8. Dose

Setting

Activities on the ORR have the potential to release small quantities of radionuclides and hazardous chemicals to the environment. These releases could result in exposures of members of the public to low concentrations of radionuclides or chemicals. Monitoring of materials released from the reservation and environmental monitoring and surveillance on and around the reservation provide data that are used to show that doses from released radionuclides and chemicals are in compliance with the law; the calculated doses are compared with existing state and federal criteria.

Update

A hypothetical maximally exposed individual could have received a total of 0.7 mrem (less than 1 mrem) from radionuclides emitted to the atmosphere from all of the sources on the ORR in 1999; this is well below the National Emission Standards for Hazardous Air Pollutants standard of 10 mrem for protection of the public.

A worst-case analysis of exposure to waterborne radionuclides for all pathways combined (drinking water, eating fish, swimming, wading, shoreline use, etc.) gives a maximum possible individual dose of about 4 mrem, which is a small percentage of the individual dose attributable to natural background radiation (~1%)

Calculations to determine possible doses from consumption of deer, geese, and wild turkey harvested on or near the ORR resulted in the following: an individual who consumed one average-weight deer containing the average concentration of radionuclides in 1999 could have received about 0.2 mrem; someone consuming a hypothetical goose containing the maximum concentration of radionuclides below the ORNL administrative limit could have received 0.3 mrem; and a person who ate an average turkey could have received a dose of 0.02 mrem. In a worst-possible-case analysis (i.e., the heaviest animal containing the highest possible concentration of radionuclides), the doses received could be as high as 6 mrem for deer, 0.6 mrem for two geese, and 0.06 mrem for consuming the heaviest, most contaminated turkey.

8.1 RADIATION DOSE

Small quantities of radionuclides were released to the environment from operations at the ORR facilities during 1999. Those releases are described, characterized, and quantified in previous chapters of this report. This chapter presents estimates of potential radiation doses to the public from the releases. These dose estimates are intended to demonstrate that no member of the public received a dose during 1999 in excess of that allowed by relevant regulatory authorities. The dose estimates are performed using monitored and estimated release data, environmental monitoring and surveillance data, estimated exposure conditions that tend to maximize the calculated dose equivalents, and environmental transport and dosimetry codes that also tend to overestimate the calculated dose equivalents. Thus, the presented dose estimates do not necessarily reflect doses received by typical people in the vicinity of the ORR; they likely are overestimates.

8.1.1 Terminology

Most doses associated with radionuclide releases to the environment are caused by interactions between radiation emitted by the radionuclides and human tissue. These interactions involve the transfer of energy from the radiation to tissue, a process that may damage the tissue. The radiation may come from radionuclides located outside the body (in or on environmental media or objects) or from radionuclides deposited inside the body (by inhalation, ingestion, and, in a few cases, absorption through the skin).

Exposures to radiation from nuclides located outside the body are called external exposures; exposures to radiation from nuclides deposited inside the body are called internal exposures. This distinction is important because external exposures occur only when a person is near or in a radionuclide-containing medium; internal exposures continue as long as the radionuclides remain inside the person. Also, external exposures may result in uniform irradiation of the entire body and all its components; internal exposures usually result in nonuniform irradiation of the body. (When taken into the body, most radionuclides deposit preferentially in specific organs or tissues and thus do not irradiate the body uniformly.)

A number of the specialized terms and units used to characterize exposures to ionizing radiation are defined in Appendix G. One of these is used repeatedly in this section, the effective dose equivalent (EDE), which is a risk-based dose equivalent that can be used to estimate health effects or risks to exposed persons. It is a weighted sum of dose equivalents to specified organs and is expressed in rem or sieverts (1 rem = 0.01 Sv).

One rem of effective dose equivalence, regardless of radiation type and method of delivery, has the same total radiological (in this case, also biological) risk effect. Because the doses being considered here are very small compared with the rem, EDEs are usually expressed in millirem (mrem), which is 1/1000 of a rem. (See Appendix G, Table G.2, for a comparison and description of various dose levels.)

8.1.2 Methods of Evaluation

8.1.2.1 Airborne Radionuclides

The radiological consequences of radionuclides released to the atmosphere from ORR operations during 1999 were characterized by calculating, for each plant and for the entire ORR, EDEs to maximally exposed off-site individuals and to the entire population residing within 80 km (50 miles) of the center of the ORR. The dose calculations were made using the CAP-88 package of computer codes (Beres 1990), which was developed under EPA sponsorship to demonstrate compliance with the National Emission Standards for Hazardous Air Pollutants (NESHAP): Radionuclides, 40 CFR 61, Subpart H, which governs the emissions of radionuclides other than radon from DOE facilities. This package implements a steady-state Gaussian plume atmospheric dispersion model to calculate concentrations of radionuclides in the air and on the ground and uses Regulatory Guide 1.109 (NRC 1977) food-chain models to calculate radionuclide concentrations in foodstuffs (vegetables, meat, and milk) and subsequent intakes by humans.

A total of 54 emission points, each of which includes one or more individual sources, on the ORR was modeled during 1999. This total includes 6 points at the Y-12 Plant, 33 points at ORNL, and 15 points at the ETTP. Table 8.1 is a list of the emission point parameter values and receptor locations used in the dose calculations.

Meteorological data used in the calculations were in the form of joint frequency distributions of wind direction, wind speed class, and atmospheric stability category. These data were derived from data collected during 1999 at the 60-m height (with wind speeds adjusted to reflect conditions at 20 m) on Tower MT6 for all sources at the Y-12 Plant; at the 100-m height on Tower MT2 for sources X-3018, X-3020, and X-3039; at the 30-m height on Tower MT2 for sources X-2001, X-2026, X-2099, X-2523, X-3074, X-3505, X-3544, X-3608, X-5505, X-7025, X-7856, X-out-of-service lab hoods, X-minor grouped sources, X-STP sludge drier, X-T1/T2, X-EW, X-W7/W9, and X-W16 at ORNL; at the 30-m height on Tower MT4 for sources X-7512, X-7567, X-7569, X-7830, X-7852, X-7860, X-7877, X-7911, X-7966 at ORNL; at the 60-m height on Tower MT1 for K-1435; and at the 10-m height on Tower MT7 for all other sources at the ETTP. During 1999, rainfall, as averaged over the four rain gauges located on the ORR, was 126 cm (50 in.). The average air temperature was 16°C (60°F), and the average mixing-layer height was 1000 m (3280 ft).

