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Oak Ridge Reservation Annual Site Environmental Report for 2005

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Acronyms and Abbreviations

AIHA	American Industrial Hygiene Association
ALARA	as low as reasonably achievable
AM	action memorandum
AMP	Annual Monitoring Plan
ANSI	American National Standards Institute, Inc.
AOC	area of concern
ARAP	aquatic resource alteration permit
ASER	annual site environmental report
ATDD	Atmospheric Turbulence and Diffusion Division
BCG	biota concentration guide
BCK	Bear Creek kilometer
BFK	Brushy Fork kilometer
BJC	Bechtel Jacobs Company LLC
BMAP	Biological Monitoring and Abatement Program
BNFL	British Nuclear Fuels Ltd.
CAA	Clean Air Act
CBOD	carbonaceous biochemical oxygen demand
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFC	chlorofluorocarbon, chlorinated fluorocarbon
CFR	Code of Federal Regulations
Chla	chloraphylla
CNF	Central Neutralization Facility
CRK	Clinch River kilometer
CROET	Community Reuse Organization of East Tennessee
CWA	Clean Water Act
CX	categorical exclusion
CY	calendar year
CYRTF	Coal Yard Runoff Treatment Facility
D&D	decontamination and decommissioning
DCG	derived concentration guide
DMR	discharge monitoring report
DNAPL	dense nonaqueous phase liquid
DOE	Department of Energy
DOE-EM	DOE Office of Environmental Management
DOE-HQ	DOE Headquarters
DOE-ORO	DOE Oak Ridge Office
dps	disintegrations per second
DWI	David Witherspoon, Inc.
EC	Environmental Compliance
EDE	effective dose equivalent
EFK	East Fork Poplar Creek kilometer
EGCR	Experimental Gas-Cooled Reactor

EIS	environmental impact statement
EM	(DOE Office of) Environmental Management
EMC	event mean concentration
EMS	environmental management system
EMWMF	Environmental Management Waste Management Facility
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
EPT	Ephemeroptera, Plectoptera, and Trichoptera (taxa)
ETTP	East Tennessee Technology Park
EWQP	ETTP Water Quality Program
FCK	First Creek kilometer
FFK	Fifth Creek kilometer
FONSI	finding of no significant impact
FY	fiscal year
HFIR	High Flux Isotope Reactor
HQ	hazard quotient
HRE	Homegeneous Reactor Experiment
HVAC	heating, ventilation, and air conditioning
IC_{25}	inhibition concentration for 25% of organisms
ICP	inductively coupled plasma
ICP-MS	inductively coupled plasma mass spectrometry
ID	identification (number)
INEEL	Idaho National Engineering and Environmental Laboratory
ISMS	Integrated Safety Management System
ISO	International Organization for Standardization
LC_{50}	concentration of an aqueous sample lethal to 50% of test organisms in a given time span
LEED	Leadership in Energy and Environmental Design
LLLW	liquid low-level radioactive waste
LLMW	low-level mixed waste
LLW	low-level radioactive waste
MACT	Maximum Achievable Control Technology
MCL	maximum contaminant level
MDA	minimum detectable activity
MEK	Melton Branch kilometer
MIK	Mitchell Branch kilometer
MLLW	mixed low-level waste
MOA	memorandum of agreement
MRF	Multiprogram Research Facility
MSDS	material safety data sheet
MSRE	Molten Salt Reactor Experiment
NAAQS	National Ambient Air Quality Standards
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NHPA	National Historic Preservation Act
NIST	National Institute of Standards and Technology

NNSA	National Nuclear Security Administration
NOAA	National Oceanic and Atmospheric Administration
NOEC	no-observed-effect concentration
NOV	notice of violation
NPDES	National Pollutant Discharge Elimination System
NTRC	National Transportation Research Center
NWTK	Northwest Tributary kilometer
OCF	Oxide Conversion Facility
ODS	ozone-depleting substance
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
ORR	Oak Ridge Reservation
ORR/PCB/FFCA	Oak Ridge Reservation Polychlorinated Biphenyl Federal Facilities Compliance Agreement
ORSSAB	Oak Ridge Site Specific Advisory Board
OST	Office of Secure Transportation
OSTI	DOE Office of Scientific and Technical Information
PAM	perimeter air monitoring
PCB	polychlorinated biphenyls
PM_{10}	particulate matter with an aerodynamic diameter less than or equal to 10 micrometers
$PM_{2.5}$	particulate matter with an aerodynamic diameter less than or equal to 2.5 micrometers
PWTC	Process Waste Treatment Complex
QA	quality assurance
QC	quality control
R&D	research and development
RAM	remote air monitoring
RCK	Racoon Creek kilometer
RCRA	Research Conservation and Recovery Act
REDC	Radiochemical Engineering Development Center
RfD	reference dose
ROD	record of decision
SADA	spatial analysis and decision assistance
SARA	Superfund Amendments and Reauthorization Act
SBMS	Standards-Based Management System
SC	DOE Office of Science
SDWA	Safe Drinking Water Act
SF	slope factor
SMU	sediment management unit
SNS	Spallation Neutron Source
sodar	sonic detection and ranging
SWEIS	sitewide environmental impact statement
SWSA	solid waste storage area

TDEC	Tennessee Department of Environment and Conservation
TRC	total residual chlorine
TRU	transuranic
TSCA	Toxic Substances Control Act
TSP	total suspended particulate
TVA	Tennessee Valley Authority
TWPC	Transuranic Waste-Processing Center
TWRA	Tennessee Wildlife Resources Agency
UEFPC	Upper East Fork Poplar Creek
UST	underground storage tank
UT	University of Tennessee
VMF	Vehicle Maintenance Facility
VOC	volatile organic compound
WAG	waste area grouping
WBK	Walker Branch kilometer
WCK	White Oak Creek kilometer
WIPP	Waste Isolation Pilot Plant
WOC	White Oak Creek
WQC	Water quality criteria
Y-12	Y-12 National Security Complex

Units of Measure and Conversion Factors

Units of measure and their abbreviations

acre	acre	millimeter	mm
becquerel	Bq	million	M
centimeter	cm	millirad	mrad
curie	Ci	millirem	mrem
day	day	millisievert	mSv
degrees Celsius	°C	minute	min
degrees Fahrenheit	°F	nephelometric turbidity unit	NTU
foot	ft	parts per billion	ppb
gallon	gal	parts per million	ppm
gallons per minute	gal/min	parts per trillion	ppt
gram	g	picocurie	pCi
hectare	hectare	pound	lb
hour	h	pounds per square inch	psi
kilogram	kg	quart	qt
kilometer	km	rad	rad
kilowell	kW	roentgen	R
liter	L	roentgen equivalent man	rem
megawatt	MW	second	s
meter	m	sievert	Sv
microcurie	µCi	standard unit (pH)	SU
microgram	µg	ton, short (2000 lb)	ton
millicurie	mCi	yard	yd
milligram	mg	year	year
milliliter	mL		

Quantitative prefixes

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	$\times 10^{2}$	centi	$\times 10^{-2}$
deka	$\times 10^{1}$	deci	$\times 10^{-1}$

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			
ppm	=	mg/L	mg/L	=	ppm
		Weight			
lb	× 0.4536	kg	kg	× 2.205	lb
ton	× 907.1847	kg	kg	× 0.00110231131	ton
		Temperature			
°C	F = (9/5) C + 32	°F	°F	C = (5/9) (F − 32)	°C
		Activity			
Bq	$\times 2.7 \times 10^{-7}$	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	× 1000	pCi	pCi	× 0.0001	nCi
mCi/km^2	=	nCi/m^2	nCi/m^2	=	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 (water)	$\times 10^{-9}$	µCi/mL (water)	µCi/mL (water)	$\times 10^9$	pCi/L (water)
pCi/m^3 (air)	$\times 10^{-12}$	$\mu Ci/cm^3$ (air)	$\mu Ci/cm^3$ (air)	$\times 10^{12}$	pCi/m^3 (air)

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1. Site and Operations Overview

The Oak Ridge Reservation (ORR), a government-owned, contractor-operated facility, contains three major operating sites: the Y-12 National Security Complex, Oak Ridge National Laboratory, and East Tennessee Technology Park. The ORR was established in the early 1940s as part of the Manhattan Project, a secret undertaking that produced materials for the first atomic bombs. The reservation's role has evolved over the years, and it continues to adapt to meet the changing defense, energy, and research needs of the United States. Both the work carried out for the war effort and subsequent research, development, and production activities have involved, and continue to involve, the use of radiological and hazardous materials.

The *Oak Ridge* Reservation *Annual Site Environmental Report* and supporting data are available at http://www.ornl.gov/Env_Rpt or from the project director.

1.1 Background

This document is prepared annually to summarize environmental activities, primarily environmental-monitoring activities, on the Oak Ridge Reservation (ORR) and within the ORR surroundings. The document fulfills the requirement of Department of Energy (DOE) Order 231.1A, "Environment, Safety and Health Reporting," for an annual summary of environmental data to characterize environmental performance. The environmental monitoring criteria are described in DOE Order 450.1, "Environmental Protection Program." The results summarized in this report are based on data collected prior to and through 2005. This report is not intended to provide the results of all sampling on the ORR. Additional data collected for other site and regulatory purposes, such as environmental restoration 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 DOE guidance and/or laws. Corrections to the report for the previous year are found in Appendix A.

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 liquid and gaseous effluents at the point of release to the environment; these measurements allow the quantification and official reporting of contaminants, assessment of radiation and chemical exposures to the public, and demonstration of compliance with applicable standards and permit requirements. Environmental surveillance consists of the collection and analysis of environmental samples from the site and its environs; these activities provide direct measurement of contaminant concentrations in air, water, groundwater, soil, foods, biota, and other media. Environmental surveillance data provide information regarding conformity with applicable DOE orders and, combined with data from effluent monitoring, allow the determination of chemical and radiation dose/exposure assessments of ORR operations and effects, if any, on the local environment.

1.2 Description of Site Locale

The city of Oak Ridge lies within the Great Valley of Eastern Tennessee between the Cumberland and Great Smoky Mountains and is bordered on two sides by the Clinch River (Fig. 1.1). The Cumberland Mountains are 16 km to the northwest; the Great Smoky Mountains are 51 km to the southeast.

The ORR encompasses about 13,401 hectares of mostly contiguous land owned by DOE in the Oak Ridge area. Most of it lies within the corporate limits of the city of Oak Ridge; 243 hectares west of the East Tennessee Technology Park (ETTP) are outside the city limits. The residential section of Oak Ridge forms the northern boundary of the reservation. The Tennessee Valley Authority's (TVA's) Melton Hill and Watts Bar reservoirs on the Clinch and Tennessee rivers form the southern and western boundaries (Fig. 1.2). The population of the ten-county region surrounding the ORR is about 884,960 with about 4% of its labor force employed on the reservation (Fig. 1.3). Other towns

ORNL 2006-G00630

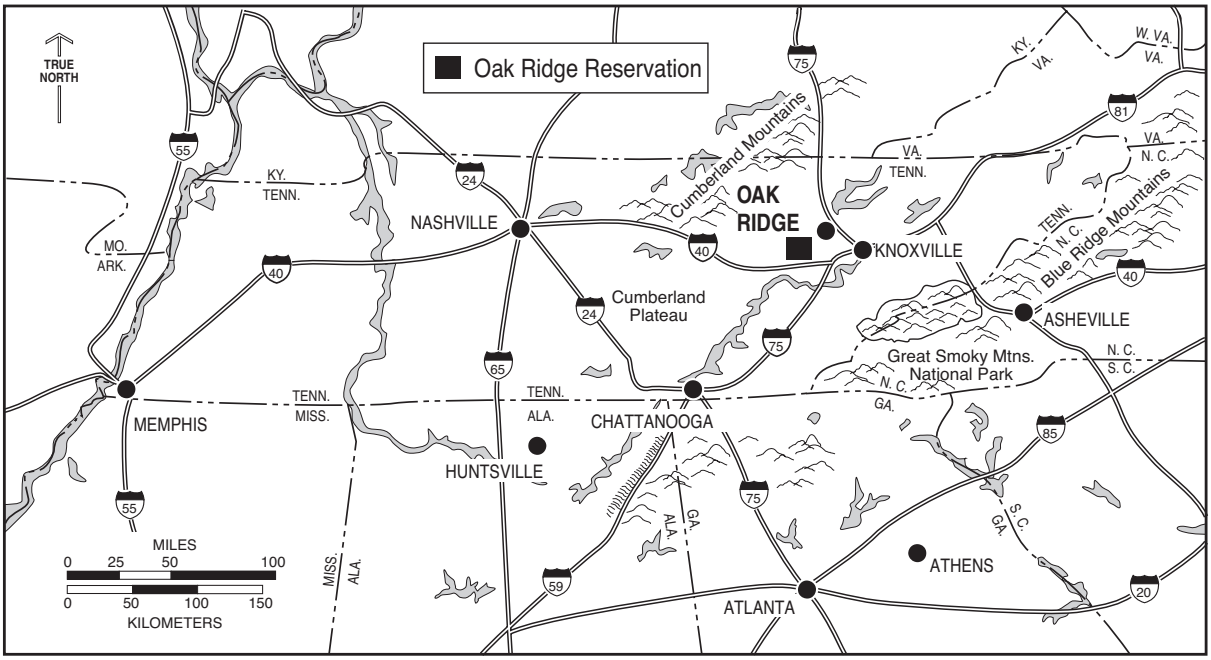


Fig. 1.1. Location of the city of Oak Ridge.

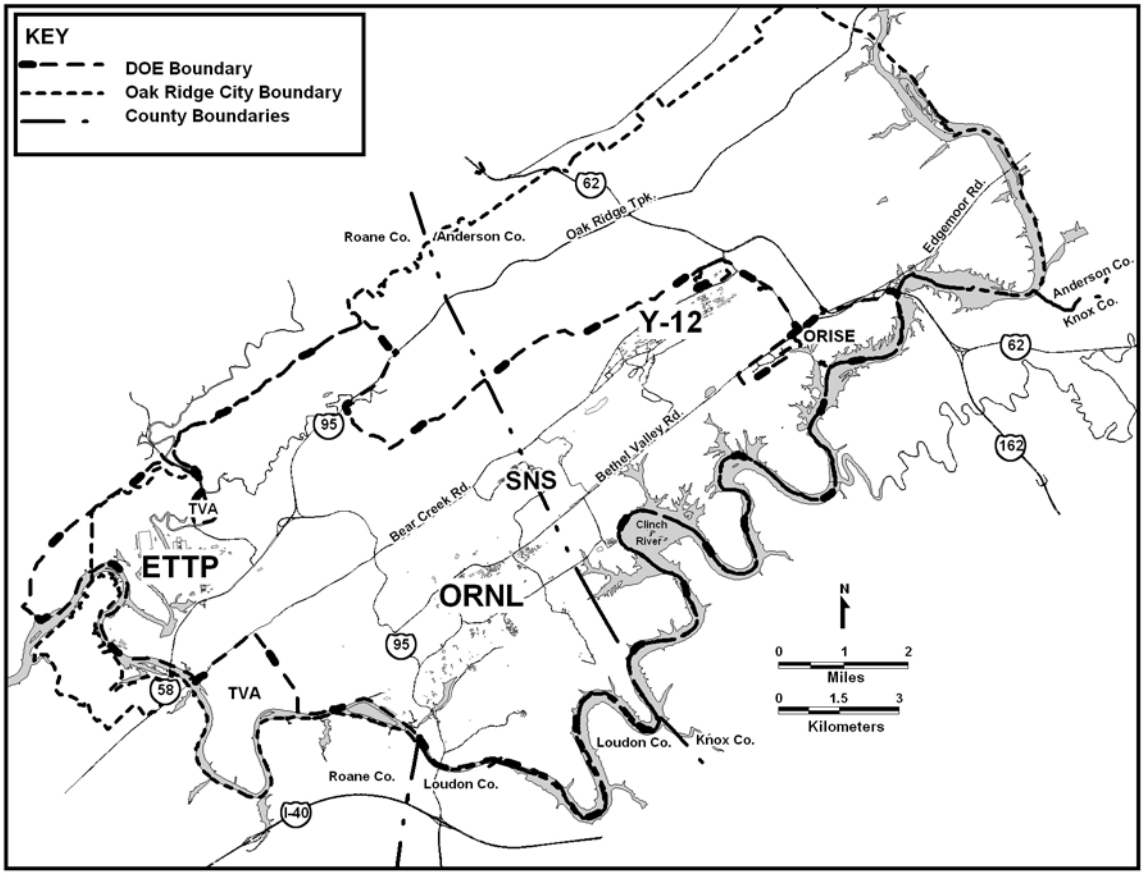


Fig. 1.2. The Oak Ridge Reservation.

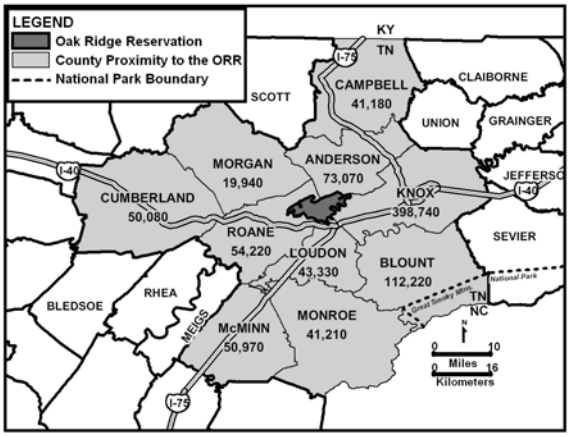


Fig. 1.3. The ten-county region surrounding the Oak Ridge Reservation (UTK 2006).

close to the reservation include Oliver Springs, Clinton, Karns, Lenoir City, Farragut, Kingston, and Harriman (Fig. 1.4).

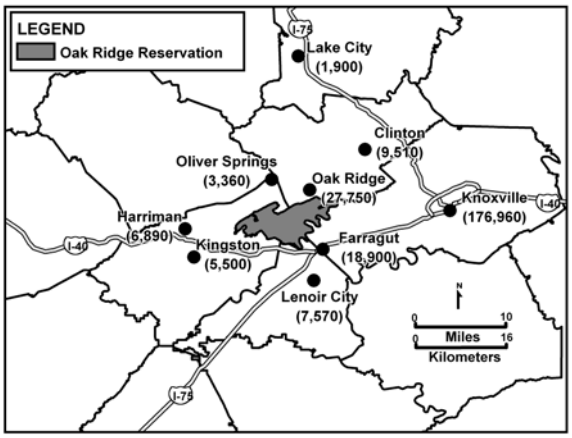


Fig. 1.4. Locations and populations of towns nearest to the Oak Ridge Reservation (UTK 2006).

Knoxville, the major metropolitan area nearest Oak Ridge, is located about 40 km to the east and has a population of about 176,960. Except for the city of Oak Ridge, the land within 8 km of the ORR is semirural and is used primarily for residences, small farms, and cattle pasture. Fishing, boating, water skiing, and swimming are popular recreational activities in the area.

1.3 Climate

The climate of the Oak Ridge region may be broadly classified as humid subtropical. The term "humid" indicates that the region receives a surplus of precipitation compared to the level of evapotranspiration that is normally experienced throughout the year. The "subtropical" nature of the local climate indicates that the region experiences warm to hot summers and cool to cold winters. Such areas typically experience significant changes in temperatures between summer and winter.

Local winters are characterized by synoptic weather systems that often produce significant precipitation events every 3 to 5 days. Although infrequent, these wet periods may be followed by arctic air outbreaks. While snow and ice are not usually associated with these systems, there is an occasional snowfall each winter. Winter cloud cover tends to be enhanced by the region's terrain.

Severe thunderstorms are most frequent during spring, although the Cumberland Mountains and the Cumberland Plateau usually inhibit the intensity of severe systems that traverse the region. Summers are characterized by warm, humid conditions. Occasional frontal systems may produce organized lines of thunderstorms (and rare damaging tornados). More frequently, however, summer precipitation is due to "air mass" thundershowers that result from daytime heating and rising humid air. Although ample precipitation usually occurs during the fall, October tends to be the driest month of the year. The occurrence of precipitation during the fall tends to be less cyclic than during other seasons, although it may be occasionally enhanced by decaying tropical systems moving north from the Gulf of Mexico. During November, winter-type cyclones again begin to dominate the weather.

Terrain often exhibits a significant influence on local climate. Primarily, these effects result in seasonal changes to cloud cover, precipitation, air mass, and wind flow regimes. These effects vary with season.

1.3.1 Temperature

The mean annual temperature for the Oak Ridge area is 14.4°C (30-year average based on data from 1976 to 2005). The coldest month is typically January, with temperatures averaging about 2.3°C. However, the minimum temperature once dipped as low as –31°C (in 1985). July tends to be the warmest month of the year, with temperatures averaging 25.3°C and on rare occasions peaking as high as 37°C.

The 2005 average temperature measured at the official Oak Ridge meteorological tower (KOQT), near the DOE Oak Ridge Office (DOE-ORO) Headquarters, was 15.2°C and the mean difference between maximum and minimum daily temperatures averages 12.6° C. Over the last 30 years, decadal temperature averages have increased by 1.8°C in Oak Ridge. Summaries of normal and extreme temperature conditions for Oak Ridge can be found in greater detail in Appendix B, Table B.1, and specific information on the frequency of subfreezing temperatures is given in Appendix B, Table B.2.

Although average daily temperatures across the ORR are not significantly affected by the local terrain, noticeable differences do occur with respect to maximum and minimum temperatures. This can result in significant temperature variations with changes in elevation as small as 10 to 20 m. This type of phenomenon occurs most frequently during night time hours (especially near sunrise) but may also occur during the approach of large-scale low pressure areas as warm air advection interacts with the local ridge-and-valley terrain.

1.3.2 Winds

Complex terrain significantly affects wind patterns in Oak Ridge and its environs. These factors result primarily from the presence of the Cumberland Plateau, the Cumberland Mountains, the Great Smoky Mountains, the orientation axis of the Great Valley, and the local ridge-and-valley terrain structure. Although surface winds tend to follow the axes of the valleys, winds above the ridge-and-valley terrain (altitudes of 100 m or more) often blow from significantly different directions than the surface winds due to several wind "forcing" mechanisms created by regional terrain. A more detailed and important discussion on local wind regimes can be found in Appendix B.

Wind speeds at 10 m above the ground averaged 1.4 m/s at Oak Ridge National Laboratory (ORNL) Tower C during 2005 [1.3 m/s at Sites A (MT4), B (MT3), C (MT2), 1208 (MT1) , and 1209 (MT7) combined; see Fig. 7.1]. This value increases to about 3 m/s for winds at 100 m above the ground (about the height of local ridgetops). The presence of the ridge-and-valley terrain reduces average wind speeds at local valley bottoms sites. This results in frequent periods of near calm conditions (particularly during clear, early morning hours). During 2005, wind speeds less than 0.5 m/s occurred 10.6% of the time. Wind direction and speed frequencies for Tower C at 10, 30, and 100 m above the ground can be found in Appendix B (Figs. B.1 thru B.3).

Although Figs. B.1 through B.3 generally represent winds on the ORR, significant variation in wind direction and speed frequency occurs between some sites on it (depending on the specific site relationship to local terrain).

1.3.3 Precipitation

The 30-year annual average precipitation (1976–2005) is 1374.3 mm, including about 27.4 cm of snowfall (NOAA 2006). Total rainfall during 2005 measured at the Oak Ridge meteorological tower on Laboratory Road (near the DOE-ORO Headquarters) was 1146.2 mm. Snowfall measured only 2.5 cm. During 2005, Oak Ridge precipitation was 228.2 mm below normal. Monthly summaries of precipitation averages, extremes, and 2005 values can be found in Appendix B, Table B.1.

1.3.4 Evapotranspiration

Evapotranspiration is defined as the total amount of water that is transferred from the earth's surface to the atmosphere from surface water and ice and from the transpiration of plants (transpiration refers to the process through which water vapor is released by plants to the atmosphere). Regionally, annual evapotranspiration has been estimated to range from 81 to 89 cm, or 60 to 65% of rainfall (Farnsworth et al. 1982). More specifically, evapotranspiration in the Oak Ridge area has been estimated at 74 to 76 cm, or 55 to 56% of annual precipitation (TVA 1972, Moore 1988, and Hatcher et al. 1989).

Evapotranspiration is greatest during the growing season, which in the vicinity of the ORR encompasses about 220 days, from late March through mid-October. During the growing season, evapotranspiration may exceed the rate of precipitation, resulting in soil moisture deficits.

1.3.5 Mixing Heights

The mixing height (atmospheric layer nearest the earth's surface where active diffusion and mixing occur) varies significantly with respect to time of day, synoptic weather, season, and proximity to terrain. The depth of the surface mixing layer is usually correlated to atmospheric stability (the tendency of the atmosphere to mix vertically). Local ridge-and-valley terrain primarily affects stability through the reduction of surface winds, which tends to allow for the development of very stable surface layers (strong temperature inversions) at night, particularly under clear skies and light background winds. Hourly mixing height statistics for the ORR during 2005 are given in Appendix B, Table B.3. Data were derived primarily from hourly sonic detection and ranging (sodar) data (< 500 m) and from the National Weather Service Rapid Update Cycle forecast model initializations (> 500 m). The annual average mixing height for 2005 was 768 m (standard deviation 773 m).

1.3.6 Stability

Stability describes the tendency of the atmosphere to mix 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). The "D" stability class represents a neutral state. 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.

Table B.4 in Appendix B shows the frequency of stability class by hour of the day for ORNL's Tower C during 2005. More than 54% of all hours during 2005 were categorized as stable (Categories E, F, and G). About 25% of the hours were characterized by unstable conditions (Categories A, B, and C).

1.3.7 Physiography

The ORR lies within the Valley and Ridge Physiographic Province, which has developed on thick, folded beds of sedimentary rock deposited during the Paleozoic era. The long axes of the folded beds control the shapes and orientations of a series of long, narrow parallel ridges and intervening valleys. These axes of the ridge-and-valley terrain within the ORR lie approximately along an east northeast–west southwest axis (60°–240°). The differing degrees of resistance to erosion of the shales, sandstones, and carbonate rocks comprised in the lithology determine local relief.

1.4 Regional Air Quality

The Environmental Protection Agency (EPA) Office of Air Quality Planning and Standards has set National Ambient Air Quality Standards (NAAQSs) for key principal pollutants, which are called "criteria" pollutants. These pollutants are sulfur dioxide (SO_2), carbon monoxide (CO), carbon dioxide (CO_2), nitrogen dioxide (NO_2), lead (Pb), ozone (O_3), particulate matter with aerodynamic diameter less than or equal to 2.5 microns ($PM_{2.5}$), and particles with an aerodynamic diameter less than or equal to 10 microns in diameter (PM_{10}). EPA evaluates NAAQS based on levels of ambient (outdoor) levels of the criteria pollutants. Areas that satisfy NAAQS are classified as attainment areas, and areas that exceed the NAAQS for a particular pollutant are classified as nonattainment areas for that pollutant.

The ORR is located in Anderson and Roane Counties in Air Quality Control Region 207 (East Tennessee-Southeastern Virginia). The EPA has designated Anderson County as a basic nonattainment area for the 8-h O_3 standard; as part of the larger Knoxville 8-h basic O_3 nonattainment area that encompasses several counties; and for $PM_{2.5}$. For all other criteria pollutants, for which EPA has made attainment designations, existing air quality in the greater Knoxville and Oak Ridge area is in attainment with the NAAQS.

1.5 Surface Water Setting

Waters drained from the ORR eventually reach the Tennessee River via the Clinch River, which forms the southern and western boundaries of the ORR (Fig. 1.2). 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 at each of the major facilities of 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.

The largest of the drainage basins is that of Poplar Creek, which receives drainage from a 352-km^2 area, including the northwestern sector of the ORR. It flows from northeast to southwest, approximately through the center of the ETTP, and discharges directly into the Clinch River.

East Fork Poplar Creek, which discharges into Poplar Creek east of the ETTP, originates within the Y-12 National Security Complex (Y-12 Complex) near the former S-3 Ponds and flows northeast along the south side of the Y-12 Complex. Various Y-12 Complex wastewater discharges to the upper reaches of East Fork Poplar Creek from the late 1940s to the early 1980s left a legacy of contamination [e.g., mercury, polychlorinated biphenyls (PCBs), uranium] that has been the subject of water quality improvement initiatives over the past 12 to 15 years. Bear Creek also originates within the Y-12 Complex with headwaters near the former S-3 Ponds, where the creek flows southwest. Bear Creek is mostly affected by stormwater 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 Oak Ridge National Laboratory (ORNL) are in the White Oak Creek drainage basin, which has an area of 16.5 km^2. White Oak Creek headwaters originate on Chestnut Ridge, north of ORNL, near the Spallation Neutron Source (SNS) site. At the ORNL site, the creek flows east along the southern boundary of the developed area and then flows southwesterly through a gap in Haw Ridge to the western portion of Melton Valley, where it forms a confluence with Melton Branch. The waters of White Oak Creek enter White Oak Lake, which is an impoundment formed by White Oak Dam. Water flowing over White Oak Dam enters the Clinch River after passing through the White Oak Creek embayment area.

1.6 Geological Setting

The ORR is located 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 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 Conasauga Group, both consisting of dolostone and limestone, constitute the Knox Aquifer. A combination of fractures and solution conduits in this aquifer control flow over substantial areas, and large quantities of water may move long distances. Active groundwater flow can occur at substantial depths in the Knox Aquifer (91.5 to 122 m deep). The Knox Aquifer is the primary source of groundwater to 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 3784 L/min.

The remaining geologic units on the ORR (the Rome Formation, the Conasauga Group below the Maynardville Limestone, and the Chickamauga Group) constitute the ORR Aquitards, which consist mainly of siltstone, shale, sandstone, and thinly bedded limestone of low to very low permeability (Fig. 1.5). Nearly all groundwater flow in the ORR Aquitards occurs through fractures. The typical yield of a well in the ORR Aquitards is less than 3.8 L/min, and the base flows of streams draining areas underlain by the ORR Aquitards are poorly sustained because of such low flow rates.

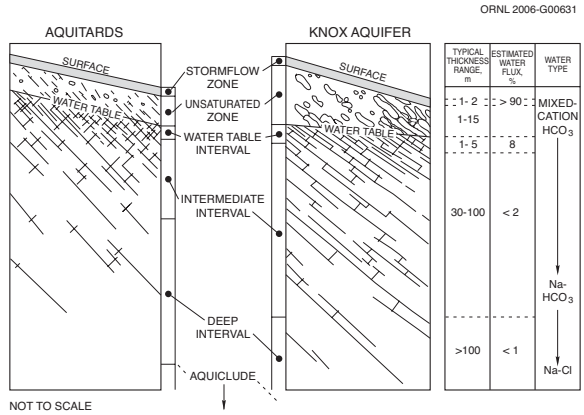


Fig. 1.5. Vertical relationships of flow zones of the ORR: estimated thicknesses, water flux, and water types.

1.6.1 Hydrogeological Setting

1.6.1.1 Groundwater Hydrology

A portion of the rainwater that falls on the land surface accumulates as groundwater by infiltrating into the subsurface. The accumulation of groundwater in pore spaces of sediments and bedrock creates sources of usable water; the water flows in response to external forces. Groundwater eventually reappears at the surface in springs, swamps, stream and river beds, and pumped wells. Thus, groundwater is a reservoir for which the primary input is recharge from infiltrating rainwater, and the output is discharged to springs, swamps, rivers, streams, and wells.

Because groundwater distribution and movement on the ORR are quite complex and are key components of the pollution potential of the ORR, it is important to discuss some of the technical essentials necessary for understanding the role of groundwater in the overall existence and movement of contaminants on the reservation. Appendix C contains a glossary of technical terms that may be useful for clarifying some of the language used in this section.

Groundwater on the ORR occurs both in the unsaturated zone as transient, shallow subsurface stormflow and within the deeper saturated zone. An unsaturated zone of variable thickness separates the stormflow zone and water table. Adjacent to surface water features or in valley floors, the water table is found at shallow depths, and the unsaturated zone is thin. Along the ridgetops or near other high topographic areas, the unsaturated zone is thick, and the water table often lies at considerable depth (15 to 50 m deep). In low-lying areas where the water table occurs near the surface, the stormflow zone and saturated zone are indistinguishable.

Two broad hydrologic units are identified on the ORR: the Knox Aquifer, which includes the Maynardville Limestone and is highly permeable, and the ORR Aquitards, which consist of less permeable geologic units. The geologic regime referred to as the ORR Aquitards comprises bedrock and residuum of the Cambrian age Rome formation and Conasauga Group (excluding the Maynardville Limestone) and the Chickamauga Group. Bedrock included in these formations is predominantly clastic sediment (shales, siltstones, well-cemented sandstones, and argillaceous to silty limestones). The ORR Aquitards include local zones where groundwater occurs in quantities sufficient to provide a potential resource of limited use. These zones typically occur within karstic carbonate members of the clastic bedrock formations. Although marginal localized groundwater resources occur within the ORR Aquitards, these formations are far less important to regional water resources, including being a source of potable water for private and public water supply and a source of baseflow to regional surface water bodies, than is the Knox Aquifer. Figure 1.6 is a generalized map showing surface distribution of the Knox/Maynardville Aquifer and the ORR Aquitards. Many waste areas on the ORR are located in areas underlain by the ORR Aquitards.

Portions of the ORR underlain by carbonate bedrock commonly exhibit karst geomorphic features. About 60% of the ORR is underlain by carbonate-dominated bedrock. Karst geomorphic features form in carbonate-rich bedrock and are evident as sinkholes, solution caverns, and sinking creeks. In addition to creation of subsurface voids in bedrock, the weathering process leaves behind the insoluble mineral components of the rock that combine with organic residues of decaying plant materials to form a soil mantle over most of the ORR. The soil mantle forms a physical and geochemical filter that reduces the direct infiltration of rainfall and contaminants into the groundwater system. Geochemical retardation of contaminants in the soil mantle reduces the mobility of many types of contaminants. Groundwater flow in most of the carbonates is quite different from flow in porous media, where advective flow conditions largely govern flow and solute transport. Groundwater flow in karst terranes manifests itself in multiple scales of porosity, such as diffusion in intergranular pores of weathered or inherently porous bedrock, flow by seepage in rock fractures with water and rock matrix interaction on fracture surfaces, or flow in conduits where rapid velocities limit the interaction between the water and bedrock. Groundwater discharge from springs and seeps is abundant on the ORR and accounts for the normal baseflow of natural stream systems in the area. Most recharge to the groundwater system occurs through dispersed percolation of rainwater through the soil mantle and via cap-

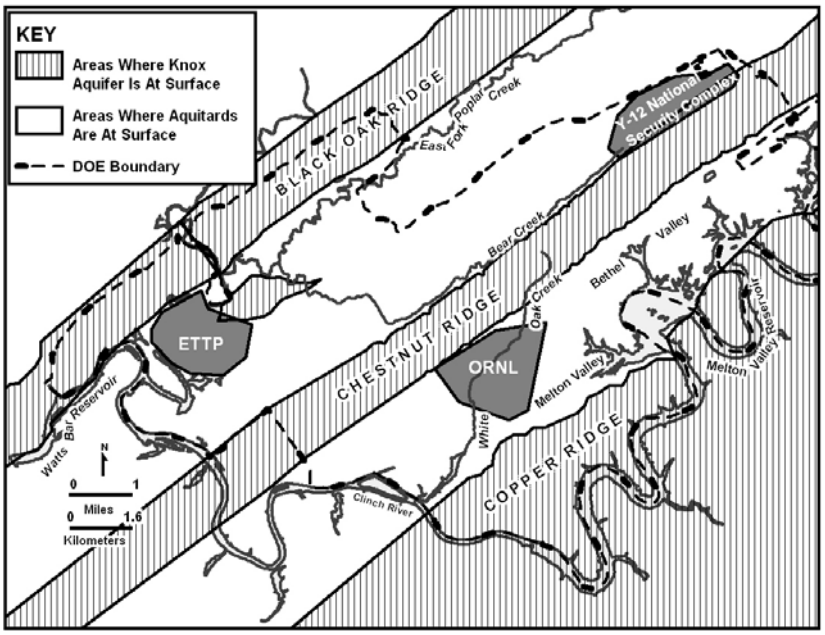


Fig. 1.6. The Knox Aquifer and the ORR Aquitards on the Oak Ridge Reservation.

ture in surface dolines during the winter and early spring months, when evapotranspiration losses of soil moisture are negligible. Groundwater storage in thick soil profiles and in the weathered bedrock zone of the Knox Group outcrop areas such as Blackoak, Chestnut, and Copper Ridges provides most of the dry season baseflow and feeds the area's largest springs. Most groundwater flow in the carbonate bedrock groundwater basins on the ORR originates as intergranular or fracture seepage through the soil mantle, and flow progresses through coalescing networks of conduits that culminate at spring discharges. Baseflow springs often occur near major geologic outcrop boundaries, where semi-confining bedrock lithologies tend to limit the orientation of conduit development and promote upward flow of groundwater to discharge at the land surface. In portions of the ORR underlain by shale-rich bedrock, such as the Conasauga Group bedrock of Bear Creek Valley and Melton Valley, groundwater seepage is typically through fractures in weathered bedrock with discharge to nearby streams. Discrete baseflow springs are not common in the shale-dominated outcrop areas; however, small seeps are abundant.

1.6.1.2 Unsaturated Zone Hydrology

Terrain at the ORR is hilly with slopes that average about 7.5% and that range from less than 3% to more than 50%. Because ORR landforms consist almost entirely of sloping land surfaces, the concepts of hillslope hydrology are appropriate to describe the active hydrologic process. Based on soil percolation capacity and soil structure, as well as direct measurement of water transmission in soil test areas, it is estimated that in undisturbed, naturally vegetated areas on the ORR, about 90% of the infiltrating precipitation does not reach the water table but travels through the 1- to 2-m stormflow zone, which approximately corresponds to the root zone. This condition exists because of the permeability contrast between the shallow stormflow zone and the underlying unsaturated zone.

Recharge of the groundwater system is strongly seasonal at the ORR, and percolation processes in the shallow soil are moderated by the amount of soil moisture present. During the active growing season (April through October) moisture evapotranspiration by plants removes moisture from the soil within the root zone. When soil moisture levels are low, any percolating rainwater is absorbed in the root zone to replenish the soil moisture deficit. During that phase little or no water reaches the water table.

When rainfall amounts exceed any existing soil moisture deficits and saturation of the shallow soils begins to occur, seepage of water begins. When saturation of the shallow soils occurs on sloping land, the downslope gradient allows lateral drainage of water through macropores (e.g., holes left by decay of dead plant roots, animal burrows) as well as vertical seepage to the water table through pervious zones. During the nongrowing season (November through March), there is little evapotranspiration to remove water from the root zone, and saturation of the shallow soils occurs more rapidly than during the summer months. Typical evapotranspiration losses from the root zone range from a low of about 0.01 in./day rainfall equivalent during January and February to a high of about 0.16 in./day rainfall equivalent during July. Thus, development of a 1-in. water deficit would require only a week without rainfall during July but would require over two months without rainfall during the winter.

The amount of water that actually recharges the groundwater zone is highly variable across the ORR, depending on shallow soil characteristics, permeability and degree of fracturing of regolith beneath the surface soils, presence of dolines that capture stormflow and focus recharge in small areas, and the presence of paved or covered areas, where little or no rainfall infiltration occurs. Higher recharge is expected in areas of karst hydrogeology such as the Knox Aquifer because of internal drainage through dolines than in areas underlain by the clastic bedrock formations.

1.6.1.3 Saturated Zone Hydrology

As shown in Fig. 1.5, the saturated zone on the ORR can be divided conceptually into four flow zones in a vertical cross section: an uppermost water table interval, an intermediate interval, a deep interval, and an aquiclude. The presence and thickness of any zone may vary across the ORR. Available evidence indicates that most water in the saturated zone in the ORR Aquitards is transmitted through a 1- to 6-m layer of closely spaced, well-connected fractures near the water table (the water table interval) as shown in Fig. 1.7.

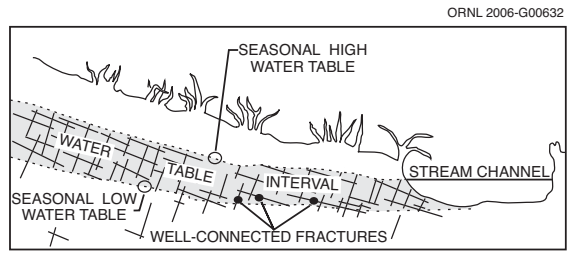


Fig. 1.7. Water table interval.

As in the stormflow zone, the bulk of groundwater in the saturated zone resides within the pore spaces of the rock matrix. The rock matrix typically forms blocks that are bounded by fractures. Contaminants migrating from sources by way of the fractures typically occur in higher concentrations than in the matrix; thus, the contaminants tend to move (diffuse) into the matrix. This process, termed "diffusive exchange" or "matrix diffusion," between water in matrix pores and water in adjacent fractures reduces the overall contaminant migration rates relative to groundwater flow velocities. For example, the leading edge of a geochemically nonreactive contaminant mass such as tritium (3H) may migrate along fractures at a typical rate of 1 m/day; however, the center of mass of a contaminant plume typically migrates at a rate less than 0.66 m/day

In the ORR Aquitards, chemical characteristics of groundwater change from a mixed-cation-HCO_3 water type at shallow depth to an Na-HCO_3 water type at deeper levels (30.5 m). This transition, not marked by a distinct change in rock properties, serves as a useful marker and can be used to distinguish the more active water table and intermediate groundwater intervals from the sluggish flow of the deep interval. There is no evidence of similar change with depth in the chemical characteristics of water in the Knox Aquifer; virtually all wells are within the monitoring regime of Ca-Mg-HCO_3 type water. Although the mechanism responsible for this change in water types is not quantified, it most likely is related to the amount of time that the water is in contact with a specific type of rock.

Most groundwater flow in the saturated zone occurs within the water table interval. Most flow is through weathered, permeable fractures and matrix rock and within solution conduits in the Knox Aquifer. The range of seasonal fluctua-

tions of water table depth and rates of groundwater flow vary significantly across the reservation. In areas underlain by the Knox Aquifer, seasonal fluctuations in water levels average 5.3 m, and mean discharge from the active groundwater zone is typically 322 L/min per 2.6 km^2. In the ORR Aquitards of Bear Creek Valley, Melton Valley, East Fork Valley, and Bethel Valley, seasonal fluctuations in water levels average 1.5 m, and typical mean discharge is 98 L/min per 2.6 km^2.

In the intermediate interval, groundwater flow paths are products of fracture density and orientation. Groundwater movement occurs primarily in permeable fractures that are poorly connected. In the Knox Aquifer, a few cavity systems and fractures control groundwater movement in this zone, but in the ORR Aquitards, the bulk of flow is through fractures, along which permeability may be increased by weathering.

The deep interval of the saturated zone is delineated by a change to an Na-Cl water type. Hydrologically active fractures in the deep interval are significantly fewer and shorter than in the other intervals, and the spacing is greater. Wells finished in the deep interval of the ORR aquitards typically yield less than 1.1 L/min and thus are barely adequate for water supply.

In the ORR Aquitards, saline water characterized by total dissolved solids ranging up to 275,000 mg/L and chlorides generally in excess of 50,000 mg/L (ranging up to 163,000 mg/L) lies beneath the deep interval of the groundwater zone, delineating an aquiclude. Chemically, this water resembles brines typical of major sedimentary basins, which originated from evaporating water bodies. The brines are thought to have been pushed westward and trapped by overthrusting rock during the formation of the Appalachian Mountains (about 250 million years ago). The chemistry suggests extremely long residence times (i.e., very low flow rates); however, some mixing with shallow groundwater has been observed (Nativ, Halleran, and Hunley 1997).

The aquiclude has been encountered at depths of 122 and 244 m in Melton and Bethel Valleys, respectively (near ORNL), and it is believed to approach 305 m in portions of Bear Creek Valley (near the Y-12 Complex) underlain by aquitard formations. The depth to the aquiclude in areas of the Knox Aquifer is not known but is believed to be greater than 366 m. The depth to the aquiclude has not been established in the vicinity of the ETTP.

1.6.2 Groundwater Flow

Many factors influence groundwater flow on the ORR. Topography, surface cover, geologic structure, karst features (see Sect.1.6.1.1), and rock type exhibit especially strong influences on the hydrogeology. Variations in these features result in variations of the total amount of groundwater moving through the system (flux). (Average flux ratios for the ORR Aquitards and the Knox Aquifer formations are shown in Fig. 1.5.) As an example, the overall decrease in open fracture density with depth results in a decreased groundwater flux with depth.

Topographic relief on the ORR is such that most active subsurface groundwater flow occurs at shallow depths. U.S. Geological Survey modeling (Tucci 1992) suggests that 95% of all groundwater flow occurs in the upper 15 to 30 m of the saturated zone in the ORR Aquitards. As a result, flow paths in the active-flow zones (particularly in the aquitards) are relatively short, and nearly all groundwater discharges to local surface water drainages on the ORR. Conversely, in the Knox Aquifer it is believed that solution conduit flow paths may be considerably longer, perhaps as much as 1.6 km long in the along-strike direction. No evidence at this time substantiates the existence of any deep, regional flow off the ORR or between basins within the ORR in either the Knox Aquifer or the ORR Aquitards. Data collected in the calendar years 1994 and 1995, however, have demonstrated that groundwater flow and contaminant transport occur off the ORR in the intermediate interval of the Knox Aquifer, near the east end of the Y-12 Complex.

Migration rates of contaminants transported in groundwater are strongly influenced by natural chemical and physical processes in the subsurface (including diffusion and adsorption). Peak concentrations of solutes, including contaminants such as tritium moving from a waste area, for instance, can be delayed for several to many decades in the ORR Aquitards, even along flow paths as short as a few hundred feet. The processes that naturally retard contaminant migration and store contaminants in the subsurface

are less effective in the Knox Aquifer than in the ORR Aquitards because rapid flow along solution features allows minimal time for diffusion to occur.

1.6.3 Groundwater Monitoring Considerations

The groundwater monitoring programs on the ORR were designed to gather information to determine the effects of past and present DOE operations on groundwater quality. Because of the complexity of the hydrogeologic framework on the ORR, groundwater flow, and, therefore, contaminant transport are difficult to predict on a local scale. Also, detailed delineation of groundwater contaminant plumes is not always feasible. Monitoring wells and piezometers are used to perform ongoing surveillance and characterization of groundwater flow and quality. Since stormflow and most groundwater discharge to ORR surface water drainages, springs, and seeps, these features are monitored for water quality to assess the extent to which groundwater from a large portion of the ORR transports contaminants.

1.6.3.1 Groundwater Monitoring Programs on the ORR

Groundwater monitoring programs at each of the major ORR facilities are discussed in the facility-specific chapters: Sect. 4.9 for the ETTP, Sect. 5.11 for ORNL, and Sect. 6.10 for the Y-12 Complex.

1.7 Description of Site Facilities and Operations

1.7.1 History of the Oak Ridge Reservation

Beginning in early 1943, thousands of scientists, engineers, and workers came from all over the United States to small crossroads communities such as Scarboro, Wheat, Robertsville, and Elza to build and operate three huge facilities that would change the history of the region and the world forever. These people came to rural East Tennessee to do whatever was necessary to end World War II and, as part of the then secret Manhattan Project, helped produce the first nuclear weapons.

The 23,600-hectare site, known as Clinton Engineering Works, was selected for use by the Manhattan Project because the Clinch River provided ample supplies of water, nearby Knoxville was a good source of labor, and the TVA could supply the huge amounts of electricity needed. About 3000 residents received court orders to vacate the homes and farms that their families had occupied for generations.

The workers' city, named Oak Ridge, was established on the reservation's northern edge. The "Secret City" grew to a population of 75,000, used one-seventh of the electrical power generated in the country at the time, and was the fifth-largest city in Tennessee; however; it was not shown on any map. At the Y-12 Plant, south of the city, an electromagnetic method was used to separate fissionable isotopes of uranium (^{235}U) from natural uranium. At its peak operation, the Y-12 Plant employed 22,000 workers. A gaseous diffusion plant, later known as K-25, was built on the reservation's western edge and included a multistory process building covering more area than any other structure ever built. Operated by 12,000 workers, the K-25 Plant separated ^{235}U from ^{238}U. Near the reservation's southwest corner, about 10 miles (16 km) from Y-12, was a third facility, known as X-10 (or Clinton Laboratories), where the Graphite Reactor was built. Employing only about 1500 people during the war, X-10 was a pilot plant for the larger plutonium production plant built at Hanford, Washington. The Graphite Reactor used neutrons emitted in the fission of ^{235}U to convert ^{238}U into a new element, plutonium-239 (^{239}Pu).

The primary missions of the three sites have evolved during the past 60+ years and continue to adapt to meet the changing defense, energy, and research needs of the United States. The reservation contains three major DOE installations: the Y-12 National Security Complex (former Y-12 Plant), ORNL (former X-10 site), and ETTP (former K-25 site). DOE also operates a number of facilities in addition to the major installation sites.

1.7.2 The Y-12 National Security Complex

The Y-12 National Security Complex (Y-12 Complex) (Fig. 1.8), operated by BWXT Y-12 for the National Nuclear Security Administration (NNSA) within the Department of Energy, is a one-of-a-kind manufacturing facility that plays an important role in the U.S. national security and is dedicated to making our nation and the world a safer place. With more than 60 years of experience to draw from, Y-12 is uniquely qualified to address the existing and emerging security challenges facing our nation and the world today. Today Y-12's roles include

- providing critical elements of NNSA's missions that ensure the safety, reliability, and performance of the U.S. nuclear weapons deterrent;
- supplying the special nuclear material for use in naval reactors;
- promoting international nuclear safety and nonproliferation;
- reducing global dangers from weapons of mass destruction; and
- supporting U.S. leadership in science and technology.

Presently, the Y-12 Complex is pursuing an aggressive program of infrastructure reduction, modernization, and investment in technology to make the site as safe and efficient as possible and to improve production capabilities. The *Y-12 National Security Complex Ten-Year Comprehensive Site Plan* (Y-12 2005) outlines the new construction, recapitalization, maintenance requirements, and excess facility demolition required to modernize the Y-12 Complex. The Y-12 Complex is making all these improvements while maintaining safety, security, and environmental stewardship as its highest priorities.

1.7.3 East Tennessee Technology Park

The ETTP was built as the home of the Oak Ridge Gaseous Diffusion Plant (ORGDP) (Fig. 1.9). The plant's original mission was production of highly enriched uranium for nuclear weapons.

Enrichment was initially carried out in two process buildings, K-25 and K-27. 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. After military production of highly enriched uranium was concluded in 1964, the two original process buildings were shut down. For the next 20 years, the plant's primary missions were production of only slightly enriched uranium to be fabricated into fuel elements for nuclear reactors and the recycling of fuel elements from nuclear reactors. Other missions during the latter part of this 20-year period included development and testing of the gas centrifuge method of uranium enrichment and the laser isotope separation research and development (R&D).

By 1985, 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 1990. In 1997, the K-25 Site was named the "East Tennessee Technology Park" to reflect its new mission.

DOE's long-term goal for ETTP is to convert the site into a private industrial park. The site is undergoing environmental cleanup, which is now expected to be completed on an accelerated schedule. The new accelerated closure plan will achieve cleanup several years ahead of the original plan, and thereby will reduce environmental and safety risks more quickly and will reduce long-term maintenance costs. The reuse of key site facilities through title transfer is part of the closure plan for the site. The accelerated cleanup approach makes land and various types of buildings (e.g., office, manufacturing) suitable for private industrial use and suitable for title transfer to the Community Reuse Organization of East Tennessee (CROET) or other entities, such as the city of Oak Ridge. The facilities may then be subleased or sold, with the goal of stimulating private industry and recruiting business to the area.

Y-12 PHOTO 306208

Fig. 1.8. The Y-12 National Security Complex.

ORNL 1439-2005

Fig. 1.9. The East Tennessee Technology Park.

The ETTP mission is to reindustrialize and reuse site assets through leasing of excess or underutilized land and facilities and incorporation of commercial industrial organizations as partners in the ongoing environmental restoration, decontamination and decommissioning, and waste treatment and disposal. During 2005, four office buildings were transferred from DOE ownership to CROET. Similar to the CROET leasing process for federally owned facilities, CROET also subleases transferred facilities.

George Jones Memorial Baptist Church, commonly called the Wheat Church (part of the early Wheat Community), located within the

ETTP, predates World War II and is included in the *National Register of Historic Places* (National Park Service 2003).

1.7.4 Oak Ridge National Laboratory

ORNL is DOE's largest science and energy laboratory (Fig. 1.10). Managed since April 2000 by a partnership of the University of Tennessee and Battelle, ORNL was established in 1943 as a part of the secret Manhattan Project to pioneer a method for producing and separating plutonium. ORNL's involvement with nuclear weapons ended after the war, and the laboratory's scientific expertise shifted in the 1950s and 1960s to peacetime research in medicine, biology, materials and physics. The Graphite Reactor evolved from a wartime role to produce the world's first medical radioisotopes for treating cancer. Following the creation of DOE in 1977, ORNL's mission broadened to include research in energy production, transmission, and consumption. The end of the Cold War and the growth of international terrorism led to a further expansion of research into a range of national security technologies. As the laboratory entered the twenty-first century, new cross-disciplinary programs in nanophase materials, computational sciences, and biology led to the term "nano-info-bio" to describe the emerging synthesis in ORNL's research agenda. As ORNL's missions have changed over the years to meet the nation's priorities and needs, the laboratory's underpinning standards in science and public service have remained.

ORNL supports DOE ORO in its responsibilities for land use planning, land management activities, and natural resource management for the ORR. ORNL also coordinates research and its associated operational and maintenance activities within the National Environmental Research Park.

The SNS site is located on approximately 32 hectares of Chestnut Ridge near ORNL. The SNS, an accelerator-based neutron source, is currently operating at low power, and will provide neutron beams with up to ten times more intensity than any other such source in the world. Construction began in 1999 and was completed in May, 2006 at a total cost of $1.4 billion. Design and construction was performed by a partnership of six DOE national laboratories (Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos, and Oak Ridge). Limted experiments are currently being conducted at the SNS, and as the SNS ramps up to full power operations in 2006 and 2007, will attract scientists and engineers from universities, industries, and government laboratories in the United States and abroad.

1.7.5 Oak Ridge National Environmental Research Park

In 1980, DOE established the Oak Ridge National Environmental Research Park (Fig. 1.11). Consisting of about 8,094 hectares, the Research Park serves as an outdoor laboratory to evaluate the environmental consequences of energy use and development as well as the strategies to mitigate these effects. The combination of protected, undeveloped areas with disturbed, developed, or developing areas within the Research Park allows the demonstration and assessment of various environmental and land-use options.

Major DOE Office of Science research programs use the ORR land to meet mission objectives. In FY 2005 almost $10 million was spent on DOE-supported environmental field-based research directly dependent on the ORR land base. This expenditure is independent of construction of new facilities such as the SNS. The Office of Science considers the research and science value of the ORR to be critical and provides primary operations funding. The Oak Ridge Research Park is one of the few sites in the nation where large-scale ecological research, environmental technology, and measurement science are integrated with 40 years of environmental monitoring and research.

The availability of the protected lands and field research sites on the ORR allows DOE to support major field experiments that could not be conducted if the lands and associated ecological systems were not protected and secured for such long-term studies. This research addresses fundamental questions about the effects of energy-related activities on ecological systems and compares such effects with the natural variation of ecological systems.

The Oak Ridge National Environmental Research Park is a DOE national user facility that has attracted more than 1200 users from ORNL, 150 colleges, universities, industries, and other

ORNL 5753-2005A

Fig. 1.10. The Oak Ridge National Laboratory.

ORNL 2006-G00633

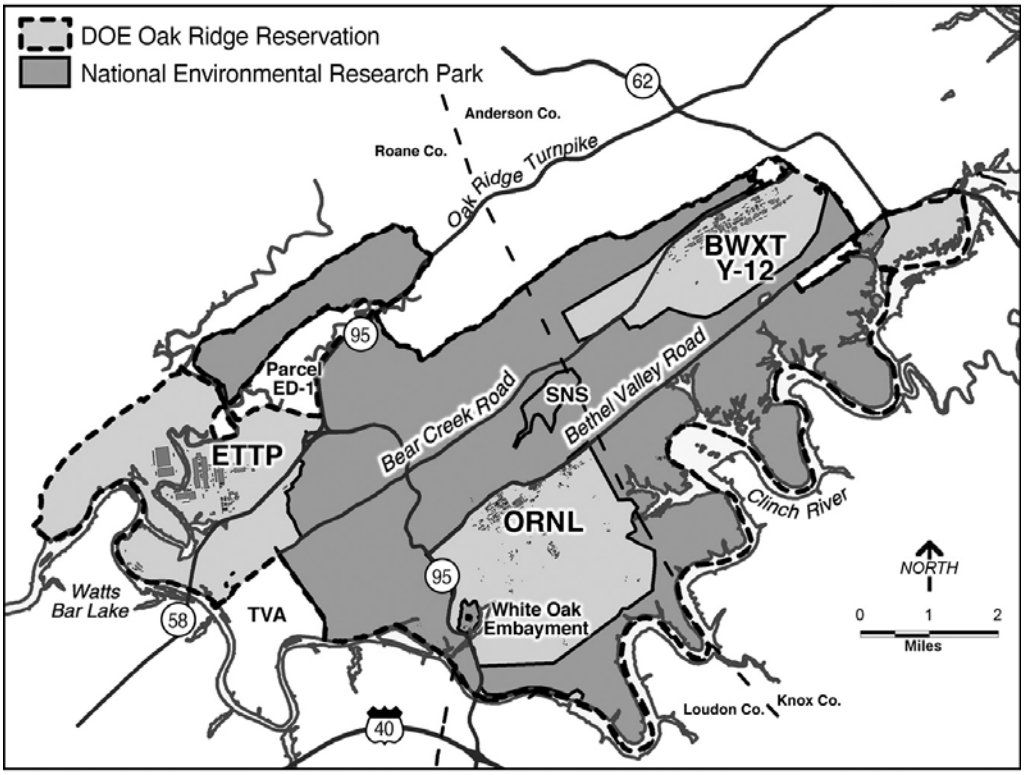


Fig. 1.11. The Oak Ridge National Environmental Research Park covers about 8,094 hectares (about 20,000 acres) on the reservation.

state and federal agencies over the past 5 years. The 270 users during 2005 represented 50 organizations, including educational institutions, state and federal agencies, and others.

1.7.6 Oak Ridge Institute for Science and Education

The Oak Ridge Institute for Science and Education (ORISE) is managed for DOE by Oak Ridge Associated Universities (ORAU), a nonprofit consortium of 91 doctoral-granting members and 10 associate members. ORISE includes 94 hectares 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, was operated by the University of Tennessee (UT).

The ORISE South Campus lies immediately southeast of the intersection of Bethel Valley Road and Pumphouse Road. The site houses offices, laboratories, and storage areas for the ORISE program offices and support departments, and it is being developed for other productive uses.

For more information, visit the ORAU home page at http://www.orau.org and the ORISE home page at http://www.orau.gov/orise.htm.

1.7.7 Other Sites

DOE operates a number of facilities in addition to the major installation sites. They are described in the following sections. Two sites formerly operated by DOE, the Water Intake Station, located at Solway Bend, and the Water Treatment Plant, located on Pine Ridge just north of the Y-12 Complex, were transferred to the city of Oak Ridge on April 1, 2000.

1.7.7.1 American Museum of Science and Energy

The American Museum of Science and Energy occupies a 7-hectare (17.3-acre) site contiguous to the ORAU campus, on South Tulane Avenue in Oak Ridge. In 1975, the American Museum of Science and Energy was moved from its previous facility (55–59 Jefferson Circle) to a masonry structure with about 53,000 ft^2. In addition to the main museum facility, the site contains the Energy House which is licensed to the city of Oak Ridge for use by the Convention and Visitors' Bureau. The museum also has warehouse space in the Office of Scientific and Technical Information (OSTI) Building 1916T-2 complex. The museum is managed by UT-Battelle.

1.7.7.2 Atmospheric Turbulence and Diffusion Division—National Oceanic and Atmospheric Administration Facility

The Atmospheric Turbulence and Diffusion Division—National Oceanic and Atmospheric Administration (ATDD-NOAA) Facility is composed of a wood-frame building built in the 1940s and several smaller buildings at 456 South Illinois Avenue in Oak Ridge. ATDD conducts meteorological and atmospheric diffusion research that is jointly supported by DOE and NOAA. It also provides services to other DOE contractors and operates the Weather Instrument Telemetering Monitoring System for DOE.

1.7.7.3 Buildings 2714 and 2715

Building 2714 (the "Laboratory Road Facility") and Building 2715 are DOE-owned facilities that DOE shares with ORISE. The facilities are used for general offices and hands-on, laboratory-based training in the areas of radiation safety (health physics). The ORISE-occupied facilities comprise about 25,477 ft^2 and are located in Oak Ridge immediately south of the Federal Office Building.

1.7.7.4 Central Training Facility

The Central Training Facility, used primarily by security forces, consists of a small office building, an indoor firing range, two classroom/storage trailers, on-site parking, fitness facilities (an outdoor track), and numerous outdoor firing ranges. The site, including a buffer area, is south of Bear Creek Road, less than 1.6 km southeast of ETTP, and currently occupies about 61 hectares (about 151 acres).

1.7.7.5 Checking Stations

Three checking stations (gatehouses), which are DOE-ORO properties, are included in the *National Register of Historic Places* (National

Park Service 2003): (1) the Oak Ridge Turnpike Checking Station (Turnpike Checking Station), (2) the Scarboro Road Checking Station (Midway Checking Station), and (3) the Bethel Valley Road Checking Station. Although these structures are listed as checking stations in the *National Register*, they were originally called "gatehouses." The main building of the Bethel Valley Road Checking Station is located on a parcel of land that was transferred to the city of Oak Ridge. However, the small associated block building just opposite the main structure is still owned by DOE-ORO.

1.7.7.6 Clark Center Recreation Park

Clark Center Recreation Park, an area containing about 32 hectares, is currently being used for recreational park purposes and is available to DOE and its contractor personnel and to the public on a limited basis. The area lies within landholding under the jurisdictional control of DOE and is managed by DOE.

1.7.7.7 DOE Information Center

The DOE Information Center, located at 475 Oak Ridge Turnpike, provides centralized public access to DOE documents and information. The Information Center consolidates Freedom of Information Act documents that were previously available at the DOE Public Reading Room and information about the DOE Environmental Management Program that was previously located at the Information Resource Center. The building, which is leased to DOE by R&R Rental Properties, has about 8000 ft^2 of space and provides public meeting rooms and office space for the Oak Ridge Site Specific Advisory Board.

1.7.7.8 Federal Office Building

The Federal Office Building, located in Oak Ridge and owned by the General Services Administration, is maintained by DOE. DOE-ORO offices occupy the vast majority of the 113,000 ft^2 of space in the building.

1.7.7.9 National Transportation Research Center

The National Transportation Research Center (NTRC), an alliance among ORNL, UT, the DOE, NTRC, Inc., and the Development Corporation of Knox County is the site of activities that span the whole range of transportation research. The center is an 85,000-ft^2 building, located on a 2.4-hectare site in the Pellissippi Corporate Center and is leased to ORNL and UT separately by Pellissippi Investors LLC.

1.7.7.10 Office of Scientific and Technical Information

The Office of Science and Technical Information (OSTI) is located in Buildings 1916T-1 and 1916T-2, two masonry buildings constructed as warehouses in the 1940s. Building 1916T-1 houses the main OSTI functions as well as other occupants. Portions of it were converted to office space in the 1950s, and additional bays were added in the 1950s and 1960s. Currently, the building has one office bay and seven other bays, for a total space of 135,000 ft^2.Building 1916T-2 houses DOE-ORO operations, including warehousing and maintenance staff. The two DOE buildings are located on an about 3-hectare tract that parallels the Oak Ridge Turnpike about 3.2 km east of the Federal Office Building. Because of their age and configuration, they are classified as Class B buildings (i.e., semipermanent buildings, constructed primarily of wood, which may need to be renewed, renovated, or rehabilitated in the near future) but are deemed adequate for current functions.

1.7.7.11 The Horizon Center

The Horizon Center (previously known as ED-1), was leased to CROET, effective April 28, 1998, and 198 hectares were transferred (by quit claim deed) to CROET in April 2003. The developable portions of the parcel were transferred. The other portions (the natural area that surrounds the East Fork Poplar Creek floodplain and other locations), remain part of the CROET leasehold. CROET may sublease the land transferred to it or may sell it to others for purposes of economic development. CROET is responsible for the protection and maintenance of all portions of the property.

1.7.7.12 Parcel ED-2

Parcel ED-2, which includes the K-1252 barge facility and an adjacent laydown/access area, is about 4 hectares in size. ED-2 is located in the K-700 area west of the main ETTP site, and it has been leased to CROET. CROET has changed its long-range plan for the barge facility and adjoining property. The current plan recognizes the advent of Rarity Ridge, a residential community across the river from the barge facility. CROET wishes to ensure that future use and further development of the peninsula would be achieved in a manner compatible with this evolving residential community and will be in contact with Rarity Ridge as plans for the barge area are identified.

1.7.7.13 Office of Secure Transportation Firing Range

The Office of Secure Transportation Firing Range, located to the east of the Central Training Facility, is operated by the NNSA Albuquerque Service Center. The surface danger zones for the Central Training Facility and the Office of Secure Transportation Firing Range overlap and together comprise about 1012 hectares.

1.7.7.14 Office of Secure Transportation Vehicle Maintenance Facility

The Office of Secure Transportation Vehicle Maintenance Facility is located on an 8-hectare site about 1.6 km east of ETTP, on the south side of State Route 58 (Oak Ridge Turnpike), near the intersection with Blair Road. The building has undergone major modifications, including the addition of security fencing, paved parking, and paved access around the building. The total site area constitutes about 40 hectares. The facility is maintained by the Y-12 Complex's Facilities, Infrastructure, and Services Organization and is funded by the NNSA Albuquerque Service Center.

1.7.7.15 Union Valley Facility

The Union Valley Facility, located on Union Valley Road, is a leased facility operated by the Y-12 Analytical Chemistry Organization. Analytical Chemistry provides a wide range of routine and nonroutine analytical services for environmental and hazardous waste programs of NNSA, DOE, and other customers.

1.7.7.16 Vance Road Facility

The DOE-owned Vance Road Facility is operated by ORISE. The 59,800 ft^2 building is located in the middle of the Oak Ridge Methodist Medical Center complex. ORISE vacated this building before June 30, 2005, to allow DOE to make it available for community reuse. A CERCLA 120h report was completed and approved by TDEC for the transfer for community reuse. Final approval is currently pending from DOE Headquarters. The transfer is expected to occur in FY 2006.

1.7.7.17 Transuranic Waste Processing Facility

The TRU Waste Processing Center (TWPC), managed by Foster-Wheeler Environmental Company, LLC, is located at 100 Wipp Road, in Lenoir City, Tennessee. The site is located on about 2 hectares of leased land adjacent to the Melton Valley Storage Tanks, along SR-95 on the western boundary of ORNL.

The TWPC's mission is to receive current inventories of retrievably-stored and legacy transuranic (TRU) wastes and future wastes to be generated from decontamination and decommissioning, remediation, and ongoing mission operations at the ORNL complex. TWPC processes, treats, repackages and ships the waste for final disposal at the Waste Isolation Pilot Plant (WIPP), Nevada Test Site, or any other designated disposal facility. The TWPC is the only facility of its type in the region specifically designed to accomplish this mission. Low-level radioactive waste, and low-level mixed wastes generated as by-products of TRU process operations are also processed for shipment to the Nevada Test Site or other appropriate disposal facility.

The TWPC consists of the Waste Processing Facility, the Contact-Handled Staging Area, the Personnel Building, and numerous support buildings and storage areas. The TWPC began processing supernatant liquid from the Melton Valley Storage Tanks in 2002, and contact-handled solids in December 2005.

2. Environmental Compliance

It is DOE-ORO and National Nuclear Security Administration (NNSA) policy to conduct their operations in compliance with federal, state, and local environmental protection laws, regulations, compliance agreements and decrees, settlement agreements, executive orders, DOE Orders (as incorporated into the operating contracts), and best management practices. DOE and its contractors make every effort to conduct operations in compliance with the letter and intent of applicable environmental statutes. The protection of the public, personnel, and the environment is of paramount importance.

Except for the few instances of noncompliance discussed in this chapter, all ORR sites were in compliance with applicable environmental regulations in 2005. Each site achieved a National Pollutant Discharge Elimination System permit compliance rate greater than 99.9% in 2005.

In 2005, all three ORR facilities operated in compliance with the regulatory dose limits of Tennessee Rule 1200-3-11-.08 (Emission Standards for Hazardous Air Pollutants for Radionuclides) and met its emission and test procedures.

No releases of reportable quantities of hazardous chemicals or asbestos were reported under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) by any of the sites.

Several private businesses operate under leasing arrangements at the ETTP under the DOE Reindustrialization Program. Lessees are accountable for complying with all applicable standards and regulations and for obtaining permits and licenses with local, state, and federal agencies as appropriate. Unless specified, lessee operations are not discussed in this report.

2.1 Introduction

DOE's operations on the reservation are required to be in conformance with environmental standards established by a number of federal and state statutes and regulations, executive orders, DOE Orders, contract-based standards, and compliance and settlement agreements. However, numerous facilities at the ETTP site have been leased to private entities over the past several years through the DOE Reindustrialization Program. Their level of compliance is not addressed in this report.

Principal among the regulating agencies are the Environmental Protection Agency (EPA) and the Tennessee Department of Environment and Conservation (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 issues are identified during routine operations or during ongoing self-assessments of compliance status, the issues are typically discussed with the regulatory agencies. In the following sections, major environmental statutes are summarized for the ORR sites.

2.2 Compliance Activities

2.2.1 Resource Conservation and Recovery Act

The Resource Conservation and Recovery Act (RCRA) was passed in 1976 to address management of the country's huge volume of solid waste. The law requires that EPA regulate the management of hazardous waste, which includes waste solvents, waste chemicals, and many other substances deemed potentially harmful to human health and to the environment. RCRA also regulates underground storage tanks (USTs) used to store petroleum and hazardous substances; recyclable used oil; and batteries, mercury containing equipment, selected pesticides, and fluorescent/hazardous-waste lamps as universal wastes.

Subtitle C of RCRA controls all aspects of the management of hazardous waste, from the point of generation to treatment, storage, disposal, and recycle. Hazardous waste generators must follow specific requirements for handling these wastes. In addition, owners and operators of hazardous waste management facilities have operating and/or postclosure care permits.

The Y-12 Complex, ORNL, and ETTP are considered RCRA large-quantity generators of hazardous waste. Each generates both RCRA

hazardous waste and RCRA hazardous waste containing or contaminated with radionuclides (mixed waste). The hazardous and/or mixed wastes are accumulated by individual generators at locations referred to as satellite accumulation areas or 90-d accumulation areas, as appropriate, where they are picked up by waste management personnel and transported to an ORR treatment, storage, disposal, and recycle facility or shipped directly off site for treatment, storage, or disposal. At the end of 2005, the Y-12 Complex had 118 generator accumulation areas for hazardous or mixed waste; ORNL had 339 generator accumulation areas; and ETTP maintained 11. Each site is also regulated as a large-quantity handler of universal waste; however, the types of universal wastes managed as such at each site may vary.

The Union Valley Facility is considered a small-quantity generator of hazardous waste. At the end of 2005, it had seven satellite accumulation areas and one 90-d accumulation area.

The Oak Ridge Institute for Science and Education (ORISE), the Central Training Facility on Bear Creek Road, the Office of Secure Transportation Vehicle Maintenance Facility, the ORNL 0800 Area, the National Transportation Research Center, and the Freel's Bend area are all classified as conditionally exempt small-quantity generators for CY 2005.

The Y-12 Complex is registered as a large-quantity generator and a treatment, storage, disposal, and recycle facility under EPA ID Number TN3890090001. During 2005, nine units operated as interim-status or permitted units. The RCRA units at the Y-12 Complex operate under two permits: TNHW-122 (formerly TNHW-083) and TNHW-127 (formerly TNHW-084). Both permits were renewed and reissued by TDEC in 2005. The permits are modified whenever necessary.

ORNL is registered as a large-quantity generator and a treatment, storage, and disposal, facility under EPA ID Number TN1890090003. During 2005, 21 units operated as interim-status or permitted units; another 5 units were proposed (new construction).

ORNL's RCRA units operate under three permits: TNHW-097, TNHW-010A, and TNHW-121 (formerly TNHW-010). TNHW-121 is the existing RCRA Hazardous and Solid Waste Amendments permit for the ORR (see Table 2.1). The permits are modified when necessary. A Class 2 permit modification of the TNHW-097 permit that was submitted to TDEC in late 2004 was approved in 2005. That modification addressed changes in container types in some units, a change in co-operator for one unit, and fencing changes around Solid Waste Storage Areas (SWSAs) 5 and 6 to accommodate remedial actions. A renewal application for the TNHW-010A permit was submitted in late 2004; action on that renewal application is still pending.

In late 2005, ORNL requested permit-by-rule status for extended storage of recyclable lead. TDEC action on that request is expected in early 2006.

At ETTP, the RCRA closure of K-1025C was completed in CY 2004, while K-1036A and K-711 were closed in CY 2005. The remaining RCRA-permitted units at the ETTP Site include K-1065 A through H, K-1423, vault K-309-2A (located in the K-25 Building), and K-1425/K-1435 TSCA Incinerator units. All other cleanup actions at ETTP are being conducted under CERCLA.

ETTP is registered as a large-quantity generator and a treatment, storage, disposal, and recycle facility under EPA ID Number TN0890090004. ETTP has received three RCRA permits (see Table 2.1). The K-1435 Toxic Substances Control Act (TSCA) Incinerator is a hazardous waste treatment unit operating under a RCRA permit (TNHW-015) issued by TDEC on September 28, 1987. A revised RCRA permit based on trial-burn results was received in December 1995. A reapplication of the permit was submitted to TDEC in March 1997. A trial burn was conducted in 2001, and the results were submitted to TDEC. A second permit (TNHW-015A) is for storage of waste at the incinerator. Permit TNHW-117 (formerly TNHW-056) covers container storage at various locations throughout the plant. Permit TNHW-117 was issued September 30, 2004.

Table 2.1. RCRA operating permits, 2005

Permit number	Building/description
	Y-12 Complex
TNHW-122	Building 9720-9 Container Storage Unit
	Building 9720-25 Container Storage Unit
	Building 9720-31 Container Storage Unit
	Portable Buildings 1 & 2 Container Storage Unit (not currently located at Y-12)
TNHW-127	Building 9206
	Building 9212
	Building 9720-12
	Organic Handling Unit
	ORNL
TNHW-10A	Building 7507W Container Storage Unit
	Building 7651 Container Storage Unit
	Building 7652 Container Storage Unit
	Building 7653 Container Storage Unit
	Building 7654 Container Storage Unit
	Building 7669 Container Storage Unit
	Portable Buildings 1 & 2 Container Storage Unit
TNHW-097	Building 7572 Container Storage Unit
	Building 7574 Container Storage Unit
	Building 7576 Container Storage Unit
	Building 7577 Container Storage Unit
	Building 7580 Container Storage Unit
	Building 7823 Container Storage Unit
	Building 7824 Container Storage Unit
	Building 7842 Container Storage Unit
	Building 7855 Container Storage Unit
	Building 7878 Container Storage Unit
	Building 7879 Container Storage Unit
	Building 7883 Container Storage Unit
	Building 7884 Container Storage Unit
	ORR
TNHW-121	Hazardous and Solid Waste Amendments
	ETTP
TNHW-015	K-1435 Toxic Substances Control Act Incinerator
TNHW-015A	K-1425 and K-1435 Container and Tank Storage Units

2.2.1.1 RCRA Assessments, Closures, and Corrective Measures

The Hazardous and Solid Waste Amendments to RCRA, passed in 1984, require any facility seeking a RCRA permit to identify, investigate, and (if necessary) clean up all former and current solid waste management units. The Hazardous and Solid Waste Amendments permit requires DOE to address past, present, and future releases of hazardous constituents to the environment. The Hazardous and Solid Waste Amendments permit requirement for corrective action has been integrated into the ORR Federal Facility Agreement (see Sect. 2.2.2 for details). The current Hazardous and Solid Waste Amendments permit (TNHW-121) was issued in September 2004.

The renewed permit addresses contaminant releases from solid waste management units and from RCRA areas of concern, but also integrates RCRA requirements with cleanups conducted

under the Federal Facility Agreement and CERCLA programs (see Sect. 2.2.3).

"Areas of concern" are areas contaminated by a release of hazardous constituents that originated from something other than a solid waste management unit. Under the new Hazardous and Solid Waste Amendments permit, DOE must notify TDEC within 30 d of identification of a new solid waste management unit or new potential areas of concern. DOE has provided to EPA the *2005 Annual Update of the Solid Waste Management Units for the Oak Ridge Reservation* (DOE 2005a) (see Table 2.2).

At the Y-12 Complex, 37 RCRA units have been closed since the mid-1980s. See Table 2.3 for RCRA units closed in 2005.

Since the mid-1980s, ORNL has closed a total of 15 RCRA units. ORNL's solid waste storage area (SWSA) 6 is an interim-status disposal site (landfill) that underwent partial closure beginning in late 1988. Although a revised closure plan for SWSA 6 (which included the eight interim-measure caps, the Hillcut Test Facility, and the Former Explosives Detonation Trench) was submitted in July 1995, actual final remediation of SWSA 6 has been deferred to CERCLA. The Melton Valley Record of Decision, which includes the selected remedy under CERCLA for SWSA 6, was signed in September 2000. A postclosure permit application for SWSA 6 was submitted to TDEC in September 2002; issuance of the postclosure permit is pending. The Interim Record of Decision for ORNL's Bethel Valley was issued in May 2002; its goal is to maintain the ORNL main plant as a controlled industrial-use facility.

Since the mid-1980s a total of 45 RCRA units at ETTP have been closed. The RCRA closure of K-1025C was completed in CY 2004, while K-1036A and K-711 were closed in CY 2005. The remaining RCRA-permitted units at the ETTP Site include K-1065 A through H, K-1423, vault K-309-2A (located in the K-25 Building), and K-1425/K-1435 TSCA Incinerator units. All other cleanup actions at ETTP are being conducted under CERCLA.

RCRA inspections conducted by TDEC at the facilities resulted in three notices of violations (NOVs) issued in 2005. At the Y-12 Complex, there was one NOV; at ORNL, there was one NOV; and at ETTP, there was one NOV. Details of the violations are presented in Sect. 2.5.

2.2.1.2 Land Disposal Restrictions

The 1984 RCRA amendments established land disposal restrictions, which prohibited the land disposal of untreated hazardous wastes. The amendments require that all untreated wastes meet treatment standards before land disposal or that they be disposed of in a land disposal unit from which there will be no migration of hazardous constituents for as long as the waste remains hazardous. These restrictions also prohibit storage of restricted hazardous or mixed waste except as necessary to facilitate recovery, treatment, or disposal. Because treatment and disposal capacity for mixed wastes was unavailable for many years, DOE's storage of the mixed wastes over a year constituted RCRA land disposal restriction violations. To become compliant with RCRA, DOE entered into agreements with EPA, and later, with TDEC (see Sect. 2.2.4).

2.2.1.3 RCRA Subtitle D Solid Waste

Located within the boundary of the Y-12 Complex are two Class II operating industrial solid waste disposal landfills and one operating Class IV construction demolition landfill. These facilities are permitted by TDEC and accept solid waste from DOE operations on the ORR. A second Class IV construction demolition landfill (Landfill VI) is closed pending certification. In addition, one Class IV facility (Spoil Area 1) is overfilled by 11,700 yd^3 and has been the subject of a CERCLA remedial investigation/feasibility study. A CERCLA record of decision for this unit was signed in 1997. One Class II facility (Landfill II) has been closed and is subject to postclosure care and maintenance. Associated TDEC permit numbers are noted in Table 2.4.

2.2.1.4 RCRA Underground Storage Tanks

The USTs containing petroleum and hazardous substances are regulated under Subtitle I of RCRA, 40 CFR 280. TDEC has been granted authority by EPA to regulate USTs containing petroleum under TDEC Rule 1200-1-15; however, hazardous-substance USTs are still regu-

Table 2.2. Summary of 2005 annual update of ORR solid waste management units[a]

Revision[b]	Number of sites/revisions
Addition of solid waste management units or area of concern to A-2 list	8
Revision made to SMU/AOC Names, Notes, and Operation end dates on A-1 list	17
Revision made to SMU/AOC Names, Notes, and Operation end dates on A-2 list	10

[a]SMU/AOC; sediment management unit/area of concern

[b]Department of Energy. 2005a. *Annual Update of the Solid Waste Management Units for the Oak Ridge Reservation*. Submitted to the Environmental Protection Agency.

Table 2.3 Closed RCRA units for ORR, CY 2005[a]

Site	Unit	Permit No.	Certified Closed Date
Y-12	9720-32 Production Waste Container Storage Unit	TNHW-092	January 5, 2005
ORNL	Building 7824, Waste Examination Assay Facility	TNHW-097	July 1, 2005
ORNL	Chemical Detonation Facility	Interim Status Unit	November 16, 2005
ETTP	K-1036-A Container Storage Unit	TNHW-117	July 15, 2005
ETTP	K-711 Waste Storage Unit	TNHW-117	November 30, 2005

[a]RCRA: Resource Conservation and Recovery Act

Table 2.4. RCRA Subtitle D landfills, 2005[a]

Facility	TDEC permit number	Comments
Industrial Landfill IV	IDL-01-103-0075	Operating, Class II
Industrial Landfill V	IDL-01-103-0083	Operating, Class II
Construction and Demolition Landfill	DML-01-103-0012	Overfilled, Class IV Subject of CERCLA record of decision
Construction and Demolition Landfill VI	DML-01-103-0036	Postclosure care and maintenance
Construction and Demolition Landfill VII	DML-01-103-0045	Operating, Class IV
Centralized Industrial Landfill II	IDL-01-103-0189	Postclosure care and maintenance

[a]RCRA: Resource Conservation and Recovery Act
CERCLA: Comprehensive Environmental Response, Compensation, and Liability Act

lated by EPA. Table 2.5 summarizes the status of USTs on the ORR.

ORNL has responsibility for 54 USTs registered with TDEC under Facility ID Number 0-730089. These 54 USTs can be classified as follows:

- 49 USTs closed to meet the RCRA Subtitle I requirements;
- 3 USTs in service that meet the 1998 standards for new UST installations;
- 2 USTs still in service that are deferred or exempt from Subtitle I because they are regulated by other statutes [one UST under the RCRA Subtitle C and one UST under the Clean Water Act (CWA)].

Of the 49 closed USTs, 24 were replaced by double-walled, concrete-encased above-ground storage tanks; 3 were replaced by the new, state-of-the-art USTs; and 22 were not replaced because they were no longer needed. Closure approval letters have been received for all USTs closed between 1988 and 1998.

The Y-12 UST Program includes four active petroleum USTs that meet all current regulatory compliance requirements. Two of these are located at the Office of Secure Transportation Vehicle Maintenance Facility. The UST registration certificates for these tanks are current, and certificates are posted at the UST locations, enabling fuel delivery until March 31, 2007.

All legacy petroleum UST sites at the Y-12 Complex have either been granted final closure by TDEC or have been deferred to the CERCLA

Table 2.5. ORR underground storage tank (UST) status, 2005

	Y-12 Complex	ORNL	ETTP
Active/in-service	4[a]	3	2
Closed	40	51[b]	14
Hazardous substance	3[c]	0[d]	6[e]
Known or suspected sites	0	0	16
Total	47	54	38

[a]Two are located off the Y-12 Complex at the Office of Secure Transportation Vehicle Maintenance Facility.

[b]The 51 "closed" USTs include deferred or excluded tanks of various categories, as detailed in the text.

[c]Two USTs are deferred because they are regulated by the Atomic Energy Act of 1954. The third is a permanently closed methanol UST.

[d]Closed tanks include two hazardous substance tanks, both of which were excavated, removed, and dismantled.

[e]Four USTs were permanently closed that had been used to store natural gas odorant and are regulated under the Pipeline Safety Act. A fifth UST, designed as a spill-overflow tank, has never permanently been placed into service. A sixth UST, which stored a methanol-gasoline mixture, was permanently closed.

process for further investigation and remediation.

The ETTP UST Program includes two active petroleum USTs that meet all current regulatory compliance requirements. The UST registration certificates are updated annually and are conspicuously posted in accordance with TDEC rules. Fourteen other petroleum USTs have been removed or closed in place with TDEC regulators' recommendation of "case closed" status. During the construction of the Haul Road, a previously undocumented UST was discovered near Portal 5. The tank was removed and closed out.

Five hazardous substance USTs at ETTP have been removed since 1996. One other hazardous substance UST designed as a spill overflow tank is present at ETTP but has never been activated.

Sixteen known and/or suspected historical USTs that were out of service before January 1, 1974, are also included in the ETTP UST Program as a best management practice. These historical UST sites could be subject to closure requirements if directed by UST regulators. Magnetic and electromagnetic geophysical techniques are being used for detection and characterization of these historical UST sites and other underground structures to provide property database information for reindustrialization of ETTP.

2.2.2 Comprehensive Environmental Response, Compensation, and Liability Act

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 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. The ORR was placed on the National Priorities List on November 21, 1989, ensuring that the environmental impacts associated with past and present activities at the ORR are thoroughly investigated and that appropriate remedial actions or corrective measures are taken as necessary to protect human health and the environment. An interagency agreement under Sect. 120(c) of CERCLA, known as the ORR Federal Facility Agreement, was effective in 1992 among EPA, TDEC, and DOE. The agreement establishes the

procedural framework and schedule for developing, implementing, and monitoring response actions on the ORR in accordance with CERCLA. Appendix C of the Federal Facility Agreement lists all of the sites/areas that will be investigated, and possibly remediated, under CERCLA. Milestones for completion of CERCLA documents are available in Appendix E of the agreement.

The progress toward achieving these goals is described in the *2005 Remediation Effectiveness Report for the U.S. Department of Energy Oak-Ridge Reservation, Oak Ridge, Tennessee* (DOE 2006b). This report describes the individual remedial actions and provides an overview of some of the monitoring conducted to evaluate the efficacy of those actions.

Staff from NNSA and BWXT Y-12 have provided periodic updates of proposed construction and demolition activities at the Y-12 Complex (including alternative financing projects) to managers and project personnel from the TDEC DOE Oversight Division, EPA Region 4, and DOE-ORO. A CERCLA screening process is used to identify proposed construction and demolition projects that warrant CERCLA oversight. The goal is to ensure that modernization efforts do not impact the effectiveness of previously completed CERCLA environmental remedial actions and that they do not adversely impact future CERCLA environmental remedial actions. A similar CERCLA screening process is being utilized by ORNL (UT-Battelle, LLC) for its revitalization/modernization efforts at ORNL.

2.2.3 RCRA-CERCLA Coordination

The CERCLA response action and RCRA corrective action processes are similar and include four steps with similar purposes (Table 2.6). The ORR Federal Facility Agreement is intended to coordinate the corrective action processes of RCRA required under the Hazardous and Solid Waste Amendments permit with CERCLA response actions.

As a further example, three RCRA postclosure permits, one for each of the three hydrogeologic regimes at Y-12, have been issued to address the seven major closed waste disposal areas at Y-12. Because it falls under the jurisdiction of two postclosure permits, the S-3 Pond Site is described as having two parts (eastern and former S-3) (see Table 2.7). Groundwater corrective actions required under the postclosure permits have been deferred to CERCLA. RCRA Groundwater monitoring data will be reported yearly to TDEC and EPA in the Annual CERCLA Remediation Effectiveness Report for the ORR.

2.2.4 Federal Facility Compliance Act

The Federal Facility Compliance Act was signed by Congress to bring federal facilities (including those under DOE) into full compliance with RCRA. The Federal Facility Compliance Act waives the government's sovereign immunity, allowing fines and penalties to be imposed for RCRA violations at DOE facilities. In addition, the act requires that DOE facilities provide comprehensive data to EPA and state regulatory agencies on mixed-waste inventories, treatment capacities, and development of site treatment plans. It ensures that the public will be informed of waste-treatment options and encourages active public participation in the decisions affecting federal facilities. TDEC is the authorized regulatory agency under the act for the DOE facilities in the state of Tennessee.

The ORR Site Treatment Plan calls for low-level waste on the ORR to be treated by a combination of commercial treatment capabilities and existing and modified on-site treatment facilities. Mixed transuranic (TRU) waste streams on the ORR, composed of both contact- and remote-handled wastes, will be treated in the Transuranic Waste Processing Facility only as necessary to meet the waste acceptance criteria for disposal at the Waste Isolation Pilot Plant (WIPP). Construction of the Transuranic Waste Processing Facility was completed in fall 2003, and operations began in early 2004. It is operated by the Foster Wheeler Corporation. The ORR Site Treatment Plan provides overall schedules, milestones, and target dates for achieving compliance with land disposal restrictions; a general framework for the establishment and review of milestones; and other provisions for implementing the plan that are enforceable under the commissioner's order.

Semiannual progress reports document the quantity of land-disposal-restricted mixed waste in storage at the end of the previous 6-month period and the estimated quantity to be placed in storage for the next 5 fiscal years. Correspon-

Table 2.6. RCRA corrective action processes and CERCLA response actions[a]

RCRA	CERCLA	Purpose
RCRA facility assessment	Preliminary assessment/site investigation	Identify releases needing further investigation
RCRA facility investigation	Remedial investigation	Characterize nature, extent, and rate of contaminant releases
Corrective measures study	Feasibility study	Evaluate and select remedy
Corrective measures implementation	Remedial design/remedial action	Design and implement chosen remedy

[a]RCRA: Resource Conservation and Recovery Act
CERCLA: Comprehensive Environmental Response, Compensation, and Liability Act

dence dated October 15, 2004, from TDEC to the DOE Office of Environmental Management (DOE-EM) denied a request from DOE-EM for an extension of the Site Treatment Plan milestones. The annual update of the plan has been issued for CY 2004.

The Site Treatment Plan will terminate in accordance with Sect. 2.7.2 of the Federal Facility Compliance Act, when there is no longer any land-disposal-restriction mixed waste, regardless of when generated, being stored on the ORR, which in the absence of a site treatment plan, would be in violation of RCRA Section 3004(j).

2.2.5 National Environmental Policy Act

The National Environmental Policy Act (NEPA) provides a means to evaluate the potential environmental impact of proposed federal activities and to examine alternatives to those actions. The NEPA review process results in the preparation of NEPA documents in which federal, state, and local environmental regulations and DOE Orders applicable to the environmental resource areas must be considered. These environmental resource areas include air, surface water, groundwater, terrestrial and aquatic ecology, threatened and/or endangered species, land use, and environmentally sensitive areas. Environmentally sensitive areas include floodplains, wetlands, prime farm land, habitats for threatened and/or endangered species, historic properties, and archaeological sites. Each ORR site NEPA program maintains compliance with NEPA through the use of its site-level procedures and program descriptions. These procedures and program descriptions assist in establishing 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 2.8 notes the types of NEPA activities conducted at the ORR during 2005.

During 2005, ORNL operated under a procedure that provided requirements for project reviews and compliance with NEPA. It called for review of each proposed project, activity, or facility for its potential to result in significant impacts to the environment. To streamline the NEPA review and documentation process, DOE-ORO approved “generic” categorical exclusions that would cover proposed bench- and pilot-scale research activities and generic categorical exclusions that would cover proposed nonresearch activities (i.e., maintenance activities, facilities upgrades, personnel safety enhancements). A categorical exclusion is one of a category of actions defined in 40 CFR 1508.4 that does not individually or cumulatively have a significant effect on the human environment and for which neither an environmental assessment nor an environmental impact statement is normally required. Table 2.8 provides the number of project-specific categorical exclusions that were approved by DOE-ORO during 2005.

The Standards-Based Management System (SBMS) is the delivery system used to manage and control work at ORNL. This system uses three work-control categories: (1) R&D programs and projects; (2) operations, maintenance and services; and (3) office environment (e.g., management, office support, and clerical activities). NEPA is an integral part of SBMS and often utilizes the divisions’ principal investigators, environmental compliance representatives, and environmental protection officers to determine the appropriate NEPA decision. The NEPA decision is based on the approved generic categorical exclusions for a particular division, NEPA

Table 2.7. RCRA postclosure status for former treatment, storage, and disposal units on the ORR[a]

Unit	Major components of closure	Major postclosure requirements
Upper East Fork Poplar Creek Hydrogeologic Regime (RCRA Postclosure Permit No. 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
Eastern S-3 Ponds Groundwater Plume	None for groundwater plume, see former S-3 Ponds (S-3 Site) for source area closure	Postclosure corrective action monitoring. Inspection and maintenance of monitoring network
Chestnut Ridge Hydrogeologic Regime (RCRA Postclosure Permit No. TNHW-088)		
Chestnut Ridge Security Pits	Engineered cap	Cap inspection and maintenance. Postclosure corrective action monitoring. Inspection and maintenance of monitoring network and survey benchmarks
Kerr Hollow Quarry	Waste removal, access controls	Access controls inspection and maintenance. Postclosure detection monitoring. Inspection and maintenance of monitoring network and survey benchmarks
Chestnut Ridge Sediment Disposal Basin	Engineered cap	Cap inspection and maintenance. Postclosure detection monitoring. Inspection and maintenance of monitoring network and survey benchmarks
Bear Creek Hydrogeologic Regime (RCRA Postclosure Permit No. TNHW-116)		
Former S-3 Ponds (S-3 Site)	Neutralization and stabilization of wastes, engineered cap, asphalt cover	Cap inspection and maintenance. Postclosure corrective action monitoring. Inspection and maintenance of monitoring network and survey benchmarks
Oil Landfarm	Engineered cap	Cap inspection and maintenance. Postclosure corrective action monitoring. Inspection and maintenance of monitoring network and survey benchmarks
Bear Creek Burial Grounds A, B, and Walk-In Pits	Engineered cap, leachate 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

[a]There were no closures of treatment, storage, and disposal units at Oak Ridge National Laboratory or East Tennessee Technology Park during this time.

RCRA: Resource Conservation and Recovery Act

CERCLA: Comprehensive Environmental Response, Compensation, and Liability Act

Table 2.8. National Environmental Policy Act (NEPA) activities during 2005

Types of NEPA documentation	Y-12 Complex	ORNL	ETTP
Categorical exclusions (CX) approved	13	3	1
Approved under generic CX documents	38	44[a]	2
Environmental assessment (EA)	2[a]		

[a]Projects that were reviewed and documented through the ORNL NEPA compliance coordinator.

[b]Alternate Financed EA and EA for transportation of enriched uranium reactor fuel.

training of the person and, when necessary, guidance from the ORNL NEPA compliance coordinator. Projects involving the assignment of a project engineer from the ORNL Facilities Development Division, projects that are outside the scope of generic categorical exclusions, and projects that will adversely impact cultural resources are reviewed and documented by the ORNL NEPA compliance coordinator.

DOE implemented the Facilities Revitalization Project at ORNL, and groundbreaking activities for the various infrastructures (e.g., parking lots, utilities) started in March 2002. The Facilities Revitalization Project is being accomplished through a cooperative effort between DOE, the state of Tennessee, and private entities. The environmental assessment and finding of no significant impact (FONSI) (DOE 2001b) that were prepared by DOE addressed the Facilities Revitalization Project phased program approach to cover construction and upgrading of facilities according to ORNL's Strategic Facilities Plan into FY 2011.

In 2005, NEPA reviews at ETTP supported one proposed title transfer action and a number of tenant modifications and improvements to several leased facilities. Other NEPA reviews covered more routine maintenance actions, such as the installation of trailers and temporary support structures. There was one site-specific categorical exclusion prepared in 2005 for ETTP that was for the expansion of the Portal 5 Parking Lot.

At the Y-12 Complex, 15 job-specific categorical exclusion documents were prepared and were approved in CY 2005 in support of the Infrastructure Reduction Program. The Infrastructure Reduction effort is focused on preparing the Y-12 Complex for modernization. During FY 2005 it reduced the Y-12 Complex "footprint" by over 214,000 ft^2 through building demolition (18 buildings or structures were demolished). In addition, two job-specific categorical exclusions prepared for the NNSA small business program were approved. Other general NEPA categorical exclusion reviews covered routine actions, such as office renovations, improvements to security systems, equipment replacements, and infrastructure improvements. A total of 53 NEPA reviews were performed and approved in CY 2005.

The Y-12 NNSA Site Office has prepared a final environmental assessment for the alternate financed facility modernization project to evaluate the need for replacement of existing facilities through collaboration with private entities to construct technical, administrative, and light laboratory facilities. The FONSI was signed February 2, 2005.

The Y-12 NNSA Site Office has initiated two additional environmental assessments. One for the sale of surplus mercury in storage at Y-12 and a second for the potable water system upgrades project. The environmental assessment for the potable water system upgrades will evaluate the repairs and upgrades to the existing system to determine the impacts. The upgrades are to increase reliability and continue to meet regulatory requirements for safe drinking water.

In addition, NNSA filed a notice of intent in the November 28, 2005, *Federal Register* to prepare a Site-Wide Environmental Impact Statement (SWEIS) for the Y-12 Complex. The new SWEIS will evaluate new proposals as well as update the analyses presented in the original SWEIS (DOE/EIS-0309) issued in November 2001. Three action alternatives are proposed for consideration in the new SWEIS in addition to the No Action Alternative. The three alternatives differ in that one includes a new fully modernized manufacturing facility optimized for safety, security, and efficiency; another consists of upgrading the existing facilities to attain the highest level of safety, security, and efficiency

possible without construction of new facilities; and the third consists of operating the current facilities until they are no longer viable followed by deactivation of those facilities and cessation of the associated operations. The public scoping period began December 15, 2005, and was extended through January 31, 2006, to provide the public with an opportunity to present comments and ask questions.

2.2.6 National Historic Preservation Act

In March 2003, President Bush signed Executive Order 13287, "Preserve America," directing federal agencies to improve their management of historic properties and to foster heritage tourism in partnership with local communities. Section 106 of the National Historic Preservation Act (NHPA) requires that federal agencies take into account the effects of their undertakings on properties included in or eligible for inclusion in the *National Register of Historic Places* (National Park Service 2003). To comply with Section 106 of the NHPA and its implementing regulations at 36 CFR 800, DOE-ORO was instrumental in the ratification of a programmatic agreement among DOE-ORO, the Tennessee state historic preservation officer, and the Advisory Council on Historic Preservation concerning management of historical and cultural properties on the ORR. The programmatic agreement was ratified on May 6, 1994, and has been incorporated into the approved *Cultural Resource Management Plan, DOE Oak Ridge Reservation* (DOE 2001a). The plan was completed in accordance with stipulations in the programmatic agreement, including historical surveys to identify significant historical properties on the ORR. Measures were implemented in 2005 to update the Plan by giving the principal players (ORNL, Y-12 Complex, and ETTP) key sections that pertain to their sites for revision. Because of plans to demolish a significant number of buildings at ORNL and at the Y-12 Complex site, a second programmatic agreement was drafted for each site. Both agreements have been approved by DOE-ORO, the state historic preservation officer, and the Council. In concurrence with the programmatic agreement, a historic preservation plan was drafted and was issued (UT-Battelle 2004) for the management and disposition of properties managed by DOE-ORO that included the Office of Science, Nuclear Energy, and EM. Requirements of the programmatic agreement (also stated in the historic preservation plan) include

1. developing and implementing an interpretive plan for ORNL by 2007,
2. developing an oral history program of current and former ORNL employees by 2005, and
3. conducting a survey to identify significant historical machinery and equipment by 2007.

The oral history program was completed in 2005, and significant progress was made in developing an interpretive plan at ORNL. Compliance with NHPA at ORNL, the Y-12 Complex, and ETTP is achieved and maintained in conjunction with NEPA compliance. The scope of proposed actions is reviewed in accordance with the *Cultural Resource Management Plan*. If warranted, consultation is initiated with the state historic preservation officer and the advisory council, and the appropriate level of documentation is prepared and submitted.

The Y-12 Complex adheres to the historic strategy as stated in the *National Historic Preservation Act Historic Preservation Plan* (BWXT 2003) and follows the recommended actions outlined in the *Interpretive Plan on Historic Preservation for the Y-12 National Security Complex* (November 2004) regarding its historic properties. The state historic preservation officer (SHPO) approved the Interpretive Plan in January 2005. A summary of the interpretive efforts completed at Y-12 were submitted to the SHPO in a document entitled *Highlights of Interpretive Efforts at the Y-12 National Security Complex for 2005*.

The Y-12 Complex, in accordance with the programmatic agreement, submitted to the state historic preservation officer Section 106 recordation, interpretation, and documentation information for the demolition of Buildings 9736, 9764, and 9206. The state historic preservation officer reviewed the information and agreed that the Section 106 documentation adequately mitigated project effects upon properties eligible for listing in the *National Register of Historic Places*.

A phase I archaeological survey for the proposed Potable Water Storage and Force Main

Facilities project was conducted at the Y-12 Complex. The impact area of the project is limited to the steep side slopes north of Bear Creek Road and the Y-12 National Security Complex. It was determined that the project area contained no historic properties or archeological resources eligible for listing in the *National Register of Historic Places*. The archeological survey report was reviewed and approved by the state historic preservation officer, December 27, 2005. An equipment and machinery survey will be conducted and completed by December 31, 2006. This survey will document the remaining machinery and equipment associated with the historic missions of the Y-12 Complex during World War II and the Cold War. The Y-12 Complex continues ongoing efforts to demonstrate its commitment to interpret the history of Y-12 by conducting oral histories of former and current employees, maintaining several interpretive centers located at Y-12, collecting artifacts throughout the plant, continuing to use and maintain its historic properties, and partnering with local businesses and organizations.

ETTP was surveyed in 1994 to identify properties eligible for inclusion in the *National Register*. An archaeological survey was also completed at ETTP. Eligible properties include the ETTP Main Plant Historic District, which includes facilities within the main plant and contains 120 contributing structures, 37 noncontributing structures, and 11 structures that are not contiguous with the historic district. More detailed information on the properties eligible for inclusion in the *National Register* is provided in the *Cultural Resource Management Plan* (DOE 2001a).

In August 2002, DOE submitted a notification of adverse effect of a proposed undertaking for decontamination and decommissioning of properties located at the ETTP. The proposed project is to decontaminate and demolish or transfer all remaining properties located within the K-25 site main plant and powerhouse historic districts located on the ORR in Roane County, Tennessee, as outlined in the Oak Ridge Comprehensive Closure Plan. The Tennessee state historic preservation officer, the advisory council, and other interested parties were invited to participate in the planning stages of the proposed undertaking and to enter into the consultation process. Consultation began to develop a path forward, and a memorandum of agreement was negotiated among the consulting parties in 2003 on the decontamination and decommissioning of the K-25 and K-27 Buildings to determine actions to avoid, minimize, or mitigate the adverse effects to these two historical properties. Other ETTP projects were reviewed in accordance with the programmatic agreement or the *Cultural Resource Management Plan*, and a memorandum of agreement was signed in 2004 for the demolition of 108 buildings/structures. Meetings were held in 2004 with the consulting parties to finalize a memorandum of agreement for the historical interpretation of the K-25 Site. The agreement was signed in 2005.

A survey of all ORISE structures was conducted to comply with the NHPA. Only one structure currently under ORISE stewardship, the Atmospheric Turbulence and Diffusion Division Laboratory main building, was identified as being included in the *National Register*. All actions performed at that site conform to the programmatic agreement with the state historic preservation officer.

2.2.7 Protection of Wetlands

The ORR implements protection of wetlands through each site's NEPA program in accordance with 10 CFR 1022, "Compliance with Floodplain/Wetlands Environmental Review Requirements," and each of the three major sites conducts surveys for the presence of wetlands on a project- or program-as-needed basis. In the 1990s, an effort was initiated to conduct a wetlands survey of the entire reservation (LMES 1995). That effort was not completed, but wetland surveys and delineations were conducted on about 5,666 hectares of the 13,931 hectares that made up the reservation at that time (LMER 1996).

Each of the sites has also conducted surveys for the presence of wetlands and conducts surveys on a project- or program-as-needed basis. About 243 hectares of wetlands were identified with most classified as forested palustrine, scrub/shrub, and emergent wetlands. Wetlands occur across the ORR at low elevation, primarily in riparian zones of headwater streams and their receiving streams, as well as in the Clinch River embayments. Wetlands identified to date range in size from several square yards at small seeps and springs to approximately 10 hectares at

White Oak Lake. Surveys of wetlands resources presented in *Identification and Characterization of Wetlands in the Bear Creek Watershed* (MMES 1993), *Wetland Survey of Selected Areas in the Oak Ridge Y-12 Plant Area of Responsibility, Oak Ridge, Tennessee* (LMES 1997), and *Wetland Survey of the X-10 Bethel Valley and Melton Valley Groundwater Operable Units at Oak Ridge National Laboratory* (Rosensteel 1996), serve as reference documents to support wetlands assessments for upcoming projects and activities.

Construction of an access road to the Spallation Neutron Source Facility at ORNL in 2000 resulted in the loss of a small amount of wetland area. To mitigate the loss, a wetlands restoration project was designed and implemented in accordance with the aquatic resources alteration permit (ARAP) issued by TDEC. The ARAP required 5 years of annual monitoring to evaluate the success of the mitigation project and required an annual report detailing vegetation, soils, hydrology, and any remedial actions necessary to address deficiencies. The fourth annual report, which detailed the results of the monitoring done in 2004, was completed in August 2005. The four years of monitoring indicate that the restored wetland acreage is functioning as a viable wetland (SNS 2005).

In 2005, the construction of the haul road from ETTP to the Environmental Management Waste Management Facility (EMWMF) raised concerns about the impact on several small wetlands areas along the proposed route. The route was surveyed by personnel from ORNL's Environmental Sciences Division. Jurisdictional wetlands areas were delineated and marked. Wherever feasible, the route of the road was modified to bypass the wetlands areas. Wetlands compensatory mitigation measures included wetlands creation and restoration and stream restoration efforts, including the construction of the Bear Creek weir bypass. The weir bypass was completed in March 2006.

2.2.8 Floodplains Management

Executive Order 11988 (issued in 1977) was established to require federal agencies to avoid to the extent possible adverse impacts associated with the occupancy and modification of floodplains and to avoid direct or indirect support of floodplain development wherever there is a practicable alternative. Agencies must determine whether a floodplain is present that may be affected by an action, assess the impacts on such, and consider alternatives to the action. The executive order requires that provisions for early public review and measures for minimizing harm be included in any plans for actions that might occur in the floodplain. Floodplain assessments and the associated notices of involvement and statements of findings are prepared in accordance with 10 CFR 1022, usually as part of the NEPA review and documentation process.

A floodplain, according to 10 CFR 1022, means the lowlands adjoining inland and coastal waters and relatively flat areas and flood prone areas of offshore islands including, at a minimum, that area inundated by a 1% or greater chance of flood in any given year. The base floodplain is defined as the 100-year (1.0%) floodplain. The critical action floodplain is defined as the 500-year (0.2%) floodplain. Floodplain assessments and the associated notices of involvement and statements of findings are prepared in accordance with 10 CFR 1022, usually as part of the NEPA review and documentation process. The TVA has conducted floodplain studies along the Clinch River, Bear Creek, and East Fork Poplar Creek. Portions of the Y-12 Complex lie within the 100- and 500-year floodplains of East Fork Poplar Creek, as do portions of ORNL within the floodplain of White Oak Creek.

2.2.9 Endangered Species Act

Good stewardship, state laws ("The Rare Plant Protection and Conservation Act of 1985," Tennessee Code Annotated Section 70-8-301 to 314, and "Tennessee Nongame and Endangered or Threatened Wildlife Species Conservation Act of 1974," Tennessee Code Annotated Section 70-8-101 to 110), and federal laws ("Endangered Species Act of 1973," 16 U.S.C. 1531 et seq.) dictate that animal and plant species of concern be considered when a proposed project has the potential to alter their habitat or otherwise harm them. At the federal level, such species are classified as endangered, threatened, or species of concern. At the state level, these species are considered endangered, threatened, of special concern (plants), or in need of manage-

ment (animals). All such species are termed "special concern" species in this report.

2.2.9.1 Special Concern Animals

Listed animal species known to be present on the reservation (excluding the Clinch River bordering the reservation) are given along with their status in Table 2.9. The list illustrates the diversity of birds on the ORR, which is also habitat for many unlisted species, some of which are in decline nationally or regionally. Other listed species may also be present, although they have not been observed recently. These include several species of mollusks (such as the spiny river snail), amphibians (such as the hellbender), birds (such as Bachman's sparrow), and mammals (such as the smoky shrew). Birds, fish, and aquatic invertebrates are the most thoroughly surveyed animal groups on the ORR. The only federally listed animal species that has been recently observed is the gray bat (federal endangered list), which has been recorded foraging over a pond on the ORR and over waters bordering the ORR (e.g., the Clinch River). The federally threatened bald eagle is increasingly seen in winter and may well begin nesting here within a few years. Similarly, several state-listed bird species, such as the anhinga, olive-sided flycatcher, and little blue heron, are currently uncommon migrants or visitors to the reservation; however, the little blue heron is probably increasing in numbers. Others, such as the cerulean warbler, northern harrier, great egret, and yellow-bellied sapsucker, are migrants or winter residents that do not nest on the reservation. The golden-winged warbler (*Vermivora chrysoptera*), listed by the state as in need of management, has been sighted once on the reservation. One federal and state threatened species, the spotfin chub (*Cyprinella monnacha*), has been sighted and collected in the city of Oak Ridge and is possibly present on the ORR. The Tennessee Dace has been found in some sections of Grassy Creek.

