III.B. Exposure Evaluation of the Clinch River and Lower Watts Bar Reservoir

> ATSDR evaluated past (Clinch River) and current exposures (Clinch River and LWBR) to radioactive contamination (based on environmental samples) that was released from X-10 via White Oak Creek. ATSDR evaluated future exposures to the Clinch River and the LWBR based on the current estimated exposure doses and the institutional and engineering controls that are in place for both of these watersheds. The highest exposure doses were estimated for people who frequently ate fish (1 to 2.5 fish meals a week) caught from the Clinch River near the mouth of White Oak Creek from 1944 to 1953. Doses were much lower for people who ate fewer fish or fished further downstream and for the other past and current exposure pathways evaluated in this public health assessment.

This section presents an overview of past, current, and future exposures to radioactive contaminants released to the Clinch River, and current and future exposure to radioactive contaminants released to the LWBR. An evaluation of potential public health hazards from likely exposures to White Oak Creek releases is presented in Section IV. Public Health Implications. ATSDR used the time periods and information presented below in its evaluation. Please note that because some studies are conducted simultaneously, the past and current time periods overlap slightly. The doses obtained from these studies are, however, based on different data. Therefore, even though the time periods overlap, the estimated *past* doses do not overlap with the estimated doses for *current* and *future* exposures.

- Past exposure: "Past" refers to the period from 1944 to 1991. For its evaluation of past exposures, ATSDR reviewed the Task 4 report and documents associated with the report. The Task 4 report is titled *Radionuclide Releases to the Clinch River from White Oak Creek on the Oak Ridge Reservation—an Assessment of Historical Quantities Released, Off-Site Radiation Doses, and Health Risks*. The complete project can be accessed through TDOH's Web site at http://www2.state.tn.us/health/CEDS/OakRidge/ORidge.html and a brief summary of the Task 4 report is provided in Appendix D.

- Current exposure: "Current" refers to the period 1988–2003. In evaluating current exposures and doses related to releases from White Oak Creek, ATSDR relied on data collected from 1988 to 1994 (as presented in its 1996 health consultation titled *Health Consultation for USDOE Oak Ridge Reservation: Lower Watts Bar Reservoir Operable Unit, Oak Ridge, Anderson County, Tennessee*) and on data collected from 1989–2003 from the Oak Ridge Environmental Information System (OREIS) (USDOE 1989–2003). A brief summary of the 1996 ATSDR health consultation on Lower Watts Bar Reservoir is provided in Appendix D.

- Future exposure: "Future" refers to exposures that occur after the present time period. ATSDR based its evaluation of future exposures on current doses and exposures related to releases from White Oak Creek, data on current contaminant levels in the LWBR and the Clinch River, consideration of the possibility that remedial activities could release radionuclides to White Oak Creek, engineering controls to prevent off-site contaminant releases, and institutional controls that are in place to monitor contaminants in the LWBR and the Clinch River. These institutional controls consist of the following: 1) prevention of sediment-disturbing activities in the Clinch River and LWBR; 2) DOE's annual monitoring of Clinch River and LWBR surface water, sediment, and biota; 3) DOE's monitoring of White Oak Creek releases; 4) TDEC's monitoring of public drinking water supplies in Tennessee under the Safe Drinking Water Act for EPA-regulated contaminants; and 5) TDEC–DOE Oversight Division's quarterly radiological monitoring of five public water supplies on the ORR and in its vicinity under the EPA's Environmental Radiation Ambient Monitoring System (ERAMS) program. Further, data show that because of remedial actions and preventive measures at X-10, physical movement of sediments from the area, and radiological decay, the radionuclide releases from White Oak Creek have decreased over time. Similarly, the concentrations of radionuclides in the water and along the shoreline have also decreased.

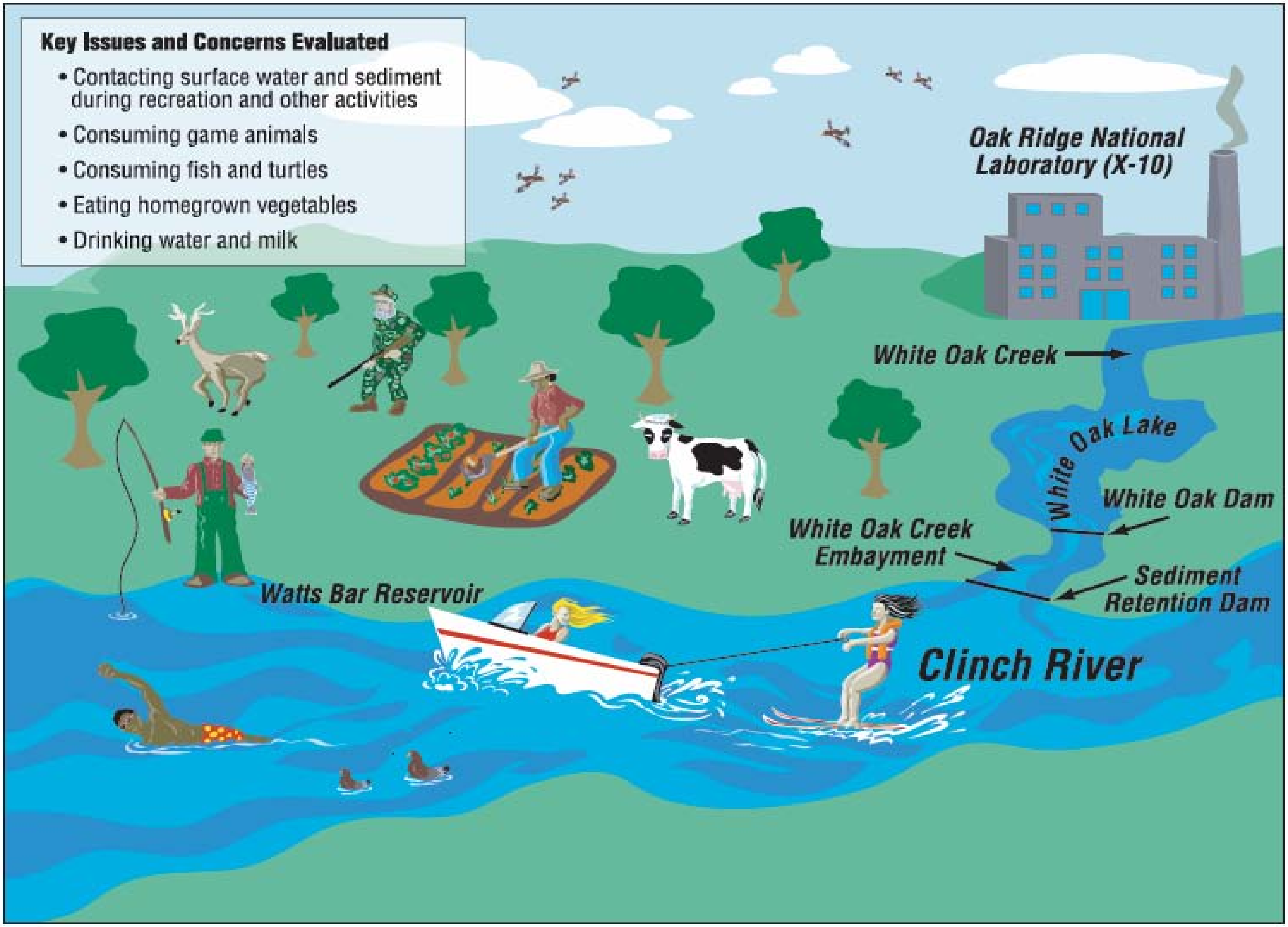
III.B.1. Possible Exposure Situations in the Clinch River and the Lower Watts Bar Reservoir Areas

People could come in contact with contaminants along the Clinch River and the Lower Watts Bar Reservoir via several different pathways. ATSDR analyzed radioactive contaminant data for surface water, sediment, and biota (aquatic and terrestrial) to determine whether the levels detected in these media might pose a past or current public health hazard. This evaluation looked at the level of contamination present, the extent to which individuals contact the contamination, and estimated doses to individuals coming in contact with the media under different exposure scenarios. ATSDR identified several exposure situations for the Clinch River and LWBR areas that required further evaluation. This PHA evaluates the following situations for exposures at the Clinch River, LWBR, or at both locations:

- Ingestion of drinking water
- External exposure from contact with water and sediment during recreational activities
- External contact with dredged sediment used as topsoil in home gardens
- Ingestion of locally produced milk and meats
- Ingestion of fish or local game animals
- Incidental ingestion of surface water during recreational activities

Exposure situations associated with radioactive contaminants released from White Oak Creek are evaluated in detail in the following discussion and depicted in Figure 20.

Figure 20. Possible Exposure Situations Along the Clinch River



To acquaint the reader with terminology and methods used in this PHA, Appendix A provides a glossary of environmental and health terms presented in the discussion. Additional background information is provided in appendices as follows: Appendix B summarizes detailed remedial activities related to the study area; Appendix C summarizes other public health activities at the ORR; Appendix D contains summaries of ATSDR, TDEC, and TDOH studies or investigations; Appendix E provides a table of Task 4 conservative screening indices (i.e., the calculated probabilities of developing cancer) for radionuclides in the Clinch River; Appendix F includes a discussion on risk; Appendix G presents responses to public comments; and Appendix H provides responses to peer reviewer comments.

III.B.2. Past Exposure (1944–1991)

TDOH's Task 4 Study

Wastes from historical X-10 operations were released to White Oak Creek, which travels south along the eastern border of the X-10 site, flows into White Oak Lake, over White Oak Dam, and into the White Oak Creek Embayment before meeting the Clinch River at Clinch River Mile (CRM) 20.8 (see Figure 3 and Figure 4). Radionuclides were released when creek flow eroded the contaminated bottom sediment of White Oak Lake and carried them into the Clinch River. Some of the upstream river sediment containing radionuclides was scoured and the transport of the suspended contaminated sediment contributed to the buildup of radionuclides in sediment further downstream. Prior to the impoundment of Melton Hill Dam in 1963, the particulate in the water column was usually deposited near CRM 14 (close to the mouth of Grassy Creek). This is an area where the river is wider and is influenced by the Watts Bar Reservoir. After 1963, however, the pattern of particulate deposition in sediment changed because of the controlled releases from Melton Hill Dam (Blaylock 2004).

In 1996−1999, TDOH's Task 4 team prepared the *Reports of the Oak Ridge Dose Reconstruction, Radionuclide Releases to the Clinch River from White Oak Creek on the Oak Ridge Reservation—An Assessment of Historical Quantities Released, Off-Site Radiation Doses, and Health Risks* (referred to as the "Task 4 report") to assess whether individuals visiting or living along the Clinch River area might have come in contact with harmful levels of radioactive materials in the past. Wastes generated at X-10 from 1944 to 1991 (the time frame covered in the

Task 4 report) included radionuclides in various chemical forms (solids and liquids). Specifically, the purpose of the Task 4 effort was to:

- Estimate the historical releases of radioactive materials from the X-10 processes to White Oak Creek.
- Review and evaluate the possible exposure pathways for the public who lived downstream from White Oak Creek along the Clinch River and the Tennessee River.
- From these potential exposure pathways, calculate both the radiation doses and risks associated with these exposures. Because historical records were not maintained to today's standards, the Task 4 team performed independent reviews of environmental monitoring reports and existing data on releases and also used mathematical models to estimate the radiation doses and the associated risks (ChemRisk 1999a).

Task 4 Screening Assessment

As an initial evaluation in 1996, the Task 4 team identified 24 radionuclides—americium 241, barium 140, cerium 144, cobalt 60, cesium137, europium 154, hydrogen 3, iodine 131, lanthanum 140, niobium 95, neodymium 147, phosphorus 32, promethium 147, praseodynium 143, plutonium 239/240, ruthenium 106, samarium 151, strontium 89, strontium 90, thorium 232, uranium 235, uranium 238, yttrium 91, and zirconium 95—that were released to the Clinch River via White Oak Creek from 1944 to 1991 (ChemRisk 1999a). The Task 4 team determined that a screening analysis would help focus its efforts on the most important radionuclides and on the ways that people could have been exposed to White Oak Creek radionuclide releases via the Clinch River. The Task 4 team used a risk-based screening process to calculate conservative human health risk estimates for reference individuals and target organs, assuming that exposure occurred between 1944 and 1991 (a period of up to 48 years, except where noted).[7] These risk estimates represented exposed individuals' increased likelihood of developing cancer—known as

> **Task 4 Phases**
>
> **Initial Assessment**
> Radionuclides released to White Oak Creek
> **24**
> ⇓
> **Screening Analysis**
> Radionuclides identified for further evaluation
> **8**
> ⇓
> **Supplemental Analysis**
> Radionuclides identified as the important contributors to dose and health hazards
> **4**

[7] For the purposes of the Task 4 study, a reference individual is a hypothetical or real unidentified person who resides in the area or who consumes contaminated foodstuffs from the area.

"excess lifetime cancer risk estimates." Because of the conservative assumptions used in calculating the estimates, the risk level would likely overestimate the public health hazard for exposed off-site populations. For comparison, the Task 4 team used an upper bound of 1 in 100,000 (1×10^{-5}) as the decision point, or minimal level of concern. This value was one-tenth of the ORHASP-recommended value of 1 in 10,000 (1×10^{-4}); thus, the value used by the Task 4 team was *more conservative* than the ORHASP-recommended value.

The same value can be presented in different ways:

0.0001
1.0E-04
1×10^{-4}
1/10,000
one in ten thousand

Through this screening process, the Task 4 team eliminated 16 out of 24 radionuclides released to the Clinch River from White Oak Creek because the estimated screening indices were below the minimal level of concern (1×10^{-5}). The eight radionuclides for which additional analysis would be necessary were cobalt 60 (Co 60), strontium 90 (Sr 90), niobium 95 (Nb 95), ruthenium 106 (Ru 106), zirconium 95 (Zr 95), iodine 131 (I 131), cesium 137 (Cs 137), and cerium 144 (Ce 144) (ChemRisk 1999a). Because the screening risk estimates for the swimming and irrigation pathways were below the minimal screening level for all 24 radionuclides, the team was able to eliminate these two exposure pathways (and therefore, consumption of locally grown crops) from further analysis. The team was also able to eliminate external exposure to dredged sediment, which only occurred in the Jones Island study area; the likelihood was low that individuals other than workers would have been exposed. The exposure pathways that required further evaluation were ingestion of fish, surface water, and meat and milk from cattle that grazed near the river, and external radiation from walking on shoreline sediment. Following this screening, the TDOH conducted a supplemental screening that included developing annual release amounts for the eight radionuclides and conducting a more comprehensive analysis of various exposure pathways.

Using its supplemental screening, the Task 4 team determined that four radionuclides (Cs 137, Co 60, Ru 106, and Sr 90) were more likely than the other four (Nb 95, Zr 95, Ce 144, and I 131) to cause adverse health effects to exposed off-site populations (ChemRisk 1999a). For more information on the screening process, see the brief summarizing the Task 4 report in Appendix D. For additional details and calculations used in the screening and supplemental screening processes in the Task 4 report, see Appendices 3A, 3B, and 4A of the document online at http://www2.state.tn.us/health/CEDS/OakRidge/WOak2.pdf.

Estimated Quantities of Radionuclides Released into White Oak Creek

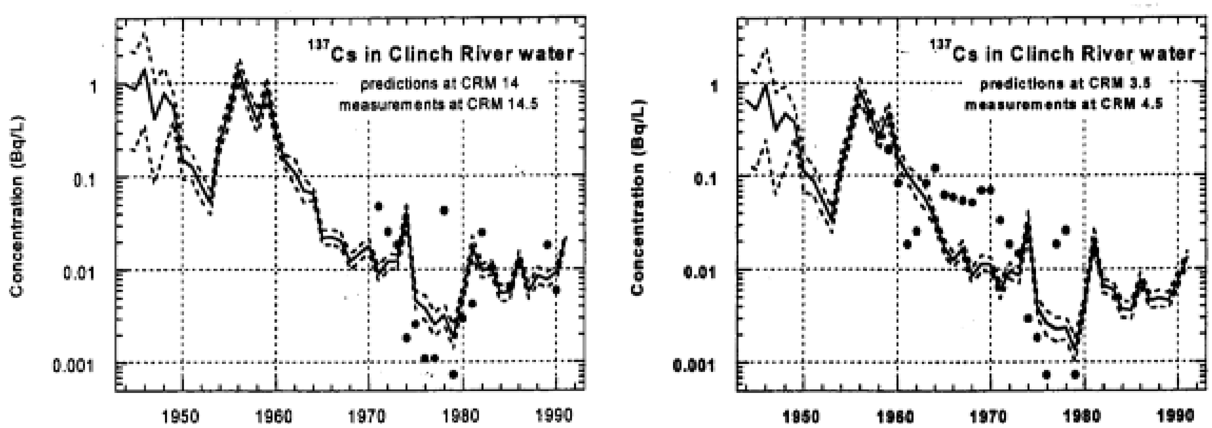
Because accurate environmental monitoring and sampling data were not available, the Task 4 team performed an in-depth evaluation to estimate the amount of radionuclides that flowed from X-10, over White Oak Dam, and to the Clinch River. Through this evaluation, the team derived annual estimates for the eight radionuclides of interest: Co 60, Sr 90, Nb 95, Ru 106, Zr 95, I 131, Cs 137, and Ce 144. In total, about 200,000 curies of radioactive material were released from White Oak Creek into the Clinch River between 1944 and 1991 (ChemRisk 1999a). Using this information, the team then performed mathematical modeling to estimate the annual average concentrations of the eight radionuclides in water and sediment at specified locations downstream of White Oak Creek. To calculate doses for Cs 137, Sr 90, Ru 106, and Co 60, the Task 4 team used—when available—actual measurements from the Clinch River water it collected 1960–1990 at CRM 14.5 (K-25 Grassy Creek) and at 4.5 (Kingston Steam Plant). For the remaining radionuclides and for time periods when data were unavailable, the Task 4 team used modeling to estimate the historical radionuclide concentrations in Clinch River water. Limited available monitoring data were used to calibrate the results of the team's modeling efforts. For more information on the Task 4 team's modeling efforts, please refer to Section 6 of the Task 4 report, which is available at http://www2.state.tn.us/health/CEDS/OakRidge/WOak1.pdf.

> Releases of radionuclides to White Oak Creek from 1955 to 1959 were believed to account for the highest concentrations of Cs 137 that reached the Clinch River.
>
> Concentrations of radionuclides in the Clinch River have decreased over time.

Of the radionuclides released to White Oak Creek, the greatest health hazards were believed to be associated with Cs 137. Cs 137 releases along White Oak Creek were highest from 1955 to 1959. The high Cs 137 releases during those years resulted when the creek flow eroded the contaminated bottom sediment of White Oak Lake after the lake was drained in 1955. This was particularly true during the heavy rains in the winter and early spring of 1956. Currently, the elevated levels of Cs 137 are limited to the subsurface sediment buried in the deep channels of the LWBR.

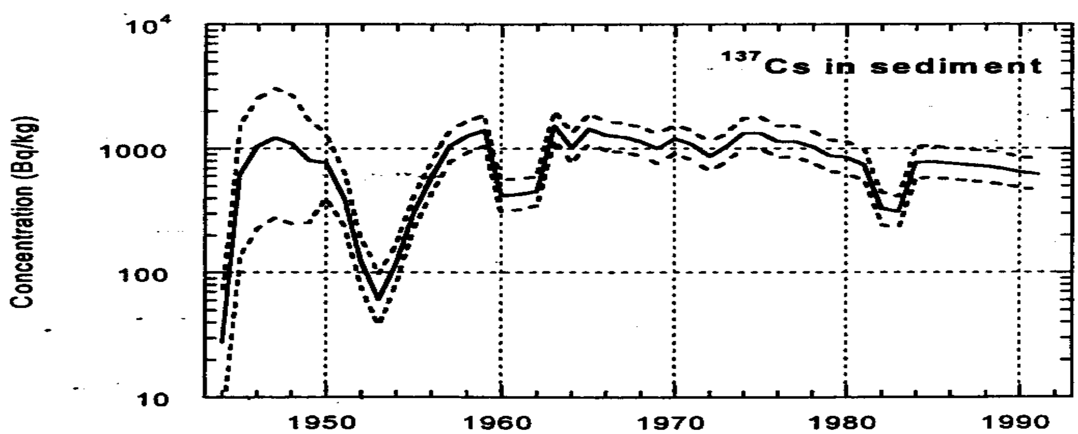
Because of remedial actions and preventive measures at X-10, physical movement of sediments from the area, and radiological decay, the radionuclide releases from White Oak Creek have decreased over time and the concentrations of radionuclides in the water and along the shoreline have decreased as well. For example, Cs 137 in the Clinch River water near CRM 14 and CRM 3 has decreased by about a factor of 100 (see Figure 21). Because Clinch River sediments are not as actively exchanged as the river water itself (i.e., the sediments do not mix as much as the surface water), the Cs 137 in sediment at CRM 14 has decreased as a function of its half-life (see Figure 22) (ChemRisk 1999a).

Figure 21. Comparison of Predicted Annual Average Concentrations of Cs 137 in Water



Comparison of predicted annual average concentrations of Cs 137 in water with measured annual average concentrations. Comparisons are shown for predictions at CRM 14 with measurements at CRM 14.5 (left) and for predictions at CRM 3.5 with measurements at CRM 4.5 (right). Solid lines indicate the central values of the predictions; dashed lines indicate predicted 95% confidence bounds based only on uncertainty in release estimates. Dark circles indicate measured values.
Source: ChemRisk 1999a

Figure 22. Annual Average Cs 137 Concentrations in Shoreline Sediment



Example of predicted annual average concentrations of Cs 137 in shoreline sediment for CRM 14. The solid line indicates the central values of the predictions; dashed lines indicate predicted 95% confidence bounds based only on the uncertainty in the release estimates.

Source: ChemRisk 1999a

Task 4 Exposure Pathways Evaluation

> The greatest exposures to White Oak Creek releases occurred between 1944 and 1963.

For the eight radionuclides (Cs 137, Co 60, Ru 106, Sr 90, Nb 95, Zr 95, Ce 144, and I 131) requiring additional analysis, the Task 4 team conducted an in-depth exposure pathway evaluation of ingestion of fish, surface water, and meat and milk from cattle that grazed near the river, and external radiation from walking on shoreline sediment. Table 9 presents the past exposure pathways, the reference populations, and the radionuclides studied in the pathway exposure evaluation. Individuals were exposed over the entire 48-year study period, except for certain years pertaining to drinking water, external exposures, and meat and milk ingestion (excluded years are noted below in the table). For the fish consumption pathway, the Task 4 team considered three categories of fish consumers to account for differences in the amount of fish that individuals consume (Category I: 1 to 2.5 fish meals/week, Category II: 0.25 to 1.3 fish meals/week, and Category III: 0.04 to 0.33 fish meals/week)[8] (ChemRisk 1999a).

