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

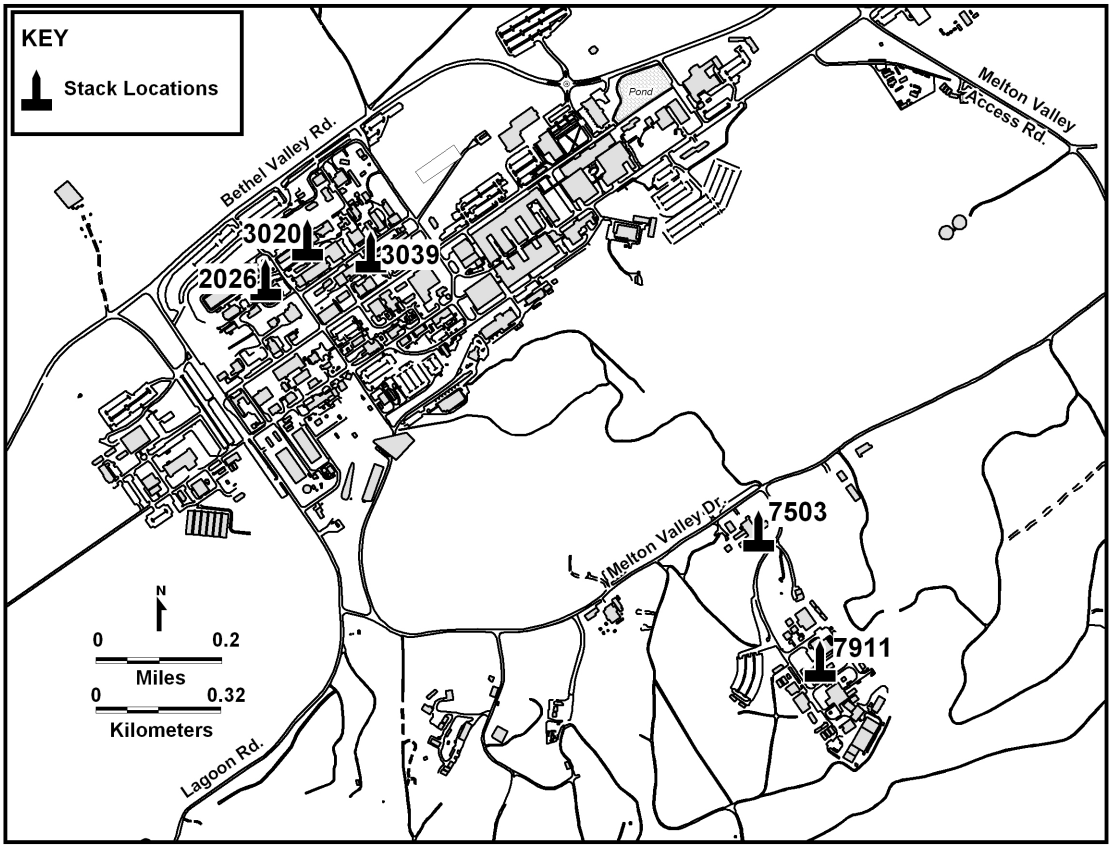


Fig. 5.1. Locations of major stacks (radiological emission points) at ORNL.

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 0.1 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.

ORNL 2006-G00646/jcn

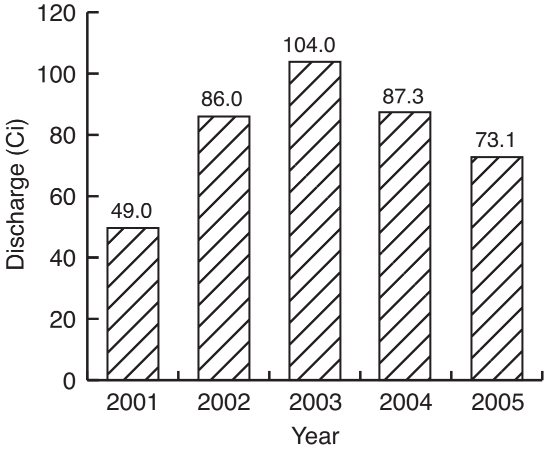


Fig. 5.2. Total discharges of ^{3}H from ORNL to the atmosphere, 2001–2005. 1 Ci = 3.7×10^{10} Bq.

ORNL 2006-G00647/jcn

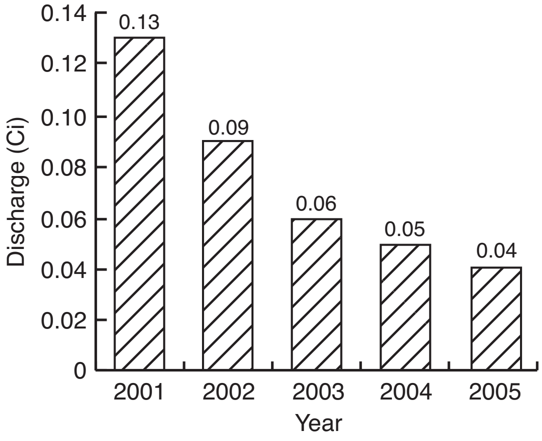


Fig. 5.3.Total discharges of ^{131}I from ORNL to the atmosphere, 2001–2005. 1 Ci = 3.7×10^{10} Bq.

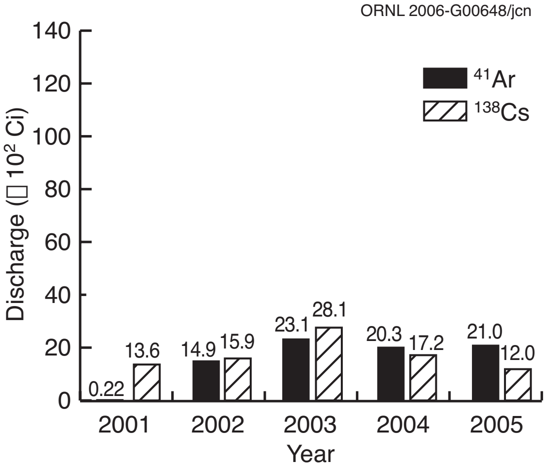


Fig. 5.4. Total discharges of ^{41}Ar and ^{138}Cs from ORNL to the atmosphere, 2001–2005. 1 Ci = 3.7 × 10^{10} Bq.

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.

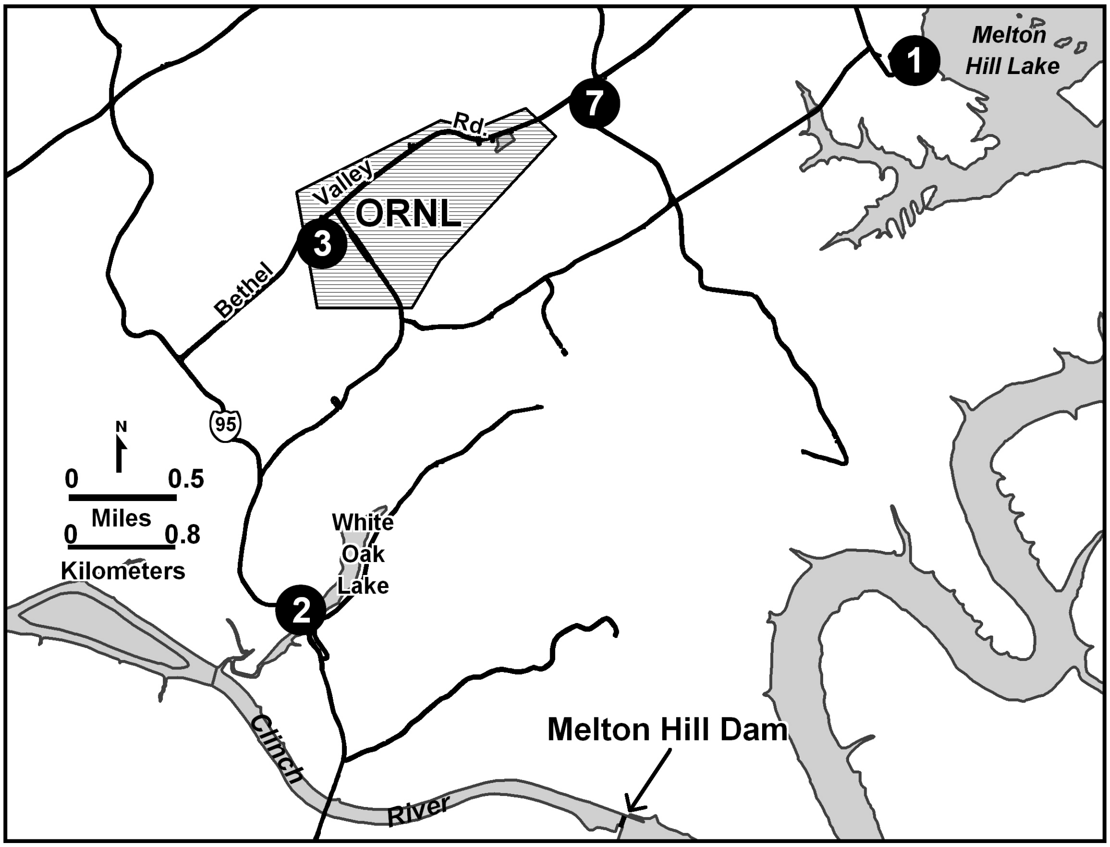


Fig. 5.5. Locations of ambient air monitoring stations at ORNL.

