.0 (42.31)
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)
2010–2016 Avg	5.8 (2.3)	9.9 (3.5)	0.5 (0.2)	0.0 (0.0)	0	0	0	0	0	0	0.3 (0.1)	2.3 (0.9)	17.8 (7.0)
1980s vs. 2010s	-5.6 (-2.2)	0.3 (0.1)	-1.8 (-0.7)	-2.3 (-0.9)	0	0	0	0	0	0	0.3 (0.1)	-5.3 (-2.1)	-15.0 (-5.9)
2000s vs. 2010s	3.8 (1.5)	4.6 (1.8)	0.5 (0.2)	0.0 (0.0)	0	0	0	0	0	0	0.3 (0.1)	0.5 (0.2)	9.7 (3.8)
2016 Totals	8.6 (3.4)	3.6 (1.4)	0.0 (0.0)	0	0	0	0	0	0	0	0	Trace	12.2 (4.8)

Table B.3. Hourly subfreezing temperature data for Oak Ridge, Tennessee, January 1985–March 2017[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[b]	130	47	11	1	64	5	0	0	82	8	0																	
Avg.	247	77	16	3	158	36	6	1	63	7	1	10	0	0	0	7	0	67	4	0	190	40	6	1	748	165	29	5

[a]Source: 1985–2015 National Oceanic and Atmospheric Administration, Atmospheric Turbulence and Diffusion Division, KOQT Station, Automated Surface Observing System; 2016-2017 Oak Ridge National Laboratory, Tower "D"
[b]2017 values through March 31, 2017.

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 0.2°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 recent decadal shifts in the patterns of rainfall on a monthly or seasonal scale. In particular, precipitation has tended to increase during winter with the exception of February, when it has decreased. During the remaining months of the year, precipitation has generally increased with the exceptions of May, August, and September, in which average precipitation has decreased. Annual precipitation during the 2010s is above the 30-year average [around 1407 mm (55.59 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 of 2016 yielded precipitation totals about 20% below the 30-year mean, with a total of 42.31 in. (1,075.0 mm). The statistics presented here encompass the period from 1948 to 2016.

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 7.0 in. (17.8 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) 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 the ORR towers that show wind direction for hours with precipitation and other relevant meteorological parameters have been compiled for 2016 and may be reviewed at http://metweb.ornl.gov/page7.htm.

Hourly values of subfreezing temperatures in Oak Ridge are presented in Table B.3 for January 1985 through March 2017. 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 at http://metweb.ornl.gov/page5.htm.

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% (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. These data are summarized for absolute and relative humidity and dew point at http://metweb.ornl.gov/page5.htm.

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 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. Monthly and annual average numbers of thunderstorm days for ORNL and Knoxville McGhee-Tyson Airport, respectively, during 2001–2016 can be viewed at http://metweb.ornl.gov/page5.htm. The highest number of thunderstorm days at ORNL was observed during 2012 (65); the lowest was observed during 2007 (34).

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%) do not result in hailstones larger than 2 cm. During the period from 1961through 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. Virtually 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.

Although greater tornado frequencies occur in Middle and West Tennessee, East Tennessee experiences infrequent tornado outbreaks (once every 3 to 6 years on average). 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 the 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 for Anderson, Knox, Loudon, and Roane Counties at http://metweb.ornl.gov.

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 air flow. 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 air flow.

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 winds aloft. The reduced wind speeds aloft allow enhanced radiation cooling at the surface, which reintensifies the inversion and allows the process to start again. Van De Weil et al. (2002) have shown that cyclical temperature oscillations up to 4°C (7°F) may result from these processes. 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 2016. They may be viewed at http://metweb.ornl.gov/page7.htm. 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 at http://metweb.ornl.gov/page5.htm.

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Appendix C. Reference Standards and Data for Water

Appendix C. Reference Standards and Data for Water

Table C.1. Reference standards for radionuclides in water

Parameter[a]	National primary drinking water standard[b]	DCS[c]
^{241}Am		170
^{214}Bi		260,000
^{109}Cd		16,000
^{143}Ce		26,000
^{60}Co		7,200
^{51}Cr		790,000
^{137}Cs		3,000
^{155}Eu		87,000
Gross alpha[d]		15
Gross beta (mrem/year)		4
^{3}H		1,900,000
^{131}I		1,300
^{40}K		4,800
^{237}Np		320
^{234m}Pa		71,000
^{238}Pu		150
$^{239/240}$Pu		140
^{226}Ra		87
^{228}Ra		25
^{106}Ru		4,100
^{90}Sr		1,100
^{99}Tc		44,000
^{228}Th		340
^{230}Th		160
^{232}Th		140
^{234}Th		8,400
^{234}U		680
^{235}U		720
^{236}U		720
^{238}U		750

[a]Only the radionuclides included in the Oak Ridge Reservation monitoring programs are listed. Unless labeled otherwise, units are pCi/L.
[b]40 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				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 (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 (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 (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
(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 with "(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 2016

Appendix D. National Pollutant Discharge Elimination System Noncompliance Summaries for 2016

D-1 Y-12 National Security Complex

During 2016, the Y-12 Complex continued its excellent record for compliance with the 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 2016 was almost 100%. About 2,300 data points were obtained from sampling required by the NPDES permit; no noncompliances were reported. The Y-12 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 NPDES permit was prepared and submitted to TDEC in May 2016.

