Members of the public could be exposed to contaminants originating from the ORR through consumption of fish caught in area waters. To characterize this exposure pathway, fish are collected annually from three locations on the Clinch River and edible flesh are analyzed for specific contaminants. Photograph by Carlos Jones.

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 activities carried out by DOE. These requirements are established in DOE O 458.1, *Radiation Protection of the Public and the Environment* (DOE 2020a), and related guidance is provided in DOE-HDBK-1216-2015, *Radiological Environmental 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.

In 2020, sampling and monitoring activities associated with some ORR environmental surveillance programs were scaled down or cancelled due to social-distancing precautions taken in response to the COVID-19 pandemic. Deer and turkey hunts are typically conducted on ORR each year, and muscle and bone samples are obtained to calculate doses to hunters. The ORR hunts were cancelled in 2020 but are expected to resume in 2021. Vegetable samples from home gardens near ORR are collected to enable estimating radiological doses to members of the public from consuming crops raised near ORR. In 2020, sampling was limited to one crop. As more people are vaccinated, and the rates of new COVID-19 cases decline, vegetable sampling is expected to be expanded to include three crops, depending on availability. ORR surveillance programs are not required by federal or state regulations, and there are no compliance issues related to the COVID-19 precautions taken in 2020.

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. Data Collection and Analysis

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 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, MT7, MT9, MT12, and MT13). Precipitation is measured at MT6 and MT9 at the Y-12 Complex; at MT7 and 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, 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). Additionally, Holian Environmental audits the Y-12-owned sites every 3 months (MT6, MT9, MT11).

Sonic detection and ranging (SODAR) devices have been installed at the east end of the Y-12 Complex (Pine Ridge) 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 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 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.

Meteorological 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.

Table 6.1. ORR meteorological towers

Tower	Alternate tower names	Location (latitude, longitude)	Altitude (meters above MSL)	Measurement heights (meters)
		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
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

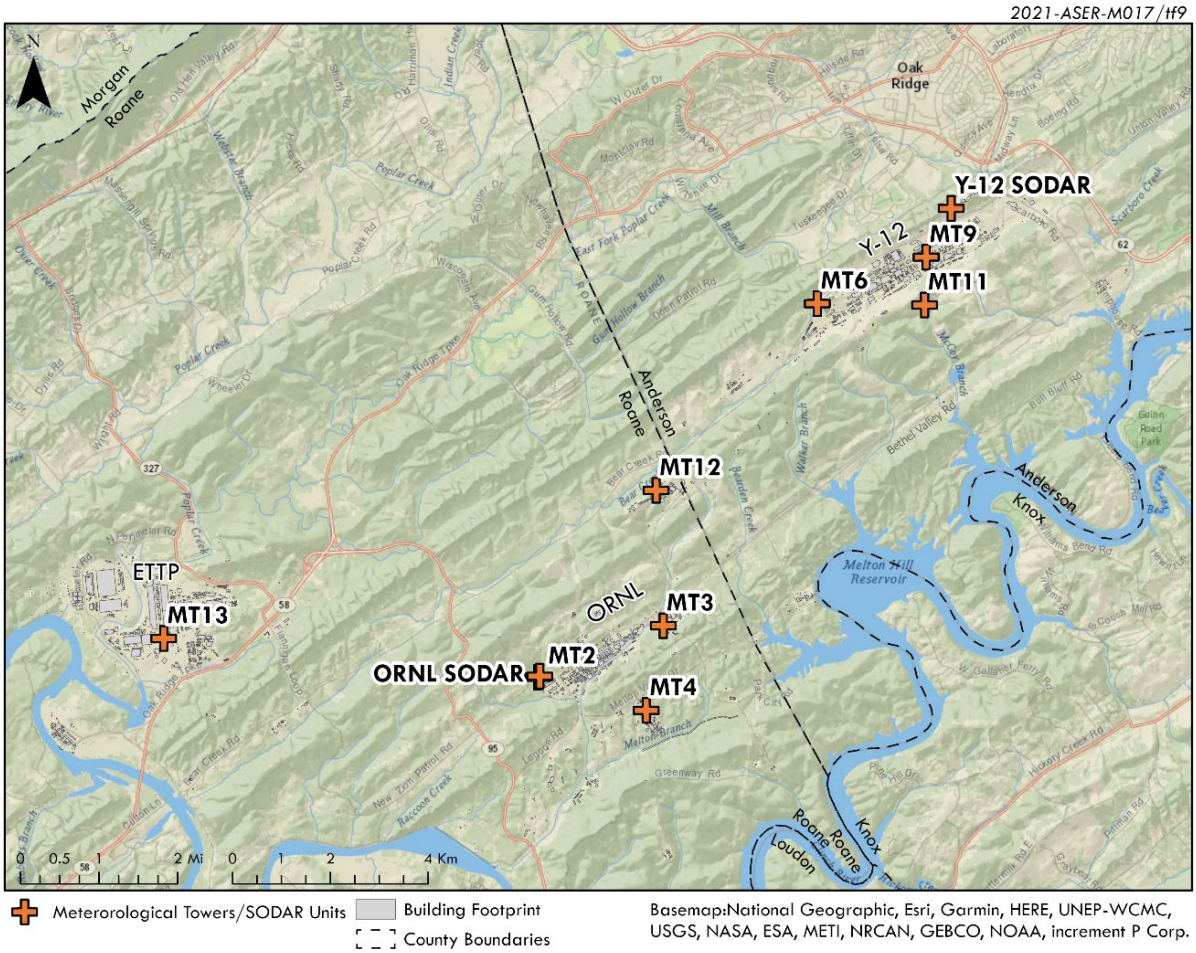


Figure 6.1. The ORR meteorological monitoring network, including sonic detection and ranging (SODAR) devices

6.1.2. Results

Prevailing winds are generally up-valley from the southwest and west-southwest or down-valley from the northeast and east-northeast, a pattern that typically results from channeling effects produced by the parallel ridges flanking the ORR sites. Winds in the valleys tend to follow the ridge axes, limiting cross-ridge flow within local valley bottoms. These conditions dominate over most of ORR, but flow variation is greater at ETTP, which is located 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 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 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 2020 (1,705.4 mm or 67.12 in.) was almost 25 percent above the long-term 1991–2020 average of 1,372.0 mm (54.00 in.). The average annual wind data recovery rates (a measure ofacceptable data) across locations used for modeling during 2020 were greater than 99.4 percent for wind sensors at ORNL sites MT2, MT3, MT4, MT10, and MT12. Annual wind data recovery from Y-12 meteorological towers during 2020 exceeded 95.4 percent (towers MT6, MT9, and MT11). At ETTP, annual wind data recovery exceeded 99.8%.

