# 6. Oak Ridge Reservation Environmental Monitoring Program

Environmental monitoring is performed on the ORR 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 DOE operations on the entire reservation and the surrounding area. Dose assessment information based on data from this program is presented in Chapter 7.

Due to different permit reporting requirements and instrument capabilities, this report uses various units of measurement. The lists of units of measure and conversion factors on pages xxvii and xxviii are included to help readers convert numeric values presented herein as needed for specific calculations and comparisons.

## 6.1 Meteorological Monitoring

Ten meteorological towers provide data on meteorological conditions and on the transport and diffusion qualities of the atmosphere on 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 10 meteorological towers on ORR are described in Table 6.1 and are depicted in Figure 6.1. In this document, the individual ORR-managed towers are designated by "MT" followed by a numeral. Other commonly used names for these 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 wind measurement height is 25 m for MT11 and 20 m for MT13. Data are collected at some towers at 30, 33, 35, and 60 m levels. Temperature, relative humidity, and precipitation are measured at some sites at 2 m, but wind speed and wind direction typically are not. 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 (when using the solar radiation delta-T method). Stability is also calculated for most sites using the sigma phi method which relies heavily on the measurement of standard deviation of vertical wind speed using three-dimensional sonic wind monitors. Barometric pressure is measured at one or more of the towers at each ORR plant (MT2, MT4, MT6, MT7, MT9, MT12, and MT13). Precipitation is measured at MT6 and MT9 at the Y-12 National Security Complex (the Y-12 Complex); at MT7 and MT13 at the East Tennessee Technology Park (ETTP); and at MT2, MT3, MT4, and MT12 at Oak Ridge National Laboratory (ORNL). Solar radiation is measured at MT6 and MT9 at the Y-12 Complex, MT7 at ETTP, and at MT2 and MT12 at ORNL. Instrument

calibrations 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*** | | |
| MT7 | L, 1209 | 35.92522N, -84.39414W | 233 | 2, 15, 30 |
| MT13 | J, YEOC | 35.93043N, -84.39346W | 237 | 20 |
| | | ***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 | 15, 30 |
| MT10 | M, 208A | 35.90947N, -84.38796W | 244 | 10 |
| MT12 | F | 35.95285N, -84.30314W | 354 | 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 | 35.98190N, -84.25504W | 352 | 25 |

[a] Tower "C" before May 2014.

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

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 (40 m up to 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 10 ORR towers.

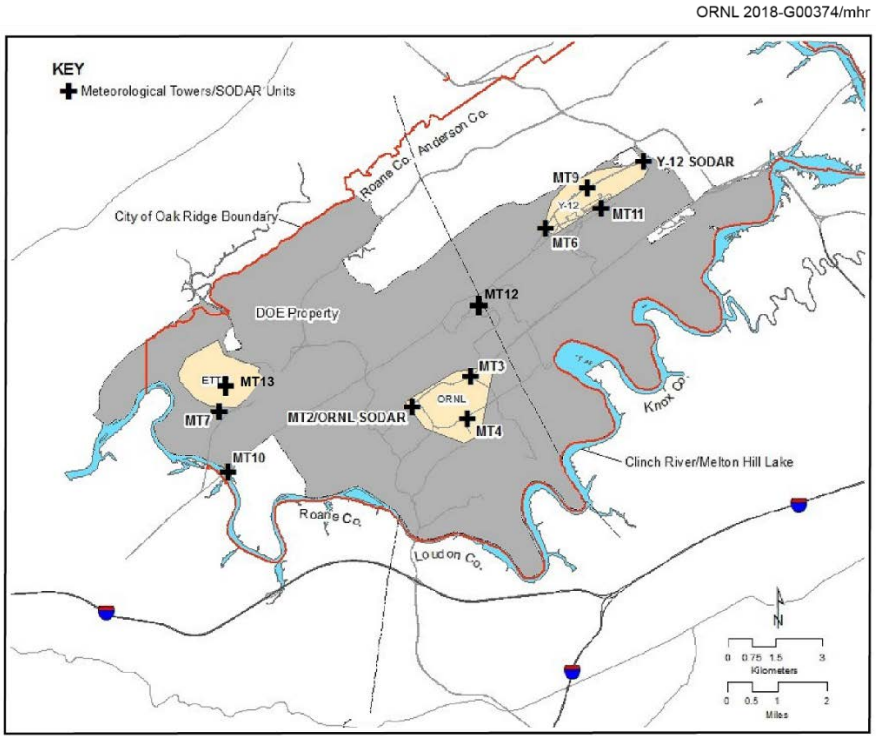


**Figure 6.1. The Oak Ridge Reservation meteorological monitoring network, including sonic detection and ranging (SODAR) devices**

## 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 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 within a less-constrained open valley bottom.

On 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) may significantly 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 frequent air mass thunderstorms. The total precipitation at ORNL during 2018 (1,597 mm or 62.87 in.) was about 20 percent above 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 2018 were greater

than 97.7 percent for wind sensors at the ORNL sites MT2, MT3, MT4, MT10, and MT12. Site MT12, located at the Spallation Neutron Source facility, successfully completed its first full calendar year of operation in 2018. Annual wind data recovery from Y-12 meteorological towers during 2018 exceeded 98 percent (towers MT6, MT9, and MT11). At ETTP, problems with the 15 m Tower MT1 wind sensor limited its recovery to 88.8 percent, but the upper 30 m sensor data recovery was nearly 99 percent. The Y-12–operated site at ETTP experienced data recovery of better than 97 percent.

