6. Oak Ridge Reservation Environmental Monitoring Program

Environmental monitoring is performed on the Oak Ridge Reservation to measure radiological and nonradiological parameters directly in environmental media adjacent to the facilities. Data from the environmental-monitoring program are analyzed to assess the environmental impact of US Department of Energy operations on the entire reservation and the surrounding area. Dose assessment information based on data from this program is presented in Chapter 7.

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

6.1 Meteorological Monitoring

Nine meteorological towers provide data on meteorological conditions and on the transport and diffusion qualities of the atmosphere on the Oak Ridge Reservation (ORR). Data collected at the towers are used in routine dispersion modeling to predict impacts from facility operations and as input to emergency response atmospheric models, which are used for simulated and actual accidental releases from a facility. Data from the towers are also used to support various research and engineering projects.

6.1.1 Description

The nine meteorological towers on ORR are described in Table 6.1 and are depicted in Fig. 6.1. In this document, the individual ORR-managed towers are designated by "MT" followed by a numeral. Other commonly used names for the sites are also provided in Table 6.1. Meteorological data are collected at different levels above the ground (2, 10, 15, 30, 33, 35, and 60 m) to assess the vertical structure of the atmosphere, particularly with respect to wind shear and stability. Stable boundary layers and significant wind shear zones (associated with the local ridge-and-valley terrain and the Great Valley of Eastern Tennessee; see Appendix B) can significantly affect the movement of a plume after a facility release (Bowen et al. 2000). Data are collected at the 10 or 15 m level at most towers, but the lowest wind measurement height for MT11 is 25 m. Additionally, data are collected at selected towers at the 30, 33, 35, and 60 m levels. At each measurement level except 2 m, temperature, wind speed, and wind direction are measured. Atmospheric stability (a measure of vertical mixing properties of the atmosphere) is measured at most towers; however, measurements involving vertical temperature profiles (i.e., measurements made by the solar radiation delta-T method) limit accurate determination of nighttime stability to the towers that are 60 m in height. Barometric pressure is measured at one or more of the towers at each ORR plant (MT1, MT2, MT4, MT6, MT7, and MT9). Precipitation is measured at MT6 and MT9 at the Y-12 National Security Complex (the Y-12 Complex); at MT1 and MT7 at the East Tennessee Technology Park (ETTP); and at MT2, MT3, and MT4 at Oak Ridge National Laboratory (ORNL). Solar radiation is measured at MT6 and MT9 at the Y-12 Complex, at MT1 and MT7 at ETTP, and at MT2 at ORNL. Calibrations of the instruments are managed by UT-Battelle and are performed every 6 months by an independent auditor (Holian Environmental).

Table 6.1. Oak Ridge Reservation meteorological towers

Tower	Alternate tower names	Location (lat., long.)	Altitude (m above MSL)	Measurement heights (m)
		ETTP		
MT1	K, 1208	35.93317N, -84.38833W	263	10, 60
MT7	L, 1209	35.92522N, -84.39414W	233	10, 30
		ORNL		
MT2	D,[a] 1047	35.92559N, -84.32379W	261	2, 15, 35, 60
MT3	B, 6555	35.93273N, -84.30254W	256	15, 30
MT4	A, 7571	35.92185N, -84.30470W	266	10/15, 30
MT10	M, 208A	35.90947N, -84.38796W	244	10
		Y-12 Complex		
MT6	W, West	35.98058N, -84.27358W	326	2, 10, 30, 60
MT9	Y, PSS Tower	35.98745N, -84.25363W	290	2, 15, 33
MT11	S, South Tower	35.98190 N,-84.25504W	352	25

Acronyms
ETTP = East Tennessee Technology Park
MSL = mean sea level
ORNL = Oak Ridge National Laboratory
PSS = plant shift superintendent
Y-12 Complex = Y-12 National Security Complex

[a]Tower "C" before May 2014 with measurement heights of 10, 30, and 100 m.

Sonic detection and ranging (SODAR) devices have been installed at the east end of the Y-12 Complex and adjacent to Tower MT2 at ORNL. The SODAR devices use acoustic waves to estimate wind direction, wind speed, and turbulence at altitudes higher than the reach of meteorological towers (60–900 m above ground level). Although SODAR measurements are somewhat less accurate than measurements made on the meteorological towers, the SODAR devices provide useful information regarding stability, upper air winds, and mixing depth. Mixing depth represents the thickness of the air layer adjacent to the ground over which an emitted or entrained inert nonbuoyant tracer could potentially be mixed by turbulence within 1 h or less.

Data are collected in real time for 1 min, 15 min, and hourly average intervals for emergency-response purposes and for dispersion modeling at the ORNL and Y-12 Complex Emergency Operations Centers.

Annual dose estimates are calculated from the archived hourly data. Data quality is checked continuously against predetermined data constraints, and out-of-range parameters are marked as invalid and are excluded from compliance modeling. Appropriate substitution data are identified when possible. Quality assurance records of missing and erroneous data are routinely kept for the nine ORR towers.

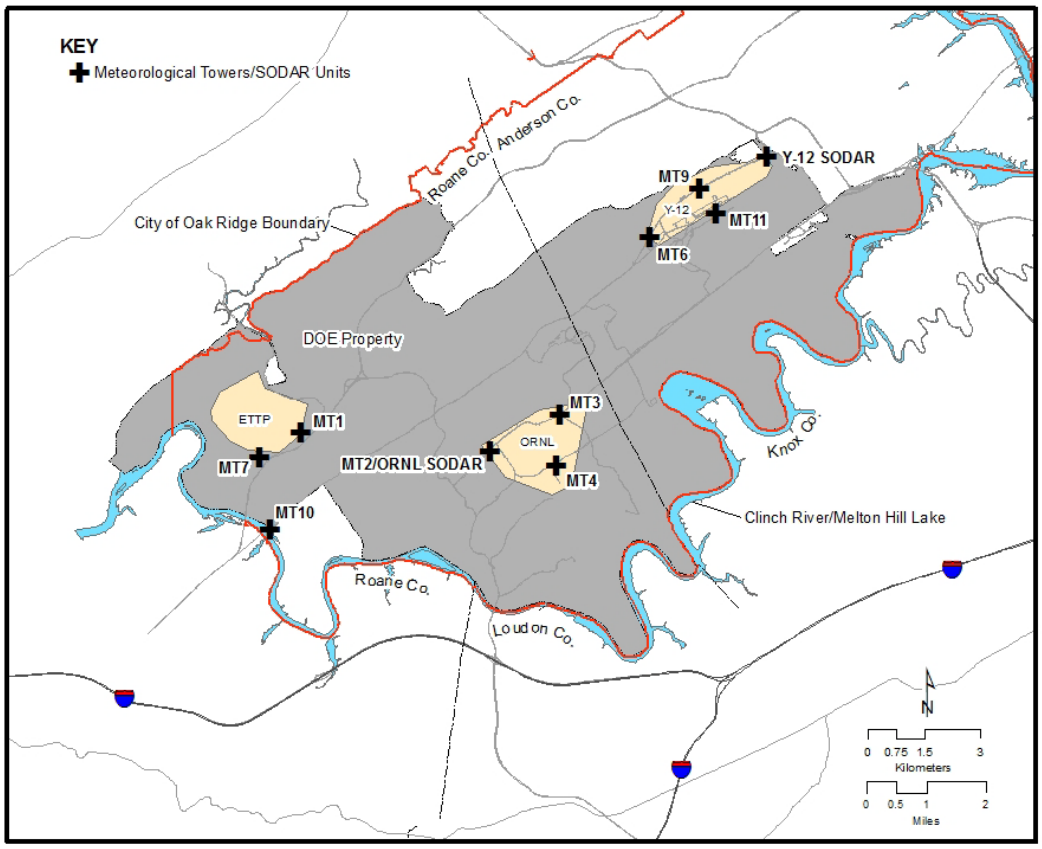

Fig. 6.1. The Oak Ridge Reservation meteorological monitoring network, including sonic detection and ranging (SODAR) devices.