D-2 East Tennessee Technology Park

During 2016, ETTP operations were conducted in compliance with contractual and regulatory environmental requirements, and there were no National Pollutant Discharge Elimination System (NPDES) permits or noncompliances. ETTP received no environmental violations in 2016. In 2016, ETTP discharged to the waters of the state of Tennessee under the individual NPDES permit TN0002950, which regulates storm water discharges.

In 2016, 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 2016 was 100%.

D-3 Oak Ridge National Laboratory

In 2016, 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 2016 was greater than 99%, with no measurements exceeding numeric NPDES permit limits. One laboratory sampling error occurred during February 2016 when the contents of the sample bottle containing the composited effluent from the week of February 8–12, 2016, was mistakenly discarded before being analyzed for the total suspended solids (TSS). A replacement sample was unable to be obtained, and so the required analysis for the weekly TSS concentration could not be measured or reported.

During 2016 TRO from outfall 231 exceeded the permit action level of 1.2 g/day in one monitoring event. The outfall receives cooling tower blowdown from Building 5800 that is dechlorinated inside the building using a sodium sulfite tablet feeder; the cause of this exceedance is not known.

Appendix E. Radiation

Appendix E. Radiation

This appendix presents basic information about radiation. The information is intended to be a basis for understanding the potential doses associated with releases of radionuclides from the Oak Ridge Reservation (ORR), and is not a comprehensive discussion of radiation and its effects on the environment and 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; types, sources, and pathways of radiation; 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 (Fig. E.1).

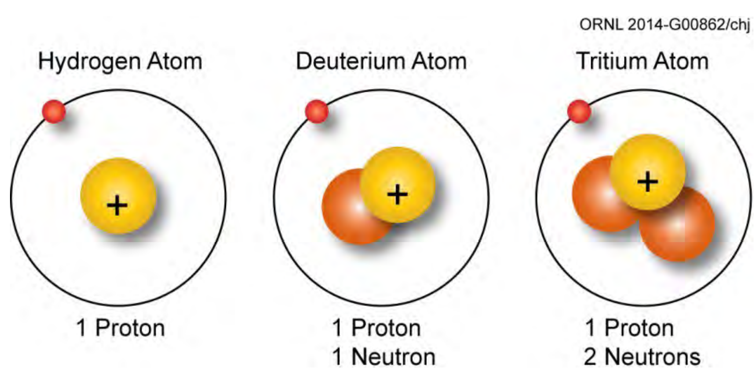

Fig. E.1. The hydrogen atom and its isotopes.

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).

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. Fig. E.2 shows the electromagnetic spectrum.

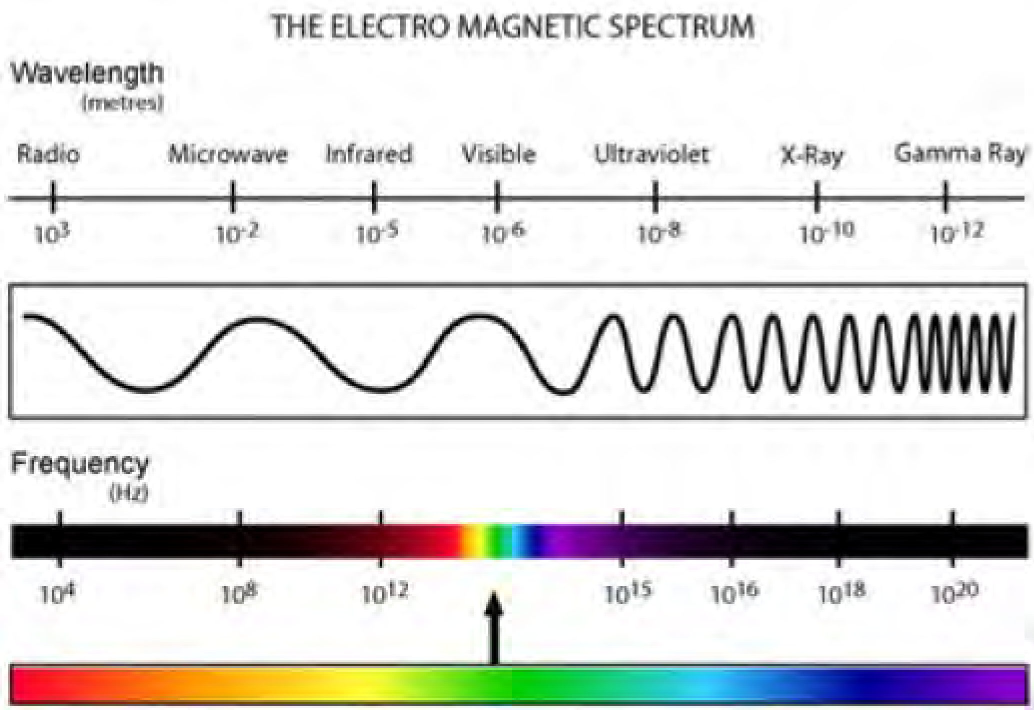

Fig. E.2. Electromagnetic Spectrum.