For occupants of residences, the dose calculations assume that the occupant remained at home (actually, outside the house), unprotected, during the entire year and obtained food according to the rural pattern defined in the NESHAP background documents (EPA 1989). This pattern specifies that 70% of the vegetables and produce, 44.2% of the meat, and 39.9% of the milk consumed are produced in the local area (e.g., a home garden). The remaining portion of each food is assumed to be produced within 80 km (50 miles) of the ORR. The same assumptions are used for occupants of businesses, but the resulting doses are divided by 2 to compensate for the fact that businesses are

Table 8.1. Emission point parameters and receptor locations used in dose calculations

ORNL sources	Type	Release height (m)	Diameter (m)	Gas exit velocity (m/s)	Gas exit temperature (°C)	Distance (m) and direction to MEI[a]	
						Plant	ORR
X-2001	Point	15.24	0.66	9.90	Ambient	3,820 SSW	9,650 NE
X-2026	Point	22.9	1.05	10.20	Ambient	3,900 SSW	9,520 NE
X-2099	Point	3.66	0.25	8.60	Ambient	3,900 SSW	9,520 NE
X-2523	Point	7	0.3	6.00	Ambient	3,640 SSW	9,740 NE
X-3018	Point	61	4.11	0.20	Ambient	4,090 SSW	9,310 NE
X-3020	Point	61	1.96	6.50	Ambient	4,090 SSW	9,310 NE
X-3039	Point	76.2	5.68	2.70	Ambient	4,010 SSW	9,350 NE
X-3074	Point	4	0.26	10.20	Ambient	4,090 SSW	9,310 NE
X-3505	Point	6.09	0.51	13.80	Ambient	3,700 SSW	9,610 NE
X-3544	Point	9.53	0.27	19.90	Ambient	3,700 SSW	9,610 NE
X-3608 F P	Point	8.99	0.36	14.20	Ambient	3,740 SSW	9,550 NE
X-3608 Air Stripper	Point	10.97	2.44	0.60	Ambient	3,740 SW	9,550 NE
X-5505 North/South Ducts	Point	11	0.91	20.20	Ambient	4,360 SSW	8,900 NNE
X-5505 Main Duct	Point	11	0.29	4.20	Ambient	4,360 SSW	8,900 NNE
X-7025	Point	4	0.3	13.60	Ambient	5,700 SW	7,560 NNE
X-7512	Point	30.5	0.91	12.90	Ambient	3,890 SW	9,370 NNE
X-7567	Point	3.8	0.31	2.00	Ambient	3,890 SW	9,370 NNE
X-7569	Point	4	0.15	2.60	Ambient	3,890 SW	9,370 NNE
X-7830	Point	4.6	0.21	11.10	Ambient	2,480 SW	10,840 NNE
X-7852	Point	2.13	0.2	2.20	Ambient	2,480 SW	10,840 NNE
X-7860	Point	18.29	0.31	3.90	Ambient	2,480 SW	10,840 NNE
X-7877	Point	13.9	0.51	8.70	Ambient	2,480 SW	10,840 NNE
X-7911	Point	76.2	3.43	2.80	Ambient	3,680 SW	9,650 NNE
X-7966	Point	6.1	0.29	12.20	Ambient	3,680 SW	9,650 NNE
X-Decommissioned Lab Hoods	Point	15	NA	NA	Ambient	4,010 SSW	9,350 NE
X-Minor Sources	Point	15	NA	NA	Ambient	4,010 SSW	9,350 NE
X-W7/W9	Point	1.22	0.16	13.9/18.6	Ambient	3,550 SSW	9,780 NE
X-T1/T2	Point	1	NA	NA	Ambient	3,890 SW	9,370 NNE
X-STP Sludge Drier	Point	7.6	0.2	11.20	Ambient	3,550 SSW	9,780 NE
X-EW-2	Point	4.6	0.3	6.80	Ambient	3,550 SSW	9,780 NE
X-7856-CIP (MVST)	Point	18.29	0.58	12.40	Ambient	2,480 SW	10,840 NNE
X-W-16	Point	1	NA	0	Ambient	3,550 SSW	9,780 NE
X-CTP	Point	4.6	0.29	6.60	Ambient	3,550 SSW	9,780 NE
Y-Monitored Sources	Point	20	NA	NA	Ambient	1,120 NNE	1,120 NNE
Y-Minor Sources	Point	20	NA	NA	Ambient	1,120 NNE	1,120 NNE
Y-Lab Hoods	Point	20	NA	NA	Ambient	1,120 NNE	1,120 NNE
Y-Unmonitored Room Exhausts	Point	20	NA	NA	Ambient	1,120 NNE	1,120 NNE
Y-9204-3	Point	20	NA	NA	Ambient	740 NW	740 NW
Y-9224	Point	10	NA	NA	Ambient	1,310 N	1,310 N
Y-ASO Union Valley	Point	4.27	0.76	13.44	Ambient	2,350 WSW	2,350 WSW
K-33 BNFL	Point	22.86	1.37	17.56	Ambient	3,690 ENE	14,840 ENE
K-1004-B Lab Hood	Point	8.5	NA	0	Ambient	1,740 N	14,040 ENE
K-1008-C Respirator Cleaning Facility	Point	3.96	NA	0	Ambient	2,830 NE	13,870 ENE
K-1066-E Yard UF6 Cylinder Venting	Point	1	NA	NA	Ambient	3,850 ENE	14,990 ENE

Table 8.1 (continued)

