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 at ORNL. 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). In 2006, construction of the Spallation Neutron Source (SNS) project was completed. The purpose of the project was to design, construct, and commission into operation an accelerator-based, pulsed neutron facility for studies of the structure and dynamics of materials. Activities that will lead to SNS start-up were initiated in April 2006. Emissions from these activities are included in this report. Radionuclide emissions from the SNS are discharged through a single emission point, the SNS Central Exhaust Facility stack (8915), which has the potential to emit radionuclides that would result in a dose equal to or greater than 0.1 mrem/year (0.001 mSv/year) to the most exposed member of the public, and therefore continuous emission sampling or monitoring is required.

The major radiological emission point sources for ORNL consist of the following five stacks located in Bethel and Melton Valleys (Fig. 5.1) and the SNS Central Exhaust Facility stack located on Chestnut Ridge:

- 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;
- 7911 Melton Valley complex, which includes the High Flux Isotope Reactor (HFIR) and the Radiochemical Engineering Development Center (REDC); and
- 8915 SNS Central Exhaust Facility stack.

In 2006, there were 19 minor point/group sources, and emission calculations/estimates were made for each of them.

5.1.1 Sample Collection and Analytical Procedure

Five of the major point sources (2026, 3020, 3039, 7503, and 7911) are 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

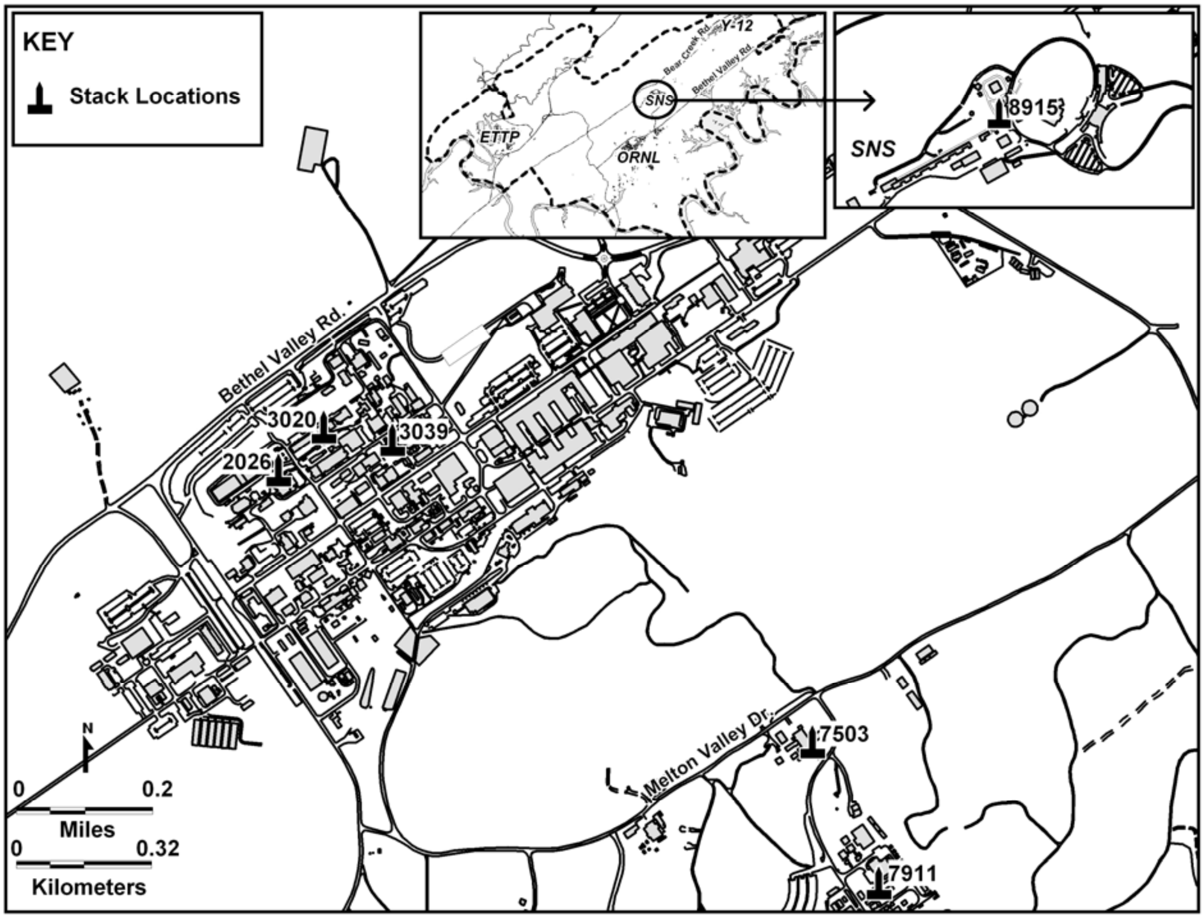

Fig. 5.1. Locations of major stacks (radiological emission points) at ORNL.

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. The 8915 stack is equipped with an in-stack radiation detector. The detector monitors radioactive gases flowing through the exhaust stack and provides a continual readout of detected activity using a scintillator probe. The detector is calibrated to correlate with isotopic emissions.

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 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, the sample probes for all of the stacks are rinsed, except for 8915, and the rinsate is collected and submitted for isotopic analysis identical to that performed on the particulate filters. A probe-cleaning program has not been determined necessary for 8915 since the sample probe is a scintillator probe used to detect radiation and not to collect a sample of stack exhaust emissions. It is not anticipated that contaminant deposits would collect on the scintillator probe.

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 in 2006 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 ^{131}I are presented in Figs. 5.2 and 5.3, respectively. The tritium emissions for 2006 totaled approximately 63.9 Ci (Fig. 5.2), which is a decrease from 2005. The ^{131}I emissions for 2006 totaled 0.05 Ci (Fig. 5.3), which is in line with reported emissions for the past four years. The major contributor to the off-site dose at ORNL historically has been ^{41}Ar, which is emitted as a nonadsorbable gas from the 7911 Melton Valley complex stack. However, due to 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 2006 were 229 Ci; ^{138}Cs emissions were 1210 Ci (Fig. 5.4). Emissions of ^{41}Ar were very low in 2006 because the HFIR was in an extended outage for installation of the Cold Neutron Source. The calculated radiation dose to the maximally exposed off-site individual from all radiological airborne release points at ORNL during 2006 was 0.06 mrem. This dose is well below the NESHAP standard of 10 mrem and is less than 0.02% 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 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 NOx and opacity. During CY 2006, no permit limits were exceeded.

Table 5.1. Radiological airborne emissions from all sources at ORNL, 2006 (Ci)[a]

Isotope	Stack							
	X-2026	X-3020	X-3039	X-7503	X-7911	X-8915	Total Minor Sources	Total ORNL
^{225}Ac							1.20E-06	1.20E-06
^{228}Ac							1.09E-05	1.09E-05
^{228}Ac							1.45E-08	1.45E-08
^{110m}Ag							2.51E-06	2.51E-06
^{241}Am	2.01E-07	1.44E-07	7.28E-07	5.41E-09	8.71E-09		7.27E-07	1.81E-06
^{243}Am							2.52E-11	2.52E-11
^{39}Ar							1.80E-05	1.80E-05
^{41}Ar					2.29E+02	5.00E-02	3.36E-02	2.29E+02
^{43}Ar[b]						5.10E-01		5.10E-01
^{44}Ar[b]						2.40E-01		2.40E-01
^{133}Ba							7.43E-09	7.43E-09
^{139}Ba					2.71E-01			2.71E-01
^{140}Ba					1.25E-04		4.90E-16	1.25E-04
^{7}Be	8.00E-08	1.67E-07	8.86E-06	1.18E-08	3.78E-07		4.68E-07	9.97E-06
^{212}Bi							4.44E-08	4.44E-08
^{212}Bi							3.34E-08	3.34E-08
^{213}Bi							1.12E-05	1.12E-05
^{214}Bi							3.43E-08	3.43E-08
^{72}Br[c]						3.00E-02		3.00E-02
^{11}C						1.25E+00	4.48E-02	1.29E+00
^{14}C							1.20E-07	1.20E-07
^{139}Ce							2.08E-09	2.08E-09
^{141}Ce							3.45E-08	3.45E-08
^{144}Ce							4.75E-11	4.75E-11
^{249}Cf							7.95E-14	7.95E-14
^{250}Cf							3.61E-07	3.61E-07
^{251}Cf							1.47E-14	1.47E-14
^{252}Cf					9.74E-10		1.00E-07	1.01E-07
^{242}Cm							3.96E-11	3.96E-11
^{243}Cm							3.69E-11	3.69E-11
^{244}Cm	1.22E-06	1.86E-08	1.55E-07	2.69E-08	8.50E-08		6.68E-05	6.83E-05
^{245}Cm							1.73E-09	1.73E-09
^{246}Cm							1.79E-09	1.79E-09
^{248}Cm							1.66E-13	1.66E-13
^{56}Co							9.99E-09	9.99E-09
^{57}Co							1.05E-06	1.05E-06
^{58}Co							1.20E-09	1.20E-09
^{60}Co			2.53E-06				1.52E-04	1.55E-04
^{51}Cr							1.08E-08	1.08E-08
^{134}Cs							7.25E-05	7.25E-05
^{136}Cs							2.76E-05	2.76E-05
^{137}Cs	3.76E-06	9.78E-07	2.26E-04	1.66E-08	8.30E-05		3.51E-03	3.83E-03
^{138}Cs					1.21E+03			1.21E+03
^{152}Eu							1.90E-05	1.90E-05
^{154}Eu							1.05E-04	1.05E-04
^{155}Eu							2.71E-05	2.71E-05
^{55}Fe							3.27E-06	3.27E-06

Table 5.1 (continued)

Isotope	Stack							
	X-2026	X-3020	X-3039	X-7503	X-7911	X-8915	Total Minor Sources	Total ORNL
^{59}Fe							8.80E-06	8.80E-06
^{67}Ga							1.82E-15	1.82E-15
^{153}Gd							3.00E-09	3.00E-09
^{68}Ge							3.75E-15	3.75E-15
^{3}H	1.39E+00		3.96E+01	1.54E+00	1.96E+01	1.10E-01	1.67E+00	6.39E+01
^{172}Hf							6.85E-14	6.85E-14
^{175}Hf							8.09E-13	8.09E-13
^{178m}Hf							5.14E-15	5.14E-15
^{181}Hf							3.51E-15	3.51E-15
^{203}Hg							4.04E-12	4.04E-12
^{117}I[d]						5.00E-02		5.00E-02
^{119}I[d]						4.00E-02		4.00E-02
^{124}I							5.27E-16	5.27E-16
^{125}I							5.22E-06	5.22E-06
^{126}I							2.33E-08	2.33E-08
^{129}I							2.60E-05	2.60E-05
^{131}I					5.19E-02		2.10E-04	5.21E-02
^{132}I					5.83E-01			5.83E-01
^{133}I					2.76E-01			2.76E-01
^{134}I					8.06E-01			8.06E-01
^{135}I					8.26E-01			8.26E-01
^{192}Ir							1.04E-08	1.04E-08
^{40}K							8.08E-05	8.08E-05
^{75}Kr[e]						3.00E-01		3.00E-01
^{77}Kr[f]						2.50E-01		2.50E-01
^{81}Kr							1.08E-12	1.08E-12
^{85}Kr					1.80E+02		9.17E-02	1.80E+02
^{85m}Kr					1.11E-01			1.11E-01
^{87}Kr					5.67E+01	1.10E-01		5.68E+01
^{88}Kr					5.04E+01			5.04E+01
^{89}Kr					2.52E+01	6.30E-01		2.58E+01
^{140}La					2.41E-03		4.63E-05	2.46E-03
^{173}Lu							7.57E-13	7.57E-13
^{174}Lu							1.60E-13	1.60E-13
^{177m}Lu							1.34E-14	1.34E-14
^{54}Mn							2.86E-06	2.86E-06
^{93}Mo							3.11E-08	3.11E-08
^{99}Mo							6.20E-03	6.20E-03
^{13}N						3.00E-02	1.69E-01	1.99E-01
^{22}Na							4.53E-09	4.53E-09
^{92}Nb							6.24E-09	6.24E-09
^{92m}Nb							3.41E-13	3.41E-13
^{93m}Nb							4.88E-09	4.88E-09
^{94}Nb							2.37E-06	2.37E-06
^{95}Nb							8.55E-09	8.55E-09
^{59}Ni							6.00E-11	6.00E-11
^{63}Ni							1.60E-08	1.60E-08

Table 5.1 (continued)

Isotope	Stack							
	X-2026	X-3020	X-3039	X-7503	X-7911	X-8915	Total Minor Sources	Total ORNL
^{239}Np							1.03E-11	1.03E-11
^{15}O						1.00E-01		1.00E-01
^{185}Os							2.18E-12	2.18E-12
^{191}Os			1.40E-02					1.40E-02
^{210}Pb							1.11E-06	1.11E-06
^{212}Pb			9.27E-01	7.08E-02			1.87E-03	1.00E+00
^{212}Pb	2.23E-01				6.67E-02		5.95E-06	2.90E-01
^{214}Pb							9.58E-09	9.58E-09
^{144}Pm							7.47E-09	7.47E-09
^{238}Pu	7.86E-08	1.07E-08	8.94E-08	3.91E-09			1.05E-06	1.23E-06
^{239}Pu	2.48E-07	1.20E-07	1.66E-06	1.43E-08	5.39E-09		9.70E-07	3.02E-06
^{240}Pu							6.75E-10	6.75E-10
^{241}Pu							6.48E-10	6.48E-10
^{242}Pu							6.97E-13	6.97E-13
^{244}Pu							1.88E-09	1.88E-09
^{225}Ra							1.00E-06	1.00E-06
^{226}Ra							4.55E-05	4.55E-05
^{228}Ra							4.27E-08	4.27E-08
^{228}Ra							1.45E-08	1.45E-08
^{88}Rb							1.76E-13	1.76E-13
^{89}Rb							2.10E-13	2.10E-13
^{188}Re							1.51E-05	1.51E-05
^{103}Ru							5.35E-11	5.35E-11
^{106}Ru							2.38E-05	2.38E-05
^{35}S							5.00E-06	5.00E-06
^{124}Sb							1.01E-07	1.01E-07
^{125}Sb							6.33E-06	6.33E-06
^{126}Sb							1.90E-16	1.90E-16
^{46}Sc							2.67E-10	2.67E-10
^{75}Se			2.20E-03					2.20E-03
^{113}Sn							4.00E-14	4.00E-14
^{85}Sr							2.00E-09	2.00E-09
^{89}Sr							3.82E-05	3.82E-05
^{90}Sr	4.14E-07	6.65E-07	3.79E-05	9.98E-09	5.55E-06		2.08E-03	2.13E-03
^{91}Sr							5.48E-08	5.48E-08
^{92}Sr							1.90E-13	1.90E-13
^{179}Ta							9.49E-14	9.49E-14
^{182}Ta							3.40E-08	3.40E-08
^{95m}Tc							2.30E-14	2.30E-14
^{96}Tc							1.97E-14	1.97E-14
^{99}Tc							2.41E-05	2.41E-05
^{99m}Tc							1.20E-16	1.20E-16
^{125m}Te							1.20E-06	1.20E-06
^{129m}Te							3.76E-07	3.76E-07
^{228}Th	3.11E-08	4.22E-09			2.57E-09		6.18E-11	3.80E-08
^{228}Th			8.43E-09	1.03E-09			3.83E-06	3.84E-06
^{229}Th							1.02E-08	1.02E-08

Table 5.1 (continued)

Isotope	Stack							
	X-2026	X-3020	X-3039	X-7503	X-7911	X-8915	Total Minor Sources	Total ORNL
^{230}Th	5.83E-09	3.94E-09			1.74E-08		1.02E-09	2.82E-08
^{230}Th			1.36E-08	3.09E-09			1.16E-08	2.83E-08
^{232}Th	3.01E-10	1.08E-09			3.00E-09		8.97E-12	4.39E-09
^{232}Th			3.48E-09	7.27E-11			1.08E-05	1.08E-05
^{234}Th							2.34E-05	2.34E-05
^{234}Th							2.51E-07	2.51E-07
^{208}Tl							5.46E-11	5.46E-11
^{208}Tl							2.54E-06	2.54E-06
^{232}U							8.07E-16	8.07E-16
^{233}U							1.06E-05	1.06E-05
^{234}U	1.95E-07	6.91E-08			2.09E-07		1.36E-04	1.36E-04
^{234}U			2.91E-07	1.86E-08			1.07E-05	1.10E-05
^{235}U	2.76E-09	1.69E-09	2.39E-08	1.70E-10	3.40E-08		1.83E-06	1.89E-06
^{236}U							3.26E-07	3.26E-07
^{238}U	3.68E-09	7.75E-09			7.74E-08		2.04E-05	2.05E-05
^{238}U			4.52E-08	1.63E-09			1.52E-06	1.56E-06
^{49}V							2.30E-10	2.30E-10
^{181}W							5.75E-09	5.75E-09
^{185}W							3.33E-08	3.33E-08
^{188}W							1.01E-05	1.01E-05
$^{118}Xe^{g}$						3.00E-02		3.00E-02
$^{119}Xe^{g}$						2.30E-01		2.30E-01
$^{121}Xe^{h}$						5.00E-02		5.00E-02
^{123}Xe						8.00E-02		8.00E-02
^{127}Xe							7.28E-09	7.28E-09
^{129m}Xe							2.29E-09	2.29E-09
^{131m}Xe					4.79E+00		2.82E-06	4.79E+00
^{133}Xe			4.50E-06		1.59E+00		2.42E-08	1.59E+00
^{133m}Xe					1.84E+00			1.84E+00
^{135}Xe					2.57E+01	4.00E-02		2.57E+01
^{135m}Xe					1.76E+01			1.76E+01
^{137}Xe					9.91E+01			9.91E+01
^{138}Xe					1.27E+02			1.27E+02
^{87}Y							1.90E-16	1.90E-16
^{88}Y							2.81E-06	2.81E-06
^{90}Y	4.14E-07	6.65E-07	3.79E-05	9.98E-09	5.55E-06		2.08E-03	2.13E-03
^{65}Zn							6.33E-06	6.33E-06
^{88}Zr							8.15E-08	8.15E-08
^{95}Zr							6.27E-06	6.27E-06

[a] 1 Ci = 3.7E+10 Bq
[b] Ar^{41} was used as a surrogate for Ar^{43} and Ar^{44}.
[c] Y^{86} was used as a surrogate for Br^{62}.
[d] I^{122} was used as a surrogate for I^{117} and I^{119}.
[e] Rb^{86} was used as a surrogate for Kr^{75}.
[f] Ga^{68} was used as a surrogate for Kr^{77}.
[g] Cs^{126} was used as a surrogate for Xe^{118} and Xe^{119}.
[h] Xe^{123} was used as a surrogate for Xe^{121}.

