Food sources are analyzed to evaluate potential radiation doses to consumers of local food crops, fish, and harvested game. In 2022, 16 Canada geese from ORR were subjected to noninvasive, live whole-body gamma scans. All results were well below the administrative release limit of 5 pCi/g ^{137}Cs. Photograph by Manuel (Dobie) Gillispie

6

Oak Ridge Reservation Environmental Monitoring Program

ORR environmental surveillance is conducted to comply with DOE requirements to protect the public and the environment against undue risks associated with DOE activities. These requirements are established in DOE Order 458.1, *Radiation Protection of the Public and the Environment* (DOE 2020), and related guidance is provided in *Environmental Radiological Effluent Monitoring and Environmental Surveillance* (DOE 2015). The objective of the ORR environmental surveillance program is to characterize environmental conditions in areas outside the ORR facility boundaries, both on and off ORR.

6.1. Meteorological Monitoring

Eight 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. Additionally, ORNL and Y-12 operate three wind profilers on ORR to better characterize upper-level winds (winds higher than 60 m above ground level).

6.1.1. Data Collection and Analysis

The eight meteorological towers on ORR are described in Table 6.1 and 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 towers are also provided in Table 6.1. Meteorological data are collected at different heights 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 most sites at 2 m, but wind speed and wind direction typically are not. Atmospheric stability (a measure of the 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 60 m towers. Stability is also calculated for most sites using the sigma phi method, which relies heavily on the measurement of the 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, MT9, MT12, and MT13). Precipitation is measured at MT6 and MT9 at the Y-12 Complex; at MT13 at ETTP; and at MT2, MT3, MT4, and MT12 at ORNL. Solar radiation is measured at MT6 and MT9 at the Y-12 Complex 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). Additionally, Holian Environmental audits the Y-12–owned towers (MT6, MT9, MT11) every 3 months.

Table 6.1. ORR meteorological towers

Tower	Alternate tower names	Location (latitude, longitude)	Altitude above MSL (m)	Measurement heights (m)
		ETTP		
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
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
MSL = mean sea level
ORNL = Oak Ridge National Laboratory
PSS = plant shift superintendent
Y-12 Complex = Y-12 National Security Complex
YEOC = Y-12 Complex Emergency Operations Center

ORNL 2022-G00307/mhr
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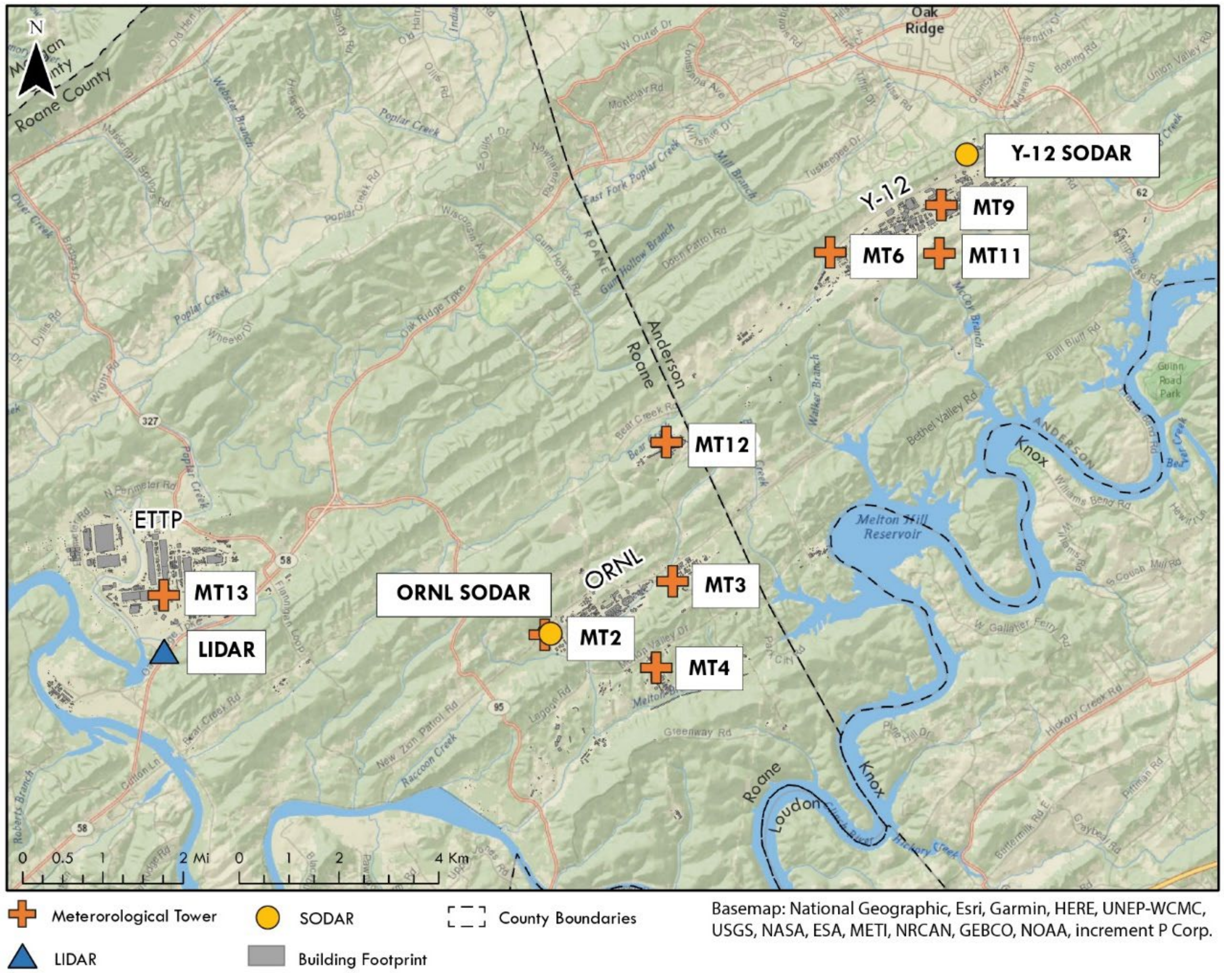


Figure 6.1. The ORR meteorological monitoring network, including light and sonic detection and ranging (LIDAR and SODAR) devices

Sonic detection and ranging (SODAR) devices have been installed at the east end of the Y-12 Complex (Pine Ridge) and adjacent to 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 (40–800 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 is the thickness of the air layer adjacent to the ground over which an emitted or entrained inert nonbuoyant tracer could be mixed by turbulence within 1 h.

In 2021, ORNL installed a light detection and ranging (LIDAR) device, which provides data similar to SODAR data, near ETTP at ORR Air Monitoring Station 35 to provide wind data for the western part of ORR. This device replaces wind measurements previously taken at the now-defunct MT7 and MT10 meteorological towers.

Meteorological data are collected in real time from the meteorological towers at 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 excluded from compliance modeling. Appropriate substitution data are identified when possible. Quality assurance records of missing and erroneous data are routinely kept for the eight ORR towers.

6.1.2. Results

Prevailing winds generally flow 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 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 is sometimes observed at ridgetop 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 from the facilities. However, high roughness values (caused by terrain and obstructions such as trees and buildings) may significantly mitigate these factors by increasing 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 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 2022 (1,449.6 mm or 57.05 in.) was about 2 percent above the long-term 1991–2020 average of 1,417.8 mm (55.80 in.). The average annual wind data recovery rates (a measure of acceptable data) across locations used for modeling during 2022 were greater than 89 percent for MT2 and MT3. Average recovery rates at MT4 and MT6 were greater than 97 and 92 percent, respectively. Annual wind data recovery from Y-12 meteorological towers during 2022 exceeded 81 percent for MT13. Y-12 tower MT6 was down the entire year for maintenance, and substitute data were used.