6.2. Ambient Air Monitoring

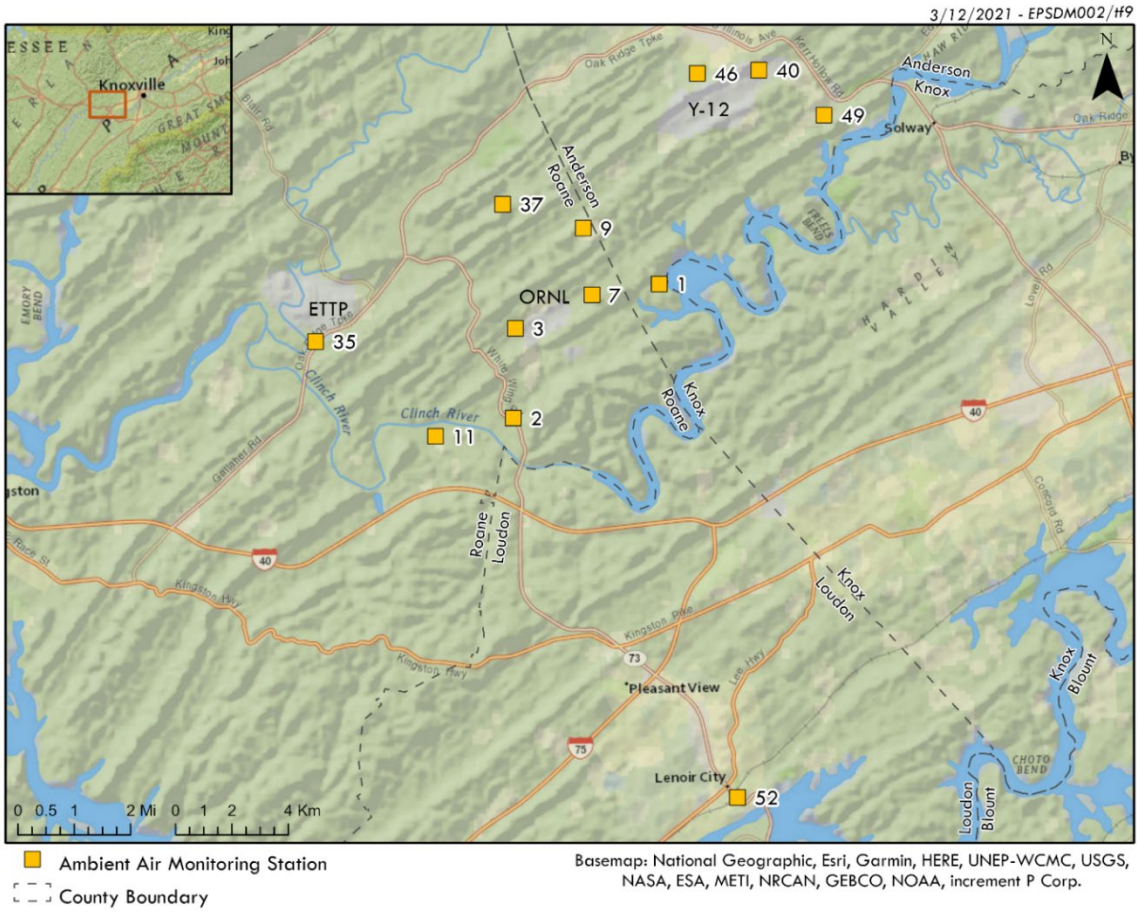
In addition to exhaust stack monitoring conducted at ORR installations (see chapters 3, 4, and 5), ambient air monitoring is performed to measure radiological parameters directly in the ambient air adjacent to the facilities (Figure 6.2). Ambient air monitoring provides a means to verify that contributions of fugitive and diffuse sources are insignificant, serves as a checkon dose-modeling calculations, and would allow 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 permits 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 to reflect changes in DOE activities and operations that had occurred since the 1990s. The stations monitored in 2020 are shown in Figure 6.3. Reference samples are collected at Station 52 (Fort Loudoun Dam). Sampling was conducted at each ORR station during 2020 to quantify levels of alpha-, beta-, and gamma-emitting radionuclides.



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

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.

6.2.2. 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 2011). All radionuclide concentrations measured at the ORR ambient air stations during 2020 were less than 1 percent of applicable DCSs.

Table 6.2. Radionuclide concentrations at ORR perimeter air monitoring stations, 2020