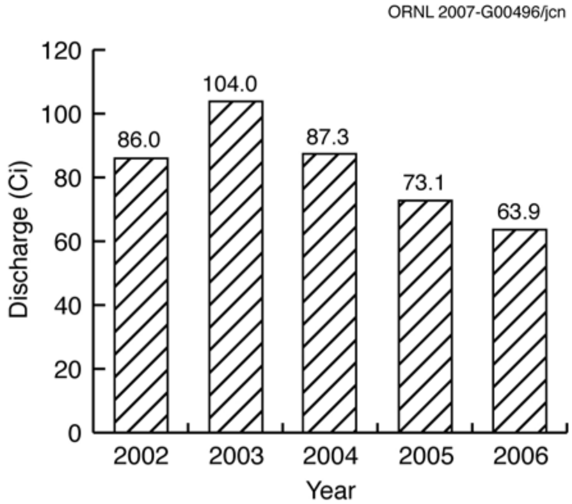

Fig. 5.2. Total discharges of ^{3}H from ORNL to the atmosphere, 2002–2006

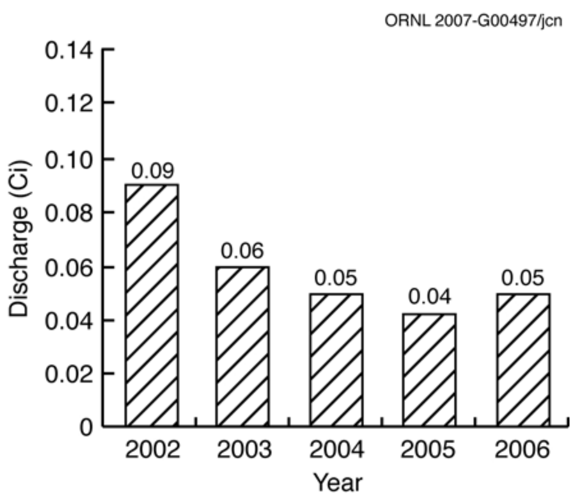

Fig. 5.3. Total discharges of ^{131}I from ORNL to the atmosphere, 2002–2006.

For the period from July 1, 2005, through June 30, 2006, ORNL paid $5,643.49 in annual emission fees to TDEC. These fees are based on a combination of actual and allowable emissions. During 2006, 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

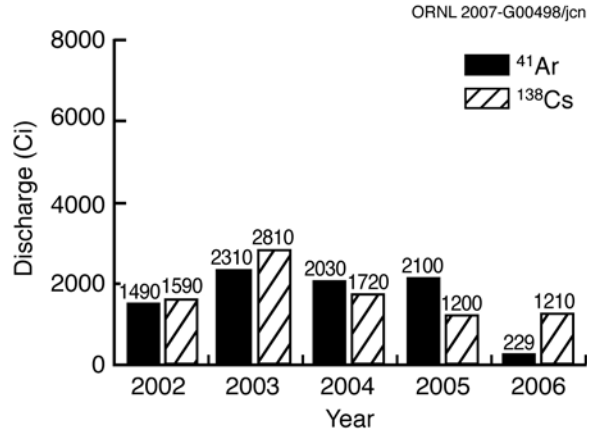

Fig. 5.4. Total discharges of ^{41}Ar and ^{138}Cs from ORNL to the atmosphere, 2002–2006.

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, 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 2006.

Table 5.2. Actual vs allowable air emissions from ORNL steam production, 2006

Pollutant	Emissions (tons per year)[a]		Percentage of allowable
	Actual	Allowable	
SO_2	6	1277	0.5%
PM	4	71	5.6%
CO	33	196	16.8%
VOC	2	14	14.3%
NO_X	66	380	17.4%

[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 ORNL NPDES Summary

5.4.1 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, but the limits and conditions of that permit remain in effect until renewal by TDEC. The 1996 NPDES permit includes 164 separate outfalls and monitoring points. Data collected to meet the requirements of the permit are submitted to the state of Tennessee in the monthly NPDES Discharge Monitoring Report.

The ORNL NPDES Permit requires sampling of point-source outfalls before discharge into receiving waters or before mixing 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—Coal Yard Runoff Treatment Facility (CYRTF),
- X12—Process Waste Treatment Complex (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),

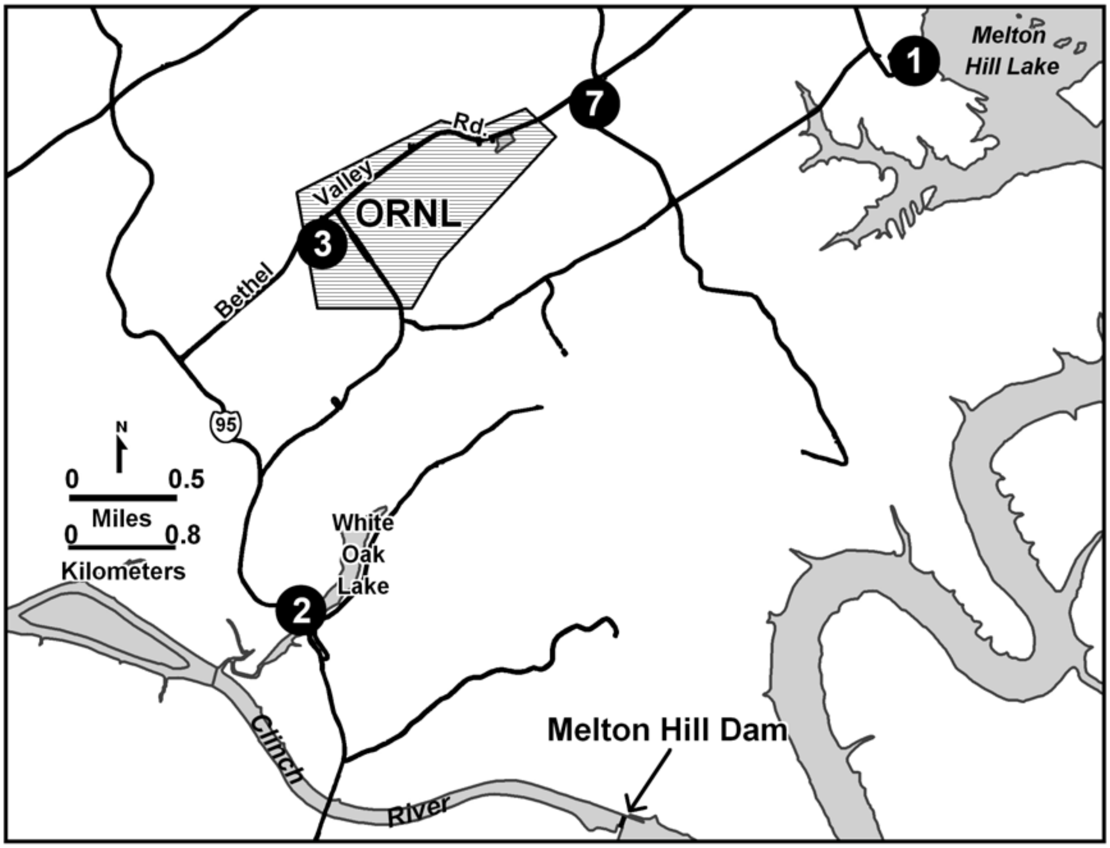

Fig. 5.5. Locations of ambient air monitoring stations at ORNL.

- 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 5.4. 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 at these three points. Permit noncompliances in 2006 are discussed below and are shown in Appendix E.

During 2006, ORNL had five measurements that exceeded numeric NPDES permit limits. Based on approximately 7000 compliance measurements and analyses, the rate of compliance with the ORNL NPDES permit was approximately 99.9%. The noncompliances occurred at the ORNL Sewage Treatment Plant (STP), where routine testing indicated a transient or temporary condition of effluent toxicity, and four temperature profile measurements on a single day indicating criterion exceedance at cooling tower blowdown outfall 281. Confirmatory toxicity testing at the sewage plant did not indicate effluent toxicity; therefore, no cause was determined for the initial condition. STP operating parameters were normal during both the initial and confirmatory toxicity tests. Additional operational modifications are being evaluated in cooperation with TDEC in an attempt to mitigate the temperature issue at outfall 281.

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.

Table 5.3. Radionuclide concentrations measured at ORNL perimeter air monitoring stations, 2006 (pCi/mL)[a]

Parameter	Average concentration	No. detected/total
	Station 1	
Alpha	1.64E-09	1/1
^{7}Be	1.99E-08	1/1
Beta	1.94E-08	1/1
^{3}H	1.32E-07	0/4
^{40}K	3.25E-07	26/26
^{234}U	1.06E-11	1/1
^{235}U	1.76E-12	1/1
^{238}U	1.03E-11	1/1
^{Tot}U	2.27E-11	1/1
	Station 2	
Alpha	9.44E-10	1/1
^{7}Be	2.14E-08	1/1
Beta	2.08E-08	1/1
^{3}H	3.60E-06	3/4
^{40}K	3.82E-07	26/26
^{234}U	1.67E-11	1/1
^{235}U	1.51E-12	1/1
^{238}U	8.12E-12	1/1
^{Tot}U	2.63E-11	1/1
	Station 3	
Alpha	8.14E-10	1/1
^{7}Be	1.84E-08	1/1
Beta	1.60E-08	1/1
^{3}H	1.73E-06	1/4
^{40}K	3.35E-07	26/26
^{234}U	1.26E-11	1/1
^{235}U	2.20E-12	1/1
^{238}U	1.96E-11	1/1
^{Tot}U	3.43E-11	1/1
	Station 7	
Alpha	1.78E-09	1/1
^{7}Be	2.21E-08	1/1
Beta	2.09E-08	1/1
^{3}H	-6.73E-07	1/4
^{40}K	3.39E-07	25/26
^{234}U	9.15E-12	1/1
^{235}U	1.15E-12	1/1
^{238}U	1.34E-11	1/1
^{Tot}U	2.37E-11	1/1

[a]1 pCi = 3.7×10^{-2} Bq.

5.4.1.1 Radiological Monitoring Plan

ORNL monitors radioactivity at NPDES outfalls that have the 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 5.5 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.

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 2006, samples were collected at 21 of the 27 category outfalls. The remaining six outfalls were not sampled, either because they are no longer in service, or because there was not any discharge or were otherwise not able to be sampled during sampling attempts.

The three treatment facilities included in the ORNL radiological monitoring plan are the STP, the CYRTF, and the 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 where applicable (there are no DCGs for gross alpha and gross beta activities) when at least one individual measurement 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

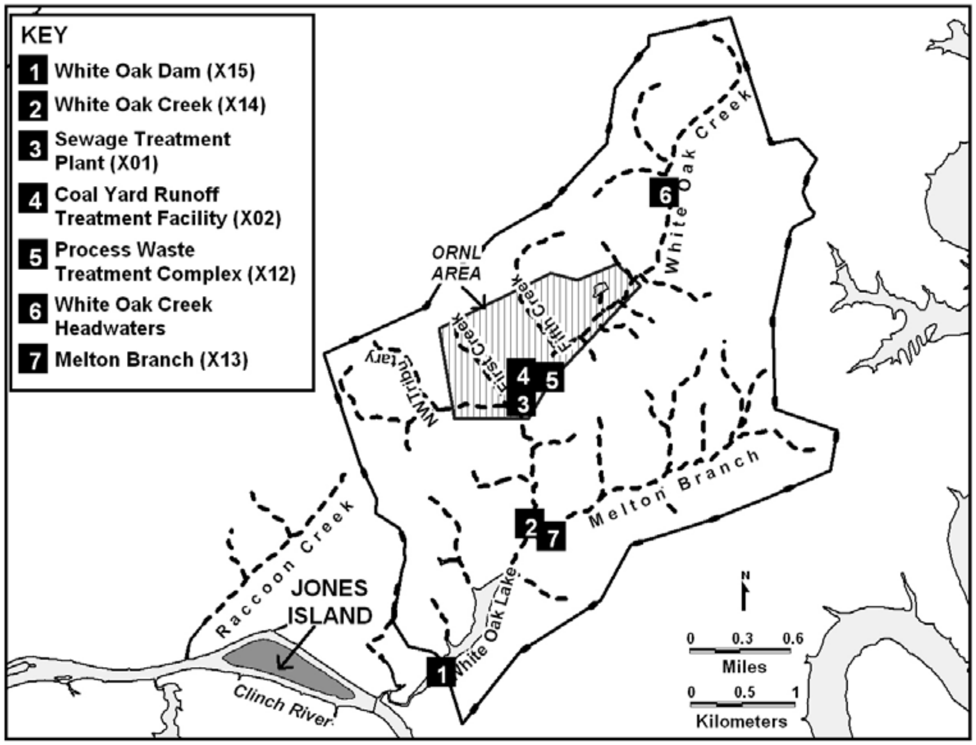

Fig. 5.6. ORNL surface water, National Pollutant Discharge Elimination System, and reference sampling locations.

instream 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 2006, one NPDES outfall had measured annual average concentrations of radioactivity equaling or exceeding 100% of DCG concentrations. The average of three measurements of $^{243/244}$Cm at outfall 080 was 1,100 pCi/L (18 times the DCG for ^{244}Cm or 22 times the DCG for ^{243}Cm. (Although the analytical test does not differentiate between ^{243}Cm and ^{244}Cm, the analyst who ran the test believed that most of the activity was from the ^{244}Cm isotope.) The average concentration of three measurements of ^{241}Am at outfall 080 was also significant (87% of the DCG) as was $^{239/240}$Pu (50% of the DCG, which is the same for both isotopes). The flow rates at the outfall when the elevated concentrations were measured were approximately 0.1 gal/min; therefore significant changes in contaminant concentrations have not been detected in downstream monitoring. Evaluation of these data, along with data from additional water samples and a sediment sample collected by Bechtel Jacobs (the Oak Ridge environmental management contractor) indicates that the contamination present at outfall 080, although greater than the DCG, is within the target human health risk range for the Record of Decision for Interim Actions in Melton Valley. The increase in contaminant concentrations at outfall 080 was first detected in June following the grouting of a nearby abandoned waste pipeline earlier in the year. It is theorized that some residual contaminated material was pushed out of the pipeline through an unknown line break as grout was pumped into the pipe, and contamination migrated into the Outfall 080 pipe network. The radiological signatures of the waste in the abandoned pipeline and the outfall effluent since June are consistent. The DOE Office of Science and DOE-EM are working together to determine appropriate monitoring and actions.

In addition to outfall 080, the annual average concentration of at least one radionuclide exceeded 4% of the relevant DCG concentration at six NPDES outfalls (X01, X12, 085, 204, 302,

Table 5.4. National Pollutant Discharge Elimination System (NPDES) compliance at ORNL, 2006
(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	1[c]	5	80
LC_{50} for fathead minnows (%)					41.1	0	4	100
Ammonia, as N (summer)	2.84	4.26	2.5	3.75		0	79	100
Ammonia, as N (winter)	5.96	8.97	5.25	7.9		0	77	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	5	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[d]	100
NOEC for fathead minnows (%)					1.3	0	0[d]	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

Table 5.4 (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]
X12 (Process Waste Treatment Complex)								
LC_{50} for *Ceriodaphnia* (%)					100	0	4	100
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	6	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	19	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	331	100
Cooling tower blowdown/ cooling water outfalls								
pH (std. units)				9.0	6.0	0	48	100
Total residual oxidant			0.011	0.019		0	48	100

[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]*Ceriodaphnia* reproduction was statistically lower than the control at all concentrations for the sample collected at X01 in May 2006. A confirmatory sample was collected later in the month and the results were within permit requirements.

