7. ORR Environmental Monitoring Programs

Setting

Environmental monitoring is a major activity on the ORR. Environmental monitoring encompasses two activities, effluent monitoring and environmental surveillance. Effluent monitoring consists of the collection and analysis of samples or measurements of liquid and gaseous effluents at their emission point to determine and quantify contaminants released. Environmental surveillance consists of the collection and analysis of samples of air, water, vegetation, biota, and other media from the ORR and its surroundings. External radiation is also measured. Data from environmental monitoring activities are used to assess exposures to members of the public and to assess effects on the local population and the environment.

Update

In 2000, the mean value for external gamma radiation as measured at five ambient-air monitoring stations on the ORR was 5.3 μR/h, which is slightly higher than the mean value of 4.8 μR/h observed at the reference location at Fort Loudoun Dam for the same time period. It is common for external gamma levels to vary with terrain, and the observed variation indicates that the contribution to external gamma levels from Oak Ridge operations, if any, is very minor. Similarly, a comparison of sampling data from the ORR perimeter air monitoring stations with data from the reference station in 2000 shows that for all radionuclides of interest with the exception of ^{3}H, there are no statistically significant differences in the average concentrations measured at the ORR and the averages measured at the reference station.

Under the ORR Environmental Monitoring Plan (EMP), samples are collected and analyzed from 22 surface water locations around the ORR. Except for two locations, which were dry when sampling was attempted, radionuclides were detected at all locations in 2000. The highest levels were detected at Melton Branch downstream from ORNL.

Analyses of locally grown hay, produce, fish, and milk provided data for assessing potential health impacts. Analytical results vary slightly from year to year, but the 2000 results are not significantly different from previous years. Potential radiation doses associated with the above products could have been 0.02, 0.03, 0.6, and 0.06 mrem (0.0002, 0.0003, 0.006, and 0.0006 mSv), respectively.

7.1 METEOROLOGICAL MONITORING

Seven meteorological towers provide data on meteorological conditions and on the transport and diffusion qualities of the atmosphere on the 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 would be used in the event of accidental releases from a facility. Data from the towers are also used to support various research and engineering projects.

7.1.1 Description

The seven meteorological towers, depicted in Fig. 7.1, consist of one 330-ft (100-m) tower (MT5) and one 200-ft (60-m) tower (MT6) at the Y-12 Complex, one 330-ft tower (MT2) and two 100-ft towers (MT3 and MT4) at ORNL, and one 200-ft tower (MT1) and one 100-ft (30-m) tower (MT7) at the ETTP.

Data are collected at different levels to determine the vertical structure of the atmosphere and the possible effects of vertical variations on releases from facilities. At the towers, data are collected at the 32.8-ft (10-m) level and at the top of the tower. At the 330-ft (100-m) towers, data are collected at an intermediate 100-ft (30-m) level as well. At each measuring level on each tower, temperature, wind speed, and wind direction are measured. Y-12 MT6 has an additional temperature measurement at 65 ft (20 m). Humidity and data needed to determine atmospheric stability (a measure of the dispersive capability of the atmosphere) are also measured at each tower.

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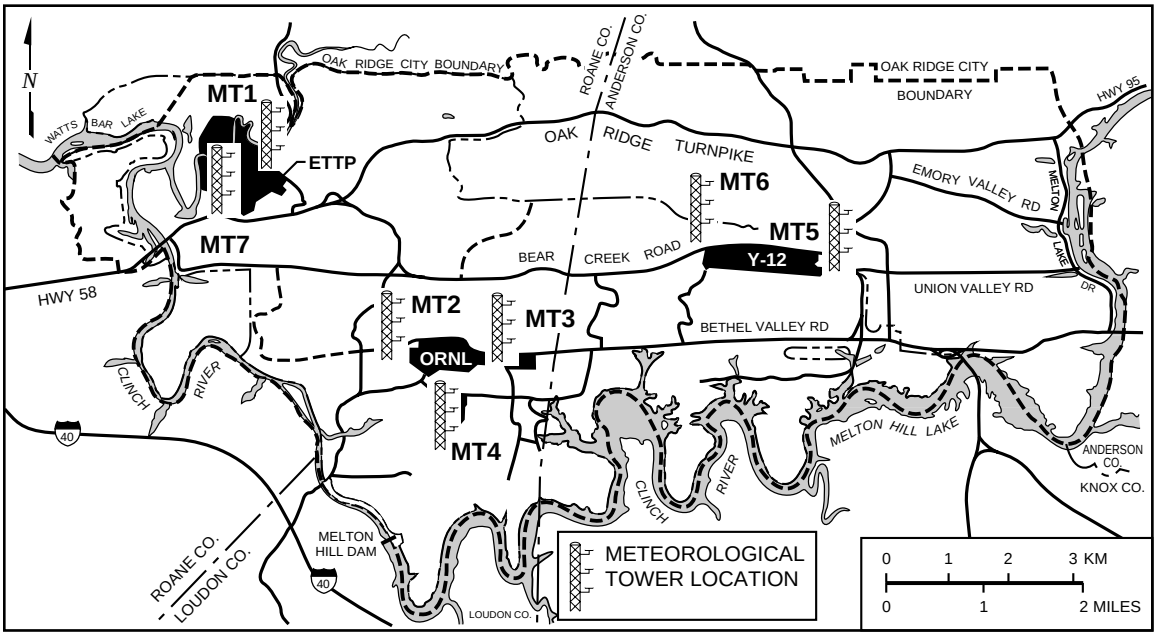

Fig. 7.1. The ORR meteorological monitoring network.

Barometric pressure is measured at one or more towers at each facility (MT1, MT2, MT5, and MT7). Precipitation is measured at MT5 and MT6 at the Y-12 Complex, at MT1 and MT7 at the ETTP, and at MT2 at ORNL; solar radiation is measured at MT2 at ORNL, MT1 and MT7 at the ETTP, and MT5 and MT6 at the Y-12 Complex.

Data from the towers at each site are collected by a dedicated control computer. The towers are polled, and the data are filed on disk. Fifteen-minute and hourly values are stored at each site for a running 24-h period, but only hourly data are routinely stored beyond 24 h. The meteorological monitoring data from ORNL are summarized monthly as wind roses and data tables. Quarterly calibration of the instruments is conducted for each site by an outside contractor.

Fifteen-minute and hourly data are used directly at each site for emergency-response purposes such as input to dispersion models. Annual dose estimates are calculated from archived data (either hourly values or summary tables of atmospheric conditions). Data quality is checked continuously against predetermined data constraints, and out-of-range parameters are marked invalid and are not input to the dispersion models.

7.1.2 Results

Prevailing winds are generally up-valley from the southwest and west-southwest or down-valley from the northeast and east-northeast. This pattern is the result of the channeling effect of the ridges flanking the site. Winds in the valleys tend to follow the ridges, with limited cross-ridge flow. These conditions are dominant over the entire reservation, with the exception of the ETTP, which is located in a relatively open area that has a more varied flow. Weaker valley flows are noted in this area, particularly in locations near the Clinch River.

On the reservation, low-speed winds predominate at the surface level. This characteristic is noted at all tower locations, as is the increase in wind speed at the height at which measurements are made. This activity is typical of tower locations and is important when selecting appropriate data for input to dispersion studies.

The atmosphere over the reservation is dominated by stable conditions on most nights and in early morning hours. These conditions, coupled with the low wind speeds and channeling effects of the valleys, result in poor dilution of material emitted from the facilities. These features are captured in the data input to the dispersion models

and are reflected in the 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 amounts resulting from frontal storms and the uneven, but occasionally intense, summer rainfall associated with thunderstorms.

The average data recovery rate (a measure of acceptable data) across all locations and at 12 tower levels was approximately 98.6% in 2000. The maximum data recovery rate was 99.9% at ETTP MT1 at 10 m. The minimum data recovery rate was approximately 96.8% at ETTP MT7 at 10 m.

7.2 EXTERNAL GAMMA RADIATION MONITORING

External gamma radiation monitoring is conducted to determine whether radioactive effluents from the ORR are increasing external radiation levels significantly above normal background levels. The data also provide a means for comparing results from year to year and establishing trends.

7.2.1 Data Collection and Analysis

External gamma measurements (exposure rates) are recorded weekly at six ambient air stations from resident external gross gamma monitors (Fig. 7.2). Each consists of a dual-range, high-pressure ion chamber sensor and digital electronic count-rate meter and totalizer. Totalizing consists of multiplying the count rate by the time of exposure to obtain total exposure.

7.2.2 Results

Table 7.1 summarizes the data collected at each station during the year. The mean observed exposure rate for the reservation network for the year was 5.3 μR/h, which is slightly higher than the mean value of 4.8 μR/h observed at the reference location. A person exposed to the mean exposure rate for 1 year could have received an effective dose equivalent (EDE) of about 35 mrem.

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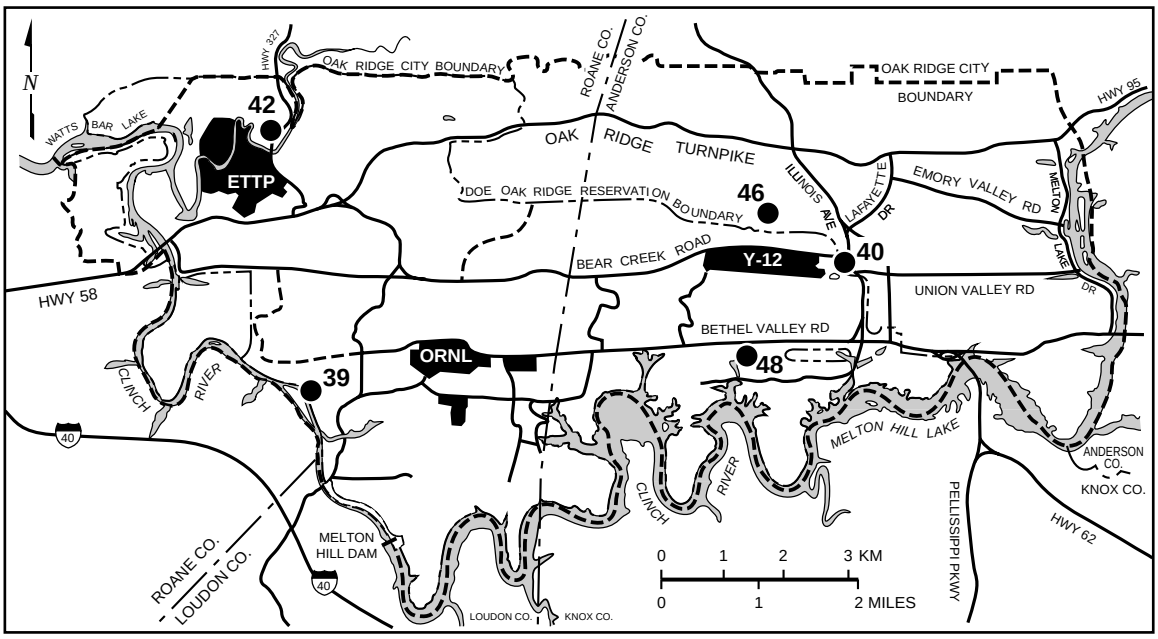

Fig. 7.2. External gamma radiation monitoring locations on the ORR. Location 52, at Fort Loudoun Dam, approximately 15 miles southwest of ORNL, is not shown on this map.

