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 1999, the mean value for external gamma radiation as measured at five ambient air monitoring stations on the ORR was 5.2 µR/h, which is not statistically different from the mean value of 5.5 µR/h observed at the reference location at Fort Loudoun Dam for the same period. The contribution to external gamma radiation from the DOE facilities, if any, is indistinguishable from background. Similarly, a comparison of sampling data from the ORR perimeter air monitoring stations with that from the reference station in 1999 shows that there are no significant differences in the average radionuclide 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 1999. 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 1999 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 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 100-m (330-ft) tower (MT5) and one 60-m (200-ft) tower (MT6) at the Y-12 Plant, one 330-ft tower (MT2) and two 100-ft towers (MT3 and MT4) at ORNL, and one 200-ft tower (MT1) and one 30-m (100-ft) 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 level and at the top of the tower. At the 330-ft towers, data are collected at an intermediate 100-ft 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 20-m (65-ft). Humidity and data needed to determine atmospheric stability (a measure of the dispersive capability of the atmosphere) are also measured at each tower. 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 Plant, at MT1 and MT7 at the ETTP, and at MT2 at ORNL; solar radiation is measured at MT2 at

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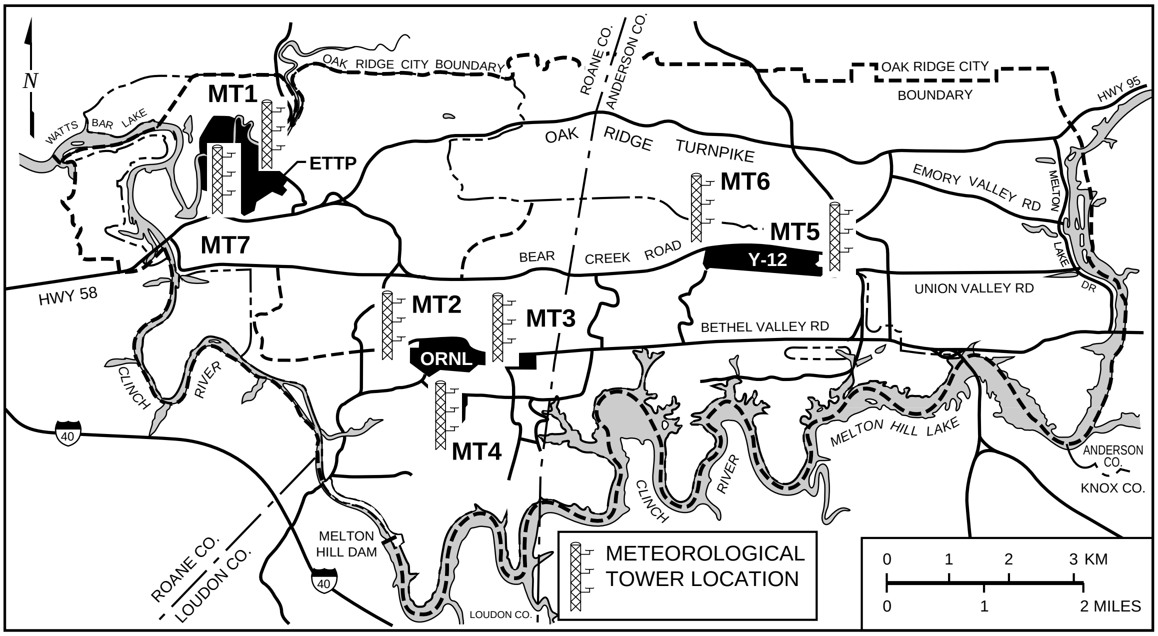

Fig. 7.1. The ORR meteorological monitoring network.

ORNL, MT1 and MT7 at the ETTP, and MT5 and MT6 at the Y-12 Plant.

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-hour period, but only hourly data are routinely stored beyond 24 hours. 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 96.6% in 1999. That average does not include the data recovery rates for ORNL MT3, which was not calibrated during 1999. That meteorological tower is being calibrated now. The maximum data recovery rate was 99.8% at Y-12 MT5 at both 10 and 30 m. The minimum data recovery rate was approximately 82.3% at ORNL MT2 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 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 dose.

7.2.2 Results

Table 7.1 summarizes the data collected at each station during the year. The minimum value of 1.6 μR/h observed at Station 48 on May 25, 1999, was thought to be the result of an instrumentation problem. A switch at the station was reset following the observation of the abnormally low reading, and dose rates immediately returned to normal levels.

The mean value for the ORR network during the year was 5.2 μR/h, which is not statistically different from the mean value of 5.5 μR/h observed at the reference location at Fort Loudoun Dam for the same period.

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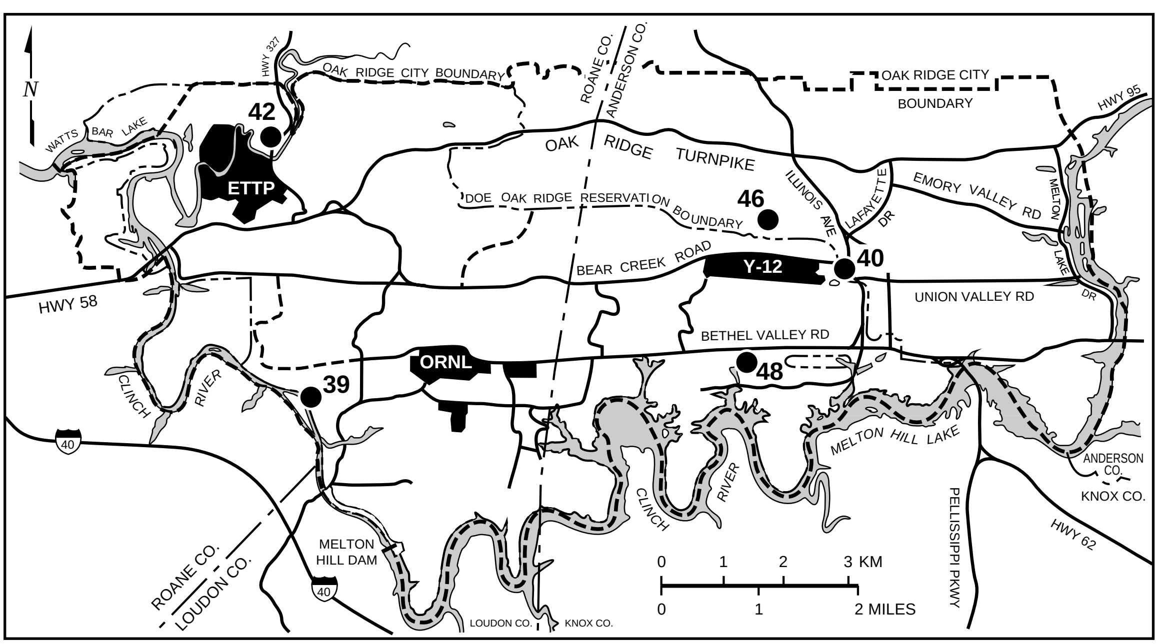

Fig. 7.2. External gamma radiation monitoring locations on the ORR. Location 52, at Fort Loudoun Dam, approximately 15 miles southwest of ORNL, is not shown on this map.