Table 9. Past Exposure Pathways Evaluated in the Task 4 Report

Exposure Pathway	*Reference Individuals*	*Radionuclide*
Fish ingestion	Adults eating fish from the Clinch River that were caught near Jones Island, K-25/Grassy Creek, Kingston Steam Plant, and the city of Kingston	Cs 137, Ru 106, Sr 90, Co 60
Drinking water ingestion*	Adult visitors to K-25 and the Kingston Steam Plant Adults and children in the city of Kingston	Cs 137, Ru 106, Sr 90, I 131
Meat ingestion*	Adults eating meat from cattle that had access to the Clinch River	Cs 137, Ru 106, Sr 90, Co 60
Milk ingestion*	Adults and children drinking milk from cows that had access to the Clinch River	Cs 137, Ru 106, Co 60, I 131
External exposure*	Adults walking along the shoreline on Jones Island, K-25/Grassy Creek, Kingston Steam Plant, and the city of Kingston	Cs 137, Ru 106, Sr 90, Co 60, Ce 144, Zr 95, Nb 95

* Drinking water exposures occurred from 1944 to 1991, except at the city of Kingston (1955–1991) and the Kingston Steam Plant (1954–1989). External exposures occurred from 1944 to 1991, except at Jones Island (1963–1991). Meat and milk ingestion exposures occurred from 1944 to 1991, except at Jones Island (1963–1991).

[8] A meal was defined as 0.1 to 0.3 kilograms (roughly 3.5 to 10.5 ounces) per meal for males and 0.08 to 0.25 kilograms (roughly 2.8 to 8.8 ounces) per meal for females.

The Task 4 study covered a broad area along the Clinch River, from the mouth of White Oak Creek to the confluence of the Clinch and Tennessee Rivers. Because exposure situations might vary with the differences in topography and land uses at various sections of the river, the Task 4 team divided the area of study into four segments. Table 10 gives the CRM range, location, and exposure situations evaluated for each segment.

Table 10. Locations and Exposure Scenarios Considered in the Task 4 Study

*Clinch River Mile**	*Location*	*Exposure Scenarios*	
		Pathway†	*Years of Exposure*
21 to 17	Jones Island	• Ingestion of fish • Ingestion of meat and milk • External exposures to shoreline sediment	1944 to 1991 1963 to 1991 1963 to 1991
17 to 5	K-25/Grassy Creek	• Ingestion of fish • Ingestion of drinking water • Ingestion of meat and milk • External exposures to shoreline sediment	1944 to 1991 1944 to 1991 1944 to 1991 1944 to 1991
5 to 2	Kingston Steam Plant	• Ingestion of fish • Ingestion of drinking water • Ingestion of meat and milk • External exposures to shoreline sediment	1944 to 1991 1954 to 1989 1944 to 1991 1944 to 1991
2 to 0	City of Kingston	• Ingestion of fish • Ingestion of drinking water • Ingestion of meat and milk • External exposures to shoreline sediment	1944 to 1991 1955 to 1991 1944 to 1991 1944 to 1991

* The river mile is the distance from the mouth of the river. That is, Clinch River Mile 0 is where the Clinch River empties into the Tennessee River. White Oak Creek enters the Clinch River at Clinch River Mile 20.8.

† The Task 4 report originally included ingesting produce, swimming, irrigating, and contacting dredged sediment (varying by segment) as pathways in its screening analysis. Given the results of its initial screening, however, the Task 4 team eliminated these pathways from further evaluation.

The Grassy Creek area includes portions of the Clinch River from Clinch River Mile (CRM) 17 to CRM 14. The mouth of Grassy Creek empties into the river at CRM 14.5; a tenth of a mile below that (CRM 14.4) is the potable water intake for the K-25 Gaseous Diffusion Plant. Associated with the intake was a combined filtration plant (using sand as the filter) and water storage facility that supplied potable water to the K-25 facility. Any radiological contaminants in the water intake for K-25 originated from the releases from White Oak Creek, approximately 7 miles upstream from the K-25 intake area. ATSDR learned about issues related to the K-25 intake from members of the public at meetings held by the Exposure Evaluation Work Group

(EEWG), formerly known as the Public Health Assessment Work Group (PHAWG), as well as from the community concerns database maintained by ATSDR and discussions with DOE. ATSDR also learned from a community member that the K-25 intake was used at the J.A. Jones Construction Camp, which is locally referred to as the Happy Valley Settlement. The Happy Valley Settlement was first occupied in 1943 and 1944, primarily by construction workers, some family members, and a few concessionaires. At its peak in 1945, Happy Valley had more than 8,700 residents, including an estimated 5,600 workers and 3,100 dependents (Keith and Baker 1946; Prince 2003). Most people began leaving the settlement between the spring and fall of 1945, as construction of gaseous diffusion facilities was completed or permanent housing became available. Even so, anecdotal reports by an Oak Ridge community member suggest that the settlement might have been occupied as late as 1948. Because of possible exposure to contaminants in drinking water at Happy Valley, ATSDR conducted a separate evaluation for the Happy Valley community for the years the community was in existence.

Task 4 and ATSDR Estimated Radiation Doses

Radionuclides along the Clinch River could have contributed to an individual's internal or external dose of radiation. *Internal exposures* were due to internally-deposited radionuclides from ingestion of radionuclides in fish, meat, milk, and surface water. The main source of *external exposure* to the Clinch River was through exposure to shoreline sediment along the river.

The Task 4 team derived radiation doses for each pathway of interest to estimate the amount of radiation that a potentially exposed individual might have received.[9] In deriving the doses, the team used the International Commission on Radiological Protection's (ICRP) critical organ concept of dose limitation. ICRP's method limits dose (and long-term effects) to the critical organ—the organ most sensitive to or receiving the highest radiation dose following an intake of radioactive material. Using this approach, the cumulative dose to an organ from internally-deposited radionuclides is estimated separately from the dose attributed to external exposure (see text box).

The Task 4 team calculated the 95% confidence intervals for the cumulative organ dose equivalents. The 95% confidence interval is defined as the range of values, centered on the

[9] The Task 4 team's estimated organ doses, estimated cancer risk coefficients, and associated uncertainties and sensitivities of variables are reported in chapters 13 and 14 of the Task 4 study (ChemRisk 1999a).

estimated mean, within which there is a 95% probability that the true mean will actually fall.[10] The distributions from which the upper and lower confidence limits for each variable are obtained are based on the individual sets of measured data. For internal doses from ingestion, the Task 4 team considered exposure to Cs 137, Sr 90, Co 60, and Ru 106 and estimated dose factors for 22 organs for an adult; the team assessed exposure to I 131 and estimated thyroid doses for a child. The Task 4 team used different methods for estimating dose factors depending on the amount and quality of information available for each radionuclide (ChemRisk 1999a). For external exposures, the team evaluated the following seven radionuclides: Cs 137, Co 60, Ru 106, Zr 95, Nb 95, Sr 90, and Ce 144. The Task 4 team assumed that people were exposed for the entire study period of 48 years (1944 to 1991), except (as noted in Table 10) for a 29-year exposure duration associated with external exposure and ingestion of meat and milk at Jones Island, a 36-year exposure duration for drinking water at the Kingston Steam Plant, and a 37-year exposure duration for drinking water at the city of Kingston.

Using the 50th percentile value of the uncertainty distribution, ATSDR summarized the Task 4 organ doses for the bone, lower large intestine, red bone marrow, breast, and skin locations. The 50th percentile (central) values represent the medians of organ doses. ATSDR selected these organs because the contaminants of concern—particularly Sr 90 and Cs 137—tend to concentrate in these organs. ATSDR uses the central values because they provide the most realistic doses for potential past exposures to radionuclides in the Clinch River. Central estimates are used because they describe the risk or dose for a typical, realistic individual. When considering central estimates, half of the potential doses will fall above, and half will fall below the estimate. Therefore, an individual's actual dose would most likely be closer to the central value than to the high or low end of the dose estimate range. Further, ATSDR's external reviewers, who evaluated documents associated with the Oak Ridge Dose Reconstruction, recommended emphasizing the central estimate rather than the upper and lower bounds of the dose distribution.

ATSDR focused its evaluation on two potential exposure locations—Jones Island and the city of Kingston (see Table 11). ATSDR narrowed its evaluation to these two locations because Jones

[10] The confidence intervals are based on the assumption that the variable is normally or log-normally distributed in the population under consideration. Lognormal distributions are often used to describe the distribution of a variable that cannot become negative.

Table 11. Summary of Estimated Organ-Specific Doses and Whole-Body Doses for Each Past Radiation Exposure Pathway and the Estimated Lifetime Organ-Specific Doses and Lifetime Whole-Body Doses From All Past Radiation Exposure Pathways

Exposure Pathway	*Location‡*	*Organ-Specific Radiation Dose (mrem over 48 years)* «*					*Whole-Body Dose† «*	
		Bone	*Lower Large Intestine*	*Red Bone Marrow*	*Breast*	*Skin*	*Annual (mrem per year)*	*Lifetime (mrem over 70 years)*
Fish ingestion	Jones Island	810	570	600	240§	310	3.4	238.6
	Kingston	96	64	65	30§	35	0.4	27
Drinking water ingestion	K-25/ Grassy Creek	110	81	46	2.1	2.4	0.3	24
	Kingston	3.5	6.2	1.7	0.12	0.14	<0.01	1.4
Meat ingestion	K-25/ Grassy Creek	1.4	2.1	0.81	0.31	0.31	<0.01	0.6
Milk ingestion	K-25/ Grassy Creek	0.84	0.13	0.42	0.046	0.048	<0.01	0.1
External radiation (walking on sediment) ¶	Jones Island	12	7.1	7.7	9.0	10	0.1	3.6
	Kingston	50	29	32	37	47	0.2	14.8
Estimated Committed Equivalent Doses (over 70 years) **		Less than 1,600 mrem	Less than 1,200 mrem	Less than 1,200 mrem	Less than 500 mrem	Less than 700 mrem	4††	278‡‡

* Data were derived from ChemRisk 1999a—Tables 13.3, 13.4, 13.5, and 13A.8. The organ-specific radiation doses are the 50th percentile (central estimate) as reported by the Task 4 authors for individuals exposed during the entire study period (48 years), except for specific years that were not included for certain areas (see Table 10).

« To compare the doses in the Task 4 report to the doses in this table, 1,000 mrem is equal to 1 centisievert (cSv). For example, 810 mrem (organ-specific radiation dose to the bone for fish ingestion at Jones Island) divided by 1,000 would equal 0.81 cSv—the same value presented in Table 13.3 of the Task 4 report.

† ATSDR approximated the annual (1-year) whole-body dose for each pathway by applying weighting factors (presented in Table 6) to Task 4's estimated 50th percentile organ-specific doses, adjusting for a 1-year exposure, and summing the adjusted organ doses across each pathway. ATSDR approximated the lifetime (70-year) whole-body dose for each pathway by adjusting the doses for a 70-year exposure and summing the adjusted doses for each pathway.

‡ The location represents the locations along the Clinch River of maximum exposure for each exposure pathway.

§ Doses are for females only; doses were too low to be significant in males.

¶ The doses are based on exposure to shoreline sediments.

** As a conservative measure, ATSDR estimated the committed equivalent doses for individuals who could have been exposed via all of the pathways and at all of the locations described above. To approximate a committed equivalent dose to an organ over 70 years, ATSDR summed the organ-specific radiation doses from the Task 4 report—based on up to 48 years of exposure—divided by 48, multiplied by 70 years, and rounded up.

†† ATSDR derived the total annual whole-body dose over a lifetime by summing the annual whole-body doses for each pathway.

‡‡ ATSDR derived the committed effective dose to the whole body by summing the equivalent doses for each organ using ICRP methodology.

Island is the closest land mass to the mouth of White Oak Creek and the city of Kingston is the closest large city downstream of the creek before the confluence of the Clinch River and Tennessee River. (For certain pathways, doses at K-25/Grassy Creek are presented as the location of maximum exposure.)

Weighting factors (explained on page 68) are used to convert an organ dose equivalent to a committed effective dose for the whole body that is lower than the organ dose. The committed effective dose is obtained by multiplying the organ dose by the weighting factor. For example, a 5 mrem dose to the thyroid would be multiplied by the weighting factor 0.05 to yield 0.25 mrem whole-body dose. For its evaluation, ATSDR applied weighting factors to the Task 4 organ doses and summed the adjusted organ doses across pathways to derive the annual and whole-body doses for each pathway. Then, ATSDR summed the annual and whole-body dose for each pathway to derive the total annual dose to the whole body and the *committed effective dose* to the whole body over 70 years. ATSDR also summed the organ doses to derive a *committed equivalent dose* to an organ over a 70-year (lifetime) exposure. When deriving the committed equivalent dose to an organ, ATSDR adjusted the Task 4 organ doses from a 48-year exposure (except in cases noted in Table 10) to a 70-year exposure so that ATSDR could compare these doses to health guidelines for radiation exposures to the public.

Table 11 presents the organ-specific and whole-body doses for all pathways of interest. As shown in Table 11, the maximum annual whole-body dose from all exposure pathways of interest is 4 mrem. This dose is about 2% of the 360 mrem that the average U.S. citizen receives each year from *background radiation* (i.e., levels typically found in the environment and in sources from human activities and products). About 300 mrem of background radiation is the amount of radiation to which a member of the general population is exposed from natural sources. These sources include terrestrial radiation from naturally occurring radionuclides in the soil, cosmic radiation originating from space, and naturally occurring radionuclides deposited in the human body. The remaining 60 mrem of background radiation results from sources related to human activities and products, such as medical and dental x-rays (Nuclear Energy Institute 2003). Of the 22 organs evaluated, the Task 4 authors predicted that the bone surface received the highest dose of radiation from any of the exposure pathways. The higher doses to the bone reflect the additional contribution from Sr 90.

After its review of Task 4 organ-specific doses and ATSDR-derived lifetime and whole-body doses, ATSDR determined that exposures to radionuclides by way of fish ingestion, water ingestion, and external radiation were more likely than the other pathways to result in higher radiation exposures in off-site populations. For comparison, doses from ingesting meat and milk were more than 1,000 times less than doses from eating fish (see Table 12). These calculated doses have been screened against the comparison values found in Table 22 of Section IV. Public Health Implications.

Table 12. Ratio of Adult Organ-Specific Radiation Doses Relative to Ingestion of Fish Caught Near Jones Island

Pathway†	*Location‡*	*Ratio of Radiation Dose**				
		Bone	*Lower Large Intestine*	*Red Bone Marrow*	*Breast*	*Skin*
Fish ingestion	Jones Island	1.0	1.0	1.0	1.0§	1.0
	Kingston	0.12	0.11	0.11	0.13	0.11
Drinking water ingestion	K-25/ Grassy Creek	0.14	0.14	0.08	0.01	0.01
	Kingston	<0.01	0.01	<0.01	<0.01	<0.01
Meat ingestion	K-25/ Grassy Creek	<0.01	<0.01	<0.01	<0.01	<0.01
Milk ingestion	K-25/ Grassy Creek	<0.01	<0.01	<0.01	<0.01	<0.01
External radiation (walking on sediment)¶	Jones Island	0.01	0.01	0.01	0.04	0.03
	Kingston	0.06	0.05	0.05	0.15	0.15

* The fish consumption dose used to calculate the ratio was the 50th percentile dose received by the maximally exposed individuals who consumed fish caught near Jones Island over the 48-year exposure.

† The pathway presented represents the maximally exposed category.

‡ When doses for two areas are given for the same pathway, ATSDR compared the highest dose to fish doses.

§ Doses are for females only; doses were too low to be significant in males.

¶ The doses are based on exposures from walking along the shoreline.

ATSDR discusses the fish ingestion, water ingestion, and external radiation exposure pathways below.

Fish Ingestion

The highest radiation dose associated with radionuclide releases to the Clinch River was from **frequent consumption of fish** (1 to 2.5 meals per week) caught near the mouth of White Oak Creek. The doses were much lower for other pathways and for individuals who ate fewer fish or caught fish further downstream.

The highest radiation doses were associated with eating fish taken from the Clinch River near Jones Island between 1944 and 1991. Doses were much lower for all other pathways (see Table 11 and Table 12). The Task 4 report's estimated organ doses

- to the bone,
- to the lower large intestine,
- to the red bone marrow,
- to the breast, and
- to the skin

from eating fish were at least 6 times greater than the radiation doses to these same organs from eating meat, drinking water and milk, and external radiation (Table 12). Likewise, ATSDR's derived annual whole-body and committed equivalent doses from eating fish were at least 10 times more than any of the other exposure pathways (Table 11).

The highest organ doses of radiation from fish consumption were estimated for the bone surface (810 mrem for males and 600 mrem for females, central values), and the lowest organ doses were estimated for the skin (310 mrem for males and 230 mrem for females, central values). Despite these differences, the organ doses varied by a factor of only 2 to 3 for males and 3 to 4 for females. This similarity between doses reflects the contribution of Cs 137 to organ doses. Cs 137 distributes rather uniformly throughout the body of the person eating the fish, and therefore, there was little difference among the various organ doses. It should be noted that because different organs are believed to have different sensitivities to radiation-induced cancer, the organ with the highest dose is not necessarily the organ with the highest probability of developing cancer.[11]

The dose for fish consumption depended on how often people ate fish and the area of the Clinch River where the fish were taken. The highest doses were received by individuals who consumed 1 to 2.5 fish meals per week and caught their fish near Jones Island, close to the mouth of White Oak Creek. The estimated annual whole-body dose of 3.4 mrem from eating frequent meals of fish caught near Jones Island was less than 1% of the average annual background dose of 360 mrem for a U.S. citizen. Doses were much lower for individuals who ate fewer fish or caught their fish further downstream from White Oak Creek and Jones Island. For example, organ-specific and whole-body doses for people who ate fish caught near Kingston were 8 times lower than doses from eating fish caught near Jones Island (see Table 12). People who ate fish caught near Kingston received an estimated annual whole-body dose of 0.4 mrem, which is 900 times less than the average annual background dose of 360 mrem for a U.S. citizen.

Drinking Water Ingestion

In Table 11, ATSDR summarizes radiation doses for drinking water at K-25/Grassy Creek (CRM 17 to 5) and the city of Kingston (CRM 0), located downstream from the mouth of White Oak Creek. These doses are from the Task 4 team's evaluation of drinking filtered, treated Clinch River water. Water from the Clinch River can travel up the Tennessee River when the Clinch River's flow is greater than the Tennessee River's flow. As a result of this backflow, the city of Kingston could receive Clinch River water (ChemRisk 1999a). The Task 4 team estimated 1) the amount of radiological contamination resulting from Clinch River backflow possibly entering the Kingston water intake and 2) the effect of water treatment on the drinking water (ORHASP 1999). The estimated organ-specific and whole-body radiation doses received from drinking water from the Clinch River were much lower than the radiation doses received from eating Clinch River fish. For example, the doses to the bone, lower large intestine, red bone marrow, breast, and skin from drinking Clinch River water were at least 7 times lower than the doses to those same organs from eating Clinch River fish. The highest annual whole-body dose from

[11] Because the risk level associated with iodine was below the screening level and none of the other radionuclides are associated with effects on the thyroid, the Task 4 team did not further evaluate the effects on this organ (ChemRisk 1999a).

drinking water of 0.3 mrem was estimated for K-25/Grassy Creek. This annual whole-body dose is more than 1,000 times less than the background dose of 360 mrem that the average U.S. citizen receives each year. Lower doses were associated with drinking water further downstream at the city of Kingston. Organ-specific doses from drinking city of Kingston water were at least 13 times less than the doses estimated for K-25/Grassy Creek drinking water.

In addition to the Task 4 team's analysis of exposure to X-10 contaminants via the K-25 water intake, ATSDR conducted a separate analysis of exposure of residents living in the Happy Valley settlement. In its evaluation, ATSDR derived whole-body doses for hypothetical residents of Happy Valley who drank water from the K-25 intake. Most information about Happy Valley indicates that workers and their families occupied the settlement between late 1943 and 1946. Anecdotal reports suggest, however, that some workers stayed on through 1948. Given the uncertainty about the actual time frame in which Happy Valley was occupied—and the duration of possible exposure—ATSDR overestimated the likely exposure period by conservatively assuming that Happy Valley residents could have been exposed over a 7-year period, from 1944 to 1950. Conservative assumptions such as this create a protective estimate of exposure, which allows ATSDR to evaluate the likelihood, if any, that the K-25 drinking water containing radionuclides could cause harm to Happy Valley residents.

ATSDR did not identify any Clinch River monitoring data for radionuclides covering the period when Happy Valley was used as a housing area. In the absence of historical monitoring data, ATSDR used the 50th percentile of the modeled radioactivity concentrations in the Grassy Creek area of Clinch River as reported in the Task 4 report. ATSDR's highest annual radiological dose estimate at the K-25 water intake was about 14 mrem/year. ATSDR predicted that Happy Valley residents who lived at the settlement from 1944 to 1950 would have received a dose of 98 mrem over the 7-year period. The whole-body dose for drinking water at Happy Valley (from the K-25 intake) was about 2.5 times less than the doses estimated for fish consumption.

External Radiation (Walking on Sediment)

Radionuclides that had accumulated in the sediment deposited along the Clinch River were found in the top layer (averaging about 6 to 7 centimeters [cm], but varying between 2 and 15 cm) of sediment. The Task 4 team derived organ doses for people who might have incurred external exposure to radionuclides while walking on Clinch River shoreline sediment from 1944 to 1991 (except at Jones Island where years of exposure evaluated were 1963 to 1991; see Table 10). When estimating doses from external exposure, the team used dose-rate factors (dose per unit intake) as reported by the ICRP and modified these factors to consider the thickness of the contaminated sediment layer and the width of the Clinch River shoreline. The Task 4 team obtained the external doses by combining the concentrations of radionuclides in sediment with the dose-rate factors and the exposure parameters.

ATSDR focused its evaluation on those exposures occurring near Jones Island and the city of Kingston. Overall, the Task 4 organ doses from walking on sediments were at least 6 times lower than doses received from eating Clinch River fish caught at or near Jones Island. Individuals walking on sediment in the Kingston area were predicted to receive slightly higher doses than individuals at Jones Island. Upstream sediment containing radionuclides was likely dislodged by the water flow and contributed to the buildup of sediment farther downstream. Even so, the maximum annual whole-body dose from external radiation by walking on Kingston sediments (0.2 mrem) is over 1,000 times less than the radiation dose of 360 mrem that the average U.S. citizen receives from background radiation each year (see Table 11).

ATSDR's Review of the Task 4 Dose Reconstruction Report

As part of its involvement at the ORR, ATSDR convened a panel of technical experts to evaluate the study design, the scientific approaches, the methodologies, and the conclusions of the Task 4 report. ATSDR had the report reviewed to determine if it would provide a foundation for follow-up public health actions or studies, particularly ATSDR's congressionally mandated public health assessment of the ORR. The reviewers agreed that the overall design and scientific approach were appropriate. One reviewer commented that the methods and analysis plan "break new and important ground in the use of uncertainty analysis in environmental assessment." The reviewers also commented that the results were generally quite valid and consistent with earlier studies, and were applicable to public health decision-making as long as careful attention was given to the assumptions behind the estimates. Some issues with the team's report raised some concern among the reviewers; in their opinion, however, the report was well written and advanced the science of dose reconstruction.