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.

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

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).

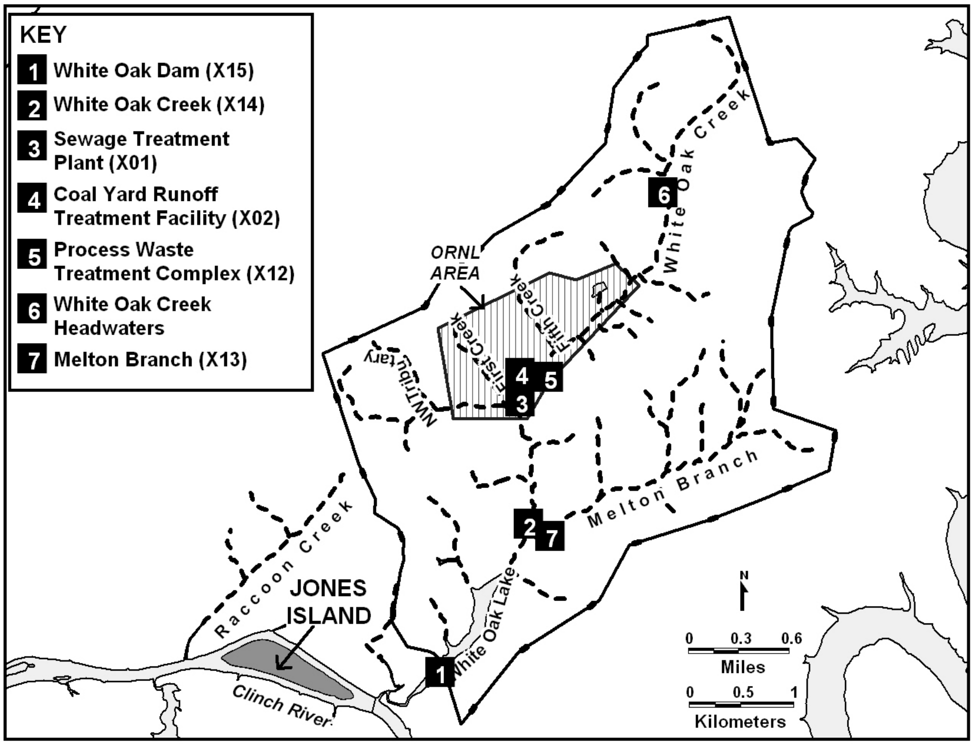


Fig. 5.6. ORNL surface water, National Pollutant Discharge Elimination System, and reference sampling locations.

ORNL 2006-G00649/jcn

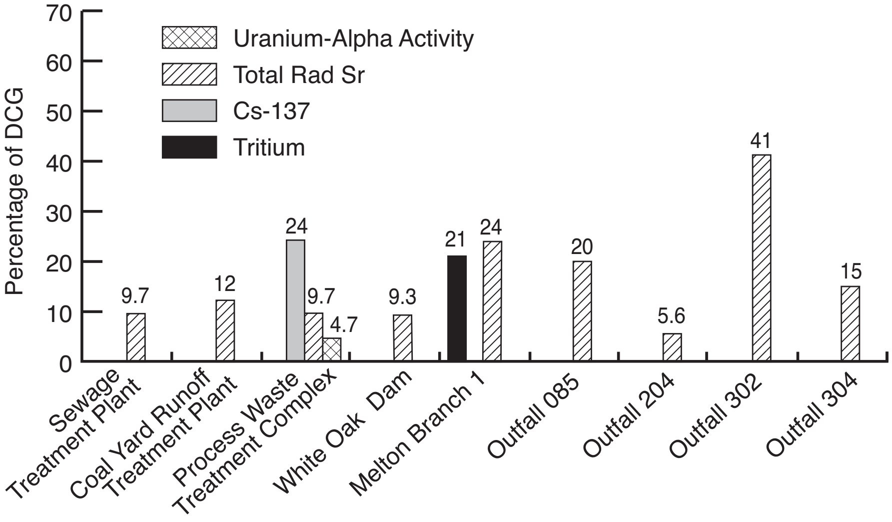


Fig. 5.7. Radionuclides at ORNL sampling sites having average concentrations greater than 4% of the relevant derived concentration guides in 2005.

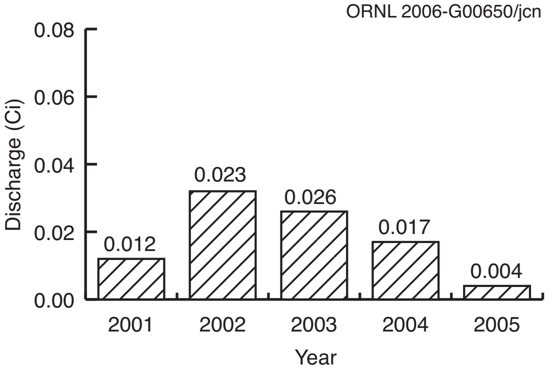


Fig. 5.8. Cobalt-60 discharges at White Oak Dam, 2001–2005. (1 Ci = 3.7 × 10^{10} Bq.)

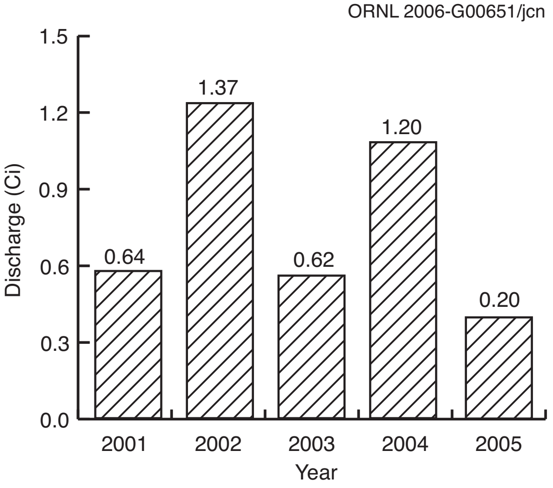


Fig. 5.9. Cesium-137 discharges at White Oak Dam, 2001–2005. (1 Ci = 3.7 × 10^{10} Bq.)

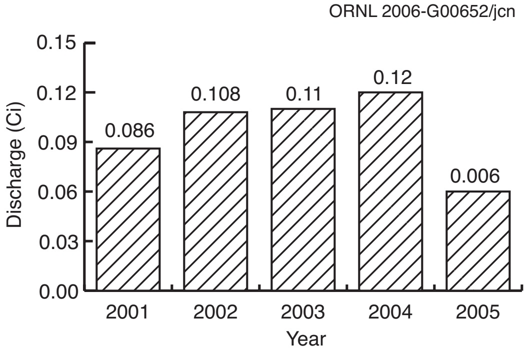


Fig. 5.10. Gross alpha discharges at White Oak Dam, 2001–2005. (1 Ci = 3.7 × 10^{10} Bq.)

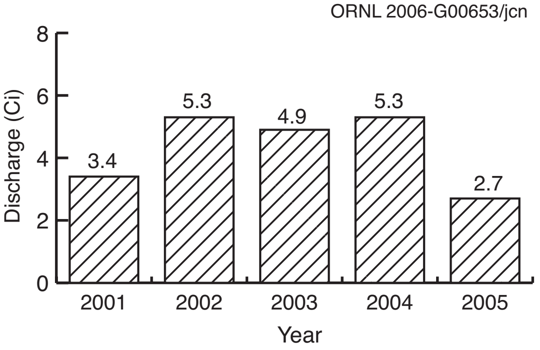


Fig. 5.11. Gross beta discharges at White Oak Dam, 2001–2005. (1 Ci = 3.7 × 10^{10} Bq.)