Table 7.1. External gamma averages, 1999

Location	Number of data values collected	Measurement (µR/h)[a]			Standard error of mean
		Min	Max	Mean	
39	48	5.4	6.6	5.7	0.00003
40	51	4.7	6.3	5.0	0.00004
42	52	4.4	6.6	4.7	0.00005
46	52	5.4	6.3	6.1	0.00002
48	52	1.6	7.2	4.6	0.00011
52	51	4.6	5.5	4.8	0.00002

[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 and other selected 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 Plant).

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 1999 to quantify levels of alpha-, beta-, and gamma-emitting radionuclides and tritium.

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. The particulates are captured using a high-volume air sampler on glass-fiber filters. 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 tritium 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 Plant operation. Station 40 of the ORR network monitors the east end of the Y-12 Plant, and Station 37 monitors the overlap of the Y-12 Plant, ORNL, and ETTP emissions.

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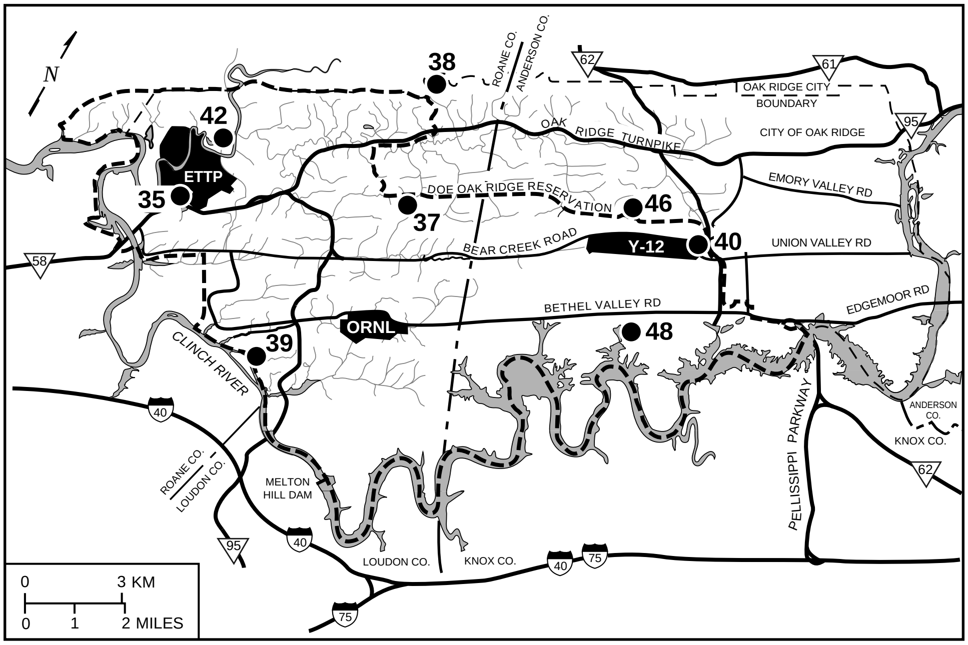

Fig. 7.3. Location of ORR perimeter air monitoring stations.

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 there are not significant differences in the average radionuclide concentrations measured at the ORR stations and those measured at the reference station at the 95% confidence level (Table 7.2).

Table 7.3 represents the average concentration of three isotopes of uranium at each station for sampling years 1996, 1997, 1998, and 1999.

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 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 0.1 to 0.2 mrem (0.001 to 0.002 mSv) at the ORR stations and 0.2 mrem (0.002 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 22 locations around the ORR to assess the impact of past and current DOE 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 Plant inputs [Bear Creek kilometer (BCK) 0.6],
- Clinch River downstream from all DOE inputs [Clinch River kilometer (CRK) 16],

Table 7.2. Radionuclide concentrations at ORR perimeter air monitoring stations, 1999[a,b]

Station	^{7}Be	^{137}Cs	^{40}K	^{3}H	^{90}Sr	^{234}U	^{235}U	^{238}U
35	4.4E–14[c]	2.08E–17	2.60E–16	1.05E–11	2.05E–17[c]	2.00E–17[c]	1.53E–18[c]	2.33E–17[c]
37	5.0E–14[c]	1.06E–17	2.80E–16	3.07E–12	2.70E–16	2.73E–17[c]	6.87E–19[c]	2.13E–17[c]
38	4.7E–14[c]	3.38E–17	6.10E–16[c]	3.91E–12	2.07E–17	1.48E–17[c]	1.13E–18[c]	1.94E–17[c]
39	3.5E–14[c]	1.09E–17	6.50E–16	8.78E–12	1.11E–16	8.94E–18[c]	7.73E–19	9.68E–18[c]
40	4.8E–14[c]	6.09E–17	4.20E–16	9.62E–13	4.63E–17	3.50E–17[c]	1.04E–18[c]	2.04E–17[c]
42	5.0E–14		2.30E–16	3.57E–12	2.10E–17	2.19E–17[c]	9.25E–19[c]	2.51E–17[c]
46	5.6E–14[c]	2.07E–17	4.70E–15	3.53E–12	1.40E–16	2.77E–17[c]	2.92E–18	2.37E–17[c]
48	4.8E–14[c]	2.72E–17	3.10E–16	2.85E–12	2.21E–16	2.06E–17[c]	7.05E–19[c]	1.86E–17[c]
52[d]	5.4E–14[c]	2.07E–17[c]	2.10E–15	5.87E–13[c]	1.85E–17	9.94E–17	2.04E–18	3.44E–17

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

- 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],
- Mitchell Branch upstream from the ETTP [Mitchell Branch kilometer (MIK) 1.4],
- 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],
- 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 also are 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 Tennessee for certain uses (e.g., domestic water supplies or recreational use). Tennessee