[d]Insufficient discharge for chronic test and determination of NOEC for each of the quarterly tests.

Table 5.5. 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	Carbon - 14
Outfall 001	Annually	X						
Outfall 080	Monthly	X	X	X	X	X		
Outfall 081	Annually		X					
Outfall 085	Quarterly	X	X			X	X	
Outfall 086[b]	When discharges		X		X			
Outfall 087	Annually		X	X				
Outfall 203	Annually		X					
Outfall 204	Quarterly	X	X			X		
Outfall 205	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[c]	Annually		X					
Outfall 265	Annually		X	X				
Outfall 281	Quarterly	X	X	X	X			
Outfall 282	Quarterly	X	X					
Outfall 284[c]	Annually		X					
Outfall 290[c]	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[f]	X		X[f]
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]Outfall no longer exists.
[c]No discharge present.
[d]Physically removed in late 2004; eliminated as part of the HFIR ponds remediation project.
[e]No longer discharges (plugged).
[f]Added to the plan in January 2006.

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 STP Discharge (outfall X01) was 12% of the DCG. Concentrations of three radionuclides measured in the discharge from the PWTC

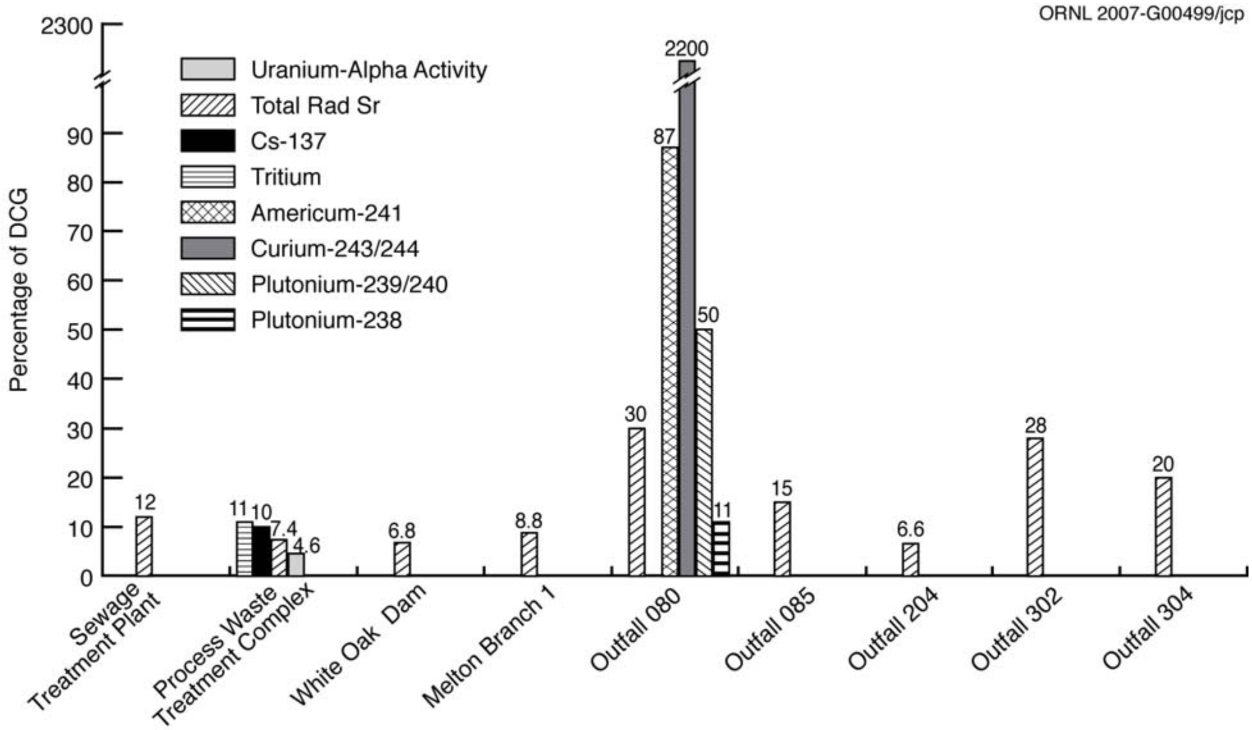

Fig. 5.7. Radionuclides at ORNL sampling sites having average concentrations greater than 4% of the relevant derived concentration guides in 2006.

(outfall X12) were greater than 4% of the DCG: ^{137}Cs (10%), $^{89/90}$Sr (7.4%), and tritium (11%). In addition to outfall 080 discussed in the paragraph above, four category outfalls had measured concentrations of a parameter that were greater than 4% of a DCG: outfall 085 ($^{89/90}$Sr, 15%), outfall 204 ($^{89/90}$Sr, 6.6%), outfall 302 ($^{89/90}$Sr, 28%), and outfall 304 ($^{89/90}$Sr, 20%). At the in-stream monitoring station on Melton Branch (Location X13), $^{89/90}$Sr was measured at 8.8% of the DCG, and at the X15 monitoring station at White Oak Dam, $^{89/90}$Sr was measured at 6.8% 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 2006 show a general decrease in levels from recent years, with the exception of ^{137}Cs, which is closer to the average. The reductions are presumably the result of the remediation activities in the WOC watershed.

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

Monitoring storm water runoff through NPDES-permitted outfalls for radioactivity is

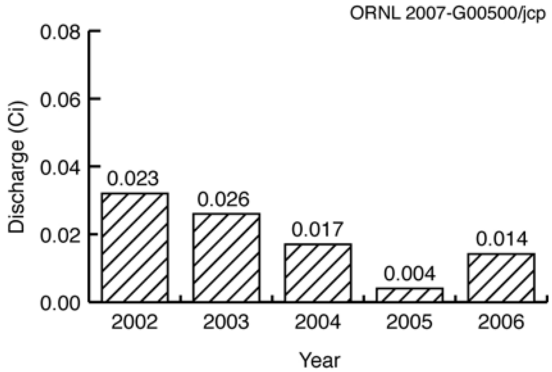

Fig. 5.8. Cobalt-60 discharges at White Oak Dam, 2002–2006.

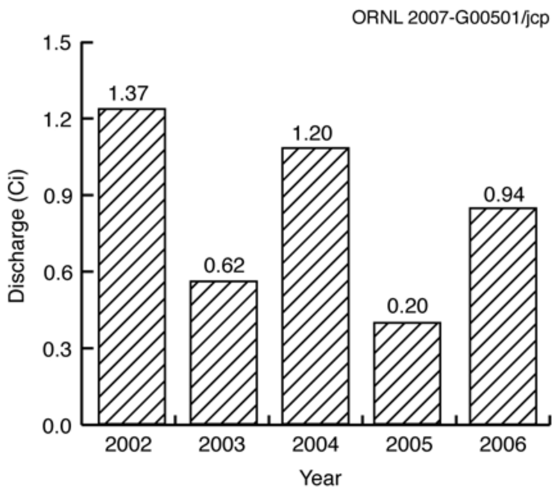

Fig. 5.9. Cesium-137 discharges at White Oak Dam, 2002–2006.

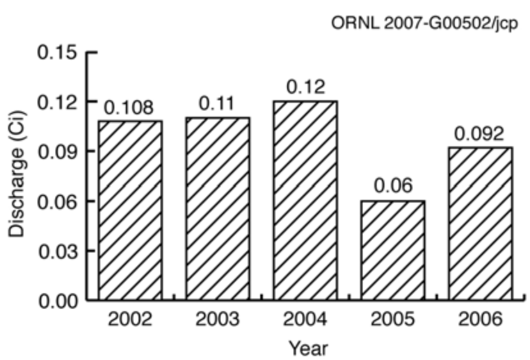

Fig. 5.10. Gross alpha discharges at White Oak Dam, 2002–2006.

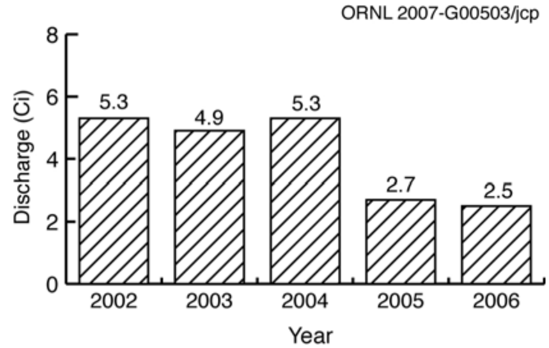

Fig. 5.11. Gross beta discharges at White Oak Dam, 2002–2006.

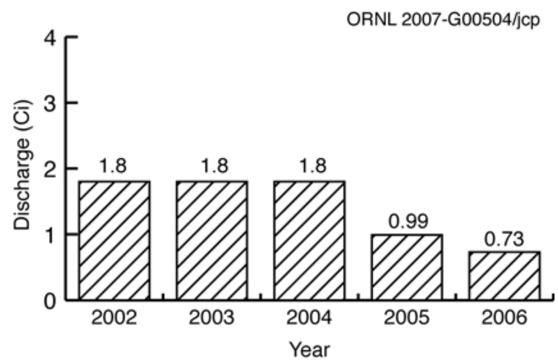

Fig. 5.12. Total radioactive strontium discharges at White Oak Dam, 2002–2006.

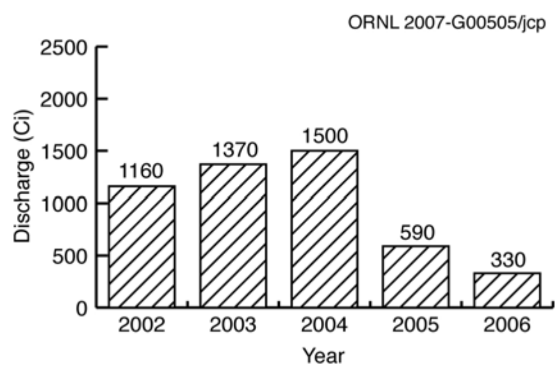

Fig. 5.13. Tritium discharges at White Oak Dam, 2002–2006.

conducted on an NPDES permit-year basis; however, storm water results are discussed on a calendar year basis in this report. A total of 24 storm water outfalls were monitored in CY 2006.

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 2006, additional analyses were performed on samples from one outfall—outfall 165—in an attempt to identify the radioisotopes contributing to the gross alpha activities in the sample. The gross alpha activity was found to be from uranium isotopes, particularly $^{233/234}$U.

Of the 127 individual storm water sample results collected in 2006, 94 (74%) 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. Two outfalls had measurements of radionuclide concentrations in storm water that were greater than 4% of DCG levels: outfall 165 ($^{89/90}$Sr, 52% and $^{233/234}$U, 4.8%) and outfall 362 (^{40}K, 5.4%).

5.4.1.2 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, depending on outfall 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 2006 at 15 outfalls. The action level was exceeded seven times at four outfalls. A report detailing monitoring results, corrective actions, and proposed modifications is submitted to TDEC annually.

5.4.1.3 Storm Water Pollution Prevention Plan

The Storm Water Pollution Prevention Plan (SWP3) 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:

- assessment and mapping of outdoor material storage/handling at ORNL,
- characterization of storm water runoff by monitoring,
- training of employees, and
- 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 SWP3 was last revised in August 2006. The document is available to personnel on the ORNL internal web.

For sampling purposes, storm water outfalls are grouped into four broad categories based on common land uses or pollutant sources and storm water pollutant potential. These four groups are further subdivided based on permit categorizations that have different monitoring schedule requirements. The permit requires that Category I and II outfalls be characterized over a 5-year period and that Category III and IV outfalls be characterized over a 3-year period. The outfalls chosen to be sampled 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 2006 are provided in Attachment 6.0 of the SWP3.

Various water-quality reference values are used to compare to ORNL storm water data collected under this SWP3 program for purposes of better characterizing outfalls and for targeting additional actions such as focused investigations into storm water pollution sources, monitoring, or best management practices. One such reference includes report levels adopted by the TDEC Multi-Sector General Storm Water Permit for Industrial Activities, which are developed specific to "sectors" or classifications of industrial activity. ORNL storm water data has been consistently lower than TDEC report levels for applicable sectors.

Reference values also include a summary of typical concentrations of pollutants compiled in a published study that undertook an international literature search of all storm water research that had been published in the 25 years prior to 1995 and that identified and quantified contaminant parameters. Although ORNL is an industrial setting, many attributes of its watersheds are comparable to urban watersheds such as its green spaces, traffic areas, large parking lots, office buildings, and a wide variety of potential storm water pollutants. ORNL's storm water data generally lie in between but toward the lower end of the broad concentration ranges published in the study.

Qualitative observations from a comparison between outfall storm water data collected to date show that grab samples generally have higher concentrations of analytes than flow-proportional composite samples. This is expected since grab samples are designed to collect and characterize the "first-flush" runoff from a watershed.

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 10 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 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, nitrate/nitrite, or zinc. Copper is found naturally in the soils and could also occur from coal-burning activities or corrosion of copper pipes. Nitrate is an inorganic form of nitrogen in water solution that can be attributed to the breakdown of many nitrogen-bearing sources (fertilizers, organic decay, etc.). 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.

5.4.2 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 2006, 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.

5.5 ORNL Wastewater Biomonitoring

Under the NPDES permit, wastewaters from the STP, the Steam Plant Wastewater Treatment Facility (SPWTF: the former 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 outfall X01 (STP) 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 outfall X02 discharge (SPWTF), 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 SPWTF, the limit for the NOEC applies only if the facility discharges for a sufficient length of time. For the outfall X12 discharge (PWTC), toxicity is demonstrated if more than 50% lethality of the test organisms occurs in 96 h in 100% effluent (LC_{50}) or if the NOEC is less than 30.9%.

During 2006, the STP, SPWTF, and PWTC were each tested four times. Numeric biomonitoring limits in the NPDES permit were met in all cases except the initial *Ceriodaphnia* test conducted on STP wastewater in May 2006. Toxicity was not detected in the confirmatory retesting of the STP required by the permit.

5.6 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 established 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 5.4).
- 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 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 to the above objectives, the BMAP conducts ecological assessments of and data collection for the receiving streams throughout the duration of the permit as appropriate. The results for bioaccumulation and macroinvertebrate and fish community studies in the WOC watershed for the BMAP in 2006 are summarized in the following sections.

5.6.1 Bioaccumulation Studies

The bioaccumulation task for the BMAP addresses two NPDES permit requirements at ORNL: (1) evaluate whether mercury (Hg) 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.

5.6.1.1 Mercury in Water

Water samples were collected from WOC at four sites on six occasions in 2006. Stream conditions were representative of seasonal baseflow conditions (dry weather, clear flow) at the time of the sampling on all dates. However, very heavy rainfall occurred three days before the September sampling event.

Mercury concentrations exceeded the Tennessee water quality standard (51 ng/L) at

Table 5.6. Toxicity test results of ORNL wastewaters, 2006

Test date	Test species	NOEC[a]	LC_{50}[b]
	Sewage Treatment Plant (outfall X01)		
January	*Ceriodaphnia*	41.1	>41.1
	Fathead minnow	41.1	>41.1
May	*Ceriodaphnia*	<9.8	>41.1
	Ceriodaphnia (confirmatory re-test)	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
	Steam Plant Wastewater Treatment Facility (outfall X02)		
January	*Ceriodaphnia*	NA[c]	>4.2[d]
	Fathead minnow	NA[c]	>4.2[d]
May	*Ceriodaphnia*	NA[c]	>4.2[d]
	Fathead minnow	NA[c]	>4.2[d]
August	*Ceriodaphnia*	NA[c]	>4.2[d]
	Fathead minnow	NA[c]	>4.2[d]
November	*Ceriodaphnia*	NA[c]	>4.2[d]
	Fathead minnow	NA[c]	>4.2[d]
	Process Waste Treatment Complex (outfall X12)		
January	*Ceriodaphnia*	100	>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	30.9	>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]Insufficient duration of discharge for chronic test and determination of NOEC.

[d]48-h LC_{50}.

White Oak Creek kilometer (WCK) 4.1 (Monitoring Station 3619) on all six dates and WCK 3.4 (weir at Melton Valley Road) on three (Fig. 5.14). The longitudinal pattern of Hg concentration in WOC observed in the most recent monitoring continued to resemble the historical pattern, with highest concentrations occurring at the site nearest source areas. Total Hg concentration in White Oak Lake is heavily influenced by resuspension of sediments, as well as, upstream inputs. Long-term trends show little evidence of an increase or decrease in the last six years.