## 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. Figure 6.2 shows locations that were monitored during 2018, and Table 6.2 summarizes the data for each station.

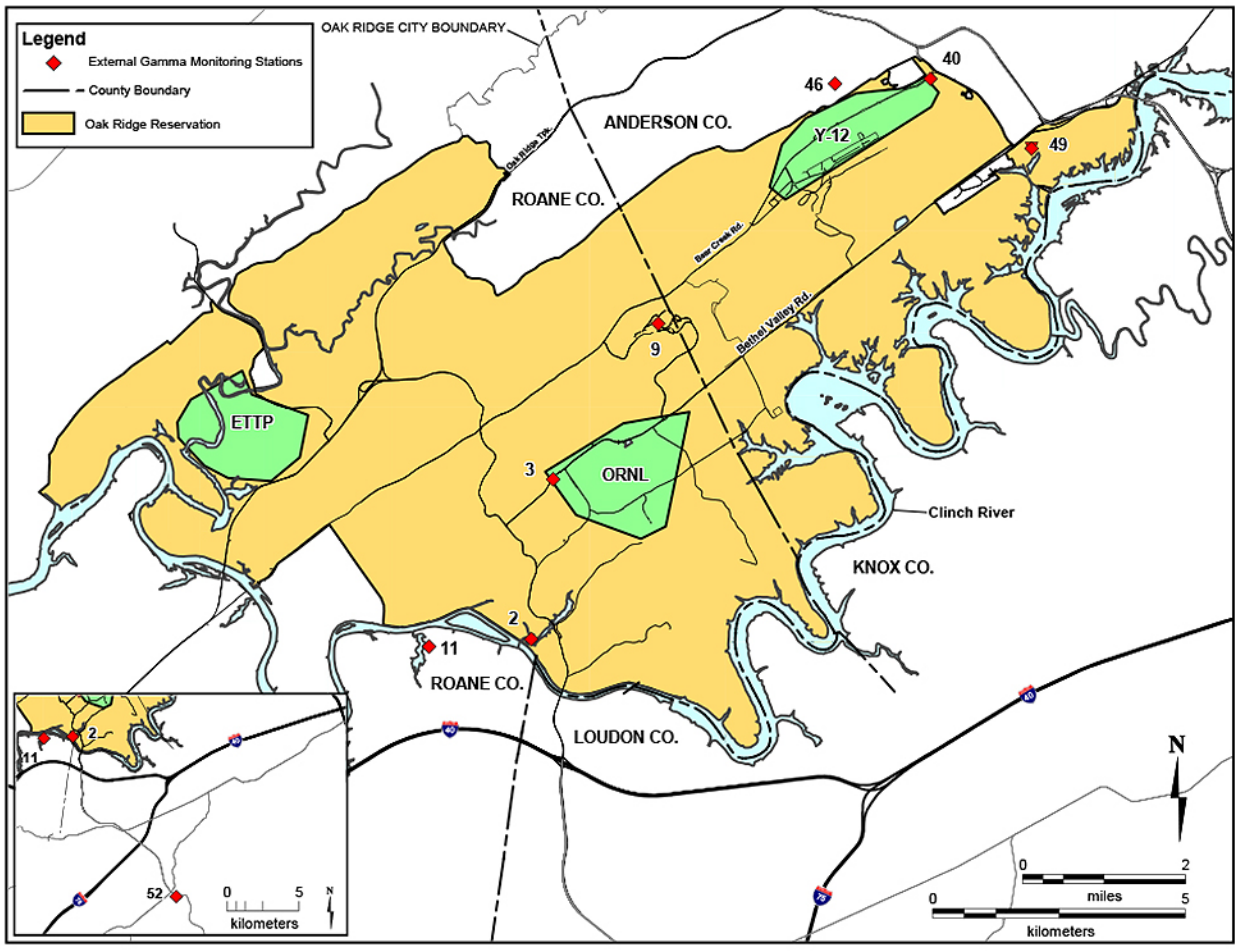


**Figure 6.2. External gamma radiation monitoring locations on the Oak Ridge Reservation**

### 6.2.2 Results

The mean exposure rate for the reservation network in 2018 was 9.9 µR/h, and the mean rate at the reference location was 9.1 µR/h. Background direct radiation exposure rates have been collected at an off-

site location for many years. From 2008 through 2017 (the preceding 10 years), the exposure rates at the background off-site location ranged from 4.2 to 11.4 µR/h. The average exposure rate for those years was 7.7 µR/h (rounded to 8 µR/h).

**Table 6.2. External gamma (exposure rate) averages for the Oak Ridge Reservation, 2018**

| Monitoring location | Number of data points (daily) | Measurement (µR/h)[a] | | |
|---|---|---|---|---|
| | | Min | Max | Mean |
| 02 | 349 | 8.6 | 10.3 | 9.1 |
| 03 | 360 | 8.9 | 10.6 | 9.3 |
| 09 | 355 | 8.9 | 12.6 | 9.6 |
| 11 | 360 | 10.1 | 12.3 | 10.8 |
| 40 | 359 | 9.3 | 11.1 | 10 |
| 46 | 352 | 10 | 11.8 | 10.5 |
| 49 | 360 | 9.1 | 11 | 9.7 |
| 52 | 358 | 8.6 | 10.6 | 9.1 |

[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 ORR 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 (Figure 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.