Table 7.1. External gamma averages, 2000

Location	Number of data values collected	Measurement (μR/h)[a]			Standard error of mean
		Min	Max	Mean	
39	50	4.6	6.9	6.3	0.00005
40	52	4.7	6.2	5.1	0.00006
42	52	2.5	5.3	4.5	0.00007
46	51	5.8	6.4	6.1	0.00002
48	46	4.2	5.3	4.6	0.00003
52	52	4.5	5.4	4.8	0.00003

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

7.3 AMBIENT-AIR MONITORING

In addition to exhaust stack monitoring conducted at the DOE Oak Ridge installations, ambient air monitoring is performed to measure radiological parameters directly in the ambient air adjacent to the facilities. Ambient-air monitoring provides direct measurement of airborne concentrations of radionuclides in the environment surrounding the facilities, allows facility personnel to determine the relative level of contaminants at the monitoring locations during an emergency, verifies that the contributions of fugitive and diffuse sources are insignificant, and serves as a check on dose-modeling calculations.

The following sections discuss the ambient-air monitoring networks for the ORR. The other monitoring programs are discussed in the site-specific chapters, Chapter 4 (ETTP), Chapter 5 (ORNL), and Chapter 6 (the Y-12 Complex).

7.3.1 ORR Ambient-Air Monitoring

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 remote location not affected by activities on the ORR. The ORR perimeter air monitoring (PAM) network includes stations 35, 37, 38, 39, 40, 42, 46, and 48 (Fig. 7.3). Reference samples are collected from Station 52 (Fort Loudoun Dam). Sampling was conducted at each ORR station during 2000 to quantify levels of alpha-, beta-, and gamma-emitting radionuclides and ^{3}H.

Atmospheric dispersion modeling was used to select appropriate sampler locations. The locations selected are those most likely to be affected by releases from the Oak Ridge facilities. Therefore, in the case of a release, no residence or business in the vicinity of the ORR would be affected by undetected releases of radioactive materials. To provide an estimate of background radionuclide concentrations, an additional station is located at Fort Loudoun Dam, a site not affected by releases from the ORR.

The sampling system consists of two separate instruments. Particulates are captured on glass-fiber filters in a high-volume air sampler. The filters are collected weekly, composited quarterly, then submitted to the laboratory for isotopic analysis. The second system is designed to collect tritiated water vapor. The sampler consists of a prefilter followed by an adsorbent trap consisting of indicating silica gel. The samples are collected weekly or biweekly, composited quarterly, then submitted to the laboratory for ^{3}H analysis.

The ORR ambient air network (Fig. 7.3) provides appropriate monitoring for all facilities within the reservation, which eliminates the necessity for site-specific ambient air programs. As part of the ORR network, an ambient-air monitoring station located in the Scarboro community of Oak Ridge (Station 46) measures off-site impacts of the Y-12 Complex operation. Station 40 of the ORR network monitors the east end of the Y-12 Complex, and Station 37 monitors the

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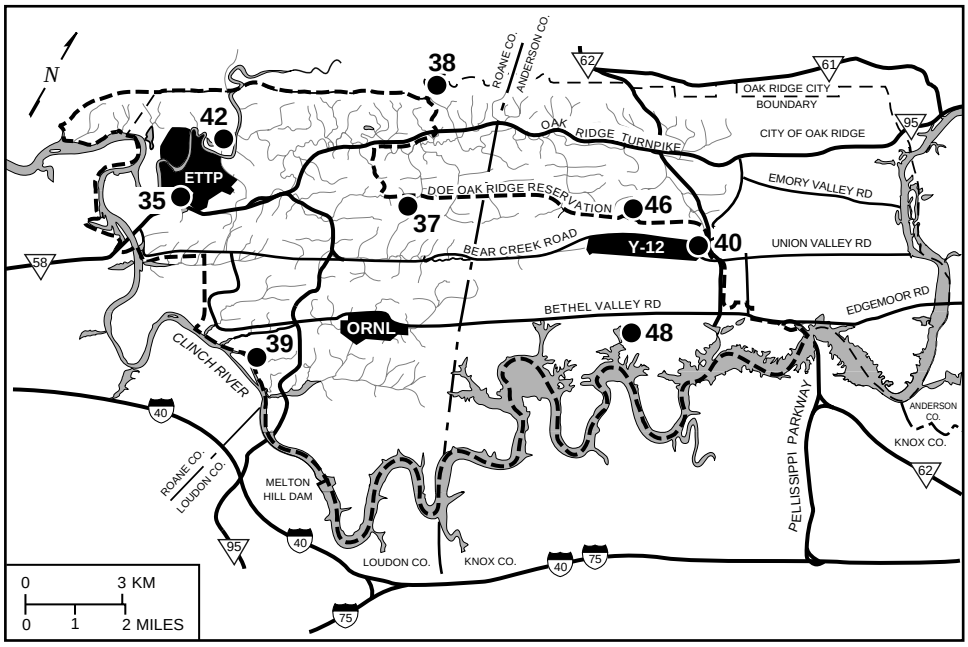

Fig. 7.3. Location of ORR perimeter air monitoring stations.

overlap of the Y-12 Complex, ORNL, and ETTP emissions.

7.3.2 Results

Data from the ORR PAM stations are analyzed to assess the impact to air quality of operations on the entire reservation. The background station provides information on reference concentrations of radionuclides and gross parameters for the region. Comparisons of ORR PAM station sampling data and data collected from reference Station 52 show that the average H^3 concentrations measured at the ORR network are greater than the concentration measured at the reference station at the 95% confidence level. Because measuring a radionuclide requires a process of counting random radioactive emissions from a sample, the same result may not be obtained if the sample were analyzed repeatedly. This deviation is referred to as the "counting uncertainty."Statistical significance at the 95% confidence levels means that there is a 5% chance that the results could be in error. There were no other statistically significant differences in any of the other radionuclides of interest (Table 7.2).

Table 7.3 represents the average concentration of three isotopes of uranium at each station for sampling years 1997, 1998, 1999, and 2000. There are no statistically significant differences between any of the concentrations for the three uranium isotopes when comparing the perimeter network averages with the concentrations measured at the reference station (Station 52).

Table 7.4 presents potential radiation doses (EDEs) to hypothetical persons who were assumed to reside at the stations for the entire year under the exposure assumptions used for the NESHAPs dose calculations (see Chap. 8). Potential doses could have been between 0.07 and 0.15 mrem (0.0007 to 0.0015 mSv) at the ORR stations and about 0.11 mrem (0.0011 mSv) at the reference station.

7.4 SURFACE WATER MONITORING

7.4.1 ORR Surface Water Monitoring

Under the *ORR Environmental Monitoring Plan* (EMP) (DOE 1998b), samples are collected and analyzed from 21 locations around the ORR to assess the impact of past and current DOE

Table 7.2. Radionuclide concentrations at ORR perimeter air monitoring stations, 2000[a,b]

	35	37	38	39	40	42	46	48	52[c]
^{241}Am	1.3E–12[d]	3.5E–12[d]	9.9E–13[d]	1.6E–12[d]	1.4E–12[d]	1.6E–12[d]	2.7E–13[d]	3.1E–12[d]	8.5E–13[d]
^{7}Be	2.8E–08[d]	2.6E–08[d]	2.8E–08[d]	2.0E–08[d]	2.9E–08[d]	2.3E–08[d]	3.0E–08[d]	3.3E–08[d]	3.1E–08[d]
$^{243/244}$Cm	5.1E–12[d]	8.2E–13[d]	3.1E–13[d]	1.6E–13[d]	4.0E–13[d]	1.8E–13[d]	6.0E–13[d]	4.0E–13[d]	2.7E–13[d]
^{60}Co	3.1E–11[d]	3.5E–11[d]	2.5E–11[d]	2.4E–11[d]	1.3E–11[d]	3.1E–11[d]	1.6E–11[d]	1.8E–11[d]	1.7E–11[d]
^{137}Cs	1.3E–11[d]	2.8E–11[d]	2.3E–11[d]	1.8E–11[d]	3.4E–11[d]	1.4E–11[d]	1.1E–11[d]	1.5E–11[d]	1.7E–11[d]
^{40}K	1.2E–09[d]	1.2E–09[d]	3.7E–09[d]	9.4E–09[d]	5.4E–09[d]	0	8.8E–09[d]	4.0E–09[d]	3.4E–09[d]
^{3}H	5.2E–06[d]	4.6E–07	5.4E–07	9.2E–06	0	5.3E–06	4.3E–08	1.9E–06	8.1E–08
^{237}Np	1.2E–13[d]	6.9E–13[d]	1.3E–12[d]	2.6E–13[d]	1.6E–13[d]	0	5.6E–13[d]	9.2E–13[d]	7.1E–13[d]
^{238}Pu	3.7E–13[d]	0	1.4E–13[d]	4.3E–13[d]	2.4E–13[d]	3.2E–13[d]	5.6E–14[d]	4.0E–13[d]	9.7E–13[d]
$^{239/240}$Pu	3.0E–13[d]	1.3E–13[d]	5.2E–13[d]	1.1E–12[d]	0	1.0E–12[d]	2.1E–12[d]	6.3E–13[d]	2.2E–12[d]
$^{89/90}$Sr	5.2E–12[d]	6.1E–12[d]	6.9E–12[d]	9.9E–12[d]	6.2E–12[d]	3.1E–12[d]	1.2E–12[d]	1.7E–12[d]	3.3E–12[d]
^{99}Tc	3.2E–09[d]	2.7E–09[d]	2.1E–09[d]	3.7E–09[d]	3.2E–09[d]	3.0E–09[d]	3.2E–09[d]	3.3E–09[d]	3.5E–09[d]
^{238}Th	6.2E–12[d]	3.6E–12[d]	3.7E–12[d]	3.3E–12[d]	5.3E–12[d]	7.0E–12[d]	4.1E–12[d]	6.5E–12[d]	7.4E–12[d]
^{230}Th	8.2E–12[d]	6.2E–12[d]	6.9E–12[d]	8.9E–12[d]	6.7E–12[d]	3.8E–10[d]	6.1E–12[d]	1.6E–11[d]	1.2E–11[d]
^{234}Th	6.9E–12[d]	7.3E–12[d]	6.0E–12[d]	6.3E–12[d]	7.1E–12[d]	1.4E–11[d]	1.0E–11[d]	8.1E–12[d]	9.2E–12[d]
^{234}U	9.8E–12[d]	8.5E–12[d]	7.9E–12[d]	7.6E–12[d]	2.8E–11[d]	1.6E–11[d]	2.4E–11[d]	1.2E–11[d]	6.2E–12[d]
^{235}U	6.8E–13[d]	4.4E–13[d]	1.1E–12[d]	5.7E–13[d]	1.8E–12[d]	1.3E–12[d]	1.9E–12[d]	7.9E–13[d]	7.8E–13[d]
^{238}U	1.1E–11[d]	1.1E–11[d]	9.5E–12[d]	8.5E–12[d]	1.2E–11[d]	1.3E–11[d]	1.4E–11[d]	1.2E–11[d]	9.2E–12[d]