6.2. 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 6.2). 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 enable the determination of contaminant levels at monitoring locations in the event of an emergency.

Figure 6.2. ORR ambient air station

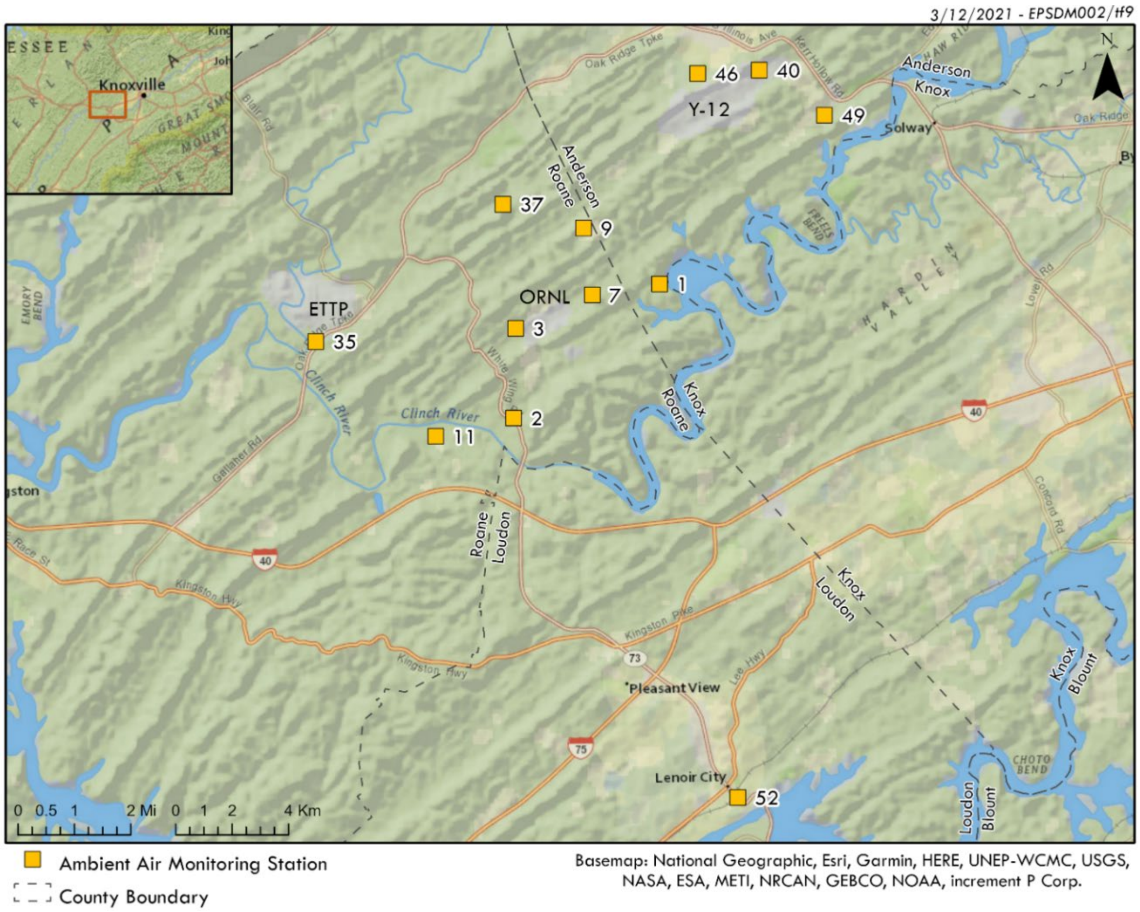
6.2.1. Data Collection and Analysis

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 enables the impacts of ORR operations to be assessed on an integrated basis.

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 and was modified in 2016 in response to changes in DOE activities and operations since the 1990s. The stations monitored in 2022 are shown in Figure 6.3. Reference samples are collected at Station 52 (Fort Loudoun Dam). Sampling was conducted at each ORR station during 2022 to quantify levels of alpha-, beta-, and gamma-emitting radionuclides.

Atmospheric dispersion modeling was used to select appropriate sampling locations 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 gross beta activity and to determine the concentrations of specific isotopes of interest on ORR. The second instrument 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 ^{3}H analysis.



Notes:

1. *Reference samples are collected at Station 52 (Fort Loudoun Dam).*
2. *Station 7 is an ORNL site-specific monitoring location and is not part of the ORR perimeter network.*

Figure 6.3. Locations of ORR perimeter air monitoring stations

6.2.2. 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 6.2) is compared with derived concentration standards (DCSs) for air established by DOE as guidelines for controlling exposure to members of the public (DOE 2021a). All radionuclide concentrations measured at the ORR ambient air stations during 2022 were less than 1 percent of applicable DCSs.

Table 6.2. Radionuclide concentrations at ORR perimeter air monitoring stations sampled annually, 2022

Station	Average concentration (pCi/mL)[a] (Number detects/n)										
	^{124}Sb	^{7}Be	^{210}Pb	^{212}Pb	^{40}K	^{99}Tc	^{208}Tl	^{3}H	^{234}U	^{235}U	^{238}U
01		4.4E-08 (4/4)	1.1E-08 (2/4)		9.5E-10 (2/4)			6.1E-06 (1/4)	1.9E-11 (4/4)	8.7E-13 (0/4)	1.9E-11 (4/4)
02		4.0E-08 (4/4)	5.0E-09 (1/4)		5.6E-10 (2/4)			6.6E-06 (1/4)	2.1E-11 (4/4)	1.9E-12 (1/4)	2.0E-11 (4/4)
03	4.7E-10 (1/4)	4.2E-08 (4/4)	7.1E-09 (1/4)		9.6E-10 (2/4)			8.7E-06 (1/4)	2.3E-11 (4/4)	1.3E-12 (0/4)	2.5E-11 (4/4)
09		4.5E-08 (4/4)	3.2E-09 (1/4)		6.3E-10 (1/4)			5.6E-05 (4/4)	2.2E-11 (4/4)	2.0E-12 (2/4)	2.6E-11 (4/4)
11		3.5E-08 (4/4)	4.1E-09 (1/4)		8.8E-10 (2/4)			6.6E-06 (1/4)	1.8E-11 (4/4)	8.4E-13 (1/4)	1.8E-11 (4/4)
35		3.6E-08 (4/4)	1.0E-08 (2/4)		5.0E-10 (1/4)	9.0E-10 (1/4)		8.7E-06 (1/4)	2.8E-11 (4/4)	1.7E-12 (3/4)	2.5E-11 (4/4)
37		3.4E-08 (4/4)	8.0E-09 (2/4)		5.0E-10 (1/4)			3.5E-06 (1/4)	2.3E-11 (4/4)	1.2E-12 (1/4)	1.9E-11 (4/4)
40		4.0E-08 (4/4)	4.4E-09 (1/4)	7.6E-11 (1/4)	8.1E-10 (2/4)			4.5E-06 (1/4)	3.2E-11 (4/4)	1.4E-12 (2/4)	2.9E-11 (4/4)
46		4.4E-08 (4/4)	1.2E-08 (2/4)		7.6E-10 (1/4)			5.5E-06 (1/4)	2.5E-11 (4/4)	8.7E-13 (0/4)	2.1E-11 (4/4)
49		4.2E-08 (4/4)	1.1E-08 (2/4)	9.1E-11 (1/4)	8.3E-10 (2/4)		9.6E-11 (1/4)	5.0E-06 (1/4)	2.4E-11 (4/4)	1.5E-12 (1/4)	2.6E-11 (4/4)
52[b]		4.7E-08 (4/4)	1.1E-08 (2/4)		7.0E-10 (2/4)	1.8E-09 (1/4)		2.0E-06 (0/4)	2.3E-11 (4/4)	2.7E-12 (3/4)	2.5E-11 (4/4)