6.1.2 Results

Prevailing winds are generally up-valley from the southwest and west-southwest or down-valley from the northeast and east-northeast, a pattern that typically results from channeling effects produced by the parallel ridges flanking the ORR sites. Winds in the valleys tend to follow the ridge axes, limiting cross-ridge flow within local valley bottoms. These conditions dominate over most of ORR, but flow variation is greater at ETTP, which is located in a less-constrained open valley bottom.

On the ORR, low wind speeds dominate near the valley surfaces, largely because of the decelerating influence of nearby ridges and mountains. Wind acceleration sometimes is observed at ridge-top level, particularly when flow is not parallel to the ridges (see Appendix B).

The atmosphere over ORR is often dominated by stable conditions at night and for a few hours after sunrise. These conditions, when coupled with low wind speeds and channeling effects in the valleys, result in poor dilution of emissions emitted from the facilities. However, high roughness values (caused by terrain and obstructions such as trees and buildings) partially mitigate these factors through an increase in turbulence (atmospheric mixing). These features are captured in dispersion model data input and are reflected in modeling studies conducted for each facility.

Precipitation data from tower MT2 are used in stream-flow modeling and in certain research efforts. The data indicate the variability of regional precipitation: the high winter rainfall resulting from frontal systems and the uneven, but occasionally intense, summer rainfall associated with thunderstorms. The

total precipitation at ORNL during 2016 (1,084 mm or 42.68 in.) was almost 20% below the long-term average of 1,337.5 mm (52.64 in.). The average annual wind data recovery rates (a measure of acceptable data) across locations used for modeling during 2016 were greater than 98% for wind sensors at the ORNL sites (towers MT2, MT3, MT4, and MT10). Annual wind data recovery from ETTP and Y-12 meteorological towers during 2016 exceeded 99% (towers MT1, MT6, MT7, MT9, and MT11).

6.2 External Gamma Radiation Monitoring

6.2.1 Data Collection and Analysis

External gamma exposure rates are continuously recorded by dual-range Geiger-Müller tube detectors colocated with ORR ambient air stations. In 2016 several changes to station locations were made to reflect changes in activities on the ORR that have occurred since the original sites were established in the 1990s. Figure 6.2 shows locations that were monitored for all or part of 2016. During the year, as new stations came on line, others were discontinued, resulting in only partial data for several locations. Table 6.2 summarizes the data for each station.

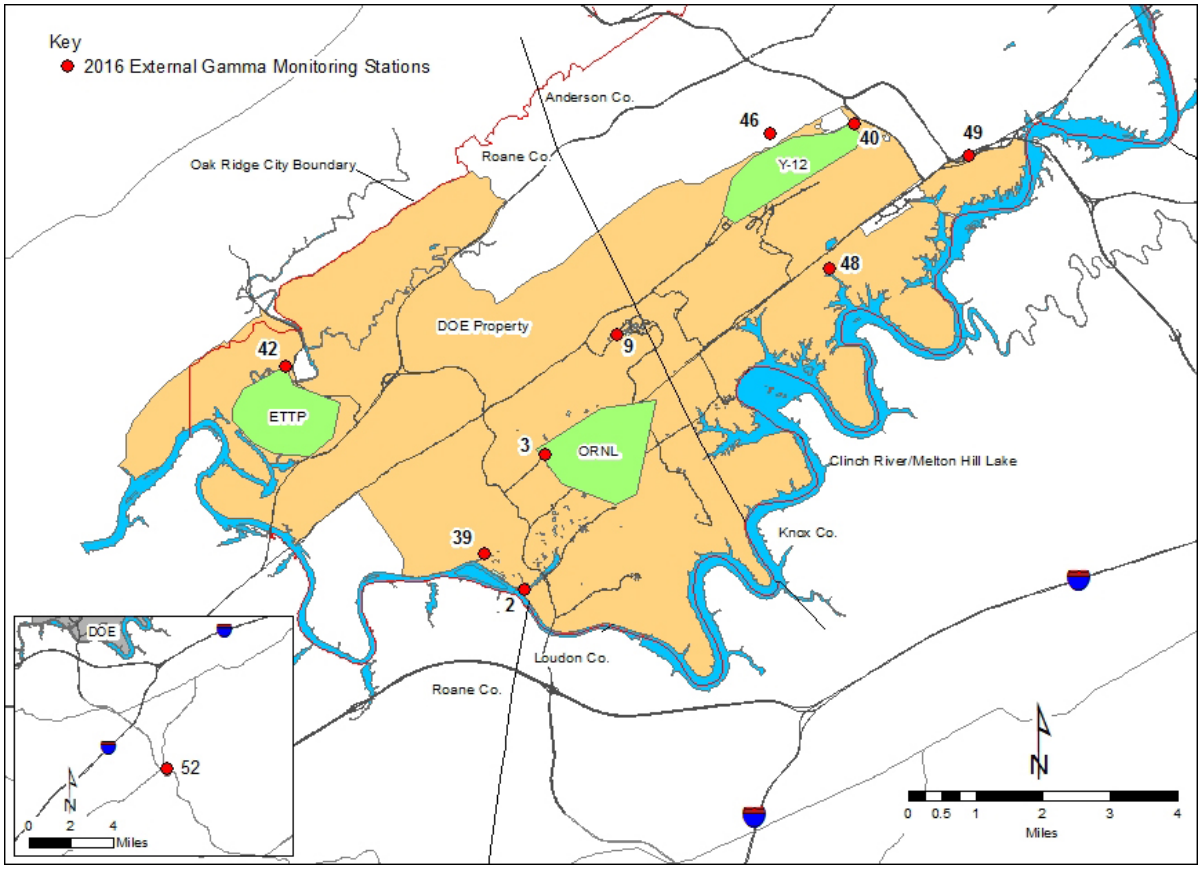

Fig. 6.2. External gamma radiation monitoring locations on the Oak Ridge Reservation.

6.2.2 Results

The mean exposure rate for the reservation network in 2016 was 10.5 µR/h, and the mean at the reference location was 9.7 µR/h. Exposure rates from background sources in Tennessee range from 2.9 to 11 µR/h.

Table 6.2. External gamma (exposure rate) averages for the Oak Ridge Reservation, 2016

Monitoring location	Number of data points (daily)	Measurement (μR/h)[a]		
		Min	Max	Mean
02	22	9.1	11.2	9.7
03	199	9.3	11.2	9.8
09	94	9.5	17.4	10.9
39	347	11.1	16.0	12.1
40	354	9.6	12.4	10.7
42	132	9.0	10.8	9.5
46	334	10.5	13.0	11.2
48	234	9.4	12.0	9.9
49	82	9.8	12.6	10.7
52	354	8.0	11.4	9.7

[a]To convert microroentgens per hour (μR/h) to milliroentgens per year, multiply by 8.760.

6.3 Ambient Air Monitoring

In addition to exhaust stack monitoring conducted at the US Department of Energy (DOE) Oak Ridge installations (see chapters 3, 4, and 5), ambient air monitoring is performed to measure radiological parameters directly in the ambient air adjacent to the facilities (Fig. 6.3). Ambient air monitoring provides a means to verify that contributions of fugitive and diffuse sources are insignificant, serves as a check on dose-modeling calculations, and would allow determination of contaminant levels at monitoring locations in the event of an emergency.