[a]All values are mean concentrations.
[b]Units are pCi/mL.
[c]Reference location.
[d]Statistically significant average at 95% confidence level.

operations on the quality of local surface water. Sampling locations include streams downstream of ORR waste sources, reference points on streams and reservoirs upstream of waste sources, and public water intakes (Fig. 7.4). Sampling locations include the following:

- Bear Creek downstream from Y-12 Complex inputs [Bear Creek kilometer (BCK) 0.6],
- Clinch River downstream from all DOE inputs [Clinch River kilometer (CRK) 16],
- water supply intake for the ETTP (CRK 23),
- Clinch River downstream from ORNL (CRK 32),
- water supply intake for Knox County (CRK 58),
- Melton Hill Reservoir above city of Oak Ridge water intake (CRK 66),
- Clinch River (Solway Bridge) upstream from all DOE inputs (CRK 70),
- EFPC prior to entering Poplar Creek [East Fork Poplar Creek kilometer (EFK) 0.1],
- EFPC downstream from floodplain (EFK 5.4),
- Melton Branch downstream from ORNL [Melton Branch kilometer (MEK) 0.2],
- WOL at WOD [White Oak Creek kilometer (WCK) 1.0],
- WOC downstream from ORNL (WCK 2.6),
- WOC upstream from ORNL (WCK 6.8),
- Grassy Creek upstream of SEG and IT Corp. at CRK 23 [Grassy Creek kilometer (GCK) 3.6],
- Ish Creek prior to entering CRK 30.8 [Ish Creek kilometer (ICK) 0.7],

Table 7.3. Uranium concentrations in ambient air on the ORR

Isotope	Concentration (10^{-15} µCi/mL)			
	1997	1998	1999	2000
Station 35				
^{234}U	4.0E–02	1.1E–02	2.0E–02	9.8E-03
^{235}U	2.1E–03	4.5E–04	1.5E–03	6.8E–04
^{238}U	4.6E–02	1.4E–02	2.3E–02	1.1E–02
Station 37				
^{234}U	5.4E–02	1.0E–02	2.7E–02	8.5E–03
^{235}U	4.4E–03	5.9E–04	6.9E–04	4.4E–04
^{238}U	5.3E–02	1.5E–02	2.1E–02	1.1E–02
Station 38				
^{234}U	5.3E–02	8.5E–03	1.5E–02	7.9E–03
^{235}U	1.8E–03	8.5E–04	1.1E–03	1.1E–03
^{238}U	4.4E–02	1.2E–02	1.9E–07	9.5E–03
Station 39				
^{234}U	4.6E–02	5.5E–03	8.9E–03	7.6E–03
^{235}U	1.6E–03	6.0E–04	7.7E–04	5.7E–04
^{238}U	6.1E–02	8.6E–03	9.7E–03	8.5E–03
Station 40				
^{234}U	2.2E–01	1.8E–02	3.5E–02	2.8E–02
^{235}U	5.8E–03	1.0E–03	1.0E–03	1.8E–03
^{238}U	5.9E–02	1.3E–02	2.0E–02	1.2E–02
Station 42				
^{234}U	7.2E–02	1.0E–02	2.2E–02	1.6E–02
^{235}U	6.2E–03	7.1E–04	9.3E–04	1.3E–03
^{238}U	3.9E–02	1.7E–02	2.5E–02	1.3E–02
Station 46				
^{234}U	1.0E–01	1.5E–02	2.8E–02	2.4E–02
^{235}U	3.7E–03	8.8E–04	2.9E–03	1.9E–03
^{238}U	4.7E–02	1.5E–02	2.4E–02	1.4E–02
Station 48				
^{234}U	5.3E–02	7.0E–03	2.1E–02	1.2E–02
^{235}U	4.3E–03	4.6E–04	7.1E–04	7.9E–04
^{238}U	4.8E–02	7.1E–03	1.9E–02	1.2E–02
Station 52				
^{234}U	4.1E–02	5.0E–03	9.9E–02	6.2E–1803
^{235}U	3.6E–03	7.5E–04	2.0E–03	7.8E–04
^{238}U	3.7E–02	4.6E–03	3.4E–02	9.2E–03

Table 7.4. Hypothetical effective dose equivalents from living at ORR ambient-air monitoring stations

Station	Effective dose equivalent	
	mrem/year	mSv/year
35	0.15	0.0015
37	0.073	0.00073
38	0.073	0.00073
39	0.11	0.0011
40	0.11	0.0011
42	0.10	0.0010
46	0.11	0.0011
48	0.13	0.0013
52	0.11	0.0011

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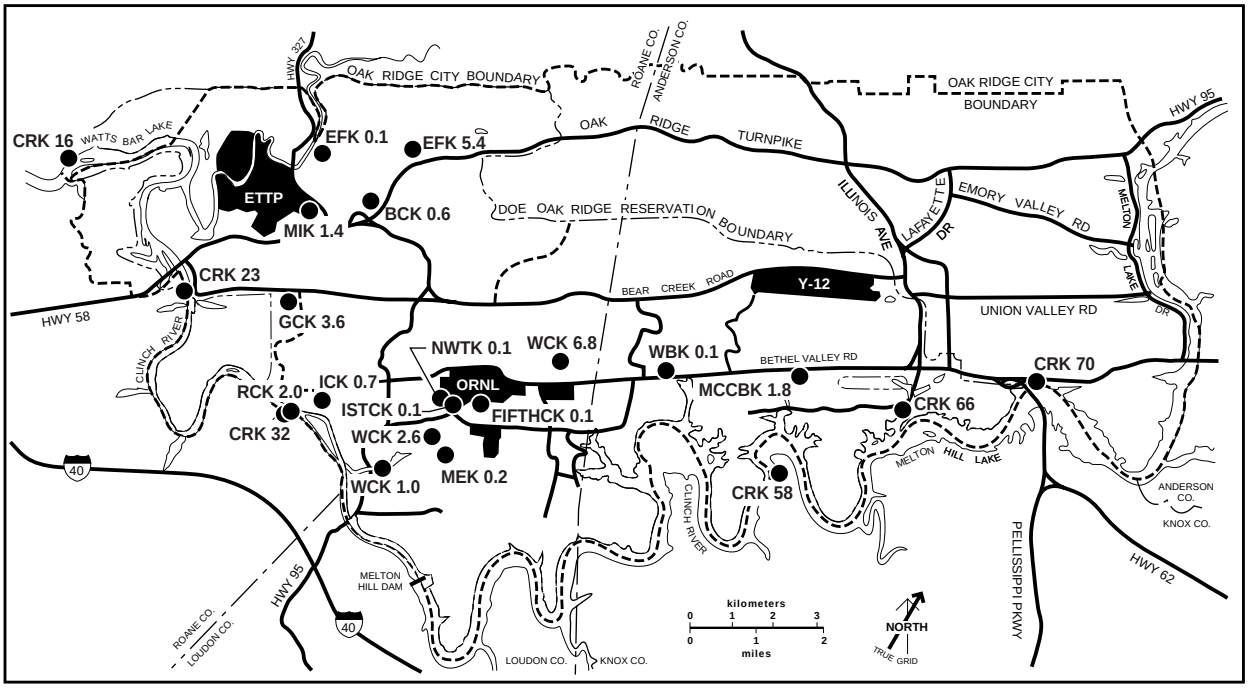

Fig. 7.4. Locations of ORR surface water surveillance sampling stations.

- Raccoon Creek sampling station prior to entering CRK 31 [Raccoon Creek kilometer (RCK) 2.0],
- Northwest Tributary prior to the confluence with First Creek [Northwest Tributary kilometer (NWTK) 0.1],
- First Creek prior to the confluence with Northwest Tributary [First Creek kilometer (1STCK) 0.1],
- Fifth Creek just upstream of White Oak Creek (ORNL) [Fifth Creek kilometer (FIFTHCK) 0.1],
- Walker Branch prior to entering CRK 53.4 [Walker Branch kilometer (WBK) 0.1], and
- McCoy Branch prior to entering CRK 60.3 [McCoy Branch kilometer (MCCBK) 1.8].

The sampling and analysis in this program are conducted in addition to requirements mandated

in National Pollutant Discharge Elimination System (NPDES) permits for individual ORR DOE facilities; frequency and analytical parameters vary between the two programs.