[a] *1 pCi = 3.7 × 10^{-2} Bq.*
[b] *Station 52 is the reference location.*

6.3. External Gamma Radiation Monitoring

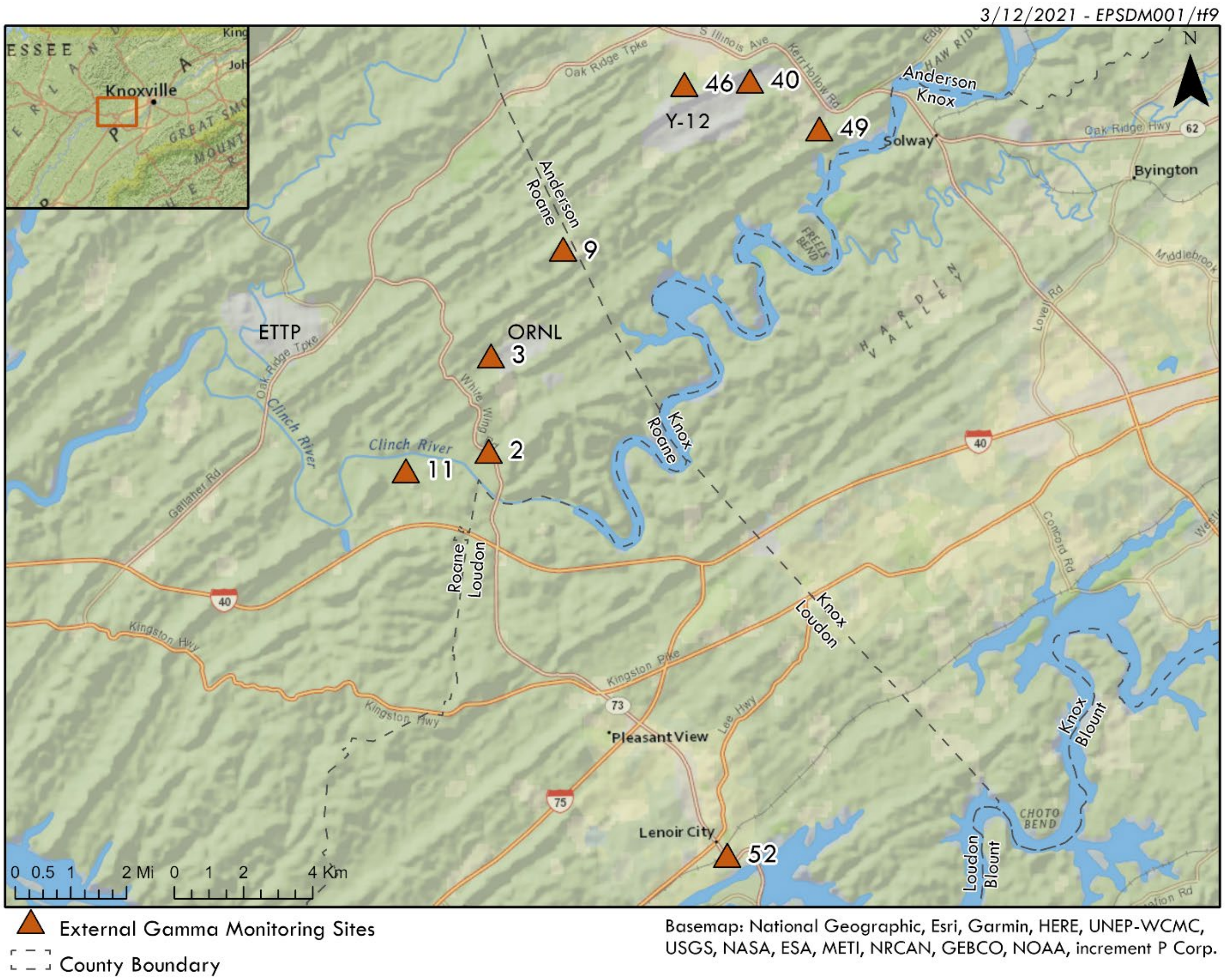
Members of the public could hypothetically be exposed directly to gamma radiation from radionuclides released into the environment, from previously released radionuclides deposited on soil and vegetation or in sediments, from radiation-generating facilities (especially high-energy accelerators), and from the storage of radioactive materials (DOE 2021b). Continuous direct radiation levels are monitored at locations around ORR to complement the sample data collected as part of the ORR ambient air monitoring program (see Section 6.2).

6.3.1. Data Collection and Analysis

External gamma exposure rates are continuously recorded every minute by dual-range Geiger-Müller tube detectors colocated with ORR ambient air stations 2, 3, 9, 11, 40, 46, 49, and 52 (see Section 6.2). The data are downloaded weekly and are averaged for the entire year. Figure 6.4 shows locations that were monitored during 2022; Table 6.3 summarizes the data for each station.

6.3.2. Results

The mean exposure rate for the reservation network in 2022 was 9.3 μR/h, and the mean rate at the reference location (Fort Loudoun Dam) was 8.7 μR/h. Background direct radiation exposure rates have been collected at the Fort Loudoun Dam (Station 52) reference location for many years. From 2012 through 2021, the exposure rates at the reference location ranged from 6.5 to 11.4 μR/h and averaged 8.8 μR/h.



Note:
Reference samples are collected at Station 52 (Fort Loudoun Dam).

Figure 6.4. External gamma radiation monitoring locations on ORR

Table 6.3. External gamma exposure rate averages for ORR, 2022

Air station number	Number of data points (daily)	Measurement (μR/h)[a]		
		Min	Max	Mean
02	358	8.0	10.7	8.7
03	363	8.3	11.3	9.0
09	365	8.4	12.3	8.9
11	359	9.1	12.2	9.8
40	363	8.7	10.6	9.4
46	365	9.7	12.8	10.2
49	365	8.6	12.0	9.3
52	365	8.0	11.4	8.7

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

6.4. 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.

6.4.1. Data Collection and Analysis

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 locations and associated sampling frequencies and parameters. Once every 5 years, additional radiological analyses are performed to confirm dose calculations (see Chapter 7). In 2022, additional radionuclides analyzed included neptunium, plutonium, strontium, thorium, and uranium.

In 2022, a more sensitive analytical method for determining mercury concentrations in surface water samples was adopted. The new method enables detecting concentrations near 0.2 ng/L, whereas the detection limit for the previously used method is about 67 ng/L. As expected, the ability to detect mercury at much lower levels resulted in detections in 10 of the 12 surface water samples collected for mercury analyses in 2022, while in the past, with the less sensitive method, mercury was rarely detected. 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. The 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 as the criterion for radionuclide comparison (DOE 2021a).

6.4.2. Results

In 2022, as has been the case since 2009, no statistical differences were found in the concentrations of routinely monitored radionuclides in surface water samples collected from the Clinch River upstream and downstream of DOE inputs.

The difference in concentrations of $^{233/,234}U$ detected downstream and upstream of DOE inputs was statistically significant. In June 2022, ^{238}U was detected at Clinch River kilometers (CRKs) 66, 58, and 16 with no statistically significant difference between upstream and downstream locations. However, ^{238}U was not detected in other 2022 samples. In March 2022, ^{230}Th was detected once at CRK 66 (upstream of DOE inputs) but was not detected at any other location or in any other quarter of 2022. No radionuclides were detected above 4 percent of the respective DCSs.

In 2021, ^{241}Am was detected by gamma spectroscopy analysis in the second-quarter grab sample from CRK 58 upstream of DOE inputs. It was not detected in samples from other surface water sampling locations and had not previously been detected at CRK 58. No ^{241}Am was detected in samples collected in the third or fourth quarters of 2021. Laboratory contamination was the suspected source of the ^{241}Am.

In 2022, as part of a regular 5-year rotation to confirm the dose modeling (see Chapter 7), additional analyses, including a more sensitive method for quantifying ^{241}Am, were performed at all ORR surface water monitoring locations on the Clinch River. There were no detections of ^{241}Am at any location in any quarter in 2022 using the more sensitive method.