III.B.3. Current and Future Exposure (Years After 1987)

Lower Watts Bar Reservoir (1988–Present and Future)

Background

The LWBR extends from the convergence of the Clinch River and the Tennessee River (about 22 river miles downstream of White Oak Dam) to the Watts Bar Dam (see Figures 4 and 11). Community members use the reservoir for recreational activities, such as boating and swimming. The LWBR is also a popular recreational fishing spot for area anglers—an estimated 10,000 to 30,000 anglers fish at the Lower Watts Bar Reservoir each year (ORHASP 1999). In addition, Kingston, Rockwood, and Spring City obtain drinking water from surface water bodies flowing into the Watts Bar Reservoir. During rare circumstances, reverse flow conditions could result in ORR contaminants backflowing into these water intakes. Kingston maintains a water intake on Watts Bar Lake, which is upstream from the Clinch River confluence on the Tennessee River at Tennessee River Mile (TRM) 568.4 (Hutson and Morris 1992; G Mize, Tennessee Department of Environment and Conservation, Drinking water program, personal communication re: Kingston public water supply, 2004). Although the intake is slightly upstream, water flow direction in this area is impacted by the Tellico and Fort Loudon Dams and releases through the Watts Bar Dam. Thus, during a rare occurrence where backflow conditions affect these dams, this intake could potentially receive ORR contaminants. Spring City obtains its water from an intake on the Piney River branch of Watts Bar Lake (Hutson and Morris 1992). The city of Rockwood receives its water supply from an intake on the King Creek branch of Watts Bar Lake (Hutson and Morris 1992; TDEC 2001, 2006b). Therefore, ORR contaminants could potentially affect these three intakes, but only during the rare occurrence of reverse flow conditions.

In March 1995, DOE released a proposed plan that called for leaving the contaminated deep sediment in place at the reservoir; deep sediment is generally considered inaccessible to the public, and the LWBR sediment—if left undisturbed—is not expected to pose a concern for public exposure (USDOE 1995a). Because the reservoir was used so widely, some community members expressed concern to ATSDR about possible exposure to contaminants in the water and sediment. The community questioned whether DOE’s proposed actions were sufficient to protect people who use the reservoir from exposure to these contaminants. Subsequently, these residents asked ATSDR to evaluate the potential health risks from exposure to the LWBR contamination and provide an independent opinion on whether DOE's selected remedial actions were adequate to protect public health. ATSDR prepared a health consultation in 1996 to respond to community concerns about potential hazards associated with contaminants in the water and deep sediments of the LWBR (ATSDR 1996). See Section II.F.1. in this document and the brief in Appendix D for more details on ATSDR's health consultation.

Since February 1991, the Watts Bar Interagency Agreement has set guidelines related to any dredging in Watts Bar Reservoir and for reviewing potential sediment-disturbing activities in the Clinch River below Melton Hill Dam, including Poplar Creek (Jacobs EM Team 1997b). Under this agreement, the Watts Bar Reservoir Interagency Working Group (WBRIWG) reviews permitting and other activities, either public or private, that could possibly disturb sediment, such as erecting a pier or building a dock (ATSDR 1996; Jacobs EM Team 1997b; USDOE 2003a). The WBRIWG consists of DOE, EPA, USACE, TDEC, and TVA because of their permit authority or their knowledge of the sediment contamination and how that contamination could impact the public if disturbed (Jacobs EM Team 1997b).

Permit coordination under the Watts Bar Interagency Agreement was established to allow TVA, USACE, and TDEC (the agencies with permit authority over actions taken in Watts Bar Reservoir) to discuss proposed sediment-disturbing activities with DOE and EPA before conducting the normal permit review process to determine if there were any DOE contaminants in the sediments. The coordination follows a series of defined processes as outlined in the agreement.

The basic process of obtaining a permit is the same for any organization or individual:

1. An application is completed and submitted to TVA/USACE/TDEC (depending on scope of activity);
2. if the proposed activity would occur within the Watts Bar Reservoir and its tributaries, the application is forwarded to the WBRIWG for review;
3. the WBRIWG reviews available data for the location involved or DOE collects any necessary existing data on sediment contamination;
4. if the location is considered to be uncontaminated or clean enough to pose no significant health risks, then the application is forwarded back to TVA/USACE/TDEC for their standard review process; and

5. if the location is considered to be contaminated and sediments may pose a health risk, DOE works with the applicant to determine how best to conduct the requested activity (assuming TVA/USACE/TDEC permit the action based on their own statutory program of review). The interagency agreement covers any potential sediment-disturbing activity (other than locations predetermined to be free of DOE-related contaminants) (Jacobs EM Team 1997b).

If dredging is necessary in an area with contaminated sediments, DOE will assume the financial and waste management responsibility that is over and above the costs that would normally be incurred. Dredging and subsequent disposal of sediments will take place in accordance with best management practices and in compliance with all state and federal laws regarding downstream impacts and disposal of hazardous or radioactive materials (Jacobs EM Team 1997b).

Environmental Monitoring Data for the Lower Watts Bar Reservoir

To address the community concerns, ATSDR evaluated environmental monitoring data for surface and deep channel sediment, surface water, and local biota collected from the LWBR by DOE and TVA during the 1980s and 1990s (Olsen et al. 1992; USDOE 1994b).[12] In addition to these data, ATSDR evaluated the institutional controls in place to monitor contaminants in the LWBR. These controls, which include measures to keep sediment in place and ongoing water monitoring, have helped to minimize the potential for human exposure to contaminants in sediment and water. Data on radionuclides that were transported downstream from the ORR by the LWBR in sediment, surface water, and fish are discussed below.

Sediment

Radionuclides (Table 13) were detected in the *surface* and deep *subsurface* layers of sediment in the LWBR. The surface samples were collected from shallow areas of the reservoir and the subsurface samples were collected from the deep river channels—beneath several meters of water and 40 to 80 centimeters of sediment. Samples collected from the surface layer contained Cs 137, Sr 89/90, and Co 60. Other radionuclides were also detected, but at much lower frequencies and concentrations. The highest concentration of Cs 137 in surface sediment was below 15 pCi/g, the screening value adopted by the Interagency Working Group. This value is

[12] Additional sources used by ATSDR's evaluation of the Lower Watts Bar Reservoir included a 1992 Clinch River Scoping Report and the data summary for the 1994 near-sediment characterization task for the Clinch River environmental restoration program.

Table 13. Maximum Radionuclide Concentrations in Lower Watts Bar Reservoir Sediment

Radionuclide	*Activity (pCi/g)*	
	Surface Sediment	*Subsurface Sediment*
Americium 241	0.168	0.30
Beryllium 7	0.417	Not reported
Cesium 137	10.31	58.35
Cobalt 60	0.34	1.21
Curium 242	0.021	Not reported
Curium 243/244	0.040	0.04
Curium 245/246	Not reported	0.06
Curium 248	Not reported	0.06
Europium 152	0.241	Not reported
Europium 154	0.072	Not reported
Potassium 40	30.36	Not reported
Plutonium 238	0.230	0.23
Plutonium 239/240	0.072	0.45
Plutonium 241	20.00	Not reported
Plutonium 242	0.07	Not reported
Strontium 89	2.30	Not reported
Strontium 90	0.90	3.30
Uranium 234	0.096	3.08
Uranium 235	0.08	0.37
Uranium 238	0.07	2.45

also below the soil screening value for Cs 137 used by ATSDR as adopted from NCRP's Report 129 (NCRP 1999).

Historical documents suggest that 2 to 5 times more strontium than cesium was released to the Clinch River between 1982 and 1992; however, higher concentrations of Cs 137 were detected in the top layers of sediment (Martin Marietta Energy Systems, Inc. 1993). Both cesium and strontium tend to bind to sediment; although, cesium binds more strongly to sediment, while strontium is released from sediment more readily under certain conditions. Cs 137, Co 60, and Sr 90 are the most common radionuclides detected in the *subsurface* sediment. The depth of the peak concentrations appears to vary with the location in the reservoir, the rate of sediment accumulation, and the type of sediment. In general, radionuclide concentrations were higher in the subsurface sediment than in the surface sediment (see Figure 23), and increased with depth within the subsurface sediment. The highest concentration of Cs 137 (58.35 pCi/g) was found in the deep river channel subsurface sediment at a depth of 15 to 33 inches (Olsen et al. 1992).

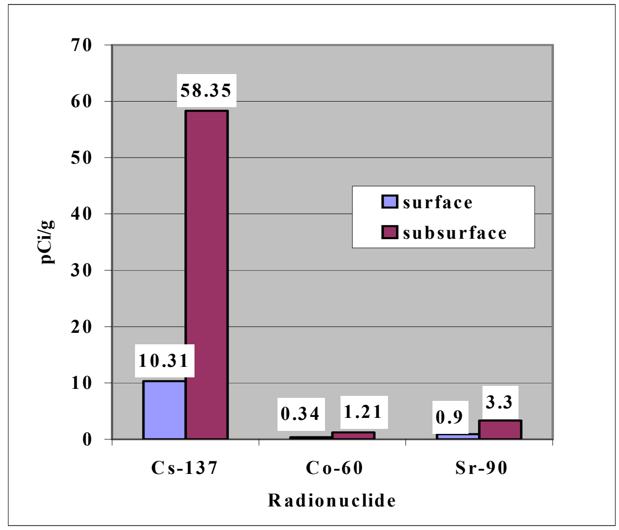


Figure 23. Radionuclide Concentrations in Surface Sediment vs. Subsurface Sediment

The vertical distribution of Cs 137 was strongly correlated to mercury (Hg) concentrations, with both exhibiting large subsurface maximum concentrations that coincided with their peak discharge histories. Sr 90 and Co 60 also existed in the subsurface sediment, but they were generally found at concentrations lower than Cs 137. Peak concentrations of Sr 90 and Co 60 do not strongly relate to peak concentrations of Cs 137 and they do not show a similar dramatic change in concentration with depth of sediment. Uranium concentrations were slightly higher than background concentrations for the region.

Surface Water

Some of the radionuclides released to White Oak Creek were suspended in the water. These radionuclides would be expected to decrease in concentration as they mixed with the surface water of the Clinch River before reaching the LWBR. To evaluate surface water sampling data for the reservoir, ATSDR reviewed TVA's 1991 sediment sampling report (TVA 1991) near major water intakes along the Tennessee River system reservoirs of the Watts Bar, Melton Hill, and Norris Dams; the *Phase 1 Data Summary Report for the Clinch River Remedial Investigation: Health Risk and Ecological Risk Screening Assessment* (Cook et al. 1992); and the *ORR 1992 Environmental Report* (Martin Marietta Energy Systems, Inc. 1993). Samples were collected from 29 locations at the reservoir and were analyzed for 11 radionuclides. ATSDR also reviewed water samples collected by TVA from the water intakes for the cities of Kingston, Spring City, and Rockwood (TVA 1991). Water sampling data consisted of both grab and composite samples. Composite samples were collected weekly, mixed in one container, and analyzed quarterly. Table 14 summarizes the surface water monitoring data for the Lower Watts Bar Reservoir.

Table 14. Maximum Radionuclide Concentrations in Lower Watts Bar Reservoir Surface Water

Radionuclide	*Maximum Concentration (pCi/L)*
Cesium 137	0.51
Cobalt 60	0.54
Hydrogen 3	853
Plutonium 238	0.0081
Plutonium 239	0.0049
Strontium 90	0.7
Uranium—total	0.13

Of the seven radionuclides detected, hydrogen 3 (H 3, also known as tritium) reached the highest concentration (853 pCi/L) in the collected surface water samples. According to the Task 4 report, over 90% of the total radioactivity released from White Oak Creek was in the form of H 3. Concentrations of the other radionuclides were less than 1 pCi/L. The likelihood of adverse health effects from H 3 is extremely low; the concentrations were well below the EPA's current maximum contaminant level (MCL) of 20,000 pCi/L of H 3, an amount that would produce a radiation dose of 4 mrem/year if ingested at 2 liters of water per day for a year.

> The MCL is the level of a contaminant that EPA allows in drinking water.

Drinking Water

The cities of Kingston, Spring City, and Rockwood have public drinking water supplies that draw water from the Tennessee River system. EPA's Safe Drinking Water Act (SDWA) requires all public water suppliers in Tennessee to monitor their water to ensure that it meets safe drinking water standards, or MCLs. The public water supplies for Kingston, Spring City, and Rockwood are monitored for substances that include 15 inorganic contaminants, 51 synthetic and volatile organic contaminants, and 4 radionuclides (USEPA 2004a). According to EPA's Safe Drinking Water Information System (SDWIS), the Kingston, Spring City, and Rockwood public water systems meet safe drinking water standards (USEPA 2004b). In 1996, TDEC's DOE Oversight Division started to participate in EPA's Environmental Radiation Ambient Monitoring System. Under this program, TDEC collects water samples from the Tennessee River system around Kingston and Spring City and analyzes them for radiological content. After its review of the public water supply monitoring and ERAMS results, ATSDR concludes that this water is safe for consumption and for other potable uses.

Fish

LWBR sediment and water quality have been affected by radioactive contaminants released from White Oak Creek to the Clinch River and the LWBR. Some of the radiological materials have long half-lives, and thus might remain in the environment for many years after being released. Even though radionuclide levels in surface water or surface sediment of the reservoir might be relatively low, certain contaminants can persist and accumulate in fish tissue. Fish are exposed to contaminants when they eat smaller fish or consume sediment that contains contaminants. Because of this process, larger and older fish can build up high levels of contaminants (TVA 1994).[13]

Limited data describing radionuclide concentrations in fish from the LWBR were available for ATSDR's review in 1995. The available data came from three sites along or downstream of the LWBR: Mid Watts Bar Reservoir (Tennessee River Mile 557.0), the LWBR north of the Watts Bar Dam (Tennessee River Mile 530.5), and the Upper Chickamaugua Reservoir (Tennessee River Mile 518.0 and below Watts Bar Dam). A combined total of 42 fish specimens were collected, coming from three different species—channel catfish, bluegill sunfish, and largemouth bass. All of the fish fillet samples were analyzed for Cs 137 and Co 60. Channel catfish samples with bones were also analyzed for Sr 90, since strontium is a bone-seeking radionuclide. As shown in Table 15, the radionuclides Cs 137, Co 60, and Sr 90 were detected at 0.16 pCi/g, 0.24 pCi/g, and 1.0 pCi/g, respectively.

Table 15. Maximum Radionuclide Concentrations in Lower Watts Bar Reservoir Area Fish

Radionuclide	*Maximum Concentration (pCi/g)*
Cesium 137	0.16
Cobalt 60	0.24
Strontium 90 (with bone)	1.00

[13] Available (though limited) sampling data of other biota (for example, turtles) were considered. No contaminants of concern were identified in these other biota samples collected at or near the Lower Watts Bar Reservoir.

Lower Watts Bar Reservoir Exposure Pathways and Estimated Radiation Doses

In its evaluation of exposures at the LWBR, ATSDR derived whole-body (committed effective) doses for hypothetical people who came in contact with radionuclides while walking on surface and dredged subsurface sediment, swimming or showering in surface water, drinking reservoir water, or consuming fish. When deriving the doses, ATSDR used *worst-case* exposure scenarios that relied on literature-based conservative (i.e., protective) assumptions for fish ingestion. The worst-case scenarios assumed that the most sensitive population (i.e., young children) was exposed to the highest concentration of radionuclides in sediment, surface water, or fish by the most likely exposure routes—inhalation, ingestion, dermal contact, and external radiation. Using these assumptions when estimating the hypothetical exposure doses likely overestimates the actual magnitude of exposure. These conservative assumptions create a protective estimate of exposure, which allows ATSDR to evaluate the likelihood, if any, that environmental media containing radionuclides could cause harm. ATSDR's estimated doses are summarized in Table 16 and in the discussion that follows.

Table 16. Estimated Whole-Body Doses for Current Lower Watts Bar Reservoir Exposure Pathways

Exposure Pathway		***Individual***	***Whole-Body Dose****	
			Annual (mrem per year)	***Estimated Committed Effective Dose (mrem over 70 years)***
Fish ingestion		Adult and child	6.0	420
Water ingestion		Child	0.25	17.5
External radiation	Contact with surface sediment	Child	15	1,050
	Contact with dredged channel sediment†		20	1,400
	Swimming or showering		0.05	3.5

* ATSDR's conservative assumptions used to estimate radiation doses likely created overestimates of the magnitude of the true exposure.

† ATSDR's evaluation of exposure to dredged sediment along LWBR also considered inhalation of, ingestion of, and dermal contact with contaminated dredged sediment.

Fish Ingestion

To determine if the consumption of contaminated fish could be detrimental to human health, ATSDR estimated doses for individuals who eat fish from the LWBR. Because uncertainty exists regarding how often people consume fish from the river and how large a portion might be eaten, ATSDR used worst-case scenarios that assumed an adult and child eat two 8-ounce meals of LWBR fish each week. ATSDR also assumed that the fish consumed contained the highest probable level of each of the primary radionuclides. For example, when evaluating the likelihood of health effects from strontium, ATSDR assumed that the fish fillet meal could include some bone because strontium is a bone-seeking radionuclide. For both an adult and a child, the dose estimated for the primary radionuclides were 6 mrem per year, or less than 420 mrem over 70 years for the committed effective dose. The annual whole-body dose of 6 mrem is more than 60 times less than the background dose of 360 mrem that the average U.S. citizen receives each year.

Water Ingestion

ATSDR examined the possibility that harmful health effects could result from exposure to the radionuclides detected in LWBR surface water. Local residents might be exposed to contaminants in unfiltered surface water through incidental ingestion of water when they use the reservoir for recreational activities, such as swimming. Residents of Kingston, Spring City, or Rockwood supplied with municipal water from the reservoir could potentially contact contaminants when they drink treated water from their taps or use it for other household purposes. That said, however, it is only possible for ORR contaminants to reach these intakes during the rare circumstances of reverse flow conditions resulting in contaminant backflow. Even so, potential exposures to harmful levels of radionuclides in the home from municipal water use are not expected—monitoring data indicate that the drinking water has met safe drinking water standards for radionuclides.

ATSDR evaluated exposure to surface water contaminants for a 10-year-old child who lives near the LWBR. ATSDR focused its evaluation on the child to consider the potential likelihood that this sensitive population might be exposed to surface water contaminants. ATSDR used conservative assumptions to examine how a child could be exposed to contaminants and how much contaminated water that child might ingest each day. In its evaluation, ATSDR assumed that the child drank unfiltered water. ATSDR's estimated dose to a child from drinking unfiltered water obtained from the LWBR is 0.25 mrem per year, or less than 17.5 mrem over 70 years for the committed effective dose. The annual whole-body dose of 0.25 mrem is about 1,440 times less than the background dose of 360 mrem that the average U.S. citizen receives each year.

External Radiation: Contact With Shoreline Sediment or Dredged Sediment

Relatively low levels of radioactive contaminants have been detected in the *surface* sediment of the LWBR (see Figure 23). People could be exposed to external radiation released from radionuclides in shallow areas of the reservoir or along the shore while swimming, fishing, or boating. The highest concentrations of radioactive contaminants are in subsurface sediment located in the deep river channels and are shielded by several meters of surface water and 15 inches or more of sediment on the river bottom—thus these areas with the highest concentrations are generally inaccessible to the public. In the unlikely event that these subsurface sediments might in the future be dredged from the river channel, ATSDR examined the potential exposure for a hypothetical individual who might come in contact with contaminants when walking on or handling sediment that was dredged from the deep river channel and deposited on the shoreline. ATSDR's committed effective doses to the whole body for individuals hypothetically exposed to external radiation from surface sediment or subsurface sediment were less than 1,050 mrem over 70 years and 1,400 mrem over 70 years, respectively.[14] These committed effective doses were based on annual doses of 15 mrem and 20 mrem for external radiation from surface sediment and subsurface sediment, respectively. These annual whole-body doses are more than 18 times less than the background dose of 360 mrem that the average U.S. citizen receives each year.

External Radiation: Swimming or Showering

Local residents might be exposed to contaminants in surface water through physical contact with water when they use the reservoir for recreational activities, such as swimming and boating. Residents of Kingston, Spring City, and Rockwood who are supplied with municipal water from the reservoir could also contact contaminants when showering or bathing. As previously noted, potential exposures to harmful levels of radionuclides in the home from municipal water use are not expected—monitoring data indicate that the drinking water has met safe drinking water standards for radionuclides.

[14] ATSDR determined that dredging might pose greater harm to human health from resuspension of sediment, which would subsequently increase the waterborne concentration of radionuclides in the Lower Watts Bar Reservoir and increase any potential exposure for employees involved in the dredging.

ATSDR used conservative, worst-case (i.e., protective) assumptions to examine how a 10-year-old child could be exposed to contaminants and how much contaminated water that child might contact each day. In its evaluation, ATSDR assumed that the child showered, or that the child swam in the reservoir, for up to 8 hours a day. In all likelihood, a child would spend far less time in either situation. Still, these assumptions enable ATSDR to calculate a conservative estimate of exposure that it uses to confidently evaluate the likelihood, if any, that contaminants in surface water could cause harm. Potential exposure was also evaluated for a person under similar circumstances who might live near the Watts Bar Lake for a lifetime (70 years). The dose to the whole body from external radiation via bathing or swimming is 0.05 mrem per year, or less than 3.5 mrem over 70 years for the committed effective dose. The annual whole-body dose is more than 7,200 times less than the background dose of 360 mrem that the average U.S. citizen receives each year.

ATSDR combined the annual doses for the surface water exposure pathways (i.e., 0.25 mrem from incidental ingestion and 0.05 mrem from contact via swimming or showering) to obtain the total dose from waterborne radioactive contaminants, which was below 1 mrem over 70 years—less than 1% of the typical background radiation dose that a U.S. citizen receives each year.

Clinch River (1989–Present and Future)

Environmental Data

To evaluate the current exposures and doses related to releases from White Oak Creek, ATSDR obtained data in electronic format from the Oak Ridge Environmental Information System (OREIS), detailed in Section II.F.4 of this document. The data received and analyzed by ATSDR covered the time period 1989–2003. Samples included surface waters collected from the LWBR and sediments from the associated shorelines. ATSDR also evaluated biota data that included fish, geese, and turtle samples. ATSDR analyzed samples for rivers in the watershed that included the Clinch River below Melton Hill Dam and the Tennessee River below the mouth of the Clinch River. For comparison, ATSDR reviewed data collected from background locations (Emory River, streams that feed into the Clinch River, the Clinch River above the Melton Hill Dam, and the Tennessee River upstream of the Clinch River). As stated previously, when contaminant concentrations in White Oak Creek surface water enter the Clinch River, those contaminant concentrations will become diluted. Further dilution will occur when the Clinch River meets the Tennessee River.

For the initial data sorting, ATSDR included the radionuclides associated with the Task 4 report, as well as the radionuclides reported in the OREIS data. The purpose of the data sorting was to collate data by the following parameters: river location, species (for biota), radionuclide, or a combination of one or more of these parameters. As a result of this sorting, ATSDR performed its evaluation on the radionuclides presented in Table 17.

Table 17. Summary of Radionuclides Evaluated for the Clinch River Area

Radionuclide	***Half-Life****	***Mode(s) of Decay†***	***Critical organ (ingestion) ‡***	***Decay Product§***
Cesium 137	30.2 years	Beta/gamma	Lower large intestine	Barium 137
Cobalt 60	5.3 years	Beta/gamma	Lower large intestine	Nickel 60
Strontium 90	28.6 years	Beta	Bone surface	Yttrium 90
Yttrium 90	64 hours	Beta/gamma	Lower large intestine	Zirconium 90
Americium 241	432 years	Alpha	Bone surface	Neptunium 237
Hydrogen 3	12.2 years	Beta	Whole body	Helium 3

* The half-life is the amount of time required for 50% of the initial amount present to physically decay.
† The mode of decay is the principal method whereby the isotope decays or releases energy. In those instances where a gamma mode is listed, this indicates that the decay product releases a gamma ray (photon) as a method of nuclear rearrangement.
‡ The critical organ, as defined by the International Commission on Radiological Protection, is the organ receiving the highest radiation dose following an intake of radioactive material.
§ The decay product is the first isotope produced during the decay of the parent radioisotope.