Ambient air monitoring conducted by individual site programs is discussed in chapters 3, 4, and 5. The ORR ambient air monitoring program complements the individual site programs and permits the impacts of the ORR operations to be assessed on an integrated basis. This program is discussed in detail in the following sections.

The objectives of the ORR ambient air monitoring program are to perform surveillance of airborne radionuclides at the reservation perimeter and to collect reference data from a location not affected by activities on the ORR. The perimeter air monitoring network was established in the early 1990s. Since then there have been significant operational changes on the ORR (e.g., addition of Spallation Neutron Source and Transuranic Waste Processing Center operations and shutdown of the Toxic Substances Control Act Incinerator), and significant cleanup and remediation projects have been completed. The network was modified in 2016 to better reflect current DOE activities and operations. The stations monitored in 2016 are shown in Fig. 6.4. Reference samples are collected from Station 52 (Fort Loudoun Dam). Sampling was conducted at each ORR station during 2016 to quantify levels of alpha-, beta-, and gamma-emitting radionuclides. Upgrades were done sequentially throughout 2016, so only partial data were available at several locations.

Fig. 6.3. Oak Ridge Reservation ambient air station.

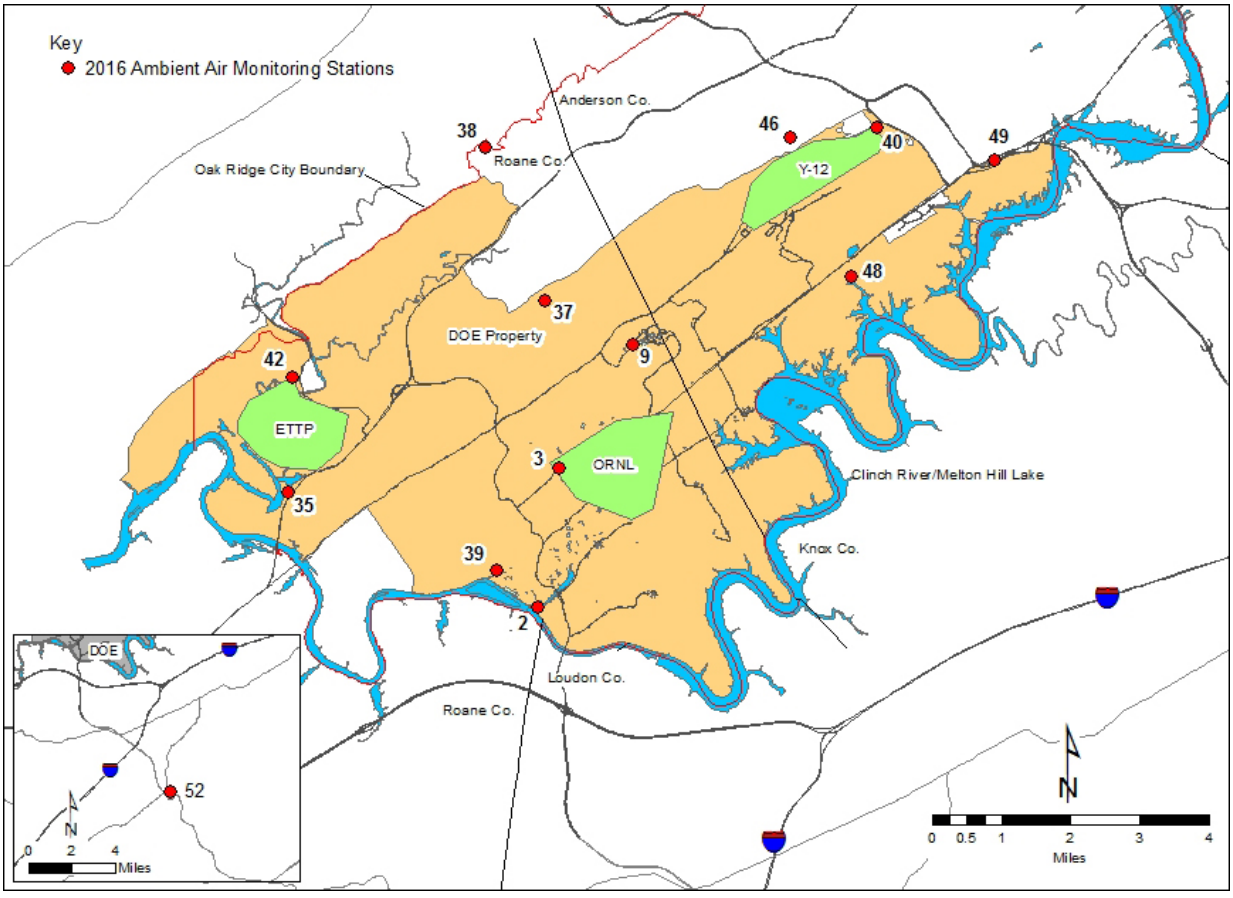

Fig. 6.4. Locations of Oak Ridge Reservation perimeter air monitoring stations.

Atmospheric dispersion modeling was used to select appropriate sampling locations. The locations selected are those likely to be affected most by releases from the Oak Ridge facilities. Therefore, in the event of a release, no residence or business near ORR should receive a radiation dose greater than doses calculated at the sampled locations.

The sampling system consists of two separate instruments. Particulates are captured by high-volume air samplers equipped with glass-fiber filters. The filters are collected weekly, composited quarterly, and then submitted to an analytical laboratory to quantify gross alpha and beta activity and to determine the concentrations of specific isotopes of interest on ORR. The second system is designed to collect tritiated water vapor. The sampler consists of a prefilter followed by an adsorbent trap that contains indicating silica gel. The samples are collected weekly or biweekly, composited quarterly, and then submitted to an analytical laboratory for tritium analysis.

6.3.1 Results

Data from the ORR ambient air network are analyzed to assess the impact of DOE operations on the local air quality. Each measured radionuclide concentration (Table 6.3) is compared with derived concentration standards (DCSs) for air established by DOE as guidelines for controlling exposure to members of the public. All radionuclide concentrations measured at the ORR ambient air stations during 2016 were less than 1% of applicable DCSs, indicating that activities on the reservation are not adversely affecting local air quality.

Table 6.3. Average radionuclide concentrations at Oak Ridge Reservation perimeter air monitoring stations, 2016

Parameter	N detected/N total	Concentration (pCi/mL)[a]		
		Average	Minimum	Maximum
		Station 1		
Be-7	4/4	4.81E-08	3.62E-08	5.89E-08
K-40	0/4	-1.36E-10	-2.34E-10	-3.98E-11
Tc-99	2/3	3.20E-10	1.24E-10	4.43E-10
Tritium	1/4	3.89E-06	5.11E-07	7.17E-06
U-234	3/4	2.72E-12	1.37E-12	3.57E-12
U-235	1/4	1.98E-13	1.54E-13	2.80E-13
U-238	4/4	2.40E-12	1.28E-12	3.77E-12
		Station 2		
Be-7	3/3	5.98E-08	3.59E-08	7.51E-08
K-40	0/3	1.34E-10	-8.65E-10	1.52E-09
Tc-99	1/2	2.65E-10	3.11E-11	4.98E-10
Tritium	1/4	6.97E-06	2.69E-06	1.03E-05
U-234	3/3	2.73E-12	1.97E-12	3.35E-12
U-235	0/3	-5.31E-15	-7.47E-14	7.13E-14
U-238	3/3	2.04E-12	1.56E-12	2.76E-12