**Figure 6.3. Oak Ridge Reservation ambient air station**

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 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 ORR. The perimeter air monitoring network was established in the early 1990s. Since then there have been significant operational changes on 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 2018 are shown in Figure 6.4. Reference samples are collected from Station 52 (Fort Loudoun Dam). Sampling was conducted at each ORR station during 2018 to quantify levels of alpha-, beta-, and gamma-emitting radionuclides.

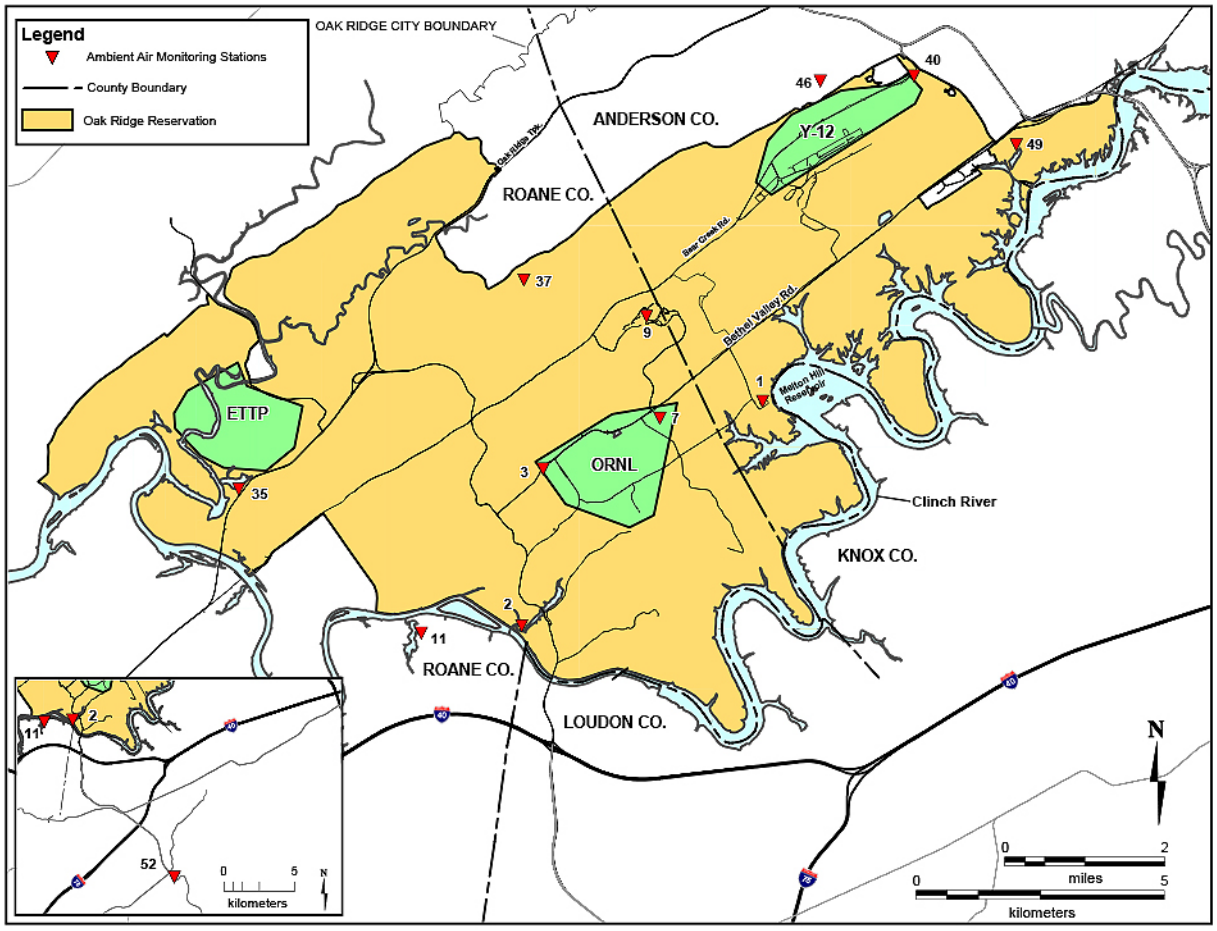


**Figure 6.4. Locations of Oak Ridge Reservation perimeter air monitoring stations**

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 (DOE 2011). All radionuclide concentrations measured at the ORR ambient air stations during 2018 were less than 1 percent of applicable DCSs, indicating that activities on the reservation are not adversely affecting local air quality.