ORNL sources	Type	Release height (m)	Diameter (m)	Gas exit velocity (m/s)	Gas exit temperature (°C)	Distance (m) and direction to MEI[a]	
						Plant	ORR
K-1131 KAFaD Rad-Laundry Facility	Point	3	NA	0	60.00	3,480 NE	14,600 ENE
K-1131 KAFaD Steel Decontamination Facility	Point	1	0.84	15.24	Ambient	3,480 NE	14,600 ENE
K-1407 Central Neutralization Facility	Point	5.79	1.22	0.63	Ambient	2,410 NE	13,500 ENE
K-1423 Container Processing Facility	Point	6.1	0.15	0	Ambient	2,810 ENE	13,950 ENE
K-1423 TSCA Incinerator Waste Repack	Point	3.05	0.61	10.02	Ambient	2,810 ENE	13,950 ENE
K-1435 TSCA Incinerator	Point	30.5	1.37	5.73	80.34	2,210 NE	13,240 ENE
K-1435 Waste Feed Tanks	Point	18.29	NA	0	Ambient	2,210 NE	13,240 ENE
K-1435-A Lab Hoods	Point	3.96	NA	0	Ambient	2,210 NE	13,240 ENE
K-1435-B TSCA Incinerator Waste Repack	Point	3.05	NA	0	Ambient	2,210 NE	13,240 ENE
K-1775 TCGRS	Point	1	NA	0	Ambient	3,850 ENE	15,000 ENE
K-1435 TSCAI IWS Demolition	Point	1	NA	0	Ambient	2,210 NE	13,240 ENE

occupied for less than one-half a year and less than one-half of a worker's food intake occurs at work. For collective EDE estimates, production of beef, milk, and crops within 80 km of the ORR was calculated using the state-specific production rates provided with CAP-88.

Results

Calculated EDEs from radionuclides emitted to the atmosphere from the ORR are listed in Tables 8.2 (maximum individual) and 8.3 (collective). The hypothetical maximally exposed individual (MEI) for the ORR was located about 1120 m (0.69 miles) north-northeast of the main Y-12 Plant release point, about 9650 m (5.9 miles) north-northeast of the X-7911 stack at ORNL, and about 13,240 m (8.2 miles) east-northeast of the K-1435 (TSCA Incinerator) stack at the ETTP. This individual could have received an EDE of about 0.69 mrem (0.0069 mSv), which is well below the NESHAP standard of 10 mrem (0.10 mSv) and well below the 300 mrem (3 mSv) that the average individual receives from natural sources of radiation. The calculated collective EDE to the entire population within 80 km (50 miles) of the ORR (about 879,546 persons) was about 19 person-rem (0.19 person-Sv), which is approximately 0.0072% of the 264,000 person-rem that this population could have received from natural sources of radiation.

Table 8.2. Calculated radiation doses to maximally exposed off-site individuals from airborne releases during 1999

Plant	Total effective dose equivalents [mrem (mSv)]	
	Plant max	ORR max
ORNL	0.5 (0.005)[a]	0.06 (0.0006)
ETTP	0.4 (0.004)[b]	0.1 (0.001)
Y-12 Plant	0.5 (0.005)[c]	0.5 (0.005)
Entire ORR	*d*	0.7 (0.007)[e]

[a]The maximally exposed individual was located 4010 m (2.5 miles) SSW of X-3039 and 3680 m (2.3 miles) SW of X-7911.

[b]The maximally exposed individual was located 2210 m (1.4 miles) NE of K-1435.

[c]The maximally exposed individual is located 1120 m (0.69 miles) NNE of the Y-12 Plant release point.

[d]Not applicable.

[e]The maximally exposed individual for the entire ORR is the Y-12 maximally exposed individual.

Table 8.3. Calculated collective EDEs from airborne releases during 1999

Plant	Effective dose equivalents[a]	
	(Person-rem)	(Person-Sv)
ORNL	7	0.07
ETTP	7	0.07
Y-12 Plant	4	0.05
Entire ORR	19	0.19

[a]Collective effective dose equivalents to the 879,546 persons residing within 80 km (50 miles) of the ORR.

The MEI for the Y-12 Plant was located about 1120 m (0.69 miles) north-northeast of the main Y-12 Plant release point. This individual could have received an EDE of about 0.53 mrem (0.0053 mSv) from Y-12 Plant emissions. Inhalation and ingestion of uranium radioisotopes (i.e., ^{234}U, ^{235}U, ^{236}U, and ^{238}U) accounted for more than 99% of the dose. The contribution of Y-12 Plant emissions to the 50-year committed collective EDE to the population residing within 80 km of the ORR was calculated to be about 4.5 person-rem (0.045 person-Sv), which is approximately 24% of the collective EDE for the ORR.

The MEI for ORNL was located about 4010 m (2.5 miles) south-southwest of the X-3039 stack and 3680 m (2.3 miles) southwest of the X-7911 stack. This individual could have received an EDE of about 0.51 mrem (0.0051 mSv) from ORNL emissions. About 72% of this dose is from immersion in airborne ^{41}Ar. Other radionuclides contributing 1% or more to the dose include ^{138}Cs (21%), ^{212}Pb (2.1%), and ^{191}Os (1.0%). The contribution of ORNL emissions to the collective EDE to the population residing within 80 km of the ORR was calculated to be about 7.1 person-rem (0.071 person-Sv), which is approximately 37% of the collective EDE for the ORR.

The MEI for the ETTP was located at a construction site about 2210 m (1.4 miles) northeast of K-1435, the TSCA Incinerator stack. The EDE received by this individual was calculated to be about 0.35 mrem (0.0035 mSv). About 50% of this dose is from ingestion and inhalation of tritium, 36% is from uranium radioisotopes, about 12% is from thorium radioisotopes, and about 2.8% is from plutonium radioisotopes. The contribution of ETTP emissions to the collective EDE to the population residing within 80 km of the ORR was calculated to be about 7.2 person-rem (0.072 person-Sv), which is approximately 38% of the collective EDE for the reservation.

The reasonableness of the calculated radiation doses can be inferred by comparison with radiation doses that could be received from measured air concentrations of radionuclides at the ORR perimeter air monitoring stations (PAMs) (Fig. 7.3) and the remote air monitoring station (RAM). Hypothetical individuals assumed to reside at the PAMs could have received EDEs between 0.12 and 0.20 mrem/year (0.0012 and 0.0020 mSv/year); these EDEs include contributions from naturally occurring (background) radionuclides, radionuclides released from the ORR, and radionuclides released from any other sources. An indication of doses from sources other than those on the ORR can be obtained from the EDE calculated at the RAM, which was an unusually high 0.23 mrem/year (0.0023 mSv/year).