Table 6.3 (continued)

Parameter	N detected/N total	Concentration (pCi/mL)[a]		
		Average	Minimum	Maximum
		Station 3		
Be-7	3/3	8.28E-08	3.77E-08	1.45E-07
K-40	0/3	6.30E-10	9.27E-12	1.51E-09
Tc-99	0/2	3.48E-10	1.17E-11	6.84E-10
Tritium	1/4	4.71E-06	1.30E-06	9.36E-06
U-234	2/3	2.79E-12	2.36E-12	3.33E-12
U-235	2/3	7.38E-13	9.34E-14	1.82E-12
U-238	3/3	2.72E-12	2.57E-12	3.03E-12
		Station 35		
Be-7	4/4	4.27E-08	3.71E-08	5.49E-08
K-40	0/4	1.81E-10	-2.52E-10	9.32E-10
Tc-99	3/4	3.69E-10	6.97E-11	6.47E-10
Tritium	1/4	3.66E-06	-2.42E-07	8.81E-06
U-234	4/4	1.26E-11	2.11E-12	3.14E-11
U-235	2/4	1.12E-12	1.82E-13	2.40E-12
U-238	4/4	3.44E-12	1.76E-12	6.72E-12
		Station 37		
Be-7	4/4	3.81E-08	2.59E-08	5.55E-08
K-40	0/4	-8.56E-11	-1.98E-10	6.00E-12
Tc-99	2/3	2.50E-10	1.53E-10	3.45E-10
Tritium	0/4	1.14E-06	-1.39E-06	3.83E-06
U-234	4/4	2.82E-12	1.82E-12	4.60E-12
U-235	3/4	1.95E-13	0	2.85E-13
U-238	4/4	2.03E-12	1.60E-12	2.78E-12
		Station 38		
Be-7	3/3	4.95E-08	3.82E-08	6.86E-08
K-40	0/3	-2.25E-10	1.63237E+12	1.94E-11
Tc-99	2/3	3.02E-10	2.02E-10	4.03E-10
Tritium	0/3	1.73E-06	3.40E-08	4.94E-06
U-234	3/3	4.50E-12	3.28E-12	5.85E-12
U-235	1/3	2.57E-13	7.10E-14	3.67E-13
U-238	3/3	2.65E-12	1.88E-12	3.60E-12
		Station 39		
Be-7	4/4	4.26E-08	2.34E-08	6.17E-08
K-40	0/4	2.61E-10	-8.13E-11	6.38E-10
Tc-99	2/3	3.90E-10	1.59E-10	5.24E-10
Tritium	1/4	1.94E-06	2.10E-07	3.92E-06
U-234	4/4	2.90E-12	1.80E-12	5.22E-12
U-235	1/4	6.28E-14	-6.10E-14	2.11E-13
U-238	4/4	1.78E-12	1.68E-12	1.90E-12

Table 6.3 (continued)

Parameter	N detected/N total	Concentration (pCi/mL)[a]		
		Average	Minimum	Maximum
		Station 40		
Be-7	4/4	4.67E-08	3.45E-08	7.59E-08
K-40	1/4	3.35E-10	-1.38E-10	1.20E-09
Tc-99	2/3	3.73E-10	1.48E-10	5.04E-10
Tritium	0/4	3.59E-06	2.86E-06	4.55E-06
U-234	4/4	7.10E-12	4.72E-12	1.09E-11
U-235	3/4	5.40E-13	4.59E-13	6.59E-13
U-238	4/4	3.79E-12	3.07E-12	4.35E-12
		Station 42		
Be-7	2/2	6.36E-08	3.70E-08	9.02E-08
K-40	0/2	-4.00E-10	-5.56E-10	-2.43E-10
Tc-99	2/2	7.87E-10	4.58E-10	1.12E-09
Tritium	0/2	1.82E-07	-2.77E-07	6.42E-07
U-234	2/2	7.11E-11	1.26E-11	1.30E-10
U-235	2/2	5.48E-12	8.52E-13	1.01E-11
U-238	2/2	1.18E-11	4.33E-12	1.92E-11
		Station 46		
Be-7	4/4	4.50E-08	3.24E-08	7.17E-08
K-40	1/4	5.14E-10	-9.91E-11	1.86E-09
Tc-99	1/3	2.98E-10	1.48E-10	4.74E-10
Tritium	1/4	2.98E-06	1.48E-06	4.49E-06
U-234	4/4	4.21E-12	2.84E-12	7.01E-12
U-235	1/4	2.89E-13	2.18E-13	3.91E-13
U-238	4/4	2.54E-12	2.05E-12	3.15E-12
		Station 48		
Be-7	3/3	4.67E-08	2.95E-08	6.70E-08
K-40	0/3	-1.60E-10	-5.28E-10	1.66E-10
Tc-99	2/3	3.22E-10	1.97E-10	4.85E-10
Tritium	0/3	1.44E-06	-1.14E-07	3.58E-06
U-234	3/3	2.46E-12	1.82E-12	3.02E-12
U-235	1/3	3.03E-13	1.08E-13	4.72E-13
U-238	3/3	2.04E-12	1.56E-12	2.46E-12
		Station 49		
Be-7	1/1	4.44E-08	4.44E-08	4.44E-08
K-40	0/4	1.00E-10	1.00E-10	1.00E-10
Tritium	0/1	3.91E-06	3.91E-06	3.91E-06
U-234	1/1	3.56E-12	3.56E-12	3.56E-12
U-235	1/1	4.01E-13	4.01E-13	4.01E-13
U-238	1/1	3.54E-12	3.54E-12	3.54E-12

Table 6.3 (continued)

Parameter	N detected/N total	Concentration (pCi/mL)[a]		
		Average	Minimum	Maximum
		Station 52		
Be-7	4/4	5.07E-08	3.44E-08	7.32E-08
K-40	0/4	-2.13E-10	-4.24E-10	1.07E-10
Tc-99	3/4	3.05E-10	1.27E-10	5.39E-10
Tritium	0/4	3.73E-07	-8.50E-07	1.56E-06
U-234	4/4	2.53E-12	1.96E-12	3.29E-12
U-235	0/4	1.61E-13	3.08E-14	2.35E-13
U-238	4/4	2.11E-12	1.50E-12	2.71E-12
		Station 9		
Be-7	1/1	4.14E-08	4.14E-08	4.14E-08
K-40	0/1	-4.43E-11	-4.43E-11	-4.43E-11
Tritium	1/1	1.54E-4	1.54E-4	1.54E-4
U-234	1/1	3.21E-12	3.21E-12	3.21E-12
U-235	0/1	1.38E-13	1.38E-13	1.38E-13
U-238	1/1	2.44E-12	2.44E-12	2.44E-12

[a]1 pCi = 3.7×10^{12} Bq.

6.4 Surface Water Monitoring

6.4.1 Oak Ridge Reservation Surface Water Monitoring

The ORR surface water monitoring program consists of sample collection and analysis from five locations on the Clinch River, including public water intakes (Fig. 6.5). The program is conducted in conjunction with site-specific surface water monitoring activities to enable an assessment of the impacts of past and current DOE operations on the quality of local surface water.

Grab samples are collected quarterly at all five locations and are analyzed for general water quality parameters, screened for radioactivity, and analyzed for mercury and specific radionuclides when appropriate. Table 6.4 lists the specific locations and associated sampling frequencies and parameters.