Table 7.3. Uranium concentrations in ambient air on the ORR

Isotope	Concentration (10^{-15} µCi/mL)			
	1996	1997	1998	1999
Station 35				
^{234}U	2.2E–02	4.0E–02	1.1E–02	2.0E–02
^{235}U	1.3E–03	2.1E–03	4.5E–04	1.5E–03
^{238}U	3.4E–02	4.6E–02	1.4E–02	2.3E–02
Station 37				
^{234}U	2.0E–02	5.4E–02	1.0E–02	2.7E–02
^{235}U	7.2E–04	4.4E–03	5.9E–04	6.9E–04
^{238}U	2.1E–02	5.3E–02	1.5E–02	2.1E–02
Station 38				
^{234}U	1.6E–02	5.3E–02	8.5E–03	1.5E–02
^{235}U	9.2E–04	1.8E–03	8.5E–04	1.1E–03
^{238}U	2.0E–02	4.4E–02	1.2E–02	1.9E–07
Station 39				
^{234}U	1.4E–02	4.6E–02	5.5E–03	8.9E–03
^{235}U	6.2E–04	1.6E–03	6.0E–04	7.7E–04
^{238}U	1.2E–02	6.1E–02	8.6E–03	9.7E–03
Station 40				
^{234}U	4.6E–02	2.2E–01	1.8E–02	3.5E–02
^{235}U	1.8E–03	5.8E–03	1.0E–03	1.0E–03
^{238}U	1.7E–02	5.9E–02	1.3E–02	2.0E–02
Station 42				
^{234}U	1.8E–02	7.2E–02	1.0E–02	2.2E–02
^{235}U	1.3E–03	6.2E–03	7.1E–04	9.3E–04
^{238}U	2.0E–02	3.9E–02	1.7E–02	2.5E–02
Station 46				
^{234}U	2.3E–02	1.0E–01	1.5E–02	2.8E–02
^{235}U	1.1E–03	3.7E–03	8.8E–04	2.9E–03
^{238}U	1.9E–02	4.7E–02	1.5E–02	2.4E–02
Station 48				
^{234}U	2.8E–02	5.3E–02	7.0E–03	2.1E–02
^{235}U	6.9E–04	4.3E–03	4.6E–04	7.1E–04
^{238}U	1.3E–02	4.8E–02	7.1E–03	1.9E–02
Station 52				
^{234}U	9.4E–03	4.1E–02	5.0E–03	9.9E–02
^{235}U	1.4E–03	3.6E–03	7.5E–04	2.0E–03
^{238}U	9.3E–03	3.7E–02	4.6E–03	3.4E–02

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

Station	Effective dose equivalent	
	mrem/year	mSv/year
35	0.19	0.0019
37	0.14	0.0014
38	0.17	0.0017
39	0.13	0.0013
40	0.12	0.0012
42	0.15	0.0015
46	0.16	0.0016
48	0.18	0.0018
52	0.22	0.0022

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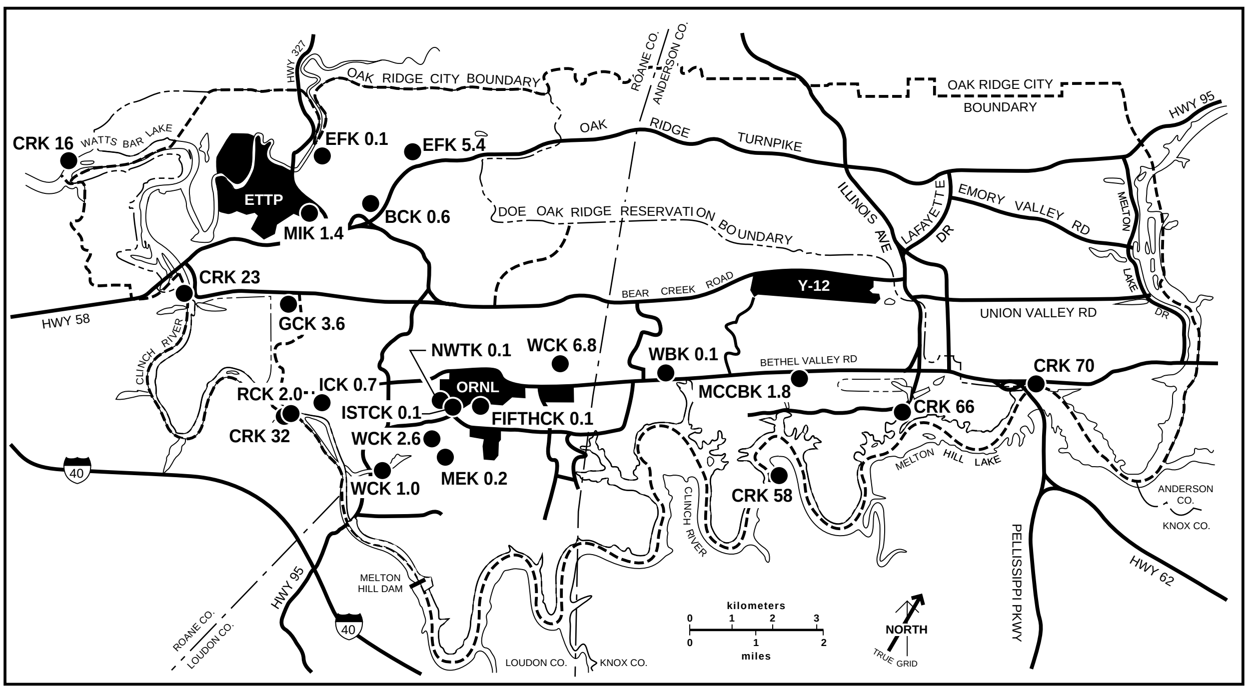

Fig. 7.4. Locations of ORR surface water surveillance sampling stations.

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 1999 except WBK 0.1 and GCK 3.6 (Table D.3 in Appendix D). GCK was dry when sampling was attempted in April and dry again during October. High levels of gross alpha, gross beta, and total radioactive strontium continue to be detected 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 believed to be related to the findings at Core Hole 8 and are being further investigated by Bechtel Jacobs Company LLC. In

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

Location (K indicates kilometer)	Frequency	Parameters
BCK 0.6; Bear Creek downstream from Y-12 Plant 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	Volatiles, metals, gross alpha, gross beta, total radioactive strontium, gamma scan, tritium, field measurements[a]
CRK 32; Clinch River downstream from ORNL	Monthly	Gross alpha, gross beta, gamma scan, total radioactive strontium, tritium, 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, tritium, 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, tritium, field measurements[a]
MIK 1.4; Mitchell Branch upstream from the ETTP	Quarterly (Feb, May, Aug, Nov)	Volatiles, PCBs, gross alpha, gross beta, field measurements[a]
WCK 1.0; White Oak Lake at White Oak Dam	Monthly	Volatiles[b], metals[b], PCBs, gross alpha, gross beta, gamma scan, total radioactive strontium, tritium, 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, tritium, 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, tritium, 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]
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
GCK 3.6; Grassy Creek upstream of SEG and IT Corp. at CRK 23	Semiannually (Apr, Oct)	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]
RCK 2.0; Raccoon Creek sampling station prior to entering CRK 31	Semiannually (Apr, Oct)	Gross alpha, gross beta, total radioactive strontium, gamma scan, tritium, 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, tritium, 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, tritium, 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, tritium, field measurements[a]

[a]Field measurements consist of dissolved oxygen, pH, and temperature.
[b]Added in July 1999.