Of particular interest is a comparison of doses calculated using measured air concentrations at PAMs located near the maximally exposed individuals for each plant and doses calculated to those individuals using CAP-88 and measured emissions. PAM 46 is located near the maximally exposed individual for the Y-12 Plant; the EDE calculated using measured air concentrations was 0.17 mrem/year (0.0017 mSv/year), which is about 25% of the 0.69 mrem/year (0.0069 mSv/year) calculated using CAP-88. PAM 39 is located at about the same distance as, but in a different wind direction from, the maximally exposed individual for ORNL; the EDE calculated using measured air concentrations was 0.13 mrem/year (0.0013 mSv/year), which is about 20% of the 0.66 mrem/year (0.0066 mSv/ year) calculated using CAP-88. PAM 37 is located in the general area of the maximally exposed individual for the ETTP; the EDE calculated using measured air concentrations at PAM 37 was 0.14 mrem/year (0.0014 mSv/year), which is about 35% of the 0.40 mrem/year (0.0040 mSv/ year) modeled value to the maximally exposed individual.

Dose estimates based on calculated and measured radionuclide concentrations are in reasonable agreement given the differences in distances and directions between maximally exposed individuals and the monitoring stations and the fact that the CAP-88 model typically overestimates doses by a factor of 2.

8.1.2.2 Waterborne Radionuclides

Radionuclides discharged to surface waters from the ORR enter the Tennessee River system by way of the Clinch River and various feeder streams (see Sect. 1.4 for the surface water setting of the ORR). Discharges from the Y-12 Plant enter the Clinch River via Bear Creek and the East Fork of Poplar Creek, both of which enter Poplar Creek before it enters the Clinch River, and by discharges from Rogers Quarry into McCoy Branch and then into Melton Hill Lake. Discharges from ORNL enter the Clinch River via White Oak Creek (WOC) and White Oak Lake (WOL). Discharges from the ETTP enter the Clinch River either directly or via Poplar Creek. This section discusses the potential radiological impacts of these discharges to persons who drink water; eat fish; and swim, boat, and use the shoreline at various locations along the Clinch and Tennessee rivers.

Two methods are used to estimate potential radiation doses to the public. The first method uses radionuclide concentrations in the medium of interest (i.e., in water and fish) that were determined by laboratory analyses of actual water and fish samples. The second method uses radionuclide concentrations in water and fish that were calculated from measured radionuclide discharges and known or estimated stream flows. The advantage of the first method is the use of measured concentrations of radionuclides in water and fish; disadvantages are the inclusion of naturally occurring radionuclides in total alpha- and beta-activity measurements, the possibility that some radionuclides of ORR origin might be present in quantities too low to be measured, and the possibility that the presence of some radionuclides might be overstated. (If the analytical laboratory looks for the presence of a given nuclide, a quantity will be reported for that nuclide even if the nuclide is not really present or is present at a quantity below the detection limit.) The advantages of the second method are that most, if not all, radionuclides discharged from the ORR will be quantified and naturally occurring radionuclides will be either not considered or accounted for separately; the disadvantage is the use of models to estimate the concentrations of the radionuclides in water and fish. Using the two methods should allow the potential radiation dose to be bracketed.

Drinking Water

There are several water treatment plants along the Clinch and Tennessee river systems that could be affected by discharges from the ORR. For purposes of assessment, highly exposed individuals were assumed to drink 730 L of water during 1999; the average person, to drink 370 L.

The only water treatment plant located on Melton Hill Lake that could be affected by discharges from the ORR is a Knox County plant. Water from this plant is not sampled. However, the plant is located near environmental monitoring plan (EMP) water sampling location CRK 58. A highly exposed individual could have received an EDE of about 1 mrem (0.01 mSv) from drinking this water. The collective dose to the estimated 37,510 persons who drink this water could have been about 20 person-rem (0.2 person-Sv). Based on known radionuclide discharges to Melton Hill Lake, the highly exposed individual could have received an EDE of about 0.0007 mrem (0.000007 mSv). (These dose estimates may be high because they are based on water samples taken before processing in the plants.)

The ETTP (Gallaher) water plant draws water from the Clinch River near CRK 23. Based on water samples taken in the plant and the assumption that workers drink half their annual water intake at work, a worker who drank 370 L of this water could have received an EDE of about 0.6 mrem (0.006 mSv), and the collective EDE to the approximately 2000 ETTP workers could have been about 0.6 person-rem (0.006 person-Sv). Based on water samples taken from the Clinch River (CRK 23), the worker could have received an EDE of about 0.9 mrem (0.009 mSv), and the collective EDE could have been about 1 person-rem (0.01 person-Sv). Using radionuclide discharge data, the maximum individual EDE was estimated to be 0.09 mrem (0.0009 mSv); the collective EDE was 0.09 person-rem (0.0009 person-Sv).

The Kingston municipal water plant draws water from the Tennessee River, just above its confluence with the Clinch River. Based on water samples taken in the plant, a highly exposed person could have received an EDE of about 0.2 mrem (0.002 mSv), and the collective EDE to the estimated 7438 water users could have been about 0.6 person-rem (0.006 person-Sv). No water samples are taken from the Tennessee River near the water plant. Using radionuclide discharge data, the maximum individual EDE was estimated to be 0.02 mrem (0.0002 mSv); the collective EDE was 0.09 person-rem (0.0009 person-Sv).

Several water treatment plants are located on tributaries of Watts Bar Lake and Chickamauga Lake. Persons drinking water from these plants could not have received EDEs greater than the 0.2 mrem (0.002 mSv) calculated for Kingston water. The estimated collective EDE, using discharge data, was about 2 person-rem (0.02 person-Sv).

Fish

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; the average person, to have consumed 6.9 kg of fish. EDEs were calculated using measured radionuclide contents in fish and by using measured concentrations of radionuclides in water and the calculated concentrations from discharges as input to the LADTAP XL code.

Fish samples were collected from Melton Hill Lake above all ORR inputs (CRK 70), from the upper part of the Clinch River (CRK 32), and from the Clinch River below all ORR inputs (CRK 16). Based on these samples, avid eaters could have received, from significantly detected radionuclides that could have been discharged from the ORR, an EDE between 0.03 and 0.3 mrem (0.0003 and 0.003 mSv) from eating CRK 70 fish, between 0.4 and 0.5 mrem (0.004 and 0.005 mSv) from eating CRK 32 fish, and between 0.08 and 0.6 mrem (0.0008 and 0.006 mSv) from eating CRK 16 fish. The collective EDE attributable to radionuclides that could have been released from the ORR could have been as much as 0.0003 person-rem (0.000003 person-Sv).