Exposure Pathways and Estimated Radiation Doses

ATSDR sorted the environmental monitoring data by pathway: ingestion of biota (fish, geese, and turtle), ingestion of water, and external radiation via walking on shoreline sediment or contacting water while swimming (see Table 18). Exposure scenarios were evaluated by using specific values from the EPA Exposure Factors Handbook, other federal guidance manuals, and/or interviews performed during ATSDR's 1998 exposure investigation that evaluated serum PCB and blood mercury levels in consumers of fish and turtles from the Watts Bar Reservoir. See Section II.F.1. in this public health assessment for additional details and Appendix D for a brief summary of the exposure investigation. In the discussion that follows, ATSDR evaluates these exposure situations and derives estimated radiation doses.

Table 18. Current Exposure Pathways Evaluated for the Clinch River Area

Exposure Pathway		*Individual*	*Description of Exposure Situation*
Biota ingestion	Fish	Adult, teenager, and child	Eating one 8-ounce fish meal each week for an adult and one 4-ounce fish meal each week for a child (ATSDR assumed lifetime exposure—until 70 years of age—for a 10-year-old child, a 15-year-old teenager, and a 20-year-old adult)
	Geese and turtle	Adult, teenager, and child	Eating about 1 pound of goose liver, 22 pounds of goose muscle, and 3.5 ounces of turtle each year (ATSDR assumed lifetime exposure—until 70 years of age—for a 10-year-old child, a 15-year-old teenager, and a 20-year-old adult)
Water ingestion (incidental ingestion of surface water)		Adult	Incidental ingestion while swimming: ingesting 0.1 liters per hour for 1 hour per day for 150 days per year
External radiation	Walking on sediment	Adult	Contact during recreational activities: 5 hours each day for 150 days per year
	Swimming	Adult	Contact while swimming: 1 hour per day for 150 days per year

ATSDR reviewed biota (fish, geese, and turtle), surface water, and sediment data for the presence of radionuclides. The samples were collected from the Clinch River below the Melton Hill Dam and from the Tennessee River below its confluence with the Clinch River. For comparison, ATSDR reviewed data collected from background locations (Emory River, streams that feed into the Clinch River, the Clinch River above the Melton Hill Dam, and the Tennessee River upstream of the Clinch River).

For the dose assessment, ATSDR looked at the critical organ and the radiation dose delivered to the whole body. For the time period of the dose assessment (1989 to the present), ATSDR set the age of an adult at 20 years and estimated the dose received until that person was 70 years of age; that is, ATSDR assumed exposure for a 50-year period. For a teenager and child, ATSDR also estimated the dose to age 70, but modified the years of exposure as appropriate for a 15-year-old (55 years) and a 10-year-old (60 years).

Biota Ingestion

ATSDR reviewed biota data for the presence of radionuclides. The biota samples included various species of fish, turtles, and geese that were collected from the Clinch River below the

Melton Hill Dam and from the Tennessee River below its confluence with the Clinch River. For comparison, ATSDR reviewed data for background locations.

Fish

In deriving radiation doses from the consumption of fish, ATSDR considered only fillet portions and muscle. ATSDR assumed that a child eating fish from the river consumes 113.4 grams (4 ounces) per week and that an adult consumes 227 grams (8 ounces) per week. Table 19 presents the estimated radiation doses by fish species consumed and the river where the samples were collected for an adult, teenager, and child (until age 70 years).

ATSDR's analysis of fish consumption indicates that the doses to the critical organ and to the whole body are very similar for the 10-year-old, the 15-year-old, and the 20-year-old. Some of the highest doses were associated with eating catfish or largemouth bass caught from the Clinch River below Melton Hill Dam. Even so, to age 70 the highest estimated whole-body dose, or committed effective dose, was 89.3 mrem. The highest committed equivalent dose of 114 mrem to the bone surface was estimated for a 15-year-old, based on a 55-year exposure. Because Sr 90 is a bone seeker and because much bone growth occurs during the teenage years, a 15-year-old could conceivably have a higher dose than either a 20-year-old adult or a 10-year-old child (see Table 19).

At one time, the Clinch River had many species of mussels and dredging for mussels took place in the lower Clinch River on a large scale. But the mussel population declined rapidly after the 1936 impoundment of Norris Dam and the 1963 impoundment of Melton Hill Dam. Many unconfirmed reports suggest that people consumed mussels from the Clinch River (usually on a very limited basis); however, there are no records of mussels being consumed on a regular basis and the Clinch River mussels were generally considered to be a poor source of food. Therefore, the likelihood is low that people consumed mussels from the Clinch River (Blaylock 2004).

Table 19. Estimated Radiation Doses From Current Ingestion of Fish

Location	*Fish Species*	*Organ†*	*Radiation Dose to Age 70 (mrem)**		
			Adult (50 years of intake)	*15-Year-Old (55 years of intake)*	*10-Year-Old (60 years of intake)*
Tennessee River below the confluence with the Clinch River	Channel catfish	Lower large intestine	2.13	2.65	4.07
		Whole body	0.99	0.818	1.01
	Largemouth bass	Lower large intestine	1.20	1.38	1.89
		Whole body	0.71	0.48	0.506
	Striped bass	Lower large intestine	0.74	0.769	0.839
		Whole body	0.56	0.31	0.26
Clinch River below Melton Hill Dam	Catfish	Lower large intestine	98.4	52.2	60.3
		Whole body	89.3	68.5	58.8
	Channel catfish	Lower large intestine	55.5	29.2	33.2
		Whole body	41.0	23.2	20.1
	Largemouth bass	Lower large intestine	109	57.2	63.8
		Whole body	82.1	45.8	39.2
	Striped bass	Lower large intestine	1.64	1.03	1.59
		Whole body	0.75	0.62	0.78
	Sunfish‡	Bone surface	46.5	114	71.7
		Whole body	3.15	4.94	4.08

* The doses are expressed in mrem calculated from age of intake to 70 years. For example, the intake for an adult occurs at age 20 and continues for 50 years.
† Doses are presented for the organ receiving the highest radiation dose and for the whole-body dose (the dose delivered to the entire body).
‡ The doses for sunfish are based on dry weight samples; all other doses are based on wet weight samples.

Turtles and Geese

Canadian geese were introduced into the X-10 area about 20 years ago. Turtles also inhabit the Clinch River environment. Contaminated geese and turtles have been identified in the radioactive ponds at X-10. Geese are grazers that only feed at the ponds in late winter and early spring. For several years, the ORR had a program to control access of waterfowl to radioactive waste ponds, mainly at X-10. These ponds were monitored, and geese that continued to use the ponds were collected. A few geese collected from 3504 waste disposal ponds at X-10 were found to have high concentrations of radionuclides, primarily Cs 137 in their tissues; however, the quantity of geese found with high radionuclide concentrations was extremely small. Further, the possibility of obtaining more than one goose or one turtle with high radioactive concentrations is "highly unlikely" (Blaylock 2004).

For hunters consuming geese, ATSDR assumed that not all portions of the animal would be consumed. Therefore, only the goose liver and the goose muscle were chosen for this analysis. ATSDR selected a consumption value of 500 grams of liver per year (about 1 pound) and 10 kilograms (approximately 22 pounds) of goose muscle per year. For turtle ingestion, only the muscle was analyzed at a consumption value of 100 grams (about 3.5 ounces) per year. For the critical organs, ATSDR used bone surface (Sr 90) and lower large intestine (Cs 137 and Co 60).

Estimated doses for the consumption of geese and turtles are shown in Table 20. As noted in the table, the estimated dose from ingestion of goose muscle and liver was greater than the estimated dose from ingestion of turtle, with most of the dose going to the bone surface. The highest committed effective dose to the whole body was 14 mrem to a 10-year-old child, based on a 60-year exposure for goose consumption. The highest committed equivalent dose was associated with eating geese—230 mrem over a 55-year exposure to the bone surface.

Table 20. Estimated Radiation Doses From Current Ingestion of Geese and Turtles

Food	*Organ†*	*Radiation Dose to Age 70 (mrem)**		
		Adult (50 years of intake)	*15-Year-Old (55 years of intake)*	*10-Year-Old (60 years of intake)*
Geese (muscle and liver)	Bone surface	154	230	190
	Lower large intestine	1.3	1.8	0.083
	Whole body	7.6	9.5	14
Turtle	Lower large intestine	0.029	0.03	0.033
	Whole body	0.022	0.025	0.021

* For radionuclides with similar critical organs, the doses from each radionuclide were added together. In the case of data reported as strontium 89/90, the doses were calculated as if the reported values were entirely strontium 90. Furthermore, the dose includes the presence of yttrium 90, which is the decay product of strontium 90.

† Doses are presented for the organ receiving the highest radiation dose and the whole-body dose (the dose delivered to the entire body).

Water Ingestion

A person swimming in the river might be exposed to radiation from incidental ingestion of radionuclides in the surface water. To evaluate potential hazards from contact with radionuclides, ATSDR estimated radiation doses for persons swimming in the river. In deriving these doses, ATSDR used exposure values published by the EPA in its *Federal Guidance Report 13*; these values are conservative and typically overestimate true exposure (USEPA 1999b). ATSDR assumed that a swimmer might incidentally ingest unfiltered surface water at a rate of 0.1 liters per hour (Stenge and Chamberlain 1995). For swimming frequency, ATSDR assumed an exposure of 1 hour per day for 150 days per year (as noted in the EPA Exposure Factors Handbook). Table 21 provides the results of this evaluation.

Table 21. Estimated Radiation Doses From Current Shoreline Recreational Activities for the Clinch River

<table>
<tr><th colspan="2" rowspan="2">Exposure Pathway</th><th rowspan="2">Location</th><th colspan="3">Radiation Dose (mrem)*</th></tr>
<tr><th>Bone Surface</th><th>Skin</th><th>Whole Body</th></tr>
<tr><td colspan="2" rowspan="3">Water ingestion (incidental ingestion of surface water)</td><td>Background†</td><td>0.41</td><td>0.01</td><td>0.04</td></tr>
<tr><td>Clinch River</td><td>2.8</td><td>0.006‡</td><td>0.13</td></tr>
<tr><td>Lower Watts Bar Reservoir</td><td>0.072</td><td><0.0001§</td><td>0.003</td></tr>
<tr><td rowspan="6">External radiation</td><td rowspan="3">Walking on shoreline sediment</td><td>Background†</td><td>1.57</td><td>0.18</td><td>0.14</td></tr>
<tr><td>Clinch River</td><td>13</td><td>1.6</td><td>9.4</td></tr>
<tr><td>Lower Watts Bar Reservoir</td><td>0.16</td><td>0.026</td><td>0.11</td></tr>
<tr><td rowspan="3">Swimming</td><td>Background†</td><td>5.83</td><td>0.62</td><td>1.15</td></tr>
<tr><td>Clinch River</td><td>1.2</td><td>3.9</td><td>0.82</td></tr>
<tr><td>Lower Watts Bar Reservoir</td><td>0.048</td><td>0.1</td><td>0.033</td></tr>
</table>

* Doses are presented for the organ receiving the highest radiation dose and the whole-body dose (the dose delivered to the entire body). For organs receiving the highest dose, ATSDR estimated the committed equivalent dose over 70 years. For doses to the whole body, ATSDR estimated the committed effective dose to age 70. For the radionuclides with similar critical organs, the doses from each isotope were added together. In the case of data reported as strontium 89/90, the doses were calculated as if the reported values were entirely strontium 90.
† Background locations include areas above Melton Hill Dam, above the confluence of the Tennessee River and the Clinch River, Emory River, and streams that feed into the Clinch River. The background dose represents the average radiation dose at these background locations.
‡ The critical organ for incidental ingestion of Clinch River water is the lower large intestinal wall.
§ The dose is too low to be significant.

The analyses indicated that the committed effective dose received by the whole body in the study area of 0.13 mrem is about 3 times higher than the dose for background locations (0.4 mrem). The critical organ for exposure from incidental ingestion of surface water depended on the radionuclide that was ingested. As would be expected, however, the doses to the bone surface of up to 2.8 mrem were higher (by about two orders of magnitude) than those for skin (up to 0.006 mrem).

External Radiation: Contact With Sediment and Surface Water

To evaluate potential hazards from contact with radionuclides in sediment and surface water, ATSDR estimated radiation doses for persons who might walk along the shoreline and swim in the river. In deriving these doses, ATSDR used exposure values published by the EPA in its *Federal Guidance Report 13*; these values are conservative and typically overestimate true exposure (USEPA 1999b). ATSDR presumed that the average recreational users of the Clinch River would be 20-year-old adults and that they would be exposed to a 2-square-meter area of shoreline for 5 hours per day and for 150 days per year. For swimming frequency, ATSDR assumed an exposure of 1 hour per day for 150 days per year (as noted in the EPA Exposure Factors Handbook). Table 21 provides the results of this evaluation.

The analyses included the doses received by the entire body, as well as the estimated radiation doses to the organs that are receiving the highest radiation doses. (The exposures from the shoreline, both from walking and swimming, basically impacted the skin.) The highest estimated dose to the whole body within the study area of 9.4 mrem is associated with walking on sediment along the Clinch River below Melton Hill Dam. Walking on sediment at this location was also associated with the highest committed equivalent dose of 13 mrem to the bone surface.

The data indicate that the dose from walking along the sediment is higher in the study area along the Clinch River (below Melton Hill Dam) and Lower Watts Bar Reservoir than at the background locations. For example, the resulting committed effective dose to the whole body from walking on the sediment in the study area is over 60 times higher than for background locations. Similarly, the radiation dose to the bone is about eight times higher in the study area than in background locations. As one would expect from the amount of skin exposure, swimming in the Clinch River resulted in the highest doses to the skin out of all pathways evaluated. The estimated dose for swimming at background locations (based on average for all background locations) was, however, actually higher than in the study area.

IV. Public Health Implications

IV.A. Introduction

When evaluating the public health impact associated with exposures to hazardous substances, CERCLA, as amended by SARA §104 [i][6][f], requires that ATSDR consider such factors as

- the nature and extent of contamination,
- the existence of potential pathways of human exposure (including ground or surface water contamination, air emissions, and food chain contamination),
- the size and potential susceptibility of the community within the likely pathways of exposure,
- the comparison of expected human exposure levels to the short-term and long-term health effects associated with identified hazardous substances and any available recommended exposure or tolerance limits for such hazardous substances, and
- the comparison of existing morbidity and mortality data on diseases that could be associated with the observed levels of exposure.

To evaluate health effects from radiation doses received by individuals exposed to radionuclides released into the Clinch River from White Oak Creek, ATSDR used a "weight-of-dose approach." The weight-of-dose approach involves conducting a critical review of available radiological, medical, and epidemiologic information to ascertain levels of significant human exposure, and then comparing the estimated radiation doses that individuals might have encountered at the Clinch River and LWBR to situations that have been associated with disease and injury. This approach is used to determine whether or not harmful health effects might be possible and observable, and to determine if the doses require a public health action to limit, eliminate, or further study any potential harmful exposures.

The exposure pathways analysis in Section III of this public health assessment indicates that radioactive materials were released from X-10 via White Oak Creek. These radioactive contaminants have migrated off site to the Clinch River and the Lower Watts Bar Reservoir (LWBR), where people have or could come in contact with these contaminants. In this section, ATSDR assesses the health implications of past, current, and future exposures to radioactive contaminants released from White Oak Creek for people who used or lived—or currently use or live—near the Clinch River and LWBR. In assessing exposure, ATSDR evaluated radiation doses presented in the Task 4 report or derived radiation doses using available environmental data. When calculating doses, ATSDR made conservative assumptions about the frequency, duration, and magnitude of radiation exposures. These conservative estimates allow ATSDR to evaluate the likelihood, if any, that exposure to radionuclides is associated with adverse health effects. Because cancer is the most recognized adverse health outcome resulting from radiation exposure (though studies are beginning to show cardiovascular effects in atomic bomb survivors), ATSDR will discuss this disease in the public health implications section.

The public health implications of past exposures at the Clinch River and current exposures associated with the Clinch River and the LWBR are presented in Table 22 and Table 23, respectively, and in the discussion that follows.

Table 22. Past Radiation Doses for the Area Along the Clinch River (1944–1991)

Organ	*Dose Type*[*]	*Estimated Dose*[†]	*Comparison Value*	*Is the Estimated Dose Above or Below the Comparison Value?*	*Conclusion*
Whole body	Annual	4 mrem	100 mrem/year ATSDR MRL, ICRP, NCRP, and NRC[‡]	Below (25 times less)	The radiation doses received by people in the past are not likely to cause adverse health effects. Past releases of radioactive material from White Oak Creek are not a public health hazard for people who used or lived near the Clinch River and LWBR.
	Committed effective dose or lifetime	278 mrem	5,000 mrem[§]	Below (18 times less)	
Bone surface	Committed equivalent dose or lifetime	Less than 1,600 mrem	390,000–620,000 mrem[¶]	Below (243 times less)	
Lower large intestine	Committed equivalent dose or lifetime	Less than 1,200 mrem	5,000 mrem[§]	Below (4 times less)	
Red bone marrow	Committed equivalent dose or lifetime	Less than 1,200 mrem	390,000–620,000 mrem[¶]	Below (325 times less)	
Breast	Committed equivalent dose or lifetime	Less than 500 mrem	10,000 mrem**	Below (20 times less)	
Skin	Committed equivalent dose or lifetime	Less than 700 mrem	9,000 mrem[††]	Below (12 times less)	

[*] Annual dose considers a 1-year exposure. Committed effective doses and committed equivalent doses consider a 70-year exposure duration.
[†] The estimated doses were taken from Table 11. Please see the discussion related to Table 11 for an explanation on the derivations of the past radiation doses.
[‡] ATSDR's MRL for ionizing radiation is based on noncancer health effects only; it is not based on a consideration of cancer effects. A MRL is an estimate of daily human exposure to a substance that is likely, during a specified duration of exposure, to be without noncarcinogenic health effects (ATSDR 1999b). For more information on MRLs, please refer to http://www.atsdr.cdc.gov/mrls.html. The ICRP, NCRP, and NRC recommended value of 100 mrem/year for the public considers both noncancer and cancer health effects (Health Physics Society 2003; ICRP 1991; Nuclear Energy Institute 2003).
[§] Based on studies of atomic bomb survivors (National Research Council 1988).
[¶] A review of human radium dial workers suggests that a threshold for bone cancers induced by radium should be between 390,000 and 620,000 mrem (Rowland 1994).
[**] Based on studies of atomic bomb survivors (Schull 1995).
[††] Based on studies of patients irradiated for the treatment of ringworm (National Research Council 1990).

Table 23. Current Radiation Doses for the Lower Watts Bar Reservoir and Clinch River

Area and Time Frame	*Organ*	*Dose Type*[*]	*Estimated Dose*[†]	*Comparison Value*	*Is the Estimated Dose Above or Below the Comparison Value?*	*Conclusion*
Lower Watts Bar Reservoir *(1988–2003)*	Whole body	Annual	Less than 30 mrem/year	100 mrem/year ATSDR MRL, ICRP, NCRP, and NRC[‡]	Below (3 times less)	The current radiation doses received by people are not likely to cause adverse health effects. Current releases of radioactive material from White Oak Creek are not a public health hazard for people who currently use or live near the Clinch River and LWBR. [‡‡]
		Committed effective dose or lifetime	Less than 1,900 mrem	5,000 mrem[§]	Below (2.5 times less)	
Clinch River *(1989–2003)*	Whole body	Annual	Less than 3.4 mrem/year	100 mrem/year[‡]	Below (29 times less)	
		Committed effective dose or lifetime	Less than 236 mrem	5,000 mrem[§]	Below (21 times less)	
	Bone	Committed equivalent dose or lifetime	Less than 218 mrem	390,000–620,000 mrem[¶]	Below (1,788 times less)	
	Lower large intestine	Committed equivalent dose or lifetime	Less than 270 mrem	5,000 mrem[§]	Below (18 times less)	
	Skin	Committed equivalent dose or lifetime	Less than 6 mrem	9,000 mrem[††]	Below (1,500 times less)	

[*] Annual dose considers a 1-year exposure. Committed effective doses and committed equivalent doses consider a 70-year exposure duration for the LWBR and an exposure to age 70 for the Clinch River.

[†] The annual and committed doses are based on all exposure pathways combined. To derive the committed effective dose and the committed equivalent dose, the dose for a pathway was adjusted for a 70-year exposure for the LWBR and to age 70 for the Clinch River.

[‡] ATSDR's MRL for ionizing radiation is based on noncancer health effects only; it is not based on a consideration of cancer effects. A MRL is an estimate of daily human exposure to a substance that, during a specified duration of exposure, is likely to be without noncarcinogenic health effects (ATSDR 1999b). For more information on MRLs, please refer to http://www.atsdr.cdc.gov/mrls.html. The ICRP, NCRP, and NRC recommended value of 100 mrem/year for the public considers both noncancer and cancer health effects (Health Physics Society 2003; ICRP 1991; Nuclear Energy Institute 2003).

[§] Based on studies of atomic bomb survivors (National Research Council 1988).

[¶] A review of human radium dial workers suggests that a threshold for radium-induced bone cancers is between 390,000 and 620,000 mrem (Rowland 1994).

[††] Based on studies of patients irradiated for the treatment of ringworm (National Research Council 1990).

[‡‡] ATSDR assessed the estimated current doses in its evaluation of future exposures. See the discussion of future exposures in Section IV.C.

IV.B. Past Radiation Exposure (1944–1991)

ATSDR determined that levels of radioactive contaminants from X-10 that entered the Clinch River via White Oak Creek are not a public health hazard for individuals who, in the past, used or lived near the Clinch River. Past exposure to these radioactive contaminants is not expected to cause adverse health effects.

For *past exposures,* which for the purposes of this PHA occurred between 1944 and 1991, ATSDR evaluated the health implications of the radiation dose estimates presented in Task 4 of the TDOH's *Reports of the Oak Ridge Dose Reconstruction, Radionuclide Releases to the Clinch River from White Oak Creek on the Oak Ridge Reservation—an Assessment of Historical Quantities Released, Off-Site Radiation Doses, and Health Risks* (referred to as the "Task 4 report"). As discussed in Section III, ATSDR evaluated the 50th percentile of the uncertainty distribution for doses reported by the Task 4 team. The doses considered past exposures (over a maximum 48-year exposure period) to radionuclides (Cs 137, Ru 106, Sr 90, Co 60, I 131, Ce 144, Zr 95, and Nb 95) via consumption of fish, meat, milk, and water, and external radiation from walking on shoreline sediment (see Table 11) (see Appendix E). ATSDR focused its evaluation on three locations: Jones Island (CRM 20.5), the K-25/Grassy Creek area (CRM 14), and the confluence of the Clinch River with the Tennessee River (CRM 0) near the city of Kingston. ATSDR then used the organ-specific doses derived by the Task 4 team to estimate both the whole-body dose (annual and committed effective dose over 70 years) and total lifetime organ doses for the bone, lower large intestine, red bone marrow, skin, and female breast.