June 1991, rock core drilling at Core Hole 8 revealed radiologically contaminated groundwater, referred to as the Core Hole 8 plume, in the uppermost portion of bedrock. The source of the plume was believed to be 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. Because groundwater flows toward First Creek from the tank area, it is thought that radionuclides detected in those surface waters originate in soils surrounding Tank W-1A (DOE 1998a). Work conducted in 1998 indicates that there is infiltration of storm drains that discharge into Outfall 341, which discharges into First Creek.

Considering the remaining 21 locations, the highest levels of gross beta, total radioactive strontium, and tritium continue to be at Melton Branch downstream from ORNL (MEK 0.2), WOC at 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.

The activity at MEK 0.2 has historically demonstrated seasonal highs in May and November. The concentration of gross beta, total radioactive strontium, and tritium observed in May of 1999 were significantly greater than corresponding values for 1998 and 1997, even when seasonal peaks are considered. Investigation into the event is inconclusive. A field duplicate taken during the event provided similar results; however, an environmental or natural cause for the high concentrations has not been identified. Results for samples collected about two weeks later at nearby Melton Branch locations for an EM activity did not reflect similar concentration elevations.

A few locations were checked for VOCs; either they were not detected or were detected in small quantities (Table D.3 in Appendix D). The common laboratory contaminants detected were either present in the associated laboratory blanks or were detected at low, estimated levels. PCBs are analyzed for at MIK 1.4 and WCK 1.0. Aroclor-1254 was detected one time out of 12 samples at WCK 1.0; the value was estimated at a low concentration and was also detected in the laboratory blank. (See Table D.3 in Appendix D).

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 (an avid fish eater consumes 21 kg of fish whose radionuclide contents were calculated by multiplying measured concentrations of radionuclides in water and the fish:water bioaccumulation factors given in the CRITER code); and from other water uses (swimming or wading for 27 hours/year, boating for 63 hours/year, and use of the shoreline for 67 hours/year). Measured concentrations of radionuclides in water and the LADTAP XL code were used to estimate potential effective dose equivalents (EDEs) from these activities.

Table 7.6 is a summary of the calculations. A person who drank 730 L of untreated river water could have received an EDE between 0.6 and 2 mrem (0.006 and 0.02 mSv), mostly due to unidentified alpha-and beta-emitting nuclides. Interestingly, the highest dose occurs before any ORR inputs (at CRK 70). A person who ate 21 kg of fish could have received an EDE between 2 and 4 mrem (0.02 and 0.04 mSv), again mostly due to the unidentified alpha- and beta-emitting nuclides. Maximum individual radiation doses associated with other activities ranged between 0.001 and 0.01 mrem (0.00001 and 0.0001 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 H.2 and refer to Appendix H for a detailed description of the chemical dose methodology). Upstream of all DOE discharge points is CRK 70. The Gallaher Water Station (CRK 23), a current drinking water supply intake location for the ETTP, is below the ORNL effluent discharge point, and CRK 16 is a location downstream of all DOE discharge points.

Only measured aluminum and iron surface water concentrations resulted in HQ values equal to or greater than one (HQs less than one are desirable). HQs equal to or greater than one for aluminum were observed in both upstream and downstream locations. Only at the downstream location (CRK 16) was an HQ greater than one estimated for iron. The derivation of the reference

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

Location	Maximum hypothetical EDE (mrem/year) from radionuclides that could have come from the ORR			
	Drinking water	Eating fish	Other uses	Total
CRK 16	1.4	4.2	0.0013	5.6
CRK 23	0.94	2.4	0.011	3.4
CRK 32	0.74	2.1	0.0099	2.9
CRK 58	1.1	2.9	0.0092	4.0
CRK 66	0.62	1.6	0.0057	2.2
CRK 70	2.0	3.3	0.0037	5.3

dose for both aluminum and iron were the secondary maximum contaminant levels (SMCLs) (see Appendix H for a discussion of SMCLs used as reference doses). The SMCLs control contaminants in drinking water that primarily affect aesthetic qualities, such as taste and odor. Toluene and 1,1,1-trichloroethane were reported as detected in only one sample (out of 12), which was collected at CRK 32; however, neither surface water concentrations resulted in an HQ greater than one.

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.

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), 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, ^{7}Be, and ^{137}Cs were detected at the upstream location (CRK 70). Downstream from ORNL at CRK 32, ^{60}Co, ^{137}Cs, ^{7}Be, and ^{40}K were detected in the samples analyzed. At CRK 16, which is downstream from all DOE inputs, only ^{137}Cs and ^{40}K were detected by the gamma scan of the samples. Potassium-40 is a naturally occurring radionuclide.

Heavy-rain-event sampling took place in March and May 1999. Gross alpha and gross beta were detected at all three locations, with the upstream location having the least and the downstream location having the most. The March results and associated counting statistics are higher than the May values. Sample size has a strong impact on counting statistics, and the March settleable-solid sample size was less than that filtered in May.

7.6 FOOD

Collection and analysis of vegetation samples serve three purposes: to evaluate potential radia-

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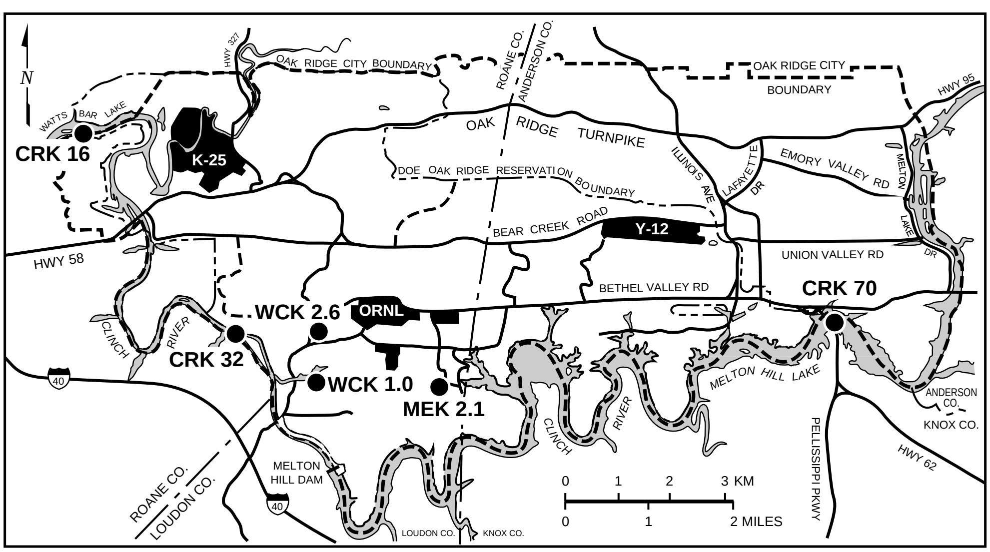