The Grassy Creek population of the Tennessee Dace is one of the most important populations of this species in Tennessee. The construction of the haulroad from ETTP to EMWMF had the potential to impact this population. As a result, several mitigation measures were incorporated into the construction. These included construction of bridges at Bear Creek and other tributaries where the dace are suspected to live (to minimize disturbance of the streams) and the use of extra large culverts and "skylights" at the cross over points where bridges were not feasible (these features reduce sedimentation and allow more light into the culvert, which facilitates migration of the fish through these points.)

2.2.9.2 Threatened and Endangered Plants

There are currently 22 listed plant species that have been observed in the last 10 years on the ORR; among them are the pink lady's-slipper and Canada lily (Table 2.10). Two species occurring on the ORR, Carey's saxifrage and the purple fringeless orchid, have been removed from the state list as of November 17, 1999. Four species (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 Fish and Wildlife Service.

Two additional species listed by the state, the Michigan lily and the hairy sharp-scaled sedge, were identified in the past on the ORR; however, they have not been found in recent years. Another listed species, large-tooth aspen, was reported in two locations on the ORR in 2002. One of the reports was confirmed, but the observed tree died during the year. In 2004 additional aspen trees were found in the vicinity of the dead tree. Several state-listed plant species currently found on adjacent lands may be present on the ORR as well, although they have not been located (Table 2.10).

2.2.10 Environmental Justice

On February 11, 1994, Executive Order 12898, "Federal Actions To Address Environmental Justice in Minority Populations and Low-Income Populations," was promulgated. The executive order requires that federal actions not have the effect of excluding, denying, or discriminating on the basis of race, color, national origin, or income level and that federal agencies must ensure that there are no disproportionate impacts from their actions on low-income and

Table 2.9. Animal species of concern reported from the Oak Ridge Reservation[a]

Sensitive wildlife species recently found on the Oak Ridge Reservation

Scientific name	Common name	Status [b]		
		Federal	State	PIF[c]
	Fish			
Phoxinus tennesseensis	Tennessee dace		NM	
	Amphibians and reptiles			
Hemidactylium scutatum	Four-toed salamander		NM	
	Birds			
Accipiter striatus	Sharp-shinned hawk		NM	
Anhinga anhinga	Anhinga		NM	
Caprimulgus carolinensis	Chuck-will's-widow			C
Ardea alba	Great egret		NM	
Circus cyaneus	Northern harrier		NM	
Contopus cooperi	Olive-sided flycatcher		NM	
Dendroica caerulescens	Black-throated blue warbler			C
Dendroica cerulean	Cerulean warbler		NM	C
Dendroica discolor	Prairie warbler			C
Egretta caerulea	Little blue heron		NM	
Egretta thula	Snowy egret		NM	
Falco peregrinus	Peregrine falcon	*d*	E	
Haliaeetus leucocephalus	Bald eagle	T[e]	NM	
Helmitheros vermivorus	Worm-eating warbler			C
Hylocichla mustelina	Wood thrush			C
Lanius ludovicianus	Loggerhead shrike		NM	
Oporornis formosus	Kentucky warbler			C
Pooecetes gramineus	Vesper sparrow		NM	
Protonotaria citrea	Prothonotary warbler			C
Seiurus motacilla	Louisiana waterthrush			C
Sitta pusilla	Brown-headed nuthatch			C
Sphyrapicus varius	Yellow-bellied sapsucker		NM	
Spizella pusilla	Field sparrow			C
Tyto alba	Barn owl		NM	
Vermivora chrysoptera	Golden-winged warbler		NM	C
Vermivora pinus	Blue-winged warbler			C
	Mammals			
Myotis grisescens	Gray bat	E	E	
Sorex longirostris	Southeastern shrew		NM	

[a]Land and surface waters of the ORR exclusive of the Clinch River, which borders the ORR. Some (e.g., anhinga) have been seen only once or a few times; others (e.g., sharp-shinned hawk, southeastern shrew) are comparatively common and widespread on the reservation.

[b]E endangered
T threatened
NM in need of management
C birds of concern

[c]Partners in Flight.

[d]The peregrine falcon was federally delisted on August 25, 1999.

[e]The bald eagle was proposed for federal delisting on July 6, 1999.

Table 2.10. Vascular plant species listed by state or federal agencies, 2006

Species	Common name	Habitat on ORR	Status code[a]
Currently known or previously reported from the ORR			
Aureolaria patula	Spreading false-foxglove	River bluff	FSC, T
Carex gravida	Heavy sedge	Varied	S
Carex oxylepis var. pubescens[b]	Hairy sharp-scaled sedge	Shaded wetlands	S
Cimicifuga rubifolia	Appalachian bugbane	River slope	FSC, T
Cypripedium acaule	Pink lady's-slipper	Dry to rich woods	E, CE
Delphinium exaltatum	Tall larkspur	Barrens and woods	FSC, E
Diervilla lonicera	Northern bush-honeysuckle	River bluff	T
Draba ramosissima	Branching whitlow-grass	Limestone cliff	S
Elodea nuttallii	Nuttall waterweed	Pond, embayment	S
Fothergilla major	Mountain witch-alder	Woods	T
Hydrastis canadensis	Golden seal	Rich woods	S, CE
Juglans cinerea	Butternut	Slope near stream	FSC, T
Juncus brachycephalus	Small-head rush	Open wetland	S
Lilium canadense	Canada lily	Moist woods	T
Lilium michiganense[c]	Michigan lily	Moist woods	T
Liparis loeselii	Fen orchid	Forested wetland	E
Panax quinquifolius	Ginseng	Rich woods	S, CE
Platanthera flava var. herbiola	Tuberculed rein-orchid	Forested wetland	T
Populus grandidentata[d]	Large-tooth aspen	Dry, woodlands	S
Ruellia purshiana	Pursh's wild-petunia	Dry, open woods	S
Scirpus fluviatilis	River bulrush	Wetland	S
Spiranthes lucida	Shining ladies-tresses	Boggy wetland	T
Thuja occidentalis	Northern white cedar	Rocky river bluffs	S
Viola tripartite var. tripartita	Three-parted violet	Rocky woods	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[e]	Ramps	Moist woods	S, CE
Berberis canadensis	American barberry	Rocky bluff, creek bank	S
Gnaphalium helleri	Catfoot	Dry woodland edge	S
Lathyrus palustris	A vetch	Moist meadows	S
Liatris cylindracea	Slender blazing star	Calcareous barren	E
Lonicera dioica	Mountain honeysuckle	Rocky river bluff	S
Meehania cordata	Heartleaf meehania	Moist calcareous woods	T
Pedicularis lanceolata	Swamp lousewort	Calcareous wet meadow	T
Pycnanthemum torrei	Torrey's mountain-mint	Calcareous barren edge	S
Solidago ptarmicoides	Prairie goldenrod	Calcareous barren	E

[a]Status codes:

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

[b]*Carex oxylepis var. pubescens* has not been observed during recent surveys.

[c]*Lilium michiganense* is believed to have been extirpated from the ORR by the impoundment at Melton Hill.

[d]*Populus grandidentata* was reported in two ORR locations in 2003. One of the reports was confirmed, but the tree died during the year. In 2004 additional trees were found in the vicinity of the dead tree.

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

minority communities surrounding their facilities.

An Environmental Justice strategy is in place at DOE-ORO under the direction of the Diversity Programs Office. It addresses the need to communicate DOE activities effectively to minority communities. In addition, the internal scoping team involved in the review and editing of NEPA documents ensures that the language is presented in a manner that does not require stakeholders to possess a technical background for them to effectively participate in the decision-making process.

Planned DOE actions to be addressed under NEPA include an analysis of the health, environmental, economic, and demographic impacts of the planned action on surrounding minority and low-income communities that could be affected by the action.

2.2.11 Safe Drinking Water Act

The Safe Drinking Water Act (SDWA) of 1974 is an environmental statute for the protection of drinking water. This act requires the EPA to establish primary drinking water regulations for contaminants that may cause adverse public health effects. Although many of the requirements of the SDWA apply to public water supply systems, Section 1447 states that each federal agency having jurisdiction over a federally owned or maintained public water system must comply with all federal, state, and local requirements regarding the provision of safe drinking water.

The city of Oak Ridge supplies potable water to the Y-12 Complex and ORNL. The water treatment plant, located north of the Y-12 Complex, is owned by the city of Oak Ridge. The K-1515 sanitary water plant provides drinking water for ETTP and for an industrial park located on Bear Creek Road south of the site. The DOE-owned facility is classified as a nontransient, noncommunity water supply system by TDEC and is subject to state regulations. On April 1, 1998, operation of this leased facility became the responsibility of Operations Management International, Inc., under contract with the Community Reuse Organization of East Tennessee (CROET).

The Y-12 Complex, ORNL, and ETTP perform certain monitoring activities, including analyses for free residual chlorine, bacteriological agents, disinfectant by-products, and copper and lead. The Y-12 Complex and ORNL potable water systems are classified as a nontransient, noncommunity water supply system by TDEC.

The Y-12 Complex and ORNL distribution systems have qualified for triennial lead and copper sampling. The Y-12 Complex distribution system was last sampled in 2005 and is scheduled to be sampled again in 2008; the ORNL system was sampled in 2003. The Y-12 Complex and ORNL were compliant with the lead and copper requirements. In addition, the Y-12 Complex and ORNL drinking water distribution system's bacteriological sample analyses were satisfactory in 2005. Y-12's and ORNL's water system's analytical results for disinfection by-products (total trihalomethanes and haloacetic acids) were satisfactory.

The Y-12 Complex, ORNL, and ETTP have cross-connection prevention programs to prevent the contamination of potable water through the use of backflow preventers, engineering design, and physical separation. Backflow preventers that fail performance checks are repaired, or the water supply to the equipment is taken out of service.

In addition Y-12 has established requirements and responsibilities for connection, installation, maintenance, operation, alteration, and sampling of the Y-12 Complex potable water system to ensure compliance with all applicable state and federal regulatory standards. A draft cross connection control plan was submitted to TDEC, Division of Water Supply on December 13, 2005, for review and approval. This plan was developed in response to an October 2004 notice of violation from TDEC. The draft plan will be reviewed and commented by TDEC to ensure actions satisfactorily address the notice of violation concerns before the procedure is finalized and issued.

2.2.12 Clean Water Act

The objective of the CWA is to restore, maintain, and protect the chemical, physical, and biological integrity of the nation's waters. With continued amendments, the CWA serves as the basis for comprehensive federal and state programs to protect the nation's waters from pollutants. Congress continues to work on amendments to and reauthorization of the CWA.

(See Appendix D for reference standards for water.)

2.2.12.1 National Pollutant Discharge Elimination System

One of the strategies developed to achieve the goals of the CWA was EPA's establishment of limits on specific pollutants that are allowed to be discharged to waters of the United States by municipal sewage treatment plants and industrial facilities. The EPA established the National Pollutant Discharge Elimination System (NPDES) permitting program to regulate compliance with these pollutant limitations. The program was designed to protect surface waters by limiting effluent discharges into streams, reservoirs, wetlands, and other surface waters. Authority for implementation and enforcement of the NPDES program has been delegated by EPA to the state of Tennessee.

Y-12 Complex

During 2005 the Y-12 Complex continued to operate under Permit TN0002968, issued in 1995, while personnel from the TDEC Division of Water Pollution Control continued efforts to act on the application for renewal that was submitted in October 1999. A draft permit was issued by TDEC in September 2005 for comment. On September 22, 2005, a public hearing on the draft permit was held by the state. TDEC Division of Water Pollution Control continues working to resolve comments received from the EPA on the new Y-12 NPDES permit. Completion of a final determination on all comments and permit issuance is expected in early 2006.

Presently about 90 active point-source discharges or storm water monitoring locations are monitored for compliance with the permit. In 2005 the Y-12 Complex achieved an NPDES permit compliance rate of 99.7%. There were eight NPDES noncompliances (Fig. 2.1). Information on the exceedances is provided in Appendix E, Sect. E.1.

ORNL

ORNL is currently operating under NPDES Permit TN0002941, which was renewed by TDEC on December 6, 1996, and went into effect February 3, 1997. A four-volume permit renewal application was submitted to TDEC and

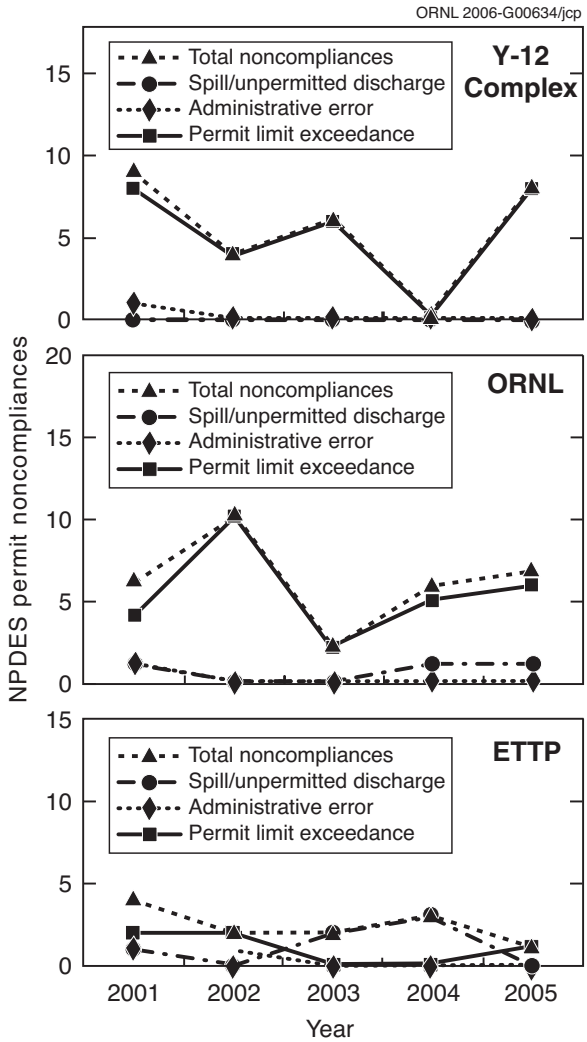


Fig. 2.1 Five-year summary of NPDES noncompliances.

EPA in June 2001. The ORNL NPDES permit lists 164 point-source discharges and monitoring points that require compliance monitoring. Approximately 100 of these are storm drains, roof drains, and parking lot drains. Compliance was determined by approximately 6500 laboratory analyses and measurements in 2005, in addition to numerous field observations by ORNL field technicians. The NPDES permit limit compliance rate for all discharge points for 2005 was nearly 100%, with only five out of about 6500 individual measurements exceeding their respective permit limit and one instance where a narrative permit standard was exceeded (Fig. 2.1). Information on the exceedances is provided in Appendix E, Sect. E.3. None of the five exceedances resulted in any discernable ecological impact.

The current permit requires ORNL to conduct detailed characterization of numerous storm water outfalls, develop and implement a radiological monitoring plan, develop and implement a storm water pollution prevention plan, implement a revised Biological Monitoring and Abatement Program (BMAP) plan, and develop and implement a chlorine-control strategy. In 1997 DOE appealed certain limits and conditions of the 1996 ORNL permit, including numeric limits on effluent mercury, arsenic, and selenium.

ETTP

An application for renewal of ETTP NPDES Permit TN0002950 was submitted to TDEC in March 1997. To facilitate the transfer of ownership and operation of ETTP facilities to other parties, it was determined that separate NPDES permits would be required for each of the ETTP treatment facilities. In addition, it was determined that a separate NPDES permit for the storm water drainage system would be necessary. A general NPDES permit for former outfalls 009 (K-1515 Sanitary Water Plant) and 013 (K-1513 Sanitary Water Intake Backwash Filter) was issued on January 14, 2000, and became effective on March 1, 2000. Issuance of the permit (Permit Number TN0074233) allowed outfalls 009 and 013 to be removed from ETTP NPDES Permit Number TN0002950. A permit for the K-1203 sewage treatment plant (permit number TN0074241) was issued by TDEC and became effective on August 1, 2003. This allowed outfall 005 to be removed from ETTP NPDES Permit Number TN0002950. A permit for the K-1407-J Central Neutralization Facility (permit number TN0074225) was issued on October 7, 2003, and became effective on November 1, 2003. The permit allowed outfall 014 to be removed from ETTP NPDES Permit Number TN0002950.

ETTP storm water outfalls continue to discharge under NPDES Permit Number TN0002950; the permit was reissued on March 1, 2004, with an effective date of April 1, 2004. The reissued NPDES Permit Number TN0002950 includes 121 storm water outfalls. Of these 121 outfalls, 39 are monitored on a routine basis as part of the requirements of the NPDES permit. In accordance with this NPDES permit, the ETTP is authorized to discharge storm water, steam condensate, and groundwater to the Clinch River, Poplar Creek, and Mitchell Branch.

In 2005, 60 spills were reported at ETTP, but none of them resulted in NPDES noncompliances. With approximately 580 laboratory analyses in 2005, this represents a compliance rate of almost 100% (Fig. 2.1). ETTP had one NPDES permit noncompliance in 2005. Details of the noncompliance are given in Sect. 4.4.1 and in Appendix E, Sect. E.2.

2.2.12.2 Sanitary Wastewater

Y-12 Complex

The CWA includes pretreatment regulations for publicly owned treatment works. Sanitary wastewater from the Y-12 Complex is discharged to the city of Oak Ridge treatment works under an industrial and commercial wastewater discharge permit. The Y-12 Complex was issued a new industrial user discharge permit by the city of Oak Ridge effective April 1, 2005. The permit establishes discharge limits for total suspended solids, biochemical oxygen demand, total nitrogen, and various metals, and requires monitoring and reporting of uranium, gross alpha and beta, and several organic compounds. Compliance with the permit is determined from samples taken at the East End Sanitary Sewer Monitoring Station, located on the east end of the complex where the Y-12 system ties into the city's sanitary sewer collection system.

City personnel performed semiannual inspections on March 8 and August 2, 2005. The City of Oak Ridge inspection report for March 8, 2005, identified excess flow from Y-12 as a contributing factor to the City of Oak Ridge sewer overflows and requested a plan to reduce excess flow from Y-12. The plan was submitted in December 2005. During 2005, the Y-12 Complex experienced 1 noncompliance of the industrial user discharge permit for exceeding the permitted allowable flow of 1.4 million gallons per day (mgd). This was associated with a rainfall event of more than 5 in. of rain that day.

Compliance to a state-issued operating permit for a holding tank/pump-and-haul at office trailer 9983-AZ was also maintained.

Sanitary sewer radiological sample results at the Y-12 Complex are routinely reviewed to determine compliance with DOE Order 5400.5, "Radiation Protection of the Public and Environment." Sample results are compared to the derived concentration guides (DCGs) listed in the order. No radiological parameter that is monitored (including uranium) has exceeded a DCG.

ORNL

At ORNL, sanitary wastewater is collected, treated, and discharged separately from other liquid wastewater streams through an on-site sewage treatment plant. Wastewater discharged into the system is regulated by means of internally administered waste-acceptance criteria based on the plant's NPDES operating permit parameters. Wastewater streams currently processed through the plant include sanitary sewage from facilities in Bethel and Melton Valleys, area runoff of rainwater that infiltrates the system, and specifically approved small volumes of nonhazardous biodegradable wastes such as scintillation fluids. The effluent stream from the sewage treatment plant is ultimately discharged into White Oak Creek through an NPDES-permitted outfall (X-01). Infiltration into the system and the discharge from the on-site laundry have, at times, caused the sludge generated during the treatment process to become slightly radioactive. ORNL has completed a line-item project for comprehensive upgrades of its sanitary sewage system to reduce infiltration of contaminated groundwater and surface water and to redirect discharges from the laundry to appropriate alternative treatment facilities. The radioactivity level of ORNL sewage treatment plant sludge continues to decline. In 1998, ORNL's sewage sludge was accepted into the city of Oak Ridge's Biosolids Land Application Program. ORNL transported no sewage sludge to the Oak Ridge sewage treatment plant in 2005 because the plant was undergoing an expansion project. During 2005, ORNL's sewage sludge was dried and handled as solid low-level waste. Shipments of sludge to the city of Oak Ridge may resume in 2006.

ETTP

ETTP domestic wastewater is treated at the on-site K-1203 sewage treatment plant and is discharged pursuant to the NPDES Permit TN0074241; this permit became effective on August 1, 2003. Beginning on April 1, 1998, operation of this leased facility became the responsibility of publicly owned treatment works under a contract with CROET. Bechtel Jacobs Company LLC (BJC) operates a holding tank/pump-and-haul system to dispose of sanitary wastewater from the K-1310-DF facility at ETTP. The permit to operate this system (State Operation Permit No. SOP-99033) was issued April 28, 2000, and expired April 28, 2005. An application to renew the permit was submitted October 20, 2004. Operations reports are submitted each month to the TDEC Environmental Assistance Center; there were no noncompliances or operational problems in 2005. Weskem LLC, a BJC subcontractor, also operates a pump-and-haul system (State Operation Permit No. SOP-01042) for sanitary waste at ETTP; the permit was issued December 1, 2001, and expires November 30, 2006.

2.2.12.3 Storm Water Protection Permits

Storm water discharges associated with construction activities that disturb one acre or more of land must be NPDES-permitted. Coverage under a general permit is typically approved for a construction project if the proper notice of intent is filed. In February 2004 a general permit for storm water associated with construction activity for the Highly Enriched Uranium Materials Facility and Hollow-Fill Project at Y-12 was approved. The permit remained in effect during 2005, and construction proceeded in compliance.

In 2005, ORNL had six construction projects covered by the Tennessee General Permit for Storm Water Runoff Associated with Construction Activity. These included the SNS project, the Advanced Materials Characterization Laboratory, the ORNL Research Support Center, the 7625 Multi-Program High Bay, the ORNL Joint Institute for Biological Studies Utilities; and the ORNL East Campus Storm Water and Utility Upgrades.

ETTP submitted one storm water notice of termination for a power line right-of-way clear-

ing activity after final stabilization had been achieved, all storm water discharges associated with the construction activity had ceased or been eliminated, and temporary erosion and sedimentation control measures had been removed.

2.2.12.4 Aquatic Resources Protection

The Army Corps of Engineers, TVA, and TDEC conduct permitting programs for projects and activities that could affect aquatic resources, including navigable waters, surface waters (including tributaries), and wetlands. These are the Corps of Engineers Section 404 dredge-and-fill permits, TDEC aquatic resource alteration permits, and TVA 26A approvals.

In February 2004, TDEC issued a general NPDES permit for discharges associated with the enriched uranium storage facility and Hollow-Fill Project. The permit remains active and the work conducted in compliance.

No TVA or Corps of Engineers permits were issued to the Y-12 Complex in 2005.

In 2005, ORNL had five projects that were conducted under aquatic resource alteration permits (ARAPs). These included two ARAPs for the East Campus Landscaping Addition project and three ARAPs for the East Campus Parking Expansion Project.

2.2.12.5 Oil Pollution Prevention

Section 311 of the CWA regulates the discharge of oils or petroleum products to waters of the United States and requires the development and implementation of a spill prevention, control, and countermeasure plan to minimize the potential for oil discharges. Currently, each facility implements a site-specific plan. This section of the CWA was significantly amended by the Oil Pollution Act of 1990, which has as its primary objective the improvement of responses to oil spills. On July 17, 2002, EPA issued the new final rule for 40 CFR Part 112, "Oil Pollution Prevention and Response; Non-Transportation-Related Onshore and Offshore Facilities," in the *Federal Register*. The rule contains significant changes in the requirements for spill prevention, control, and countermeasure plans, including how the plans are prepared, reviewed, and certified, and the information that must be included in the plans. Existing plans must be amended as necessary to bring them into compliance with rule revisions, and the amended plans must be fully implemented by October 31, 2007.

2.2.12.6 Clean Water Action Plan

The Clean Water Action Plan, which essentially reflects a commitment by federal agencies to work cooperatively to improve water quality in the United States, is structured around watershed-based approaches in four key areas of need:

- prioritizing and undertaking water quality assessments,
- preparing restoration action strategies,
- developing and refining water quality standards, and
- enhancing stewardship of water resources on federal lands.

On a national level, the Department of Agriculture and the Department of the Interior are developing the Unified Federal Policy for Ensuring a Watershed Approach to Federal Land and Resource Management, to which other agencies (including DOE) are contributing. The goals and principles of this multiagency policy are to

- use a consistent and scientific approach to managing lands and resources and for assessing, protecting, and restoring watersheds;
- identify specific watersheds in which to focus budgetary and other resources and to accelerate improvements in water quality and watershed condition;
- use the results of watershed assessments to guide planning and management activities;
- work closely with states, tribes, local governments, and stakeholders to implement this policy;
- meet CWA responsibilities to adhere to federal, state, tribal, interstate, and local water quality requirements to the same extent as nongovernmental entities; and
- take steps to ensure that federal land and resource management actions are consistent with federal, state, tribal, and, where appropriate, local government water quality management programs.

2.2.13 Clean Air Act

Authority for implementation and enforcement of the Clean Air Act (CAA) has been delegated to the state of Tennessee by EPA as described in the State Implementation Plan. Air pollution control rules are developed and administered by TDEC.

2.2.13.1 General CAA Compliance

The TDEC air pollution control rules ensure compliance with the CAA. The TDEC Air Permit Program is the primary method by which emission sources are reported to and regulated by the state.

CAA compliance program staff participate in regulatory inspections and internal audits to verify compliance with applicable regulations or permit conditions. Air emission sources subject to the permitting requirements are permitted, and relevant compliance documentation for these sources is maintained at each site. In addition, a number of sources that are exempt from permitting requirements under state rules but subject to listing on Title V major source operation permits are documented, and information about them is available upon request from the state. Programs for permitting, compliance inspection, and documentation are in place and ensure that all ORR operations remain in compliance with all federal and state air pollution control regulations.

2.2.13.2 Title V Operating Permits

All three sites are subject to the CAA Title V Operating Permit Program. Permit applications were submitted and were determined to be complete by TDEC. During 2005, compliance and reporting was implemented for four Title V permits, which were issued for operations at the Y-12 Complex and ORNL in 2004. During 2005, a permit application for a significant modification to the Title V permit was submitted for the Y-12 steam plant maintenance project. Several minor permit modifications and amendments were made to the Y-12 Title V permit in 2005. An update to the September 1996 Title V permit application for operations at ETTP was submitted in August 2004. As required by regulation and permit, the TSCA Incinerator conducted a Compliance Performance Test in March and a permit compliance test in November of 2005. Updated Title V application forms were submitted that reflected the results of each test. TDEC has not committed to a potential target date for the issuance of the Title V permit for ETTP at this time.

DOE/NNSA and BWXT Y-12 implemented compliance and reporting for a Title V permit reporting for 35 air emission sources and more than 100 air emission points. All remaining emission sources are categorized as insignificant and exempt from permitting. The first semiannual report was submitted in November 2005 for the period April to September 2005. One construction permit was in effect for the Purification Facility and will be incorporated into the Title V permit when the source becomes operational.

DOE and UT-Battelle were issued a Title V permit covering ten emission sources for ORNL Office of Science Operations. One construction permit was also active for the Central Exhaust Facility located at the SNS facility. All remaining emission sources are categorized as insignificant and are exempt from permitting. The first semiannual report under this permit for the period from April 1 to September 30, 2005, was submitted on time and with no compliance issues.

DOE and BJC were issued two Title V permits in October and November 2004 for two air emission sources located at ORNL and one source at Y-12. At the end of 2005, there were 82 active air emission sources under DOE control at ETTP. The total includes 25 sources covered by 3 TDEC operating permits and 2 new construction permits. A new construction permit was issued for the TSCA Incinerator that supersedes the previous permit to operate until such time that a Title V permit is issued for ETTP that included recently promulgated regulations not covered by the previous permit. The second construction permit was issued for the K-1423 TSCA Solid Waste Repacking facility that reflects changed compliance requirements due to a new member of the public location. All remaining active air emission sources are exempt from permitting requirements. Permitted sources under DOE's Reindustrialization Program are not reported in this report except for the portion of the year that the source was under DOE control.

Air permit data are summarized in Appendix F.

2.2.13.3 National Emission Standards for Hazardous Air Pollutants for Radionuclides

Under Section 112 of the CAA, on December 15, 1989, the EPA promulgated National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities at 40 CFR 61, Subpart H. This emission standard limits emissions of radionuclides to the ambient air from DOE facilities not to exceed amounts that would cause any member of the public to receive in any year an effective dose equivalent of 10 mrem/year. As noted in the preamble to the rule, the entire DOE facility at Oak Ridge, Tennessee, must meet this emission standard.

On June 10, 1996, EPA delegated authority for regulation of airborne radionuclide emissions from DOE facilities in Tennessee to the TDEC Division of Air Pollution Control. TDEC adopted the federal rule verbatim as Tennessee Rule 1200-3-11-.08, Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities. In addition, TDEC codified that all past formal agreements between DOE and EPA, including the March 1994 *Compliance Plan* (MMES 1994), would be recognized provided that they are current, valid, and supported by appropriate documentation. The TDEC Division of Air Pollution Control has given primary administrative authority of the radionuclide emission standard to the TDEC Division of Radiological Health, which also licenses non-DOE nuclear facilities in the state. However, authority to approve alternative methods and procedures still resides with EPA Region 4.

In October 2001, EPA Region 4 approved two addendums to the compliance plan, Addendum C.1, "Monitoring for Fugitive and Diffuse Sources," and Addendum C.2, "Monitoring Plan for On-Site Receptors." Addendum C.1 formalizes the use of environmental measurements from ambient air monitoring to confirm compliance for fugitive and diffuse sources for the ORR. This compliance approach has been in place since January 1993. Addendum C.2 formalizes EPA guidance, in a February 1, 2001, guidance letter, that allows the use of environmental measurements from ambient air monitors in lieu of continuous stack monitoring as an alternative method to demonstrate compliance with 40 CFR Part 61, Subpart H, for sources that are major when modeled to "on-site" receptors, but minor when modeled to off-site receptors. In March 2005, EPA Region 4 approved a third addendum to the plan, Addendum C.3, "ANSI/HPS N13.1-1999 Upgrade Policy," which clarifies when an existing source on the ORR undergoing a modification must be upgraded to meet the new design criteria of the ANSI/HPS N13.1-1999 Standard in accordance with the September 9, 2002, amendment to 40 CFR Part 61, Subpart H. During the March 2005 approval cycle, the title page to the compliance plan was updated with a DOE document number (DOE 1994), and a revision to Sect. 2.1 of the plan was approved that incorporated updated criteria under 10 CFR Part 835.

Beginning in 2000, the TDEC Division of Radiological Health required DOE to assess the dose from airborne radionuclide emissions to members of the public located on the ORR. Specifically, dose was determined for lessees located in areas of the ORR where access to the public is not restricted. Beginning in 2001, dose was also determined for construction workers supporting activities at construction sites that were deeded to a non-DOE entity.

During 2005, the ORR facilities operated in compliance with the Radionuclide National Emission Standards for Hazardous Air Pollutants (NESHAP) dose limit of 10 mrem/year to the most exposed member of the public. Based on modeling of radionuclide emissions from all major and minor point sources, the effective dose equivalent in 2005 to the most exposed member of the public was 0.9 mrem/year.

Continuous sampling for radionuclide emissions is conducted at the ETTP TSCA Incinerator, major sources at ORNL, and exhaust stacks serving uranium-processing areas at the Y-12 Complex. Compliance with the off-site dose limit is demonstrated by using grab samples and other EPA-approved estimation techniques on the remaining minor emission points and on grouped area sources to estimate confirmatory measurements of emissions. Fugitive emissions continue to be monitored by the ORR Perimeter Air Monitoring System. In addition, ETTP continued to operate a site-specific ambient air monitoring system for surveillance of TSCA Incinerator uranium emissions and fugitive

emissions from remedial actions and decontamination and decommissioning projects. In addition to the ORR regulatory compliance program, the EPA and DOE Oversight Division also conduct independent ambient air monitoring programs.

2.2.13.4 NESHAP for Asbestos

The ORR facilities have 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. No releases of reportable quantities of asbestos were reported at ETTP, ORNL, or the Y-12 Complex in 2005.

2.2.13.5 NESHAP for Source Categories

The EPA has missed congressionally established promulgation dates for a number of NESHAP "Maximum Achievable Control Technology" (MACT) standards (see 40 CFR Part 63, Subpart B, starting at § 63.50). Sources that may be subject to a delayed standard must comply with the "MACT hammer" permitting provisions in Section 112(j) of the CAA. Impacted sources must submit applications for case-by-case MACT determinations in two parts. Part 1 notifies agencies of the applicability of the delayed MACT standard to the facility. Part 2 is a detailed application based on a number of requirements and is due on a specific date, depending upon the applicable MACT standard.

A number of MACT standards potentially applicable to ORR sources are being developed by EPA [e.g., industrial, commercial, and institutional boilers and process heaters; miscellaneous metal parts (surface coating); site remediation; and off-site waste and recovery operations]. In 2003, ORR facilities submitted Part 1 applications regarding applicability of several MACT standards (e.g., industrial heaters/process boilers, site remediation). There are currently only two sources on the ORR subject to MACT standards. One source is the TSCA Incinerator; the other source, registered with the EPA, is a waste drum storage area at ETTP designated for storage of waste received from off site, making this area subject to the Off-Site Waste and Recovery Operations standard.

2.2.13.6 Stratospheric Ozone Protection

DOE remains committed to continued reductions in the use of regulated ozone-depleting substances and, where possible, replacing them with materials that have less ozone-depleting potential. For example, DOE has committed to replacing refrigeration appliances at all DOE installations if the appliances were installed before 1984, contain Class I ozone-depleting substances, and have cooling capacities of 150 tons or greater, except in certain cases where replacement is not economical and will not benefit the environment. All units meeting this criterion at ETTP, ORNL, and the Y-12 Complex have been evaluated and replaced.

2.2.13.7 Chemical Accident Release Prevention

All sites on the ORR have evaluated all DOE processes for inventories of chemicals contained in quantities exceeding thresholds specified in rules pursuant to Title III, Section 112(r), "Prevention of Accidental Releases." No risk management program plans are required for a regulated substance at any DOE facility on the ORR. Administrative measures were implemented for some processes to limit the quantity of a regulated substance that could be present in a process at any given time.

2.2.14 Toxic Substances Control Act

The Toxic Substances Control Act (TSCA) was passed in 1976 to address the manufacture, processing, distribution in commerce, use, and disposal of chemical substances and mixtures that present an unreasonable risk of injury to human health or the environment. TSCA mandated that EPA identify and control chemical substances manufactured, processed, distributed in commerce, and used within the United States. EPA imposes strict information-gathering requirements on both new and existing chemical substances, including polychlorinated biphenyls (PCBs).

2.2.14.1 Polychlorinated Biphenyls

TSCA specifically bans the manufacture, processing, and distribution in commerce of PCBs but authorizes the continued use of some existing PCBs and PCB equipment. TSCA also imposes marking, storage, and disposal requirements for PCBs. The regulations governing PCBs mandated by TSCA are administered by EPA. Most of the regulatory requirements are matrix- and concentration-dependent. TDEC restricts PCBs from being disposed of in landfills and classifies PCBs as special wastes under Tennessee solid waste regulations. A special waste approval is required from the state of Tennessee to dispose of solid PCB-contaminated waste in landfills. Several special waste approvals for receipt of drained PCB equipment, PCB remediation waste, and PCB bulk product waste (painted construction debris and/or equipment) at the Y-12 landfill have been approved by TDEC.

British Nuclear Fuels Limited (BNFL), a prime contractor to DOE, was contracted to clean up the K-33, K-31, and K-29 facilities at the ETTP. Over a 7-year period, BNFL shipped a total net weight of 16,229,107 lb of PCB waste for disposal. The waste was shipped to a number of disposal facilities, including Envirocare of Utah, Trans-Cycle Industries, the EMWMF, and the TSCA Incinerator.

2.2.14.2 PCB Compliance Agreements

The Oak Ridge Reservation Polychlorinated Biphenyl Federal Facilities Compliance Agreement (ORR/PCB/FFCA) between EPA Region 4 and DOE-ORO became effective on December 16, 1996. The agreement addresses PCB compliance issues at ETTP, ORNL, the Y-12 Complex, and ORISE. It specifically addresses the unauthorized use of PCBs, storage and disposal of PCB wastes, PCB spill cleanup and/or decontamination, PCBs mixed with radioactive materials, PCB R&D, and records and reporting requirements for the ORR.

In 2005, UT-Battelle requested a risk-based disposal approval for the management of PCB bulk product and PCB remediation waste for UT-Battelle operations at ORNL and at ORNL/Y-12. EPA approval of the request is expected in 2006.

In 2005, EPA approved BWXT/Y-12's request for a risk-based disposal approval for the management of PCB bulk product waste at the Y-12 site.

2.2.14.3 Authorized and Unauthorized Uses of PCBs

Specific applications of PCBs are authorized by EPA for continued use under restricted conditions. A variety of PCB systems and equipment have been in service at the ORR during its 60-year history. Many of these systems and equipment were used in accordance with industry standards at the time, and their continued use was authorized under the 1979 PCB regulations. Systems that were authorized included transformers, capacitors, and other electrical distribution equipment; heat-transfer systems; and hydraulic systems. The vast majority of these PCB uses have been phased out on the ORR. Small amounts of PCBs remain in service in PCB light ballasts; however, ballasts containing PCBs are being replaced by non-PCB ballasts during normal maintenance. Most transformers that contained PCBs either have been retrofilled (replacement of PCB fluid with non-PCB dielectric fluid) to reduce the PCB concentration to below regulated limits or have been removed from service altogether.

The 1979 regulations did not anticipate the use of PCBs in many applications for which they were used. The proposals to the 1998 "Mega Rule" that would have addressed uses still prevalent on the ORR were omitted from the final rule. As a result, past uses not specifically authorized continue to present compliance issues for DOE under TSCA.

At the ORR, unauthorized uses of PCBs have been found in building materials, lubricants, paint coatings, paint sealants, adhesives, and nonelectrical systems (including a rolling mill and a reactor-positioning device). More such unauthorized uses are likely to be found during the course of decontamination and decommission activities. The most widespread of these unauthorized uses of PCBs are PCBs in paint and PCB-impregnated gaskets in the gaseous diffusion process motor ventilation systems at ETTP. The discoveries of such uses include rubber gasket components used to seal glovebox units, paint coatings used on hydraulic equipment at the Y-12 Complex, and interior

and exterior wall paints. In 1998, ORNL reported finding PCBs at regulated levels in roofing paint used on Buildings 2000 and 2001. An annual sampling and monitoring plan was prepared and was submitted for the site. EPA approval of the sampling and monitoring plan was verbally issued on February 11, 1999. Annual monitoring has been conducted since 1999. Summaries of the 1999, 2002, 2003, 2004, and 2005 results of that sampling were submitted to EPA as required. Submittals of the 2000 and the 2001 monitoring results were not required. In 2005, ORNL reported finding PCBs in paint. In 2005, DOE notified EPA of issues regarding historical uses of PCBs associated with the calutron operations in Building 9204-3 (ORNL/Y-12) and proposed that these issues be addressed under the ORR/PCB/FFCA. These issues are related to the large number of old oil-filled transformers and capacitors (both large and small) that are in use or stored for future reuse.

In 2005, BWXT Y-12 reported finding PCBs at regulated levels in interior and exterior paint for several facilities and/or their structural components. The Y-12 Complex issued notification letters to EPA, in accordance with the terms of the ORR/PCB/FFCA, declaring that a pre-TSCA PCB use had been discovered. Administrative controls and postings are in place to ensure that painted surfaces are not disturbed until proper evaluations are conducted. Additionally, administrative and engineering controls are used to ensure the protection of workers and the environment.

In 1998, depleted uranium hexafluoride (UF_6) steel cylinders were found to contain high concentrations of PCBs in the paint. The ETTP notified EPA of the UF_6 cylinder population under terms of the compliance agreement. DOE obtained approval from Regions 4 and 5 to ship contaminated cylinders to the Portsmouth Gaseous Diffusion Plant in Portsmouth, Ohio, in 2005. Once the containers arrive at the Portsmouth plant, the product remaining in the cylinders will be processed, and the cylinders will be disposed of as PCB bulk product waste. Since shipments began in the summer of 2005, 759 of the 1,274 cylinders have been shipped to Portsmouth. Currently, 515 cylinders with PCB concentration of 50 ppm or greater remain at ETTP, and the final shipments are scheduled to take place in 2006. The K-1066-B and K-1066-K cylinder storage yards are currently empty, and the K-1066-B yard demolition has been completed. The concrete rubble from the demolition of the K-1066-B concrete storage pad is planned for use as fill material for the on-site K-25 D&D Project.

2.2.14.4 ETTP TSCA Incinerator PCB Disposal Approval

The ETTP TSCA Incinerator is currently operating under an extension of EPA Region 4 approval granted on March 20, 1989. This extension is based on submittal of a reapplication for PCB disposal approval filed with EPA Region 4 on December 20, 1991, which was within the time frame allowed for reapplication. Minor amendments, updates, and corrections to this reapplication identified by DOE have been made in the interim and have been submitted to EPA. Since the submittal of the December 20, 1991, reapplication, a joint RCRA/PCB permit reapplication has been under development. This joint reapplication was submitted in March 1997 to TDEC under RCRA for treatment of hazardous wastes and to EPA Region 4 for disposal of PCB wastes. The new reapplication will replace the December 20, 1991, PCB disposal reapplication. In anticipation of this joint application, EPA Region 4 has delayed action on renewal of the PCB incineration approval.

2.2.15 Federal Insecticide, Fungicide, and Rodenticide Act

The Federal Insecticide, Fungicide, and Rodenticide Act governs the sale and use of pesticides and requires that all pesticide products be registered by EPA before they can be sold. If a pesticide can be used according to directions without unreasonable adverse effects on the environment or applicator (i.e., if no special training is required), it is classified for general use. A pesticide that can harm the environment or injure the applicator, even when being used according to directions, is classified for restricted use. The regulations for the application of restricted-use pesticides are presented in 40 CFR 171.

The Y-12 Complex, ETTP, and ORNL maintain procedures for the storage, application, and disposition of pesticides.

No restricted-use pesticide products are used at the Y-12 Complex, ETTP, or ORNL. An inventory of pesticide products is maintained at each facility.

2.2.16 Emergency Planning and Community Right-to-Know Act

The Emergency Planning and Community Right-to-Know Act (EPCRA), also referred to as SARA Title III, requires reporting to federal, state, and local authorities of emergency planning information, hazardous chemical inventories, and releases of certain toxic chemicals to the environment. The ongoing requirements are contained in Sections 302, 303, 304, 311, 312, and 313 of EPCRA and in 40 CFR Parts 355, 370, and 372. Table 2.11 describes the main parts of EPCRA. All DOE-ORO sites in Oak Ridge are in compliance with all aspects of EPCRA. Executive Order 13148, "Greening the Government Through Leadership in Environmental Management," requires all federal agencies to comply with provisions of EPCRA and the Pollution Prevention Act.

2.2.16.1 Planning Notification and Extremely Hazardous Substance Release Notifications (Sections 302–304)

The ORR did not have any releases of extremely hazardous substances, as defined by EPCRA, in 2005.

2.2.16.2 Material Safety Data Sheet/Chemical Inventory (Sections 311–312)

The required Sect. 311 notifications were made as hazardous materials were determined to be over threshold for the first time. 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 the Sect. 312 requirements. Of the chemicals identified for CY 2005 on the ORR, 68 were located at the Y-12 Complex, 31 at ORNL, and 12 at ETTP.

Private-sector lessees associated with the reindustrialization effort were not included in the CY 2005 submittals. Under terms of their lease, lessees must evaluate their own inventories of hazardous and extremely hazardous chemicals and must submit information as required by the regulations.

2.2.16.3 Toxic Chemical Release Reporting (Section 313)

DOE submits annual toxic release inventory reports to EPA and TDEC on or before July 1 of each year. The reports cover the previous calendar year and address releases of certain toxic chemicals to air, water, and land as well as waste management, recycling, and pollution prevention activities. Threshold determinations and reports for each of the ORR facilities are made separately. Operations involving toxic release inventory 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 one or more of the thresholds.

The following text explains how the reporting thresholds were exceeded. Table 2.12 summarizes releases and off-site transfers for those chemicals exceeding reporting thresholds.

Y-12 Complex

Total 2005 reportable toxic releases to air, water, and land and waste transferred off site for treatment, disposal, and recycling was less than the amounts reported for the Y-12 Complex in 2004 . Hydrochloric acid was removed from the report due to newly available sampling data vs previously used EPA emissions factors. The resulting estimated decrease in emissions fell well below the reporting threshold. This same sampling data resulted in a slight increase in the estimated mercury emissions. Freon 113 emissions decreased below the applicable threshold as a result of a decreased usage in operations areas. The following list describes the reported chemicals for the Y-12 Complex.

- **Chromium, cobalt, copper, and nickel.** The processing threshold for each of these metals was exceeded as a result of off-site metal recycling and metal machining and welding operations.

Table 2.11. Descriptions of the main parts of The Emergency Planning and Community Right-to-Know Act (EPCRA)

Title	Description
Sections 302–303, 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
Section 311–312, Material safety data sheet/chemical inventory	Requires that either material safety data sheets (MSDSs) or lists of hazardous chemicals for which MSDSs 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 the Environmental Protection Agency.
Section 313, Toxic chemical release reporting	Requires that releases of toxic chemicals be reported annually to the Environmental Protection Agency

- **Sulfuric acid (aerosol form).** Sulfuric acid aerosols were coincidentally manufactured in excess of the reporting threshold as a combustion by-product from burning coal at the steam plant.
- **Lead and lead compounds.** The otherwise-use threshold for lead was exceeded at the steam plant and the Central Training Facility firing range. The processing threshold for lead was exceeded as a result of off-site metal for recycling.
- **Mercury and mercury compounds.** Mercury compounds were otherwise used and coincidently manufactured as a combustion by-product from burning coal in excess of the 10-lb reporting threshold at the steam plant.
- **Methanol.** Most of the methanol at the Y-12 Complex is otherwise used in the chiller buildings for the brine-methanol system.
- **Nitrate compounds.** Nitrate compounds were coincidentally manufactured in excess of the reporting threshold as by-products of neutralizing nitric acid wastes. The compounds are also contained in various mixtures used throughout the complex.
- **Nitric acid.** Nitric acid was used in excess of the otherwise-use threshold as a chemical-processing aid.

ETTP

The otherwise-use activity threshold for PCBs was exceeded at ETTP by the incineration of PCBs in waste received from off site in the TSCA Incinerator.

ORNL

ORNL reported nitric acid and nitrate compounds. Lead metal was not reported for the first time since the beginning of TRI reporting in 1988 because the lead shop was shut down in October 2004 and did not operate during CY 2005. Nitric acid is used to regenerate ion-exchange columns at the Process Waste Treatment Complex and at the High Flux Isotope Reactor (HFIR), in the separation process for californium by the Nuclear Science and Technology Division, and for pH adjustment at the Process Waste Treatment Complex. Nitrate compounds are coincidentally manufactured as by-products of neutralizing nitric acid waste and as by-products of sewage treatment.

2.2.17 Environmental Occurrences

CERCLA requires that the National Response Center be notified if a nonpermitted release of a reportable quantity or more of a hazardous substance (including radionuclides) is released to the environment within a 24-h period. The CWA requires that the National Response Center be notified if an oil spill causes a sheen on navigable waters, such as rivers, lakes, or streams. When notified, the National Response Center alerts federal, state, and local regulatory emergency organizations for determination of appropriate government response.

Table 2.12. EPCRA Section 313 toxic chemical release and off-site transfer summary for the ORR, 2005

	Year	Quantity (lb)[a]			
		Y-12 Complex	ORNL	ETTP	Total
Chromium	2004	1,465	*b*	*b*	1,465
	2005	1,274	*b*	*b*	1,274
Cobalt	2004	*c*	*b*	*b*	*b,c*
	2005	*b*	*b*	*b*	*b*
Copper	2004	*b*	*b*	*b*	*b*
	2005	932	*b*	*b*	932
Copper/Copper Compounds	2004	7,560	*b*	*b*	7,560
	2005	*b*	*b*	*b*	*b*
Freon 11	2004	*b*	*b*	*b*	*b*
	2005	*b*	*b*	*b*	*b*
Freon 113	2004	14,000	*b*	*b*	14,000
	2005	*b*	*b*	*b*	*b*
Hexachlorobenzene	2004	*b*	*b*	*b*	*b*
	2005	*b*	*b*	*160*	160
Hydrochloric acid (aerosol)	2004	110,000	*b*	*b*	110,000
	2005	*b*	*b*	*b*	*b*
Lead/lead compounds	2004	62,803	72,357	*b*	135,160
	2005	9,626	*b*	*b*	9,626
Manganese	2004	2,986	*b*	*b*	2,986
	2005	*b*	*b*	*b*	*b*
Mercury/mercury compounds	2004	59	*b*	*b*	59
	2005	109	*b*	*b*	109
Methanol	2004	56,017	*b*	*b*	56,017
	2005	34,307	*b*	*b*	34,307
Nickel	2004	2,359	*b*	*b*	2,359
	2005	3,393	*b*	*b*	3,393
Nitrate compounds	2004	6,956	83,000	*b*	89,956
	2005	7,922	51,000	*b*	58,922
Nitric acid	2004	18,200	94,160	*b*	112,360
	2005	18,701	53,990	*b*	72,691
Ozone	2004	*b*	*b*	*b*	*b*
	2005	*b*	*b*	*b*	*b*
PCBs	2004	*b*	*b*	684	684
	2005	*b*	*b*	2,951	2,951
Sulfuric acid (aerosol)	2004	48,000	*b*	*b*	48,000
	2005	52,000	*b*	*b*	52,000
Total	2004	330,405	249,517	684	580,606
	2005	128,264	104,990	3,111	236,365

[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. 1 lb = 2.205 kg.

[b]No reportable releases because the site did not exceed the applicable Toxic Release Inventory reporting thresholds.

[c]Not applicable because releases were less than 500 lb, and hence a Form A was submitted.

There were no releases of hazardous substances exceeding reportable quantities, no reportable oil sheens, and no fish kills at Y-12 during 2005. The Y-12 Complex reported a release of hazardous material to the environment on April 4, 2005, when a small pool of mercury was found to have drained from a broken monometer that had been sent off-site to excess property sales. The spill was cleaned, and there was no environmental insult. Further evaluation determined that the quantity of mercury spilled was less than a reportable quantity (1 lb for mercury).

On September 9, 2005, a fuel spill occurred at the Y-12 gas station when a fuel delivery truck driver dispensed unleaded gasoline from a tanker truck and overfilled the underground fuel storage tank. The storage tank's overfill alarms did not function properly when the overfill occurred. Spill response personnel estimated approximately 5 gal of fuel was spilled, based on the size of the spill pattern on the concrete and asphalt.

On October 25, 2005 personnel at Y-12 became aware of a possible brine leak from a cooling system when a large quantity of methanol had to be added to the brine system. Brine is a mixture of methanol and water (21% and 79%, respectively) and is used in the chiller facilities to provide equipment cooling at the Y-12 Complex. Efforts were initiated to identify the source of the leak and to implement repairs. On November 2, 2005, a brine leak was discovered in the basement area of Building 9201-5. The source of the leak was determined to be from a brine coil in an inoperable air handling unit. The leak allowed the brine to enter a sump in the basement of the building. The sump is part of the influent system to the Central Mercury Treatment System (CMTS). The sump pump was shut down to isolate the brine solution and prevent any further discharge to the CMTF. The total amount of methanol lost as a result of this leak was estimated to be 1,471 lbs/d, which is below the reportable quantity of 5,000 lbs/d.

The brine leak, and subsequent inflow to the CMTS, affected the CMTS ability to consistently treat mercury, which resulted in NPDES violations from the effluent samples taken in October, November, and December 2005. Operation of the CMTS was suspended on December 15 due to viability of the system to effectively reduce mercury to levels below NPDES permit limits. Corrective actions are being implemented, and the CMTS is expected to return to full-time reliable operation in early 2006.

During 2005, ETTP had no releases of reportable quantities of hazardous substances.

In 2005, ORNL had no releases of reportable quantities of hazardous substances, no reportable oil sheens, and no fish kills.

2.2.18 DOE Order 450.1, Environmental Protection Program

DOE Order 450.1, “Environmental Protection Program,” encompasses environmental management systems (EMSs), pollution prevention, affirmative procurement, ozone-depleting substances, energy management and fleet management, and beneficial landscaping requirements. The order affirms DOE’s approach to improving environmental performance through the use of management systems and aggressive pollution prevention initiatives.

The ORR sites are addressing the requirements of this order as well as all other requirements related to these areas. The 2005 efforts and associated results across the ORR are summarized in the remainder of this section.

2.2.18.1 Implementation of Environmental Management Systems

The site’s environmental management systems (EMSs) are integrated with the sites’ Integrated Safety Management System (ISMS). ISMS and EMS both strive for continual improvement through a “plan-do-check-act” cycle. Under ISMS, the term “safety” also encompasses environmental safety and health, including pollution prevention, waste minimization, and resource conservation. Therefore, the guiding principles and core functions in ISMS are as applicable to the protection of the environment as they are to safety. Figure 2.2 depicts the relationship between EMS and ISMS.

UT-Battelle, as the management and operating contractor for ORNL, and BWXT Y-12 have both chosen to implement EMSs that are modeled after the international standard established by the International Organization for Standardization (ISO) 14001. The purpose of this system

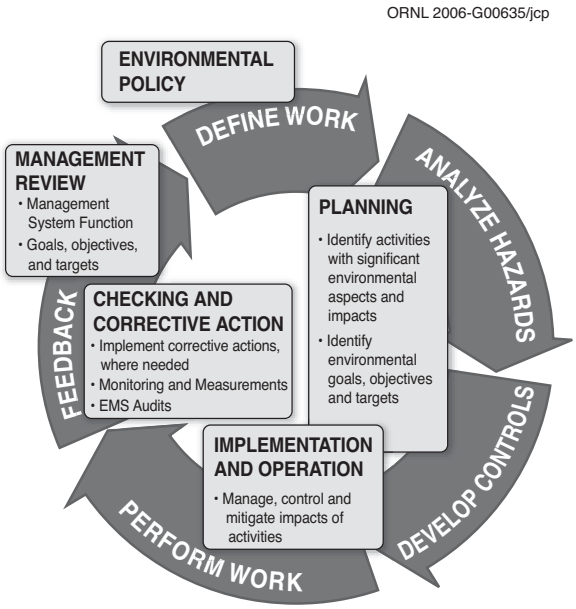


Fig. 2.2. The relationship between EMS and ISMS.

is to achieve, maintain, and demonstrate continuing environmental improvement by assessing and controlling the impact of activities and facilities on the environment. The system is designed to ensure that activities are in compliance with environmental laws and regulations, and it provides a framework for integrating compliance, pollution prevention, and other environmental considerations into the planning and implementation phases of site activities. The ISO 14001 EMS is consistent with ISMS core functions and guiding principles and includes the following features:

- policy,
- identified significant environmental aspects and controls,
- applicable legal requirements,
- objectives and targets,
- training requirements,
- communication with stakeholders,
- records and document control requirements,
- monitoring and measurement requirements,
- an emergency preparedness and response program, and
- provisions for handling nonconformances and corrective/preventive actions.

Environmental aspects are elements of an organization's activities, products, or services that can interact with the environment. In the ISMS, these may be thought of as environmental hazards associated with a facility operation or work activity.

UT-Battelle EMS Implementation Status

The UT-Battelle EMS is integrated into ISMS through the work control process. All significant environmental aspects are incorporated into work control to ensure that appropriate controls are in place.

In 2004, UT-Battelle's EMS was registered to the ISO 14001 Standard by a third-party registrar. Several minor deficiencies were noted during the registration audit. Corrective action plans have been developed and are being implemented.

ISO 14001 encourages organizations to make their environmental policy and significant environmental aspects of their activities available to the public.

The UT-Battelle Policy for ORNL is a high-level document that contains both scientific/technical and environment, safety, and health commitments. As required by ISO 14001, the policy contains commitments to (1) comply with applicable requirements, (2) prevent pollution, and (3) continually improve. The environmental policy statements in the UT-Battelle Policy for ORNL are available on the external web site at http://train.ornl.gov/wbt/EnvPolicy.cfm.

UT-Battelle has identified the following aspects as potentially having significant environmental impacts:

- hazardous waste,
- radioactive waste,
- PCB waste,
- mixed waste,
- air emissions,
- liquid discharges,
- storage or use of chemicals or radioactive materials.

Activities containing these aspects are carefully controlled to minimize or eliminate impacts to the environment. Monitoring activities associated with these aspects are described in Chapters 3, 5, and 7.

BWXT Y-12 EMS Implementation Status

The BWXT Y-12 EMS is based on the principles of the International Organization of Standardization (ISO) 14001 standard and is integrated with the BWXT Y-12 Integrated Safety Management System (ISMS) policies and procedures. An independent assessment of the EMS, led by personnel from Honeywell Federal Manufacturing & Technologies, management and operating contractor for the NNSA Kansas City Plant, was conducted July 25–29, 2005. The planning, conducting, and documenting of this assessment was based on established practices for ISO 14001 and with the self-declaration guidance as described in DOE G 450.1-1, *Implementation Guide for Use with DOE O 450.1, Environmental Protection Program.* The results of this evaluation were that BWXT Y-12 had successfully developed and implemented an EMS in accordance with the principles of the ISO 14001 standard, and the integration of the EMS with the BWXT Y-12 Integrated Safety Management System (ISMS) policies and procedures.

The DOE Office of Independent Oversight and Performance Assurance inspection of environment, safety, and health (ES&H) programs at the Y-12 during August and September 2005 included an evaluation of the EMS and Pollution Prevention Program focusing on the requirements of DOE Order 450.1. The evaluation addressed key elements of the EMS including environmental policy, environmental aspects, requirements, training and awareness, objectives and targets. The assessment concluded that "The EMS is fully integrated within ISM and the required elements from ISO 14001 have been achieved."

BWXT Y-12 EMS criteria for defining significant aspects are based on actual and perceived impacts and on regulatory requirements. The following aspects have been identified as potentially having significant environmental impact:

- Waste generation—excess materials and chemicals, low-level radiological, hazardous, mixed, PCB waste, universal, special industrial, medical, and sanitary
- Air emissions—criteria pollutants, hazardous air pollutants and other non-radiological air contaminants, ozone, and radiological emissions
- Liquid discharges—process wastewater, cooling water, sanitary wastewater, flow management, chlorinated water discharges
- Potential releases from spills, leaks, runoff—storage of radiological and nonradiological materials, oil and gas, waste, storm water runoff
- Spread of legacy contamination—historical waste management units, legacy mercury and PCB spills, demolition of excess and surplus facilities, groundwater contamination
- Interactions with historical and cultural resources and wildlife habitat
- Natural resource consumption—power and energy use
- Natural resource conservation—purchasing materials with recycled content, recycling, and preventing pollution.

Activities involving these aspects are evaluated and controlled to minimize potential impacts to the environment. Monitoring activities associated with these aspects are described in Chaps. 6 and 7.

As part of the ongoing activities to integrate the principles of the ISO 14001 EMS with the Y-12 ISMS, a number of environmental objectives and targets are established. Monitoring progress in achieving the environmental objectives and targets is a way to measure improvement. Of the 20 environmental targets established for 2005, 10 were achieved by the end of FY 2005.

BJC EMS Implementation Status

BJC uses ISMS core functions and guiding principles to integrate EMS considerations into work activities. By integrating EMS considerations within the elements of ISMS, the BJC Environment, Safety, and Health Organization provides procedures and processes for identifying environmental protection controls and compliance impacts and concerns prior to performing a scope of work, during work activities, and after the work is completed. Issued in September 2000, the BJC environmental management policy is a key attribute of the EMS. The policy reflects the mission, goals, and responsibilities of the company with respect to

environmental aspects and impacts, including pollution prevention. At the beginning of each project, subject-matter experts, called "environmental compliance and protection leads," are assigned to each subcontractor's work activity to support the formation of project and subproject teams in identifying and analyzing environmental hazards and in implementing controls that comply with DOE Work Smart Standards and applicable laws and regulations. The EMS is supported by communication between BJC and its subcontractors through the project's environmental compliance and protection lead. The EMS ensures that periodic assessments against the EMS attributes are conducted to evaluate the ISMS performance of each project and the subcontractor in charge of managing the project.

During 2005 BJC updated the company's ISMS description document to incorporate EMS, completed implementation of an Awareness Training Program on the EMS, and updated the self-performed EMS implementation gap analysis initiated in 2003. During 2005 BJC formally identified six significant environmental aspects and 48 accompanying activities that could result in environmental impacts, six targets, and five objectives for the EMS and integrated these into the ISMS Description. BJC performed an independent assessment of the EMS in September 2005 to confirm that the system met all requirements under DOE Order O 450.1, *Environmental Protection Program*. In December 2005, BJC formally self-declared to DOE ORO that the EMS was fully implemented to meet both the DOE Order and Executive Order 13148.

2.2.18.2 Pollution Prevention

During 2005, the ORR continued to implement a substantial number of pollution prevention projects which were reported to DOE. Reported results are summarized by program secretarial office in Table 2.13. Pollution-prevention-specific information is also available on the DOE pollution prevention homepage at http://www.eh.doe.gov/p2/.

The ORR sites' pollution prevention programs are driven by federal and state laws and regulations, executive orders, and DOE policies, notices, and orders. During 2005, in addition to supporting the implementation of pollution prevention projects, the ORR facilities performed activities to ensure the requirements established by DOE Order 450.1 as well as all other existing requirements were addressed. The ORR facilities must complete pollution-prevention-related requirements such as planning and reporting to comply with many regulatory requirements, including RCRA, the Tennessee Hazardous Waste Reduction Act, and the EPCRA/Pollution Prevention Act. The ORR facilities must also comply with DOE requirements, including reporting of pollution prevention project and program activities. The *Annual Report on Waste Generation and Pollution Prevention Progress*, the annual *Environmentally Preferable Purchasing Report*, and reports on pollution prevention projects completed by each site are designed to provide data used to measure progress toward DOE's FY 2005 and 2010 pollution prevention goals. Reported reduction results for FY 2005 (percentages based on a 1993 baseline) are summarized by program secretarial office or by the site as appropriate in Table 2.14.

The ORR also supports DOE's goal of reducing off-site releases and transfers of toxic chemicals by assessing operations associated with these releases and transfers. However, because of substantial changes since 1993 in the operations included in the EPCRA-related reporting from which these values are obtained, the ORR does not anticipate an overall reduction when compared with the 1993 baseline. Information on program secretarial office-specific and site-specific waste generation, recycling, and affirmative procurement is also available on the DOE pollution prevention homepage at http://www.eh.doe.gov/p2/.

Additionally, each site's data are included in DOE's complex-wide reports. Elements of DOE's annual reports are extracted and included in DOE's central internet database, which provides national-level DOE waste management and cleanup data to the public, as required by the December 1998 settlement agreement between DOE and the Natural Resources Defense Council, Inc.

In FY 2005, ORR-related activities received the following pollution-prevention awards in recognition of specific 2004 pollution-prevention accomplishments.

- 2005 DOE Office of Science (SC) Pollution Prevention—Best in Class Award. The Oak Ridge National Laboratory received this

Table 2.13. 2005 ORR pollution prevention project implementation results summary

Program secretarial office	Total projects reported in FY 2005	Total quantity of waste reduced in FY 2005 (MT or m^3)	Total cost avoidance in FY 2005 (Millions of $)
NNSA[a]	83	20,796.61	2.4
EM[b]	6	784.8	*c*
SC[d]/Other R&D	24	1,621.74	6.1

[a]National Nuclear Security Administration.

[b]Environmental Management.

[c]The EM Program at the ETTP site is also using Six Sigma projects as a means of capturing additional pollution prevention project-related data. The project –specific waste volume reduction and cost avoidance data is not as yet being reported as it is confidential information proprietary to Bechtel Jacobs Company, LLC, and undergoes a review prior to public release.

[d]Office of Science.

Table 2.14. 2005 ORR affirmative procurement and waste reduction progress summary

Program secretarial office	Waste reduction by office (%)				Site	Sanitary waste reduction by site (%)	
	Transuranic	Mixed low-level and RCRA	Low-level waste	Affirmative procurement		Landfill	Recycling
NNSA[a]	N/A	98	65	95	Y-12	87	57
EM[b]	N/A	*c*	*c*		ETTP	*d*	*d*
SC[e]/Other R&D	89	83	69	50	ORNL	37	28

[a]National Nuclear Security Administration.

[b]Environmental Management.

[c]The facilities at ETTP are undergoing decontamination and decommissioning (D&D) to support privatization and reindustrialization of ETTP or for demolition as part of site closure activities. In addition, the accelerated closure contract established in FY 2004 is resulting in increased waste generation volumes. As a result, waste generation from on-site DOE activities is expected to fluctuate significantly from year to year. Also, normal fluctuations could be expected from year to year when generating small volumes of a given waste stream.

[d]As a result of ongoing D&D activities at the ETTP site as well as those activities associated with the accelerated closure contract, on-site recycling activities can be expected to fluctuate significantly from year to year.

[e]Office of Science.

award for Overall Laboratory Operations. Specifically ORNL was recognized for leadership in the implementation of source reduction and recycling initiatives and incorporation of sustainable building design and operating in principles throughout the Laboratory.

- BWXT Y-12 was awarded the FY 2005 National Nuclear Security Administration Pollution Prevention Award for FY 2004 Environmental Stewardship Best in Class Award—Y-12 Environmental Management System Sustainability Initiative.
- BWXT Y-12 was awarded the FY 2005 National Nuclear Security Administration Pollution Prevention Award for FY 2004 Environmental Stewardship Award—Y-12 Cross-Complex Nitric Acid Transfer Initiative.
- BWXT Y-12 was awarded the FY 2005 National Nuclear Security Administration Pollution Prevention Award for FY 2004 Environmental Stewardship Award—Y-12 Pollution Prevention Integration in Construction in Radiological Areas.

To support future pollution prevention implementation, compliance, and goal achievement, the ORR sites' pollution prevention programs continue to pursue site projects, perform required activities, and complete required reporting.

2.2.18.3 Ozone-Depleting Substances Phase-Out Efforts

Significant progress has been made in eliminating use of Class I and Class II ozone-depleting substances at the Y-12 Complex, and a number of projects have been identified to further reduce ozone-depleting substance uses. The *Y-12 Complex Ozone Depleting Substances (ODS) Phase-Out and Management Plan* (Y-12 2003), was revised and updated in June 2005 and provides a complete discussion of requirements and compliance activities at the Y-12 Complex.

Y-12 has implemented an ongoing program to identify and retrofit or replace chillers that use Class I ODS to satisfy DOE goals and requirements. As of March 2004, the Y-12 Complex had replaced all of their large-capacity chillers ($\geq$ 150 tons) containing Class I ODS. Additional projects scheduled for 2005 addresses elimination of Class I ODS from two of the three remaining Class I ODS chillers in operation at Y-12.

ORNL has implemented a plan to eliminate the use of Class I ozone-depleting substances. This plan includes the replacement, retrofit, or decommissioning of all chillers that require Class I substances, the gradual phase out of smaller refrigeration systems that require Class I substances, the elimination of all fire-protection systems that use Class I substances, and the elimination of all other systems or processes that require Class I substances. Currently, Class I substances are used in small refrigeration systems such as refrigerators and window air conditioners. As these units fail, they are replaced with new units that use Class II or unregulated refrigerants.

ETTP completed the phaseout of Class 1 ozone-depleting substances equipment in the mid-90s. At that time, ETTP surplused and moved all Class 1 ozone-depleting substances to other DOE sites so they are no longer part of the ETTP ozone-depleting substances inventory. One exception exists, a small amount—270 lb of Class 1 R-12 refrigerant—was maintained in the ETTP inventory in CY 2004 for servicing older, small units/appliances (i.e., freezers and refrigerators) for the duration of their expected service life.

2.2.18.4 Energy Management (Including Fleet Management)

BWXT Y-12 prepared a multiyear Energy Management Plan that defines the general energy requirements of the Y-12 Complex and provides a brief history of energy-reduction efforts and a timetable for further energy-saving measures. The primary focus for energy conservation is on electricity, with secondary concentrations on reducing the use of natural gas, fuel (gasoline and diesel), coal, and water.

Over the past 15 years, the energy consumption at the Y-12 Complex has been reduced by more than 40%. Much of this reduction came as a result of reduced production activities and energy savings measures, such as replacing chillers, eliminating cooling towers, and regularly overhauling steam plant boilers.

ORNL's Energy Management and Implementation Plan outlines the strategy for managing and implementing short- and long-range energy-related activities. As a result of ORNL's emphasis on energy and utilities management and projects, standard building energy intensity has been reduced by approximately 24% compared with FY 1985 usage (based on British thermal units per gross square foot). Also, the energy intensity for high-energy-use facilities has been reduced by 13%. Specific activities include the following.

- **Energy Star.** In FY 2000 ORNL was awarded the EPA's Energy Star Award for a building, the first DOE building to achieve this rating and only the second building in the state of Tennessee to do so. A second building at ORNL received the Energy Star Award in FY 2004. Additional reviews are ongoing.
- **Leadership in Energy and Environmental Design (LEED) and Sustainability.** The recent East Campus Modernization project at ORNL used third-party financing to add three buildings and over 300,000 ft^2 of energy-efficient office, laboratory, and computer space and achieve a savings of $0.5 million in annual energy costs (30% savings compared with the baseline conventional design). All three facilities have been approved by the U.S. Green Building Council as LEED-certified. Additionally, a fourth building has been LEED-certified, and the fifth building in the grouping has been certified LEED-Silver. One project in construction is also on track to become certified LEED-Silver.
- **Chlorinated fluorocarbon (CFC) reductions.** As part an aggressive chiller replacement program, ORNL has replaced 17 chillers totaling 8,460 tons in cooling capacity, well ahead of legislated requirements. As a result, chiller energy use has dropped an average of 21% for an annual savings of $280 thousand, and CFC emissions have been cut by over 5000 lb/year. ORNL continues to replace smaller CFC chillers and has transferred all R-113 and most of the R-11 stored refrigerant to a refrigerant recycler.
- **Water savings.** Water-related projects and management efforts have resulted in water usage being reduced by 198 million gal, 18%, since FY 2000.
- **Green power.** ORNL participates in TVA's "Green Power Switch" program. ORNL was TVA's first industrial green power participant and purchases 675 MWh in green power annually.
- **Distributed energy resource.** Combining solar power with natural-gas-fired turbine technology, ORNL's 30-kW distributed energy resource research project won a Federal Energy Saver Showcase Award in FY 2002.
- **Greenhouse gas emission reductions.** Even though the gross square footage of non-process facilities at ORNL has increased almost 29% since FY 1995, improvements at the central steam plant has reduced CO_2-equivalent greenhouse gas emissions by 8.6% over the same time period.
- **Vehicle fleet management.** ORNL is working to minimize the use of petroleum-based fuels in the vehicle fleet. To minimize gasoline consumption, a total of 92 ethanol-burning vehicles are in service. Additional alternative fuel vehicles are being added to the fleet as funding allows. E-85, a mixture of 85% ethanol and 15% petroleum, is available at the Y-12 garage for use in flex fuel vehicles in the Y-12 fleet. Approximately 13% of the Y-12 fleet are flex fuel vehicles and the number of petroleum vehicles continues to be downsized. The use of E-85 in the flex fuel vehicles is expected to reduce combined criteria air emissions from the Y-12 fleet during 2006 by approximately 31% (~790 lbs/year) compared to 100% gasoline usage.

2.2.18.5 Beneficial Landscaping Practices

DOE Order 450.1 incorporates Executive Order 13148, "Guidance for Presidential Memorandum on Environmentally and Economically Beneficial Landscape Practices on Federal Landscaped Grounds." The guidance applicable to DOE-site landscaping includes

- use of regionally native plants for landscaping,
- design, use, or promotion of construction practices that minimize adverse effects on the natural habitat,
- seeking to prevent pollution,

- implementing water and energy efficient practices,
- creating outdoor demonstration projects, and
- other initiatives.

Y-12/NNSA partners with ORNL regarding stewardship responsibilities for lands on the ORR. Y-12 requires extensive use of erosion controls in construction projects (e.g., use of settling ponds and storm water detention areas), minimal use of water for irrigation, and use of trees where possible to provide shade for energy conservation. Active environmental compliance and preservation programs, such as an ongoing sitewide Pollution Prevention Program, Storm Water Pollution Prevention Plan activities, and policies requiring minimal use of pesticides and fertilizers also minimize environmental impacts. Additionally, Y-12 has limited its modernization construction to brownfield sites, thereby preserving ORR greenfield space.

ORNL has various ongoing programs and initiatives that involve or facilitate environmentally and economically beneficial landscaping practices. These include

- incorporation of native plants into planning for restoration or landscaping in areas across ORNL;
- development of the ORNL Conceptual Landscape Plan and Design Guidelines, which calls for use of native plant species;
- use of an internal stream corridor protection effort to encourage the growth of native plants in the riparian zone surrounding ORNL creeks;
- the formation of an informal interagency Native Grass Working Group;
- integration of native-plant requirements into facilities-development projects;
- evaluation of upcoming projects by the ORNL Land and Facilities Use Committee on potential impacts, including impact on natural habitat;
- creation of an ongoing sitewide Pollution Prevention Program and a Storm Water Pollution Prevention Plan and Program;
- minimal use of pesticides and fertilizers, and use of organic fertilizers;
- extensive use of erosion controls in construction projects (e.g., settling ponds and bioretention areas);
- minimal use of water for irrigation;
- incorporation of plants into project designs for energy conservation by providing shade and cooling to paved surfaces;
- provision of public-awareness interaction on invasive plants, nuisance wildlife, and restoration of native grasses;
- use of brownfield areas for siting new ORNL developments, when practicable; and
- implementation of an interagency cooperative agreement on conversion of TVA power-line rights-of-way from fescue grass to native grasses and shrubs.

2.2.19 Release of Property

DOE Order 5400.5 establishes standards and requirements for operations of DOE and its contractors with respect to protection of members of the public and the environment against undue risk from radiation. In addition to discharges to the environment, the release of property containing residual radioactive material is a potential contributor to the dose received by the public, and DOE Order 5400.5 specifies limits for unrestricted release of property to the public.

BWXT-Y-12, UT Battelle, and Bechtel Jacobs Company each utilize a graded approach for release of material and equipment for unrestricted use by the public. Material 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 the following:

- documents, mail, diskettes, compact disks, and other office media;
- nonradioactive items or materials received which are immediately (within the same shift) determined to have been misdelivered or damaged;
- personal items or materials;
- paper, plastic products, aluminum beverage cans, toner cartridges, and other items released for recycling;
- office trash;
- nonradiological area housekeeping materials and associated waste;
- break-room, cafeteria, and medical wastes;
- medical and bioassay samples; and
- other items with an approved release plan.

Items originating from nonradiological areas within the sites' controlled areas not in the listed

categories are surveyed prior to release to the public, or a process knowledge evaluation is conducted to ensure that 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.) When the process knowledge approach is employed, the item's custodian is required to sign a statement that specifies the history of the material and that confirms that no radioactive material has passed through or contacted the item. Items advertised for public sale via an auction are also surveyed on a random basis by state of Tennessee personnel, giving further assurance that material and equipment are not being released with inadvertent contamination.

A similar approach is used for material released to state-permitted landfills on the ORR. The only exception is for items that could be contaminated in depth; items contaminated in depth are also sampled by laboratory analysis to ensure that landfill permit criteria are met.

ORR contractors continue to follow the requirements of the scrap metal moratorium. No scrap metal originating from radiological areas is being released for recycle.

2.3 Appraisals and Surveillances of Environmental Programs

Numerous appraisals, surveillances, and audits of ORR environmental activities were conducted during 2005 (see Tables 2.15, 2.16, and 2.17). These tables do not include internal DOE prime contractor assessments for 2005.

2.4 Environmental Permits

Table 2.18 contains a summary of environmental permits for the three ORR sites. Continuing permits, required at each of the ORR facilities, are RCRA operating permits, NPDES permits, and air operating permits.

2.5 Notices of Violations and Penalties

ORNL received one NOV from TDEC in 2005 for a RCRA nonconformances and two NOVs for NPDES permit nonconformances. The RCRA issues were based on observations found during the May 2005 RCRA inspection. The NOV included violation of the Low-Level Waste Management Agreement and violation of the conditions of the waste analysis plan for permit TNHW-010A. Corrective actions were undertaken where necessary; TDEC was satisfied with the actions taken. The NPDES NOVs were for the accidental release of an herbicide-and-dye mixture to an ORNL site storm water drain in December 2004, and for exceedance of Tennessee stream temperature criteria caused by cooling-water discharge in August 2005. Both situations were investigated, corrective actions were taken, and there has been no recurrence of either condition.

One NOV was issued by TDEC in 2005 for ETTP RCRA operations. This NOV covered four items of noncompliance.

Y-12 received one NOV in late 2005 for RCRA violations found during the November 2005 inspection. Issues included lack of immediate access to communication devices in two 90-day accumulation areas, mischaracterization of stored hazardous wastes, and storing mixed wastes greater than one year without adequate burden of proof documentation. Resolution of that NOV is expected in 2006.

2.6 Tennessee Oversight Agreement

The Tennessee Oversight Agreement is a voluntary agreement entered into between DOE and the state of Tennessee. This agreement reflects an extension through June 30, 2006, of the agreement between the DOE and the state executed on May 13, 1991, and continues to reflect the obligations and agreements regarding DOE's technical and financial support.

The agreement is designed to assure the citizens of Tennessee that their health, safety, and environment are being protected through existing programs and through substantial new commitments by DOE. Through a program of independent monitoring and oversight, the state

Table 2.15. Summary of environmental audits and assessments conducted at the Y-12 Complex, 2005[a]

Date	Reviewer	Subject	Issues
		BWXT Y-12	
2/22/2005	TDEC	HEUMF Project	0
3/8/2005	City of Oak Ridge	Sanitary Sewer pretreatment inspection	0
3/30/2005	TDEC—Knoxville Office	TDEC Annual Clean Air Compliance Inspection	0
8/2/2005	City of Oak Ridge	Sanitary Sewer pretreatment inspection	1
11/7/2005	TDEC	TDEC Annual RCRA inspection	0
		Bechtel Jacobs Company	
12/14/2005	TDEC	TDEC Annual RCRA inspection	2

[a]Abbreviations

HEUMF Highly Enriched Uranium Materials Facility
RCRA Resource Conservation and Recovery Act
TDEC Tennessee Department of Environment and Conservation

Table 2.16. Summary of environmental audits and assessments conducted at ORNL, 2005[a]

Date	Reviewer	Subject	Issues
		UT-Battelle	
1/10/05–1/15/05	DOE HQ	DOE 830 audit	0
1/10/05	TDEC	Stream permitting	0
2/11/05	TDEC	Stream permitting	0
5/23 & 25/05	TDEC	NPDES permit renewal	0
12/14/05	TDEC	Title V Air Permit	0
5/2–5/05	TDEC, RCRA	TDEC Annual RCRA Inspection	0
		BJC	
5/2–5/05	TDEC	TDEC Annual RCRA Inspection	2

[a]Abbreviations:

DOE HQ Department of Energy Headquarters
NPDES National Pollutant Discharge Elimination System
ORNL Oak Ridge National Laboratory
RCRA Resource Conservation and Recovery Act
TDEC Tennessee Department of Environment and Conservation

Table 2.17. Summary of environmental audits and assessments conducted at the ETTP, 2005[a]

Date	Reviewer	Subject	Issues
1/5/05	TDEC	Air Source Inspection	0
2/22/05	TDEC	Annual RCRA Inspection	4

[a]Abbreviations:

TDEC Tennessee Department of Environment and Conservation
RCRA Resource Conservation and Recovery Act

Table 2.18. Summary of permits as of December 2005

	Y-12 Complex	ORNL	ETTP
Resource Conservation and Recovery Act (RCRA)			
RCRA operating (Parts A and B)	2	2[a]	3
Part B applications in process	0	0[b]	0
Postclosure	3[c]	0	0
Solid waste landfills	6[d]	0	0
Annual petroleum underground storage tank facility certificate	2	1	1
Transporter permit	1	1	1
Hazardous and Solid Waste Amendments Permit	1[e]	1[e]	1[e]
Clean Water Act			
National Pollutant Discharge Elimination System (NPDES)	1[f]	2	4[g]
Storm water	1[h]	1[h]	1[h]
Aquatic resource alteration	1	5	1
Army Corps of Engineers 404 permits	0	0	1
General storm water construction	1[i]	2	0
Clean Air Act			
Operating Title V Major Source Permit	2	2	8
Construction	2	1	2
Prevention of significant deterioration	0	0	0
Sanitary Sewer			
Sanitary sewer	1	0	0
Pump-and-haul permit	2	2[j]	2
Toxic Substances Control Act (TSCA)			
TSCA Incinerator	0	0	1
Research and development for alternative disposal methods	0	0	0
Safe Drinking Water Act			
Class V underground injection control permits	0	0	0

[a]Two permits have been issued, representing 16 active units and 5 proposed units. One additional permit covers corrective action (Hazardous and Solid Waste Amendments) only.

[b]The permit application for the Chemical Detonation Facility was terminated; closure is planned.

[c]Three permits have been issued, representing units closed under RCRA in Bear Creek Hydrogeologic Regime, Chestnut Ridge Hydrogeologic Regime, and Upper East Fork Poplar Creek Regime.

[d]Three landfills are operational; one is inactive and has a record of decision under the Comprehensive Environmental Response, Compensation, and Liability Act; one is closed pending certification; and one is in postclosure care and maintenance.

[e]Oak Ridge Reservation (ORR) permit (TNHW-121). Requirements for corrective action have been integrated into the ORR Federal Facility Agreement.

[f]Issued 4/28/95 and effective 7/1/95. TDEC has incorporated requirements for storm water into individual NPDES permits.

[g]Only two NPDES permits are directly administered by DOE contractor. Two permits are administered through the Community Reuse Organization of East Tennessee.

[h]TDEC has incorporated into individual NPDES permits.

[i]Notice of intent that accesses a general NPDES permit. A notice of intent remains on file for construction of Building 9720-82 and hollow-fill.

[j]This includes one pump-and-haul permit for Y-12 and two for office trailers at ORNL, as well as one at Clark Center Park, which is operated by East Tennessee Mechanical Contractors.

will advise and assist in verifying that DOE's activities do not adversely impact the public health, public safety, or the environment. DOE and the state, in a spirit of partnership and cooperation, agree to find ways to achieve clean air, water, and land in concert with sustainable economic growth.

To date, a variety of activities have been conducted under the agreement. DOE has provided security clearances and training necessary for state employees to gain access to the sites. Environmental data and documents pertaining to the environmental management, restoration, and emergency management programs are provided or are made available to the state for its review. The TDEC/DOE Oversight Division routinely visits the three DOE sites to attend formal meetings and briefings, conduct walk-throughs of buildings operations to assess compliance with environmental regulations. The TDEC/DOE Oversight Division also collects air samples, water samples, and soil samples and occasionally does radiological surveys. Also, prior to surplus sales, the TDEC/DOE Oversight Division routinely does a radiological survey of all equipment and material to be auctioned off.

The TDEC/DOE Oversight Division also prepares an annual environmental monitoring report of its activities (TDEC 2005) and is available on the web at http://www.state.tn.us/ environment/doeo/.

3. Environmental Management and Reservation Activities

Much of the work accomplished by the DOE Oak Ridge Office of Environmental Management (EM) on the ORR is performed as a result of the requirements of the Federal Facility Compliance Act and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The 1992 Federal Facility Compliance Agreement requires that all DOE facilities manage and dispose of mixed waste in accordance with their respective site treatment plans. Bechtel Jacobs Company LLC has established programs to address the storage, transportation, treatment, disposal, and recycling of legacy and newly generated waste from the ORR. Bechtel Jacobs LLC manages the Toxic Substances Control Act (TSCA) Incinerator, wastewater treatment facilities, landfill operations, and certain other treatment and recycle facilities that also contribute to meeting the requirements of the Federal Facility Compliance Agreement and other EM milestones.

Another large portion of the EM work conducted at ORR is performed according to the requirements of CERCLA, which is implemented by the 1991 Federal Facility Agreement. The Federal Facility Agreement, signed by DOE, Tennessee Department of Environment and Conservation (TDEC), and EPA, addresses contamination resulting from past activities of DOE operations that remain in structures, buildings, facilities, soil, groundwater, surface water, or other environmental media.

3.1 Introduction

For more than half a century, one of the primary missions of DOE and its predecessor agencies was the production of nuclear weapons for the nation's defense. Production of materials for nuclear weapons, which began in 1943, produced hazardous and radioactive waste and resulted in contamination of facilities, structures, and environmental media. Two laws passed by Congress included requirements to address these problems. These two laws are the Federal Facility Compliance Act and CERCLA. The Federal Facility Compliance Agreement, made in accordance with the Federal Facility Compliance Act, requires that all DOE facilities manage and dispose of waste in accordance with their respective site treatment plans. The Waste Disposition and Waste Operations projects address waste stored, treated, disposed of, or recycled on the ORR in accordance with the Site Treatment Plan. The DOE Environmental Management program also operates and maintains waste treatment, storage, disposal, and recycling facilities at each of the three Oak Ridge sites (ETTP, ORNL, and the Y-12 Complex). These activities are included in the Waste Operations Project.

CERCLA addresses any environmental contamination resulting from past industrial operations, not just those performed at federal facilities. CERCLA requires that sites requiring cleanup actions be placed on the National Priorities List. Once on the list, the responsible entities are required to investigate and remedy abandoned or uncontrolled hazardous waste sites where a release has occurred or may occur. The ORR was placed on the National Priorities List in 1989. In 1990, DOE Headquarters (DOE-HQ) established the Office of Environmental Management (EM), making DOE-ORO responsible for cleanup of the reservation. CERCLA also requires public involvement to ensure that citizens will be informed of cleanup decisions that may affect them or the area in which they live.

The following sections highlight some of the EM activities for 2005 and some related activities carried out to ensure good stewardship of the reservation.

3.2 East Tennessee Technology Park

3.2.1 Decontamination and Decommissioning

3.2.1.1 K-29, K-31, and K-33 Project Completed

In August 1997, DOE signed an action memorandum (AM) to decontaminate and remove equipment from the K-29, K-31, and K-33 gaseous diffusion buildings. The contractor,

BNG America, under a fixed-price contract with DOE awarded in August 1997, completed the work in FY 2005. K-31 and K-33 Buildings were 98% and 85%, respectively, decontaminated to specified radiological end-point criteria. DOE plans to complete the decontamination of the K-31 Building utilizing another contractor and will pursue making Building K-31 available for reuse. Building K-33 decontamination will not be completed until a reuse has been identified and a decision on the final disposition is made prior to December 2007. Building K-29 has been determined to not be in satisfactory condition for reuse and will be demolished as part of the Remaining Facilities Removal Action. A total of 159,000 tons of material has been dismantled, removed, and dispositioned as waste or recycle material for the entire project. DOE will submit the Removal Action Report to the regulators in FY 2006.

- More than 75% of waste from the K-29, K-31, and K-33 buildings was shipped to either Envirocare of Utah or the Nevada Test Site.
- The original estimate of metal that would have to be dispositioned from the buildings was 126,000 tons, but the project dispositioned almost 160,000 tons.
- More than 463 miles of piping were removed from the buildings.

3.2.1.2 K-25/K-27 Facilities Decontamination and Decommissioning

The three-story, U-shaped K-25 Building was built during the Manhattan Project and contained 3,018 stages of gaseous diffusion process equipment and associated auxiliary systems. Each stage consists of a converter, compressors, motors, and associated piping. The K-27 Building covers 383,000 ft^2 and contains 540 stages of gaseous diffusion equipment and associated auxiliary equipment.

An AM for the demolition of the K-25 and K-27 Buildings was signed in February 2002. The AM stipulates that the buildings be demolished to the slab and that the associated waste be disposed of. The first phase of the demolition, hazardous materials removal, started in December 2001 and was completed in June 2005. Hazardous materials removal primarily included the removal of asbestos-containing building material, such as transite panels and insulation, from inside the K-25 and K-27 Buildings. During the 3.5-year period, a total of 944 waste shipments, comprising approximately 621,000 ft^3 of waste, were transported to the Environmental Management Waste Management Facility (EMWMF), a CERCLA disposal facility located near the Y-12 National Security Complex.

Process equipment removal is under way with the shipment of 115 loose converters to the Nevada Test Site (NTS) and EMWMF for disposal, 75 of which were shipped in 2005. Excess materials are also being removed from the buildings. Excess materials consist of nonprocess items, such as laboratory equipment, laboratory samples, office equipment, tools, wooden pallets and crates, and drums of chemicals. In 2005, a total of 465 waste shipments, containing approximately 339,000 ft^3 of waste, were transported to the EMWMF for disposal.

At the end of 2005, removal of fixed process equipment was awaiting completion of the Operational Readiness Review and transmittal of the Notice to Proceed from DOE Headquarters. Approximately 1,500 stages in the K-25 Building have been purged of residual process gas in preparation for fixed, process equipment removal.

K-25 Building demolition continued in 2005 with the removal of approximately 117,000 ft^2 of transite panels from the exterior of the building, demolition of 72 of the 114 filter houses, and removal of transite enclosures from about half of the 150 interior stairways. The building demolition waste-handling plan was approved in FY 2005.

The memorandum of agreement (MOA) regarding historical preservation of the K-25 Building was ratified on March 28, 2005. This MOA allows the east and west wings of the U-shaped K-25 Building to be demolished, but retains the north wing for historic preservation purposes. The MOA also allows the placement of concrete rubble within the vaults of the east and west wings. The vault walls of the east and west wings along the interior of the “U” will be preserved. Filling and grading of the vault areas will leave the upper portion of the wall available for use by others to portray the history of Oak Ridge (e.g., murals). The footprint of the K-25 Building will be preserved and nominated as an historic landmark.

3.2.1.3 Group II Buildings, Phase II Buildings (K-1064 Peninsula)

DOE signed an AM in July 2002 for the demolition of facilities and the removal of scrap material located in the K-1064 peninsula area. During 2004 and 2005, 17 of the 19 facilities were demolished. Demolition of the remaining facilities and removal of the scrap are planned to be completed in 2006.

3.2.1.4 Remaining Facilities

In September 2003, DOE signed an AM to demolish the approximately 500 remaining facilities. In 2005, 45 predominantly uncontaminated facilities, 19 low-risk/low-complexity facilities, and 9 facilities in a grouping called "Balance of Site - Laboratories Group" were demolished, transferred, or sold; characterization and utility deactivation continued in preparation for demolition work in 2006; removal of universal waste was started in the K-29 Building; and waste-handling plans were approved for K-1401, K-1420, K-29, and Centrifuge Equipment Removal.

3.2.1.5 Zone 2 Record of Decision Developed

The focused feasibility study, focused feasibility study addendum, and proposed plan for cleanup of the Zone 2 portion of ETTP were approved in 2004 by the Federal Facility Agreement parties (DOE, EPA, and TDEC). These documents detail the options and selected remedy for remediation of the site. A public meeting was held on August 24, 2004, to discuss the Zone 2 Proposed Plan.

Zone 2 includes the area within the main fence of the plant (approximately 324 hectares). Zone 1 is the area surrounding ETTP outside the fence. These documents address soil, slab, subsurface structure, and burial ground contamination. Remedial action objectives have been set to provide for protection of a future industrial work force and to protect underlying groundwater. A record of decision (ROD) has been developed for EPA and TDEC to review and was approved in April 2005.

3.2.1.6 ETTP Soil Remediation

The soil at ETTP will be remediated to protect a future industrial work force and to protect underlying groundwater. Two RODs have been signed that address soil, slabs, subsurface structures, and burial grounds.

The Zone 1 ROD was signed by DOE, the TDEC, and the EPA in November 2002. Zone 1 is the 567-hectare area surrounding ETTP outside the fence. The Zone 2 ROD was signed by DOE, TDEC, and EPA in April 2005. Zone 2 includes the area within the main fence of ETTP (approximately 324 hectares). The Remedial Design Report/Removal Action Work Plan for Soils, Slabs, and Subsurface Structures was approved by EPA and TDEC in September 2005.

Work associated with the K-901 and Duct Island areas was completed in 2005, and the Phased Construction Completion Report was submitted to the EPA and TDEC for approval. Schedules associated with this work are contained in the Federal Facility Agreement, Appendix E, on the web at www.bechteljacobs.com/pdf/ffa/appendices/appendex.pdf.

3.2.1.7 ETTP Site-Wide ROD Project Under Way

The ETTP site-wide ROD addresses contamination in groundwater, surface water, and sediment for the protection of human health and the environment. In addition, it will determine whether additional soil action is necessary to protect the environment. The geographic areas included in this decision are Zone 1 (outside the main plant) and Zone 2 (inside the plant fencing).

After a series of data-quality-objective workshops focusing on groundwater, surface water, sediment, and soil actions were held, a work plan for additional investigations was developed and was submitted to EPA and TDEC for approval. Fish sampling and aquatic community surveys were conducted as stated in the work plan. Additionally, the three Federal Facility Agreement parties developed a detailed schedule of the ensuing activities to allow for signature of the ROD in early 2007.

3.2.1.8 ETTP Begins Removing Scrap Waste

The ETTP Scrap Removal Project began shipping contaminated scrap from the K-770 Scrap Yard to the EMWMF on July 26, 2004. Almost 22,000 tons of contaminated scrap metal were disposed at EMWMF during 2005 under the ETTP Scrap Removal Project. This project is responsible for disposing of approximately 47,000 tons of scrap metal from the K-770 Scrap Yard, K-1131 Area, K-1064 Scrap Yard, K-1300 Area, and K-1066-G Maintenance Yard. Remediation of contaminated soil at these sites is planned for 2007.

3.2.1.9 ETTP Outdoor Legacy Waste

The ETTP Outdoor Legacy Waste is composed of 6209 containers of low-level waste that were the result of past operations at the site. This waste has been characterized to support disposal and shipment to the EMWMF, which is in progress.

3.2.1.10 UF_6 Cylinders Being Shipped Off Site

More than 6000 cylinders containing uranium hexafluoride (UF_6) are being shipped to the Portsmouth Site for disposition. Most contain depleted UF_6. These steel cylinders hold approximately 10 to 14 tons of depleted UF_6. They are stored in storage yards in aisles and are stacked two high. 2,747 cylinders of depleted UF_6, and 429 cylinders of uranium compounds other than depleted UF_6 were shipped in 2005.

Natural uranium in the form of UF_6 was used as feed material during the gaseous diffusion process to enrich uranium at the former K-25 Site. The percentage of uranium-235 was increased from the original feed material in the process (i.e., enriched). The remaining material is depleted UF_6. It is stored as a white, crystalline solid that is slightly less radioactive than natural uranium.

3.2.1.11 Blair Quarry Remediation Completed

More than 15,000 tons of contaminated soil and debris have been removed from Blair Quarry, a former waste disposal site adjacent to ETTP, and site restoration is complete.

The remediation project kicked off in mid-November 2004 and was completed in early 2005 with no recordable injuries, first aid cases, or transportation incidents. The material was disposed of at EMWMF.

Blair Quarry was created in the early 1940s by excavating into McKinney Ridge, forming a U-shaped amphitheater with exposed rock on three sides. The rock material was used to support construction of the K-25 Site. It operated as a quarry until 1945 and was then used for open burning of trash and debris through the late 1950s.

Several investigations of the type and extent of contamination at Blair Quarry were conducted before the remediation project began. The project served as a pilot for the strategy that was developed and approved for the characterization and verification of Zone 1 and Zone 2 areas at ETTP. Additional contaminants of lesser concern included polychlorinated biphenyls (PCBs) and low levels of radionuclides and metals. Based on these investigations, only 0.4 hectare of the initial 27-hectare area required remediation.

3.2.1.12 TSCA Incinerator Hazardous Waste Treatment

The TSCA Incinerator, located at ETTP, treated 325,520 lb of liquid waste and 167,482 lb of solid waste in 2005. Plans are in place to increase the throughput at the incinerator to ensure cost-effective operations in support of the DOE complex's cleanup mission. The TSCA Incinerator plays a key role in treatment of radioactive PCB and hazardous wastes (mixed wastes) from the ORR as well as other facilities across the DOE complex, thus facilitating compliance with regulatory and site closure milestones.

3.2.1.13 Central Neutralization Facility

The Central Neutralization Facility (CNF) is ETTP's primary wastewater treatment facility and processes both hazardous and nonhazardous waste streams arising from multiple waste treatment facilities and remediation projects. The facility removes heavy metals and suspended solids from the wastewater, adjusts pH, and discharges the treated effluent into the

Clinch River. Sludge from the treatment facility is treated, packaged, and disposed of off-site. The CNF treated approximately 28 million gallons of wastewater in 2005.

3.3 Oak Ridge National Laboratory

3.3.1 Melton Valley Remedial Actions

The Federal Facility Agreement parties signed the Melton Valley ROD in September 2000. The Melton Valley ROD presents the selected remedy for environmental remediation of various burial grounds and other contaminated waste units within the ORNL Melton Valley area. Remediation will be accomplished through a combination of responses that includes containment, stabilization, removal, treatment, monitoring, and interim land-use controls.

Regulators approved a remedial design work plan in May 2001, with the approval of the land use control implementation plan still outstanding. The plan specifies what actions must be taken to implement and maintain the required land use controls. Remediation work mandated by the Melton Valley ROD has been ongoing and will continue through 2006. Individual actions completed before 2004 include remediation of both the Process Waste Sludge Basin and the Old Hydrofracture Facility, demolition of various surface structures in Melton Valley, and excavation and disposal of contaminated soil from the Intermediate Holding Pond.

During 2005, construction of 11 caps covering 104 acres of solid waste storage areas (SWSAs) 5 and 6, and Seepage Pits and Trenches, continued. Collection and treatment of groundwater from the Seepage Pits and Trench 7 began and continued in 2005.

3.3.2 Hydrofracture Wells Plugging and Abandonment

Between the 1960s and mid-1980s, the process of deep waste injection was used at ORNL to dispose of radioactive liquids and sludge in mixtures of waste with cement-based grout and various additives. Two test injection wells were constructed, along with boreholes and wells, so that the behavior of the injected grout in the injection zone bedrock could be observed. At these two test sites, small quantities of radionuclides were added to the injected grout to make the grout sheets detectable by gamma detectors. The third and fourth injection wells, located within the Old Hydrofracture Facility and New Hydrofracture Facility, respectively, were constructed for large-scale waste disposal. More than 5 million gal of liquid waste-grout mix, containing approximately 1.4 million Ci of activity, were injected into artificially induced fractures in a shale formation at depths of 300 to 1000 ft. All large-scale disposals were at depths greater than 780 ft. Contamination levels in hydrofracture monitoring wells have been reported as high as 97 million pCi/L gross beta.

These surplus wells are potential pathways for the migration of contaminated fluids from the grout sheets and from deep groundwater to shallower groundwater zones. To prevent this migration, a remedial action was initiated in 2001 to plug and abandon 111 wells consisting of 4 injection wells and 107 monitoring wells. Plugging and abandonment of the last well (injection well 1968), which was located within the New Hydrofracture Facility, were completed in March 2004. The Phased Construction Completion Report was drafted, and comments were received in 2005. Approval of the final report is expected in 2006.

3.3.3 New Hydrofracture Facility Decontamination and Decommissioning

The New Hydrofracture Facility was built at ORNL between 1979 and 1982 and operated from 1982 to 1984. It replaced the Old Hydrofracture Facility, which operated between the late 1950s to the mid-1970s. The New Hydrofracture Facility was designed to facilitate the injection of a mixture of radioactive waste solutions and grout into an impermeable shale formation at depths between 700 and 1000 ft below grade. The hydrofracture process is essentially a batch process in which the waste/grout mixture is pumped down a tubing string in the injection well and out into the shale formation. The high injection pressure of approximately 3000 psi fractures the subsurface shale and forces the waste/grout mixture into the fractures, where it hardens into “grout sheets.”

The objective of the decontamination and decommissioning of the New Hydrofracture Fa-

cility is the removal and disposition of the main and ancillary facilities, including some subsurface structures. The majority of the New Hydrofracture Facility has been demolished. Only three rooms, or cells, of the main structure remain. All process equipment and piping have been removed from these cells in preparation for demolition of the cell structures, scheduled to be completed in 2006.

3.3.4 SWSA 4 Hydrologic Isolation

Work on the SWSA 4 project includes the hydrologic isolation of the SWSA 4 burial ground, Liquid Waste Disposal Pit 1, the Pilot Pits Area, and the 7819 Decontamination Area, as well as the excavation of the Intermediate Holding Pond. Hydrologic isolation includes the installation of a multilayer cap, upgradient storm-flow diversion trenches, and downgradient collection trenches. To facilitate cap installation, this project also included plugging and abandonment of unneeded, shallow, non-hydrofracture wells within the cap boundary; developing a borrow area and associated haul roads; and relocating Lagoon Road.

From 1951 to 1959, DOE used SWSA 4 for disposing various liquid and solid radioactively contaminated wastes in unlined trenches and auger holes. SWSA 4 contains approximately 20,000 Ci of radioactive wastes and contributes approximately 27% of the total risk in surface water to a hypothetical resident at White Oak Dam.

Pit 1 was constructed in 1951 to test the feasibility of disposing liquid waste in pits excavated in the natural clays in Melton Valley. Pit 1 received liquid waste from August to October 1951. In 1981 Pit 1 was backfilled and covered with an asphalt cap. In 1991 a portion of the wastes disposed of in Pit 1 was stabilized as part of an in situ vitrification technology demonstration. In situ vitrification is a process that uses electrical power to heat and melt contaminated soil, fusing the soil and waste into a glasslike solid.

Construction of an approximately 12-hectare cap, upgradient and downgradient groundwater interception trenches, and a groundwater treatment unit were completed in 2004. Groundwater collection and treatment began at SWSA 4 and continued in 2005.

3.3.5 HRE Ancillary Facilities

The HRE ancillary facilities consist of 11 separate structures external to the HRE reactor building, which provided support capabilities (waste management, storage, etc.) during reactor operation. The ancillary facilities include a liquid waste evaporator, a charcoal absorber that cleaned up gaseous effluents prior to discharge to the atmosphere, a decontamination pad and storage shed, an office building, and other miscellaneous structures. Decontamination and decommissioning (D&D) of three of the ancillary facilities was completed in 2005. Planning and characterization of the remaining facilities was performed. D&D is scheduled to be completed in 2006.

3.3.6 Molten Salt Reactor Experiment Fuel and Flush Salts Removal

The Molten Salt Reactor Experiment (MSRE) facility operated from 1965 to 1969 to test the molten salt concept. Unlike most current commercial reactors that have fuel confined to fuel rods, the MSRE was fueled by molten salt that flowed through the reactor chamber, where the nuclear chain reaction produced heat.

A CERCLA action to remove the fuel and flush salt is under way. Testing of fuel and flush salt removal equipment and a cold trap system was successfully completed in 2003. Operating procedures were developed based on results of the testing, and training of operators was completed. Melting of the salt in preparation for removal began in December 2004, and processing of the initial flush salt tank was completed in 2005. Completion of salt removal is scheduled for late 2006.

3.3.7 22-Trench Area TRU Waste Retrieval

During the 1970s, packages of transuranic (TRU) waste were retrievably stored in the 22-Trench. Since the 1980s, packages of newly generated TRU waste have been stored in constructed facilities. Radionuclides in the TRU waste containers represent some of the most toxic and longest-lived radioisotopes stored on the ORR. In a consent agreement signed in September 2000, DOE committed to the state of

Tennessee to retrieve the TRU waste from the 22-Trench Area under DOE's Atomic Energy Act authority.

A request for proposals for the 22-Trench Area retrieval project was issued for bid early in 2003. The proposals were evaluated, and a subcontract was awarded. The scope of work consists of retrieving the TRU waste packages, placing the waste packages in overpacks, and staging the waste in appropriate areas pending transport to the TRU Waste Processing Facility when directed by DOE. There the wastes will be repackaged to meet the acceptance criteria for off-site disposal facilities and then shipped off site for disposal. Soil exceeding remediation levels in the Melton Valley ROD and debris waste associated with the excavation will be disposed of at the EMWMF or other appropriate facility. Retrieval of waste packages began in December 2004. As of the end of 2005, 191 of the anticipated 204 packages had been retrieved, overpacked, and staged.

3.3.8 Melton Valley Hydrologic Isolation

In addition to the SWSA 4 cap, the Melton Valley ROD calls for construction of caps on several other waste disposal areas (SWSA 5, SWSA 6, and selected pits and trenches). Approximately 40 hectares of multilayer caps, several groundwater interception trenches, and a groundwater treatment unit will be constructed. Cap construction at SWSA 5 South and SWSA 6 began in 2004 and continued through 2005. Downgradient groundwater interception trenches were completed at Seepage Pits 2, 3, and 4 and SWSA 5. Groundwater collection and treatment has begun at the Seepage Pits, Trench 7, and Seep D.

3.3.9 T-1, T-2, and HFIR Tanks Remediation

The T-1, T-2, and High Flux Isotope Reactor (HFIR) tanks were the last inactive liquid low-level waste (LLLW) tanks at ORNL to be remediated. The HFIR Tank was stabilized in 2004 by being filled with grout. The residual sludge in Tanks T-1 and T-2 was to have been treated to destroy organic resins; however, it was determined that the quantity of resins in the sludge would not adversely impact the LLLW system. Therefore, the sludge was transferred directly to the active LLLW system in 2004, and Tanks T-1 and T-2 were stabilized with grout. The phased construction completion report documenting completion of the tanks remediation in accordance with the ROD was approved during 2005, completing the tanks remediation activities.

3.3.10 Soils and Sediments Remediation

Several inactive waste ponds and areas of soil with radioactive contamination above criteria established in the Melton Valley ROD require excavation. In CY 2005 four inactive ponds and associated contaminated soil at the HFIR were excavated and disposed of, as was the former Homogenous Reactor Experiment (HRE) Pond and lesser-contaminated soil surrounding the pond. Remediation efforts at the HFIR facility entailed the shipment of more than 600 truckloads of contaminated sediment and soil to EMWMF, comprising approximately 6,200 yd^3. At HRE, 578 truckloads containing an estimated 5,000 yd^3 of contaminated soil were shipped to EMWMF for disposal. Contaminated soil removed from areas adjacent to the HRE Pond, 1,374 truckloads containing about 13,000 yd^3 of contaminated soil were transported to one of the Melton Valley Hydrologic Isolation capping sites for beneficial reuse as contour fill.

In addition, five contaminated soil sites in Melton Valley were remediated, resulting in the removal of approximately 4,500 yd^3 of contaminated soil. The soil from these sites, primarily derived from previous leaks from the ORNL LLW system, was also dispositioned as contour fill beneath one of the MVHI caps. Gamma walkover surveys and soil sampling across Melton Valley identified 20 small hot spots that were also remediated, entailing the excavation and transport of approximately 15 yd3 of contaminated soil (also placed beneath an MVHI cap as contour fill).

Pipeline remediation activities began in the summer of 2005 and continued through the end of the calendar year, at which point approximately 20,000 linear feet of inactive LLLW and process waste lines had been grouted.

3.3.11 Decontamination and Decommissioning Projects

A number of structures and facilities, including ancillary HRE facilities, the 7841 Equipment Storage Area, and Shielded Transfer Tanks, will undergo D&D. The remedial design report/remedial action work plans for these activities were approved by the regulators in 2004. Field mobilization was completed, and processing of material from the 7841 Equipment Storage Area began during 2005. Decontamination and decommissioning of five of the HRE ancillary facilities was completed in 2005. The HRE ancillary facilities consist of 11 separate structures external to the HRE reactor building, which provided support capabilities (waste management, storage, etc.) during reactor operation. The ancillary facilities include a liquid waste evaporator, a charcoal absorber that cleaned up gaseous effluents prior to discharge to the atmosphere, a decontamination pad and storage shed, an office building, and other miscellaneous structures. Planning and characterization of the remaining facilities was performed. D&D is scheduled to be completed in 2006.

3.3.12 In Situ Grouting of Trenches 5 and 7

The selected remedial action for Seepage Trenches 5 and 7 in the Melton Valley ROD was in situ vitrification. During 2003, a predesign field investigation and a procurement for design and construction services were conducted in preparation for performing in situ vitrification. New information resulted from these activities and prompted a reassessment. The new information included the presence of standing water in the trenches and a much higher cost for performing the in situ vitrification than was expected. After further evaluation, DOE proposed in an amendment to the ROD that an alternative treatment, in situ grouting, be substituted for in situ vitrification for Trenches 5 and 7. This remedy change and the associated ROD amendment were approved in 2004 by the regulatory agencies.

The requirements decision record/remedial action work plan for the in situ grouting of the trenches was approved in September 2004. The trenches will be treated by the permeation grouting method, utilizing portland-cement-based grouts injected under low pressure into the crushed limestone trench material. The grout will form a solid mass with the crushed limestone and the finer sediments, greatly reducing the permeability of the trench materials. The soil adjacent to the trench walls will be treated with a solution grout (e.g., polyacrylamide) to reduce migration of contaminants away from the trench by sealing off seepage pathways. Nuclear safety and overall safety considerations during actual grouting prompted extension of the schedule for completion to 2006.