Mercury was detected in 10 of the 12 samples collected in 2022. Results from one sample collected from CRK 32 and one from CRK 66 were below the method detection level. As previously discussed, an increase in mercury detections was anticipated because a more sensitive analytical method was used. All detected mercury values in 2022 were well below the 67 ng/L detection level of the test method previously used.

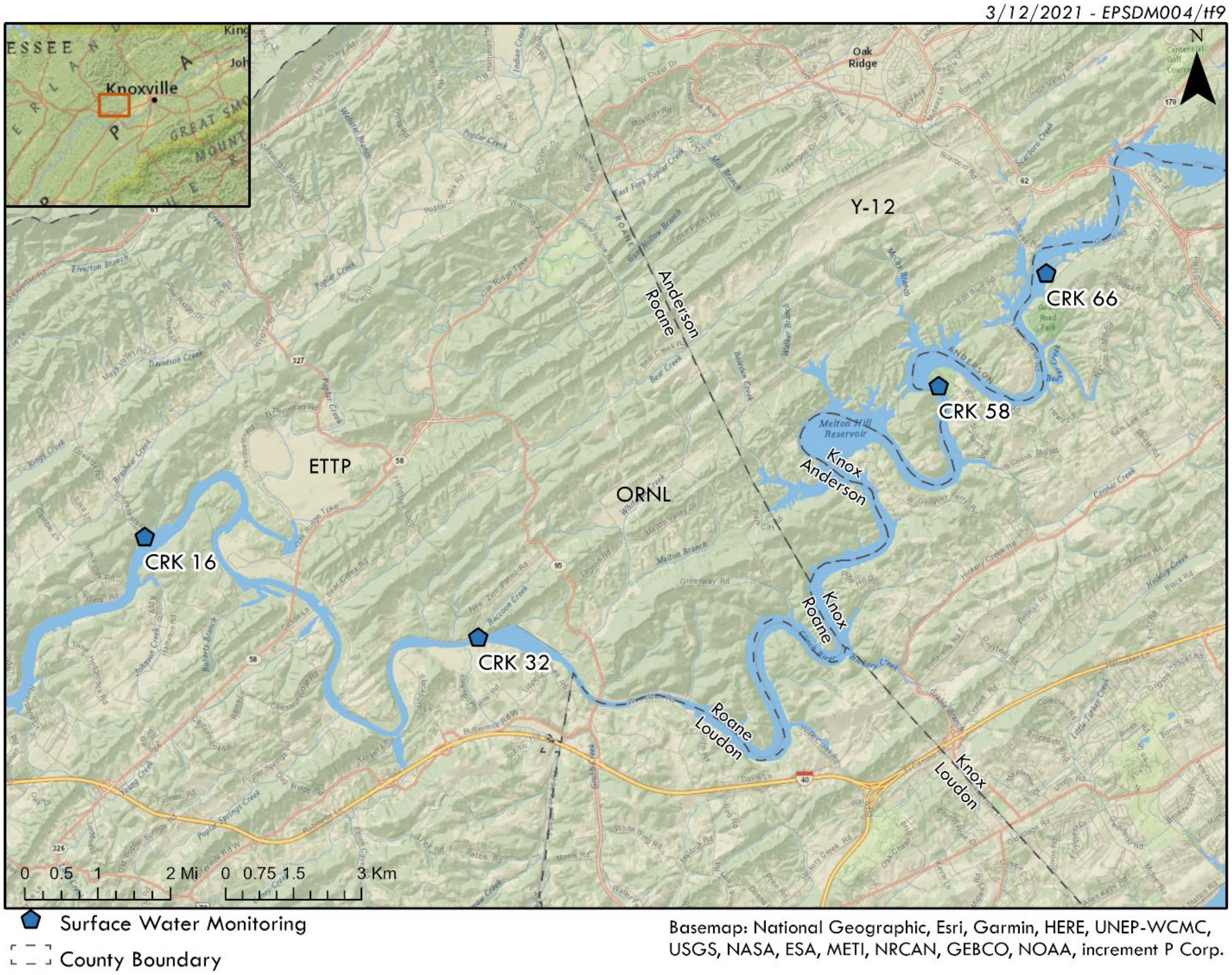


Figure 6.5. ORR surface water surveillance sampling locations

Table 6.4. ORR surface water sampling locations, frequencies, and parameters, 2022

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 in the 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 2022 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). Work performed during 2022 under the ORR Groundwater Program included the first year of sampling from three multizone exit pathway groundwater monitoring wells in west Bethel Valley adjacent to the Clinch River. Work continued on site-scale groundwater flow models for ETTP.

6.5.1. Off-Site Groundwater Assessment

During fiscal year (FY) 2022, the Oak Ridge Office of Environmental Management (OREM) 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 2023 *Remediation Effectiveness Report* (DOE 2023).

DOE completed an off-site groundwater assessment project and issued a final report 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. To follow up on work from the off-site groundwater assessment, DOE conducts 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 a framework to support creation of smaller, site-scale groundwater flow models for use in planning and monitoring the effectiveness of future cleanup decisions and actions. During FY 2022, DOE further refined groundwater flow models for the Molten Salt Reactor Experiment site to support the development of an updated feasibility study of remedial alternatives for that reactor facility.

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 2022 because no dairies were found in potential ORR deposition areas. Surveys are conducted annually to determine whether any dairies are operating in areas of interest.

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" principle to ensure that doses to consumers are managed at levels well below regulatory dose thresholds. This 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. The 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

Eating beef and drinking milk obtained from cattle that eat hay are potential radiation exposure pathways to humans. Hay from an area on the eastern edge of ORR is made available to an off-site farming operation and is sampled annually to characterize any possible doses from this pathway.

6.6.1.1. Data Collection and Analysis

Hay was collected and analyzed from the location on the eastern edge of ORR when it was cut for off-site use in August 2022. Samples were analyzed for gross alpha, gross beta, gamma emitters, and uranium isotopes.

6.6.1.2. Results

Radionuclides detected in hay are shown in Table 6.5.

Table 6.5. Concentrations of radionuclides detected in hay,[a] August 2022 (pCi/kg)[b]

Radionuclide	Result
Gross alpha	c
Gross beta	4,650
^{7}Be	7,020
^{40}K	9,920
^{234}U	c
^{235}U	c
^{238}U	c

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

6.6.2. Vegetables

Contaminants may reach vegetation by deposition of airborne materials, uptake from soil, and deposition of materials contained in irrigation water. As available, food crops are sampled annually from garden locations that have the potential to be affected by airborne releases from ORR to evaluate possible radiation doses to consumers. Vegetables are also sampled from a reference location for comparison. If available, crops that represent broad-leaf systems (e.g., lettuce, turnip greens), root-plant-vegetable systems (e.g., tomatoes), and root-system vegetables (e.g., turnips, potatoes) are obtained from each location and analyzed for radionuclides. Vegetable availability varies greatly from year to year.

6.6.2.1. Data Collection and Analysis

Tomatoes were purchased in 2022 from farms near ORR and from reference locations. No broadleaf or root vegetables were available in 2022. The locations were chosen based on availability and the likelihood of being affected by routine releases from the Oak Ridge facilities. All vegetable samples were analyzed for gross alpha, gross beta, gamma emitters, and uranium isotopes.

6.6.2.2. Results

Analytical results for vegetable samples are provided in Table 6.6. No gamma-emitting radionuclides were detected above the minimum detectable activity except for the naturally occurring radionuclide ^{40}K. Uranium isotopes were not detected above minimum detectable activities in any of the samples.

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. Since 2016, no dairies in potential ORR deposition areas have been located, and no milk samples have been collected. Surveys to identify dairies in potential deposition areas are conducted each year, and milk sampling will resume when dairy operations in appropriate areas are located.