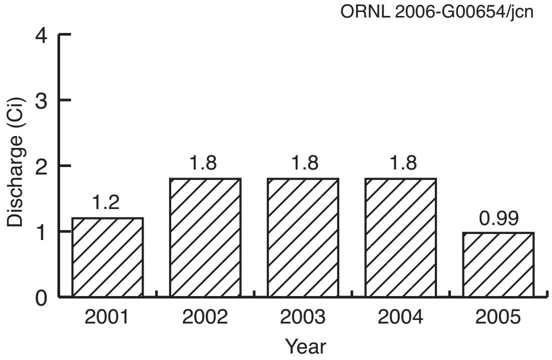


Fig. 5.12. Total radioactive strontium discharges at White Oak Dam, 2001–2005. (1 Ci = 3.7 × 10^{10} Bq.)

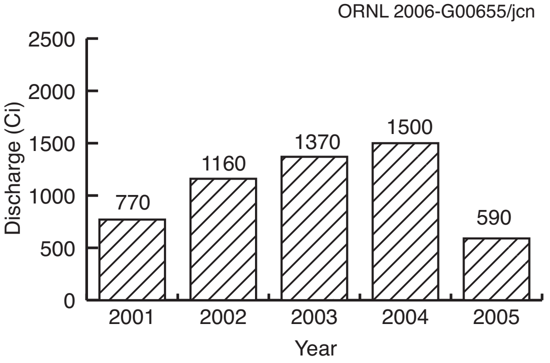


Fig. 5.13. Tritium discharges at White Oak Dam, 2001–2005. (1 Ci = 3.7 × 10^{10} Bq.)

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.

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

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.

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 are 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

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}.

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 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.

ORNL 2006-G00656/jcn

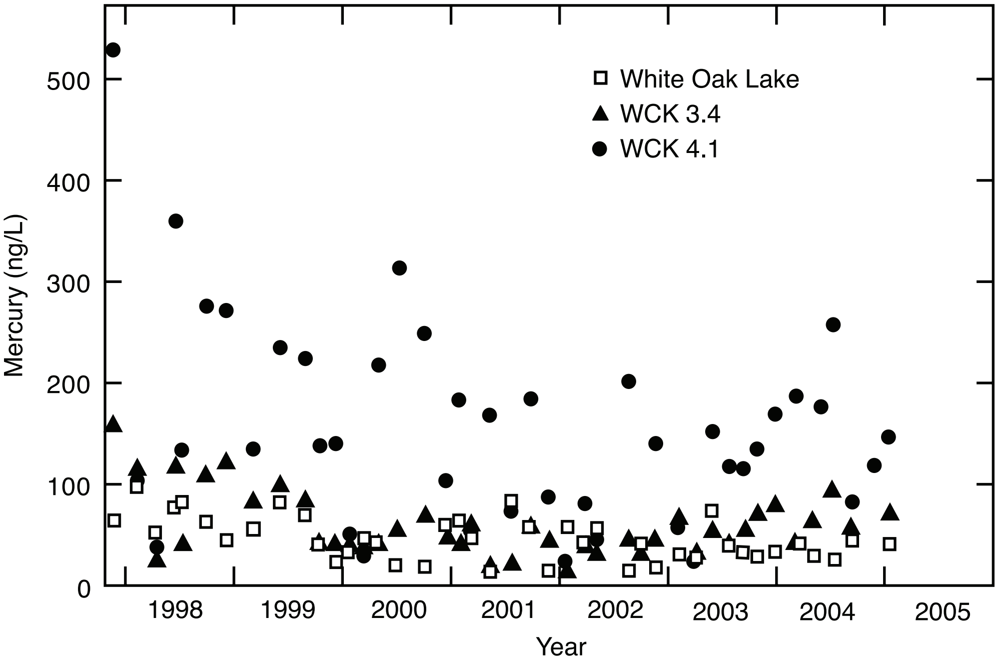


Fig. 5.14. Total aqueous mercury concentrations at sites in White Oak Creek downstream from ORNL, 1998–2005. (WCK = White Oak Creek kilometer.)

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 blue gill (*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 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

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

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 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 (FCK) 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 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

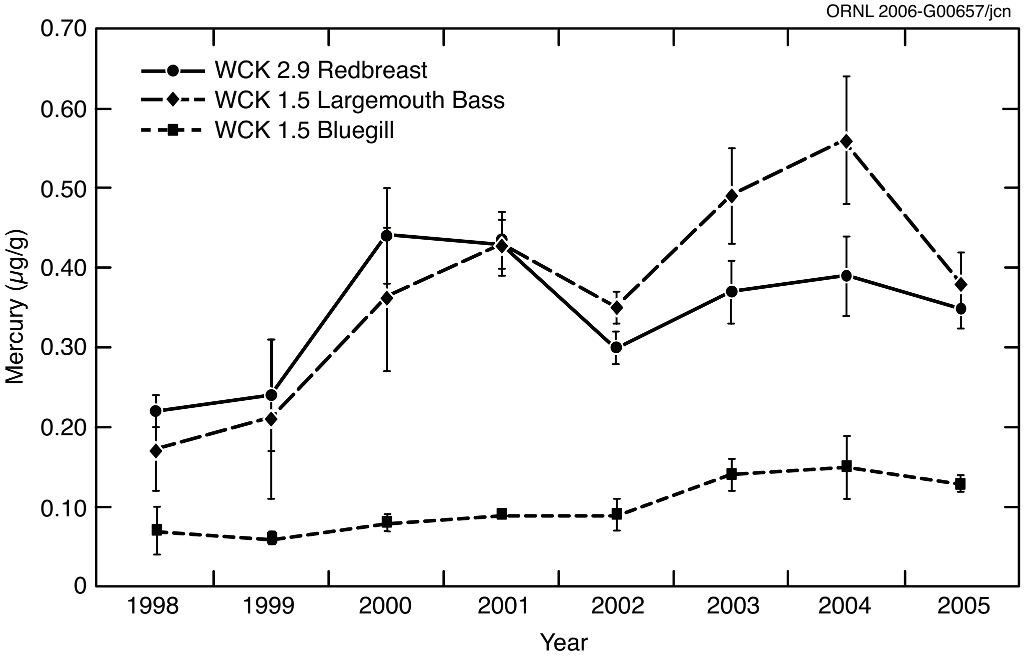


Fig. 5.15. Mean mercury concentrations (µg/g, ± SE) in fish fillets collected from the WOC watershed, 1998–2005. (WCK = White Oak Creek kilometer.)

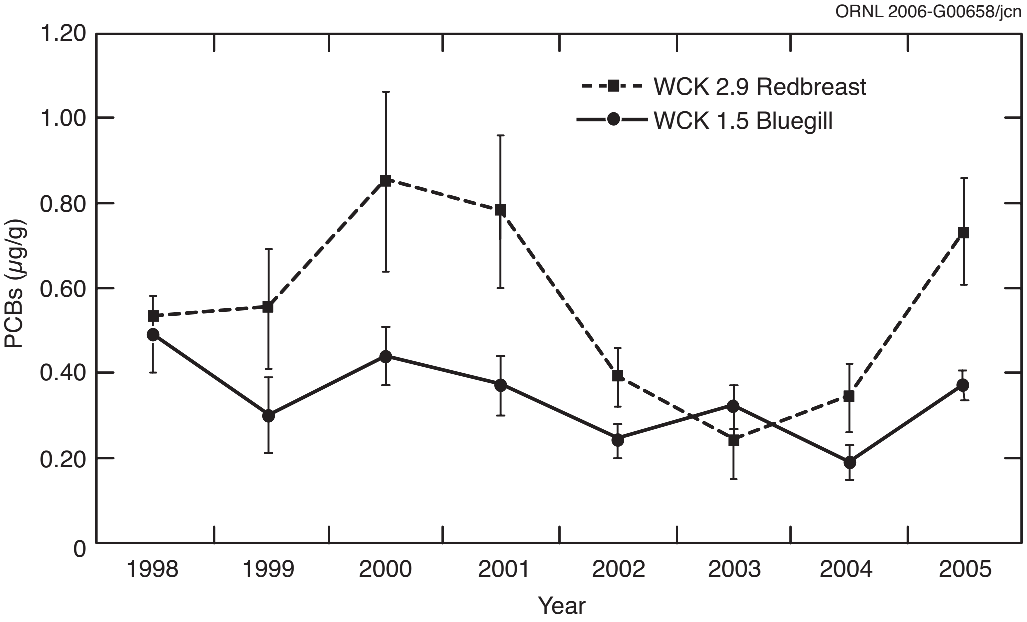


Fig. 5.16. Mean total PCB concentrations (µg/g, ± SE) in sunfish fillets collected from the WOC watershed, 1998–2005. (WCK = White Oak Creek kilometer.)