Bioaccumulation

Fish were collected for contaminant analysis on April 7, 2006, and May 11, 2006. To provide data directly applicable to assessing human health concerns, redbreast sunfish (*Lepomis auritus*) were collected from WCK 2.9, and bluegill sunfish (*Lepomis macrochirus*) and largemouth bass (*Micropterus salmoides*) were collected from White Oak Lake (WCK 1.5). Collections were restricted to fish of a size large enough to be kept by sport fishermen (> 50 g for sunfish, and > 500 g for bass). Fillet tissue was taken from six individual fish of each species for both Hg and PCB analysis. The stoneroller

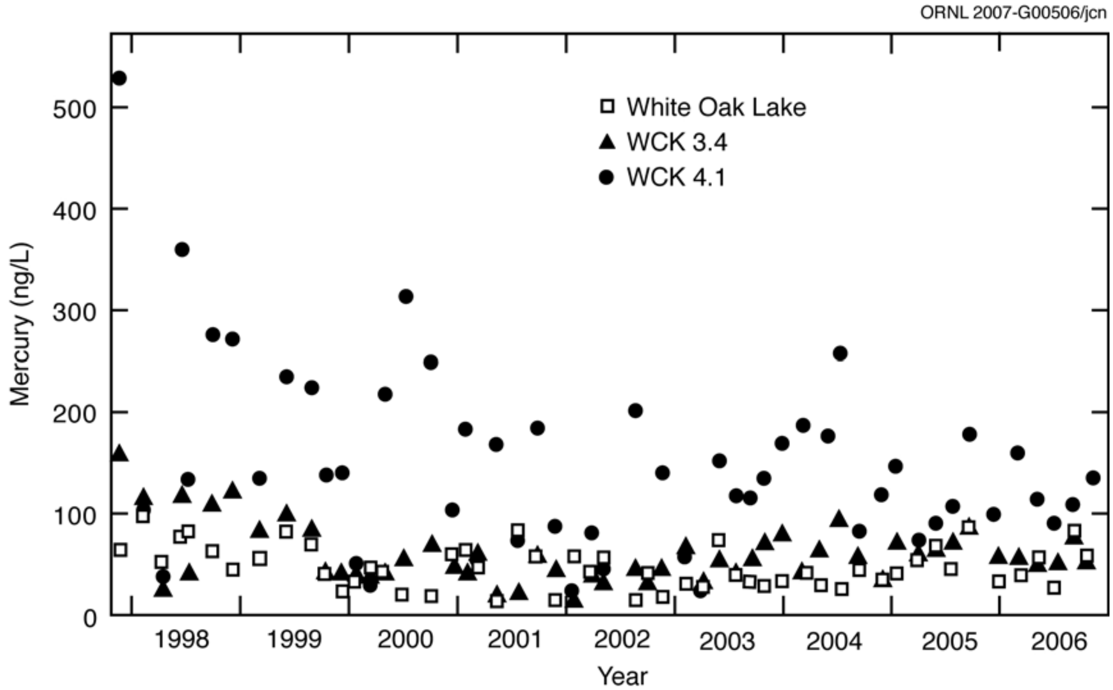

Fig. 5.14. Total aqueous mercury concentrations at sites in White Oak Creek downstream from ORNL, 1998–2006.

minnow (*Campostoma oligolepis*) is a forage species that readily accumulates particle-associated contaminants such as PCBs. Specimens were collected at WCK 3.9 to provide a measure of the possible exposure of fish-eating wildlife to PCBs. For stonerollers, 10 whole-body fish comprised each of 3 composite samples.

Mercury. Mean total Hg concentrations in WOC fish collected in 2006 are reported in Table 5.7. Average Hg concentrations in redbreast sunfish from WCK 2.9 were approximately five-fold higher (0.51 ± 0.06 µg/g) than in redbreast sunfish from Hinds Creek (0.08 ± 0.02 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 (0.10 ± 0.00 µg/g). Concentrations of Hg in largemouth bass from White Oak Lake reflected their higher position in the food chain, averaging 0.31 ± 0.06 µg/g. Nine (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. All six redbreast sunfish from WCK 2.9, and 3 of 6 largemouth bass from White Oak Lake attained or exceeded the EPA Hg fish tissue criterion for methylmercury of 0.3 mg/kg (ppm); no bluegill collected from White Oak Lake in 2006 exceeded this level.

Compared with 2005, mean total Hg concentrations in fish were slightly lower in 2006 in White Oak Lake, but higher at WOC sites (Fig. 5.15). Since 1998, a modest increase in Hg concentrations in fish (1.5 to 2-fold) continues, particularly at WCK 2.9.

PCBs. Mean PCB concentrations in WOC fish collected in 2006 are reported in Table 5.7. The mean PCB concentrations in sunfish from WCK 2.9 and White Oak Lake were 0.28 ± 0.04 µg/g and 0.34 ± 0.06 µg/g, respectively. Such levels of PCBs are relatively high for short-lived, lipid-poor fish such as sunfish. Largemouth bass from White Oak Lake typically have substantially higher levels of PCBs, and averaged 1.21 ± 0.30 µg/g in 2006. Reference site sunfish analyzed concurrently had average PCB concentrations of < 0.01 µg/g. PCB concentrations in stonerollers collected near the main ORNL Campus averaged 1.17 ± 0.33 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

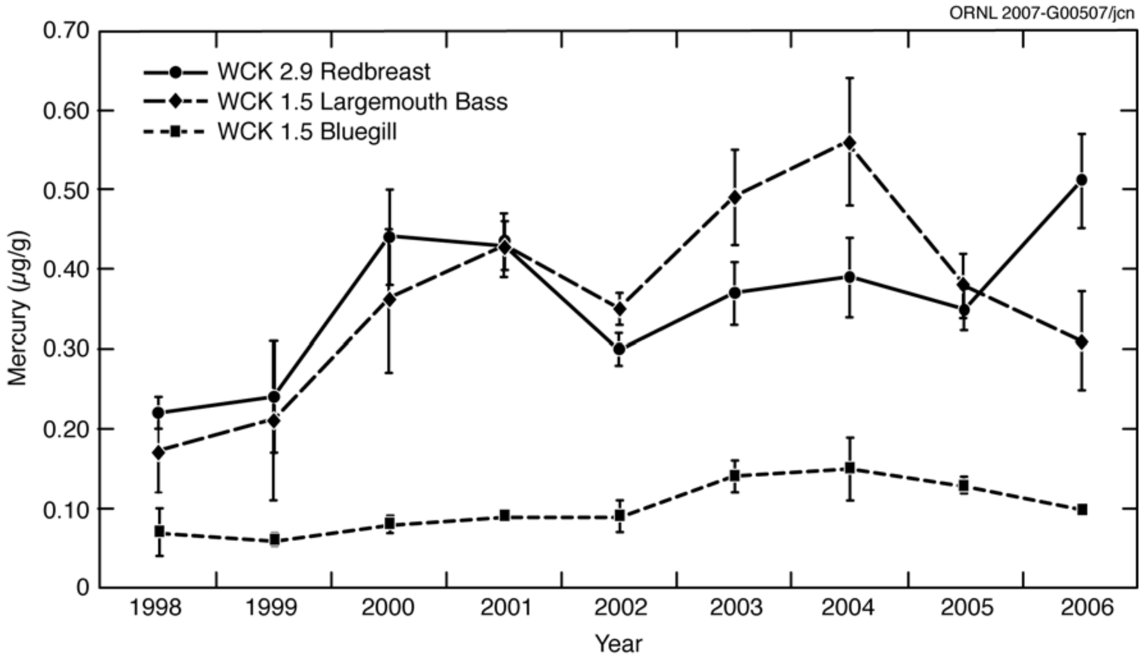

Fig. 5.15. Mean mercury concentrations (µg/g, ± SE) in fish fillets collected from the WOC watershed, 1998–2006.

Table 5.7. Total mercury and PCB (Aroclor 1254 + 1260) concentrations in fish (mean ± SE; range in parenthesis) from sites in White Oak Creek and a reference stream, Hinds Creek, April 2006[a]

Site[b]	Species[c]	Mercury (µg/g)	PCBs (µg/g)[d]
WCK 3.5	Stoneroller	Not analyzed	1.17 ± 0.33
	Redbreast sunfish	0.32 ± 0.03	0.18 ± 0.08
		(0.22 - 0.41)	(0.06 - 0.56)
WCK 2.9	Redbreast sunfish	0.51 ± 0.06	0.28 ± 0.04
		(0.34 - 0.66)	(0.11 - 0.36)
WOL	Bluegill	0.10 ± 0.00	0.34 ± 0.06
		(0.09 - 0.11)	(0.16 - 0.58)
WOL	Largemouth bass	0.31 ± 0.06	1.21 ± 0.30
		(0.12 - 0.16)	(0.53 - 2.30)
WCK 3.8	Stoneroller	Not analyzed	<0.01
Hinds Creek	Redbreast sunfish	0.08 ± 0.02	<0.01
		(0.02 - 0.16)	

[a]N = 6 individual fish for each site/species combination, and samples are of fillets only. Stoneroller samples are mean ± SE of three 10-fish composites.

[b]WCK = White Oak Creek kilometer; WOL = White Oak Lake.

[c]Largemouth bass (*Micropterus salmoides*), bluegill sunfish (*Lepomis macrochirus*), redbreast sun-fish (*Lepomis auritus*), and stoneroller (*Campostoma oligolepis*).

[d]PCB = polychlorinated biphenyl.

WOC near ORNL indicates the likelihood of continuing inputs into the stream.

Mean PCB concentrations in 2006 were lower than in 2005 at both sites in all species but were well within the historical range (Fig. 5.16). The dramatic year-to-year differences in large-mouth bass (Fig. 5.16) concentrations are most likely due to annual changes in prey. Gizzard shad and bluegill are favorite prey species for bass but differ greatly in their PCB concentrations (shad are lipid rich and can accumulate higher levels of PCBs).

5.6.2.1 Benthic Macroinvertebrate Communities

Monitoring of the benthic macroinvertebrate communities in WOC, First Creek, and Fifth Creek continued in 2006. 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 downstream of effluent discharges have recovered significantly since 1986, but community characteristics indicate that ecological impairment remains (Figs. 5.17, 5.18, and 5.19). Relative to reference sites, total taxonomic richness and richness of the pollution-intolerant taxa (i.e., Ephemeroptera, Plecoptera, and Trichoptera [EPT] richness) continue to be low at sites adjacent to and downstream of the main ORNL Campus. Except for First Creek, trends in annual changes in total and EPT taxa richness at downstream sites over the past 5 years have generally been similar to those at the reference sites, suggesting that no unusual changes have occurred. While both metrics increased at First Creek kilometer (FCK) 0.1 and decreased at FCK 0.8, values at both sites were within their historic ranges observed during the past five years, suggesting that like the downstream sites in WOC and Fifth Creek, the macroinvertebrate community in lower First Creek also remains stable.

Samples collected from Melton Branch at Melton Branch kilometer (MEK) 0.6 in April 2006 using routine ORNL protocols, and a sample collected from that site in August 2006 using TDEC protocols were processed in FY 2006; results are presented in Table 5.8. Since this station is currently the only one in WOC watershed monitored with TDEC protocols, the results were compared with results from other nearby streams on the ORR that are monitored for other projects to put them into better perspective with conditions in this geographic area (Table 5.8). Results of samples collected in April 2006 following BMAP protocols suggested that the condition of the macroinvertebrate community at MEK 0.6 compared favorably with the macroinvertebrate communities in nearby reference streams and McCoy Branch. McCoy Branch is a small stream located in Bethel Valley just east of ORNL. Since major abatement actions were taken in the early 1990s to improve that stream's water quality, the macroinvertebrate community has recovered significantly (Smith 2003). The Biotic Index score calculated following TDEC protocols gave a slightly different result from the results obtained with ORNL protocols. Based on TDEC protocols, the macroinvertebrate community at MEK 0.6 is slightly impaired, and as such, would be classified by the state as partially supportive of healthy biological conditions. Biotic Index scores for slightly impaired conditions range from 21 to 31, thus, the score for MEK 0.6 was only slightly lower than scores classified by TDEC as indicative of nonimpaired conditions (i.e., ~32). Comparison of results for MEK 0.6 with those for a stream in Bear Creek Valley that also has been subjected to major stream channel restoration efforts within the past 5 years (i.e., NT3), suggests that recovery of MEK 0.6 has progressed at a faster rate (Table 5.8).

5.6.2.2 Fish Communities

Monitoring of the fish communities in WOC and its major tributaries continued in 2006. Samples were taken at nine 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,

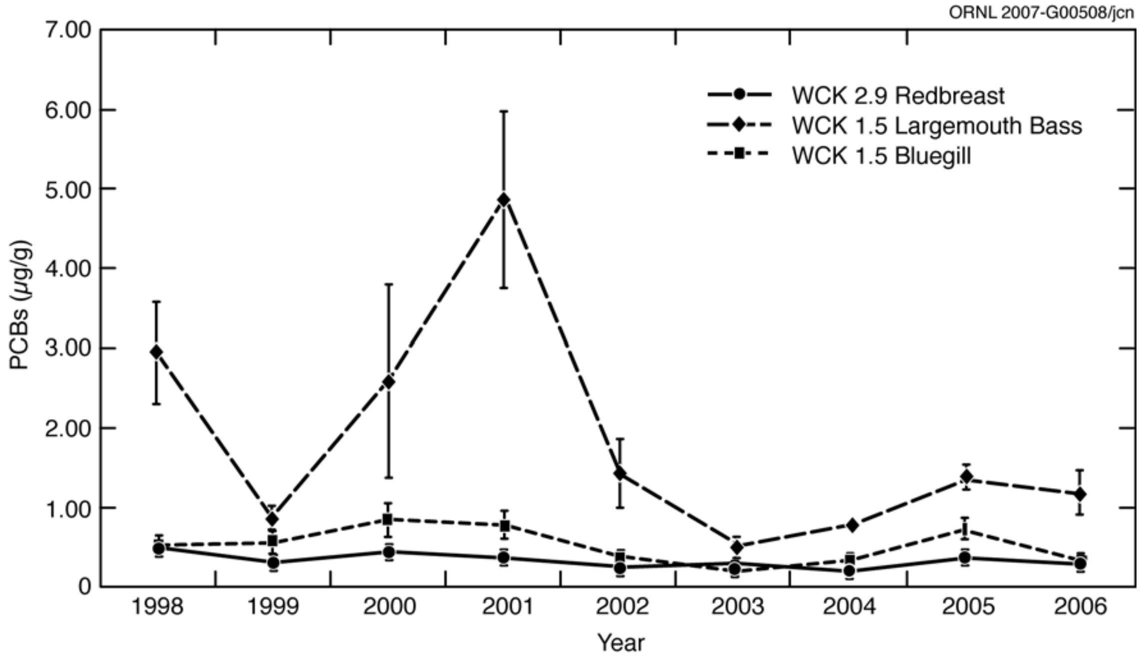

Fig. 5.16. Mean total PCB concentrations (µg/g, ± SE) in largemouth bass and sunfish fillets collected from the WOC watershed, 1998–2006.

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 at the respective reference site (Fig. 5.20). In the past, these sites had very high densities (~14–17 fish/m^2) that were at least tenfold higher than at reference sites. Often in recovering streams, as fish density declines, species richness will increase, reflecting an overall improvement. However, in WOC, there has not been a corresponding increase in species richness as density has decreased. The low species richness seen in WOC watershed, relative to off-site reference locations, is partially a result of barriers that limit immigration of new species from the Clinch River drainage.

Generally, the fish communities in tributary sites adjacent to and downstream of ORNL outfalls remained somewhat impacted in 2005 relative to reference streams or upstream sites. 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 community in First Creek showed little change in 2006 relative to 2005 (Fig. 5.21), and the density in Fifth Creek continues to fluctuate considerably, especially in lower Fifth Creek (FFK 0.2; Fig. 5.22). Compared with previous years, fish density in Melton Branch (Melton Branch kilometer 1.4) has been higher in the most recent sampling periods (Fig. 5.23).