3.3.13 Bethel Valley Remediation

The Bethel Valley ROD, signed by the Federal Facility Agreement parties in May 2002, presents the remedy selected for environmental remediation of various contaminated areas within the ORNL Bethel Valley area. Higher-risk sites will be addressed first. Remediation work mandated by the Bethel Valley ROD will continue through FY 2014. The first three projects to be performed under the ROD are the Bethel Valley Groundwater Engineering Study; remediation of the T-1, T-2, and HFIR Tanks; and partial remediation of the Hot Storage Garden.

3.3.14 Bethel Valley Groundwater Engineering Study

The Bethel Valley ROD specified that a groundwater engineering study be conducted to satisfy data needs for the design of several remedial actions related to groundwater, including (1) deep groundwater extraction at the Corehole 8 plume, (2) in situ biodegradation at the East Bethel Valley volatile organic compound (VOC) plume, (3) groundwater monitoring in West Bethel Valley, and (4) soil excavation at known leak sites to minimize impacts to groundwater. Planning for the groundwater engineering study was summarized in the *Engineering Study Work Plan for Groundwater Actions in Bethel Valley*, issued as a final document in 2003. The work plan includes an evaluation of existing, relevant data from previous characterization activities and defines the scope of work to be performed to design groundwater and soil remedial actions under the record of decision. The engineering study data have been collected, and a report summarizing the results has been issued.

In CY 2005, the Bethel Valley Groundwater Engineering Study completed the components of the required fieldwork. Two hundred and eighty-three soil push probes were completed to obtain soil and groundwater samples. The soil gas installations were completed, and the data were acquired and analyzed. Based upon the soil gas monitoring, seven groundwater monitoring wells were installed to provide additional data about the VOC plume. All of the surface water, groundwater, process waste system, storm sewer, and outfall sampling has been completed. Additional groundwater monitoring wells were installed and sampled to obtain radiological data about the Corehole 8 plume and leak sites. The data from the Engineering Study was evaluated and summarized in the *Bethel Valley Groundwater Engineering Report*. This report has been approved by regulatory agencies.

3.3.15 Hot Storage Garden

Beginning in the mid-1950s, the Hot Storage Garden supported research at ORNL by storing radioactive material, including spent fuel rods, in the below-grade wells and in a partially above-grade, water-filled canal. All the fuel was transferred for storage to a solid waste storage area in the mid-1980s. The facility was then placed in the surveillance and maintenance program.

In 2003, some additional funding was made available to perform D&D on a facility currently in the surveillance and maintenance program. The Hot Storage Garden was selected because it was a small facility that could be decontaminated and decommissioned with the available funding, and existing documentation indicated that the source material had been removed with no indication of residual contamination. Additional characterization data were obtained by analyzing radiological smears from the below-grade canal, residual well water, and wells. However, smears of the removable well sleeves were only obtained to approximately one-half the well depth.

The project started in the summer of 2004. All the surface structures were removed, and 5 of the 14 well sleeves were removed and cut. High concentrations of removable alpha-emitting contamination were found near the bottom of one of the well sleeves. Each of the sleeves had been cut in half using a reciprocating saw. The vibration caused by the reciprocating saw is believed to have caused the contaminants to become airborne. As a result, four workers received an unexpected dose of less than 500 millirem, or 10% of the maximum annual dose allowed by nuclear regulations.

The project was immediately stopped, and the area was secured. The project performed additional characterization on the five removed well sleeves. The characterization included sampling and analysis to ensure that all the residual radionuclides on the well sleeves are identified and quantified. The sampling was performed in a negative-air enclosure to minimize the chance of creating airborne contamination. After sampling, a fixative was applied to the interior and exterior of the well sleeves. The analytical data were reviewed to determine the appropriate approach to containerization and disposition. Based upon the review of the data, the removed well sleeves were containerized and transported to the EMWMF disposal facility. The remaining nine wells will remain sealed until a final cleanup effort begins in 2009.

3.4 Y-12 National Security Complex

3.4.1 Upper East Fork Poplar Creek

Remediation of the Upper East Fork Poplar Creek (UEFPC) Watershed is being conducted in stages using a phased approach. Phase 1 addresses interim actions for remediation of mercury-contaminated soil, sediment, and groundwater discharges that contribute contamination to surface water. The focus of the second phase is remediation of the balance of contaminated soil, scrap, and buried materials within the Y-12 Complex, the major contaminated area in the UEFPC Watershed. Decisions regarding final land use and final goals for surface water, groundwater, and soils will be addressed in future decision documents.

During FY 2005, regulators provided comments on the draft proposed plan for Phase 2 interim remedial actions for accessible soil, buried waste, or subsurface structures that contribute significantly to contamination above acceptable risk levels in UEFPC. The proposed plan was finalized, and a public meeting was held in March 2005. Comments from the public

meeting and from members of the public were addressed in the Responsiveness Summary portion of the draft ROD. Regulator comments on the draft ROD were received at the end of FY 2005. The Phase 2 ROD is anticipated to be finalized and approved in FY 2006.

3.4.2 Big Spring Water Treatment System

To mitigate the mercury being released into UEFPC, the Big Spring Water Treatment System was designed and constructed as the first action of the approved ROD for Phase 1 Interim Source Control Actions in the UEFPC Characterization Area.

The 300-gal/min water treatment system uses a series of granular activated carbon columns to reduce the mercury concentrations in the system effluent to levels of 200 ppt or less. The system influent will include the Outfall 51 discharge and 9201-2 sump water. The existing East End Mercury Treatment System will be removed. Construction of the new water treatment system began in March 2004 and was completed on March 2005. Initial operations began August 4, 2005.

3.5 Off-Reservation Activities

3.5.1 David Witherspoon Inc. 901 Site Cleanup

The David Witherspoon, Inc. (DWI) 901 Site, located on Maryville Pike in Knoxville, Tenn., consists of a 3.4-hectare parcel formerly owned and operated as the DWI Recycling Center and a 0.2-hectare parcel owned by CSX Transportation, Inc. A 1993 court order forced cessation of DWI operations at the site, and the Tennessee Division of Superfund took control of the property. The objective of this off-site project is to perform interim actions and to complete the supporting documentation, resulting in a ROD at the DWI 901 Site.

The scope of the project is to decontaminate and demolish the main building, a metal office building, the incinerator, the magnet house, the compactor house, the control house, the scale house and scale, the bailer house, and the breaker house. Contaminated soils will be excavated and disposed of in the EMWMF as radioactive PCB mixed waste. The contaminated soils will be excavated and treated to meet land disposal restrictions.

The interim action for D&D and debris removal started in April 2004. During April of 2005 all 10 buildings had been demolished, all site debris had been shipped. Approximately 1400 yd3 of building material and debris had been sent to the Y-12 Landfill, approximately 6400 yd3 of site debris were shipped to the EMWMF, and five loads of universal waste were shipped for off-site disposal.

During 2005, the soil removal interim action work plan was completed, and excavation of soil began. Presently 56,000 cy of soils have been excavated and shipped to the EMWMF. This phase of the Witherspoon work is scheduled to be completed in the Fall of 2006.

3.5.2 DWI 1630 Site Cleanup

The DWI 1630 Site consists of five separate tracts of land located at 1630 Maryville Pike in Knoxville, Tennessee. The 19-hectare site includes a closed 2-hectare landfill plus roughly 8 hectares of dismantled vehicles, equipment, scrap metal, drums, large containers, transformers, ferrous and nonferrous materials, soil-like debris, miscellaneous trash, and other surficial debris from the DWI business operation.

The DWI 1630 Site operated as an unregulated industrial landfill in the early 1950s until its closure in 1974. The area surrounding the landfill was also used by DWI for storage, treatment, and disposal of scrap metal and equipment, including contaminated items. Contaminants include metals (e.g., lead, chromium, and cadmium); volatile organic analytes; semivolatile organic analytes; PCBs; pesticides; dioxins/furans; and radionuclides, including various isotopes of uranium, thorium, and associated radioactive decay products.

DOE has agreed to undertake remedial actions at the site as specified under a Consent Order with the state of Tennessee (Consent Order No. 90-3443, April 4, 1991) and as further delineated by a Memorandum of Understanding (MOU) between DOE and the state of Tennessee (MOU Regarding Implementation of Consent Orders, October 6, 1994).

The objective of this off-site project is to perform interim actions and complete the supporting documentation, resulting in a ROD for the DWI 1630 Site. The scope of the project is to

(1) remove contaminated equipment, debris, and soil and (2) repair the landfill cap. Essentially all of the contaminated waste will be disposed of in the EMWMF.

The schedule currently calls for starting additional field investigation in the spring of 2006, starting on-site interim action in November 2006, completing removal of waste in July 2008, and completing landfill cap repair and site restoration in August 2008. This phase of the Witherspoon work is scheduled to be completed by September 2008.

3.6 Waste Treatment and Disposal

3.6.1 Tons of Wastes Placed in the EMWMF and Other Landfills

The EMWMF, located in East Bear Creek Valley near the Y-12 Complex, is an on-site waste facility that is being used to contain the wastes generated during cleanup of the ORR and associated sites in Tennessee. The EMWMF accepted its first waste shipment in May 2002. Since then, projects from all over the ORR have shipped waste to EMWMF for disposal. In fiscal year 2005, 82,436 tons of waste were disposed of at the EMWMF. The operations also effectively controlled site erosion and sediments, resulting in an 80% reduction in total suspended solids measured in surface waters during the year.

DOE also operates solid waste disposal facilities located near the Y-12 Complex, called the ORR Sanitary Landfills. In FY 2005, 136,000 yd^3 of industrial, construction/demolition, classified, and spoil material waste were disposed of at this facility.

3.6.2 EMWMF Upgrades

3.6.2.1 Build-Out to Add to Disposal Capability

Another notable construction project was completed at the EMWMF in 2005. A build-out to add 800,000 yd^3 of disposal capacity kicked off in June. Cells 3 and 4 were added to the two cells that were completed in 2002. Waste disposal operations in the new cells can commence upon approval of the construction completion report by EPA and TDEC. The construction completion report is the compilation of all of the quality control and quality assurance testing and monitoring that was performed to ensure that the build-out was constructed in accordance with the approved design.

3.6.2.2 Haul Road Completed

It became apparent in early 2004 that removing shipments of ETTP waste bound for the EMWMF from public roads would better serve project and public interests. Conceptual design work to identify feasible routes to construct a haul road between ETTP and the EMWMF was initiated in early summer. The road enhances public safety by eliminating the hazards presented by large trucks mixing with passenger vehicles on public roads. It also reduces cleanup costs by decreasing the cycle time for each load of ETTP waste that is disposed at the EMWMF. Construction started in 2005, and was completed in 2006 just in time for the start of the intensive waste-hauling campaign from the ETTP cleanup.

3.6.3 Millions of Gallons of Wastewater Treated in FY 2005

During 2005, the EM Program treated 24 million gal of contaminated groundwater at the Groundwater Treatment Facility, East End Mercury Treatment System, Central Mercury Treatment System, and East End VOC System.

The West End Treatment Facility and the Central Pollution Control Facility at the Y-12 Complex processed wastewater, primarily in support of National Nuclear Security Administration (NNSA) operational activities. This wastewater included hazardous materials such as PCBs, cyanide, mercury, cadmium, chromium, and uranium. The hazardous materials end up in the sludge that results from wastewater treatment. In fall 2005, construction was completed on a 300-gal/min water treatment facility near Building 9201-2, identified as the “Big Springs West Treatment System.” The system uses a series of granular activated carbon columns to reduce mercury concentrations in the system effluent to 200 ppt or less. The system influent will include the outfall 51 discharge and 9201-2 sump water. The existing East End Mercury Treatment System will be removed.

At ORNL, 153 million gal of wastewater was treated and released at the Process Waste Treatment Complex. New zeolite columns and associated transfer equipment (pumps, piping, valve) were installed in 2005 that allowed all of the wastewater processed at Building 3544 to be treated for cesium removal (up to 300 gal/min). The system used prior to this upgrade had a throughput limited to 100 gal/min. The LLLW evaporator at ORNL also treated 143,500 gal of waste. Gaseous waste was also treated at the ORNL 3039 Stack Facility. These important waste treatment activities supported both EM and Office of Science mission activities in a safe and compliant manner.

3.6.4 Transuranic, Low-Level, and Mixed Waste Operations

Operations at the ORR produce wastes that frequently contain radionuclides. Such wastes are characterized as either LLW or TRU wastes. Mixed low-level wastes (MLLWs) are those that contain materials deemed hazardous and are regulated under Resource Conservation and Recovery Act (RCRA).

TRU wastes from throughout the DOE complex are to be disposed of at the Waste Isolation Pilot Plant (WIPP), near Carlsbad, New Mexico. Before being shipped to the WIPP, however, TRU wastes must be treated, packaged, and certified to meet its waste acceptance criteria.

DOE awarded a contract to Foster Wheeler Environmental Corporation in 1998 to build and operate a TRU waste treatment facility on the ORR. In 2001, an approximately 1000-ft extension to the access road from White Wing Road (State Route 95) and fencing of the approximately 8-hectare site were completed. Waste processing at the TRU waste treatment facility began in 2004. In 2005, preparations were made to begin processing contact handled TRU wastes. Processing of this material is scheduled to begin in 2006.

The ORR has the largest inventory of legacy LLW (i.e., waste from historic reservation operations) in the DOE complex. In addition, active DOE missions at the Y-12 Complex and ORNL produce newly generated LLW that must be managed and disposed of safely and efficiently. In 2004, DOE shipped 40 legacy LLW monoliths (2161 yd^3) to the Nevada Test Site for disposal. Disposal of the legacy LLW inventory got well under way in 2004. Much of the inventory was shipped for disposal. The ORR also has a large inventory of MLLW, but most of it has been dispositioned since the sewage treatment plant agreement was signed in 1995.

3.7 Public Involvement

3.7.1 Public Input on Environmental Management Initiatives

Many projects have moved from the decision-making phase to actual fieldwork. However, DOE is still seeking public involvement in many decisions affecting cleanup of the ORR. Public input was sought in 2005 on a variety of initiatives, including the following:

- Proposed plan for remedial actions in Zone 2 (fenced area) at ETTP;
- Draft management plan for approximately 3,000 acres of the Black Oak Ridge Conservation Area located on the ORR;
- Proposed plan for interim actions for contaminated soils and scrap yard in UEFPC;
- Covenant deferral request to transfer a parcel of vacant land, known as Parcel ED-5 East, to Heritage Center LLC, a subsidiary of the Community Reuse Organization of East Tennessee;
- Interim action work plan for soil removal at the DWI site;
- Construction of the ETTP-to-EMWMF haul road and bridges;
- Covenant deferral request to transfer approximately 1 acre of federal property located at ORNL to the State of Tennessee; and
- Draft environmental assessment for transferring approximately 360 acres, known as Parcel ED-6, to the City of Oak Ridge.

DOE continued distributing its monthly stakeholder newsletter, *Public Involvement News*, to the community and elected officials. Several EM project fact sheets were also revised and combined into three main fact sheets: ETTP, Melton Valley, and Balance of Reservation.

3.7.2 Oak Ridge Site Specific Advisory Board

The Oak Ridge Site Specific Advisory Board (ORSSAB) posted several accomplishments in 2005 in its mission to provide informed advice and recommendations to DOE on its Oak Ridge EM Program and to involve the public in environmental decision-making. ORSSAB is an independent, volunteer, federally appointed citizens' panel formed in 1995.

The board generated eight recommendations this year on a variety of EM topics, including;

- Recommendations on the natural resources damage assessment process;
- EM SSAB recommendations on waste disposition issues;
- Recommendations for long-term stewardship of contaminated areas on the ORR;
- Recommendation for standardized language submitted to land record authorities of land with notices of contamination;
- EM SSAB recommendation on establishing local advisory boards and establishing mechanisms for national meetings;
- Comments and recommendations on the public health assessment for the TSCA Incinerator;
- EM SSAB recommendation that DOE sponsor a national waste disposition workshop; and
- Comments on the Proposed Plan for Interim Actions for Contaminated Soils and Scrapyard in Upper East Fork Poplar Creek (DOE/OR/01-2173&D2).

3.7.3 Annotated Outline for a Long-Term Stewardship Implementation Plan

Stewardship of contaminated areas of the ORR following cleanup has long been an ORSSAB priority. So when DOE signed the Long-Term Stewardship Strategic Plan for the Oak Ridge Reservation in March 2004, the board's Stewardship Committee took the next logical step by producing an Annotated Outline for a Long-Term Stewardship Implementation Plan.

The outline is specifically tailored to the known contaminated areas of the reservation with the hope that this approach will result in an implementation plan that provides detailed functional specifications. A solid implementation plan will enable the design and execution of an ORR-specific stewardship system that meets both current and future needs and also has the acceptance of local stakeholders.

The Annotated Outline is available on the Board's web site at www.oakridge.doe.gov/em/ssab/recommendations/FY2004/R7-14-04.8.pdf.

3.7.4 Student Summary of ORR Stakeholder Report on Stewardship

In 1999, ORSSAB published the second volume of its two-volume *Oak Ridge Reservation Stakeholder Report on Stewardship* (ORSSAB 1999). As time passed, though, it became apparent that the report was too detailed for some audiences—notably the high school students whom the board was trying to reach through its public outreach program.

To address the problem, the ORSSAB Stewardship Committee asked advance-placement science classes at Oak Ridge and Roane County high schools to summarize the report. The resulting *Student Summary of the Oak Ridge Reservation Stakeholder Report on Stewardship* (ORSSAB 2004) was published in May 2004 and does an outstanding job of distilling the original reports into language easily understood by high school students. The summary is available on the ORSSAB web site, www.oakridge.doe.gov/em/ssab/Publications/StudentSummary.pdf

The student summary was widely distributed to local schools and libraries to help ensure long-term awareness and understanding of the community's responsibility for stewardship of contamination that will remain on the reservation following cleanup.

4. ETTP Environmental Monitoring Programs

The ETTP, formerly known as the Oak Ridge Gaseous Diffusion Plant or K-25 Site, was originally built as part of the Manhattan Project. Uranium was enriched for weapons and nuclear reactor fuel elements and included recycling of reactor return fuel elements. Other activities included research and support operations. After the enrichment operations ceased in 1985, the primary focus of the plant shifted to environmental restoration, reindustrialization, and reuse of the facilities.

Environmental monitoring remains a major activity on the ETTP. Environmental monitoring encompasses two activities: effluent monitoring and environmental surveillance. Effluent monitoring consists of the collection and analysis of samples or measurements of liquid or gaseous effluents at the point of emission to determine and quantify contaminants released. Environmental surveillance consists of the collection and analysis of samples of air, water, soil, vegetation, biota, and other media from the ETTP and its surroundings. External direct radiation is also measured. Data from environmental monitoring activities are used to assess exposures to members of the public and the environment, to assess the effects of ETTP operations on the public and the environment, to help plan remediation projects, and to evaluate the efficacy of these projects.

In 2005, the emissions of radionuclides from ETTP operations were well within the allowable derived concentration guides (DCGs) published in DOE Order 5400.5 and were similar in most respects to 2004 emissions. Potential direct radiation to the public from uranium hexafluoride cylinder storage yards and the K-770 scrap metal yard at ETTP remained below the requirements in DOE Orders. Nonradiological emissions were also within limits, and compliance with permit limits was better than 99%.

4.1 ETTP Radionuclide Airborne Effluent Monitoring

To demonstrate compliance with DOE Order 5400.5 and Tennessee Rule 1200-3-11-.08, "Emission Standards for Emission of Radionuclides Other than Radon from Department of Energy Facilities" [i.e., National Emission Standards for Hazardous Air Pollutants (NESHAP)], all airborne radionuclide emissions from DOE sources at ETTP must be determined for purposes of estimating dose to the most exposed member of the public.

Locations of airborne radionuclide point sources at the ETTP are shown in Fig. 4.1. Radionuclide emission information for these release points is compiled under the direction of Bechtel Jacobs Company LLC (BJC) from operators subject to NESHAP regulations. Point sources shown in Fig. 4.1 include both individual point sources and grouped point sources, such as laboratory hoods. Radionuclide emissions data were determined from either EPA-approved sampling results or Environmental Protection Agency (EPA)-approved calculation methods.

4.1.1 Radionuclide Emissions Monitoring Approach

4.1.1.1 Minor Sources

The number of minor sources in 2005 varied from the previous year's total because of fluctuations in site operations. For this reporting period, a total of five point sources and one grouped minor source subject to NESHAP regulations operated. Minor sources are grouped if they have similar characteristics (e.g., general location, type of activity, or type of control) and provided that any one group does not have potential radionuclide emissions that would cause a dose in excess of 0.1-mrem/year effective dose equivalent (EDE) as defined under the rule. An example of a minor source is the TSCA Incinerator tank farm with 15 emission points.

Emissions from the various minor sources located at the ETTP were estimated by means of one of the following EPA-approved methods:

- radionuclide inventory (i.e., material balance)—five point sources and one grouped source, health physics air measurements where room ventilation emissions exceeded 10% of derived air concentration worker protection guidelines—no sources,

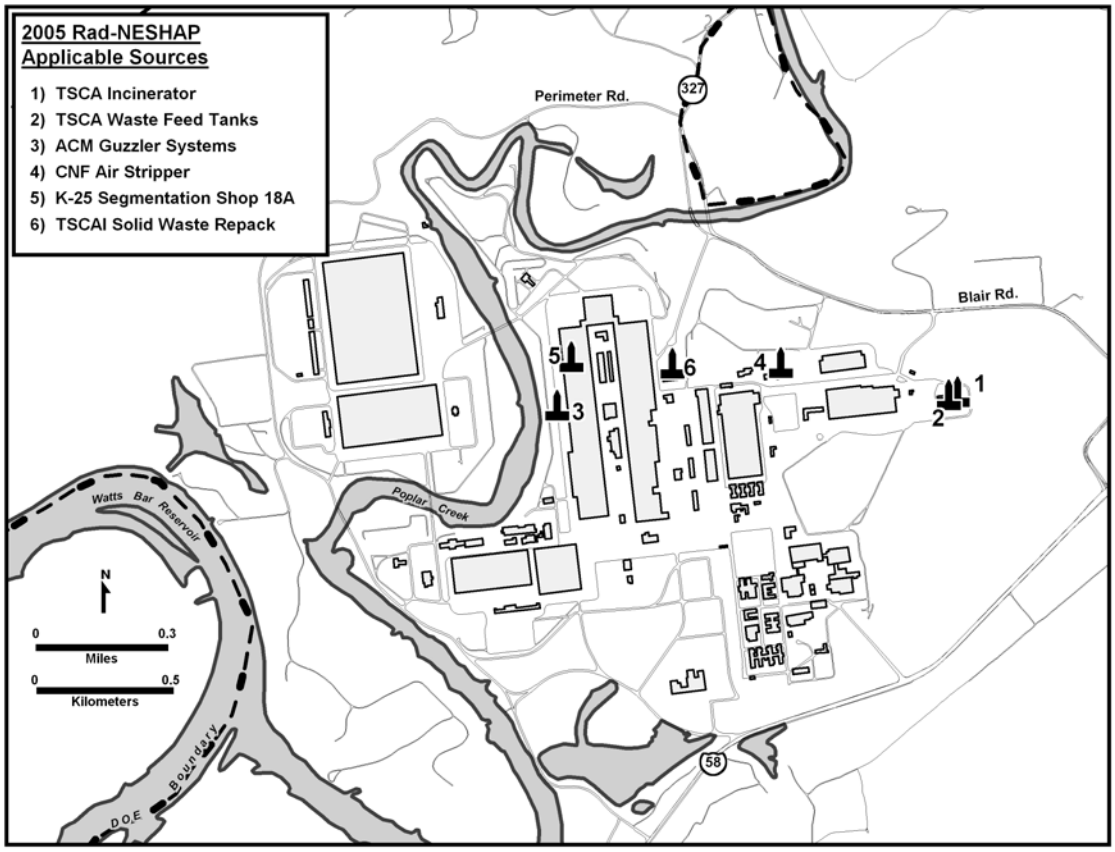


Fig. 4.1. Locations of airborne radionuclide point sources at the ETTP.

- surrogate emission data from similar sources—no sources, and
- evaporative emissions—one grouped source.

All techniques are conservative methods of estimating emissions based on the physical form of the radionuclides and the maximum operating temperature of the process or activity.

Any remaining emissions were classified as major sources or diffuse/fugitive sources that are spatially distributed in nature or that were not emitted with forced air from a stack, vent, or other confined conduit. Typical examples of diffuse/fugitive sources include

- emissions from shutdown buildings;
- resuspension of contaminated soils, debris, or other materials;
- unventilated tanks;
- wastewater treatment systems;
- outdoor storage and processing areas;
- emissions from piping, valves, or other piping equipment and pump components; and
- decontamination and demolition activities.

Fugitive emission sources are monitored by way of the ORR and ETTP ambient air surveillance programs.

4.1.1.2 Major sources

One ETTP major source operated during 2005. Radionuclide emission measurements from the Toxic Substances Control Act (TSCA) Incinerator were determined by means of a continuous stack-sampling system. The system is designed to automatically adjust sample flow rate to maintain near-isokinetic sampling conditions at the stack. The effluent is passed through filter media to collect particulate matter and through impingers with absorbing and adsorbing media to collect gaseous radionuclides. Measurements of TSCA Incinerator emissions were based on monthly composites of weekly stack samples.

4.1.2 Results

The ETTP 2005 radionuclide emissions from the major and minor emission sources are shown in Table 4.1. Additionally, Figs. 4.2 and 4.3 show a comparison of the total discharges of uranium with those of previous years. The total curies and mass of uranium discharged to the air can vary from year to year. The variations are attributable to changes in project activities and source process rates. The resulting airborne dose from all ETTP radionuclide emissions was less than the reservation maximum limit of 10 mrem/year.

4.2 ETTP Nonradiological Airborne Emissions Monitoring

Under an application shield granted by the Tennessee Department of Environment and Conservation, (TDEC) Division of Air Pollution Control, the ETTP has five major air emission sources listed as subject to Tennessee Title V Major Source Operating Permit program rules as of the end of this reporting period.

No direct monitoring of airborne emissions is required for nonradionuclide air contaminants from permitted sources. Instead, monitoring of key process and air pollution control device parameters is performed to ensure compliance with all permitted emission limits.

The ETTP is required to pay a major source emission fee each year for all regulated pollutants, excluding carbon monoxide and pollutants from exempt emission sources. To verify the air emission fee that is based on a combination of permitted allowable and actual emissions for air pollutants, an inventory of regulated emissions from the permitted sources at the ETTP is updated annually. Table 4.2 shows the results of the annual inventory of emissions of criteria pollutants from ETTP operations for the past 5 years. In June 2004 the ETTP steam plant was permanently shut down, and the associated air permits were surrendered. The ETTP paid an annual fee in 2005 amounting to $3500 based on the fee rate of $19.50 per ton of emissions but not less than $3500 during that period for a facility subject to Title V Major Source Operating Permit requirements. Table 4.3 shows the inventoried regulated emissions during the 2005 reporting period from the ETTP.

The TSCA Incinerator is permitted as a major source of air emissions from the ETTP. Emissions from the incinerator are controlled by extensive exhaust-gas treatment. For fee-reporting purposes, permitted allowable limits are used to determine the total potential emissions from the incinerator. A comparison of actual and allowable TSCA Incinerator emissions is presented in Table 4.4. All other permitted sources have emissions inventoried based on permit allowable limits.

4.3 Liquid Discharges—ETTP Radiological Monitoring Summary

The ETTP conducts radiological monitoring of liquid effluent and storm water discharges to determine compliance with applicable dose standards. It also applies the “as low as reasonably achievable” (ALARA) process to minimize potential exposures to members of the public.

4.3.1 Sample Collection and Analytical Procedure

The ETTP monitored the treated effluent from the K-1407-J Central Neutralization Facility (CNF) (outfall 001). Weekly samples were collected from the CNF and were composited into monthly samples. The samples were then analyzed for radionuclides. Results of these sampling efforts were compared with the DCGs listed in DOE Order 5400.5.

The Storm Water Pollution Prevention Program, which is described in more detail in Sect 4.5, included sampling for gross alpha and beta radioactivity as well as specific radionuclides at selected storm water outfalls. Results were used to estimate the total discharge of each radionuclide from ETTP via the storm water discharge system. Figure 4.4 shows the location of the major National Pollutant Discharge Elimination System (NPDES) outfalls.

4.3.2 Results

The sum of the fractions of the DCGs at the CNF was calculated at 14.8% for 2005, slightly down from 17.2% in 2004. Table 4.5 lists radionuclides discharged from the ETTP CNF to

Table 4.1. East Tennessee Technology Park radionuclide air emission totals, 2005 (Ci)[a]

Radionuclide	Total major	TSCAI (major)[b]	Total minor	Total ETTP
^{228}Ac	–	–	2.19E–08	2.19E–08
^{241}Am	–	–	4.95E–07	4.95E–07
^{243}Am	–	–	5.87E–10	5.87E–10
^{207}Bi	–	–	7.61E–09	7.61E–09
^{14}C	6.19E–05	6.19E–05	1.43E–04	2.05E–04
^{137}Cs	1.22E–04	1.22E–04	1.13E–05	1.34E–04
^{57}Co	5.23E-08	5.23E-08	–	5.23E–08
^{60}Co	–	–	1.05E–10	1.05E–10
^{244}Cm	–	–	1.54E–08	1.54E–08
^{245}Cm	–	–	5.91E–10	5.91E–10
^{247}Cm	–	–	8.31E–10	8.31E–10
^{248}Cm	–	–	3.79E–10	3.79E–10
^{152}Eu	–	–	7.85E–07	7.85E–07
^{154}Eu	–	–	6.38E–07	6.38E–07
^{85}Kr	2.76E–03	2.76E–03	2.18E–09	2.76E–03
^{210}Pb	–	–	1.19E–07	1.19E–07
^{212}Pb	–	–	7.12E–09	7.12E–09
^{237}Np	4.36E–07	4.36E–07	2.46E–07	6.82E–07
^{238}Pu	4.57E–07	4.57E–07	1.04E–07	5.61E–07
^{239}Pu	8.00E–06	8.00E–06	6.62E–07	8.66E–06
^{242}Pu	–	–	1.27E–08	1.27E–08
^{244}Pu	–	–	9.30E–11	9.30E–11
^{231}Pa	–	–	2.67E–08	2.67E–08
^{234m}Pa	8.61E–03	8.61E–03	1.53E–06	8.61E–03
^{226}Ra	–	–	1.68E–06	1.68E–06
$^{89/90}$Sr	3.43E–06	3.43E–06	2.10E–06	5.53E–06
^{99}Tc	2.73E–03	2.73E–03	3.98E–04	3.12E–03
^{208}Tl	–	–	5.90E–09	5.90E–09
^{228}Th	3.06E–05	3.06E–05	1.18E–07	3.07E–05
^{230}Th	1.75E–04	1.75E–04	9.07E–07	1.76E–04
^{232}Th	3.15E–05	3.15E–05	4.25E–05	7.40E–05
^{234}Th	1.20E–03	1.20E–03	8.13E–05	1.28E–03
^{3}H	1.61E+02	1.61E+02	6.41E–07	1.61E+02
^{232}U	–	–	1.11E–10	1.11E–10
^{233}U	–	–	1.01E–05	1.01E–05
^{234}U	5.21E–04	5.21E–04	5.64E–05	5.77E–04
^{235}U	1.44E–04	1.44E–04	4.07E–06	1.48E–04
^{236}U	–	–	5.04E–07	5.04E–07
^{238}U	8.64E–04	8.64E–04	1.04E–04	9.68E–04
Totals	1.61E+02	1.61E+02	8.61E–04	1.61E+02

[a]1 Ci = 3.7×10^{10} Bq.

[b]Toxic Substances Control Act Incinerator.

off-site surface waters in 2005. Total uranium discharges from the CNF were 0.0058 Ci in 2005. Total discharge of transuranics was 0.0000052 Ci, which is three orders of magnitude less than the contribution from uranium.

In terms of total activity of the discharges, ^{3}H, ^{14}C, and ^{99}Tc were the greatest contributors. However, their allowable DCGs are greater than those for the uranium isotopes, so their contribution to the sum of the fractions of the DCGs is relatively small. Technetium-99 accounted for just under 2% of the sum of the fractions, ^{14}C for 3%, while ^{3}H accounted for 0.077%. Uranium discharges from the CNF during a 5-year period were investigated to observe their trend (Fig. 4.5). Uranium isotopes were the major con-

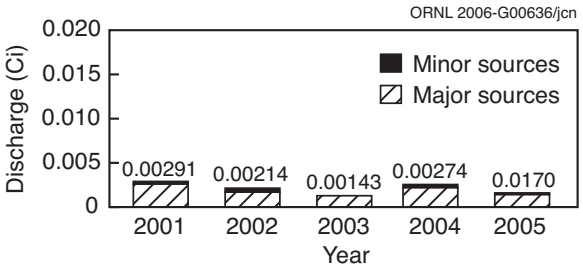


Fig. 4.2. Total curies of uranium discharged from the ETTP to the atmosphere, 2001–2005. (1 Ci = 3.7 × 10^{10} Bq.)

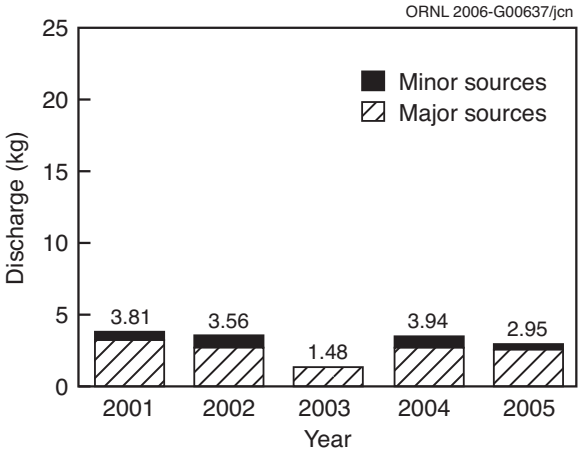


Fig. 4.3. Total kilograms of uranium discharged from the ETTP to the atmosphere, 2001–2005.

tributors to the fraction of the DCG, contributing two-thirds of the sum of the fraction of the DCG (Fig. 4.6). All of the remaining isotopes cumulatively accounted for less than 1% of the allowable DCG. TSCA Incinerator wastewater, which is sent to the CNF for treatment before being discharged to the Clinch River, is a major contributor of uranium; other operations contribute smaller amounts.

4.4 Nonradiological Liquid Discharges—ETTP Surface Water Effluents

The current ETTP NPDES permit (Permit Number TN0002950) for storm water discharges went into effect on April 1, 2004. This permit authorizes the ETTP to discharge storm water runoff, groundwater infiltration, groundwater from sumps, noncontact cooling water, and steam condensate to the Clinch River, Poplar Creek, and Mitchell Branch through 121 storm water outfalls. The 121 outfalls were divided into four groups based on the volume and nature of the monitored discharge. Of the 121 total outfalls, 39 are monitored as being representative of the four outfall groups. Samples from these outfalls are collected and analyzed as specified in NPDES permit TN0002950.

The current NPDES permit (Permit Number TN0074255) for the CNF went into effect on November 1, 2003. This permit authorizes treated industrial effluent from outfall 001 to be discharged to the Clinch River. Table 4.6 details the requirements and compliance records for the two NPDES permits for 2005. The table provides a list of the discharge points, effluent parameters, effluent limits, number of noncompliances, and the percentage of compliance for 2005. Samples from this outfall are collected and analyzed as specified in NPDES permit TN0074255.

4.4.1 Results

The ETTP had one NPDES noncompliance in 2005 under NPDES Permit No. TN0002950. On January 24, 2005, sampling personnel were performing the weekly sampling at storm water outfall 100 as required by NPDES permit TN0002950. At the time the samples were being collected, sampling personnel noticed that the flow in the outfall was elevated above normal levels, despite the absence of a recent rainfall event. A small amount of foam was also observed on the surface of the discharge. All required samples were collected from the outfall, including a sample for total residual chlorine (TRC). Because of the short holding time for this sample, it was immediately taken to an onsite laboratory for analysis. The laboratory determined that the TRC level in the sample was 1.25 mg/L. This result exceeded the NPDES permit requirement of 0.14 mg/L for this outfall.

Upon verification of the elevated TRC result, an investigation into the source of the chlorine was conducted. It was determined that utility subcontractor personnel had identified a sanitary water line break near building K-1004-L. Sanitary water was observed by utilities subcontractor personnel to be bubbling up from beneath a sidewalk in this area. The discharge from the broken water line entered a portion of the storm drain system that discharged through storm water outfall 100. The broken sanitary

Table 4.2. Allowable emissions of criteria pollutants from the East Tennessee Technology Park, 2001–2005

Pollutant	Allowable emissions (tons/year)				
	2001	2002	2003	2004	2005
Particulate matter	13	13	13	13	14
Volatile organic compounds	14	14	14	14	11
Sulfur dioxide	39	39	39	39	39
Nitrogen oxides	20	20	20	20	20
Carbon monoxide	19	19	19	19	19
Hazardous air pollutants	20	21	21	21	21
Miscellaneous	0	0	0	0	0
Total	125	126	126	126	124

[a]1 ton = 907.2 kg.

Table 4.3. Actual emissions of criteria pollutants from permitted East Tennessee Technology Park sources, 2005

Pollutant	Actual emissions[a]	
	(lb/year)	(tons/year)
Particulate matter	333.7	0.167
Volatile organic compounds	625.8	0.313
Sulfur dioxide	7.2	0.004
Nitrogen oxides	20,872	10.44
Carbon monoxide	5,218	2.61

[a]1 lb = 2.205 kg.
1 ton = 907.2 kg.

water line was immediately valved off immediately after it was discovered. There was no way of estimating the amount of sanitary water discharged from the broken water line before the flow could be shut off.

The K-1007-P1 pond receives discharges from storm water outfall 100. Environmental compliance subcontractor personnel inspected in the K-1007-P1 pond to determine if any environmental impact had occurred as a result of this discharge of sanitary water. No dead fish were noted, and no impact to other biota in the pond was observable. No threat to human health or the environment is believed to have occurred as a result of this discharge of sanitary water.

4.5 Storm Water Pollution Prevention Program

4.5.1 Storm Water Monitoring Strategy

Development and implementation of the ETTP Storm Water Pollution Prevention Program is required by Part IV of ETTP NPDES Permit No. TN0002950. The objective of the program is to minimize the discharge of pollutants in storm water runoff from the ETTP.

The purpose of the ETTP Storm Water Pollution Prevention Program is to assess the quality of storm water discharges from ETTP, determine potential sources of pollutants affecting storm water, and provide effective controls to reduce or eliminate these pollutant sources. It provides a means whereby sources of pollutants that are likely to affect the quality of storm water discharges are identified, best management practices to control the entry of pollutants into storm water discharges are developed, and methods for implementing pollution prevention practices are devised.

During 2005, the ETTP Storm Water Pollution Prevention Program sampling was conducted in support of two primary goals:

- **Sampling** for the ETTP Water Quality Program (EWQP)—Surface water samples were collected at locations that are exit pathways for contaminants from ETTP. The locations have a direct discharge or potential for direct discharge to Poplar Creek or the Clinch River.
- Sampling in preparation for the application for ETTP NPDES permit renewal—Selected

Table 4.4. Actual vs allowable air emissions from the Toxic Substances Control Act Incinerator at the East Tennessee Technology Park, 2005

Pollutant	Emissions (tons/year)[a]		Percentage of allowable
	Actual[b]	Allowable	
Semivolatile metals	0.0045	0.04	
Beryllium	0.00005	0.004	1.3
Low-volatile metals	0.0013	0.004	32.5
Mercury	0.00081	0.02	4.1
Hydrogen fluoride	0.0031	3.0	0.1
Hydrogen chloride	0.122	15.7	0.8
Sulfur dioxide	0.0036	38.5	<0.1
Volatile organic compounds	0.313	5.0	6.3
Dioxin/furan	*c*	*c*	1.0
Particulate matter	0.167	5.64	3.0

[a]1 ton = 907.2 kg.

[b]Actual emissions based on removal efficiencies measured during permit required air emission tests conducted during 2005.

[c]The criterion for dioxin and furan is the "destruction/removal efficiency." Actual: 99.999%; allowable: 99.99%.

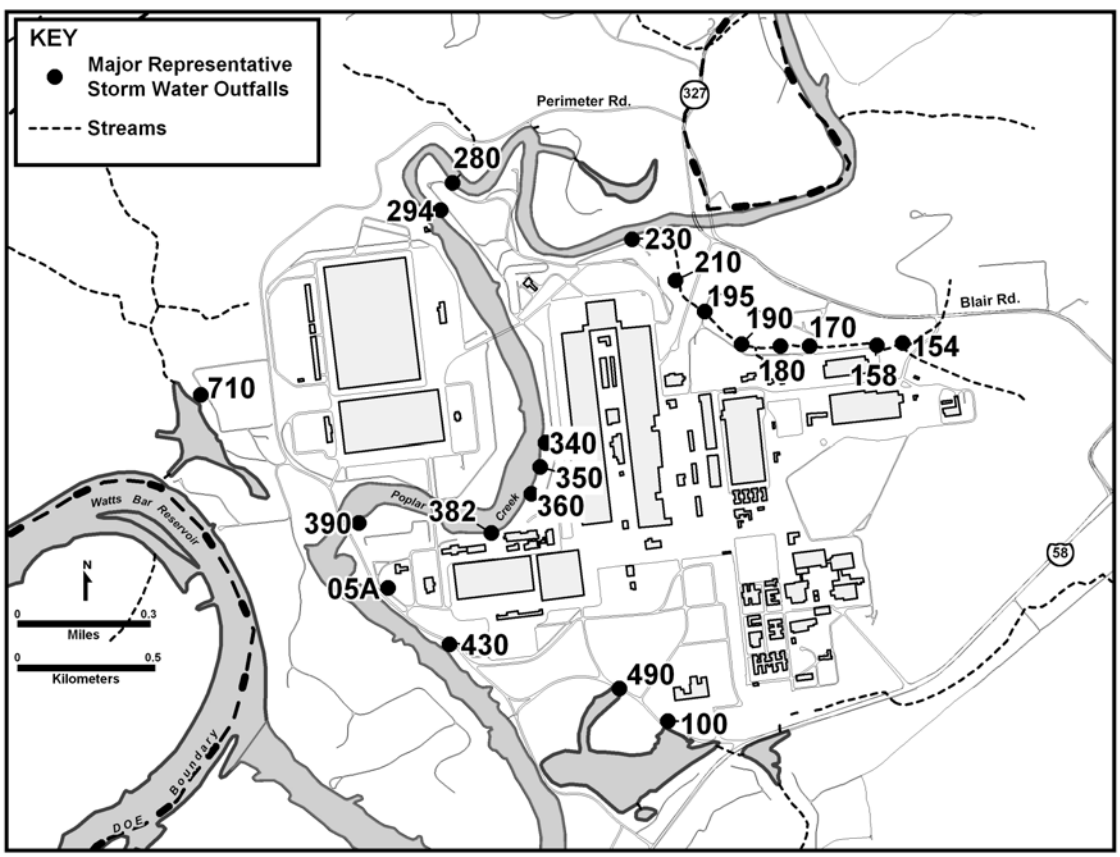


Fig. 4.4. ETTP National Pollutant Discharge Elimination System major representative storm water outfalls.

Table 4.5. Radionuclides released to off-site surface waters from the ETTP, 2005

Effluent discharge location: Central Neutralization Facility

Radionuclide	Amount (Ci)[a]	Radionuclide	Amount (Ci)[a]
^{14}C	2.3E–1	^{234}U	1.5E–3
^{3}H	1.5E–1	^{235}U	1.4E–4
^{239}Pu	5.2E–6	^{236}U	4.1E–5
^{99}Tc	2.0E–1	^{238}U	4.1E–3

[a]1 Ci = 3.7×10^{10} Bq.

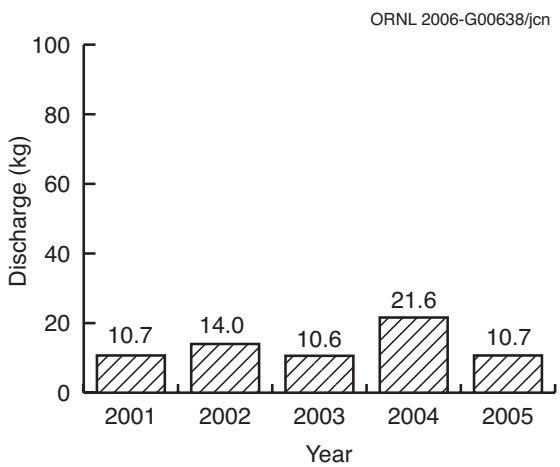


Fig. 4.5. Five-year trend of uranium releases to surface waters from the K-1407-J Central Neutralization Facility.

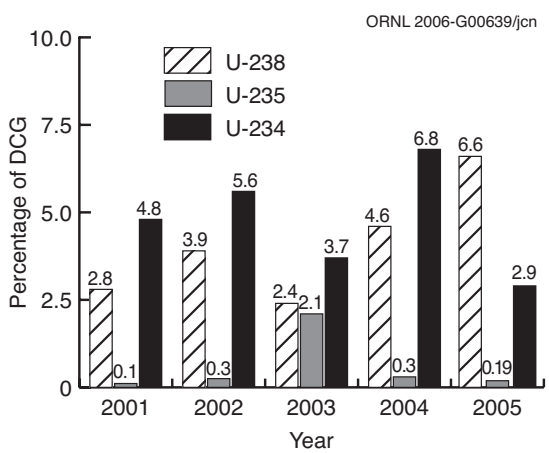


Fig. 4.6. Percentage of DOE derived concentration guides for uranium isotopes from the K1407-J Central Neutralization Facility.

outfalls that were designated as group representatives in the reissued ETTP NPDES Permit Number TN0002950 were sampled, and the results will be incorporated in the ETTP NPDES permit renewal application. The current ETTP NPDES permit expires on March 31, 2008; the permit renewal application must be submitted to Tennessee Department of Environment and Conservation (TDEC) 180 d prior to permit expiration.

4.5.2 ETTP Water Quality Program Monitoring Program Results

In 2005, surface water samples were collected at locations that are exit pathways for contaminants from ETTP as part of the Storm Water Pollution Prevention Program and in association with the ETTP Water Quality Program (EWQP) monitoring program. These locations have a direct discharge or potential for direct discharge to Poplar Creek or the Clinch River. Data from the analysis of these samples will be used to identify areas where contaminants may be discharging directly to surface waters located outside the ETTP boundaries. In addition, surface water samples were collected at interior locations within ETTP. The data from these samples will be used to evaluate changes in contaminant concentrations near potential contaminant sources and to identify contaminants that may be discharging to surface waters within the boundaries of ETTP.

In CY 2005, gross alpha radiation was detected above screening levels at storm water outfalls 180 and 190. These measurements exceeded the screening level of 15 pCi/L for this analyte. No gross alpha or gross beta contamination above the screening levels was found at any of the other storm water outfalls that were sampled in CY 2005 as part of the EWQP sampling

Table 4.6. National Pollutant Discharge Elimination System compliance at the ETTP, 2005

Effluent parameter	Effluent limits[a]		Number of noncompliances	Compliance (%)
	Monthly average	Daily maximum		
Outfall 001 (K-1407-J Central Neutralization Facility to the Clinch River)				
Benzene		0.005		100
Cadmium	0.18	0.69		100
Carbon tetrachloride	0.5	0.5		100
Chloride, total	35,000	70,000		100
Chloroform	0.5	0.5		100
Chromium	1.71	2.77		100
Copper	1.34	2.15		100
Cyanide, total	0.650	1.200		100
Ethylbenzene		0.01		100
Lead	0.38	0.69		100
Nickel	2.38	3.98		100
Oil and grease	26	30		100
PCB	0.00022	0.00045		100
pH, standard units		6.0–9.0		100
Silver	0.24	0.43		100
Suspended solids	31	40		100
Tetrachloroethylene		0.7		100
Toluene		0.01		100
Total toxic organics		2.13		100
Trichloroethylene	0.5	0.5		100
Vinyl chloride	0.2	0.2		100
Zinc	1.48	2.61		100
Group I storm water outfalls				
pH, standard units		4.0–9.0		100
Group II storm water outfalls				
pH, standard units		4.0–9.0		100
Group III storm water outfalls				
pH, standard units		4.0–9.0		100
Group IV storm water outfalls				
Chlorine, total residual		0.140	1	98
pH, standard units		6.0–9.0		100

[a]Units are mg/L unless otherwise stated.

effort. In addition, no levels of transuranics or isotopic uranium exceeding 4% of the DCG level were detected in samples from any of the other storm water outfalls sampled in CY 2005 as part of the EWQP sampling effort. Volatile organic compounds including 1,2-dichloroethene, cis-1,2-dichloroethene, tri-chloroethene, and vinyl chloride were found at levels above screening criteria at storm water outfall 190 in samples collected as part of the EWQP sampling effort during CY 2005. Field measurements for dissolved oxygen were below the screening level of 6.0 mg/L at outfalls 170, 180, and 190 during EWQP monitoring performed during CY 2005. No polychlorinated biphenyls (PCBs) were detected at levels above detection limits at any of the locations sampled as part of the EWQP monitoring effort during CY 2005. Analytical results for the EWQP this sampling effort are presented in Tables 4.7 and 4.8.

4.5.3 Radiological Monitoring of Storm Water Discharges

In 2005, radiological monitoring of storm water discharges was performed as part of the Storm Water Pollution Prevention Program

Table 4.7 EWQP storm water monitoring—radiological monitoring results that exceeded screening criteria, 2005[a]

Storm water outfall	Gross alpha radiation (pCi/L)
180b	16.6
190b	56.1
190c	24.5

[a]Screening levels are 15 pCi/L alpha radiation and < 6.0 mg/L dissolved oxygen.
1 pCi = 3.7×10^{-2} Bq.
[b]Sample collected during first quarter of 2005.
[c]Sample collected during third quarter of 2005.

NPDES permit renewal sampling effort. Analytical results above screening criteria for the radiological monitoring are presented in Table 4.9. A synopsis of the results from radiological monitoring at all the storm water outfalls is given in Table 4.10.

4.5.4 Nonradiological Monitoring of Storm Water Discharges

Storm water from several outfalls that were sampled in 2005 contained metals and organic compounds that were present in concentrations above the screening criteria levels. The exact sources of the materials are unknown. It is likely that some are the results of natural components of the soils and sediments in the area. Analytical results above the screening criteria for the nonradiological parameters are presented in Table 4.11.

4.6 ETTP Biological Monitoring and Abatement Program

BMAP is a requirement of the NPDES permit. Its purpose is to assess the ecological health of the ETTP's receiving streams and ponds. In 2005, the BMAP consists of four tasks:

- toxicity monitoring,
- bioaccumulation monitoring,
- ecological surveys of instream communities (both fish and benthic macroinvertebrates), and
- waterfowl monitoring.

The BMAP is conducted by the ORNL Environmental Sciences Division under the direction of the ETTP Environmental Compliance and Protection Organization.

4.6.1 BMAP Toxicity Monitoring

The toxicity monitoring task for BMAP includes semiannual tests of effluent from storm water outfalls 170 and 190 concurrently with surface water from ambient sites in Mitchell Branch . These sites are Mitchell Branch kilometer (MIK) 0.12 (beginning in October), 0.45, 0.71, and 0.78. The number following "MIK" indicates the distance in kilometers from the mouth of Mitchell Branch on Poplar Creek. *Ceriodaphnia dubia* were used to evaluate effluent from storm water outfalls 170 and 190, and the ambient monitoring locations, for toxicity.

In June and October, survival and reproduction toxicity tests using *Ceriodaphnia dubia* on water from storm water outfall 170 and all ambient locations revealed no toxicity (Table 4.12). However, effluent from storm water outfall 190 reduced both reproduction and survival in the June test, and reproduction in the October test. Interestingly, in the June test, effluent from storm water outfall 190 reduced reproduction at all tested concentrations and survival in all but the lowest (6%) tested concentration. However, the October test was one of only three tests since 1999 that did not reduce survival. Thus, the overall trend is one of some level of toxicity to *Ceriodaphnia* from storm water outfall 190, with no or very infrequent toxicity from the ambient locations and occasional toxicity at storm water outfall 170. Although the source of the problem at storm water outfall 190 was not positively identified, the data gathered in previous studies indicated that groundwater was percolating through waste in the K-1070-B Classified Burial Ground and leaching out small quantities of metals. Some of this groundwater was then flowing into the storm drain system and could contribute to the toxicity. Nickel and zinc are present in water collected from the storm drain system near K-1070-B, at levels that have been shown to be toxic to *Ceriodaphnia.*

4.6.2 BMAP Bioaccumulation Studies

In June and July 2005, caged clams *(Corbicula fluminea)* were placed at several locations around ETTP. The clams were allowed to remain in place for 4 weeks, then were analyzed

Table 4.8. EWQP storm water monitoring—nonradiological monitoring results that exceeded screening criteria[a]

Storm water outfall	Dissolved oxygen	1,2 Dichloroethene (µg/L)	*cis*-1,2 Dichloroethene (µg/L)	Trichloroethene (µg/L)	Vinyl chloride (µg/L)
170[b]	5.8				
180[b]	5.3				
190[a]		510	510	120	210
190[b]	3.8	800	810	150	370

[a]Sample collected during first quarter of 2005.
[b]Sample collected during third quarter of 2005.

Table 4.9. Maximum exceedances of radiological screening criteria for storm water outfalls, 2005 (pCi/L)[a]

Storm water outfall	Alpha	Beta	U-233/234	U-238
180	26.3			
190	28.4			
350	242	76.5	139	106
360	52.9		28.8	
724	99.4		77.3	59.8

[a]Screening levels are 15 pCi/L alpha radiation, 50 pCi/L beta radiation, 20 pCi/L ^{234}U, and 24 pCi/L ^{238}U. 1 pCi = 3.7×10^{-2} Bq.

Table 4.10. Radionuclides released to off-site surface waters from the ETTP storm water system, 2005[a]

Radionuclide	Amount (Ci)	Radionuclide	Amount (Ci)
^{237}Np	1.7E–5	^{234}U	5.6E–3
^{238}Pu[a]	2.2E–6	^{235}U	2.7E–4
^{239}Pu	–3.5E–6	^{236}U	1.9E–5
^{99}Tc	3.6E–2	^{238}U	3.1E–3

[a]All results less than or equal to laboratory error values. 1 Ci = 3.7×10^{10} Bq.

for uptake of PCBs. Results from the 2005 monitoring were similar in most respects to the results of earlier monitoring. The highest concentrations (7.3 µg/g) were found in the clams from storm water outfall 100, with lesser concentrations found in clams from other locations in the P1 pond. Clams from the Mitchell Branch and K-901-A locations also exhibited elevated levels of PCBs in comparison to the clams from the reference stream, with clams from Mitchell Branch accumulating more significant concentrations. Mitchell Branch clams averaged 2.4 ppm, while clams from the K-901-A Pond outfall contained concentrations an order of magnitude lower (0.25 ppm). Also, the composition of the PCBs from the three locations differ in that the PCBs from the Mitchell Branch clams are almost entirely Aroclor-1254, while the K-1007-P1 Pond clams contain both Aroclor-1254 and Aroclor-1248, and the K-901-A Pond clams contain Aroclor-1254 and Aroclor-1260. In Mitchell Branch, the concentration of PCBs in clams increases downstream of storm water outfall 190. In the K-901-A Pond, clams from near the two major storm water outfalls that discharge into the pond (storm water outfalls 700 and 710) contain higher concentrations than in the clams from the K-901-A Pond outfall, indicating that these two storm water outfalls may be the proximate source of PCB contamination in the pond. Clams from the K-725 Slough and K-1007-P3 Pond exhibit levels (0.07 and 0.04 ppm, respectively) that are roughly consistent with those in clams from the reference stream (0.06 ppm).

Fish were collected from Mitchell Branch, K-1007-P1 Pond, and K-901-A Pond in May 2005. Largemouth bass were collected from the pond sites, and redbreast sunfish were collected from Mitchell Branch. Game fish of a size large enough to be taken by sports fishermen were selected both to provide more accurate data of potential human health concerns and to reduce the amount of variation in contamination levels in the individual fish due to age and size differences. Fillets were taken from each game fish

Table 4.11 Maximum exceedances of nonradiological screening criteria for each storm water outfall, 2005 (µg/L)

Outfall	Parameter	Monitoring result	Criteria
180	Aluminum	931	750
180	Iron	10100	1000
180	Manganese	5120	1000
180	Zinc	115	65
190	Aluminum	769	750
190	Iron	3180	1000
190	Zinc	102	65
190	Aroclor-1260	0.9	0.5
195	Aluminum	1930	750
195	Iron	21900	1000
195	Manganese	2710	1000
195	Zinc	244	65
280	Aluminum	7560	750
280	Iron	10200	1000
280	Zinc	192	65
280	Aroclor-1254	0.68	0.5
294	Zinc	68	65
340	Zinc	237	65
350	Aluminum	1640	750
350	Iron	3020	1000
382	Aluminum	2630	750
382	Iron	4370	1000
382	Zinc	310	65
510	Bis(2-ethylhexyl)phthalate	200	100
510	Zinc	115	65
890	Aluminum	937	750
890	Iron	1670	1000
900	Aluminum	1720	750
900	Iron	1920	1000
992	Aluminum	1580	750
992	Iron	9990	1000
992	Manganese	1820	1000

Table 4.12. Mitchell Branch and associated storm water outfall toxicity test results, 2005[a]

Test	MIK 0.78	SD 170	MIK 0.71	SD 190	MIK 0.45	MIK 0.12
Second quarter, June						
Ceriodaphnia survival	NR	NR	NR	R	NR	NS
Ceriodaphnia reproduction	NR	NR	NR	R	NR	NS
Fourth quarter, October						
Ceriodaphnia survival	NR	NR	NR	NR	NR	NR
Ceriodaphnia reproduction	NR	NR	NR	R	NR	NR

[a]NR: No significant reduction compared with the control population. R: Significant reduction compared with the control population. NS: Not sampled.

and analyzed for PCBs. Table 4.13 gives a synopsis of the results. Results from the Mitchell Branch and K-901-A Pond monitoring are similar to historical results, with fish from both locations containing concentrations (an average of 2.2 and 0.9 ppm, respectively) near or above the State of Tennessee posting limit of 1 ppm. In the bass from K-1007-P1 pond, the 2004 results showed a significant decrease in PCB concentrations when compared to previous year's monitoring results. Results from the 2005 monitoring (an average of 16.1 ppm) returned to the range of historical levels.

4.6.3 BMAP Ecological Surveys of Instream Communities

Although past ETTP operations had adversely affected the communities of Mitchell Branch, and although there continue to be some impacts, the results to date overall indicate that the institution of best management practices and remediation efforts have resulted in gradual, but more or less continuous, improvement of conditions in the stream.

In April 2005, the benthic macroinvertebrate community was sampled at four Mitchell Branch locations (MIK 0.45, 0.71, 0.78, and 1.43). MIK 1.43 serves as the reference location. Except for short-term negative impacts to benthic macroinvertebrate communities at MIK 0.45 and 0.71 in 1998 (associated with stream relining) and 2003, the benthic macroinvertebrate community at all locations in lower Mitchell Branch has generally increased in species richness and numbers of pollution-intolerant species over approximately the last 10 years (Figs. 4.7 and 4.8). The results from the 2003 sampling showed declines in species richness and richness of the pollution-intolerant species in Mitchell Branch. However, the results of the 2004 and 2005 sampling at MIK 0.71 and MIK 0.45 show a strong increase in these parameters to levels more typical of the previous sampling events, and the levels at MIK 0.78 even exceeded those of the reference locality. Community differences between the reference site (MIK 1.43) and MIKs 0.45 and 0.71 are still apparent in 2005, with the persistence of lower densities of stoneflies at the downstream sites (i.e., 5 to >20 times lower than at MIKs 1.43). Overall, however, it appears that past actions taken to improve water quality (e.g., effluent dechlorination) have provided significant ecological benefits.

Fish communities in Mitchell Branch (MIK 0.45 and 0.71) were sampled in April. Species richness, density, and biomass were examined. The communities at both MIK 0.45 and MIK 0.71 showed a significant increase in both density and biomass. Density at MIK 0.71 was the highest recorded for that location, and the density at MIK 0.45 was the second highest. Species richness in the 2005 sampling was similar to or slightly better than recent years' results at both locations. The stream is still dominated by more tolerant fish species, so although the conditions and fish community structure are improving they have not yet reached a stable community structure typical of less impacted streams in the area.

4.6.4 BMAP Waterfowl Surveys

Waterfowl surveys were conducted twice per year in 2004 and the first half of 2005, but as of October 2005 they will no longer be conducted as part of the BMAP. During the waterfowl survey conducted in April 2005, the following species were observed at ETTP: the osprey (*Pandion haliateus*), common loon (*Gavia immer*), double-crested cormorant (*Phalacrocorax auritus*), great blue heron (*Ardea herodius*), American coot (*Fulica americana*) killdeer (*Charadrius vociferous*) belted kingfisher (*Ceryle alcyon*), American kestrel (*Falco sparverius*), and the Canada goose (*Anser canadensis*). During the last several years, the number of species of waterfowl, as well as the number of individuals, has fluctuated. It is not clear at this time whether or not the fluctuations represent a temporary plateau on the route to recovery, or whether the avian community has more or less reached a steady state.

4.7 ETTP Ambient Air Monitoring

DOE Order 450.1 requires surveillance of ambient air to assess the impact of DOE operations on air quality. In addition, airborne radionuclide monitoring is required for compliance with radionuclide NESHAP regulatory agreements. DOE Order 5400.5 also specifies requirements for airborne radionuclide surveillance. The ETTP ambient air monitoring program is designed to monitor selected air con-

Table 4.13. PCB concentrations in biota at ETTP, 2005[a]

Location	Species	Mean concentration (ppm)	Range	Number >1 ppm/N
MIK 0.2	Redbreast sunfish (*Lepomis auritus*)	2.2	0.74–3.5	5/6
K-1007-P1	Largemouth bass (*Micropterus salmoides*)	16	7.5–29	6/6
K-901-A	Largemouth bass (*Micropterus salmoides*)	0.88	0.58–1.6	1/6
Hinds Creek (reference)	Rockbass (*Ambloplites rupestris*)	<0.03	<0.03–0.04	0/6
MIK 0.78	Asiatic clams (*Corbicula fluminea*)	0.1	N/A	N/A
MIK 0.71 (SD170)	Asiatic clams (*Corbicula fluminea*)	0.1	N/A	N/A
MIK 0.45 (SD190)	Asiatic clams (*Corbicula fluminea*)	1.2	N/A	N/A
MIK 0.2	Asiatic clams (*Corbicula fluminea*)	2.4	N/A	N/A
SD100 (inside drain)	Asiatic clams (*Corbicula fluminea*)	4.7	N/A	N/A
SD100 (discharge to P1 Pond)	Asiatic clams (*Corbicula fluminea*)	7.3	N/A	N/A
SD120	Asiatic clams (*Corbicula fluminea*)	1.5	N/A	N/A
K-1007P3	Asiatic clams (*Corbicula fluminea*)	0.04	N/A	N/A
SD490	Asiatic clams (*Corbicula fluminea*)	0.78	N/A	N/A
K-1007P1	Asiatic clams (*Corbicula fluminea*)	3.9	N/A	N/A
K-901-A	Asiatic clams (*Corbicula fluminea*)	0.25	N/A	N/A
SD700	Asiatic clams (*Corbicula fluminea*)	0.71	N/A	N/A
SD710	Asiatic clams (*Corbicula fluminea*)	0.61	N/A	N/A
Little Sewee Creek (reference)	Asiatic clams (*Corbicula fluminea*)	0.06	N/A	N/A
SD930	Asiatic clams (*Carbicula fluminea*)	0.07	N/A	N/A

[a]1 ppm = 1 mg/L.

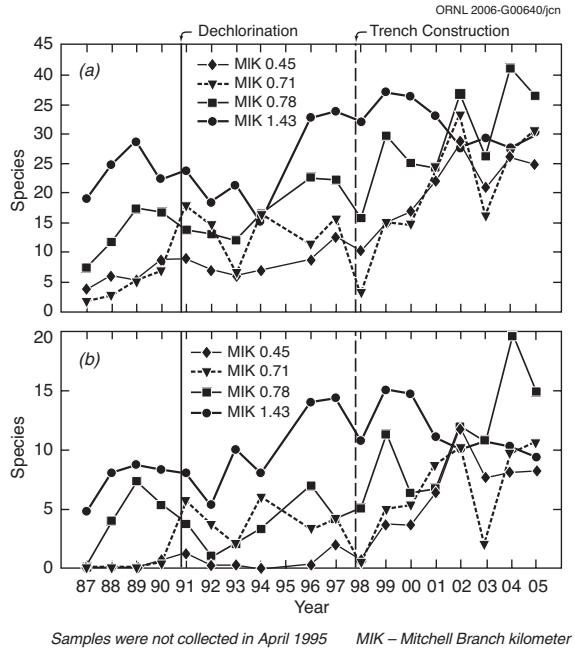


Fig. 4.7. (a) Total taxonomic richness. (b) Richness of pollution-sensitive taxa.

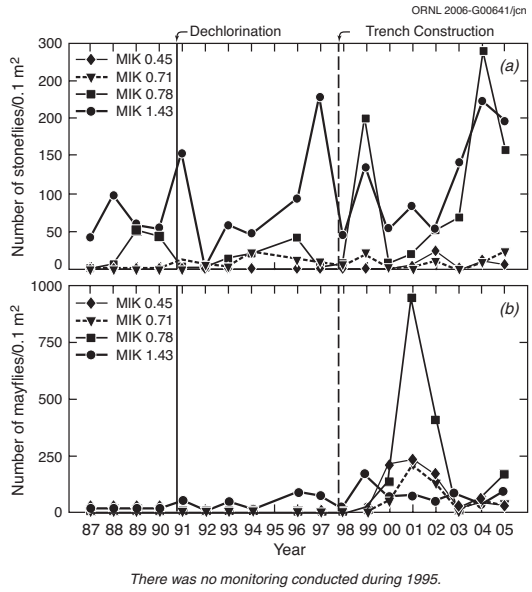


Fig. 4.8. Density of (a) pollution-intolerant stoneflies and (b) pollution-tolerant mayflies in Mitchell Branch.

taminants for the ongoing monitoring of the impact of plant operations on the immediate environment. Specific locations were selected to determine air contaminant concentrations in the prevailing directions, upwind and downwind of the site, and to obtain airborne radiological measurements in the direction of both the nearest and most exposed member of the public. The current locations of these monitoring stations are shown in Fig. 4.9. The ETTP ambient air monitoring program complies with all requirements of DOE Orders. One new station was activated in November of 2005 due to planned DOE facility access changes that would require on-site monitoring of radiological emissions. This station will ensure compliance with NESHAP regulations and will be consistent with previously approved sampling methodologies defined in the ORR NESHAP Compliance Plan (DOE 1994).

National ambient air quality standards are referenced by DOE Orders as guidance with respect to ambient air concentrations of certain air contaminants. These regulations specify 24-h, quarterly, and annual standards for specific or criteria pollutants. Additionally, results are compared with any applicable risk-specific dose and reference air concentration listed in 40 CFR 266, Subpart H.

The ambient air sampling schedule and monitored parameters are listed in Table 4.14. All parameters were chosen with consideration of existing and proposed regulations and the nature of operations in and around the ETTP. Changes in emissions, wind profile, site activities, or any other parameter that may alter the potential impact of ETTP activities within the facility, on nearby communities, or the environment may warrant periodic changes of air contaminants measured, number of stations, or relocation of existing stations. The principal parameters monitored during 2005 were arsenic, beryllium, cadmium, chromium, lead, and uranium. Uranium was analyzed by both inorganic and radiochemical methods. Radiochemical analyses included isotopes of uranium (^{234}U, ^{235}U, ^{236}U, and ^{238}U), ^{99}Tc, ^{237}Np, ^{238}Pu, and ^{239}Pu.

During this reporting period, the ambient air monitoring network consisted of four ETTP sampling stations and utilized information obtained from two ORR perimeter air monitoring (PAM) stations. Samples were collected weekly from the following stations: K2, K6, K9, K11, and PAM 35 and 42. During 2005, sample compositing was performed quarterly (every 3 months) prior to analysis for all pollutant analyses.

4.7.1 Results

No standards were exceeded, and, with the exception of uranium levels, there were no significant variations of annual pollutant concentrations associated with site operations when compared with data from the previous year. Sampling results assessing the impact of specific site activities on air quality show that the ETTP, including project-specific measurements, did not have any impact of concern on local air quality. Also, radiochemical analyses of ambient air samples confirm low radiological emissions from the ETTP.

4.7.2 Criteria Pollutant Levels

Lead results were determined from analyses of quarterly composites of continuous weekly samples from stations K2, K6, and K9. Station K11 results consisted of only 2 months of sampling. The total mass quantities of lead for each sample were determined by the inductively coupled plasma mass spectrometry (ICP-MS) analytical technique. Lead analytical results are summarized in Table 4.15 and are compared with the Tennessee and national quarterly ambient air quality standard of 1.5 $\mu g/m^3$. There are no 24-h, monthly, or annual ambient air quality standards for lead. The maximum individual lead result was 0.0012 $\mu g/m^3$. This value was only 0.08% of the quarterly standard for lead. No lead concentrations of environmental concern were measured (see Fig. 4.10 for a 5-year lead trend).

4.7.3 Hazardous Air Pollutant Carcinogenic Metal Levels

Analyses of hazardous air pollutant carcinogenic metals (arsenic, beryllium, cadmium, and chromium) were performed on quarterly composite samples of continuous weekly samples from stations K2, K6, and K9. Station K11 results consisted of only 2 months of sampling. Total mass of each selected metal was determined by the ICP-MS analytical technique.

Table 4.14. Summary of types and frequencies of samples collected at East Tennessee Technology Park perimeter ambient air monitoring stations, 2005

Parameter	Sampling locations	Sampling period	Collection frequency	Analysis frequency[a]
Criteria pollutants				
Lead	K2, K6, K9, K11	Continuous	Weekly	Quarterly
Hazardous air pollutants carcinogen metals				
Arsenic	K2, K6, K9, K11	Continuous	Weekly	Quarterly
Beryllium	K2, K6, K9, K11	Continuous	Weekly	Quarterly
Cadmium	K2, K6, K9, K11	Continuous	Weekly	Quarterly
Chromium	K2, K6, K9, K11	Continuous	Weekly	Quarterly
Organic compounds				
Polychlorinated biphenyls	TSCAI[b] 1, 2	*c*	*c*	*c*
Furan	TSCAI 1, 2	*c*	*c*	*c*
Dioxin	TSCAI 1, 2	*c*	*c*	*c*
Hexachlorobenzene	TSCAI 1, 2	*c*	*c*	*c*
Radionuclides (by inorganic analysis)				
Uranium (total)	TSCAI 1, 2	*c*	*c*	*c*
Radionuclides (by radiochemical analysis)				
^{99}Tc, ^{237}Np, ^{238,239}Pu, ^{234,235,236,238}U	K2, K6, K9, K11	Continuous	Weekly	Quarterly

[a] Quarterly frequencies are composite sample analyses of all weekly samples collected over the identified period.

[b] Toxic Substances Control Act (TSCA) Incinerator.

[c] Stations are activated automatically only if a TSCA Incinerator operational upset occurs. Identified samples are then immediately submitted for analysis.

Table 4.15. Lead concentrations in ambient air at the East Tennessee Technology Park, 2005

Station	Quarterly averages of monthly composites (μg/m^3)				Maximum quarterly result (μg/m^3)	Maximum percent of quarterly standard[a]
	1	2	3	4		
K2	0.00108	0.00042	0.00019	0.00041	0.00108	0.07
K6	0.00089	0.00025	0.00012	0.00036	0.00089	0.06
K9	0.00118	0.00048	0.00039	0.00047	0.00118	0.08
K11[b]	—	—	—	0.00071	0.00071	0.05
Quarterly average	0.00105	0.00038	0.00023	0.00041	0.00105	0.07
Quarterly maximum	0.00118	0.00048	0.00039	0.00071	0.00118	0.08
Annual average for all stations = 0.00057 μg/m^3						

[a]Tennessee and national air quality standard for lead is 1.5 μg/m^3 quarterly arithmetic average.

[b]New station activated during the fourth quarter of 2005.

There are no Tennessee or national ambient air quality standards for these hazardous air pollutant carcinogenic metals. However, comparisons have been made against risk-specific doses and reference air concentrations.

The annual average arsenic concentration for all measurement sites was 0.00019 μg/m^3, well below the risk-specific dose of 0.0023 μg/m^3. The individual maximum measured result was 0.00036 μg/m^3. Annual beryllium measurements were at or near the minimum detectable concentrations of the analytical method, orders of magnitude below the risk-specific dose of 0.0042 μg/m^3. The combined beryllium average for all sites was < 0.000005 μg/m^3 with the individual maximum result of 0.000055 μg/m^3. The maximum cadmium concentration result was 0.00008 μg/m^3. The cadmium annual average was 0.00004 μg/m^3. Both results are well below the risk-specific dose of 0.0056 μg/m^3. Individual chromium measurements ranged from approximately < 0.00001 to 0.00015 μg/m^3. The annual average result for chromium was 0.00006 μg/m^3, well below the risk-specific dose of 0.00088 μg/m^3 for chromium VI. The form of chromium was not determined, and therefore the most conservative risk-specific dose (chromium VI) was used. A summary of the hazardous air pollutant carcinogenic metals measurements is presented in Table 4.16.

4.7.4 Radionuclide Levels

Total uranium metal was measured as quarterly composites from stations K2, K6, and K9. Station K11 results consisted of only 2 months of sampling. The total uranium mass for each sample was determined by the ICP-MS analytical technique. The annual uranium averages and maximum individual concentration measurements for all sites are presented in Table 4.17. The average annual results for each station ranged from a minimum of approximately 0.00001 to 0.00005 μg/m^3. The highest single quarterly result, 0.00014 μg/m^3, was measured at Station K2, which is in one of the prevailing wind directions from the TSCA Incinerator. The annual average value for all stations due to uranium was 0.00003 μg/m^3. The ICP-MS results are compared with a dose based on the DCG for natural uranium. (The DCG is based on an annual air concentration exposure that would give a dose of 100 mrem.) The sampling location with the highest annual average concentration of uranium was at K9. The annual result was only 0.00005 μg/m^3, which corresponds to 0.03% of the DCG (see Fig. 4.11 for 5-year uranium trend).

Periodic radiochemical analyses were initiated during 2000 on selected monthly composite samples collected at Stations K2, K6, and K9. For 2004, analyses were based on quarterly composite samples from these stations. The selected isotopes of interest were ^{237}Np, ^{238}Pu, ^{239}Pu, ^{99}Tc, and isotopic uranium (^{234}U, ^{235}U, ^{236}U, and ^{238}U). The resulting annual concentrations for all nuclides measured are presented in Table 4.18. Results from stations K2, K6, and K9 are averages of four quarterly composite sample analyses and represent an annual average for this report. Station K11 results consisted of only 2 months of sampling. For comparison, the total uranium results associated with ICP-MS analyses of composite samples are comparable with the uranium results determined by radiochemical techniques.

4.7.5 Organic Compound Levels

Currently, measurements of selected semi-volatile organics are performed only during an operational upset of the TSCA Incinerator. The incinerator experienced one automatic thermal relief vent opening during 2005 due to a power loss in the ETTP distribution grid. This event occurred during the incineration of solid wastes. If an unplanned release occurred, organic compound ambient air sampling stations TSCA1 and TSCA2 (see Fig. 4.9) would be activated automatically or manually. However, the potential release of organic compounds from this event was established to be below levels that would be detectable by ambient air monitoring. This decision was based on the characterizations of the wastes being processed at that time of the event and on the current inventory in the incinerator. The calculated waste inventory could not produce a detectable off-site impact. Additionally, meteorological conditions would not carry any potential release from the vent in the direction of either sampling station. Therefore, the samplers were not activated for this event.

Table 4.16. Hazardous air pollutant concentrations in ambient air at the East Tennessee Technology Park, 2005

Parameter	Ambient air concentration ($\mu g/m^3$)			Percentage of standard[a]
	Annual average (all stations)	Quarterly maximum	Maximum station	
Arsenic	0.00019	0.00036	K2	8.2
Beryllium	0.000005	0.000055	K9	<0.1
Cadmium	0.00004	0.00008	K2	0.7
Chromium	0.00006	0.00015	K2	
Cr-111				<0.1
Cr-VI				6.4

[a]There are no Tennessee or national ambient air quality standards; however, annual averages are compared to risk-specific doses for As, Be, Cd, and Cr-VI and the reference air concentration for Cr-III as listed in 40 CFR 266.

Table 4.17. Total uranium in ambient air by inductively coupled plasma mass spectrometry analysis at the East Tennessee Technology Park, 2005

Station	Samples	Concentration[a]				Percent of DCG[b] (%)	
		($\mu g/m^3$)		(μCi/mL)			
		Average	Maximum[c]	Average	Maximum[c]	Average	Maximum[c]
K2	4	0.000046	0.000140	3.09E-17	9.36E-17	0.03	0.09
K6	4	0.000008	0.000025	5.38E-18	1.69E-17	<0.01	0.02
K9	4	0.000050	0.000075	3.39E-17	4.99E-17	0.03	0.05
K11	1	0.000008	0.000008	5.35E-18	5.35E-18	<0.01	<0.01
ETTP total	16	0.000028	0.000140	1.87E-17	9.36E-17	0.02	0.09

[a]Mass-to-curie concentration conversions assume a natural uranium assay of 0.717% ^{235}U.
1 μCi = 3.7×10^4Bq.

[b]DOE Order 5400.5 Derived Concentration Guide (DCG) for naturally occurring uranium is an annual concentration of 1×10^{-13} μCi/mL, which is equivalent to a 100-mrem annual dose.

[c]Maximum individual sample analysis result with dose calculations conservatively assuming the value to be an annual concentration.

Table 4.18. Radionuclides in ambient air by radiochemistry at the East Tennessee Technology Park, 2005

Station	Concentration (μCi/mL)[a]								
	^{237}Np	^{238}Pu	^{239}Pu	^{99}Tc	^{234}U	^{235}U	^{236}U	^{238}U	Total U
K2	ND	ND	5.28E-19	1.24E-15	2.17E-17	2.12E-18	2.18E-18	5.22E-17	7.82E-17
K6	ND	ND	1.13E-18	5.15E-16	9.36E-18	2.95E-18	7.89E-19	9.50E-18	2.26E-17
K9	4.58E-19	3.49E-18	1.75E-18	8.79E-16	8.19E-17	6.70E-18	5.84E-18	6.68E-17	1.61E-16
K11	ND	ND	ND	2.34E-16	4.23E-18	ND	ND	3.48E-18	7.71E-18

[a]K2, K6, K9 annual results are the average of four quarterly composite analyses. New station K11 was activated during the fourth quarter of 2005, and the result is based on a single composite sample.
1 μCi = 3.7×10^4 Bq.

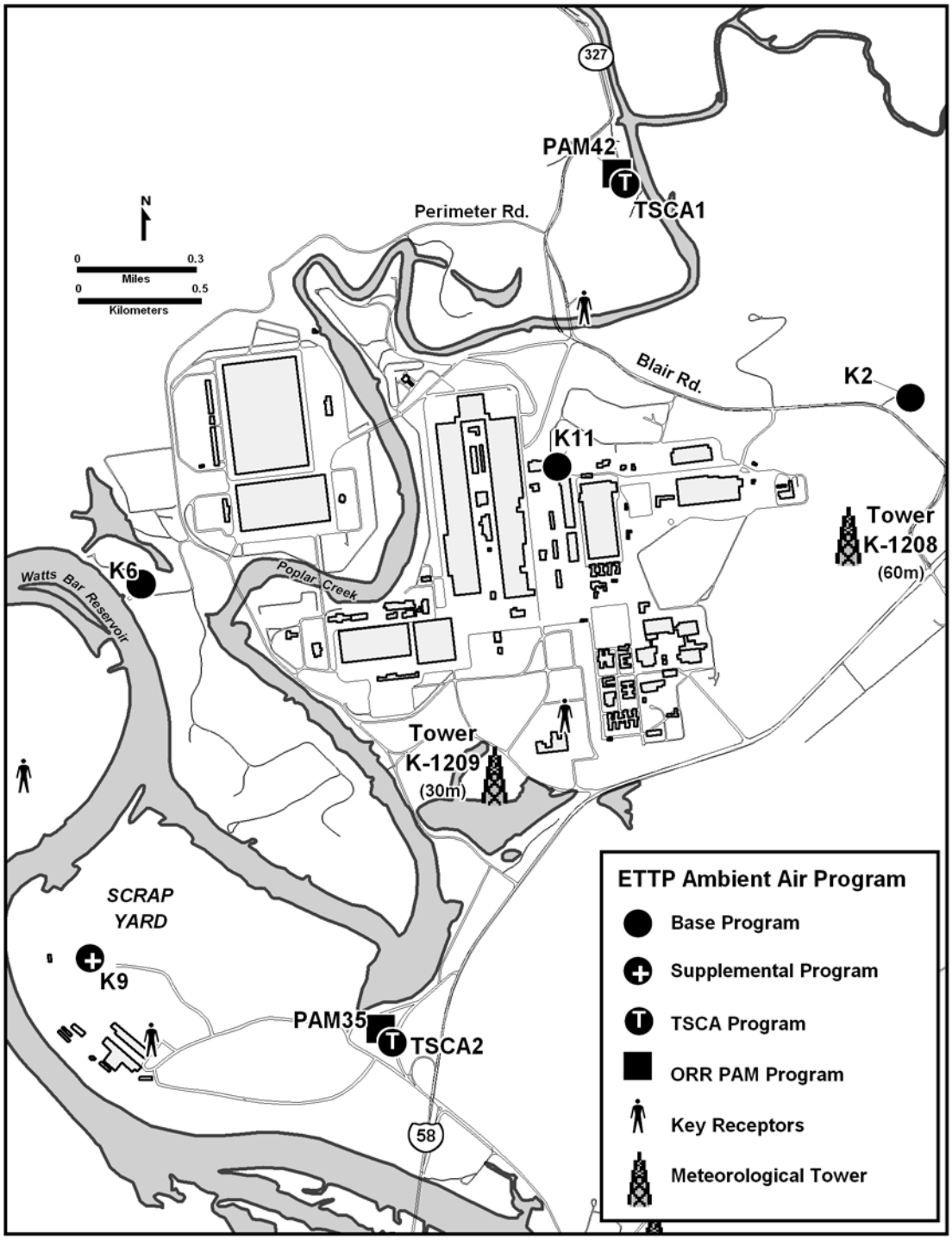


Fig. 4.9. Locations of ambient air monitoring stations at the ETTP.

4.7.6 Five-Year Trends

Five-year summaries of ETTP ambient air monitoring data are shown in Figs. 4.10 and 4.11 for lead and uranium, respectively. Variations of lead measurements were insignificant and most likely reflect background concentration variations of air quality. Uranium levels reflect typical levels that can be associated with normal ETTP operations.

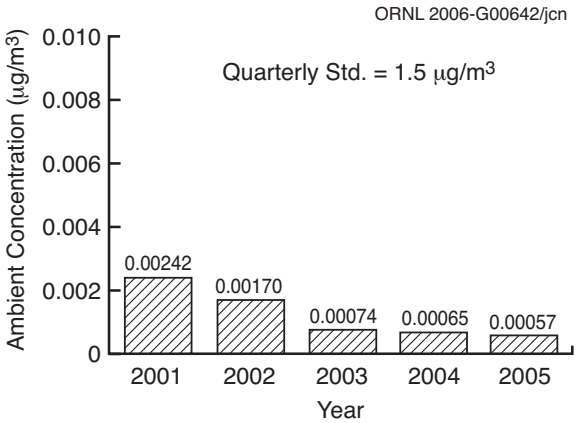


Fig. 4.10. Ambient air monitoring 5-year trend results for lead at the ETTP.

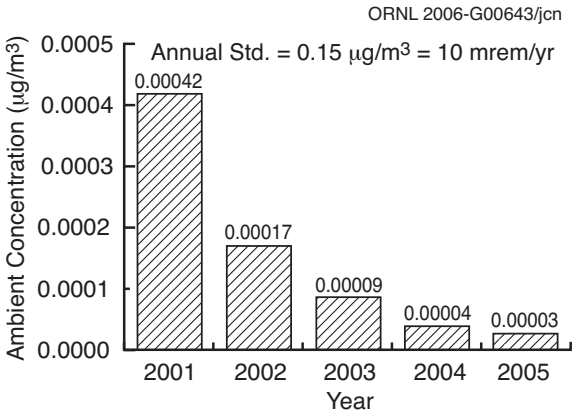


Fig. 4.11 Ambient air monitoring 5-year trend results for uranium at the ETTP.

Arsenic, beryllium, and cadmium measurements were initiated in 1993, and chromium measurements were initiated in 1986. Over the last 5 years, arsenic, cadmium, and chromium have been typically indistinguishable from background levels except during specific projects that have included major demolition activities. All beryllium measurements, historical and current, have been at or near analytical minimum detectable concentrations. During the 5-year period, no ambient air measurements have indicated any level of concern based on comparisons with any applicable standards.

4.8 ETTP Surface Water Monitoring

Surface water surveillance was conducted at nine locations at the ETTP (Fig. 4.12). Stations K-1710, MIK 1.4, and Clinch River kilometer (CRK) 23 provide information on conditions upstream of the ETTP. Stations K-716 and CRK 16 are located downstream from most ETTP operations and provide information on the cumulative effects of the ETTP activities as well as those upstream. The remaining sampling locations are at points where drainage in the major surface water basins converges before discharging to Poplar Creek (Stations K-1007-B, K-700 Slough, and K-1700) or to the Clinch River (Station K-901-A). In 2005, the K-700 Slough was dropped from the monitoring program, and CRK 23 was added.

At most surveillance stations, semiannual sampling and analyses for radionuclides, metals, and field readings (dissolved oxygen, temperature, and pH) were conducted. At the Clinch River sites (CRK 16 and 23) volatile organic compounds were also monitored semiannually. Quarterly monitoring for volatile organics, metals, radionuclides and field readings, is conducted at the K-1700 and MIK 1.4 locations. Radionuclide results are compared with the DCGs. Nonradiological results are compared with Tennessee water quality standards for fish and aquatic life. The water quality standards use the numeric values given in the Tennessee general water quality criteria, which are a subset of the water quality standards.

In most instances, results of the monitoring for nonradiological parameters are well within the applicable standards. Heavy metals were often detected at CRK16, K-901-A, and K-1700 (barium was the most common heavy metal detected), and certain volatile organics (primarily trichloroethane, vinyl chloride, and 1,2-dichloroethane) were regularly detected at K-1700, but in all instances the results were below the applicable water quality standard. Dissolved oxygen measurements at K-901-A fell below the minimum water quality standard of 5.0 mg/L during two summer sampling events,

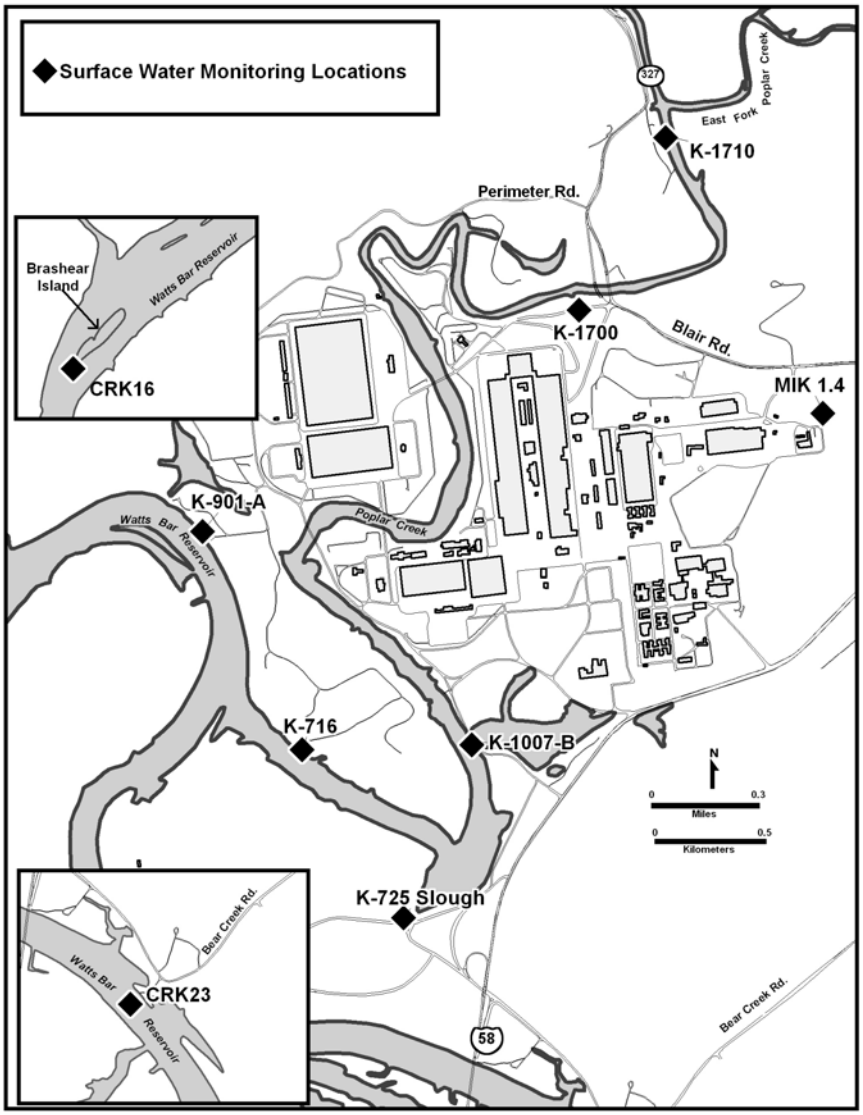


Fig. 4.12. Monitoring locations for surface water at the ETTP.

and once at K-1700, due to a combination of elevated temperatures and the stagnation due to very low flows at that location. Water bodies in the vicinity of the ETTP are regularly inspected for signs of stress on aquatic organisms during low-flow periods. For the remaining analyses, results were within the reference standards or below detection limits for the instrument and method. Moreover, analytical results for samples collected upstream of the ETTP were chemically similar in most respects to those collected below the ETTP.

The sum of the fractions of the DCGs for most stations remained below 1% of the DCG values for ingestion (Fig. 4.13). The highest sum of the fractions, 1.8% of the DCGs, was reported for sampling location K-1700. The results at the other surface water surveillance locations are all below 1% of the DCGs. These data are consistent with the historical results. Due to this stasis, monitoring at the surveillance locations will continue to be maintained at the reduced frequency until significant changes are detected or until ETTP operations change to include activities with the potential to affect discharges.

4.9 ETTP Groundwater Monitoring

Groundwater monitoring at the ETTP is focused primarily on investigating and characterizing sites for remediation under CERCLA. As a

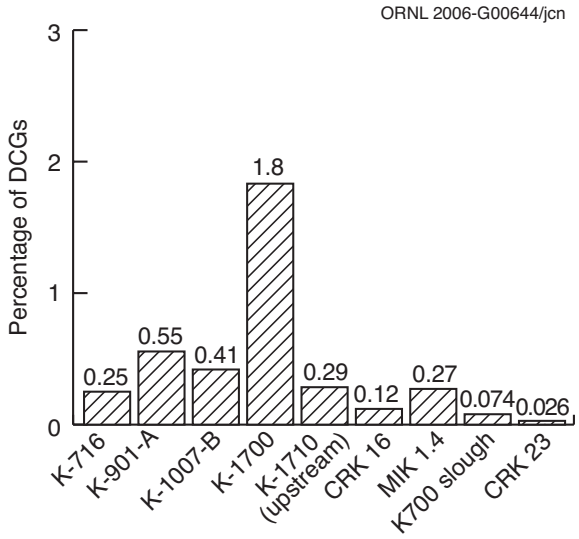


Fig. 4.13. Percentage of DOE derived concentration guides for ETTP surface water monitoring locations.

result of the Federal Facility Agreement and certification of closure of the K-1407-B and K-1407-C Ponds, the principal driver at the ETTP is CERCLA.

The cleanup strategy described in *Accelerating Cleanup: Paths to Closure* (DOE 1999a) has been developed to accelerate the transition of areas of concern from characterization to remediation by making decisions at the watershed scale based on recommended land use. The watershed is a surface-drainage basin that includes an area of concern or multiple areas of concern to be investigated and/or remediated. This approach allows for the systematic monitoring and evaluation of contaminant sources and migration through the use of integrated surface-water and groundwater monitoring.

ETTP Groundwater Protection Program requirements are incorporated into the Water Resources Restoration Program. The Water Resources Restoration Program, which was established to provide a consistent approach to watershed monitoring across the ORR, is responsible for conducting groundwater surveillance monitoring at the ETTP, including exit pathway monitoring wells. Groundwater discharges into Poplar Creek, the Clinch River, and the three main surface water bodies at ETTP (the K-901 Pond, K-1007 Pond, and Mitchell Branch). Many of the contaminants at ETTP migrate toward one of these surface water bodies, which are monitored by the ETTP Environmental Monitoring Plan surface water surveillance program. The 2005 *Remediation Effectiveness Report* (DOE 2006b) includes summaries of groundwater monitoring actions required for individual cleanup actions at the ETTP, along with recommendations to modify any requirements that would further ensure protection of human health and the environment.

4.10 ETTP Direct Radiation

The UF_6 cylinder storage yards and K-770 Scrap Yard at ETTP are potential sources of direct gamma and neutron radiation exposure to the public. Measured exposure rates and a hypothetical model of a maximally exposed individual were used to calculate theoretical doses. The calculated effective dose equivalents (EDEs) were based on gamma and neutron dose rates measured at the K-1066-J and K-1066-E Cylinder Yards along the near bank of Poplar Creek, the parking lot adjacent to the K-1066-K Cylinder Yard, and the near bank of the Clinch River in the vicinity of the K-770 Scrap Yard. The dose levels to the public calculated from the measured exposure rates are less than the 100-mrem/year limit established by DOE Order 5400.5.

Gamma and neutron dose rates from each area were measured in February 2005 with tissue-equivalent dose rate meters. Background readings were established at the ambient air monitoring stations north and northeast of ETTP off Blair Road, south and southwest of ETTP in the Powerhouse Area, and west of ETTP at the K-901 pumping station. The average gamma background was 0.004 mrem/h. The average neutron background was 0.002 mrem/h.

The potential maximally exposed individual model used for exposure from the K-1066-J or K-1066-E Cylinder Yard is a hypothetical fisherman who was assumed to have spent 250 h/year near the point of average exposure. This hypothetical individual could have received an EDE above background of about 0.25 mrem from gamma radiation and 0.25 mrem from neutron radiation along the bank of Poplar Creek near the K-1066-J Cylinder Yard, or 0.75 mrem from gamma radiation and 0.50 mrem from neutron radiation along the bank of Poplar Creek near the K-1066-E Cylinder Yard during 2005. This section of the creek runs through the ETTP plant and is used at times by fishermen; how-

ever, it is very unlikely that anyone would fish this stretch of Poplar Creek for 250 h/year.

General area dose rates were recorded in the vicinity of the K-770 Scrap Yard, along the near bank of the Clinch River. A hypothetical fisherman who was assumed to have spent 250 h/year near the point of average exposure could have received an EDE above background of about 0.25 mrem from gamma radiation and 0.25 mrem from neutron radiation along the bank of the Clinch River near the K-770 Scrap Yard during 2005.

The parking lot adjacent to the K-1066-K Cylinder Yard is used by workers and the public; therefore, it was included in the survey. This parking lot is intended for employees and has no public facilities. A potential maximally exposed individual is someone assumed to have spent 30 min per work day (125 h/year) waiting in the parking lot at the point of average exposure along the edge closest to the K-1066-K Cylinder Yard. This hypothetical individual could have received an EDE above background of about 0.75 mrem from gamma radiation and 0.25 mrem from neutron radiation during 2005.

4.11 Modernization and Reindustrialization

DOE-ORO established the Reindustrialization Program in 1996 as an innovative way to address some of the environmental and financial challenges left at the end of the Cold War. Under the program, transfers of excess or underutilized land and facilities are made available. The goal is to accelerate cleanup by reducing costs, while allowing for the productive use of the assets by the private sector. The process helps to offset negative impacts on the community caused by DOE downsizing, facility closeouts, and workforce restructuring. DOE-ORO worked with local officials and business leaders to establish the Community Reuse Organization of East Tennessee (CROET). Through CROET, the Reindustrialization Program has successfully leased land and facilities at the ETTP. DOE-ORO has transitioned to an accelerated cleanup of ETTP in preparation for its closure as a DOE site. ETTP will then be available for use as a private-sector industrial park. As part of this accelerated process, the emphasis is on facility transfer of ownership (title transfer).

In 2003, DOE-ORO completed a “finding of no significant impact” to allow the transfer of property to Horizon Center LLC. The property, in the past known as Parcel ED-1, only consists of the portions suitable for development. The remainder of the property, known as the Natural Area, will continue to be leased by Horizon Center LLC and owned by DOE.

DOE has been working with the state of Tennessee to grant the state an indefinite-term conservation easement of approximately 1,214 hectares to be located on the west end of the ORR. This action, the result of an agreement-in-principle related to the Natural Resources Damage Act affecting the ORR, was granted in early 2005.

5. ORNL Environmental Monitoring Programs

Compliance and environmental monitoring programs required by federal and state regulations and by DOE orders are conducted for air, water, and a variety of environmental media. These programs include regulatory and monitoring activities for ORNL site facilities and other locations in Bethel Valley, Melton Valley, and the ORR.

5.1 ORNL Radiological Airborne Effluent Monitoring

Airborne discharges from DOE Oak Ridge facilities, both radioactive and nonradioactive, are subject to regulation by EPA and the Tennessee Department of Environment and Conservation (TDEC) Division of Air Pollution Control. Radioactive emissions are regulated by EPA under National Emissions Standards for Hazardous Air Pollutants (NESHAP) regulations in 40 CFR 61, Subpart H, and by the rules of the TDEC Division of Air Pollution Control, 1200-3-11.08. (See Appendix G, Table G.1 for a list of radionuclides and their radioactive half-lives.)

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. These 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, adsorbable gases (e.g., iodine), tritium, and nonadsorbable gases (e.g., noble gases). The major radiological emission point sources for ORNL consist of the following five stacks located in Bethel and Melton Valleys (Fig. 5.1):

- 2026 Radioactive Materials Analytical Laboratory;
- 3020 Radiochemical Development Facility;
- 3039 central off-gas and scrubber system, which includes the 3500 and 4500 areas cell ventilation system, isotope solid-state ventilation system, 3025 and 3026 areas cell ventilation system, 3042 ventilation system, and 3092 central off-gas system;
- 7503 (formerly 7512) Molten Salt Reactor Experiment Facility; and
- 7911 Melton Valley complex, which includes the High Flux Isotope Reactor (HFIR) and the Radiochemical Engineering Development Center (REDC).

In 2005, there were 25 minor point/group sources, and emission calculations/estimates were made for each of them.

5.1.1 Sample Collection and Analytical Procedure

Each of the five major point sources is equipped with a variety of surveillance instrumentation. Only data resulting from analysis of the continuous samples are used in this report. ORNL in-stack source-sampling systems comply with criteria in the American National Standards Institute (ANSI) standard ANSI N 13.1 (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. In addition to that instrumentation, the system at Stack 7911 includes a high-purity germanium detector with a NOMAD™ analyzer, which allows continuous isotopic identification and quantification of radioactive noble gases (e.g., ^{41}Ar) in the effluent stream. The sample probes are annually removed, inspected, and cleaned.

Velocity profiles are performed quarterly following the criteria in EPA Method 2 at major and some minor sources. 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.

In addition to the major sources, ORNL has a number of minor sources that have the potential to emit radionuclides to the atmosphere. A

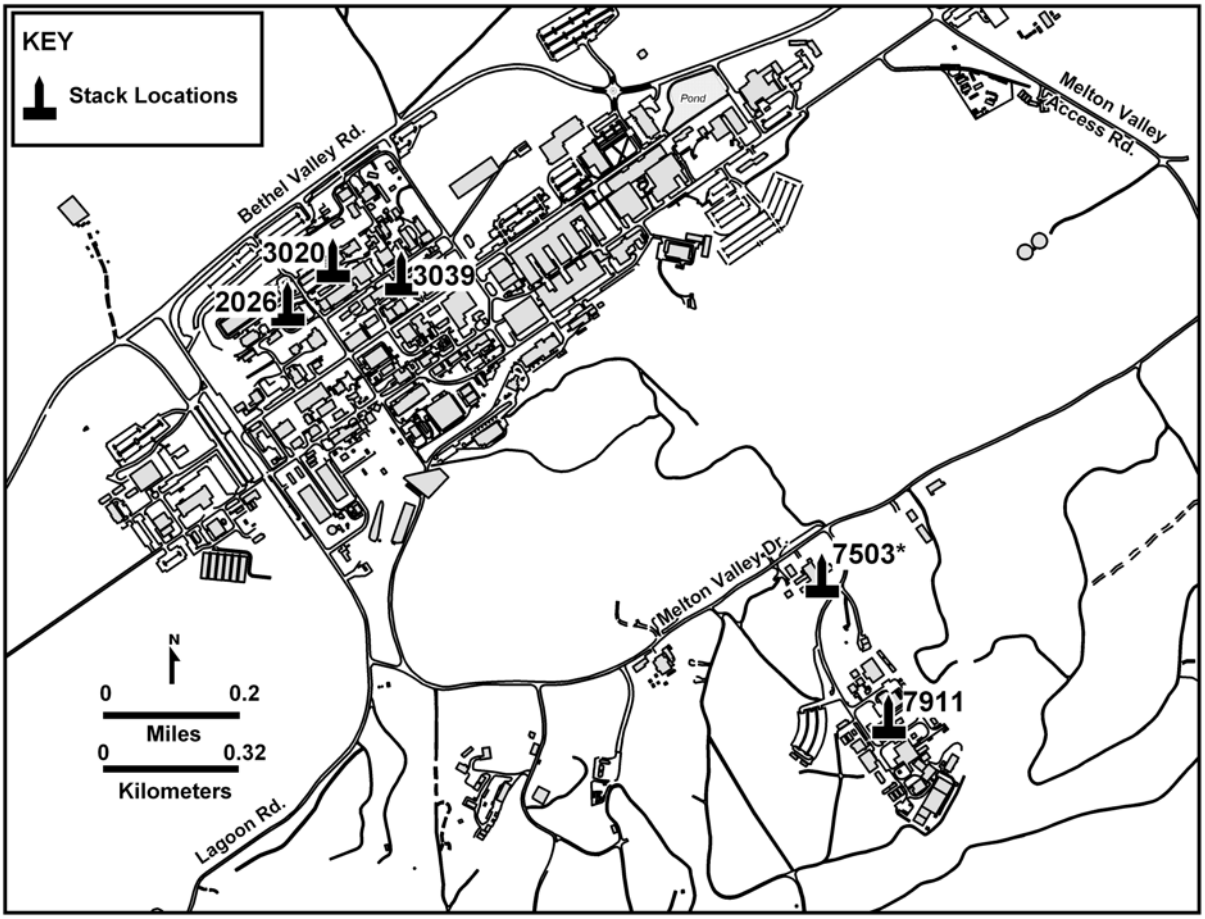


Fig. 5.1. Locations of major stacks (rad emission points) at ORNL.

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 ORNL Nuclear and Radiological Protection Division. A variety of methods are used to determine the emissions from the various minor sources. Methods used for minor source-emission calculations comply with criteria agreed upon by EPA. These minor sources are evaluated on a 1- to 5-year basis. Emissions, major and minor, 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 prior to 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 and are analyzed for alpha-, beta-, and gamma-emitting isotopes. Compositing provides a better opportunity for quantification of the low-concentration isotopes. Silica-gel traps are used to capture tritium water vapor. Analysis is performed weekly to biweekly. At the end of the year, each sample probe is rinsed, and the rinsate is collected and submitted for isotopic analysis identical to that performed on the particulate filters. The data

from the charcoal cartridges, silica gel, probe wash, and the quarterly filter composites are compiled to give the annual emissions for each major source and some minor sources.

5.1.2 Results

Annual radioactive airborne emissions for ORNL major sources in 2005 are presented in Table 5.1. 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 a process of 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 and iodine-131 are presented in Figs. 5.2 and 5.3, respectively. The tritium emissions for 2005 totaled approximately 73 Ci (Fig. 5.2), which is a decrease from 2004. The ^{131}I emissions for 2005 (also decreased from 2004) totaled 0.04 Ci (Fig. 5.3). The major contributor to the off-site dose at ORNL historically is ^{41}Ar, which is emitted as a nonadsorbable gas from the 7911 Melton Valley complex stack. However, because of a long maintenance period in 2001 and changes in HFIR operations, ^{138}Cs has remained the major contributor to the off-site dose since 2001. Emissions of ^{41}Ar result from HFIR operations and research activities. Emissions of ^{138}Cs result from REDC research activities, which also exhaust through the 7911 Melton Valley complex stack. The ^{41}Ar emissions for 2005 were 2100 Ci; ^{138}Cs emissions were 1200 Ci (Fig. 5.4). Even though the curie amount of ^{41}Ar exceeded that of ^{138}Cs, the resultant dose from ^{138}Cs dominated the off-site dose. The calculated radiation dose to the maximally exposed off-site individual from all radiological airborne release points at ORNL during 2005 was 0.9 mrem. This dose is well below the NESHAP standard of 10 mrem and is less than 0.3% of the 300 mrem that the average individual receives from natural sources of radiation. (See Sect. 8.1.2.1 for an explanation of how the airborne radionuclide dose was determined.)

5.2 ORNL Nonradiological Airborne Emissions Monitoring

ORNL holds a Title V permit for ten emission sources. ORNL also holds one construction permit for the Central Exhaust Facility at the Spallation Neutron Source (SNS) (see Appendix F, Table F.2). The ORNL Steam Plant (six boilers) and four small package-unit boilers account for 75% of ORNL's allowable emissions. Boiler 6, a 125-MBtu/h boiler, is subject to 40 CFR 60 Subpart Db continuous emission monitoring requirements for NO_x and opacity. During calendar year (CY) 2005, no permit limits were exceeded.

For the period from July 1, 2004, through June 30, 2005, ORNL paid $40,041.30 in annual emission fees to TDEC. These fees are based on allowable emissions (actual emissions are lower than allowable emissions). During 2005, TDEC inspected all permitted emissions sources; all were found to be in compliance.

As required by Title VI of the Clean Air Act Amendments of 1990, actions have been implemented to comply with the prohibition against releasing ozone-depleting substances 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 ozone-depleting substances. All critical applications of Class I ozone-depleting substances have been eliminated, replaced, or retrofitted with other materials. Work is progressing as funding becomes available for noncritical applications with no disruption of service.

Another UT-Battelle-operated facility, the National Transportation Research Center, is in Knox County and is permitted with the local regulatory agency there.

5.2.1 Results

The primary sources of nonradioactive emissions at ORNL include the steam plant,

Table 5.1. Major sources of radiological airborne emissions at ORNL, 2005 (Ci)[a]

Isotope	Stack				
	X-2026	X-3020	X-3039	X-7503	X-7911
^{110m}Ag	8.95E-08		8.07E-07		
^{241}Am	8.66E-08	2.72E-07	4.31E-06	2.48E-09	2.86E-08
$^{242/243}$Am	4.63E-09	1.13E-08	2.24E-08	1.44E-09	
^{41}Ar					2.10E+03
^{139}Ba					3.47E-01
^{140}Ba	5.31E-06				1.67E-04
^{7}Be	1.16E-06	7.89E-08	1.14E-05	3.91E-08	1.17E-07
^{214}Bi			2.99E-07		
^{141}Ce					8.60E-07
^{252}Cf					3.17E-09
$^{243/244}$Cm	9.59E-07	1.94E-08	6.36E-08	1.38E-08	1.02E-07
$^{245/246}$Cm	1.16E-08	4.62E-09	2.16E-08	8.49E-10	1.19E-08
^{57}Co			7.73E-07		
^{58}Co					9.49E-08
^{60}Co			3.56E-06		
^{51}Cr				6.72E-07	
^{137}Cs	2.86E-06	2.59E-06	1.10E-04	4.04E-08	4.72E-06
^{138}Cs					1.20E+03
^{152}Eu			1.12E-06		
^{154}Eu				4.16E-08	
^{155}Eu	1.22E-07				
^{59}Fe			7.87E-07		
^{3}H	3.07E+00		2.64E+01	1.65E+00	4.00E+01
^{203}Hg	1.25E-07		2.16E-06		
^{131}I			1.90E-06		4.20E-02
^{132}I					6.11E-01
^{133}I			1.41E-05		2.39E-01
^{134}I					2.74E-01
^{135}I					8.04E-01
^{40}K				2.46E-07	
^{85}Kr					2.21E+03
^{85m}Kr					6.22E-03
^{87}Kr					9.47E+01
^{88}Kr					4.97E+01
^{89}Kr					3.01E+01
^{140}La					1.57E-04
^{22}Na				1.55E-08	
^{95}Nb			3.67E-07		
^{191}Os			1.02E-01		
^{212}Pb	4.92E-01	1.25E-07	1.03E+00	2.93E-01	6.53E-02
^{214}Pb		1.09E-07		4.19E-08	
^{146}Pm					1.51E-07
^{238}Pu	3.68E-08	2.22E-08	3.80E-09	5.05E-10	3.24E-09
$^{239/240}$Pu	1.10E-07	1.71E-07	9.94E-07	9.19E-09	6.21E-08

Table 5.1 (continued)

Isotope	Stack				
	X-2026	X-3020	X-3039	X-7503	X-7911
^{244}Pu		5.23E-09	2.36E-08		1.18E-08
^{106}Ru		4.37E-07			6.03E-05
^{75}Se			3.56E-03		
$^{89/90}$Sr	3.78E-07	1.22E-06	4.96E-05	6.60E-09	6.68E-06
^{228}Th	2.73E-08	1.44E-08	2.18E-08	1.27E-09	6.12E-09
^{230}Th	6.50E-09	8.73E-09	3.01E-08	4.40E-09	2.18E-08
^{232}Th	1.80E-10	4.29E-09	1.45E-08	5.81E-10	5.53E-09
^{234}Th	2.66E-06				
^{208}Tl	7.32E-08				
^{234}U	1.07E-07	1.49E-07	1.14E-07	1.23E-08	9.22E-08
^{235}U	3.13E-09	9.23E-09	3.42E-08	5.93E-10	3.10E-08
^{238}U	3.66E-09	3.04E-08	8.14E-08	2.41E-09	1.32E-08
^{131M}Xe					4.93E-05
^{133}Xe					5.64E-03
^{133M}Xe					3.15E+00
^{135}Xe					3.58E+01
^{135M}Xe					2.35E+01
^{137}Xe					1.01E+02
^{138}Xe					1.27E+02
^{90}Y	3.78E-07	1.22E-06	4.96E-05	6.60E-09	6.68E-06
^{95}Zr	1.10E-07				

[a]1 Ci = 3.7×10^{10} Bq.