Table 22 presents ATSDR's estimated whole-body dose (annual dose and committed effective dose over 70 years) and the committed equivalent dose to organs (bone, lower large intestine, red bone marrow, breast, and skin) for *past exposures* along the Clinch River. An individual exposed to the primary radionuclides in Clinch River water, fish, shoreline sediment, meat, and milk was expected to receive a committed effective dose to the whole body of less than 300 mrem over 70 years and an annual whole-body dose from combining the organ doses of 4 mrem/year. This whole-body dose is well below (18 times less than) ATSDR's radiogenic comparison value of 5,000 mrem over 70 years and the annual whole-body dose is well below (25 times less than) ATSDR's radiogenic minimal risk level (MRL) of 100 mrem/year, which is also the maximum dose constraint for members of the public as recommended by the International Commission on Radiological Protection (ICRP), the U.S. Nuclear Regulatory Commission (NRC), and the

National Council on Radiation Protection and Measurements (NCRP). ATSDR also evaluated potential exposures to radionuclides in drinking water (from the K-25 intake) for residents who lived in the Happy Valley settlement camp between 1944 and 1950. ATSDR's estimates suggest that residents of the camp would have received an annual dose of 14 mrem to the whole body, which is at least 7 times less than the ATSDR radiogenic MRL of 100 mrem/year and the ICRP, NRC, and NCRP recommended maximum dose for the public of 100 mrem/year. ATSDR's evaluation of radiological, epidemiological, and medical literature shows that the estimated whole-body radiation doses were well below levels likely to cause observable or detectable health effects.

ATSDR derived the *radiogenic comparison value* of 5,000 mrem over 70 years after reviewing the peer-reviewed literature and other documents developed to review the health effects of ionizing radiation. Doses below this value are not expected to result in observable health effects. ATSDR's *MRL for ionizing radiation* of 100 mrem/year is based on noncancer health effects only; it is not based on a consideration of cancer effects. MRLs are estimates of daily human exposures to substances unlikely to result in noncancer effects over a specified duration (ATSDR 1999b). The ICRP, NRC, and NCRP maximum dose constraint for the public of 100 mrem/year considers both noncancer and cancer health effects (Health Physics Society 2003; ICRP 1991; Nuclear Energy Institute 2003).

The doses from past exposure to radionuclides in and along the Clinch River varied by the critical organ. ATSDR's further evaluation of the organ doses is in the discussion that follows.

- The bone received the highest estimated total committed equivalent dose over a lifetime (70 years) of exposure to the primary radionuclides along the Clinch River. ATSDR's estimates, however, suggest that the dose to the bone was less than 1,600 mrem over 70 years—at least 243 times lower than the doses of 390,000 to 620,000 mrem shown to cause bone cancers in radium dial workers. Eating many fish meals from the Jones Island area resulted in the highest estimated organ dose to the bone (810 mrem) (see Table 11). Doses to the bone were much lower for people who ate fewer fish or fished further downstream and for all other pathways. Strontium most likely contributed to the higher levels in the bone because it seeks out and accumulates in bone.

  Radiation effects on individual organs have not been studied extensively. Most of the available studies on the effects of radiation involve exposures associated with luminous dial painting, the atomic bombing of Japan, medical treatments, and uranium mining. ATSDR's comparison value for the dose to the bone comes from studies that evaluated exposures of radium dial painters to levels of radium known to cause adverse health effects following acute intakes of radium. Workers in these studies were exposed to larger doses and for longer periods of time than exposures associated with White Oak Creek releases. Bone cancers induced by radium exposure were evident in dial workers at doses ranging between 390,000 and 620,000 mrem (Rowland 1994). More recent studies have included workers at nuclear plants and other nuclear industries. For example, studies of nuclear workers at the Mayak facility in Russia suggest that chronic radiation exposure resulting in "chronic radiation syndrome" is associated with cumulative exposures to radiation above 100,000 mrem (USDOE, Office of International Health Programs 2001).[15] In 1999, the Airlie Conference concluded that 10,000 mrem was the lowest dose at which a statistically significant radiation risk has been shown, and that the effects of low-level radiation below 100 mrem/year above background are currently indistinguishable from those of everyday natural health hazards (Mossman et al. 2000).[16] The doses received by individuals in these studies are in substantial excess of the estimated doses from past exposures to White Oak Creek radionuclide releases.

- The committed equivalent dose to the *lower large intestine* was less than 1,200 mrem over 70 years. Exposure from eating fish, from drinking water, and from walking along the shoreline (external exposures) resulted in the highest doses to the lower large intestine. This estimated dose, however, is 4 times lower than ATSDR's radiogenic comparison value of 5,000 mrem over 70 years.

- The committed equivalent dose to the *red bone marrow* was less than 1,200 mrem over 70 years. Exposure from eating fish, drinking Clinch River water, and walking along the shoreline (external exposures) resulted in the highest doses to the red bone marrow. The highest committed equivalent dose, however, is more than 325 times lower than the lowest doses between 390,000 and 620,000 mrem, which is where bone cancers were first observed in radium dial workers with measured amounts of radium in their bodies (Rowland 1994). ATSDR's estimated committed equivalent dose to the red bone marrow for past exposure is also below the levels that epidemiological studies can detect, and below 25,000 mrem, which is the level generally related to blood disorders associated with acute exposures. Doses on the order of 25,000 mrem are believed to affect the formation of blood cells and may induce leukemia. Studies in the atomic bomb survivors indicated that leukemia was observed with acute doses as low as 50,000 millirads (assumed 50,000 mrem), with most of the leukemia occurring within the first 20 years following the bombings (Radiation Effects Research Foundation 2003).

- The committed equivalent dose to the *breast in females* was less than 500 mrem over a 70-year lifetime. Exposure to radionuclides from eating fish and walking on shoreline sediment contributed the highest doses to the breast. For comparison, the committed equivalent dose is 20 times less than doses shown to cause effects in atomic bomb survivors (Schull 1995).

- The committed equivalent dose to the *skin* over a 70-year lifetime of exposure to external radiation was less than 700 mrem. Organ doses to the skin from eating fish and walking along the shoreline exceeded dose estimates for all other pathways. Even so, the committed

[15] Please see http://www.utah.edu/radiobiology/mayak/index.html#toc for additional information.
[16] Please see http://www.inea.org.br/bridradia.htm for more details.

equivalent dose is 12 times below the value of 9,000 mrem, which is based on the Biological Effects of Ionizing Radiation (BEIR) V report of patients irradiated for the treatment of ringworm (National Research Council 1990).

Organ doses for people who ate fish from the Clinch River exceeded dose estimates for all other exposure pathways (drinking water, meat ingestion, milk ingestion, and external radiation) by at least a factor of 6 (see Table 12). Primarily, the organ dose depended on how often people ate fish and the area of the Clinch River where the fish were collected. The highest cumulative organ doses (1944–1991) were for individuals who consumed fish frequently (1 to 2.5 fish meals per week) and caught their fish near Jones Island, close to the mouth of White Oak Creek. For individuals who frequently ate fish caught near Jones Island and received maximum exposure to radionuclides released from White Oak Creek (see Table 11), ATSDR determined that the estimated doses to each organ were well below ATSDR's comparison values and levels associated with the development of disease or cancer.

Organ doses for people walking along the shore and ingesting milk, water, and meat were much lower than the doses received by people consuming fish (see Tables 11 and 12). For an individual with no exposures other than to shoreline contaminants, the bone and skin were the organs that received the greatest dose. The estimated doses to the bone and skin from walking along the shoreline are well below ATSDR's comparison values and levels associated with the development of disease or cancer. Also, individuals exposed to radionuclides in the past from walking along the shoreline or ingesting milk, water, meat, or fish (further downstream from Jones Island) were not expected to develop adverse health effects or cancer.

Lifetime inhabitants of Grassy Creek (CRM 14) who ingested meat, milk, and water received the highest radiation dose to the bone. ATSDR used the tissue weighting factors to convert each organ dose to the corresponding whole-body dose, and summed the values to achieve a whole-body dose less than 20 mrem. ATSDR does not expect these exposures to have resulted in any observable adverse health effects.

All the estimated doses for past exposure to radionuclides in the Clinch River released from White Oak Creek are lower than ATSDR's comparison values and doses reported in radiological and epidemiological studies on the effects of radiation exposure. Therefore, ATSDR does not expect carcinogenic health effects to have occurred from past exposure to radionuclides in the Clinch River.

IV.C. Current and Future Radiation Exposure (1988–Present and Future)

ATSDR determined that current and future exposure to radioactive materials is not a public health hazard for individuals who use or live near the Clinch River and the Lower Watts Bar Reservoir. Radiation doses for individuals who might contact even the highest current concentrations of radionuclides in Lower Watts Bar Reservoir or Clinch River fish, turtles, geese, surface water, and sediment are too low to be a health hazard now or in the future.

IV.C.1. Current Exposure

For *current exposures* (1988–present), ATSDR estimated radiation doses for conservative hypothetical scenarios that considered likely pathways of exposure for people who use the LWBR and the Clinch River. ATSDR evaluated current users' exposures to LWBR sediment, surface water, and fish (see Tables 13, 14, 15 for the maximum detected concentrations). ATSDR also evaluated current users' exposures to Clinch River biota (fish, turtles, and geese), external radiation (walking on sediment and swimming), and incidental ingestion of surface water (see Table 17 for the radionuclides evaluated and Table 18 for the exposure pathways evaluated). ATSDR's evaluation shows that current exposures to even the highest detected concentrations of radionuclides in the Clinch River or LWBR biota, sediment, and surface water are not likely to cause health effects for current users of these waterways. In addition, ATSDR analyzed drinking water samples collected around the cities of Kingston, Spring City, and Rockwood from 1990 to the present. ATSDR evaluated these samples for radiological content, and determined that all water samples were below the U.S. Environmental Protection Agency's maximum contaminant levels (MCLs), and therefore, ATSDR considers this water safe for consumption and other potable uses now and in the future.

Lower Watts Bar Reservoir (1988–present)

ATSDR's estimated committed effective dose to the whole body for all pathways combined is less than 1,900 mrem over 70 years—2.5 times below ATSDR's radiogenic CV of 5,000 mrem over 70 years. The estimated annual whole-body dose is less than 30 mrem, and below ATSDR's screening comparison value and ICRP's, NCRP's, and NRC's recommended values for the public of 100 mrem/year. Therefore, the estimated exposures for the LWBR are not expected to result in adverse health effects.

Clinch River (1989–present)

ATSDR's estimated committed effective dose to the whole body for all pathways along the Clinch River combined is less than 240 mrem to 70 years of age—more than 20 times below ATSDR's radiogenic CV of 5,000 mrem over 70 years. The estimated annual whole-body dose is less than 3.4 mrem, and nearly 30 times below the dose of 100 mrem per year recommended for the public by ATSDR, ICRP, NCRP, and NRC. Therefore, the estimated exposures for the Clinch River are not expected to result in adverse health effects.

The current radiation doses from exposure to radionuclides along the Clinch River varied by organ as summarized below.

- ATSDR estimated that the *bone* receives the highest total committed equivalent dose over a lifetime (i.e., to age 70) of exposure to the primary radionuclides detected along the Clinch River. The highest committed equivalent doses to the bone were estimated for a 15-year-old adolescent based on a 55-year exposure from ingestion of goose muscle or liver (230 mrem) and fish (114 mrem), which resulted in a committed equivalent dose of 344 mrem over 55 years. ATSDR's estimates indicate that the teenager would receive the highest dose because of the age-weighted dose coefficients associated with accelerated bone growth in this age group. The committed equivalent dose to the bone from all pathways combined was based on exposures for adults occurring over a 50-year period. Estimates suggest that the committed equivalent dose to the bone for adults from all pathways is less than 218 mrem to 70 years of age. This is at least 1,788 times lower than the doses of 390,000 to 620,000 mrem associated with bone cancers in radium dial workers. Much lower doses were associated with ingestion of Clinch River water (2.8 mrem) and external exposures from walking on sediment (13 mrem) and swimming (1.2 mrem) in the study area. Note that the bone dose for swimming at background locations (expressed as the average of all background locations under study) of 5.83 mrem exceeds the dose incurred from swimming in the Clinch River study area.

- On the basis of exposures estimated for a 20-year-old adult over 50 years, the committed equivalent dose to the *lower large intestine* from all pathways combined is less than 270 mrem. This estimated dose is about 18 times lower than ATSDR's radiogenic comparison value of 5,000 mrem over 70 years, which is based on studies of atomic bomb survivors, radiation workers, and radiation workers' children. Exposure to radionuclides from adults eating fish contributed to the highest committed equivalent dose—109 mrem—to the lower large intestine.

- The committed equivalent dose to the *skin* over a 50-year exposure for adults is less than 6 mrem, which is 1,500 times below the value of 9,000 mrem that is based on a review of the

BEIR V report of patients irradiated for ringworm treatment (National Research Council 1990). As one would expect from the amount of skin exposure, swimming in the Clinch River resulted in the highest dose to the skin (3.9 mrem) out of all pathways evaluated.

Estimated doses for current exposure to radionuclides in the LWBR and Clinch River released from White Oak Creek in the present are lower than ATSDR's screening comparison values and doses reported in radiological and epidemiological studies on the effects of radiation exposure. ATSDR does not expect these current exposures to result in any adverse health effects.

IV.C.2. Future Exposure

For *future exposures* (exposures occurring after the "current" time period), ATSDR evaluated current doses and exposures related to releases from White Oak Creek, data on current contaminant levels in the LWBR and the Clinch River, consideration of the possibility that radionuclides could be released to White Oak Creek during remedial activities, engineering controls to prevent off-site releases, and institutional controls that are in place to monitor contaminants in the LWBR and the Clinch River. These institutional controls consist of

- prevention of sediment-disturbing activities in the Clinch River and LWBR,
- the Department of Energy's (DOE) annual monitoring of Clinch River and LWBR surface water, sediment, and biota,
- DOE's monitoring of White Oak Creek releases,
- the Tennessee Department of Environment and Conservation's (TDEC) monitoring of public drinking water supplies in Tennessee under the Safe Drinking Water Act for EPA-regulated contaminants, and
- TDEC DOE Oversight Division's quarterly radiological monitoring of five public water supplies on the ORR and in its vicinity under the EPA's Environmental Radiation Ambient Monitoring System program.

Lower Watts Bar Reservoir and Clinch River

Because the current radionuclide levels in the Clinch River and LWBR are not expected to result in adverse health effects, because on-site engineering controls are in place to prevent off-site contaminant releases, and because institutional controls reduce and monitor contaminants released from White Oak Creek, ATSDR concludes that future contaminant levels in the Clinch River and LWBR will not increase as a result of White Oak Creek releases. This conclusion is also based on DOE continuing its expected comprehensive system of monitoring (e.g., of remedial activities and contaminant levels in media), maintenance, and institutional and engineering controls. Further, because of remedial actions and preventive measures at X-10, and because of physical movement of sediments from that area and radiological decay, the radionuclide releases from White Oak Creek have decreased over time. The concentrations of radionuclides in the water and along the shoreline have decreased as well. Though a slight potential remains that radionuclides could be released to White Oak Creek due to remedial activities taking place at the ORR, these releases are expected to be minimal, and as noted previously, would be monitored by DOE. Therefore, as current exposures are not expected to result in adverse health effects, ATSDR does not expect adverse health effects to result from future concentrations of radionuclides in the Clinch River or Lower Watts Bar Reservoir fish, geese, turtles, sediment, or surface water.

V. Health Outcome Data Evaluation

Health outcome data are measures of disease occurrence in a population. Common sources of health outcome data are existing databases (cancer registries, birth defects registries, death certificates) that measure morbidity (disease) or mortality (death). Health outcome data can provide information on the general health status of a community—where, when, and what types of diseases occur and to whom they occur. Public health officials use health outcome data to look for unusual patterns or trends in disease occurrence by comparing disease occurrences in different populations over periods of years. These health outcome data evaluations are descriptive epidemiologic analyses. They are exploratory as they could provide additional information about human health effects and they are useful to help identify the need for public health intervention activities (for example, community health education). That said, however, health outcome data cannot—and are not meant to—establish cause and effect between environmental exposures to hazardous materials and adverse health effects in a community.

ATSDR scientists generally consider health outcome data evaluation when there is a plausible, reasonable expectation of adverse health effects associated with the observed levels of exposure to contaminants. In this public health assessment on X-10 radionuclide releases to the Clinch River and the Lower Watts Bar Reservoir from White Oak Creek, ATSDR scientists determined that people using the Clinch River and the Lower Watts Bar Reservoir for food, water, and recreation were exposed to radionuclides released via White Oak Creek from the 1940s to 2003.

Criteria for Conducting a Health Outcome Data Evaluation

To determine how to use or analyze health outcome data in the public health assessment process, or even whether to use it at all, ATSDR scientists receive input from epidemiologists, toxicologists, environmental scientists, and community involvement specialists. These scientists consider the following criteria, based only on site-specific exposure considerations, to determine whether a health outcome data evaluation should be included in the public health assessment.

1. Is there at least one current (or past) potential or completed exposure pathway at the site?
2. Can the time period of exposure be determined?
3. Can the population that was or is being exposed be quantified?

4. Are the estimated exposure doses(s) and the duration(s) of exposure sufficient for a plausible, reasonable expectation of health effects?
5. Are health outcome data available at a geographic level or with enough specificity to be correlated to the exposed population?
6. Do the validated data sources or databases have information on the specific health outcome(s) or disease(s) of interest—for example, are the outcome(s) or disease(s) likely to occur from exposure to the site contaminants—and are those data accessible?

Using the findings of the exposure evaluation in this public health assessment, ATSDR sufficiently documented completed exposure pathways to radionuclides via the surface water, sediment, and biota pathways from the mid-1940s to 2003 for people using the Clinch River and the Lower Watts Bar Reservoir. In this public health assessment, the documented evidence of off-site exposure to radionuclides indicates that estimates of past and current radiation doses are below doses associated with health effects (see Section IV. Public Health Implications).

The estimated radiation doses for people using the Clinch River and the Lower Watts Bar Reservoir for food, water, and recreation are less than the 1) average U.S. background radiation dose, 2) ATSDR's screening values for ionizing radiation, 3) the NCRP's, ICRP's, and NRC's recommended limits of exposure to the public, and 4) organ-specific doses shown to cause adverse health effects. Therefore, residents using the river and reservoir have not been exposed to harmful levels of radionuclides from White Oak Creek, and they are not currently being exposed to harmful levels of radionuclides released to White Oak Creek from the X-10 site. Because the estimated radiation doses are not expected to cause health effects, no further analysis of health outcome data is appropriate. Analysis of site-related health outcome data is not scientifically reasonable unless the level of estimated exposure is likely to result in an observable number of health effects. And because such an estimate of exposure cannot be made, the requirement to consider analysis of site-related health outcome data on the basis of exposure is complete.

Responding to Community Concerns

Responding to community health concerns is an essential part of ATSDR's overall mission and commitment to public health. Concerns of all community members are important and must be addressed during the public health assessment process. The individual community health concerns addressed in the Community Health Concerns section (Section VI) of this public health assessment are concerns from the ATSDR Community Health Concerns Database that are related to issues associated with radionuclides released from White Oak Creek.

Area residents have also voiced concerns about cancer. Citizens living in the communities surrounding the ORR expressed many concerns to the ORRHES about a perceived increase in cancer in areas surrounding the ORR. A 1993 TDOH survey of eight counties surrounding the ORR indicated that cancer was mentioned as a health problem more than twice as much as any other health problem. The survey also showed that 83% of the surveyed population in the surrounding counties believed it was very important to examine the actual occurrence of disease among residents in the Oak Ridge area.

To address these concerns, ORRHES requested that ATSDR conduct an assessment of health outcome data (cancer incidence) in the eight counties surrounding the ORR. Therefore, ATSDR conducted an assessment of cancer incidence using data already collected by the Tennessee Cancer Registry. This assessment is a descriptive epidemiologic analysis that provides a general picture of the occurrence of cancer in each of the eight counties. The purpose of this evaluation was to provide citizens living in the Oak Ridge Reservation area with information regarding cancer rates in their county compared to the state of Tennessee. The evaluation only examines cancer rates at the population level—not at the individual level. It is not designed to evaluate specific associations between adverse health outcomes and documented human exposures, and it does not—and cannot—establish cause and effect.

> "Cancer incidence" refers to newly diagnosed cases of cancer that are reported to the Tennessee Cancer Registry.

The results of the assessment of cancer incidence, released in 2006, indicated both higher and lower rates of certain cancers in some of the counties examined when compared to cancer incidence rates for the state of Tennessee. Most of the cancers in the eight-county area occurred at expected levels, and no consistent pattern of cancer occurrence was identified. The reasons for the increases and decreases of certain cancers are unknown. ATSDR's ORR Assessment of Cancer Incidence is available online at http://www.atsdr.cdc.gov/HAC/oakridge/phact/cancer_oakridge/index.html.

In addition, over the last 20 years, local, state, and federal health agencies have conducted public health activities to address and evaluate public health issues and concerns related to chemical and radioactive substances released from the Oak Ridge Reservation. For more information, please see the Compendium of Public Health Activities at http://www.atsdr.cdc.gov/HAC/oakridge/phact/c_toc.html.

VI. Community Health Concerns

ATSDR actively gathers comments and other information from those who live or work near the ORR. ATSDR is particularly interested in hearing from area residents, civic leaders, health professionals, and community groups. ATSDR will be addressing these community site-related health concerns in the ORR public health assessments that are related to those concerns.

To improve the documentation and organization of community health concerns at the ORR, ATSDR developed a *Community Health Concerns Database* specifically designed to compile and track community health concerns related to the site. The database allows ATSDR to record, track, and respond appropriately to all community concerns, and also to document ATSDR's responses to these concerns.

From 2001 to 2005, ATSDR compiled more than 3,000 community health concerns obtained from the ATSDR/ORRHES community health concerns comment sheets, written correspondence, phone calls, newspapers, comments made at public meetings (ORRHES and work group meetings), and surveys conducted by other agencies and organizations. These concerns were organized in a consistent and uniform format and imported into the database.

The community health concerns addressed in this public health assessment are those concerns in the ATSDR Community Health Concerns Database that are related to issues associated with radionuclide releases from White Oak Creek. The following table contains the actual comments and ATSDR's responses. These concerns and responses are sorted by category (e.g., X-10 facility processes and exposure pathway concerns, concerns about radionuclides associated with X-10's releases to White Oak Creek, concerns about contaminants released from the Oak Ridge Reservation, and general concerns related to the Oak Ridge Reservation).