Water samples were collected from Melton Hill Lake (CRK 70, 66, and 58); from the Clinch River below Melton Hill Dam (CRK 32, 23, and 16); from Poplar Creek above and below the ETTP; and from East Fork Poplar Creek, just before it joins Poplar Creek. Based on analyses of these samples, avid fish eaters could have received, from radionuclides that could have been discharged from the ORR, EDEs between 2 and 3 mrem (0.02 and 0.03 mSv) from fish taken from Melton Hill Lake; between 2 and 4 mrem (0.02 and 0.04 mSv) from fish taken from the Clinch River; and between 0.08 and 1 mrem (0.0008 and 0.01 mSv) from fish taken from Poplar Creek.

Based on radionuclide discharges to Melton Hill Lake, the Clinch River, and the Poplar Creek system, maximum EDEs to avid fish eaters could have been 0.0009 (0.000009), 0.2 (0.002), and 0.6 mrem (0.006 mSv), respectively. The collective EDE from eating fish from the above locations and from the Tennessee River system down to Chattanooga could have been 0.7 person-rem (0.007 person-Sv).

Other Uses

Other uses include swimming or wading, boating, and use of the shoreline. A highly exposed other user was assumed to swim or wade for 27 hours/year, boat for 63 hours/year, and use the shoreline for 67 hours/year. Measured and calculated concentrations of radionuclides in water and the LADTAP XL code were used to estimate potential EDEs from these activities. When compared with EDEs from eating fish from the same waters, the EDEs from these other uses are relatively insignificant.

Based on the above-noted water samples, highly exposed other users could have received EDEs between 0.004 and 0.009 mrem (0.00004 and 0.00009 mSv) from using Melton Hill Lake; between 0.001 and 0.01 (0.00001 and 0.0001 mSv) from using the Clinch River; and between 0.00002 and 0.008 mrem (0.0000002 and 0.00008 mSv) from using Poplar Creek.

Based on radionuclide discharges to the Clinch River–Poplar Creek system, a user could have received an EDE between 0.000001 and 0.0008 mrem (0.00000001 and 0.000008 mSv); the collective EDE could have been 0.006 person-rem (0.00006 person-Sv).

Summary

Table 8.4 is a summary of potential EDEs from waterborne radionuclide discharges. Adding worst-case EDEs for all pathways in a water-body segment gives a maximum imaginable individual EDE of about 4 mrem (0.04 mSv). The maximum imaginable collective EDE to the 50-mile population was estimated to be about 3 person-rem (0.03 person-Sv). These are small percentages of individual and collective doses attributable to natural background radiation, about 1% and 0.001%, respectively.

8.1.2.3 Radionuclides in Other Environmental Media

The CAP-88 computer codes are used to calculate radiation doses from ingestion of meat, milk, and vegetables that contain radionuclides released to the atmosphere. These doses are included in the dose calculations for airborne radionuclides. However, some environmental media, including the three mentioned, are sampled as part of the surveillance program. The following dose estimates are based on environmental sampling results and may include contributions from radionuclides occurring in the natural environment, released from the ORR, or both.

Milk

Milk collected at three locations near the ORR was found to contain small quantities of radiostrontium, ^{3}H, ^{7}Be, ^{40}K, and ^{131}I. All of these radionuclides are found in the natural environment, and all but ^{7}Be and ^{40}K also are emitted from the ORR. The sample data were used to calculate potential EDEs to hypothetical persons who drank 310 L of sampled milk during the year.

Table 8.4. Summary of annual maximum individual EDEs (mrem)[a] from waterborne radionuclides

Type of sample	Drinking water	Eating fish	Other uses	Total of highest
Melton Hill Lake, CRK 70				
Fish		0.3		
Water	2	3	0.009	3
Discharge	0.0007	0.0009	0.000001	0.002
Upper Clinch River, Gallaher Water Plant, CRK 32				
Drinking water	0.6			
Fish		0.5		
Water	0.9	2	0.01	3
Discharge	0.09	0.2	0.0005	0.3
Lower Clinch River, CRK 16				
Fish		0.6		
Water		4	0.001	4
Discharge		0.2	0.0003	0.2
Upper Watts Bar Lake, Kingston Municipal Water Plant				
Drinking water	0.2			
Discharge	0.02	0.05	0.00009	0.07
Lower System (Lower Watts Bar Lake and Chickamauga Lake)				
Discharge	0.02	0.04	0.00008	0.06
Poplar Creek				
Water		1	0.008	1
Discharge		0.6	0.0008	0.6

[a]1 mrem = 0.01 mSv.

These hypothetical persons could have received an EDE between 0.046 and 0.068 mrem (0.46 and 0.68 μSv) from radionuclides that could have been emitted from the ORR; the average EDE could have been 0.056 mrem (0.56 μSv). The average EDE associated with just total strontium and ^{131}I in milk in EPA Region 4 is about 0.090 mrem (0.90 μSv) (EPA 1993).

For perspective, the doses resulting from the naturally occurring ^{7}Be and ^{40}K in the sampled milk could be between 6.9 and 9.0 mrem (69 and 90 μSv).

Food Crops

Samples of tomatoes, lettuce, turnip greens, and turnips were collected from five gardens around the ORR during 1999. These vegetable types are representative of fruit-bearing, leafy, and root vegetables. The samples were found to contain small quantities of ^{7}Be, ^{40}K, ^{60}Co, ^{137}Cs, ^{234}U, ^{235}U, and ^{238}U. All of these radionuclides 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 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 home grown produce could have received EDEs between 0 and 0.0031 mrem (0 and 0.031 μSv) from eating tomatoes, between 0.00071 and 0.027 mrem (0.0071 and 0.27 μSv) from eating leafy vegetables, and between 0 and 0.0057 mrem (0 and 0.057 μSv) from eating turnips. Thus, a person receiving the maximum potential dose from all three types of produce could have received a total EDE of about 0.036 mrem (0.36 μSv) from radionuclides that could have been released from the ORR.

If the doses from the naturally occurring ^{7}Be and ^{40}K are included, the maximum potential dose could have been about 3.8 mrem (38 μSv).

Hay

As shown in Sect. 7.6.2, the maximum EDE to a person eating beef and drinking milk from cattle that eat hay gathered from the ORR was about 0.02 mrem (0.0002 mSv) from radionuclides that could have been emitted from the ORR. If doses due to naturally occurring ^{40}K and ^{7}Be are added, the EDE from drinking milk and eating beef was estimated to be about 9.5 mrem (0.095 mSv).