**Table 6.3. Radionuclide concentrations at Oak Ridge Reservation perimeter air monitoring stations, 2018**

| Parameter | N detected/N total | Concentration (pCi/mL)[a] | | |
|---|---|---|---|---|
| | | Average | Minimum | Maximum |
| | | ***Station 1*** | | |
| $^{7}$Be | 4/4 | 4.02E-08 | 2.42E-08 | 4.69E-08 |
| $^{40}$K | 0/4 | -7.97E-11[b] | -5.30E-10[b] | 3.49E-10 |
| Tritium | 0/4 | 1.73E-06 | 6.38E-07 | 2.96E-06 |
| $^{234}$U | 4/4 | 2.18E -12 | 1.84E-12 | 2.46E-12 |
| $^{235}$U | 0/4 | 1.91E-13 | -2.59E-14[b] | 3.91E-13 |
| $^{238}$U | 4/4 | 1.85E-12 | 1.34E-12 | 2.06E-12 |
| | | ***Station 2*** | | |
| $^{7}$Be | 4/4 | 3.91E-08 | 1.90E-08 | 5.23E-08 |
| $^{40}$K | 0/4 | 1.05E-10 | -7.28E-11[b] | 4.52E-10 |
| Tritium | 0/4 | 1.97E-06 | 6.62E-07 | 3.48E-06 |
| $^{234}$U | 4/4 | 2.31E-12 | 1.91E-12 | 3.46E-12 |
| $^{235}$U | 0/4 | 3.18E-14 | -3.44E-14[b] | 1.45E-13 |
| $^{238}$U | 4/4 | 1.30E-12 | 9.83E-13 | 1.53E-12 |
| | | ***Station 3*** | | |
| $^{7}$Be | 4/4 | 3.97E-08 | 1.38E-08 | 5.51E-08 |
| $^{40}$K | 0/4 | 6.20E-11 | -1.97E-10[b] | 2.29E-10 |
| Tritium | 0/4 | 9.94E-07 | 3.64E-07 | 1.37E-06 |
| $^{234}$U | 4/4 | 2.07E-12 | 1.29E-12 | 2.71E-12 |
| $^{235}$U | 2/4 | 2.04E-13 | 1.51E-14 | 3.78E-13 |
| $^{238}$U | 4/4 | 1.39E-12 | 1.05E-12 | 1.84E-12 |
| | | ***Station 9*** | | |
| $^{7}$Be | 4/4 | 3.56E-08 | 1.70E-08 | 4.87E-08 |
| $^{40}$K | 0/4 | -1.47E-11[b] | -1.25E-10[b] | 1.13E-10 |
| Tritium | 3/4 | 7.94E-06 | 1.89E-06 | 1.38E-05 |
| $^{234}$U | 4/4 | 3.22E-12 | 2.28E-12 | 4.48E-12 |
| $^{235}$U | 1/4 | 3.13E-13 | 2.27E-13 | 3.95E-13 |
| $^{238}$U | 4/4 | 1.91E-12 | 1.01E-12 | 2.36E-12 |

**Table 6.3 Radionuclide concentrations at Oak Ridge Reservation perimeter air monitoring stations, 2018 (continued)**

| Parameter | N detected/N total | Concentration (pCi/mL)[a] | | |
|---|---|---|---|---|
| | | Average | Minimum | Maximum |
| | ***Station 11*** | | | |
| $^{7}$Be | 4/4 | 3.50E-08 | 1.27E-08 | 5.42E-08 |
| $^{40}$K | 0/4 | -2.77E-11[b] | -2.38E-10[b] | 1.80E-10 |
| Tritium | 0/4 | 1.18E-06 | 7.70E-07 | 1.73E-06 |
| $^{234}$U | 4/4 | 2.17E-12 | 1.24E-12 | 4.49E-12 |
| $^{235}$U | 0/4 | 1.23E-13 | -1.87E-14[b] | 2.69E-13 |
| $^{238}$U | 4/4 | 1.25E-12 | 9.76E-13 | 1.49E-12 |
| | ***Station 35*** | | | |
| $^{7}$Be | 4/4 | 3.67E-08 | 1.46E-08 | 5.95E-08 |
| $^{40}$K | 0/4 | -7.23E-11[b] | -2.62E-10[b] | 1.34E-10 |
| $^{99}$Tc | 1/4 | 2.17E-10 | -3.11E-10[b] | 1.14E-09 |
| Tritium | 1/4 | 1.90E-06 | 3.56E-07 | 4.68E-06 |
| $^{234}$U | 4/4 | 5.25E-11 | 9.20E-13 | 2.05E-10 |
| $^{235}$U | 3/4 | 4.00E-12 | 2.95E-13 | 1.46E-11 |
| $^{238}$U | 4/4 | 2.08E-11 | 8.77E-13 | 7.43E-11 |
| | ***Station 37*** | | | |
| $^{7}$Be | 4/4 | 4.14E-08 | 1.97E-08 | 5.64E-08 |
| $^{40}$K | 0/4 | -1.07E-10[b] | -2.54E-10[b] | 8.89E-11 |
| Tritium | 0/4 | 6.51E-07 | 3.23E-07 | 1.14E-06 |
| $^{234}$U | 4/4 | 2.58E-12 | 1.85E-12 | 3.61E-12 |
| $^{235}$U | 0/4 | 3.24E-13 | 2.26E-13 | 4.17E-13 |
| $^{238}$U | 4/4 | 1.77E-12 | 7.45E-13 | 3.67E-12 |
| | ***Station 40*** | | | |
| $^{7}$Be | 4/4 | 3.83E-08 | 1.93E-08 | 5.53E-08 |
| $^{40}$K | 0/4 | -1.11E-10[b] | -7.91E-10[b] | 2.13E-10 |
| Tritium | 0/4 | 1.01E-06 | 6.30E-08 | 3.13E-06 |
| $^{234}$U | 4/4 | 6.73E-12 | 4.36E-12 | 8.52E-12 |
| $^{235}$U | 3/4 | 6.72E-13 | 2.15E-13 | 1.52E-12 |
| $^{238}$U | 4/4 | 2.30E-12 | 1.70E-12 | 2.68E-12 |
| | ***Station 46*** | | | |
| $^{7}$Be | 4/4 | 4.12E-08 | 1.26E-08 | 5.36E-08 |
| $^{40}$K | 0/4 | 2.22E-11 | -3.72E-10[b] | 2.78E-10 |
| Tritium | 0/4 | 9.28E-07 | -4.03E-07[b] | 2.09E-06 |
| $^{234}$U | 4/4 | 4.05E-12 | 2.87E-12 | 5.77E-12 |
| $^{235}$U | 3/4 | 3.55E-13 | 1.71E-13 | 6.14E-13 |
| $^{238}$U | 4/4 | 1.77E-12 | 9.39E-13 | 2.39E-12 |
| | ***Station 49*** | | | |
| $^{7}$Be | 4/4 | 3.78E-08 | 1.53E-08 | 5.10E-08 |
| $^{40}$K | 0/4 | -2.53E-10[b] | -3.89E-10[b] | -1.67E-10[b] |
| Tritium | 0/4 | 2.09E-06 | 1.49E-07 | 5.01E-06 |