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, beta, and gamma radiation.

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* online). However, in the discussion that follows the term "radiation" is used to describe ionizing radiation.

E.3 Measuring 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 g 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, it is usually expressed as millirem (mrem), which is 1/1,000 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 (Fig. E.3). Potential routes for internal and/or external exposure are referred to as pathways. For example, radionuclides in air could be inhaled directly or 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.

Fig. E.3. 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 for workers that results from their occupations

Figure E.4 gives the 2006 percent contributions of various sources of exposure to total collective dose for the US population. As shown, the major sources are radon and thoron (37%), computed tomography (24%), and nuclear medicine (12%) (NCRP 2009). Consumer, occupational, and industrial sources contribute about 2% to the total US collective dose.

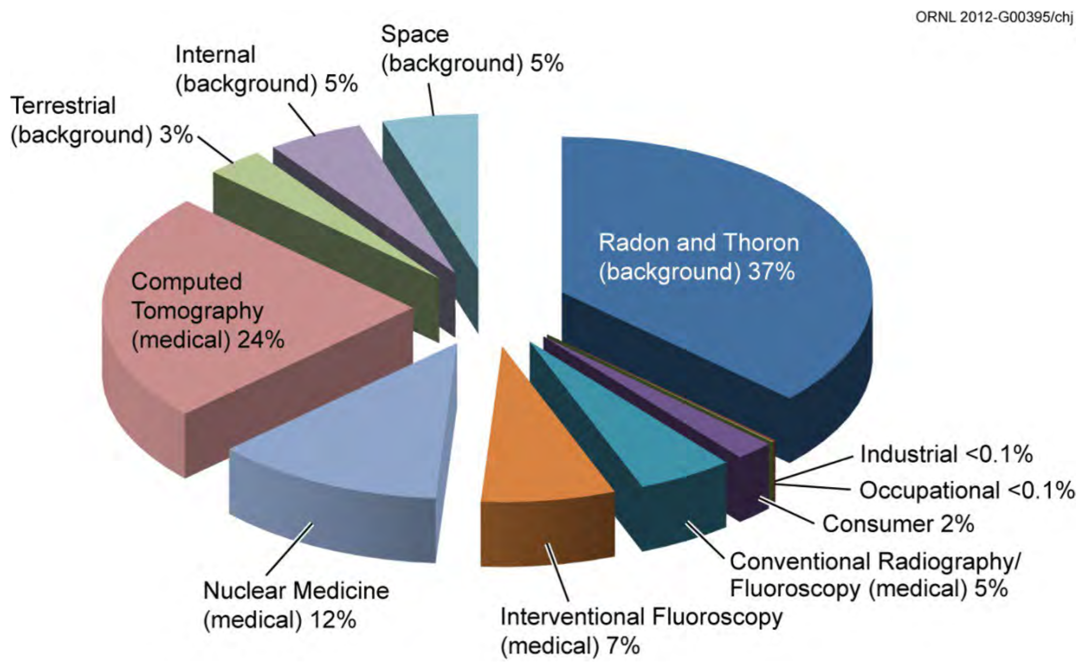

Fig. E.4. All exposure categories for collective effective dose for 2006 (NCRP 2009).

E.5.1 Background Radiation

Naturally occurring radiation is the major source of radiation in the environment. Sources of background radiation exposure include

- 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 (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 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 elsewhere about 46 mrem (0.46 mSv) (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 Fig. E.3, 37% of the dose from all exposure categories is from radon and thoron and 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 ^{238}U series. The primary source of ^{40}K in body tissues is food, and it comes primarily from 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, fallout from atmospheric atomic bomb tests, and industrial by-products. 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% of this dose. Other important sources are building materials (27%), commercial air travel (26%), mining and agriculture (6%), miscellaneous consumer-oriented products (3%), combustion of fossil fuels (2%), highway and road construction materials (0.6%), and glass and ceramics (<0.003%). 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 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 irradiated uniformly. 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 the preparation of medical instruments, including the sterilization of 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 distributed uniformly 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. Using 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, exposures 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 70 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 680 L (180 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 2.55 L, or those in fish by 0.07 kg. This intake is first multiplied by the exposure duration (30 years) and exposure frequency (350 days/year) and then divided by an averaging time (30 years for noncarcinogens and 70 years for carcinogens). 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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