White-Tailed Deer

As shown in Sect. 7.10.2, the maximum EDE associated with eating deer harvested from the ORR was estimated to be 6.4 mrem (0.064 mSv), based solely on estimated quantities of ^{137}Cs and ^{90}Sr in edible tissue.

A special study of some deer harvested during 1998 indicates that some alpha-emitting radionuclides could be present in deer tissue that could contribute from 10% to 100% to the doses based solely on ^{137}Cs and ^{90}Sr measurements. These are preliminary analytical results; however, it is recommended that additional analyses be conducted on future deer tissue samples.

Canada Geese

As shown in Sect. 7.11.1, the maximum EDE associated with eating a goose harvested from the ORR was estimated to be 0.3 mrem (0.003 mSv), based solely on estimated quantities of ^{137}Cs in edible tissue.

A special study of some geese harvested during 1998 indicates that some alpha-emitting radionuclides may be present in goose tissue that could contribute from 54 to 94% to doses based solely on ^{137}Cs measurements. These are preliminary analytical results; however, it is recommended that additional analyses be conducted on future goose tissue samples.

Eastern Wild Turkey

As shown in Sect. 7.11.2, the maximum EDE associated with eating turkey harvested from the ORR was estimated to be 0.06 mrem (0.0006 mSv), based solely on estimated quantities of ^{137}Cs in edible tissue. It would be of interest to determine, as was done for deer and geese, if some alpha-emitting radionuclides could be present in turkey meat.

Direct Radiation

External exposure rates from background sources in the state of Tennessee average about 6.4 µR/hour and range from 2.9 to 11 µR/hour. These exposure rates translate into annual EDE rates that average 42 mrem/year (0.42 mSv/year) and range between 19 and 72 mrem/year, or 0.19 and 0.72 mSv/year (Myrick et al. 1981). External radiation exposure rates are measured at a number of locations on and off the ORR. The average exposure rate at PAMs around the ORR during 1999 was about 5.2 µR/hour. This rate corresponds to an EDE rate of about 36 mrem/year (0.36 mSv/year). Except for two locations, all measured exposure rates at or near the ORR boundaries are near background levels. The two exceptions are a stretch of bank along the Clinch River and a section of Poplar Creek that flows through the ETTP.

During 1997, external exposure rate measurements were taken along a 1.7-km (1.1-mile) length of Clinch River bank. Measured exposure rates along this stretch of bank averaged 8.4 µR/hour and ranged between 6.9 and 9.3 µR/hour. This corresponds to an average exposure rate of about 2 µR/hour (0.0015 mrem/hour) above background.

A potential maximally exposed individual is a hypothetical fisherman who was assumed to have spent 5 hours/week (250 hours/year) near the point of average exposure. This hypothetical maximally exposed individual could have received an EDE of about 0.38 mrem (0.0038 mSv) during 1999.

The UF_6 cylinder storage yards at ETTP may be sources of potential exposure to the public from gamma radiation from radionuclides in the cylinders. Measured exposure rates and a hypothetical model of a maximally exposed individual were used to calculate theoretical doses. The calculated effective dose equivalents (EDEs) were based on gamma dose rates measured at the K-1066-J and K-1066-E Cylinder Yards along the near bank of Poplar Creek, the parking lot adjacent to the K-1066-K Cylinder Yard, and the road alongside the Clinch River in the vicinity of the K-770 Scrap Yard. The measured exposure rates indicate levels well below the requirements in DOE orders.

Gamma dose rates from each area were measured in January 2000 with a tissue-equivalent dose rate meter. Background readings were established at the ambient air monitor station north of ETTP off Blair Road. The average gamma background was 0.005 mrem/hour, and all three neutron measurements were 0 mrem/hour. Neutron measurements at the monitoring locations were determined to be negligible.

The potential maximally exposed individual model used for exposure from the K-1066-J or K-1066-E Cylinder Yard is a hypothetical fisherman who was assumed to have spent 250 h/year near the point of average exposure. This hypothetical, maximally exposed individual could have received an EDE of about 0.25 mrem along the bank of Poplar Creek near K-1066-J Cylinder Yard, or 2.0 mrem along the bank of Poplar Creek near K-1066-E Cylinder Yard during 1999. This section of the creek runs through the ETTP plant and is used at times by fishermen; however, it is very unlikely that anyone would fish this stretch of Poplar Creek for 250 h/year.

In the vicinity of the K-770 Scrap Yard general area dose rates were recorded every 100 ft along the road, approximately 10 to 12 ft inside the perimeter fence. The average gamma dose rate was equivalent to the background level of 0.005 mrem/hour; therefore, a hypothetical Clinch River fisherman would not be expected to have received any EDE attributable to the K-770 Scrap Yard during 1999.

Because the parking lot adjacent to the K-1066-K Cylinder Yard began receiving heavier use by the public and workers, it was included in the 1999 survey. A potential maximally exposed individual is someone assumed to have spent 30 min per work day (125 hours/year) waiting in the parking lot at the point of average exposure along the edge closest to the K-1066-K Cylinder Yard. This hypothetical, maximally exposed individual could have received an EDE of about 1.1 mrem during 1999.

8.1.3 Doses to Aquatic Biota

DOE Order 5400.5, Chapter II, sets an interim absorbed dose rate limit of 1 rad/day (0.01 Gy/day) to native aquatic organisms (see Appendix G for definitions of absorbed dose and the rad). To demonstrate compliance with this limit, absorbed dose rates to fish, crustacea (e.g., crayfish), and muskrats were calculated using the computer code CRITR2 (Baker and Soldat 1993). Fish and crustacea are considered to be primary aquatic organisms, those that reside in the aquatic ecosystem. Muskrats are considered to be secondary organisms, those that subsist on aquatic plants. Maximum and average concentrations of radionuclides measured in surface waters on and around the ORR are used to estimate dose rates from internal and external exposures. Internal dose rates are calculated using organism- and nuclide-specific bioaccumulation factors and absorbed energy fractions. External dose rates are calculated for submersion in water and irradiation from bottom sediments. Exposure to sediments is particularly meaningful for crawling or fixed organisms (such as crayfish and mollusks). Direct radiation doses from sediment are estimated from water concentrations using factors such as a geometry roughness factor, sediment deposition transfer factor, and nuclide-specific ground-surface irradiation dose factors. Table 8.5 lists average and maximum total dose rates to aquatic organisms from waterways at ORNL, the Y-12 Plant, and the ETTP.