Station	Average concentration (pCi/mL)[a] (Number detects/n)						
	^{7}Be	^{40}K	^{3}H	^{234}U	^{235}U	^{238}U	^{99}Tc
01	4.24E-08 (4/4)	4.61E-10 (0/4)	1.98E-06 (0/4)	2.06E-12 (4/4)	2.44E-13 (1/4)	1.72E-12 (4/4)	
02	3.61E-08 (4/4)	2.11E-10 (0/4)	4.08E-06 (0/4)	1.73E-12 (4/4)	1.36E-13 (0/4)	1.20E-12 (3/4)	
03[b]	4.00E-08 (4/4)	-5.83E-11[c] (0/4)	4.66E-06 (0/4)	2.20E-12 (4/4)	2.88E-13 (2/4)	1.64E-12 (4/4)	
09	4.29E-08 (4/4)	2.55E-10 (0/4)	3.09E-05 (3/4)	3.67E-12 (4/4)	2.78E-13 (1/4)	1.82E-12 (4/4)	
11	4.20E-08 (4/4)	9.89E-11 (0/4)	2.16E-06 (0/4)	1.74E-12 (4/4)	2.70E-14 (0/4)	1.13E-12 (3/4)	
35	3.60E-08 (4/4)	-6.71E-12[c] (0/4)	4.25E-06 (1/4)	1.71E-12 (4/4)	1.60E-13 (1/4)	1.52E-12 (4/4)	-2.32E-11[c] (0/4)
37	3.60E-08 (4/4)	-6.08E-13[c] (0/4)	2.51E-06 (1/4)	2.31E-12 (4/4)	2.93E-13 (1/4)	1.19E-12 (4/4)	
40	4.27E-08 (4/4)	2.52E-10 (0/4)	3.93E-06 (0/4)	9.93E-12 (4/4)	8.09E-13 (3/4)	2.76E-12 (4/4)	
46	3.75E-08 (4/4)	-1.55E-10[c] (0/4)	-2.28E-07[c] (0/4)	5.18E-12 (4/4)	4.46E-13 (3/4)	1.69E-12 (4/4)	
49	3.84E-08 (4/4)	-5.10E-10[c] (0/4)	2.51E-06 (0/4)	2.32E-12 (4/4)	1.45E-13 (0/4)	1.57E-12 (4/4)	
52[d]	3.98E-08 (4/4)	5.48E-10 (1/4)	7.48E-07 (0/4)	1.70E-12 (4/4)	1.10E-13 (0/4)	1.45E-12 (4/4)	-3.09E-11[c] (0/4)

[a] *1 pCi = 3.7 × 10^{-2} Bq.*

[b] *An additional radionuclide, ^{124}Sb, was detected at Station 03 in the second quarter of 2020 with a concentration of 2.36E-10 pCi/mL. The ^{124}Sb radionuclide was not detected and not reported in the other quarters.*

[c] *A negative concentration of radioactivity is reported by the laboratory when the sample count rate minus the background count rate is negative (i.e., the background count rate was greater than the sample count rate). When the background activity is subtracted from the sample activity to obtain a net value, a negative value results.*

[d] *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, previously released radionuclides deposited on soil and vegetation or in sediments, radiation-generating facilities, especially high-energy accelerators, and the storage of radioactive materials (DOE 2021a). 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). Unlike the quantified filter and silica gel results for a range of radionuclides obtained by the ambient air monitoring program, external gamma radiation is monitored continuously; data are logged at 1 min intervals and averaged for the entire year.

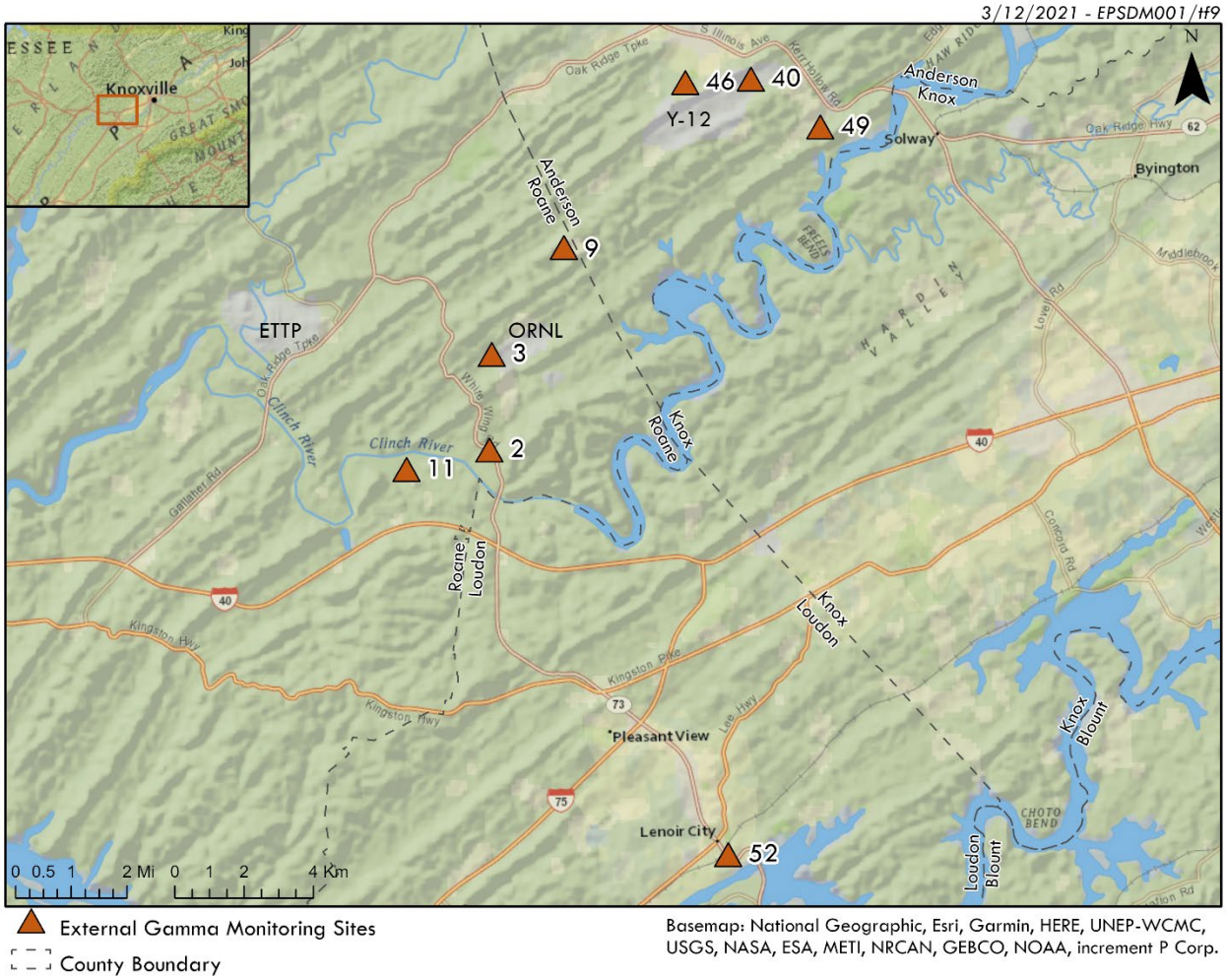
6.3.1. Data Collection and Analysis

External gamma exposure rates are continuously recorded by dual-range Geiger-Müller tube detectors co-located with ORR ambient air stations (see Section 6.2). Dose rates are recorded by the instruments every minute, and the data are downloaded weekly. Figure 6.4 shows locations

that were monitored during 2020; Table 6.3 summarizes the data for each station.