Sampling frequency and parameters vary by site. Grab samples are collected and analyzed for general water quality parameters at all locations, and all are screened for radioactivity and analyzed for specific radionuclides when appropriate. A few sites are also checked for volatile organic compounds (VOCs) and/or polychlorinated biphenyls (PCBs). Samples at three Clinch River sites (CRK 16, CRK 23, and CRK 70) are analyzed for metals. Table 7.5 lists the specific locations and their sampling frequencies and parameters.

Most of these sampling locations are classified by the state of Tennessee for certain uses (e.g., domestic water supplies or recreational use). Tennessee water quality criteria for domestic water supplies, for freshwater fish and aquatic life, and for recreation (water and organisms) are used as references for locations where they are applicable. The Tennessee water quality criteria do not include criteria for radionuclides.

7.4.2 Results

Radionuclides were detected (statistically significant at a 95% confidence interval) at all surface water locations in 2000. The highest levels of gross beta, total radioactive strontium, and ^{3}H continue to be at Melton Branch downstream from ORNL (MEK 0.2), White Oak Creek (WOC) at White Oak Dam (WOD) (WCK 1.0), and WOC downstream from ORNL (WCK 2.6) (Table D.3 in Appendix D). These data are consistent with historical data and with the processes or legacy activities nearby or upstream from these locations. This was the first year since April 1998 that Grassy Creek (GCK 3.6) has not been dry, and samples were collected during both 2000 events.

Remediation efforts by Bechtel Jacobs Company, LLC (BJC) have resulted in decreases in levels of gross alpha, gross beta, and total radioactive strontium at the First Creek (1STCK 0.1) location. The levels are seasonal: lower in the spring (wet season) because of dilution. Uranium isotopes, including ^{233}U, ^{234}U, ^{235}U, and ^{238}U, were determined to be the primary alpha emitters. These phenomena are related to radiologically contaminated groundwater whose source is leakage to backfill and soil from underground radioactive waste storage Tank W-1A, which is located in the North Tank Farm within the main ORNL facilities complex. Work conducted in 1998 indicates that there is infiltration of storm drains that discharge into Outfall 341, which discharges into First Creek. BJC began pumping a well south of the North Tank Farm in 2000 to remediate the groundwater; one of the consequences of this effort is the decline in radionuclides detected insurface water at First Creek (DOE 2001).

A few locations were monitored for VOCs. Acetone, a common laboratory contaminant, was detected at low, estimated levels in two samples. PCBs are analyzed for at WCK 1.0. No PCBs were detected in 2000 sampling events.

Two locations, Northwest Tributary (NWTK 0.1) and Raccoon Creek (RCK 2.0), also had elevated levels of gross beta and total radioactive strontium. Results at both locations have a seasonal pattern. Concentrations at Northwest Tributary are higher in the spring whereas concentrations at Raccoon Creek are higher in the fall. Both of these locations are impacted by contaminated groundwater from Solid Waste Storage Area (SWSA) 3.

7.4.2.1 Dose—Radiological

This section discusses the potential radiological impacts of measured radionuclide concentrations to hypothetical persons who drink water; eat fish; and swim, boat, and use the shoreline at sampled locations that are accessible to the public. One should remember that radionuclide concentrations found in environmental samples include naturally occurring radionuclides, especially in reported total alpha- and beta-activity measurements. Potential doses to the hypothetical persons were calculated for drinking water (730 L of untreated river water) even though not all sampling locations are potential drinking water sources; eating fish [a hypothetical “avid” fish eater would be one who consumes 21 kg (46 lb) of fish whose radionuclide contents are calculated by multiplying measured concentrations of radionuclides in water and the fish:water bioaccumulation factors given in the CRITER code];

Table 7.5. Surface water sampling locations, frequencies, and parameters; 2000

Location (K indicates kilometer)	Frequency	Parameters
BCK 0.6; Bear Creek downstream from Y-12 Complex inputs	Semiannually (Apr, Oct)	Gross alpha, gross beta, gamma scan, field measurements[a]
CRK 16; Clinch River downstream from all DOE inputs	Monthly	Volatiles, metals, gross alpha, gross beta, gamma scan, field measurements[a]
CRK 23; water supply intake for the ETTP	Monthly	Gross alpha, gross beta, total radioactive strontium, gamma scan, ^{3}H, field measurements[a]
CRK 32; Clinch River downstream from ORNL	Monthly	Gross alpha, gross beta, gamma scan, total radioactive strontium, ^{3}H, field measurements[a]
CRK 58; water supply intake for Knox County	Monthly	Gross alpha, gross beta, gamma scan, field measurements[a]
CRK 66; Melton Hill Reservoir above city of Oak Ridge water intake	Monthly	Gross alpha, gross beta, gamma scan, field measurements[a]
CRK 70; Solway Bridge	Monthly	Volatiles, metals, gross alpha, gross beta, total radioactive strontium, gamma scan, ^{3}H, field measurements[a]
EFK 0.1; East Fork Poplar Creek prior to entering Poplar Creek	Semiannually (Apr, Oct)	Gross alpha, gross beta, gamma scan, field measurements[a]
EFK 5.4; East Fork Poplar Creek downstream from floodplain	Semiannually (Apr, Oct)	Gross alpha, gross beta, gamma scan, field measurements[a]
MEK 0.2; Melton Branch downstream from ORNL	Bimonthly (Jan, Mar, May, Jul, Sep, Nov)	Gross alpha, gross beta, gamma scan, total radioactive strontium, ^{3}H, field measurements[a]
WCK 1.0; White Oak Lake at White Oak Dam	Monthly	Volatiles, metals, PCBs, gross alpha, gross beta, gamma scan, total radioactive strontium, ^{3}H, field measurements[a]
WCK 2.6; White Oak Creek downstream from ORNL	Bimonthly (Jan, Mar, May, Jul, Sep, Nov)	Gross alpha, gross beta, gamma scan, total radioactive strontium, ^{3}H, field measurements[a]
WCK 6.8; White Oak Creek upstream from ORNL	Quarterly (Feb, May, Aug, Nov)	Gross alpha, gross beta, total radioactive strontium, gamma scan, ^{3}H, field measurements[a]
WBK 0.1; Walker Branch prior to entering CRK 53.4	Semiannually (Apr, Oct)	Gross alpha, gross beta, gamma scan, field measurements[a]
GCK 3.6; Grassy Creek upstream of SEG and IT Corp. at CRK 23	Semiannually (Apr, Oct)	Lead, gross alpha, gross beta, gamma scan, field measurements[a]
ICK 0.7; Ish Creek prior to entering CRK 30.8	Semiannually (Apr, Oct)	Gross alpha, gross beta, gamma scan, field measurements[a]
MCCBK 1.8; McCoy Branch prior to entering CRK 60.3	Semiannually (Apr, Oct)	Gross alpha, gross beta, gamma scan, field measurements[a]

Table 7.5 (continued)

Location (K indicates kilometer)	Frequency	Parameters
RCK 2.0; Raccoon Creek sampling station prior to entering CRK 31	Semiannually (Apr, Oct)	Gross alpha, gross beta, total radioactive strontium, gamma scan, ^{3}H, field measurements[a]
NWTK 0.1; Northwest Tributary prior to the confluence with First Creek	Semiannually (Apr, Oct)	Gross alpha, gross beta, total radioactive strontium, gamma scan, ^{3}H, field measurements[a]
1STCK 0.1; First Creek prior to the confluence with Northwest Tributary	Semiannually (Apr, Oct)	Gross alpha, gross beta, total radioactive strontium, gamma scan, ^{3}H, field measurements[a]
FIFTHCK 0.1; Fifth Creek just upstream of White Oak Creek (ORNL)	Semiannually (Apr, Oct)	Gross alpha, gross beta, total radioactive strontium, gamma scan, ^{3}H, field measurements[a]

[a]Field measurements consist of dissolved oxygen, pH, and temperature.

and from other water uses (swimming or wading for 27 h/year, boating for 63 h/year, and use of the shoreline for 67 h/year). Measured concentrations of radionuclides in water and the LADTAP XL code were used to estimate potential EDEs from these activities.

Table 7.6 is a summary of the calculations. A hypothetical person who drank 730 L of untreated river water could have received an EDE between 0.4 and 1.03 mrem (0.004 and 0.013 mSv). The highest calculated dose occurs at CRK32, a location from which drinking water is not obtained, but all doses are relatively low. A person who ate 21 kg of fish could have received an EDE between 0.8 and 2.7 mrem (0.008 and 0.027 mSv), mostly due to the unidentified alpha- and beta-emitting nuclides. Maximum individual radiation doses associated with other activities ranged between 0.0007 and 0.02 mrem (0.000007 and 0.0002 mSv). Thus a hypothetical person who drank untreated water, ate fish, and participated in other waterborne activities could have received an EDE between 1 and 4 mrem (0.01 and 0.04 mSv). If the unidentified alpha and beta activities are assumed to be due to naturally occurring radionuclides, the hypothetical person's dose due to radionuclides emitted from the ORR drops to between 0.05 and 2 mrem (0.0005 and 0.02 mSv).

7.4.2.2 Dose—Chemical

To evaluate the drinking water pathway, hazard quotients (HQs) were estimated upstream and downstream of the ORR discharge points (see Table 7.7 and refer to Appendix H for a detailed description of the chemical dose methodology). This year chemical analytes were measured in surface water samples collected at CRK 70 and CRK 16. Located upstream of all DOE discharge points is CRK 70, and located downstream of all DOE discharge points is CRK 16. As shown in Table 7.7, HQs were less than one for detected chemical analytes for which there are RfDs or MCLs.

7.5 ORR SEDIMENT

Stream and lake sediments act as a record of some aspects of water quality by concentrating and storing certain contaminants. Sampling sites for sediment are the Clinch River downstream from all DOE inputs (CRK 16), the Clinch River downstream from ORNL (CRK 32), and one background location, the Clinch River at the Solway Bridge, upstream from all DOE inputs (CRK 70) (Fig. 7.5). The locations are sampled annually, and gamma scans are performed on the samples.