The sampling locations are classified by the State of Tennessee for recreation and domestic use. Tennessee Water Quality Criteria (WQCs) associated with these classifications are used as references where applicable (TDEC 2008). The Tennessee WQCs do not include criteria for radionuclides. Four percent of the DOE DCS is used for radionuclide comparison because this value is roughly equivalent to the 4 mrem dose limit from ingestion of drinking water on which the US Environmental Protection Agency (EPA) radionuclide drinking water standards are based.

6.4.2 Results

In 2016, analyses of surface water samples collected for ORR-wide surveillance at Clinch River kilometers (CRKs) 66, 58, 32, 23, and 16 were transitioned from a commercial laboratory to the ORNL Radioactive Materials Analytical Laboratory (RMAL). Following the transition, analytical results for several radionuclides were higher than those previously reported by the commercial laboratory. The major reasons for the increases are thought to be the result of higher radiation background in the RMAL

counting laboratory, cross-contamination found in RMAL laboratory equipment, and the contributions of naturally occurring short-lived radionuclides that likely decayed significantly during transport to the commercial laboratory. Corrective actions have been identified and implemented to address these issues. During the year, surface water samples were also collected at CRKs 23 and 16 for ETTP site-specific monitoring. The results from the samples were used in dose calculations instead of those obtained via the ORR-wide program to eliminate the bias that was likely to be introduced by higher background and cross-contamination.

A comparison of radionuclide concentrations from 2016 sampling results for surface water collected upstream of DOE inputs with concentrations in surface water collected downstream of DOE inputs shows no statistically significant differences. No radionuclides were detected above 4% of the respective DCSs or the 4 mrem dose limit, which is the maximum contaminant level (MCL) for beta and photon emitters in community drinking water systems.

Mercury was detected above MCL once in the March sample from CRK 16; otherwise, mercury was not detected above MCL during the other three quarters at CRK 16 or at the other two sampling locations where mercury samples are collected.

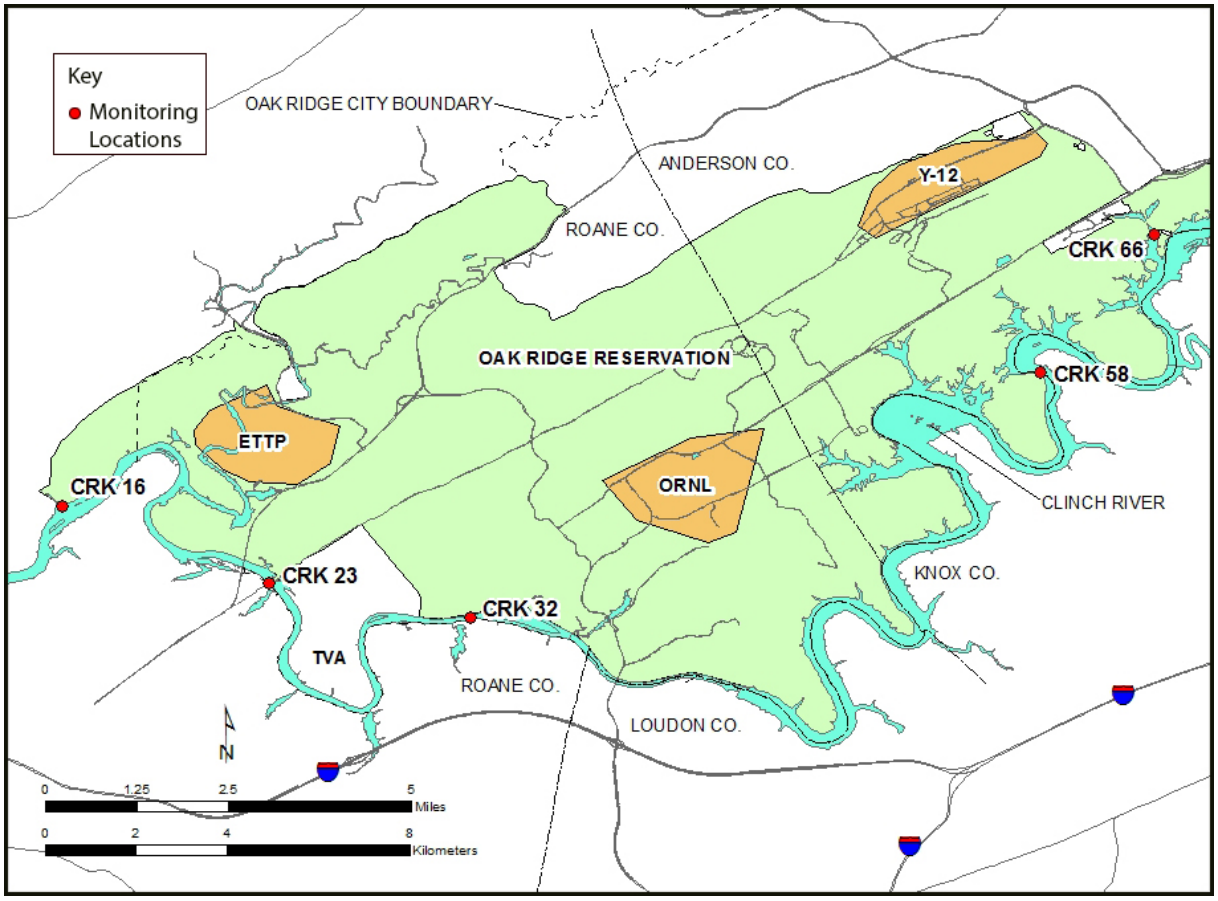

Fig. 6.5. Oak Ridge Reservation surface water surveillance sampling locations.

Table 6.4. Oak Ridge Reservation surface water sampling locations, frequencies, and parameters, 2016

Location[a]	Description	Frequency	Parameters
CRK 16	Clinch River downstream from all DOE ORR inputs	Quarterly	Mercury, gross alpha, gross beta, gamma scan, ^{3}H, field measurements[b]
CRK 23	Former water supply intake for ETTP	Quarterly	Mercury, gross alpha, gross beta, gamma scan, ^{3}H, field measurements[b]
CRK 32	Clinch River downstream from ORNL	Quarterly	Gross alpha, gross beta, gamma scan, total radioactive strontium, ^{3}H, field measurements[b]
CRK 58	Water supply intake for Knox County	Quarterly	Gross alpha, gross beta, gamma scan, ^{3}H, field measurements[b]
CRK 66	Melton Hill Reservoir above city of Oak Ridge water intake	Quarterly	Mercury, gross alpha, gross beta, gamma scan, total radioactive strontium, ^{3}H, field measurements[b]

[a]Locations indicate the water body and distances upstream of the confluence of the Clinch and Tennessee Rivers (e.g., CRK 16 is 16 km upstream from the confluence of the Clinch River with the Tennessee River, Watts Bar Reservoir).
[b]Field measurements consist of dissolved oxygen, pH, and temperature.

Acronyms
CRK = Clinch River kilometer
DOE = US Department of Energy
ETTP = East Tennessee Technology Park
ORNL = Oak Ridge National Laboratory
ORR = Oak Ridge Reservation

6.5 Groundwater Monitoring

Work continued in 2016 to implement key recommendations from the *Groundwater Strategy for the U.S. Department of Energy Oak Ridge Reservation* (DOE 2013), which was agreed to in 2014 by DOE, EPA, and the Tennessee Department of Environment and Conservation (TDEC). During 2016 the ORR Groundwater Program focused on activities in two tasks, an assessment of off-site groundwater and construction and calibration of a regional-scale flow model.

6.5.1 Offsite Groundwater Assessment

An off-site groundwater assessment project to evaluate off-site groundwater quality and movement continued in FY 2016. The project is a cooperative effort by DOE, EPA, and TDEC. Two sampling events were completed in FY 2015 in accordance with an approved work plan. A confirmatory sampling event was completed in FY 2016, and a report of results was prepared and issued in November 2016 (DOE 2016).