6.3.2. Results

The mean exposure rate for the reservation network in 2020 was 9.7 μR/h, and the mean rate at the reference location (Fort Loudoun Dam) was 8.9 μR/h. Background direct radiation exposure rates have been collected at the Fort Loudoun Dam (Station 52) reference location for many years. From 2010 through 2019 (the preceding 10 years), the exposure rates at the reference location ranged from 6.3 to 11.4 μR/h and averaged 8.4 μR/h (rounded to 8 μR/h).



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 6.4. External gamma radiation monitoring locations on ORR

Table 6.3. External gamma exposure rate averages for ORR, 2020

Air station number	Number of data points (daily)	Measurement (μR/h)[a]		
		Min	Max	Mean
02	364	8.4	11.0	9.1
03	366	8.9	11.3	9.4
09	366	8.4	12.1	9.4
11	360	9.5	12.7	10.4
40	366	8.9	11.6	9.8
46	360	9.9	12.0	10.6
49	366	8.9	12.1	9.6
52	361	8.1	10.8	8.9

[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 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

In 2020, as has been the case since 2009, there were no statistical differences in radionuclide concentrations in surface water samples collected from the Clinch River upstream and downstream of DOE inputs. No radionuclides were detected above 4 percent of the respective DCSs.

Mercury was not detected in 2020 in samples from any of the three sampling locations where mercury samples are collected, Clinch River kilometer (CRK) 66, CRK 32, and CRK 16.

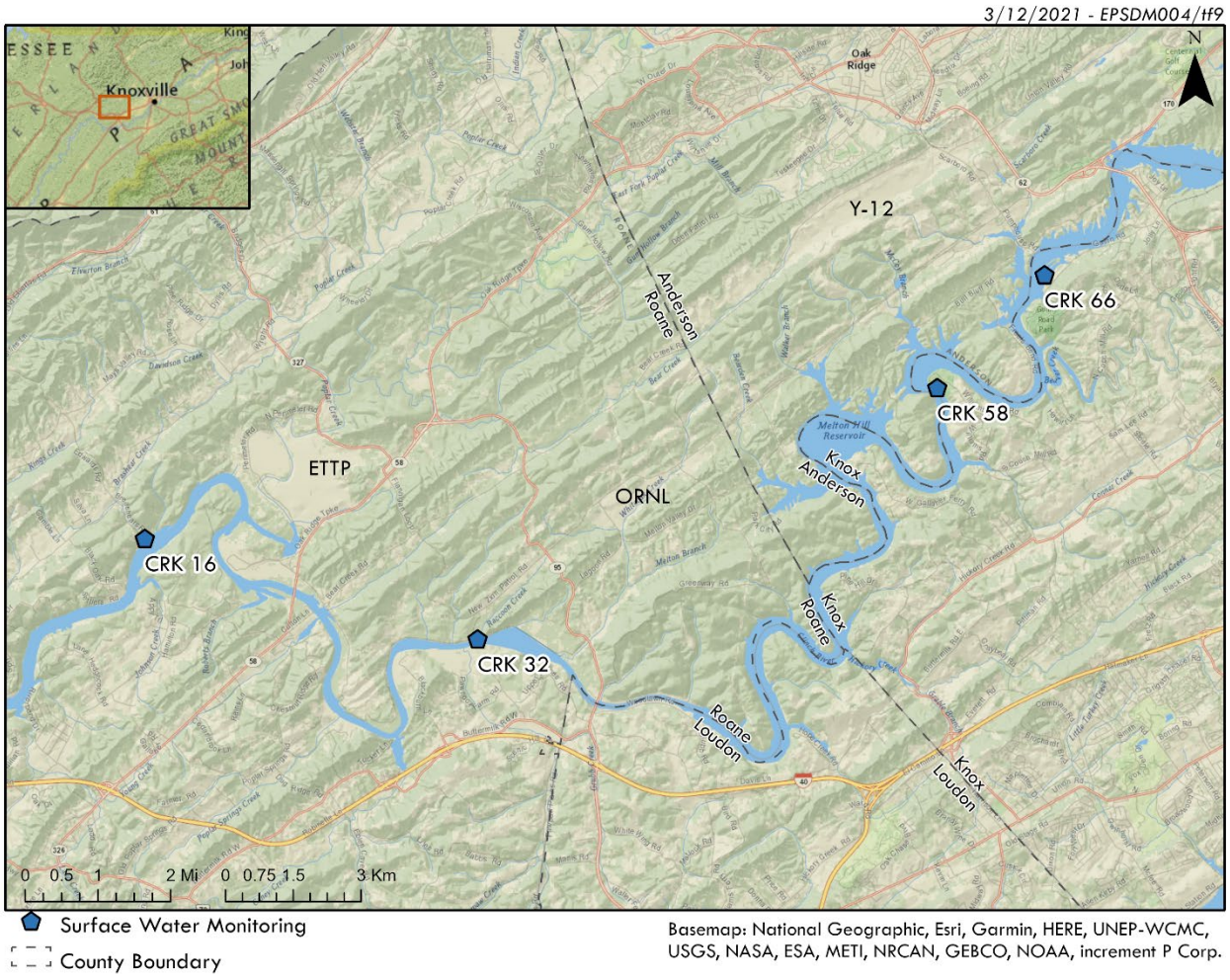


Figure 6.5. ORR surface water surveillance sampling locations

Table 6.4. ORR surface water sampling locations, frequencies, and parameters, 2020

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 2020 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 2020 the 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 2020 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 2020 remediation effectiveness report (DOE 2020b).