5.7 ORNL Surface Water Monitoring at NPDES Reference Location

WOC headwaters were monitored in 2006 as a 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 all parameters in water. See Tables 2.3 and 3.4

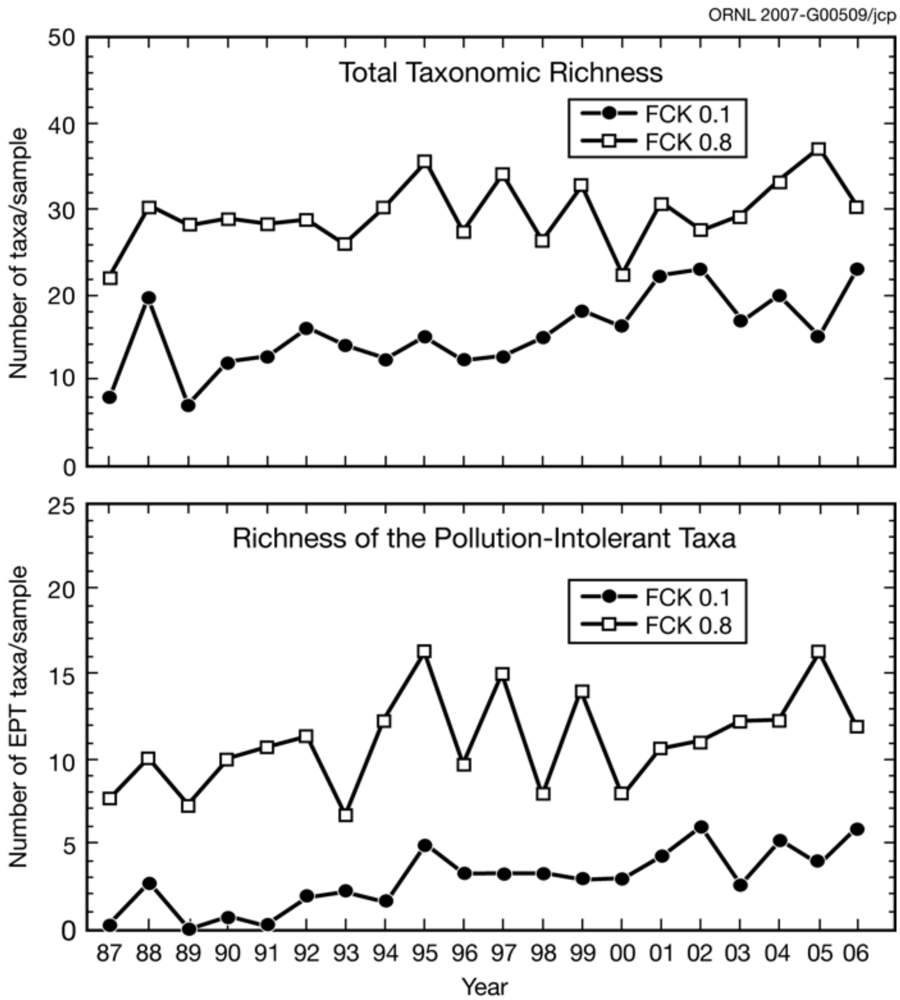

Fig. 5.17. Taxonomic richness (top) and richness of the pollution-intolerant taxa (bottom) of the benthic macroinvertebrate community in First Creek, April sampling periods, 1987−2006. (FCK = First Creek kilometer; EPT = Ephemeroptera, Plecoptera, and Trichoptera; FCK 0.8 = reference site.)

in *Environmental Monitoring on the Oak Ridge Reservation: 2006 Results* (DOE 2007b) for surface water analyses.

5.8 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 assessing 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. 5.24).

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 appropriate. Samples from White Oak Lake at White Oak Dam are also checked for volatile organic

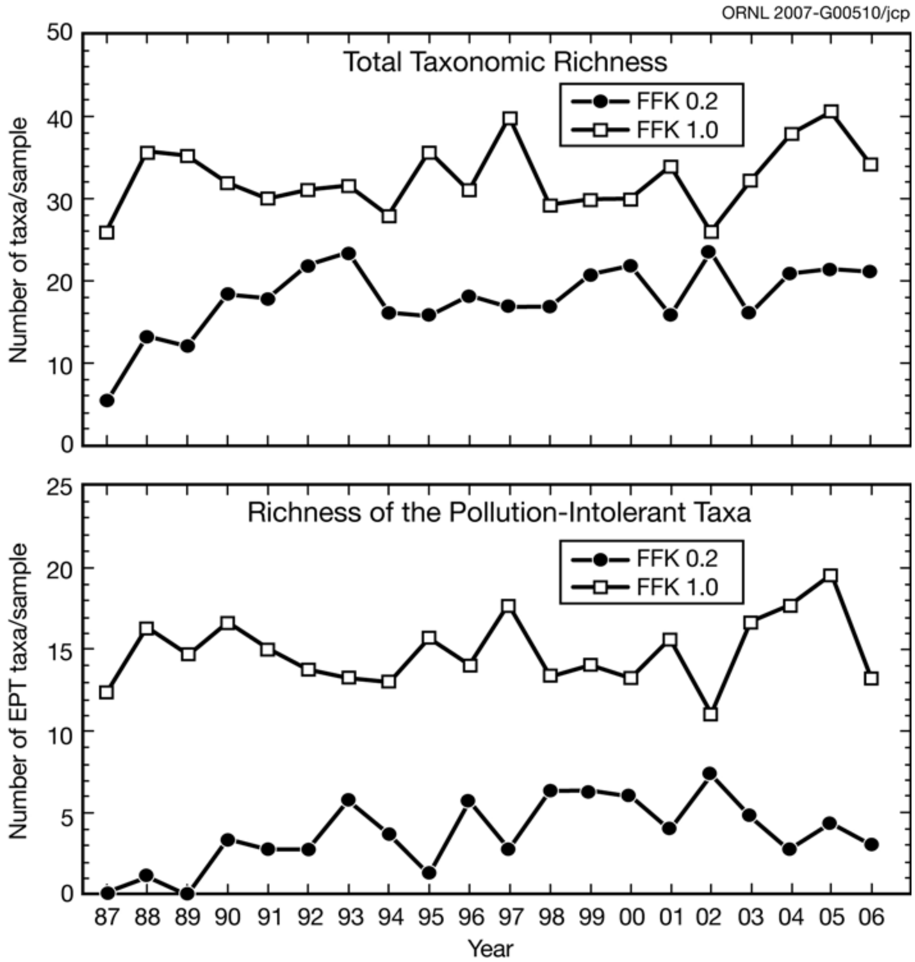

Fig. 5.18. Taxonomic richness (top) and richness of the pollution-intolerant taxa (bottom) of the benthic macroinvertebrate community in Fifth Creek, April sampling periods, 1987−2006. (FFK = Fifth Creek kilometer; EPT = Ephemeroptera, Plecoptera, and Trichoptera; FFK 1.0 = reference site.)

compounds (VOCs), PCBs, and metals. Table 5.9 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. Four percent of the DOE derived concentration guide (DCG) is used for radionuclide comparison because this value is roughly equivalent to the 4-mrem dose limit from ingestion of drinking water on which the EPA radionuclide drinking water standards are based.

5.8.1 Results

Radionuclides were detected above MDAs at all surface water locations in 2006. 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.

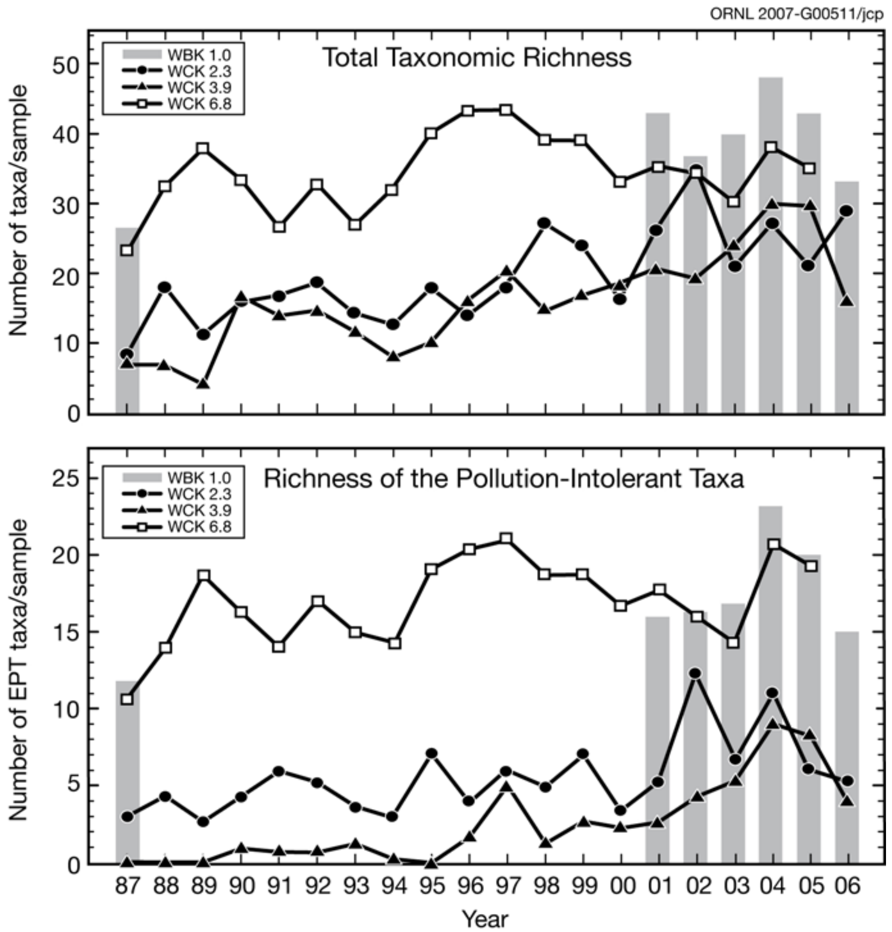

Fig. 5.19. Taxonomic richness (top) and richness of the pollution-intolerant taxa (bottom) of the benthic macroinvertebrate communities in White Oak Creek, April sampling periods, 1987−2006. (WCK = White Oak Creek kilometer; WBK = Walker Branch kilometer; EPT = Ephemeroptera, Plecoptera, and Trichoptera; WBK 1.0 = reference site.)

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 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, bromodichloromethane, tetrachloroethene, and common laboratory contaminants acetone and methylene chloride were detected at WOC at White Oak Dam in 2006, mostly at low estimated levels.

Table 5.8. Benthic macroinvertebrate results for lower Melton Branch (MEK 0.6) in 2006
Results from other Oak Ridge Reservation streams are included for comparison

Site[a]	BMAP protocols (April)		TDEC protocols (August)[c]	
	Total richness (no. taxa/sample)	EPT richness[b] (no. EPT taxa/sample)	Biotic Index score	Narrative rating
		WOC Watershed		
MEK 0.6	38.3	17.3	30	Slightly-impaired
		Bear Creek reference sites		
GHK 1.6	46.0	23.7	NS[d]	NS[d]
GHK 2.9	37.3	15.3	NS	NS
MBK 1.6	40.7	17.3	NS	NS
		Bear Creek tributary		
NT3	21.7	7.3	22	Slightly-impaired
		McCoy Branch		
MCK 1.4	39.0	14.7	32	Non-impaired
MCK 1.9	33.0	13.7	40	Non-impaired

[a]MEK = Melton Branch kilometer; GHK = Gum Hollow Branch kilometer; MBK = Mill Branch kilometer; NT3 = Bear Creek North Tributary number 3; MCK = McCoy Branch kilometer.

[b]EPT = Ephemeroptera, Plecoptera, and Trichoptera (i.e., mayflies, stoneflies, and caddisflies). EPT richness is an indicator-metric of a stream's ability to support pollution-intolerant invertebrate species, and is typically 11 in small relatively undisturbed streams on the Oak Ridge Reservation.

[c]Details of the Tennessee Department of Conservation (TDEC) protocols can be found at http://www.state.tn.us/environment/wpc/publications/bugsop06.pdf.

[d]NS = Samples using TDEC protocols were not collected from these sites.

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; however this pattern appears to be disrupted in the past several years perhaps due to change in rainfall precipitation pattern. Both of these locations are impacted by contaminated groundwater from SWSA 3.

5.9 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. 5.25). The locations are sampled annually, and gamma scans are performed on the samples.

In addition, each year, two samples 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. 5.25). These samples are filtered, and the residue (settleable

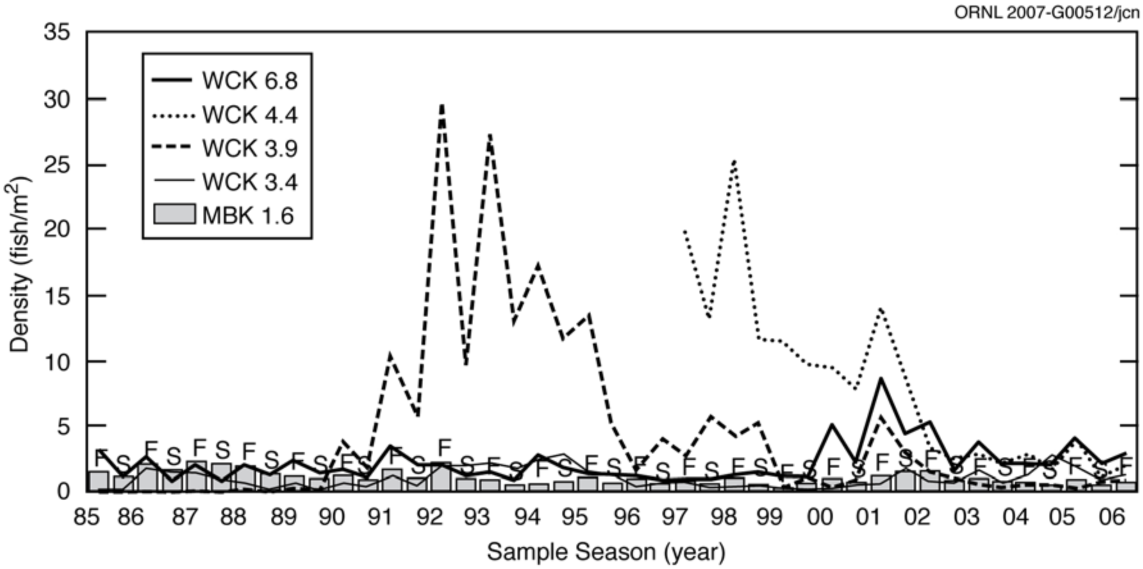

Fig. 5.20. Density (fish/m^2) estimates for fish in spring and fall samples from upper White Oak Creek and from a reference site on Mill Branch (MBK 16), 1985–2006. (WCK = White Oak Creek kilometer; MBK = Mill Branch kilometer.).

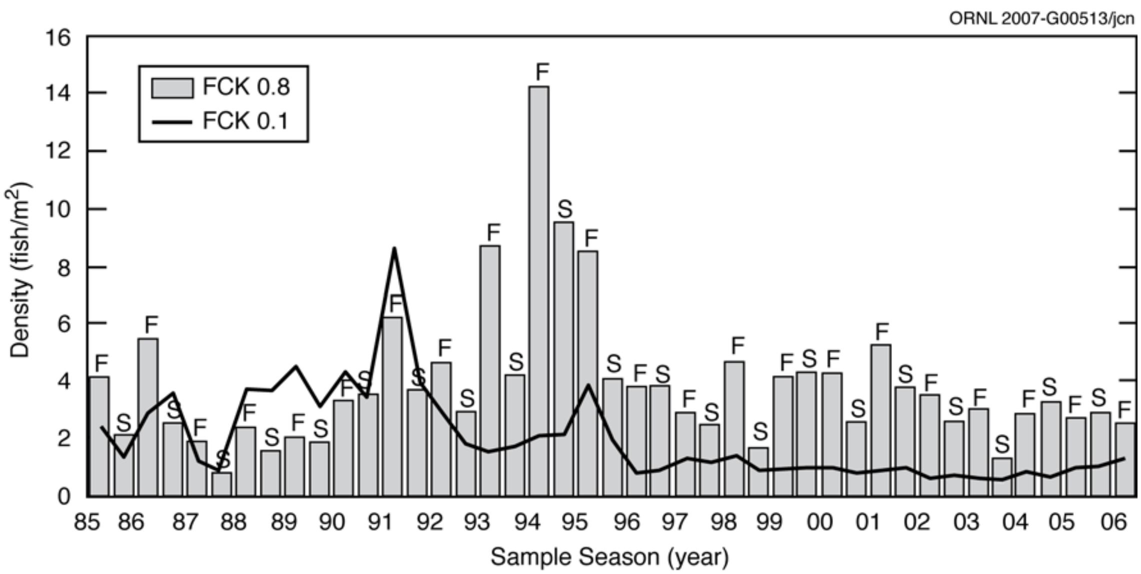

Fig. 5.21. Density (fish/m^2) estimates for fish in spring and fall samples from First Creek, 1985–2006. (FCK = First Creek kilometer; FCK 0.8 is a reference site.).

solids) is analyzed for gross alpha, gross beta, and gamma emitters.

5.9.1 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 January and April 2006. The concentrations of radionuclides associated with each of these rain events are higher at the locations downstream of ORNL than at the upstream locations.