6.6.4. Fish

Members of the public could be exposed to contaminants originating from DOE ORR activities by consuming 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)
- Clinch River downstream from all DOE ORR inputs (CRK 16)

6.6.4.1. Data Collection and Analysis

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 2022, 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. Once every 5 years, additional radiological analyses are performed to confirm the dose calculations (see Chapter 7). In 2019, additional analyses were performed on fish samples, and detected radionuclides included neptunium, plutonium, thorium, and uranium isotopes. Based on the 2019 results, additional radionuclide analyses were again performed in 2020, 2021, and 2022, including analyses for americium, neptunium, plutonium, and thorium. Results are presented in Table 6.7.

TDEC issues advisories on consumption of certain fish species caught in specified Tennessee waters. The advisories apply to fish that could contain potentially hazardous contaminants. TDEC has issued a “do not consume” advisory for catfish in the entire Melton Hill Reservoir, not just in areas that could be affected by ORR activities, because of PCB contamination. Similarly, TDEC has issued a precautionary advisory for catfish in the Clinch River arm of Watts Bar Reservoir because of PCB contamination (TDEC 2020). TDEC also issues advisories for consumption of fish when mercury levels exceed 0.3 ppm; the three locations on the Clinch River where ORR fish are collected do not have mercury “do not consume” advisories (Denton 2007).

Table 6.6. Concentrations of radionuclides detected in tomatoes, 2022 (pCi/kg)[a]

Location	Gross alpha	Gross beta	^{7}Be	^{40}K	^{234}U	^{235}U	^{238}U
			Tomatoes				
North of Y-12	*b*	2,030	*B*	1,970	*b*	*b*	*b*
East of ORNL	*b*	1,810	*B*	1,680	*b*	*b*	*b*
West of ETTP	*b*	1,460	*B*	1,200	*b*	*b*	*b*
Reference location	*b*	1,810	*B*	1,550	*b*	*b*	*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

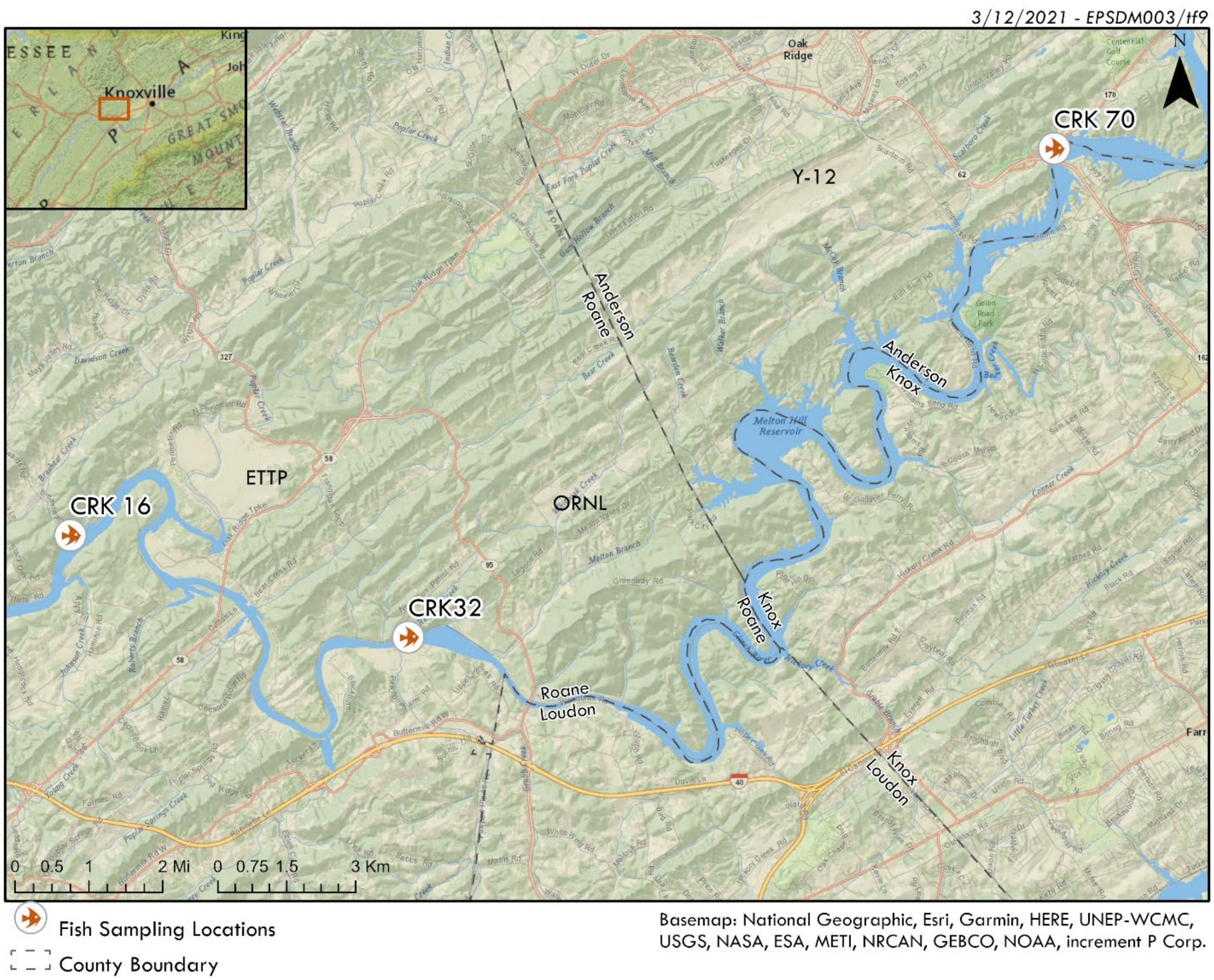


Figure 6.6. Fish-sampling locations for the ORR Surveillance Program

Table 6.7. Tissue concentrations in catfish and sunfish for detected PCBs and radionuclides, 2022[a]

	CRK 16 Downstream		CRK 32		CRK 70 Upstream	
	Catfish	Sunfish	Catfish	Sunfish	Catfish	Sunfish
Metals (mg/kg)						
Hg	*b*	*b*	B0.22[c]	*b*	*b*	*b*
Pesticides and PCBs (μg/kg)						
PCB-1254	197	*b*	20.3	*b*	*b*	*b*
PCB-1260	247	*b*	62.2	*b*	*b*	*b*
Radionuclides (pCi/g)						
Beta activity	2.2	3.3	2.6	2.8	2.5	2.2
^{40}K	*b*	3.2	2.8	3.7	3.1	2.9
^{230}Th	*b*	*b*	0.06	*b*	*b*	0.093
^{232}Th	*b*	*b*	*b*	0.0097	0.010	*b*

[a] Only parameters that were detected for at least one species are listed in the table.
[b] Value was less than or equal to minimum detectable activity.
[c] "B" indicates that the analyte was detected in the associated method blank.
Acronyms:
CRK = Clinch River kilometer
PCB = polychlorinated biphenyl

6.6.4.2. Results

PCBs, specifically Aroclor-1260 and 1254, were detected in catfish at CRK 16 and CRK 32 in 2022. Mercury was detected in catfish at CRK 32 within the historic range of values at this location; the lab reported that mercury was detected in the associated method blank, indicating this result may be biased high. Mercury was not detected above the minimum detectable level at any other location in 2022.These results are consistent with the TDEC advisories. Detected PCBs, mercury, and radionuclide concentrations are shown in Table 6.7.

6.6.5. White-Tailed Deer

In 2022, three quota hunts were conducted on ORR: November 5 and 6, November 12 and 13, and December 10 and 11.