ORNL 2006-G00659/jcn

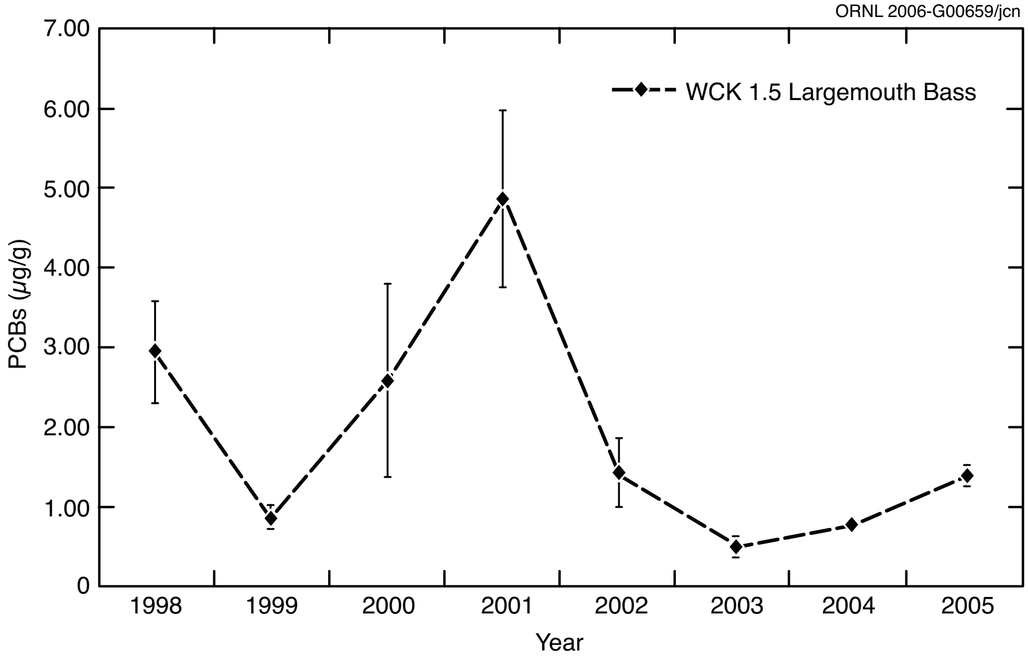


Fig. 5.17. Mean total PCB concentrations (μg/g, ± SE) in largemouth bass fillets collected from WCK 1.5 (White Oak Lake), 1998–2005. (WCK = White Oak Creek kilometer.)

(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.

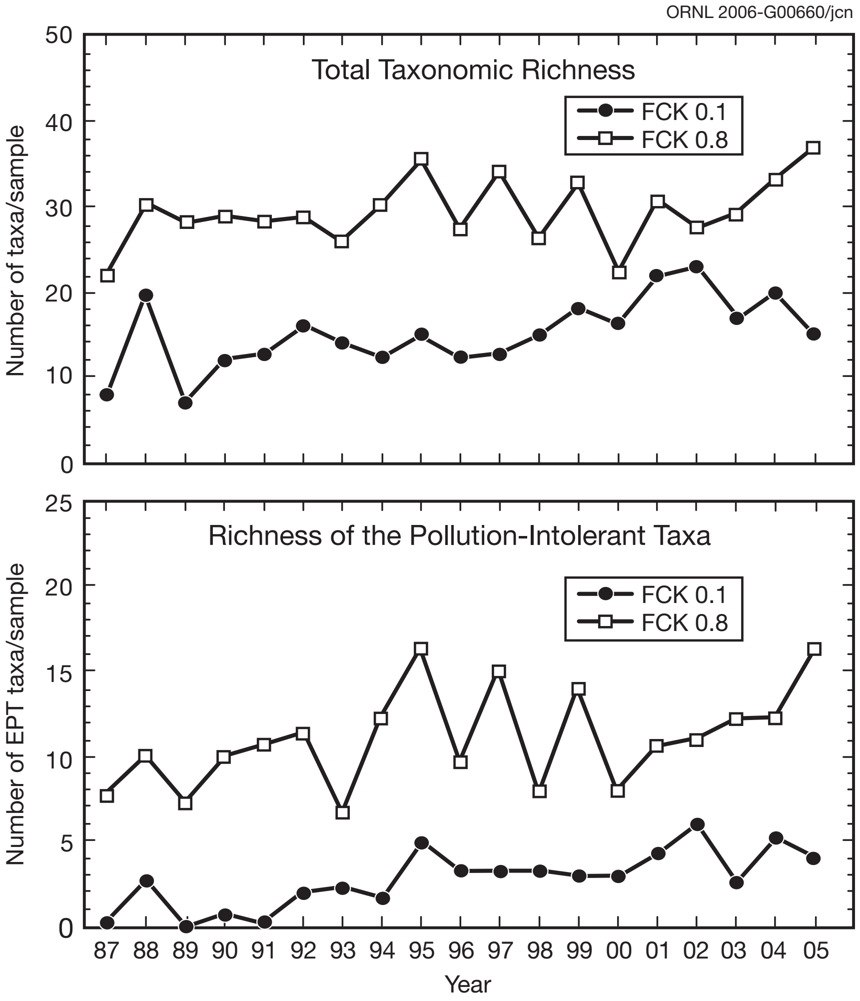
The density of the snail, *Elimia*, appears to have increased slightly at WCK 6.8 and WCK 3.9 in 2005 (i.e., ~11 individuals/0.1 m^2); however, their density at WCK 6.8 remains below the average of 37 individuals/0.1 m^2 present before 2001 (Fig. 5.21). Although *Elimia* density was slightly lower at 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.

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 out-



FCK - First Creek kilometer
EPT - Ephemeroptera, Plecoptera, and Trichoptera

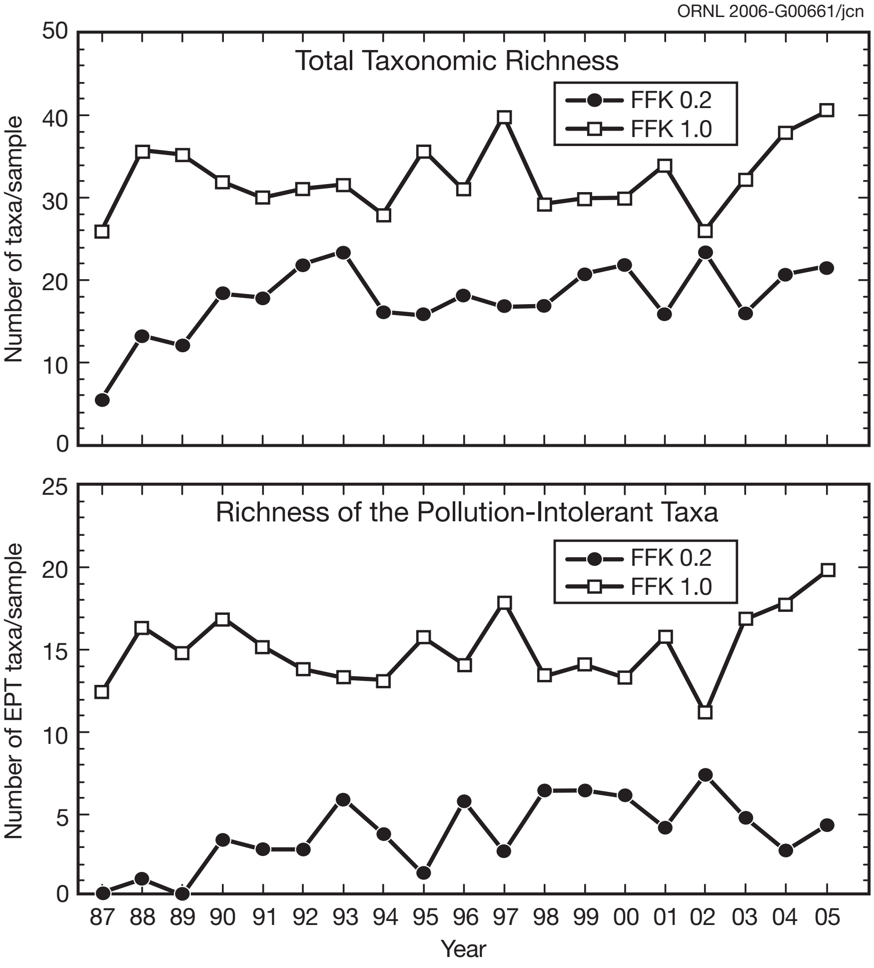
Fig. 5.18. Taxonomic richness (top) and richness of the pollution-intolerant taxa (bottom) of the benthic macroinvertebrate community in First Creek, April sampling periods, 1987–2005.