Fig. 7.5. ORR environmental monitoring plan sediment sampling locations.

tion doses received by people consuming food crops; 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.

7.6.1 Hay

Hay is cut on the ORR and sold to area farmers for fodder. Six areas from which hay is 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 is near Fort Loudoun Dam 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 Plant 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 1999, and samples were analyzed for gross alpha, beta, and gamma emitters. Table 7.7 summarizes the results of the sampling effort. Composite samples from Areas 1,2, and 3 and Area 8 had significant [although below the minimum detectable activity (MDA)] concentrations of ^{137}Cs, indicating no appreciable difference between the radionuclide content of hay from the ORR-influenced sites and the off-site reference site. There were no other significant radiological results in the 1999 hay samples.

Another environmental pathway that was evaluated using sampling data is eating beef and drinking milk obtained from bovines that ate hay harvested from the ORR. Statistically significant concentrations were found only for ^{7}Be, ^{40}K, and ^{137}Cs. Essentially all of the dose to humans (99.8%) 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

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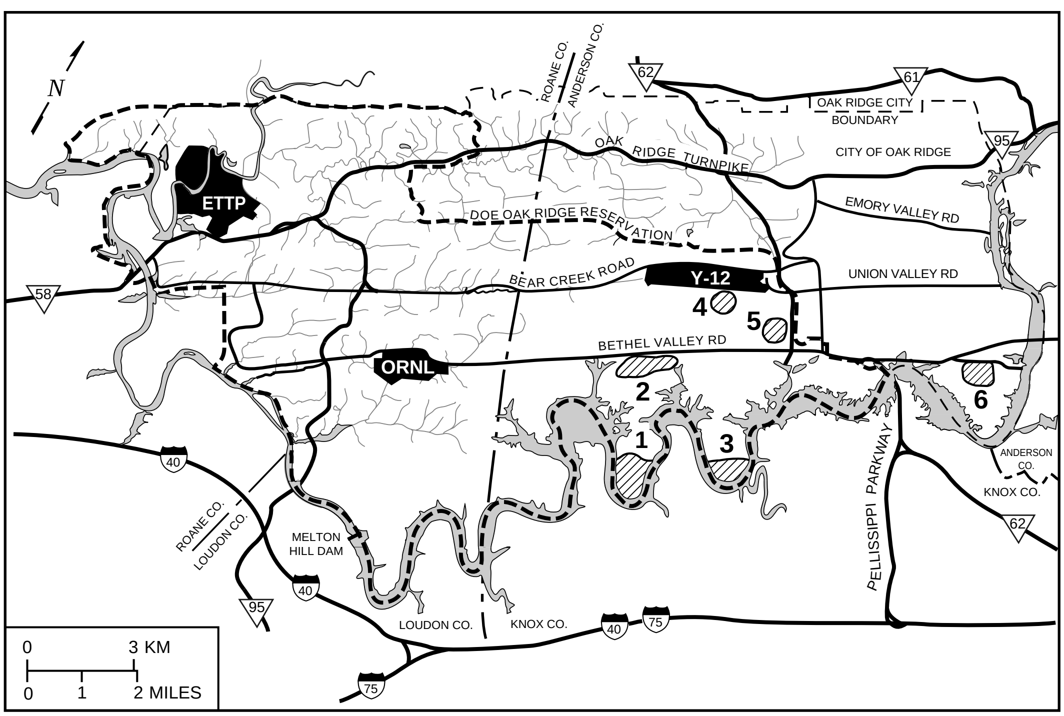

Fig. 7.6. Hay sampling locations on the ORR, indicated by numbered areas. Area 8 is a reference location at Fort Loudoun Dam and is not shown on this map.

Table 7.7 Significant concentrations of radionuclides in hay from the ORR, 1999[a]

Analyte	Area			
	1,2,3	2,4,5	6	8[b]
^{137}Cs	26	*c*	*c*	6

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

^{40}K and ^{7}Be, the average EDE from drinking milk and eating beef was estimated to be about 9.5 mrem (0.095 mSv); excluding ^{40}K and ^{7}Be, the average EDE was estimated to be about 0.02 mrem (2E-4 mSv).

7.7 VEGETABLES

Tomatoes, turnips, and lettuce were purchased from local farmers near the ORR. The locations were chosen based on availability and the likelihood of being affected by routine releases from the Oak Ridge facilities. Turnips and turnip greens were also purchased from an additional Scarboro location in support of another surveillance activity.

7.7.1 Results

Samples were analyzed for gross alpha, gross beta, and gamma emitters. Table 7.8 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 produce 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.

Nationwide Food Consumption Survey (NFCS) data were used to estimate consumption rates and potential EDEs for eating home-produced foods (EPA 1997). A home gardener was assumed to have eaten 32 kg (71 lb) of home-grown tomatoes, 10 kg (22 lb) of homegrown

Table 7.8. Radiological constituents in tomatoes, turnips, and lettuce at sites near the ORR, 1999[a]

Location	Concentration (pCi/kg)[a]	
	Co-60	Cs-137
Lettuce		
East of the Y-12 Plant	7.0	*b*
Northeast of the Y-12 Plant, Scarboro #1	*b*	*b*
South of ORNL	*b*	*b*
Tomatoes		
East of the Y-12 Plant	*b*	*b*
Northeast of the Y-12 Plant, Scarboro #1	*b*	*b*
South of ORNL	*b*	1.8
West of the ETTP	*b*	*b*
Turnip greens		
Northeast of the Y-12 Plant, Scarboro #2	*b*	*b*
Turnips		
East of the Y-12 Plant	*b*	*b*
Northeast of the Y-12 Plant, Scarboro #1	*b*	*b*
South of ORNL	3.8	*b*
Northeast of the Y-12 Plant, Scarboro #2	*b*	3.1

[a]1 pCi = 3.7E–02 Bq.
[b]No significant result.

leafy vegetables, and 37 kg (82 lb) of turnips during the year.