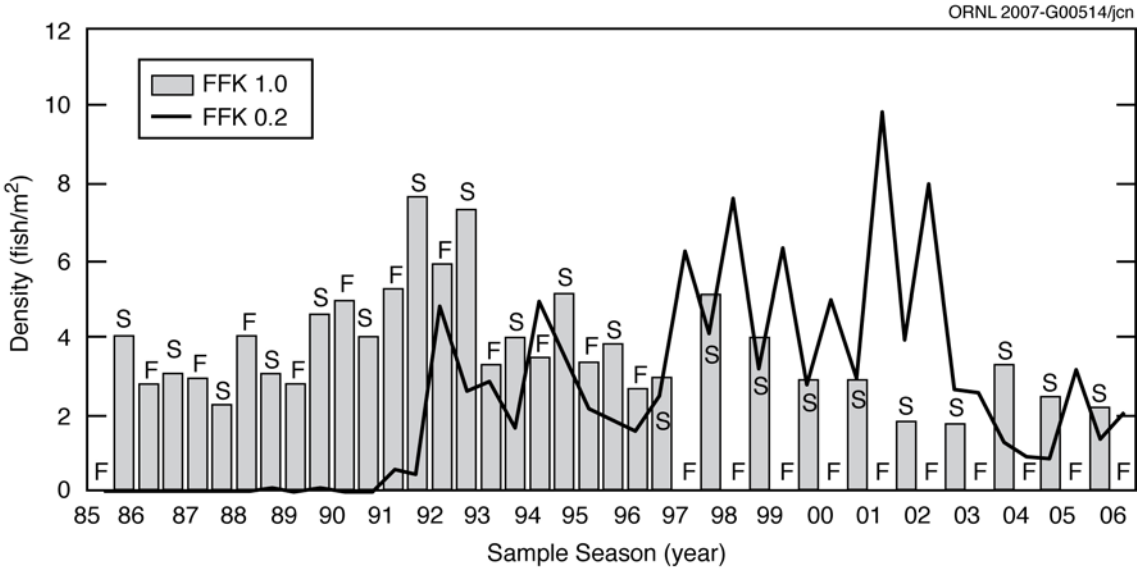

Fig. 5.22. Density (fish/m^2) estimates for fish in spring and fall samples from Fifth Creek; 1985–2006. (FFK = Fifth Creek kilometer; FFK 1.0 is a reference site.)

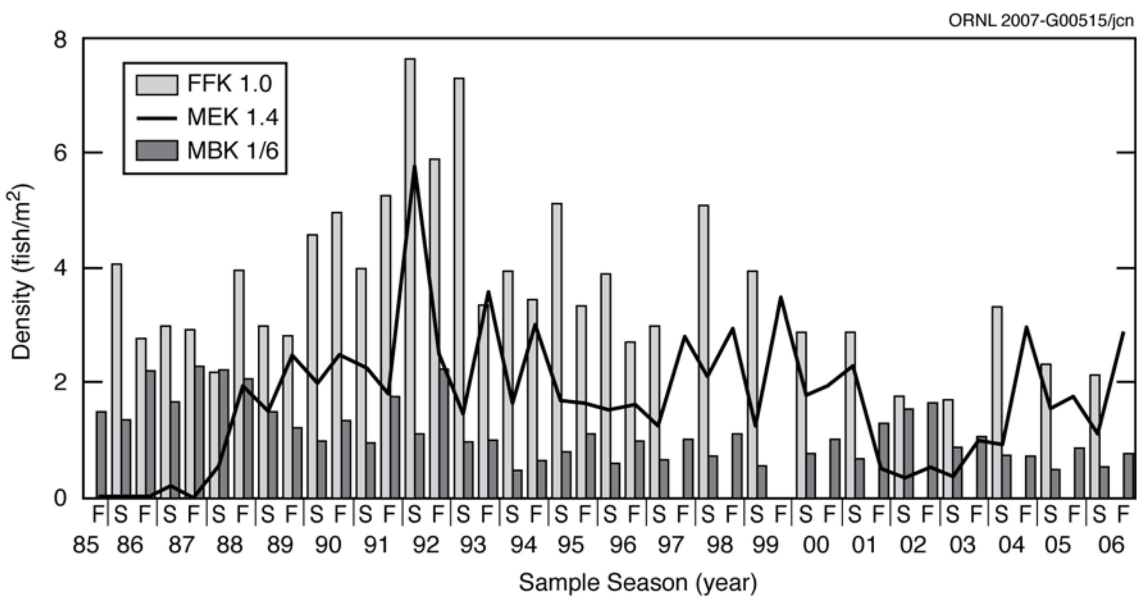

Fig. 5.23. Density (fish/m^2) estimates for fish in spring and fall samples from Melton Branch, 1985–2006. (MEK = Melton Branch kilometer; Upper Fifth Creek [FFK 1.0]; and Mill Branch [MBK 1.6] are reference sites.)

5.10 Groundwater Monitoring at ORNL

5.10.1 Background

Groundwater monitoring at ORNL consisted of two programmatic components in 2006: the DOE Environmental Management and Enrichment Facilities (EMEF) groundwater monitoring program and the DOE Office of Science (OS) groundwater monitoring surveillance program. Bechtel Jacobs Company (BJC) is the contractor responsible for monitoring conducted under the auspices of the EMEF 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 con-

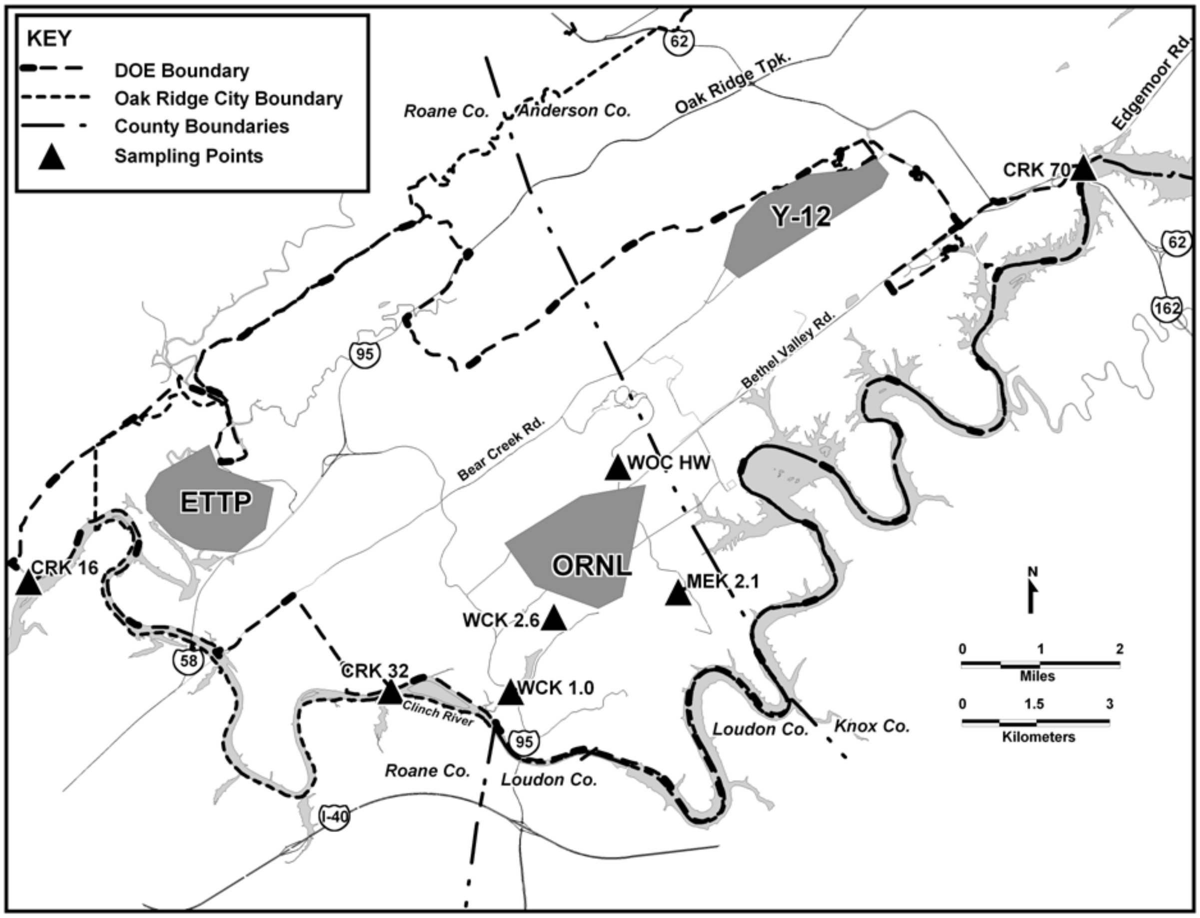

Fig. 5.24. ORNL surface water sampling locations.

taminated sites undergoing cleanup. The Water Resources Restoration Program (WRRP) has been managed by BJC for the EMEF program since its inception and is the vehicle for DOE to carry out the regulatory monitoring requirements outlined in the Federal Facility Agreement to conduct remedial action monitoring. The WRRP uses a watershed approach to environmental monitoring, which has resulted in the assignment of two watersheds to ORNL: Bethel Valley and Melton Valley. Groundwater and surface water monitoring results for remedial actions that are in progress or that have been completed during 2006 are reported annually in the EMEF Program *2006 Remediation Effectiveness Report/Second Reservation-wide CERCLA Five Year Review for the U.S. Department of Energy Oak Ridge Reservation, Oak Ridge, Tennessee* (DOE 2007a) (RER). In the case of waste area grouping (WAG) 6, which is regulated under both the RCRA and the CERCLA, specific monitoring results and interpretations required by RCRA are reported in the annual *Groundwater Quality Assessment Report for Solid Waste Storage Area 6 at the Oak Ridge National Laboratory, Oak Ridge, Tennessee CY 2006* (BJC 2007b), which is also issued annually to TDEC, Division of Solid Waste Management. The OS monitoring effort is managed by UT-Battelle and has two functions: exit pathway groundwater surveillance and "active sites" groundwater surveillance monitoring. Groundwater surveillance monitoring conducted by UT-Battelle for the OS is reported herein and is the focus of this section.

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

Table 5.9. ORNL surface water sampling locations, frequencies, and parameters, 2006

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.

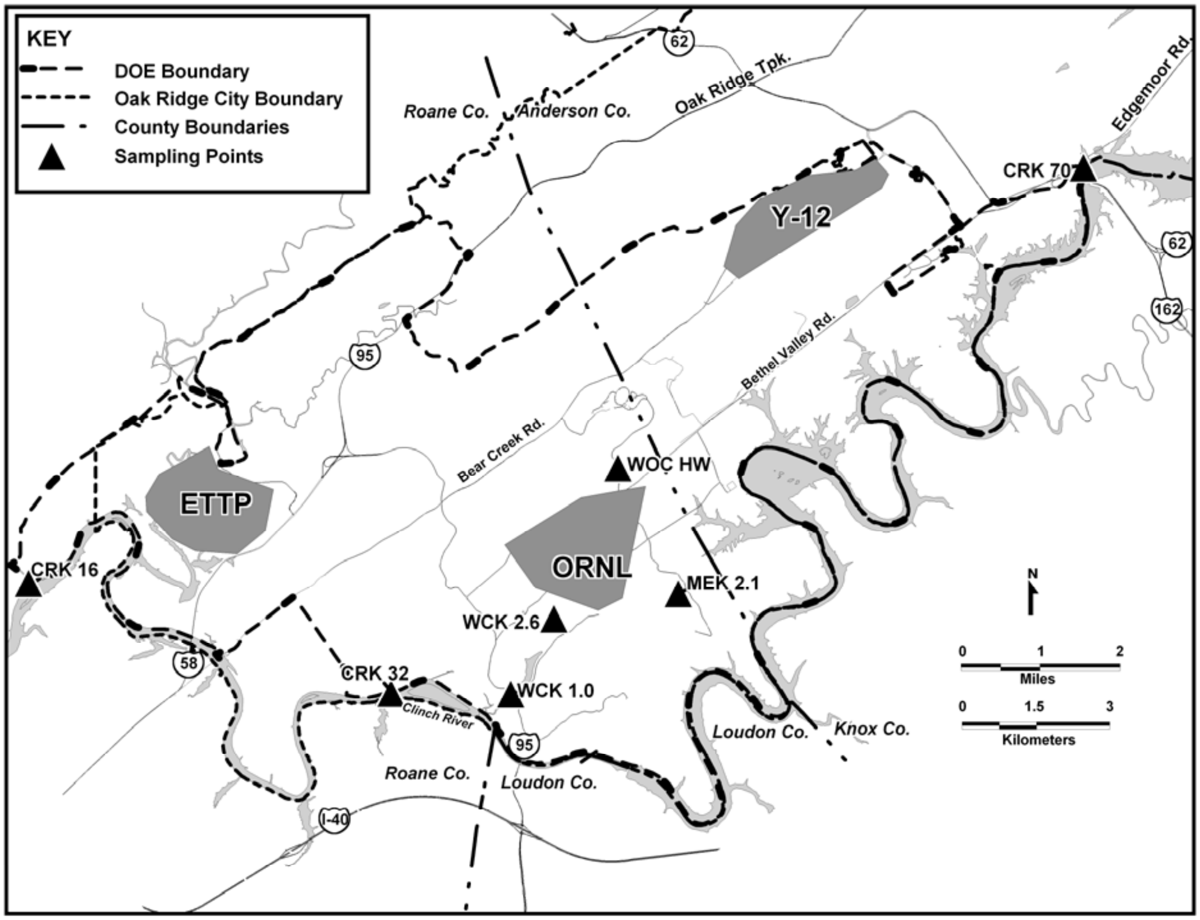

Fig. 5.25. ORNL sediment sampling locations.

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 approach 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 UT-Battelle facilities potentially posing risk to groundwater resources at ORNL ("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 2004).

The exit pathway and active sites groundwater surveillance monitoring points sampled during 2006 included selected seep/spring and surface water monitoring locations as well as groundwater surveillance monitoring wells. Seep/spring and surface water monitoring locations were used in the absence of monitoring wells located in appropriately selected groundwater discharge areas. The network of groundwater monitoring wells sampled by UT-Battelle consists of water quality wells constructed to RCRA specifications and piezometer wells. In the past the water quality wells were used in site characterization and compliance monitoring, while the piezometers sampled in 2006 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 the OS, federal drinking water standards and Tennessee water quality criteria for domestic water supplies (TDEC 2004) are used as reference values in the following discussions. Four percent of the DOE DCG was 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.

Monitoring conducted by BJC and the exit pathway and active sites monitoring approach used by UT-Battelle comprise the 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.

5.10.2 Exit Pathway Monitoring

During 2006, 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 2006b) (Exit Pathway SAP). Groundwater exit pathways at ORNL include watersheds or portions of watersheds (subwatersheds) where groundwater discharges to the Clinch River/Melton Hill Reservoir to the west, south, and east of the main campus 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 five 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 5.26 shows the locations of the specific monitoring points sampled in 2006.

Samples were collected during 2006 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. The inclusion of the multiport wells enables multiple shallow to deep water-bearing strata to be monitored. Sampling data generated by these wells were used to supplement the data generated by the WOC Discharge Area Exit Pathway. These data were reviewed by UT-Battelle, but are not reported herein. The multiport monitoring well analytical data are reported in the annual RER.

Samples collected from the UT-Battelle exit pathway groundwater surveillance monitoring points in 2006 were analyzed for VOCs, semivolatile organic compounds, metals (including mercury), and radionuclides (including gross alpha/gross beta activity, gamma emitters, total radioactive strontium, and tritium). Under the monitoring strategy in place per the Exit Pathway SAP, samples were collected semiannually during wet and dry seasons during 2006.

5.10.3 Active Sites Monitoring–HFIR and SNS

Active sites groundwater surveillance monitoring was performed in 2006 at the HFIR and SNS sites. These UT-Battelle–managed facilities were monitored based on known releases of contaminants to the subsurface (HFIR) or the potential for adverse impact on groundwater resources at ORNL should a release occur (SNS).

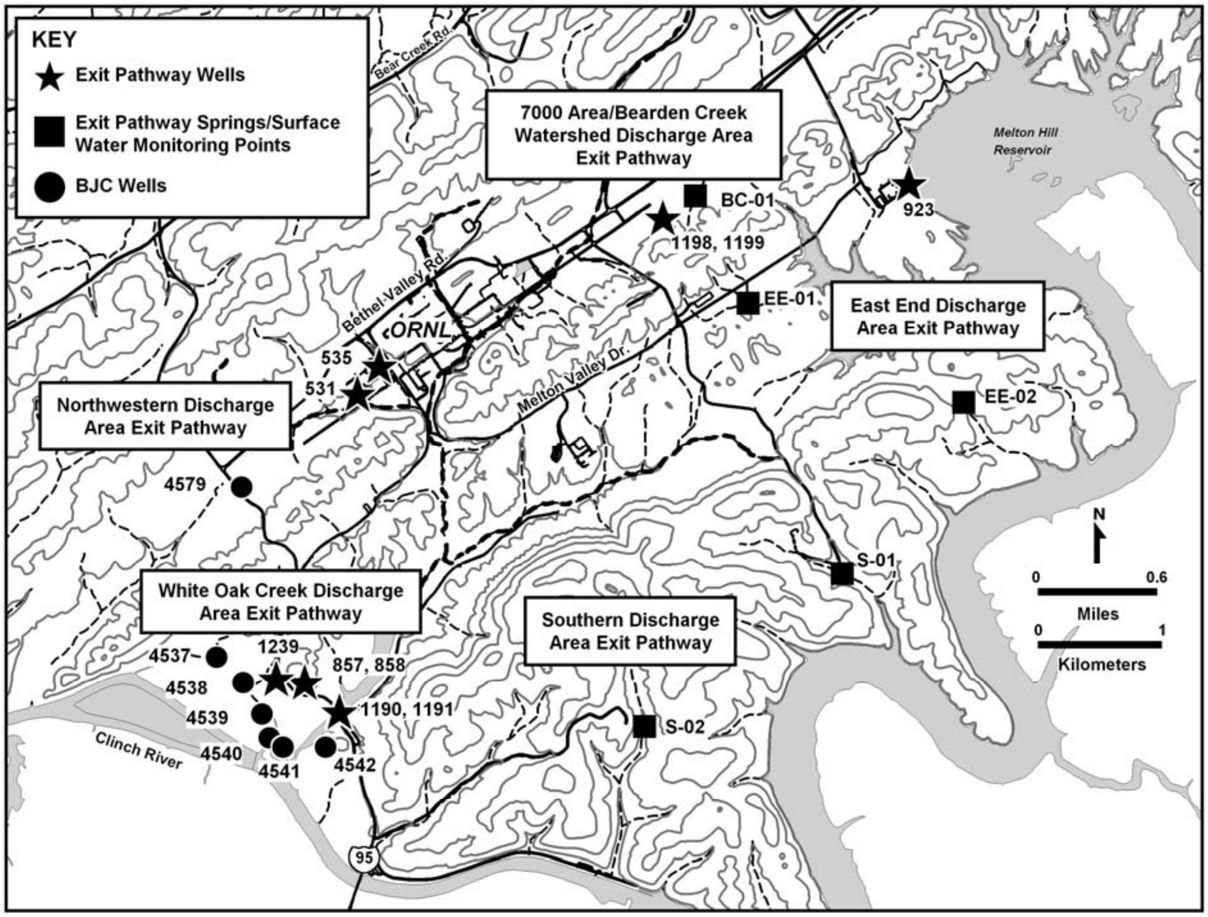

Fig. 5. 26. UT-Battelle exit pathway groundwater monitoring locations at ORNL, 2006.