falls remained somewhat impacted in 2005 relative to reference streams or upstream sites. 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 (TDEC 2004) 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



FFK - Fifth Creek kilometer
EPT - Ephemeroptera, Plecoptera, and Trichoptera

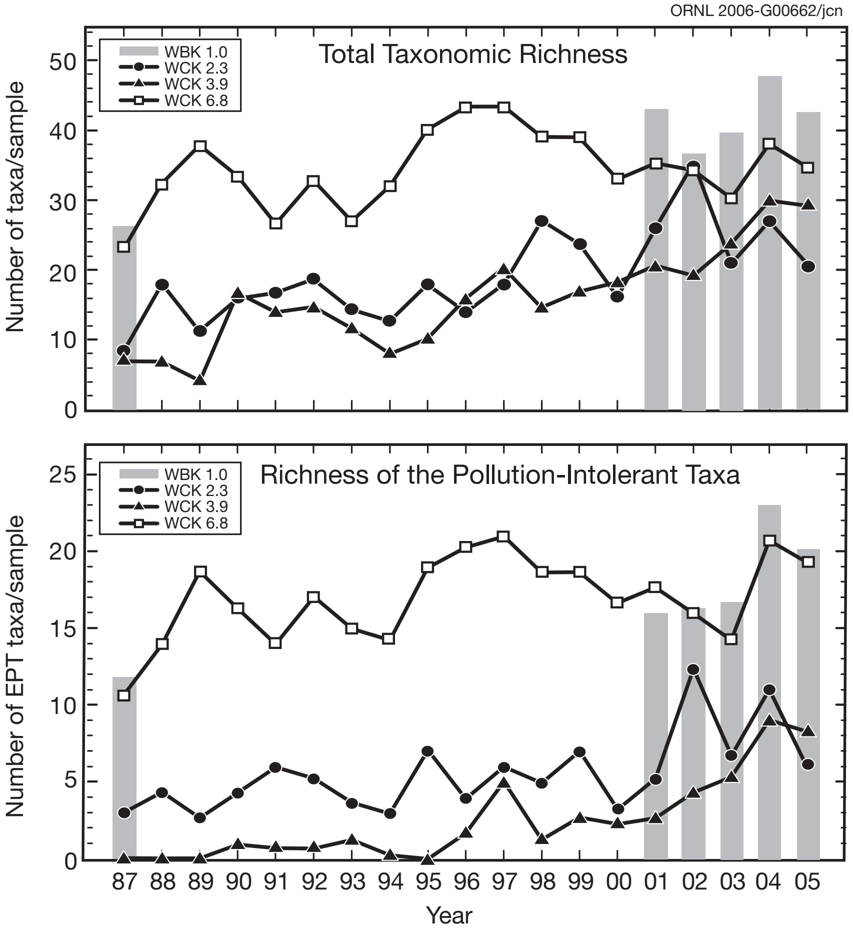
Fig. 5.19. Taxonomic richness (top) and richness of the pollution-intolerant taxa (bottom) of the benthic macroinvertebrate community in Fifth Creek, April sampling periods, 1987–2005. (FFK 1.0 = reference site.)

all parameters 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-



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. (WBK 1.0 = reference site.)

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 (TDEC 2004). 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

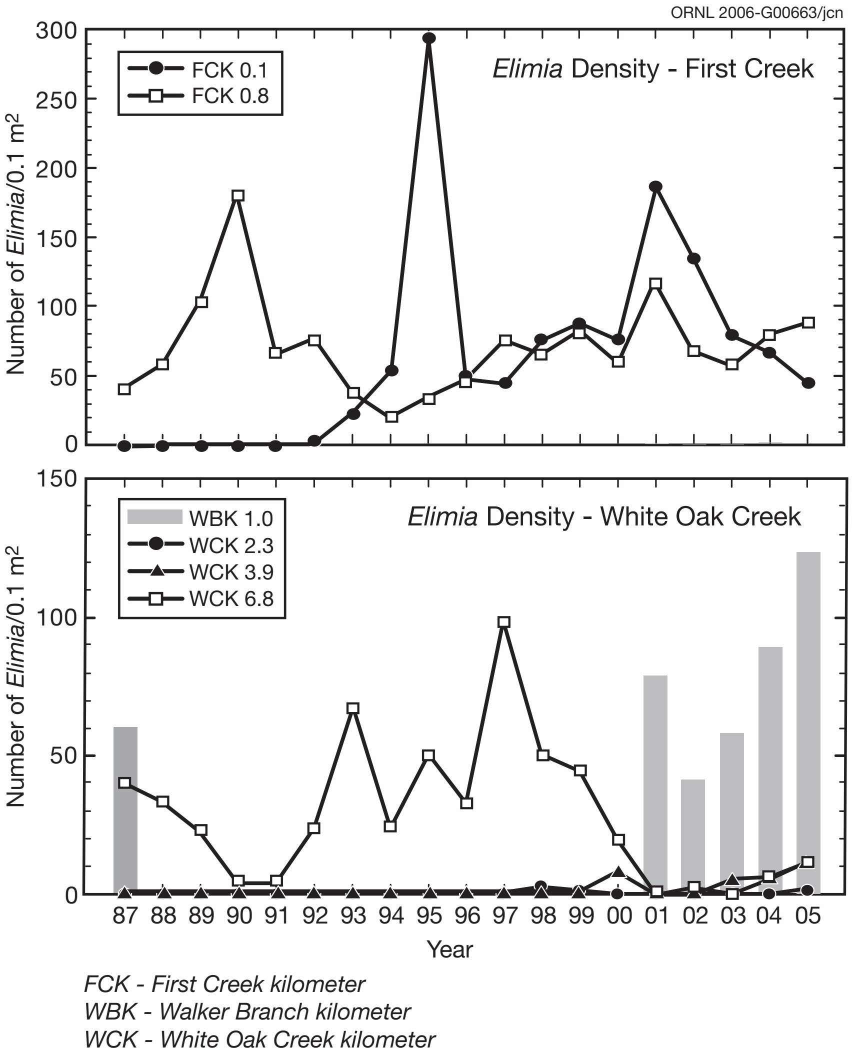


Fig. 5.21. Density (number/0.1 m^2) of the snail *Elimia* in White Oak Creek, First Creek, and Walker Branch, April sampling periods, 1987–2005. (Fifth Creek excluded because *Elimia* rarely occurs in that stream.)

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.

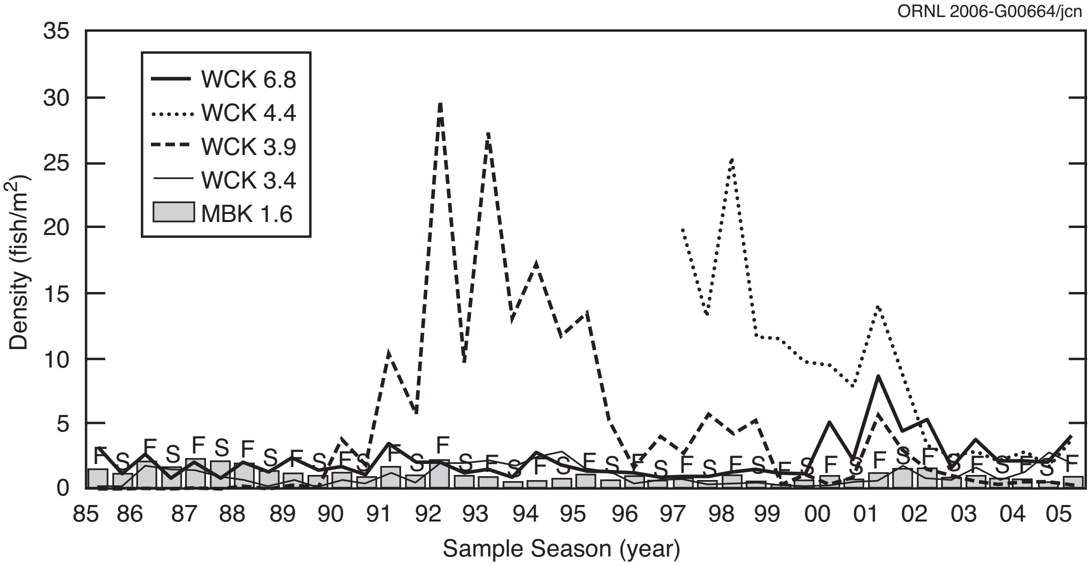


Fig. 5.22. Density (fish/m^2) estimates for fish in spring and fall samples from upper White Oak Creek and from a reference site on Mill Branch (MBK 16), 1985–2005. (WCK = White Oak Creek kilometer; MBK = Mill Branch kilometer.)