At ORNL, doses to aquatic organisms are based on water concentrations at nine different sampling locations (see Table 8.5): Melton Branch (kilometer 0.2), WOC (kilometers 0.1, 2.6, and 6.8), First Creek, Fifth Creek, Raccoon Creek, Ish Creek, and Northwest Tributary. The results from these calculations indicate that absorbed dose rates to aquatic biota are less than 1 rad/day (0.01 Gy/day). The highest dose rate to fish, crustacea, and muskrats (based on maximum radionuclide concentrations in water) occurred at Melton Branch (MEK 0.2): 2E–2 rad/day (2E–4 Gy/day), 4E–3 rad/day (4E–5 Gy/day), and 7E-2 rad/day (7E-4 Gy/day), respectively. Even with maximum radionuclide concentrations at these locations, the absorbed doses were significantly less than the limit of 1 rad/day (0.01 Gy/day).

At the Y-12 Plant, doses to aquatic organisms were estimated from concentrations of radionuclides in water obtained from East Fork Poplar Creek at SWHISS 9422-1 (formerly Station 17), Bear Creek at BCK 4.55 (formerly Outfall 304), and Rogers Quarry discharge point S-19 (formerly Outfall 302). At Y-12, the highest dose rates to fish, crustacea, and muskrats (based on maximum radionuclide concentrations in water) occurred at SWHISS 9422-1: 8E–4 rad/day (8E–6 Gy/day), 4E–3 rad/day (4E–5 Gy/day), and 5E–1 rad/day (5E–3 Gy/day), respectively. The dominant radionuclide contributor to the muskrat dose was ^{228}Ra, a decay product of ^{232}Th, a naturally occurring radionuclide.

Similar analyses were conducted at the ETTP. The waterways evaluated were Mitchell Branch at K-1700, Poplar Creek at K-1007-B and K-1710, Clinch River at K-901-A, and East Fork Poplar Creek (kilometers 0.1 and 5.4). At K-901-A, the maximum dose rates to fish, crustacea, and muskrats were 1E–4 rad/day (1E–6 Gy/day), 3E–4 rad/day (3E–6 Gy/day), 5E–4 rad/day (5E–6 Gy/day), respectively. Even with maximum radionuclide concentrations at these locations, the absorbed doses were less than the limit of 1 rad/day (0.01 Gy/day).

Absorbed doses estimated from maximum radionuclide water concentrations determined on the ORR resulted in doses that were less than the 1 rad/day (0.01 Gy/day) limit prescribed in DOE Order 5400.5.

A pilot study of the proposed DOE standard, “Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota” was conducted using ORNL surface water data. The Radionuclide Biota Concentration Guide (RAD-BCG) calculator, a companion electronic calculational tool to the technical standard, was used to determine compliance with the proposed standard. The results of the pilot study indicated that the doses to aquatic organisms would be less than the 1 rad/day limit prescribed in DOE Order 5400.5.

8.1.4 Current-Year Summary

A summary of the maximum EDEs to individuals by pathway of exposure is given in Table 8.6. It is very unlikely (if not impossible) that any real person could have been irradiated by all of these sources and pathways for the duration of 1999;

Table 8.5. 1999 total dose rate for aquatic organisms (rad/day)[a,b]

Measurement location	Fish		Crustacea		Muskrat	
	Av	Max	Av	Max	Av	Max
ORNL						
Upstream locations						
White Oak Creek (WCK 6.8)	1E–5	3E–5	2E–5	4E–5	4E–6	1E–5
On-site stream locations						
Fifth Creek (FIFTHCK 0.1)	5E–5	5E–5	9E–6	9E–6	2E–4	2E–4
First Creek (1STCK 0.1)						
Northwest Tributary (NWTK 0.1)	1E–3	3E–4	2E–3	4E–5	7E–4	9E–4
Downstream locations						
Melton Branch (MEK 0.2)	4E–3	2E–2	9E–4	4E–3	2E–2	7E–2
White Oak Creek (WCK 2.6)	6E–4	2E–3	1E–4	3E–4	1E–3	5E–3
White Oak Lake/White Oak Dam (WCK 0.1)	6E–4	9E–4	2E–4	3E–4	2E–3	2E–3
Ish Creek (ICK 0.7)	2E–5	3E–5	3E–5	5E–6	4E–6	1E–5
Raccoon Creek (RCK 2.0)	1E–4	2E–4	4E–5	5E–5	3E–4	6E–4
Y-12 Plant						
On-site stream locations						
East Fork Poplar Creek (SWHISS 9422-1)	1E–4	8E–4	5E–4	4E–3	5E–2	5E–1
Bear Creek (BCK 4.55)[c]	2E–4	6E–4	9E–4	3E–3	1E–1	3E–1
Rogers Quarry (Outfall S19)[d]	1E–4	6E–4	3E–4	2E–3	1E–1	5E–1
Downstream location						
Bear Creek (BCK 0.6)	3E–5	4E–5	4E–5	6E–5	1E–4	1E–4
ETTP						
Upstream locations						
Poplar Creek (K-1710)	5E–6	9.E–6	4E–5	1E–4	2E–5	3E–5
East Fork Poplar Creek (EFK 0.1)	2E–5	3E–5	2E–5	3E–5	4E–5	4E–5
East Fork Poplar Creek (EFK 5.4)	7E–6	1E–5	1E–6	2E–6	3E–6	4E–6
On-site stream location						
Mitchell Branch (K-1700)	2E–5	4E–5	8E–5	2E–4	1E–4	2E–4
Downstream locations						
Poplar Creek (K-1007B)	2E–6	5E–6	3E–5	9E–5	9E–6	2E–5
Clinch River (K-901-A)	2E–5	1E–4	8E–5	3E–4	7E–5	5E–4

[a]Total dose rate includes the contribution of internally deposited radionuclides, sediment exposure (derived from water concentrations), and water immersion.
[b]To convert from rad/day to Gy/day divide by 100.
[c]Formerly NPDES Outfall 304.
[d]Formerly NPDES Outfall 302.

however, if someone were, that person could have received a total EDE of about 9 mrem (0.09 mSv): 0.7 mrem (0.007 mSv) from airborne emissions, 2 mrem (0.02 mSv) from drinking CRK 58 water, 4 mrem (0.04 mSv) from eating fish from CRK 16, 2.0 mrem (0.02 mSv) from fishing on Poplar Creek inside the ETTP, and 0.01 mrem (0.0001 mSv) from other water uses on Melton Hill Lake. This dose is about 3% of the annual dose [300 mrem (3 mSv)] from background radiation. If this person also was the person who received the highest EDEs from eating wildlife harvested on the ORR, that person could not have received an additional committed EDE greater than about 7 mrem (0.07 mSv).