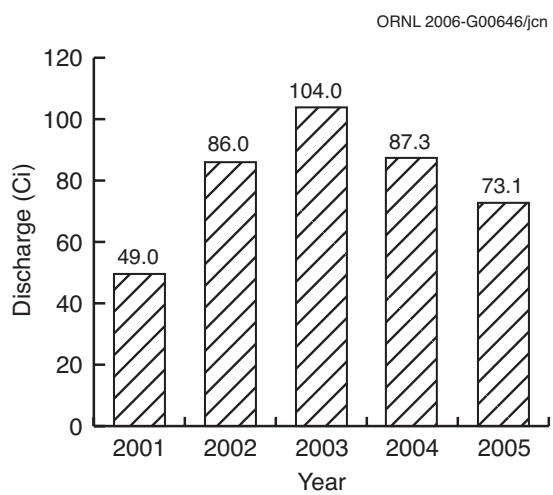


Fig. 5.2. Total discharges of ^{3}H from ORNL to the atmosphere, 2001–2005. 1 Ci = 3.7×10^{10} Bq.

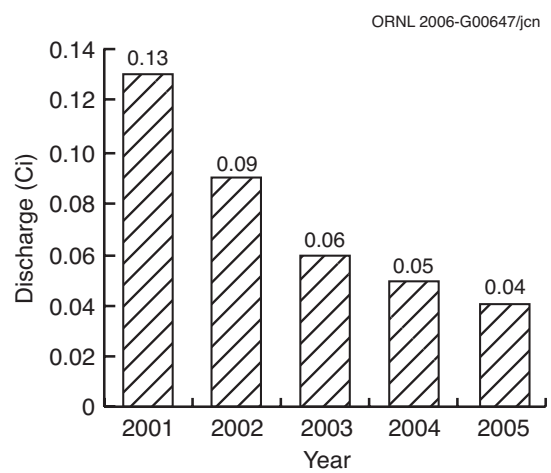


Fig. 5.3.Total discharges of ^{131}I from ORNL to the atmosphere, 2001–2005. 1 Ci = 3.7×10^{10} Bq.

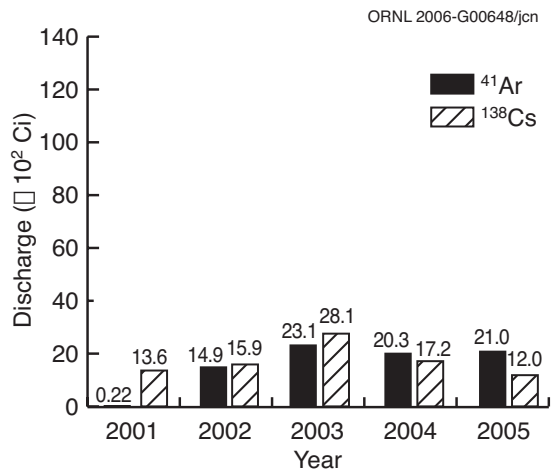


Fig. 5.4. Total discharges of ^{41}Ar and ^{138}Cs from ORNL to the atmosphere, 2001–2005. 1 Ci = 3.7 × 10^{10} Bq.

boilers 1–6 on the main ORNL site, two boilers located at the 7600 complex, and four boilers located at the SNS site. These units use fossil fuels; therefore, criteria pollutants are emitted.

Actual and allowable emissions from these sources are compared in Table 5.2. Actual emissions were calculated from fuel usage and EPA emission factors. All ORNL emission sources operated in compliance with permit conditions during 2005.

Table 5.2. Actual vs allowable air emissions from ORNL steam production, 2005

Pollutant	Emissions (tons per year)[a]		
	Actual	Allowable	Percentage of allowable
SO_2	6	1277	0.5%
PM	3	71	4.2%
CO	31	196	15.9%
VOC	2	14	14.5%
NO_X	59	380	15.5%

[a]1 ton = 907.2 kg.

5.3 ORNL Ambient Air Monitoring

The objectives of the ORNL ambient air monitoring program are to collect samples at perimeter air monitoring (PAM) stations most likely to show impacts of airborne emissions from the operation of ORNL and to provide for emergency response capability. Four stations, identified as Stations 1, 2, 3, and 7 (Fig. 5.5) make up the ORNL PAM network. Sampling is conducted at each ORNL station to quantify levels of tritium; adsorbable gases (e.g., iodine); and gross alpha-, beta-, and gamma-emitting radionuclides (Table 5.3).

The sampling system consists of a low-volume air sampler for particulate collection in a 47-mm glass-fiber filter. The filters are collected biweekly, composited annually, then submitted to the laboratory for analysis. Following the filter is a charcoal cartridge that collects adsorbable gases and is collected and analyzed on a biweekly basis. A silica-gel column is used for collection of tritium as tritiated water. These samples are collected biweekly or weekly and composited quarterly for tritium analysis.

5.3.1 Results

The ORNL PAM stations are designed to provide data for collectively assessing the specific impact of ORNL operations on local air quality. Sampling data from the ORNL PAM stations (Table 5.3) are compared with the derived concentration guides (DCGs) for air established by DOE as reference values for conducting radiological environmental protection programs at DOE sites. (DCGs are listed in DOE Order 5400.5.) Average radionuclide concentrations measured for the ORNL network were less than 1% of the applicable DCG in all cases.

5.4 Liquid Discharges—ORNL Radiological Monitoring Summary

ORNL monitors radioactivity at National Pollutant Discharge Elimination System (NPDES) outfalls that have a potential to discharge radioactivity and at in-stream monitoring stations under a radiological monitoring plan required by Part III, Section J, of the ORNL NPDES permit. The current version of the plan was implemented on November 1, 1999. Table 5.4 details the monitoring frequency and target analyses for 27 category outfalls (dry-weather component of discharge), three treatment facility outfalls, and three in-stream monitoring locations.

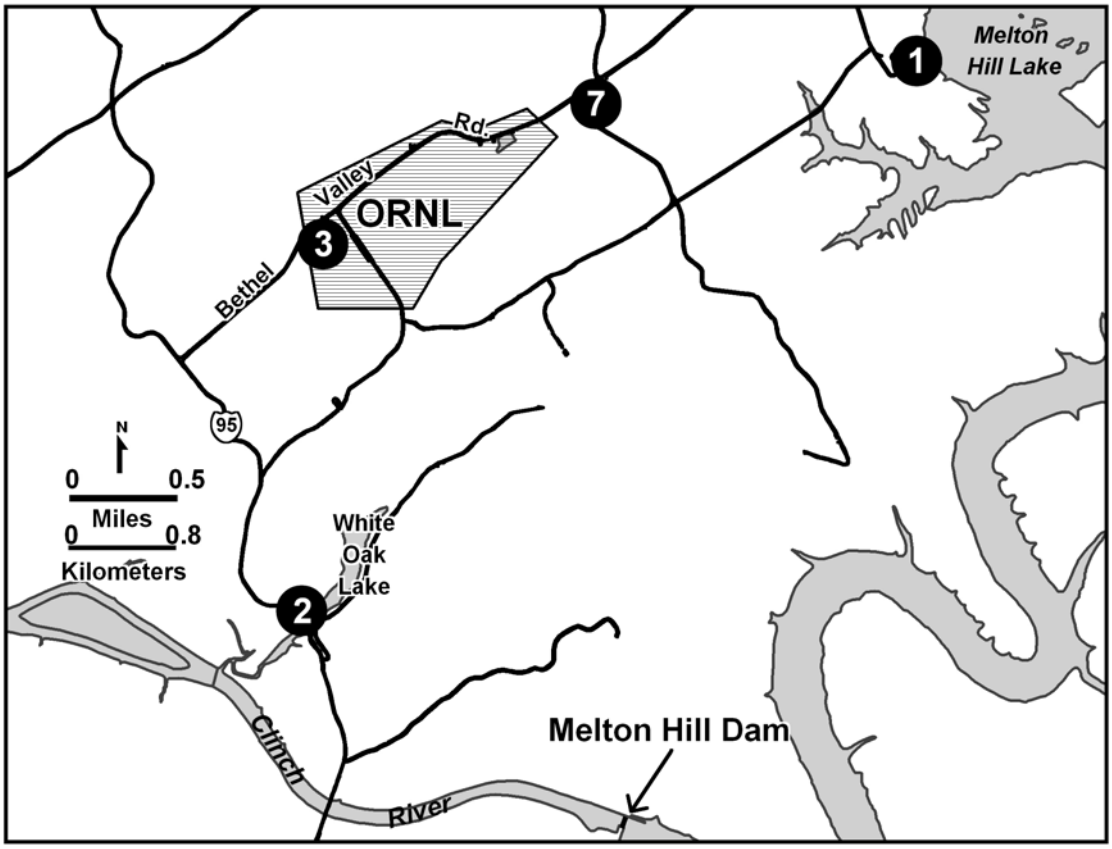


Fig. 5.5. Locations of ambient air monitoring stations at ORNL.

Category outfalls are outfalls that discharge effluents with relatively minor constituents that receive little or no treatment prior to discharge. Dry-weather discharges from category outfalls are primarily cooling water, groundwater, and steam condensate. In 2005, samples were collected at 18 of the 27 category outfalls. The remaining nine outfalls were not sampled, either because they are no longer in service, or because they were not discharging or were otherwise not able to be sampled during sampling attempts.

The three treatment facilities included in the ORNL radiological monitoring plan are the Sewage Treatment Plant, the Coal Yard Runoff Treatment Facility (CYRTF), and the Process Waste Treatment Complex (PWTC). Three in-stream locations are also monitored under the Radiological Monitoring Plan: X13 on Melton Branch, X14 on White Oak Creek (WOC), and X15 at White Oak Dam (Fig. 5.6).

The DOE DCG values are used in this section as a means of standardized comparison for effluent points with different radioisotope signatures. Annual average concentrations were compared with DCG concentrations if a DCG existed for that parameter (there are no DCGs for gross alpha and gross beta activities) and if there was at least one individual measurement that indicated detectable activity [i.e., one individual measurement where the measured concentration was greater than or equal to the measurement's minimum detectable activity (MDA)]. For analyses that cannot differentiate between two radioisotopes (e.g., $^{89/90}$Sr) and for radioisotopes that have more than one DCG for different gastrointestinal tract absorption factors, the most restrictive (lowest) DCG was used in the comparisons. DCGs are not thresholds for in-stream values but are useful as a frame of reference. The comparison of effluent and in-stream concentrations with DCGs for ingestion of water does not imply that effluents from ORNL outfalls or ORNL ambient-water-sampling stations are sources of drinking water.

In 2005, no NPDES outfall had measured annual average concentrations of radioactivity

Table 5.3. Radionuclide concentrations measured at ORNL perimeter air monitoring stations, 2005 (pCi/mL)[a]

Parameter	Average concentration	No. detected/total
Station 1		
^{7}Be	1.78E-08	1/1
^{3}H	7.31E-07	0/4
^{40}K	2.70E-07	15/26
^{234}U	1.12E-11	1/1
^{235}U	2.32E-12	0/1
^{238}U	1.58E-11	1/1
^{Tot}U	2.93E-11	1/1
Station 2		
^{7}Be	2.14E-08	1/1
^{3}H	6.09E-06	4/4
^{40}K	2.86E-07	15/26
^{234}U	1.31E-11	1/1
^{235}U	1.22E-12	0/1
^{238}U	1.47E-11	1/1
^{Tot}U	2.90E-11	1/1
Station 3		
^{7}Be	2.36E-08	1/1
^{3}H	1.96E-06	1/4
^{40}K	3.33E-07	22/26
^{234}U	7.36E-12	1/1
^{235}U	1.16E-12	0/1
^{238}U	1.59E-11	1/1
^{Tot}U	2.44E-11	1/1
Station 7		
^{7}Be	2.19E-08	1/1
^{3}H	6.83E-07	0/4
^{40}K	3.09E-07	19/26
^{234}U	1.34E-11	1/1
^{235}U	5.98E-13	0/1
^{238}U	9.26E-12	1/1
^{Tot}U	2.32E-11	1/1

1 pCi = 3.7×10^{-2} Bq.

equaling or exceeding 100% of DCG concentrations. (As required by DOE Order 5400.5, where more than one radionuclide was detected at an outfall, the DCG percentages of the individually measured radionuclides were summed and the sum of percentages was compared with 100%.) The annual average concentration of at least one radionuclide exceeded 4% of the relevant DCG concentration at seven NPDES outfalls (X01, X02, X12, 085, 204, 302, and 304) and at in-stream sampling locations X13 and X15 (Fig. 5.7). Four percent of the DCG is roughly equivalent to the 4-mrem dose limit on which the EPA radionuclide drinking water standards are based (4% of a DCG is a convenient comparison point, but it should not be concluded that ORNL effluents or ambient waters are direct sources of drinking water). The annual average concentration of $^{89/90}$Sr in the ORNL Sewage Treatment Plant Discharge (outfall X01) was 9.7% of the DCG. Concentrations of three radionuclides measured in the discharge from the PWTC (outfall X12) were greater than 4% of the DCG: ^{137}Cs (24%), $^{89/90}$Sr (9.7%), and $^{233/234}$U (4.7%). Four category outfalls had measured concentrations of a parameter that were greater than 4% of a DCG: outfall 085 ($^{89/90}$Sr, 20%), outfall 204 ($^{89/90}$Sr, 5.6%), outfall 302 ($^{89/90}$Sr, 41%) and outfall 304 ($^{89/90}$Sr, 15%). At the in-stream monitoring station on Melton Branch (Location X13), ^{3}H and $^{89/90}$Sr were measured at concentrations exceeding 4% of the DCG, 21% and 24%, respectively). At the X15 monitoring station at White Oak Dam, $^{89/90}$Sr was measured at 9.3% of the DCG.

The amounts of radioactivity in stream water passing White Oak Dam, the final monitoring point on WOC before the stream flow leaves ORNL, were calculated from concentration and flow. The total annual discharges (or amounts) of radioactivity released at White Oak Dam during each of the past 5 years are shown in Figs. 5.8 through 5.13. The amounts of radioactivity passing this monitoring station in 2005 show a decrease in levels from recent years.

Table 5.4. ORNL National Pollutant Discharge Elimination System Radiological Monitoring Plan

Location	Frequency	Gross alpha[a]	Gross beta[a]	Gamma scan	Tritium	Total rad Sr	Isotopic uranium
Outfall 001	Annually	X					
Outfall 080[b]	Monthly	X	X	X	X	X	
Outfall 081	Annually		X				
Outfall 085	Quarterly	X	X			X	X
Outfall 086[c]	When discharges		X		X		
Outfall 087	Annually		X	X			
Outfall 203[b]	Annually		X				
Outfall 204	Quarterly	X	X			X	
Outfall 205[b]	Annually		X				
Outfall 207	Quarterly	X	X	X		X	
Outfall 211	Quarterly		X			X	
Outfall 217	Annually		X				
Outfall 219	Annually		X				
Outfall 234	Annually	X					
Outfall 241[b]	Annually		X				
Outfall 265	Annually		X	X			
Outfall 281	Quarterly	X	X	X	X		
Outfall 282	Quarterly	X	X				
Outfall 284[b]	Annually		X				
Outfall 290	Annually			X			
Outfall 302	Monthly	X	X	X	X	X	
Outfall 304	Monthly	X	X	X	X	X	
Outfall 365	Quarterly	X	X				
Outfall 368	Quarterly	X	X	X			
Outfall 381[d]	Quarterly		X	X	X		
Outfall 382[e]	Annually		X	X			
Outfall 383	Annually		X		X		
Sewage Treatment Plant (X01)	Monthly	X	X			X	
Coal Yard Runoff Treatment Facility (X02)	Monthly	X	X				
Process Waste Treatment Complex (X12)	Monthly	X	X	X	X	X	X
Melton Branch 1 (X13)	Monthly	X	X	X	X	X	
White Oak Creek (X14)	Monthly	X	X	X	X	X	
White Oak Dam (X15)	Monthly	X	X	X	X	X	

[a]Isotopic analyses are performed to identify contributors to gross activities when results exceed screening criteria described in the Radiological Monitoring Plan, June 1999.

[b]No discharge present.

[c]Outfall no longer exists.

[d]Physically removed in late 2004; eliminated as part of the HFIR ponds remediation project.

[e]No longer discharges (plugged).

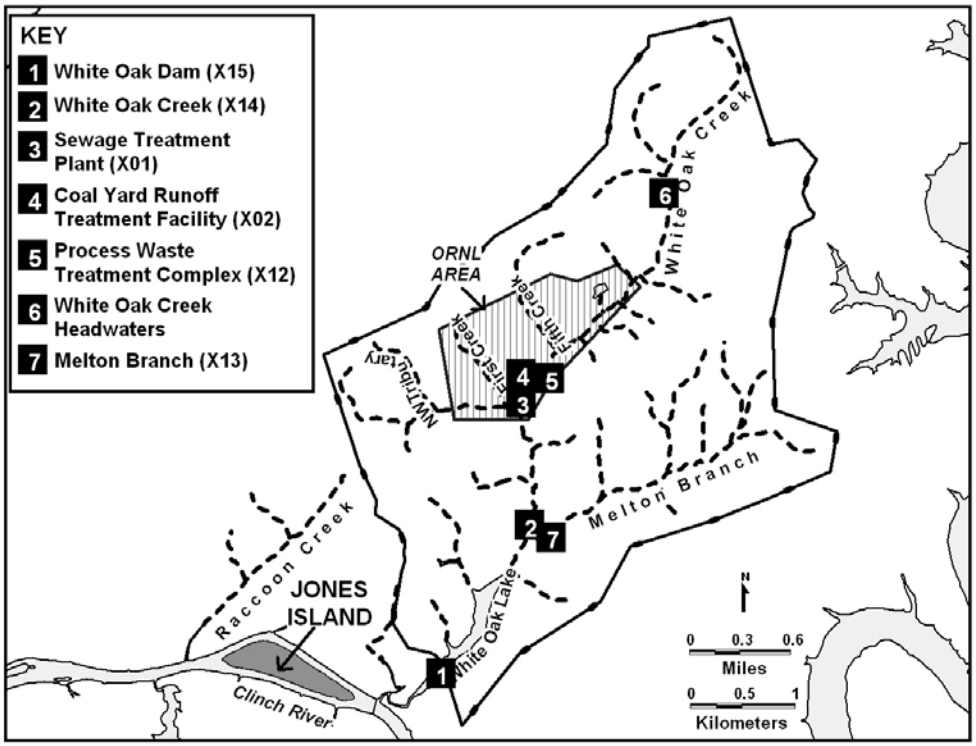


Fig. 5.6. ORNL surface water, National Pollutant Discharge Elimination System, and reference sampling locations.

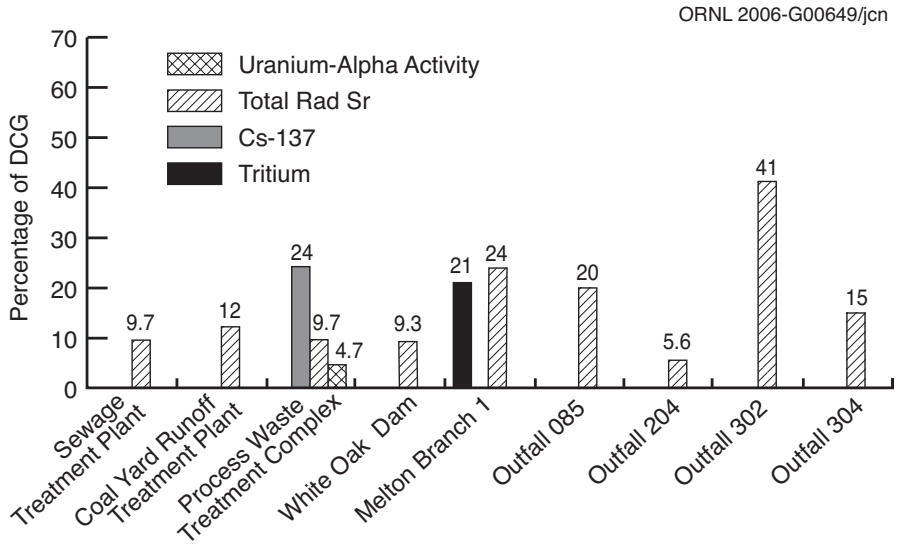


Fig. 5.7. Radionuclides at ORNL sampling sites having average concentrations greater than 4% of the relevant derived concentration guides in 2005.

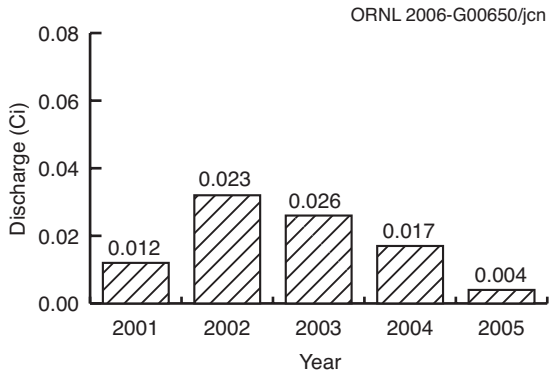


Fig. 5.8. Cobalt-60 discharges at White Oak Dam, 2001–2005. 1 Ci = 3.7 × 10^{10} Bq.

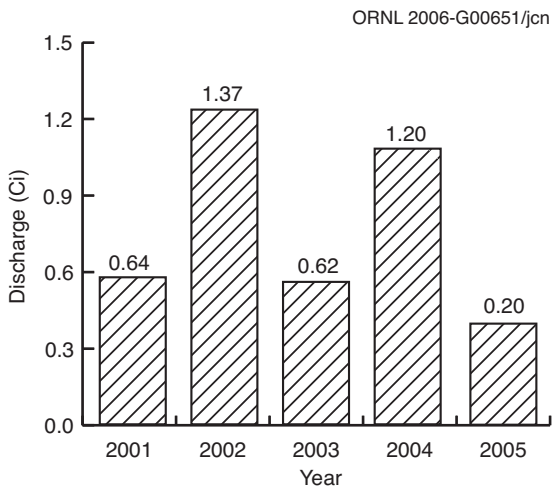


Fig. 5.9. Cesium-137 discharges at White Oak Dam, 2001–2005. 1 Ci = 3.7 × 10^{10} Bq.

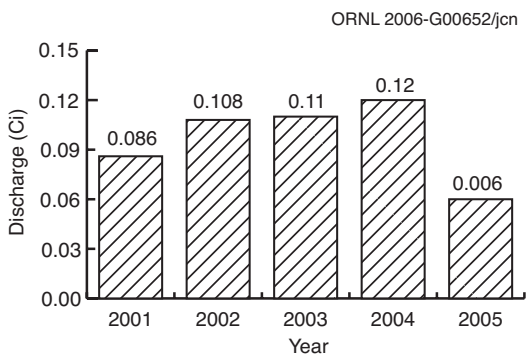


Fig. 5.10. Gross alpha discharges at White Oak Dam, 2001–2005 1 Ci = 3.7 × 10^{10} Bq.

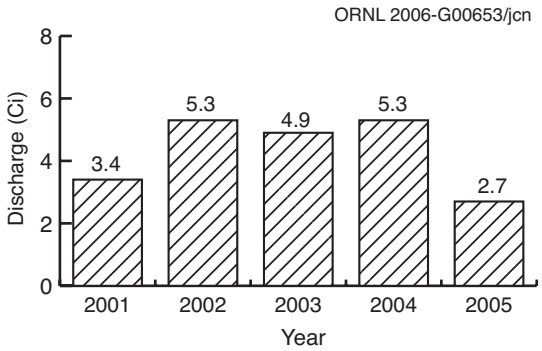


Fig. 5.11. Gross beta discharges at White Oak Dam, 2001–2005. 1 Ci = 3.7 × 10^{10} Bq.

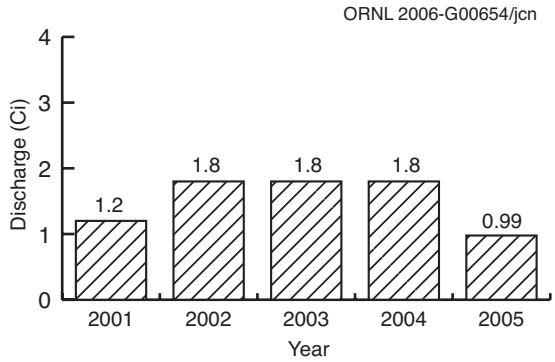


Fig. 5.12. Total radioactive strontium discharges at White Oak Dam, 2001–2005. 1 Ci = 3.7 × 10^{10} Bq.

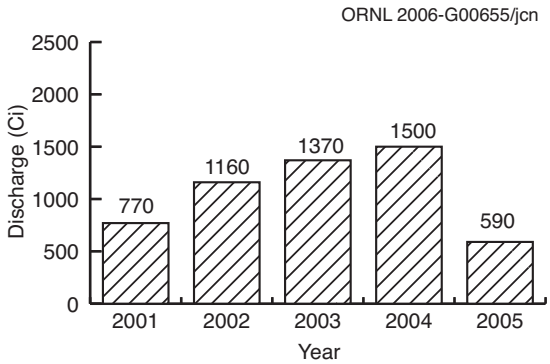


Fig. 5.13. Tritium discharges at White Oak Dam, 2001–2005. 1 Ci = 3.7 × 10^{10} Bq.

The ORNL Radiological Monitoring Plan also includes monitoring of radioactivity at category outfalls during storm conditions. There were 102 outfalls targeted for periodic storm water sampling when the plan was developed. Since that time, two of those outfalls were physically removed (outfalls 115 and 381) and another was plugged (outfall 382). The storm water outfalls were grouped into eight different categories with the knowledge that outfalls would be moved from one category to another as storm water data were collected. The storm water categories were defined by the availability of historic data and, when data were available, by the levels of radioactivity detected in past monitoring. The goal set for storm water monitoring in the Radiological Monitoring Plan is to perform monitoring at the rate of 20 outfalls per NPDES permit year (February 3 to February 2). The plan set frequency goals rather than strict requirements because opportunities for storm water sampling are dependent on the weather.

Monitoring of storm water runoff through NPDES-permitted outfalls for radioactivity is conducted on an NPDES permit-year basis; however, storm water results are discussed on a calendar year basis in this report. A total of 20 storm water outfalls were monitored in CY 2005.

When storm water monitoring locations are selected, outfalls are chosen so that various areas of the ORNL site are represented. Storm water samples are analyzed for gross alpha, gross beta, and tritium activities. A gamma scan is also routinely performed. Under the Radiological Monitoring Plan, additional analyses are added when there is enough gross alpha and/or gross beta activity in an outfall's discharges to indicate that DCG levels may be exceeded. In 2005, additional analyses were performed on samples from two outfalls—outfall 218 and outfall 288—in an attempt to identify the radioisotopes contributing to the gross alpha activities in the samples. Multiple tests were added, but for the most part, they were not successful in accomplishing that goal. The alpha-emitting radioisotopes may have been bound to sediments and not accurately measured in the analytical tests, which are more effective at measuring soluble constituents.

Of the 126 individual storm water sample results collected in 2005, 101 (80%) were less than the MDAs of the tests. Concentrations of radioactivity in storm water discharges were compared with DCGs if a DCG existed for that parameter (there are no DCGs for gross alpha and gross beta activities) and if the concentration was greater than or equal to the MDA for the measurement. No outfalls had measurements of radionuclide concentrations in storm water that were greater than 4% of DCG levels.

5.5 ORNL NPDES Summary

5.5.1 NPDES Permit Monitoring

ORNL submitted the application for renewal of NPDES Permit TN0002941 on June 1, 2001, fulfilling the requirement that an application be made 6 months prior to permit expiration. The December 6, 1996, ORNL NPDES Permit expired in December 2001, and the limits and conditions of that permit remain in effect until renewal by TDEC. Data collected as required by the permit are submitted to the state of Tennessee in the monthly NPDES Discharge Monitoring Report. The 1996 NPDES permit includes 164 separate outfalls and monitoring points.

The ORNL NPDES Permit requires that point-source outfalls be sampled before they are discharged into receiving waters or before they mix with any other wastewater stream (see Fig. 5.6). Under the existing permit, there are numeric and narrative effluent limits applied at the following locations:

- X01—Sewage Treatment Plant,
- X02—CYRTF,
- X12—PWTC,
- X13—Melton Branch (MB1),
- X14—White Oak Creek,
- X15—White Oak Dam,
- in-stream chlorine monitoring points (X16–X26),
- steam condensate outfalls,
- groundwater from building foundation drains,
- Category I outfalls (storm drains, water discharged under best management practices, groundwater, steam, and water condensate),
- Category II outfalls (storm drains, water discharged under best management practices, groundwater, steam, and water condensate),
- Category III outfalls (storm drains, water discharged under best management practices, groundwater, steam, water condensate,

cooling water, and cooling tower blowdown),
- Category IV outfalls (storm drains, water discharged under best management practices, groundwater, steam, water condensate, cooling water, and cooling tower blowdown), and
- cooling systems (cooling water and cooling tower blowdown).

Permit limits and compliance statistics are shown in Table 5.5. In-stream data collection points X-13, X-14, and X-15 are not included in the table because only flow measurements and narrative conditions are required under the ORNL NPDES Permit at those three points. Permit noncompliances in 2005 are discussed below and are shown in Appendix E.

During 2005, ORNL experienced two instances of noncompliance with numeric NPDES permit limits. Based on approximately 6500 compliance measurements and analyses, the rate of compliance with the ORNL NPDES permit was approximately 99.9%. The noncompliances occurred at an ORNL stormwater and cooling water outfall; a July 31, 2005 exceedance of a chlorine limit in a cooling water dechlorination system caused both daily and monthly average limits to be exceeded. Four other instances of NPDES permit nonconformance (not reflected in Table 5.5, as explained in the preceding paragraph) resulted when a cooling water effluent caused exceedance of temperature criteria in a receiving stream on August 25, 2005. No impacts on aquatic systems were noted in either situation. Corrective actions included repair and enhanced protection of the damaged dechlorinator and rerouting of the cooling water effluent to provide additional temperature mitigation prior to discharge.

Under the NPDES permit, ORNL conducts several monitoring plans and programs. These include the Radiological Monitoring Plan, the Chlorine Control Strategy, and the Storm Water Pollution Prevention Plan. These are discussed in the following sections.

5.5.1.1 Radiological Monitoring Plan

In 2005, ORNL continued to sample and analyze under the revised Radiological Monitoring Plan implemented on November 1, 1999. Results for the 2005 monitoring are presented in Sect. 5.4.

5.5.1.2 Chlorine Control Strategy

The NPDES permit regulates the discharge of chlorinated water at ORNL by setting either total residual chlorine concentration limits or total residual oxidant mass-loading action levels at outfalls, depending on the outfall's location and the volume of discharge. At ORNL, total residual oxidant measurements may include both chlorine and bromine residuals. Most outfalls with total residual oxidant mass-loading action levels are monitored semiannually; the rest are monitored either weekly, semimonthly, or quarterly. A number of outfalls that do not have dry-weather total residual oxidant discharges were dropped from the Chlorine Control Strategy during the duration of the NPDES permit. Outfalls included in the Chlorine Control Strategy have a mass-loading action level for total residual oxidants that requires ORNL to reduce or eliminate total residual oxidants in the discharge if they exceed the action level. The 1.2-g/day action level is calculated by multiplying the instantaneously measured concentration by the instantaneous flow rate of the outfall.

ORNL monitored 146 measurable dry-weather discharges during 2005 at 25 outfalls. No outfalls exceeded the action level. A report detailing monitoring results, corrective actions, and proposed modifications is submitted to TDEC annually.

Table 5.5. National Pollutant Discharge Elimination System (NPDES) compliance at ORNL, 2005

(NPDES permit effective February 3, 1997)

Effluent parameters[a]	Permit limits					Permit compliance		
	Monthly average (kg/d)	Daily max (kg/d)	Monthly average (mg/L)	Daily max (mg/L)	Daily min (mg/L)	Number of noncompliances	Number of samples	Percentage of compliance[b]
X01 (Sewage Treatment Plant)								
LC_{50} for *Ceriodaphnia* (%)					41.1	0	4	100
LC_{50} for fathead minnows (%)					41.1	0	4	100
Ammonia, as N (summer)	2.84	4.26	2.5	3.75		0	78	100
Ammonia, as N (winter)	5.96	8.97	5.25	7.9		0	78	100
Carbonaceous BOD	8.7	13.1	10	15		0	156	100
Dissolved oxygen					6	0	156	100
Fecal coliform (col/100 mL)			1000	5000		0	156	100
NOEC for *Ceriodaphnia* (%)					12.3	0	4	100
NOEC for fathead minnows (%)					12.3	0	4	100
Oil and grease	8.7	13.1	10	15		0	156	100
pH (std. units)				9	6	0	156	100
Total residual chlorine			0.038	0.066		0	156	100
Total suspended solids	26.2	39.2	30	45		0	156	100
X02 (Coal Yard Runoff Treatment Facility)								
LC_{50} for *Ceriodaphnia* (%)					4.2	0	4	100
LC_{50} for fathead minnows (%)					4.2	0	4	100
Copper, total			0.07	0.11		0	24	100
Iron, total			1.0	1.0		0	24	100
NOEC for *Ceriodaphnia* (%)					1.3	0	0[c]	100
NOEC for fathead minnows (%)					1.3	0	0[c]	100
Oil and grease			10	15		0	52	100
pH (std. units)				9.0	6	0	52	100
Selenium, total			0.22	0.95		0	24	100
Silver, total				0.008		0	24	100
Total suspended solids				50		0	52	100
Zinc, total			0.87	0.95		0	24	100
X12 (Process Waste Treatment Complex)								
LC50 for *Ceriodaphnia* (%)					100	0	4	100
LC50 for fathead minnows (%)					100	0	4	100

Table 5.5 (continued)

Effluent parameters[a]	Permit limits					Permit compliance		
	Monthly average (kg/d)	Daily max (kg/d)	Monthly average (mg/L)	Daily max (mg/L)	Daily min (mg/L)	Number of noncompliances	Number of samples	Percentage of compliance[b]
Cadmium, total	0.79	2.09	0.008	0.034		0	52	100
Chromium, total	5.18	8.39	0.22	0.44		0	52	100
Copper, total	6.27	10.24	0.07	0.11		0	52	100
Cyanide, total	1.97	3.64	0.008	0.046		0	4	100
Lead, total	1.3	2.09	0.028	0.69		0	52	100
Nickel, total	7.21	12.06	0.87	3.98		0	52	100
NOEC for *Ceriodaphnia* (%)					30.9	0	4	100
NOEC for fathead minnows (%)					30.9	0	4	100
Oil and grease	30.3	45.4	10	15		0	52	100
pH (std. units)				9.0	6.0	0	156	100
Silver, total	0.73	1.3		0.008		0	52	100
Temperature (ºC)				30.5		0	156	100
Total toxic organics		6.45		2.13		0	12	100
Zinc, total	4.48	7.91	0.87	0.95		0	52	100
Instream chlorine monitoring points								
Total residual oxidant			0.011	0.019		0	264	100
Steam condensate outfalls								
pH (std. units)				9.0/8.5	6.0/6.5	0	12	100
Groundwater/ pumpwater outfalls								
pH (std. units)				9.0/8.5	6.0/6.5	0	4	100
Cooling tower blowdown outfalls								
pH (std. units)				9.0	6.0	0	4	100
Category I outfalls								
pH (std. units)				9.0	6.0	0	20	100
Category II outfalls								
pH (std. units)				9.0	6.0	0	20	100
Category III outfalls								
pH (std. units)				9.0	6.0	0	49	100
Category IV outfalls								
pH (std. units)				9.0	6.0	0	333	100
Cooling tower blowdown/ cooling water outfalls								
pH (std. units)				9.0	6.0	0	48	100
Total residual oxidant			0.011	0.019		2[d]	49	96

[a]LC_{50} = the concentration (as a percentage of full-strength wastewater) that kills 50% of the test species in 96 h. NOEC = no-observed-effect concentration; the concentration as a percentage of full-strength wastewater that caused no reduction in *Ceriodaphnia* survival or reproduction or fathead minnow survival or growth.

[b]Percentage compliance = 100 – [(number of noncompliances/number of samples) * 100].

[c]Insufficient discharge for chronic test and determination of no-observed-effect concentration for each of the quarterly tests

[d]One incident caused two reportable noncompliances.

5.5.1.3 Storm Water Pollution Prevention Plan

The Storm Water Pollution Prevention Plan is a requirement of the ORNL NPDES Permit to document existing material management practices and to evaluate the vulnerability of those practices in contributing pollutants to area streams via storm water runoff. The plan consists of four major components:

1. assessment and mapping of outdoor material storage/handling at ORNL,
2. characterization of storm water runoff by monitoring,
3. training of employees, and
4. implementation of measures to minimize storm water pollution in areas of ORNL that may be vulnerable.

These four components of the plan were initiated in 1997 and are reviewed and updated by the facility at least annually. The plan was updated in June 2005 to include observations and data from the previous year. ORNL has a storm water pollution prevention program that includes an inspection program, the analysis of storm water data collected as part of the NPDES program, training for ORNL employees and contractors, and an annual review and revision of the program document. (The document is available to personnel on the ORNL internal web.)

For sampling purposes, ORNL categorizes its storm water outfalls into four broad groups based on common land uses or pollutant sources and storm water pollutant potential. These four groups are further subdivided based on permit categorizations that have different monitoring schedule requirements. The permit requires that Category I and II outfalls be characterized over a 5-year period and that Category III and IV outfalls be characterized over a 3-year period. The outfalls chosen to be sampled were thought to be representative of the group or were thought to be more vulnerable to runoff pollution. Other factors considered in selecting representative outfalls from each group include interest in a particular runoff quality at an outfall and ease of obtaining a representative sample. A rotation of representative outfalls occurs each sampling period as directed by the permit. The results of the storm water outfall effluent sampling as of 2005 are provided in Attachment 6.0 of the *Storm Water Pollution Prevention Plan.*

The EPA Nationwide Urban Runoff Program was developed to expand the understanding of urban runoff pollution by instituting data collection and applied research projects in the urban areas of the United States. Urban stormwater runoff pollutant-loading factors for ten standard water quality constituents, called "event mean concentrations" (EMCs), were developed for the 1983 program's final report. Program findings were updated in 1999 by using results of storm water data collected by the U.S. Geological Survey and the NPDES Storm Water Program to refine the EMCs.

In a comparison of recent ORNL data from 18 storm water outfalls with data from the Nationwide Urban Runoff Program, most values for the 10 water quality constituents measured are well below the EMCs. Patterns of values exceeding the EMCs can be generalized by exceedances of copper or zinc. Copper is found naturally in the soils and could also occur from coal-burning activities or corrosion of copper pipes. Zinc can be attributed to vehicular degradation. There were also a few exceedances of suspended solids that can probably be attributed to the numerous construction projects in and around the main ORNL campus.

5.5.2 Results and Progress in Implementing Programs and Corrective Actions: ORNL Sink and Drain Survey Program

In 1997, ORNL completed a comprehensive verification of the routing of all wastewater discharges from points of entry such as sinks and floor drains. As a result, more than 9000 sink and drain records were produced and are stored in a central database. In 2005, an annual division-by-division recertification of ORNL sinks and drains was continued to ensure discharges are routed to the proper wastewater collection systems. Program management continues to communicate sink and drain responsibilities to the ORNL site population.

5.6 ORNL Wastewater Biomonitoring

Under the NPDES permit, wastewaters from the Sewage Treatment Plant, the CYRTF, and

the PWTC were evaluated for toxicity. The results of the toxicity tests of wastewaters from the three treatment facilities are given in Table 5.6, which provides, for each wastewater location, the month the test was conducted, the wastewater's no-observed-effect concentration (NOEC), and the concentration that kills 50% of the test organisms (LC_{50}) for fathead minnows (*Pimephales promelas*) and daphnia (*Ceriodaphnia dubia*). The NOEC is the highest concentration tested that does not significantly reduce survival or growth of fathead minnows or survival or reproduction of *Ceriodaphnia*. The 96-h LC_{50} is the concentration of wastewater that kills 50% of the test organisms in 96 h. The NPDES permit defines the limits for the biomonitoring tests. For the X01 (Sewage Treatment Plant) discharge, toxicity is demonstrated if more than 50% lethality of the test organisms occurs in 96 h in 41.1% effluent or if the NOEC is less than 12.3%. For the X02 discharge (CYRTF), toxicity is demonstrated if more than 50% lethality of the test organisms occurs in 96 h in 4.2% effluent or if the NOEC is less than 1.3%. Because of the batch mode of discharge at the CYRTF, the limit for the NOEC applies only if the facility discharges for a sufficient length of time. For the X12 discharge (PWTC), toxicity is demonstrated if more than 50% lethality of the test organisms occurs in 96 h in 100% effluent (LC_{50}) or if the NOEC is less than 30.9%.

During 2005, the Sewage Treatment Plant, CYRTF, and PWTC were each tested four times. Numeric biomonitoring limits in the NPDES permit were not exceeded during 2005.

5.7 ORNL Biological Monitoring and Abatement Program

As a condition of the NPDES permit issued to ORNL in April 1986, the Biological Monitoring and Abatement Program (BMAP) was set forth to assess the condition of aquatic life in WOC, the Northwest Tributary of WOC, Melton Branch, Fifth Creek, and First Creek (Loar et al. 1991); the BMAP continued as a condition of the most recent NPDES permit that was effective February 3, 1997 (Kszos et al. 1997). The program addresses the following objectives as described in the NPDES permit part III (I):

- Temperature loadings shall be within state water criteria for protection of fish and aquatic life for warm summer conditions. This should be verified and reported annually (see Table 5.5).
- In-stream water analysis for mercury shall be part of the BMAP so that it can be determined whether mercury at the site is being contributed to the stream and, if so, whether it will impact fish and aquatic life or violate the recreation criteria.
- Sediment and oil and grease from storm discharges shall not create stream impacts.
- The status of polychlorinated biphenyl (PCB) contamination in fish tissue in the WOC watershed shall be determined.
- The Chlorine Control Strategy's protection of the stream in the main plant area shall be assessed.
- In addition, the BMAP shall continue studies evaluating the receiving streams' biological communities throughout the duration of the permit.

5.7.1 Bioaccumulation Studies

The bioaccumulation task for the BMAP addresses two NPDES permit requirements at ORNL: (1) evaluate whether mercury at the site is contributing to a stream so that it will impact fish and aquatic life or violate the recreational criteria (in-stream water analyses for mercury should be part of this activity), and (2) monitor the status of PCB contamination in fish tissue in the WOC watershed.

5.7.1.1 Mercury in Water

Water samples were collected from WOC at four sites on six occasions in FY 2005. Stream conditions were representative of seasonal baseflow conditions (dry weather, clear flow) at the time of the sampling on all dates. However, the sample collection in FY 2005 was conducted 1 week after a large (~12-cm) rainfall associated with the remnants of a hurricane. Although stream flow was not turbid, baseflow was higher than typical for late summer.

The spatial pattern of aqueous mercury in WOC showed a clear pattern of decreasing concentration with distance from the main ORNL complex (Fig. 5.14), as it has in previous monitoring. Total waterborne mercury in WOC above the PWTC [WOC kilometer (WCK) 4.1] exceeded the Tennessee Water Quality Standard of

Table 5.6. Toxicity test results of ORNL wastewaters, 2005

Test date	Test species	NOEC[a]	LC_{50}[b]
	Sewage Treatment Plant (outfall X01)		
February	*Ceriodaphnia*	<9.8[c]	>41.1
	Fathead minnow	41.1	>41.1
May	*Ceriodaphnia*	41.1	>41.1
	Fathead minnow	41.1	>41.1
August	*Ceriodaphnia*	41.1	>41.1
	Fathead minnow	41.1	>41.1
November	*Ceriodaphnia*	41.1	>41.1
	Fathead minnow	41.1	>41.1
	Coal Yard Runoff Treatment Facility (outfall X02)		
February	*Ceriodaphnia*	NA[d]	>4.2[e]
	Fathead minnow	NA[d]	>4.2[e]
May	*Ceriodaphnia*	NA[d]	>4.2
	Fathead minnow	NA[d]	>4.2
August	*Ceriodaphnia*	NA[d]	>4.2[e]
	Fathead minnow	NA[d]	>4.2[e]
November	*Ceriodaphnia*	NA[d]	>4.2[e]
	Fathead minnow	NA[d]	>4.2[e]
	Process Waste Treatment Complex (outfall X12)		
February	*Ceriodaphnia*	30.9	>100
	Fathead minnow	100	>100
May	*Ceriodaphnia*	100	>100
	Fathead minnow	100	>100
August	*Ceriodaphnia*	100	>100
	Fathead minnow	100	>100
November	*Ceriodaphnia*	100	>100
	Fathead minnow	100	>100

[a]NOEC = no-observed-effect concentration; the concentration (as percentage of full-strength wastewater) that caused no reduction in *Ceriodaphnia* survival or reproduction or fathead minnow survival or growth.

[b]LC_{50} = the concentration (as percentage of full-strength wastewater) that kills 50% of the test species in 96 h.

[c]This low value was determined to be the result of unusual test circumstances (abnormally successful reproduction in control organisms that led to a statistical indication of toxicity), rather than actual effluent toxicity.

[d]Insufficient duration of discharge for chronic test and determination of NOEC.

[e]48-h LC_{50}.

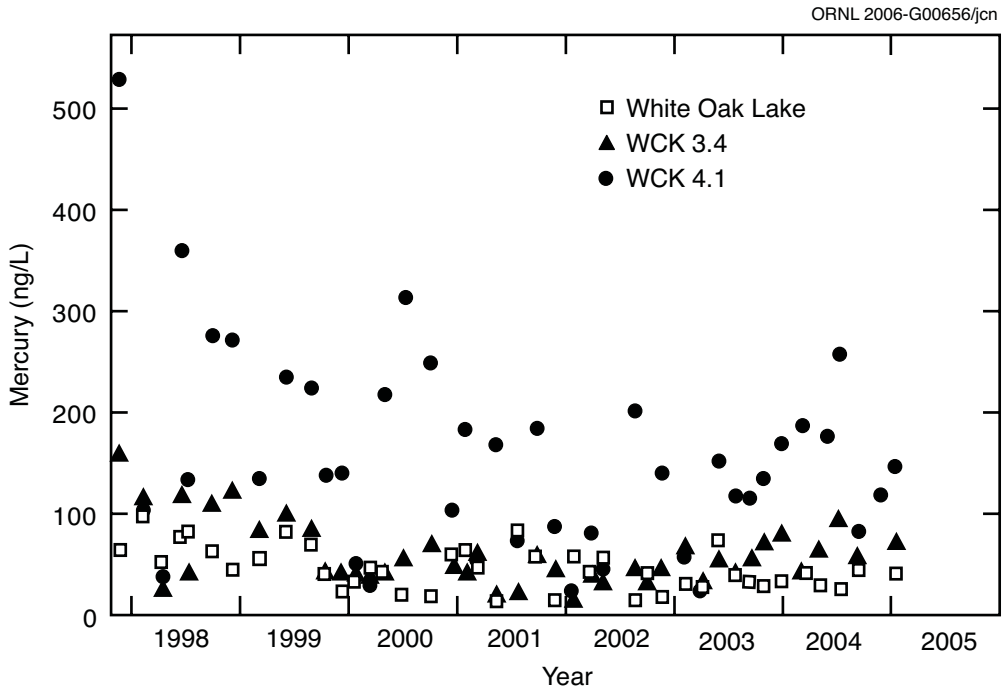


Fig. 5.14. Total aqueous mercury concentrations at sites in White Oak Creek downstream from ORNL, 1998–2005. (WCK = White Oak Creek kilometer.)

51 ng/L on all sampling dates in FY 2005. At the Bethel Valley Integration Point (WCK 3.4, near the 7500 Bridge), the mercury concentration exceeded the standard on five of six sampling dates. In White Oak Lake, mercury concentrations exceeded the Tennessee Water Quality Standard on two of six dates. The annual mean mercury concentration in water at the upstream reference site for WOC (WCK 6.8) was typical of uncontaminated streams, ranging from 1 to 5 ng/L. (Fig. 5.14).

The increase in mercury concentrations at WCK 4.1 between September 2004 and January 2005 roughly coincided with the occurrence of unusually high mercury concentrations in samples taken by Bechtel Jacobs Corporation (BJC) at WCK 3.4. (However, the BMAP grab samples were not duplicates of the BJC samples and thus would not be expected to produce identical results). The longitudinal pattern of mercury concentration in WOC observed in the most recent monitoring continued to resemble the historical pattern, and while the September–January samples may suggest a trend, the values were not atypical of previous monitoring.

Bioaccumulation

Fish were collected from WOC for contaminant analysis in the spring of 2005. To provide data directly applicable to assessing human health concerns, redbreast sunfish (*Lepomis auritus*) were collected from WCK 2.9, and bluegill (*Lepomis macrochirus*) and largemouth bass (*Micropterus salmoides*) were collected from WCK 1.5 (White Oak Lake). Collections were restricted to fish of a size large enough to be kept by sport fisherman (> 50 g for sunfish, and > 500 g for bass). Fillet tissue was taken from six individual fish of each species for both mercury and PCB analysis. Stoneroller minnows (*Campostoma oligolepis*), a forage species that readily accumulates particle-associated contaminants such as PCBs, were collected at WCK 3.5 to provide a measure of the possible exposure of fish-eating wildlife to PCBs. For stonerollers, 10 whole-body fish made up each of three composite samples analyzed.

Mercury. Mean total Hg concentrations in WOC fish collected in 2005 are reported in Table 5.7. Redbreast sunfish from WCK 2.9 were approximately four-fold higher in average Hg concentration (0.35 ± 0.05, μg/g ± SE) than Hinds Creek redbreast sunfish (0.09 ± 0.01

Table 5.7. Total mercury and PCB (Aroclor 1254 + 1260) concentrations in fish (mean ± SE; range in parenthesis) from the White Oak Creek watershed and a reference stream, Hinds Creek, April 2005

Sunfish and bass concentrations are means of six individual fish fillet samples. Stoneroller minnow concentrations represent mean concentrations of three composites of ten fish.

Site	Species	Mercury (μg/g)	PCB (μg/g)
WCK 3.5	Stoneroller minnows	Not analyzed	1.69 ± 0.08
WCK 2.9	Redbreast sunfish	0.35 ± 0.05 (0.27–0.54)	0.37 ± 0.07 (0.21–0.69)
WCK 1.5	Bluegill sunfish	0.13 ± 0.02 (0.08–0.17)	0.73 ± 0.25 (0.15–1.64)
	Largemouth bass	0.38 ± 0.08 (0.28–0.74)	1.38 ± 0.29 (0.52–2.57)
Hinds Creek	Redbreast sunfish	0.09 ± 0.01 (0.04–0.10)	<0.03
	Stoneroller minnows	Not analyzed	0.05 ± 0.01

μg/g). Concentrations of Hg in bluegill collected further downstream in White Oak Lake were far lower than at the upstream site, with Hg concentrations approaching those at the reference stream (0.13 ± 0.02 μg/g). Concentrations of Hg in largemouth bass from WCK 1.5 reflected their higher position in the food chain, averaging 0.38 ± 0.08 μg/g. Three (of 18) fish from the WOC watershed exceeded 0.5 μg/g, the Hg level currently used by the state of Tennessee in issuing fish consumption advisories. Three of six redbreast sunfish from WCK 2.9, and four of six largemouth bass from WCK 1.5 exceeded EPA's Hg fish tissue criterion for methyl mercury of 0.3 mg/kg (ppm): no bluegill collected from WCK 1.5 in 2005 exceeded this level.

Mean total Hg concentrations in fish sampled in 2005 were slightly lower than 2004 levels at all sites monitored (Fig. 5.15). Since 1998, a modest increase in Hg concentrations in fish (1.5- to 2-fold) is evident.

PCBs. Mean PCB concentrations in WOC fish collected in 2005 are reported in Table 5.7. The mean PCB concentrations in sunfish from WCK 2.9 and WCK 1.5 were 0.37 ± 0.07 μg/g and 0.73 ± 0.25 μg/g respectively. These levels are relatively high for short-lived, lipid-poor fish such as sunfish. Largemouth bass from WCK 1.5 typically have substantially higher levels of PCBs and averaged 1.38 ± 0.29 μg/g in 2005. Reference site sunfish analyzed at the same time had average PCB concentrations of <0.03 μg/g. PCB concentrations in stonerollers collected near the main ORNL campus averaged 1.69 ± 0.08 μg/g. Although resuspension of sediments in White Oak Lake and food chain factors undoubtedly affect PCB levels in largemouth bass, the presence of high concentrations of PCBs in stonerollers in WOC near ORNL indicates the likelihood of continuing inputs to the stream.

Mean PCB concentrations in 2005 were higher than in 2004 at both sites in all species but were well within historical ranges (Figs. 5.16 and 5.17). The dramatic year-to-year differences in largemouth bass concentrations (Fig. 5.17) are most likely due to annual changes in prey. Gizzard shad and bluegill are favorite prey species for bass, but they differ greatly in their PCB concentrations (shad are lipid-rich and can accumulate higher levels of PCBs).

5.7.2 Ecological Surveys

5.7.2.1 Benthic Macroinvertebrate Communities

Monitoring of the benthic macroinvertebrate communities in WOC, First Creek, and Fifth Creek continued in 2005. Benthic macroinvertebrate samples are collected at sites upstream and downstream of the influence of ORNL operations. These sites include impacted and unimpacted (reference site) locations. The objectives of this activity are to (1) help assess ORNL's compliance with the current NPDES permit requirements and (2) evaluate and verify the effectiveness of pollution abatement and remedial actions taken at ORNL.

The benthic macroinvertebrate communities in First Creek, Fifth Creek, and WOC down

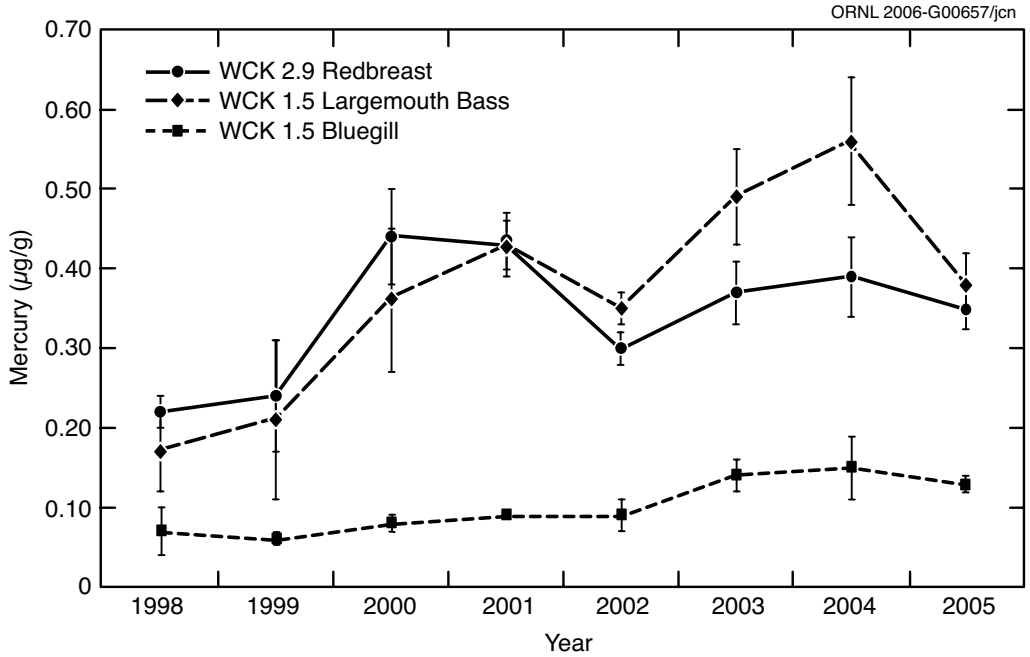


Fig. 5.15. Mean mercury concentrations (μg/g, ± SE) in fish fillet collected from the WOC watershed, 1998–2005.

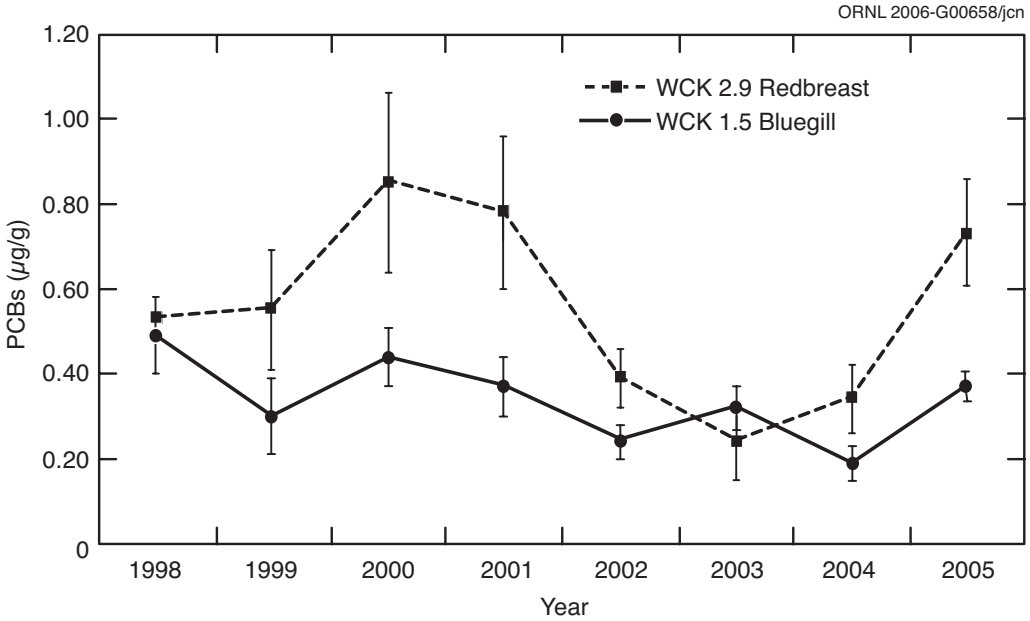


Fig. 5.16. Mean total PCB concentrations (μg/g, ± SE) in sunfish fillet collected from the WOC watershed, 1998–2005.

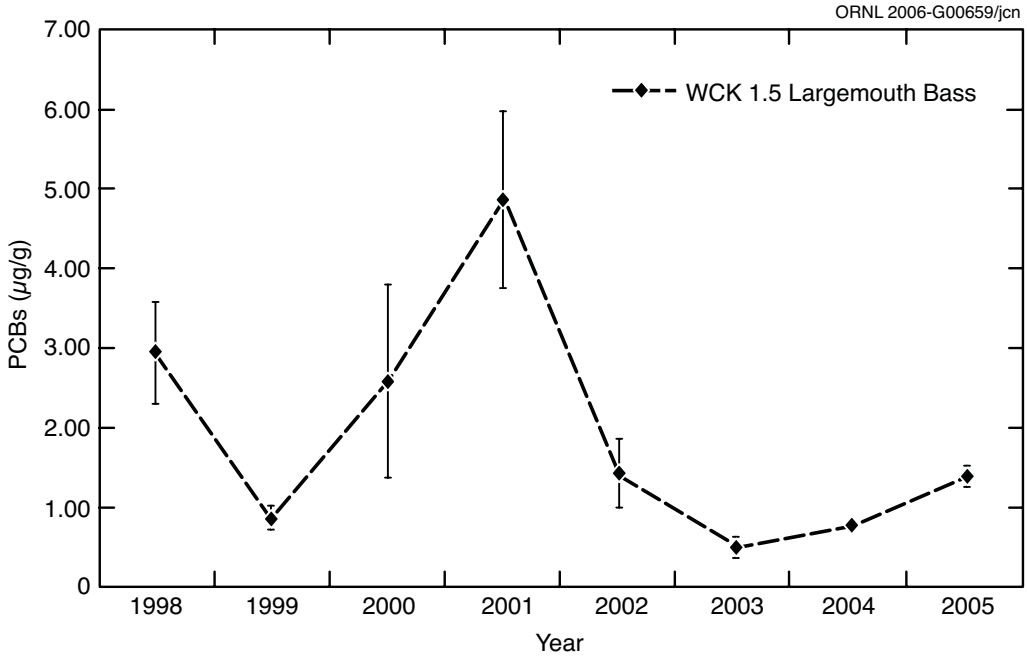


Fig. 5.17. Mean total PCB concentrations (μg/g, ± SE) in largemouth bass fillets collected from WCK 1.5 (White Oak Lake), 1998–2005.

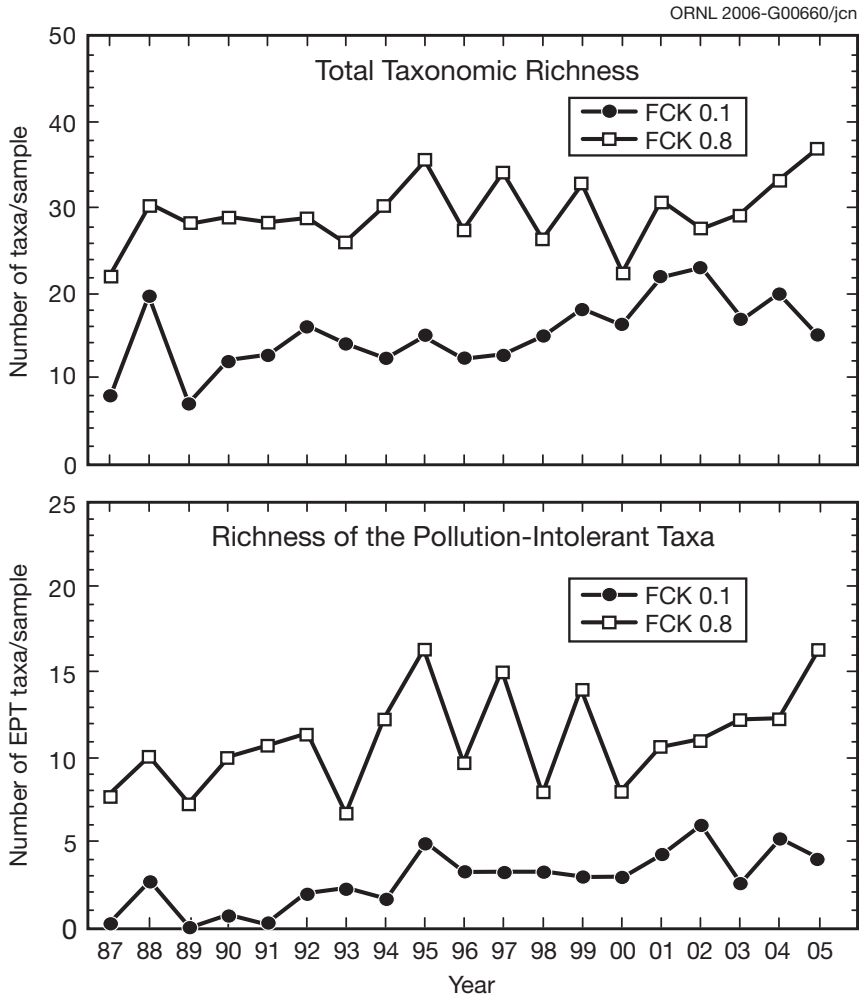
stream of effluent discharges have recovered significantly since 1986, but characteristics of ecological impairment remain (Figs. 5.18, 5.19, and 5.20). Relative to reference sites, total taxonomic richness and richness of the pollution-intolerant taxa [i.e., Ephemeroptera, Plectoptera, and Trichoptera (EPT) richness] continue to be low at the downstream sites. The macroinvertebrate community in lower First Creek (First Creek kilometer 0.1) appears to have stabilized since the mid-1990s, with total taxa richness ranging from approximately 15 to 20 taxa/sample during this period, and richness of the pollution-intolerant taxa ranging from about 3 to 5 EPT taxa/sample (Fig. 5.18). It remains unclear if the consecutive declines in richness of the pollution-intolerant taxa that were observed at Fifth Creek kilometer (FFK) 0.2 in 2003 and 2004 (J. G. Smith et al., Biannual ORNL BMAP Progress Report submitted to C. K. Valentine, May 19, 2005) were caused by natural changes in environmental or biological conditions (e.g., abnormally low or high precipitation) or an unidentified impact (Fig. 5.19). However, results for FFK 0.2 in 2005 suggested that the condition of the invertebrate community was comparable to the period prior to 2003.

The macroinvertebrate community at WOC immediately adjacent to the main ORNL campus (WCK 3.9) showed little change in 2005 relative to 2004, suggesting that recovery at this site may have slowed (Fig. 5.20). The macroinvertebrate community at WCK 2.3 continued to exhibit extensive inter-annual change, with no evidence that significant changes occurred in April 2005 (Fig. 5.20). Total taxa richness and richness of the pollution-intolerant taxa at WCK 6.8 were well within that site's historical ranges and only slightly lower than at Walker Branch kilometer 1.0.

The density of the snail, *Elimia*, appears to have increased slightly at WCK 6.8 and WCK 3.9 in 2005 (i.e., ~11 individuals/0.1 m^2); however, their density at WCK 6.8 remains below the average of 37 individuals/0.1 m^2 present before 2001 (Fig. 5.21). Although *Elimia* density was slightly lower at FCK 0.1 in 2005, it remained within the range observed since the mid-1990s (Fig. 5.21).

5.7.2.2 Fish Communities

Monitoring of the fish communities in WOC and its major tributaries continued in 2005. Samples were taken at 11 sites in WOC watershed in the spring and fall. Mill Branch, a stream located on the north side of Pine Ridge within the city of Oak Ridge, was also sampled as a reference site.

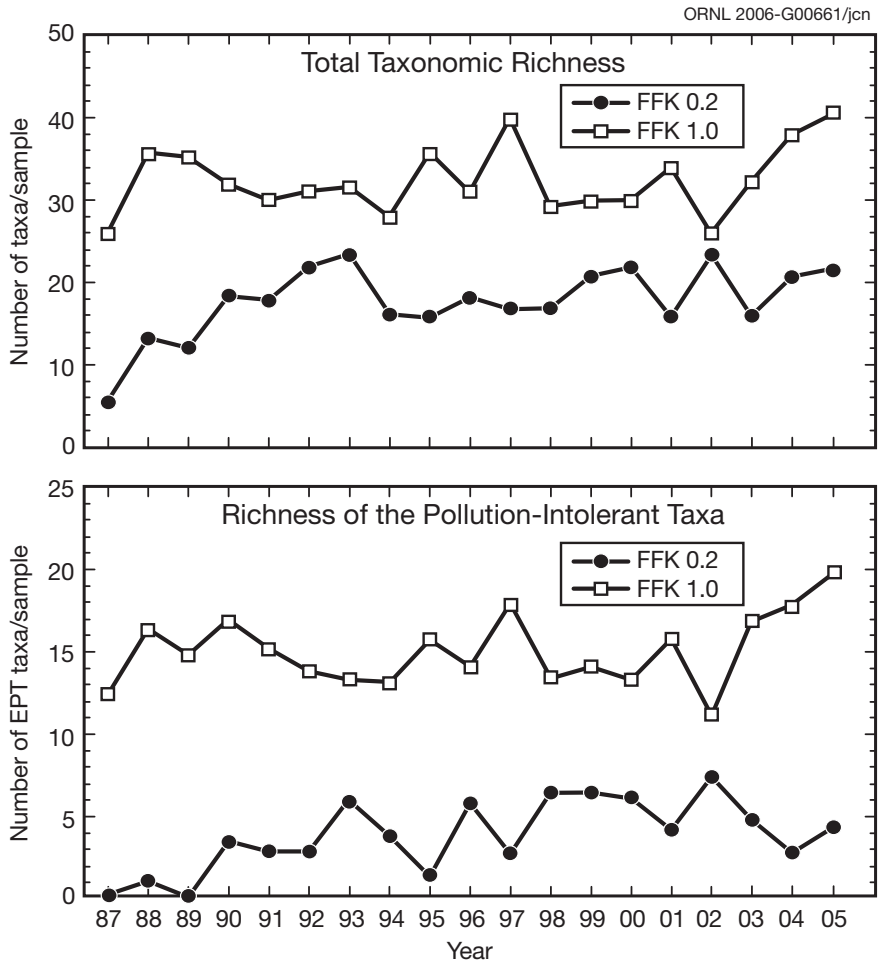


FCK - First Creek kilometer
EPT - Ephemeroptera, Plecoptera, and Trichoptera

Fig. 5.18. Taxonomic richness (top) and richness of the pollution-intolerant taxa (bottom) of the benthic macroinvertebrate community in First Creek, April sampling periods, 1987–2005. (FCK = First Creek kilometer. EPT = Ephemeroptera, Plecoptera, and Trichoptera. FCK 0.8 = reference site.)

In WOC, the fish community continued to display characteristics of degraded conditions, with sites closest to the outfalls having lower species richness (number of species), fewer pollution-sensitive species, more pollution-tolerant species, and elevated density (number of fish per square meter) compared with similar-sized reference streams. After decreasing in the early 2000s, densities at WOC sites have generally stabilized over the past couple of years, although at most sites they remain ~2 times higher than in respective reference sites (Fig. 5.22). In the past, these sites had very high densities (~14–17 fish/m2) that were at least tenfold higher than at the larger reference sites. Often in recovering streams, as fish density declines, species richness will increase, reflecting an overall improvement. However, in WOC, there has not been a corresponding increase in species richness as density has decreased. The low species richness seen in WOC watershed, relative to off-site reference locations, is partially a result of barriers that limit immigration of new species from the Clinch River drainage.

Generally, the fish communities in tributary sites adjacent to and downstream of ORNL outfalls remained somewhat impacted in 2005 relative to reference streams or upstream sites.



FFK - Fifth Creek kilometer
EPT - Ephemeroptera, Plecoptera, and Trichoptera

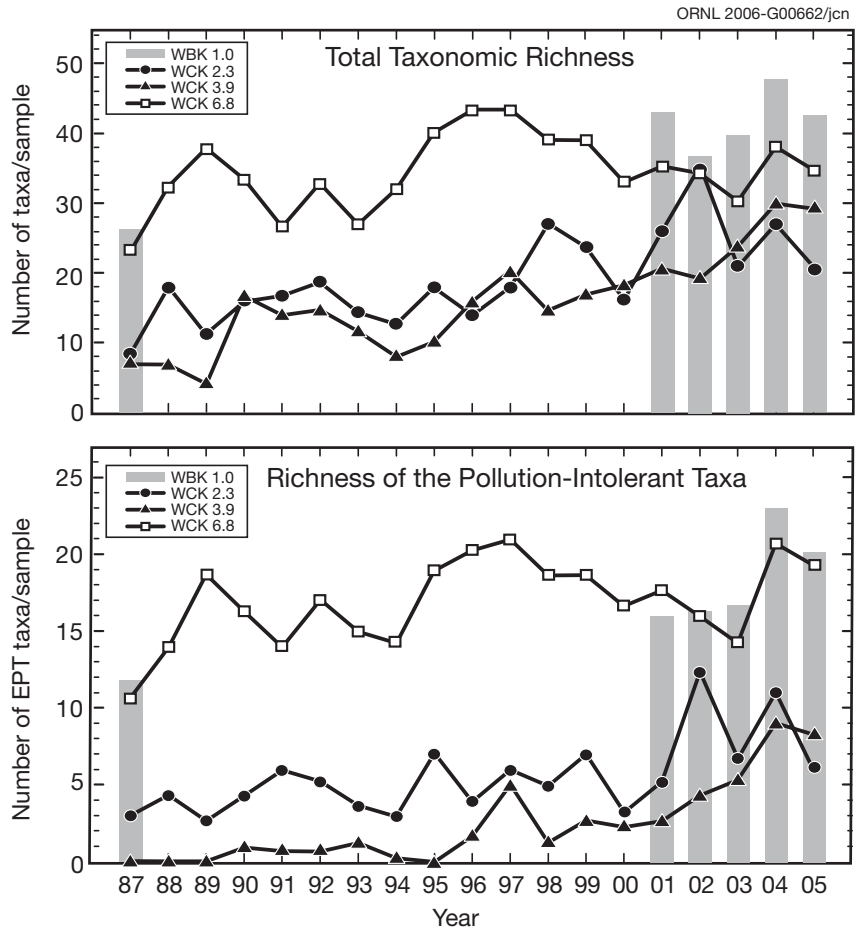
Fig. 5.19. Taxonomic richness (top) and richness of the pollution-intolerant taxa (bottom) of the benthic macroinvertebrate community in Fifth Creek, April sampling periods, 1987–2005. (FFK = Fifth Creek kilometer. EPT = Ephemeroptera, Plecoptera, and Trichoptera. FFK 1.0 = reference site.)

Species richness of fish in tributaries to WOC remained slightly lower in 2005 relative to reference streams not in the WOC watershed. The primary difference between these tributaries and their reference streams is the absence of pollution-sensitive species, such as darters, from the tributaries. The density of fish communities of First Creek showed little change in 2005 relative to 2004 (Fig. 5.23) but has increased modestly in lower Fifth Creek (Fig. 5.24). Compared with previous years, fish density in Melton Branch (Melton Branch kilometer 1.4) has been higher in the most recent sampling periods (Fig. 5.25).

5.8 ORNL Surface Water Monitoring at NPDES Reference Location

WOC headwaters were monitored in 2005 as a background or reference location for ORNL NPDES surface water monitoring.

In an effort to provide a basis for evaluation of analytical results and for assessment of nonradiological surface water quality, Tennessee General Water Quality Criteria have been used as reference values. The criteria for fish and aquatic life have been used at WOC headwaters. [See Appendix D, Table D.2, for Tennessee General Water Quality Criteria for all parame-



WBK - Walker Branch kilometer
WCK - White Oak Creek kilometer
EPT - Ephemeroptera, Plecoptera, and Trichoptera

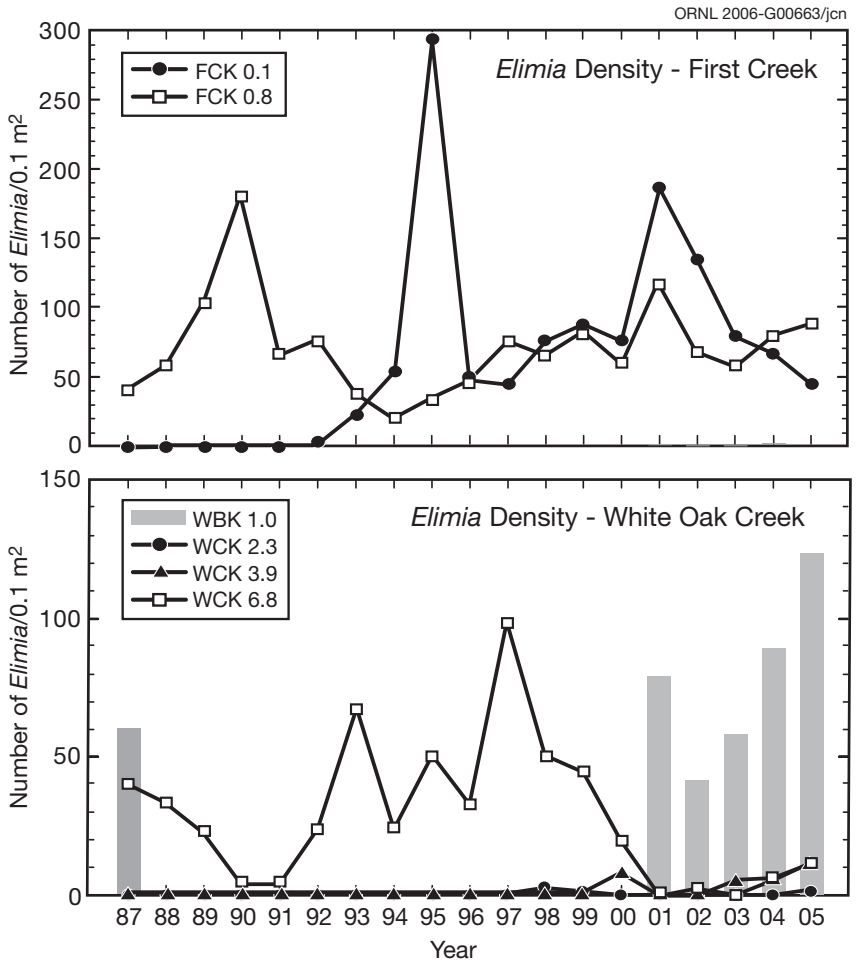
Fig. 5.20. Taxonomic richness (top) and richness of the pollution-intolerant taxa (bottom) of the benthic macroinvertebrate communities in White Oak Creek, April sampling periods, 1987–2005. WCK = White Oak Creek kilometer; WBK = Walker Branch kilometer. EPT = Ephemeroptera, Plecoptera, and Trichoptera. WBK 1.0 = reference site.

ters in water. See Tables 2.3 and 3.4 in *Environmental Monitoring on the Oak Ridge Reservation: 2005 Results* (DOE 2006a) for surface water analyses.]

5.9 ORNL Surface Water Surveillance Monitoring

The ORNL surface water monitoring program includes sample collection and analysis from 18 locations at ORNL and around the ORR. This program is conducted in conjunction with the ORR surface water monitoring activities discussed in Sect. 7.4 to enable an assessment of the impacts of past and current DOE operations on the quality of local surface water. These programs are conducted in addition to surface water monitoring required by NPDES permits at ORNL facilities; sampling location, frequency, and analytical parameters vary among them. Sampling locations include streams downstream of ORNL waste sources, reference points on streams and reservoirs upstream of waste sources, and public water intakes (see Fig. 5.26).

Sampling frequency and parameters vary by site. Grab samples are collected and analyzed for general water quality parameters at all locations and all are screened for radioactivity and analyzed for specific radionuclides when appropri-



FCK - First Creek kilometer
WBK - Walker Branch kilometer
WCK - White Oak Creek kilometer

Fig. 5.21. Density (number/0.1 m^2) of the snail *Elimia* in White Oak Creek, First Creek and Walker Branch, April sampling periods, 1987–2005. FCK = First Creek kilometer; WBK = Walker Branch kilometer; WCK = White Oak Creek kilometer. Fifth Creek excluded because Elimia rarely occurs in that stream.

ate. White Oak Lake at White Oak Dam is also checked for volatile organic compounds (VOCs), PCBs, and metals. Table 5.8 lists the specific locations and their sampling frequencies and parameters.

Ten of the 18 sampling locations are classified by the state of Tennessee for certain uses (e.g., domestic water supplies or recreational use). Tennessee water quality criteria for domestic water supplies, for freshwater fish and aquatic life, and for recreation (water and organisms) are used as references for locations where applicable. The Tennessee water quality criteria do not include criteria for radionuclides.

5.9.1 Results

Radionuclides were detected above MDAs at all surface water locations in 2005. The levels of gross beta, total radioactive strontium, and tritium continue to be highest at Melton Branch kilometer (MEK) 0.2, WOC at White Oak Dam (WCK 1.0), and WCK 2.6. These data are consistent with historical data and with the processes or legacy activities nearby or upstream from these locations.

Remediation efforts by BJC, including removal of contaminated soil in the North Tank Farm and pumping groundwater from Well 4411 to a treatment system, have resulted in decreases

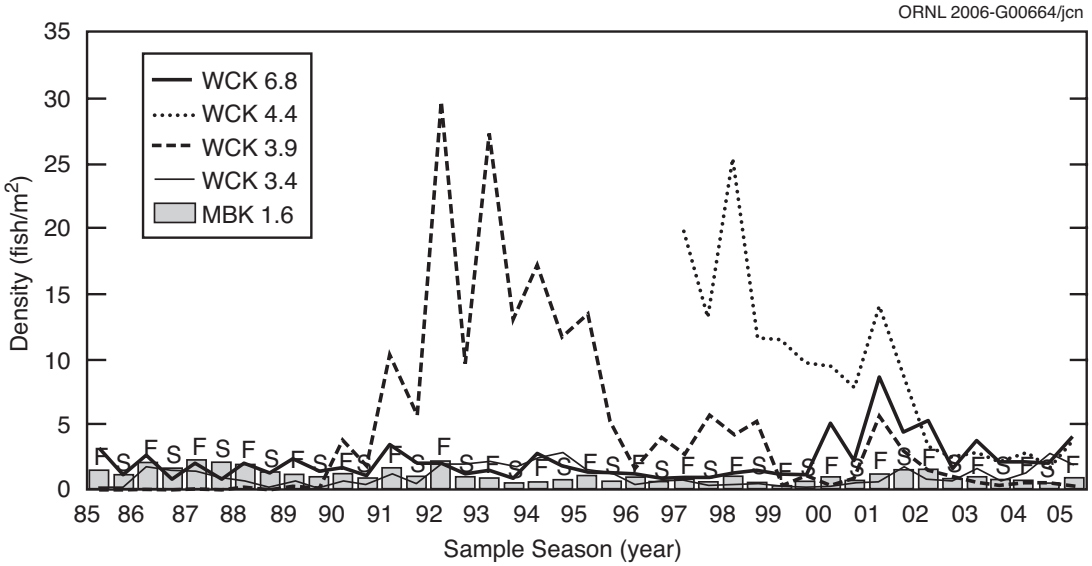


Fig. 5.22. Density (fish/m^2) estimates for fish in spring and fall samples from upper White Oak Creek (WCK = White Oak Creek kilometer) and reference site Mill Branch (MBK = Mill Branch kilometer), 1985–2005.

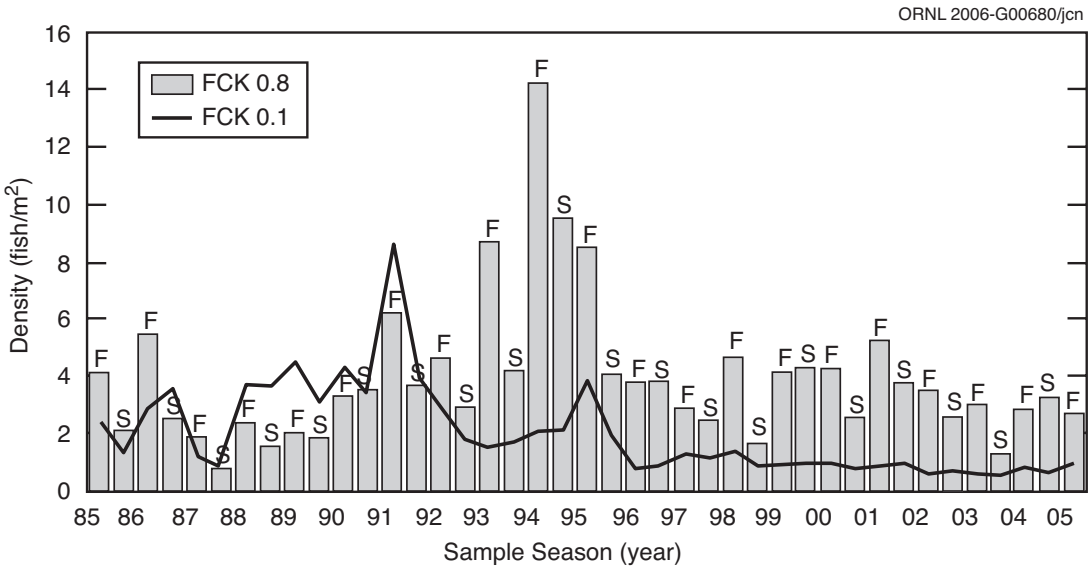


Fig. 5.23. Density (fish/m^2) estimates for fish in spring and fall samples from First Creek (FCK= First Creek kilometer), 1985–2005. FCK 0.8 is a reference site.

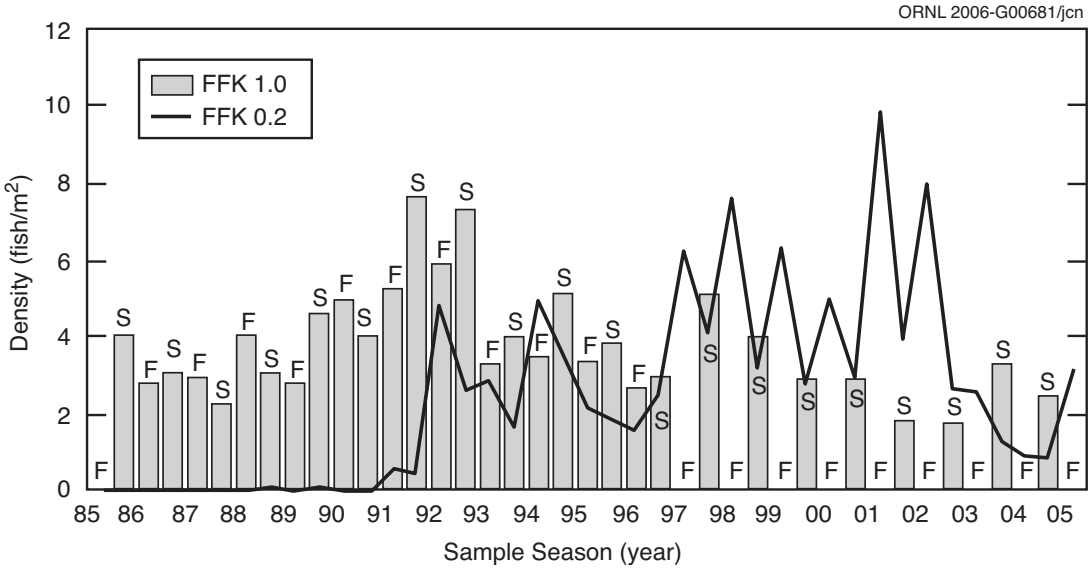


Fig. 5.24. Density (fish/m^2) estimates for fish in spring and fall samples from Fifth Creek (FFK= Fifth Creek kilometer), 1985–2005. FFK 1.0 is a reference site.

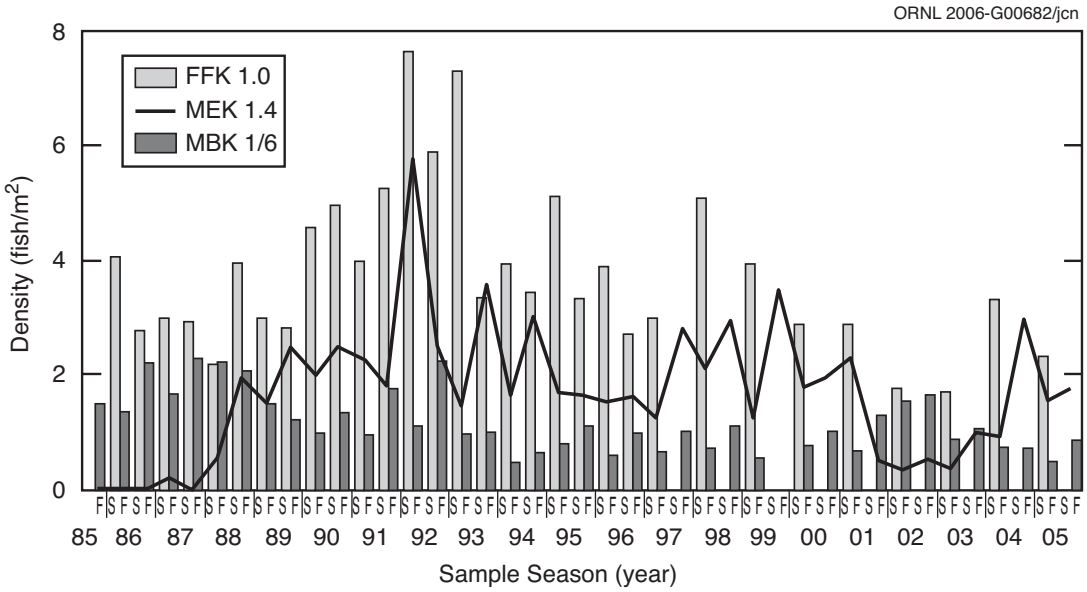


Fig. 5.25. Density (fish/m^2) estimates for fish in spring and fall samples from Melton Branch (MEK= Melton Branch kilometer), 1985–2005. Upper Fifth Creek FFK 1.0 and Mill Branch (MBK 1.6) are reference sites.

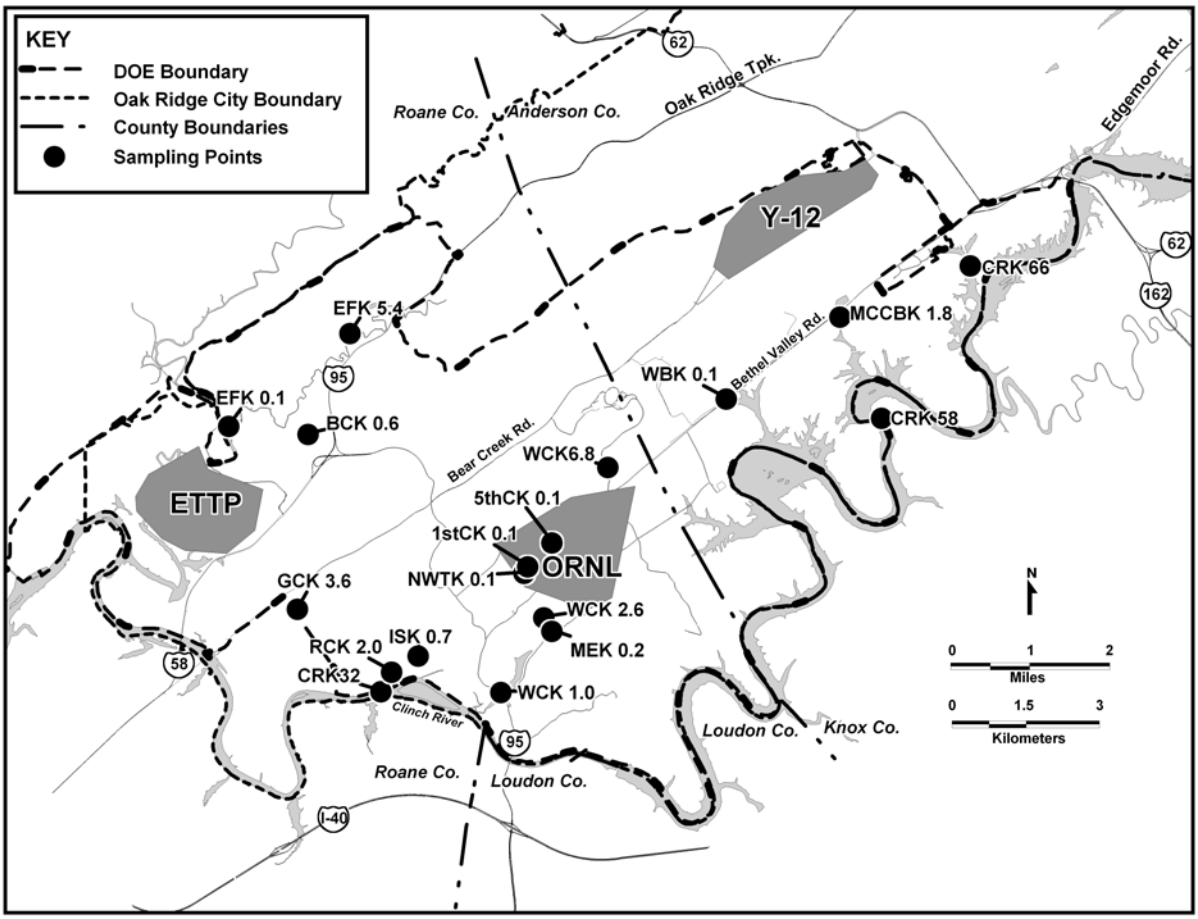


Fig. 5.26. ORNL surface water sampling locations.

in levels of gross alpha, gross beta, and total radioactive strontium at the First Creek location. Although greatly diminished from concentrations measured in the mid 1990s, the levels remain seasonally variable because of dilution in First Creek flow. Ongoing monitoring and investigations performed during the Bethel Valley Groundwater Engineering Study confirm that there is infiltration of approximately 2.5 gpm of plume water into storm drains that discharge into outfall 341, which discharges into First Creek. The Groundwater Engineering Study has identified additional contaminated soil near the North Tank Farm that may contribute to the plume and needs to be removed for groundwater protection consistent with the Interim Record of Decision for the Bethel Valley Watershed, Oak Ridge National Laboratory, Oak Ridge, Tennessee. The Engineering Study also identified options for optimizing management of the Core Hole 8 plume.

The VOCs chloroform, toluene, and acetone (a common laboratory contaminant) were detected at WOC at White Oak Dam in 2005. The toluene was detected once at a low estimated level and was probably due to laboratory contamination.

Two locations, one on Northwest Tributary [Northwest Tributary kilometer (NWTK) 0.1] and one on Raccoon Creek [Raccoon Creek kilometer (RCK) 2.0], also had elevated levels of gross beta and total radioactive strontium. Historically, results at both locations have a seasonal pattern; concentrations at Northwest Tributary are usually higher in the spring, whereas concentrations at Raccoon Creek are usually higher in the fall. This pattern has been disrupted in the past several years. The apparent change in rainfall precipitation patterns since the fall of 2000 probably accounts for the change in the seasonality pattern. Both of these locations

Table 5.8. ORNL surface water sampling locations, frequencies, and parameters, 2005

Location[a]	Description	Frequency	Parameters
BCK 0.6	Bear Creek downstream from DOE inputs	Semiannually (April, Oct)	Gross alpha, gross beta, gamma scan, field measurements[b]
CRK 32	Clinch River downstream from ORNL	Monthly	Gross alpha, gross beta, gamma scan, total radioactive strontium, ^{3}H, field measurements[b]
CRK 58	Water supply intake for Knox County	Monthly	Gross alpha, gross beta, gamma scan, field measurements[b]
CRK 66	Melton Hill Reservoir above city of Oak Ridge water intake	Monthly	Gross alpha, gross beta, gamma scan, field measurements[b]
EFK 0.1	East Fork Poplar Creek prior to entering Poplar Creek	Semiannually (April, Oct)	Gross alpha, gross beta, gamma scan, field measurements[b]
EFK 5.4	East Fork Poplar Creek downstream from floodplain	Semiannually (April, Oct)	Gross alpha, gross beta, gamma scan, field measurements[b]
MEK 0.2	Melton Branch downstream from ORNL	Bimonthly (Jan, Mar, May, Jul, Sep, Nov)	Gross alpha, gross beta, gamma scan, total radioactive strontium, ^{3}H, field measurements[b]
WCK 1.0	White Oak Lake at White Oak Dam	Monthly	Volatiles, metals, PCBs, gross alpha, gross beta, gamma scan, total radioactive strontium, ^{3}H, field measurements[b]
WCK 2.6	White Oak Creek downstream from ORNL	Bimonthly (Jan, Mar, May, July, Sep, Nov)	Gross alpha, gross beta, gamma scan, total radioactive strontium, ^{3}H, field measurements[b]
WCK 6.8	White Oak Creek upstream from ORNL	Quarterly (Feb, May, Aug, Nov)	Gross alpha, gross beta, total radioactive strontium, gamma scan, ^{3}H, field measurements[b]
WBK 0.1	Walker Branch prior to entering CRK 53.4	Semiannually (April, Oct)	Gross alpha, gross beta, gamma scan, field measurements[b]
GCK 3.6	Grassy Creek upstream of SEG and IT Corp. at CRK 23	Semiannually (April, Oct)	Lead, gross alpha, gross beta, gamma scan, field measurements[b]
ICK 0.7	Ish Creek prior to entering CRK 30.8	Semiannually (April, Oct)	Gross alpha, gross beta, gamma scan, field measurements[b]
MCCBK 1.8	McCoy Branch prior to entering CRK 60.3	Semiannually (April, Oct)	Gross alpha, gross beta, gamma scan, field measurements[b]
RCK 2.0	Raccoon Creek sampling station prior to entering CRK 31	Semiannually (April, Oct)	Gross alpha, gross beta, total radioactive strontium, gamma scan, ^{3}H, field measurements[b]
NWTK 0.1	Northwest Tributary prior to the confluence with First Creek	Semiannually (April, Oct)	Gross alpha, gross beta, total radioactive strontium, gamma scan, ^{3}H, field measurements[b]
FCK 0.1	First Creek prior to the confluence with Northwest Tributary	Semiannually (April, Oct)	Gross alpha, gross beta, total radioactive strontium, gamma scan, ^{3}H, field measurements[b]
FFK 0.1	Fifth Creek just upstream of White Oak Creek (ORNL)	Semiannually (April, Oct)	Gross alpha, gross beta, total radioactive strontium, gamma scan, ^{3}H, field measurements[b]

[a]Locations identify bodies of water and locations on them (e.g., CRK 32 = 32 km upstream from the confluence of the Clinch and the Tennessee Rivers).

[b]Field measurements consist of dissolved oxygen, pH, and temperature.

are impacted by contaminated groundwater from SWSA 3.

5.10 ORNL Sediment

Stream and lake sediments act as a record of some aspects of water quality by concentrating and storing certain contaminants. Sampling sites for sediment are the Clinch River downstream from all DOE inputs [Clinch River kilometer (CRK) 16], the Clinch River downstream from ORNL (CRK 32), and the Clinch River at the Solway Bridge, upstream from all DOE inputs (CRK 70) (Fig. 5.27). The locations are sampled annually, and gamma scans are performed on the samples.

In addition, two samples per year containing settleable solids are collected in conjunction with a heavy rain event to characterize sediments that exit ORNL during a storm event. The sampling locations are Melton Branch upstream from ORNL (MEK 2.1), White Oak Lake at White Oak Dam (WCK 1.0), WOC downstream from ORNL (WCK 2.6), and WOC Headwaters as a reference location (Fig. 5.27). These samples are filtered, and the residue (settleable solids) is analyzed for gross alpha, gross beta, and gamma emitters.

5.10.1 Results

Potassium-40, a naturally occurring radionuclide, was detected in sediments at all three locations. Cesium-137 was also detected in the samples collected at CRK 16 and CRK 32. These radionuclide detections are consistent with historical detections in Clinch River sediment sampling programs.

Heavy-rain-event sampling took place in March and July 2005. The concentrations of radionuclides associated with each of these rain events are higher at the locations downstream of ORNL than at the upstream locations.

5.11 Groundwater Monitoring at ORNL

5.11.1 Background

Groundwater monitoring at ORNL consisted of two programmatic components in 2005: the DOE Environmental Management and Enrichment Facilities (EMEF) groundwater monitoring program and the DOE Office of Science (OS) groundwater monitoring surveillance program. Under the EMEF program, groundwater monitoring has been performed as part of a comprehensive cleanup effort, and the scope has largely been remediation effectiveness monitoring at contaminated sites undergoing remediation. The OS groundwater monitoring program has two functions: exit pathway groundwater surveillance and "active sites" groundwater surveillance monitoring.

In 1996, DOE established the Integrated Water Quality Program (IWQP) to conduct long-term environmental monitoring throughout the ORR. The Water Resources Restoration Program (WRRP) succeeded the IWQP in fall 1999. The WRRP has been managed by BJC for the EMEF program since its inception and is the vehicle for DOE to carry out the regulatory requirements outlined in the Federal Facility Agreement to conduct post-remedial action monitoring. The WRRP uses a watershed approach to remediation, which has resulted in the assignment of two watersheds to ORNL: Bethel Valley and Melton Valley. Groundwater monitoring results for remedial actions that are in progress or that have been completed during 2005 are reported annually in the EMEF Program *Remediation Effectiveness Report* (RER) (DOE 2006b). In the case of waste area grouping (WAG) 6, which is regulated under both the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act, specific monitoring results and interpretations required by RCRA are reported in the annual *Groundwater Quality Assessment Report for Solid Waste Storage Area 6* (BJC 2006d), which is also issued annually.

From 1996 until 2004, the WAG concept was used as the basis of the OS groundwater monitoring program at ORNL. A WAG consists of multiple contaminated sites that are geographically contiguous and/or that occur within geohydrologically defined areas. At ORNL, 20 WAGs were identified by the RCRA Facility Assessment conducted in 1987. The WAG concept was developed to facilitate evaluation of potential sources of releases to the environment. Discussion of past WAG-based monitoring results can be found in previous editions of this document.

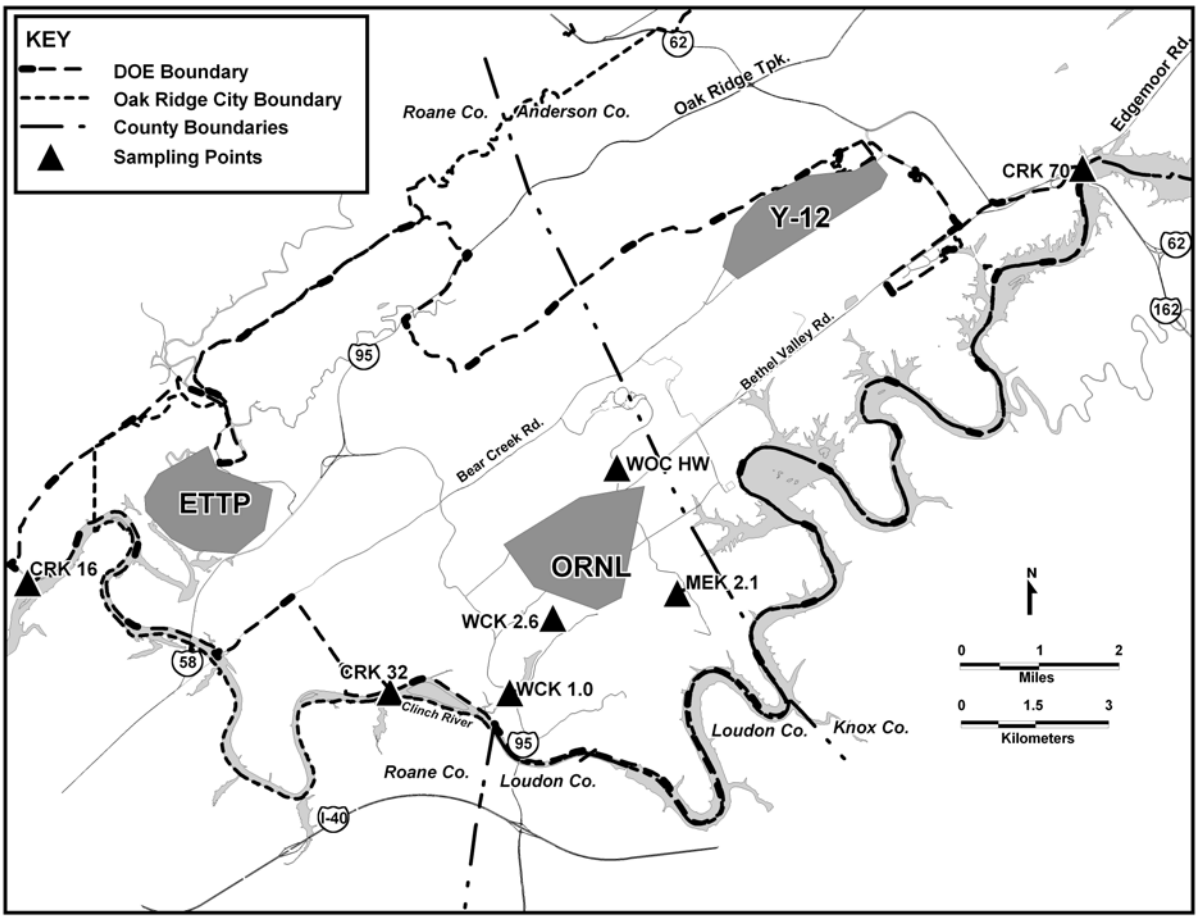


Fig. 5.27. ORNL sediment sampling locations.

The groundwater monitoring was reviewed in 2004 and revised to meet DOE Order 450.1 requirements and UT-Battelle management objectives. DOE Order 450.1 is the primary contractual requirement document specifying the implementation of a site-wide groundwater protection program at ORNL. As part of the site-wide groundwater protection program, and to be consistent with UT-Battelle management objectives, a groundwater surveillance monitoring strategy was developed to enable groundwater exit pathways and facilities actively managed by UT-Battelle ("active sites") to be assessed and monitored. The changes to the OS groundwater monitoring strategy were documented in the *Data Quality Objectives for the UT-Battelle Groundwater Surveillance Monitoring Program at ORNL* (Bonine 2004b).

The exit pathway and active sites groundwater surveillance monitoring points sampled during 2005 included selected seep/spring and surface water monitoring locations as well as groundwater surveillance monitoring wells. Seep/spring and surface water monitoring locations were used in the absence of monitoring wells located in appropriately selected groundwater discharge areas. The network of groundwater monitoring wells sampled by UT-Battelle consists of water quality wells constructed to RCRA specifications and piezometer wells. Water quality wells were installed for site characterization and compliance purposes, while piezometers were used to characterize groundwater flow.

Groundwater monitoring performed under the exit pathway groundwater surveillance and active sites monitoring programs is not regulated by federal or state regulations. Consequently, no permit or standards exist with which to compare sampling results. In an effort to provide a basis for evaluation of analytical results and for assessment of groundwater quality monitored by

UT-Battelle for DOE-OS, federal drinking water standards and Tennessee Water Quality Criteria for domestic water supplies were used as reference values in the following discussions. Four percent of the DOE DCG is used for comparison if no federal or state standards have been established for a radionuclide. Although drinking water standards are 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.

The watershed-based remediation monitoring approach conducted by BJC and the exit pathway and active sites monitoring approaches used by UT-Battelle for DOE-OS during 2005 make up a comprehensive site-wide monitoring program for ORNL. The combination of both monitoring programs meets the DOE Order 450.1 requirement of a comprehensive site-wide groundwater monitoring program.

5.11.2 Exit Pathway Monitoring

During 2005, exit pathway groundwater surveillance monitoring was performed under the auspices of *UT-Battelle Sampling and Analysis Plan for Surveillance Monitoring of Exit Pathway Groundwater at Oak Ridge National Laboratory* (Bonine 2005). Groundwater exit pathways at ORNL include watersheds or portions of watersheds (sub-watersheds) where groundwater discharges to the Clinch River/Melton Hill Reservoir to the west, south, and east of the main campus of ORNL. No exit pathway monitoring was performed to the north of ORNL because of the influence of Y-12 legacy contamination in Bear Creek Valley, located north of ORNL. The exit pathway monitoring points were chosen based on hydrologic features, screened intervals (for wells), and locations relative to discharge areas proximal to the ORNL main campus. The groundwater exit pathways at ORNL include four discharge zones identified by the groundwater data quality objectives process. In addition, one of the original exit pathway zones was split into two zones for the sake of geographic expediency. The four zones include (1) the WOC Discharge Area Exit Pathway (Wells 857, 858, 1190, 1191, and 1239), (2) the 7000 Area/Bearden Creek Watershed Discharge Area Exit Pathway (Wells 1198 and 1199 and Spring BC-01), (3) the East End Discharge Area Exit Pathway (Well 923 and Springs/Surface Water Monitoring Points EE-01 and EE-02), (4) the Northwestern Discharge Area Exit Pathway (Wells 531 and 535), and (5) the Southern Discharge Area Exit Pathway (Springs/Surface Water Monitoring Points S-01 and S-02), which was originally part of the East End Discharge Area exit pathway. Figure 5.28 shows the locations of the specific monitoring points sampled in 2005.

Monitoring data from seven multi-port monitoring wells (BJC Wells 4537, 4538, 4539, 4540, 4541, 4542, and 4579) installed west of the main campus of ORNL by BJC are to be included in the WOC Discharge Area Exit Pathway. Sampling data generated by these wells will be used to supplement the data generated by the WOC Discharge Area Exit Pathway. These data will be reviewed on an annual basis as the data are made available. The inclusion of the multi-port wells will enable multiple shallow to deep water-bearing strata to be monitored.

Because of the change in the groundwater surveillance monitoring strategy involving new monitoring points at the exit pathways, and given that samples from wells sampled under the previous monitoring program had not been analyzed for a comprehensive list of analytical parameters, changes were made to the analytical suite and sample collection frequency. Samples collected from the exit pathway groundwater surveillance monitoring points in 2005 were analyzed for VOCs, semi-volatile organic compounds, metals (including mercury), and radionuclides (including gross alpha/gross beta activity, gamma emitters, total radioactive strontium, and tritium). Under the new monitoring strategy, samples will be collected semiannually during wet and dry seasons. However, because the initiation of the new exit pathway groundwater monitoring program occurred in July 2005, only dry season samples were collected in 2005.