Table 7.6. Hypothetical EDEs from water-related activities based on sampled water

Location	Maximum hypothetical EDEs (mrem/year) due to radionuclides that could have come from the ORR and from unidentified gross alpha and beta activities			
	Drinking water	Eating fish	Other uses	Total
CRK 16	1.2	0.98	0.016	2.2
CRK 23	1.1	2.3	0.0064	3.4
CRK 32	1.3	2.7	0.023	4.0
CRK 58	0.39	0.77	0.0086	1.2
CRK 66	0.55	0.88	0.00074	1.4
CRK 70	1.0	1.7	0.00067	2.7

Table 7.7. 2000 chemical hazard quotients for drinking water[a]

Chemical	Hazard quotient	
	CRK 70[b]	CRK 16[c]
Barium	0.02	0.02
Manganese	0.04	0.04
Zinc	~0.005	

[a]A tilde (~) indicates that estimated values and/or detection limits were used in the calculation, and a blank space indicates the parameter was undetected.

[b]Melton Hill Reservoir above city of Oak Ridge input.

[c]Clinch River downstream of all DOE inputs.

In addition, two samples per year containing settleable solids are collected in conjunction with a heavy rain event to characterize sediments that exit ORNL during a storm event. The sampling locations are Melton Branch upstream from ORNL (MEK 2.1), White Oak Lake (WOL) at WOD (WCK 1.0), and WOC downstream from ORNL (WCK 2.6) (Fig. 7.5). These samples are filtered, and the residue (settleable solids) is analyzed for gross alpha, gross beta, and gamma emitters.

7.5.1 Results

Potassium-40 was detected at the upstream location (CRK 70). Downstream from ORNL at CRK 32, ^{137}Cs, ^{7}Be, and ^{40}K were detected in the samples analyzed. At CRK 16, which is downstream from all DOE inputs, ^{137}Cs, ^{7}Be, and ^{40}K were detected by the gamma scan of the samples. Potassium-40 and ^{7}Be are naturally occurring radionuclides.

Heavy-rain-event sampling took place in April and May 2000. Gross alpha and gross beta were detected at all three locations, with the upstream location having the lowest concentrations and the downstream location having the highest concentrations. Sample size has a strong impact on results and associated counting statistics and probably accounts for the variability between the April and May results at each location. The quantity of residue from the May sample was larger than that from the April sample at MEK 2.1 and WCK 2.6, and the quantity from the April sample was larger than that from the May sample at WCK 1.0.

7.6 FOOD

Collection and analysis of vegetation samples serve three purposes: to evaluate potential radiation doses received by people consuming foodcrops; to predict possible concentrations in meat, eggs, and milk from animals consuming grains; and to monitor trends in environmental contamination and possible long-term accumulation of radionuclides.

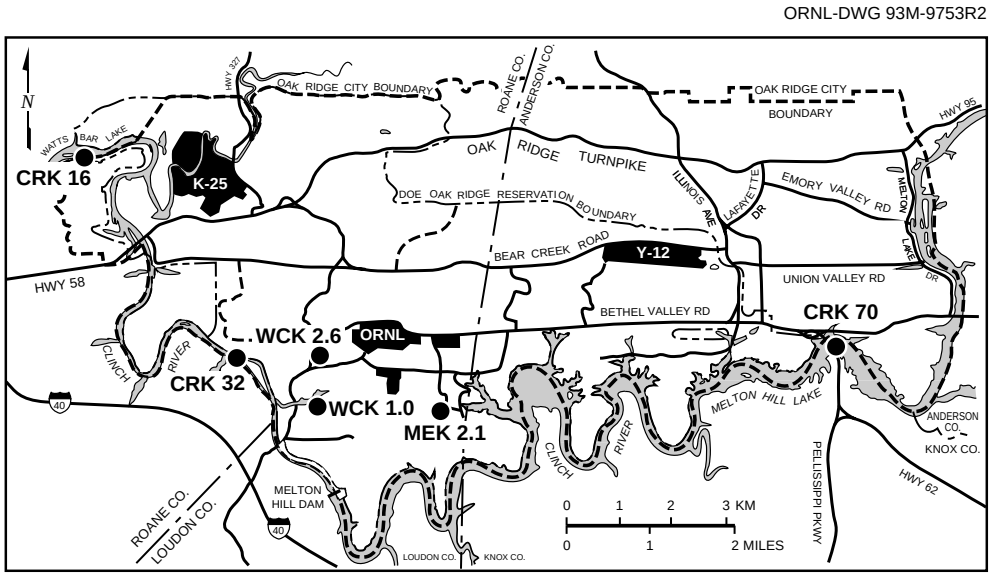

Fig. 7.5. ORR environmental monitoring plan sediment sampling locations.

7.6.1 Hay

Hay has been cut on the ORR and sold to area farmers for fodder. Six areas from which hay has been cut have been identified as potential depositional areas for airborne materials from ORR sources (Fig. 7.6). Areas 1, 2, and 3 are within the predicted air plume for an ORNL source and could also be affected by the ETTP. Area 8, near Fort Loudoun Dam is outside the influence of the ORR. Baled hay was collected from sites 1, 2, and 3 and composited for analysis. Areas 2, 4, 5, and 6 are within the predicted air plume for an ETTP, an ORNL, and a Y-12 Complex source. Baled hay was collected from each of these sites and composited for laboratory analysis. Area 6 best represents the combined plumes from all three sites; baled hay was collected from this site. Area 8, not shown on Fig. 7.6, represents a reference site near the Fort Loudoun ambient-air monitoring station (Station 52).

7.6.2 Results

Hay samples were collected during August 2000, and samples were analyzed for gross alpha, beta, and gamma emitters. Table 7.8 summarizes the results of the sampling effort. Composite samples from Areas 2, 4, 5, and 6 had statistically significant concentrations of ^{137}Cs and ^{60}Co; however, only the ^{137}Cs measured at Area 6 was above the minimum detectable activity (MDA). Each of the hay samples from the ORR measured statistically significant concentrations of ^{191}Os, which is routinely detected at NESHAP monitoring points and at the ORNL ambient air stations.

Another environmental pathway that was evaluated using sampling data is eating beef and drinking milk obtained from cows that ate hay harvested from the ORR. Statistically significant concentrations were found for ^{7}Be, ^{40}K, ^{137}Cs, ^{60}Co, and ^{191}Os. Most of the dose to humans (95%) from eating beef and drinking milk from cattle that eat hay was from the naturally occurring ^{40}K and ^{7}Be. Including the contribution from ^{40}K and ^{7}Be, the average EDE from drinking milk and eating beef was estimated to be about 13 mrem (0.13 mSv). Excluding ^{40}K and ^{7}Be, the average EDE was estimated to be about 0.7 mrem (0.007 mSv); the primary radionuclide contributor to this dose equivalent was ^{191}Os. The hay samples collected from Areas 2, 4, and 5 resulted in the maximum EDE of 1.3 mrem (0.013 mSv) from eating beef and drinking milk (excluding the naturally occurring radionuclides ^{40}K and ^{7}Be).

7.7 VEGETABLES

Tomatoes, turnips, and lettuce were purchased from local farmers near the ORR. The locations

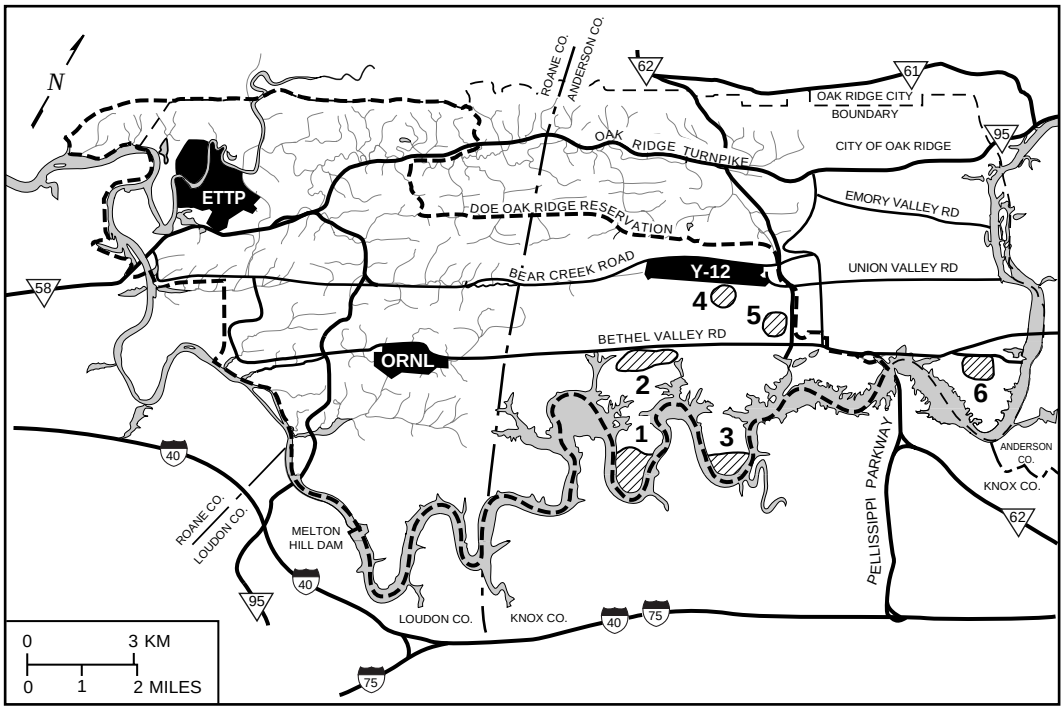

Fig. 7.6. Hay sampling locations on the ORR, indicated by numbered areas. Area 8 is a reference location at Fort Loudoun Dam and is not shown on this map.

Table 7.8. Statistically significant concentrations of radionuclides in hay from the ORR, 2000[a]

Analyte	Area			
	1,2,3	2,4,5	6	8[b]
^{191}Os	500	860	240	*c*
^{137}Cs	*c*	21	21	*c*
^{60}Co	*c*	17	16	*c*

[a]All radionuclide data are given in picocuries per kilogram (1 pCi = 3.7E–02 Bq).
[b]Reference site.
[c]Not statistically significant.

were chosen based on availability and on the likelihood of being affected by routine releases from the Oak Ridge facilities.

7.7.1 Results

Samples were analyzed for gross alpha, gross beta, and gamma emitters. Table 7.9 summarizes the results of the sampling effort. Cesium-137, ^{60}Co, ^{7}Be, and ^{40}K are detected by the gamma scan. Beryllium-7 and ^{40}K are naturally occurring radionuclides.

All of the radionuclides found in the produce monitored through this program also are found in the natural environment and in commercial fertilizers, and all but ^{7}Be and ^{40}K also are emitted from the ORR. The sampling results were used to calculate potential EDEs to persons eating these foods.