Since 1985, 13,674 deer have been harvested from the Oak Ridge Wildlife Management Area, of which 218 (approximately 1.59 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 approximately 87 lb. (All weights are field-dressed weights.) The oldest deer harvested was a doe estimated to be 12 years old (1989); the average age of all harvested deer is approximately 2 years. See the ORR hunt information website **here** for more information.

6.6.6. Waterfowl

The consumption of waterfowl is a potential pathway for exposing members of the public to radionuclides released from ORR operations. Canada goose hunting was allowed on the Three Bends Area of ORR (excluding the shoreline of Gallaher Bend) during the statewide season in 2022, one-half hour before sunrise until noon on September 5, 10–11, and 17–18, and on October 8–9 and 15–16. Hunting was allowed for wood duck and teal on September 10–11.

6.6.6.1. Data Collection and Analysis

Canada geese are rounded up each summer for noninvasive gross radiological surveys to characterize concentrations of gamma-emitting radionuclides accumulated by waterfowl that feed and live on ORR.

6.6.6.2. Results

Sixteen geese (4 adults and 12 juveniles) were captured during the June 23, 2022, roundup on ORR. All 16 captured geese were subjected to live whole-body gamma scans. Gamma scan results showed that all were all well below the administrative release limit of 5 pCi/g ^{137}Cs.

6.6.7. Wild Turkey

Two wild turkey quota hunts were scheduled for April 16–17 and April 23–24. However, the turkey hunts were cancelled because of the COVID-19 pandemic.

Since 1997, 924 turkeys have been harvested on spring turkey hunts. Eleven additional turkeys have been harvested since 2012 by archery hunters during fall deer hunts. The largest turkey ever harvested on ORR weighed 25.7 lb (harvested in 2009). Of all turkeys harvested, only three (less than 0.34 percent) have been retained because of potential radiological contamination: one in 1997, one in 2001, and one in 2005. Additional information is available on the ORR hunt website **here**.

6.7. Habitat Quality Improvement

Maintaining ecosystems, protecting natural areas, and ensuring functioning of facilities and their support infrastructures (power and communications rights-of-way, roadways, and waterways) through active management is crucial, not only in natural areas, but in developed areas as well. A portion of ecosystem maintenance involves control of invasive plants. Invasive plants disrupt vital habitats of threatened and endangered species as well as other native wildlife and plant life by decreasing native plant diversity through crowding out native plants and disrupting natural plant-animal interactions. Another aspect of habitat quality improvement, once invasive plant control has been accomplished, is restoration of native plant communities.

6.7.1. Invasive Plant Management.

Invasive non-native plant species are among the greatest ecological threats to the United States and the world. Invasive plants can threaten forests, wetlands, and cultural and other resources by increasing the risk of fire and storm damage and by encroaching onto roads, railroads, power structures, waterways, and agricultural sites. To address these threats, the Federal Noxious Weed Act (1974) was amended and incorporated into the Federal Plant Protection Act (2000), which mandates federal agencies to develop and coordinate a management program for controlling invasive plants on lands under their respective jurisdictions. Each agency must adequately fund an integrated pest management plan that will meet the regulatory requirements of federal laws, executive orders, presidential memoranda, contracts, and agreements. Other federal directives regarding control of invasive plants and subsequent restoration practices include "Environmentally and Economically Beneficial Practices on Federal Landscaped Ground" (Presidential Memorandum 1994), which was replaced in 2000 by Executive Order 13148; *Federal Memorandum of Understanding to Establish a Federal Interagency Committee for the Management of Noxious and Exotic Weeds* (1994); Executive Order 13112 (1999); Presidential Memorandum (2014), which involves "creating a federal strategy to promote the health of honeybees and other pollinators," including control and removal of invasive plants and restoration and establishment of natural habitats; and Executive Order 13751, "Safeguarding the Nation from the Impacts of Invasive Plants" (2016). DOE has maintained an invasive plant management plan on ORR since 2004. Details of federal and state laws and regulations driving this plan can be found in *Invasive Plant Management Plan for the Oak Ridge Reservation* (Parr et al. 2004) and in the two subsequent revisions of that report (Quarles et al. 2011, McCracken and Giffen 2017).

The technical report *Assessment of Nonnative Invasive Plants in the DOE Oak Ridge National*

Environmental Research Park (Drake et al. 2002) details the results of extensive survey efforts. These and subsequent surveys have been performed to identify invasive plant problems on ORR. The data are used to develop control plans identifying which invasive species to target and in which locations.

More than 1,100 species of plants are found on ORR, and approximately 170 are non-native. Fifty-seven aggressive non-native (invasive) plant species have been identified on ORR, but control efforts have been primarily focused on a subset of 12 highly invasive species (see Table 6.8). These species have been found across ORR in disturbed areas; on powerline and gas line rights-of-way; throughout riparian buffer zones; and along state highways, railroad lines, and remote-access fire roads. They have invaded natural areas to varying degrees, causing vast ecological harm in both plant and animal communities. Other invasive plant species are also targets for control and are addressed according to the guidance found in *Early Detection and Rapid Response* (DOI 2020).

Table 6.8. Twelve most problematic invasive plants on ORR

Common name	Scientific name
Japanese grass, Nepal grass	*Microstegium vimineum*
Japanese honeysuckle	*Lonicera japonica*
Chinese privet	*Ligustrum sinense*
Kudzu	*Pueraria montana*
Multiflora rose	*Rosa multiflora*
Tree of heaven	*Ailanthus altissima*
Autumn olive	*Elaeagnus umbellate*
Oriental bittersweet	*Celastrus orbiculatus*
Princess tree	*Paulownia tomentosa*
Winter creeper	*Euonymus hederaceus*
Bradford/Callery pear	*Pyrus calleryana*
Mimosa	*Albizia julibrissin*

The 32,258.54-acre ORR consists mostly of undeveloped land, such as forested land, extensive areas of undisturbed wetlands, open waterways and riparian vegetation, and several hundred acres of grassland communities and fallow fields.

Three major developed facilities lie within ORR boundaries: ORNL, the Y-12 Complex, and ETTP. Surrounding these developed facilities and woven throughout ORR are safety and security areas, utility corridors, access roads, research and education areas, cultural and historic preservation sites, contamination areas that are undergoing cleanup and remediation, regulatory and monitoring sites, emergency corridors, new facility construction and laydown areas, and public use areas. This multiplicity of land uses presents challenges for effectively preventing and managing invasive species.

Numerous DOE contractors have responsibilities for land management of portions of ORR, as do other federal and state agencies, such as the Tennessee Valley Authority and the Tennessee Wildlife Resources Agency. The Natural Resources Management Team for ORR receives sitewide funding annually, a portion of which is designated for creation and implementation of an invasive plant management plan mainly directed toward control efforts in natural areas and reference areas; however, efforts have included specific invasive plant incursions into locations within and surrounding campuses of developed facilities on ORR. The *Invasive Plant Management Plan for the Oak Ridge Reservation* (Parr et al. 2004) and two subsequent revisions (Quarles et al. 2011, McCracken and Giffen 2017) explain options for addressing the problem of invasive plants on ORR and discuss selection of appropriate control measures. Areas selected for invasive plant control tend to cover several acres or are spread out across portions of ORR. Use of select herbicides is the most cost-effective treatment method in most cases, and the invasive plants that are present determine which herbicides will be most effective without harming surrounding native plant and animal habitats.

Invasive plant control on ORR has been conducted annually from 2003, when the invasive plant management program began, through 2022. Table 6.9 indicates the extent of annual invasive plant treatments; Figure 6.7 shows the major treatment areas.