5.11.3 Active Sites Monitoring

Active sites groundwater surveillance monitoring was performed in 2005 at the HFIR and SNS sites. These UT-Battelle–managed facilities were monitored based on known releases of contaminants to the subsurface or potential effects on groundwater resources at ORNL. The HFIR

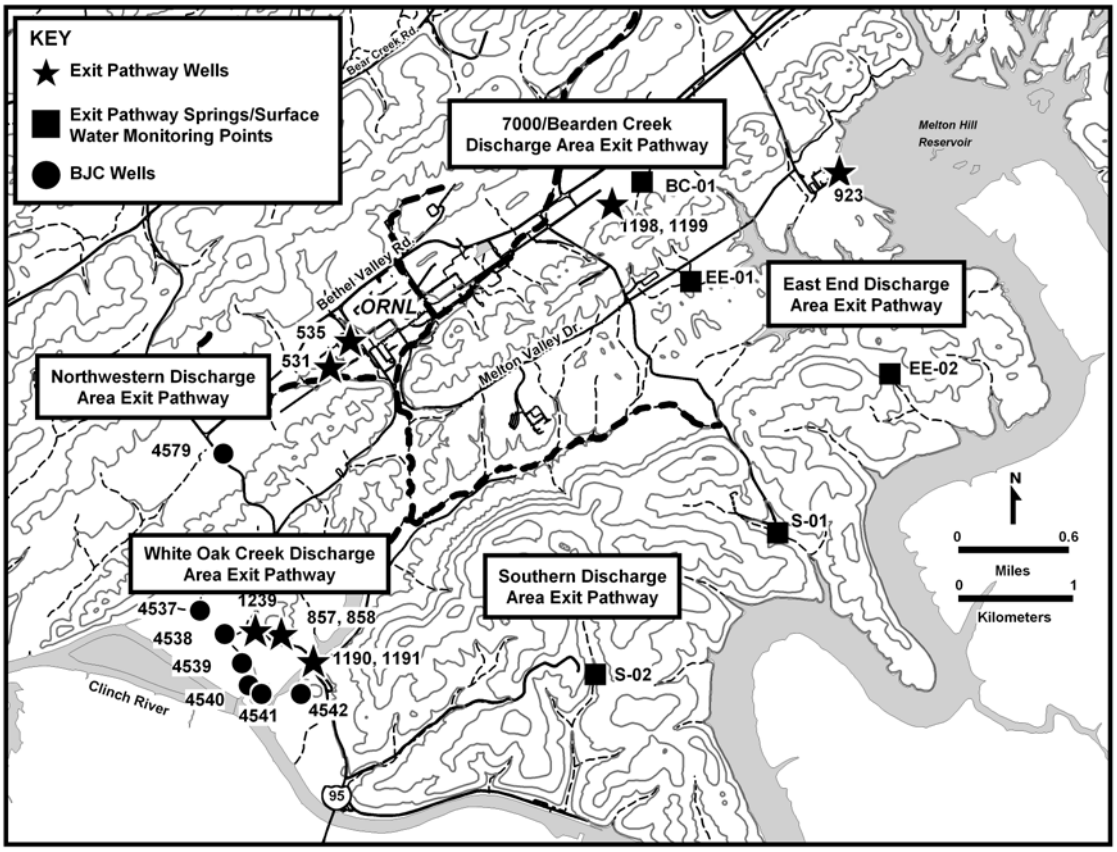


Fig. 5.28. 2005 UT-Battelle exit pathway groundwater monitoring locations at ORNL.

monitoring activities were initiated following the discovery in 2000 of a tritium release to the subsurface environment (tritium release sites were repaired in 2001). HFIR monitoring was performed under the auspices of the *Annual Monitoring Plan for the High Flux Isotope Reactor Site, Monitoring Period: 2004–2005* (Bonine 2004a) (Annual Monitoring Plan). Monitoring at the SNS site continued under the auspices of the *Baseline Groundwater Monitoring Plan for the Spallation Neutron Source Site: Monitoring Period 2004–2006* (Baseline Monitoring Plan) (Bonine, Ketelle, and Trotter, 2004).

5.11.4 HFIR Site

The HFIR site is located in Melton Valley about one-half mile south of the main ORNL facilities, which are located in Bethel Valley. The site slopes to the southeast, and small stream valleys lie to the east and west of the HFIR complex. Surface water drainage from the site flows into Melton Branch via these small streams or through storm drains. Melton Branch is located south of the HFIR site and flows west into WOC. WOC ultimately discharges into the Clinch River.

The water table surface in Melton Valley is typically a subdued replica of surface topography. The dry season water table typically occurs at or slightly above the top of bedrock. Groundwater data gathered before the tritium release indicate a water table high to the north of HFIR and a general gradient toward the adjacent streams. Estimates of groundwater flow directions are based on the generally observed tendency for groundwater to flow parallel to geologic strike (parallel to the orientation of the rock beds). Extensive historic investigations performed at Oak Ridge over several decades indicate that 90% or more of infiltrating precipitation (groundwater recharge) flows directly to the nearest stream. Because of this, in small watersheds, groundwater contaminants not subject to geochemical transport retardation, such as tritium, are readily detected in surface water samples.

The most significant observation for the HFIR facility, based on water table conditions and other data related to the reactor building (Building 7900), is that two flow regimes exist within the uppermost portion of the aquifer underlying the HFIR complex. A rapid-flow pathway is associated with the shallowest groundwater flow into subsurface piping traces (the HFIR building foundation drain and auxiliary piping to the south), and a slower-flow pathway is associated with deeper groundwater flow beneath the site.

The objectives of the monitoring program outlined in the Annual Monitoring Plans include (1) early detection of releases to groundwater from HFIR operational activities or system failures, (2) tracking the mass of the tritium plume in the vicinity of HFIR, and (3) monitoring potential sources of groundwater contamination located hydraulically up-gradient of the HFIR. Figure 5.29 shows the locations of the specific monitoring points sampled in 2005 at the HFIR site. Tritium was the only contaminant of concern monitored at all HFIR monitoring points.

The foundation drain and auxiliary waste piping system gravity-feed into Melton Branch, forming a capture zone beneath and around the building. Leakage from HFIR would therefore seep into the foundation drain system and waste piping ditch lines, resulting in flow to the southeast and south toward ultimate discharge through NPDES outfalls at Melton Branch. Building 7900's east foundation drain intercepts the rapid-flow pathway and has been monitored at J-1, a monitoring point proximal to the Building 7900, for several years. Likewise, waste piping ditch lines associated with Building 7900 intercept the rapid-flow pathway and have been monitored regularly for several years at NPDES outfall 383 (OF-383). Both J-1 and OF-383 were sampled on a routine basis during 2005. Six groundwater monitoring wells (Wells 658, 661, 892, 4532, 4529, and 4533) were also sampled routinely during 2005 to monitor the deeper, slower-flow pathway. Wells 4529 and 4533 are up-gradient wells proximal to the HFIR site.

5.11.5 SNS Site

SNS operations have the potential for inducing radioactivity (neutron activation) in the shielding berm surrounding the SNS linac, accumulator rings, and/or beam transport lines. A principal concern is the potential for water infiltrating the berm soils to transport radionuclide contamination 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 confounded by uncertainties associated with potential contaminant interactions with existing pore water, precipitation, earth materials encountered, and the additional uncertainties associated with diffusive and advective flow in the vadose and phreatic zones attributable to the presence of karst geomorphic features found on the SNS site. Objectives of the baseline groundwater monitoring program at the SNS include (1) demonstration of compliance with applicable environmental quality standards and public exposure limits outlined in DOE Orders 450.1 and 5400.5, respectively; (2) determination of background levels and site contributions of contaminants to the environment (obtain baseline data and continue development of a data set that describes the concentration of pollutants); and (3) determination of seasonal and annual trends in water quality. This monitoring program was instituted during the 2004–2006 period prior to startup of the SNS and will continue during SNS operations.

A total of seven seeps/springs and surface water sampling points (springs S-1, S-2, S-3, S-4, S-5, and SP-1 and surface water point SW-1) were routinely monitored as analogues to, and in lieu of, groundwater monitoring wells during 2005. Spring S-6 is sampled when accessible. S-6 is routinely inundated by beaver activity on Bear Creek, making the sampling location inaccessible. The locations of the SNS monitoring points were chosen based on geohydrological factors and proximity to the beam line. Figure 5.30 shows the locations of the specific monitoring points sampled in 2005 at the SNS site. Because of the presence of karst geomorphic features at the SNS site, sampling of the seeps/springs was performed to characterize conditions throughout the expected range of flow observed at the selected monitoring loca-

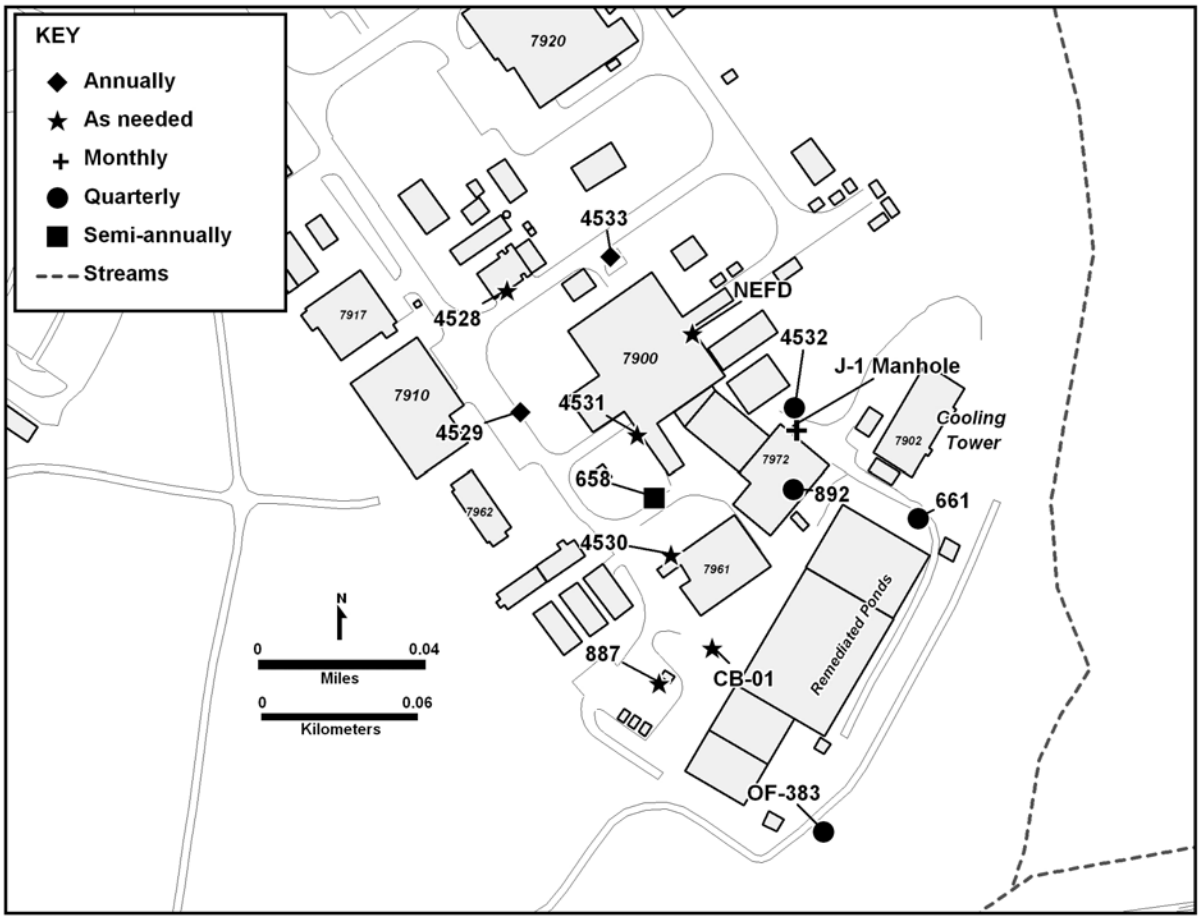


Fig. 5.29. 2005 Groundwater Monitoring Locations at HFIR.

tions. A minimum of three grab samples were collected from each seep/spring per quarter—one to represent base flow and the remaining samples collected at higher stage/flow rates (i.e., one representing the rising limb of the hydrograph and one representing the recession limb of the hydrograph). These monitoring points were sampled on a quarterly basis during 2005 in accordance with the baseline monitoring plan. The parameters of interest included neutron activation products consisting of tritium, ^{14}C, gross alpha and beta activity, and gamma emitters (^{22}Na, ^{26}Al, ^{54}Mn, ^{40}K, etc). All samples were analyzed using EPA analytical methods by a certified laboratory.

5.11.6 Monitoring Results

5.11.6.1 2005 Exit Pathway Groundwater Surveillance Monitoring

From the 49 wells sampled under the previous WAG monitoring program, only Wells 857, 858, 1190, 1191, 1198, 1199, and 1239 were retained in the exit pathway groundwater surveillance monitoring program. Trend analyses were performed on exit pathway well data that exceeded reference values during 2005 using historical data collected from 1991 through the 2005 monitoring period. Concentrations of naturally occurring inorganic contaminants (metals such as aluminum, iron, manganese, and zinc) that exceeded reference values were not subjected to trend analysis because these constituents are commonly found in the soil and rock composing the earth's crust and are regularly

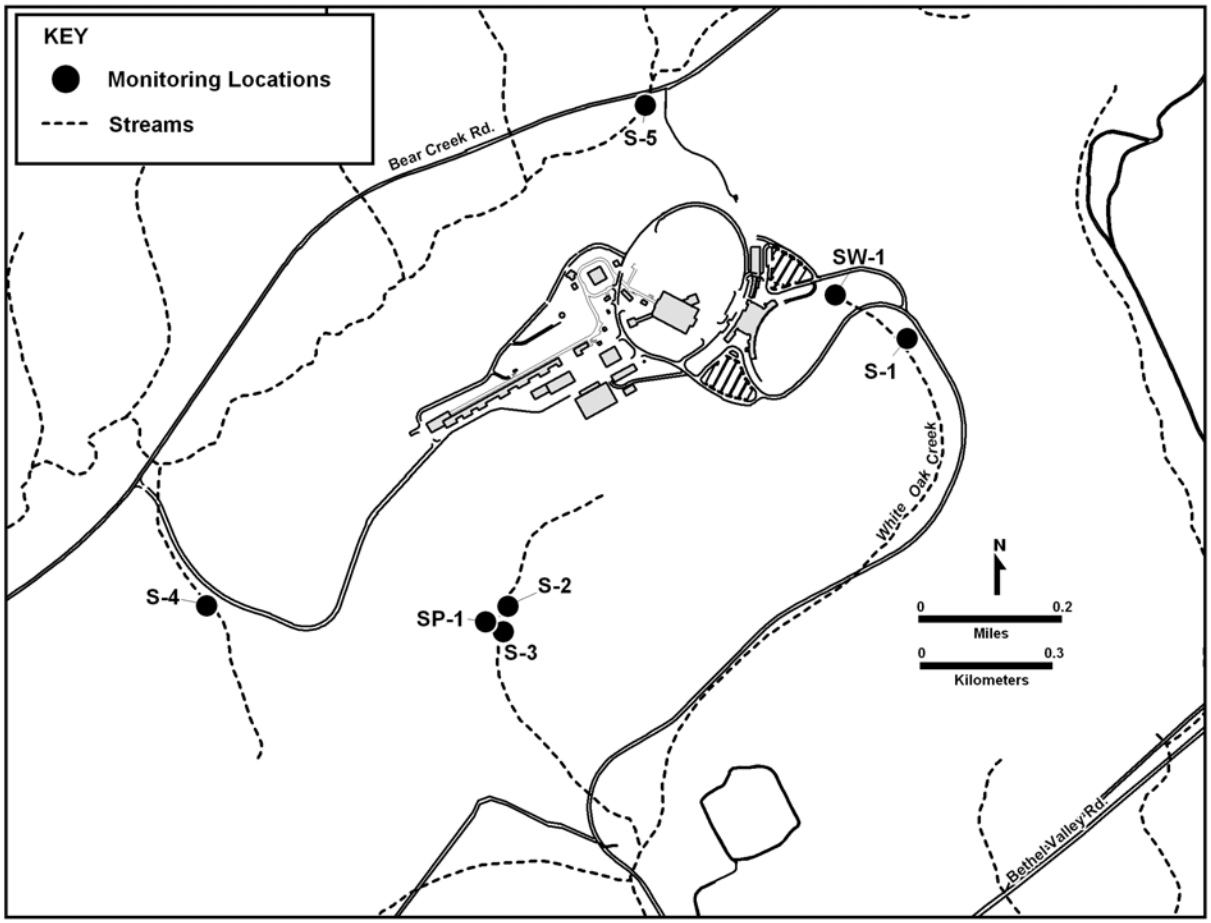


Fig. 5.30. 2005 Groundwater Monitoring Locations at SNS.

found in groundwater samples collected from wells at ORNL.

5.11.6.2 WOC Discharge Area Exit Pathway

Monitoring wells 857, 858, 1190, 1191, and 1239 were sampled by ORNL during 2005. Three contaminants of concern were found in two wells at concentrations greater than reference values used for comparison. The three radiological contaminant constituents that exceeded reference values were tritium in Well 1190 and gross beta activity, total radioactive strontium, and tritium in Well 1191. Statistically significant downward trends were observed for all of the contaminants mentioned. The presence of the radiological contaminants in these wells is related to continued discharges of legacy contamination associated with past waste disposal activities within Melton Valley. Lead-214 was detected in Well 857, but its concentration was well below the reference value. Several metals exceeded reference values during 2005, but these metals (aluminum, iron, and manganese) are commonly found in the soil and rock composing the earth's crust. Carbon disulfide detected at low estimated levels in samples from Wells 1190 and 1191 is attributed to laboratory contamination. No other organic compounds were present above detection limits in samples collected from WOC Discharge Area monitoring points.

Recent EMEF Program activities associated with the WOC Discharge Area Exit Pathway (BJC Wells 4537, 4538, 4539, 4540, 4541, 4542, and 4579) are summarized in the 2005 RER.

5.11.6.3 7000 Area/Bearden Creek Watershed Discharge Area Exit Pathway

Wells 1198 and 1199 and Spring BC-01 were sampled by UT-Battelle during 2005. No radiological constituents were present above reference values in samples collected from 7000 Area/Bearden Creek Watershed Discharge Area monitoring points; however, tritium was detected in samples from all three monitoring locations. Two metal contaminants (aluminum and iron) exceeded reference values, but these metals are commonly found in the soil and rock composing the earth's crust. Carbon disulfide was detected at a low, estimated value in Well 1199 and is attributed to laboratory contamination. No other organic compounds were present above their detection limits in samples collected from 7000 Area/Bearden Creek Watershed Discharge Area monitoring points.

Recent EMEF Program activities associated with the 7000 Area/Bearden Creek Watershed Discharge Area Exit Pathway are summarized in the 2005 RER.

5.11.6.4 East End Discharge Area Exit Pathway

Well 923 and Springs/Surface Water Monitoring Points EE-01 and EE-02 were sampled by UT-Battelle during 2005. No radiological constituents were present above reference values in samples collected from East End Discharge Area monitoring points, however tritium was detected in samples collected from EE-01 and Well 923. Additionally, gross beta activity was detected in Well 923. Two metals (aluminum and iron) exceeded reference values, but these metals are commonly found in the soil and rock composing the earth's crust. Toluene and methylene chloride were detected at low, estimated levels in Well 923 during 2005, but at concentrations below reference values. The presence of toluene in Well 923 may be due to leakage from past degreasing operations at the Experimental Gas Cooled Reactor (EGCR). The presence of methylene chloride is attributed to laboratory contamination. No other organic compounds were present above detection limits in samples collected from East End Discharge Area monitoring points.

Recent EMEF Program activities associated with the East End Discharge Area Exit Pathway are summarized in the annual RER.

5.11.6.5 Northwestern Discharge Area Exit Pathway

Wells 531 and 535 were sampled by ORNL during 2005. No radiological constituents were present above reference values in samples collected from Wells 531 and 535; however, tritium was detected in Well 535. Aluminum, iron, and manganese exceeded reference values, but these metals are commonly found in the soil and rock composing the earth's crust. No organic compounds were present above reference levels in samples collected from Northwestern Discharge Area monitoring points. However, benzene, toluene, and total xylene were detected in Well 531 and are attributed to leakage of gasoline from cars parked in nearby parking lots. There are no known active or legacy sources of these compounds near Well 531. Acetone and diethyl phthalate were also detected in Well 531 at low, estimated levels (neither organic compound has reference values). The presence of both compounds is attributed to laboratory contamination. Benzene and toluene were also detected at low, estimated levels in Well 535 during 2005 but at concentrations below reference values. The presence of these organics is attributed to leakage of gasoline from cars parked in nearby parking lots. There are no known active or legacy sources of these compounds near Well 535. Methylene chloride and diethyl phthalate were also detected at low, estimated levels in Well 535. The presence of both organics is attributed to laboratory contamination.

Recent EMEF Program activities associated with the Northwestern Discharge Area Exit Pathway are summarized in the annual RER.

5.11.6.6 Southern Discharge Area Exit Pathway

Monitoring points S-01 and S-02 were sampled by ORNL during 2005. Manganese exceeded its reference value during 2005 (at S-02). Manganese is commonly found in the soil and rock composing the earth's crust. No radiological constituents or organic compounds were present above their detection limits in samples

collected from Southern Discharge Area monitoring points.

5.11.6.7 Active Sites Monitoring

Because of limited data density in HFIR data sets generated under the 2004/2005 Annual Monitoring Plan , trend analyses were performed on HFIR monitoring point data sets using biennial (2003–2005) monitoring data. The lack of data density was a function of changes in sampling frequencies at the various monitoring points prescribed by the *Annual Monitoring Plan for the High Flux Isotope Reactor Site, Monitoring Period: 2003 –2004* (Bonine 2003) and the 2004–2005 Annual Monitoring Plan.

Trend analyses were performed on historical HFIR monitoring point data sets observed to have multiple exceedences of reference values during 2005.

5.11.6.8 HFIR Site

During 2005, no evidence of tritium releases to the subsurface from the HFIR was observed. Overall trends in tritium concentration decreased at all monitoring points and were statistically significant in Wells 658, 892, and 4533.

5.11.6.9 SNS Site

Results of the 2005 monitoring program at SNS indicate the presence of gross alpha activity at concentrations that exceeded reference value 7 out of 12 times at monitoring point S-5. Trend analysis of the S-5 gross alpha activity data revealed a statistically significant increase in alpha activity in 2005. Monitoring point S-5 is a karst feature (spring) that is geohydrologically connected to both Bear Creek Valley and the SNS site groundwater. Therefore, the gross alpha activity is attributed to uranium-contaminated groundwater from Y-12 facilities in Bear Creek Valley.

Other radionuclides exceeded reference values only once during 2005 at SNS monitoring locations: ^{238}U at S-1; gross alpha and beta activity, ^{228}Ra, ^{230}Th, and ^{232}Th at S-2; and ^{238}U at S-4, S-5, and S-6. These radiological constituents are naturally occurring in carbonate-based groundwater on the Oak Ridge Reservation.

5.12 Modernization and Reindustrialization Activities at ORNL

During 2005, several utility distribution systems were upgraded to support planned modernization activities. A 400-slot parking lot was constructed just off Bethel Valley Road across from ORNL's visitor center, as well as a roundabout added as a traffic calming devise. Design for an additional 200 slots on the North Hill above the Flag Pole parking lot will begin in mid-2006. On the main campus, construction of the Multiprogram Research Facility, a privately financed 211,000-ft^2 office and light laboratory facility began. Design for the 30,000-ft^2 State of Tennessee Joint Institute for Biological Sciences was completed, and construction is planned during 2006. On the Chestnut Ridge campus, construction of the Center for Nanophase Material Sciences was completed. Design for expansion of the Chestnut Ridge utility distribution system is under way with construction planned for the second quarter of 2006. Design for the 30,000-ft^2 State of Tennessee Joint Institute for Neutron Sciences was completed, and construction is planned to start in 2006. The design for the ORNL User Housing facility will begin late in 2006. Several trailers were replaced on the Melton Valley campus during the first quarter of 2006. Efforts to dispose of legacy materials, equipment, and facilities continue; the major accomplishment in 2005 was decommission and demolition of Building 1000.

5.12 Spallation Neutron Source

On May 31, 2006, construction of the SNS was completed. This state-of-the-art pulsed-neutron facility is located on Chestnut Ridge at ORNL. This major new accelerator-based neutron research facility will significantly increase the capability for neutron beam research in the United States and the world. The primary mission of SNS is to provide a reliable, high-intensity source of pulsed neutrons for neutron beam research, with intensity and resolution unmatched in any major research facility in the world. The SNS facility is composed of an ion source, linear accelerator (linac), storage ring, target, and instrument facilities, as well as support facilities.

Construction of the SNS access roads affected wetlands. Routes were evaluated, and improving the Chestnut Ridge Road was selected as the action affecting the smallest area of wetlands. Construction affected 0.055 acres, and careful attention to erosion control and equipment movement limited impacts to other nearby wetland areas. The SNS developed a wetlands mitigation plan to compensate for the impacts to the 0.055 acres by restoring 0.138 acres (a mitigation ratio of 2.511) of wetlands located in the same watershed. TDEC accepted the wetlands mitigation plan on June 29, 2000, and the 0.138 acres of wetlands were restored in August 2000. This mitigation action is complete, and the restored areas are routinely monitored to ensure the survival rate of the indigenous shrubs and vegetation planted in the restored area. No significant impacts on the wetlands have resulted from construction activities. The wetlands mitigation activities were evaluated and reported in 2002, 2003, 2004, and 2005. These reviews have found that the SNS mitigation wetland is functioning as a viable wetland community. The site has the necessary wetland vegetation, soils, and hydrology to be classified as a jurisdictional wetland. In 2006, the fifth and final annual wetland monitoring report will be prepared and submitted to the state, thereby fulfilling monitoring and reporting requirements as delineated in the respective Aquatic Resource Alteration Permit.

On November 3, 2003, the TDEC Division of Water Pollution Control issued an NPDES permit that became effective on December 1, 2003. It authorized DOE to discharge cooling tower blowdown and heating, ventilation, and air-conditioning condensate water from the SNS to a storm water detention pond that discharges to WOC at approximate stream mile 4.2 through outfall 435. Furthermore, the pond emergency spillway, designated as outfall 437, will discharge in large storm runoff situations to mile 0.6 of a tributary to WOC. The SNS began discharging blowdown waters to the detention pond in December 2, 2003. Since that time, the SNS has been fully compliant with all permit limits (see Table 5.9). The current NPDES permit will expire on October 31, 2006, and an application for renewal of the permit has been submitted to the TDEC.

Regarding the protection of groundwater, the SNS has implemented a series of engineering controls designed to prevent any migration of radionuclides to groundwater. Furthermore, the SNS implemented a baseline groundwater monitoring program that began in 2004 and was completed in 2006. At present, the groundwater monitoring program has transitioned from a preliminary monitoring program to establish the baseline to an operational monitoring program designed to ensure that any releases of contaminants from the facility do not cause an unacceptable impact to groundwater or surface water on, or adjacent to, the site.

The SNS operates two 8.37-MMBTU/h natural gas-fired-only boilers located in the Central Utilities Building and two 14.65-MMBTU/h natural gas-fired-only boilers located in the Central Laboratory and Office Building. All these emission sources are permitted under the Title V Permit for 73-0112 (Office of Science) issued by the TDEC. In addition, the SNS has a permit for construction of the SNS Central Exhaust Facility. The Central Exhaust Facility will collect, monitor, and discharge radionuclides from operational components of the SNS. Sources will include accelerator tunnels, beam dumps, and the target building. At present, the start-up date of this air contaminant source will occur in mid-year in 2006.

Table 5.9. National Pollutant Discharge Elimination System (NPDES) compliance at SNS, 2005

(NPDES permit effective December 1, 2003)

Effluent parameters	Permit limits					Permit compliance		
	Monthly average (kg/d)	Daily max (kg/d)	Monthly average (mg/L)	Daily max (mg/L)	Daily min (mg/L)	Number of noncompliances	Number of samples	Percentage of compliance[a]
pH (std. units)				9	6.5	0	104	100
Total residual chlorine			0.011	0.019		0	104	100

[a]Percentage compliance = 100 – [(number of noncompliances/number of samples) * 100].

6. Y-12 Environmental Monitoring Programs

Compliance and environmental monitoring programs required by federal and state regulation and by DOE orders are conducted at the Y-12 National Security Complex for air, water, and groundwater environmental media.

6.1 Y-12 Complex Radiological Airborne Effluent Monitoring

The release of radiological contaminants, primarily uranium, into the atmosphere at the Y-12 National Security Complex (Y-12 Complex) occurs almost exclusively as a result of plant production, maintenance, and waste management activities. NESHAP regulations for radionuclides require continuous emission sampling of major sources (a "major source" is considered to be any emission point that potentially can contribute more than 0.1 mrem/year effective dose equivalent to an off-site individual). As of January 1, 2005, the Y-12 Complex had continuous monitoring capability on a total of 55 stacks, 46 of which were active and nine of which were temporarily shut down. During 2005, 42 of the 55 stacks suitable for continuous monitoring were judged to be major sources. Eighteen of the stacks with the greatest potential to emit significant amounts of uranium are equipped with alarmed breakthrough detectors, which alert operations personnel to process-upset conditions or to a decline in filtration-system efficiencies, allowing investigation and correction of the problem before a significant release occurs.

Emissions from unmonitored process and laboratory exhausts, categorized as minor emission sources, are estimated according to calculation methods approved by the EPA. In 2005, there were 46 unmonitored processes operated by Y-12. These are included as minor sources in the Y-12 Complex source term.

Uranium and other radionuclides are handled in millicurie quantities at facilities within the boundary of the Y-12 Complex as part of Bethel Jacobs Company, LLC, (BJC), UT-Battelle, and BWXT Y-12 laboratory activities. Twenty-nine minor emission points were identified from laboratory activities at facilities within the boundary of the Y-12 Complex as being operated by BWXT Y-12. In addition, the BWXT Y-12 Analytical Chemistry Organization laboratory is operated in a leased facility that is not within the ORR boundary; it is located approximately a mile east of the Y-12 Complex on Union Valley Road. The emissions from the Analytical Chemistry Organization Union Valley laboratory are included in the Y-12 Complex source term. Two minor emission points were identified at the laboratory. The releases from these emission points are minimal, however, and have a negligible impact on the total Y-12 Complex dose.

Emissions from Y-12 Complex room ventilation systems are estimated from radiation control data collected on airborne radioactivity concentrations in the work areas. Areas where the monthly average concentration exceeded 10% of the DOE derived air concentration worker-protection guidelines are included in the annual emission estimate. In 2005, three emission points where room ventilation emissions exceeded 10% of the guidelines were identified in Building 9212. However, because the emissions were vented to stacks UB-017, and UB-128, their distributions were not specifically identified or included in the stack emissions.

6.1.1 Sample Collection and Analytical Procedure

Uranium stack losses were measured continuously on monitored operating process exhaust stacks in 2005. Particulate matter (including uranium) was filtered from the stack emissions. Filters at each location were changed routinely, from one to three times per week, and were analyzed for total uranium. In addition, the sampling probes and tubing were removed quarterly and were washed with nitric acid; the washing was analyzed for total uranium. At the end of the year, the probe-wash data were

included in the final calculations in determining total emissions from each stack.

6.1.2 Results

An estimated 0.016 Ci (1.4 kg) of uranium was released into the atmosphere in 2005 as a result of Y-12 activities (Figs. 6.1 and 6.2). The specific activity of enriched uranium is much greater than that of depleted uranium, and about 96% of the curie release was composed of emissions of enriched uranium particulate, even though approximately 16% of the total mass of uranium released was enriched material.

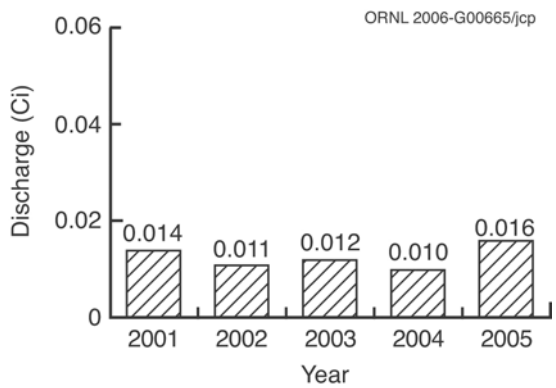


Fig. 6.1. Total curies of uranium discharged from the Y-12 Complex to the atmosphere, 2001–2005. 1 Ci = 3.7 × 10^{10} Bq.

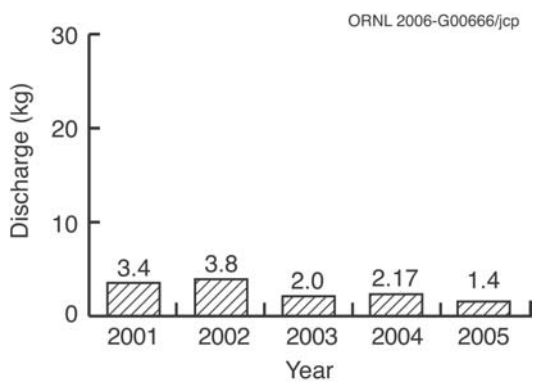


Fig. 6.2. Total kilograms of uranium discharged from the Y-12 Complex to the atmosphere, 2001–2005.

6.2 Y-12 Complex Nonradiological Airborne Emissions Monitoring

The release of nonradiological contaminants into the atmosphere at the Y-12 Complex occurs as a result of plant production, maintenance, waste management operations, and steam generation. Most process operations are served by ventilation systems.

In CY 2005, the Y-12 Complex implemented complete compliance and reporting activities for its first Major Source (Title V) Operating Air Permit. the permit covers 35 air emission sources and more than 100 air emission points. Other emission sources at the Y-12 Complex are categorized as being insignificant and exempt from air permitting. Under the Title V operating permit for the complex, sampling, continuous monitoring, and record keeping of key process parameters are recorded and reported to the TDEC in quarterly, semiannual, and annual reports. The initial semiannual report under Title V was submitted in November 2005.

Approximately three-fifths of the permitted air sources release primarily nonradiological contaminants. The remaining two-fifths of the permitted sources process primarily radiological materials. TDEC air permits for the nonradiological sources do not require stack sampling or monitoring except for the two opacity monitors and three NO_x monitors used at the steam plant to ensure compliance with visible emission standards and ozone season emission limits, respectively. For nonradiological sources where direct monitoring of airborne emissions is not required, monitoring of key process parameters is done to ensure compliance with all permitted emission limits.

The 2005 Y-12 Complex annual emission fee was calculated based on 10,033 tons per year of allowable emission of regulated pollutants, with an annual emission fee of $195,643.50. In accordance with TDEC regulations, Rule 1200-3-26-.02(9)(i), when there is no applicable standard or permit condition for a pollutant, the allowable emissions are based on the maximum actual emissions calculations (maximum design capacity for 8760 h/year). More than 90% of the Y-12 Complex pollutant emissions to the atmosphere are attributed to the operation of the steam plant. The emission fee rate was based on $19.50 per ton of regulated-pollutant allowable emissions. The actual emissions are much lower than the allowable amount; however, major sources are required to pay their annual emission fees based on allowable emissions until the issuance of the major source operating permit.

6.2.1 Results

The primary source of criteria pollutants at the Y-12 Complex is the steam plant, where coal and natural gas are burned. Information regarding actual vs allowable emissions from the steam plant is provided in Table 6.1. In addition, the annual toxic release inventory report (required by EPCRA Sect. 313) provides information on other nonradiological Y-12 Complex air emissions (Sect. 2.2.16.3).

Condition E12-6 of the Y-12 Title V operating air permit for the Y-12 Steam Plant requires the opacity monitoring systems to be fully operational 95% of the operational time of the monitored units during each month of the calendar quarter. During 2005, the opacity monitoring systems were operational for more than 95% of the operational time of the monitored units during each month.

Condition E12-7 of the Y-12 Title V operating air permit requires that calibration error tests of the opacity monitoring systems be performed on a semiannual basis. The calibration error tests will be performed on January 1 for both the east and west opacity monitors and again on August 15 and September 8 for the east monitor; the reports will be submitted to the technical secretary for his approval and records. Six 6-min periods of excess emissions occurred during 2005. Quarterly reports of the status of the Y-12 Steam Plant opacity monitors are submitted to personnel at TDEC within 30 days after the end of each calendar quarter. Table F.4 in Appendix F is a record of excess emissions and inoperative conditions for the east and west stack opacity monitors for 2005.

Condition E12-10 of the Y-12 Title V operating air permit requires continuous monitoring of NO_x mass emissions during the ozone season (May 1 through September 30). The cumulative NO_x mass emissions measured from the steam plant for the 2005 ozone season were 215.4 tons of NO_x; the limit is 232 tons.

The results of monitoring a number of key process parameters were provided in a report to TDEC in November 2005. All monitored results were in compliance with the exception of three deviations. All three deviations were at the Dry Ash Handling Facility, where compliance with a particulate emissions limit is demonstrated by daily readings of pressure drop across the bag house filter control device (Permit Condition E17-1). There were two instances of missed readings and one 10-day period when pressure drop readings were outside the expected range. This occurred immediately following routine maintenance to replace old bags with new bags. There were no excess emissions to the environment as a result of this event. The control device was being maintained and operated as expected. A minor permit modification was issued in December 2005 to allow the broader range of pressure-drop readings.

Table 6.1. Actual vs allowable air emissions from the Oak Ridge Y-12 Steam Plant, 2005

Pollutant	Emissions (tons/year)[a]		Percentage of allowable
	Actual	Allowable	
Particulate	33	945	3.5
Sulfur dioxide	2,313	20,803	11.1
Nitrogen oxides[b]	707	5,905	12.0
Nitrogen oxides (ozone season only)	215.4[c]	232	92.8
Volatile organic compounds[b]	2.3	41	5.6
Carbon monoxide[b]	21	543	3.9

[a]1 ton = 907.2 kg.

[b]When there is no applicable standard or enforceable permit condition for some pollutants, 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 8760 h/year). The emissions for both the actual and allowable emissions were calculated based on the latest EPA compilation of air pollutant emission factors. (EPA 1995 and 1998. *Compilation of Air Pollutant Emission Factors AP-42, Fifth Edition, Volume 1: Stationary Point and Area Sources.* Environmental Protection Agency, Research Triangle Park, N.C. January 1995 and September 1998.)

[c]Monitored emissions.

6.3 Y-12 Complex Ambient Air Monitoring

There are no federal regulations, state regulations, or DOE orders that require ambient air monitoring within the Y-12 complex. All ambient air monitoring systems at the Y-12 Complex are operated 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. ORR air sampling stations (see Chap. 7), operated in accordance with DOE orders, are located around the reservation. Their locations were selected so that areas of potentially high exposure to the public are monitored continuously for parameters of concern.

BWXT Y-12 maintains three uranium ambient air monitors within the Y-12 boundary that, since 1999, have been utilized by TDEC personnel in their environmental monitoring program. Each of the monitors use 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 approximately two standard cubic feet per minute. These samplers were operated by TDEC in 2005. In addition, two boundary mercury-monitoring stations (stations 2 and 8) remain in operation and monitor long-term spatial and temporal trends in ambient mercury vapor. The locations of the monitoring stations are shown in Fig. 6.3.

In preparation for the restart of the Oxide Conversion Facility (OCF), an ambient fluoride monitor was co-located with an existing ORR ambient air station in the Scarboro Community. (The ORR ambient network is discussed in Sect. 7.3.) As a measure to quantify any off-site fluoride dispersions, monitoring capability for fluorides was initiated in November 2004 and continued through 2005. In 2005 the OCF was loaded with hydrogen fluoride.

6.3.1 Mercury

The Oak Ridge 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 concentration in ambient air, to identify long-term spatial and temporal trends in ambient mercury vapor, and to demonstrate protection of the environment and human health from releases of mercury at the Y-12 Complex to the atmosphere. Originally, four monitoring stations were operated at the Y-12 Complex, including two within the former mercury-use area. The two atmospheric mercury monitoring stations currently operating at the Y-12 Complex, Ambient Air Station No. 2 (AAS2) and Ambient Air Station No. 8 (AAS8), are located near the east and west boundaries of the complex, respectively (see Fig. 6.3). Since their establishment in 1986, AAS2 and AAS8 have monitored mercury in ambient air continuously with the exception of short periods of downtime because of electrical or equipment outages. In addition to the plant monitoring stations, a control or reference site (Rain Gauge No. 2) was operated on Chestnut Ridge in the Walker Branch Watershed for a 20-month period in 1988 and 1989 to establish local background concentrations at that time.

At the two monitoring sites, airborne mercury vapor is collected by pulling ambient air through a sampling train consisting of a Teflon filter, a flow-limiting orifice, and an iodated charcoal-filled sampling trap. The flow-limiting orifice restricts airflow through the sampling train to about 1 L/min. Actual flow rates are measured weekly in conjunction with trap change-out with a calibrated Gilmont flowmeter. Cold vapor atomic fluorescence after acid digestion is used to analyze the charcoal in each trap for total absorbed mercury. The average concentration of mercury vapor in the ambient air for each 7-day sampling period is calculated by dividing the total quantity of mercury collected on the charcoal by the total volume of air pulled through the charcoal trap.

Average ambient mercury concentrations at the monitoring sites have declined significantly since the late-1980s, with average mercury vapor concentrations at AAS8 declining almost tenfold and at AAS2 approximately threefold. Recent average annual concentrations at these

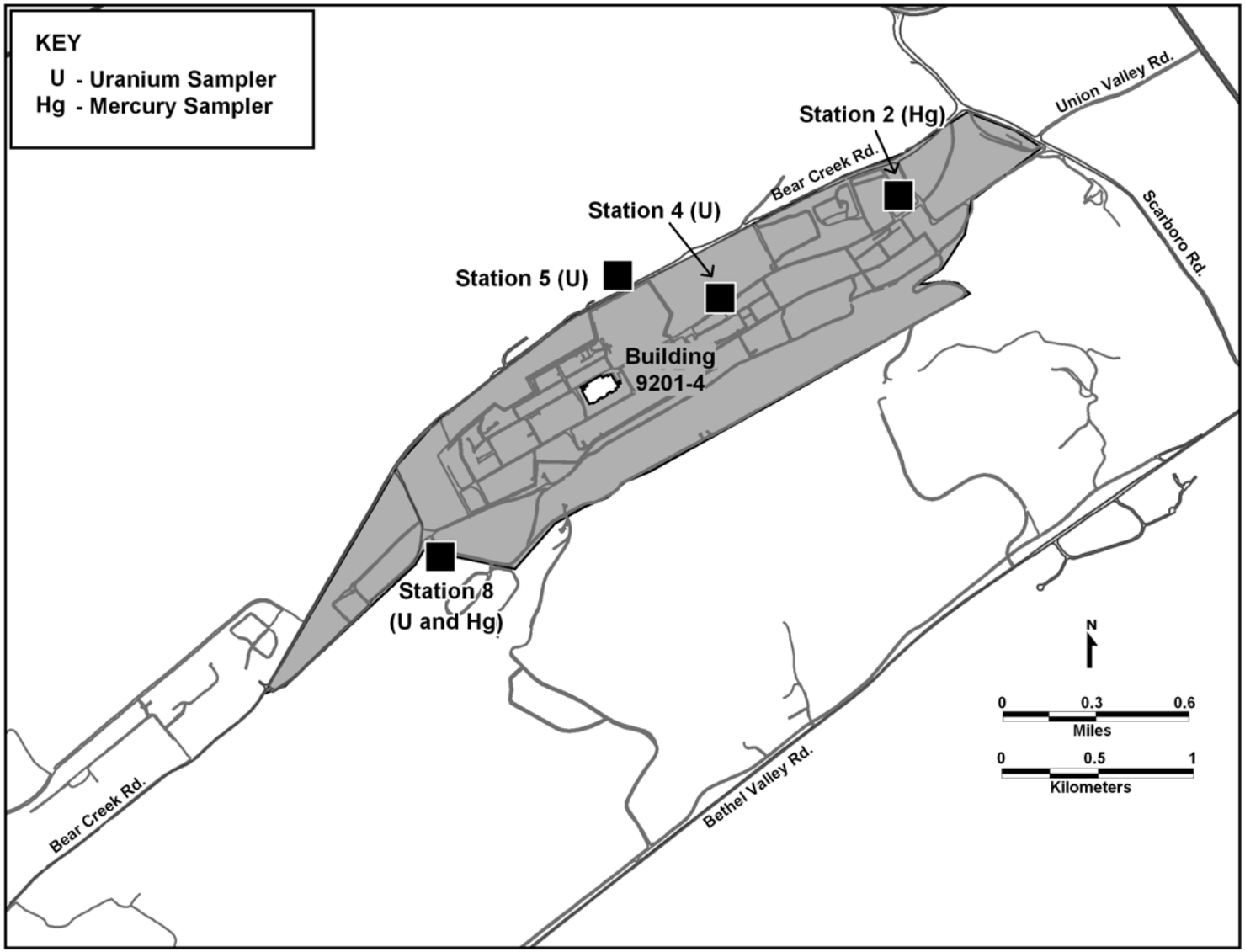


Fig. 6.3. Locations of ambient air monitoring stations at the Y-12 Complex.

two boundary stations are comparable to concentrations measured in 1988 and 1989 at the Chestnut Ridge reference site (see Table 6.2) and only slightly elevated above concentrations reported for continental background (i.e., ~0.002 μg/m^3). Average mercury concentration measured at the AAS2 site during 2005 was 0.0036 μg/m^3 and thus was unchanged from the reported 2003 and 2004 average. At monitoring station AAS8, the average annual concentration increased from 0.0050 μg/m^3 in 2004 to 0.0055 μg/m^3 in 2005. Though the difference in the average concentration from 2004 to 2005 is not significant, the 2005 average is significantly different from the 2003 average of 0.0043 μg/m^3 (Student's t-test) and continues an upward trend in mercury at AAS8 dating back to 2003. This upward trend may reflect a temporary increase in ambient concentrations due to the recent increased demolition and excavation in the western end of the plant, resulting in possible disturbances of Hg-contaminated soil and sediment. A similar, though much greater, increase in concentration at AAS8 was observed in the late 1980s (Fig. 6.4, plot B) and is thought to be related to the Perimeter Intrusion Detection and Assessment System and utility restoration projects in progress then. Table 6.2 summarizes the 2005 mercury results and the results from the period from 1986 through 1988 for comparison. Plots A, B, and C in Fig. 6.4 illustrate temporal trends in mercury concentration for the two active mercury monitoring sites since the inception of the program in 1986 through December 2005 (plots A and B) and seasonal trends at AAS8 from 1993 thru 2005 (plot C).

Annual average mercury concentrations during 2005 at the two monitoring stations are comparable to reference levels measured on Chestnut Ridge in 1988 and 1989. These concentrations continue to be below current environmental and occupational health standards for inhalation exposure to mercury vapor:

- the National Institute for Occupational Safety and Health recommended exposure limit of 50 μg/m^3 (time-weighted average for a 10-h workday, 40-h work week),
- the American Conference of Governmental Industrial Hygienists workplace threshold limit value of 25 μg/m^3 (time-weighted average for an 8-h workday and 40-h work week), and
- the current EPA reference concentration for elemental mercury for daily inhalation exposure without appreciable risk of harmful effects during a lifetime (0.3 μg/m^3).

6.3.2 Fluorides

State of Tennessee regulation 1200-3-3-.01 does not define primary standards (affecting public health) for hydrogen fluoride. However, secondary standards (affecting public welfare, i.e., vegetation, aesthetics) are defined in 1200-3-3-.02 for gaseous fluorides expressed as hydrogen fluoride. In anticipation of the startup of the hydrogen fluoride system during CY 2005, arrangements were made to monitor the community adjacent to the Y-12 Complex for the presence of fluorides.

The monitoring methodology chosen for use is in accordance with ASTM D3266, which designates the use of a dual-tape sampler. The time period over which the monitoring occurs is 7 days, and results in a total of fifty-six

Table 6.2. 2005 summary results for the Oak Ridge Y-12 National Security Complex mercury in ambient air monitoring program

Results of the 1986 through 1988 monitoring period are shown for reference

Ambient air monitoring stations	Mercury vapor concentration (μg/m^3)			
	2005 average	2005 maximum	2005 minimum	1986–1988 average
AAS2 (east end of Y-12)	0.0036	0.0086	0.0017	0.010
AAS8 (west end of Y-12)	0.0055	0.0118	0.0019	0.033
Reference Site, Rain Gauge No.2 (1988[a])	N/A	N/A	N/A	0.006
Reference Site, Rain Gauge No.2 (1989[b])	N/A	N/A	N/A	0.005

[a]Data for period from February 9 through December 31, 1988.
[b]Data for period from January 1 through October 31, 1989.

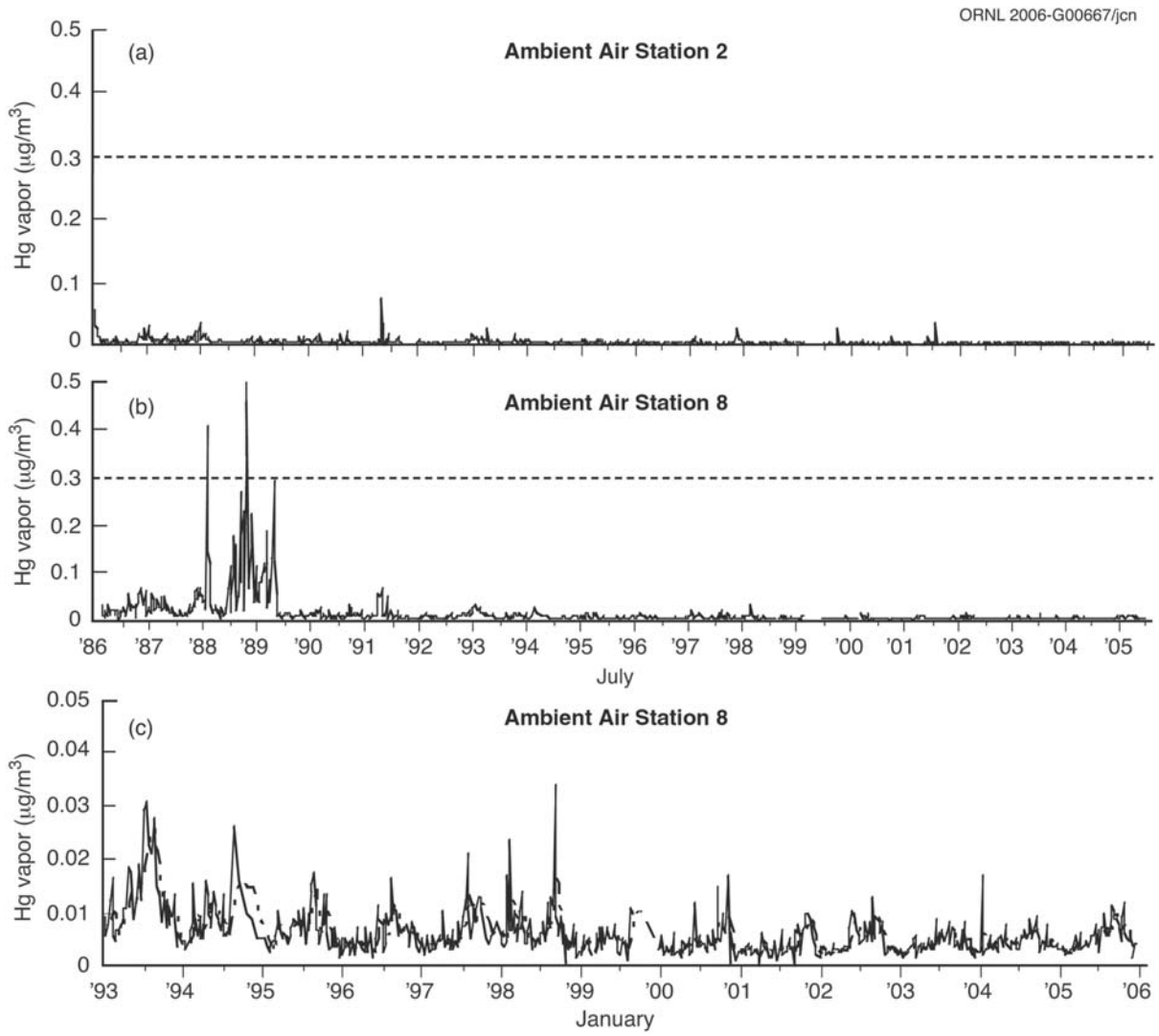


Fig. 6.4. Temporal trends in mercury vapor concentration for the four active airborne mercury monitoring sites at the Oak Ridge Y-12 Complex, July 1986 through January 2006.

samples being generated per week (three hours per sample, eight samples per day; seven days per week). Table 6.3 presents the results of the analyses of these samples for the year 2005. The results represent a composite (seven-day average) and serve to provide background information on the presence of fluorides in the surrounding area. The regulatory secondary standard for the 7-day average is 1.6 μg/m^3. Actual monitoring data indicate a maximum of 0.102 μg/m^3.

Table 6.3. 2005 Summary results for HF measured as fluorides (7-day average) in the Scarboro Community

Date	Run time (h)	Volume (m^3)	FL (μg)	Result (μg/m^3)
1/4	167.3	150.38	10.1	0.067
1/11	168.2	151.21	8.57	0.057
1/18	167.4	150.44	3.59	0.024
1/25	167.8	150.82	2.97	0.020
2/1	168	150.96	11.3	0.075

Table 6.3. (continued)

Date	Run time (h)	Volume (m^3)	FL (µg)	Result (µg/m^3)
2/8	168.5	151.48	10.2	0.067
2/15	167.6	150.52	15.3	0.102
2/22	168.3	150.87	11	0.073
3/1	167.3	150.32	8.6	0.057
3/8	168.4	151.39	5.55	0.037
3/15	167.1	150.18	5.78	0.038
3/22	168.7	151.62	8.24	0.054
3/29	167.6	150.65	4.27	0.028
4/5	167.4	150.46	5.28	0.035
4/12	No samples	0.28	0	0.000
4/19	168.5	151.39	4.92	0.032
4/26	167.2	150.28	4.13	0.027
5/3	168.3	151.23	2.58	0.017
5/10	167.4	150.51	3.24	0.022
5/17	168	151.06	5.52	0.037
5/24	167.3	150.42	2.22	0.015
5/31	167.9	150.55	2.77	0.018
6/7	167.3	150.31	3.89	0.026
6/14	No samples	0.01	0	0.000
6/21	168.2	150.69	5.38	0.036
6/28	168	151.84	4.92	0.032
7/5	167.3	150.34	3.69	0.025
7/12	138.1	138.12	3.21	0.023
7/19	25 samples	69.93	2.61	0.037
7/26	168	150.3	3.06	0.020
8/2	134.5	117.35	2.78	0.024
8/9	119.8	104.53	1.85	0.018
8/16	167.6	150.48	3.87	0.026
8/23	168.4	151.33	3.24	0.021
8/30	169.9	150.3	3.81	0.025
9/6	168.2	150.35	3.33	0.022
9/13	167.4	150.49	3.9	0.026
9/20	168.6	151.55	3.33	0.022
9/27	167.3	150.51	1.87	0.012
10/4	168.1	151.12	3.9	0.026
10/11	166.5	149.65	3.21	0.021
10/18	169.2	152.12	2.71	0.018
10/25	167	148.02	2.24	0.015
11/1	168	150.87	1.67	0.011
11/8	166.6	148.86	3.09	0.021
11/15	166	19.94	0.357	0.018
11/22	169.4	150.92	2.43	0.016
11/29	168.6	149.27	2.37	0.016
12/6	167.7	150.71	1.72	0.011
12/13	168.2	151.23	1.91	0.013
12/20	167.4	150.192	2.17	0.014
12/27	167.7	150.14	2.12	0.014

6.4 Liquid Discharges—Y-12 Complex Radiological Monitoring Summary

A radiological monitoring plan is in place at the Y-12 Complex to address compliance with DOE orders and NPDES Permit TN002968. The permit requires the Y-12 Complex to submit results from the monitoring program 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 current 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 6.4).

The radiological monitoring plan also addresses monitoring of the sanitary sewer. The Y-12 Complex is permitted to discharge domestic wastewater to the city of Oak Ridge publicly owned treatment works under Industrial and Commercial User Wastewater Discharge Permit No. 1-91. As required by the discharge permit, radiological monitoring of this discharge is conducted and reported to the city of Oak Ridge, although there are no city-established limits. 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 the "as low as reasonably achievable" goals. Radiological monitoring of storm water is also required by the NPDES permit. A comprehensive monitoring plan, *Storm Water Pollution Prevention Plan for the Oak Ridge Y-12 Plant*, has been designed to fully characterize pollutants in storm water runoff. The most recent revision of the plan (BWXT 2002) was issued in November 2002, and incorporates radiological-monitoring requirements. There are 75 storm water outfalls and monitoring points located at the Y-12 Complex, and the NPDES permit requires characterization of a minimum of 25 storm water outfalls per year.

6.4.1 Results

Radiological monitoring plan locations sampled in 2005 are noted in Fig. 6.5. Table 6.5 identifies the monitored locations, the frequency of monitoring, and the sum of the percentages of the derived concentration guides (DCG)s for radionuclides measured in 2005. Radiological data were well below the allowable DCGs.

In 2005, the total mass of uranium and associated curies released from the Y-12 Complex at

Table 6.4. Radiological parameters monitored at the Y-12 Complex in 2005

Parameters	Specific isotopes	Rationale for monitoring
Uranium isotopes	^{238}U, ^{235}U, ^{234}U, total U, weight % ^{235}U	These parameters reflect the major activity, uranium processing, throughout the history of Y-12 and are the dominant detectable radiological parameters in surface water
Fission and activation products	^{90}Sr, ^{3}H, ^{99}Tc, ^{137}Cs	These parameters reflect a minor activity at Y-12, processing recycled uranium from reactor fuel elements, from the early 1960s to the late 1980s, and will continue to be monitored as tracers for beta and gamma radionuclides, although their concentrations in surface water are low
Transuranium isotopes	^{241}Am, ^{237}Np, ^{238}Pu, $^{239/240}Pu$	These parameters are related to recycle uranium processing. Monitoring has continued because of their half-lives and presence in groundwater
Other isotopes of interest	^{232}Th, ^{230}Th, ^{228}Th, ^{226}Ra, ^{228}Ra	These parameters reflect historical thorium processing and natural radionuclides necessary to characterize background radioisotopes

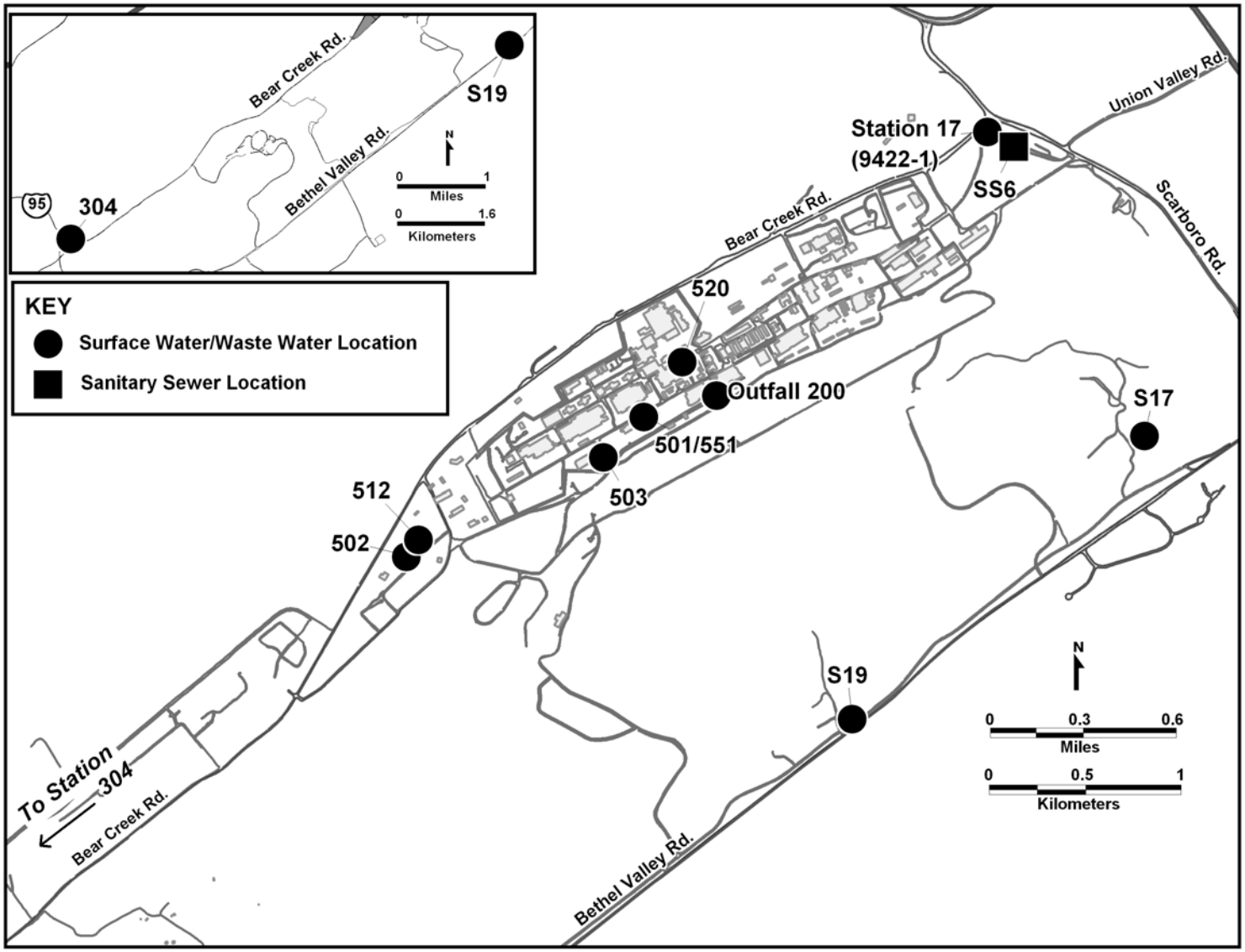


Fig. 6.5. Surface water and sanitary sewer radiological sampling locations at the Y-12 Complex.

Table 6.5. Summary of Y-12 Complex radiological monitoring plan sample requirements

Outfall No.	Location	Sample frequency	Sample type	Sum of DCG percentage
	Y-12 Complex wastewater treatment facilities			
501	Central Pollution Control Facility	1/week	Composite during batch operation	2.4
502	West End Treatment Facility	1/week	24-h composite	3.5
503	Steam Plant Wastewater Treatment Facility	1/week	24-h composite	No flow
512	Groundwater Treatment Facility	1/week	24-h composite	2.5
520 (402)[a]	Steam condensate	1/week	Grab	0.14
551	Central Mercury Treatment Facility	1/month	24-h composite	2.4
	Other Y-12 Complex point and area source discharges			
S17 (301)[a]	Kerr Hollow Quarry	1/month	24-h composite	0.18
S19 (302)[a]	Rogers Quarry	1/month	24-h composite	0.22
	Y-12 Complex instream locations			
BCK 4.55 (304)[a]	Bear Creek, complex exit (west)	1/week	7-day composite	1.9
Station 17	East Fork Poplar Creek, complex exit (east)	1/week	7-day composite	0.91
200	North/south pipes	1/week	24-h composite	43.2
	Y-12 Complex Sanitary sewer			
SS6	East End Sanitary Sewer Monitoring Station	1/week	7-day composite	0.87

[a]Outfall identifications were changed by the NPDES permit effective July 1, 1995. Former outfall identifications are shown here in parentheses.

the easternmost monitoring station, Station 17 on Upper East Fork Poplar Creek, and at the westernmost monitoring station, at Bear Creek kilometer (BCK) 4.55 (the former NPDES outfall 304), was 169 kg, or 0.077 Ci (Table 6.6). Figure 6.6 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.

Table 6.6. Release of uranium from the Y-12 Complex to the off-site environment as a liquid effluent, 2001–2005

Year	Quantity released	
	Ci[a]	Kg
Station 17		
2001	0.043	82
2002	0.062	140
2003	0.073	167
2004	0.067	161
2005	0.043	93
Outfall 304		
2001	0.065	136
2002	0.070	141
2003	0.078	179
2004	0.133	142
2005	0.034	76

1 Ci = 3.7×10^{10} Bq.

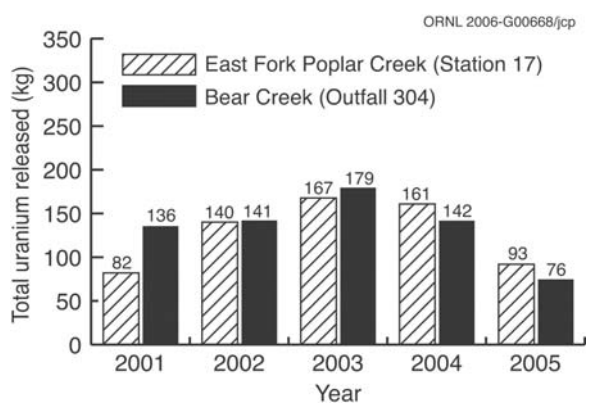


Fig. 6.6. Five-year trend of Y-12 Complex release of uranium to surface water.

The City of Oak Ridge Industrial and Commercial User Wastewater Discharge Permit allows the Y-12 Complex to discharge wastewater to be treated at the Oak Ridge publicly owned treatment works through the East End Sanitary Sewer Monitoring Station, also

identified as SS6 (Fig. 6.5). Compliance samples are collected there. Results of radiological monitoring are reported to the city of Oak Ridge in quarterly monitoring reports.

Table 6.7 presents a summary of 2005 storm water data that exceeded screening levels. More detailed results are given in *Environmental Monitoring on the Oak Ridge Reservation: 2005 Results* (DOE 2006a). (See http://www.ornl.gov/aser.) Uranium remains the dominant radiological constituent and increases during storm flow. This increase is likely due to increased groundwater flow and storm water runoff from historically contaminated areas.

6.5 Nonradiological Liquid Discharges—Y-12 Complex Surface Water and Liquid Effluents

The current Y-12 NPDES permit, issued on April 28, 1995, and effective on July 1, 1995, requires sampling, analysis, and reporting for approximately 90 outfalls. Major outfalls are noted in Fig. 6.7. 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: East Fork Poplar Creek, Bear Creek, and several unnamed tributaries on the south side of Chestnut Ridge. These creeks and tributaries eventually drain to the Clinch River.

Discharges to surface water allowed under the permit include storm drainage, cooling water, cooling tower blowdown, steam condensate, and treated process wastewaters, including effluents from wastewater treatment facilities. Groundwater inflow into sumps in building basements and infiltration to the storm drain system are also permitted for discharge to the creek. The monitoring data collected by the sampling and analysis of permitted discharges are compared with NPDES limits if a limit exists 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 historical legacy operations. Discharges from the Y-12 Complex processes flow into East Fork Poplar Creek before the water exits the Y-12 Complex. East Fork Poplar Creek 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.

The effluent limitations contained in the permit are based on the protection of water quality in the receiving streams. The permit emphasizes storm water runoff and biological, toxicological, and radiological monitoring. Some of the requirements in the permit and the status of compliance are as follows:

- chlorine limitations based on water quality criteria at the headwaters of East Fork Poplar Creek (monitoring ongoing);
- instream pH limitations on tributaries to Bear Creek and various other tributaries on the south side of Chestnut Ridge (monitoring ongoing);
- a radiological monitoring plan requiring monitoring and reporting of uranium and other isotopes at pertinent locations (see Sect. 6.4);
- implementation of a storm water pollution prevention plan and sampling and characterization of storm water at a minimum of 25 locations per year (see Sect. 6.5.2);
- a requirement to manage the flow of East Fork Poplar Creek such that a minimum flow of 7 million gal/day (26.5 million L/day) is guaranteed by adding raw water from the Clinch River to the headwaters of East Fork Poplar Creek (see Sect. 6.5.4);
- toxicity limitation for the headwaters of East Fork Poplar Creek (see Sect. 6.6); and
- quarterly toxicity testing at the wastewater treatment facilities and storm drain locations (see Sect. 6.6).

An agreed-to consent order, dated September 27, 1999, resolved outstanding appeals to the NPDES permit by deleting mercury monitoring requirements and instream limits from the permit and deferring them to the CERCLA program. The CERCLA record of decision will define any mercury remediation requirements for East Fork Poplar Creek. As required, an NPDES permit application was

Table 6.7. Summary of storm water data above screening levels at the Y-12 Complex

	Outfalls																			
Parameters	017	021	034	042	045	046	047	054	064	102	113	135	200	Sta. 8	S02	S05	S11	S17	S24	S26
Alpha activity															X				X	X
Beryllium																	X			
Chromium			X														X		X	X
Copper		X			X	X	X	X		X	X	X	X				X		X	X
E. coli		X		X	X	X	X	X	X	X			X			X		X	X	
Fecal coliform						X							X						X	
Iron																	X		X	X
Lead																	X			
Manganese	X	X			X	X	X	X		X			X	X	X	X	X	X	X	X
Mercury					X		X		X				X	X			X		X	X
Nitrate as nitrogen																X				
Phosphorus		X			X	X				X			X				X		X	X
Titanium																	X		X	X
Total suspended solids					X	X		X	X	X			X				X		X	X
Uranium-234															X					
Uranium-238															X					
Zinc		X			X	X	X	X	X	X		X	X				X			X
PCB						X	X													

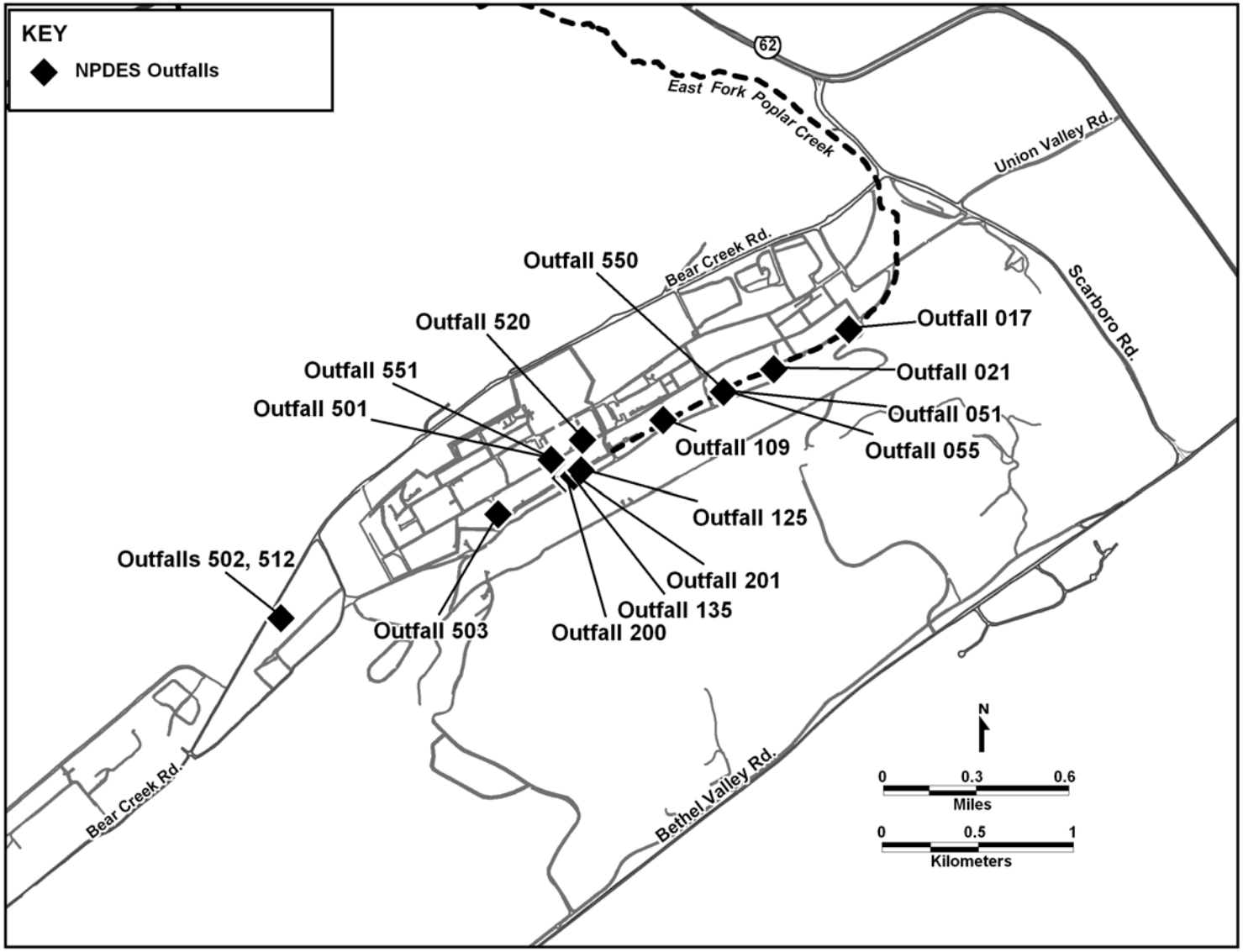


Fig. 6.7. Major Y-12 Complex NPDES outfalls.

submitted in October 1999, six months prior to the expiration date of the current permit (April 28, 2000). Since April 28, 2000, the Y-12 Complex has continued operation under the current permit. In late 2004, personnel from the TDEC Division of Water Pollution Control initiated efforts related to renewal of the permit.

6.5.1 Sanitary Wastewater

Sanitary wastewater from the Y-12 Complex is discharged to the city of Oak Ridge publicly owned treatment works under Industrial and Commercial Users Wastewater Permit Number 1-91. Monitoring is conducted under the terms of the permit for a variety of organic and inorganic pollutants. During 2005, the wastewater flow in this system averaged about 600,000 gal/day.

Compliance sampling is conducted at the East End Sanitary Sewer Monitoring Station (SS-6, Fig. 6.5) weekly. This monitoring station is also used for 24-h flow monitoring. As part of the city of Oak Ridge pretreatment program, city personnel use this monitoring station to perform compliance monitoring as required by pretreatment regulations.

6.5.2 Storm Water

The development and implementation of a storm water pollution prevention plan (BWXT 2002) 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.

Storm water outfalls at the Y-12 Complex are located in subbasins (drainage areas) and are routinely sampled as required by the NPDES permit. The outfalls are categorized into four categories based on characteristics of the discharged water and are grouped within each category based on similarity as to land use of area drained and possible pollutants. A full chemical and radiological characterization of the discharge during a rain event is not required of all storm water outfalls each year. Representative sampling is permitted due to similarity within the same outfall groupings. A minimum of 25 storm water outfalls is required to be sampled and characterized each year during storm events, including both grab and composite sampling.

During 2005 approximately 3500 data points were generated from storm water samples at the Y-12 Complex. By assessing the quality of storm water discharges from the site and by determining potential sources of pollutants affecting storm water, effective controls can be identified and put into place to reduce or eliminate the pollutant sources.

The storm water pollution prevention plan is reviewed at least annually and is updated as necessary to reflect changes in operations and to incorporate revised monitoring strategies based on data from past years. The most recent revision of this plan was issued in November 2002.

6.5.3 Results and Progress in Implementing Corrective Actions

In 2005, the Y-12 Complex experienced eight NPDES excursions. Three were deviations from the monthly average. Table 6.8 lists the NPDES compliance monitoring requirements and 2005 compliance record. Appendix E provides additional detail on the NPDES compliance.

During 2005, the Y-12 Complex experienced one exceedance of the Industrial and Commercial Users Wastewater Permit for discharge of sanitary wastewater to the city of Oak Ridge publicly owned treatment works. Table 6.9 lists the Industrial and Commercial Users Wastewater Permit compliance monitoring requirements and the 2005 compliance record.

Review of storm water data from past years indicates that pollutant loads increase during storm events and that water quality may be affected by uncovered scrap metal storage sites. For example, some outfalls are showing levels above screening limits of total suspended solids, fecal coliform, PCBs, and metals during storm events (see Table 6.7). However, some monitored pollutants are not present at specific

Table 6.8. NPDES compliance monitoring requirements and record for the Y-12 Complex, January through December 2005

Discharge point	Effluent parameter	Effluent limits				Percentage of compliance	No. of samples
		Daily avg (lb/d)[a]	Daily max (lb/d)[a]	Daily avg (mg/L)	Daily max (mg/L)		
Outfall 066	pH, standard units			*b*	9.0	*c*	0
Outfall 068	pH, standard units			*b*	9.0	*c*	0
Outfall 117	pH, standard units			*b*	9.0	*c*	0
Outfall 073	pH, standard units			*b*	9.0	*c*	0
	Total residual chlorine				0.5	*c*	0
Outfall 077	pH, standard units			*b*	9.0	100	12
	Total residual chlorine				0.5	100	12
Outfall 122	pH, standard units			*b*	9.0	*c*	0
	Total residual chlorine				0.5	*c*	0
Outfall 133	pH, standard units			*b*	9.0	*c*	0
	Total residual chlorine				0.5	*c*	0
Outfall 125	pH, standard units			*b*	9.0	100	12
	Total residual chlorine				0.5	100	12
Category I outfalls (Storm water, steam condensate, cooling tower blowdown, and groundwater)	pH, standard units			*b*	9.0	100	46
Category I outfalls (Outfalls S15 and S16)	pH, standard units			*b*	10.0	100	4
Category II outfalls (cooling water, steam condensate, storm water, and groundwater)	pH, standard units			*b*	9.0	100	119
	Total residual chlorine				0.5	100	75
Category II outfalls (S21, S22, S25, S26, S27, S28, and S29)	pH, standard units			*b*	10.0	100	24
Outfall S19 (Rogers Quarry)	pH, standard units			*b*	9.0	100	13
Category III outfalls (storm water, cooling water, cooling tower blowdown, steam condensate, and groundwater)	pH, standard units			*b*	9.0	100	151
	Total residual chlorine				0.5	100	142

Table 6.8. (continued)

Discharge point	Effluent parameter	Effluent limits				Percentage of compliance	No. of samples
		Daily avg (lb/d)[a]	Daily max (lb/d)[a]	Daily avg (mg/L)	Daily max (mg/L)		
Outfall 201 (below the North/South pipes)	Total residual chlorine		8.5	0.011	0.019	100	156
	Temperature, degrees C			*b*	30.5	100	156
	pH, standard units			*b*		100	156
	NOEC *Ceriodaphnia*[d]				100	80	5
	NOEC Fathead minnows[d]				100	100	4
Outfall 200 (North/ South pipes)	Hexane extractable material			10	15	100	157
Outfall 021	Total residual chlorine			0.080	0.188	100	158
	Temperature, degrees C			*b*	30.5	100	158
	pH, standard units				9.0	100	158
Outfall 017	pH, standard units			*b*	9.0	100	53
	Ammonia as N			32.4	64.8	100	52
Outfall 055	pH, standard units			*b*	9.0	100	104
	Mercury				0.004	99	104
	Total residual chlorine				0.5	100	101
Outfall 55A	pH, standard units			*b*	9.0	*c*	0
	Mercury				0.004	*c*	0
Outfall 550	pH, standard units			*b*	9.0	100	52
	Mercury			0.002	0.004	100	52
Outfall 551	pH, standard units				9.0	100	46
	Mercury			0.002	0.004	90	46
Outfall 051	pH, standard units			*b*	9.0	100	105
Outfall 501 (Central Pollution Control Facility)	pH, standard units			*b*	9.0	100	1
	Total suspended solids			31.0	40.0	100	1
	Total toxic organics				2.13	100	1
	Oil and grease			10	15	100	1
	Cadmium	0.16	0.4	0.075	0.15	100	1
	Chromium	1.0	1.7	0.5	1.0	100	1
	Copper	1.2	2.0	0.5	1.0		1
	Lead	0.26	0.4	0.1	0.2	100	1
	Nickel	1.4	2.4	2.38	3.98	100	1
	Nitrate/nitrite				100		1
	Silver	0.14	0.26	0.05	0.05	100	1
	Zinc	0.9	1.6	1.48	2.0	100	1
	Cyanide	0.4	0.72	0.65	1.20		1
	PCB				0.001		1

Table 6.8. (continued)

Discharge point	Effluent parameter	Effluent limits				Percentage of compliance	No. of samples
		Daily avg (lb/d)[a]	Daily max (lb/d)[a]	Daily avg (mg/L)	Daily max (mg/L)		
Outfall 502 (West End Treatment Facility)	pH, standard units			*b*	9.0	100	15
	Total suspended solids	18.6	36.0	31.0	40.0	100	15
	Total toxic organics				2.13	100	3
	Nitrate/nitrite			100	150	100	15
	Hexane extractables			10	15	100	15
	Cadmium	0.16	0.4	0.075	0.15	100	15
	Chromium	1.0	1.7	0.5	1.0	100	15
	Copper	1.2	2.0	0.5	1.0	100	15
	Lead	0.26	0.4	0.10	0.20	100	15
	Nickel	1.4	2.4	2.38	3.98	100	15
	Silver	0.14	0.26	0.05	0.05	100	15
	Zinc	0.9	1.6	1.48	2.0	100	15
	Cyanide	0.4	0.72	0.65	1.20	100	15
	PCB				0.001	100	3
Outfall 503 (Steam Plant Wastewater Treatment Facility)	pH, standard units			*b*	9.0	*c*	0
	Total suspended solids	125	417	30.0	40.0	*c*	0
	Oil and grease	62.6	83.4	10	15	*c*	0
	Iron	4.17	4.17	1.0	1.0	*c*	0
	Cadmium			0.075	0.15	*c*	0
	Chromium	0.83	0.83	0.20	0.20	*c*	0
	Copper	4.17	4.17	0.20	0.40	*c*	0
	Lead			0.10	0.20	*c*	0
	Zinc	4.17	4.17	1.0	1.0	*c*	0
Outfall 512 (Groundwater Treatment Facility)	pH, standard units			*b*	9.0	100	121
	Iron				1.0	100	120
	PCB				0.001	100	12
Outfall 520	pH, standard units				9.0	100	18
Outfall 05A	pH, standard units				9.0	*c*	0

[a] 1 lb = 2.205 kg.

[b] Not applicable.

[c] No discharge.

[d] The no-observed-effect concentration (NOEC) is the concentration of effluent that does not reduce survival, growth, or reproduction of the biomonitoring test organisms during a 6- or 7-day test.

Table 6.9. Y-12 Complex Discharge Point SS6, Sanitary Sewer Station 6, January through December 2005

Effluent parameter	Number of samples	Daily average value (effluent limit)[a]	Daily maximum value (effluent limit)[b]	Percentage of compliance
Flow, mgd	365	*c*	1.4	99
pH, standard units	51	*c*	9/6[d]	100
Silver	52	0.05	0.1	100
Arsenic	52	0.01	0.015	100
Benzene	12	0.01	0.015	100
Biochemical oxygen demand	52	200	300	100
Cadmium	52	0.0033	0.005	100
Chromium	52	0.05	0.075	100
Copper	52	0.14	0.21	100

Table 6.9. (continued)

Effluent parameter	Number of samples	Daily average value (effluent limit)[a]	Daily maximum value (effluent limit)[b]	Percentage of compliance
Cyanide	12	0.041	0.062	100
Iron	52	10	15	100
Mercury	52	0.023	0.035	100
Kjeldahl nitrogen	52	45	90	100
Methylene chloride	12	0.027	0.041	100
Nickel	52	0.021	0.032	100
Oil and grease	52	25	50	100
Lead	52	0.049	0.074	100
Phenols—total recoverable	52	0.3	0.5	100
Suspended solids	52	200	300	100
Toluene	12	0.01	0.02	100
Trichloroethene	12	0.018	0.027	100
Zinc	52	0.35	0.75	100

[a]Units in milligrams per liter unless otherwise indicated.
[b]Industrial and Commercial Users Wastewater Permit limits.
[c]Not applicable.
[d]Maximum value/minimum value.

outfalls. Detailed storm water data summary tables are given in *Environmental Monitoring on the Oak Ridge Reservation: 2005 Results* (DOE 2006a). (See http://www.ornl.gov/aser/.)

6.5.4 Flow Management (or Raw Water)

Because of concern about maintaining water quality and stable flow in the upper reaches of East Fork Poplar Creek, the NPDES permit requires addition of Clinch River water to the headwaters of East Fork Poplar Creek (North/South Pipe-outfall 200 area) so that a minimum flow of 7 million gal/day is maintained at the point where East Fork Poplar Creek leaves the reservation (Station 17). The permit required that this project be implemented by March 1997, but the work was completed ahead of schedule (August 1996). With the completion of the project, instream water temperatures decreased approximately 5°C (from approximately 26°C at the headwaters).

During CY 2005 the flow of Upper East Fork Poplar Creek was maintained in accordance with the permit conditions. The average daily flow during CY 2005 was 8.4 million gal/day.

6.5.5 Mercury Removal from Storm Drain Catch Basins

In May 2003, metallic mercury was observed in two storm drain catch basins located in the west end of the Y-12 Complex. The storm drain line on which the catch basins are located flows into East Fork Poplar Creek at outfall 200. Mercury tends to collect at these low spots in the drain system following heavy rains. During 2005, Y-12 spill response and waste services personnel conducted seven removals and recovered an estimated 12 lb of mercury. A total of 53 lb have been recovered since 2003 and recovery of mercury is expected to continue in 2006.

6.6 Biomonitoring Program

In accordance with the 1995 NPDES permit (Part III-C, p. 39), a biomonitoring program is required that evaluates an East Fork Poplar Creek instream monitoring location (outfall 201), wastewater treatment system discharges, and locations in the storm drain system. Table 6.10 summarizes the results of biomonitoring tests conducted during 2005 on effluent samples from wastewater treatment systems and storm drainage systems. The results of the

Table 6.10. Y-12 Complex Biomonitoring Program summary information for wastewater treatment systems and storm sewer effluents for 2005[a]

Site/building	Test date	Species	48-h LC_{50}[b] (%)	IWC[c] (%)
Central Mercury Treatment System (551)	1/6/05	*Ceriodaphnia*	>100	0.11
Storm sewer D3321	1/7/05	*Ceriodaphnia*	61.4	*d*
Storm sewer D3353	1/7/05	*Ceriodaphnia*	70.7	*d*
Groundwater Treatment Facility (512)	1/11/05	*Ceriodaphnia*	17.3	0.06
Storm sewer D2236	1/11/05	*Ceriodaphnia*	13.7	*d*
Storm sewer D2236 (dechlorinated)	1/11/05	*Ceriodaphnia*	>100	*d*
Storm sewer D2321	1/11/05	*Ceriodaphnia*	24.8	*d*
Storm sewer D2321 (dechlorinated)	1/11/05	*Ceriodaphnia*	>100	*d*
Groundwater Treatment Facility (512)	4/13/05	*Ceriodaphnia*	>100	0.13
Storm sewer D2236	4/13/05	*Ceriodaphnia*	31.4	*d*
Storm sewer D2236 (dechlorinated)	4/13/05	*Ceriodaphnia*	40.5	*d*
Storm sewer D2321	4/13/05	*Ceriodaphnia*	70.7	*d*
Storm sewer D2321 (dechlorinated)	4/13/05	*Ceriodaphnia*	74.3	*d*
Storm sewer D3321	4/15/05	*Ceriodaphnia*	12.1	*d*
Storm sewer D3321 (dechlorinated)	4/15/05	*Ceriodaphnia*	71.8	*d*
Storm sewer D3353	4/15/05	*Ceriodaphnia*	>100	*d*
Central Mercury Treatment System (551)	4/19/05	*Ceriodaphnia*	>100	0.10
Central Pollution Control Facility	6/22/05	*Ceriodaphnia*	>100	0.13
Outfall 520	6/27/05	*Ceriodaphnia*	15.0	*e*
Outfall 520	7/8/05	*Ceriodaphnia*	17.8	*e*
Groundwater Treatment Facility (512)	7/13/05	*Ceriodaphnia*	>100	0.05
Storm sewer D4010 (150)	7/14/05	*Ceriodaphnia*	22.6	*d*
Storm sewer D4010 (150) (dechlorinated)	7/14/05	*Ceriodaphnia*	>100	*d*
Storm sewer D4004 (160)	7/14/05	*Ceriodaphnia*	25.5	*d*
Central Mercury Treatment System (551)	7/15/05	*Ceriodaphnia*	>100	0.34
Storm sewer 9422-12	7/19/05	*Ceriodaphnia*	74.3	*d*
Storm sewer 9422-12 (dechlorinated)	7/19/05	*Ceriodaphnia*	>100	*d*
Storm sewer 9422-15	7/19/05	*Ceriodaphnia*	70.7	*d*
Storm sewer 9422-15 (dechlorinated)	7/19/05	*Ceriodaphnia*	>100	*d*
Groundwater Treatment Facility (512)	11/15/05	*Ceriodaphnia*	93.8	0.09
Storm sewer D4010 (150)	11/17/05	*Ceriodaphnia*	50.0	*d*
Storm sewer D4010 (150) (dechlorinated)	11/17/05	*Ceriodaphnia*	94.8	*d*
Storm sewer D4004 (160)	11/17/05	*Ceriodaphnia*	34.2	*d*
Storm sewer D3311 (163)	11/22/05	*Ceriodaphnia*	70.7	*d*
Storm sewer D3311 (163) (dechlorinated)	11/22/05	*Ceriodaphnia*	70.7	*d*
Storm sewer E3411 (169)	11/22/05	*Ceriodaphnia*	>100	*d*
Storm sewer E3411 (169) (dechlorinated)	11/22/05	*Ceriodaphnia*	>100	*d*
West End Treatment Facility (502)	12/7/05	*Ceriodaphnia*	44.6	0.95

[a]Summarized are the effluents and their corresponding 48-h LC_{50}s and instream waste concentrations. Note: Discharges from treatment facilities are intermittent because of batch operations.

[b]The concentration of effluent (as a percentage of full-strength effluent diluted with laboratory control water) that is lethal to 50% of the test organisms in 48 h.

[c]IWC = instream waste concentration based on actual flows at Station 17 in East Fork Poplar Creek.

[d]This point is in the storm sewer system; therefore, an IWC is not applicable.

[e]Effluent flowrates are unavailable.

biomonitoring tests are expressed as the concentration of effluent that is lethal to 50% of the test organisms (LC_{50}) during a 48-h period. Thus, the lower the value, the more toxic an effluent. The LC_{50} is compared with the effluent's calculated instream waste concentration to determine the likelihood that the discharged effluent would be harmful to aquatic life in the receiving stream. If the LC_{50} is much greater than the instream waste concentration, it is less likely that there is an instream impact.

Effluent samples from the four wastewater treatment system discharges were tested on *Ceriodaphnia dubia* at least once during 2005. With LC_{50}s greater than 100% in each of three tests, effluents from the Central Mercury Treatment System were consistently nontoxic throughout the year. Effluent from the Groundwater Treatment Facility varied in toxicity, with LC_{50}s ranging from 17.3% to greater than 100% in four 2005 tests. The LC_{50}s for effluents from the West End Treatment Facility and the Central Pollution Control Facility were 44.6% and >100%, respectively, from the single tests conducted on effluent from each of these facilities during 2005. In all cases, the calculated instream waste concentrations of the effluent were less than the LC_{50}s, suggesting that effluents from the individual treatment facilities would not be acutely toxic to the aquatic life of East Fork Poplar Creek.

Various locations in the storm drainage system upstream of outfalls 200 and 201 were also monitored during the year. When chlorine or similar chemicals (e.g., bromine) were detected in a sample, side-by-side tests were conducted with a sample that was treated (dechlorinated) to remove the chlorine or chlorine-like chemical. In all cases where toxicity was detected in the nontreated sample (LC_{50} less than 100%), survival was higher in the dechlorinated sample than in the nontreated sample. In many cases, the full-strength dechlorinated sample did not continue to reduce *Ceriodaphnia* survival, indicating that toxicity was due solely to chlorine or similar chemicals. Because flow is not measured at these storm-drain points, it is not possible to know the contribution of each to the total flow at outfall 201 (i.e., the instream waste concentration). It is notable, however, that the results of the biomonitoring tests at outfall 201 (Table 6.11) demonstrated that when all discharges were combined (treated effluent, storm sewer contribution, plus flow management water) the result was generally an absence of toxicity at outfall 201.

Table 6.11. Y-12 Complex Biomonitoring Program summary information for outfall 201 for 2005[a]

Test date	Species	NOEC[b] (%)	96-h LC_{50}[c] (%)
1/6	*Ceriodaphnia*	80	>100
	Fathead minnow	100	>100
1/21[d]	*Ceriodaphnia*	100	>100
4/2	*Ceriodaphnia*	100	>100
	Fathead minnow	100	>100
7/13	*Ceriodaphnia*	100	>100
	Fathead minnow	100	>100
10/6	*Ceriodaphnia*	100	>100
	Fathead minnow	100	>100

[a]Summarized are the no-observed-effect concentrations (NOECs) and the 96-h LC_{50}s for the instream monitoring location, outfall 201.

[b]NOEC as a percentage of full-strength effluent from outfall 201 diluted with laboratory control water. The NOEC must equal one of the test concentrations and is the concentration that does not reduce *Ceriodaphnia* survival or reproduction or fathead minnow survival or growth.

[c]The concentration of effluent (as a percentage of full-strength effluent diluted with laboratory control water) that is lethal to 50% of the test organisms in 96 h.

[d]Confirmatory toxicity test conducted in response to January 6, 2005 test results.

Table 6.11 summarizes the no-observed-effect concentrations (NOECs) and 96-hour LC_{50}s for the instream monitoring location outfall 201. The NOEC is the concentration of effluent that does not reduce survival, growth, or reproduction of the biomonitoring test organisms during a 6- or 7-day test. Thus, like the LC_{50}, the lower the value, the more toxic the effluent. Water from the instream monitoring point, outfall 201, was tested four times in 2005 using fathead minnow larvae (*Pimephales promelas*) and five times using *Ceriodaphnia dubia*. The NOECs were 100% for all *Ceriodaphnia* and fathead minnow tests, with the exception of the January 6, 2005 *Ceriodaphnia* test which had an NOEC of 80%; the 96-h LC_{50}s were consistently

greater than 100% for both *Ceriodaphnia* and fathead minnows.

6.7 Biological Monitoring and Abatement Programs

The NPDES permit issued to the Y-12 Complex in 1995 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, East Fork Poplar Creek. The BMAP consists of four major tasks that reflect complementary approaches to evaluating the effects of Y-12 Complex discharges on the aquatic integrity of East Fork Poplar Creek. These tasks are (1) toxicity monitoring; (2) biological indicator studies; (3) bioaccumulation studies; and (4) ecological surveys of the periphyton, benthic macroinvertebrate, and fish communities.

Monitoring is currently being conducted at five primary East Fork Poplar Creek sites, although sites may be excluded or added, depending upon the specific objectives of the various tasks. The primary sampling sites include upper East Fork Poplar Creek at East Fork Poplar Creek kilometer (EFK) 24.4 and 23.4 (upstream and downstream of Lake Reality, respectively); EFK 18.7 (also EFK 18 and 19), located off the ORR and below an area of intensive commercial and light industrial development; EFK 13.8 (also EFK 14), located upstream from the Oak Ridge Wastewater Treatment Facility; and EFK 6.3, located approximately 1.4 km below the ORR boundary (Fig. 6.8). Brushy Fork at Brushy Fork kilometer (BFK) 7.6 is used as a reference stream in most tasks of the BMAP. Additional sites off the ORR are also occasionally used for reference, including Beaver Creek, Bull Run, Cox Creek, Hinds Creek, Paint Rock Creek, and the Emory River in Watts Bar Reservoir (Fig. 6.9).

Trends of increases in species richness and diversity at upstream locations over the last decade, along with similar but more subtle trends in a number of other BMAP indicators, demonstrate that the overall ecological health of East Fork Poplar Creek continues to improve. However, the pace of improvement in the health of East Fork Poplar Creek has slowed in recent years, and fish and invertebrate communities continue to be degraded in comparison with similar communities in reference streams.

6.7.1 Toxicity Monitoring

Toxicity monitoring employs EPA-approved methods with *Ceriodaphnia dubia* and fathead minnows to provide systematic information that is used to verify the biological water quality of East Fork Poplar Creek at intervals throughout the year. *Ceriodaphnia* tests were conducted quarterly in 2005 for one site upstream of Bear Creek Road (EFK 24.1). In addition, quarterly toxicity tests with both fathead minnows and *Ceriodaphnia* were conducted at outfall 201 as required by the Y-12 Complex's NPDES permit. Because of the close proximity of outfall 201 (an instream NPDES location in Upper East Fork Poplar Creek) to EFK 25.1, the tests of water from outfall 201 also met the intent of the Y-12 BMAP Plan (Adams et al. 2000) to conduct quarterly toxicity tests at the latter location.

No evidence of toxicity was observed in the 2005 *Ceriodaphnia* tests of EFK 24.1 or fathead minnow tests of outfall 201. One 2005 *Ceriodaphnia* test of outfall 201 demonstrated toxicity through a decrease in reproduction in full-strength effluent, but no toxicity was detected in a follow-up test conducted a few weeks later. These results are generally consistent with the findings of previous *Ceriodaphnia* and fathead minnow tests conducted since flow management began in the latter half of 1996. Toxicity of East Fork Poplar Creek water was detected in other 2005 chronic tests involving fish embryos and clams, which appear more sensitive to water quality conditions in the stream. Fish embryo-larval test results are discussed in Sect. 6.7.3; clam tests are discussed in Sect. 6.7.4.

6.7.2 Bioaccumulation Studies

Mercury and PCBs have been historically elevated in East Fork Poplar Creek fish relative to fish in uncontaminated reference streams. Fish are monitored regularly in East Fork Poplar Creek for mercury and PCBs to assess spatial and temporal trends in bioaccumulation associated with ongoing remedial activities and plant operations.

As part of this monitoring effort, redbreast sunfish (*Lepomis auritus*) and rock bass (*Ambloplites rupestris*) were sampled twice

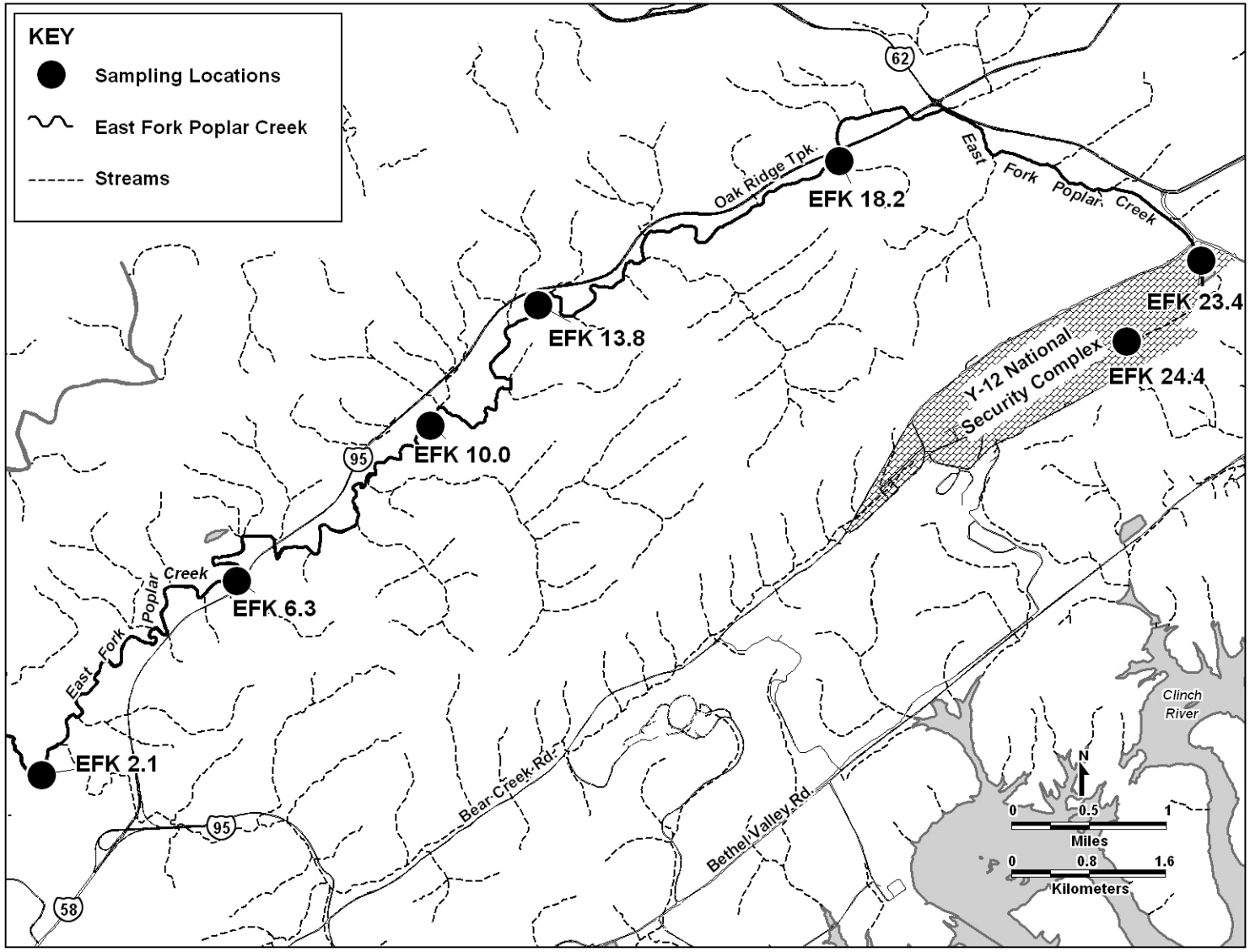


Fig. 6.8. Locations of biological monitoring sites on East Fork Poplar Creek in relation to the Oak Ridge Y-12 National Security Complex.

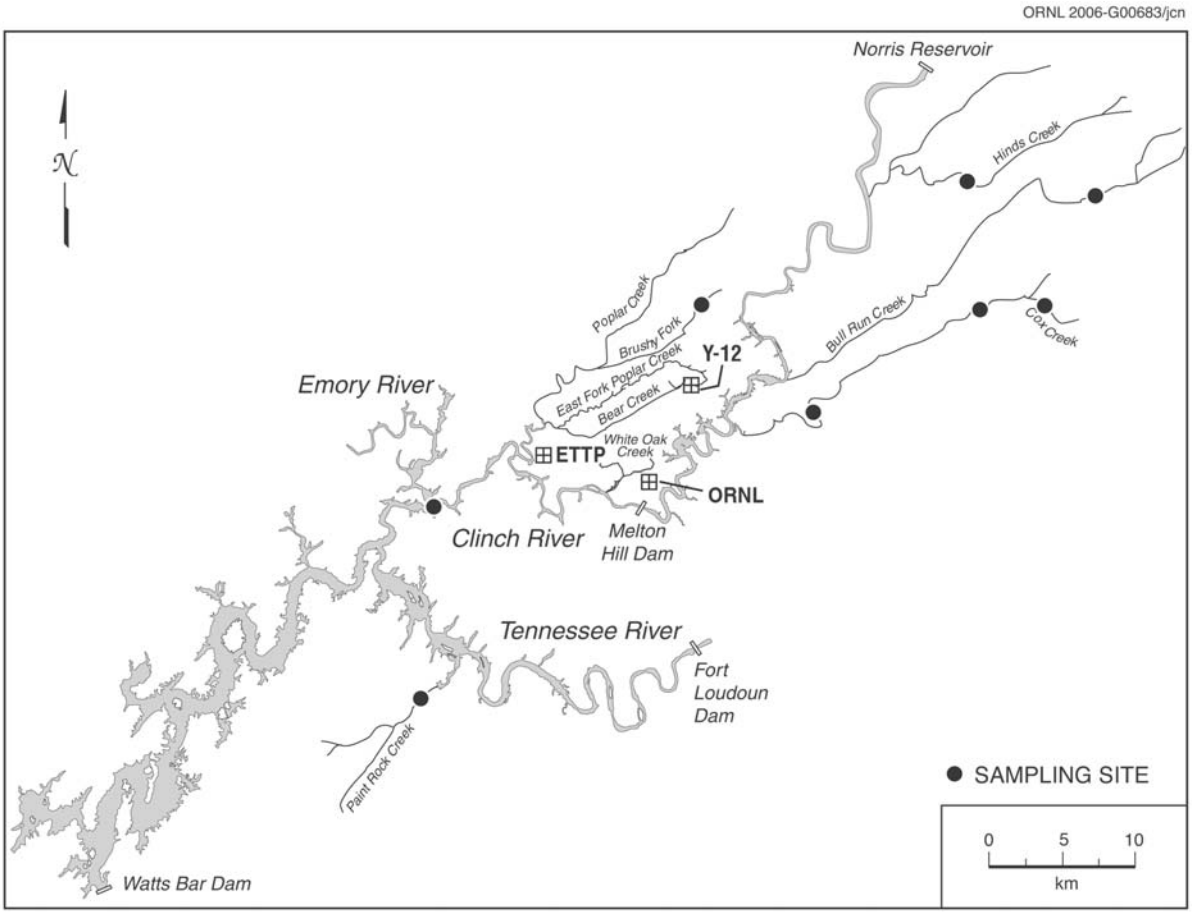


Fig. 6.9. Locations of biological monitoring reference sites in relation to the Oak Ridge Y-12 National Security Complex.

during 2005 from the middle to upper reaches of East Fork Poplar Creek and were analyzed for tissue concentrations of the two environmental contaminants. Largemouth bass (*Micropterus salmoides*) were collected once in 2005 from a site in Upper East Fork Poplar Creek (EFK 23.4) to monitor maximum bioaccumulation in larger piscivorous fish of the system. Large scale stoneroller minnows (*Campostoma oligolepis)* were collected from EFK 24.5 to evaluate potential ecological concerns associated with the accumulation of other metals by these prey fish.

Mercury concentrations remained much higher during 2005 in fish from East Fork Poplar Creek than in fish from reference streams. Elevated mercury concentrations in fish from the upper reaches of East Fork Poplar Creek indicate that the Y-12 Complex remains a continuing source of mercury to fish in the stream. Although concentrations have leveled off in recent years, mercury concentrations in water in the upper reaches of East Fork Poplar Creek have decreased significantly over the last fifteen years. In contrast, mercury concentrations in fish have remained relatively constant since the late 1980s (Fig. 6.10). PCB concentrations measured in East Fork Poplar Creek sunfish during 2005 were within ranges typical of past monitoring efforts at these sites, although mean concentrations at EFK 23.4 appear to be trending downward over time (Fig. 6.11).

6.7.3 Biological Indicator Studies

The biological indicator task is designed to evaluate the effects of water quality and other environmental variables on the health and reproductive condition of individual fish and fish populations in East Fork Poplar Creek. Redbreast sunfish and rock bass were sampled from three sites in East Fork Poplar Creek and from two reference streams in the spring of 2005 prior

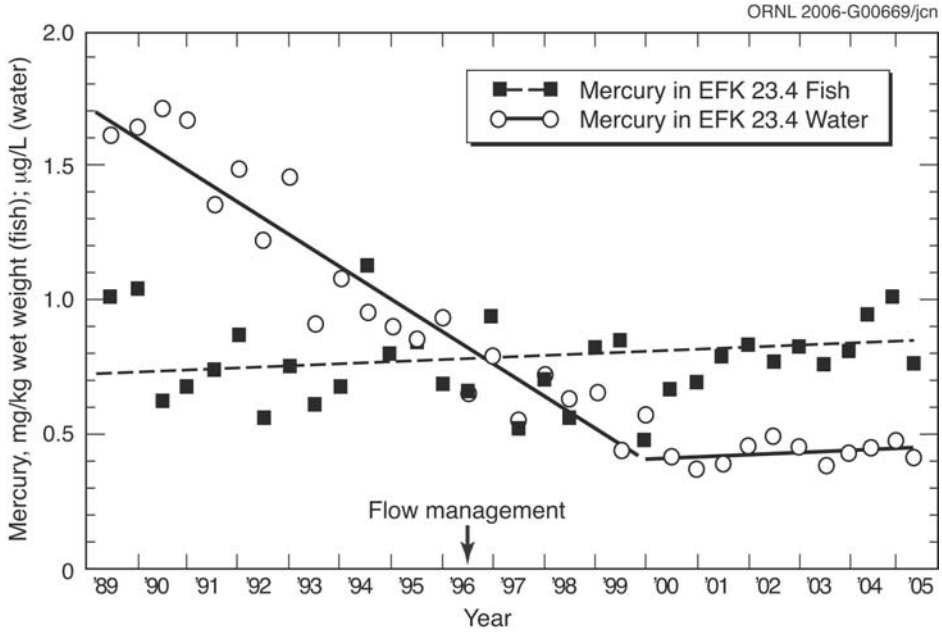


Fig. 6.10. Semiannual average mercury concentration in muscle fillets of redbreast sunfish and water in East Fork Poplar Creek at Station 17 through spring 2005.