**Table 6.3 Radionuclide concentrations at Oak Ridge Reservation perimeter air monitoring stations, 2018 (continued)**

| Parameter | N detected/N total | Concentration (pCi/mL)[a] | | |
|---|---|---|---|---|
| | | Average | Minimum | Maximum |
| $^{234}U$ | 4/4 | 2.75E-12 | 1.57E-12 | 4.50E-12 |
| $^{235}U$ | 1/4 | 1.76E-13 | 0 | 3.70E-13 |
| $^{238}U$ | 4/4 | 1.49E-12 | 7.92E-13 | 2.14E-12 |
| ***Station 52[c]*** | | | | |
| $^{7}Be$ | 4/4 | 3.68E-08 | 1.92E-08 | 4.62E-08 |
| $^{214}Bi$ | 0/4 | 4.94E-11 | 0 | 1.98E-10 |
| $^{40}K$ | 0/4 | -1.69E-10[b] | -3.67E-10[b] | 1.07E-10 |
| $^{99}Tc$ | 2/4 | 3.85E-10 | -3.59E-10[b] | 1.76E-09 |
| Tritium | 0/4 | -4.61E-07[b] | -1.09E-06[b] | 1.49E-07 |
| $^{234}U$ | 4/4 | 1.77E-12 | 1.10E-12 | 2.29E-12 |
| $^{235}U$ | 0/4 | 1.01E-13 | -6.79E-14[b] | 3.11E-13 |
| $^{238}U$ | 4/4 | 1.39E-12 | 8.13E-13 | 1.80E-12 |

[a] 1 pCi = $3.7 \times 10^{-2}$ Bq.
[b] At very low sample activity levels, close to the instrument background, it is possible to obtain a sample result that is less than the background. When the background activity is subtracted from the sample activity to obtain a net value, a negative value results.
[c] Station 52 is the reference location.

## 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 four locations on the Clinch River, including public water intakes (Figure 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 four 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.

At the sampling locations, the Clinch River is classified by the State of Tennessee for multiple uses, including recreation and domestic supply. These two designated uses have numeric Tennessee Water Quality Criteria (WQCs) related to protection of human health. These WQCs are used as references where applicable (TDEC 2014). The Tennessee WQCs do not include criteria for radionuclides. Four percent of the DOE DCS is used for radionuclide comparison.

### 6.4.2 Results

A comparison of radionuclide concentrations from 2018 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 percent of the respective DCSs.

Mercury was detected above its MCL in the third-quarter 2018 samples from each of the three sampling locations where mercury samples are collected, Clinch River kilometer (CRK) 66, CRK 32, and CRK 16.