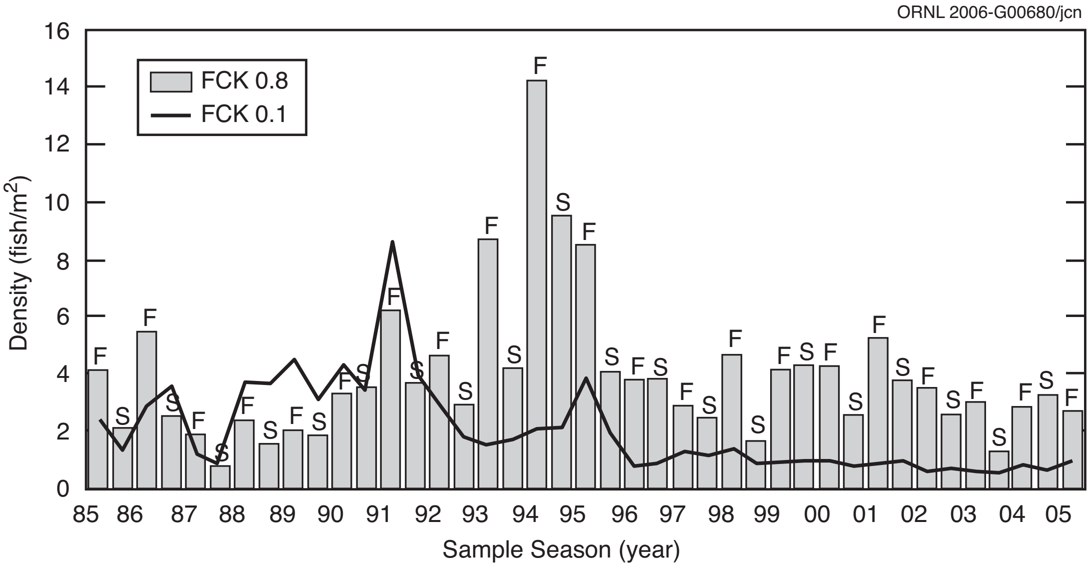


Fig. 5.23. Density (fish/m^2) estimates for fish in spring and fall samples from First Creek 1985–2005. (FCK= First Creek kilometer.) **(**FCK 0.8 is a reference site.)

ORNL 2006-G00681/jcn

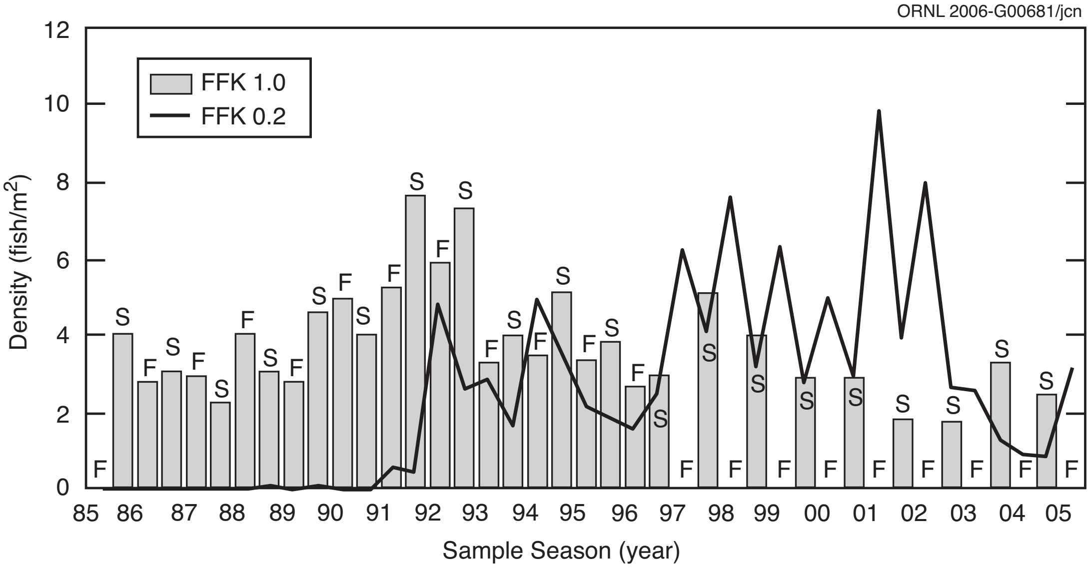


Fig. 5.24. Density (fish/m^2) estimates for fish in spring and fall samples from Fifth Creek 1985–2005. (FFK= Fifth Creek kilometer.) **(**FFK 1.0 is a reference site.)

ORNL 2006-G00682/jcn

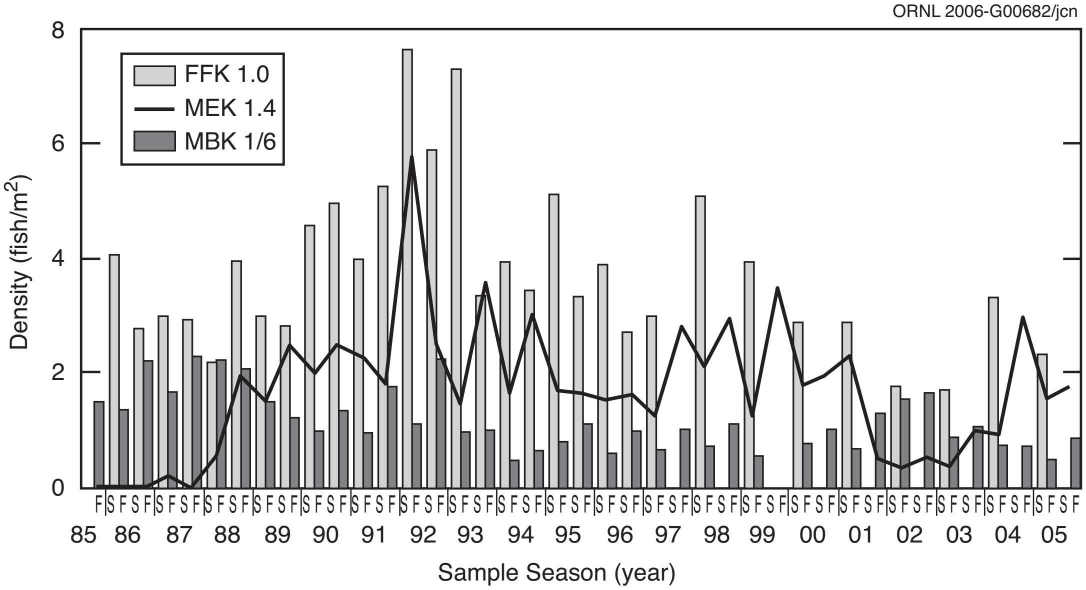


Fig. 5.25. Density (fish/m^2) estimates for fish in spring and fall samples from Melton Branch 1985–2005. (MEK= Melton Branch kilometer.) Upper Fifth Creek FFK 1.0 and Mill Branch (MBK 1.6) are reference sites.