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). During 2006 HFIR monitoring was performed under the Annual Monitoring Plan for the High Flux Isotope Reactor Site, Monitoring Period: 2005-2006 (Bonine 2006a) (Annual Monitoring Plan). Sampling under the Annual Monitoring Plan began in December 2005 and was completed in December 2006.

Monitoring at the SNS site continued in 2006 under the *Baseline Groundwater Monitoring Plan for the Spallation Neutron Source Site: Monitoring Period 2004–2006* (Baseline Monitoring Plan) (Bonine, Ketelle, and Trotter 2005). Baseline monitoring ended and coincided with the initiation of operational monitoring in April 2006 due to the operational startup of the SNS. Operational monitoring was initiated under the draft *Operational Groundwater Monitoring Plan for the Spallation Neutron Source Site* (Bonine, Ketelle, and Trotter, 2007) (Operational Monitoring Plan). Operational monitoring will continue during SNS operations.

5.10.3.1 HFIR Site

The HFIR site is located in Melton Valley about one-half mile south of the main ORNL facilities, which are located in Bethel Valley. The site slopes to the southeast, and small stream valleys lie to the east and west of the HFIR complex. Surface water drainage from the site flows into Melton Branch via these small streams or through storm drains. Melton Branch is located south of the HFIR site and flows west into WOC. WOC ultimately discharges into the Clinch River.

The water table surface in Melton Valley is typically a subdued replica of surface topography. The dry season water table typically occurs at or slightly above the top of bedrock. Groundwater data gathered before the tritium release indicate a water table high to the north of HFIR and a general gradient toward the adjacent streams. Estimates of groundwater flow directions are based on the generally observed tendency for groundwater to flow parallel to geologic strike (parallel to the orientation of the rock beds). Extensive historic investigations performed at Oak Ridge over several decades indicate that 90% or more of infiltrating precipitation (groundwater recharge) flows directly to the nearest stream. Because of this, in small watersheds, groundwater contaminants not subject to geochemical transport retardation, such as tritium, are readily detected in surface water samples.

The tritium release sites were on the southwest side of the HFIR Building near Wells 4531 and 658 (see Figure 5.27). The releases occurred in two sections of the HFIR process waste drain system.

The most significant observation for the HFIR facility, based on water table conditions and other data related to the reactor building, is that two interrelated 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 Plan 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 5.27 shows the locations of the specific monitoring points sampled in 2006 at the HFIR site. Tritium was the only contaminant of concern monitored at all HFIR monitoring points.

The HFIR Building foundation drain and auxiliary waste piping system gravity-feed into Melton Branch, and this piping system forms 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. The HFIR's east foundation drain intercepts the rapid-flow pathway and has been monitored at J-1, a monitoring point proximal to the HFIR, for several years. Likewise, waste piping ditch lines associated with the HFIR 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 2006 (although OF-383 was sampled under the aegis of NPDES monitoring program and not under the Annual Monitoring Plan). Four down-gradient groundwater monitoring wells (Wells 658, 661, 892, and 1152) were also sampled routinely during 2006 to monitor the deeper, slower-flow pathway. Well 4533 is an up-gradient well located proximal to the HFIR site sampled during 2006. All samples were analyzed using EPA analytical methods by a certified laboratory. In addition, field parameter measurements were made during sampling events. Dissolved oxygen, pH, conductivity, turbidity, redox, and temperature measurements were made at monitoring wells sampled under the Annual Monitoring Plan with a calibrated and standardized flow cell/meter during each sampling event.

5.10.3.2 SNS Site

SNS Baseline Groundwater Monitoring. SNS operations have the potential for inducing radioactivity (neutron activation) in the shielding berm surrounding the SNS linac, accumulator ring, and/or beam transport lines. A principal concern is the potential for water infiltrating the berm soils to transport radionuclide contamination generated by neutron activation to saturated groundwater zones. The ability to accurately model the fate and transport of neutron activation products generated by beam interactions with the engineered soil berm is confounded by uncertainty associated with potential contaminant interactions. These interactions include existing pore water, percolating precipitation, earth materials encountered, and diffusive and advective flow in the vadose and phreatic zones attributable to the presence of karst geomorphic features found on the SNS site. These uncertainties necessitated the initiation of a groundwater

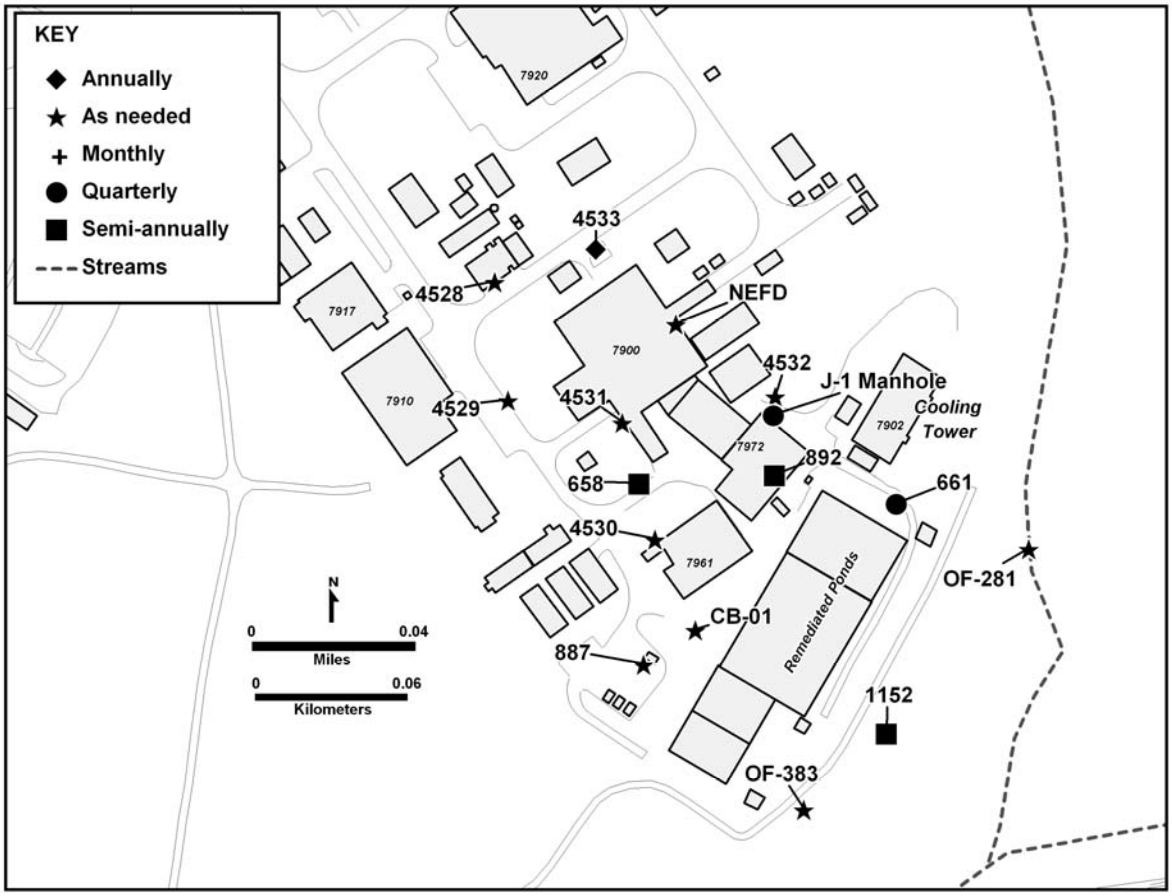

Fig. 5.27. Groundwater monitoring locations at HFIR, 2006.

surveillance monitoring program at the SNS site. Groundwater surveillance monitoring started as the baseline monitoring program. Objectives of the baseline groundwater monitoring program at the SNS include: 1) determination 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 contaminant radionuclides to the environment (obtain baseline data); and 3) determination of trends in pre-operational groundwater quality. The baseline monitoring program was conducted during the April 2004–April 2006 period prior to startup of the SNS. Operational monitoring was initiated at SNS startup (April 2006) and will continue during SNS operations.

A total of seven seeps/springs and surface water sampling points (seeps/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 the baseline monitoring period (see Fig. 5-28). Another monitoring point, spring S-6, was sampled sporadically during baseline monitoring. Since the inception of baseline monitoring at SNS, monitoring point S-6 has been periodically inundated by beaver activity on Bear Creek creating difficulties in collecting representative samples of the spring. Because representative samples were difficult to collect, monitoring was discontinued at this monitoring point during the baseline monitoring period.

The locations of the SNS monitoring points were chosen based on hydrogeological factors and proximity to the beam line. Sampling locations were within the seeps/springs or in surface water bodies immediately adjacent to these features. Fig. 5.28 shows the locations of the

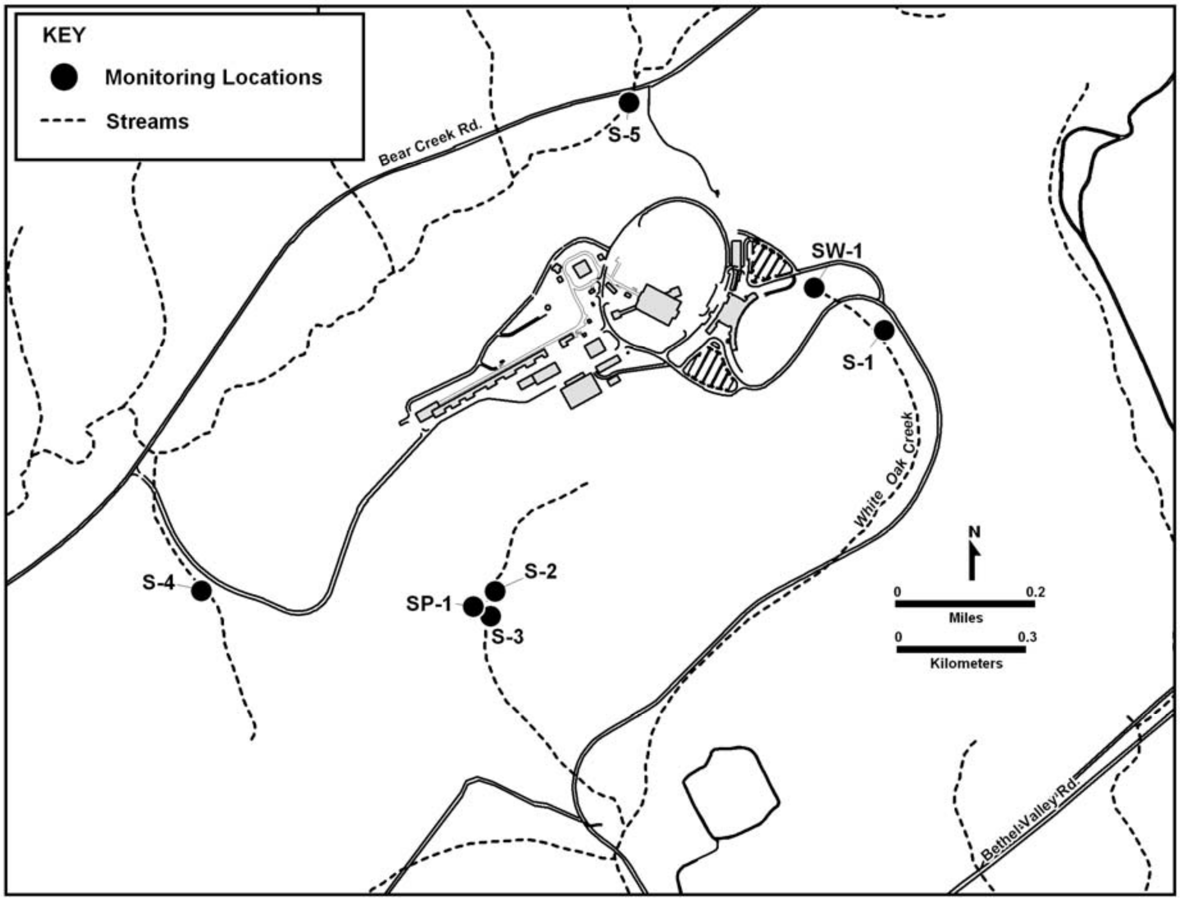

Fig. 5. 28. Groundwater monitoring locations at SNS, 2006.

specific monitoring points sampled during the baseline 2004–2006 period 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 water quality throughout the expected range of flow observed at the selected monitoring locations. A minimum of three grab samples was collected from each seep/spring per quarter—one representing base flow; samples were collected at higher stage/flow rates (i.e., one representing the rising limb of the storm hydrograph and one representing the recession [falling] limb of the storm hydrograph). These monitoring points were sampled on a quarterly basis during the 2004-2006 monitoring period in accordance with the Baseline Monitoring Plan. The parameters of interest included neutron activation products consisting of H-3, C-14, gross alpha and beta activity, and gamma emitters (Na-22, Al-26, Mn-54, K-40, etc). Initially none of the samples collected were filtered. However, due to the presence of higher than expected gross alpha and beta activity in samples collected at several monitoring points, filtered and unfiltered samples were collected to determine the source of the gross activity. All samples were analyzed using EPA analytical methods by a certified laboratory. In addition to the aforementioned analytical suite of interest, field parameter measurements were made during sampling events. Dissolved oxygen, pH, conductivity, turbidity, and temperature measurements were made with calibrated and standardized portable water quality meters during each sampling event.

SNS Operational Groundwater Monitoring. SNS began operational testing in April 2006. Concurrent with the initiation of operational testing and the completion of baseline monitoring, operational monitoring began under the Operational Monitoring Plan. All seven monitoring points sampled under the Baseline Monitoring Plan were retained under the Operational Monitoring Plan. Fig. 5.28 shows the locations of these monitoring points. The flow-based sampling scheme described above was maintained under the Operational Monitoring Plan. Based on observations made during baseline monitoring, monitoring frequency changes, vis-à-vis parameters of interest, are outlined in the Operational Monitoring Plan. Tritium and ^{14}C are the principal groundwater constituents of concern at the SNS site. Sample collection began in April 2006 on a quarterly basis for ^{3}H and ^{14}C analyses. In accordance with the Operational Monitoring Plan, samples will be collected annually during the wet season base flow conditions for gross activity (alpha and beta) and gamma spectroscopy analyses. Unfiltered samples will be collected and analyzed using EPA analytical methods by a certified laboratory. In addition to the aforementioned analytical suite of interest, field parameter measurements will continue to be made during sampling events. Dissolved oxygen, pH, conductivity, turbidity, and temperature measurements will be made with calibrated/standardized water quality meters during each sampling event.

5.10.4 Monitoring Results

5.10.4.1 2006 Exit Pathway Groundwater Surveillance Monitoring

From the 49 wells sampled under the previous WAG-based monitoring program, only Wells 857, 858, 1190, 1191, 1198, 1199, and 1239 were retained in the exit pathway groundwater surveillance monitoring program. Wells 531, 535, and 923 were added to the exit pathway monitoring program in 2005 as well as a number of springs and/or surface water bodies (BC-01, EE-01, EE-02, S-01, and S-02). Trend analyses were performed on 2006 exit pathway data that exceeded reference values using historical data collected from 1991 through the 2006. Where there was insufficient data density to perform statistical trend analysis, trending was not performed. Concentrations of naturally occurring metals (e.g., aluminum, iron, manganese, zinc, magnesium, etc.) that exceeded reference values were not subjected to trend analysis because these constituents are relatively common in the soil and rock composing the Valley and Ridge Physiographic Province and are regularly found in groundwater samples collected from wells at ORNL. In addition, requested detection limits were not met for several semivolatile organic compounds during the 2006 monitoring period. Requested detection limits were not met for atrazine, benzo(a)pyrene, hexachlorobenzene, and pentachlorophenol in any of the exit pathway monitoring points sampled during 2006. The detection limits for the aforementioned compounds exceeded their reference values (Tennessee water quality criteria for domestic water supplies). No trending was performed on data for these parameters. A common plasticizer [bis(2-ethylhexyl) phthalate], acetone, and toluene were routinely detected in low, estimated concentrations in many groundwater samples collected from the exit pathway wells. Less frequently, benzyl alcohol and carbon disulfide were also reported by the laboratory at low, estimated concentrations in several exit pathway wells. This is suggestive of low-level contamination of samples during laboratory analysis. Due to dry conditions encountered, samples were not collected at BC-01 and S-01 during the dry season, and EE-02 during the wet and dry seasons because of the climatic-based moisture deficit effecting East Tennessee during 2006.