Community Health Concerns From the Oak Ridge Reservation Community Health Concerns Database

	Actual Comment	*ATSDR's Response*
X-10 Processes and Exposure Pathways Evaluated		
1	My first thoughts are what are the routes of entry, what are we looking at from the waterway, from the airway, from the soil. Because if you are talking about the water and fisherman and residents you're talking downstream. But if you're talking wind, I don't know where that ends. I would like to hear what are you're thoughts are on what routes are we looking at. That would expand it even further if you look at sports men and the hunting migration.	This public health assessment evaluates the releases of radionuclides from the X-10 facility (now known as the Oak Ridge National Laboratory [ORNL]) into the water in White Oak Creek, and also assesses past, current, and future off-site exposures to these radionuclides in the water for residents living within the White Oak Creek study area (the area along the Clinch River and the Lower Watts Bar Reservoir from the Melton Hill Dam to the Watts Bar Dam [see Figure 11]). This public health assessment evaluates the following key issues and concerns: surface water and sediment (surface and deep channel), and surface water, milk, game animals, fish, turtles, and homegrown vegetables. Please see Section. III.B. Exposure Evaluation of the Clinch River and Lower Watts Bar Reservoir and Figure 20. Possible Exposure Situations Along the Clinch River for more details.
2	How did they/are we looking at the X-10's major processes that may still be delivering an effect? There were cesium releases from the dam in 1985. And a flood in 1964 along with regular releases.	The Tennessee Department of Health's 1999 *Reports of the Oak Ridge Dose Reconstruction, Radionuclide Releases to the Clinch River from White Oak Creek on the Oak Ridge Reservation—an Assessment of Historical Quantities Released, Off-Site Radiation Doses, and Health Risks* (referred to as the "Task 4 report") focused on historical X-10 radionuclide releases to White Oak Creek dating back to 1944. ATSDR has evaluated the historical data, as well as data that were collected since the dose reconstruction (for example, data from the state of Tennessee, EPA, and DOE). As a result, this public health assessment evaluates the past and current, as well as future, off-site exposures related to radionuclides from X-10. In this public health assessment, ATSDR considers the potential effects from the releases of cesium that occurred in 1956 when severe rains caused a flood that eroded the bottom sediment of White Oak Lake (Blaylock et al. 1993; ChemRisk 1999a). In addition, the Task 4 report estimated the amount of radionuclides that were released to White Oak Dam, and ATSDR considers these releases in its public health assessment (ChemRisk 1999a). See Appendix D for a brief on the Task 4 report. Copies of the Task 4 report are available at the DOE Information Center located at 475 Oak Ridge Turnpike, Oak Ridge, Tennessee (telephone number: 865-241-4780) or through DOE's public-use database at http://cedr.lbl.gov/DR/dror.html.

	Actual Comment	ATSDR's Response
3	The problems of the buried waste include little documentation on low-level waste, and that the X-10 records on high-level waste were destroyed in 1984. Some were reconstructed, but in general that is not an accurate inventory. That makes more important the good records of the outflows off the reservation.	In general, the records on X-10's earlier operations are not complete. However, a rather accurate account of X-10's major waste generating programs has been created from reviewing available records and by interviewing employees who worked at X-10 throughout most of its operational history. Six activities were determined to be responsible for basically all of X-10's waste production and on-site waste disposal. The six activities were the following (USEPA 1996): • Fuel reprocessing • Isotope production • Waste management • Radioisotope applications • Reactor developments • Multi-program laboratory operations The liquid and solid waste streams that were generated by these activities at X-10 can be described as non-hazardous, chemically hazardous, radioactive, or mixed (for example, consisting of both hazardous chemicals and radioactive substances). Even though X-10 generates various types of waste streams, the majority of its hazardous waste is mixed or radioactive. In addition to X-10's on-site waste production, a large amount of solid, low-level radioactive wastes that were produced at other sites are brought to the X-10 site for disposal. Several remedial activities have been conducted at the X-10 site (USEPA 1996). See Section II.C. Remedial and Regulatory History for more details. In addition, the Tennessee Department of Health evaluated radioactive waste disposal at X-10 dating back to 1944 in its Task 4 report titled *Radionuclide Releases to the Clinch River from White Oak Creek on the Oak Ridge Reservation—an Assessment of Historical Quantities Released, Off-Site Radiation Doses, and Health Risks*. See Appendix D for a brief on the 1999 Task 4 report. Copies of the Task 4 report are available at the DOE Information Center located at 475 Oak Ridge Turnpike, Oak Ridge, Tennessee (telephone number: 865-241-4780) or through DOE's public-use database at http://cedr.lbl.gov/DR/dror.html.

	Actual Comment	ATSDR's Response
4	A subcommittee member asked whether, since vegetables and fish are the dominant pathways, people who live downstream are at higher risk.	In 1996, ATSDR conducted a health consultation to evaluate the health implications of current exposure to chemical and radiological contaminants in the Lower Watts Bar Reservoir (LWBR) surface water, sediment, and fish. ATSDR concluded that only PCBs in reservoir fish were of potential public health concern. The current levels of other contaminants in surface water, sediment, and fish were not a public health hazard. See Appendix D for a brief on the *1996 Health Consultation on the Lower Watts Bar Reservoir*. ATSDR evaluated radioactive contaminant data for the Clinch River and the LWBR surface water, sediment, and fish, as well as Clinch River vegetables, turtles, and local game animals. The agency's purpose was to determine whether the levels of radionuclides might pose a past, current, or future public health hazard. The evaluation included the following exposure scenarios (depending on the waterway and time period): • Incidental ingestion of water during recreational activities • Use of river or reservoir water as drinking water • Contact with water while recreating, while irrigating, or while showering • Contact with surface sediment • Contact with dredged sediment used as topsoil in home gardens • Consumption of locally grown milk, meat, or produce • Consumption of fish, turtles, or local game animals ATSDR concluded that people who used or who lived near the Clinch River could have contacted these radionuclides in the past by eating fish and meat, by drinking milk and water, and by walking along shoreline sediment. In the past, the highest cumulative organ doses were for people who frequently ate fish (i.e., 1 to 2.5 fish meals per week) caught near Jones Island, close to the mouth of White Oak Creek. For persons who frequently ate fish caught near Jones Island and who received maximum exposure to radionuclides released from White Oak Creek, ATSDR determined that the estimated doses to each organ were well below ATSDR's comparison values and below levels associated with the development of disease or cancer. In addition, past exposure to radionuclides from drinking milk and water, walking along the shoreline, or eating meat and fish further downstream from Jones Island is not a health hazard and is not expected to result in adverse health effects or cancer. Therefore, ATSDR concluded that past exposures to radionuclides in sediment, surface water, and food in the Clinch River pose *no apparent public health hazard*. ATSDR concluded that current and future exposures to radionuclides from drinking surface water, contacting surface water and shoreline sediment via recreation, and consuming fish and game is not a health hazard because current exposure to radionuclides in the Clinch River and LWBR would result in radiation doses below levels expected to cause adverse health effects. Thus, current exposure to radionuclides released to the Clinch River and the LWBR via White Oak Creek poses *no apparent public health hazard*.

	Actual Comment	ATSDR's Response
4	*continued*	ATSDR is still evaluating past exposure to mercury and PCBs in the Clinch River and Lower Watts Bar Reservoir, and will address the health implications of past exposure to these contaminants in future public health assessments.
5	My question is about safe gardening. How could you consider safe gardening in a contaminated soil?	The general answer is that it depends on what the soil is contaminated with and how much is contaminated. This public health assessment evaluates exposures to radioactive contaminants released to the Clinch River and the Lower Watts Bar Reservoir via White Oak Creek. In the dose reconstruction of radionuclides released historically, the Task 4 report determined that the radionuclide levels in irrigation water (for homegrown vegetables) were below screening levels and therefore were not considered a hazard to people who ate locally grown vegetables. Given its assessment of both past and current data, ATSDR does not believe that radionuclides in soil within the White Oak Creek study area present a health hazard for people who consume vegetables from their gardens. ATSDR will address this question further when it considers other contaminants in future public health assessments. As a general rule, ATSDR recommends that everyone wash and peel all homegrown fruits, vegetables, and root crops before consumption. For more information on ATSDR's analysis of homegrown vegetables, see Section III.B. Exposure Evaluation of the Clinch River and Lower Watts Bar Reservoir for more details.
6	Was any analysis done of the game living on the reservation?	The annual DOE monitoring reports include analysis of some of the game that live on the reservation. Also, some of the ecological studies conducted under EPA's Superfund clean up work will include data on game. These DOE monitoring reports are available from the DOE Information Center located at 475 Oak Ridge Turnpike, Oak Ridge, Tennessee. You can obtain documents from the Information Center at http://www.oakridge.doe.gov/info_cntr/index.html or by calling 865-241-4780. This public health assessment evaluates the past consumption of fish and the current (1988–2003) consumption of fish, geese, and turtles that might have lived on the reservation property. Please see Section III.B. Exposure Evaluation of the Clinch River and the Lower Watts Bar Reservoir for more information.

	Actual Comment	ATSDR's Response
7	People, actually, some of you might kind of take this lightly, but a lot of people in Oak Ridge feel this same way, a lot of people in Oak Ridge don't drink Oak Ridge water. They buy water. They don't drink Oak Ridge water.	Oak Ridge is supplied with public water from a water treatment plant that draws surface water from Melton Hill Lake. The intake at the lake is located approximately 1 mile upstream of the ORR. Until May 2000, DOE owned and operated the water treatment plant at its Y-12 facility and sold drinking water to the city of Oak Ridge for distribution to residents and businesses. The city of Oak Ridge now owns and operates the water distribution system (City of Oak Ridge 2002). Under the Safe Drinking Water Act, EPA sets health-based standards for hundreds of substances in drinking water and specifies treatments for providing safe drinking water (USEPA 1999a). The public water supply for Oak Ridge is continually monitored for these regulated substances. The Tennessee Department of Environment and Conservation (TDEC) receives a copy of the monitoring report to ensure that people are receiving clean drinking water. More information about the quality of the Oak Ridge public water supply system can be found at: http://www.cortn.org/PW-html/CCR2004.pdf (City of Oak Ridge 2002.) To ask specific questions related to your drinking water, please call TDEC's Environmental Assistance Center in Knoxville, Tennessee at 865-594-6035. To find additional information related to your water supply or other water supplies in the area, please call EPA's Safe Drinking Water Hotline at 800-426-4791 or visit EPA's Safe Drinking Water Web site at http://www.epa.gov/safewater. You can also look up monitoring results for the Oak Ridge or other public water supplies by visiting EPA's Safe Drinking Water Information System at http://www.epa.gov/enviro/html/sdwis/sdwis_query.html.

	Actual Comment	ATSDR's Response
8	Do agencies do some of their own sampling even when it has already been done before? The Ten Mile area gets water from a company in Spring City and this company has another company of choice test it. The State has never tested it independently and did not follow-up on water testing. Could ATSDR take a sample?	If ATSDR believed that the water at Spring City was a public health issue, then it would recommend that sampling be conducted. However, based on this PHA's findings and ongoing monitoring programs, additional sampling is not necessary. Under the Safe Drinking Water Act, EPA sets health-based standards for hundreds of substances in drinking water and specifies treatments for providing safe drinking water (USEPA 1999a). The public water supplies for Kingston, Spring City, and Rockwood—systems in the White Oak Creek public health assessment study area that draw their water from the Tennessee River system—are continually monitored for these regulated substances. According to EPA's Safe Drinking Water Information System (SDWIS), the Kingston, Spring City, and Rockwood public water supply systems have not had any significant violations (USEPA 2004b). To look up information for these water supplies or other supplies in the area, go to EPA's SDWIS Web site at http://www.epa.gov/enviro/html/sdwis/sdwis_query.html. In 1996, the Tennessee Department of Environment and Conservation's (TDEC) DOE Oversight Division began participating in EPA's Environmental Radiation Ambient Monitoring System (ERAMS). Under this program, TDEC has conducted filter backwash sludge sampling at Spring City because contaminants from the ORR could potentially move downstream into community drinking water supplies. Also since 1996, EPA has analyzed samples from five public water suppliers located on and near the ORR through its ERAMS drinking water program. On a quarterly basis, TDEC takes finished drinking water samples from these locations and EPA analyzes the samples for radionuclides. The public water suppliers are as follows: Kingston Water Treatment Plant (TRM 568.4), DOE Water Treatment Plant at K-25 (CRM 14.5), West Knox Utility (CRM 36.6), DOE Water Treatment Plant at Y-12 (CRM 41.6), and Anderson County Utility District (CRM 52.5) (TDEC 2003b). In addition, the Tennessee Valley Authority (TVA) conducts sampling of radionuclides in fish tissues, and also analyzes the PCBs, pesticides, and metals in sediments from the river mile at Spring City.
9	When you're thinking of Bradbury (TN), that's basically going west of Exit 10. So the impact is basically southwest of the fact—to me it looks that people along the interstate, that area, would have been most susceptible to iodine than Bradbury. But Bradbury would be the most susceptible to some of the stuff dumped in White Oak Creek.	This public health assessment evaluates the X-10 releases of radionuclides into the water in White Oak Creek, which flows into the Clinch River and the Lower Watts Bar Reservoir. This assessment evaluates past, current, and future exposure to radionuclide releases for people who use or live along the Clinch River and the Lower Watts Bar Reservoir (the area along the Clinch River from the Melton Hill Dam to the Watts Bar Dam [see the study area in Figure 11]). Bradbury and I-40 areas are in the study area. This document does not address the X-10 releases of iodine 131 into the air. ATSDR will evaluate the release of iodine 131 into the air in a future public health assessment.
10	Two community members noted that there was a barrier at White Oak Creek, but that people still fished there. The community members continued that the barrier was simply a cable that went across with a sign that said not to enter the area. They said that people would lift this up, go under the cable, and fish at the creek.	White Oak Creek is located on the Oak Ridge Reservation. Because White Oak Creek is on the ORR, access to the creek is restricted and controlled by DOE (ChemRisk 1999a). DOE has a cable barrier that runs across White Oak Creek to prevent trespassers from entering the creek for fishing and other prohibited activities. Also, DOE has posted warning signs at the creek so that people will not enter the area (EEWG [former PHAWG] meeting minutes, May 5, 2003). Therefore, people who fish or enter White Oak Creek for other purposes are trespassing on DOE property.

	Actual Comment	*ATSDR's Response*
11	She wondered if there are any substances in the drinking water.	Kingston maintains public water supplies in the vicinity of the Oak Ridge Reservation (see Figure 13). The Kingston water supply has two water intakes, but only one of the intakes—located upstream on the Tennessee River in Watts Bar Lake at Tennessee River Mile (TRM) 568.4—would potentially be impacted by ORR contaminants (Hutson and Morris 1992; G. Mize, Tennessee Department of Environment and Conservation, Drinking Water Program, personal communication re: Kingston public water supply, 2004). Spring City obtains its water from an intake on the Piney River branch of Watts Bar Lake (Hutson and Morris 1992). The city of Rockwood receives its water from an intake on the King Creek branch of Watts Bar Lake, located at TRM 552.5 (TDEC 2001, 2006b; TVA 1991). Under the Safe Drinking Water Act, the EPA has set health-based standards for substances in drinking water and specified treatments for providing safe drinking water since 1974 (USEPA 1999a). In 1977, EPA gave the state of Tennessee authority to operate its own Public Water System Supervision Program under the Tennessee Safe Drinking Water Act. Through this program, TDEC's Division of Water Supply regulates drinking water at all public water systems. As a requirement of this program, all public water systems in Tennessee individually monitor their water supply for EPA-regulated contaminants and report their monitoring results to TDEC. The public water supplies for Kingston, Spring City, Rockwood, and other supplies in Tennessee are monitored for substances that include 15 inorganic contaminants, 51 synthetic and volatile organic contaminants, and 4 radionuclides (USEPA 2004a). EPA's monitoring schedules for each contaminant is available at http://www.epa.gov/safewater/pws/pdfs/qrg_smonitoringframework.pdf (USEPA 2004a). On a quarterly basis, TDEC submits the individual water supply data to EPA's Safe Drinking Water Information System (SDWIS) (TDEC 2003c). According to EPA's SDWIS, the Kingston, Spring City, and Rockwood public water supply systems have not had any significant violations (USEPA 2004b). To look up information related to these and other public water supplies, go to EPA's Local Drinking Water Information Web Site at http://www.epa.gov/safewater/dwinfo.htm. In addition, in 1996 TDEC's DOE Oversight Division started to participate in EPA's Environmental Radiation Ambient Monitoring System (ERAMS). As part of the Oak Ridge ERAMS program, TDEC collects samples from five facilities on the ORR and in its vicinity. Under the Oak Ridge ERAMS, TDEC collects finished drinking water samples from the Kingston Water Treatment Plant on a quarterly basis and then submits the samples to EPA for radiological analyses. The schedule and contaminants sampled at the Kingston Water Treatment Plant are presented in Section II.F.3. Also see the TDEC–DOE Oversight Division's annual report to the public at http://www.state.tn.us/environment/doeo/active.shtml for a summary of radiological drinking water sampling results. TDEC has also conducted filter backwash sludge sampling at Spring City because radioactive contaminants from the ORR could potentially move downstream into community drinking water supplies. TDEC analyzed Spring City samples for gross alpha, gross beta, and gross gamma emissions (TDEC 2002, 2003a, 2003b). To ask specific questions related to your drinking water, please call TDEC's Environmental Assistance Center in Knoxville, Tennessee at 865-594-6035 or call EPA's Safe Drinking Water Hotline at 800-426-4791. More details are also available at EPA's Safe Drinking Water Web site at http://www.epa.gov/safewater/.

	Actual Comment	*ATSDR's Response*
Radionuclides Associated with X-10's Releases to White Oak Creek		
12	A subcommittee member asked about known health effects of niobium, sheet metal form.	Niobium has been used on the Oak Ridge Reservation at both the X-10 and Y-12 plants. In *Phase I of the Oak Ridge Health Studies (Dose Reconstruction Feasibility Study)*, the Tennessee Department of Health investigated niobium from the Oak Ridge Reservation and determined that it was not a high priority contaminant. In, however, the *Reports of the Oak Ridge Dose Reconstruction, Radionuclide Releases to the Clinch River from White Oak Creek on the Oak Ridge Reservation—an Assessment of Historical Quantities Released, Off-Site Radiation Doses, and Health Risks* (referred to as the "Task 4 report"), TDOH reevaluated niobium 95 releases into White Oak Creek and the radiation dose from niobium 95 was included in the evaluation of external exposure from shoreline sediments. In addition, the state reevaluated niobium from Y-12 in the *Task 7 Report—Screening-level Evaluation of Additional Potential Materials of Concern*. Through its assessment, the state determined that quantities of niobium from Y-12 were not large enough to present health risks to off-site populations (ATSDR et al. 2000; ChemRisk 1999b). Data on the toxicological effects of niobium are very limited, and EPA has not established regulatory limits for chronic exposure to niobium (ChemRisk 1999b). Most people rarely encounter niobium compounds. Unless known otherwise, all niobium compounds should be regarded as highly toxic in the laboratory. The metal dust causes eye and skin irritation, and is likely to represent a fire hazard. See Appendix D for briefs on the 1993 Phase I *Dose Reconstruction Feasibility Study*, the 1999 Task 4 report, and the 1999 Task 7 report. Copies of these three reports are available at the DOE Information Center located at 475 Oak Ridge Turnpike, Oak Ridge, Tennessee (telephone number: 865-241-4780) or through DOE's public-use database at http://cedr.lbl.gov/DR/dror.html.
13	Does cesium stay in the muscle?	Cesium can enter the body through ingestion, inhalation, or injury to the skin. Once cesium enters the body, it is dispersed throughout the body's soft tissues. Slightly larger concentrations of cesium are found in muscle compared with amounts of cesium found in bone and fat. Compared with some of the other radionuclides, cesium remains in the body for a fairly short period of time (USEPA 2003a). Cesium does not stay in the muscle or other tissues. Cesium has a physical half-life of about 30 years and a biological half-life of 70 days. Therefore, the cesium is removed from the body through urine in about 70 days (EEWG [former PHAWG] meeting minutes from December 10, 2001; USEPA 2003a).

	Actual Comment	*ATSDR's Response*
14	A community member thought that over 2,000 curies (Ci) were released in one year (1956) over White Oak Dam, but this was a short half-life. He thought that it was two weeks for ruthenium 106. The community member thought that ruthenium went to rhodium, which had the largest beta of any radionuclide.	Ruthenium (Ru) 106 is a fission product with a radioactive half-life of approximately 368 days. Ru 106 decays, releasing a beta particle with energy of 0.039 million electron volts (MeV). This means that Ru 106 is a very weak emitter; however, its decay product rhodium (Rh) 106 is a very strong beta particle emitter. Rh 106 has a radioactive half-life of about 30 seconds and the maximum beta particle energy emission is 3.5 MeV. Rh 106 also emits several gamma rays of varying energy. When Ru 106 is taken into the body, the dose methodology and the dose coefficients used take into account the production of rhodium by the radioactive decay of the ruthenium. However, the dose delivered by the rhodium is not considered because its half-life of 30 seconds is too short to have an impact. In fact, neither the ICRP nor the EPA publish dose coefficients for Rh 106.
15	Back in the 1950s and 1960s when they were doing a lot of testing, strontium was a big worry. I'd never heard of I 131. Everyone was concerned then about health effects from strontium. Now all this talk about I 131. All of this was from same fallout (I 131 and strontium). Strontium pathway is basically the same as iodine.	The Task 4 report evaluated the estimated amount of radioactivity that was released from X-10 into White Oak Creek. During its evaluation, the state determined that specific radionuclides required further investigation; strontium 90 and iodine 131 were both included in this group. In this PHA, ATSDR evaluated past and current exposure to strontium contamination released from White Oak Creek, and determined that the levels of strontium in the water, sediment, vegetables, fish, and game were too low to be of public health concern (ChemRisk 1999a). See Section III. Evaluation of Environmental Contamination and Potential Exposure Pathways in this PHA for ATSDR's analysis of past and present exposures to strontium. ATSDR will address historical exposures to iodine 131 released into the air from X-10 in a future PHA. Inhalation, drinking water, and food consumption are the pathways for both iodine and strontium. However, the primary health effects differ between these two radionuclides. Strontium 90 affects bone marrow and bone surfaces; its 29-year radioactive half-life and 30-year biological half-life make strontium one of the more hazardous contaminants associated with radioactive fallout. The primary health concerns for strontium include bone tumors and tumors in the blood cell forming organs. Whereas iodine 131 is deposited into the thyroid, and consequently, the primary health concern for iodine 131 is thyroid tumors. Traditionally, the primary exposure pathway to iodine 131 has been drinking milk from cows that consumed contaminated crops. Consumption of fruits and vegetables, and also inhalation, are other exposure pathways for iodine 131 (INEEL 2001a, 2001b). ATSDR will provide additional information on iodine from X-10 in a future PHA on iodine 131.

<table>
<tr><th></th><th>Actual Comment</th><th>ATSDR's Response</th></tr>
<tr><td colspan="3">Evaluation of Contaminants Released from the Oak Ridge Reservation</td></tr>
<tr><td>16</td><td>The board (ORRHES) should familiarize itself with the off-site contamination that has gone on down river and downstream.

There are 6 initial contaminants of concern (which include iodine 131, mercury, uranium, radionuclides in White Oak Creek, polychlorinated biphenyls, fluorine/fluoride), although there may be others.

Why weren't the Oak Ridge signature contaminants of nickel, strontium, cesium, and chromium, which are in residents' bodies, included in the Phase I evaluation, and why was it not peer reviewed?</td><td>At the March 2001, June 2001, December 2001, and February 2002 Oak Ridge Reservation Health Effects Subcommittee (ORRHES) meetings, and at the Exposure Evaluation Work Group (formerly known as the Public Health Assessment Work Group [PHAWG]) meetings in 2001 and 2002, ATSDR presented and discussed in detail its screening process for evaluating past exposures (1944–1990) and determining contaminants of concern that warrant further evaluation. This comprehensive screening analysis included an evaluation of releases of hazardous substances (chemical and radiological) into the air, creeks, streams, and rivers from the Oak Ridge Reservation and the potential of off-site exposure to contaminants downstream. These detailed presentations also included discussions of ATSDR's review and analysis of the Tennessee Department of Health's

• 1993 Phase I of the Oak Ridge Health Study—Dose Reconstruction Feasibility Study, and
• 1999 Reports of the Oak Ridge Dose Reconstruction, The Report of Project Task 7—Screening-Level Evaluation of Additional Potential Materials of Concern.