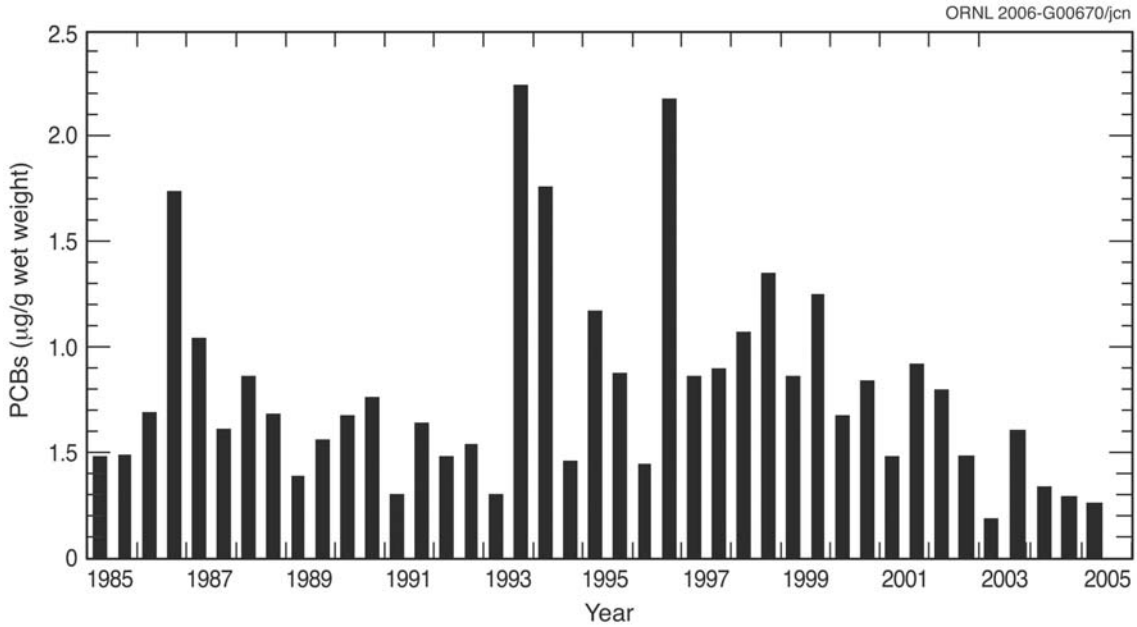


Fig. 6.11. Mean concentrations of PCBs in redbreast sunfish muscle fillets in East Fork Poplar Creek at Station 17 through spring 2005.

to the onset of the breeding season. A fish embryo-larval test using the medaka (*Oryzias latipes*), a small model fish, was conducted on water from several sites in East Fork Poplar Creek in order to test the ability of young fish to successfully develop in the stream.

Overall trends in many contamination-related bioindicators suggest that there has been measurable improvement in overall fish health in Upper East Fork Poplar Creek in recent years. However, the health and reproductive condition of fish from upstream East Fork Poplar Creek

sites remain lower in many respects than in fish from reference sites or downstream East Fork Poplar Creek sites (see Fig. 6.12 for example of decreasing bioenergetic condition of rock bass moving upstream toward the Y-12 Complex). Furthermore, the abundance of redbreast sunfish, which is not native to the region, continues to decline in both East Fork Poplar Creek and reference streams.

Water from East Fork Poplar Creek upstream of the Oak Ridge Wastewater Treatment Facility adversely affected fish embryos in two of four medaka embryo-larval toxicity tests conducted during 2005 (Table 6.12), demonstrating an improvement in the results of these tests from the previous year.

Table 6.12. Results of medaka development toxicity tests conducted on water from ambient sites in East Fork Poplar Creek, 2005

Embryo larval survival (%)

Sample[a]	Quarter			
	First	Second	Third	Fourth
Control	92	96	100	96
EFK 25.1	71	63[b]	55[b]	83
EFK 24.6	75	67[b]	70[b]	96
EFK 23.4	83	42[b]	100	79
EFK 18.2	92	83	90	87
EFK 13.8	100	100	75	87
EFK 10.0	42[b]	21[b]	10[b]	46[b]
EFK 6.3	42[b]	8[b]	15[b]	33[b]

[a]EFK = East Fork Poplar Creek kilometer.
[b]Significant difference from control at $p = 0.05$.

6.7.4 Ecological Surveys

Periphyton was monitored twice during 2005 from three sites along East Fork Poplar Creek. Algal biomass (Table 6.13) and photo synthetic rates remained higher in East Fork Poplar Creek than in reference streams.

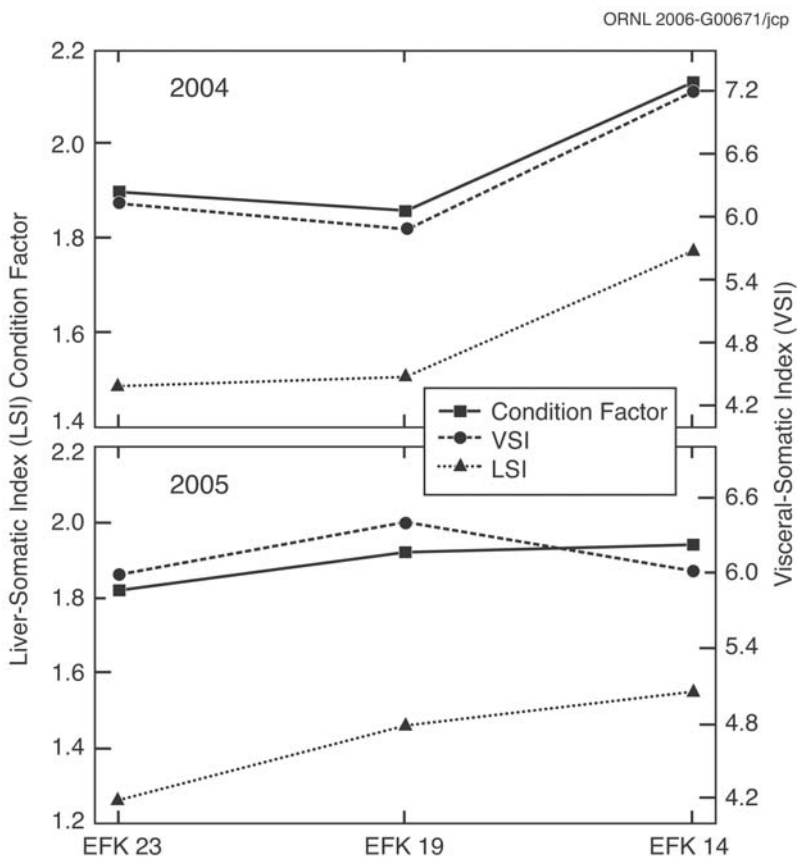


Fig. 6.12. Downstream trends in three bioindicators of fish health in rock bass sampled in 2004 and 2005 from East Fork Poplar Creek.

Table 6.13. Biomass of periphyton sampled from sites on East Fork Poplar Creek and Brushy Fork, 2005

Algal biomass (µg/Chla/cm)[a]

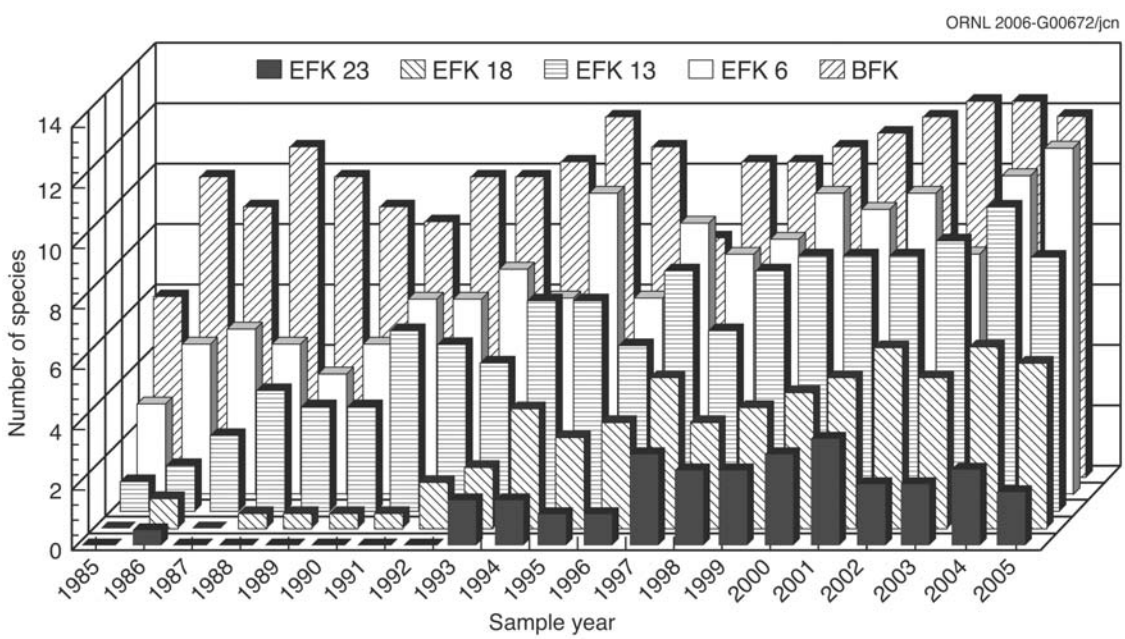
Sample[b]	Season	
	Spring	Fall
EFK 24.4	30.0 ± 14.6	39.5 ± 7.8
EFK 23.4	37.7 ± 27.3	31.9 ± 10.5
EFK 6.3	9.9 ± 4.4	34.7 ± 6.9
BFK 7.6	12.6 ± 5.2	26.5 ± 10.8

[a]Chla = chlorophyll *a*
[b]EFK = East Fork Poplar Creek kilometer
BFK = Brushy Fork kilometer

Fish communities were monitored in the spring and fall of 2005 at five sites along East Fork Poplar Creek and at two reference streams. Over the past two decades, overall species richness, density, and the number of pollution-sensitive fish species have increased at all sampling locations below Lake Reality (Fig. 6.13). However, improvement in the fish community of East Fork Poplar Creek has slowed in recent years, particularly at sites closest to the Y-12 Complex. Despite improvements, the fish community continues to lag behind reference stream communities in most important metrics of fish diversity and community structure.

Benthic macroinvertebrate communities were monitored at three sites in East Fork Poplar Creek and at two reference streams in the spring of 2005. The macroinvertebrate communities at EFK 23.4 and EFK 24.4 remained significantly degraded compared with reference communities, especially in the richness of pollution-sensitive community taxa (Fig. 6.14). The pace of improvement in benthic macroinvertebrate communities has slowed in recent years at these sites in the upper reaches of East Fork Poplar Creek.

The effects of in situ exposure on clam growth and survival were tested during 2005 at three sites in East Fork Poplar Creek and at three reference streams. In contrast with previous tests conducted in recent years, all clams placed at EFK 23.4 and EFK 24.4 died within the first 3-week exposure period (Fig. 6.15). In comparison, all clams placed at EFK 13.8 and in the reference streams survived through this initial exposure period. This 2005 clam test was stopped after only 3 weeks as a result of the premature deaths of test organisms at the upstream sites.



EFK = East Fork Poplar Creek kilometer; BFK = Brushy Fork kilometer.

Fig. 6.13. Comparison of mean abundance of sensitive fish species collected during each year from 1985 through 2005 from four sites in East Fork Poplar Creek and a reference site (Brushy Fork).

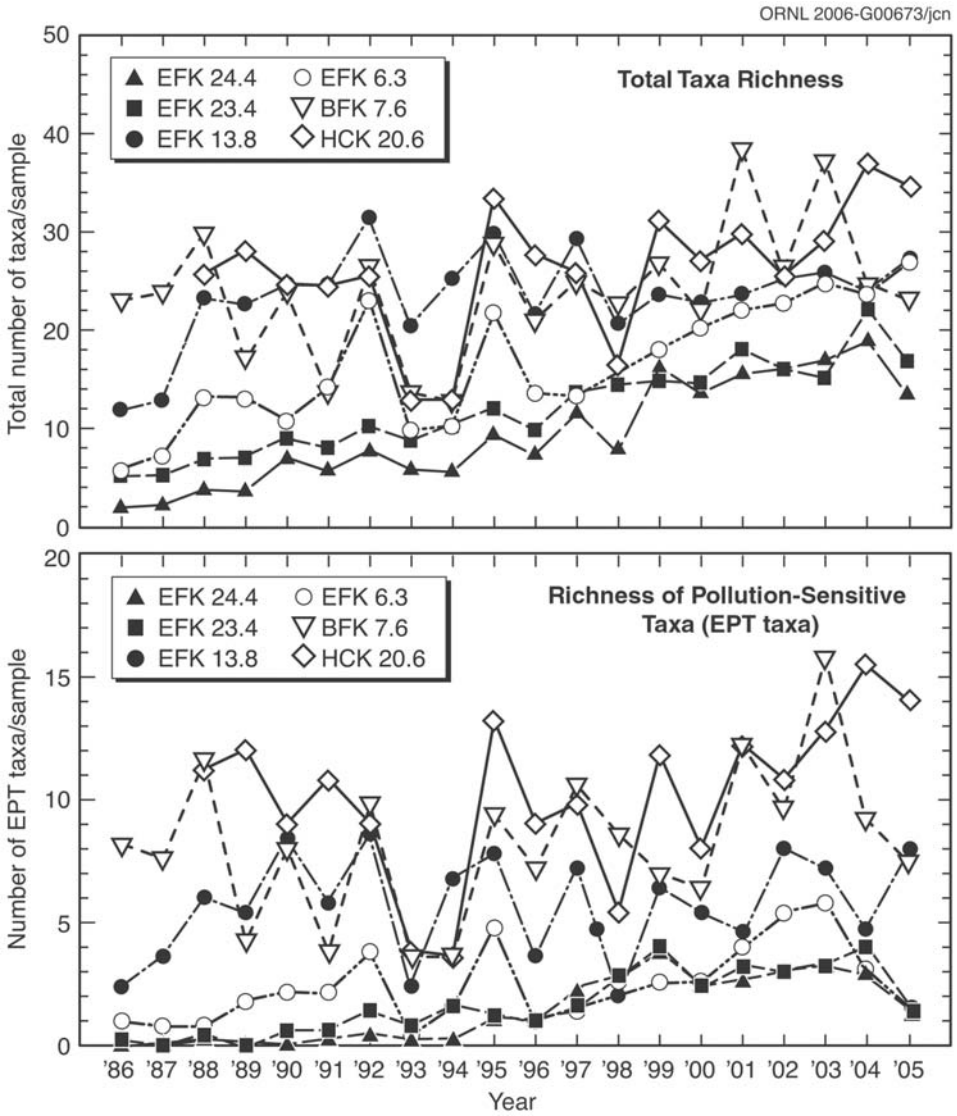


Fig. 6.14. Total taxonomic richness (mean number of taxa/sample) and total taxonomic richness of the Ephemeroptera, Plecoptera, and Trichoptera (EPT) (mean number of EPT taxa/sample) of the benthic macroinvertebrate communities in East Fork Poplar Creek and two reference sites, one on Brushy Fork and one on Hinds Creek (BFK 7.6 and HCK 20.6).

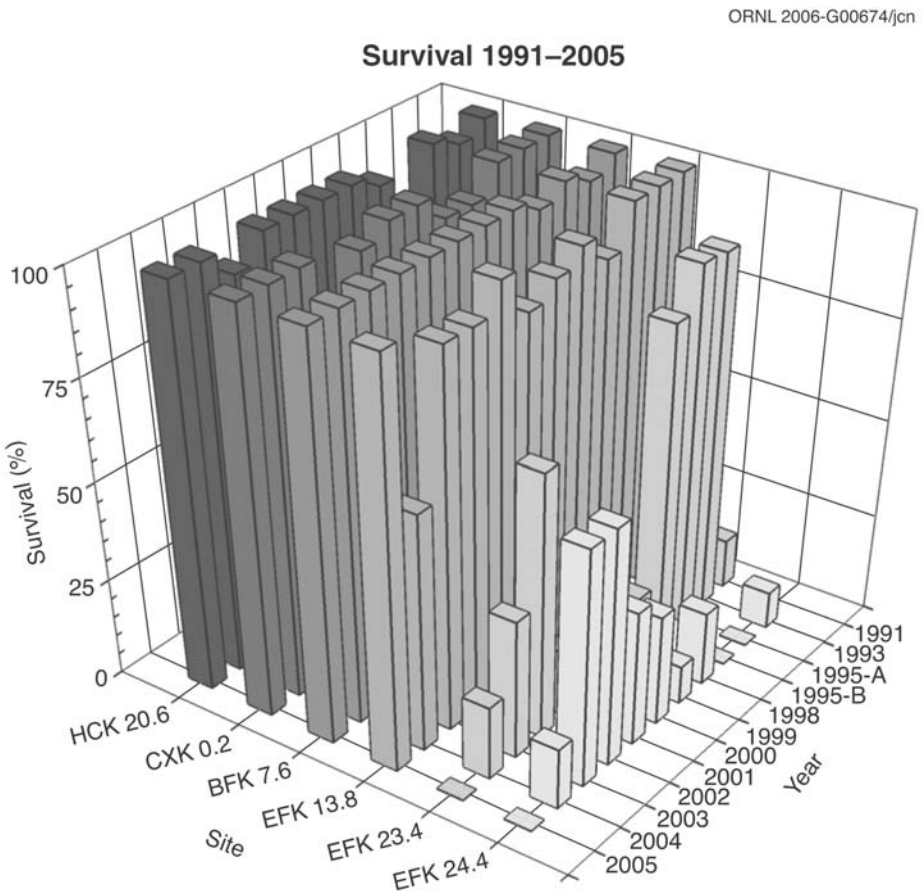


Fig. 6.15. Growth and survival of fingernail clams in in situ bioassays in East Fork Poplar Creek, 1991–2005.

6.8 Y-12 Complex Ambient Surface Water Monitoring

Routine surface water surveillance monitoring, above and beyond that required by the NPDES permit, is performed as a best management practice. The Y-12 Environmental Compliance Department staff monitor the surface water as it exits from each of the three hydrogeologic regimes that serve as exit pathways for surface water (Fig. 6.16).

Monitoring is conducted in East Fork Poplar Creek at Station 17 (9422-1), near the junction of Scarboro and Bear Creek roads. The current sampling program consists of one 7-day composite each week. These samples are analyzed for mercury, ammonia-N, inductively coupled plasma (ICP) metals, and total suspended solids. Monitoring is conducted in Bear Creek at BCK 4.55 (former NPDES Station 304), which is at the western boundary of the Y-12 Complex area of responsibility. A surveillance sample (a 7-day composite sample) is collected monthly for analysis for mercury; anions (sulfate, chloride, nitrate, nitrite); ICP metals; total phenols; and total suspended solids.

The exit pathway from the Chestnut Ridge Hydrogeologic Regime is monitored via NPDES location S19 (former NPDES Station 302) at Rogers Quarry. S19 is an instream location of McCoy Branch and is sampled monthly (a 24-h composite) for ICP metals. The NPDES requirement for this location other than a pH limit is to monitor and report metals data only.

In addition to those exit pathway locations, a network of real-time monitors is located at instream locations along Upper East Fork Poplar Creek and at key points on the storm drain system that flows to the creek. The Surface Water Hydrological Information Support System is available for real-time water quality measurements, such as pH, temperature, dissolved oxygen, conductivity, and chlorine. The locations are noted in Fig. 6.17. Not all locations or parameters are operated on a routine basis.

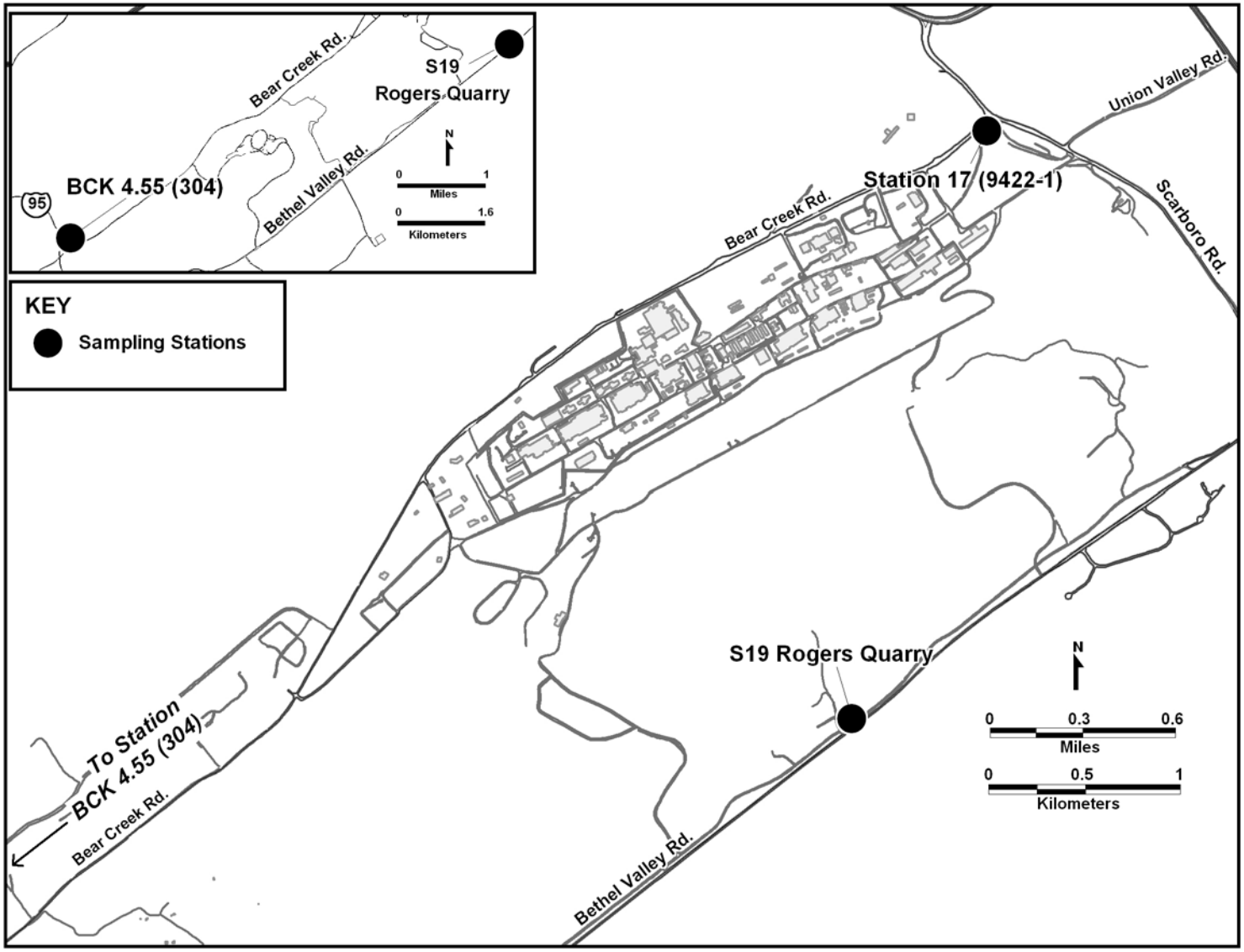


Fig. 6.16. Locations of Y-12 Complex surface water surveillance sampling stations.

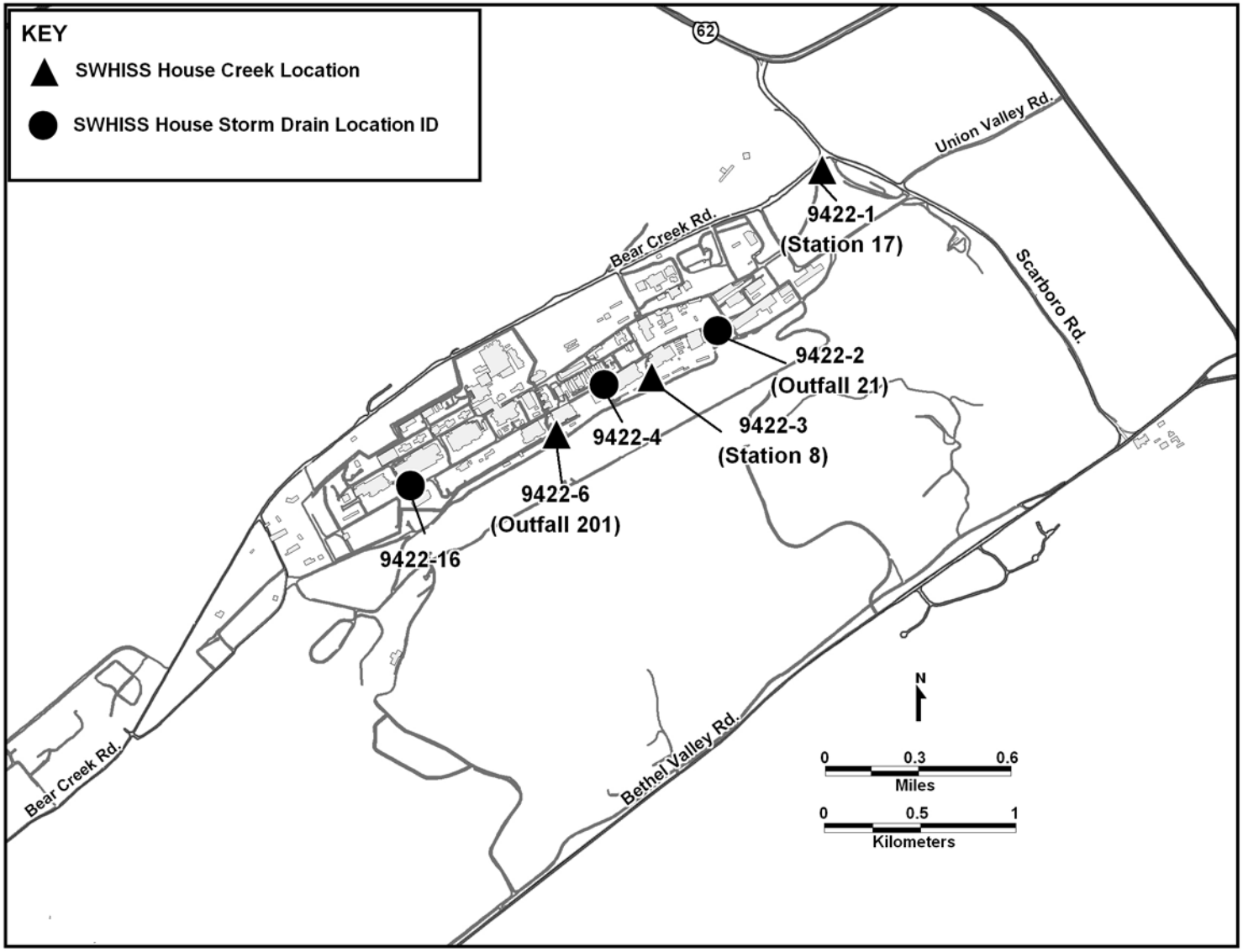


Fig. 6.17. Surface Water Hydrological Information Support System monitoring locations.

For nonradiological parameters that are sampled and detected above the analytical method reporting detection limit, the data are compared with Tennessee water quality criteria. The most restrictive of either the "freshwater fish and aquatic life criterion maximum concentration" or the "recreation concentration for organisms only" standard is used. This comparison serves as a record of water quality, and the comparison to state water quality criteria limits is for informational purposes only; as such, no attempt is made to achieve the lowest possible detection limit for all parameters.

More than 4000 surface water surveillance samples were collected in 2005. Comparisons with Tennessee water quality criteria indicate that only mercury, chromium, zinc, and copper from samples collected at Station 17 were detected at values exceeding a criteria maximum. Results are shown in Table 6.14. Of all the parameters measured in the surface water as a best management practice, mercury is the only demonstrated contaminant of concern.

Additional surface-water sampling is conducted on Bear Creek in accordance with the Y-12 Groundwater Protection Program to monitor trends throughout the Bear Creek Hydrogeologic Regime (see Sect. 6.10.4.3).

6.9 Y-12 Sediment Sampling

Historical data have shown that mercury, PCBs, and isotopes of uranium are present at detectable levels in sediment. Therefore, as a best management practice, the Y-12 Complex maintains an annual sampling program to determine whether these constituents are accumulating in the sediments of East Fork Poplar Creek and Bear Creek as a result of Y-12 Complex discharges. Results of the most recent monitoring activity are given in Table 6.15. The monitoring results indicate that the radiological levels, including isotopes of uranium and thorium, have not significantly changed.

This activity is also used to comply with DOE Order 5400.5, which states in Chapter II.3.a.2 that measures be taken to prevent the buildup of radionuclides in sediments caused by releases of waste streams to natural waterways. The order limits the amount of activity that may be present in released settleable solids. Because waste streams from the Y-12 Complex have very low settleable-solid contents, this sampling program to measure activity in the sediments of East Fork Poplar Creek and Bear Creek is used to determine whether a buildup of radionuclide concentrations is occurring.

6.10 Groundwater Monitoring at the Y-12 Complex

More than 200 sites have been identified at the Y-12 Complex that represent known or potential sources of contamination to the environment as a result of past waste management practices. Figure 6.18 depicts the major facilities considered as known and/or potential contaminant source areas for which groundwater monitoring was performed during CY 2005. Because of that contamination, extensive groundwater monitoring is performed to comply with regulations and DOE orders.

During CY 2005, routine groundwater monitoring at Y-12 was conducted primarily by two programs, the Y-12 Groundwater Protection Program, managed by BWXT Y-12 LLC, and the Water Resources Restoration Program, managed by BJC. Each program is responsible for monitoring groundwater to meet specific compliance requirements. In CY 2005, the Groundwater Protection Program performed monitoring to comply with DOE orders, while the Water

Table 6.14. Surface water surveillance measurements exceeding Tennessee water quality criteria at the Y-12 Complex, 2005

Parameter detected	Location	Number of samples	Concentration (mg/L)			Water quality criteria (mg/L)	Number exceeding criteria
			Detection limit	Max	Avg		
Chromium	Station 17	111	0.02	0.15	<0.02	0.016	1
Copper	Station 17	111	0.02	0.0575	<0.02	0.0177	2
Mercury	Station 17	360	0.0002	0.0182	<0.0005	0.000051	339
Zinc	Station 17	111	0.05	0.344	<0.06	0.12	3

Table 6.15. Results of Y-12 Complex sediment monitoring[a]

	2001	+/–	MDA	2002	+/–	MDA	2003	+/–	MDA	2005	+/–	MDA
Station 17												
^{226}Ra (pCi/g)	0.96	0.91	0.065	0.053	0.056	0.56	0.42	0.32	1.3	0.28	0.79	0.065
^{228}Th (pCi/g)	0.039	0.056	0.098	0.00063	0.0035	0.0058	0.46	0.24	0.19	0.44	0.13	0.067
^{230}Th (pCi/g)	0.11	0.064	0.062	–0.015	0.006	0.0057	0.77	0.4	0.15	0.26	0.11	0.092
^{232}Th (pCi/g)	0.042	0.043	0.062	0.0020	0.0029	0.0044	0.36	0.2	0.15	0.34	0.11	0.037
^{234}U (pCi/g)	1.5	0.26	0.063	0.25	0.039	0.0054	0.81	0.21	0.060	1.2	0.29	0.11
^{235}U (pCi/g)	0.050	0.041	0.023	0.012	0.0078	0.0072	0.047	0.057	0.062	0.1	0.071	0.070
^{238}U (pCi/g)	1.2	0.22	0.044	0.31	0.044	0.0054	1.2	0.26	0.050	1.2	0.26	0.050
Mercury (µg/g)	6.67			8.14			37.1			31.5		
Total PCBs (µg/kg)	270			1400			310			330		
BCK 9.4												
^{226}Ra (pCi/g)	1.0	0.77	0.075	0.26	0.096	0.31	–0.16	0.1	1.2	0.45	0.16	2
^{228}Th (pCi/g)	0.51	0.13	0.038	0.51	0.07	0.0075	0.52	0.17	0.10	0.51	0.15	0.071
^{230}Th (pCi/g)	0.21	0.075	0.016	0.21	0.038	0.0074	0.39	0.2	0.088	0.25	0.11	0.098
^{232}Th (pCi/g)	0.41	0.11	0.016	0.37	0.055	0.0043	0.25	0.11	0.069	0.37	0.12	0.040
^{234}U (pCi/g)	1.1	0.21	0.083	2.1	0.21	0.0043	3.9	0.53	0.056	0.19	0.077	0.058
^{235}U (pCi/g)	0.11	0.061	0.022	0.10	0.022	0.0051	0.25	0.11	0.047	0.063	0.037	0.013
^{238}U (pCi/g)	2.5	0.37	0.042	4.1	0.4	0.0045	8.2	0.96	0.050	9	0.96	0.052
Mercury (µg/g)	0.187			0.277			0.167			0.169		
Total PCBs (µg/kg)	550			590			490			640		

[a]MDA = minimum detectable activity.

1 pCi = 3.7×10^{-2} Bq.

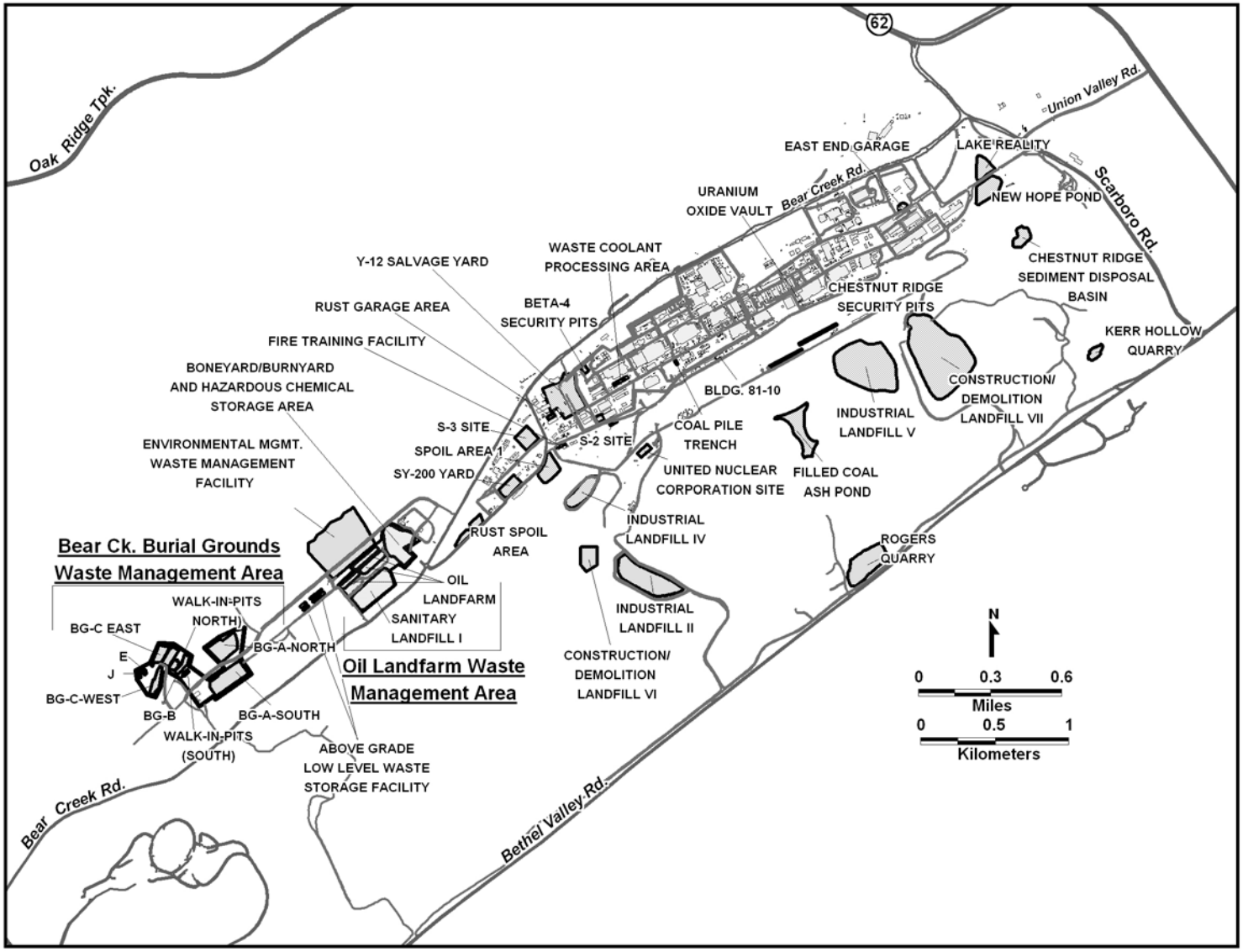


Fig. 6.18. Known or potential contaminant sources for which groundwater monitoring was performed on the Y-12 Complex during CY 2005.

Resources Restoration Program performed groundwater monitoring in compliance with CERCLA and RCRA. In addition to the monitoring performed by the Water Resources Restoration Program, BJC monitors groundwater at the solid waste disposal landfills on Chestnut Ridge and the EMWMF, in Bear Creek Valley.

Although the Groundwater Protection Program, the Water Resources Restoration Program, and other projects have differing technical objectives and responsibilities, considerable efforts are made to maintain consistency in groundwater monitoring activities at the Y-12 Complex. Communication among the programs has been crucial in eliminating any redundancies in monitoring activities. In addition, communication and cooperation provided for more consistent and efficient data collection, evaluation, and overall quality. All groundwater monitoring data obtained by all programs are evaluated to provide a comprehensive view of groundwater quality at the Y-12 Complex.

6.10.1 Hydrogeologic Setting

The Y-12 Complex is divided into three hydrogeologic regimes, which are delineated by surface water drainage patterns, topography, and groundwater flow characteristics. The regimes are further defined by the waste sites they contain. These regimes include the Bear Creek Hydrogeologic Regime, the Upper East Fork Poplar Creek Hydrogeologic Regime, and the Chestnut Ridge Hydrogeologic Regime (Fig. 6.19). Most of the Bear Creek and Upper East Fork Poplar Creek regimes are underlain by the ORR Aquitards. The southern portion of these two regimes is underlain by the Maynardville Limestone, which is part of the Knox Aquifer. The entire Chestnut Ridge regime is underlain by the Knox Aquifer (Fig. 1.6). In general, groundwater flow in the water table interval follows topography. Shallow groundwater flow in the Bear Creek regime and the Upper East Fork regime is divergent from a topographic and groundwater divide located near the western end of the Y-12 Complex that defines the boundary between the two regimes (Fig. 6.19). In addition, flow converges on the primary surface streams (Bear Creek and Upper East Fork Poplar Creek) from Pine Ridge and Chestnut Ridge. In the Chestnut Ridge regime, a groundwater divide exists that approximately coincides with the crest of the ridge. Shallow groundwater flow tends to be toward either flank of the ridge, with discharge primarily to surface streams and springs located in Bethel Valley to the south and Bear Creek Valley to the north.

In Bear Creek Valley, groundwater in the intermediate and deep intervals moves predominantly through fractures in the ORR Aquitards, converging on and then moving through fractures and solution conduits in the Maynardville Limestone. 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 ORR Aquitards (< 1 ft/year) but can be quite rapid within solution conduits in the Maynardville Limestone (tens to thousands of feet per day).

The rate of groundwater flow perpendicular to geologic strike from the ORR aquitards to the Maynardville Limestone has been estimated to be very slow below the water table interval. Most contaminant migration appears to be via surface tributaries to Bear Creek or along utility traces and buried tributaries in the Upper East Fork regime. In the Bear Creek regime, strike-parallel transport of some contaminants can occur within the ORR aquitards for significant distances. Continuous elevated levels of nitrate within the ORR Aquitards are known to extend east and west from the S-3 Site for thousands of feet. Volatile organic compounds at source units in the ORR Aquitards, however, tend to remain close to source areas because they tend to adsorb to the bedrock matrix, diffuse into pore spaces within the matrix, and degrade prior to migrating to exit pathways, where rapid transport occurs for long distances. Regardless, extensive volatile organic compound contamination occurs throughout the groundwater system in both the Bear Creek and Upper East Fork regimes.

Groundwater flow in the Chestnut Ridge regime is primarily 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 primarily toward Bear Creek Valley to the north and Bethel Valley to the south. Groundwater from intermediate and deep zones

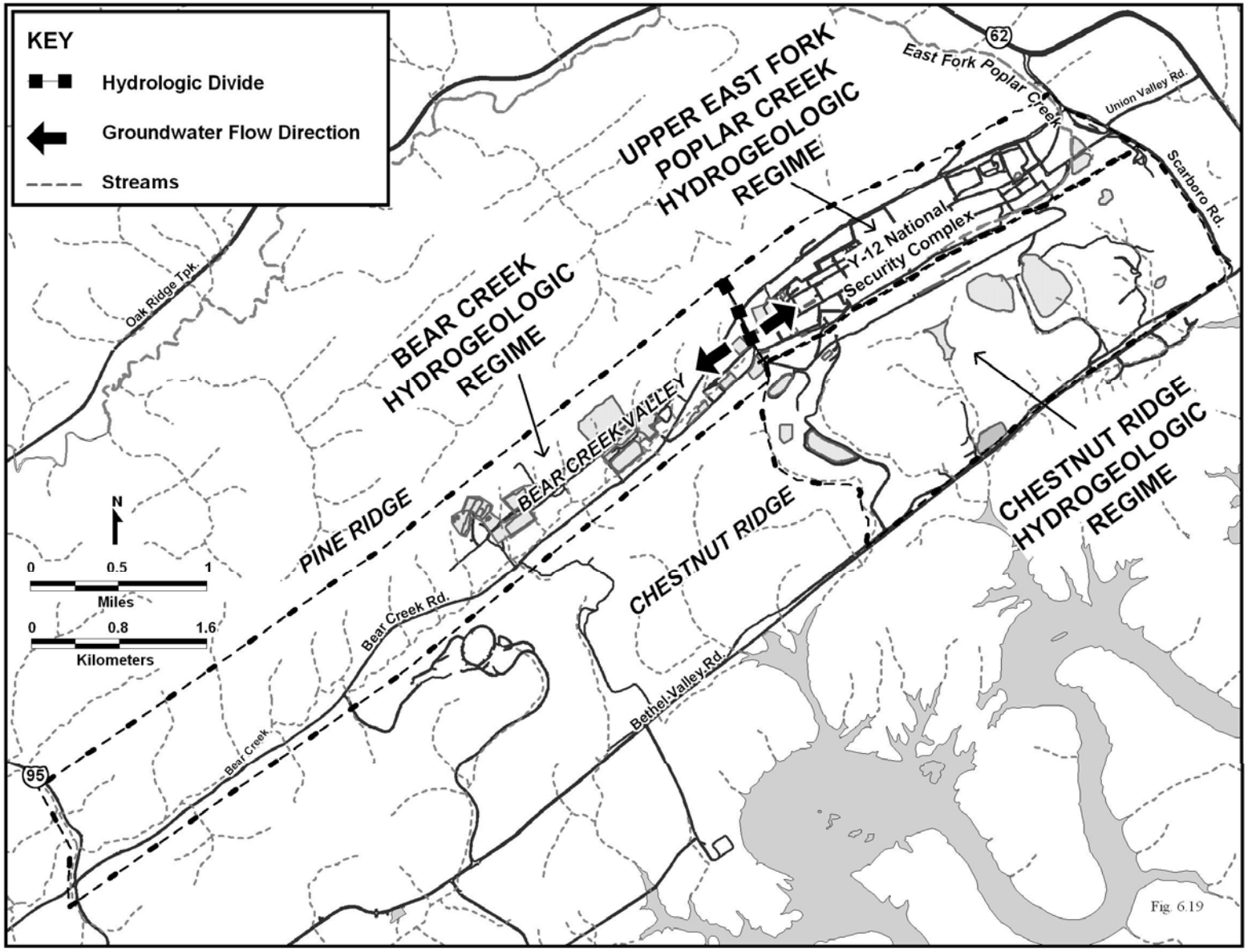


Fig. 6.19. Hydrogeologic regimes at the Y-12 Complex.

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.

6.10.2 Well Installation and Plugging and Abandonment Activities

A number of monitoring devices are routinely 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 specifications. Piezometers are primarily temporary devices used to measure groundwater table levels and are often constructed of polyvinyl chloride or other low-cost materials. Other devices or techniques are sometimes employed to gather data, including well points and push probes. In CY 2005, eight surveillance monitoring wells were installed. One was of a conventional design. The remaining seven wells consist of two coreholes with three and four dedicated BarCad™ pump systems, respectively, for vertical delineation of groundwater quality. Also, 65 piezometers/wells were installed in support of activities by the Natural and Accelerated Bioremediation Research Field Research Center at the S-3 Site. The purpose of the field research center is to provide the fundamental science that will serve as the basis for development of cost-effective bioremediation of contaminant radionuclides and metals in the subsurface at DOE sites.

Well plugging and abandonment activities are conducted to protect human health and the environment, maintain the Y-12 monitoring well network, and meet operational needs. Wells that are damaged beyond rehabilitation, that interfere with planned construction activities, or from which no useful data can be obtained, are selected for plugging and abandonment. In 2005, no wells or piezometers were plugged and abandoned.

6.10.3 CY 2005 Monitoring Program

Groundwater monitoring in CY 2005 was performed to comply with DOE orders and regulations by the Groundwater Protection Program, the Water Resources Restoration Program, and other BJC projects. Compliance requirements were met by the monitoring of 194 wells and 48 surface water locations and springs, and one building sump (Table 6.16). Figure 6.20 shows the locations of ORR perimeter/exit pathway groundwater monitoring stations as specified in the *Environmental Monitoring Plan for the Oak Ridge Reservation* (DOE 2003a).

Comprehensive water quality results of monitoring activities at Y-12 in CY 2005 are presented in the annual *Groundwater Monitoring Report* (BWXT Y-12 2006).

Details of monitoring efforts performed specifically for CERCLA baseline and remediation evaluation are published in the FY 2005 and FY 2006 water resources restoration program sampling and analysis plans (BJC 2004a and BJC 2005), and the 2005 *Remediation Effectiveness Report* (DOE 2006b).

Groundwater monitoring compliance reporting to meet RCRA postclosure permit requirements can be found in the RCRA annual reports (BJC 2006a, BJC 2006b, BJC 2006c).

6.10.4 Y-12 Groundwater Quality

Historical monitoring efforts have shown that four types of contaminants have affected groundwater quality at the Y-12 Complex: nitrate, volatile organic compounds, metals, and radionuclides. Of those, nitrate and volatile organic compounds are the most widespread. Some radionuclides, particularly uranium and ^{99}Tc, are significant, principally in the Bear Creek regime and the western and central portions of the Upper East Fork regime. Trace metals, the least extensive groundwater contaminants, generally occur in a small area of low-pH groundwater at the western end of the complex, near the S-2 and S-3 sites. Historical data have shown that plumes from multiple-source units have mixed with one another and that contaminants (other than nitrate and ^{99}Tc) are no longer easily associated with a single source.

6.10.4.1 Upper East Fork Poplar Creek Hydrogeologic Regime

The Upper East Fork regime contains contaminant source areas and surface water and groundwater components of the hydrogeologic

Table 6.16. Summary of CY 2005 groundwater monitoring at the Y-12 Complex

	Purpose for which monitoring was performed				
	Restoration[a]	Waste management[b]	Surveillance[c]	Other[d]	Total
Number of active wells	63	34	97	65	259
Number of other monitoring stations (e.g., springs, seeps, surface water)	27	5	16	7	55
Number of samples taken[e]	190	112	230	250	782
Number of analyses performed	9,956	8,711	26,555	3,730	48,952
Percentage of analyses that are non-detects	70.3	74.6	65.1	59.7	67.4
Ranges of results for positive detections, VOCs (µg/L)[f]					
Chloroethenes	1–4,500	0.19–7.6	1–71,000	1–1,500	
Chloroethanes	2–680	0.47–20	1–2,600	5–5	
Chloromethanes	1–2,000	7.2–12	1–1,300	6–24	
Petroleum hydrocarbons	1–10,000	0.1–0.3	1–1,700	3–3	
Uranium (mg/L)	0.00466–0.627	0.00095–0.0013	0.0005–0.338	0.05–60.36	
Nitrates (mg/L)	0.02–8,650	0.024–1.7	0.0339–4,350	2.4–23,000	
Ranges of results for positive detections, radiological parameters (pCi/L)[g]					
Gross alpha activity	1.15–775	1.8–4.9	2.2–106	NA	
Gross beta activity	2.34–13,700	1.57–18.3	4.4–5,500	NA	

[a]Monitoring to comply with Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requirements and with Resource Conservation and Recovery Act postclosure detection and corrective action monitoring.

[b]Solid waste landfill detection monitoring and CERCLA landfill detection monitoring.

[c]DOE Order 450.1 surveillance monitoring.

[d]Research related groundwater monitoring associated with activities of the DOE Natural and Accelerated Bioremediation Research Field Research Center.

[e]The number of unfiltered samples, excluding duplicates.

[f]These ranges reflect concentrations of individual contaminants (not summed VOC concentrations):

Chloroethenes—includes tetrachloroethene, trichloroethene, 1,2-dichloroethene (*cis* and *trans*), 1,1-dichloroethene, and vinyl chloride.

Chloroethanes—includes 1,1,1-trichloroethane, 1,2-dichloroethane, and 1,1-dichloroethane.

Chloromethanes—includes carbon tetrachloride, chloroform, and methylene chloride.

Petroleum hydrocarbon—includes benzene, toluene, ethylbenzene, and xylene.

[g]1 pCi = 3.7×10^{-2} Bq.

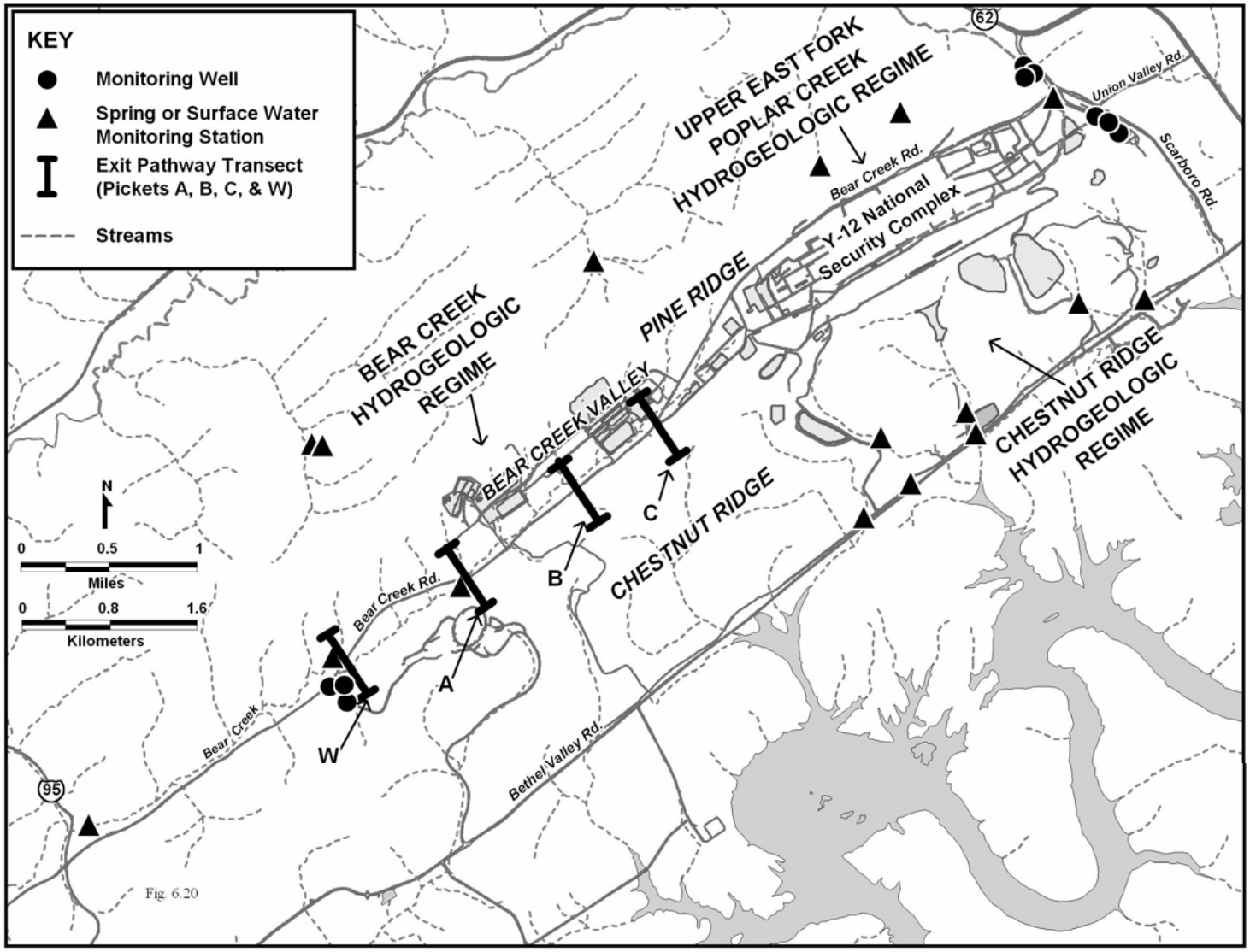


Fig. 6.20. Locations of ORR perimeter/exit pathway well, spring, and surface water monitoring stations in the *Environmental Monitoring Plan for the Oak Ridge Reservation* (Department of Energy Oak Ridge Office, DOE/OR/011066/R5, 2003).

system within the Y-12 Complex and Union Valley to the east and off the ORR. Among the three hydrogeologic regimes on the Y-12 Complex, the Upper East Fork 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 6.17. Chemical constituents from the S-3 Site (primarily nitrate and ^{99}Tc) dominate groundwater contamination in the western portion of the Upper East Fork regime, while groundwater in the eastern portion, including Union Valley, is predominantly contaminated with volatile organic compounds.

Plume Delineation

Sources of groundwater contaminants monitored during CY 2005 include the S-2 Site, the Fire Training Facility, the S-3 Site, the Waste Coolant Processing Facility, the 9418-3 Uranium Oxide Vault, petroleum USTs, 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 East Fork regime from the Bear Creek regime, it has contributed to groundwater contamination in the western part of this regime.

Table 6.17. History of waste management units and underground storage tanks included in CY 2005 groundwater monitoring activities, Upper East Fork Poplar Creek Hydrogeologic Regime[a]

Site	Historical data
New Hope Pond	Built in 1963. Regulated flow of water in Upper East Fork Poplar Creek before exiting the Y-12 Complex grounds. Sediments include PCBs, mercury, and uranium but not hazardous according to toxicity characteristic leaching procedure. Closed under RCRA in 1990
Salvage Yard Scrap Metal Storage Area	Used from 1950 to present for scrap metal storage. Some metals contaminated with low levels of depleted or enriched uranium. Runoff and infiltration are the principal release mechanisms to groundwater
Salvage Yard Oil/Solvent Drum Storage Area	Primary wastes included waste oils, solvents, uranium, and beryllium. Both closed under RCRA. Leaks and spills represent the primary contamination mechanisms for groundwater
Salvage Yard Oil Storage Tanks	Used from 1978 to 1986. Two tanks used to store PCB-contaminated oils, both within a diked area
Salvage Yard Drum Deheader	Used from 1959 to 1989. Sump tanks 2063-U, 2328-U, and 2329-U received residual drum contents. Sump leakage is a likely release mechanism to groundwater
Building 81-10 Area	Mercury recovery facility operated from 1957 to 1962. Potential historical releases to groundwater 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. Petroleum product releases to groundwater are documented
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 fire-fighting training. Sources of contamination to soil include flammable liquids and chlorinated solvents. Infiltration is the primary release mechanism to groundwater
Beta-4 Security Pits	Used from 1968 to 1972 for disposal of classified materials, scrap metals, and liquid wastes. Site is closed and capped. Primary release mechanism to groundwater is infiltration
S-2 Site	Used from 1945 to 1951. An unlined reservoir received liquid wastes. Infiltration is the primary release mechanism to groundwater

Table 6.17. (continued)

Site	Historical data
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
Coal Pile Trench	Located beneath the current steam plant coal pile. Disposals included solid materials (primarily alloys). Trench leachate is a potential release mechanism to groundwater

[a]Abbreviations
PCB = polychlorinated biphenyl
RCRA = Resource Conservation and Recovery Act
UST = underground storage tank

Nitrate

Nitrate concentrations in groundwater at the Y-12 Complex exceed the 10 mg/L drinking water standard in a large part of the western portion of the Upper East Fork regime (a complete list of national drinking water standards is presented in Appendix D). The two primary sources of nitrate contamination are the S-3 and S-2 sites. In CY 2005, groundwater containing nitrate concentrations as high as 8650 mg/L (Well GW-108) occurred in the unconsolidated zone and in shallow bedrock just east of the S-3 Site (Fig. 6.21). These results are consistent with results in previous years. The extent of the nitrate plume is essentially defined in the unconsolidated and shallow bedrock zones. An increasing trend in nitrate concentrations at monitoring wells in the eastern portion of Y-12 has been observed. This increase indicates that the nitrate plume in the Maynardville Limestone is migrating into the eastern area of the Y-12 Complex from the S-2 and/or the S-3 sites. Historical results from monitoring wells in near source areas indicate generally decreasing trends.

Trace Metals

Concentrations of barium, beryllium, cadmium, chromium, lead, mercury, nickel, thallium, and uranium exceeded drinking water standards during CY 2005 in samples collected from various monitoring wells and surface water locations downgradient of the S-2 Site, the S-3 Site, the Salvage Yard, and throughout the complex. Elevated concentrations of these metals in groundwater were most commonly observed from monitoring wells in the unconsolidated zone. Trace metal concentrations above standards tend to occur only adjacent to the source areas due to their low solubility in natural water systems. However, some metals, such as uranium and mercury, are being transported through the surface water and groundwater systems and have been observed in concentrations above the drinking water standards. Concentrations of uranium exceed the standard (0.03 mg/L) in a number of source areas (e.g., production areas, the Uranium Oxide Vault, and the Former Oil Skimmer Basin) and contribute to the uranium concentration in Upper East Fork Poplar Creek.

Volatile Organic Compounds

Because of the many legacy source areas, volatile organic compounds are the most widespread groundwater contaminants in the East Fork regime. Dissolved volatile organic compounds in the regime primarily consist of chlorinated solvents and petroleum hydrocarbons. In CY 2005, the highest concentration of dissolved chlorinated solvents (78,100 µg/L) was found in groundwater at Well 55-3B in the western portion of the Y-12 Complex adjacent to manufacturing facilities. The highest dissolved concentration of petroleum hydrocarbons (24,000 µg/L) was obtained from Well GW-658 at the closed East End Garage.

The CY 2005 monitoring results generally confirm findings from the previous years of monitoring. A continuous dissolved plume of volatile organic compounds in groundwater in

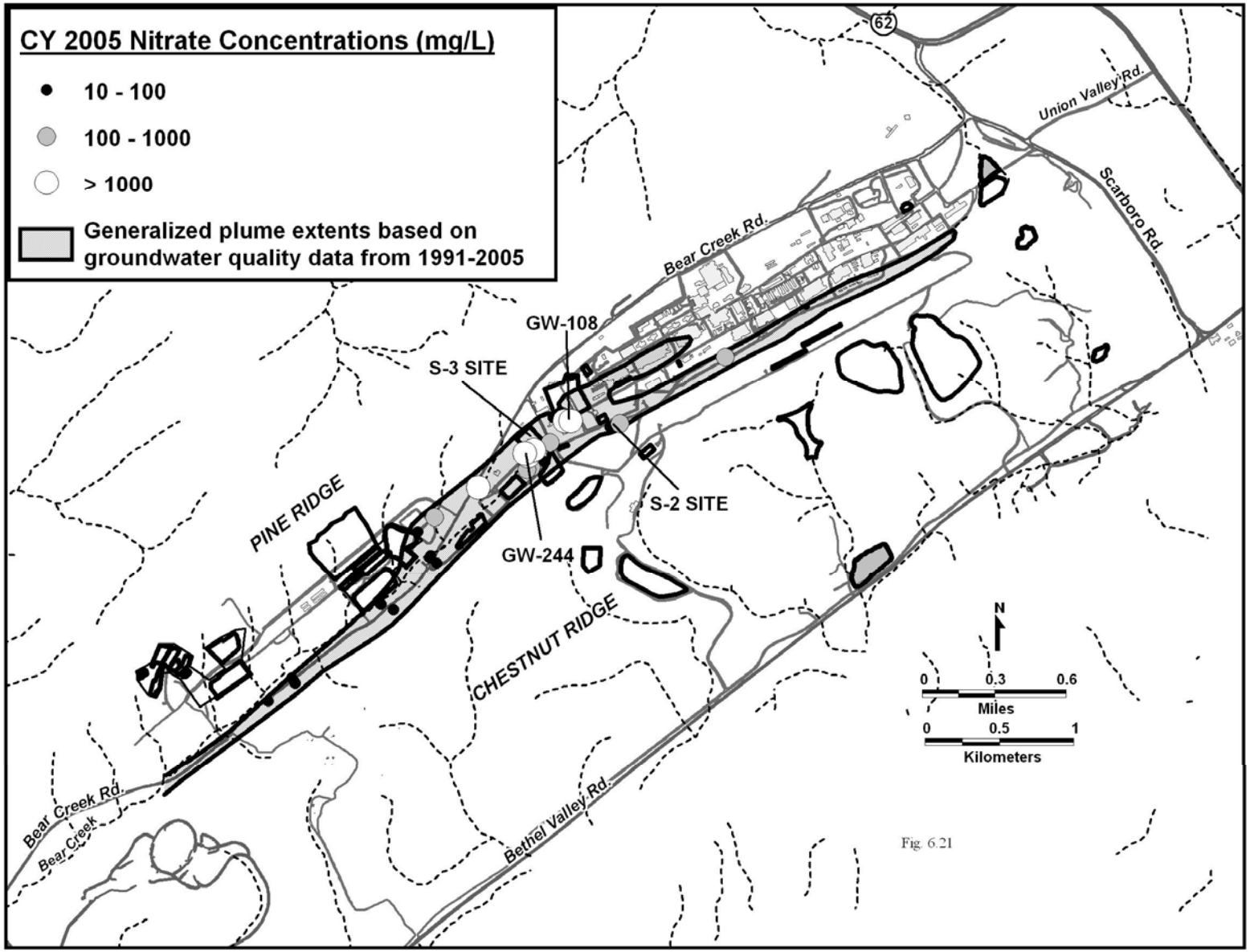


Fig. 6.21. Nitrate (as Nitrogen) observed in groundwater at the Y-12 Complex.

the bedrock zone extends eastward from the S-3 Site over the entire length of the regime (Fig. 6.22). The primary sources are the Waste Coolant Processing Facility, fuel facilities (Rust Garage and East End) 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, tetrachloroethene and isomers of dichloroethene are almost ubiquitous throughout the extent of the plume, indicating many source areas. Chloromethane compounds (carbon tetrachloride, chloroform, and methylene chloride) are the predominant volatile organic compounds in the eastern portion of the complex.

Variability in concentration trends of chlorinated volatile organic compounds near source areas is seen within the East Fork 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. Increasing trends are observed in monitoring wells associated with the Waste Coolant Processing Facility, some production/process facilities, and the East End volatile organic compound plume, indicating that some portions of the plume are still mobile. Within the exit pathway the general trends are also stable or decreasing. These 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, or (4) adsorption by surrounding bedrock and soil media. Wells to the southeast of New Hope Pond are displaying the effects of the pumping well (GW-845) operated to capture the plume prior to migration off of the ORR into Union Valley. Wells east of the New Hope Pond and north of Well GW-845 exhibit an increasing trend in volatile organic compound 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 migration seems to be limited.

Monitoring wells at two former petroleum hydrocarbon contaminant sources (the Rust Garage Area and the East End Garage) were sampled to evaluate the present condition of groundwater. A well at the Rust Garage has shown a significant increase in concentration since the early 1990s. A well at the East End Garage shows petroleum hydrocarbon concentrations consistent with those observed during the early 1990s. These observations indicate that there is still an accumulation of hydrocarbon contaminants within and surrounding each well.

Radionuclides

The primary alpha-emitting radionuclides found in the East Fork regime during CY 2005 are isotopes of uranium. Groundwater with gross alpha activity greater than 15 pCi/L (the drinking water standard) occurs in scattered areas throughout the East Fork regime (Fig. 6.23). Historical data show that gross alpha activity consistently exceeds the drinking water standard and that it is most extensive in groundwater in the unconsolidated zone in the western portion of the Y-12 Complex near source areas such as the S-3 Site, the S-2 Site, and the Y-12 Salvage Yard. However, the highest gross alpha activity (775 pCi/L) in groundwater in Well GW-154 was observed during CY 2005 east of the Former Oil Skimmer Basin.

The primary beta-emitting radionuclides observed in the East Fork regime during CY 2005 are technetium-99 and uranium. Elevated gross beta activity in groundwater in the East Fork regime shows a pattern similar to that observed for gross alpha activity, where technetium-99 is the primary contaminant exceeding the screening level of 50 pCi/L in groundwater in the western portion of the regime, with the primary source being the S-3 Site (Fig. 6.24). The highest gross beta activity in groundwater was observed during CY 2005 from well GW-108 (13,700 pCi/L), east of the S-3 site.

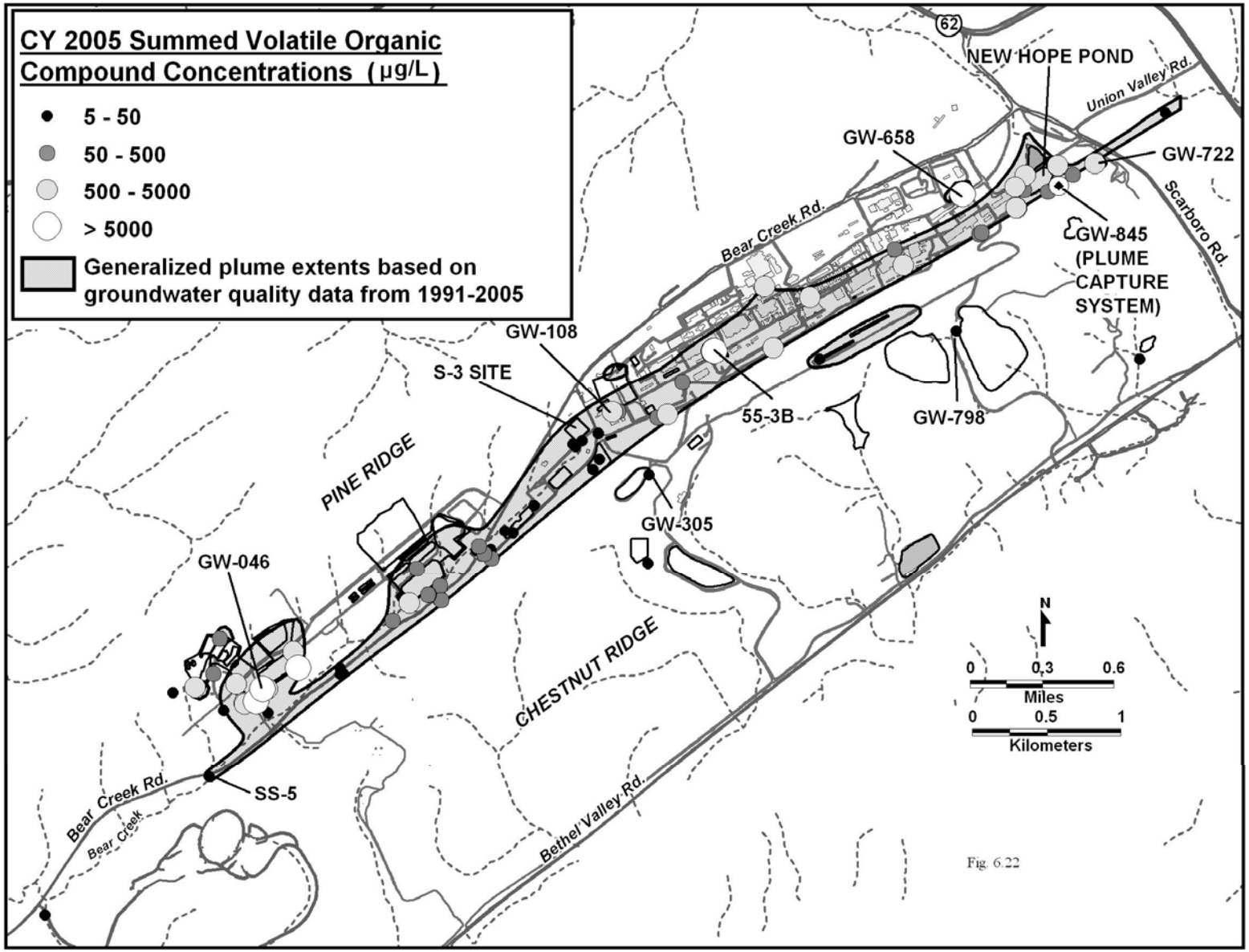


Fig. 6.22. Summed volatile organic compounds observed in groundwater at the Y-12 Complex.

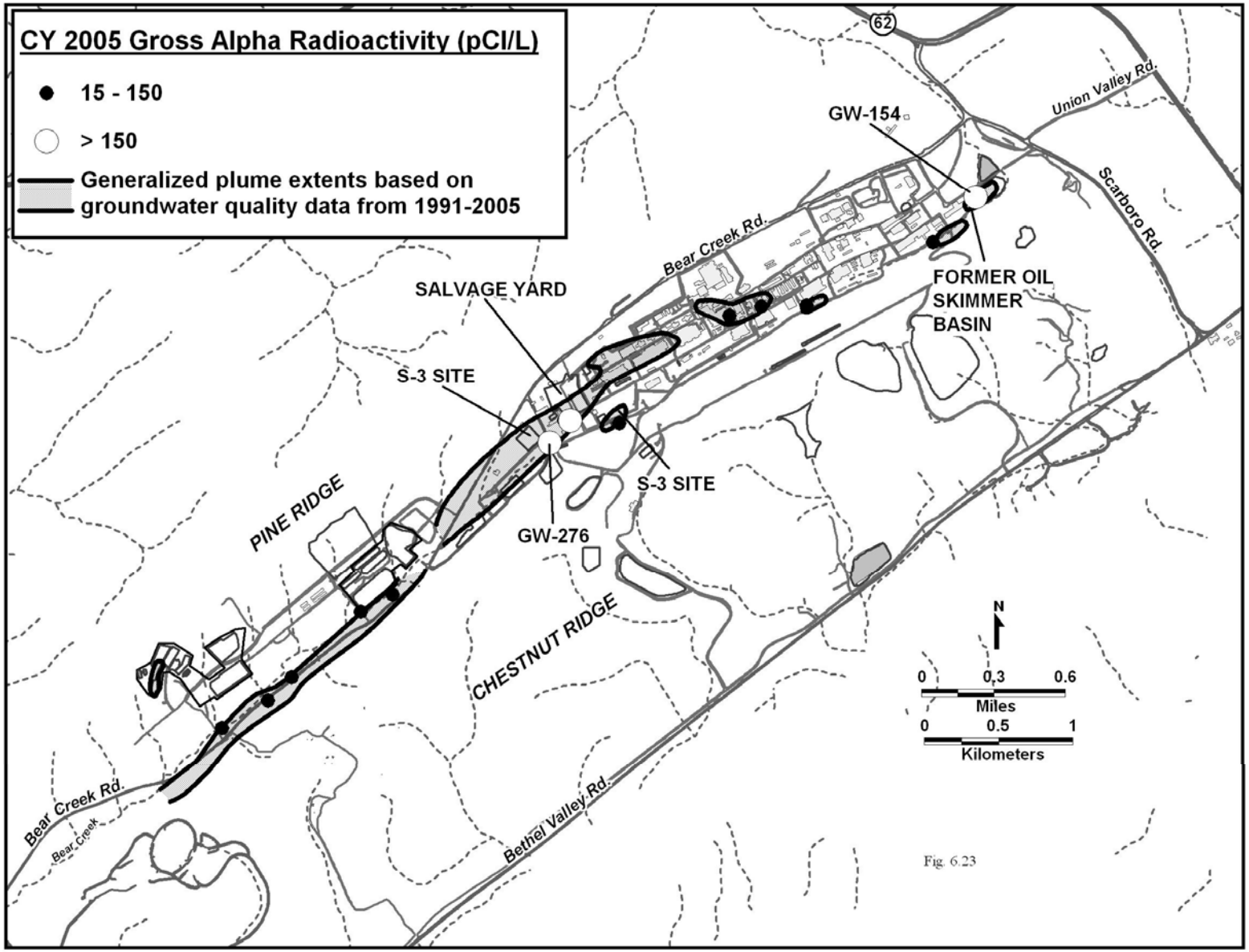


Fig. 6.23. Gross alpha radioactivity observed in groundwater at the Y-12 Complex. 1 pCi = 3.7×10^{-2} Bq.

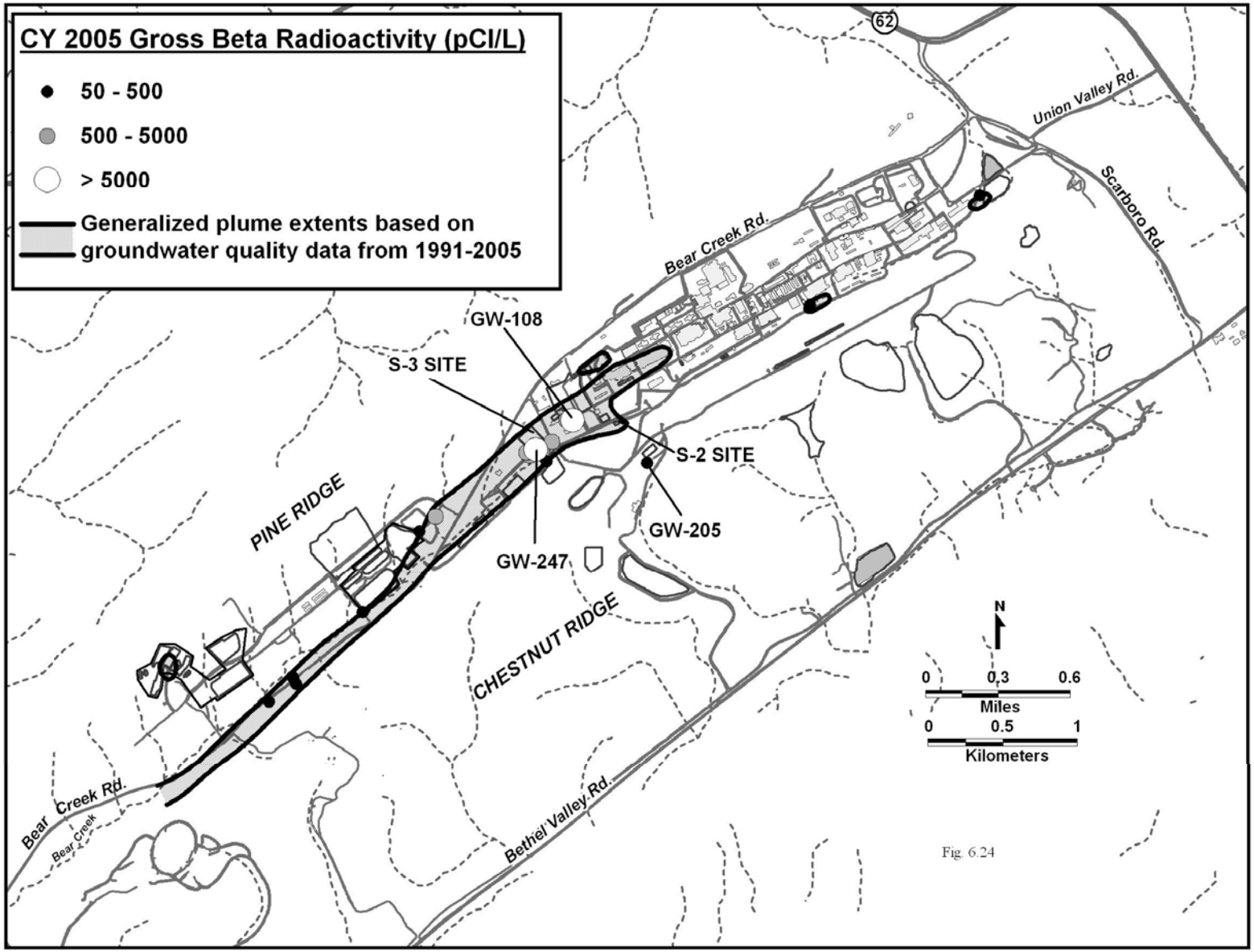


Fig. 6.24. Gross beta radioactivity observed in groundwater at the Y-12 Complex. 1 pCi = 3.7×10^{-2} Bq.

Exit Pathway and Perimeter Monitoring

Data collected to date indicate that volatile organic compounds are the primary class of contaminants that are migrating through the exit pathways in the East Fork regime. The compounds are migrating at depths of almost 500 ft in the Maynardville Limestone, the primary intermediate to the deep groundwater exit pathway 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 the 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 East Fork Poplar Creek is also monitored. Historically, volatile organic compounds have been observed near Lake Reality from wells, a dewatering sump, and the New Hope Pond distribution channel underdrain. 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 East Fork Poplar Creek.

During CY 2005, the observed concentrations of volatile organic compounds at the New Hope Pond distribution channel underdrain continue to remain low. This may be because the continued operation of the groundwater plume-capture system in Well GW-845 southeast of the New Hope Pond may be reducing the levels of volatile organic compounds in the area. BJC completed the installation of the system in June 2000. This system pumps groundwater from the intermediate bedrock depth to mitigate off-site migration of volatile organic compounds. Groundwater is continuously pumped from the Maynardville Limestone at about 25 gal/min, passes through a treatment system to remove the volatile organic compounds, and then discharges to Upper East Fork Poplar Creek.

As previously mentioned, monitoring wells near Well GW-845 have shown some encouraging response to pumping activities. The multiport system installed in Well GW-722, approximately 500 ft east and downgradient of Well GW-845, permits sampling of ten discrete zones within the Maynardville Limestone between 87 and 560 ft below ground surface. This well has been instrumental in characterizing the vertical extent of the east-end plume of volatile organic compounds and is critical in the evaluation of the effectiveness of the plume capture system. Monitoring results from some sampled zones in Well GW-722 indicate reductions in volatile organic compounds due to groundwater pumping upgradient at Well GW-845. Other wells also show decreases that may be attributable to the plume capture system operation. These indicators show that operation of the plume capture system is decreasing volatile organic compounds upgradient and downgradient of Well GW-845.

Three wells, located in the large gap in Pine Ridge through which Upper East Fork Poplar Creek exits the Y-12 Complex, are used to monitor shallow, intermediate, and deep groundwater intervals (Fig. 6.20). Shallow groundwater moves through this exit pathway, and very strong upward vertical flow gradients exist; two of the three wells located in this area are artesian (water flows from the well casing due to unusually high naturally occurring water pressure). Continued monitoring of the wells since about 1990 has not shown that any contaminants are moving via this exit pathway.

Five sampling locations continue to be monitored north and northwest of the Y-12 Complex to evaluate possible contaminant transport from the ORR. These locations are considered unlikely groundwater or surface water contaminant exit pathways; however, monitoring was performed due to previous public concerns regarding potential health impacts from Y-12 operations to nearby residences. Two of the stations monitored tributaries that drain the north slope of Pine Ridge on the ORR and that discharge 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 two locations monitor Gum Hollow Branch as it discharges from the ORR and flows adjacent to the Country Club Estates community. Samples were obtained and analyzed for metals, inorganic parameters, volatile organic compounds, and gross alpha and gross beta activities. No results exceeded a drinking water standard, nor

were there any indications that contaminants were being discharged from the ORR into those communities.

6.10.4.2 Union Valley Monitoring

Groundwater monitoring data obtained in 1993 provided the first strong indication that volatile organic compounds were being transported off the ORR through the deep Maynardville Limestone exit pathway. The Upper East Fork Poplar Creek remedial investigation (DOE 1998) provided a discussion of the nature and extent of the volatile organic compounds.

In CY 2005, monitoring of locations in Union Valley continued, showing an overall decreasing trend in the concentrations of contaminants forming the groundwater contaminant plume in Union Valley.

Under the terms of an interim record of decision, administrative controls, such as restriction on potential future groundwater use, have been established. Additionally, the previously discussed plume capture system (Well GW-845) was installed and initiated to mitigate the migration of groundwater contaminated with volatile organic compounds into Union Valley (DOE 2006).

6.10.4.3 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 6.18 describes each of the waste management sites within the Bear Creek regime.

Plume Delineation

The primary groundwater contaminants in the Bear Creek regime are nitrate, trace metals, volatile organic compounds, and radionuclides. The S-3 Site is a source of all four of these contaminants. The Oil Landfarm waste management area, consisting of the Oil Landfarm, the Boneyard/Burnyard, the Hazardous Chemical Disposal Area, and Landfill I, is a significant source of uranium, other trace metals, and volatile organic compounds. Other sources of volatile organic compounds include the Rust Spoil Area, and the Bear Creek Burial Grounds waste management area. Volatile organic compounds such as tetrachloroethene, trichloroethene, 1,1-dichloroethene, 1,2-dichloroethene, and high concentrations of PCBs have been observed as deep as 270 ft below the Bear Creek Burial Grounds.

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 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 in both the Knox Aquifer and the ORR Aquitards.

Nitrate

Unlike many groundwater contaminants, nitrate is highly soluble and moves easily with groundwater. The limits of the nitrate plume probably define the maximum extent of subsurface contamination in the Bear Creek regime. The horizontal extent of the nitrate plume is essentially defined in groundwater in the upper to intermediate part of the aquitard and aquifer (less than 300 ft below the ground surface).

Data obtained during CY 2005 indicate that nitrate concentrations in groundwater exceed the drinking water standard in an area that extends west from the S-3 Site for approximately 8000 ft down Bear Creek Valley, which is consistent with the nitrate observations from CY 2004. During CY 2003 the western extent was reported at about 11,000 ft, indicating that some variability in the plume in the Maynardville Limestone is occurring due to the reduction in contaminants as well as attenuation by uncontaminated groundwater. Nitrate concentrations greater than 100 mg/L continue to persist out to about 2500 ft west of the S-3 Site, indicating little significant change from previous years in the Nolichucky Shale. Historically, the highest nitrate concentrations are observed adjacent to the S-3 Site in groundwater in the unconsolidated zone and at shallow depths (less than 100 ft below ground surface) in the aquitard. This was observed in CY 2005 with the highest nitrate concentration (4,350 mg/L) at Well

Table 6.18. History of waste management units included in CY 2005 groundwater monitoring activities, Bear Creek Hydrogeologic Regime[a]

Site	Historical data
S-3 Site	Four unlined surface impoundments constructed in 1951. Received liquid nitric acid/uranium-bearing wastes via the Nitric Acid Pipeline until 1983. 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
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
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 as part of Boneyard/Burnyard remedial activities
Sanitary Landfill I	Used from 1968 to 1982. TDEC-permitted, nonhazardous industrial landfill. May be a source of certain contaminants to groundwater. Closed and capped under TDEC requirements in 1985
Bear Creek Burial Grounds: A, C, and Walk-in Pits	A and C received waste oils, coolants, beryllium and uranium, various metallic wastes, and asbestos into unlined trenches and standpipes. Walk-in Pits received chemical wastes, shock-sensitive reagents, and uranium saw fines. Activities ceased in 1981. Final closure 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, J, and Oil Retention Ponds 1 and 2	Burial Grounds B, D, E, and J, unlined trenches, received depleted uranium metal and oxides and minor a mounts of debris and inorganic salts. 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 Grounds B and part of C was granted 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 volatile organic compounds to shallow groundwater according to CERCLA remedial investigation
Spoil Area I	Used from 1980 to 1988 for disposal of construction debris and other stable, non-rad wastes. Permitted under TDEC solid waste management regulations in 1986; closure began shortly thereafter. Soil contamination is of primary concern. CERCLA record of decision issued in 1996
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 record of decision issued in 1996
Above-Grade LLW Storage Facility	Constructed in 1993. Consists of six above-grade storage pads used to store inert, low-level radioactive debris and solid wastes packaged in steel containers

[a]Abbreviations

CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
LLW = low-level radioactive waste
PCB = polychlorinated biphenyl
RCRA = Resource Conservation and Recovery Act
TDEC = Tennessee Department of Environment and Conservation

GW-244 adjacent to the S-3 Site at a depth of 47 ft below ground surface (Fig. 6.21). In previous years, elevated concentrations of nitrate have been observed as deep as 740 ft below ground surface. Surface water nitrate results exceeding the drinking water standard during CY 2005 were observed as far as 11,000 ft west of the S-3 Site. The extent of nitrate contamination in the surface waters of the Bear Creek regime appears to be similar to the extents observed in CY 2004.

Trace Metals

During CY 2005, uranium, barium, cadmium, lead, beryllium, nickel, arsenic, and selenium 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. Disposal of acidic liquid wastes at the S-3 Site reduced the pH of the groundwater, which allows the metals to remain in solution. Elsewhere 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. In CY 2005, the listed trace metals were evident at elevated concentrations within the surface water and groundwater downgradient of the S-3 Site, the Bear Creek Burial Ground, and the Oil Landfarm waste management areas.

The most prevalent trace metal contaminant observed within the Bear Creek regime is uranium, indicating that geochemical conditions are favorable for its migration. The Boneyard/Burnyard site was identified as the primary source of uranium contamination of surface water and groundwater. Historically, uranium is 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, BJC performed the final remedial actions at the Boneyard/Burnyard with the objective of removing materials contributing to surface water and groundwater contamination to meet existing record-of-decision goals. Approximately 86,000 yd^3 of waste materials were excavated and placed in the EMWMF (DOE 2006b). There has been a 99% decrease in uranium in the surface water tributary immediately downstream of the Boneyard/Burnyard, which indicates that the remedial actions performed from 2002 to 2003 were successful in removing much of the primary source of uranium in Bear Creek Valley. In CY 2005, a corresponding decrease in uranium concentrations were observed downstream in Bear Creek (Table 6.19); however, the decreases were not as dramatic as that observed immediately downstream of the Boneyard/Burnyard due to other contributing ungauged sources. Other trace metal contaminants that have been observed in the Bear Creek regime are antimony, boron, chromium, cobalt, manganese, strontium, and thallium. Concentrations have commonly exceeded background values in groundwater near contaminant source areas.

Table 6.19. Nitrate and uranium concentrations in Bear Creek

Bear Creek Monitoring Station (distance from S-3 site)	Contaminant	Average concentration (mg/L)				
		1990–93	1994–97	1998–2001	2002–04	2005
BCK-11.84 to 11.97	Nitrate	119	80	80	84	63.3
(~0.5 miles downstream)	Uranium	0.196	0.134	0.139	0.119	0.088
BCK-09.20 to 09.47	Nitrate	16.4	9.6	10.6	11.9	6.6
(~2 miles downstream)	Uranium	0.091	0.094	0.171	0.099	0.038
BCK-04.55	Nitrate	4.6	3.6	2.6	3.5	1.1
(~5 miles downstream)	Uranium	0.034	0.031	0.036	0.029	0.017
CK-00.63	Nitrate	NS[a]	1.8	1.5	1.4	0.63
(~7.5 miles downstream)	Uranium	NS[a]	0.024	0.022	0.013	0.0097

[a]NS—not sampled.

Volatile Organic Compounds

Volatile organic compounds are widespread in groundwater in the Bear Creek regime. The primary compounds are tetrachloroethene, trichloroethene, 1,2-dichloroethene, 1,1-dichloroethane, and vinyl chloride. In most areas, they are dissolved in the groundwater and can occur in bedrock at depths greater than 270 ft below the Bear Creek Burial Ground waste management area. Groundwater in the aquitards that contains detectable levels of volatile organic compounds occurs primarily within about 1000 ft of the source areas. The highest concentrations observed in CY 2005 in the Bear Creek regime occurred in the unconsolidated zone at the Bear Creek Burial Ground waste management area, with a maximum summed volatile organic compound concentration of 10,838 µg/L in Well GW-046 (Fig 6.22). This result is consistent with the maximum summed concentration observed in CY 2004. The extent of the dissolved plumes of volatile organic compounds is greater in the underlying bedrock. The highest levels in bedrock, in the Bear Creek regime, occur just south of the Bear Creek Burial Ground waste management area. Historical levels have been as high as 7,000,000 µg/L in groundwater near the source area. Downgradient of the Bear Creek Burial Ground waste management area in the aquitards, increasing trends indicate that some migration of volatile organic compounds is occurring. This migration through the aquitards parallel to the valley axis and toward the exit pathway (Maynardville Limestone) is occurring in both the unconsolidated and bedrock intervals.

Significant transport of volatile organic compounds has occurred in the Maynardville Limestone. Data obtained from exit pathway monitoring locations show that in the vicinity of the water table, an apparently continuous dissolved plume extends at least 7400 ft westward from the S-3 Site to just southeast of the Bear Creek Burial Ground waste management area.

Radionuclides

The primary radionuclides identified in the Bear Creek regime are isotopes of uranium and ^{99}Tc. ^{237}Np, ^{241}Am, radium, strontium, thorium, plutonium, and tritium are secondary and less widespread radionuclides, primarily present in groundwater near the S-3 Site. Evaluations of their extent in groundwater in the Bear Creek regime during CY 2005 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) was assumed to be present in the groundwater monitored by the well. A similar rationale was used for annual average gross beta activity that exceeded 50 pCi/L. Technetium-99, a more volatile radionuclide, is qualitatively screened by gross beta activity analysis and, at certain monitoring locations, is evaluated isotopically.

Groundwater with elevated levels of gross alpha activity occurs near the S-3 Site and the Oil Landfarm and Bear Creak Burial Grounds waste management areas. In the bedrock interval, gross alpha activity exceeds 15 pCi/L in groundwater in the aquitards only near source areas (Fig. 6.23). Data obtained from exit pathway monitoring stations 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 9,000 ft west of the S-3 Site. The highest gross alpha activity observed in CY 2005 was 268 pCi/L in Well GW-276 located adjacent to the S-3 Site.

The distribution of gross beta radioactivity in groundwater is similar to that of gross alpha radioactivity. During CY 2005, it appears that the lateral extent of gross beta activity within the exit pathway groundwater interval and surface water above the drinking water standard has not changed from those observed in recent years. Gross beta activities exceeded 50 pCi/L within the Maynardville Limestone exit pathway for 8,000 to 10,000 ft from the S-3 Site (Fig. 6.24). The highest gross beta activity in groundwater in the Bear Creek Regime this year was 5,500 pCi/L at Well GW-247 located immediately downgradient of the S-3 Site.

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 surface water in Bear Creek, springs along the valley floor, and groundwater in the Maynardville Limestone are hydraulically connected. The western exit pathway well transect (Picket W) serves as the ORR perimeter well location for the Bear Creek regime (Fig. 6.20).

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 2005 from the exit pathway monitoring wells indicate that groundwater between Pickets A and B is not consistently contaminated above drinking water standards in the Maynardville Limestone. However, nitrate and uranium concentrations and gross alpha and gross beta activities exceeding their respective drinking water standards have been observed in surface water west of the burial grounds (BWXT 2006).

Surface water samples collected during CY 2005 indicate that water in Bear Creek contains many of the compounds found in the groundwater. The concentrations in the creek decrease with distance downstream of the waste disposal sites (Table 6.19). Individual monitoring locations along Bear Creek also show a decrease in concentration with respect to time, reflecting the positive steps toward remediation of legacy wastes and active mitigating practices of pollution prevention.

6.10.4.4 Chestnut Ridge Hydrogeologic Regime

The Chestnut Ridge Hydrogeologic Regime is south of the Y-12 Complex and is flanked to the north by Bear Creek Valley and to the south by Bethel Valley Road (Fig. 6.19). 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 only documented source of groundwater contamination in the regime. Contamination from the Security Pits is distinct and does not mingle with plumes from other sources. Table 6.20 summarizes the operational history of waste management units in the regime.

Plume Delineation

The horizontal extent of the volatile organic compound plume at the Chestnut Ridge Security Pits is reasonably well defined in the water table and shallow bedrock zones. With one exception, historical monitoring indicates that the volatile organic compound plume from the Chestnut Ridge Security Pits has not migrated very far in any direction (< 1000 ft). Groundwater quality data obtained during CY 2005 indicate that the western lateral extent of the plume of volatile organic compounds at the site has not changed significantly from previous years. An increase in volatile organic compound contaminants over the past several years at a well approximately 1500 ft southeast of the Chestnut Ridge Security Pits shows that some migration of the eastern plume is occurring.

Nitrate

Nitrate concentrations were below the drinking water standard of 10 mg/L at all monitoring stations in the Chestnut Ridge Hydrogeologic Regime.

Trace Metals

Groundwater concentrations of trace metals exceeded regulatory standards during CY 2005 at three locations. Concentrations above the drinking water standard for nickel were observed in samples from one monitoring well. Two surface water monitoring stations showed elevated concentrations of arsenic.

Nickel concentrations above the drinking water standard (0.1 mg/L) were observed from one well at the Industrial Landfill IV (Fig. 6.18). The presence of nickel in groundwater samples from monitoring wells at the Y-12 Complex, with the exception of the S-3 Site, is not due to historical waste disposal, but is probably due to corrosion of well casings. Nickel is a primary component of stainless steel, and its presence indicates the occurrence of corrosion and subsequent dissolution of stainless steel well casing and screen materials due to chemical or biochemical processes (LMES 1999).

Elevated concentrations of arsenic above the drinking water standard (0.01 mg/L) were

Table 6.20. History of waste management units included in CY 2005 groundwater monitoring activities, Chestnut Ridge Hydrogeologic Regime[a]

Site	Historical data
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. Closed in 1992; CERCLA record of decision has been issued
Industrial Landfill II	Central sanitary landfill for the Oak Ridge Reservation. Detection monitoring under postclosure plan has been ongoing since 1996
Industrial Landfill IV	Permitted to receive only nonhazardous industrial solid wastes. Detection monitoring under TDEC solid-waste-management regulations has been ongoing since 1988
Industrial Landfill V	Facility completed and initiated operations April 1994. Baseline groundwater monitoring began May 1993 and was completed January 1995. Currently under TDEC solid-waste-management detection monitoring
Construction/Demolition Landfill VI	Facility completed and initiated operations December 1993. Baseline groundwater quality monitoring began May 1993 and was completed December 1993. Currently under permit-required detection monitoring per TDEC
Construction/Demolition Landfill VII	Facility construction completed in December 1994. TDEC granted approval to operate January 1995. Baseline groundwater quality monitoring began in May 1993 and was completed in 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. A CERCLA record of decision has been issued. Remedial action complete

[a]Abbreviations
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act.
RCRA = Resource Conservation and Recovery Act.
TDEC = Tennessee Department of Environment and Conservation.

observed in two surface water monitoring location downstream from the Filled Coal Ash Pond, which is monitored under a CERCLA record of decision (DOE 2005). A constructed wetland area is being utilized to prevent surface water contamination by effluent from the Filled Coal Ash Pond. During CY 2005, the locations where elevated arsenic levels were detected are both upgradient and downgradient of this wetland area. Downgradient of the wetlands, concentrations are noticeably lower and surface water samples obtained approximately 2000 ft downstream (Rogers Quarry) exhibit no detectable arsenic.

Volatile Organic Compounds

Efforts to delineate the extent of volatile organic compounds in groundwater attributable to the Chestnut Ridge Security Pits have been in progress since 1987. A review of historical data indicates that concentrations of volatile organic compounds in groundwater at the site have generally decreased since 1988. However, a general increasing trend in volatile organic compounds in groundwater samples from monitoring well GW-798 to the southeast and downgradient of the Chestnut Ridge Security Pits has been developing since CY 2000 (Fig 6.22). This trend seems to have peaked at the beginning of CY 2003 and has stabilized between 15 and 20 µg/L. The volatile organic compounds detected in CY 2005 are characteristic of the Chestnut Ridge Security Pits plume; none of the detected compounds were observed to exceed their respective drinking water standards. These results indicate that there is some migration occurring through the developed fracture and conduit system of the karst dolostone to the southeast of the Chestnut Ridge Security Pits.

At Industrial Landfill IV, a number of volatile organic compounds 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 been on a shallow increase. In CY 2005, the fourth-quarter result for one of the compounds, 1, 1-dichloroethene, was 7.6 µg/L, which exceeded the drinking water standard (7 µg/L) for the first time.

Radionuclides

In CY 2005, there was no gross alpha activity above the drinking water standard of 15 pCi/L. Gross beta activities were below the screening level of 50 pCi/L at all monitoring stations except at monitoring well GW-205 (Fig. 6.24) at the United Nuclear Corporation site (the maximum detected activity was 68.7 pCi/L). This location has consistently exceeded the screening level since August 1999. Isotopic analyses show a correlative increase in the beta-emitting radionuclide potassium-40, which is not a known contaminant of concern at the United Nuclear site. The source of the radioisotope is not known.

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. Tracer studies have been used in the past to attempt to identify exit pathways. Based on the results of tracer studies to date, no springs or surface streams that represent discharge points for groundwater have been conclusively correlated to a waste management unit that is a known or potential groundwater contaminant source.

Monitoring of natural groundwater exit pathways is a basic monitoring strategy in a karst regime such as that of Chestnut Ridge. Perimeter springs and surface water tributaries were monitored to determine whether contaminants are exiting the downgradient southern side of the regime. Five springs and three surface water monitoring locations were sampled during CY 2005. No contaminants were detected at these natural discharge points.

6.11 Modernization Activities at the Y-12 National Security Complex

The NNSA has embarked on a significant facility and infrastructure modernization program at the Y-12 Complex. The objectives of the program are to

- consolidate operations to reduce footprint and maintenance cost,

- upgrade facilities and site infrastructure systems to be used in the future,
- replace obsolete, ineffective facilities with new modernized structures designed for their intended use, and
- demolish or disposition surplus facilities and materials no longer required to perform missions.

Overall implementation of the modernization program is consistent with the current site-wide environmental impact statement for the Y-12 Complex and its associated record of decision. NNSA is presently updating the site-wide environmental impact statement. Key considerations of the modernization strategy include maintaining compliance with regulatory requirements and coordinating NNSA's modernization activities with CERCLA requirements. The construction of new NNSA facilities has begun prior to completion of remediation of the soils and groundwater of the Upper East Fork Poplar Creek characterization areas.

6.11.1 Infrastructure Reduction

The Facility and Infrastructure Recapitalization Program, an NNSA initiative to revitalize the physical infrastructure, includes funding for the demolition of non-process contaminated excess facilities across the nuclear weapons complex. By removing excess buildings and equipment, the program is helping reduce NNSA liabilities and costs. The Y-12 Complex's infrastructure reduction effort focuses on removing excess buildings and infrastructure to support reduction in maintenance and operating cost and to provide real estate for future modernization needs. The efforts help support the strategic goal of reducing the active footprint at the complex by 50% in the next decade.

BWXT Y-12's infrastructure reduction activities have already significantly changed the face of the Y-12 Complex. In FY 2005, an additional 214,424 ft^2 of floor space was demolished, bringing Y-12's total to more than 885,000 ft^2 demolished since the program was initiated in 2001.

6.11.2 New Construction

As part of the modernization of the Y-12 Complex, numerous construction projects are under way or are planned for the future. Some are refurbishments or upgrades to plant systems, such as those for potable water, compressed air, and the steam plant. Others involve construction of new buildings, such as the following.

- Purification Facility—Construction was completed in 2005, and operations have started. This is the first major production facility built at the Y-12 Complex in more than 30 years.
- New Garage Office Building—Construction was completed in 2004, and the service bays are expected to be completed in FY 2006. The new garage will replace the existing garage, which is scheduled to be demolished in FY 2006.
- New East End Records Storage Facility and Technical Support Facility—Construction is complete on the Technical Support Facility, and the building is occupied. The records facility will be completed in 2006.
- Highly Enriched Uranium Materials Facility—The new, state-of-the-art storage facility will replace multiple aging facilities. Construction is under way and completion is scheduled in FY 2007. Full-scale operations are slated to start in 2008.
- Uranium Processing Facility—The Uranium Processing Facility, cornerstone of the Y-12 Complex's enriched uranium modernization strategy, will replace current enriched-uranium and other processing operations. NNSA published a notice of intent in the Federal Register (70 FR 71270) on November 28, 2005, announcing its intent to prepare a site-wide environmental impact statement to analyze alternatives. Completion of the Uranium Processing Facility is projected for 2015.
- Beryllium Capability Project—This project will provide new equipment within existing facilities to support ongoing beryllium operations at the Y-12 Complex. The project will address modern technologies and engineered controls for beryllium operations. Construction is expected to be completed by FY 2008.

6.11.3 Operating Lease Project

Staff at theY-12 Complex are working with a private-sector entity to provide for the construction of two new technical and

administrative support facilities: the Jack Case Center and the New Hope Building.

The Jack Case Center, to be built north of the recently demolished Y-12 Administration Building, will house administrative, technical, and scientific functions now scattered across the site. The Jack Case Center is named in honor of Jack M. Case, a former Y-12 Plant Manager who rose through the ranks to become plant manager and had the longest tenure—15 years.

The New Hope Building will be located where the small community of New Hope once stood at the east end of the complex. The structure will house a visitor's center and other functions requiring frequent interaction with the public.

Together, these new facilities will replace about 1 million ft^2 of obsolete workspace with about 540,000 ft^2 of modern office and laboratory space for about 1,500 employees. To accommodate the construction, NNSA transferred two parcels of land at the Y-12 Complex to a private developer, who will finance, design, and build the facilities for long-term lease by NNSA to support Y-12 missions. Construction has started, and occupancy is scheduled for late 2007.

7. ORR Environmental Monitoring Program

In addition to environmental monitoring conducted at the three major Oak Ridge DOE installations, reservation-wide surveillance monitoring is performed to measure radiological and nonradiological parameters directly in environmental media adjacent to the facilities. Data from the ORR surveillance programs are analyzed to assess the environmental impact of DOE operations on the entire reservation and the surrounding area. Dose assessment information based on data from ORR surveillance programs is given in Chapter 8.

7.1 Meteorological Monitoring

Eight meteorological towers provide data on meteorological conditions and on the transport and diffusion qualities of the atmosphere on the 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 would be used in the event of accidental releases from a facility. Data from the towers are also used to support various research and engineering projects.

7.1.1 Description

The eight meteorological towers are depicted in Fig. 7.1:

Tower	Height (m)
Y-12 Complex	
MT5/East	100
MT6/West	60
ORNL	
MT2/C	100
MT3/B	30
MT4/A	30
ETTP	
MT1/K (1208)	60
MT7/L (1209)	30
ORNL/ETTP	
M (208A)	10

Meteorological data are collected at different altitudes (10, 30, 60, and 100 m above ground) to assess the vertical structure of the atmosphere, particularly with respect to wind shear and stability. Stable boundary layers and significant wind shear zones (related to local ridge-and-valley terrain as well as the Great Valley; see Sect. 1.3) can significantly affect the movement of a plume after a facility release (Bowen et al. 2000). All of the towers collect data at the 10-m level. Additionally, selected towers collect data at the 30-, 60-, and 100-m levels. At each measurement level, temperature, wind speed, and wind direction are measured. Data needed to determine atmospheric stability (a measure of vertical mixing properties of the atmosphere) are measured at most towers. Barometric pressure is measured at one or more of the towers at each facility (MT1, MT2, MT5, and MT7). Precipitation is measured at Towers MT5 and MT6 at the Y-12 Complex, Towers MT1 and MT7 at the ETTP, and at Tower MT2 at ORNL. Solar radiation is measured at Towers MT5 and MT6 at the Y-12 Complex, Towers MT1 and MT7 at the ETTP, and Tower MT2 at ORNL.

Data from the towers at each site are collected by a dedicated control computer (DASMET). The towers are polled, and data are archived on both hard disk and DVD-R disks. Values collected at 1-min, 15-min, and hourly intervals are stored at two locations (Y-12 for Y-12 sites, ORNL for ORNL and ETTP sites). Long-term archives are kept of 1-min data for ORNL and ETTP and of 15-min and hourly data for all sites. The meteorological monitoring data from the ORR are summarized monthly as wind roses and daily as data tables. General quarterly calibrations of the instruments are managed by ORNL and the Y-12 Complex.

Fifteen-minute and hourly data are used directly at each site for emergency-response purposes, such as for input to dispersion models.

Annual dose estimates are calculated from archived data (hourly values). Data quality is checked continuously against predetermined data constraints, and out-of-range parameters are marked invalid and are excluded from compli-

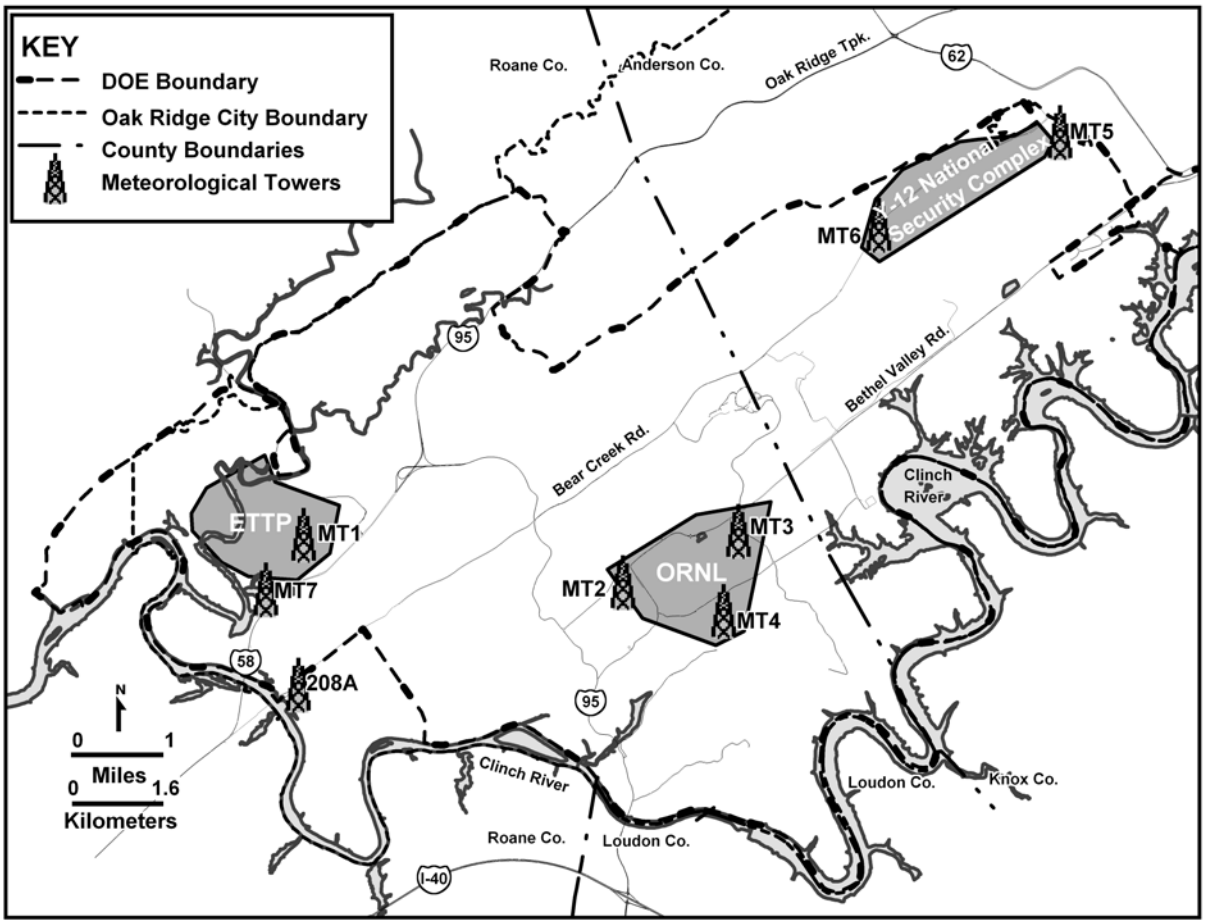


Fig. 7.1. The ORR meteorological monitoring network.

ance modeling. Records of data problems and errors are routinely kept for all eight tower sites.

7.1.2 Meteorological Impacts on Modeling Results

Prevailing winds are generally up-valley from the southwest and west-southwest or down-valley from the northeast and east-northeast. This pattern is the result of the channeling effect of the ridges flanking the ORR sites. Winds in the valleys tend to follow the ridge axes, with limited cross-ridge flow within local valley bottoms. These conditions are dominant over most of the reservation, with the exception of the ETTP, which is located in a relatively open valley bottom (which results in more varied flow).

On the reservation, low-speed winds dominate near the surface level. This characteristic is typical of most near-surface measurements but is amplified by the nearby ridges. Winds sometimes accelerate near ridge top level (see Sect. 1.3).

The atmosphere over the reservation is dominated by stable conditions on most nights and during much of the morning hours. These conditions, when coupled with the low wind speeds and channeling effects of the valleys, result in poor dilution of material emitted from the facilities. However, high roughness values (caused by terrain and obstructions such as trees and buildings) may partially mitigate these factors through the increased turbulence (mixing) that results. These features are captured in the data input to the dispersion models and are reflected in the modeling studies conducted for each facility.

Precipitation data from Tower MT2/C 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. Unlike the previous 3 years (which had above normal precipitation), 2005 yielded precipitation totals of 43.49 inches at Tower MT2 / C and 46.22 inches at Tower MT1 / K(1208) (approximately 10–15% below the 30-year mean).

The average data recovery rate (a measure of acceptable data) across locations used for modeling during 2005 was 98.4% for ORNL sites (Towers MT2, MT3, MT4), 98.7% for ETTP sites (Towers MT1, MT7), and 99.6% for Y12 sites (Tower West).

7.2 External Gamma Radiation Monitoring

External gamma radiation monitoring is conducted to determine whether radioactive effluents from the ORR are increasing external radiation levels significantly above normal background levels. The data also provide a means for comparing results from year to year and for establishing trends.

7.2.1 Data Collection and Analysis

External gamma measurements (exposure rates) are recorded weekly at six ambient air stations from resident external gross gamma monitors (Fig. 7.2). Each consists of a dual-range, high-pressure ion chamber sensor and digital electronic count-rate meter and a totalizer. Totalizing consists of multiplying the count rate by the time of exposure to obtain total exposure.

7.2.2 Results

Table 7.1 summarizes the data collected at each station during the year. The mean observed exposure rate for the reservation network for 2005 was 5.3 μR/h, and the average at the reference location was 4.6 μR/h. Exposure rates from background sources in Tennessee range from 2.9 to 11 μR/h. The measured ORR exposure rate was within the range of normal background levels in Tennessee, indicating that activities on the ORR do not increase external gamma levels in the area above normal background levels.