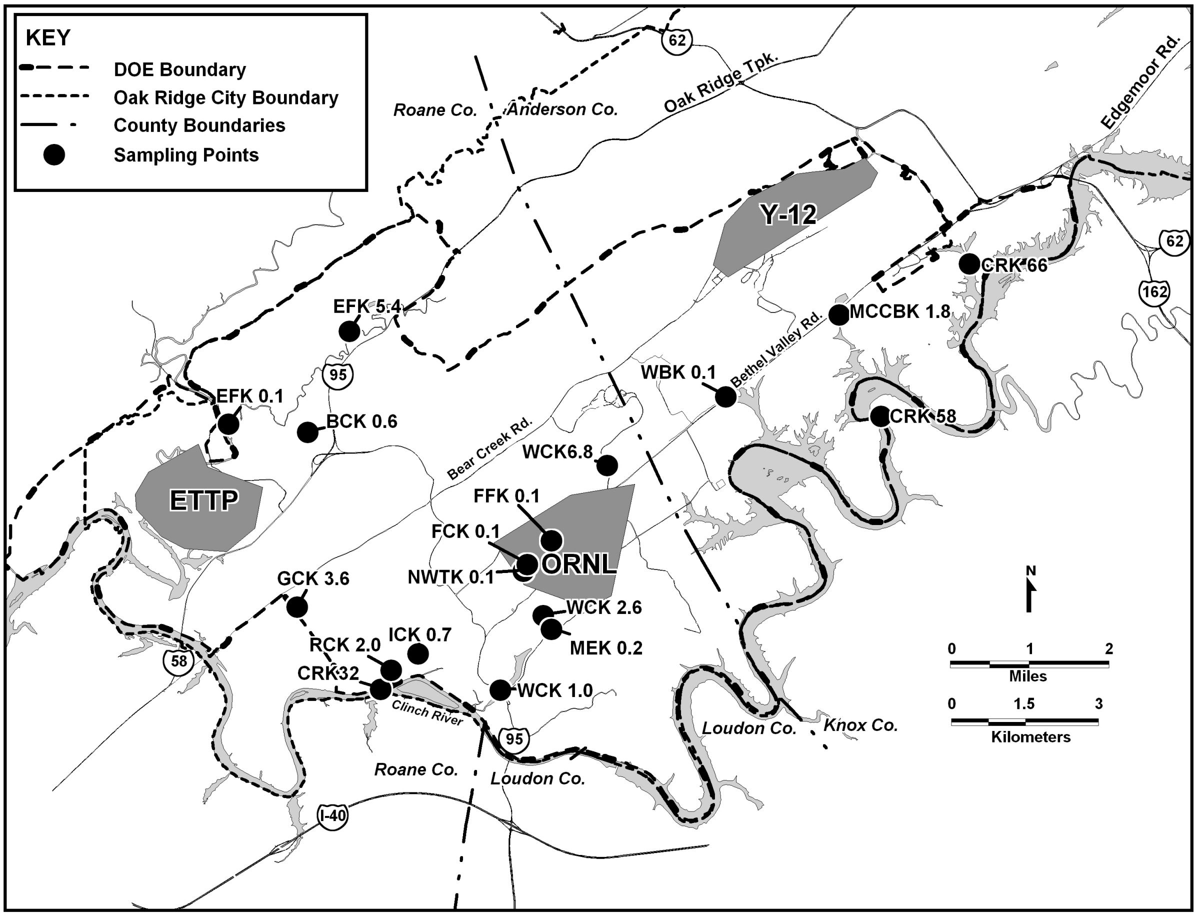


Fig. 5.26. ORNL surface water sampling locations.

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 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.

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.

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.

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

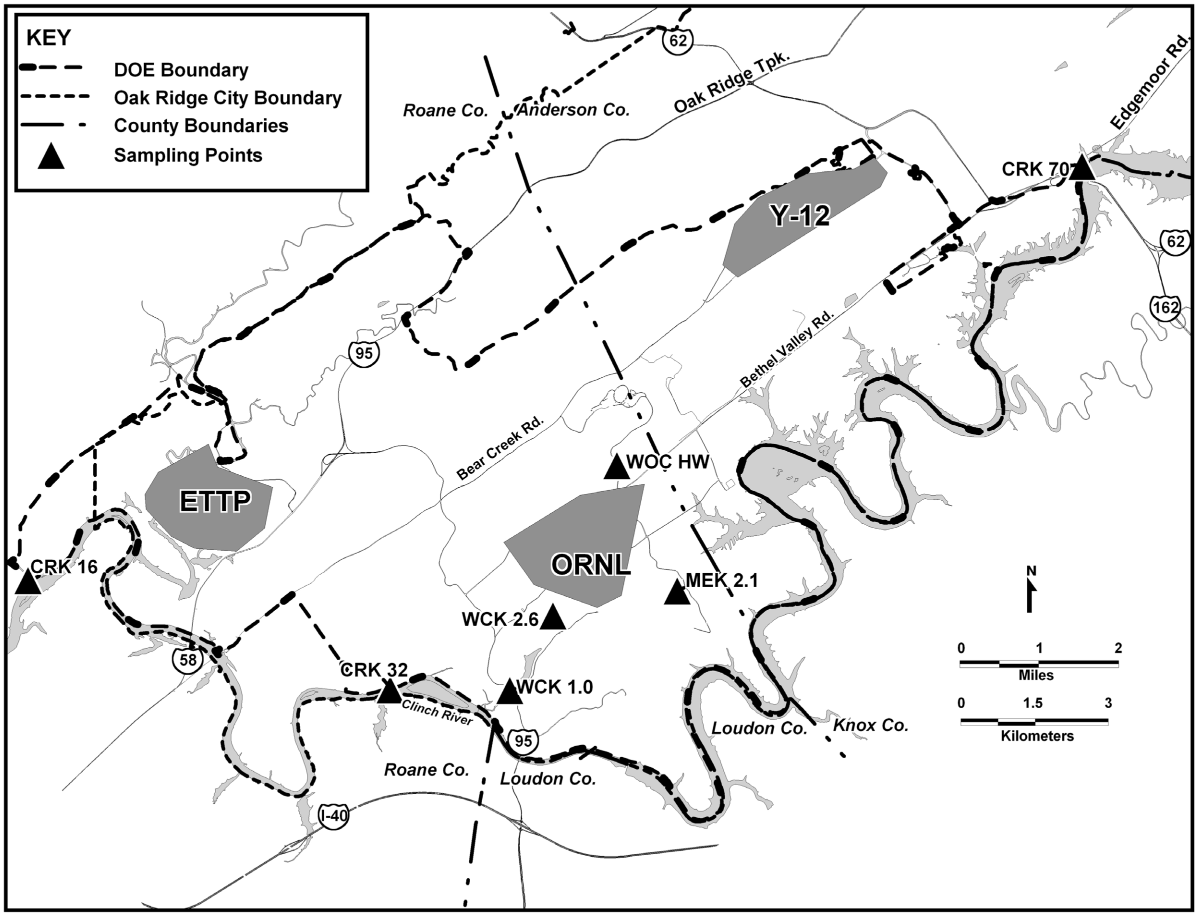


Fig. 5.27. ORNL sediment sampling locations.

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 (TDEC 2004). 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 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) 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

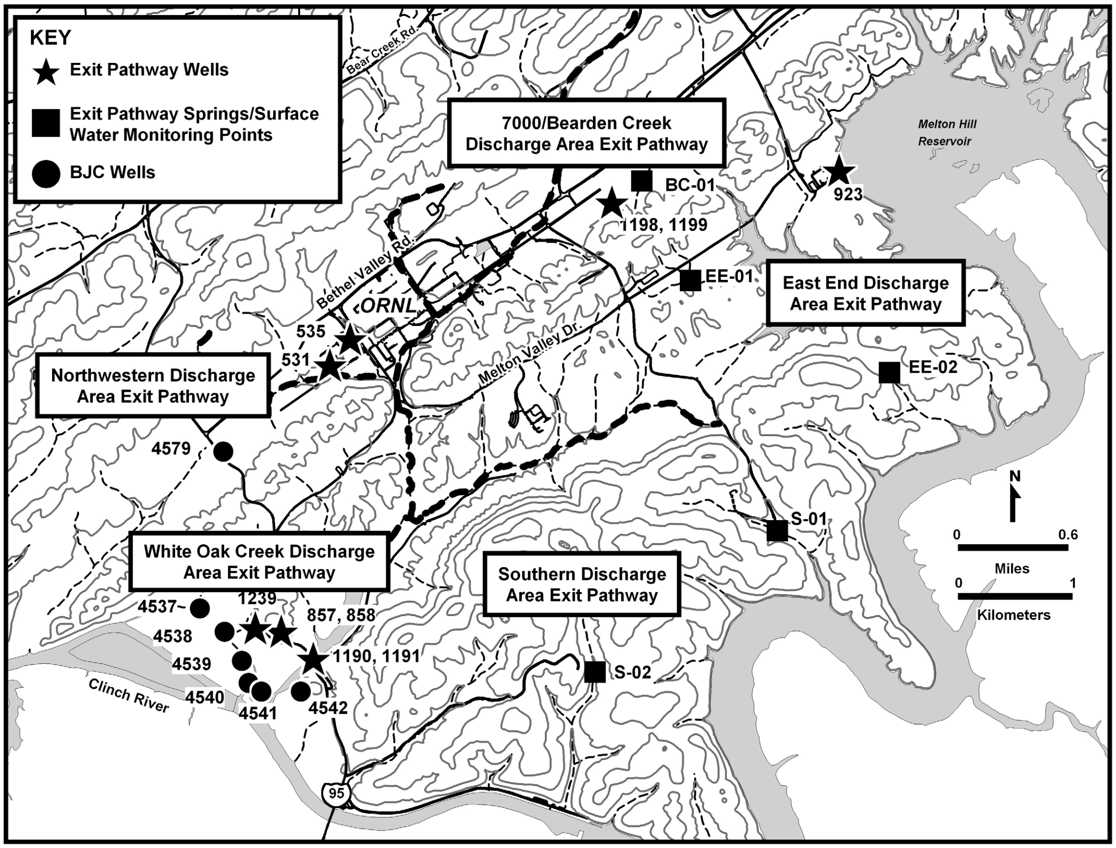


Fig. 5.28. UT-Battelle exit pathway groundwater monitoring locations at ORNL, 2005.