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 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 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 2020 DOE developed more refined groundwater flow models for the ORNL site to

support the *Phased Groundwater Remedial Investigation Work Plan for the Bethel Valley Final Groundwater Record of Decision* (DOE 2021b). 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 2020 because no dairies in potential ORR deposition areas were located. Surveys are conducted annually to determine if 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. The as-low-as-reasonably-achievable 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 from an area on the eastern edge of ORR is made available to an off-site farming operation and is sampled annually. Eating beef and drinking milk obtained from cattle that eat hay is a potential radiation exposure pathway to humans, and hay is sampled to characterize any possible doses from this pathway.

6.6.1.1. Data Collection and Analysis

Hay is collected and analyzed from one location on ORR. Hay samples collected on ORR during July 2020 were analyzed for gross alpha, gross beta, gamma emitters, and uranium isotopes. Once every 5 years, additional radiological analyses are performed to confirm the dose model (see Chapter 7). In 2020, additional radionuclides analyzed included neptunium, plutonium, strontium, and thorium.

6.6.1.2. Results

Radionuclides detected in hay are shown in Table 6.5. Statistically significant concentrations of gross alpha activity, gross beta activity, ^{7}Be, ^{40}K, ^{234}U, ^{235}U, and ^{238}U were detected in July 2020.

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 received by 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.

Table 6.5. Concentrations of radionuclides detected in hay, July 2020 (pCi/kg)[a]

Radionuclide	Result
Gross alpha	240
Gross beta	12,600
Be-7	6,350
K-40	17,100
Np-237	*b*
Pu-238	*b*
Pu-239/240	*b*
Sr-90	*b*
Th-228	*b*
Th-230	*b*
Th-232	*b*
Tritium	*b*
U-234	7.77
U-235	1.79
U-238	6.08

[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.

6.6.2.1. Data Collection and Analysis

Tomatoes were purchased in 2020 from farms near ORR and from reference locations. The locations were chosen based on availability and on the likelihood of effects from routine releases from the Oak Ridge facilities. No sources for root vegetables or leafy greens near ORR were found in 2020. The tomato 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 radionuclides ^{7}Be and ^{40}K.

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 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)
- Clinch River downstream from all DOE ORR inputs (CRK 16)

Table 6.6. Concentrations of radionuclides detected in tomatoes, 2020 (pCi/kg)[a]

Location	Gross alpha	Gross beta	^{7}Be	^{40}K	^{234}U	^{235}U	^{238}U
North of Y-12	40.7	993	*b*	*b*	2.17	*b*	*b*
South of ORNL	*b*	1,240	*b*	1,800	*b*	*b*	*b*
East of ORNL	22.6	899	*b*	*b*	5.2	*b*	*b*
West of ETTP	52.5	1,160	*b*	1,360	6.08	*b*	1.01
Reference location	61.4	1,150	*b*	*b*	3.78	*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

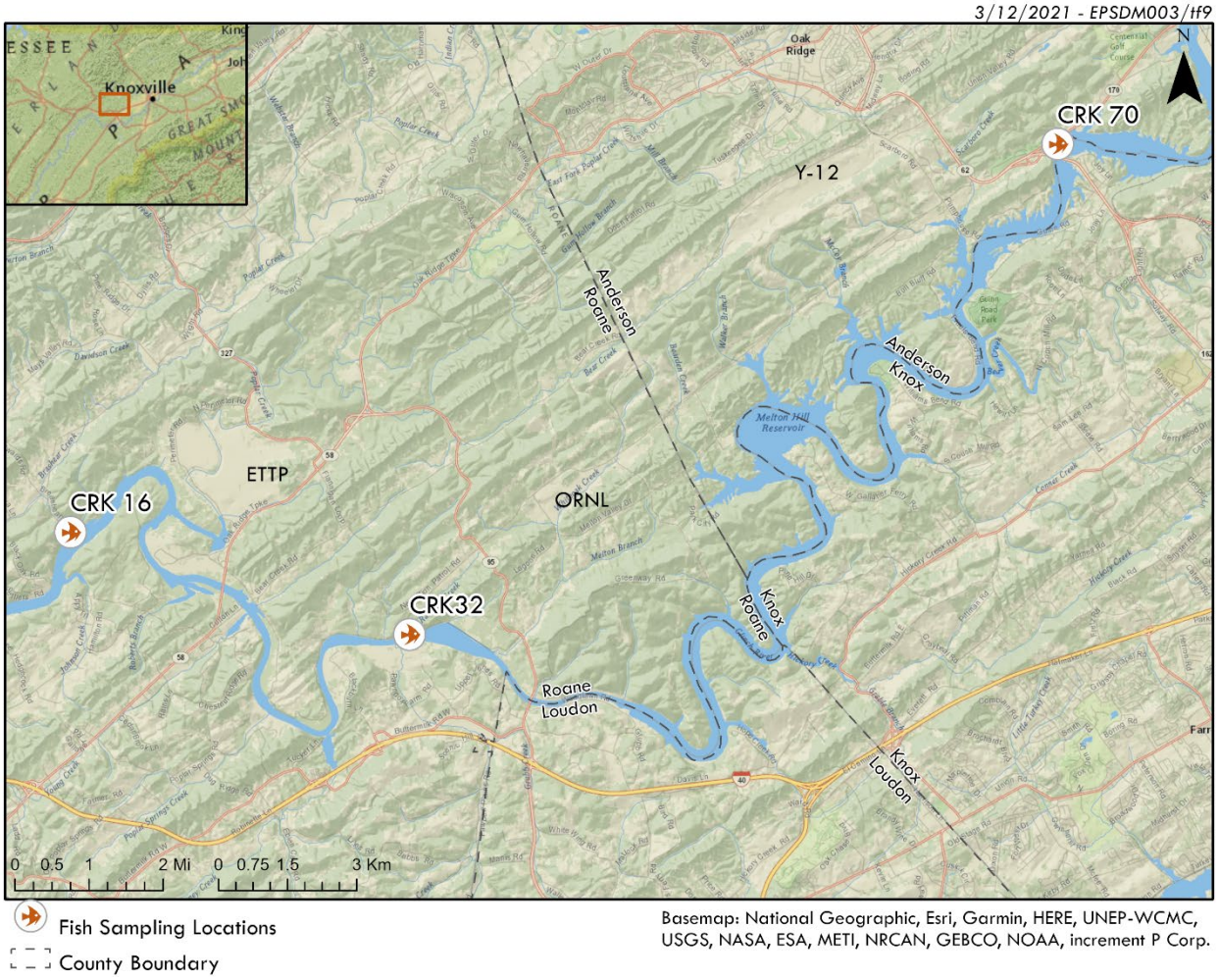


Figure 6.6. Fish-sampling locations for the ORR Surveillance Program

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 2020, 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 model (see Chapter 7). In 2019, additional radionuclides detected included neptunium, plutonium, thorium, and uranium isotopes. Based on the 2019 results, some additional radionuclide analyses were again performed in 2020, including 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. 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 2020). 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 waters (Denton 2007).