6.5.2 Regional-Scale Flow Model

Construction and calibration of a regional-scale flow model was completed in FY 2016. The model will serve as an underlying framework to support future cleanup decisions and actions. A technical advisory group composed of experts from DOE, EPA, TDEC, and industry has met several times annually since 2014. Members of the advisory group reviewed progress and made recommendations for development and future use of the model.

6.6 Food

Food sources were analyzed to evaluate potential radiation doses to consumers of local food crops, fish, and harvested game and to monitor trends in environmental contamination and possible long-term accumulation of radionuclides. Samples of vegetables, milk, fish, deer, Canada geese, and turkeys were collected from areas that could be affected by activities on the reservation and from off-site reference locations.

The wildlife administrative release limits associated with deer, turkey, and geese harvested on ORR are conservative and were established based on the "as low as reasonably achievable (ALARA)" principle to ensure that doses to consumers are managed at levels well below regulatory dose thresholds. The ALARA concept is not a dose limit but rather a philosophy that has the objective of maintaining exposures to workers, members of the public, and the environment below regulatory limits and as low as can be reasonably achieved. An administrative release limit of 5 pCi/g ^{137}Cs is based on the assumption that one person consumes all of the meat from a maximum-weight deer, goose, or turkey. This limit ensures that members of the public who harvest wildlife on the reservation will not receive significant radionuclide doses from that consumption pathway. In addition, a conservative administrative limit of 1.5 times background for gross beta activity has been established, a threshold that is near the detection limit for field measurements of $^{89/90}$Sr in deer leg bone.

6.6.1 Vegetables

Tomatoes, lettuce, and turnips were purchased from farms near ORR and from reference locations outside the potential DOE impact area. The locations were chosen based on availability and on the likelihood of effects from routine releases from the Oak Ridge facilities.

6.6.1.1 Results

Samples were analyzed for gross alpha, gross beta, gamma emitters, and uranium isotopes. No gamma-emitting radionuclides were detected above the minimum detectable activity (MDA), except for the naturally occurring radionuclides ^{7}Be and ^{40}K (Table 6.5).

Table 6.5. Concentrations of radionuclides detected in vegetables, 2016 (pCi/kg)[a]

Location	Gross alpha	Gross beta	^{7}Be	^{40}K	^{234}U	^{235}U	^{238}U
			Lettuce				
East of Y-12, Claxton vicinity	0.0000768	0.00419	0.000672	0.00539	0.00000379	*b*	*b*
West of ETTP	*b*	0.00537	*b*	0.00735	*b*	*b*	*b*
North of Y-12	*b*	0.00526	*b*	0.00664	*b*	*b*	0.00000275
South of ORNL	*b*	0.00423	*b*	0.0052	*b*	0.0000018	*b*
Southwest of ORNL, Lenoir City	*b*	0.00308	*b*	0.00229	0.00000396	*b*	*b*
Reference location	*b*	0.00139	*b*	0.00125	0.00000344	*b*	*b*
			Tomato				
East of Y-12, Claxton vicinity	*b*	0.00229	*b*	0.00159	*b*	*b*	*b*

Table 6.5 (continued)

Location	Gross alpha	Gross beta	^{7}Be	^{40}K	^{234}U	^{235}U	^{238}U
West of ETTP	*b*	0.0013	*b*	0.00178	*b*	*b*	*b*
North of Y-12	*b*	0.00216	*b*	0.00276	*b*	*b*	*b*
South of ORNL	*b*	0.00219	*b*	0.00203	*b*	*b*	*b*
Southwest of ORNL, Lenoir City	*b*	0.00144	*b*	0.00179	*b*	*b*	0.00000184
Reference location	*b*	0.0015	*b*	0.00153	0.00000281	0.0000022	*b*

[a]Detected radionuclides are those at or above minimum detectable activity. 1 pCi = 3.7×10^{-2} Bq.
[b]Value was less than or equal to minimum detectable activity.

Acronyms
ETTP = East Tennessee Technology Park
ORNL = Oak Ridge National Laboratory
Y-12 = Y-12 National Security Complex

6.6.2 Milk

Milk is a potentially significant exposure pathway to humans for some radionuclides deposited from airborne emissions because of the relatively large surface area on which a cow can graze daily, the rapid transfer of milk from producer to consumer, and the importance of milk in the diet.

Surveys to locate dairies in areas that could receive deposition from ORR activities are conducted annually, and bimonthly grab samples are collected at those locations and at a reference location in an unimpacted area. For many years, the only known dairy with potential to be affected by DOE ORR activities was east of the ORR (Fig. 6.6) in the Claxton community. However, in April 2016 that dairy went out of business, and no further milk samples were collected during the year. The 2016 milk samples collected in February and April were analyzed for gamma emitters and for total radioactive strontium (^{89}Sr + ^{90}Sr).

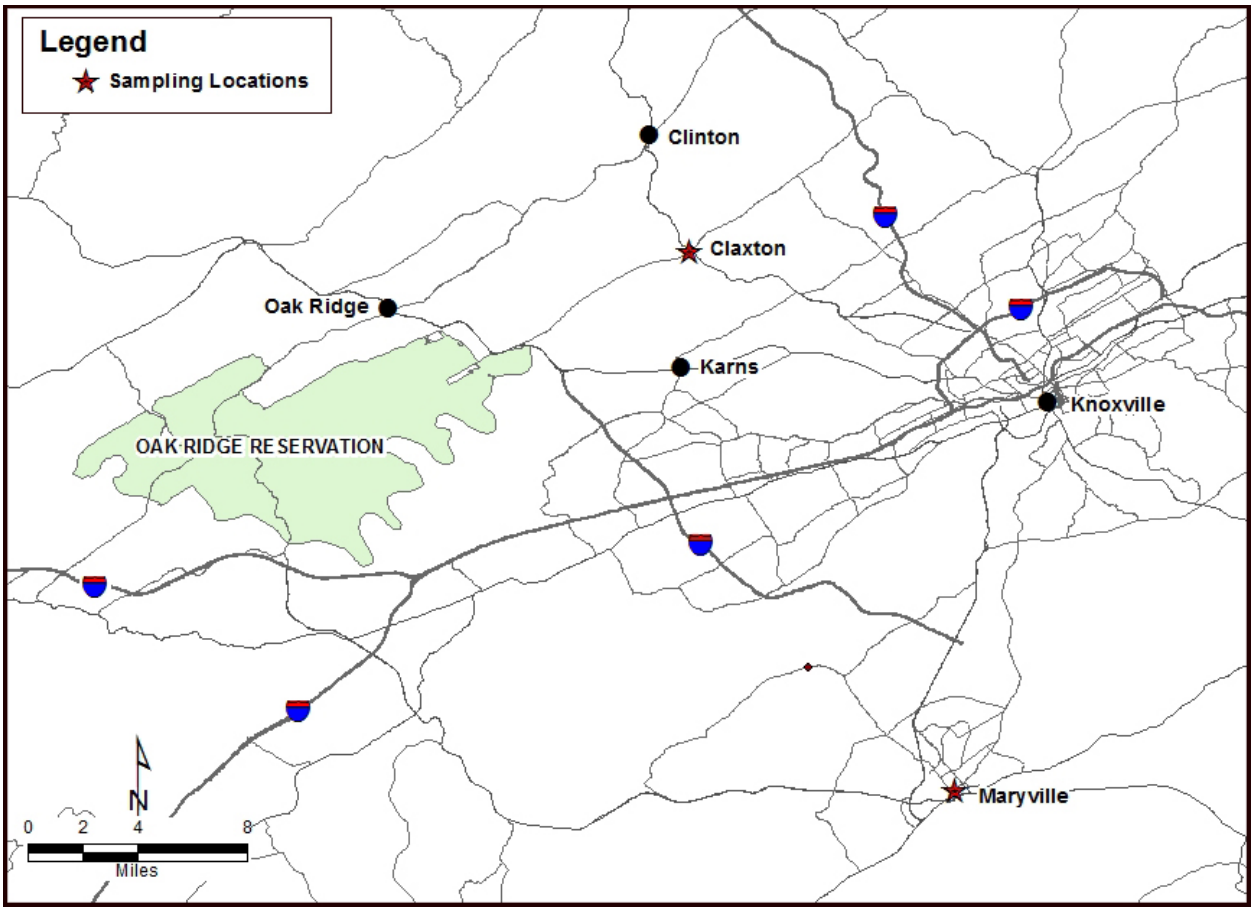

Fig. 6.6. Milk-sampling locations in the vicinity of the Oak Ridge Reservation.