Based on a nationwide food consumption survey (EPA 1997), a hypothetical home gardener was assumed to have eaten 32 kg (71 lb) of homegrown tomatoes, 10 kg (22 lb) of homegrown leafy vegetables, and 37 kg (82 lb) of homegrown turnips during the year. Coupling these ingestion rates with statistically significant detected concentrations in vegetables of positively identified radionuclides (see Table 7.9) that could have been emitted from the ORR, the hypothetical gardener could have received a 50-year committed EDE between 0.04 and 0.1 mrem (0.0004 and 0.001 mSv), depending on garden location. Of this total, between 0.006 and 0.02 mrem (0.00006 and 0.0002 mSv) could have come from eating tomatoes, between 0.01 and 0.07 mrem (0.0001 and 0.0007 mSv) from eating leafy vegetables, and

Table 7.9. Radiological constituents in tomatoes, turnips, and lettuce at sites near the ORR, 2000

Location	Concentration (pCi/kg)[a]	
	^{60}Co	^{137}Cs
Lettuce		
East of the Y-12 Complex	5.8	*b*
East of the Y-12 Complex, Claxton	*b*	6.4
Northeast of the Y-12 Complex, Scarboro #1	10	*b*
Northeast of the Y-12 Complex, Scarboro #2	*b*	*b*
South of ORNL	11	*b*
West of the ETTP	6.4	13
Tomatoes		
East of the Y-12 Complex	*b*	*b*
East of the Y-12 Complex, Claxton	*b*	*b*
Northeast of the Y-12 Complex, Scarboro #1	*b*	*b*
Northeast of the Y-12 Complex, Scarboro #2	*b*	*b*
South of ORNL	*b*	*b*
West of the ETTP	*b*	*b*
Turnips		
East of the Y-12 Complex	4.2	5.1
East of the Y-12 Complex, Claxton	7.9	7.2
Northeast of the Y-12 Complex, Scarboro #1	6.9	6.4
Northeast of the Y-12 Complex, Scarboro #2	3.8	*b*
South of ORNL	5.4	5.4
West of the ETTP	4.8	5.0

[a]1 pCi = 3.7E–02 Bq.
[b]Not statistically significant.

between 0.02 and 0.03 mrem (0.0002 and 0.0003 mSv) from eating turnips.

Many of the samples contained detected activities of unidentified beta- and alpha-particle-emitting radionuclides. By subtracting identified activities of beta- and alpha-particle-emitting radionuclides from the unidentified beta and alpha activities, excess beta and alpha activities were estimated. If the excess unidentified beta and alpha activities were ^{90}Sr and ^{210}Po, respectively, the hypothetical home gardener could have received an EDE between 2 and 5 mrem (0.02 and 0.05 mSv). Of this total, between 0.2 and 2 mrem (0.002 and 0.02 mSv) could have come from eating tomatoes, between 0.01 and 2 mrem (0.001 and 0.02 mSv) from eating leafy vegetables, and between 0.1 and 2 mrem (0.001 and 0.02 mSv) from eating turnips. It is believed that most of the excess unidentified beta and alpha activities are due to naturally occurring or fertilizer-introduced radionuclides, not radionuclides discharged from the ORR.

An example of a naturally occurring and fertilizer-introduced radionuclide is ^{40}K, which is specifically identified in the samples and accounts for most of the beta activity found in them. (Potassium-40 actually accounts for all the beta activity found in leafy-vegetable samples.) The presence of ^{40}K in the samples adds around 4 mrem (0.04 mSv) to the hypothetical home gardener's EDE.

7.8 MILK

Ingestion is one of the pathways of exposure to radioactivity for humans. Radionuclides can be transferred from the environment to people via food chains such as the grass-cow-milk pathway. Milk is a potentially significant source to humans

of some radionuclides deposited from airborne emissions because of the relatively large surface area that a cow can graze daily, the rapid transfer of milk from producer to consumer, and the importance of milk in the diet.

The 2000 milk-sampling program consisted of grab samples collected every other month from two locations in the vicinity of the ORR (Fig. 7.7) and from a commercial dairy in Powell that processes milk from various locations in east Tennessee. Two of the dairies (Buttermilk Road and Karns) went out of business in 2000; two other dairies were added to the program, one located in Claxton and the other in Maryville (as a reference location). Milk samples are analyzed for radioactive iodine (^{131}I) by gamma spectrometry and for total radioactive strontium (^{89}Sr + ^{90}Sr)by chemical separation and low-background beta counting. Liquid scintillation is used to analyze for ^{3}H.

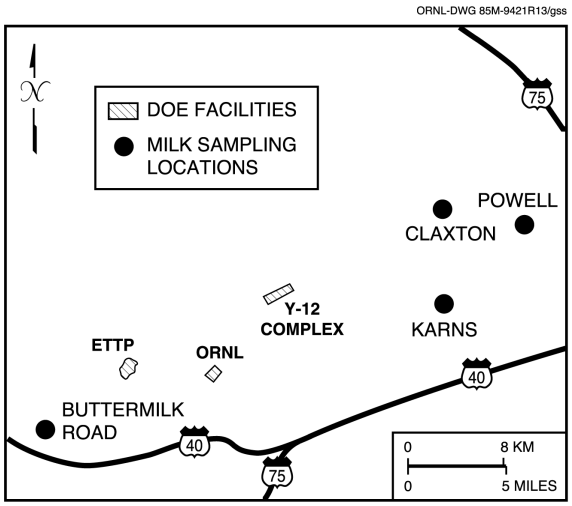

Fig. 7.7. Milk sampling locations in the vicinity of the ORR.

7.8.1 Results

Radioactivity measurements are reported as the net activity (the difference between the gross activity and instrument background). A 95% confidence level is used to determine statistical significance. Concentrations of radionuclides detected in milk are presented in Table 7.10. Tritium was detected in only one sample out of five at the Karns location and not at all at the other two locations in the ORR vicinity (see Table 7.10).

A hypothetical person who drank 310 L of sampled milk (NRC 1977) could have received, from radionuclides that could have been emitted from the ORR, an EDE between 0.05 and 0.08 mrem (0.0005 and 0.0008 mSv); the EDE averaged over the four sampling locations near the ORR could have been 0.06 mrem (0.0006 mSv). The EDE associated with milk from the Maryville (background) dairy could have been 0.06 mrem (0.0006 mSv). The average EDE associated with just total strontium and ^{131}I in milk in EPA Region 4 is about 0.09 mrem (0.9 µSv) (EPA 1993).

For perspective, EDEs resulting from naturally occurring ^{40}K, which also was measured in the milk samples, could have been between 7 and 9 mrem (70 and 90 µSv); the highest value was calculated for the Maryville dairy.

7.9 FISH

Members of the public potentially could be exposed to contaminants originating from DOE-ORO activities through consumption of fish caught in area waters. This exposure pathway is monitored by collecting fish from three river locations annually and analyzing edible fish flesh. The river locations are on the Clinch River (see Fig. 7.8):

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

Sunfish (*Lepomis macrochirus*, *L. auritus*, and *Ambloplites rupestris*) are collected from each of the three river locations, filleted, and frozen. When enough fish have been collected (typically 150 to 200 per location), the samples are thawed and fillets from 6 of the largest are analyzed for selected metals, pesticides, PCBs, and ^{3}H. The rest (separated into composite samples; two composites in 2000) are ashed and analyzed for gross alpha and gross beta, gamma-emitting radionuclides, and total radioactive strontium.

Table 7.10. Concentration of radionuclides detected in raw milk, 2000

Analysis	No. Detected/ No. Total	Detected concentration			Standard error of mean
		Max[b]	Min[b]	Avg[b]	
Buttermilk Road					
Total rad Sr	1/1	1.4*	1.4*	1.4	*c*
Claxton					
^{3}H	1/4	640*	–34	170	160
Total rad Sr	4/4	1.4*	0.54*	1.0*	0.21
Karns					
Total rad Sr	2/2	1.8*	1.7*	1.8*	0.050
Maryville					
^{3}H	1/4	710*	–390	68	230
Total rad Sr	4/4	1.9*	0.91*	1.3*	0.22
Powell					
^{3}H	2/6	490*	–220	44	99
Total rad Sr	4/6	2.0*	0.33	1.1*	0.27
Network Summary					
^{3}H	4/17	710*	–390	69	69
Total rad Sr	15/17	2.0*	0.33	1.2*	0.12

[a]1 pCi = 3.7E–02 Bq.

[b]Individual and average concentrations significantly greater than zero at the 95% confidence level are identified by an asterisk (*).

[c]Not applicable.

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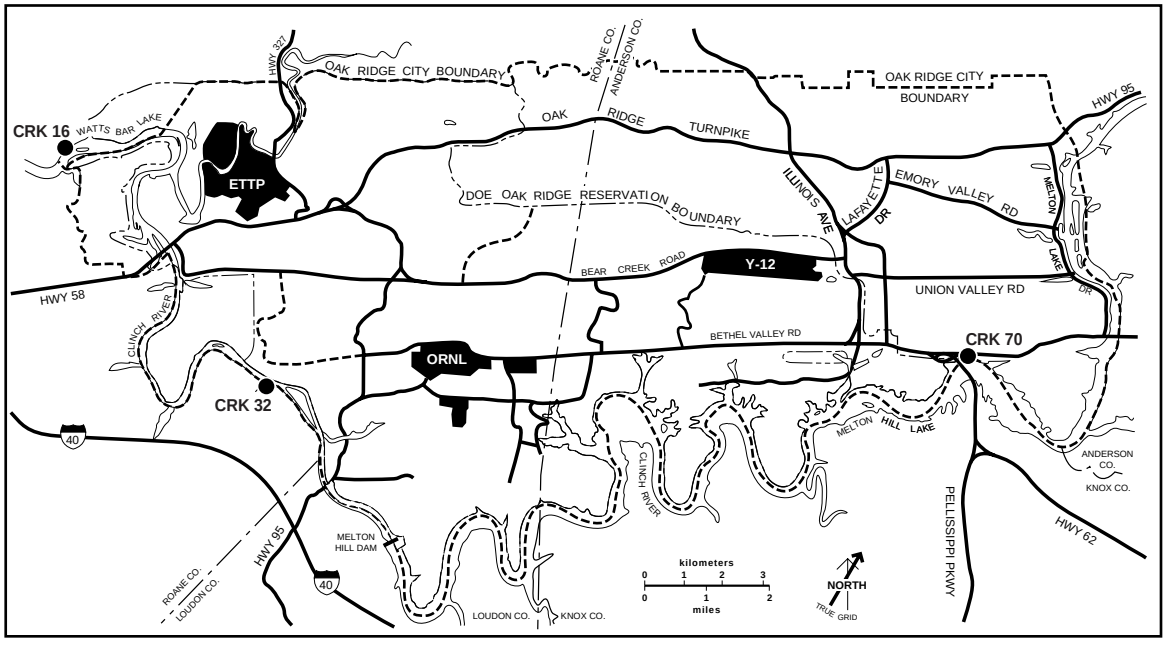

Fig. 7.8. Fish sampling locations for ORR environmental monitoring plan.