7.3 Ambient Air Monitoring

In addition to exhaust stack monitoring conducted at the DOE Oak Ridge installations, ambient air monitoring is performed to measure radiological parameters directly in the ambient air adjacent to the facilities. Ambient air monitoring also 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.

The following sections discuss the ambient air monitoring networks for the ORR. Other air monitoring programs are discussed in the site-specific chapters.

7.3.1 ORR Ambient Air Monitoring

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 ORR perimeter air monitoring network includes stations 35, 37, 38, 39, 40, 42, 46, and 48 (Fig. 7.3). Reference samples are collected from Station 52 (Fort Loudoun Dam). Sampling was conducted at each ORR station during 2005 to quantify levels of alpha-, beta-, and gamma-emitting radionuclides and ^{3}H.

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 in the vicinity of the 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 on glass-fiber filters in a high-volume air sampler. The filters are collected weekly, composited quarterly, and then submitted to the laboratory for isotopic analysis. The second system is designed to collect tritiated water vapor. The sampler consists of a prefilter followed by an adsorbent trap consisting of indicating silica gel. The samples are collected weekly or biweekly, composited quarterly, then submitted to the laboratory for ^{3}H analysis.

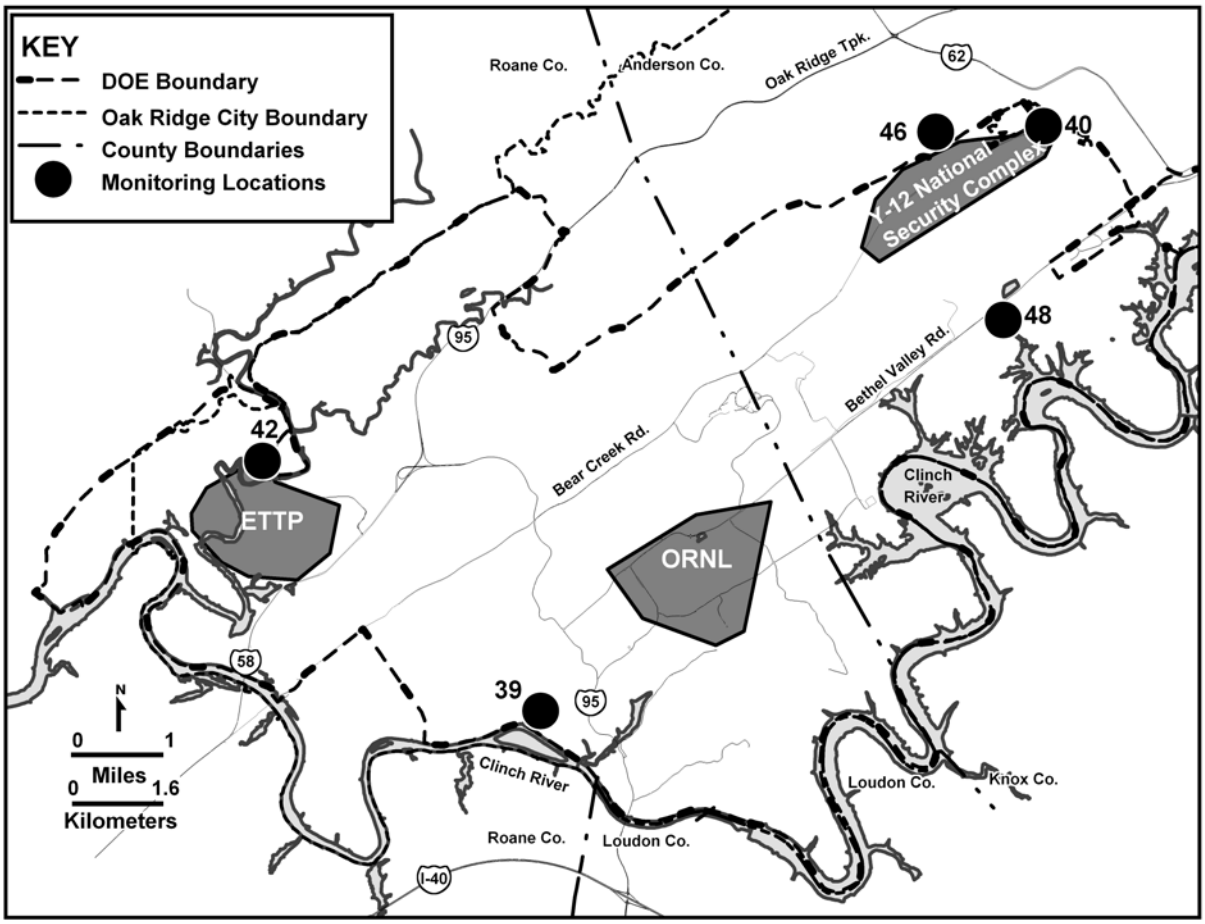


Fig. 7.2. External gamma radiation monitoring locations on the ORR.

Table 7.1. External gamma averages for the ORR, 2005

Monitoring location	Number of data values collected	Measurement (μR/h)[a]			Standard error of mean
		Min	Max	Mean	
39	52	5.3	6.6	5.9	0.00004
40	52	4.6	6.0	5.5	0.00003
42	52	4.0	5.2	4.7	0.00004
46	52	5.3	6.4	6.1	0.00003
48	52	4.4	6.2	4.6	0.00004
52	52	3.5	4.8	4.6	0.00003

[a]To convert microroentgens per hour (μR/h) to milliroentgens per year, multiply by 8.760.

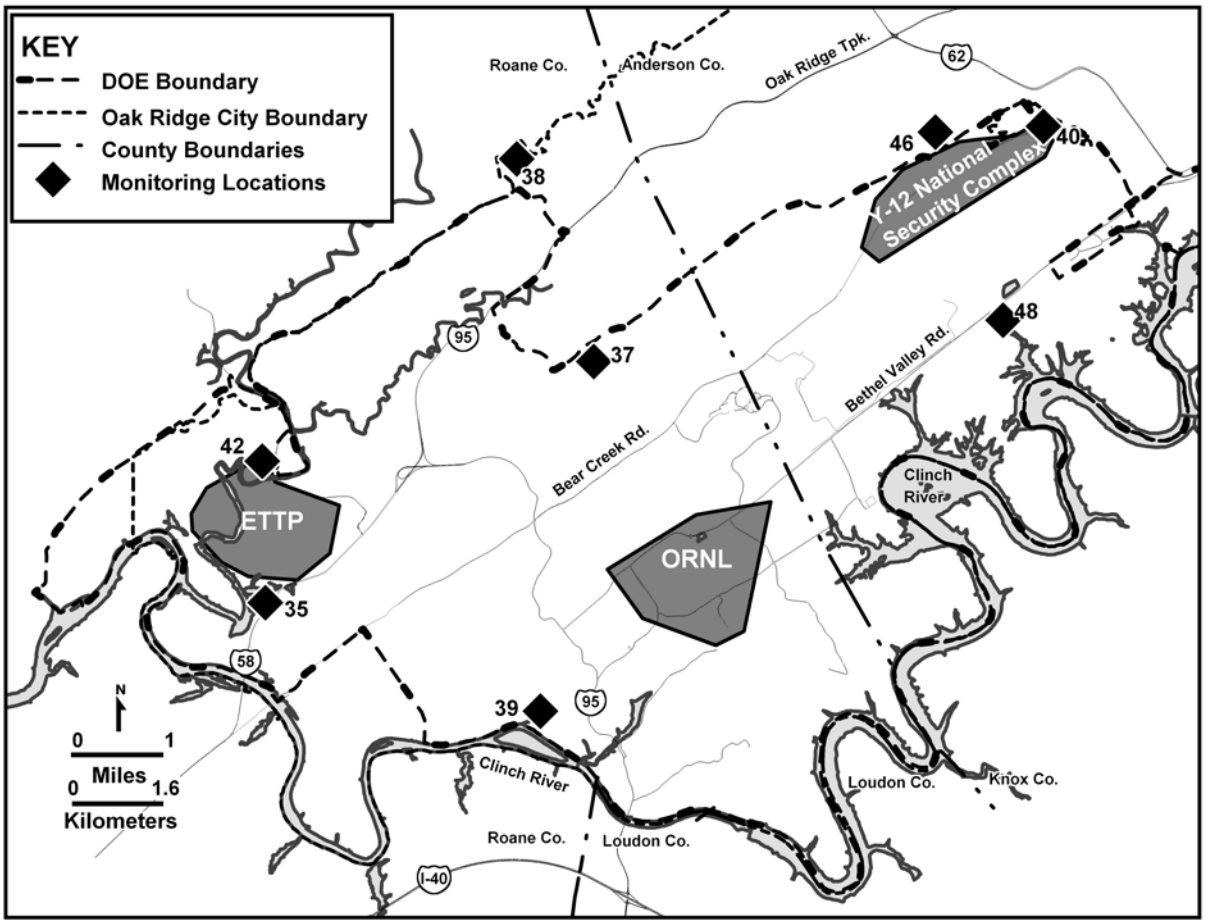


Fig. 7.3. Locations of ORR perimeter air monitoring stations.

The ORR ambient air network (Fig. 7.3) provides appropriate monitoring for all facilities within the reservation and thus eliminates the necessity for site-specific ambient air programs. As part of the ORR network, an ambient-air monitoring station located in the Scarboro community of Oak Ridge (Station 46) measures off-site impacts of the Y-12 Complex operation. Station 40 monitors the east end of the Y-12 Complex, and Station 37 monitors the overlap of Y-12 Complex, ORNL, and ETTP emissions.

7.3.2 Results

Data from the ORR ambient air stations are analyzed to assess the impact of DOE operations on the local air quality. Each measured radionuclide concentration is compared with appropriate derived concentration guides (DCGs), which serve as references for conducting environmental protection programs at DOE sites. All radionuclide concentrations measured at the ORR ambient air stations were less than 1% of applicable DCGs. Statistical significance testing is also performed to compare average radionuclide concentrations measured at ORR ambient air stations with concentrations measured at the reference location. This test reflects the mathematical probability of certain outcomes but is not an indication of environmental significance. There were no calculated statistical differences in average concentrations of ^{3}H, ^{7}Be, ^{238}U or ^{40}K. The concentrations of ^{234}U and ^{235}U at the ORR ambient air stations were slightly higher than those observed at the background location at the 95% confidence level. A summary of radionuclide concentrations measured at the ambient air stations is presented in Table 7.2. Table 7.3 represents the average concentration of three isotopes of uranium at each station for sampling years 2002, 2003, 2004, and 2005.

Table 7.2. Average radionuclide concentrations at ORR perimeter air monitoring stations, 2005 (pCi/mL)[a]

Parameter	No. detected/ no. total	Average	Min	Max
		Station 35		
^{7}Be	4/4	4.90E-08	4.20E-08	5.79E-08
^{40}K	0/4	2.35E-10	–4.45E-11	4.69E-10
Tritium	1/4	4.99E-06	5.73E-07	1.09E-05
^{234}U	4/4	1.24E-11	6.35E-12	1.86E-11
^{235}U	3/4	1.01E-12	4.63E-13	1.40E-12
^{238}U	4/4	2.16E-11	8.21E-12	5.66E-11
		Station 37		
^{7}Be	4/4	5.10E-08	3.95E-08	5.91E-08
^{40}K	0/4	9.15E-11	–2.19E-10	4.08E-10
Tritium	0/4	1.57E-06	–8.82E-07	4.44E-06
^{234}U	4/4	8.01E-12	5.50E-12	9.28E-12
^{235}U	1/4	9.22E-13	3.86E-13	1.48E-12
^{238}U	4/4	1.03E-11	6.60E-12	1.39E-11
		Station 38		
^{7}B	4/4	5.33E-08	4.79E-08	6.29E-08
^{40}K	0/4	1.26E-10	-9.53E-12	2.83E-10
Tritium	0/4	2.03E-06	4.71E-07	5.15E-06
^{234}U	4/4	6.21E-12	4.17E-12	7.61E-12
^{235}U	2/4	5.72E-13	–5.88E-14	9.95E-13
^{238}U	4/4	7.50E-12	4.07E-12	1.16E-11
		Station 39		
^{7}Be	4/4	4.05E-08	3.60E-08	4.75E-08
^{40}K	0/4	1.63E-10	–5.10E-11	4.06E-10
Tritium	1/4	3.80E-06	2.80E-07	5.76E-06
^{234}U	4/4	4.58E-12	3.28E-12	5.40E-12
^{235}U	1/4	5.74E-13	1.87E-13	1.19E-12
^{238}U	4/4	4.40E-12	3.74E-12	5.37E-12
		Station 40		
^{7}Be	4/4	4.97E-08	3.51E-08	5.99E-08
^{40}K	0/4	5.65E-11	–2.70E-10	3.42E-10
Tritium	0/4	1.61E-06	1.55E-07	3.57E-06
^{234}U	4/4	2.85E-11	1.58E-11	5.26E-11
^{235}U	2/4	1.43E-12	6.76E-13	2.56E-12
^{238}U	4/4	8.73E-12	6.79E-12	1.19E-11
		Station 42		
^{7}Be	4/4	4.03E-08	2.76E-08	5.10E-08
^{40}K	0/4	2.14E-10	4.14E-11	3.41E-10
Tritium	0/4	5.61E-07	–9.71E-07	2.60E-06
^{234}U	4/4	7.51E-12	5.93E-12	8.73E-12
^{235}U	1/4	4.58E-13	0	8.66E-13
^{238}U	4/4	1.03E-11	3.82E-12	2.15E-11

Table 7.2. (continued)

Parameter	No. detected/ no. total	Average	Min	Max
		Station 46		
^{7}Be	4/4	4.74E-08	3.87E-08	5.34E-08
^{40}K	0/4	3.93E-10	1.99E-10	5.76E-10
Tritium	0/4	2.54E-06	–7.99E-08	5.76E-06
^{234}U	4/4	1.82E-11	8.00E-12	2.92E-11
^{235}U	3/4	1.10E-12	4.40E-13	1.69E-12
^{238}U	4/4	1.04E-11	4.94E-12	1.65E-11
		Station 48		
^{7}Be	4/4	4.53E-08	2.19E-08	5.53E-08
^{40}K	0/4	2.28E-10	–2.73E-10	5.54E-10
Tritium	0/4	1.49E-06	–4.29E-07	3.66E-06
^{234}U	4/4	7.63E-12	1.67E-12	1.24E-11
^{235}U	2/4	5.01E-13	0	1.06E-12
^{238}U	4/4	6.06E-12	3.72E-12	7.84E-12
		Station 52		
^{7}Be	4/4	4.56E-08	2.60E-08	6.12E-08
^{4}K0	0/4	2.34E-10	–9.10E-12	3.63E-10
Tritium	0/4	1.31E-06	–2.46E-08	3.09E-06
^{234}U	4/4	5.03E-12	4.41E-12	6.02E-12
^{235}U	2/4	5.31E-13	3.74E-13	6.88E-13
^{238}U	4/4	3.95E-12	2.84E-12	5.19E-12

1 pCi = 3.7×10^{-2} Bq.

7.4 Surface Water Monitoring

7.4.1 ORR Surface Water Monitoring

The ORR surface water monitoring program includes sample collection and analysis from three locations on the Clinch River. This program is conducted in conjunction with the ORNL surface water monitoring activities discussed in Chapter 5 to enable an assessment of the impacts of past and current DOE operations on the quality of local surface water. These programs are conducted in addition to the surface water monitoring required by National Pollutant Discharged Elimination System permits for individual DOE ORR facilities; sampling location, frequency, and analytical parameters vary among them. Sampling locations include streams downstream of ORR waste sources, reference points on streams and reservoirs upstream of waste sources, and public water intakes (see Fig. 7.4 and Table 7.4).

Sampling frequency and parameters vary by site. Grab samples are collected at all locations and are analyzed for general water quality parameters, screened for radioactivity, and analyzed for metals and specific radionuclides when appropriate. Samples from two of the sites are also checked for volatile organic compounds, and one is checked for polychlorinated biphenyls (PCBs). Table 7.4 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 associated with these classifications are used as references where they are applicable. The Tennessee water quality criteria do not include criteria for radionuclides.

7.4.2 Results

Comparison of surface water sample results from locations upstream of DOE inputs with results from surface water samples obtained downstream of DOE inputs shows that there were no statistically significant differences in

Table 7.3. Uranium concentrations in ambient air on the ORR[a]

Isotope	Concentration (10^{-15} μCi/mL)			
	2002	2003	2004	2005
		Station 35		
^{234}U	2.0E–02	6.9E–02	2.38E–02	1.24E-02
^{235}U	1.6E–03	3.6E–03	1.36E–03	1.10E-03
^{238}U	2.1E–02	2.3E–02	1.56E–02	2.16E-02
		Station 37		
^{234}U	9.3E–03	9.1E–03	1.24E–02	8.01E-03
^{235}U	1.1E–03	4.6E–04	5.40E–04	9.22E-04
^{238}U	8.3E–03	5.6E–03	7.90E–03	1.01E-02
		Station 38		
^{234}U	1.4E–02	1.3E–02	9.47E–03	6.21E-03
^{235}U	1.8E–03	8.1E–04	6.17E–04	5.72E-04
^{238}U	1.1E–02	8.3E–03	8.50E–03	7.50E-03
		Station 39		
^{234}U	7.1E–03	5.1E–03	4.84E–03	4.58E-03
^{235}U	3.3E–04	2.8E–04	4.36E–04	5.74E-04
^{238}U	7.1E–03	3.9E–03	4.03E–03	4.40E-03
		Station 40		
^{234}U	2.6E–02	3.1E–02	3.83E–02	2.85E-02
^{235}U	1.5E–03	1.4E–03	1.43E–03	1.43E-03
^{238}U	1.3E–02	7.8E–03	7.74E–03	8.73E-03
		Station 42		
^{234}U	2.4E–02	7.0E–02	2.00E–02	7.51E-03
^{235}U	2.5E–03	3.9E–03	1.06E–03	4.58E-04
^{238}U	2.4E–02	2.8E–02	1.31E–02	1.03E-02
		Station 46		
^{234}U	2.3E–02	1.6E–02	2.09E–02	1.82E-02
^{235}U	1.2E–03	8.4E–04	1.47E–03	1.10E-03
^{238}U	1.4E–02	7.8E–03	9.88E–03	1.04E-02
		Station 48		
^{234}U	9.3E–03	8.0E–03	7.31E–03	7.63E-03
^{235}U	6.8E–04	4.9E–04	6.15E–04	5.01E-04
^{238}U	8.2E–03	5.9E–03	5.93E–03	6.60E-03
		Station 52		
^{234}U	1.2E–02	3.9E–03	5.00E–03	5.03E-03
^{235}U	9.3E–04	3.2E–04	3.72E–04	5.31E-03
^{238}U	8.2E–03	3.4E–03	4.26E–03	3.95E-03

[a]1 μCi = 3.7×10^4 Bq.

any of the parameters of interest. Radionuclides were not detected above 4% of the respective DCG at any location. Acetone, a common laboratory contaminant, was detected in a few samples in 2005. Toluene, a volatile organic compound that is not a common laboratory contaminant, was detected in the April samples at low, estimated levels.

7.5 Food

Collection and analysis of vegetation samples serve three purposes: to evaluate potential radiation doses received by people consuming food crops, to predict possible concentrations in meat and milk from animals consuming hay, and to monitor trends in environmental contamination and possible long-term accumulation of radionuclides.

7.5.1 Hay

Hay is sampled annually from five areas on the ORR and from one area immediately adjacent to the reservation (Fig. 7.5) that have the potential for deposition of airborne materials from ORR sources. Areas 1, 2, and 3 are within the predicted air plume for an ORNL source and could be affected by ETTP sources. Areas 4, 5, and 6 are within the predicted air plumes for ETTP, ORNL, and Y-12 sources. Individual samples are collected from all six sites; a composite sample from areas 1, 2, and 3 and a composite sample from Areas 2, 4, and 5 are submitted for laboratory analyses. In addition, a sample from area 6 is submitted separately because it best represents the combined plumes from all three sites. A reference sample is collected from a site near Norris Dam (Area 7, not shown on Fig. 7.5), which is outside the influence of ORR sources.

7.5.1.1 Results

Hay samples were collected during June 2005, and samples were analyzed for gross alpha, gross beta, gamma emitters, and uranium isotopes. None of the locations had gamma-emitting radionuclides that were detected above minimum detectable activity, with the exception of the naturally occurring radionuclides ^{7}Be and ^{40}K. Concentrations of radionuclides detected above minimum detectable activity in hay are shown in Table 7.5.

7.5.2 Vegetables

Tomatoes, lettuce, and turnips were purchased from local farmers near the ORR. The locations were chosen based on availability and on their likelihood of being affected by routine releases from the Oak Ridge facilities.

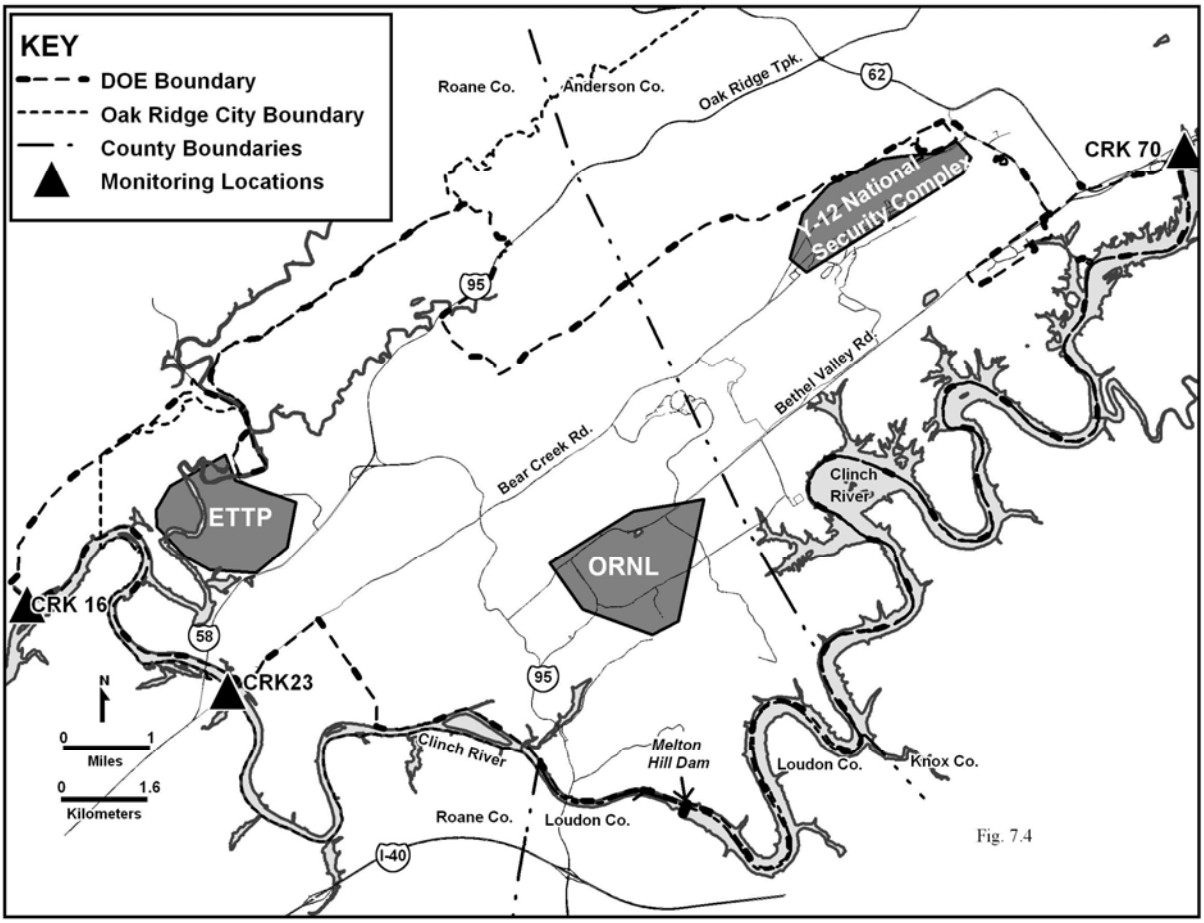


Fig. 7.4. Locations of ORR surface water surveillance sampling stations.

Table 7.4. ORR surface water sampling locations, frequencies, and parameters, 2005

Location[a]	Description	Frequency	Parameters
CRK 16	Clinch River downstream from all DOE ORR inputs	Monthly	Volatiles, metals, gross alpha, gross beta, gamma scan, field measurements[b]
CRK 23	Water supply intake for the ETTP	Monthly	Gross alpha, gross beta, total radioactive strontium, gamma scan, ^{3}H, field measurements[b]
CRK 70	Solway Bridge	Monthly	Volatiles, metals, gross alpha, gross beta, total radioactive strontium, gamma scan, ^{3}H, field measurements[b]

[a]Locations indicate bodies of water and km designation (e.g., CRK 16 = 16 km upstream from the confluence of the Clinch and the Tennessee rivers).

[b]Field measurements consist of dissolved oxygen, pH, and temperature.

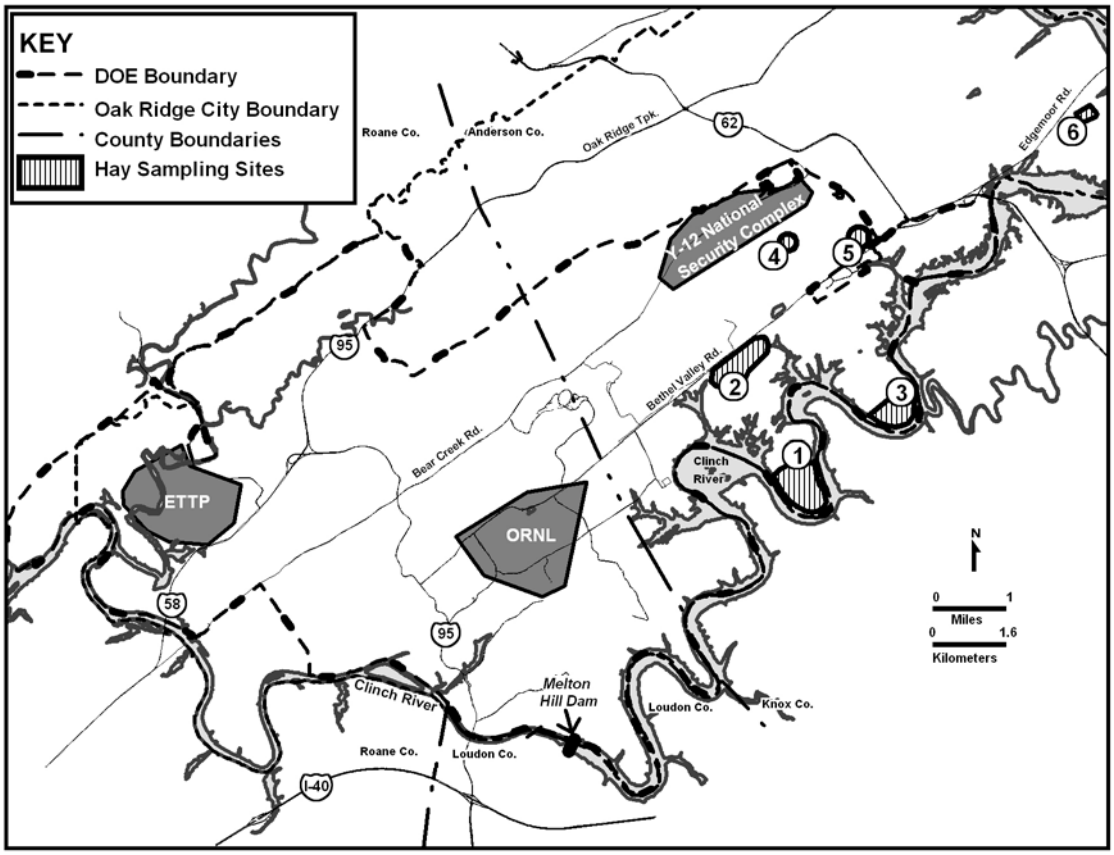


Fig. 7.5. Hay sampling locations on the ORR, indicated by numbered areas.

Table 7.5. Concentrations of radionuclides detected in hay, 2005 (pCi/kg)[a]

Gross alpha	Gross beta	^{7}Be	^{40}K	^{234}U	^{235}U	^{238}U
			Area 1-2-3 composite			
b	0.011	*b*	0.017	*b*	*b*	*b*
			Area 2-4-5 composite			
0.000083	0.0099	*b*	0.028	0.0000080	*b*	0.0000057
			Area 6			
0.00012	0.0094	0.010	0.017	*b*	*b*	0.0000090
			Area 7–Norris reference location			
b	0.0092	*b*	0.023	*b*	*b*	0.0000021

[a]Detected radionuclides are detected above the minimum detectable activity.
1 pCi = 3.7×10^{-2} Bq.
[b]Value was not detected above the minimum detectable activity.

7.5.2.1 Results

Samples were analyzed for gross alpha, gross beta, gamma emitters, and uranium isotopes. None of the vegetables had gamma-emitting radionuclides that were detected above minimum detectable activity, with the exception of the naturally occurring radionuclide ^{40}K. Concentrations of radionuclides detected above minimum detectable activity are shown in Table 7.6.

7.5.3 Milk

Ingestion is one of the pathways of exposure to radioactivity for humans. Radionuclides can be transferred from the environment to people via food chains such as the grass-cow-milk pathway. Milk is a potentially significant source to humans of some radionuclides deposited from airborne emissions because of the relatively large surface area that a cow can graze daily, the rapid transfer of milk from producer to consumer, and the importance of milk in the diet.

The 2005 milk-sampling program consisted of grab samples collected every other month from three locations (Fig. 7.6). One is a commercial dairy in Powell that processes milk from various locations in east Tennessee; the second dairy is in Claxton, and the third is in Maryville (a reference location). Milk samples are analyzed for gamma emitters and for total radioactive strontium (^{89}Sr + ^{90}Sr) by chemical separation and low-background beta counting. Liquid scintillation is used to analyze for ^{3}H.

7.5.3.1 Results

Concentrations of radionuclides detected above minimum detectable activity in milk are presented in Table 7.7. Total radioactive strontium (^{89}Sr + ^{90}Sr) was detected at least once at each of the locations.

7.6 Fish

Members of the public could be exposed to contaminants originating from DOE-ORO activities through consumption of fish caught in area waters. This exposure pathway is monitored by collecting fish from three locations on the Clinch River annually and analyzing edible fish flesh. The locations are as follows (see Fig. 7.7):

- Clinch River upstream from all DOE ORR inputs [Clinch River kilometer (CRK) 70],
- Clinch River downstream from ORNL (CRK 32), and
- Clinch River downstream from all DOE ORR inputs (CRK 16).

Sunfish (*Lepomis macrochirus*, *L. auritus*, and *Ambloplites rupestris*) and catfish (*Ictalurus punctatus*) are collected from each of the three locations, filleted, and frozen. In 2005, two composite samples of flesh from each species at each location were analyzed for selected metals, pesticides, PCBs, ^{3}H, gross alpha, gross beta, and gamma-emitting radionuclides and for total radioactive strontium.

7.6.1 Results

The Tennessee Department of Environment and Conservation (TDEC) has adopted the Environmental Protection Agency method for establishing fish consumption advisories for carcinogenic contaminants found in fish collected in waters designated for recreation and domestic water supply. There is a “do not consume” fish advisory (applicable to typical fishermen consumers) for catfish in Melton Hill Reservoir in its entirety because of PCB contamination, and a precautionary fish advisory for catfish in the Clinch River arm of Watts Bar Reservoir because of PCB contamination (TDEC 2002). This advisory is applicable to atypical consumers, those persons who, because of physiological factors or previous exposures, are more sensitive to specific pollutants; this may include pregnant or nursing women, children, and subsistence fishermen.

In 2005, mercury and radionuclides were detected in both sunfish and catfish at all locations. The 2005 results also show pesticides and PCBs detected in both species of fish at all locations. The pesticides 4,4'-DDE, alpha chlordane, and gamma chlordane were detected in all of the catfish composites from all of the locations. The pesticide 4,4'-DDD was found in both catfish composite samples from CRK 16, in none of the catfish composite samples from CRK 32, and in one of the catfish composite samples from CRK 70. PCB-1254 and PCB-1260 were found in all of the catfish composite samples from all of the locations. The pesticide 4,4'-DDE was found in both sunfish composite samples from CRK 16

Table 7.6. Concentrations of radionuclides detected in vegetables, 2005 (pCi/kg)[a]

Location	Gross alpha	Gross beta	^{40}K	^{234}U	^{235}U	^{238}U
		Lettuce				
East of Y-12, #1	*b*	0.0027	0.0043	0.0000086	0.0000032	*b*
East of Y-12, Claxton	0.000046	0.0024	0.0047	0.0000076	*b*	0.0000040
Northeast of Y-12, Scarboro #1	0.000049	0.0021	0.0038	0.0000094	*b*	0.000011
Northeast of Y-12, Scarboro #2	0.00014	0.0023	0.0065	0.000012	0.0000045	0.0000073
Southeast of ORNL	0.00014	0.0033	0.0044	0.0000088	0.0000059	0.0000092
West of ETTP	0.000044	0.0031	0.0034	0.0000088	*b*	0.0000040
		Tomato				
East of Y-12, #1	0.000070	0.0019	0.0026	0.0000080	*b*	*b*
East of Y-12, Claxton	0.00005	0.0013	0.0015	*b*	*b*	*b*
Northeast of Y-12, Scarboro #1	*b*	0.0015	0.0029	*b*	*b*	*b*
Northeast of Y-12, Scarboro #2	*b*	0.0014	*b*	0.0000063	*b*	0.0000071
Southeast of ORNL	0.000021	0.0014	*b*	*b*	*b*	*b*
West of ETTP	*b*	0.0016	0.0024	*b*	*b*	*b*
		Turnip				
East of Y-12, #1	*b*	0.0014	0.0026	*b*	*b*	0.0000065
East of Y-12, Claxton	*b*	0.0013	0.0023	*b*	*b*	*b*
Northeast of Y-12, Scarboro #1	*b*	0.0016	0.0029	0.0000046	*b*	*b*
Northeast of Y-12, Scarboro #2	*b*	0.002	0.0052	0.0000070	*b*	*b*
Southeast of ORNL	*b*	0.0021	0.0038	*b*	*b*	*b*
West of ETTP	*b*	0.0021	0.0026	*b*	*b*	*b*

[a]Detected radionuclides are detected above the minimum detectable activity. 1 pCi = 3.7×10^{-2} Bq.
[b]Value was not detected above the minimum detectable activity.

and CRK 32; and 4,4'-DDD was found in both sunfish composite samples from CRK 32. PCB-1260 was found in all of the sunfish composite samples from all of the locations. TDEC has issued a fish advisory for the Melton Hill Reservoir in its entirety because of PCB contamination, and the 2005 ORR fish data at upstream and downstream locations are consistent with the advisory.

7.7 White-Tailed Deer

The twentieth annual deer hunts managed by DOE and the Tennessee Wildlife Resources Agency (TWRA) were held on the ORR during the final quarter of 2005. ORNL staff, TWRA personnel, and student members of the Wildlife Society (University of Tennessee chapter) performed most of the necessary operations at the checking station.

The 2005 hunts were held on three weekends. Shotgun/muzzleloader and archery hunts were held November 12–13, December 3–4, and December 17–18. In 2005, there were about 500 shotgun/muzzleloader-permitted hunters and 525 archery-permitted hunters. The Tower Shielding area, Park City Road area, Chestnut Ridge area, and Poplar Creek Road area were opened for an archery-only hunt on all three weekends. There was a two-deer limit for the November and December hunts. Two deer could be harvested; however, only one antlered buck could be harvested. It had to have four or more 1-in. antler points on one side of the rack or an outside antler spread of 15 in. or larger.

The year's total harvest was 350 deer. From the total harvest of 350 animals, 153 (43.7%) were bucks and 197 (56.3%) were does. The heaviest buck had eight antler points and weighed 177 lb. The greatest number of antler points found on one buck was 13. The heaviest doe weighed 125 lb.

Since 1985, 9215 deer have been harvested. Of these only 183 (2.0%) have been retained as a result of potential radiological contamination. The heaviest buck was 218 lb (harvested in 1998), and the average weight is 85.6 lb. The eldest deer harvested was 12 years old; the average age is 1.9 years. For more information, see

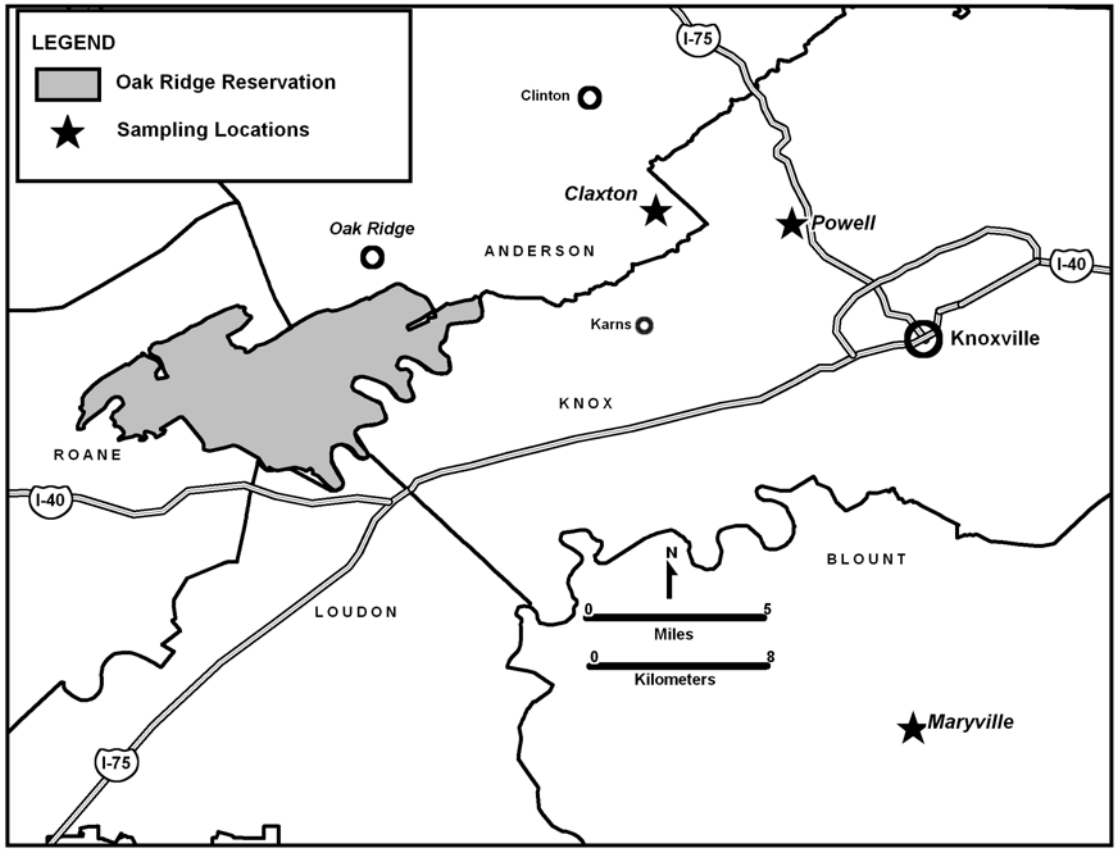


Fig. 7.6. Milk sampling locations in the vicinity of the ORR.

Table 7.7. Concentration of radionuclides detected in raw milk, 2005

Analysis	No. detected/ no. total	Detected concentration (pCi/L)[a,b]			Standard error of mean
		Max	Min	Avg	
Claxton					
Potassium-40	6/6	1300*	1100*	1300*	37
Total rad Sr	1/6	1.9*	0.39	0.86	0.22
Tritium	2/6	1100*	87	510*	150
Maryville					
Potassium-40	6/6	1500*	1200*	1400*	46
Total rad Sr	2/6	2.0*	0.2	1.1*	0.28
Tritium	2/6	980*	–180	390	200
Powell					
Potassium-40	6/6	1300*	1100*	1200*	32
Total rad Sr	1/6	2.2*	0.6	1.3*	0.26
Tritium	2/6	1100*	-60	490*	170

[a]Detected radionuclides are those detected above minimum detectable activity. 1 pCi = 3.7×10^{-2} Bq.

[b]Individual and average concentrations significantly greater than zero at the 95% confidence level are identified by an asterisk (*).

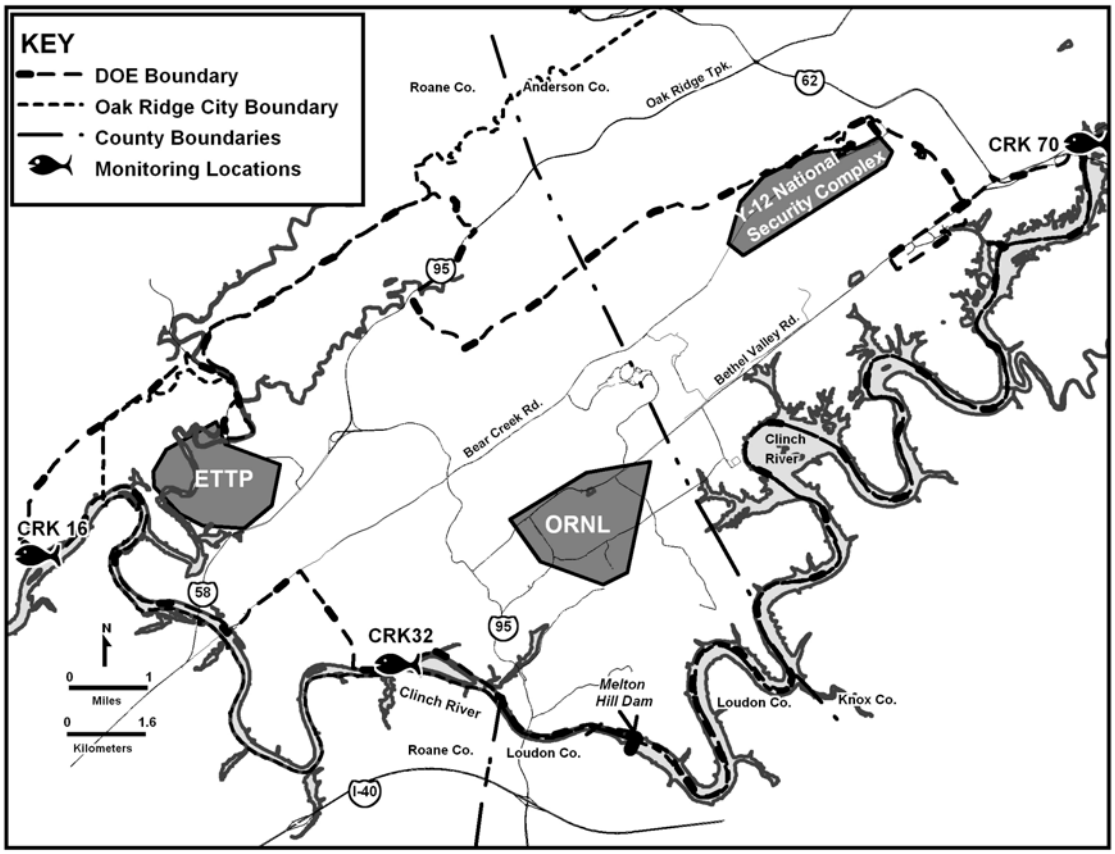


Fig. 7.7. Fish sampling locations for the ORR.

the ORNL wildlife webpage: http://www.ornl.gov/sci/rmal/huntinfo.htm.

7.7.1 Results

In the 2005 hunts, 350 deer were harvested. Of the deer harvested, three (0.9%) were retained for exceeding the administrative release limits (1.5 times the background for beta activity in bone (~20 pCi/g) or 5 pCi/g of ^{137}Cs in edible tissue). The three retained deer exceeded the limit for beta-particle activity in bone. The average weight of the released deer was 84.53 lb; the maximum weight was 176.9 lb. The average ^{137}Cs concentration in the released deer was 0.48 pCi/g, and the maximum ^{137}Cs concentration in the released deer was 0.82 pCi/g.

It is assumed that 55% of the field weight is edible meat; therefore, the average deer would yield 46.5 lb of meat. Based on the average weight, the total harvest of edible meat (347 released deer) is estimated to be 16,133 lb.

7.8 Fowl

7.8.1 Waterfowl Surveys—Canada Geese

The consumption of Canada geese is a potential pathway for exposure of members of the public to radionuclides released from Oak Ridge operations because open hunts for Canada geese are held in counties adjacent to the ORR each year. To determine concentrations of gamma-emitting radionuclides accumulated by waterfowl that feed and live on the ORR, Canada geese are rounded up each summer and are subjected to noninvasive gross radiological surveys. At a minimum, three geese, selected from the different roundup locations, are sacrificed to conduct further radiological analysis. The 2005 ORR roundup was conducted on June 23 and 24.

From the roundup, 167 geese were subjected to live whole-body gamma scans. The geese were collected from ETTP (21), ORNL (117),

Y-12 (8), and Clark Center Park (21). None exceeded the administrative release limits.

7.8.1.1. Results

The average ^{137}Cs concentration in the released geese was 0.23 pCi/g. The maximum ^{137}Cs concentration in the released geese was 0.79 pCi/g. The average weight of the geese screened during the roundup was 7.8 lb, and the maximum goose weight was 11.1 lb. Three adult geese were sacrificed for radiological analyses. Laboratory analyses of the sacrificed geese are used to verify that the field screening approach is an appropriate method for quantifying radionuclide concentrations.

7.8.2 Turkey Monitoring

Two wild turkey hunts managed by DOE and TWRA were held on the reservation April 9–10, 2005, and April 16–17, 2005. Hunting was open for both shotguns and archery. Thirty-eight turkeys were harvested, of which 10 (26.3%) were juveniles and 28 (73.7%) were adults. The average turkey weight was about 18.4 lb. The largest tom weighed 24.1 lb and had 1.5-in. spurs and a 11.0-in. beard. The longest beard (11.7 in.) was measured on a tom weighing 21.4 lb.

Since 1997, 458 turkeys have been harvested. Of these, only three (0.66%) have been retained because of potential radiological contamination. The heaviest turkey was 24.6 lb; the average weight is 18.6 lb. The longest spur on turkey harvested on the ORR was 1.5 in. (average 0.8 in.) and the longest beard was 13.5 in. (average 9.2 in.). See the ORNL wildlife webpage (http://www.ornl.gov/rmal/huntinfo.htm) for additional information.

7.8.2.1 Results

In 2005, 38 birds were harvested, and one exceeded the administrative release limits established for radiological contamination. The average ^{137}Cs concentration in the released turkeys was 0.1 pCi/g, and the maximum ^{137}Cs concentration in the released birds was 0.3 pCi/g. It is assumed that about 50% of the field weight is edible meat; therefore, the average turkey would yield about 9.2 lb of meat. Based on the average weight, the total harvest of edible meat (37 released birds) is estimated to be about 340.4 lb.

8. Dose

Activities on the ORR have the potential to release small quantities of radionuclides and hazardous chemicals to the environment. These releases could result in exposures of 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 that are used to show that doses from released radionuclides and chemicals are in compliance with the law; the calculated doses are compared with existing state and federal criteria.

A hypothetical maximally exposed individual could have received a total effective dose equivalent (EDE) of about 0.9 mrem from radionuclides emitted to the atmosphere from all of the sources on the ORR in 2005; this is well below the National Emission Standards for Hazardous Air Pollutants standard of 10 mrem for protection of the public.

A worst-case analysis of exposures to waterborne radionuclides for all pathways combined gives a maximum possible individual EDE of about 0.4 mrem. This dose is based on a person eating 21 kg/year of the most contaminated accessible fish, drinking 730 L/year of the most contaminated drinking water, and using the shoreline near the most contaminated stretch of water for 60 h/year.

Calculations to determine possible doses from consumption of deer, geese, and turkey harvested on or near the ORR resulted in the following: an individual who consumed an average-weight deer containing the average ^{137}Cs concentration could have received an EDE of about 0.5 mrem, an individual who consumed an average-weight goose containing the average ^{137}Cs concentration of could have received 0.02 mrem, and an individual who consumed an average-weight turkey containing the average ^{137}Cs concentration of could have received 0.02 mrem. In worst-case analyses, hypothetical persons who consume the heaviest deer, two geese, and two turkeys, each containing the maximum concentration of measured radionuclides, could have received an EDE of approximately 5 mrem.

8.1 Radiation Dose

Small quantities of radionuclides were released to the environment from operations at the ORR facilities during 2005. Those releases are 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 are performed using monitored and estimated release data, environmental monitoring and surveillance data, estimated exposure conditions that tend to maximize the calculated dose equivalents, and environmental transport and dosimetry codes that also tend to overestimate the calculated dose equivalents. Thus, the presented dose estimates do not necessarily reflect doses received by typical people in the vicinity of the ORR; these estimates likely are overestimates.

8.1.1 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 the 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 G. An important term to understand is “effective dose equivalent” (EDE). EDE is a risk-based dose equivalent that can be 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 rems or sieverts (1 rem = 0.01 Sv).

One rem of effective dose equivalence, regardless of radiation type or method of delivery, has the same total radiological (in this case, also biological) risk effect. Because the doses being

considered here are very small, EDEs are usually expressed in millirem (mrem), which is one one-thousandth of a rem. (See Appendix G, Table G.2, for a comparison and description of various dose levels.)

8.1.2 Methods of Evaluation

8.1.2.1 Airborne Radionuclides

The radiological consequences of radionuclides released to the atmosphere from ORR operations during 2005 were characterized by calculating, for each plant and for the entire ORR, EDEs to maximally exposed off-site individuals, to on-site members of the public where no physical access controls are managed by DOE, and to the entire population residing within 50 miles of the center of the ORR. The dose calculations were made using the CAP-88 package of computer codes (Beres 1990), which was developed under EPA sponsorship to demonstrate compliance with 40 CFR 61, Subpart H, which governs the emissions of radionuclides other than radon from DOE facilities. This package implements a steady-state Gaussian plume atmospheric dispersion model to calculate concentrations of radionuclides in the air and on the ground and uses Regulatory Guide 1.109 (NRC 1977) food-chain models to calculate radionuclide concentrations in foodstuffs (vegetables, meat, and milk) and subsequent intakes by humans.

A total of 48 emission points on the ORR, each of which includes one or more individual sources, was modeled during 2005. The total includes 8 points at the Y-12 Complex, 34 points at ORNL, and 6 points at ETTP. Table 8.1 is a list of the emission point parameter values and receptor locations used in the dose calculations.

Meteorological data used in the calculations for 2005 were in the form of joint frequency distributions of wind direction, wind speed class, and atmospheric stability category. (See Table 8.2 for a summary of tower locations used to model the various sources.) During 2005, rainfall, as averaged over the four rain gauges located on the ORR, was 1146.2 mm. The average air temperature was 14.6°C, and the average mixing-layer height was 768 m. The mixing height is the depth of the atmosphere adjacent to the surface within which air is mixed.

For occupants of residences, the dose calculations assume that the occupant remained at home (actually, unprotected outside the house) during the entire year and obtained food according to the rural pattern defined in the National Emission Standards for Hazardous Air Pollutants (NESHAP) background documents (EPA 1989). 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 is assumed to be produced within 80 km 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 one-half a year and that less than one-half of a worker's food intake occurs at work. For collective EDE estimates, production of beef, milk, and crops within 80 km of the ORR was calculated using production rates provided with CAP-88.

Results

Calculated EDEs from radionuclides emitted to the atmosphere from the ORR are listed in Table 8.3 (maximum individual) and Table 8.4 (collective). The hypothetical maximally exposed individual for the ORR was located about 1,120 m north-northeast of the main Y-12 National Security Complex release point, about 9,652 m north-northeast of the 7911 stack at ORNL, and about 13,236 m east-northeast of the TSCA Incinerator (stack K-1435) at the ETTP. This individual could have received an EDE of about 0.9 mrem, which is well below the NESHAP standard of 10 mrem and is 0.3% of the 300 mrem that the average individual receives from natural sources of radiation. The calculated collective EDE to the entire population within 80 km of the ORR (about 1,040,041 persons) was about 10.9 person-rem, which is approximately 0.004% of the 312,012 person-rem that this population received from natural sources of radiation (based on an individual dose of 300 mrem/year).

The maximally exposed individual for the Y-12 National Security Complex was located at

Table 8.1. Emission point parameters and receptor locations used in the dose calculations

Source ID	Stack height (m)	Stack diameter (m)	Effective exit gas velocity (m/s)	Exit gas temperature (°C)	Distance (m) and direction to the maximally exposed individual			
					Plant maximum		ORR maximum	
X-1000 Lab Hoods	15		0	Ambient	5613	ENE	10019	NE
X-2026	22.9	1.05	10.65	Ambient	5296	E	9524	NE
X-2099	3.66	0.178	22.1	Ambient	5296	E	9524	NE
X-2523	7	0.3	7.61	Ambient	5339	E	9741	NE
X-3000 Lab Hoods	15	0	0	Ambient	5064	E	9378	NE
X-3018	61	4.11	0.23	Ambient	5125	E	9308	NE
X-3020	61	1.22	14.78	Ambient	5125	E	9308	NE
X-3039	76.2	2.44	13.28	Ambient	5060	E	9354	NE
X-3074 Group	4	0.25	0	Ambient	5125	E	9308	NE
X-3544	9.53	0.279	21.15	Ambient	5081	ENE	9613	NE
X-3597	1	0.19	0	Ambient	4916	E	9381	NE
X-3608 Air Stripper	10.97	2.44	0.57	Ambient	4966	ENE	9547	NE
X-3608 Filter Press	8.99	0.36	9.27	Ambient	4966	ENE	9547	NE
X-4000 Lab Hoods	15	0	0	Ambient	4633	E	9063	NE
X-5505M	11	0.305	2.83	Ambient	4361	E	8898	NNE
X-5505NS	11	0.96	0	Ambient	4361	E	8898	NNE
X-6000 Lab Hoods	15	0	0	Ambient	4164	E	8470	NNE
X-7000 Lab Hoods	15	0	0	Ambient	3212	NE	9636	NNE
X-7025	4	0.3	13.92	Ambient	3143	E	7558	NNE
X-7503	30.5	0.91	12.35	Ambient	4289	ENE	9369	NNE
X-7567	4.6	0.248	8.3	Ambient	4289	ENE	9369	NNE
X-7567 D&D	3.8	0.2	0	Ambient	4289	ENE	9369	NNE
X-7830	4.6	0.248	8.3	Ambient	5342	ENE	10840	NNE
X-7831-A	0.38	.69	0	Ambient	6637	ENE	11927	NNE
X-7856-CIP	18.29	0.483	13.32	Ambient	5342	ENE	10840	NNE
X-7877	13.9	0.406	13.56	Ambient	5342	ENE	10840	NNE
X-7911	76.2	1.52	13.18	Ambient	4259	ENE	9652	NNE
X-7966	6.1	0.292	10.11	Ambient	4259	ENE	9652	NNE
X-Decon Areas	15	0	0	Ambient	5060	E	9354	NE
X-HFIR Tank	0.38	0.3	0	Ambient	4250	ENE	9699	NNE
X-Soil & Sediment	0.38	0.2	0	Ambient	4289	ENE	9369	NNE
X-STP	7.6	0.203	12.73	Ambient	5219	ENE	9776	NE
X-SWSA-5 TRU	.305	.87	0	Ambient	5151	ENE	10212	NNE
X-T-1/T-2	.38	.357	0	Ambient	4289	ENE	9369	NNE
K-1407-U CNF	7.16	1.22	0.625	Ambient	1686	WSW	13497	ENE
K-1423 SWR	7.62	0.71	12.8	Ambient	1283	SW	13951	ENE
K-1435 Incinerator	30.5	1.37	5.64	79.76	1953	WSW	13236	ENE
K-1435 Tanks	18.29	0.2	0	Ambient	1953	WSW	13236	ENE
K-25 Guzzler	3.66	0.305	36.3	Ambient	1686	WSW	13497	ENE
K-25 Seg Shop 18A	18.3	1.37	2.56	Ambient	1028	SW	14234	ENE

Table 8.1 (continued)

Source ID	Stack height (m)	Stack diameter (m)	Effective exit gas velocity (m/s)	Exit gas temperature (°C)	Distance (m) and direction to the maximally exposed individual			
					Plant maximum		ORR maximum	
Y-9422-22 Air Stripper	3.96	0.153	0	Ambient	2018	W	2018	W
Y-9616-7 Degas	12.2	0.2	4.36	Ambient	2855	NE	2855	NE
Y-9616-7 Lab Hood	12.2	0.25	0.69	Ambient	2855	NE	2855	NE
Y-9623 Lab Hood	8.5	0.25	0.64	Ambient	1341	NNE	1341	NNE
Y-Monitored	20	0	0	Ambient	1120	NNE	1120	NNE
Y-Union Valley Lab	4.27	0.762	13.08	Ambient	2362	WSW	2362	WSW
Y-Unmonitored Processes	20	0	0	Ambient	1120	NNE	1120	NNE
Y-Unmonitored Lab Hoods	20	0	0	Ambient	1120	NNE	1120	NNE

Table 8.2. Summary of ORR meteorological towers, sampling heights, and sources

Tower	Height (m)	Source
		Y-12 Complex
MT6	60[a]	All sources
		ETTP
MT1	10	K-1435 Tanks
MT1	60	K-1435 Incinerator
MT7	10	K-1407-U CNF, K-1423-SWR, and K-25 Guzzler
MT7	30	K-25 Segmentation Shop 18A
		ORNL
MT4	10	X-7567, X-7567 D&D, X-7830, X-7831-A, X-7966, X-HFIR Tank, X-SWSA-5 TRU, X-T-1/T-2, and X-Soil and Sediment
MT4	30	X-7503, X-7856-CIP, X-7877, X-7911, and X-7000 Lab Hoods
MT3	10	X-7025
MT3	30	X-6000 Lab Hoods
MT2	10	X-2099, X-2523, X-3074, X-3544, X-3597,X-3608FP, and X-STP
MT2	30	X-2026, X-3608AS, X-5505(NS & M), X-Decon Areas, and X-1000, 3000, & 4000 Lab Hoods
MT2	100	X-3018, X-3020, and X-3039

[a]Wind speeds adjusted to match conditions at a height of 20 m.

Table 8.3. Calculated radiation doses to maximally exposed off-site individuals from airborne releases during 2005

Plant	Total effective dose equivalents [mrem (mSv)]	
	At plant max	At ORR max
ORNL	0.1 (0.001)[a]	0.02 (0.0002)
ETTP	0.04 (0.0004)[b]	0.008 (0.00008)
Y-12	0.8 (0.008)[c]	0.8 (0.008)
Entire ORR	*d*	0.9 (0.009)[e]

[a]The maximally exposed individual was located 5060 m E of X-3039 and 4259 m ENE of X-7911.

[b]The maximally exposed individual was located 1953 m WSW of K-1435.

[c]The maximally exposed individual is located 1120 m NNE of the Y-12 National Security Complex release point.

[d]Not applicable.

[e]The maximally exposed individual for the entire ORR is the Y-12 maximally exposed individual.

Table 8.4. Calculated collective effective dose equivalents from airborne releases during 2005

Plant	Effective dose equivalents[a]	
	(Person-rem)	(Person-Sv)
ORNL	2.7	0.027
ETTP	1.4	0.014
Y-12	6.8	0.068
Entire ORR	10.9	0.109

[a]Collective effective dose equivalents to the 1,040,041 persons residing within 80 km of the ORR.

a residence about 1120 m north-northeast of the main Y-12 National Security Complex release point. This individual could have received an EDE of about 0.8 mrem from Y-12 National Security Complex emissions. Inhalation and ingestion of uranium radioisotopes (i.e., ^{232}U, ^{233}U, ^{234}U, ^{235}U, ^{236}U, and ^{238}U) accounted for essentially all (more than 99.5%) of the dose. The contribution of Y-12 Complex emissions to the 50-year committed collective EDE to the population residing within 80 km of the ORR was calculated to be about 6.8 person-rem, which is approximately 63% of the collective EDE for the ORR.

The maximally exposed individual for ORNL was located at a residence about 5060 m east of the 3039 stack and 4260 m east-northeast of the 7911 stack. This individual could have received an EDE of about 0.1 mrem from ORNL emissions. Radionuclides contributing 1% or more to the dose include ^{138}Cs (37.2%), ^{41}Ar (31.6%), ^{212}Pb (9.2%), uranium radioisotopes (3.6%) ^{244}Cm (3.1%), ^{241}Am (1.7%), ^{3}H (1.7%), ^{88}Kr (1.3%), ^{131}I (1.2%), and ^{138}Xe (1.1%). The contribution of ORNL emissions to the collective EDE to the population residing within 80 km of the ORR was calculated to be about 2.7 person-rem, which is approximately 25% of the collective EDE for the ORR.

The maximally exposed individual for the ETTP was located at a business about 1950 m west-southwest of the TSCA Incinerator stack (K-1435). The EDE received by this individual was calculated to be about 0.04 mrem. About 56% of the dose is from ingestion and inhalation of uranium radioisotopes, about 30% is from thorium radioisotopes, and about 11% is from ^{3}H. The contribution of ETTP emissions to the collective EDE to the population residing within 80 km of the ORR was calculated to be about 1.4 person-rem, which is approximately 13% of the collective EDE for the reservation.

The reasonableness of the estimated radiation doses can be inferred by comparing EDEs estimated from measured radionuclide air concentrations with EDEs estimated from calculated (using CAP-88 and emission data) radionuclide air concentrations at the ORR perimeter air monitoring stations (PAMs) (Table 7.2). Based on measured radionuclide air concentrations that could have been released from operations on the ORR (i.e., excluding naturally occurring 7Be and 40K), hypothetical individuals assumed to reside at the PAMs could have received EDEs between 0.01 and 0.08 mrem/year. Based on calculated radionuclide air concentrations released from operations on the ORR, hypothetical individuals assumed to reside at the PAMs could have received EDEs between 0.1 and 0.7 mrem/year. EDEs calculated using CAP-88 tended to be higher than EDEs calculated using measured air concentrations (Table 8.5).

An indication of doses from sources other than those on the ORR can be obtained from the EDE calculated at the background air monitoring station (Station 52), which was 0.01 mrem/year. (The isotopes 7Be and 40K also were not included at the background air monitor-

Table 8.5. Hypothetical effective dose equivalents from living at ORR and ETTP ambient-air monitoring stations during 2005

Station	Calculated effective dose equivalent			
	Using air monitor data		Using CAP-88 and emission data	
	mrem/year	mSv/year	mrem/year	mSv/year
35	0.08	0.0008	0.2	0.002
37	0.02	0.0002	0.3	0.003
38	0.01	0.0001	0.2	0.002
39	0.05	0.0005	0.2	0.002
40	0.04	0.0004	0.7	0.007
42	0.02	0.0002	0.1	0.001
46	0.03	0.0003	0.6	0.006
48	0.01	0.0001	0.1	0.001
52	0.01	0.0001	*a*	*a*
K2	0.09	0.0009	*a*	*a*
K6	0.1	0.001	*a*	*a*
K9	0.2	0.002	*a*	*a*

[a]EDEs were not calculated using CAP-88 and emission data.

ing station calculation). It should be noted that measured air concentrations of ^{7}Be and ^{40}K were similar at the PAM stations and at the background air monitoring station.

Of particular interest is a comparison of doses calculated using measured air concentrations of radionuclides at PAMs located near the maximally exposed individuals for each plant and doses calculated for those individuals using CAP-88 and measured emissions. PAM 46 is located near the maximally exposed individual for the Y-12 Complex. The EDE calculated using measured air concentrations was 0.6 mrem/year, which is similar to the EDE of 0.9 mrem/year calculated using CAP-88 at the maximally exposed individual location for the Y-12 complex. PAM 39 is located near the second highest dose location for ORNL (in same wind direction at a closer in distance); the EDE calculated using measured air concentrations was 0.05 mrem/year, which is similar to the 0.1 mrem/year calculated using CAP-88. PAM 35 is located near the maximally exposed individual (at a business) for ETTP; the EDE calculated using measured air concentrations, adjusted for a business exposure, was 0.04 mrem/year, which was essentially the same dose estimated using CAP-88.

Several air monitors also were located on the ETTP site (see Fig. 4.9). EDEs calculated from air concentrations of radionuclides at these monitors were between 0.09 and 0.2 mrem/ year.

8.1.2.2 Waterborne Radionuclides

Radionuclides discharged to surface waters from the ORR enter the Tennessee River system by way of the Clinch River (see Sect. 1.5 for the surface water setting of the ORR). Discharges from the Y-12 Complex enter the Clinch River via Bear Creek and East Fork Poplar Creek, 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 and enter Melton Hill Lake via some small drainage creeks. Discharges from the 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 confluence of the Clinch and Tennessee Rivers to below Kingston), (6) Lower System (the remainder of Watts Bar Lake and Chicamauga Lake to Chat-

tanooga), and (7) Poplar Creek (including the confluence of East Fork Poplar Creek).

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 Sects. 7.4 and 7.6). The second method calculates possible radionuclide concentrations in water and fish from measured radionuclide discharges and known or estimated stream flows. 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, the possibility that some radionuclides of ORR origin might be present in quantities too low to be measured, and the possibility that the presence of some radionuclides might be misstated (e.g., present in a quantity below the detection limit). Estimated doses from measured radionuclide concentrations are presented without and with contributions of naturally occurring radionuclides. The advantages of the second method are that most radionuclides discharged from the ORR will be quantified and that naturally occurring radionuclides will not be considered or will 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, combining the two methods should allow the potential radiation doses to be bounded.

In the following drinking water and fish subsections, the estimated maximum EDE is based on either the first method, which uses radionuclide concentrations measured in the medium of interest (i.e., in water and fish), or by the second method, which calculates possible radionuclide concentrations in water and fish from measured radionuclide discharges and known or estimated stream flows. The EDEs estimated by both methods, in each of the surface water segments are provided in Appendix G.

Drinking Water

Several water treatment plants that draw water from the Clinch and Tennessee River systems could be affected by discharges from the ORR. No in-plant radionuclide concentration data are available for any of these plants; all of the dose estimates given below likely are high because they are based on radionuclide concentrations in water before it enters its processing plant. For purposes of assessment, it was assumed that the drinking water consumption rate for the maximally exposed individual is 730 L/year and the drinking water consumption rate for the average person is 370 L/year. The average drinking water consumption rate is used to estimate the collective EDE. As explained in Appendix G, EDEs were calculated from measured concentrations of radionuclides in water and from radionuclide concentrations in water that were calculated using measured radionuclide discharges and streamflow data. At all locations in 2005, estimated maximum EDEs to a person drinking water were calculated using measured radionuclide concentrations in off-site surface water and exclude naturally occurring radionuclides, such as ^{40}K.

Melton Hill Lake above all possible ORR inputs. For reference purposes, the EDE to a hypothetical highly exposed person drinking water at CRK 70, which is located upstream of all ORR inputs, was estimated to be about 0.05 mrem. The collective EDE to the 29,315 persons who drink water from the city of Oak Ridge water plant could have been 0.7 person-rem. If naturally occurring radionuclides are included, the EDEs could have been 2 mrem and 26 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 highly exposed individual could have received an EDE of about 0.05 mrem; the collective dose to the 48,120 persons who drink water from this plant could have been 0.7 person-rem. If naturally occurring radionuclides are included, the EDEs could have been 2 mrem and 48 person-rem.

Upper Clinch River. The ETTP (Gallaher) water plant draws water from the Clinch River near CRK 23. For assessment purposes, it is assumed that workers obtain half their annual wa-

ter (370 L) intake at work. Such a worker could have received an EDE of about 0.05 mrem; the collective dose to the 1750 workers who drink water from this plant could have been about 0.05 person-rem. If naturally occurring radionuclides are included, the EDEs could have been 3 mrem and 2 person-rem.

Lower Clinch River. There are no drinking water intake locations in this river segment (from the confluence with Poplar Creek to the confluence 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 highly exposed individual could have received an EDE about 0.03 mrem; the collective dose to the 21,303 persons who drink water from these plants could have been about 0.4 person-rem. If naturally occurring radionuclides are included, the EDEs could have been 0.5 mrem and 5 person-rem.

Lower System. Several water treatment plants are located on tributaries of Watts Bar Lake and Chickamauga Lake. Based on discharge and Clinch River water data, persons drinking water from these plants could not have received EDEs greater than about 0.03 mrem calculated for Kingston and Rockwood water. The collective dose to the 258,193 persons who drink water within the lower system could be about 3.5 person-rem. If naturally occurring radionuclides are included, the EDEs could have been 0.5 mrem and 47 person-rem.

Poplar Creek. There are no drinking water intake locations on Poplar Creek.

Eating Fish

Fishing is quite common on the Clinch and Tennessee River systems. For purposes of assessment, it was assumed that avid fish consumers would have eaten 21 kg of fish during 2005 and that the average person, who is used for collective dose calculations, would have consumed 6.9 kg of fish. As mentioned above, the estimated maximum EDE will be based on either the first method, measured radionuclide concentrations in fish, or by the second method, which calculates possible radionuclide concentrations fish from measured radionuclide discharges and known or estimated stream flows and exclude naturally occurring radionuclides (e.g., ^{40}K). The EDEs estimated by both methods, in each of the surface water segment, are provided in Appendix G.

Melton Hill Lake above all possible ORR inputs. For reference purposes, a hypothetical avid fish consumer who ate fish caught at CRK 70, which is above all possible ORR inputs, could have received an EDE of about 0.08 mrem. If naturally occurring radionuclides are included, the EDE could have been 8 mrem.

Melton Hill Lake. An avid fish consumer who ate fish from Melton Hill Lake could have received an EDE of about 0.08 mrem. The collective EDE to the 876 persons who could have eaten such fish could be about 0.003 person-rem. If naturally occurring radionuclides are included, the EDEs could have been 9 mrem and 0.3 person-rem.

Upper Clinch River. An avid fish consumer who ate fish from the Upper Clinch River could have received an EDE of about 0.3 mrem. The collective EDE to the 700 persons who could have eaten such fish could have been about 0.06 person-rem. If naturally occurring radionuclides are included, the EDEs could have been 10 mrem and 2 person-rem. (The EDEs including naturally occurring radionuclides ignore an unusually high ^{40}K measurement in water at CRK 23. If this measurement is included, the EDEs could have been 63 mrem and 11 person-rem. This exclusion affects calculated maximum doses in all the downstream water bodies. Actual radionuclide concentration measurements in fish collected at CRK 16, 32, and 70 indicate the dose from eating fish to be between 1 and 3 mrem.)

Lower Clinch River. An avid fish consumer who ate fish from the Lower Clinch River (CRK 16) could have received an EDE of about 0.1 mrem. The collective EDE to the 1634 persons who could have eaten such fish could have been about 0.05 person-rem. If naturally occurring radionuclides are included, the EDEs could have been 10 mrem and 4 person-rem.

Upper Watts Bar Lake. An avid fish consumer who ate fish from Upper Watts Bar Lake could have received an EDE about 0.02 mrem. The collective EDE to the 2335 persons who could have eaten such fish could be about 0.009 person-rem. If naturally occurring ra-

dionuclides are included, the EDEs could have been 2 mrem and 1 person-rem.

Lower System. An avid fish consumer who ate fish from Lower System could have received an EDE of about 0.01 mrem. The collective EDE to the 45,030 persons who could have eaten such fish could have been about 0.1 person-rem. If naturally occurring radionuclides are included, the EDEs could have been 2 mrem and 18 person-rem.

Poplar Creek. An avid fish consumer who ate fish from Poplar Creek could have received an EDE of about 0.09 mrem. Assuming 100 people could have eaten fish from Poplar Creek, the collective EDE is estimated to be about 0.003 person-rem. If naturally occurring radionuclides are included, the EDEs could have been 8 mrem and 0.3 person-rem.

Other Uses

Other uses of the 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 21 h/year, and use the shoreline for 20 h/year. Measured and calculated concentrations of radionuclides in water and the LADTAP XL code (Hamby 1991) were used to estimate potential EDEs from these activities. At all locations in 2005, the estimated highly exposed individual EDEs were based on measured off-site surface water radionuclide concentrations and exclude naturally occurring radionucides, such as ^{40}K. When compared with EDEs from eating fish from the same waters, the EDEs from these other uses are relatively insignificant.

Melton Hill Lake above all possible ORR inputs. For reference purposes, an individual other user of Melton Hill Lake above ORR inputs could have received an EDE of about 0.0004 mrem. If naturally occurring radionuclides are included, the EDE could have been 0.1 mrem.

Melton Hill Lake. An individual other user of Melton Hill Lake could have received an EDE of about 0.0003 mrem. The collective EDE to the 4428 other users could have been about 0.00006 person-rem. If naturally occurring radionuclides are included, the EDEs could have been 0.1 mrem and 0.03 person-rem.

Upper Clinch River. An other user of the Upper Clinch River could have received an EDE of about 0.0005 mrem. The collective EDE to the 700 other users could have been about 0.0002 person-rem. If naturally occurring radionuclides are included, the EDEs could have been 0.1 mrem and 0.02 person-rem. (Inclusion of the unusually high ^{40}K measurement could raise the EDEs to 0.3 mrem and 0.09 person-rem.)

Lower Clinch River. An other user of the Lower Clinch River could have received an EDE of about 0.004 mrem. The collective EDE to the 8,263 other users could have been about 0.01 person-rem. If naturally occurring radionuclides are included, the EDEs could have been 0.1 mrem and 0.4 person-rem.

Upper Watts Bar Lake. An other user of Upper Watts Bar Lake could have received an EDE of about 0.0007 mrem. The collective EDE to the 11,804 other users could have been about 0.003 person-rem. If naturally occurring radionuclides are included, the EDEs could have been 0.02 mrem and 0.1 person-rem.

Lower System. An other user of the Lower System could have received an EDE of about 0.0006 mrem. The collective EDE to the 227,637 other users could have been about 0.04 person-rem. If naturally occurring radionuclides are included, the EDEs could have been 0.02 mrem and 2 person-rem.

Poplar Creek. An other user of Poplar Creek could have received an EDE of about 0.006 mrem. The collective EDE to the 100 other users could have been about 0.00000005 person-rem. If naturally occurring radionuclides are included, the EDEs could have been 0.07 mrem and 0.000001 person-rem.

Summary

Table 8.6 is a summary of potential EDEs from identified waterborne radionuclides around the ORR. Adding worst-case EDEs for all pathways in a water-body segment gives a maximum individual EDE of about 0.4 mrem to a person obtaining his or her full annual complement of fish, drinking water, and participation in other water uses from the Upper Clinch River. The maximum collective EDE to the 50-mile population could be as high as 5.8 person-

Table 8.6. Summary of annual maximum individual (mrem) and collective (person-rem) effective dose equivalents from waterborne radionuclides[a,b]

	Drinking water	Eating fish	Other uses	Total[c]
Upstream of All ORR Discharge Locations CRK 70				
Individual EDE	0.05	0.08	0.0004	0.1
Collective EDE	0.7	0.003	9E–5	0.7
Melton Hill Lake CRK 70,CRK 66, CRK 58				
Individual EDE	0.05	0.08	0.0003	0.1
Collective EDE	0.7	0.003	6E–5	0.7
Upper Clinch River, CRK 23, Gallaher Water Plant, CRK 32				
Individual EDE	0.05	0.3	0.0005	0.4
Collective EDE	0.05	0.06	0.0002	0.1
Lower Clinch River, CRK 16				
Individual EDE	NA[d]	0.1	0.004	0.1
Collective EDE	NA[d]	0.05	0.01	0.06
Upper Watts Bar Lake, Kingston Municipal Water Plant				
Individual EDE	0.04	0.02	0.0007	0.05
Collective EDE	0.4	0.009	0.003	0.4
Lower System (Lower Watts Bar Lake and Chickamauga Lake)				
Individual EDE	0.03	0.01	0.0006	0.05
Collective EDE	3.5	0.1	0.04	3.7
Poplar Creek				
Individual EDE	NA[d]	0.09	0.006	0.1
Collective EDE	NA[d]	0.003	5E–8	0.003

[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]Rounded difference between individual pathway doses and total.

[d]Not at drinking water supply locations.

rem. These are small percentages of individual and collective doses attributable to natural background radiation, about 0.1% and 0.003%, respectively.

8.1.2.3 Radionuclides in Other Environmental Media

The CAP-88 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 the three mentioned, 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.

Milk

Milk collected at two locations near the ORR and at a remote location was found to contain small quantities of radio-strontium and tritium (Sect. 7.5.3). The sample data were used to calculate potential EDEs to hypothetical persons who drank 310 L (NRC 1977) of sampled milk during the year.

These hypothetical persons could have received an EDE of about 0.07 mrem from drinking milk from the near locations and about 0.06 mrem from the remote location, excluding the contribution from ^{40}K, a naturally occurring radionuclide.

Food Crops

The food-crop sampling program is described in Sect. 7.5. Samples of tomatoes, lettuce, and turnips were obtained from six local gardens. These vegetable types are representative of fruit-bearing, leafy, and root vegetables. All radionuclides found in the food crops are found in the natural environment and in commercial fertilizers, and all but ^{7}Be and ^{40}K also are emitted from the ORR.

Dose estimates are based on hypothetical consumption rates of vegetables that contain statistically significant amounts of certain radionuclides that could have come from the ORR. Based on a nationwide food consumption survey (EPA 1997), a hypothetical home gardener was assumed to have eaten 32 kg of homegrown tomatoes, 10 kg of homegrown lettuce, and 37 kg of homegrown turnips. The hypothetical gardener could have received a 50-year committed EDE of between 0.04 and 0.07 mrem, depending on garden location. Of this total, between 0.00007 and 0.002 mrem could have come from eating tomatoes, between 0.04 and 0.06 mrem from eating lettuce, and between 5×10^{-8} and 7×10^{-8} mrem from eating turnips. The highest dose to a gardener could have been about 0.07 mrem from consuming all three types of homegrown 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. (Potassium-40 actually accounts for all the beta activity found in leafy-vegetable samples.) The presence of ^{40}K in the samples adds, on average, about 1 mrem to the hypothetical home gardener's EDE.

Many of the samples contained detected activities of unidentified beta- and alpha-emitting radionuclides. By subtracting identified activities of beta- and alpha-emitting radionuclides from the unidentified beta and alpha activities, excess beta and alpha activities were estimated. If the excess unidentified beta and alpha activities were from ^{90}Sr and ^{210}Po, a hypothetical home gardener could have received an additional EDE of between 0.004 and 2 mrem. Of this total, between 0.002 and 0.004 mrem could have come from eating tomatoes, between 0.5 and 2 mrem from eating lettuce, and between 1×10^{-7} and 8×10^{-7} mrem from eating turnips. It is believed that most of the excess unidentified beta and alpha activities are due to naturally occurring or fertilizer-introduced radionuclides, not radionuclides discharged from the ORR.

Hay

Another environmental pathway that was evaluated using sampling data is eating beef and drinking milk obtained from cows that ate hay harvested from the ORR. Statistically significant concentrations were found for ^{7}Be and ^{40}K and uranium (^{234}U and ^{238}U) at all sampling locations, including the background location. Excluding the doses from ^{7}Be and ^{40}K (both naturally occurring), the average EDE from drinking milk and eating beef from Areas 1, 2, and 3; 2, 4, and 5; and 6 (see Sect. 7.5.1 and Fig. 7.5) was estimated to be about 0.01 mrem. Also, excluding the doses from ^{7}Be and ^{40}K resulted in a maximum EDE of about 0.004 mrem for the hay samples collected from Area 7 (the background location) . It should be noted that hay in no longer sold for off-site use.

White-Tailed Deer

The TWRA conducted three 2-day deer hunts during 2005 on the Oak Ridge Wildlife Management Area, which is part of the ORR (see Sect. 7.7). During the hunts, 350 deer were harvested and were brought to the TWRA checking station. At the station, a bone sample and a tissue sample were taken from each deer and were field-counted for radioactivity to ensure that the deer met release criteria (less than 20 pCi/g of beta-particle activity in bone or 5 pCi/g of 137Cs in edible tissue). Three deer exceeded the limit for beta-particle activity in bone and were confiscated. The remaining 347 deer were released to the hunters.

The average 137Cs concentration in tissue of the 347 released deer, as determined by field counting, was 0.48 pCi/g; the maximum ^{137}Cs concentration in a released deer was 0.82 pCi/g. The average weight was 84.53 lb, and the maximum weight of the released deer was 176.9 lb. The EDEs attributed to field-measured ^{137}Cs concentrations and actual field weights of the released deer ranged from 0.008 to 1.2 mrem. An individual who consumed one average-weight deer (84.5 lb), assuming 55% field

weight is edible meat, containing the 2005 average concentration of ^{137}Cs (0.48 pCi/g) could have received an EDE of about 0.5 mrem.

In 2005, the maximum field-measured $_{137}$Cs concentration was 0.82 pCi/g, and the maximum deer weight was 176.9 lb. A hypothetical hunter who consumed a deer of maximum weight and ^{137}Cs content could have received an EDE of 2 mrem. Accounting for the maximum field measured ^{137}Cs concentration of 0.82 pCi/g, a maximum weight of 176.9 lb, and the maximum 90Sr concentration of 0.4 pCi/g measured in deer (released and retained) tissue (ORNL 1999), the maximum hypothetical EDE to a hunter who consumed a deer harvested from the ORR in 2005 was estimated to be 4.6 mrem.

Tissue samples collected in 2004 from 20 deer (10 released and 10 retained) were subjected to laboratory analysis. Requested radioisotopic analyses included ^{137}Cs, ^{90}Sr, and ^{40}K radionuclides. Comparison of the field to analytical ^{137}Cs concentrations results found that the field ^{137}Cs concentrations where either greater than or within the statistical range of the ^{137}Cs analytical results. All were less than the administrative limit of 5 pCi/g. The ^{90}Sr concentrations measured in these tissue samples ranged from 0.003 and 0.1 pCi/g.

The maximum EDE to an individual consuming venison from two deer was also evaluated. There were about 49 hunters who harvested two deer or more from the ORR. There were four cases where three or four deer were harvested per a household in 2005. Based on ^{137}Cs concentrations determined by field counting and actual field weight, the EDE range to a hunter who consumed two or more harvested deer was estimated to range between 0.3 to 2.5 mrem.

The collective EDE from eating all the harvested venison from ORR with a 2005 average field-derived ^{137}Cs concentration of 0.48 pCi/g and average weight of 84.5 lb is estimated to be about 0.2 person-rem.

Canada Geese

During the 2005 goose roundup, 167 geese were weighed and subjected to whole-body gamma scans. The average ^{137}Cs concentration in the released geese was 0.23 pCi/g. The maximum ^{137}Cs concentration in the released geese was 0.79 pCi/g. The average weight of the geese screened during the roundup was about 3.53 kg. The maximum goose weight was about 5.1 kg. The EDEs attributed to field-measured ^{137}Cs concentrations and actual field weights of the geese ranged from 0.0003 to 0.03 mrem. If a person consumed a released goose with an average weight of 3.53 kg and an average ^{137}Cs concentration of 0.23 pCi/g, the estimated EDE would be about 0.02 mrem. It is assumed that approximately half the weight of a Canada goose is edible. The maximum estimated EDE to an individual who consumed a hypothetical released goose with the maximum ^{137}Cs concentration of 0.79 pCi/g and the maximum weight of 5.1 kg was about 0.1 mrem.

It is possible that one person could eat more than one goose that spent time on the ORR. Most hunters harvest on average one to two geese per hunting season (USFWS 1995). If one person consumed two geese of maximum weight with the highest measured concentration of ^{137}Cs, that person could have received an EDE of about 0.2 mrem.

In a follow-up on a special study initiated in 1998, muscle samples were analyzed from three geese sacrificed during the 2005 roundup. One goose each from ETTP, ORNL (West End), and Clark Center Park were sacrificed, and the tissue was analyzed. Requested radioisotopic analyses, in addition to the routine analyses of ^{137}Cs and ^{90}Sr, included uranium (^{234}U and ^{238}U) and transuranics, such as ^{239}Pu and ^{241}Am. Based on statistically significant radionuclide concentrations (excluding ^{40}K, a naturally occurring radionuclide) and the actual weights of the geese, the estimated EDEs ranged from about 0.06 to 0.07 mrem.

Eastern Wild Turkey

Two wild turkey hunts were held on the reservation, one on April 9 and 10 and the other on April 16 and 17, 2005. Thirty-eight birds were harvested, and one exceeded the administrative release limits established for radiological contamination in wildlife. The average ^{137}Cs concentration in the measured in the released turkeys was 0.1 pCi/g, and the maximum ^{137}Cs concentration was 0.3 pCi/g.

If a person consumed a wild turkey with an average weight of 8.3 kg and an average ^{137}Cs concentration of 0.1 pCi/g, the estimated EDE would be about 0.02 mrem. The maximum esti-

mated EDE to an individual who consumed a hypothetical released turkey with the maximum ^{137}Cs concentration of 0.3 pCi/g and the maximum weight of 10.9 kg was about 0.08 mrem. It is assumed that approximately half the weight of a wild turkey is edible. The collective EDE from eating all the harvested wild turkey meat (37 birds) with an average field-derived ^{137}Cs concentration of 0.1 pCi/g and average weight of 8.3 kg is estimated to be about 0.0008 person-rem.

A radioisotopic analysis was conducted on the tissue of the retained turkey; this included ^{137}Cs, ^{90}Sr, uranium (^{234}U and ^{238}U), thorium (^{228}Th, ^{230}Th, and ^{232}Th), and transuranics, such as ^{239}Pu and ^{241}Am. Based on statistically significant radionuclide concentrations (excluding ^{40}K, a naturally occurring radionuclide) and the actual weight of the turkey, the estimated EDE was 0.1 mrem.

Direct Radiation

External exposure rates from background sources in the state of Tennessee average about 6.4 μR/h and range from 2.9 to 11 μR/h. These exposure rates translate into annual EDE rates that average 42 mrem/year and range between 19 and 72 mrem/year (Myrick et al. 1981). External radiation exposure rates are measured at a number of locations on and off the ORR. The average exposure rate at PAMs around the ORR during 2005 was about 5.4 μR/h. This rate corresponds to an EDE rate of about 34 mrem/year. All measured exposure rates at or near the ORR boundaries are near background levels.

External exposure rate measurements taken during 1997 along a 1.7-km length of Clinch River shoreline averaged 8.4 μR/h and ranged between 6.9 and 9.3 μR/h. This corresponds to an average exposure rate of about 2.0 μR/h (0.0015 mrem/h) above background. A potential maximally exposed individual would be a hypothetical fisherman who was assumed to have spent 5 h/week (250 h/year) near the point of average exposure on the Clinch River shoreline. This hypothetical maximally exposed individual could have received an EDE of about 0.4 mrem above background during 2005.

The potential above-background annual EDE to a hypothetical maximally exposed individual (hypothetical fisherman who is assumed to fish 250 h/year near the point of average exposure) would be about 0.25 mrem from gamma radiation and 0.25 mrem from neutron radiation (total EDE of 0.5 mrem from both gamma and neutron radiation) along the bank of Poplar Creek near the K-1066-J Cylinder Yard and 0.75 mrem from gamma radiation and 0.5 mrem from neutron radiation (total EDE of 1.25 mrem from both gamma and neutron radiation) along the bank of Poplar Creek near the K-1066-E Cylinder Yard. That section of the creek runs through the ETTP plant and is used at times by fisherman; however, it is very unlikely that anyone would fish it 250 h/year. The gamma and neutron dose rates along the near bank of the Clinch River in the vicinity of the K-770 Scrap Yard would be about 0.25 mrem from gamma radiation and 0.25 mrem from neutron radiation (total EDE of 0.5 mrem from both gamma and neutron radiation). The estimated annual dose to a hypothetical individual assumed to spend 30 min per work day in the parking lot adjacent to the K-1066-K Cylinder Year could be about 0.75 mrem from gamma radiation and 0.25 mrem from neutron radiation (total EDE of 1.25 mrem from both gamma and neutron radiation).

8.1.3 Doses to Aquatic and Terrestrial Biota

8.1.3.1 Aquatic Biota

DOE Order 5400.5, Chap. II, 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 G for definitions of absorbed dose and the rad). To demonstrate compliance with this limit, the aquatic organism assessment was conducted using the RESRAD-Biota code (Version 1.0), 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 "next-generation" biota dose evaluation tool and uses the screening [i.e., biota concentration guides (BCGs)] and analysis methods contained in the technical standard.

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 the limiting organisms for the general screening phase of the graded approach for aquatic organisms. The graded approach for evaluating radiation doses to aquatic biota consists of a three-step process that involves (1) data assembly, (2) general screening of media-specific radionuclide concentrations to media-specific BCGs, and (3) site-specific screening and analysis. In the general screening phase, surface water radionuclide concentrations and sediment radionuclide concentrations can be compared to the media-specific BCGs using default parameters. This aquatic dose assessment was based primarily on surface water sampling data.

At ORNL, doses to aquatic organisms are based on surface water concentrations at ten different sampling locations:

- Melton Branch (MEK 0.2),
- White Oak Creek (WCK 1.0, 2.6, and 6.8),
- First Creek,
- Fifth Creek,
- Raccoon Creek, and
- Clinch River (CRK 32).

Two additional surface water sampling locations on the ORR were also evaluated: Bear Creek (BCK 0.6) and East Fork Poplar Creek (EFK 5.4) All but two of these locations, WCK 1.0 (White Oak Creek at the dam) and White Oak Creek (WCK 2.6), passed the screening phase (using default parameters for BCGs). At WCK 1.0 and WCK 2.6, the default bioaccumulation factors for both ^{137}Cs and ^{90}Sr in fish were adjusted to reflect on-site bioaccumulation of these radionuclides in fish. Riparian organisms are the limiting receptor for both ^{137}Cs and ^{90}Sr in surface water; however, the best available bioaccumulation data for White Oak Creek are for fish. Because fish are consumed by riparian organisms (e.g., raccoons), adjustment of the fish bioaccumulation factor modified the bioaccumulation of both ^{90}Sr and ^{137}Cs in riparian organisms. This resulted in absorbed dose rates to aquatic organisms below the DOE aquatic dose limit of 1 rad/day at all twelve sampling locations.

At the Y-12 Complex, doses to aquatic organisms were estimated from surface water concentrations at ten different sampling locations:

- Station 9422-1 (Station 17), Bear Creek at BCK 4.55 (formerly outfall 304) and at BCK 0.6,
- Rogers Quarry Discharge Point S19 (formerly outfall 302),
- Discharge Point S17 (unnamed tributary to the Clinch River),
- West End Treatment Facility (outfall 502),
- outfall 512,
- outfall 520,
- Central Pollution Control Facility (discharge point 501),and
- Central Mercury Treatment Unit (outfall 551).

All locations passed the general screening. This resulted in absorbed dose rates to aquatic organisms below the DOE aquatic dose limit of 1 rad/day at all ten Y-12 locations.

At ETTP, doses to aquatic organisms were estimated from surface water concentrations at ten different sampling locations:

- Mitchell Branch at K1700 and at MIK 1.4 (upstream location),
- Poplar Creek at K-716 (downstream),
- K1007-B and K-1710 (upstream location),
- K901-A (downstream of ETTP operations),
- K-700, K-1407-J (the Central Neutralization Facility), and
- Clinch River (CRK 16 and CRK 23).

All of these locations passed the initial general screening (using default parameters for BCGs).

8.1.3.2 Terrestrial Biota

DOE Orders 450.1 and 5400.5 include requirements to demonstrate radiation protection of biota within terrestrial systems as well as aquatic systems.

As required by CERCLA, baseline ecological risk assessments have been conducted for a number of watershed areas on the ORR. The results of these assessments provide the basis for selection of future terrestrial biota sampling locations on the ORR. The ecological impacts

identified in the assessments for the following sites are summarized below.

ORNL is divided into two watershed areas, the Bethel Valley watershed and the Melton Valley watershed. The Bethel Valley watershed, as approached in the baseline ecological risk assessment, was divided into four geographical areas: the Raccoon Creek area, West Bethel Valley, Central Bethel Valley, and East Bethel Valley. Based on the results of the assessment for Bethel Valley (DOE 1999b), the only area where there appear to be potential risks to terrestrial organisms exposed to radiological contaminants was West Bethel Valley, but the risks were not widespread. Potential risks from exposure to radionuclides in surface soil were identified for soil invertebrates and all wildlife receptors (e.g., soil invertebrates, shrews, white-footed mice, red fox, deer, red-tailed hawk, turkey, and mink) except plants. Cesium-137 was the risk driver for all receptors. Uranium-234 was an additional radionuclide of concern for turkeys at this location.

In the Melton Valley watershed ecological assessment (DOE 1997a), ecological risks were estimated for plants, soil invertebrates, and terrestrial wildlife exposed to radionuclide contaminants in surface soil within each subbasin in the watershed for which surface soil data were available. Radiological data were available for 28 subbasins. Radionuclide exposures resulted in potential risks to terrestrial biota at 16 subbasins. Radionuclide risks were highest in the East Seep subbasin, with ^{137}Cs driving risks for all receptors. In five subbasins, calculated dose rates were above limits for plants. Estimated doses exceeded dose limits for soil invertebrates in 7 subbasins and for wildlife receptors (e.g., shrews and mice) in 16 subbasins. However, doses to piscivorous wildlife (e.g., mink, kingfisher, great blue heron) were below dose limits to all piscivorous receptors. The data collected for a recent Melton Valley ecological monitoring report (DOE 2004) indicate that the ecological contaminants of concern in Melton Valley surface soil, surface water, and sediment pose little or no risk to wildlife receptors. This report suggests that the earlier ecological risk assessment overestimated the exposure and risk to wildlife receptors.

The Y-12 site was divided into two watershed areas, Upper East Fork Poplar Creek and Bear Creek. In the Upper East Fork Poplar Creek watershed, the characterization area encompasses Upper East Fork Poplar Creek, Lake Reality, the main industrialized part of the Y-12 Plant, and the East End carbon tetrachloride plume (which extends into Union Valley) (DOE 1998). Upper East Fork Poplar Creek extends from its headwaters at the North/South Pipe downstream to Station 17, where it crosses the Y-12 Complex property boundary and becomes Lower East Fork Poplar Creek. The baseline ecological risk assessment addressed only surface water and sediment exposures to contaminants in Upper East Fork Poplar Creek, Lake Reality, wetlands, and seeps associated with the East End carbon tetrachloride plume because the characterization area includes no substantial habitat for terrestrial biota. In 2005 a sampling project was conducted in the northwest part of the industrialized Y-12 Complex. A data set was collected for purposes of characterizing an area for new construction. To evaluate whether the soil concentrations could result an absorbed dose of 0.1 rad/day, the RESRAD-Biota for Windows (Version 1.0), which is a companion tool for implementing DOE technical standard entitled *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE 2002), was used. Maximum radionuclide soil concentrations, regardless of sample interval depth, were used in the screening. These maximum radionuclide concentrations passed the initial general terrestrial biota screening.

The Bear Creek watershed consists of Bear Creek from its confluence with Lower East Fork Poplar Creek to the headwaters at the western edge of the Y-12 Plant, the associated floodplain and tributaries, and the source area in upper Bear Creek Valley (DOE 1997b). The primary sources considered in the ecological assessment were the waste and secondary contamination at the S-3 Ponds, the Bone Yard/Burn Yard, Sanitary Landfill 1, and Bear Creek Burial Grounds. No detectable radiation effects are anticipated for individual terrestrial biota (plant, earthworm, terrestrial, or semiaquatic wildlife receptors) frequenting Bear Creek, its floodplain, or source area sites. The overall current dose rate was below the effects thresholds for all receptors at all of these sites. Alpha radiation exposures related to ingestion of contaminated prey accounted for

virtually the entire dose for all receptors. External exposures were determined to be inconsequential.

At ETTP data were aggregated within geographic areas and were used to evaluate possible risks to fish and other aquatic organisms, piscivorous wildlife, terrestrial plants, soil invertebrates, and terrestrial wildlife receptors (BJC 2004b, BJC 2004c). The primary areas of concern for aquatic organisms appear to be the K-901-A Holding Pond, the K-1007 P1 Pond, and Mitchell Branch. Potential risks to aquatic organisms or piscivorous or aerial insectivorous wildlife receptors were evident or likely in these three water bodies while potential risks at other ETTP water bodies (the K-720 Slough, K-770 Embayment, K-1007 P3, P4, and P5 Ponds, and upper reach of Mitchell Branch) were considerably lower and less extensive. Dose rate calculations for fish, benthic invertebrates, and piscivorous wildlife indicated that radionuclides in surface water and sediment were unlikely to be a concern for those receptors.

All geographic areas included at least one surface soil analyte with a maximum concentration exceeding benchmark levels for at least one terrestrial receptor; metals and/or PCBs in the K-770 Scrapyard within the Powerhouse area, the K-25 North Trash Slope within the K-27/K-29/K-1064 process area, and portions of the habitat area along Mitchell Branch in the Mitchell Branch support area appear to pose the greatest likelihood of unacceptable risks to terrestrial receptors. These same areas also had radionuclide levels potentially resulting in doses above threshold levels for one or more terrestrial receptors. In all cases internal exposures to uranium isotopes were identified as the primary contributors to elevated radiation dose levels.

8.1.4 Current-Year Summary

A summary of the maximum EDEs to individuals by pathway of exposure is given in Table 8.7. It is very unlikely (if not impossible) that any real person could have been irradiated by all of these sources and pathways for the duration of 2005; however, if someone were, that person could have received a total EDE of about 7.8 mrem. Of that total, 0.9 mrem would have come from airborne emissions, 0.4 mrem would have come from drinking Clinch River water, 0.3 mrem would have come from eating fish from the Clinch River, 1.3 mrem would have come from direct radiation while fishing on Poplar Creek inside the ETTP, and 0.004 mrem would have come from other water uses on the Clinch River. This dose is about 1 % of the annual dose (300 mrem) from background radiation. The EDE of 7.8 mrem includes the person who received the highest EDEs 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 2.8 mrem.

DOE Order 5400.5 limits the EDE 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 2005 maximum EDE should not have exceeded about 7.8 mrem, or about 7.8% of the limit given in DOE Order 5400.5. (For further information, see Table G.2 in Appendix G, which provides a summary of dose levels associated with a wide range of activities.)

The total collective EDE to the population living within a 80-km radius of the ORR was estimated to be about 13.2 person-rem. This dose is about 00.4 % of the 312,012 person-rem that this population received from natural sources during 2005.

8.1.5 Five-Year Trends

Dose equivalents associated with selected exposure pathways for the years from 2001 to 2005 are given in Table 8.8. The variations in values over the 5-year period likely are not statistically significant. The dose estimates for direct irradiation along the Clinch River have been corrected for background.

8.1.6 Potential Contributions from Non-DOE Sources

There are several non-DOE facilities on or near the ORR that could contribute radiation doses to the public. These facilities submit annual reports to demonstrate compliance with NESHAP regulations and the terms of their operating licenses. DOE requested information pertaining to potential radiation dose to members of the public who also could have been affected by releases from these facilities. Five facilities responded to the DOE request. Based on these responses, no member of the public

Table 8.7. Summary of maximum potential radiation dose equivalents to an adult during 2005 and locations of the maximum exposures

Pathway	Dose to maximally exposed individual		Percentage of DOE100 mrem/year limit (%)	Estimated population dose		Population within 80 km	Estimated background radiation population dose (person-rem)[a]
	mrem	mSv		person-rem	person-Sv		
Airborne effluents:							
All pathways	0.9	0.009	0.9	10.9	0.109	1,040,041[a]	
Liquid effluents:							
Drinking water	0.4	0.004	0.4	0.7	0.007	358,681[b]	
Eating fish	0.3	0.003	0.3	0.1	0.001	51,652[c]	
Other activities	0.004	0.0004	0.004	0.01	0.0001	774,820[d]	
Eating deer	4.6	0.046[e]	4.6	0.2	0.002	347	
Eating geese	0.2	0.002[f]	0.2	*g*	*g*		
Eating turkey	0.2	0.002[h]	0.2	0.0008	8E–6	38	
Direct radiation	1.3	0.013[l]	1.3	0.13	0.0013	100	
All pathways	7.8	0.078	7.8	13.2	0.132	1,040,041	312,012

[a]Estimated background population dose is based on 300 mrem/year individual dose and the population within 80 km of the ORR.

[b]Population based on 2000 census data.

[c]Population estimates based on community and non-community drinking water supply data from TDEC, Division of Water.

[d]Population estimates based on the number of fish harvested in Melton Hill, Watts Bar, and Chickamuaga reservoirs.

[e]The maximum EDE from consumption of a deer harvested on the ORR in 2005 and the population dose is 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]Population doses were not estimated for the consumption of geese since there are no goose hunts on the ORR.

[h]From consuming two hypothetical worst-case turkey, each a combination of the heaviest turkey harvested and the highest measured concentrations of ^{137}Cs in released turkey.

[i]Direct radiation dose estimate based on exposure to a fisherman on Poplar Creek.

Table 8.8. Trends in total effective dose equivalent (mrem)[a] for selected pathways

Pathway	2001	2002	2003	2004	2005
All air	0.8	0.3	0.2	0.4	0.9
Fish consumption (Clinch River)	0.2	0.3	1	0.2	0.3
Drinking water (Kingston)	0.03[b]	0.04[b]	0.1	0.04	0.03
Direct radiation (Clinch River)	0.4[c]	0.4[c]	0.4	0.4	0.4
Direct radiation (Poplar Creek)	2[c]	2[c]	2[d]	3[d]	1[d]

[a]1 mrem = 0.01 mSv.

[b]Based on water samples from the Clinch River System.

[c]These values have been corrected by removing the contribution of natural background radiation and by using International Commission on Radiological Protection recommendations for converting external exposure to effective dose equivalent.

[d]Included gamma and neutron radiation measurement data.

should have received an EDE greater than 2.7 mrem due to airborne releases from these facilities. The maximally exposed individual dose of 1.9 mrem/year was estimated at the boundary of one of the facilities. Four facilities responded stating that there had been no water releases.

8.2 Chemical Dose

8.2.1 Drinking Water Consumption

To evaluate the drinking water pathway, hazard quotients (HQs) were estimated upstream and downstream of the ORR discharge points (Table 8.9). (See Appendix H for a detailed description of the chemical dose methodology). As in 2000 through 2004, chemical analytes were measured only in surface water samples collected at CRK 70 and CRK 16. CRK 70 is located upstream of all DOE discharge points, and CRK 16 is located downstream of all DOE discharge points. As shown in Table 8.9, HQs were less than 1 for detected chemical analytes for which there are reference doses or maximum contaminant levels. Acceptable risk levels for carcinogens typically range from 10^{-4} to 10^{-6}. Risk values greater than 10^{-5} were calculated for the intake of arsenic in water collected at both upstream and downstream locations.

Table 8.9. 2005 chemical hazard quotients and estimated risks for drinking water[a]

Chemical	Hazard quotient	
	CRK 70[b]	CRK 16[c]
Antimony	~0.03	~0.03
Arsenic	~0.2	~0.2
Acetone	~0.0002	~0.0002
Barium	~0.02	0.02
Beryllium		~0.001
Boron	0.002	0.005
Cadmium	~0.005	~0.005
Chromium	~0.01	~0.01
Lead	0.1	0.1
Manganese	0.02	0.01
Molybdenum	~0.005	~0.003
Nickel	0.002	0.002
Selenium	~0.01	0.01
Silver	~0.0009	~0.0009
Strontium	0.005	0.004
Thallium	~0.2	0.2
Toluene	~0.0001	~0.0001
Uranium	0.002	0.003
Vanadium	~0.01	~0.01
Zinc	0.0006	0.0006
Risk for carcinogens		
Arsenic	~8E–5	~3E–5

[a]A tilde (~) indicates that estimated values were used in the calculation.

[b]Melton Hill Reservoir above city of Oak Ridge input.

[c]Clinch River downstream of all DOE inputs.

8.2.2 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. In the current assessment, a fish consumption rate of 60 g/day (21 kg/year) is assumed for both the noncarcinogenic and carcinogenic pollutants. It is the same fish consumption rate used in the estimation of the maximum exposed radiological dose from consumption of fish. (See Appendix H for a detailed description of the chemical dose methodology.)

As shown in Table 8.10, for consumption of sunfish and catfish, HQ values of less than 1 were calculated for the all detected analytes except for arsenic and Aroclor-1260 at all three locations.

For carcinogens in sunfish and catfish, risk values greater than 10–5 were calculated for the intake of arsenic and Aroclor-1260 found in sunfish and catfish collected at all three locations. For catfish, risk values greater than 10–5 were also calculated for the intake of Aroclor-1254 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 and has issued a precautionary fish consumption advisory for catfish in the Clinch River arm of Watts Bar Reservoir (TDEC 2002).

Table 8.10. 2005 chemical hazard quotients and estimated risks for carcinogens in fish[a]

Carcinogen	Sunfish			Catfish		
	CRK 70[b]	CRK 32[c]	CRK 16[d]	CRK 70[b]	CRK 32[c]	CRK 16[d]
Hazard quotient for metals						
Antimony						
Arsenic	1.2	1.2	1.1	1.0	1.2	1.1
Barium	0.002	0.002	0.0008	0.00007	0.0001	0.0001
Beryllium		~0.0007				
Boron	0.0003	0.0002	0.0003	0.0002	0.0003	0.0003
Chromium	0.03	0.03	0.02	0.01	0.02	0.02
Lead	0.3	~0.3	~0.2	0.2	2.5	
Manganese	0.01	0.02	0.007	0.0009	0.001	0.001
Mercury	0.1	0.1	0.7	0.2	0.3	0.6
Molybdenum	0.006	0.008	0.01	~0.005	~0.005	0.006
Nickel	0.001					
Selenium	0.2	0.1	0.1	0.07	0.04	0.04
Silver	0.003	0.002	0.003			~0.003
Strontium	0.004	0.004	0.002	0.00007	0.00009	0.0001
Thallium	0.09	0.1	0.1	0.03	0.04	0.03
Uranium	0.0004	0.0004	0.0004	0.0003	0.0002	0.0003
Vanadium	0.002	0.002	~0.001		~0.002	
Zinc	0.05	0.05	0.04	0.02	0.02	0.02
Hazard quotient for pesticides and Aroclors						
Aroclor-1254				2.8	3.9	5.3
Aroclor-1260	0.98	~0.6	~0.8	9.0	9.5	11.9
Chlordane, alpha				0.01	0.02	0.01
Chlordane,gamma				0.008	0.01	0.007
Risks for carcinogens						
Arsenic	2E-4	2E-4	2E-4	2E-4	2E-4	2E-4
Aroclor-1254				5E-5	7E-5	9E-5
Aroclor-1260	2E-5	~1E-5	~1E-5	2E-4	2E-4	2E-4
Chlordane, alpha				9E-7	1E-6	9E-7
Chlordane, gamma				6E-7	8E-7	5E-7
4,4'-DDD				~4E-7		7E-7
4, 4′-DDE	~1E-7	~1E-7	~2E-7	8E-7	2E-6	2E-6
PCBs (mixed)[e]	2E-5	~1E-5	~1E-5	2E-4	2E-4	3E-4

[a]A tilde (~) indicates that estimated values were used in the calculation, and a blank space indicates that the parameter was undetected.

[b]Melton Hill Reservoir, above Oak Ridge city input.

[c]Clinch River, downstream of ORNL.

[d]Clinch River, downstream of all DOE inputs.

[e]Mixed PCBs consists of the summation of Aroclors detected or estimated.

9. Quality Assurance

The overall goal of a well-designed and well-implemented sampling and analysis program is to measure accurately what is really there. Environmental decisions are made on the assumption that analytical results are, within known limits of accuracy and precision, representative of site conditions. Many sources of error exist that could affect the analytical results, including sample collection methods; sample handling, preservation, and transport; personnel training; analytical methods; data reporting; and record keeping. Quality assurance programs are designed to minimize these sources of error and to control all phases of the monitoring process.

9.1 Introduction

The application of quality assurance/quality control (QA/QC) programs for environmental monitoring activities on the ORR is essential for generating data of known and defensible quality. Each aspect of an environmental monitoring program, from sample collection to data management, must address and meet applicable quality standards.

9.2 Field Sampling Quality Assurance

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

- use of work planning and control and standard operating procedures for sample collection and analysis;
- use of chain-of-custody and sample-identification procedures;
- instrument standardization, calibration, and verification;
- technician and analyst training;
- sample preservation, handling, and decontamination; and
- use of QC samples, such as field and trip blanks, duplicates, and equipment rinses.

9.3 Analytical Quality Assurance

The contract analytical laboratories that perform the analyses of environmental samples from the ORR environmental monitoring programs are required to have documented QA/QC programs, well-trained and qualified staff, and appropriately maintained equipment and facilities and applicable certifications. The analytical laboratories conduct extensive internal QC programs, participate in external QA programs, and use statistics to evaluate and continuously improve performance.

9.3.1 Internal Quality Control

Analytical 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 the National Institute of Standards and Technology (NIST), DOE sources, or EPA are used (when available) for such work. The laboratories operate under specific QA/QC criteria.

QA/QC measurement control programs external to the sample analysis groups include the submission of single- and double-blind control samples to monitor performance. The results of such periodic measurement programs are statistically evaluated and reported to the laboratories and their customers. Reports are issued routinely, and some laboratories compile annual summary reports. These reports assist in evaluating the adequacy of analytical support programs and procedures. If serious deviations are noted by the QA/QC groups, the operating laboratories are promptly notified so that corrective actions can be initiated and problems can be resolved.