6.6.2.1 Results

Concentrations of radionuclides detected above MDA in milk are presented in Table 6.6.

A comparison of results for milk collected from the Claxton dairy with those for milk collected from the reference dairy indicate that ORR activities are not significantly impacting radionuclide concentrations in milk.

Table 6.6. Concentrations of radionuclides detected in raw milk, 2016

Analysis	Number detected/ total number	Detected concentration (pCi/L)[a]			Standard error of mean
		Maximum	Minimum	Average	
		Claxton			
^{40}K	2/2	1,350[b]	1,310[b]	1,330[b]	20
		Reference location			
^{40}K	2/2	1,360[b]	1,290[b]	1,325[b]	35

[a]Detected radionuclides are those above minimum detectable activity. 1 pCi = 3.7×10^{12} Bq.
[b]Individual and average concentrations significantly greater than zero at the 95% confidence level.

6.6.3 Fish

Members of the public could be exposed to contaminants originating from DOE ORR activities through consumption of fish caught in area waters. This potential exposure pathway is monitored annually by collecting fish from three locations on the Clinch River and by analyzing edible flesh for specific contaminants. The locations are as follows (Fig. 6.7):

- Clinch River upstream from all DOE ORR inputs (CRK 70),
- Clinch River downstream from ORNL (CRK 32), and
- Clinch River downstream from all DOE ORR inputs (CRK 16).

Sunfish (*Lepomis macrochirus*, *L. auritus*, and *Ambloplites rupestris*) and catfish (*Ictalurus punctatus*) are collected from each of the three locations to represent both top-feeding and bottom-feeding-predator species. In 2016, a composite sample of each of those species at each location was analyzed for selected metals, polychlorinated biphenyls (PCBs), tritium, gross alpha, gross beta, gamma-emitting radionuclides, and total radioactive strontium. To accurately estimate exposure levels to consumers, only edible portions of the fish were submitted for analysis.

TDEC issues advisories on consumption of certain fish species caught in specified Tennessee waters. These advisories apply to fish that could contain potentially hazardous contaminants. TDEC has issued a "do not consume" advisory for catfish in the Melton Hill Reservoir in its entirety, not just in areas that could be impacted by ORR activities, because of PCB contamination. Similarly, a precautionary advisory for catfish in the Clinch River arm of Watts Bar Reservoir has been issued because of PCB contamination (TDEC 2008).

6.6.3.1 Results

PCBs, specifically Aroclor-1260, and mercury were detected in both sunfish and catfish at all three locations in 2016. These results are consistent with the TDEC advisories. Detected PCBs, mercury, and radionuclide concentrations are shown in Table 6.7.

Radiological analyses for fish tissues sampled in 2016 showed few statistical differences (at the 95% confidence level) between the upstream and downstream locations, indicating that DOE activities on the ORR are not significant contributors to the public radiological dose from fish consumption.

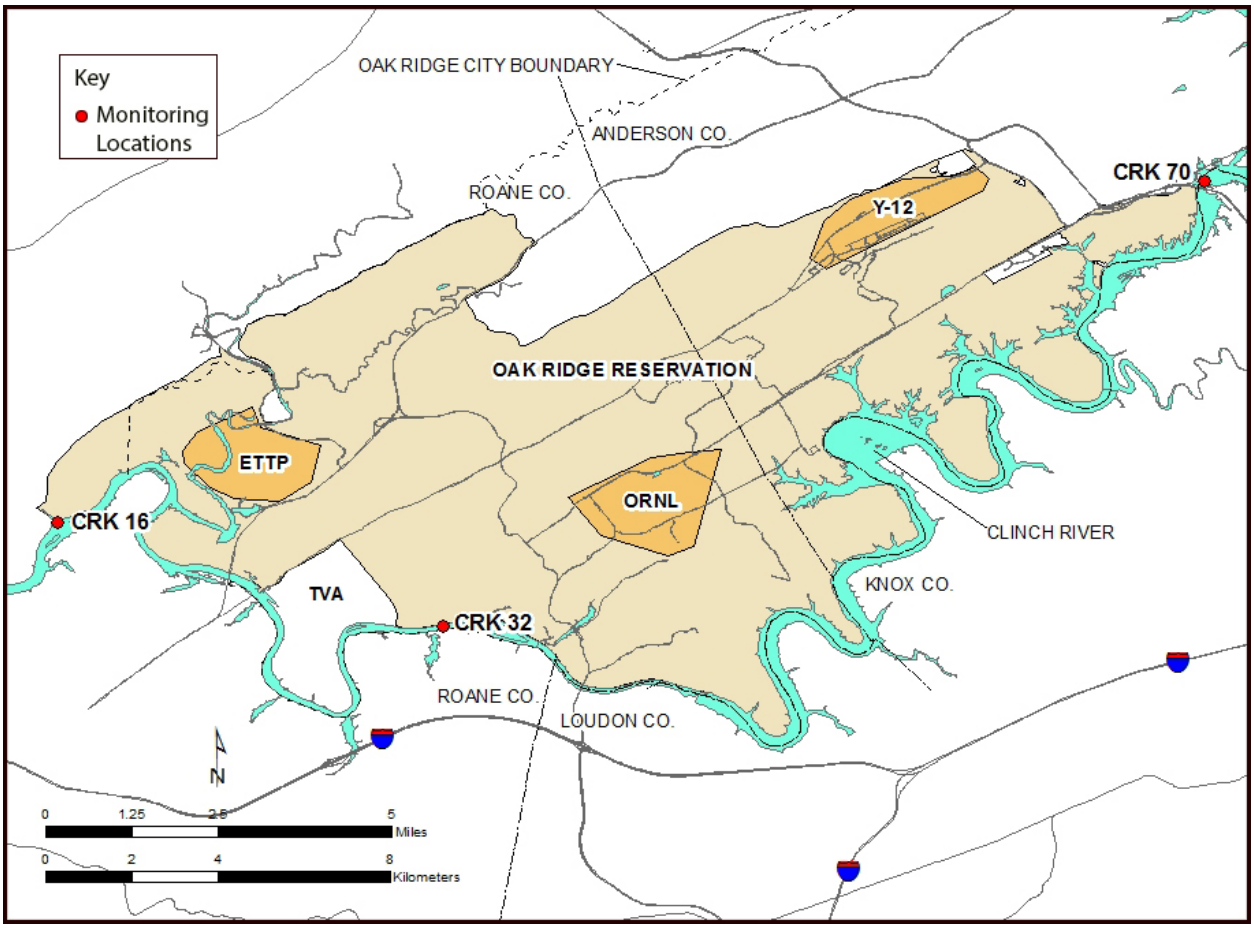

Fig. 6.7. Fish-sampling locations for the Oak Ridge Reservation Surveillance Program.