Table 6.7. Tissue concentrations in catfish and sunfish for detected mercury, PCBs, and radionuclides, 2020[a]

	CRK 16 Downstream		CRK 32		CRK 70 Upstream	
	Species					
Metals (mg/kg)	**Catfish**	**Sunfish**	**Catfish**	**Sunfish**	**Catfish**	**Sunfish**
Hg	0.049	0.12	0.053	0.041	0.08	J0.025[b]
Pesticides and PCBs (µg/kg)						
PCB-1260	170	J10[b]	140	J7.3[b]	33	J13[b]
Radionuclides (pCi/g)						
Alpha activity	c	0.37	0.33	0.36	c	c
Beta activity	3.4	4.1	3.1	4.3	3.7	3.2
^{40}K	3.1	4.3	3.1	3.4	4.4	3.5
Tritium	c	c	0.21	c	c	c
^{237}Np	0.0050	c	0.018	c	c	c
^{238}Pu	c	c	0.006	c	c	c
$^{239/240}Pu$	c	c	c	c	0.011	0.0073

[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] *Value was less than or equal to minimum detectable activity.*
Acronyms:
CRK = Clinch River kilometer
PCB = polychlorinated biphenyl

6.6.4.2. Results

PCBs, specifically Aroclor-1260, and mercury were detected in both sunfish and catfish at all three locations in 2020. 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

Three quota hunts were scheduled for 2020: November 3–4, November 10–11, and December 8–9. However, the hunts were cancelled due to the COVID-19 pandemic.

Since 1985, 13,334 deer have been harvested from the Oak Ridge Wildlife Management Area, of which 218 (approximately 1.67 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 86 lb. 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

Canada goose hunting was allowed on the Three Bends Area of ORR (excluding the shoreline of Gallaher Bend) during the statewide season in 2020, one half hour before sunrise until noon on 5 days during September and 4 days during October. Hunting was allowed for wood duck and teal for 2 days in September. The consumption of waterfowl is a potential pathway for exposing members of the public to radionuclides released from ORR operations.

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

Twenty-eight geese (all adults) were captured during the June 25, 2020, roundup on ORR. All 28 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 to occur on April 13–14 and April 27–28. However, the turkey hunts were cancelled due to 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. Invasive Plant Management

Invasive non-native plant species are among the greatest ecological threats across the country and around the world. Maintaining ecosystems, protecting natural areas, and ensuring functioning of facilities and their support infrastructures, power and communications rights-of-way, roadways, and waterways through actively managing invasive plant incursions is crucial, not only in natural areas, but in developed areas as well. Invasive plants can threaten forests, wetlands, cultural assets, and other resources through increased risk of fire; storm damage; and encroachment onto roads, railroads, power structures, waterways, and farmland. Invasive plants disrupt vital habitats of threatened and endangered species as well as other native wildlife and plant life by decreasing native plant diversity,

crowding out native plants, and disrupting natural plant-animal interactions.

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 control of invasive plants on lands under each agency's respective jurisdiction. Each agency must adequately fund the publication of an integrated pest management plan that will meet the regulatory requirements of federal laws, executive orders, presidential memorandums, contracts, and agreements. Other federal directives regarding control of invasive plants and subsequent restoration practices include the following:

- Presidential Memorandum, "Environmentally and Economically Beneficial Practices on Federal Landscaped Ground" (1994), which was replaced in 2000 by Executive Order 13148, "Greening the Government Through Leadership in Environmental Management" (2000)
- "Federal Memorandum of Understanding to Establish a Federal Inter-agency Committee for the Management of Noxious and Exotic Weeds" (1994)
- Executive Order 13112, "Invasive Species" (1999)
- Presidential Memorandum, "Creating a Federal Strategy to Promote the Health of Honey Bees and Other Pollinators," (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
- Executive Order 13751, "Safeguarding the Nation from the Impacts of Invasive Species." (2016)

The DOE has maintained an invasive plant management plan on ORR since 2004. For details of federal and state laws and regulations driving the DOE plan, see *Invasive Plant Management Plan for the Oak Ridge Reservation* (*Invasive Plant Management Plan for the Oak Ridge Reservation* (Parr et al. 2004, Quarles et al. 2011, McCracken and Giffen 2017).

A 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 done 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 of these approximately 170 plant species are non-native plants. Fifty-seven aggressive non-native (invasive) plant species have been identified on ORR, but control efforts are primarily focused on a subset of 10 species (see Table 6.8). The selected invasive 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 targets for control as well, using US Department of the Interior Early Detection and Rapid Response guidance (DOI 2020) and in concert with control efforts on the 10 highly invasive species listed in Table 6.8.

Table 6.8. Ten most problematic invasive plants on the 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*

The 32,800-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.