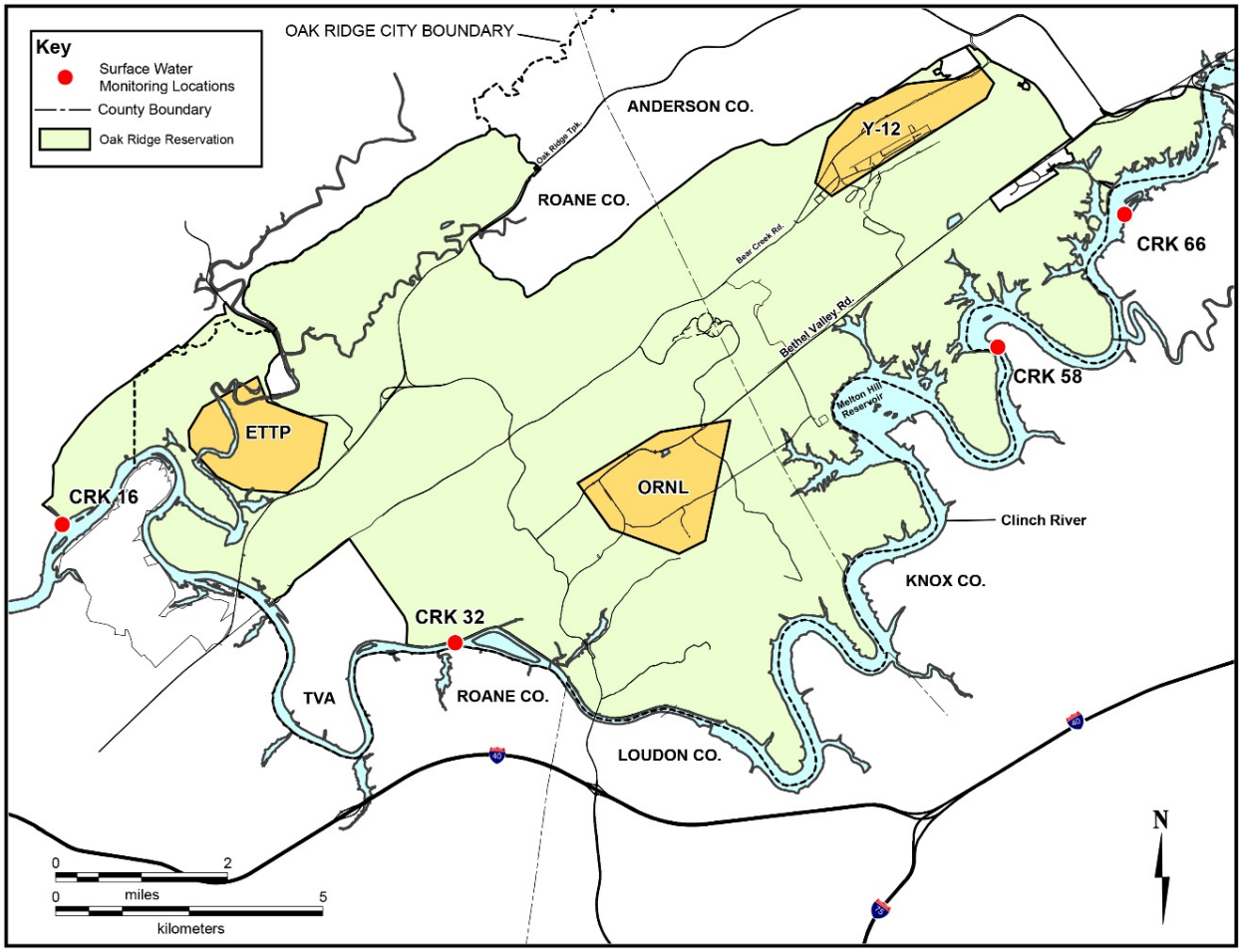


**Figure 6.5. Oak Ridge Reservation surface water surveillance sampling locations**

**Table 6.4. Oak Ridge Reservation surface water sampling locations, frequencies, and parameters, 2018**

| 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 32 | Clinch River downstream from ORNL | Quarterly | Mercury, 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
ORNL = Oak Ridge National Laboratory
ORR = Oak Ridge Reservation

## 6.5 Groundwater Monitoring

Work continued in 2018 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 2018 ORR Groundwater Program transitioned from previous tasks, including off-site groundwater quality assessment and regional-scale groundwater flow model development, to planning continued off-site monitoring and development of site-scale groundwater flow models for the ORNL site.

### 6.5.1 Off-site Groundwater Assessment

During FY 2018 OREM (the Oak Ridge Office of Environmental Management) continued to collect and analyze samples from the off-site groundwater monitoring well array west of the Clinch River adjacent to Melton Valley. In addition, exit pathway groundwater monitoring in Melton Valley is conducted as part of the OREM program, including sampling at six multiport monitoring wells in western Melton Valley (wells 4537, 4538, 4539, 4540, 4541, and 4542). Results of this monitoring are summarized in the 2019 remediation effectiveness report (DOE 2019).

DOE completed an off-site groundwater assessment project and issued a final report on the off-site groundwater study in October 2017 (DOE 2017). The project was a cooperative effort among the parties to the ORR Federal Facility Agreement to investigate off-site groundwater quality and potential movement. As follow-on work from the off-site groundwater assessment, DOE plans to conduct annual sampling and analysis of groundwater from several off-site residential wells and springs.

### 6.5.2 Regional and Site-Scale Flow Model

During FY 2017 DOE completed a project to construct and calibrate a regional-scale groundwater flow model that encompasses ORR and adjacent areas. The regional model provides an underlying framework

to support creation of smaller, site-scale groundwater flow models for use in planning and monitoring effectiveness of future cleanup decisions and actions. During FY 2018 DOE developed more refined groundwater flow models for the ORNL site. The new models can be used for evaluating groundwater contaminant migration in the vicinity of Bethel and Melton Valleys.

## 6.6 Food

Food sources are 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 hay, vegetables, milk, fish, deer, Canada geese, and turkeys are usually collected every year from areas that could be affected by activities on the reservation and from off-site reference locations. Milk was not collected in 2018 because the dairy that had supplied milk samples went out of business in 2016. The areas identified as potential areas of impact from DOE activities will be checked during 2019 for dairy operations.

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 Hay

Hay is collected and analyzed from one location on ORR. Eating beef and drinking milk obtained from hypothetical cattle that eat hay is an environmental pathway to potential radiation doses to consumers. Hay samples collected on ORR during June 2018 were analyzed for gross alpha, gross beta, gamma emitters, and uranium isotopes. Radionuclides detected in hay are shown in Table 6.5. Statistically significant concentrations of gross beta activity, $^{7}$Be, $^{40}$K, $^{234}$U, and $^{238}$U were detected at that sampling location.

**Table 6.5. Concentrations of radionuclides detected in hay, 2018 (pCi/kg)[a]**

| Gross alpha | Gross beta | $^{7}$Be | $^{40}$K | $^{234}$U | $^{235}$U | $^{238}$U |
|---|---|---|---|---|---|---|
| *b* | 2,060 | 10,800 | 4,230 | 3.92 | *b* | 4.58 |

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

### 6.6.2 Vegetables

Turnip greens and turnips were purchased in 2018 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.