Table 6.9. Invasive plant control on ORR, 2003–2022

Year	Treated area	
	Acres	Road miles
2003	98	
2004	136	
2005	125	
2006	254	
2007	236	
2008	427	
2009	526	
2010	884	
2011	806	
2012	615	
2013	329	
2014	950	
2015	629	
2016	952	
2017	542	47
2018	507	53
2019	450	57
2020	400	65
2021	400	51
2022	266	77

Invasive plant management activities were completed in 2022 in the following locations at each of the three facilities and in natural areas on the ORR (Figure 6.7):

- ORNL
  - First Creek, Fifth Creek, and White Oak Creek riparian buffer zones
  - First Creek grassland area management
  - Demonstration plot at Spallation Drive and Bethel Valley Road management
  - Bethel Valley Road and Old Bethel Valley Road invasive plant control
  - East Bethel Valley Road native grasslands
  - Check Station native grasslands
  - Haw Ridge former steam line kudzu patch
  - Fire road invasive plant control
  - Three Bends Area invasive plant control
  - Gallaher Bend kudzu control using goats
- Y-12
  - Kudzu control on Pine Ridge and Chestnut Ridge overlooking the Y-12 campus
  - Midway Turnpike invasive plant control
  - Coal ash ponded area kudzu control
  - Walnut Orchard four corners kudzu control
  - Watson Road fields invasive plant control
  - Old County Road, McNew Hollow Road, and Gum Branch Road invasive plant control
- ETTP
  - McKinney Ridge kudzu control
  - Black Oak Ridge Conservation Easement—West kudzu and invasive plant control
  - Black Oak Ridge Conservation Easement—East greenway and trail invasive plant control
  - Powerhouse Trail invasive plant control
  - Wheat Church Vista invasive plant control

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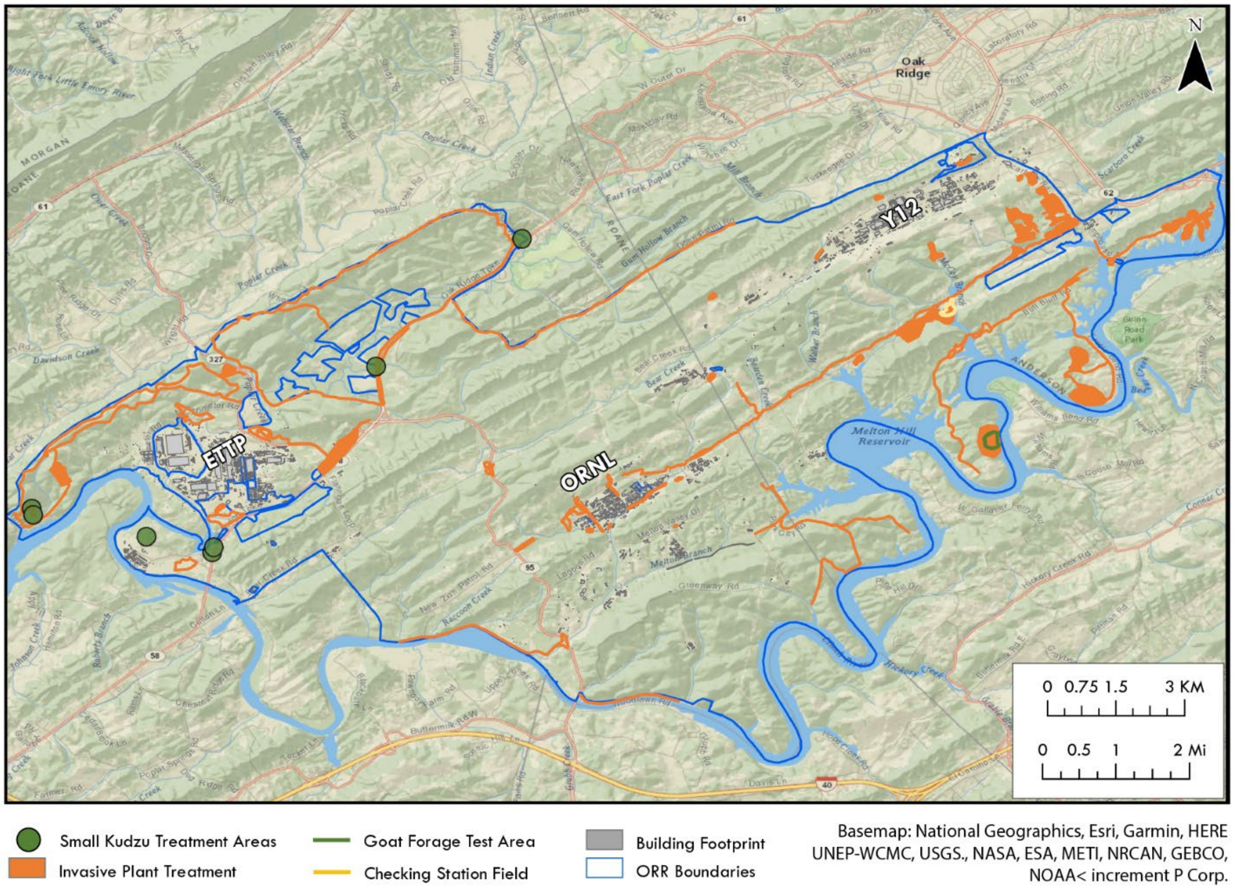

Figure 6.7. Map of invasive plant treatment areas on ORR for 2022

6.7.2. Wetlands

Wetland delineations are conducted to facilitate compliance with TDEC and US Army Corps of Engineers wetland protection requirements. In 2022, a wetland delineation was conducted on ORR on land along the Oak Ridge Turnpike. The wetland delineation was used to define easement boundaries and land use requirements.

6.7.3. Special Projects

Invasive plant treatment methods generally have involved a combination of herbicide use, mechanical removal, and prescribed burning. Biological control methods can also be used to control invasive plants. In the summers of 2020, 2021, and 2022, a project was carried out on Gallaher Bend (Figure 6.8) to investigate the effectiveness and costs of using goats for kudzu control. Goats were rotated through fenced sections of a 46-acre plot during the summer of 2020. A prescribed burn of the area was conducted after grazing season in the spring of 2021. In 2021, goats were rotated through the same fenced sections twice during grazing season. A reduced area of 20 acres was managed using goats in 2022. Results from this 3-year study indicate that using only goats to control large patches of mature kudzu is not economically feasible, nor is it particularly successful. Indications are that multiple years of continual grazing would be needed to control mature kudzu plots. Additionally, goat grazing can leave areas barren of most plants and subject to erosion.

Figure 6.8. Experimental kudzu control using goats grazing. The area to the left of the road was managed using goats, whereas the area to the right of the road was not managed. Photograph by Kitty McCracken

6.8. Fire Protection Management and Planning

Wildland fire management is an important part of DOE's overall management of ORR. A comprehensive wildfire management program has been established and implemented for the entire ORR. The *Oak Ridge Reservation Wildland Fire Management Plan* (WFMP) (DOE 2021c) assigns responsibilities for wildland fire management and is reviewed every 3 years and revised as needed. The *Oak Ridge Reservation Wildland Fire Implementation Plan* (WFIP) (DOE 2021d) contains details on program implementation. The WFMP was prepared to satisfy the requirements of DOE Order 420.1C, *Facility Safety, Change 3* (DOE 2019); DOE Standard 1066, *Fire Protection* (DOE 2016); and relevant portions of Chapters 19 through 23 in National Fire Protection Association 1140, *Standard for Wildland Fire Protection* (NFPA 2022).

The WFMP outlines the overall goals and strategies necessary to manage, plan, and respond to fire in the wildland areas of ORR and to reduce the risk of wildland fire to personnel and facilities on the ORR and to the public. The WFMP is reviewed at least annually.

The WFMP applies to all DOE employees, contractors, and subcontractors working on the ORR and to all DOE ORR tenant activities. The DOE ORR federal manager is responsible for ORR wildland fire management activities.

The primary goal of the WFMP is to lower the overall risk of wildland fire on ORR by conducting fire prevention activities and actions to reduce the spread of a fire should one start. Another goal of the WFMP is to contain wildfires that do start to the ORR unit of origin by conducting suppression activities.