Results of EMEF Program monitoring at Bechtel Jacobs well locations proximal to the WOC Discharge Area Exit Pathway exit pathways are summarized in the 2006 RER.

5.10.4.1.1 WOC Discharge Area Exit Pathway Results

Monitoring wells 857, 858, 1190, 1191, and 1239 were sampled in April and September 2006 by UT-Battelle. Three radiological constituents were found in two wells at concentrations greater than the reference values used for comparison. The three radiological constituents that exceeded reference values were tritium in Well 1190 and gross beta activity, total radioactive strontium, and tritium in Well 1191. A statistically significant downward trend exists for all three radiological constituents. Other radiological constituents were detected but did not exceed their reference values (^{214}Bi, ^{214}Pb, and ^{40}K). The presence of the radiological constituents in these wells is related to continued discharges of legacy contamination associated with past waste disposal activities within Melton Valley (gross beta activity, tritium and total radioactive strontium), or occur naturally (^{214}Bi, ^{214}Pb, and ^{40}K). One metal of interest (lead) exceeded its reference value in Well 857 in samples collected during 2006. Lead exhibits a statistically significant downward trend in Well 857. Several other metals exceeded their reference values during 2006, but these metals (aluminum, iron, and manganese) are commonly found in the soil, rock, and groundwater at ORNL. As mentioned above, detection limits for several semi-volatile organic compounds exceeded their reference values. No other organic compounds were present above their reference values in samples collected from WOC Discharge Area monitoring points.

5.10.4.1.2 7000 Area/Bearden Creek Watershed Discharge Area Exit Pathway Results

Wells 1198 and 1199 and Spring BC-01 were sampled by UT-Battelle in April and August 2006 (BC-01 was not sampled in August 2006 because the spring was dry). One radiological parameter (^{241}Am) was reported above its reference value in the sample collected from Well 1198 in April 2006; however the counting uncertainty reported by the laboratory exceeded the reported value casting doubt as to the validity of the reported value. Americium-241 was not reported in the sample collected from Well 1198 in August 2006. Trace levels of tritium were detected in samples collected from all three monitoring locations. Two metal constituents (aluminum and iron) exceeded reference values, but these metals are common in groundwater at ORNL. As noted in Sect. 5.10.4.1, detection limits for several semi-volatile organic compounds exceeded their reference values. No other organic compounds were present above their reference values in samples collected from the 7000 Area/Bearden Creek Watershed Discharge Area monitoring points.

5.10.4.1.3 East End Discharge Area Exit Pathway Results

Well 923 and EE-01 were sampled by UT-Battelle in April and August 2006. EE-02 was not sampled in 2006 because this monitoring point was dry during the wet and dry seasons. No radiological constituents were present above reference values in samples collected from East End Discharge Area monitoring points, however very low concentrations of tritium were detected in the sample collected from EE-01 in August 2006. The concentration of lead exceeded its reference value in the April 2006 sample collected from Well 923 (trending of lead data was not performed due to a lack of data density). Aluminum, iron, manganese, and thallium also exceeded reference values, but these metals are relatively common in the soil, rock, and groundwater at ORNL. As mentioned above, detection limits for several semi-volatile organic compounds exceeded their reference values. No other organic compounds were detected in samples collected from East End Discharge Area monitoring points.

5.10.4.1.4 Northwestern Discharge Area Exit Pathway Results

Wells 531 and 535 were sampled in May and August 2006 by UT-Battelle. No radiological constituents were present above reference values in samples collected from Wells 531 and 535; however, low levels of tritium were detected in the samples collected in Well 535. The concentration of lead exceeded its reference value in the August 2006 sample collected from Well 535 (trending of lead data was not performed due to a lack of data density). Aluminum, iron, and manganese exceeded reference values, but as stated above, these metals are common in groundwater at ORNL. As mentioned above, detection limits for several semi-volatile organic compounds exceeded their reference values. No other organic compounds were present above reference levels in samples collected from Northwestern Discharge Area monitoring points. However, a low, estimated concentration of nitrobenzene was detected in a sample collected at Well 531 in addition to the common laboratory contaminants acetone, carbon disulfide, and toluene. Plasticizers diethyl phthalate, and dimethyl phthalate were detected at low, estimated levels in Well 535 along with low, estimated concentrations of benzidene, acetone, and toluene. There are no known active or legacy sources of these compounds near either well, however, the casings for both wells are made of polyvinyl chloride which may explain the presence of the phthalates in the groundwater samples.

5.10.4.1.5 Southern Discharge Area Exit Pathway Results

Monitoring point S-01 was sampled by UT-Battelle in April 2006 but not in August 2006 because the monitoring point was dry. Monitoring point S-02 was sampled in April and August 2006; aluminum, iron, and manganese exceeded their reference values at S-02 in 2006. As stated above, these metals are common constituents of earth materials at ORNL. No radiological constituents or organic compounds were present above their detection limits in samples collected from Southern Discharge Area monitoring points. As mentioned above, detection limits for several semi-volatile organic compounds exceeded their reference values.

5.10.4.2 Active Sites Monitoring—HFIR and SNS

Monitoring continued at the HFIR and SNS sites during 2006 under the HFIR Annual Monitoring Plan and the SNS Baseline Monitoring Plan, respectively. Operational monitoring at SNS coincided with the completion of baseline monitoring in April 2006.

Trend analysis was performed on a subset of HFIR monitoring locations—those in the pathway of the tritium plume migration (i.e., monitoring point J-1 and Wells 658, 892, and 661). Because of changes in monitoring strategy at HFIR in 2006 where there was sufficient data density to perform the trend analysis on 2006 data, those data were used exclusively. Where there was not sufficient data density, biennial (2004–2006) or historical (pre-2005) data were used.

Well 658 is located nearest to the tritium release sites, Well 892 is located down-gradient of the release sites, and Well 661 is located further down-gradient and near the remediated liquid waste storage ponds and Melton Branch. The east foundation drain monitoring point, J-1, is the closest monitoring point to the HFIR–within the rapid flow pathway described above. Action levels (Action Level 1 – 40,000 pCi/L and Action Level 2 – 80,000 pCi/L) established for J-1 in past Annual Monitoring Plans continued to be used as the basis for making decisions regarding contingency actions to be taken in the event of an observed excursion above the action levels.

Comparison of baseline SNS data to reference values was performed; however, trending of data was not performed on the baseline 2006 SNS data set.

5.10.4.2.1 HFIR Site Results

During 2006, no evidence of tritium releases to the subsurface from the HFIR was observed - there were no exceedences of Action Level 1 or 2 thresholds at J-1 during in 2006 and the trend in tritium concentrations at J-1 is downward.

Observations of tritium plume behavior were made by trending the tritium concentration data for Wells 658, 892, and 661. Trend analysis of biennial tritium concentration data for Wells 658 and 892 reveal a statistically significant downward trend in tritium concentration. A trend analysis of 2006 tritium data for Well 661 revealed a statistically insignificant increasing trend in tritium concentration at 661. With time, the main mass of the tritium plume has migrated from the release area near Well 658 and the HFIR through the area monitored by Well 892, and has caused the increased trend in tritium concentrations observable in Well 661.

Tritium concentrations fell during 2006 at J-1 and the aforementioned wells. It is postulated that the recent remediation of the liquid waste ponds located down-gradient of the HFIR site has hastened the reduction of tritium concentrations in the nearby monitoring points. Removal of the hydraulic barrier posed by the ponds appears to have allowed groundwater to flow more easily toward Melton Branch, essentially emptying the reservoir of contaminated groundwater previously held by the ponds.

5.10.4.2.2 SNS Site Results

SNS Baseline Monitoring Plan Results (sampling conducted April 2004 through March 2006). Tritium and C-14 are considered to be important potential neutron activation products produced by beam/earth material interactions, and given their fate and transport characteristics, results for these constituents are summarized below. Results of gross alpha and beta activity are summarized given the number of detected results reported by the laboratory for these constituents. Given the relatively low presence in samples collected, only those gamma emitters whose analytical results exceeded reference values are summarized in the following paragraph. The summaries provided are for all flow conditions described above.

Results of the baseline monitoring program at SNS indicate that ^{3}H was detected in 3 of 191 total samples collected during the monitoring period (0 of 44 filtered samples and 3 of 147 unfiltered samples). Likewise, ^{14}C was detected in 4 of 183 samples collected (2 of 44 filtered samples and 2 of 139 unfiltered samples). Tritium and ^{14}C concentrations did not exceed their reference values during the 2004–2006 monitoring period. ^{3}H and ^{14}C act effectively as tracers in groundwater, and if produced by the neutron activation of the earth materials surrounding the beam line and beam dump, these two radionuclides would be transported via the karst groundwater flow system without significant retardation by earth materials on site.

Gross alpha activity was detected in 55 of 157 total samples collected during the monitoring period (10 of 44 filtered samples and 45 of 113 unfiltered samples). Gross beta activity was detected in 70 of 157 samples collected (19 of 44 filtered samples and 51 of 113 unfiltered samples). Gross alpha activity was detected at concentrations that exceeded its reference value 9 out of 157 times at monitoring point S-5. Monitoring point S-5 is a spring that is connected to both Bear Creek Valley and the SNS site via karst conduits. As such, the gross alpha activity found in S-5 is attributed to uranium-contaminated groundwater from Y-12 facilities in Bear Creek Valley. The only other monitoring location where gross alpha and beta activities were present in excess of their reference values was monitoring point S-2 (1 out of 157 samples collected).

Filtration of samples was instituted to determine if the source of the higher observed alpha and beta activities were alpha and beta emitting radionuclides sorbed onto the suspended solids in the groundwater. Generally, gross alpha and beta activities were observed at lower concentrations in filtered samples collected during the monitoring period. Consequently, the suspended solids were deemed to be the contributor to the increased activity in the unfiltered samples. Suspended solids in samples collected during higher water flow velocities associated with storm flow conditions contribute to the higher suspended solid loading in the samples and therefore, the higher gross activities measured.

Several gamma-emitting radionuclides exceeded their reference values at different times during the baseline monitoring period at SNS monitoring locations: ^{238}U at S-1, S-3, S-4, and S-5 as well as ^{228}Ra and ^{232}Th at S-2. The reference value for ^{230}Th was exceeded at all monitoring stations during the monitoring period. These radiological constituents are naturally occurring in carbonate-based groundwater on the Oak Ridge Reservation. Additionally, ^{241}Am exceeded its reference value in one sample collected from S-4 during the monitoring period. ^{241}Am was likely misidentified by the reporting laboratory.

Table 5.10 summarizes the mean values for concentrations of ^{13}H, ^{14}C, gross alpha activity, and gross beta activities detected over the baseline monitoring period. For comparison, Table 5.11 displays averaged background concentrations of these radionuclides in groundwater in the main campus area of ORNL. Mean tritium and ^{14}C concentrations at the SNS site were lower during baseline monitoring than the averaged results found in background monitoring wells at ORNL. Likewise, mean ^{3}H concentrations in samples collected at the SNS site were lower than those reported for mean concentrations of ^{3}H in background surface water samples at the ORNL main campus area (839.7 pCi/L) (Bechtel National, Inc., 1992). Gross beta and alpha activity mean concentrations in groundwater at the SNS site are slightly higher than the averaged results in background monitoring wells at ORNL (see Table 5.11).

Operational Groundwater Monitoring Plan Results (Sampling conducted April 2006 through December 2006). Results of the 2006 operational monitoring program at SNS indicate the presence of ^{238}U at concentrations that exceeded its reference value at monitoring point S-3. Thorium-230 was the only other radionuclide that exceeded its reference value during operational monitoring at SNS. This exceedence occurred at SW-1. Both of these radiological constituents are naturally occurring in carbonate-based groundwater on the ORR. No other radiological constituents were observed to exceed their reference values. Table 5.12 outlines the

Table 5.10. Mean concentrations for radiological parameters detected at SNS (all flow conditions) – April 2004 through March 2006

Parameter	F/U[a]	Mean Concentration (pCi/L)
Tritium	F	-
Tritium	U	254.3
Carbon-14	F	9.7
Carbon-14	U	6.6
Alpha	F	8.7
Alpha	U	9.8
Beta	F	9.3
Beta	U	12.5

[a]F = filtered samples, U = unfiltered samples

Table 5.11. Mean radionuclide concentrations in groundwater sampled from background wells at ORNL[a]

Parameter	Filtered (pCi/L)	Unfiltered (pCi/L)
Tritium	797.5	1161.7
Carbon-14	100	100
Gross alpha	2.9	3.5
Gross beta	4.4	3.3

[a]Source: Bechtel National Inc., Sept. 1992.

radionuclides detected, their frequency of detection, and their average concentrations during operational monitoring activities in 2006.

5.11 Modernization and Reindustrialization Activities at ORNL

During 2006, SNS went into operation as did the newly constructed Center for Nanophase Materials Sciences (CNMS). The Chestnut Ridge Utility Expansion project extended branch electrical, water, sewer and natural gas lines as part of the master campus site plan. Design of a 25 bed user housing facility will start in 2007 with construction scheduled to be completed prior to 2009.

The state-funded Joint Institute for Biological Sciences is under construction in West Campus. It is scheduled to be completed during the fourth quarter of 2007. Renovations to existing laboratory buildings and the construction of a new 5,500 ft^2 West End Research Support Facility will support the West Campus co-location of biosciences and environmental sciences capabilities. Planned projects will upgrade First Street, the entrance into the West Campus, parking and landscaping as well as the disposition of ponds and structures excess to current mission.

A portion of the Central Campus has been leased to the Community Reuse Organization of East Tennessee (CROET) to create the Innovation Valley Science and Technology Park. Construction of two 100,000 ft^2 facilities is planned during 2007 and 2008. The park boundaries will eventually expand to 40 acres.

The privately funded 200,000 ft^2 Multiprogram Research Facility was completed with initial occupancy in September 2006. Construction of the North Hill Parking lot, scheduled to be completed in June 2007, will provide an additional 200 parking slots west of the Multiprogram Research Facility. Planned reconfiguration and expansion of East Campus electrical substations and chilled water distribution systems will be started during 2007 to support growing computer and computational capacity. These up grades follow the 2006 completion of the

Table 5.12. Radiological Constituents Detected in Groundwater at SNS—Operational Monitoring, April through December 2006

Constituent	No. Detected/N	Mean Concentration (pCi/L)
Tritium	11/63	191
Gross alpha	3/63	5.5
Gross beta	5/63	7.5
Bismuth-214	2/63	13.6
Thorium-230	3/63	11.5
Uranium-238	1/63	182

TVA substation, which replaced ORNL's 1940 vintage primary electrical substation. A DOE-funded, 140,000 ft^2 Multiprogram Research Laboratory Facility is planned to relocate a portion of the chemical and material science laboratories located in the Building 4500N/S Complex. The Flagpole Parking Lot on Central Avenue is the planned building site. FY 2009 is the proposed start of construction.

During 2006, ORNL's excess facility disposition program removed several Freels Bend out buildings which were deemed a public nuisance. Demolition of the old cafeteria Building 2010 is also planned for 2007.

5.12 Spallation Neutron Source

On May 31, 2006, construction of the SNS, a state-of-the-art pulsed-neutron facility located on Chestnut Ridge at ORNL, was completed. This major new accelerator-based neutron research facility significantly increases the capability for neutron beam research in the United States and worldwide. 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. The facility is currently being commissioned, with beam power increasing, with a goal of achieving full power operations in FY 2008-2009.

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 and commissioning 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 was 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 retention pond in December 2, 2003. Since then, the SNS has been fully compliant with all permit limits (see Table 5.13). The current NPDES permit expired on October 31, 2006. An application for renewal was submitted to and received by the TDEC on April 19, 2006.

The SNS has implemented a series of engineering controls designed to prevent any migration of radionuclides to groundwater. Furthermore, as reported above, 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. No impacts to groundwater have been detected.

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 facility will collect, monitor, and discharge radionuclides from operational components of the SNS. Sources will include accelerator tunnels, beam dumps, and the target building. The start-up of this air contaminant source will occur in late 2007.

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Table 5.13. National Pollutant Discharge Elimination System (NPDES) compliance at SNS, 2006
(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].