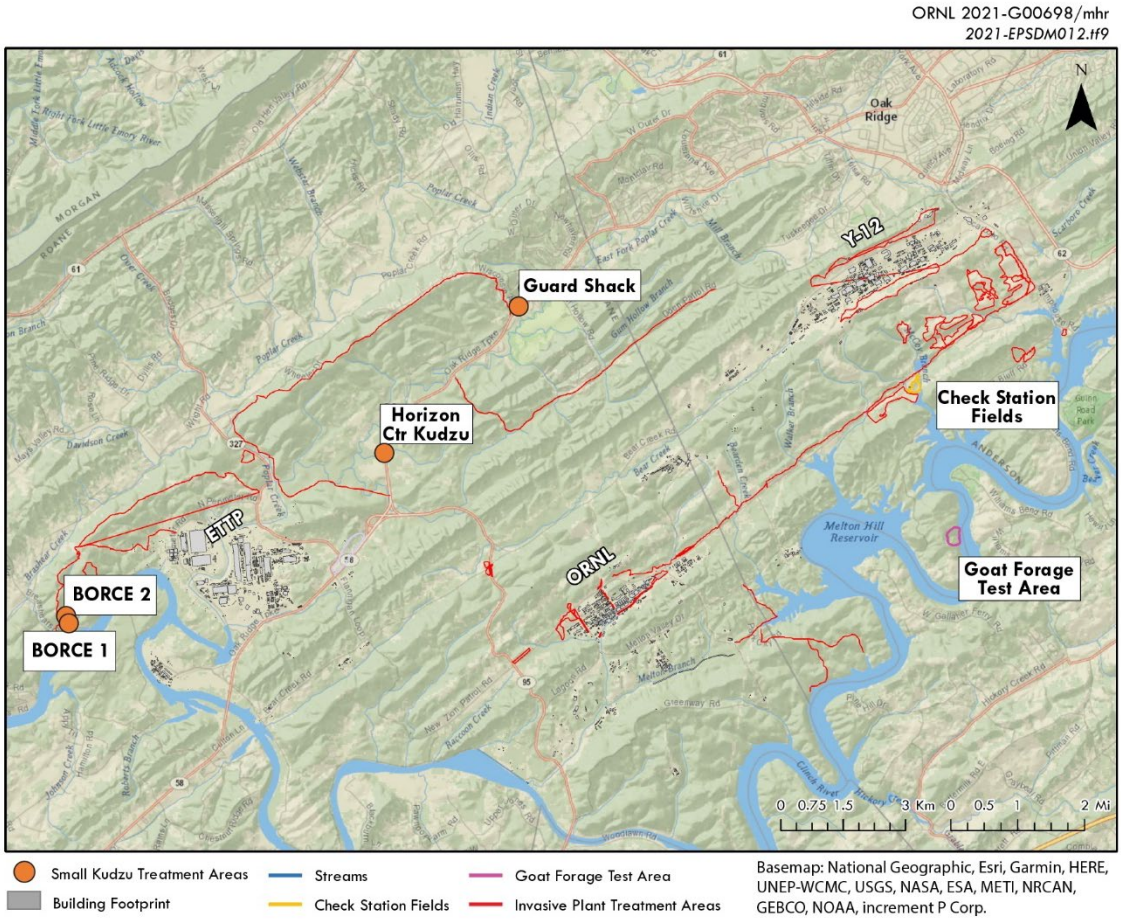
Numerous DOE contractors have responsibilities for land management of portions of ORR, as do other federal and state agencies, such as the Tennessee Valley Authority and the Tennessee Wildlife Resources Agency. The Natural Resources Management Team for ORR receives site-wide funding annually, a portion 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 and 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 selected herbicides is the most cost-effective treatment method in most cases, and the invasive plants present inform which herbicides will be most effective without causing harm to 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 2020. 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, 2003–2020

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

Restoration of selected natural areas is done in addition to herbicide treatment of invasive plants. *The Native Grass Community Management Plan for the Oak Ridge Reservation* (Ryon et al. 2007) and the *Grassland Ecosystem Management Plan for the Oak Ridge Reservation* (Herold and McCracken 2018) discuss demonstration projects and larger grassland restoration projects across ORR. Demonstration projects have been done at ETTP, the Y-12 Complex, and ORNL. Native plant restoration projects totaling several hundred acres across ORR are located within the Oak Ridge National Environmental Research Park's natural areas.



Acronym: *BORCE = Black Oak Ridge Conservation Easement*

Figure 6.7. Map of invasive plant treatment areas on ORR for 2020

Invasive Plant management and grassland restoration completed in 2020 at each of the three facilities on ORR include the following:

- ORNL
  - First Creek grassland area management
  - First Creek riparian buffer zone
  - Fifth Creek riparian buffer zone
  - White Oak Creek riparian buffer zone
  - 1000 area invasive plant control
  - 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
  - Park City Road/Price Road invasive plant treatment
  - Three Bends Area invasive plant control
  - Gallaher Bend kudzu control using goats
- Y-12
  - Y-12 Native Grassland Area invasive plant treatment
  - 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
  - Fire road invasive plant control
  - Mt. Vernon Road pine removal area
- ETTP
  - EU-29 demonstration field invasive plant control
  - Black Oak Ridge Conservation Easement kudzu and invasive plant control
  - Black Oak Ridge Conservation Easement greenway and trail invasive plant control

6.8. Fire Protection Management and Planning

Wildland fire management plays a major part in DOE's overall management of ORR. A comprehensive wildfire management program has been established and implemented for the entire ORR. The *Wildland Fire Management Plan at the Oak Ridge Reservation* (DOE 2005), assigns responsibilities for wildland fire management, and Appendix A of the *Oak Ridge Reservation Wildland Fire Implementation Plan* (DOE 2008) provides specific details on achieving complete implementation of the program. The most recent guidance for forest management is defined in a DOE Oak Ridge Wildland Fire Memorandum dated April 5, 2007. A revised ORR wildland fire management plan and ORR wildland fire implementation plan are to be introduced during 2021. DOE actions associated with wildland fire management include the following:

- Development of burn plans and authorization by the reservation manager
- Conducting routine operational controlled burns
- Incorporation of wildland fire mitigation and response activities and procedures into the ORR land-use planning process
- Preparing and updating pre-fire planning maps
- Ensuring that hard-copy maps of ORR are available for wildland fire response and mitigation
- Conducting wildland fire scenarios in emergency management exercises as necessary or appropriate, and developing after-action reports identifying areas of weakness or needs for improvement
- Development of stakeholder involvement plans in support of the wildland fire program
- Review of current wildland fire-potential data, including indications of wildland fire risk
- Preparing a wildland fire risk report, including a wildland fire hazard severity analysis based on the National Fire Protection Association *Standard for Wildland Fire Management* (NFPA 2018)
- Identifying equipment necessary to perform forest management activities and assignments

The DOE roads and grounds contractor has the responsibility for establishing and maintaining the wildland fire roads, many of which delineate wildland management units (Figure 6.8), and maintaining barricades that control access to ORR secondary roads. The management contractors at each of the three major 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 personnel who are trained and equipped to respond to wildland fires and heavy equipment, including fire plows, when requested to assist with wildland fires.