The WFMP is implemented by multiple organizations, including non-DOE entities such as the City of Oak Ridge and the State of Tennessee Division of Forestry. Memorandums of understanding that ensure collaboration between organizations are maintained for each organization that provides firefighting support on ORR.

DOE actions associated with wildland fire management include the following:

- Controlling ignition sources in the wildland areas, particularly on days when fire danger is forecasted
- Managing wildfire fuels in and near developed areas
- Developing and implementing controlled burning plans authorized by the DOE ORR federal manager
- Preparing and updating wildland fire pre-plans that include maps of fuel types, topographic features, roads, cultural resources, sensitive natural resources, contamination areas, and potential hazards
- Developing stakeholder involvement plans in support of the wildland fire program
- Reviewing current data to determine the potential for wildland fire, including indications of wildland fire risk
- Preparing a wildland fire risk report, including a wildland fire hazard severity analysis based on the *Standard for Wildland Fire Protection* (NFPA 2022)
- Maintaining a wildland fire road grid to support fire detection, containment, and suppression
- Conducting tabletop wildland fire exercises at least once every 3 years and full-scale exercises at least once every 5 years
- Incorporating wildland fire mitigation and response activities and procedures into the ORR land use planning process

The DOE roads and grounds contractor is responsible for establishing and maintaining the wildland fire roads, many of which delineate wildland management units (Figure 6.9), and for maintaining barricades that control access to ORR secondary roads. The management contractors at each of the three major ORR sites are responsible for providing personnel and equipment for initial response to wildland fire events and for establishing incident command. The City of Oak Ridge has entered into a mutual aid agreement with DOE to provide assistance for wildland fire activities. The State of Tennessee Department of Agriculture Division of Forestry has entered into a memorandum of understanding to provide trained personnel and heavy equipment, including fire plows, when requested to assist with wildland fires on ORR.

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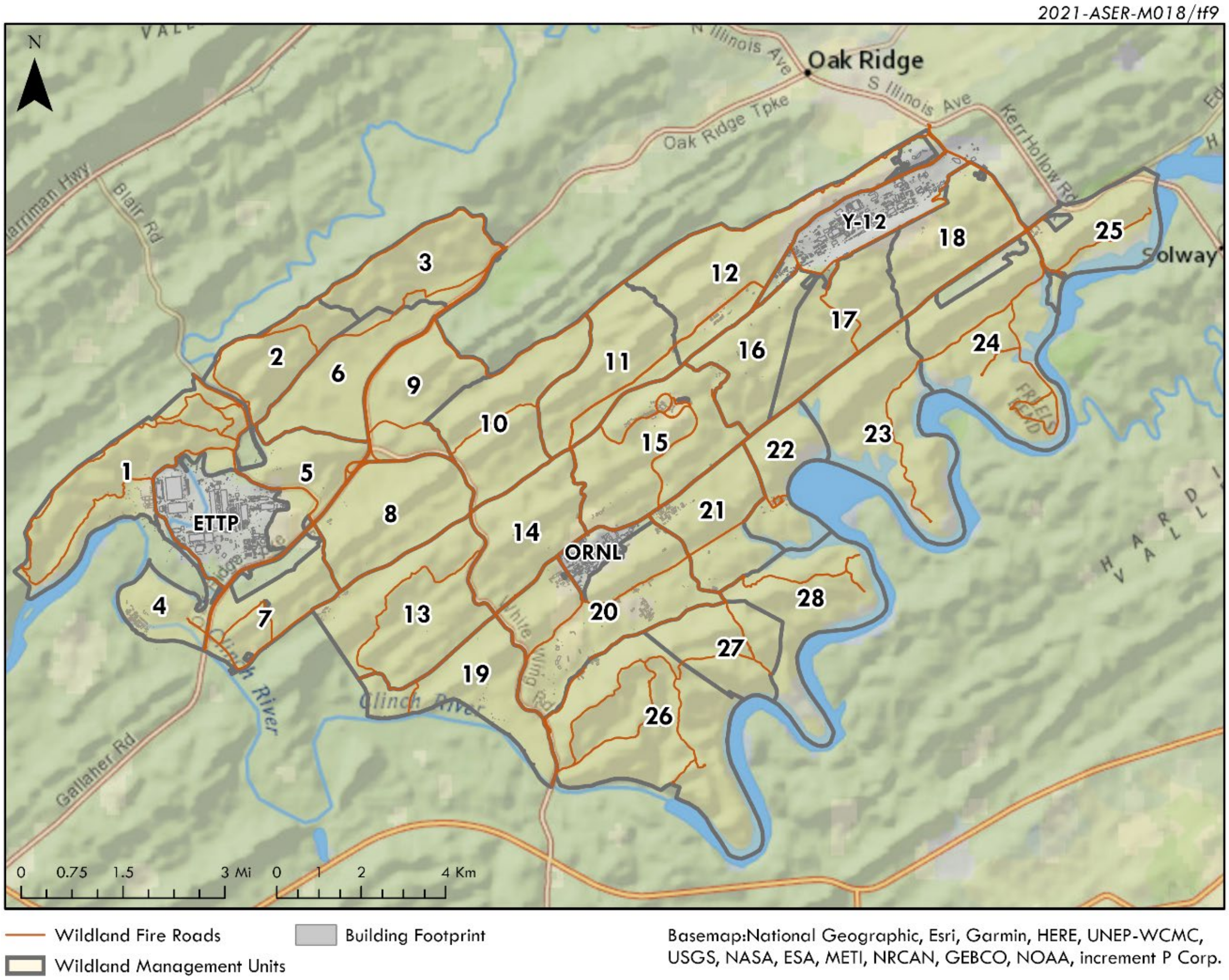

Figure 6.9. Wildland management units on ORR

Because ORR is a large (32,258.54 acres), mostly forested property with access restrictions, it is a challenge for site emergency personnel to maintain familiarity with all remote areas and back roads and to quickly recognize and assess concerns associated with those areas. Wildland management unit pre-fire plans are designed to aid responders who may or may not be familiar with an area.

The pre-fire plans are concise documents for each of the 28 ORR wildlife management units (Figure 6.9) that summarize access issues, assets, and hazard concerns. Each plan includes the wildlife management unit's name and identification number, its general location within ORR, and its boundaries and size. Important information and hazard descriptions are listed early in the document, followed by guidance on tactics, access, vegetation and fuels, water sources, topographic considerations, and hazard controls. Plan maps depict access points, utilities, hazards, research areas, fuel types, water sources, urban interface areas, and sensitive resources. Pre-fire plans are reviewed on a 3-year cycle and are updated as significant changes occur.

Copies of the plans are kept in responder vehicles for immediate reference during remote events and are available to site fire departments and emergency operations centers, shift superintendent offices, and appropriate management staff. The plans are easily updated, stored, and shared electronically. They are meant to enable quick decisions but not to dictate tactics. The ORR forester is the point of contact for plan distribution.

The 2016 Great Smoky Mountains wildfires, also known as the Gatlinburg wildfires, demonstrated that large fires, although more frequent in western states, can occur on or near ORR. Issues related to wildland/urban interface areas are a growing concern. These areas may be characterized by relatively high housing density and increasing recreational use by the public. DOE has prioritized interface areas and has conducted controlled wildfire fuel reduction burns to limit the spread of fire to and from the community. The presence of dense pine forests increases community vulnerability to potential high-intensity wildfires. Actions to protect these areas include thinning or replacing dense pine growth, mechanical treatments to proactively thin younger pine, and mulching heavy logging slash and insect-damaged timber to interrupt fuel beds.

6.9. Quality Assurance

UT-Battelle performs the activities associated with administration, sampling, data management, and reporting for ORR environmental surveillance programs. Project scope is established by a task team whose members represent DOE, UT-Battelle, Consolidated Nuclear Security LLC, and United Cleanup 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.)

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