### 6.6.2.1 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 6.6).

**Table 6.6. Concentrations of radionuclides detected in vegetables, 2018 (pCi/kg)[a]**

| Location | Gross alpha | Gross beta | $^{7}$Be | $^{40}$K | $^{234}$U | $^{235}$U | $^{238}$U |
|---|---|---|---|---|---|---|---|
| | | | ***Turnips*** | | | | |
| East of Y-12, Claxton vicinity | *b* | 1,300 | *b* | 4,110 | *b* | *b* | *b* |
| South of ORNL | *b* | 1,110 | *b* | 2,740 | *b* | *b* | *b* |
| East of ORNL | *b* | 2,040 | *b* | 3,000 | *b* | *b* | *b* |
| Reference location | 42.5 | 1,550 | *b* | 2,200 | 3.46 | *b* | *b* |
| | | | ***Turnip Greens*** | | | | |
| East of Y-12, Claxton vicinity | *b* | 4,440 | *b* | 3,970 | *b* | *b* | *b* |
| South of ORNL | *b* | 4,240 | *b* | 4,660 | 3.59 | *b* | *b* |
| East of ORNL | 78.5 | 5,040 | 1,740[c] | 3,820 | *b* | 1.37 | *b* |
| Reference location | *b* | 3,770 | *b* | 2,320 | 2.65 | *b* | *b* |

[a] Detected radionuclides are those at or above minimum detectable activity. 1 pCi = $3.7 \times 10^{-2}$ Bq.
[b] Value was less than or equal to minimum detectable activity.
[c] There was no peak for the analyte. There were random counts in the region of interest above the background, and the software net-quantifies a result; flagged to indicate that the activity is not from the analyte. The absence of a peak indicates that the analyte is not present.

**Acronyms**
ORNL = Oak Ridge National Laboratory
Y-12 = Y-12 National Security Complex

## 6.6.3 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.

The one dairy that had been supplying milk samples to ORNL went out of business in 2016. During the 2 years since, surveys to locate dairies in areas that could receive deposition from ORR activities were conducted; however, no dairies were identified to replace the one that closed. When a dairy or dairies are located, ORNL will resume milk-sampling and analyses.

## 6.6.4 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 (Figure 6.6):

- 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 2018, 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 affected 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 2019). TDEC also issues advisories for consumption of fish when mercury levels are over 0.3 ppm; the three locations on the Clinch River where ORR fish are collected do not have mercury "do not consume" advisories. See additional information **here**.

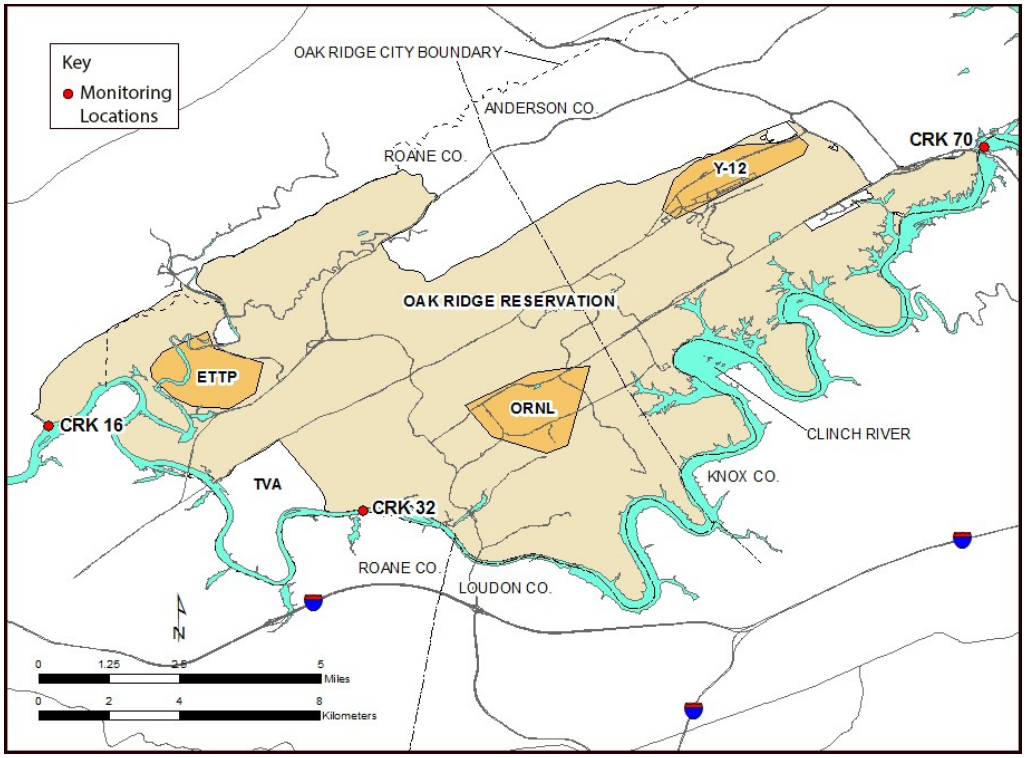


**Figure 6.6. Fish-sampling locations for the Oak Ridge Reservation Surveillance Program**

### 6.6.4.1 Results

PCBs, specifically Aroclor-1260, and mercury were detected in both sunfish and catfish at all three locations in 2018. These results are consistent with the TDEC advisories. Detected PCBs, mercury, and radionuclide concentrations are shown in Table 6.7.