Annual catfish sampling was initiated in 1993. Typically, six to ten catfish are collected, and two composite samples per location are analyzed for selected metals, pesticides, PCBs, and ^{3}H. Two composite samples are also ashed and analyzed for gross alpha and gross beta, gamma-emitting radionuclides, and total radioactive strontium.

7.9.1 Results

In 2000, most nonradiological parameters analyzed in sunfish and catfish were undetected or were detected in only a few samples The Tennessee Department of Environment and Conservation (TDEC) adopted the EPA method for establishing fish consumption advisories for carcinogenic contaminants found in fish collected in waters designated for recreation and domestic water supply. There is a "do not consume" fish advisory (applicable to typical fishermen consumers) for catfish in Melton Hill Reservoir (in its entirety) because of PCB contamination and a precautionary fish advisory (applicable to atypical consumers, those persons who, because of physiological factors or previous exposures, are more sensitive to specific pollutants; this may include pregnant or nursing women, children, and subsistence fishermen) for catfish in the Clinch River arm of Watts Bar Reservoir because of PCB contamination (TDEC 1993).

PCBs were not detected in the sunfish samples; 4,4'-DDE, a pesticide, was detected in five of the six sunfish composite samples collected at CRK 16. Methyloxyclor, a pesticide, was detected in sunfish collected at all three locations. Dieldrin was also detected in one of six sunfish composite samples collected at CRK 32. Aroclor-1254, Aroclor-1260, and 4,4'-DDE were detected in each of the catfish composite samples collected at all three locations. Information regarding potential health impacts associated with chemical and radiological constituents detected in the sunfish and catfish are discussed in the following two sections as well as in Chap. 8.

7.9.1.1 Radiological Dose

Fishing is quite common on the Clinch and Tennessee River systems even though, for nonradiological reasons, advisories have been issued that discourage consumption of fish found in these rivers. For the purpose of assessing potential maximum radiation doses due to eating Clinch and Tennessee River fish, we assume, as suggested by the U. S. Nuclear Regulatory Commission (NRC 1977), that a hypothetical avid fish eater consumes 21 kg (46 lb) of fish per year. Coupling this ingestion rate with statistically detected concentrations in fish of radionuclides that could have been discharged from the ORR, an avid fish eater could have received 50-year committed EDE between 0.003 and 0.1 mrem (0.00003 and 0.001 mSv), depending on type of fish and harvest location. Eating catfish taken from CRK 70 could have resulted in an EDE of 0.003 mrem (0.00003 mSv); eating sunfish from that location could have resulted in an EDE of 0.008 mrem (0.00008 mSv). Eating catfish taken from CRK 32 could have resulted in an EDE of 0.03 mrem (0.0003 mSv); eating sunfish from that location could have resulted in an EDE of 0.1 mrem (0.001 mSv). Eating catfish taken from CRK 16 could have resulted in an EDE of 0.04 mrem (0.0004 mSv); eating sunfish from that location could have resulted in an EDE of 0.0005 mrem (0.000005 mSv). The presence of naturally occurring ^{40}K adds about 1 mrem (0.01 mSv) to all of the above doses.

Many of the samples contained detected activities of unidentified beta- and alpha-particle-emitting radionuclides. Excess beta and alpha activities were estimated by subtracting activities of identified beta- and alpha-particle-emitting radionuclides from the corresponding unidentified activities. If the excess unidentified beta and alpha activities were ^{234}Th and ^{226}Ra, respectively, the hypothetical avid fish eater could have received an EDE between 0.08 and 6 mrem (0.0008 and 0.06 mSv). Eating catfish taken from CRK 70 could have resulted in an EDE of 0.08 mrem (0.0008 mSv), 97% of which is due to excess beta activity; eating sunfish from that location could have resulted in an EDE of 0.1 mrem (0.001 mSv), 95% of which is due to excess beta activity. Eating catfish taken from CRK 32 could have resulted in an EDE of 6 mrem (0.06 mSv), 99% of which is due to excess alpha activity; eating sunfish from that location could have resulted in an EDE of 0.2 mrem (0.002 mSv), 28% of which is due to excess beta activity. Eating catfish taken from CRK 16 could have resulted in an EDE of 2 mrem (0.02 mSv), 98% of which is

due to excess alpha activity; eating sunfish from that location could have resulted in an EDE of 0.08 mrem (0.0008 mSv), 94% of which is due to excess beta activity. It is believed that essentially all of the excess activities are due to naturally occurring radionuclides, not to radionuclides that were discharged from the ORR. The presence of naturally occurring ^{40}K adds about 1 mrem (0.01 mSv) to all of the above doses.

7.9.1.2 Chemical Dose

Chemicals in water can be accumulated by aquatic organisms that may be eaten by humans. To evaluate the potential health effects from the fish consumption pathway, hazard quotients (HQs) were estimated for the consumption of noncarcinogens, and intake/chronic-daily-intake ratios I/I(10^{-5}) were estimated for the consumption of carcinogens detected in sunfish and catfish collected both upstream and downstream of the ORR discharge points. In the current assessment, a fish consumption rate of 60 g/day (~0.13 lb/day) [21 kg/year (46 lb/year)] is assumed for both the noncarcinogenic and carcinogenic pollutants; this is the same fish consumption rate used in the estimation of the maximally exposed radiological dose from consumption of fish. The fish consumption rate of 60 g/day is similar to the EPA default locally caught fish ingestion rate of 54 g/day fish (EPA 1991). TDEC uses a method developed by EPA to establish fish consumption advisories for carcinogenic pollutants [as described in TDEC 1200-4-3-.03 (j)]. Using the mean daily consumption rate of 6.5 g/day would reduce both the HQ values and the I/I(10^{-5}) values by a factor of approximately 10. Refer to Appendix H for a detailed description of the chemical dose methodology.

No HQ values equal to or greater than one were calculated for consumption of sunfish collected at all three locations. For consumption of catfish, HQ values greater than one were calculated for Aroclor-1254 and Aroclor-1260 at all three locations (see Table 7.11).

For carcinogens, I/I(10^{-5}) ratios greater than one indicate a cancer risk greater than 10^{-5}. I/I(10^{-5}) ratios greater than one were calculated for the intake of dieldrin found in sunfish and catfish collected at CRK 32. I/I(10^{-5}) ratios greater than one were calculated for mixed PCBs (Aroclor-1254 and Aroclor-1260) in catfish collected at all locations, including upstream and downstream of ORR. TDEC has issued a fish advisory that states that catfish should not be consumed from Melton Hill Reservoir (in its entirety) because of PCB contamination and has issued a precautionary fish consumption advisory for catfish in the Clinch River arm of Watts Bar Reservoir (TDEC 1993). For perspective, as of 1998, 37 states have issued 679 advisories for PCBs. These advisories inform the public that high concentrations of PCBs have been found in local fish at levels of public health concern (EPA 1999).

7.10 WHITE-TAILED DEER

The sixteenth annual deer hunts managed by DOE and the Tennessee Wildlife Resources Agency (TWRA) were held on the ORR during the final quarter of 2000. ORNL staff, TWRA, and student members of the Wildlife Society (University of Tennessee Chapter) performed most of the necessary operations at the checking station.

The 2000 hunts were held on three weekends. Shotgun/muzzleloader hunts were held October 14–15, November 11–12, and December 9–10 with 800 permitted hunters for each hunt. During the November 11–12 hunt, the Tower Shielding/Park City Road area was opened for an archery-only hunt with 350 permitted hunters. A few areas are also designated as archery only during the gun hunts and do not require special permitting. For the 2000 hunt, a limit of one deer, either sex, was established for all hunt areas.

The year's total harvest was 370 deer. From the total harvest of 370 animals, 203 (54.9%) were bucks and 167 (45.1%) were does. The heaviest buck had 8 antler points and weighed 81.7 kg (180 lb). The greatest number of antler points (10) was found on 4 bucks. The heaviest doe weighed 52.6 kg (116 lb).

7.10.1 Results

Of the 370 deer harvested, five were confiscated because they exceeded established release limits (5 pCi/g for ^{137}Cs and/or 20 pCi/g for ^{90}Sr).

Table 7.11. 2000 chemical hazard quotients (HQs) and estimated dose/chronic daily intake I/I(10^{-5}) for carcinogens in fish[a]

Parameters	Sunfish			Catfish		
	CRK 70[b]	CRK 32[c]	CRK 16[d]	CRK 70[b]	CRK 32[c]	CRK 16[d]
HQs for metals						
Chromium		~0.1		0.1		
Copper		~9E-3		0.01	0.01	0.01
Mercury	~0.2	0.2	1	0.7	0.7	0.4
Zinc	0.04	0.04	0.03	0.03	0.02	0.02
HQs for pesticides and Aroclors						
Aroclor-1254				7.8	7	17
Aroclor-1260				17.3	8.6	6
Chlordane (alpha)				0.02	0.03	0.05[e]
Dieldrin		~0.1			0.2	
Methyloxychlor	~6E–3	~5E–3	~8E–3			
I/I(10^{-5}) *for carcinogens*						
4,4′-DDE[f]			~0.09	J0.4	J0.2	J0.3
Chlordane (alpha) [f]				J0.2	J0.2	J0.4[e]
Dieldrin		~4.5			J6.2	
PCBs (mixed)[g]				43	27	40

[a]A tilde (~) indicates that estimated values were used in the calculation, and a blank space indicates that the parameter was undetected.
[b]Melton Hill Reservoir, above Oak Ridge city input.
[c]Clinch River, downstream of ORNL.
[d]Clinch River, downstream of all DOE inputs.
[e]Includes both alpha and gamma chlordane.
[f]Detected below detection limits therefore value was estimated.
[g]Mixed PCBs consists of the summation of Aroclors detected or estimated.