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

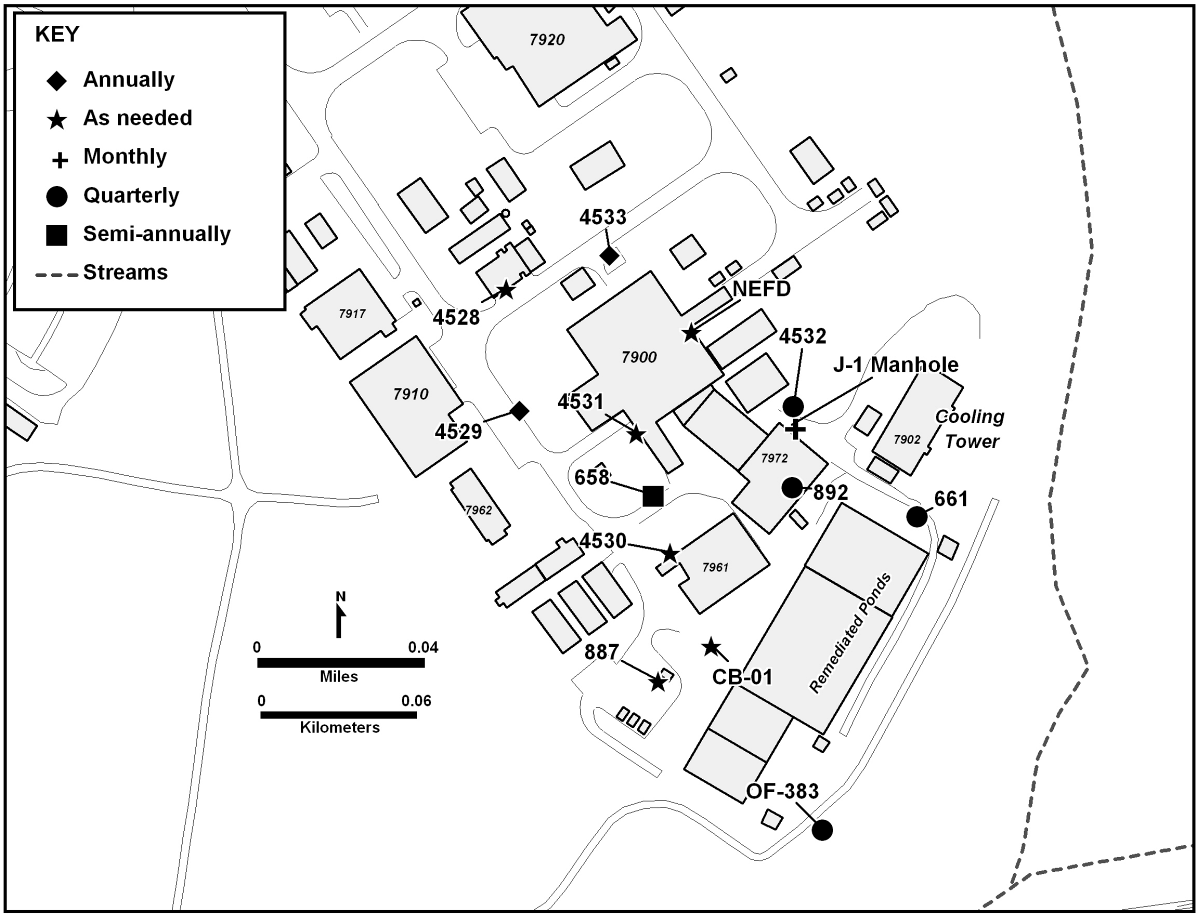


Fig. 5.29. Groundwater monitoring locations at HFIR, 2005.

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. 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 locations. 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 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

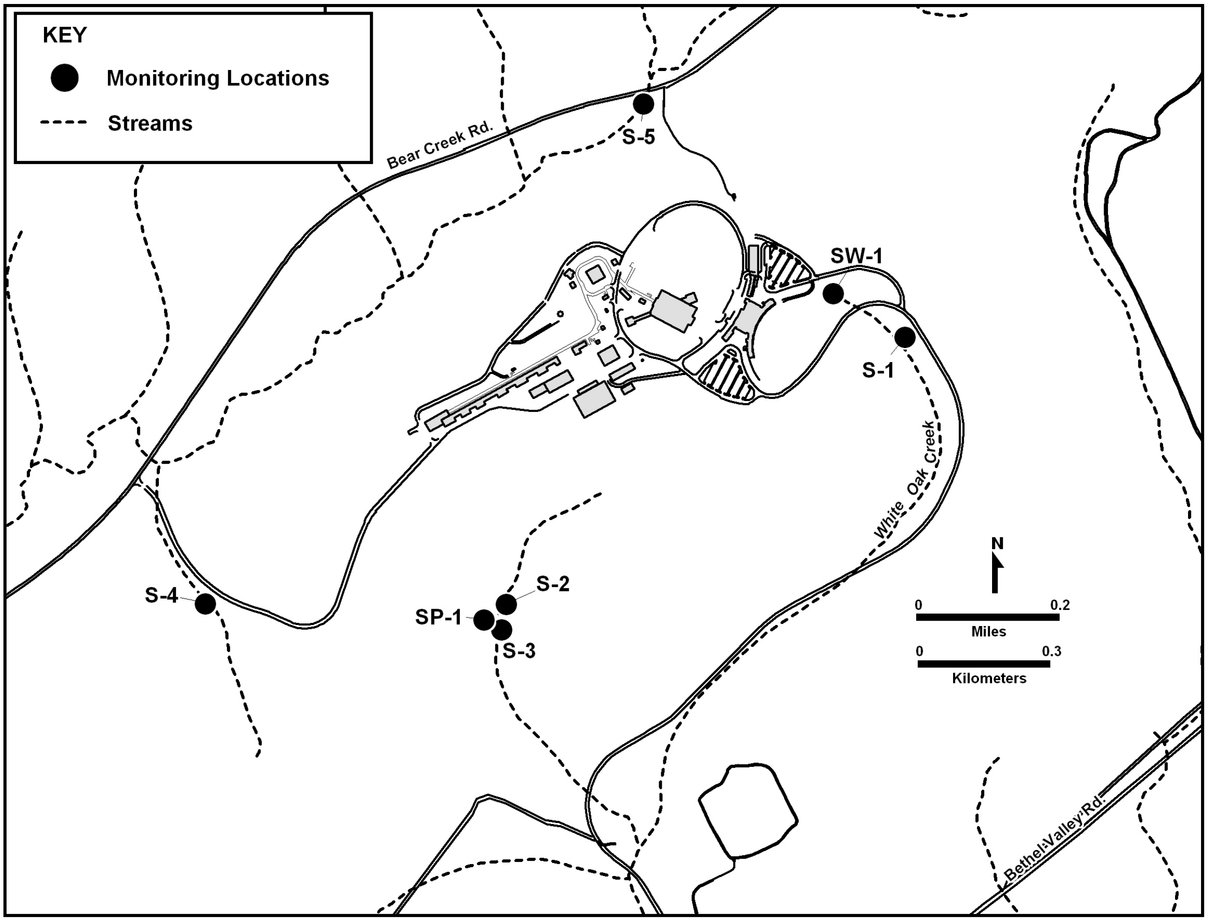


Fig. 5.30. Groundwater monitoring locations at SNS, 2005.

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.

5.13 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 2006–2007.

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].