These studies evaluated past chemical and radionuclide releases from the Oak Ridge Reservation and the potential of their releases to impact the health of people living near the reservation.

Using ATSDR's screening process for evaluating past exposures, ATSDR scientists are conducting public health assessments on the release of and exposure to uranium, iodine 131, mercury, PCBs, radionuclides from White Oak Creek, fluorides, and other topics, such as the TSCA incinerator and off-site groundwater. ATSDR will evaluate past and current off-site exposures to these contaminants.

In addition, the EEWG conducted an evaluation of ATSDR's screening process for past exposures. The EEWG's evaluation consisted of a detailed review and understanding of ATSDR's screening presentations to the subcommittee, ATSDR's independent technical reviewers' comments, the subcommittee's review and assessment of technical documents (as needed), and related public concerns or issues (as needed). After completing its evaluation, the EEWG recommended at the February 2002 ORRHES meeting that the ORRHES endorse ATSDR's screening process for determining contaminants of concern for past exposures (1944–1990 data). This endorsement begins with using the state of Tennessee's screening process and associated findings that identified ORR off-site releases warranting further evaluation. The ORRHES approved the EEWG's recommendation to endorse ATSDR's screening evaluation of past exposures. The February 2002 ORRHES meeting minutes are available on the ATSDR Web site at http://www.atsdr.cdc.gov/HAC/oakridge/meet/orr/m8_27.html.</td></tr>
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	Actual Comment	ATSDR's Response
16	*Continued*	Cesium and strontium were first evaluated by the state of Tennessee in its 1993 *Phase I of the Oak Ridge Health Study Dose Reconstruction Feasibility Study* and then reevaluated in the 1999 *Reports of the Oak Ridge Dose Reconstruction, Radionuclide Releases to the Clinch River from White Oak Creek on the Oak Ridge Reservation—an Assessment of Historical Quantities Released, Off-Site Radiation Doses, and Health Risks* (referred to as the "Task 4 report"). ATSDR evaluated past, current, and future exposure to cesium and strontium in this public health assessment. Nickel and chromium were evaluated in the 1993 *Phase I of the Oak Ridge Health Study—Dose Reconstruction Feasibility Study* and reevaluated in the 1999 *Reports of the Oak Ridge Dose Reconstruction, The Report of Project Task 7—Screening-Level Evaluation of Additional Potential Materials of Concern* (ATSDR et al. 2000; ChemRisk 1999b). The Tennessee Department of Health had the 1993 *Phase I of the Oak Ridge Health Study—Dose Reconstruction Feasibility Study* reviewed by SENES Oak Ridge in 1995. This report titled A *Review of the Preliminary Screening Analysis Carried Out During the Oak Ridge Dose Reconstruction Feasibility Study* was evaluated by ATSDR and the EEWG (former PHAWG). See Appendix D for briefs on the 1993 Phase I feasibility study, 1999 Task 4 report, and the 1999 Task 7 report. Copies of the Tennessee Department of Health reports are available at the DOE Information Center located at 475 Oak Ridge Turnpike, Oak Ridge, Tennessee (telephone number: 865-241-4780) or through DOE's public-use database at http://cedr.lbl.gov/DR/dror.html.

	Actual Comment	ATSDR's Response
17	I had some questions about your study of the hundred and sixteen people in the southern Watts Bar area. I don't know if I am being premature in my questions to you, but did you all come to the conclusion that there was no danger from eating the fish for anything other than PCBs, when that was the only thing you tested for? If your testing was accurate and your conclusions were accurate, why hasn't something changed so far as all of those fish advisories? I don't think the community would mind if you had an advisory on don't eat the turtles.	ATSDR conducted a health consultation in 1996 to evaluate the public health implications of current exposure to chemical and radiological contaminants in the Lower Watts Bar Reservoir surface water, sediment, and fish and the effectiveness of the Department of Energy's (DOE) proposed remedial action plan for protecting public health. ATSDR found that only PCBs in the reservoir fish were of potential public health concern. The current levels of other contaminants in the surface water, sediment, and fish are not a public health hazard. After reviewing current levels of contaminants in the water, in sediment, and in local fish populations, ATSDR concluded that: • The levels of PCBs in the Lower Watts Bar Reservoir fish posed a public health concern. Frequent and long-term ingestion of fish from the reservoir posed a moderately increased risk of cancer in adults and increased the possibility of developmental effects in infants whose mothers consumed fish regularly during gestation and while nursing. Turtles in the reservoir might also contain PCBs at levels of public health concern. • Current levels of contaminants in the reservoir surface water and sediment were not a public health hazard. The reservoir was safe for swimming, skiing, boating, and other recreational purposes. Drinking water from the municipal water systems, which draw surface water from tributary embayments in the Lower Watts Bar Reservoir and the Tennessee River upstream from the Clinch River and Lower Watts Bar Reservoir, was safe to drink. • DOE's selected remedial action was protective of public health. ATSDR recommended that the Lower Watts Bar Reservoir fish advisory remain in effect to minimize exposure to PCBs. ATSDR followed up the 1996 health consultation by conducting the *Watts Bar Reservoir Exposure Investigation* in March 1998. This study was done to measure *actual* PCB and mercury levels in people who have eaten large amounts of Watts Bar Reservoir fish or turtles. ATSDR tested for PCBs because previous investigations estimated that people who eat certain fish or turtles *might* have higher than average levels of PCBs in their bodies and suggested that the levels of PCBs in fish were a public health concern. ATSDR tested the blood samples for mercury because mercury was a historic contaminant of concern. Recent studies, however, have not detected mercury at levels of health concern in surface water, sediments, or fish from the Watts Bar Reservoir.

	Actual Comment	ATSDR's Response
17	*Continued*	The ATSDR exposure investigation revealed that the 116 study participants who consumed moderate to large amounts of fish and turtles had PCB levels similar to those of the general population. The PCB and mercury levels were less than ATSDR health officials expected for people who consume moderate to large amounts of certain fish or turtles from the Watts Bar Reservoir. Five people (4% of the 116 participants) had elevated serum levels of PCBs (above 20 micrograms per liter), one person had PCB levels above those in the general population, and one person had elevated blood mercury levels (above 10 micrograms per liter). ATSDR health officials believed that health effects were not likely based on the PCB and mercury levels seen in the exposure investigation participants. ATSDR recommended that health education activities be targeted to local health care providers, pregnant and nursing mothers, and any other potentially vulnerable populations to minimize exposure to PCBs. ATSDR developed an instructive brochure on the Tennessee Department of Environment and Conservation (TDEC) fish consumption advisories for the Watts Bar Reservoir. The brochure was the result of the collaborative effort of local citizens, organizations, and state officials. See Appendix D for a brief of the exposure investigation and Section II.F.1. for ATSDR's public health activities related to White Oak Creek radionuclide releases (ATSDR et al. 2000; ORHASP 1999).
18	Since the contamination from fish ingestion will not necessarily be measurable in the bloodstream at high levels at all times, a challenge test is needed to detect it. This was not used by ATSDR and is not normally used in a standard physician's office visit test. The ATSDR study results are countered by other studies, and communities in the southeast whose problems were addressed by ATSDR were not helped.	There are reliable and accurate medical tests that measure the level of mercury in the body by analyzing blood, breast milk, hair, or urine samples. These are not routine clinical tests, but they could be requested from a doctor. Most of these tests do not determine the form of mercury to which an individual is exposed. These clinical tests can show if mercury exposure has occurred, provide an idea as to the extent of exposure, and can be used to assess if harmful health effects are likely to occur, but they cannot tell exactly how much exposure has occurred (ATSDR 1999a). For more information on mercury, review ATSDR's toxicological profile on mercury at http://www.atsdr.cdc.gov/toxprofiles/phs46.html. PCBs are pervasive environmental contaminants that are found in body tissue and fluids of the general population. There are also medical tests that measure the level of PCBs in the body by analyzing blood, body fat, and breast milk. Serum or plasma lipid PCB concentrations are an indicator of PCB body burden. These are not routine clinical tests, but they could be requested from a doctor. These tests can indicate if a person was exposed to PCBs, but they cannot determine the exact amount of exposure, type of PCBs, or if adverse health effects will occur. Though, these tests can indicate whether you have been exposed to PCBs to a greater extent than the general public. Blood tests are the best method for detecting recent exposure to large amounts of PCBs. Thus, a physician with a background in environmental and occupational health should carefully interpret the test results (ATSDR 2000). For more information on PCBs, visit ATSDR's Web site for the PCB toxicological profile at http://www.atsdr.cdc.gov/toxprofiles/phs17.html.

	Actual Comment	ATSDR's Response
18	*Continued*	Previous investigations identified PCBs in reservoir fish as a possible contaminant of public health concern. TDEC and DOE had detected PCBs at levels up to about 8 ppm in certain species of reservoir fish during past studies. In an investigation on turtles in the Watts Bar Reservoir and the Clinch River, TDEC detected the highest PCB concentrations in the fat tissue (ranged from 0.274 to 516 ppm) of snapping turtles. The PCB concentrations detected in the muscle tissue of turtles ranged from 0.032 to 3.38 ppm. In 1994 and 1996 remedial investigations, based on estimated PCB exposure doses and estimated excess cancer risks for people consuming large amounts of fish over an extended time period, DOE determined that the fish ingestion pathway had the greatest potential to cause adverse health effects in the Lower Watts Bar Reservoir and the Clinch River/Poplar Creek, respectively. ATSDR also conducted a 1996 health consultation on the Lower Watts Bar Reservoir that reached similar conclusions as found in the remedial investigation. None of these studies, however, considered actual blood levels in fish and turtle consumers nor confirmed if people were actually exposed to PCBs or had elevated PCB levels. Because of these reasons and since so many uncertainties are involved in estimating exposure doses and excess cancer risk from ingesting reservoir fish and turtles, ATSDR conducted an exposure investigation to actually measure the serum PCB levels in fish and turtle consumers. In fact, ATSDR knows of no other studies in the Oak Ridge area that measured actual blood levels in community members to evaluate exposures from fish and turtle consumption. For this investigation, ATSDR targeted people who consumed moderate to large amounts of reservoir fish and turtles. Based on the actual measurements of serum PCB levels in participants, only 1 out of 116 had a serum PCB level higher than levels observed in the general population. Therefore, based on actual levels—not theoretical estimates as used in previous studies—of people who consumed moderate to high amounts of fish and turtles from the reservoir, PCB levels were comparable to the general population. See Appendix D for a brief on the *1998 Watts Bar Reservoir Exposure Investigation* and a brief on the *Turtle Sampling in Watts Bar Reservoir and Clinch River.*
19	Concerning studies of PCBs and blood samples in people who eat fish, I wonder how valid the information would be. Do PCBs stay in the blood, for example, and were they are a lot higher, one would presume, right after eating a meal than a week later? Were those factors taken into account in the study?	The *1998 Watts Bar Reservoir Exposure Investigation* was a cross-sectional study because it evaluated PCB and mercury exposures at a specific point in time. Blood tests are the best method for detecting exposure to PCBs. Serum or plasma lipid PCB concentrations are indicators of PCB body burden and can indicate whether you have been exposed to PCBs to a greater extent than the general public. In this type of study (a cross-sectional study), PCB and mercury blood levels indicate both chronic and acute (short-term) exposures, depending on recent fish consumption. PCB blood levels are likely to be higher right after eating a fish meal containing PCBs. This factor was taken into account in the exposure investigation. The investigation is discussed in more detail in Section II.F.1. of this document. In addition, ATSDR will address issues solely related to PCBs in a separate public health assessment that will be released in the near future. See Appendix D for a brief on the *1998 Watts Bar Reservoir Exposure Investigation*.

	Actual Comment	ATSDR's Response
20	A community member said there are a couple of other dimensions that will complicate matters but she hopes they will be considered. One is the time frame. The workers and residents who lived nearby in the 50s and 60s had different exposures than now and will have different symptoms now. Also, geographically, the flow of water, the underground aquifer, that sort of thing. The two dimensions are geography and time will complicate this and shouldn't be overlooked. There may be people who lived in different locations and the well water was of different composition.	In this public health assessment, ATSDR evaluates radionuclides released into the surface water in White Oak Creek, and assesses past, current, and future impact from exposures to these radionuclide releases in the water for residents living off the Oak Ridge Reservation within the White Oak Creek study area (the area along the Clinch River and the Lower Watts Bar Reservoir from the Melton Hill Dam to the Watts Bar Dam [see Figure 11]). This PHA evaluates the following key issues and concerns: contacting surface water and sediment (both surface and deep channel) and consuming surface water, milk, game animals, fish, turtles, and homegrown vegetables. In addition to this PHA, ATSDR scientists are conducting public health assessments on the releases of iodine 131, mercury, PCBs, uranium, fluorides, and other topics including off-site groundwater. The geography and characteristics of the aquifer are considered in the groundwater public health assessment available at http://www.atsdr.cdc.gov/HAC/PHA/region_4.html#groundwater. In conducting PHAs, ATSDR scientists are evaluating and analyzing the information, data, and findings from previous studies and investigations to assess the public health implications of past, current, and future exposures.
21	Will exposure investigations be done as they were for PCBs at Watts Bar?	ATSDR is not planning additional exposure investigations at this time. Instead, ATSDR is conducting public health assessments on the releases of iodine 131, mercury, PCBs, uranium, fluorides, and other topics. In conducting these public health assessments, ATSDR scientists are evaluating and analyzing the information, data, and findings from previous studies and investigations to assess the public health implications of past, current, and future exposures. ATSDR uses the public health assessment process to • Identify populations (groups of people) off the site who could have been exposed to hazardous substances at levels of health concern, • Determine the public health implications of exposure, • Address the site-specific health concerns of people in the community, • Recommend any needed follow-up public health actions to address exposure, and • Communicate ATSDR's findings to the public.
General Concerns Related to the Oak Ridge Reservation		
22	What is the probability of a clinic for residents closely associated and who live close by incinerators and the Clinch River and East Fork Poplar Creek?	ATSDR is using the public health assessment process to evaluate previous studies and environmental data to determine whether releases of hazardous substances from the Oak Ridge Reservation could have affected the health of people in communities near the reservation. The public health assessment is the primary public health process ATSDR uses to • Identify populations (groups of people) off the site who could have been exposed to hazardous substances at levels of health concern, • Determine the public health implications of exposure,

	Actual Comment	ATSDR's Response
22	*Continued*	• Address the site-specific health concerns of people in the community, • Recommend any needed follow-up public health actions to address exposure, and • Communicate ATSDR's findings to the public. ATSDR worked with the Oak Ridge Reservation Health Effects Subcommittee (ORRHES) to ensure that the public health questions of people living in the Oak Ridge Reservation area were answered. In response to community concerns regarding a clinic, the ORRHES Needs Assessment Work Group conducted a comprehensive program review of the various federal agencies to determine whether it was possible to establish an occupational/environmental clinic or another form of clinical intervention near the Oak Ridge Reservation. On August 27, 2002, the ORRHES made the following recommendation to ATSDR. "The Oak Ridge Reservation Health Effects Subcommittee (ORRHES) has determined that discussion of public health activities related to the establishment of a clinic, clinical evaluations, medical monitoring, health surveillance, health studies, and/or biological monitoring is premature. Thus, the ORRHES recommends that formal consideration of these issues be postponed until the ATSDR public health assessment (PHA) process identifies and characterizes an exposure of an off-site population at levels of health concern. If this exposure warrants follow-up public health activities, the ORRHES will then consider these issues in making its recommendations to ATSDR." This ORRHES recommendation was based on the review, evaluation, and understanding of the comprehensive program review presented by the Needs Assessment Work Group at the August 27, 2002, ORRHES meeting. The August 27, 2002, ORRHES meeting minutes are available on ATSDR's Web site at http://www.atsdr.cdc.gov/HAC/oakridge/meet/orr/m8_27.html.
23	Will you screen the effects of the environmental pollutants from the Kingston and Bull Run power plants whose interaction with the ORR concerns many people?	ATSDR is not evaluating all sources of contaminants in the area and is not adding exposures from these other sources. Congress created ATSDR to implement the health related sections of the 1980 Superfund law. ATSDR's congressional mandate is to conduct a public health assessment at EPA's National Priorities List for Uncontrolled Hazardous Waste Sites (NPL). The DOE Oak Ridge Reservation (ORR) is on the NPL. ATSDR's focus is on ORR releases of contaminants to off-site locations. ATSDR is not going to conduct an evaluation of releases of contaminants from other industries in the area. However, environmental samples (air, water, sediment, and soil) collected in and around the ORR may contain contaminants released from other industries in the area (for example, arsenic, mercury, and uranium released from the two large Tennessee Valley Authority [TVA] power plants). ATSDR will evaluate the levels of contaminants in these samples regardless of the source of the contaminants. If ATSDR identifies contaminants in off-site locations during its assessment that are of public health concern, then ATSDR will address exposures to these contaminants in the PHA.

	Actual Comment	ATSDR's Response
24	This second paper in Radiation Research (after the Mangano paper) was a study of the mortality of 106,020 workers employed between 1943 and 1985 at the federal nuclear plants in Oak Ridge (who also live in communities around ORR). This second paper DID NOT find an increase in leukemia deaths relative to U.S. white males. A smaller group of 28,347 white males employed at X-10 or Y-12 who were at risk for exposure to external penetrating radiation was examined to determine if there was a relationship between rates of death from selected causes and level of radiation dose. There was no evidence for an association between leukemia deaths and external radiation. Leukemia death rates for X-10 workers were higher than U.S. rates and other similar Oak Ridge workers.	ATSDR is conducting public health assessments to evaluate whether the releases of contaminants from the Oak Ridge Reservation could be harmful to people who live in communities near the reservation. This assessment focuses on exposures to contaminants that occurred off the reservation. ATSDR does not evaluate health issues related to workplace exposures. ATSDR did, however, conduct an assessment of cancer incidence that evaluated cancers in the eight counties surrounding the reservation. For the review, ATSDR used cancer incidence data from the state of Tennessee's cancer registry. The assessment of cancer incidence report is available at http://www.atsdr.cdc.gov/HAC/oakridge/phact/cancer_oakridge/index.html. Information specific to workers can be found on the Internet at http://cedr.lbl.gov. This site provides information about epidemiologic studies of U.S. Department of Energy workers, including studies of workers at the Y-12, X-10, and K-25 sites.

VII. Child Health Considerations

ATSDR recognizes that infants and children can be more sensitive to environmental exposure than adults in communities faced with contamination of their water, soil, air, or food. This sensitivity is a result of the following factors: 1) children are more likely to be exposed to certain media (for example, soil or surface water) because they play and eat outdoors; 2) children are shorter than adults, which means that they can breathe dust, soil, and vapors close to the ground; and 3) children are smaller; therefore, childhood exposure results in higher doses of chemical exposure per body weight. Children can sustain permanent damage if these factors lead to toxic exposure during critical growth stages. ATSDR is committed to evaluating the special interests of children at sites such as the ORR.

Children playing in and living along the Clinch River and Watts Bar Reservoir could have been exposed to radiation when they used these waterways for food, water, or recreation. In addition, *in utero* and infant exposures could have resulted from exposure of pregnant or lactating women (or both) to radiation in and near the Clinch River and Watts Bar Reservoir. Radionuclide levels in water, sediment, and biota are, however, below levels shown to cause adverse health effects in these populations. For past exposures, the Task 4 team concluded that its estimated radiological doses and excess lifetime cancer risks were "incremental increases above those resulting from exposure to natural and other anthropogenic sources of radiation." Still, they were "not large enough for a commensurate increase in health effects in the population to be detectable, even by the most thorough of epidemiological investigations." The Task 4 team noted that "in most cases, the estimated organ-specific doses are clearly below the limits of epidemiological detection (1 to 30 cSv [1,000 to 30,000 mrem]) for radiation-induced health outcomes that have been observed following irradiation of large cohorts of individuals exposed either in utero (Doll and Wakeford 1997), as children, or as adults (NRC [National Research Council] 1990; Thompson et al. 1994; Pierce et al. 1996) (ChemRisk 1999a)."

Further, dose and risk factors for most radionuclides in the Task 4 analysis do not differ greatly between children and adults (ChemRisk 1999a). Exposure to iodine 131 has been shown to increase the likelihood of thyroid disorders in children—that is, exposed children could have an increased likelihood of developing a disease (e.g., thyroid cancer) in their lifetimes

(Vykhovanets et al. 1997; Astakhova et al. 1998; Heidenreich et al. 1999; Hahn et al. 2001). Nevertheless, based on the Task 4 analysis, the levels of iodine 131 in the surface water of the Clinch River and in the locally produced milk are too low to cause such health effects in children living near the Clinch River.

Therefore, even past radiation exposures—when doses were the highest—were not expected to cause harmful health effects *in utero*, in infants, and in children. Accordingly, because estimated doses for exposures to the Clinch River and Lower Watts Bar Reservoir have decreased over time, exposures to radiation *in utero*, in infants, and in children are not expected to cause adverse health effects in the present or in the future.

VIII. Conclusions

Having thoroughly evaluated past public health activities and available current environmental information, ATSDR has reached the following conclusions.

ATSDR concludes that exposures to X-10 radionuclides released from White Oak Creek to the Clinch River and to the Lower Watts Bar Reservoir are not a health hazard. Past and current exposures are below levels associated with adverse health effects and regulatory limits. Adults or children who have used, or might continue to use, the waterways for recreation, food, or drinking water are not expected to have adverse health impacts due to exposure. ATSDR has categorized those situations as posing *no apparent public health hazard* from exposure to radionuclides related to X-10. This classification means that people could be or were exposed, but that their level of exposure would not likely result in any adverse health effects. (Definitions of ATSDR's public health categories are included in the glossary in Appendix A.)

> ATSDR uses the ***no apparent public health hazard*** category in situations in which human exposure to contaminated media might be occurring, might have occurred in the past, or might occur in the future, but where the exposure is not expected to cause any harmful health effects.

Past Exposure

ATSDR concludes that past exposures to White Oak Creek radionuclide releases from walking on the shoreline, drinking milk and water, or eating meat and fish from the Clinch River are not a health hazard and are not expected to result in adverse health effects or cancer.

- Using the results of the Task 4 report, ATSDR re-evaluated *past* exposures (1944–1991) to radionuclides released from White Oak Creek into the Clinch River. People who used or lived near the Clinch River could have come in contact with X-10 radionuclides by eating fish and meat, drinking milk and water, and walking on shoreline sediment. Using organ doses from the Task 4 report, ATSDR estimated whole-body doses (annual dose and committed effective dose over 70 years). An individual exposed to the primary radionuclides in Clinch River fish, shoreline sediment, meat, milk, and drinking water was expected to receive a committed effective dose to the whole body of less than 300 mrem over 70 years. This dose is about 18 times less than ATSDR's radiogenic comparison value of 5,000 mrem over 70 years. Doses below the radiogenic comparison value are not expected to result in observable health effects.