DOE Order 5400.5 limits to no more than 100 mrem (1 mSv) the EDE that an individual may receive from all exposure pathways from all

Table 8.6. Summary of maximum potential radiation dose equivalents to an adult during 1999 and locations of the maximum exposures

Pathway	Location	Effective dose equivalent (mrem)[a]
Gaseous effluents:	Maximally exposed resident to	
Inhalation, immersion, direct radiation from ground, and food chains	Y-12 Plant	0.5
	ORNL	0.5
	ETTP	0.4
	ORR	0.7
Liquid effluents:		
Drinking water	Melton Hill Lake, CRK 58	1
Eating fish	Clinch River, CRK 16	4
Other activities	CRK 32	0.01
Eating deer		6.4[b]
Eating geese		0.6[c]
Eating turkey		0.06[d]
Direct radiation	Clinch River shoreline	0.4
	Poplar Creek (ETTP)	2.0

[a]1 mrem = 0.01 mSv.

[b]From consuming a hypothetical worst-case deer, a combination of the heaviest deer harvested and the highest measured concentrations of ^{137}Cs and ^{90}Sr found in released deer.

[c]From consuming two hypothetical worst-case geese, each a combination of the heaviest goose harvested and the highest measured concentrations of ^{137}Cs and ^{90}Sr in released geese.

[d]From consuming a hypothetical worst-case turkey, a combination of the heaviest turkey harvested and the highest measured concentration of ^{137}Cs in turkey.

radionuclides released from the ORR during one year. As described in the preceding paragraph, the 1999 maximum EDE could not conceivably have exceeded about 16 mrem (0.16 mSv), or about 16% of the limit given in DOE Order 5400.5. For further information, see Table G.2 in Appendix G, which provides a summary of dose levels associated with a wide range of activities.

The highest imaginable total collective EDE to the population living within a 50-mile (80-km) radius of the ORR was estimated to be about 30 person-rem (0.3 person-Sv). This dose is about 0.01% of the 264,000 person-rem (2640 person-Sv) that this population received from natural sources during 1999.

8.1.5 Five-Year Trends

Dose equivalents associated with selected exposure pathways for the years from 1995 to 1999 are given in Table 8.7. The variations in values over this 5-year period likely are not statistically significant. The dose estimates for direct irradiation along the Clinch River have been corrected for background.

8.1.6 Potential Contributions from Off-Site Sources

Four off-site facilities could contribute to radiation doses received by members of the public around the ORR. These facilities include a waste processing facility located on Bear Creek Road, a depleted uranium processing facility located on Kerr Hollow Road, a decontamination facility located on Flint Road in Oak Ridge, and a waste processing facility located on Gallaher Road in Kingston.

Table 8.7. Trends in total effective dose equivalent for selected pathways

Pathway	Effective dose equivalent (mrem)[a]				
	1995	1996	1997	1998	1999
All air	0.5	0.45	0.41	0.73	0.7
Fish consumption	0.9	1.2	0.96	2.3	4
Drinking water (Kingston)	0.15	0.32	0.40	0.19	0.16
Direct radiation (Clinch River)	1[b,c]	1[b,c]	0.25[b]	0.25[b]	0.25[b]
Direct radiation (Poplar Creek)	1[b]	1[b]	1[b]	1[b]	2[b]

[a]1 mrem = 0.01 mSv.

[b]These values have been corrected by removing the contribution of natural background radiation and by using International Commission on Radiological Protection recommendations for converting external exposure to effective dose equivalent.

[c]This is an overestimate of the potential dose because the source of the direct radiation was remediated during 1993 and 1994.

These facilities submit annual reports to demonstrate compliance with NESHAP regulations. These reports indicate that no individual located in the vicinity of the ORR should have received in EDE in excess of 2.0 mrem (0.020 mSv) because of airborne emissions from these facilities. When combined with doses that could have been caused by emissions from the ORR, no individual should have received an EDE in excess of EPA or DOE annual limits. No information was obtained about waterborne releases, if any, from these facilities.

8.1.7 Findings

The maximally exposed off-site individual could have received a 50-year committed EDE of about 0.69 mrem (0.0069 mSv) from airborne effluents from the ORR. This dose is below 10 mrem (0.10 mSv) per year, the limit specified in the Clean Air Act for DOE facilities. No individual EDE could have exceeded the 100-mrem/year (1.0-mSv/year) limit prescribed by DOE. The estimated collective committed EDE to the approximately 880,000 persons living within 50 miles (80 km) of the ORR was about 20 person-rem (0.20 person-Sv) for 1999 airborne emissions. This represents about 0.0076% of the 264,000 person-rem (2640 person-Sv) that the surrounding population would receive from all sources of natural radiation.

8.2 CHEMICAL DOSE

8.2.1 Drinking Water Consumption

As described in Sect. 7.4.2.2 (and summarized in Appendix H, Table H.2), only measured aluminum and iron surface water concentrations resulted in hazard quotient (HQ) values equal to or greater than 1 (HQs less than 1 are desirable). HQs equal to or greater than 1 for aluminum were observed in both upstream and downstream locations. Only at the downstream location (CRK 16) was an HQ greater than 1 estimated for iron. The derivation of the reference 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. Refer to Appendix H for a detailed description of the chemical dose methodology.

8.2.2 Fish Consumption

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, as described in Sect. 7.9.1.2 and summarized in 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 1 were calculated for mercury, Aroclor-1254, and Aroclor-1260. Only mercury resulted in an HQ greater than 1 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). Aroclor-1254 and Aroclor-1260 measured in catfish tissue collected from CRK 32 and CRK 16 also resulted in HQs greater than 1.

For carcinogens, intake/chronic daily intake (I/CDI) ratios greater than 1 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. 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). Refer to Appendix H for a detailed description of the chemical dose methodology.

I/CDI ratios greater than one were calculated for the intake of mixed PCBs found in catfish collected from downstream locations (CRK 32 and CRK 16).