Based on the assumed food consumption rates and statistically significant quantities of radionuclides that could have come from the ORR, a person who ate homegrown produce could have received EDEs between 0 and 0.003 mrem (0 and 0.03 µSv) from eating tomatoes, between 0.0007 and 0.03 mrem (0.007 and 0.3 µSv) from eating leafy vegetables, and between 0 and 0.006 mrem (0 and 0.06 µSv) from eating turnips. Thus, a person receiving the maximum potential dose from consuming all three types of produce could have received a total EDE of about 0.04 mrem (0.4 µSv) from radionuclides that could have been released from the ORR.

If doses from strictly naturally occurring ^{7}Be and ^{40}K are included, the maximum potential dose could have been about 4 mrem (40 µSv).

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 1999 milk-sampling program consisted of grab samples collected every other month from three locations in the vicinity of the ORR (Fig. 7.7). September samples were not available from the Karns 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 tritium (^{3}H).

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 7.9. Tritium was detected in only one sample out of five at the Karns location and not at all at the other two locations (see Table 7.9).

Hypothetical persons who drank 310 L of milk could have received an EDE between 0.05 and 0.07 mrem (0.5 and 0.7 µSv) from radionuclides that could have been emitted from the ORR; the average EDE could have been 0.06 mrem (0.6 µSv). 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, the doses resulting from the naturally occurring ^{40}K, which also was measured in the milk samples, could have been between 7 and 9 mrem (70 and 90 µSv).

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.

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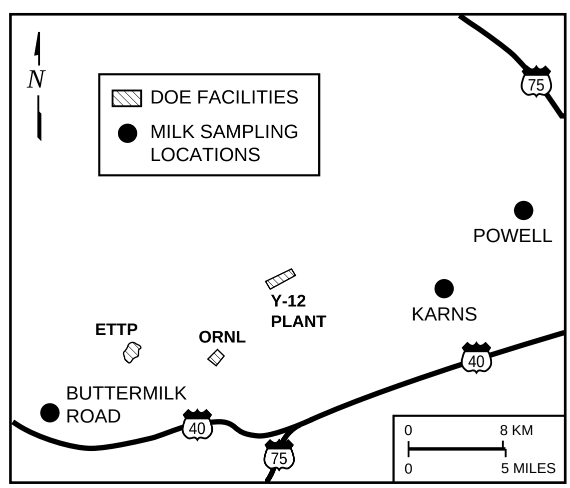

Fig. 7.7. Milk sampling locations in the vicinity of the ORR.

Table 7.9. Concentrations of radionuclides detected in raw milk, 1999

Analysis	No. detected/ No. total	Detected concentration (pCi/L)[a]			Standard error of mean
		Max[b]	Min[b]	Avg[b]	
Buttermilk Road					
Total rad Sr	4/6	1.8*	0.47	1.2*	0.22
Karns					
^{3}H	1/5	200*	–290	–9.8	79
Total rad Sr	3/5	1.3*	0.19	0.96*	0.22
Powell					
^{131}I	1/6	2.2*	–0.78	0.40	0.46
Total rad Sr	4/6	2.8*	0.21	1.4*	0.38
Network Summary					
^{3}H	1/17	200	–290	21	29
^{131}I	1/17	2.2	–12	–0.48	0.76
Total rad Sr	11/17	2.8	0.19	1.2*	0.16

[a]1 pCi/L = 3.7E-02 Bq.
[b]Individual and average concentrations significantly greater than zero at the 95% confidence level are identified by an asterisk (*).

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 six of the largest are analyzed for selected metals, pesticides, PCBs, and tritium. The rest (separated into composite samples; four composites in 1999) are ashed and analyzed for gross alpha and gross beta, gamma emitting radionuclides, and total radioactive strontium. To provide data from a second species, annual catfish sampling was initiated in 1993. Typically, six to ten catfish are collected, and a composite sample per location is analyzed for selected metals, pesticides, PCBs, and tritium. A composite sample is also ashed and analyzed for gross alpha and gross beta, gamma-emitting radionuclides, and total radioactive strontium.

7.9.1 Results

In 1999, most nonradiological parameters analyzed in sunfish and catfish were undetected or detected in only a few samples. For PCBs, reported values for sunfish and catfish were below the U.S. Food and Drug Administration (FDA) tolerance of 2 ppm (FDA 1984a); for mercury, all reported values were below the FDA action level of 1 ppm (FDA 1984a). These limits apply only to fish sold commercially and consumed at rates applicable to the ordinary consumer. For the purposes of this report, much lower tolerance levels are used as proposed by EPA (EPA 1991a) for individuals consuming fish caught in local rivers and streams and consumed at higher levels.

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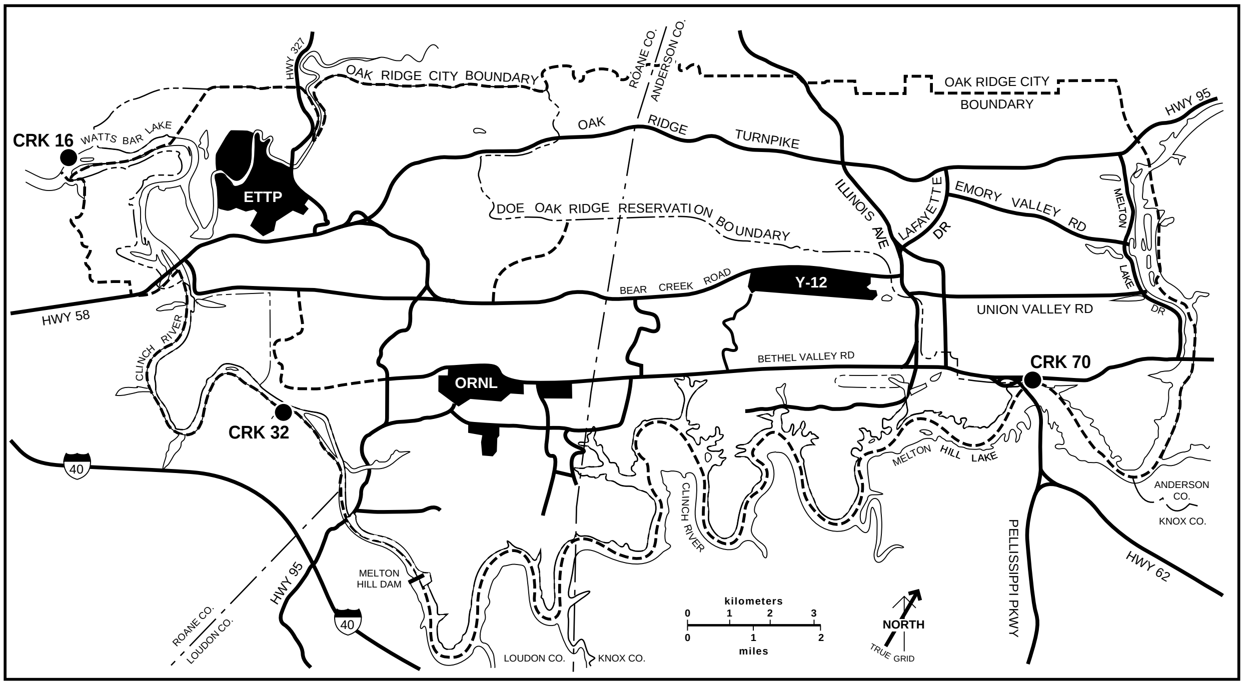