Table 6.7. Tissue concentrations in catfish and sunfish for detected mercury, PCBs, and radionuclides, 2016[a]

Parameter	Catfish[b]	Sunfish[b]
Clinch River downstream from all DOE ORR inputs (CRK 16)		
Metals (mg/kg)		
Hg	0.063	0.061
Pesticides and PCBs (µg/kg)		
PCB-1260	30	210
Radionuclides (pCi/g)[b]		
Beta activity	3.0[c]	2.6[c]
^{40}K	3.8[c]	2.9[c]
Clinch River downstream from ORNL (CRK 32)		
Metals (mg/kg)		
Hg	J0.026[d]	0.16
Pesticides and PCBs (µg/kg)		
PCB-1260	26	290

Table 6.7 (continued)

Parameter	Catfish[b]	Sunfish[b]
Radionuclides (pCi/g)[b]		
Beta activity	3.1[c]	2.5[c]
^{137}Cs	0.00016[c]	0.0000074
^{40}K	3.8[c]	3.6[c]
^{90}Sr	0.044[c]	−0.00073
Tritium	2.4[c]	0.098
Clinch River (Solway Bridge) upstream from all DOE ORR inputs (CRK 70)		
Metals (mg/kg)		
Hg	J0.0088[d]	J0.028[d]
Pesticides and PCBs (µg/kg)		
PCB-1260	160	48
Radionuclides (pCi/g)[b]		
Beta activity	3.0[c]	2.6[c]
^{40}K	3.1[c]	2.0[c]

[a]Only parameters that were detected for at least one species are listed in the table.
[b]Radiological results are reported after background activity has been subtracted. Negative values are reported when background activity exceeds sample activity.
[c]Radionuclide concentrations were significantly greater than zero. Detected radionuclides are at or above the minimum detectable activity.
[d]"J" indicates that the result is an estimated value.

Acronyms
CRK = Clinch River kilometer
DOE = US Department of Energy
ORNL = Oak Ridge National Laboratory
ORR = Oak Ridge Reservation
PCB = polychlorinated biphenyl

6.6.4 White-Tailed Deer

Three weekend quota deer hunts were held on the ORR during the final quarter of 2016. The hunts took place October 29–30, November 12–13, and December 10–11. Each hunt was limited to 450 shotgun/ muzzleloader permittees and 600 archery permittees. UT-Battelle staff, Tennessee Wildlife Resources Agency (TWRA) personnel, and student members of the Wildlife Society (University of Tennessee [UT] chapter) performed most of the necessary operations at the checking station.

Approximately 27,107 acres were available to deer hunters on the Oak Ridge Wildlife Management Area (ORWMA) in 2016 (16,073 acres for gun hunting and 11,034 acres for archery hunting). The ORWMA includes some properties not owned by DOE, including Haw Ridge Park (city of Oak Ridge), the Clinch River Small Modular Reactor Site (the Tennessee Valley Authority), and the UT Arboretum. The total harvest in 2016 was 361 deer, of which 209 (~57.9%) were bucks, and 152 (~42.1%) were does. The heaviest buck weighed 179 lb and had eight antler points. The greatest number of antler points found on one buck was 15. The heaviest doe weighed 115 lb.

Since 1985, 12,842 deer have been harvested from the ORWMA, of which 218 (~1.7%) have been retained because of potential radiological contamination. The heaviest buck ever harvested weighed 218 lb (1998), and the heaviest doe ever harvested weighed 139 lb (1985). The average weight of all harvested

deer is ~86.1 lb. The oldest deer harvested was a doe estimated to be 12 years old (1989), and the average age of all harvested deer is ~2 years. See the ORR hunt information website for more information (http://web.ornl.gov/sci/rmal/hunts/).

6.6.4.1 Results

Two of the 361 (~0.6%) deer harvested on ORR during the 2016 hunts were retained for exceeding the administrative release limit of 1.5 times background for beta activity in bone (~20 pCi/g $^{89/90}$Sr). None of the deer harvested in 2016 exceeded 5 pCi/g ^{137}Cs in edible tissue.

6.6.5 Canada Geese

Statewide, Canada goose hunting was allowed September 1–15, 2016, October 8–25, 2016, November 26–27, 2016, and December 3, 2016–January 29, 2017. On the Three Bends region of ORR, Canada goose hunting was allowed until noon on five days of the September season and four days of the October season. The consumption of Canada geese is a potential pathway for exposing members of the public to radionuclides released from ORR operations. To determine concentrations of gamma-emitting radionuclides accumulated by waterfowl that feed and live on ORR, Canada geese are rounded up each summer for noninvasive gross radiological surveys.

6.6.5.1 Results

Fifty geese (20 adults, 30 goslings) were captured during the June 30, 2016, roundup, including 43 from Clark Center Park (15 adults, 28 goslings) and seven from Solway Boat Ramp (5 adults, 2 goslings). Twenty-seven geese (20 adults, 7 goslings) were subjected to live whole-body gamma scans; 20 from Clark Park (15 adults, 5 goslings); and all seven that were captured at Solway Boat Ramp. Gamma scan results of the 27 geese (0.082–0.67 pCi/g ^{137}Cs) showed that all were well below the administrative release limit of 5 pCi/g ^{137}Cs.

6.6.6 Turkey Monitoring

Two wild turkey hunts, managed by DOE and TWRA, were held on the reservation (April 9–10 and April 16–17, 2016). Each hunt was limited to 225 hunters, preselected in a quota drawing. Approximately 24,000 acres were available to turkey hunters in 2016, of which 255 acres were available to archery-only hunters. Twenty-seven male turkeys were harvested on the two hunts, of which four (~ 14.8%) were juveniles and 23 (~ 85.2%) were adults. The average weight of all turkeys harvested during spring 2016 hunts was ~18.1 lb, and the largest turkey weighed 23.6 lb. The average beard length was ~8.6 in., and the longest beard was 11.2 in. The average spur length was ~0.8 in., and the longest spur was 1.3 in.

In addition, two adult turkeys (an 8.0 lb female and a 17.0 lb male) were legally harvested by archery hunters on October 29 during the 2016 deer hunts. The male had a 7.0 in. beard and 0.8 in. spurs. The largest turkey harvested to date on ORR weighed 25.7 lb (harvested in 2009).

6.6.6.1 Results

None of the 29 turkeys harvested in 2016 exceeded the administrative release limits established for radiological contamination. Since 1997, 839 turkeys have been harvested on spring turkey hunts. Eight additional turkeys have been harvested (since 2012) by archery hunters during fall deer hunts. Of all turkeys harvested, only three (< 0.4%) have been retained because of potential radiological contamination; one in 1997, one in 2001, and one in 2005. For additional information, see http://web.ornl.gov/sci/rmal/hunts/.

6.7 Quality Assurance

The activities associated with administration, sampling, data management, and reporting for the ORR environmental surveillance programs are performed by UT-Battelle. Project scope is established by a task team whose members represent DOE; UT-Battelle; Consolidated Nuclear Security, LLC; and URS | CH2M Oak Ridge LLC. UT-Battelle integrates quality assurance, environmental, and safety considerations into every aspect of ORR environmental monitoring. (See Chap. 5, Sect. 5.7, for a detailed discussion of UT-Battelle quality assurance program elements for environmental monitoring and surveillance activities.)

6.8 References

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