The average concentration of ^{137}Cs (based on field measurements) in the deer released to the public was 0.14 pCi/g (0.005 Bq/g). The deer confiscated during the 2000 hunt represent 1.4% of the total deer harvested on the ORR. Since the hunts began in 1985, 7842 deer have been harvested with a total of 170 (2.2%) retained because of radiological contamination.

7.10.2 Dose

The released deer had an average field-dressed weight of about 39.5 kg (87 lb). Because about 55% of the dressed weight is edible meat, the average deer would yield about 22 kg (47.8 lb) of meat. Therefore, based on the average weight, the total harvest of edible meat was about 7923 kg (17,467 lb).

The average ^{137}Cs concentration in tissue of the 365 released deer, as determined by field measurement, was 0.14 pCi/g (0.005 Bq/g); the maximum ^{137}Cs concentration in a released deer was 2.24 pCi/g (0.08 Bq/g). The maximum concentration of ^{90}Sr found in tissue samples from deer harvested on the ORR during 1990–97 was used to estimate potential maximum EDEs from eating deer harvested during 2000. The maximum ^{90}Sr concentration in released deer was 0.4 pCi/g (0.015 Bq/g).

An individual who consumed one average-weight deer containing the 2000 average concentration of ^{137}Cs (0.14 pCi/g) could have received

an EDE of about 0.15 mrem (0.0015 mSv). The maximum EDE to a hunter who harvested and consumed a deer from the ORR in 2000 was estimated to be 7.8 mrem (0.078 mSv) (5 mrem attributed to ^{137}Cs and 2.8 mrem attributed to ^{90}Sr), based on a ^{137}Cs concentration of 2.24 pCi/g, a maximum ^{90}Sr concentration of 0.4 pCi/g, and maximum field-dressed weight of 180 lb (81.6 kg).

The maximum EDE to an individual consuming venison from two deer was also evaluated. There were about 13 hunting households (more than one hunter per household) who harvested 2 deer from the ORR in 2000. The maximum EDE to a hunter who consumed two harvested deer could have been about 3.0 mrem (0.7 mrem from ^{137}Cs and 2.3 mrem ^{90}Sr). The collective EDE from eating all the harvested venison with a 2000 average field-derived ^{137}Cs concentration of 0.14 pCi/g (0.005 Bq/g) is estimated to be about 0.06 person-rem (0.0006 person-Sv).

In 2000, two muscle samples were obtained from deer harvested in Jackson County and one sample was obtained from a deer harvested by TWRA in the Park City/Tower Shielding area. The two deer collected from Jefferson County are considered to be background or reference deer since it is unlikely that these deer would have resided on the ORR. In addition to the routine analysis of ^{137}Cs and ^{90}Sr, additional analyses for these deer were requested; these analyses included ^{3}H; uranium (^{234}U, ^{235}U, and ^{238}U); thorium (^{228}Th, ^{230}Th, and ^{232}Th); and transuranics, such as plutonium (^{238}Pu, ^{239}Pu/^{240}Pu); ^{241}Am; and ^{244}Cm. Statistically significant radionuclide concentrations of ^{3}H, ^{90}Sr, ^{239}Pu, ^{230}Th, ^{234}U, and ^{238}U were measured in the deer muscle samples collected in Jackson County as well as the muscle sample collected from the ORR Tower Shielding area. Based on the statistically significant radionuclide concentrations (excluding ^{40}K, since it was only measured in one sample and is a naturally occurring radionuclide) and the average weight of deer harvested from the ORR in 2000, the estimated EDEs due to consumption of venison harvested in Jackson County were about 0.2 and 0.7 mrem, respectively. The estimated EDE resulting from consumption of venison from the Tower Shielding area was about 0.6 mrem, within the estimated EDE range resulting from consumption of venison harvested from deer collected from the background location.

7.11 FOWL

7.11.1 Waterfowl Surveys—Canada Geese

Two primary objectives of the ORR waterfowl program are to monitor the number and distribution of waterfowl on the ORR and to determine concentrations of gamma-emitting radionuclides accumulated by waterfowl that feed and live on the ORR. Canada geese are rounded up each summer and are subjected to noninvasive, gross radiological surveys. The 2000 ORR roundup was conducted on June 27 and 28.

From the roundup, 77 geese were subjected to live whole-body gamma scans. These geese were collected from ETTP (20), ORNL (37), and Oak Ridge Marina (20). Of the 77 geese scanned, none exceeded the administrative release limits (which would require retention for further analyses).

Because of the unusually high number of geese (38) retained from the west end of ORNL in 1998, 18 geese were collected from the west end of ORNL in 2000. In addition, three geese were sacrificed and tissue samples were collected.

The number of waterfowl observations made per survey (363) in 2000 is comparable to that for the period 1995–1999, in which 319 to 397 observations were made per survey. The total number of species observed (36) in 2000, is also comparable to the number of species observed (33–40) per year for the 1995–1999 period. Nonetheless, when only Canada goose observations are considered, it is apparent that the resident goose population has been in decline since about 1990. The average number of geese observed per 2000 survey was 156, a decline from 296 per survey in 1995. Previous waterfowl research showed a 25% decline in the Oak Ridge area goose population from 1990 to 1994. An apparent increase, however, in local non-goose waterfowl has occurred concurrently with the decline in resident Canada geese. Non-goose waterfowl observations averaged 207 per survey in 2000, up from 86 per survey in 1995. In addition to monitoring local waterfowl population trends, waterfowl surveys

have proved useful in documenting threatened and endangered bird species on the ORR.

7.11.1.1 Results

The average ^{137}Cs concentration in the released geese was 0.15 pCi/g (0.006 Bq/g). The maximum ^{137}Cs concentration in the released geese was 0.52 pCi/g (0.02 Bq/g). No geese were retained in 2000. The average weight of the Canada geese screened during the roundup was about 4.2 kg (9.3 lb). The maximum goose weight was about 6.6 kg (14.6 lb).

7.11.1.2 Dose

During the 2000 goose roundup, 77 geese were weighed and subjected to whole-body gamma scans. None of these geese exceeded the administrative limit. If a person consumed a goose with an average weight of 4.2 kg (9.3 lb) and an average ^{137}Cs concentration of 0.15 pCi/g, the estimated EDE would be about 0.02 mrem (0.0002 mSv). The maximum estimated EDE to an individual who consumed a hypothetical released goose with the maximum ^{137}Cs concentration of 0.52 pCi/g and the maximum weight of 6.6 kg (14.6 lb) was about 0.09 mrem (0.0009 mSv). It is assumed that approximately half the weight of a goose is edible.

It is possible that one person could eat more than one goose that spent time on the ORR. Most hunters harvest on average one to two geese per hunting season (USFWS 1995). If one person consumed two hypothetical geese of maximum weight with the highest measured concentration of ^{137}Cs, that person could have received an EDE of about 0.2 mrem (0.002 mSv).

Muscle samples were analyzed from three geese sacrificed in 2000. Radioisotopic analyses, in addition to the routine analyses of ^{137}Cs and ^{90}Sr, were requested—including ^{3}H; uranium (^{234}U, ^{235}U, and ^{238}U); thorium (^{228}Th, ^{230}Th, and ^{232}Th); and transuranics, such as plutonium (^{238}Pu, ^{239}Pu); ^{241}Am; and ^{244}Cm. Based on statistically significant radionuclide concentrations (excluding ^{40}K, a naturally occurring radionuclide) and the average weight of geese, the estimated EDEs ranged from about 0.05 to 0.1 mrem (0.0005 to 0.001 mSv). Analysis of the goose collected at ORNL resulted in the higher EDE, due primarily to ^{137}Cs and ^{241}Am.

7.11.2 Turkey Monitoring

Two wild turkey hunts managed by DOE and TWRA were held on the reservation April 8–9, 2000, and April 15–16, 2000. Hunting was open for both shotguns and archery. A total of 53 birds was harvested, and none exceeded the administrative release limits established for radiological contamination. Of the birds harvested, 6 were juveniles and 47 were adults. The average turkey weight was about 18.9 lb (8.6 kg). The largest tom weighed 23 lb (10.4 kg), had 1.2-in. spurs, and had a 10.6-in. beard. The longest beard (11.6 in.) was measured on a tom weighing 20.5 lb (9.3 kg).

As mentioned earlier, the released turkeys had an average whole weight of about 18.9 lb (8.6 kg), it is assumed that about 50% of the field weight is edible meat; therefore, the average turkey would yield about 9.3 lb (4.3 kg) of meat. Based on the average weight, the total harvest of edible meat is estimated to be about 555 lb (227 kg).

The average ^{137}Cs concentration in the released turkeys was 0.12 pCi/g (0.004 Bq/g), and the maximum ^{137}Cs concentration was 0.58 pCi/g (0.02 Bq/g). A person who ate a turkey with the average weight (assuming 50% of the weight was edible tissue) and an average ^{137}Cs concentration could have received an EDE of about 0.03 mrem (0.0003 mSv). A person who ate a turkey with the maximum weight and maximum ^{137}Cs concentration could have received an EDE of about 0.2 mrem (0.002 mSv). The collective EDE from eating all of the harvested edible turkey meat with an average ^{137}Cs concentration of 0.12 pCi/g (0.004 Bq/g) and average field weight of 18.9 lb (8.6 kg) is estimated to be about 0.001 person-rem (0.00001 person-Sv).

The muscle sample of one turkey, which was a roadkill, was analyzed in 2000. This sample was analyzed for a number of radionuclides: ^{3}H; ^{90}Sr; uranium (^{234}U, ^{235}U, and ^{238}U); thorium (^{228}Th, ^{230}Th, and ^{232}Th); and transuranics, such as plutonium (^{238}Pu, ^{239}Pu); ^{241}Am; and ^{244}Cm. Based on statistically significant radionuclide concentrations (^{3}H, ^{234}U, and ^{238}U) and the average weight of turkey harvested during the hunt, the estimated EDE from consumption of this turkey was about 0.013 mrem (0.00013 mSv).