Fig. 7.8. Fish sampling locations for ORR environmental monitoring plan.

Fishermen are reported to consume 3 to 4 times as much fish as the ordinary consumer. 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). The PCB concentration in catfish tissue that corresponds to the precautionary advisory is estimated to be about 0.06 mg/kg, using the methodology cited in TDEC 1200-4-3-.03 (j).

PCBs were detected in two of the sunfish samples; one of these was from a fish collected at CRK 70 (upstream from all ORR inputs) and the other fish was collected at CRK 16 (downstream from all DOE inputs). Aroclor-1254 and Aroclor-1260 were detected in each of the catfish composite samples collected at CRK 16 and CRK 32. 4,4'-DDE, a pesticide, was detected also in the catfish composites from CRK 16 and CRK 32. Information regarding potential health impacts associated with chemical and radiological constituents detected in the sunfish and catfish are discussed (below and in Chap. 8 and Appendix H).

7.9.1.1 Radiological Dose

Fishing is quite common on the Clinch and Tennessee river systems. For purposes of assessment, avid fish eaters were assumed to have consumed 21 kg of fish during 1999. Based on measured concentrations of radionuclides in fish, avid eaters could have received, from significantly detected radionuclides that could have been discharged from the ORR, an EDE of about 0.03 mrem (0.0003 mSv) from eating CRK 70 fish, between 0.3 and 0.4 mrem (0.003 and 0.004 mSv) from eating CRK 32 fish, and between 0.04 and 0.6 mrem (0.0004 and 0.006 mSv) from eating CRK 16 fish.

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/CDIs) 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 (21 kg/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 1991b). TDEC uses a method developed by the 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/CDI 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 1 were calculated for consumption of sunfish with the exception of Beta-BHC, Aroclor-1254, and Aroclor-1260 (see Appendix H, Table H.3). However, average concentrations were estimated in sunfish tissue from values below the reported analytical detection limits of the instruments. Therefore, actual HQ values could be less, perhaps much less, than the calculated HQs. For consumption of catfish, HQ values greater than one were calculated for mercury, Aroclor-1254, and Aroclor-1260. Only mercury resulted in an HQ greater than one in catfish tissue collected at all locations, both upstream and downstream of the ORR. Mercury is known to be a contaminant of potential concern for the fish consumption pathway in the Clinch River (DOE 1996). Mercury was also used at the Y-12 Plant in the past. Almost 68% of all fish advisories issued in the United States are a result of mercury contamination in fish and shellfish (EPA 1999a). Aroclor-1254 and Aroclor-1260 measured in catfish tissue collected from CRK 32 and CRK 16 also resulted in HQs greater than one.

For carcinogens, I/CDI ratios greater than one indicate a cancer risk greater than 10^{-5}. I/CDI ratios greater than one were calculated for the intake of mixed PCBs (e.g., Aroclor-1060, 1248, 1254, 1260) found in sunfish collected both upstream (CRK 70) and downstream (CRK 16) of the ORR. However, average PCB concentrations were estimated in sunfish tissue from values below the reported analytical detection limits of the instruments. Therefore, actual I/CDI ratios could be less, perhaps much less, than the calculated I/CDI ratios.

I/CDI ratios greater than one were calculated for mixed PCBs (Aroclor-1254 and Aroclor-1260) in catfish collected at CRK 32 and at CRK 16, which is downstream of the ORR. An I/CDI ratio value of 92 was estimated for catfish collected at CRK 32. An I/CDI ratio value of 75 was estimated for catfish collected at CRK 16. 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 1999b).

7.10 WHITE-TAILED DEER

The 15th annual deer hunts managed by DOE and the Tennessee Wildlife Resources Agency (TWRA) were held on the ORR during the final quarter of 1999. 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 1999 hunts were held on three weekends. Shotgun/muzzle loader hunts were held October 16–17, November 13–14, and December 11–12 with 800 permitted hunters for each hunt. During the November 13–14 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 1999 hunt, a limit of one deer, either sex, was established for all hunt areas.

The year's total harvest was 349 deer. From the total harvest of 349 animals, 227 (65.0%) were bucks and 122 (35.0%) were does. The heaviest buck had nine antler points and weighed 76.2 kg (168 lb). The greatest number of antler points (11) were found on three bucks. The heaviest doe weighed 47.2 kg (104 lb).

7.10.1 Results

Of the 349 deer harvested, 4 were confiscated because they exceeded established release limits (5 pCi/g for ^{137}Cs and/or 20 pCi/g for ^{90}Sr). The average concentration of ^{137}Cs (based on field measurements) in the deer released to the public was 0.16 pCi/g (0.006 Bq/g). The deer confiscated during the 1999 hunt represent 1.15% of the total deer harvested on the ORR. Since the hunts began in 1985, 7472 deer have been harvested; a total of 165 (2.2%) were retained because of radiological contamination.

7.10.2 Dose

The released deer had an average field-dressed weight of about 38.3 kg (84.3 lb). Because about 55% of the dressed weight is edible meat, the average deer would yield about 21 kg (46.4 lb) of meat. Therefore, based on the average weight, the total harvest of edible meat was about 7258 kg (16,004 lb).

The average ^{137}Cs concentration in tissue of the 345 released deer, as determined by field counting, was 0.16 pCi/g (0.006 Bq/g); the maximum ^{137}Cs concentration in a released deer was 1.81 pCi/g (0.07 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 1999. 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 1999 average concentration of ^{137}Cs (0.16 pCi/g) could have received an EDE of about 0.2 mrem (0.002 mSv). The maximum EDE to a hunter who harvested and consumed a deer from the ORR in 1999 was estimated to be 6.4 mrem (0.064 mSv), based on a ^{137}Cs concentration of 1.81 pCi/g, a maximum ^{90}Sr concentration of 0.4 pCi/g, and maximum field-dressed weight of 168 lb (76.2 kg).