**Table 6.7. Tissue concentrations in catfish and sunfish for detected mercury, PCBs, and radionuclides, 2018[a]**

| Parameter | Catfish | Sunfish |
|---|---|---|
| ***Clinch River downstream from all DOE ORR inputs (CRK 16)*** | | |
| Metals (mg/kg) | | |
| Hg | 0.045 | 0.08 |
| Pesticides and PCBs (µg/kg) | | |
| PCB-1260 | 41 | J12[b] |
| Radionuclides (pCi/g)[c] | | |
| Alpha activity | 0.13 | 0.14 |
| Beta activity | 1.5 | 1.3 |
| $^{40}$K | 2.3 | 3.6 |
| ***Clinch River downstream from ORNL (CRK 32)*** | | |
| Metals (mg/kg) | | |
| Hg | 0.059 | 0.028 |
| Pesticides and PCBs (µg/kg) | | |
| PCB-1260 | 34 | J6.6[b] |
| Radionuclides (pCi/g)[c] | | |
| Alpha activity | 0.096 | 0. 22 |
| Beta activity | 0.76 | 1.3 |
| $^{40}$K | 1.3 | 2.8 |
| ***Clinch River (Solway Bridge) upstream from all DOE ORR inputs (CRK 70)*** | | |
| Metals (mg/kg) | | |
| Hg | 0.035 | J0.014[b] |
| Pesticides and PCBs (µg/kg) | | |
| PCB-1260 | 50 | J9.2[b] |
| Radionuclides (pCi/g)[c] | | |
| Beta activity | 0.97 | 1.0 |
| $^{40}$K | 1.8 | 3.0 |

[a] Only parameters that were detected for at least one species are listed in the table.
[b] "J" indicates that the result is an estimated value.
[c] Radionuclide concentrations were significantly greater than zero. Detected radionuclides are at or above the minimum detectable activity.

**Acronyms**

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

## 6.6.5 White-Tailed Deer

Three weekend quota deer hunts were held on ORR during the final quarter of 2018. The hunts took place November 3 and 4, November 10 and 11, and December 8 and 9. 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 25,053 acres were available to deer hunters on the Oak Ridge Wildlife Management Area (ORWMA) in 2018 (15,227 acres for gun hunting and 9,826 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 2018 was 194 deer, of which 116 (~59.8 percent) were bucks and 78 (~40.2 percent) were does. The heaviest buck weighed 175 lb, was 3.5 years old, and had 12 antler points, which was the greatest number of antler points on any buck harvested. The heaviest doe weighed 126 lb and was also 3.5 years old. The harvest was higher than it was in 2017 but still somewhat lower than it had been in previous years. This is most likely due to the inclement weather during the last weekend hunt, which resulted in a lower hunter turnout than in years past. The outbreak of epizootic hemorrhagic disease (EHD) in the Tennessee deer herds during the summer of 2017 impacted deer populations on the ORWMA, as evidenced by the number of 2017's dead deer reports and low harvest numbers.

Since 1985, 13,173 deer have been harvested from the ORWMA, of which 218 (~1.7 percent) 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 lb. The oldest deer harvested was a doe estimated to be 12 years old (1989); the average age of all harvested deer is ~2 years. See ORR hunt information website **here** for more information.

#### 6.6.5.1 Results

None of the 194 deer harvested on ORR during the 2018 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), nor for exceeding 5 pCi/g $^{137}$Cs in edible tissue.

### 6.6.6 Canada Geese

On the Three Bends Area of ORR (excluding the shoreline of Gallaher Bend), Canada goose hunting was allowed during the statewide season, one half-hour before sunrise until noon on 5 days during September and 4 days during October. 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.

#### 6.6.6.1 Results

Nineteen geese (17 adults, 2 goslings) were captured during the June 21, 2018, roundup at the Solway Boat Ramp, Anderson County. All 19 geese were subjected to live whole-body gamma scans. Gamma scan results for the 17 adult geese and 2 goslings showed that all were well below the administrative release limit of 5 pCi/g $^{137}$Cs.

### 6.6.7 Turkey Monitoring

Two wild turkey hunts, managed by DOE and TWRA, were held on the reservation in 2018 (April 14 and 15 and April 28 and 29). Each hunt was limited to 225 hunters, preselected in a quota drawing. Approximately 21,879 acres were available to turkey hunters in 2018 because the 255 acres that were designated as archery-only in 2017 were eliminated and were converted to safety zones in 2018. Twenty-three male turkeys were harvested on the two hunts, of which 3 (~ 15 percent) were juveniles and 20 (~ 85 percent) were adults. The average weight of all turkeys harvested during spring 2018 hunts was ~19.2 lb, and the largest turkey weighed 22.2 lb. The average beard length was ~9.1 in., and the longest beard was 11.2 in. The average spur length was ~ 1.3 in., and the longest spur was 1.75 in. The largest turkey harvested to date on ORR weighed 25.7 lb (harvested in 2009).

#### 6.6.7.1 Results

None of the 23 turkeys harvested in 2018 exceeded the administrative release limits established for radiological contamination. Since 1997, 892 turkeys have been harvested on spring turkey hunts. Ten additional turkeys have been harvested (since 2012) by archery hunters during fall deer hunts. Of all turkeys harvested, only three (< 0.4 percent) have been retained because of potential radiological contamination; one in 1997, one in 2001, and one in 2005. Additional information is available **here**.

## 6.7 Quality Assurance

The activities associated with administration, sampling, data management, and reporting for 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 Chapter 5, Section. 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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