9.3.2 External Quality Assurance

In addition to the internal programs, all contract analytical laboratories participate in external QA programs. The external QA programs typically consist of the contract laboratories analyzing samples of unknown composition sup-

plied by various DOE- or EPA-approved proficiency-testing supplier organizations. The supplying organizations know the true composition of the samples and provide the contract laboratories with data reports on their analytical performance. The following sections describe external QA programs in which contract analytical laboratories may be required to participate.

9.3.2.1 EPA Water Pollution and Water Supply Performance Studies

Participation in the Water Pollution Program and the Water Supply Program studies is required by most states for laboratories performing analyses of water samples for regulatory programs. The Water Supply Program is used by the state of Tennessee to certify laboratories for drinking water analysis. To maintain a certification, a laboratory must meet a specified set of criteria relating to technical personnel, equipment, work areas, QA/QC operating procedures, and successful analysis of QA samples. This program is also used by other states as part of their certification programs. Participation in the Water Pollution Program satisfies the EPA and National Pollutant Discharge Elimination System (NPDES) program requirement that laboratories performing Clean Water Act analyses participate in a Discharge Monitoring Report Quality Assurance Program.

Since October 24, 1999, all water pollution and water supply studies except whole effluent toxicity testing have been performed by commercial vendors. NIST certifies non-EPA proficiency testing providers to prepare performance evaluation samples and to evaluate laboratory performance. EPA continues to issue standard operating procedures for use in the water supply and water pollution programs.

9.3.2.2 American Industrial Hygiene Association Proficiency Analytical Testing Program

The American Industrial Hygiene Association (AIHA) administers the Proficiency Analytical Testing Program as part of its AIHA accreditation process for laboratories performing analyses of industrial hygiene air samples.

9.3.2.3 Intercomparison Radionuclide Control Program

The EPA Intercomparison Radionuclide Control Program administered by the National Exposure Research Laboratory at Las Vegas has been replaced by a vendor-supplied program approved by EPA. A samples is composed of a water matrix. The state of Tennessee requires participation for drinking water certification of radionuclide analysis. This program is also used by other states as part of their laboratory certification processes.

9.3.2.4 AIHA Environmental Lead Proficiency Analytical Testing Program

The Environmental Lead Proficiency Analytical Testing Program is administered by AIHA. This program was established in 1992 to evaluate analysis of environmental lead samples in paint, soil, and dust wipes. In addition, a laboratory may request to become accredited for lead analysis in this program.

9.3.2.5 DOE Mixed Analyte Performance Evaluation Program

The Mixed Analyte Performance Evaluation Program is set up by the DOE Radiological and Environmental Sciences Laboratory in conjunction with the Laboratory Management Division of the Office of Technology Development to evaluate analysis of mixed-waste samples. Participation is required by DOE for laboratories that perform environmental analytical measurements in support of environmental management activities. Various matrices, such as soil, water, air filters, and vegetation, are submitted semiannually for analysis of a variety of radioactive isotopes as well as metals and organic parameters. A statistical report is issued for each study.

9.3.2.6 DOE Environmental Measurements Laboratory Quality Assessment Program

The Radionuclide Quality Assessment Program (QAP) was administered by the DOE En-

vironmental Measurements Laboratory (EML) in New York and was funded by the Energy Research and Development Administration and DOE. The program was an external, independent, performance evaluation program designed to test the quality of environmental radiological measurements. This program was terminated in 2004, and no more reports will be issued. In its place, DOE has expanded the Mixed Analyte Performance Evaluation Program to include the matrices previously provided via the EML QAP, such as soil, water, air, and vegetation.

9.3.2.7 Proficiency Evaluation Testing Programs

The Proficiency Evaluation Testing Programs are services purchased from outside vendors. They are required for many contract analytical laboratories to meet the need for a QA program for environmental analyses. The samples are supplied by commercial companies at concentrations that meet EPA-established guidelines. The analytical data are reported to the supplier, and a report on the precision and accuracy of the results is provided to the laboratory. This report includes a percentage recovery of the referenced value, deviation from the mean of all reported data, specific problems in a laboratory, and other statistical information. Matrices can include water as well as soils. In addition, program participation via some vendors may satisfy requirements for participating in discharge monitoring report QA studies for the NPDES program and/or meet other certification program requirements imposed on laboratories.

9.3.3 Y-12 Analytical Chemistry Organization Scores on FY 2005 Performance Evaluation Programs

The BWXT Y-12 Analytical Chemistry Organization subscribes to a number of independent, external QC programs that submit blind samples and score the quality of the results. This is necessary to retain numerous certifications required by customers and to ensure the quality of the analyses. The Analytical Chemistry labs achieved an overall FY 2005 score of 98.02% from 68 different studies. This compares with a national average of 94.4% among programs for which data are available On 53 of the studies, the Analytical Chemistry Organization labs received a score of 100%.

9.3.4 Quality Assessment Programs for Subcontracted Laboratories

Competitive award systems are used by UT-Battelle and by DOE's Sample Management Office to select laboratories that are contracted under Basic Ordering Agreements to perform analytical work. Commercial laboratories approved by the Sample Management Office are required to comply with the requirements set forth in the Integrated Contractor Procurement Team Basic Ordering Agreement terms and conditions. Oversight of subcontracted commercial laboratories is performed by the DOE Environmental Management Consolidated Audit Program, which is supported by the Sample Management Office. DOE, the Sample Management Office, and other subcontractors from across the DOE complex work together in the Environmental Management Consolidated Audit Program to conduct on-site laboratory reviews and to monitor the performance of all subcontracted laboratories. Awards are made to laboratories to provide analytical support to projects based on the best value added to the project. Best value is a graded approach that comprises price and performance history.

The Sample Management Office contractor manages the Integrated Performance Indicator Program to report quality indicators that will assess trends for commercial analytical laboratories used to support Sample Management Office projects (and their subcontractors) within DOE-ORO. The objective of the Integrated Performance Indicator Program is to evaluate all analytical laboratories based on a set of standardized performance criteria that can then be quantitatively tracked and trended. The Sample Management Office contractor uses these performance indicators to monitor the labs' performance.

A limited basic order agreement with commercial laboratories has been established by UT-Battelle for the procurement of analytical services to characterize environmental and waste samples. Laboratories included in the agreement are required to comply with the terms and conditions of the Integrated Contractor Procurement Team Contract, Basic Order Agreement. A

statement of work for each project specifies any additional QA/QC requirements and includes detailed information, data, deliverables, turnaround times, and required methods.

9.3.4.1 Single-Blind Performance Evaluation Program

If applicable, laboratories participate in external single-blind performance evaluation programs. All results that are officially reported by the responsible agency (EPA or DOE) during the period of evaluation are used in computing the single-blind performance evaluation score. Single-blind performance evaluation program results are categorized into radiochemistry, organic, and inorganic methodology areas.

9.3.4.2 Double-Blind Performance Evaluation Program

Double-blind performance evaluation programs are employed to quantitatively evaluate the total laboratory process. Performance samples are submitted to laboratories with batches of actual field samples in order to ensure that the laboratory is not able to distinguish them as QA samples. Once the project data have been received, the performance evaluation results are evaluated and scored. Double-blind performance evaluation program results are categorized into radiological, organic, and inorganic methodology areas.

The Sample Management Office combines single- and double-blind performance evaluation scores to obtain a total Integrated Performance Indicator Program performance evaluation score. A laboratory must score 80% or better to remain in good standing. A score of 64 to 79% would result in a laboratory's being placed on probation.

9.4 Data Management, Verification, and Validation

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 with 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.

Over the years, the environmental data verification and data validation processes used by ORR environmental programs have evolved to meet continuing regulatory changes and monitoring objectives. 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. For example, the requirements for self-monitoring of surface water and wastewater effluents under the terms of an NPDES permit require the permittee to conduct the analyses as defined in 40 CFR 136 and to certify that the data reported in the monthly discharge monitoring report are true and accurate.

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 against a predetermined standard or contract.

Certain projects may perform a more thorough technical validation of the data as mandated by the project's data quality objectives. For example, sampling and analyses conducted as part of a remedial investigation to support the Comprehensive Environmental Response, Compensation, and Liability Act 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 that case, the data quality objectives of the project may mandate a more thorough technical evaluation of the data against predetermined criteria. For example, EPA has established functional guidelines for validation of organic and inorganic data collected under the protocol of EPA's Contract

Laboratory Program. These guidelines are used to offer assistance to the data user in evaluating and interpreting the data generated from monitoring activities that require Contract Laboratory Program performance.

The validation process may result in the identification of data that do not meet predetermined QC criteria (in flagging quantitative data that must be considered qualitative only) 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.

Integration of compliance-monitoring data for the ORR with sampling and analysis results from remedial investigations is a function of the Oak Ridge Environmental Information System (OREIS). OREIS is necessary to fulfill requirements prescribed in both the Federal Facility Agreement and the Tennessee Oversight Agreement and to support data management activities for DOE. The Federal Facility Agreement, a tripartite agreement among DOE, EPA Region 4, and the state of Tennessee, requires DOE to maintain one consolidated database for environmental data generated at DOE facilities on the ORR. According to the Federal Facility Agreement, the consolidated database is to include data generated pursuant to the agreement as well as data generated under federal and state environmental permits. The Tennessee Oversight Agreement further defines DOE staff obligations to develop a quality-assured, consolidated database of monitoring information that will be shared electronically on a near-real-time basis with the state staff.

OREIS is the primary component of the data management program for restoration projects, providing consolidated, consistent, and well-documented environmental data and data products to support planning, decision-making, and reporting activities. OREIS provides a direct electronic link of ORR monitoring and remedial investigation results to EPA Region 4 and the Tennessee Department of Environment and Conservation/DOE Oversight Division.

Appendix A. Errata

Appendix A. Errata

The following table is a corrected version of Table 4.1 in the *Oak Ridge Reservation Annual Site Environmental Report for 2003*, DOE/ORO/2185.

Table 4.1. ETTP radionuclide air emission totals, 2003 (Ci)[a]

Radionuclide	Total major	TSCAI (major)[b]	Total minor	Total ETTP
^{228}Ac	-	-	1.03E-08	1.03E-08
^{241}Am	-	-	3.31E-08	3.31E-08
^{243}Am	-	-	2.40E-10	2.41E-10
^{212}Bi	-	-	7.34E-09	7.34E-09
^{214}Bi	-	-	8.07E-09	8.07E-09
^{14}C	1.52E-05	1.52E-05	1.10E-05	2.62E-04
^{137}Cs	1.15E-04	1.15E-04	5.09E-06	1.20E-04
^{57}Co	-	-	2.20E-09	2.20E-09
^{60}Co	-	-	2.66E-07	2.66E-07
^{244}Cm	-	-	7.34E-10	7.34E-10
^{152}Eu	-	-	7.34E-10	7.34E-10
^{154}Eu	-	-	4.25E-07	4.25E-07
^{131}I	-	-	5.21E-08	5.21E-08
^{85}Kr	1.41E-03	1.41E-03	1.48E-06	1.41E-03
^{210}Pb	-	-	6.51E-08	6.51E-08
^{212}Pb	-	-	7.34E-09	7.34E-09
^{214}Pb	-	-	6.63E-09	6.63E-09
^{237}Np	3.98E-07	3.98E-07	1.56E-07	5.53E-07
^{95}Nb	-	-	7.34E-10	7.34E-10
^{238}Pu	2.75E-07	2.75E-07	6.60E-08	3.41E-07
^{239}Pu	3.28E-07	3.28E-07	1.06E-07	4.33E-07
^{242}Pu	-	-	2.23E-09	2.23E-09
^{40}K	-	-	2.71E-07	2.71E-07
^{231}Pa	-	-	3.57E-10	3.57E-10
^{233}Pa	-	-	5.14E-09	5.14E-09
^{234}Pa	-	-	1.31E-07	1.31E-07
^{234m}Pa	7.18E-03	7.18E-03	3.71E-05	7.22E-03
^{226}Ra	-	-	2.53E-07	2.53E-07
^{228}Ra	-	-	7.34E-10	7.34E-10
^{89}Sr	2.94E-06	2.94E-06	-	2.94E-06
^{90}Sr	-	-	1.08E-06	1.08E-06
^{99}Tc	9.44E-04	9.44E-04	2.73E-05	9.71E-04
^{208}Tl	-	-	2.94E-09	2.94E-09
^{228}Th	8.31E-06	8.31E-06	4.85E-08	8.36E-06
^{230}Th	6.44E-05	6.44E-05	9.07E-08	6.45E-05
^{231}Th	-	-	1.47E-09	1.47E-09
^{232}Th	3.45E-05	3.45E-05	5.32E-08	3.45E-05
^{234}Th	3.23E-03	3.23E-03	2.63E-05	3.26E-03

Table 4.1. (continued)

Radionuclide	Total major	TSCAI (major)[b]	Total minor	Total ETTP
^{3}H	7.35E+00	7.35E+00	1.34E-02	7.37E+00
^{233}U	-	-	3.35E-06	3.35E-06
^{234}U	1.94E-04	1.94E-04	3.79E-05	2.32E-04
^{235}U	8.27E-04	8.27E-04	2.22E-06	8.29E-04
^{236}U	-	-	5.18E-07	5.18E-07
^{238}U	3.30E-04	3.28E-04	2.73E-05	3.67E-04
Totals	7.37E+00	7.37E+00	1.36E-02	7.38E-00

[a]1 Ci = 3.7E+10 Bq
[b]Toxic Substances Control Act Incinerator

The following corrections pertain to the Oak Ridge Reservation Annual Site Environmental Report for 2004, DOE/ORO/2204.

On p. 5-33, in the right-hand column, the sentence that begins fourteen lines from the bottom should read as follows.

Statistically significant downward trends are observed (at a significance level of 0.01) for tritium in Well 1190 as well as for gross beta, total radioactive strontium, and tritium in Well 1191.

On p. 5-35, in the right-hand column, the reference citation beginning seven lines from the bottom should read as follows.

Annual Monitoring Plan for the High Flux Isotope Reactor Site–Monitoring Period 2003–2004 (Bonine 2003).

On p. 7-14, Sect. 7.8.2, second paragraph, the first sentence should read as follows.

Since 1997, 381 turkeys have been harvested. Of these, only two (0.5%) have been retained due to potential radiological contamination.

Appendix B. Climate Overview for the Oak Ridge Area

Appendix B. Climate Overview for the Oak Ridge Area

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 thermal circulations, and mountain-valley circulations. Pressure-driven channeling and vertically coupled flow (unstably stratified conditions) affect wind flow on scales comparable to that of the Great Valley (hundreds of kilometers). Forced channeling occurs on similar scales but is also quite important at smaller spatial scales such as that of the local ridge-and-valley (Birdwell 1996). Along-valley and mountain-valley circulations are thermally-driven and occur within a large range of spatial scales. Thermal flows are more prevalent under conditions of clear skies and low humidity.

Pressure-driven channeling, in its simplest 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 pressure gradient superimposed on the valley's 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 "weather"-induced 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 flow 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).

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 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 Oak Ridge Reservation (Kossman and Sturman 2002).

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 to the 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 related to 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 (Froude and Rossby ratios in the meteorological field). Consequently, the leeward mountain range (Smoky Mountains) becomes more effective at blocking or redirecting the winds.

Vertically coupled winds occur when the atmosphere is unstable (characterized by cooler temperatures aloft). When a strong horizontal wind component is also present (as in conditions behind a winter cold front), winds "ignore" the terrain, flowing over it in 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 25° to the left (Birdwell 1996).

Thermally driven winds are common in areas of significantly 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 air flow, depending on the ambient weather conditions. Eckman (1998) suggested that the presence of daytime up-valley winds and night time down-valley (drainage) flows between the ridge-and-valley terrain of the Oak Ridge area tended to reverse at about 9:00 to 11:00 a.m. and at about 5:00 to 7:00 p.m. local time. The terrain-following nature of drainage winds suggests that they would be more directly impacted by the presence of the ridge-and-valley than daytime flows, which tend to be accompanied by significant vertical motions.

Figures B.1, B.2, and B.3 are wind roses for data obtained during 2005 at ORNL Meteorological Tower C, at 10, 30, and 100 m above ground level, respectively. The wind roses represent typical trends and should be used with caution.

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 that winds blow from that direction. The concentric circles represent increasing frequencies from the center outward.

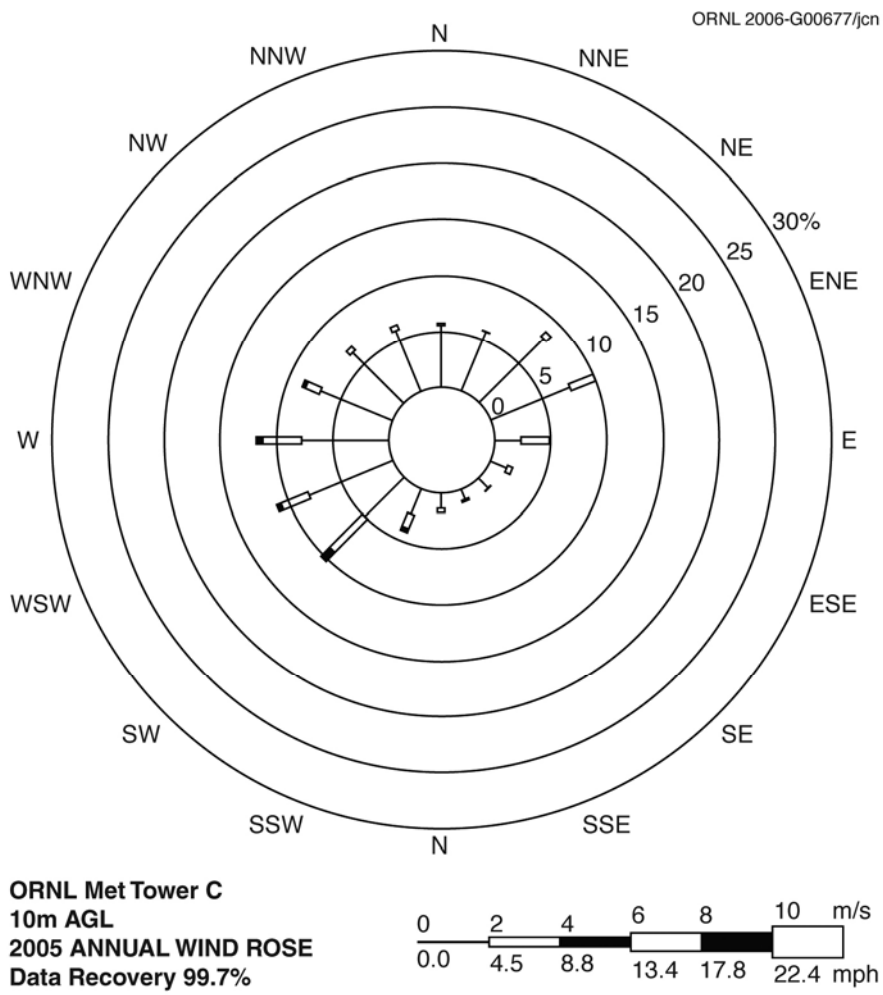


Fig. B.1. Wind rose for ORNL Meteorological Tower C for data taken at 10 m above ground level, 2005.

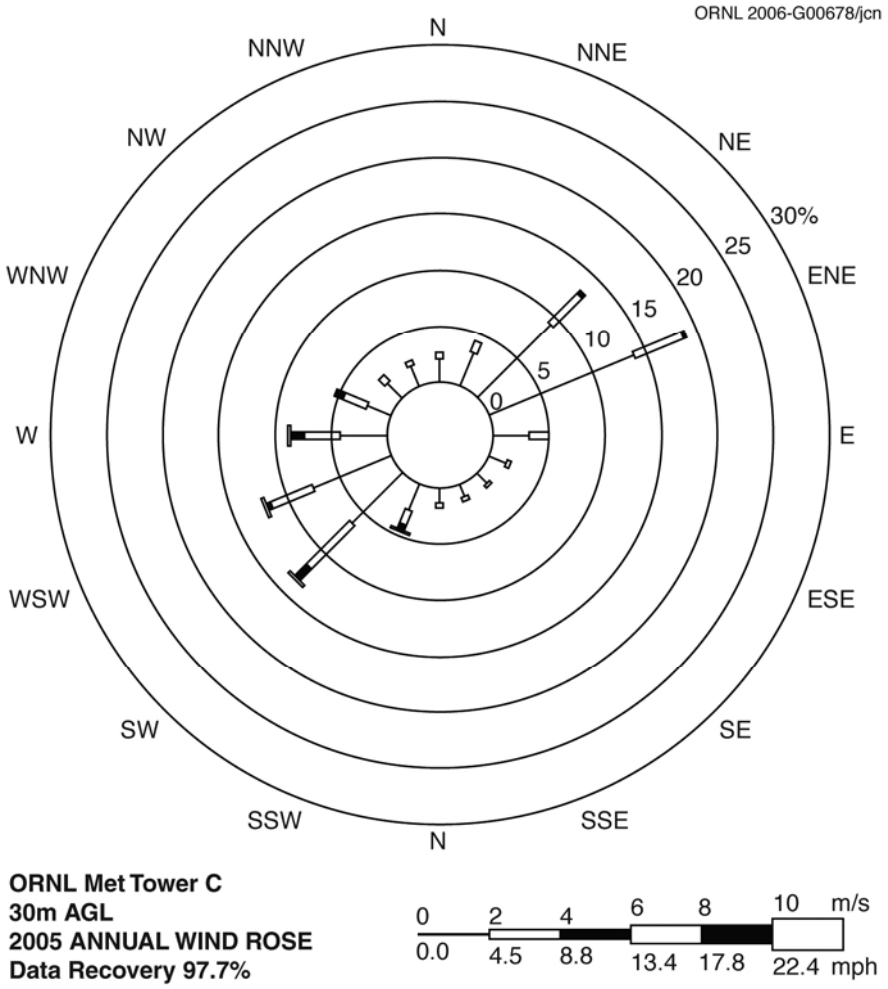


Fig. B.2. Wind rose for ORNL Meteorological Tower C for data taken at 30 m above ground level, 2005.

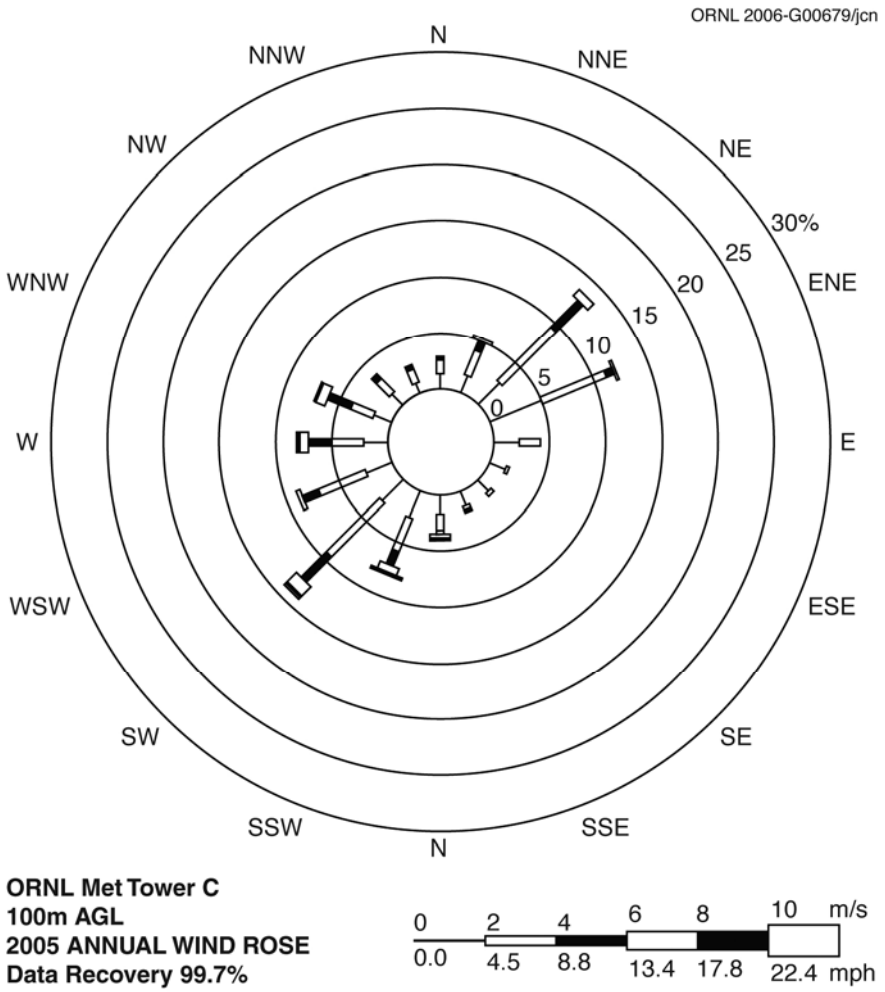


Fig. B.3. Wind rose for ORNL Meteorological Tower C for data taken at 100 m above ground level, 2005.

Stability

Stability describes the tendency of the atmosphere to mix 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). The "D" stability class represents a neutral state. (see Table B.1). 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 significantly reduce these effects. (see Table B.2).

The suppression of vertical motions during stable conditions increases the frequency with which air motion is impacted by the local terrain. 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 true 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 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 is released due to the condensation of moisture. Surface air underlying the clouds may remain relatively cool (as it is 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 a 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 large-scale "weather"-related pressure gradient). Ridge-and-valley terrain may have a significant ability to block such winds and their associated mechanical energy (Carlson and Stull 1986). Consequently, enhanced radiational cooling at the surface results since there is less wind energy available to remove chilled air.

Stable boundary layers also exhibit intermittent turbulence that has been associated with a number of the above factors. The process results from a "give-and-take" between the effects of friction and radiational cooling. As a stable surface layer intensifies via a radiation 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 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.

Temperature and Precipitation

Temperature and precipitation normals (1975–2005) and extremes (1948–2005), and their durations are summarized for the city of Oak Ridge in Table B.3. Hourly freeze data (1985–2005) are given in Table B.4.

Table B.1. 2005 Stability distribution by hour of the day measured at ORNL Tower C (local time)

Hour	Stability class[a]						
	A	B	C	D	E	F	G
1	0	0	0	28	45	187	105
2	0	0	0	24	54	192	95
3	0	0	0	21	55	202	87
4	0	0	0	21	56	207	81
5	0	0	0	19	55	214	77
6	0	0	0	23	47	218	77
7	0	0	0	24	49	229	63
8	0	0	0	365	0	0	0
9	0	108	9	248	0	0	0
10	0	191	55	119	0	0	0
11	19	168	103	75	0	0	0
12	75	134	91	65	0	0	0
13	96	134	82	53	0	0	0
14	91	137	85	52	0	0	0
15	71	137	101	56	0	0	0
16	47	134	99	85	0	0	0
17	0	0	0	175	182	8	0
18	0	0	0	121	209	35	0
19	0	0	0	78	184	99	4
20	0	0	0	39	121	191	14
21	0	0	0	36	73	210	46
22	0	0	0	32	55	187	91
23	0	0	0	29	57	173	106
24	0	0	0	23	53	186	103

[a]Stability classes range from “A” (very unstable) to “G” (very stable). The “D” stability class represents a neutral state.

Table B.2. Hourly mixing height statistics for the Oak Ridge Reservation during 2005 (eastern standard time)

Hour	Average height (m)				
	Annual	Dec–Feb	Mar–May	Jun–Aug	Sep–Nov
0100	329	395	384	253	286
0200	324	374	369	262	290
0300	319	367	350	265	297
0400	323	355	363	284	289
0500	329	378	359	279	303
0600	336	390	366	289	299
0700	319	357	360	287	271
0800	344	365	416	295	299
0900	412	396	532	376	343
1000	595	482	786	675	435
1100	876	560	1113	1109	711
1200	1093	642	1338	1388	994
1300	1219	752	1533	1495	1085
1400	1366	820	1575	1816	1243
1500	1402	902	1667	1729	1297
1600	1420	933	1723	1696	1314
1700	1397	898	1789	1607	1283
1800	1155	669	1668	1419	849
1900	688	486	1128	830	299
2000	362	443	412	301	292
2100	332	418	383	238	290
2200	337	437	386	251	275
2300	337	398	365	275	262
2400	318	412	332	236	295
All	663.3	526.2	820.7	735.3	566.7

Table B.3. Climate normals (1776–2005) and extremes (1948–2005) for Oak Ridge, Tennessee (Town Site) with 2005 comparisons

Monthly variables	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Temperature, °C (°F)													
30-year average max	7.5 (45.5)	11.0 (51.8)	16.3 (61.4)	21.7 (71.0)	25.7 (78.2)	29.5 (85.1)	31.3 (88.4)	30.9 (87.6)	27.5 (81.5)	22.7 (72.9)	15.4 (59.7)	9.3 (48.7)	20.7 (69.3)
2005 average max	10.6 (51.1)	11.9 (53.4)	15.4 (59.7)	20.9 (69.7)	24.7 (76.4)	29.4 (84.9)	30.3 (86.6)	31.7 (89.1)	30.5 (86.9)	22.4 (72.3)	16.8 (62.2)	7.7 (45.9)	21.0 (69.9)
58-year record max	24 (76)	26 (79)	30 (86)	33 (92)	34 (93)	38 (101)	41 (105)	39 (103)	39 (102)	32 (90)	28 (83)	26 (78)	41 (105)
30-year average min	-2.9 (26.7)	-1.1 (30.1)	2.9 (37.2)	6.9 (44.5)	12.1 (53.8)	16.8 (62.3)	19.4 (66.9)	18.9 (66.0)	14.9 (58.9)	8.1 (46.5)	3.1 (37.6)	-1.4 (29.4)	8.1 (46.7)
2005 average min	0.8 (33.5)	1.7 (35.1)	2.6 (36.7)	8.2 (46.8)	10.9 (51.6)	18.6 (65.4)	21.2 (70.1)	20.9 (69.6)	16.1 (61.0)	9.7 (49.5)	3.6 (38.5)	-1.6 (29.1)	9.4 (48.9)
58-year record min	-27 (-17)	-25 (-13)	-17 (1)	-7 (20)	-1 (30)	4 (39)	9 (49)	10 (50)	1 (33)	-6 (21)	-18 (0)	-22 (-7)	-27 (-17)
30-year average	1.4 (34.6)	4.0 (39.2)	9.0 (48.2)	14.8 (58.6)	18.5 (65.3)	22.7 (72.8)	24.6 (76.2)	24.8 (76.6)	21.2 (70.2)	14.8 (58.7)	8.8 (47.9)	3.9 (39.0)	14.0 (57.3)
2005 average	5.7 (42.3)	6.8 (44.3)	9.0 (48.2)	14.8 (58.7)	17.8 (64.0)	24.0 (75.2)	25.8 (78.4)	26.3 (79.4)	23.3 (74.0)	16.1 (60.9)	10.2 (50.4)	3.1 (37.5)	15.2 (59.4)
2005 departure from average	4.3 (7.7)	2.8 (5.1)	0	0.1 (0.1)	-0.7 (-1.3)	1.3 (2.4)	1.2 (2.2)	1.6 (2.8)	2.1 (3.8)	1.2 (2.2)	1.4 (2.5)	-0.8 (-1.5)	1.2 (2.2)
30-year average heating degree days, °C (°F)[a]													
	497 (895)	378 (681)	279 (502)	133 (239)	43 (77)	3 (5)	0	0	16 (28)	126 (226)	278 (500)	442 (796)	2194 (3949)
30-year average cooling degree days, °C (°F)[a]													
	0	0	1 (2)	12 (22)	58 (105)	147 (264)	218 (393)	200 (360)	103 (185)	14 (26)	1 (2)	0	755 (1359)
Precipitation, mm (in.)													
30-year average	122.2 (4.81)	121.7 (4.79)	129.8 (5.11)	111.5 (4.39)	122.5 (4.82)	118.1 (4.65)	138.0 (5.43)	86.1 (3.39)	99.6 (3.92)	71.9 (2.83)	125.3 (4.93)	127.5 (5.02)	1374.3 (54.09)
2005	125.5(4.94)	102.9 (4.05)	75.2 (2.96)	159.6 (6.28)	81.1 (3.19)	101.9 (4.01)	193.1 (7.60)	35.6 (1.40)	47.3 (1.86)	46.0 (1.81)	104.4 (4.11)	73.7 (2.90)	1146.2 (45.11)
2005 departure from average	3.3 (0.13)	-18.8 (-0.74)	-54.6 (-2.15)	48.0 (1.89)	-41.4 (-1.63)	-16.3 (-0.64)	55.1 (2.17)	-50.6 (-1.99)	-52.3 (-2.06)	-25.9 (-1.02)	-20.8 (-0.82)	-53.9 (-2.12)	-228.2 (-8.98)
58-year record 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)	176.6 (6.95)	176.6 (6.95)	310.5 (12.22)	321.2 (12.64)	489.6 (19.27)
58-year record max 24-h	108.0 (4.25)	131.6 (5.18)	120.4 (4.74)	158.5 (6.24)	112.0 (4.41)	94.0 (3.70)	124.8 (4.91)	190.1 (7.48)	129.8 (5.11)	67.6 (2.66)	130.1 (5.12)	130.1 (5.12)	190.1 (7.48)
58-year record min monthly	23.6 (0.93)	21.3 (0.84)	54.1 (2.13)	22.4 (0.88)	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)	13.5 (0.53)
Snowfall, mm (in.)													
30-year average	99.1 (3.9)	101.6 (4.0)	12.7 (0.5)	5.1 (0.2)	0	0	0	0	0	0	2.5 (0.1)	53.4 (2.1)	274.4 (10.8)
2005	25.4 (1.0)	Trace	Trace	Trace	0	0	0	0	0	0	0	0	25.4 (1.0)
58-year record monthly	243.9 (9.6)	437.0 (17.2)	533.6 (21.0)	149.9 (5.9)	Trace	0	0	0	0	Trace	165.2 (6.5)	533.6 (21.0)	533.6 (21.0)
58-year record 24-h	210.9 (8.3)	287.1 (11.3)	304.9 (12.0)	137.2 (5.4)	Trace	0	0	0	0	Trace	165.2 (6.5)	304.9 (12.0)	304.9 (12.0)

Table B.3 (continued)

Monthly variables	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Days, average, maximum, and minimum temperature													
30-year average max ≥ 32°C	0	0	0	0.1	0.9	5.1	14.5	11.7	3.8	0	0	0	36.1
2005 average max ≥ 32°c	0	0	0	0	0	4	10	18	6	0	0	0	38
30-year average min ≤ 0°C	22.7	17.2	12.1	2.8	0.1	0	0	0	0	2.2	11.4	20.3	88.8
2005 min ≤ 0°C	14	11	12	0	0	0	0	0	0	1	9	20	67
30-year average max ≤ 0°C	3.4	1.3	0.2	0	0	0	0	0	0	0	0.1	1.8	6.8
2005 max ≤ 0°C	3	0	0	0	0	0	0	0	0	0	0	0	3
Days, average, maximum, and minimum precipitation													
30-year average ≥ 0.01 in.	11.6	10.6	12.0	10.2	11.6	11.6	12.3	9.7	9.3	8.1	10	11.1	128.1
2005 ≥ 0.01 in.	12	13	11	13	6	12	18	9	4	5	10	11	124
30-year average ≥ 1.00 in.	1.3	1.2	1.5	0.8	1.5	1.4	1.5	0.8	1.3	0.8	1.4	1.4	14.9
2005 ≥ 1.00 in.	2	1	0	2	1	1	2	2	1	1	2	0	15

[a]Unit degrees, not absolute degrees.

Table B.4. Hourly freeze data for Oak Ridge, Tennessee 1985–2005

Number of hours at or below a given temperature (°C)[a]

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
Avg.	249	77	17	4	149	37	8	1	72	8	1	13	0	0	0	8	0	73	4	0	216	49	8	2	781	176	34	6

[a]Source: 1985–2000 National Oceanic and Atmospheric Administration Atmospheric Turbulence and Diffusion Division KOQT Station, Automated Surface Observing System.

Appendix C. Glossary

Appendix C. Glossary

absorption, atomic — The process by which the number and energy of particles or photons entering a body of matter is reduced by interaction with the matter.

accuracy — The closeness of the result of a measurement to the true value of the quantity.

ACM — Asbestos-containing materials.

aliquot — The quantity of sample being used for analysis.

alkalinity — A measure of the buffering capacity of water, and because pH has a direct effect on organisms as well as an indirect effect on the toxicity of certain other pollutants in the water, the buffering capacity is important to water quality.

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.

ash — Inorganic residue remaining after ignition of combustible substances.

assimilate — To take up or absorb into the body.

atom — The smallest particle of an element capable of entering into a chemical reaction.

atomic absorption spectrometry (AA) — Chemical analysis performed by vaporizing a sample and measuring the absorbance of light by the vapor.

Atomic Energy Commission (AEC) — A federal agency created in 1946 to manage the development, use, and control of nuclear energy for military and civilian applications. It was abolished by the Energy Reorganization Act of 1974 and was succeeded by the Energy Research and Development Administration (now part of the Department of Energy and the Nuclear Regulatory Commission).

base/neutral and acid extractables (BNA) — A group of organic compounds analyzed as part of Appendix IX of 40 CFR 264 and the Environmental Protection Agency (EPA) list of priority pollutants.

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. 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.

carcinogen — A cancer-causing substance.

cation — A positively charged ion.

CERCLA-reportable release — A release to the environment that exceeds reportable quantities as defined by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

chain-of-custody — A form that documents sample collection, transport, analysis, and disposal.

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.

chlorocarbons — Compounds of carbon and chlorine, or carbon, hydrogen, and chlorine, such as carbon tetrachloride, chloroform, and tetrachloroethene. They are among the most significant and widespread environmental contaminants. Classified as hazardous wastes, chlorocarbons may have a tendency to cause detrimental effects, such as birth defects.

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.

DAPC — Division of Air Pollution Control (state of Tennessee).

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 one year by one exposure mode (i.e., ingestion of water, submersion in air, or inhalation), would result in either an effective dose equivalent of 0.1 rem (1 mSv) or a dose equivalent of 5 rem (50 mSv) to any tissue, including skin and lens of the eye. The guides for radionuclides in air and water are given in DOE Order 5400.5.

desorption — The process of removing a sorbed substance by the reverse of adsorption or absorption.

dilution factor — The mathematical factor by which a sample is diluted to bring the concentration of an analyte in a sample within the analytical range of a detector (e.g., 1 mL sample + 9 mL solvent = 1:10 dilution, or a dilution factor of 10).

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 desirable indicator of satisfactory water quality in terms of low residuals of biologically available organic materials. Dissolved oxygen prevents the chemical reduction and subsequent leaching of iron and manganese from sediments.

dose — The energy imparted to matter by ionizing radiation. The unit of absorbed dose is the rad, equal to 0.01 joules per kilogram in any medium.

> **absorbed dose** — The quantity of radiation energy absorbed by an organ, divided by the organ's mass. Absorbed dose is expressed in units of rad (or gray) (1 rad = 0.01 Gy).
>
> **dose equivalent** — The product of the absorbed dose (rad) in tissue and a quality factor. Dose equivalent is expressed in units of rem (or sievert) (1 rem = 0.01 sievert).

committed dose equivalent — The calculated total dose equivalent to a tissue or organ over a 50-year period after known intake of a radionuclide into the body. Contributions from external dose are not included. Committed dose equivalent is expressed in units of rem (or sievert).

committed effective dose equivalent — The sum of the committed dose equivalents to various tissues in the body, each multiplied by the appropriate weighting factor. Committed effective dose equivalent is expressed in units of rem (or sievert).

effective dose equivalent — The sum of the dose equivalents received by all organs or tissues of the body after each one has been multiplied by an appropriate weighting factor. The effective dose equivalent includes the committed effective dose equivalent from internal deposition of radionuclides and the effective dose equivalent attributable to sources external to the body.

collective dose equivalent/collective effective dose equivalent — The sums of the dose equivalents or effective dose equivalents of all individuals in an exposed population within a 50-mile (80-km) radius, and expressed in units of person-rem (or person-sievert). When the collective dose equivalent of interest is for a specific organ, the units would be organ-rem (or organ-sievert). The 50-mile distance is measured from a point located centrally with respect to major facilities or DOE program activities.

dosimeter — A portable detection device for measuring the total accumulated exposure to ionizing radiation.

dosimetry — The theory and application of principles and techniques involved in the measurement and recording of radiation doses. Its practical aspect is concerned with using various types of radiation instruments to make measurements.

downgradient — In the direction of decreasing hydrostatic head.

downgradient well — A well that is installed hydraulically downgradient of a site and may be capable of detecting migration of contaminants from a site.

DRH — Division of Radiological Health (state of Tennessee).

drinking water standard (DWS) — Federal primary drinking water standards, both proposed and final, as set forth by the EPA.

duplicate result — A result derived by taking a portion of a primary sample and performing the identical analysis on that portion as is performed on the primary sample.

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.

Environmental Restoration — A DOE 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.

fecal coliform — The coliform group comprises all of the aerobic, non-spore-forming, rod-shaped bacteria. Testing determines the presence or absence of coliform organisms.

formation — A mappable unit of consolidated or unconsolidated geologic material of a characteristic lithology or assemblage of lithologies.

friable asbestos — Asbestos that is brittle or readily crumbled.

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.

gamma spectrometry — A system consisting of a detector, associated electronics, and a multichannel analyzer that is used to analyze samples for gamma-emitting radionuclides.

genotoxicology — The study of the effects of chemicals or radioactive contaminants on the genetics of individual animals or plants.

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).

groundwater, unconfined — Groundwater exposed to the unsaturated zone.

half-life, biological — The time required for a biological system, such as that of a human, to eliminate by natural processes half the amount of a substance (such as a radioactive material) that has entered it.

half-life, radiological — The time required for half of a given number of atoms of a specific radionuclide to decay. Each nuclide has a unique half-life; half-lives can range in duration from less than a second to many millions of years.

halogenated compound — An organic compound bonded with one of the five halogen elements (astatine, bromine, chlorine, fluorine, or iodine).

halomethane — Any compound that includes a methane group (CH_3) bonded to a halogen element (astatine, bromine, chlorine, fluorine, or iodine).

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.

heavy water — Water in which the molecules contain oxygen and deuterium, an isotope of hydrogen that is heavier than ordinary hydrogen.

herbaceous — Having little or no woody tissue.

hydrogeology — Hydrologic aspects of site geology.

hydrology — The science dealing with the properties, distribution, and circulation of natural water systems.

in situ — In its original place; field measurements taken without removing the sample from its origin; remediation performed while groundwater remains below the surface.

internal dose factor — A factor used to convert intakes of radionuclides to dose equivalents.

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.

ion exchange — Process in which a solution containing soluble ions is passed over a solid ion exchange column that removes the soluble ions by exchanging them with labile ions from the surface of the column. The process is reversible so that the trapped ions are removed (eluted) from the column and the column is regenerated.

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.

lower limit of detection (LLD) — The smallest concentration/amount of analyte that can be reliably detected in a sample at a 95% confidence level.

maximally exposed individual — A hypothetical individual who remains in an uncontrolled area and would, when all potential routes of exposure from a facility's operations are considered, receive the greatest possible dose equivalent.

mercury — A silver-white, liquid metal solidifying at 38.9ºC to form a tin-white, ductile, malleable mass. It is widely distributed in the environment and biologically is a nonessential or nonbeneficial element. Human poisoning from this highly toxic element has been clinically recognized.

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 — 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 in order 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.

parts per billion (ppb) — A unit measure of concentration equivalent to the weight/volume ratio expressed as micrograms per liter or nanograms per milliliter.

parts per million (ppm) — A unit measure of concentration equivalent to the weight/volume ratio expressed as milligrams per liter.

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 6, basic solutions have a pH > 7, and neutral solutions have a pH = 7.

piezometer — An instrument used to measure the potentiometric surface of the groundwater. Also, a well designed for this purpose.

precision — The closeness of approach of a value of similar or replicate results to a common value in a series of measurements.

priority pollutants — A group of approximately 130 chemicals (about 110 are organics) that appear on an EPA list because they are toxic and relatively common in industrial discharges.

process sewer — Pipe or drain, generally located underground, used to carry off process water and/or waste matter.

process water — Water used within a system process.

purge — To remove water prior to sampling, generally by pumping or bailing.

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.

quality factor — The factor by which the absorbed dose (rad) is multiplied to obtain a quantity that expresses, on a common scale for all ionizing radiation, the biological damage to exposed persons. It is used because some types of radiation, such as alpha particles, are more biologically damaging than others.

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 used to calibrate an apparatus, to assess a measurement method, or to assign values to materials.

regression analysis — A collection of statistical techniques that serve as a basis for drawing inferences about relationships among quantities in a scientific system.

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. See Environmental Restoration.

RFI Program — RCRA Facility Investigation Program; EPA-regulated investigation of a solid waste management unit with regard to its potential impact on the environment.

RFI/RI Program — RCRA Facility Investigation/Remedial Investigation Program; on the ORR, the expansion of the RFI Program to include CERCLA and hazardous substance regulations.

roentgen — A unit of exposure from X or gamma rays. One roentgen equals 2.58×10^{-4} coulombs per kilogram of air.

screened interval — In well construction, the section of a formation that contains the screen, or perforated pipe, that allows water to enter the well.

seepage basin — An excavation that receives wastewater. Insoluble materials settle out on the floor of the basin, and soluble materials seep with the water through the soil column, where they are removed partially by ion exchange with the soil. Construction may include dikes to prevent overflow or surface runoff.

self-absorption — Absorption of radiation by the sample itself, preventing detection by the counting instrument.

sensitivity — The capability of a methodology or an instrument to discriminate between samples with differing concentrations or containing varying amounts of analyte.

settleable solids — Material settling out of suspension within a defined period.

settling basin — A temporary holding basin (excavation) that receives wastewater, which is subsequently discharged.

sievert (Sv) — The SI (International System of Units) unit of dose equivalent, 1 Sv = 100 rem.

slurry — A suspension of solid particles (sludge) in water.

specific conductance — The ability of water to conduct electricity; this ability varies in proportion to the amount of ionized minerals in the water.

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.

split sample — A sample that has been portioned into two or more containers from a single sample container or sample-mixing container.

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 deviation — An indication of the dispersion of a set of results around their average.

standard reference material (SRM) — A reference material distributed and certified by the National Institute of Standards and Technology.

statistical significance testing — A procedure for decision making and data evaluation based on mathematical probability that provides a consistent, scientific methodology for collecting, analyzing, and presenting data. Statistical significance testing reflects the mathematical likelihood of certain outcomes but says nothing about its environmental significance.

storm water runoff — Surface streams that appear after precipitation.

strata — Beds, layers, or zones of rocks.

substrate — The substance, base, surface, or medium in which an organism lives and grows.

surface water — All water on the surface of the earth, as distinguished from groundwater.

temperature — The thermal state of a body considered with its ability to communicate heat to other bodies.

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 quantity of radioactive decay particles that are emitted from a sample.

total dissolved solids — Dissolved solids and total dissolved solids are terms generally associated with freshwater systems and consist of inorganic salts, small amounts of organic matter, and dissolved materials.

total organic halogens — A measure of the total concentration of organic compounds that have one or more halogen atoms.

total solids — The sum of total dissolved solids and suspended solids.

total suspended particulates — The concentration of particulates in suspension in the air irrespective of the nature, source, or size of the particulates.

transect — A line across an area being studied. The line is composed of points where specific measurements or samples are taken.

transmissive zone — A zone of sediments sufficiently porous and permeable to allow the flow of groundwater through the zone.

transuranic waste — Solid radioactive waste containing primarily alpha-emitting elements heavier than uranium.

transuranium elements — Elements with higher atomic weights than uranium; all 13 known transuranic elements are radioactive and are produced artificially.

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.

tritium (^{3}H) — The hydrogen isotope with one proton and two neutrons in the nucleus. It emits a low-energy beta particle (0.0186 MeV maximum) and has a half-life of 12.5 years.

t-test — Statistical method used to determine whether the means of groups of observations are equal.

turbidity — A measure of the concentration of sediment or suspended particles in solution.

unconsolidated zone — Soil zone located above the water table.

uncontrolled area — Any area to which access is not controlled for the purpose of protecting individuals from exposure to radiation and radioactive materials.

upgradient — In the direction of increasing hydrostatic head.

volatile organic compounds — Used in many industrial processes; the levels of these carcinogenic compounds must be kept to a minimum. They are measured by volatile organic content analyses. 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, inundated or saturated by surface water or groundwater sufficiently to support hydrophytic vegetation typically adapted for life in saturated soils.

wind rose — A diagram in which statistical information concerning direction and speed of the wind at a location is summarized.

Appendix D. Reference Standards and Data for Water

Table D.1. Reference standards for radionuclides in water

Parameter[a]	National primary drinking water standard[b]	4% of DCG[c]	DCG[d]
^{241}Am		1.2	30
^{214}Bi		24,000	600,000
^{109}Cd		400	10,000
^{143}Ce		1,200	30,000
^{60}Co		200	5,000
^{51}Cr		40,000	1,000,000
^{137}Cs		120	3,000
^{155}Eu		4,000	100,000
Gross alpha[e]	15		
Gross beta (mrem/year)	4[f]		
^{3}H	20,000[g]	80,000	2,000,000
^{131}I		120	3,000
^{40}K		280	7,000
^{237}Np		1.2	30
^{234m}Pa		2,800	70,000
^{238}Pu		1.6	40
$^{239/240}$Pu		1.2	30
^{226}Ra	5[h]	4	100
^{228}Ra	5[h]	4	100
^{106}Ru		240	6,000
^{90}Sr	8[g]	40	1,000
^{99}Tc		4,000	100,000
^{228}Th		16	400
^{230}Th		12	300
^{232}Th		2	50
^{234}Th		400	10,000
Thorium, natural		2	50
^{234}U		20	500
^{235}U		24	600
^{236}U		20	500
^{238}U		24	600
Uranium, natural		24	600
Uranium, total[i] (μg/L[j])	30	20	500

[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.

[c]Four percent of the derived concentration guide represents the DOE criterion of 4 mrem effective dose equivalent from ingestion of drinking water.

[d]DOE Order 5400.5 Chapter III, "Derived Concentration Guides for Air and Water."

[e]Excludes radon and uranium.

[f]Per the discussion in 40 CFR 141.66(b), compliance with the 4-mrem/year standard can be assumed if the average annual gross beta particle activity is less than 50 pCi/L and if the average annual concentrations of ^{3}H and ^{90}Sr are less than 20,000 pCi/L and 8 pCi/L, respectively, provided that, if both radionuclides are present, the sum of their annual dose equivalents to bone marrow is less than 4 mrem/year. In the text of this document, 50 pCi/L is referred to as the "screening level."

[g]These values are not maximum contaminant levels (MCLs), but are concentrations that result in the effective dose equivalent of the MCL for gross beta emissions, which is 4 mrem/year.

[h]Applies to combined ^{226}Ra and ^{228}Ra.

[i]Minimum of uranium isotopes.

[j]Effective December 8, 2003.

Table D.2. Reference standards for chemicals and metals in water

Parameter	National drinking water standards		Tennessee water quality criteria[c]				
	Primary[a]	Secondary[b]	Domestic water supply	Fish and aquatic life		Recreation	
				CMC	CCC	Organisms	Water and organisms[d]
Anions (mg/L)							
Chloride		250					
Fluoride	4	2					
Nitrate	10						
Nitrite	1						
Sulfate, as SO_4		250					
Base/neutral/acid extractable organics (µg/L)							
1,2-Dichlorobenzene (*ortho*)	600		600			17,000	2,700
1,2-Diphenylhydrazine						2.0	0.36
1,2,4-Trichlorobenzene	70		70			940	260
1,3-Dichlorobenzene (*meta*)						960	320
1,4-Dichlorobenzene (*para*)	75		75			2,600	400
2,4-Dichlorophenol						290	77
2,4-Dimethylphenol						850	380
2,4-Dinitrophenol						5,300	69
2,4-Dinitrotoluene						34	1.1
2,4,6-Trichlorophenol						24	14
2-Chlorophenol						150	81
2-Chloronaphthalene						1,600	1,000
2-Methyl-4,6-Dinitrophenol						280	13
3,3-Dichlorobenzidine						0.28	0.21
3,4-Benzo(b)fluoranthene						0.18	0.038
Benzo(k)fluoranthene						0.18	0.038
Acenaphthene						990	670
Anthracene						40,000	8,300
Benzidine						0.0020	0.00086
Benzo(a)anthracene						0.18	0.038
Benzo(a)pyrene	0.2		0.2			0.18	0.038
bis-(2-chloroethyl)ether						5.3	0.30
bis-(2-Chloro-isopropyl)ether						65,000	1,400
bis-(2-ethylhexyl)phthalate	6		6			22	12
Butylbenzyl phthalate						1,900	1,500
Chrysene						0.18	0.038
Di-n-butyl phthalate						4,500	2,000
Dibenz(a,h)anthracene						0.18	0.038
Diethyl phthalate						44,000	17,000
Dimethyl phthalate						1,100,000	270,000
Fluoranthene						140	130
Fluorene						5,300	1,100
Hexachlorobenzene	1		1			0.0029	0.0028
Hexachlorobutadiene						180	4.4
Hexachlorocyclopentadiene	50		50			17,000	240

Table D.2 (continued)

Parameter	National drinking water standards		Tennessee water quality criteria[c]				
	Primarya	Secondary[b]	Domestic water supply	Fish and aquatic life		Recreation	
				CMC	CCC	Organisms	Water and organisms[d]
Hexachloroethane						33	14
Ideno(1,2,3-cd)pyrene						0.18	0.038
Isophorone						9,600	350
N-Nitrosodimethylamine				19		30	0.0069
N-Nitrosodi-n-propylamine						5.1	0.05
N-Nitrosodiphenylamine						60	33
Nitrobenzene						690	17
Pentachlorophenol (pH 7.8)	1		1			30	2.7
Phenol						1,700,000	21,000
Pyrene						4,000	830
Field measurements							
Chlorine, (TRC), µg/L				19			
Dissolved oxygen, mg/L				5		(min)	
Temperature, µC			30.5	30.5		30.5	30.5
Turbidity, JTU[e]	1						
pH, standard units		(6.5, 8.5)	(6.0, 9.0)	(6.0, 9.0)		(5.5, 9.0)	(5.5, 9.0)
Metals (mg/L)							
Aluminum		0.05–0.2					
Antimony	0.006		0.006			0.64	0.0056
Arsenic	0.01[f]		0.010	0.340 (III)	0.15	0.010	0.010
Barium	2		2				
Beryllium	0.004		0.004				
Cadmium	0.005		0.005	0.002[g]	0.00025		
Chromium, total	0.1		0.1				
Chromium (hexavalent)				0.016	0.10		
Copper	1.3[h]	1		0.013[g]	0.011		
Iron		0.3					
Lead	0.015[h]		0.005	0.065[g]	0.009		
Manganese		0.05					
Mercury	0.002		0.002	0.0014	0.0025	0.000051	0.00005
Nickel			0.1	0.470[g]	0.00077	4.6	0.61
Selenium	0.05		0.050	0.02	0.052		
Silver		0.1		0.0032[g]	0.005		
Thallium	0.002		0.002			0.0063	0.0017
Zinc		5		0.120[g]	0.120		
Others							
Asbestos (fibers/L)	7,000,000						
Chlorine (TRC)				0.019			
Color (color units)		15					
Cyanide (mg/L)	0.2		0.2	0.022		220	0.7
E. coli (no./100 mL, geometric mean)			630	630		126	126
E. coli (no./100 mL, individual sample)				2,880		941	941

Table D.2 (continued)

Parameter	National drinking water standards		Tennessee water quality criteria[c]				
	Primary[a]	Secondary[b]	Domestic water supply	Fish and aquatic life		Recreation	
				CMC	CCC	Organisms	Water and organisms[d]
Odor (threshold odor number)		3					
Total dissolved solids (mg/L)		500	500				
Pesticides/herbicides/PCBs (µg/L)							
2,3,7,8-TCDD (Dioxin)	0.00003		0.00003			0.000001	0.000001
2,4-D	70		70				
2,4,5-TP (Silvex)	50		50				
4,4'-DDT				1.1		0.0022	0.0022
4,4'-DDE						0.0022	0.0022
4,4'-DDD						0.0031	0.0031
a-BHC						0.049	0.026
b-BHC						0.17	0.091
Alachlor	2		2				
Aldrin				3.0		0.00050	0.00049
Atrazine	3		3				
Carbofuran	40		40				
Chlordane	2		2	2.4		0.0081	0.0080
Dalapon	200		200				
1,2-Dibromo-3-chloropropane	0.2		0.2				
Di(ethylhexyl)adipate	400		400				
Dieldrin				0.24		0.00054	0.00052
Di(ethylhexyl)phthalate[i]							
Dinoseb	7		7				
Diquat	20		20				
a-Endosulfan				0.22		89	62
b-Endosulfan				0.22		89	62
Endosulfan sulfate						89	62
Endothall	100		100				
Endrin	2		2	0.086		0.81	0.76
Endrin aldehyde						0.30	0.29
Ethylene dibromide	0.05		0.05				
Glyphosate	700		700				
Heptachlor	0.4		0.4	0.52		0.00079	0.00079
Heptachlor epoxide	0.2		0.2	0.52		0.00039	0.00039
g-BHC (Lindane)	0.2		0.2	2.0		0.63	0.19
Methoxychlor	40		40				
Oxamyl (Vydate)	200		200				
PCB Aroclors (EPA 119-125)						0.00064	0.00064

Table D.2 (continued)

Parameter	National drinking water standards		Tennessee water quality criteria[c]				
	Primary[a]	Secondary[b]	Domestic water supply	Fish and aquatic life		Recreation	
				CMC	CCC	Organisms	Water and organisms[d]
PCB, total	0.5		0.5			0.00064	0.00064
Picloram	500		500				
Simazine	4		4				
Toxaphene	3		3	0.73		0.0028	0.0028
1,1,1-Trichloroethane	200		200				
1,1-Dichloroethene	7		7			32	0.57
1,1,2-Trichloroethane	5		5			160	5.9
Volatile organics (µg/L)							
1,1,2,2-Tetrachloroethane						40	1.7
1,2-Dichloroethane	5		5			370	3.8
1,2-Dichloroethene[j]							
cis-1,2-Dichloroethene	70		70				
trans-1,2-Dichloroethene	100		100			140,000	700
1,2-Dichloropropane	5		5			150	5.0
cis-1,3-Dichloropropene						1,700	10
trans-1,3-Dichloropropene						1,700	10
Acrolein						290	190
Acrylonitrile						2.5	0.51
Benzene	5		5			510	22
Bromodichloromethane	80[k]					170	5.5
Bromoform	80[k]					1,400	43
Carbon tetrachloride	5		5			16	2.3
Chlorobenzene	100		100			21,000	680
Chloroform	80[k]					4,700	57
Dibromochloromethane	80[k]					130	4.0
Ethylbenzene	700		700			29,000	3,100
Methylbromide						1,500	47
Methylene chloride (Dichloromethane)	5		5			5,900	46
Styrene	100		100				
Tetrachloroethene	5		5			33	6.9
Toluene	1,000		1,000			200,000	6,800
Trichloroethene	5		5			300	25

Table D.2 (continued)

Parameter	National drinking water standards		Tennessee water quality criteria[c]				
	Primary[a]	Secondary[b]	Domestic water supply	Fish and aquatic life		Recreation	
				CMC	CCC	Organisms	Water and organisms[d]
Trihalomethanes, total	80k						
Vinyl chloride	2		2			5,300	20
Xylene, total	10,000		10,000				

[a]40 CFR Part 141—National Primary Drinking Water Regulations, Subparts B and G, as amended.

[b]40 CFR Part 143—National Secondary Drinking Water Regulations, as amended.

[c]Rules of Tennessee Department of Environment and Conservation, Division of Water Pollution Control, Chapter 1200-4-3, General Water Quality Criteria, as amended. CMC = criterion maximum concentration; CCC= continuous concentration criteria.

[d]These criteria, for the protection of public health, pertain to the consumption of water and organisms. They apply only to waters designated for both recreation and domestic water supply.

[e]Jackson turbidity unit (JTU) and nephelometric turbidity unit (NTU) are roughly equivalent in the range of 25 to 1000 JTU.

[f]As of January 23, 2006.

[g]The standard is a function of total hardness. The values in this table correspond to a total-hardness value of 100 mg/L.

[h]"Action level" for initiation of corrosion-control studies and treatment techniques, applicable to community water systems and nontransient, noncommunity water systems.

[i]See bis(2-ethylhexyl)phthalate.

[j]See cis-1,2-Dichlorethene and trans-1,2-Dichloroethene.

[k]Limit for total trihalomethanes (bromodichloromethane + bromoform + chloroform + dibromochloromethane).

Appendix E. National Pollutant Discharge Elimination System Noncompliance Summaries for 2005

Appendix E. National Pollutant Discharge Elimination System Noncompliance Summaries for 2005

E.1. Y-12 COMPLEX

E.1.1. Toxicity Test Failure

Description and Cause

Toxicity tests at East Fork Poplar Creek in-stream National Pollutant Discharge Elimination System (NPDES) monitoring point 201 [East Fork Poplar Creek kilometer (EFK) 25.1] were conducted January 6 to 13, 2005, using *Ceriodaphnia dubia* and fathead minnows as test species. The 96-h LC_{50} (the concentration of an aqueous sample lethal to 50% of test organisms in a given time span) was greater than 100% for both species. The no-observed effect concentration (NOEC) for fathead minnows' survival and growth and the *Ceriodaphnia* survival were 100%. However, the NOEC for *Ceriodaphnia* reproduction was 80%. A confirmation test was conducted at the 201 monitoring point January 21 to 28, 2005, using *Ceriodaphnia dubia* as the test species. The 96-h LC_{50} was greater than 100%, and the NOECs fo*r Ceriodaphnia* survival and reproduction were 100%. Toxicity tests are conducted quarterly at monitoring point 201, and for years the toxicity as measured by the LC_{50} and NOEC has remained stable at 100% for both test species. During the same time period of the original test (January 6 to 13, 2005) another toxicity test was conducted as part of the Y-12 Biological Monitoring and Abatement Program downstream at EFK 24.1. That test showed no toxicity. The cause of toxicity demonstrated for *Ceriodaphnia* reproduction is not known.

E.1.2. Permit Limit Noncompliance at Outfall 55

Description and Cause

A sample for mercury obtained on July 7, 2005, at outfall 55 had a concentration of 0.00482 mg/L, which is above the permit daily maximum limit of 0.004 mg/L. Approximately 1.2 in. of rain fell on that date, which could have caused some movement of legacy contamination from the area of Building 9201-2. The outfall receives discharges including storm water from Building 9201-2. However, no single causative factor was determined for this event.

E.1.3. Permit Limit Noncompliances at Central Mercury Treatment System

Description and Cause

The Central Mercury Treatment System (outfall 551) is designed to treat groundwater and surface water containing mercury, which accumulates in sumps in former mercury use buildings at the Y-12 Complex. In one of the buildings (9201-5) a leak developed in a cooling system that contains a solution of tap water and approximately 21% methanol. The methanol-water solution leaked into the basement sump and was pumped along with other influent wastewaters into an in-ground equalization tank known as the 2100-U tank. The methanol was carried into the treatment facility and adversely affected the ability of the facility, especially the carbon columns, to treat mercury. Noncompliance to the daily maximum mercury permit limit of 0.004 mg/L occurred on October 25, November 30, December 7, and December 14, 2005. The monthly average for mercury of 0.002 mg/L was exceeded in November and December, 2005.

Corrective Action

Corrective actions to resolve the problem include shutdown of the treatment facility, cleaning and disinfecting lines and treatment equipment, replacement of carbon, and collection of sump water in storage

tanks to hold and treat. Testing of several types of carbon to find more efficiency in treatment have also been conducted. Investigations continue to remedy the problem and to return the treatment system to full-time reliable operation. Additional information about the event is provided in Sect. 2.2.17, "Environmental Occurrences."

E.2 East Tennessee Technology Park

E.2.1 Sanitary Water Line Break

Description and Cause

On January 24, 2005, routine sampling at storm water outfall 100 returned a result of total residual chlorine of 1.25 mg/L. The NPDES permit limit at that location is 0.14 mg/L. An investigation revealed that a sanitary water line break had occurred near Building K-1004-L and that some of the water was entering the storm water network.

Corrective Actions

The section of water line was immediately valved off, and repairs were effected. Subsequent monitoring of the outfall and the receiving waters revealed no detectable impacts.

E. 3. OAK RIDGE NATIONAL LABORATORY

E.3.1 Bypass

Description and Cause

Untreated sewage backed up in a collection line and overflowed onto the grass and nearby streets and was discharged to First Creek through outfalls 001 and 014.

Corrective Action

Blockage in the sewer line was cleared, and the contaminated areas were cleaned up. All ORNL staff received an internal communication between January 9–13, 2006, reminding them of appropriate discharges to the sanitary sewer and the risks of inappropriate materials.

E.3.2. Total Residual Oxidant

Description and Cause

A lawn mower hit and damaged an aboveground hose that conveys water from a supply water faucet and through a dechlorinator as a mechanism of mixing dechlorination chemical with source streams. The faucet was mistakenly turned off, stopping the leak and unknowingly stopping the dechlorination of outfall 081.

Corrective Action

The existing supply water configuration was repaired, and an administrative control tag has been added to the faucet. A daily inspection program of the faucet and hose was implemented and well as required awareness training for staff working in the area.

E.3.3. Temperature Change

Four instream temperature change limits were exceeded during the annual temperature sampling campaign, which was conducted during an extended outage of the High Flux Isotope Reactor.

Corrective Action

A longer, shallower discharge flow path had been utilized to mitigate thermal load for the outfall 281 discharge. Over time, the sand bag dam that diverted water into the flow path deteriorated such that the discharge traveled a shorter and deeper tributary, providing less time and distance for heat dissipation. All cooling system equipment was checked and was found to be operating properly. Flow was diverted to a new path, which provides more aeration and additional cooling time before the discharging into Melton Branch. Compliance with temperature requirements is being evaluated by additional monitoring.

Appendix F. Air Permits

Table F.1. Air Permits at the Y-12 Complex, 2005

Emission source reference number	Permit number	Source description
01-0020-15	554701	Metal Fabrication Shop
01-0020-17	554701	Graphite Carbon Machine Shop
01-0020-59	554701	Tool Fabrication Shop
01-0020-99	554701	General Machine Shop
01-1020-31	554701	Y-12 Steam Plant
01-1020-19	554701	Rubber Shop
01-1020-99	554701	Classified Paper Waste Incinerator
01-0020-35	554701	Brine/Methanol System
01-0020-38	554701	Brine/Methanol System
01-1020-82	554701	Dry Ash Handling System
01-0020-44	554701	Arc Melt Operation
01-0020-21	554701	East Machine Shop
01-1020-18	554701	North Machine Shop
01-0020-30	554701	Plating Shop
01-0020-21	554701	West Machine Shop
01-0020-06	554701	Beryllium Laboratory
01-1020-56	554701	Metal Forming and Heat Treating Operation
01-0020-13	554701	Foundry Operation
01-0020-37	554701	Machine Shop
01-1020-51	554701	O-Wing Metal Working Operation
01-1020-52	554701	P-Wing Operations
01-1020-53	554701	Third Mill Operation
01-1020-84	554701	R & D Facility
01-1020-12	554701	Metal Forming & Heat Treating Operation
01-0020-03	554701	Chemical Process Operation
01-0020-21	554701	Air Bearing Operation
01-0020-05	554701	Special Processing Operation
01-0020-02	554701	Metal Casting and Recovery Operation
01-1020-72	554701	Chemical Process Operation
01-1020-55	554701	Dry Chemistry Operation
01-1020-55	554701	Special Material Operation
01-1020-79	554701	Ceramic Machine Shop
01-0020-71	554701	Electrolytic Cell Process
01-1020-57	554701	Wet Chemistry Operation
01-0020-68	554701	Disassembly and Storage Operation
01-0020-27	956248P	Special Materials Purification Facility

Table F.2. Oak Ridge National Laboratory air permits, 2005

Emission source reference number	Permit number	Source description
73-0112-01	556850	Radioactive Materials Analytical Laboratory
73-0112-02	556850	Radiochemical Development Facility
73-0112-03	556850	Steam Plant
73-0112-05	556850	Manipulator Boot Shop
73-0112-07	556850	Boilers
73-0112-09	556850	Surface Coating and Cleaning Operation
73-0112-11	956542P	Spallation Neutron Source and Central Exhaust Facility (construction permit)
73-0112-24	556850	Boilers
73-0112-25	556850	Boilers
73-0112-37	547563[a]	Air Stripper (Bechtel Jacobs Company permit)
73-0112-82	556850	High Flux Isotope Reactor & Radiochemical Engineering Development Center
73-0112-93	547563[a]	Off Gas & Hot Cell Ventilation (Bechtel Jacobs Company permit)
Not applicable	0904-12[b]	National Transportation Research Center

[a]Title V Major Source Operating Permit issued October 2004 superseding previously issued operating permit 739974P for 3039 and permit 730489P for 3608.

[b]Permit issued by Knox County Department of Air Quality Management.

Table F.3. East Tennessee Technology Park air permits, 2005

ETTP source number	Emission source reference number	Permit number	Source description	Permit type
K1202ST1[a]	73-1106-20	033203P	Tank storing waste oils and solvents for incinerator	Operating
K1202ST2[a]	73-1106-41	034392P	Tank storing waste oils and solvents for incinerator	Operating
K1420AI[a]	73-0106-82	034619P	Flammable materials storage tank	Operating
K1423TSCAREPACK	73-0106-02	958435P	Rad-contaminated solids sorting/packaging	Construction
K1425WOSA	73-0106-11	029895P	Waste oil and solvent storage tanks	Operating
K1425WOSB	73-0106-11	029895P	Waste oil and solvent storage tanks	Operating
K1425WOSC	73-0106-11	029895P	Waste oil and solvent storage tanks	Operating
K1425WOSD	73-0106-11	029895P	Waste oil and solvent storage tanks	Operating
K1435TSCAINCIN[b]	73-0106-78	957808I	Toxic Substances Control Act Incinerator	Construction
K1435CTANKFARM	73-0106-75	037460P	Tank farm for hazardous liquid wastes	Operating
K1407CNFAIRSTRIPPER	73-0106-90	045253P	Air stripper for removing volatile organic compounds at Central Neutralization Facility	Operating
ETTPFUGITIVEEMISSIONS	73-1106-38	043016P	Number of sources logged into permit	Operating

[a]Sources permanently removed from service; request to rescind permits submitted with Title V permit reapplication submitted August 2004.

[b]Permit to Construct or Modify the Toxic Substances Control Act Incinerator issued in January 2005.

Table F.4. Periods of excess emissions and out-of-service conditions for Y-12 Steam Plant east and west opacity monitors in 2005

Date	Stack	Condition	Comments
February 8	East	False reading of 45 6-min periods of excess emissions	The optical head misalignment occurred due to opacity monitor weather cover supports becoming loose over time. The problem was corrected the same day it occurred.
July 13	East	Opacity monitoring system was inoperative	Opacity monitor malfunction
August 10	West	One 6-min period of excess emissions	Start-up of fans on Boiler 1 during overhaul
August 15	West	Opacity monitoring system was inoperative	Optical head alignment was adjusted.
August 29	West	One 6-min period of excess emissions	Start-up of fans on Boiler 1 during overhaul
September 12	East	Opacity monitoring system was inoperative	Mounting bracket bolts became loose, causing the optical head to drift out of alignment
September 13	East	Opacity monitoring system was inoperative	Mounting bracket bolts became loose causing the optical head to drift out of alignment. This problem was repaired on September 13
September 23	East	Opacity monitoring system was inoperative	Opacity monitor malfunction
November 4, 5	East	Opacity monitoring system was inoperative	Monitor optical head and purge blower malfunction
November 9	East	Opacity monitoring system was out of service	Monitor purge blower motor malfunction
November 14	West	Three 6-min periods of excess emissions	A bag was blown off in Compartments 2 and 3 of Baghouse 1
December 10	West	One 6-min period of excess emissions	A bag was torn in Compartment 3 of Baghouse 1
December 10	East	Opacity monitoring system was inoperative	Opacity monitor malfunction

Appendix G. Radiation

Appendix G. Radiation

This appendix presents basic facts 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), not as a comprehensive discussion of radiation and its effects on the environment and biological systems.

Radiation comes from natural and human-made sources. People are exposed to naturally occurring radiation constantly. 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, including atoms and isotopes; types, sources, and pathways of radiation; radiation measurement; and dose information.

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. G.1).

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; and
- uranium-234 has 92 protons and 142 neutrons.

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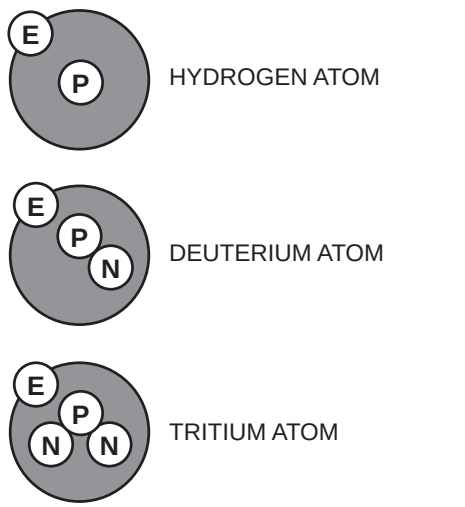

	PROTONS	NEUTRONS
HYDROGEN	1	0
DEUTERIUM	1	1
TRITIUM	1	2

Fig. G.1. The hydrogen atom and its isotopes.

Some isotopes are stable, or nonradioactive; some are radioactive. Radioactive isotopes are called "radionuclides" or "radioisotopes." In an attempt to become stable, radionuclides "throw away," or 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 that it takes 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 G.1).

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.

Table G.1. Radionuclide half-lives

Radionuclide	Symbol	Half-life	Radionuclide	Symbol	Half-life
Americium-241	^{241}Am	432.2 years	Plutonium-238	^{238}Pu	87.75 years
Americium-243	^{243}Am	7.38E+3 years	Plutonium-239	^{239}Pu	2.41E+4 years
Antimony-125	^{125}Sb	2.77 years	Plutonium-240	^{240}Pu	6.569E+3 years
Argon-41	^{41}Ar	1.827 hours	Potassium-40	^{40}K	1.2777E+9 years
Beryllium-7	^{7}Be	53.44 days	Promethium-147	^{147}Pm	2.6234 years
Californium-252	^{252}Cf	2.639 years	Protactinium-234*m*	^{234m}Pa	1.17 minutes
Carbon-14	^{14}C	5.730E+3 years	Radium-226	^{226}Ra	1.6E+3 years
Cerium-141	^{141}Ce	32.50 days	Radium-228	^{228}Ra	5.75 years
Cerium-143	^{143}Ce	1.38 days	Ruthenium-103	^{103}Ru	39.35 days
Cerium-144	^{144}Ce	284.3 days	Ruthenium-106	^{106}Ru	368.2 days
Cesium-134	^{134}Cs	2.062 years	Strontium-89	^{89}Sr	50.55 days
Cesium-137	^{137}Cs	30.17 years	Strontium-90	^{90}Sr	28.6 years
Cobalt-58	^{58}Co	70.80 days	Technetium-99	^{99}Tc	2.13E+5 years
Cobalt-60	^{60}Co	5.271 years	Thorium-228	^{228}Th	1.9132 years
Curium-242	^{242}Cm	163.2 days	Thorium-230	^{230}Th	7.54E+4 years
Curium-244	^{244}Cm	18.11 years	Thorium-232	^{232}Th	1.405E+10 years
Iodine-129	^{129}I	157E+7 years	Thorium-234	^{234}Th	2.41E+1 day
Iodine-131	^{131}I	8.04 days	Tritium	^{3}H	12.28 years
Krypton-85	^{85}Kr	10.72 years	Uranium-234	^{234}U	2.445E+5 years
Krypton-88	^{88}Kr	2.84 hours	Uranium-235	^{235}U	7.038E+8 years
Manganese-54	^{54}Mn	312.7 days	Uranium-236	^{236}U	2.3415E+7 years
Neptunium-237	^{237}Np	2.14E+6 days	Uranium-238	^{238}U	4.468E+9 years
Niobium-95	^{95}Nb	35.06 days	Xenon-133	^{133}Xe	5.245E+9 years
Osmium-185	^{185}Os	93.6 days	Xenon-135	^{135}Xe	9.11 hours
Phosphorus-32	^{32}P	14.29 days	Yttrium-90	^{90}Y	64.1 hours
Polonium-210	^{210}Po	138.378 days	Zirconium-95	^{95}Zr	64.02 days

Source: DOE 1989. *Radioactive Decay Data Tables: A Handbook of Decay Data for Application to Radioactive Dosimetry and Radiological Assessments*, DOE/TIC-11026.

Examples include alpha and beta particles. Radiation also is characterized as ionizing or nonionizing because of the way in which it interacts with matter.

Ionizing Radiation

Normally, an atom has an equal number of protons and electrons; however, atoms can lose or gain electrons in a process known as ionization. Some forms of radiation (called ionizing radiation) can ionize atoms by “knocking” electrons off atoms. Examples of ionizing radiation include alpha, 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.

Non-ionizing Radiation

Non-ionizing radiation bounces off or passes through matter without displacing electrons. Examples include visible light and radio waves. At this time, it is unclear whether non-ionizing radiation is harmful to human health. In the discussion that follows, the term radiation is used to describe ionizing radiation.

Sources of Radiation

Radiation is everywhere. Most occurs naturally; a small percentage is human-made. Naturally occurring radiation is known as background radiation.

Background Radiation

Many materials are naturally radioactive. In fact, this naturally occurring radiation is the major source of radiation in the environment. Although people have little control over the amount of background radiation to which they are exposed, this exposure must be put into perspective. Background radiation remains relatively constant over time and is present in the environment today much as it was hundreds of years ago.

Sources of background radiation include uranium in the earth, radon in the air, and potassium in food. Background radiation is categorized as cosmic, terrestrial, or internal, depending on its origin.

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, Colorado, is exposed to more cosmic radiation than a person in New Orleans, Louisiana.

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.

Internal Radiation

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 ^{210}Po; others include ^{87}Rb and ^{14}C (NCRP 1987).

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).

Consumer Products

Some consumer products are sources of radiation. The radiation in some of these products, such as smoke detectors and airport X-ray baggage inspection systems, is essential to the performance of the device. In other products, such as televisions and tobacco products, the radiation occurs incidentally to the product's function.

Medical Sources

Radiation is an important tool of diagnostic medicine and treatment and is the main source of exposure to the public from human-made radiation. Exposure is deliberate and directly beneficial to the pa-

tients exposed. In general, medical exposures from diagnostic or therapeutic X rays result from beams directed to specific areas of the body. Thus, all body organs generally are not 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.

Other Sources

Radioactive fallout, the by-product of nuclear-weapons testing in the atmosphere, is a source of radiation. 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.

Pathways of Radionuclides

People can be exposed to radionuclides in the environment through a number of routes (Fig. G.2). Potential routes for internal and/or external exposure are referred to as pathways. For example, radionuclides in the air could fall on a pasture. The grass then could be eaten by cows, and the radionuclides deposited on the grass would show up in milk. People drinking the milk would be exposed to this radiation. People could also inhale the airborne radionuclides. Similarly, radionuclides in water could be ingested by fish, and people eating the fish would also ingest the radionuclides in the fish tissue. People swimming in the water would be exposed also.

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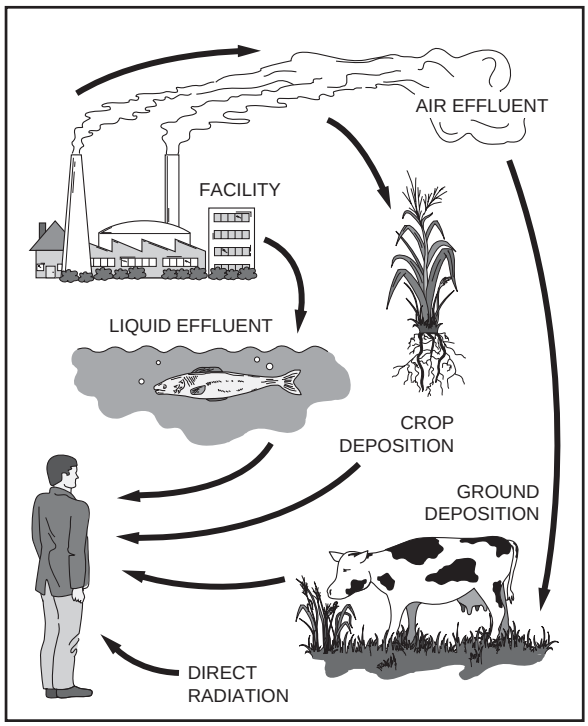

Fig. G.2. Examples of radiation pathways.

Measuring Radiation

To determine the possible effects of radiation on the health of the environment and people, the radiation must be measured. More precisely, its potential to cause damage must be ascertained.

Activity

When we measure the amount of radiation in the environment, what is actually being measured is the rate of radioactive decay, or activity. The rate of decay varies widely among the 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, one curie equals 3.7×10^{10} (37,000,000,000) atomic disintegrations per second (dps). In the international system of units, 1 dps equals 1 becquerel (Bq).

Absorbed Dose

The total amount of energy absorbed per unit mass of the exposed material as a result of exposure to radiation is expressed in a unit of measure known as a rad. In this case, it is the effect of the absorbed energy (the biological damage that it causes) that is important, not the actual amount. In the international system of units, 100 rad equals 1 gray (Gy).

Dose Equivalent

The measure of potential biological damage to specific body organs or tissues caused by exposure to and subsequent absorption of radiation is expressed in a unit of measure known as a rem. One rem of any type of radiation has the same total damaging effect. Because a rem represents a fairly large dose equivalent, dose equivalents are usually expressed as millirem (mrem), which is 1/1000 of a rem. In the international system of units, 1 sievert (Sv) equals 100 rem; 1 millisievert (mSv) equals 100 mrem. Specific types of dose equivalents are defined as follows:

- **committed dose equivalent:** the total dose equivalent to an organ during the 50-year period following intake.
- **effective dose equivalent (EDE):** the weighted sum of dose equivalents to a specified list of organs. The organs and weighting factors are selected on the basis of risk to the entire body. "EDE" is the unit used in the *Annual Site Environmental Report*.
  - **committed effective dose equivalent:** the total effective dose to specified organs in the human body during the 50-year period following intake.
  - **collective effective dose equivalent:** the sum of effective dose equivalents of all members of a given population.

Dose Determination

Determining dose is an involved process in which complex mathematical equations based on several factors, including the type of radiation, the rate of exposure, weather conditions, and typical diet, are used. Basically, radioactive decay, or activity, generates radiant energy. People absorb some of the energy to which they are exposed. 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.

Many terms are used to report dose. The terms take several factors into account, including the amount of radiation absorbed, the organ absorbing the radiation, and the effect of the radiation over a 50-year period. The term "dose," in this report means the committed EDE, which is the total effective dose equivalent that will be received during a specified time (50 years) from radionuclides taken into the body in the current year, and the EDE attributable to penetrating radiation from sources external to the body.

Dose Conversion Factor

A dose conversion factor is defined as the dose equivalent received from exposure to a unit quantity of a radionuclide by way of a specific exposure pathway. Two types of dose conversion factors exist. One type gives the committed dose equivalent (rem) resulting from intake (by inhalation and ingestion) of a unit activity (1.0 μCi) of a radionuclide. The second gives the dose equivalent rate (millirem per year) per unit activity (1.0 μCi) of a radionuclide in a unit (cubic or square centimeters) of an environmental compartment (air volume or ground surface). All dose conversion factors used in this report were approved by the Department of Energy or by the Environmental Protection Agency (DOE 1988a; DOE 1988b; EPA 1993).

Comparison of Dose Levels

Table G.2 presents a scale of dose levels, with an example of the type of exposure that may cause such a dose, or the special significance of such a dose. This information is intended to help the reader become familiar with a range of doses that various individuals may receive.

Dose from Cosmic Radiation

The average annual dose equivalent to people in the United States from cosmic radiation is about 27 mrem (0.27 mSv) (NCRP 1987). The average dose equivalent caused by cosmic radiation in Tennessee is about 45 mrem per year (0.45 mSv per year) (Tsakeres 1980). When shielding and the time spent

Table G.2. Comparison and description of various dose levels

Dose level	Description
1 mrem	Approximate daily dose from natural background radiation, including radon
2.5 mrem	Cosmic dose to a person on a one-way airplane flight from New York to Los Angeles
10 mrem	Annual exposure limit set by the Environmental Protection Agency (EPA) for exposures from airborne emissions from operations of nuclear fuel cycle facilities, including power plants, uranium mines, and mills
45 mrem	Average yearly dose from cosmic radiation received by people in the Paducah, Kentucky, area
46 mrem	Estimate of the largest dose any off-site person could have received from the March 28, 1979, Three Mile Island nuclear accident
66 mrem	Average yearly dose to people in the United States from human-made sources
100 mrem	Annual limit of dose from all Department of Energy (DOE) facilities to a member of the public who is not a radiation worker
110 mrem	Average occupational dose received by U.S. commercial radiation workers in 1980
244 mrem	Average dose from an upper gastrointestinal diagnostic X-ray series
300 mrem	Average yearly dose to people in the United States from all sources of natural background radiation
1 to 5 rem	Level at which EPA Protective Action Guidelines state that public officials should take emergency action when this is a probable dose to a member of the public from a nuclear accident
5 rem	Annual limit for occupational exposure of radiation workers set by the Nuclear Regulatory Commission and DOE
10 rem	Estimated level at which an acute dose would result in a lifetime excess risk of death from cancer of 0.8%
25 rem	EPA guideline for voluntary maximum dose to emergency workers for non-lifesaving work during an emergency
75 rem	EPA guideline for maximum dose to emergency workers volunteering for lifesaving work
50 to 600 rem	Level at which doses received over a short period of time produce radiation sickness in varying degrees. At the lower end of this range, people are expected to recover completely, given proper medical attention. At the top of this range, most people will die within 60 days

Adapted from Westinghouse Savannah River Company 1994. *Savannah River Site Environmental Report for 1993, Summary Pamphlet*, WSRC-TR-94-076 (WSRC 1994).

indoors are considered, the dose for the surrounding population is reduced to 80%, or about 36 mrem (0.36 mSv) per year.

Dose from Terrestrial Radiation

The average annual dose from terrestrial gamma radiation is about 28 mrem (0.28 mSv) in the United States but varies geographically across the country (NCRP 1987). Typical reported values are about 16 mrem (0.16 mSv) on the Atlantic and Gulf coastal plains and about 63 mrem (0.63 mSv) on the eastern slopes of the Rocky Mountains.

Dose from Internal Radiation

The major contributors to the annual dose equivalent for internal radionuclides are the short-lived decay products of radon, which contribute an average dose of about 200 mrem (2.00 mSv) per year. This dose estimate is based on an average radon concentration of about 1 pCi/L (0.037 Bq/L) (NCRP 1987).

The average dose from other internal radionuclides is about 39 mrem (0.39 mSv) per year, which is predominantly attributed to the naturally occurring radioactive isotope of potassium, ^{40}K. The concentration of radioactive potassium in human tissues is similar in all parts of the world (NCRP 1987).

Dose from Consumer Products

The U.S. average annual dose to an individual from consumer products is about 10 mrem (0.10 mSv) (NCRP 1987); however, not all members of the U.S. population are exposed to all of these sources.

Dose from Medical Sources

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 EDE, 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 EDE from medical examinations is 53 mrem (0.53 mSv), including 39 mrem (0.39 mSv) for diagnostic X rays and 14 mrem (0.14 mSv) for nuclear medicine procedures (NCRP 1989). The actual doses to individuals who receive such medical exams are much higher than these values, but not everyone receives such exams each year (NCRP 1989).

Doses from Other Sources

A few additional sources of radiation contribute minor doses to individuals in the United States. 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 as a result 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).

Water Pathway Dose Methodology

People can be exposed to radionuclides in the environment through a number of routes (Fig. G.2). Potential routes for internal and/or external exposure are referred to as exposure pathways. Several such pathways exist for exposures of humans to radionuclides in water. People may directly ingest (drink) the water. They may eat fish that were caught from the water and, thus, contain radionuclides taken in from the water. Also, people may swim in the water, may boat on the water, and may use shoreline that has absorbed radionuclides from the water. The following sections discuss the methodologies used to calculate potential radiological impacts to persons who drink water; eat fish; and swim, boat, and use the shoreline at various locations along the Clinch and Tennessee rivers. The results of these calculations are summarized in Sect. 8.1.2.2.

Radionuclides discharged to surface waters from the ORR enter the Tennessee River system by way of the Clinch River and various feeder streams (see Sect. 1.5 for the surface water setting of the ORR). Discharges from the Y-12 Complex enter the Clinch River via Bear Creek and East Fork Poplar Creek, 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 and Melton Hill Lake via some small drainage creeks. Discharges from the ETTP enter the Clinch River either directly or via Poplar Creek. For convenience, and to correspond to water sampling locations, surface waters around and below the ORR are divided into seven segments (which we call water bodies):

- Melton Hill Lake above all possible ORR inputs,
- Melton Hill Lake,
- Upper Clinch River from Melton Hill Dam to confluence with Poplar Creek,
- Lower Clinch River (from confluence with Poplar Creek to confluence with the Tennessee River),
- Upper Watts Bar Lake (from around the confluence with the Clinch River to below Kingston),
- Lower System (remainder of Watts Bar Lake and Chicamauga Lake), and
- Poplar Creek, including the confluence of East Fork Poplar Creek.

Since East Fork Poplar Creek is posted against water use, dose estimates for such uses are not reported.

The LADTAP XL methodology (Hamby 1991) is used to calculate individual and population doses via waterborne exposure pathways. All dose calculations require definition of radionuclide concentrations in the medium of interest (water, fish, and shoreline) in the water body of interest.

Two methods, determined by the type of data used, 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) that were determined by laboratory analyses of actual water and fish samples (see Sects. 7.4 and 7.6). The second method estimates radionuclide concentrations in water and fish that were calculated from measured radionuclide discharges and known or estimated stream flows.

The advantage of the first method is the use of radionuclide concentrations actually measured in water and fish; disadvantages are the inclusion of naturally occurring radionuclides especially in gross alpha- and beta-activity measurements, the possibility that some radionuclides of ORR origin might be present in quantities too low to be measured, and the possibility that the presence of some radionuclides might be misstated (e.g., present in a quantity below the detection limit). The advantages of the second method are that most radionuclides discharged from the ORR will be quantified and that naturally occurring radionuclides will not be considered or will be accounted for separately; the disadvantage is the lack of complete river, discharge, and stream flow data. Both methods use models to estimate the concentrations of the radionuclides in water and fish, except at locations (water bodies) where actual measurements are made. Using the two methods should allow the potential radiation doses to be bounded.

For some water bodies, radionuclide concentrations are measured directly. These concentrations are used to calculate concentrations in fish and shoreline, as described below. Concentrations in the water body downstream of the measured water body are obtained by multiplying the measured water body concentrations by the ratio of the measured water body flow (L/year) to the downstream water body flow (L/year); in essence, the concentrations in the upstream water body are diluted by any additional water input to the downstream water body. This dilution calculation continues for all other downstream water bodies.

For other water bodies, data are available on the activities of radionuclides discharged to a water body. These data may be in the form of (1) total activities discharged per year (Ci/year) or (2) activities per unit volume of water (Ci/L) plus the total volume of water discharged per year (L/year). Radionuclide concentrations in the receiving water body are calculated simply by dividing the measured discharge activities (Ci/year) by the total annual flow of the receiving water body (L/year). The process for calculating concentrations in downstream water bodies is the same as that described in the previous paragraph. It should be noted that the discharge flow rate is usually negligible with respect to the receiving water body flow rate.

Equations used to estimate water pathway doses from radionuclide concentrations in water are given in the following sections.

Drinking Water

Several water treatment plants along the Clinch and Tennessee River systems could be affected by discharges from the ORR. Since no in-plant radionuclide concentration data are available for any of these plants; all of the dose estimates given below likely are high because they are based on concentrations of radionuclides in water before it enters a processing plant. For purposes of assessment, it was assumed that maximally exposed individuals drink 730 L/year of water and that the average person drinks 370 L/year.

Table G.3 is a summary of potential EDEs from identified waterborne radionuclides around the ORR and shows the variation in dose based on method used to estimate dose. The EDE from ingestion of water is given by

$$H_{E,i,drink} = U_{drink} * C_{w,i} * DF_{i,ing} * \mathrm{EXP}(-\lambda_{r,i} * t_{drink}) \ ,$$

where $H_{E,i,drink}$ = EDE due to drinking water containing nuclide i (mrem/year),
U_{drink} = water consumption rate (L/year),

$C_{w,i}$	=	concentration of nuclide *i* in water (μCi/L),
$DF_{i,ing}$	=	dose conversion factor for ingestion of nuclide *i* (mrem/μCi),
$\lambda_{r,i}$	=	radioactive decay constant for nuclide *i* (I/d),
t_{drink}	=	time between entry of nuclide into plant and consumption (assumed one day).

Eating Fish

Fishing is quite common on the Clinch and Tennessee River systems. For purposes of assessment, it was assumed that avid fish consumers eat 21 kg/year of fish and that the average person consumes 6.9 kg/year of fish. EDEs were calculated from measured radionuclide contents in fish (see Sect. 7.6), measured concentrations of radionuclides in water, and calculated concentrations in water. The EDE from consumption of fish containing nuclide *i* is given by

$$H_{E,i,fish} = U_{fish} * C_{w,i} * DF_{i,ing} * B_{i,fish} * \mathrm{EXP}(-\lambda_{r,i} * t_{fish}) \ ,$$

where	$H_{E,i,fish}$	=	EDE due to eating fish containing nuclide *i* (mrem/year),
	U_{fish}	=	fish consumption rate (kg/year),
	$C_{w,I}$	=	concentration of nuclide *i* in water (μCi/L),
	$DF_{i,ing}$	=	dose conversion factor for ingestion of nuclide *i* (mrem/μCi),
	$B_{i,fish}$	=	bioaccumulation factor (L/kg),
	$\lambda_{r,i}$	=	radioactive decay constant for nuclide *i* (I/d),
	t_{fish}	=	time between harvest and consumption (assumed 10 days).

Fish samples are collected from Melton Hill Lake above all ORR inputs [Clinch River kilometer (CRK) 70], from the upper part of the Clinch River (CRK 32), and from the Clinch River below all ORR inputs (CRK 16). Unidentified beta and alpha activities are often detected in many of the fish samples. Excess beta and alpha activities are estimated by subtracting activities of identified beta- and alpha-particle-emitting radionuclides from the corresponding unidentified activities. The excess unidentified beta and alpha activities are assumed to be from the naturally occurring radionuclides ^{234}Th and ^{226}Ra.

Other Uses

Other uses of the 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. Measured and calculated concentrations of radionuclides in water and the LADTAP XL methodology were used to estimate potential EDEs from these activities.

The EDE from swimming in water containing nuclide i (except tritium) is given by

$$H_{E,i,swim} = 0.142 * C_{w,i} * U_{swim} * DF_{i,WS} \ ,$$

where	$H_{E,i,swim}$	=	EDE from swimming in water containing nuclide *i* (mrem/year),
	0.142	=	unit conversion factor (1000 L/m^3 divided by 8760 h/year),
	U_{swim}	=	time spent swimming (h/year),
	$C_{w,i}$	=	concentration of nuclide *i* in water (μCi/L),
	$DF_{i.WS}$	=	dose conversion factor for submersion in water containing nuclide *i* (mrem-m^3/year-μCi).

Complete submersion is assumed while swimming. For tritium, the swimming dose equation is

$$H_{E,T,swim} = C_{W,T} * U_{swim} * I_T * DF_{T,ing} \ ,$$

where	$H_{E,T,swim}$	=	EDE from swimming in water containing tritium (mrem/year),
	U_{swim}	=	time spent swimming (h/year),

$C_{W,T}$	=	concentration of tritium in water (μCi/L),
I_T	=	absorption factor for tritium via whole body immersion in water (= 0.035 L/h),
$DF_{T,ing}$	=	dose conversion factor for ingestion of tritium (mrem/μCi).

The EDE from boating on water containing nuclide i (except tritium) is given by

$$H_{E,i,boat} = 0.5 * (0.142 * C_{w,i} * U_{boat} * DF_{i,WS}) \ ,$$

where

$H_{E,i,boat}$	=	EDE from boating on water containing nuclide *i* (mrem/year),
0.5	=	correction factor,
0.142	=	unit conversion factor (1000 L/m^3 divided by 8760 h/year),
U_{boat}	=	time spent boating (h/year),
$C_{w,i}$	=	concentration of nuclide *i* in water (μCi/L),
$D_{Fi.WS}$	=	dose conversion factor for submersion in water containing nuclide *i* [mrem-m^3/year-μCi].

The 0.5 correction factor arises from the assumption used in LADTAP XL that doses per unit from boating equal one-half the doses from swimming. Any shielding by the boat's hull is ignored. The dose attributable to any tritium, which emits only very weak beta radiation, in the water is assumed to be 0.

The EDE from using a shoreline containing nuclide *i* is given by

$$H_{E,i,shore} = C_{i,shore} * U_{shore} * (G_{shore} / 8760) * DF_{i,soil} \ ,$$

where

$H_{E,i,shore}$	=	EDE due to use of shoreline containing nuclide *i* (mrem/year),
$C_{i,shore}$	=	annual average concentration of nuclide *i* in shoreline soil (μCi/m^2),
U_{shore}	=	duration of time spent on the shoreline (h/year),
G_{shore}	=	unitless shoreline width correction factor (0.2 for rivers),
8760	=	number of hours in a year (h/year), and
$DF_{i,soil}$	=	dose conversion factor for infinitely thick soil containing nuclide (mrem-m^2/μCi-year).

The annual average concentration of nuclide i in shoreline soil is obtained by

$$C_{i,shore} = C_{W,i} * F_{i,W\text{-}S} * T_{1/2,i} * (1 - \mathrm{EXP}[-\lambda_{r,i} * 365 * t_{S\text{-}W}]) \ ,$$

$C_{W,i}$	=	annual average concentration of nuclide i in water (μCi/L),
$F_{i,W\text{-}S}$	=	water-to-sediment transfer coefficient nuclide i (= 100 L/m^2-day),
$T_{1/2,i}$	=	radioactive half-life of nuclide *i* (d),
$\lambda_{r,I}$	=	radioactive decay constant for nuclide *i* (1/d),
$t_{S\text{-}W}$	=	time over which shoreline soil is exposed to water containing nuclide *i* (= 50 years), and
365	=	number of days in a year (d/year).

It is assumed that the buildup and decay of nuclides in shoreline soil has occurred at the current year's rates for the past 50 years.

When compared with EDEs from drinking water and eating fish from the same waters, the EDEs from these other uses are relatively small. Table G.3 is a summary of potential EDEs from identified waterborne radionuclides around the ORR and shows the variation in dose based on method used to estimate dose.

Table G.3. Summary of annual maximum individual effective dose equivalents from waterborne radionuclides (mrem)[a]

Type of sample	Drinking water	Eating fish	Other uses	Total of highest
Melton Hill Lake above ORR inputs, CRK 70				
Fish[b]				
Water[c]	0.05	0.08	0.0004	0.1
Maximum	0.05	0.08	0.0004	0.1
Melton Hill Lake, CRK 70, 66, and 58				
Water[c]	0.05	0.08	0.0003	0.1
Discharge[d]	0.000003	0.000005	0.0000004	0.000009
Maximum	0.05	0.08	0.0003	0.1
Upper Clinch River, CRK 23, Gallaher Water Plant, CRK 32				
Fish[b]		0.3		0.3
Water[c]	0.05	0.1	0.0005	0.2
Discharge[d]	0.0001	0.0003	0.00004	0.00004
Maximum	0.05	0.3	0.0005	0.4
Lower Clinch River, CRK 16				
Fish[b]		0.1		0.1
Water[c]	NA[e]	0.1	0.004	0.1
Discharge[d]	NA[e]	0.00004	1E-9	0.00004
Maximum	NA[e]	0.1	0.004	0.1
Upper Watts Bar Lake, Kingston Municipal Water Plant				
Water[c]	0.04	0.02	0.0007	0.05
Discharge[d]	1E–10	6E–11	5E–13	2E–10
Maximum	0.04	0.02	0.0007	0.06
Lower System (Lower Watts Bar Lake and Chickamauga Lake)				
Water[c]	0.03	0.01	0.0006	0.05
Discharge[d]	6E–10	2E–10	4E–12	7E–10
Maximum	0.03	0.01	0.0006	0.05
Poplar Creek				
Water[c]	NA[e]	0.09	0.006	0.1
Discharge[d]	NA[e]	0.003	5E–5	0.003
Maximum	NA[e]	0.09	0.006	0.1

[a]1 mrem = 0.01 mSv.
[b]Doses based on measured radionuclide concentrations in fish tissue.
[c]Doses based on measured radionuclide concentrations in water.
[d]Doses based on measured discharges of radionuclides from on-site outfalls.
[e]Not at drinking water supply locations.

Appendix H. Chemicals

Appendix H. Chemicals

This appendix presents basic facts about chemicals. The information is intended to be a basis for understanding the dose or relative toxicity assessment associated with possible releases from the Oak Ridge Reservation (ORR), not a comprehensive discussion of chemicals and their effects on the environment and biological systems.

Perspective on Chemicals

The lives of modern humans have been greatly improved by the development of chemicals such as pharmaceuticals, building materials, housewares, pesticides, and industrial chemicals. Through the use of chemicals, we can increase food production, cure diseases, build more efficient houses, and send people to the moon. At the same time, we must be cautious to ensure that our own existence is not endangered by uncontrolled and overexpanded use of chemicals (Chan et al. 1982).

Just as all humans are exposed to radiation in the normal daily routine, 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. Aflatoxin is a known toxin found in peanuts, and 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 for 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 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.

Pathways of Chemicals From the ORR to the Public

Pathways refer to the route or way in which a person can come in contact with a chemical substance. Chemicals released to the air may remain suspended for long periods of time, 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 by 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. People eating the fish would then be exposed to the chemical. Less likely would be exposure by directly drinking from the stream or river.

The public is not normally exposed to chemicals on the 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 to the public.

Definitions

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 a toxic and a carcinogenic effect. The toxic effect can be acute (short-term severe health effect) or chronic (longer-term persistent health effect). Toxicity is often evident in a shorter length of time than the carcinogenic effect. The potential health effects of noncarcinogens range from skin irritation to fatality. 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 the form of food, water, and sometimes medications. Even those chemicals usually 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 are thought to have an adverse effect on human health. These concentration limits can be used to calculate a chemical dose that would not harm even individuals who are particularly sensitive to the chemical.

Dose Terms for Noncarcinogens

Reference Dose

A reference dose is an estimate of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime. Units are expressed as milligrams of chemical per kilogram of an adult's body weight per day (mg/kg-day). These values are given in Table H.1.

Values for reference doses are derived from doses of chemicals that result 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 the sensitive human populations. The Environmental Protection Agency (EPA) maintains the Integrated Risk Information System data base, which contains verified reference doses and up-to-date health risk and EPA regulatory information for numerous chemicals.

Primary Maximum Contaminant Levels

For chemicals for which reference doses are not available in the Integrated Risk Information System, national primary drinking water maximum contaminant levels, expressed in milligrams of chemical per liter of drinking water, are converted to reference dose values by multiplying by 2 liters (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). These values are given in Table H.1.

Dose Term for Carcinogens

Slope Factor

A slope factor is a plausible upper-bound estimate of the probability of a response per unit intake of a chemical during a lifetime. The slope factor is used to estimate an upper-bound probability of an individual developing cancer as a result of a lifetime exposure to a particular level of a potential carcinogen. Units are expressed as risk per dose (mg/kg-day). These values are given in Table G.1.

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 of 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.

Table H.1. Chemical reference doses and slope factors used in drinking water and fish intake analysis

Elements			Compounds		
Chemical	Factor	Reference[a]	Chemical	Factor	Reference[a]
Antimony	4.0E–04	RfD	Acetone	9.0E–01	RfD
Arsenic	3.0E–04	RfD	Aroclor-1254	2.0E–05	RfD
	1.5E+00	SF	Aroclor-1260	2.0E–05	RfD[b]
Barium	2.0E–01	RfD	Chlordane (alpha,beta)	5.0E–04	RfD
Beryllium	2.0E–03	RfD		3.5E–01	SF
Boron	2.0E–01	RfD	4,4′-DDD	2.4E-01	SF
Cadmium	5.0E–04	RfD	4,4′-DDE	3.4E–01	SF
Chromium VI	3.0E–03	RfD	PCBs (mixed)	2.0E+00	SF[f]
Lead	1.4E–04	*c,d*	Toluene	8.0E–02	RfD
Manganese	1.4E–01	RfD			
Mercury	3.0E–04	RfD[e]			
Molybdenum	5.0E–03	RfD			
Nickel	2.0E–02	RfD			
Selenium	5.0E–03	RfD			
Silver	5.0E–03	RfD			
Strontium	6.0E–01	RfD			
Thallium	5.7E–05	*c,g*			
Uranium	3.0E–03	RfD			
Vanadium	7.0E–03	RfD			
Zinc	3.0E–01	RfD			

[a]RfD: reference dose (mg kg^{-1} day^{-1}); SF: slope factor (risk per mg/kg-day).

[b]The RfD for Aroclor-1254 is also used for Aroclor-1260.

[c]The water quality criteria (WQC) are given in units of micrograms per liter. To convert the concentration to an RfD (mg kg^{-1} day^{-1}), divide by 1000 (to convert to milligrams per liter), multiply by the consumption rate (2 L/day), and divide by the mass of a reference man, 70 kg.

[d]This value is based on the 2004 Tennessee WQC for lead for domestic water supplies.

[e]An EPA-approved oral chronic RfD, SF, or other guideline for elemental mercury in water or aquatic organisms is not available. Most guidelines refer to "recoverable" or inorganic mercury. RfD values exist for several inorganic mercury salts. The EPA oral RfD for soluble mercuric chloride ($HgCl_2$) is 3.0E–04 mg/kg/day.

[f]The cancer potency of PCB mixtures is determined using a three-tiered approach. This value is the upper bound slope factor for the High Risk and Persistence Tier.

[g]This value is based on the 2004 Tennessee WQC for thallium for domestic water supplies, which reflects the maximum contaminant level value (2 µg/L).

Measuring Chemicals

Environmental samples are collected in areas surrounding the ORR and are analyzed for those chemical constituents most likely to be released from the 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, they have limits below which they cannot detect the 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 those concentrations detected above the detection limits of the instruments. Health effect calculations using these estimated values are indicated with tildes (~) or "J." The tilde indicates that estimated values were used in estimating the average concentration of a chemical. "J" indicates

that the chemical concentration is detected below the reported analytical detection limits of the instruments and is recorded by the laboratory as an estimated value.

Risk Assessment Methodology

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 way. Clinch River surface water and fish samples are analyzed to estimate chemical contaminant concentrations. It is assumed that individuals drink 2 L (0.53 gal) of water per day directly from the river, which amounts to 730 L (193 gal) per year, and that they eat 0.06 kg of fish per day from the river (21 kg per year). Estimated daily intakes or estimated doses to the public are calculated by multiplying measured (statistically significant) concentrations in water by 2 L or those in fish by 0.06 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 actual individual would receive.

Dose Estimate

When the contaminant oral daily intake via exposure pathways 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 individual. 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."

The daily intake or dose from ingestion of water is estimated by the following equation:

$$I = \frac{CW \times IR \times EF \times ED}{BW \times AT},$$

where

I	=	intake (mg/kg-day)
CW	=	Concentration in water (mg/L)
IR	=	Ingestion rate (2 L/day)
EF	=	Exposure frequency (350 days/year)
ED	=	Exposure duration (30 years)
BW	=	Body weight (70 kg)
AT	=	Averaging time for noncarcinogens (365 days/year $\times$ ED) or for carcinogens (365 days/year $\times$ 70 years)

The daily intake rate or dose from consumption of fish obtained by recreational anglers is estimated by the following equation:

$$I = \frac{CW \times IR \times EF \times ED}{BW \times AT},$$

where

I	=	intake (mg/kg-day)
CW	=	Concentration in fish tissue wet weight (mg/kg)
IR	=	Ingestion rate (0.06 kg/day)
EF	=	Exposure frequency (350 days/year)

ED = Exposure duration (30 years)
BW = Body weight (70 kg)
AT = Averaging time for noncarcinogens (365 days/year × *ED*) or for carcinogens (365 days/year × 70 years)

Calculation Methodology

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. The hazard quotient is a ratio that compares the estimated exposure dose or intake (*I*) to the reference dose as follows:

$$HQ = \frac{I}{RfD},$$

where
HQ = hazard quotient (unitless),
I = estimated intake or dose (mg/ kg-day),
RfD = reference dose (mg/kg-day).

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. In previous reports, the estimated dose from ingesting water or fish from rivers and streams surrounding the ORR is compared to the chronic daily intake I(10^{-5}) derived from assuming a human lifetime risk of developing cancer of 10^{-5} (1 in 100,000). However, as in typical human health risk assessments, risk levels are derived as follows:

$$R = I \times SF,$$

where
R = risk
I = estimated intake or (mg/kg-day),
SF = slope factor, oral (risk per mg/ kg-day).

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 of 1 in 10,000) to 10^{-6} (risk of developing cancer over a human lifetime is 1 in 1,000,000). The tilde (~) indicates that estimated values were used in estimating the average concentrations of a chemical.

References

References

Note: *In this report we refer to a number of documents (e.g., plans, reports) that are intended for internal use. For the most part, these documents function as a means of communication between governmental agencies and the tenant companies on the Oak Ridge Reservation or as the means by which analytical laboratories deliver results. As such, these documents are not readily available to the public and therefore are not cited in the list of references.*

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