The maximum EDE to an individual consuming venison from two or more deer was also evaluated. There were about 11 hunters (individuals or members of a household) who harvested two or three deer from the ORR in 1999. The maximum EDE to a hunter who consumed two harvested deer could have been about 2.0 mrem (0.6 mrem from ^{137}Cs and 1.4 mrem ^{90}Sr). There is one case where three deer were harvested by hunters within the same household. The maximum EDE to an individual consuming all of the venison from three deer could have been about 0.8 mrem (0.15 mrem resulting from ^{137}Cs and 0.7 mrem ^{90}Sr). The collective EDE from eating all the harvested venison with a 1999 average field-derived ^{137}Cs concentration of 0.16 pCi/g (0.006 Bq/g) is estimated to be about 0.06 person-rem (0.0006 person-Sv).

Selected muscle samples were analyzed from seven deer harvested in 1999. In addition to the routine analyses of Cs-137 and Sr-90, additional analyses for retained deer were requested; these include tritium (H-3), uranium (U-234, U-235, and U-238), thorium (Th-228, Th-230, and Th-232), and transuranics, such as plutonium (Pu-238, Pu-239/Pu-240) and americium (Am-241). Using statistically significant radionuclide concentrations (excluding K-40, a naturally occurring radionuclide), the estimated EDEs ranged from 0.07 to 1.1 mrem. The contribution to the dose from the radionuclides, other than Cs-137 and Sr-90, ranged from about 10% to 100%. The primary contributors were Am-241 and U-234. Based on these preliminary analytical results, it is recommended that in addition to the analyses for Cs-137 and Sr-90 in tissue that other radionuclides also be analyzed for in deer tissue.

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 subjected to noninvasive, gross radiological surveys. The 1999 ORR roundup was conducted on the ORR June 24 and 25. In addition, TWRA/TDEC collected additional geese off site on June 28.

From the roundup, 134 geese were subjected to live whole-body gamma scans. These geese were collected from ETTP (34), Y-12 (1), ORNL (37), Melton Hill Dam (24), Clark Center (18), and at an off-site residence (20). Of the 134 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, 28 geese were collected from the west end of ORNL in 1999. In addition, four geese were sacrificed and tissue samples were collected.

The numbers of waterfowl observations (7665) and of species observed (40) on the ORR in 1999 prove interesting when compared with results of previous years. While diversity of species was very good in 1999 (40 species only recorded once before, in 1996), the number of observations was quite low. In 1998 there were only 7373 observations made of 33 species, but only 22 (rather than the usual 24) surveys were conducted that year. For the 1995–98 period, the mean number of observations per year is 8498, and the mean number of species observed per year is 36. Estimates of numbers of individuals using the ORR can be made from survey observations. Though these surveys underestimate both numbers (of individuals) and diversity of waterfowl present, they are likely to be fairly reliable indicators of local waterfowl trends.

7.11.1.1 Results

The average ^{137}Cs concentration in the released geese was 0.23 pCi/g (0.009 Bq/g). The maximum ^{137}Cs concentration in the released geese was 2.0 pCi/g (0.07 Bq/g). No geese were retained in 1999. The average weight of the Canada geese screened during the roundup was about 3 kg (6.6 lb). The maximum goose weight was about 5.2 kg (11.4 lb).

7.11.1.2 Dose

During the 1999 goose roundup, 134 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 3 kg (6.6 lbs) and an average ^{137}Cs concentration of 0.23 pCi/g, the estimated EDE would be 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 2.0 pCi/g and the maximum weight (5.2 kg) was about 0.3 mrem (0.003 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 0.6 mrem (0.06 mSv).

Selected muscle and liver samples were analyzed from three geese sacrificed in 1998. In addition to the routine analyses of Cs-137 and Sr-90, additional radioisotopic analyses were also requested—these include tritium (H-3), uranium (U-234, U-235, and U-238), thorium (Th-228, Th-230, and Th-232), and transuranics, such as plutonium (Pu-238, Pu-239/Pu-240) and americium (Am-241). Using statistically significant radionuclide concentrations (excluding K-40, a naturally occurring radionuclide), the estimated EDEs ranged from 0.05 to 0.2 mrem. The contribution to the dose from the radionuclides, other than Cs-137 and Sr-90, ranged from about 54% to

94%. The primary contributors were Am-241 and U-234. Based on these preliminary analytical results, it is recommended that in addition to the analyses for Cs-137 and Sr-90 in tissue that other radionuclides also be analyzed for in goose tissue.

7.11.2 Turkey Monitoring

Two wild turkey hunts managed by DOE and TWRA were held on the reservation April 17–18, 1999, and April 24–25, 1999. Hunting was open for both shotguns and archery. A total of 61 birds were harvested, and none exceeded the administrative release limits established for radiological contamination. Of the birds harvested, 5 were juveniles and 56 were adults. The average turkey weight was 18.2 lb (8.3 kg). The largest tom weighed 23.1 lb (10.48 kg), had 1.1-in. spurs, and had a 10.5-in. beard. Two toms had 1.3-in. spurs and weighed 17.6 and 19.5 lb, respectively. The longest beard (13.5 in.) was measured on a tom weighing 20.2 lb (9.2 kg).

The released turkeys had an average whole weight of about 18.2 lb (8.3 kg). It is assumed that about 50% of the field weight is edible meat; therefore, the average turkey would yield about 9.1 lb (4.1 kg) of meat. Based on the average weight, the total harvest of edible meat is estimated to be about 555 lb (252 kg).

The average ^{137}Cs concentration in the released turkeys was 0.1 pCi/g (0.004 Bq/g), and the maximum ^{137}Cs concentration was 0.23 pCi/g (0.009 Bq/g). A person who ate a turkey with the average weight (assuming 50% of weight was edible tissue) and an average ^{137}Cs concentration could have received an EDE of about 0.02 mrem (0.0002 mSv). A person who ate a turkey with the maximum weight and maximum ^{137}Cs concentration could have received an EDE of about 0.06 mrem (0.0006 mSv). The collective EDE from eating all of the harvested edible turkey meat with a average ^{137}Cs concentration of 0.1 pCi/g (0.007 Bq/g) and average field weight of 18.2 lb (8.3 kg) is estimated to be about 0.001 person-rem (0.00001 person-Sv).