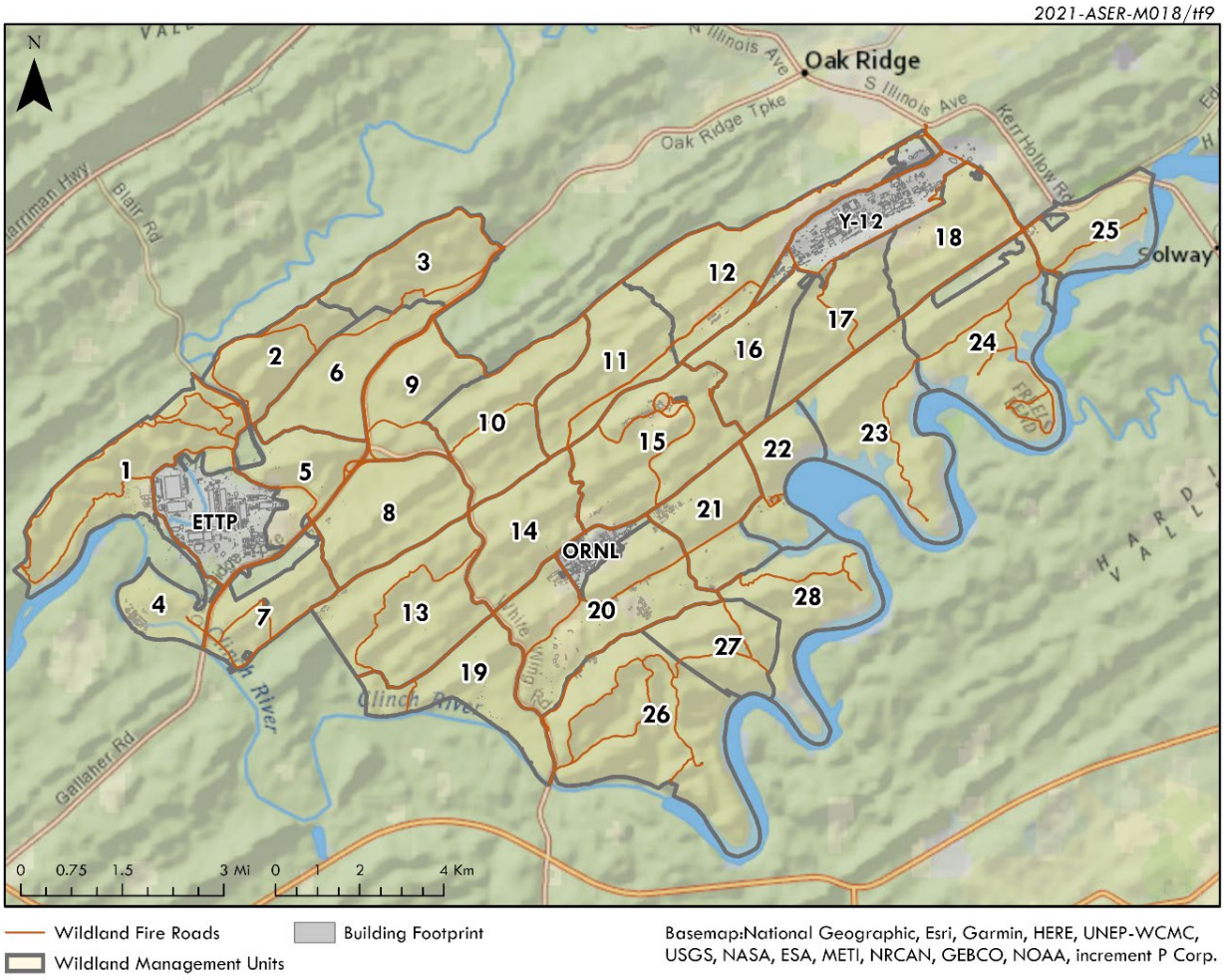


Figure 6.8. Wildland management units on ORR

Because ORR is a large (32,866.54 acres), mainly forested property with access restrictions, it is a challenge for most site emergency personnel to maintain familiarity with all remote areas and back roads and to quickly recognize and size up concerns associated with those areas. The ORR wildland management unit pre-fire plans are designed to aid those not familiar with an area and to assist the recall of those who are. Because DOE's wildfire strategy now relies on outside agencies for assistance with large or difficult wildfires, the plans also serve as guidance for those responders who may have little or no experience on ORR. The plans offer awareness of ORR's unique hazards and can help avoid inadvertent impacts to structural, cultural, environmental, and research assets.

The pre-fire plans are a series of brief documents covering each of 28 ORR wildlife management units (Figure 6.8). Each plan summarizes access issues, assets, and hazard concerns within its area. Hard copies of the plans are intended to remain in responder vehicles for immediate reference during remote events. Terse and compact in format, the plans are easily updated, stored, and shared electronically. Pre-fire plan copies are also maintained at site fire departments and emergency operations centers and by shift superintendents and certain managers. The plans are meant to influence quick decisions but are not meant to dictate tactics.

A pre-fire plan is a single-page synopsis that provides a wildlife management unit's identification number and name, general location

within ORR, and its boundaries and size. The most important information or hazards are highlighted near the top of the form, followed by topical guidance on tactics, access, vegetation and fuels, water sources, topographic considerations, and hazards. Plan maps depict access, fuel types, water sources, and urban interface areas. Utilities, hazards, research areas, and sensitive resources are also depicted. Pre-fire plans are reviewed on a 3-year cycle and are updated as significant changes occur. The ORR forester is the point of contact for plan distribution.

Events during 2016 demonstrated that large fires, more frequent in the western states, can occur in the region containing ORR. As a result, issues related to wildland/urban interface are a growing concern. These areas may feature 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 fire spread to and from the community. Actions have also been taken in areas exposed to potential high-intensity wildfires due to the presence of dense pine forests, including harvests to thin or replace dense pine, 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 UCOR. 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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