- ATSDR's estimated annual whole-body dose from combining the organ doses was 4 mrem/year and well below (25 times less than) ATSDR's MRL of 100 mrem/year and the

ICRP, NRC, and NCRP maximum dose recommendation of 100 mrem/year for members of the public. ATSDR's MRL for ionizing radiation is based on noncancer health effects only; it is not based on a consideration of cancer effects. MRLs are estimates of daily human exposures to substances that are unlikely to result in noncancer effects over a specified duration. The maximum dose constraint for members of the public of 100 mrem/year recommended by the ICRP, NRC, and NCRP considers both noncancer and cancer health effects.

- The estimated committed equivalent doses to all the organs from eating fish caught near Jones Island exceeded dose estimates for all other exposure pathways (walking along the shore and ingesting water, milk, and meat) by at least a factor of six. The estimated committed equivalent doses to the organs from past exposures to radionuclides in and along the Clinch River varied by critical organ (bone, lower large intestine, red bone marrow, breast, and skin).

- The highest committed equivalent dose to the organs was 810 mrem to the bone for people who ate fish often (1 to 2.5 fish meals per week) and caught their fish near Jones Island. Doses to the bone were much lower for people who consumed fewer fish and who caught their fish further downstream. The estimated total committed equivalent dose to the bone over a lifetime (70 years) from all exposure pathways was less than 1,600 mrem over 70 years. This estimated total lifetime bone dose is well below (243 times less than) the doses of 390,000 to 620,000 mrem shown to cause bone cancers in radium dial workers.

- ATSDR analyzed radiation doses from drinking water at K-25/Grassy Creek (CRM 17 to 5) and the city of Kingston (CRM 2 to 0), located downstream from the mouth of White Oak Creek. The doses to the bone, lower large intestine, red bone marrow, breast, and skin from drinking Clinch River water were at least 7 times lower than the doses to those same organs from eating Clinch River fish. The highest annual whole-body dose from drinking water of 0.3 mrem was estimated for K-25/Grassy Creek. This annual whole-body dose is more than 1,000 times less than the background dose of 360 mrem that the average U.S. citizen receives each year. Lower doses were associated with drinking water further downstream at the city of Kingston. Organ-specific doses from drinking city of Kingston water were at least 13 times less than the doses estimated for K-25/Grassy Creek drinking water.

- After reviewing information provided by a community member about the former Happy Valley settlement, ATSDR conducted a separate analysis of possible exposures to radionuclides for Happy Valley residents who relied on the K-25 water intake for their drinking water. ATSDR's estimated annual whole-body dose of 14 mrem from drinking water for a former Happy Valley resident is at least 7 times lower than ATSDR's MRL of 100 mrem/year and the ICRP, NRC, and NCRP maximum dose recommendation of 100 mrem/year for members of the public.

- The estimated total committed equivalent dose to the lower large intestine from all pathways was less than 1,200 mrem over 70 years. This estimated dose is 4 times less than ATSDR's radiogenic comparison value of 5,000 mrem over 70 years, which is based on studies of atomic bomb survivors, radiation workers, and radiation workers' children.

- The estimated total committed equivalent dose to the red bone marrow over a lifetime (70 years) from all exposure pathways was less than 1,200 mrem over 70 years. This estimated total lifetime bone dose is well below (i.e., 325 times less than) the doses of 390,000 to 620,000 mrem associated with bone cancers in radium dial workers.

- The estimated total committed equivalent dose to the breast in females over a lifetime (70 years) from all exposure pathways was less than 500 mrem over 70 years, which is well below (20 times less than) the 10,000 mrem dose shown to cause effects in atomic blast survivors.

- The estimated total committed equivalent dose to the skin over a lifetime (70 years) from all exposure pathways was less than 700 mrem over 70 years, which is well below (12 times less than) the 9,000 mrem dose shown to cause effects in patients irradiated for the treatment of ringworm.

- All the estimated organ doses and whole-body doses from past exposure to radionuclides in the Clinch River are lower than ATSDR's comparison values and doses reported in radiological and epidemiological studies on the effects of radiation exposure. Therefore, considering the many conservative assumptions used in calculating the dose estimates, ATSDR believes that the actual likelihood of developing disease for people who were exposed to radionuclides in the Clinch River is small, if it exists at all.

Current Exposure

ATSDR concludes that current exposures to White Oak Creek radionuclide releases to the Clinch River and LWBR are not a health hazard and are not expected to result in adverse health effects or cancer. This conclusion is based on ATSDR's evaluation of current exposure to radionuclides by consumption of surface water, by dermal contact with surface water and sediment, and by consumption of fish from the Clinch River and the Lower Watts Bar Reservoir, as well as by consumption of turtles and geese from the Clinch River.

Lower Watts Bar Reservoir

- Using available environmental data collected from 1988 to 1994, ATSDR evaluated current exposures to radionuclides via ingestion of fish, ingestion of surface water, and external exposure from dermal contact with surface water and shoreline and dredged channel sediment of the Lower Watts Bar Reservoir. Even assuming maximum concentrations of radionuclides and using conservative exposure scenarios, current exposure to radionuclides in the Lower Watts Bar Reservoir would result in radiation doses below levels expected to cause adverse health effects. ATSDR's estimated committed effective dose to the whole body for all pathways combined is less than 1,900 mrem over 70 years—2.5 times below ATSDR's radiogenic CV of 5,000 mrem over 70 years. The estimated annual whole-body dose is less than 30 mrem, and below ATSDR's screening comparison value of 100 mrem/year. Therefore, the estimated exposures for the LWBR are not expected to result in adverse health effects based on an evaluation of radiological, epidemiological, and medical literature.

Clinch River

- Using available environmental data collected from 1989 to 2003, ATSDR evaluated current exposures to radionuclides via ingestion of biota (i.e., fish, geese, and turtles), incidental ingestion of surface water, and external exposure from dermal contact with surface water and shoreline sediment of the Clinch River. ATSDR's estimated committed effective dose to the whole body for all pathways along the Clinch River combined is less than 240 mrem to 70 years of age—more than 20 times below ATSDR's radiogenic CV of 5,000 mrem over 70 years. The estimated annual whole-body dose is less than 3.4 mrem, nearly 30 times below ATSDR's screening comparison value of 100 mrem/year. Therefore, the estimated exposures for the Clinch River are not expected to result in adverse health effects.

- Doses to organs varied by exposure pathway. ATSDR's estimates show that the *bone* would receive the highest total committed equivalent dose over a lifetime (to 70 years of age) of exposure to the radionuclides detected along the Clinch River. The highest doses to the bone were from ingestion of geese muscle or liver (230 mrem) and fish (114 mrem) by a 15-year-old based on a 55-year exposure, resulting in a committed equivalent dose of 344 mrem over 55 years. The committed equivalent dose to the bone from all pathways combined was based on exposures for adults, considering exposure to 70 years of age. The estimated dose to the bone is less than 218 mrem to 70 years of age—at least 1,788 times lower than the doses of 390,000 to 620,000 mrem associated with bone cancers in radium dial workers.

- The committed equivalent dose to the lower large intestine from all pathways combined, based on a 20-year-old adult exposed to age 70, was less than 270 mrem. This estimated dose is about 18 times lower than ATSDR's radiogenic comparison value of 5,000 mrem over 70 years.

- The committed equivalent dose to the skin over a 50-year exposure for adults is less than 6 mrem—1,500 times less than the value of 9,000 mrem. This is based on a review of the Biological Effects of Ionizing Radiation (BEIR) V report of patients irradiated for the treatment of ringworm.

- ATSDR analyzed drinking water samples collected around the cities of Kingston, Spring City, and Rockwood from 1990 to the present. ATSDR evaluated these samples for radiological content, and determined that all water samples were below EPA's maximum contaminant level (MCL). Therefore, ATSDR considers this water safe for consumption and other potable uses.

Future Exposure

Lower Watts Bar Reservoir and Clinch River

- ATSDR concludes that future exposures to White Oak Creek radionuclides released to the Clinch River and LWBR are not a health hazard and are not expected to result in adverse health effects or cancer. This is based on ATSDR's evaluation of current doses and exposures related to releases from White Oak Creek, data on current contaminant levels in the LWBR and the Clinch River, and consideration of the possibility that radionuclides could be released to White Oak Creek during remedial activities. ATSDR also factored in engineering controls to prevent off-site contaminant releases and institutional controls in place to monitor contaminants in the LWBR and the Clinch River, as well as the assumption that DOE will continue its expected appropriate and comprehensive system of monitoring, maintenance, and institutional and engineering controls. These institutional controls consist of

- prevention of sediment-disturbing activities in the Clinch River and LWBR,
- DOE's annual monitoring of Clinch River and LWBR surface water, sediment, and biota,
- DOE's monitoring of White Oak Creek releases,
- TDEC's monitoring of public drinking water supplies in Tennessee under the Safe Drinking Water Act for EPA-regulated contaminants, and
- TDEC DOE Oversight Division's quarterly radiological monitoring of five public water supplies on the ORR and in its vicinity under the EPA's Environmental Radiation Ambient Monitoring System program.

IX. Recommendations

Having evaluated the past, current, and future public health activities and the available environmental information, ATSDR offers the following:

1. Tennessee Department of Environment and Conservation (TDEC) should continue to monitor public drinking water supplies in Tennessee under the Safe Drinking Water Act for U.S. Environmental Protection Agency (EPA)-regulated contaminants, and TDEC's Department of Energy (DOE) Oversight Division should continue its quarterly radiological monitoring of public water supplies on the Oak Ridge Reservation (ORR) and in its vicinity under the EPA's Environmental Radiation Ambient Monitoring System program.
2. Contaminants are not uniformly distributed in the sediment of the Lower Watts Bar Reservoir (LWBR) and their concentrations vary by sediment composition, location, and depth. Therefore, the contaminated sediment of the LWBR should not be removed, dredged, or otherwise disturbed without careful review by the Watts Bar Interagency Working Group in accordance with the permitting process outlined in the Watts Bar Interagency Agreement. Given the current knowledge of contamination, ATSDR believes that the measures undertaken by the working group, if followed, are protective of public health.
3. DOE should continue to annually monitor the Clinch River and the LWBR for ORR-related radiological contaminants in surface water, biota, and sediment, and also continue its regular monitoring of White Oak Creek radionuclide releases.

X. Public Health Action Plan

The Public Health Action Plan (PHAP) for White Oak Creek describes actions to be taken by ATSDR and other government agencies at and in the vicinity of the site after the completion of this public health assessment. The purpose of this PHAP is to ensure that this public health assessment not only identifies public health hazards, but that it also provides a plan of action designed to mitigate and prevent adverse human health effects resulting from exposure to hazardous substances in the environment. If additional information about White Oak Creek releases to the Clinch River and the Lower Watts Bar Reservoir becomes available, then that information could change a conclusion or the conclusions of this public health assessment; if that occurs, then human exposure pathways should be re-evaluated and these conclusions and recommendations should be amended, as necessary, to protect public health.

- ORR staff will notify ATSDR if environmental monitoring data indicate that statistically significant contaminant levels in the Clinch River or the Lower Watts Bar Reservoir are increasing. Upon such notification, ATSDR will determine appropriate public health actions.
- ATSDR will develop and implement additional environmental health education materials as necessary to help community members understand the findings and implications of this public health assessment.
- ATSDR supports DOE's remedial actions for the Lower Watts Bar Reservoir (LWBR) as being protective of public health. These actions include leaving the contaminated sediment in place with ongoing environmental monitoring and applying institutional controls to prevent disruption of contaminated sediment. Under the Watts Bar Interagency Agreement (established by DOE, EPA, TVA, TDEC, and USACE), the agencies will continue to work together to review permitting and any other activities that could possibly disturb LWBR contaminated sediment.

XI. Preparers of Report

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Appendix A. ATSDR Glossary of Environmental Health Terms

The Agency for Toxic Substances and Disease Registry (ATSDR) is a federal public health agency with headquarters in Atlanta, Georgia, and 10 regional offices in the United States. ATSDR's mission is to serve the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposures and diseases related to toxic substances. ATSDR is not a regulatory agency, unlike the U.S. Environmental Protection Agency (EPA), which is the federal agency that develops and enforces environmental laws to protect the environment and human health.

This glossary defines words used by ATSDR in communications with the public. It is not a complete dictionary of environmental health terms. If you have questions or comments, call ATSDR's toll-free telephone number, 1-888-42-ATSDR (1-888-422-8737).

Absorption
The process of taking in. For a person or animal, *absorption* is the process through which a substance gets into the body through the eyes, skin, stomach, intestines, or lungs.

Activity
The number of radioactive nuclear transformations occurring in a material per unit time. The term for *activity* per unit mass is specific activity.

Acute
Occurring over a short time [compare with chronic].

Acute exposure
Contact with a substance that occurs once or for only a short time (up to 14 days) [compare with intermediate-duration exposure and chronic exposure].

Adverse health effect
A change in body function or cell structure that might lead to disease or health problems.

Ambient
Surrounding (for example, *ambient* air).

Analytic epidemiologic study
A study that evaluates the association between exposure to hazardous substances and disease by testing scientific hypotheses.

Background level
An average or expected amount of a substance or radioactive material in a specific environment, or typical amounts of substances that occur naturally in an environment.

Background radiation
The amount of radiation to which a member of the general population is exposed from natural sources, such as terrestrial radiation from naturally occurring radionuclides in the soil, cosmic radiation originating from outer space, and naturally occurring radionuclides deposited in the human body, as well as the amount of radiation from human activities and products, such as medical x-rays.

Becquerel (Bq)
The Systeme International basic unit of radioactivity. The number of curies must be multiplied by 3.7×10^{10} to obtain an equivalent number of Bq.

Biota
Plants and animals in an environment. Some of these plants and animals might be sources of food, clothing, or medicines for people.

Body burden
The total amount of a substance in the body. Some substances build up in the body because they are stored in fat or bone or because they leave the body very slowly.

Cancer
Any one of a group of diseases that occurs when cells in the body become abnormal and grow or multiply out of control.

Cancer risk
A theoretical risk of getting cancer if exposed to a substance every day for 70 years (a lifetime exposure). The true risk might be lower.

Carcinogen
A substance that causes cancer.

Case-control study
A study that compares exposures of people who have a disease or condition (cases) with people who do not have the disease or condition (controls). Exposures that are more common among the cases may be considered as possible risk factors for the disease.

Central nervous system
The part of the nervous system that consists of the brain and the spinal cord.

CERCLA
[See Comprehensive Environmental Response, Compensation, and Liability Act of 1980.]

Chronic
Occurring over a long time (more than 1 year) [compare with acute].

Chronic exposure
Contact with a substance that occurs over a long time (more than 1 year) [compare with acute exposure and intermediate-duration exposure].

Committed Effective Dose Equivalent (CEDE)
The sum of the products of the weighting factors applicable to each of the body organs or tissues that are irradiated and the committed dose equivalent to the organs or tissues. The *committed effective dose equivalent* is used in radiation safety because it implicitly includes the relative carcinogenic sensitivity of the various tissues. The unit of dose for the CEDE is the rem (or, in SI units, the sievert—1 sievert equals 100 rem).

Comparison value (CV)
Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening level during the public health assessment process. Substances found in amounts greater than their CVs might be selected for further evaluation in the public health assessment process.

Completed exposure pathway
[See exposure pathway.]

Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)
CERCLA, also known as Superfund, is the federal law that concerns the removal or cleanup of hazardous substances in the environment and at hazardous waste sites. ATSDR, which was created by *CERCLA,* is responsible for assessing health issues and supporting public health activities related to hazardous waste sites or other environmental releases of hazardous substances.

Concentration
The amount of a substance present in a certain amount of soil, water, air, food, blood, hair, urine, breath, or any other medium.

Contaminant
A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.

Curie (Ci)
A unit of radioactivity. One *curie* equals that quantity of radioactive material in which there are 3.7×10^{10} nuclear transformations per second. The activity of 1 gram of radium is approximately 1 Ci; the activity of 1.46 million grams of natural uranium is approximately 1 Ci.

Decay product/daughter product/progeny
A new nuclide formed as a result of radioactive decay: from the radioactive transformation of a radionuclide, either directly or as the result of successive transformations in a radioactive series. A *decay product* can be either radioactive or stable.

Depleted uranium (DU)
Uranium having a percentage of U 235 smaller than the 0.7% found in natural uranium. It is obtained as a byproduct of U 235 enrichment.

Dermal
Referring to the skin. For example, *dermal* absorption means passing through the skin.

Dermal contact
Contact with (touching) the skin [see route of exposure].

Descriptive epidemiology
The study of the amount and distribution of a disease in a specified population by person, place, and time.

Detection limit
The lowest concentration of a chemical that can reliably be distinguished from a zero concentration.

Disease registry
A system of ongoing registration of all cases of a particular disease or health condition in a defined population.

DOE
The United States Department of Energy.

Dose (for chemicals that are not radioactive)
The amount of a substance to which a person is exposed over some time period. *Dose* is a measurement of exposure. *Dose* is often expressed as milligrams (a measure of quantity) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the *dose,* the greater the likelihood of an effect. An "exposure dose" is how much of a substance is encountered in the environment. An "absorbed dose" is the amount of a substance that actually gets into the body through the eyes, skin, stomach, intestines, or lungs.

Dose (for radioactive chemicals)
The radiation *dose* is the amount of energy from radiation that is actually absorbed by the body. This is not the same as measurements of the amount of radiation in the environment.

Dose-response relationship
The relationship between the amount of exposure (dose) to a substance and the resulting changes in body function or health (response).

EMEG
Environmental Media Evaluation Guide, a media-specific comparison value that is used to select contaminants of concern. Levels below the EMEG are not expected to cause adverse noncarcinogenic health effects.

Enriched uranium
Uranium in which the abundance of the U 235 isotope is increased above normal.

Environmental media
Soil, water, air, biota (plants and animals), or any other parts of the environment that can contain contaminants.

Environmental media and transport mechanism
Environmental media include water, air, soil, and biota (plants and animals). *Transport mechanisms* move contaminants from the source to points where human exposure can occur. The *environmental media and transport mechanism* is the second part of an exposure pathway.

EPA
The United States Environmental Protection Agency.

Epidemiologic surveillance
The ongoing, systematic collection, analysis, and interpretation of health data. This activity also involves timely dissemination of the data and use for public health programs.

Epidemiology
The study of the distribution and determinants of disease or health status in a population; the study of the occurrence and causes of health effects in humans.

Equilibrium, radioactive
In a radioactive series, the state that prevails when the ratios between the activities of two or more successive members of the series remain constant.

Exposure
Contact with a substance by swallowing, breathing, or touching the skin or eyes. *Exposure* can be short-term [see acute exposure], of intermediate duration [see intermediate-duration exposure], or long-term [see chronic exposure].

Exposure assessment
The process of finding out how people come into contact with a hazardous substance, how often and for how long they are in contact with the substance, and how much of the substance they are in contact with.

Exposure-dose reconstruction
A method of estimating the amount of people's past exposure to hazardous substances. Computer and approximation methods are used when past information is limited, not available, or missing.

Exposure investigation
The collection and analysis of site-specific information and biological tests (when appropriate) to determine whether people have been exposed to hazardous substances.

Exposure pathway
The route a substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact with (or get exposed to) it. An *exposure pathway* has five parts: a source of contamination (such as an abandoned business); an environmental media and transport mechanism (such as movement through groundwater); a point of exposure (such as a private well); a route of exposure (eating, drinking, breathing, or touching), and a receptor population (people potentially or actually exposed). When all five parts are present, the *exposure pathway* is termed a completed exposure pathway.

Exposure registry
A system of ongoing follow up of people who have had documented environmental exposures.

Feasibility study
A study by EPA to determine the best way to clean up environmental contamination. A number of factors are considered, including health risk, costs, and what methods will work well.

Food chain
An arrangement of organisms within an ecological community according to the order of predation in which each uses the next usually lower member as a food source.

Grand rounds
Training sessions for physicians and other health care providers about health topics.

Gray (Gy)
The Systeme International unit for the energy absorbed from ionizing radiation, equal to one joule per kilogram.

Groundwater
Water beneath the earth's surface in the spaces between soil particles and between rock surfaces [compare with surface water].

Half-life ($t_{½}$)
The time it takes for half the original amount of a substance to disappear. In the environment, the *half-life* is the time it takes for half the original amount of a substance to disappear when it is changed to another chemical by bacteria, fungi, sunlight, or other chemical processes. In the human body, the *half-life* is the time it takes for half the original amount of the substance to disappear either by being changed to another substance or by leaving the body. In the case of radioactive material, the *half-life* is the amount of time necessary for one half the initial number of radioactive atoms to change or transform into other atoms (normally not radioactive). After two *half-lives,* 25% of the original number of radioactive atoms remain.

Hazard
A source of potential harm from past, current, or future exposures.

Hazardous waste
Potentially harmful substances that have been released or discarded into the environment.

Health consultation
A review of available information or collection of new data to respond to a specific health question or request for information about a potential environmental hazard. *Health consultations* are focused on a specific exposure issue. They are therefore more limited than public health assessments, which review the exposure potential of each pathway and chemical [compare with public health assessment].

Health education
Programs designed with a community to help it know about health risks and how to reduce these risks.

Health investigation
The collection and evaluation of information about the health of community residents. This information is used to describe or count the occurrence of a disease, symptom, or clinical measure and to estimate the possible association between the occurrence and exposure to hazardous substances.

Health statistics review
The analysis of existing health information (i.e., from death certificates, birth defects registries, and cancer registries) to determine if there is excess disease in a specific population, geographic area, and time period. A *health statistics review* is a descriptive epidemiologic study.

Indeterminate public health hazard
The category used in ATSDR's public health assessment documents when a professional judgment about the level of health hazard cannot be made because information critical to such a decision is lacking.

Incidence
The number of new cases of disease in a defined population over a specific time period [contrast with prevalence].

Ingestion
The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see route of exposure].

Inhalation
The act of breathing. A hazardous substance can enter the body this way [see route of exposure].

Intermediate-duration exposure
Contact with a substance that occurs for more than 14 days and less than a year [compare with acute exposure and chronic exposure].

Ionizing radiation
Any radiation capable of knocking electrons out of atoms and producing ions. Examples: alpha, beta, gamma and x rays, and neutrons.

Isotopes
Nuclides having the same number of protons in their nuclei, and hence the same atomic number, but differing in the number of neutrons, and therefore in the mass number. Identical chemical properties exist in *isotopes* of a particular element. The term should not be used as a synonym for "nuclide," because "isotopes" refers specifically to different nuclei of the same element.

Lowest-observed-adverse-effect level (LOAEL)
The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.

Metabolism
The conversion or breakdown of a substance from one form to another by a living organism.

mg/kg
Milligrams per kilogram.

mg/m^3
Milligrams per cubic meter: a measure of the concentration of a chemical in a known volume (a cubic meter) of air, soil, or water.

Migration
Moving from one location to another.

Minimal risk level (MRL)
An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is likely to be without a measurable risk of harmful (adverse), noncancerous effects. *MRLs* are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic). *MRLs* should not be used as predictors of harmful (adverse) health effects [see reference dose].

Mortality
Death. Usually the cause (a specific disease, condition, or injury) is stated.

Mutagen
A substance that causes mutations (genetic damage).

Mutation
A change (damage) to the DNA, genes, or chromosomes of living organisms.

National Priorities List for Uncontrolled Hazardous Waste Sites (National Priorities List or NPL)
EPA's list of the most serious uncontrolled or abandoned hazardous waste sites in the United States. The *NPL* is updated on a regular basis.

No apparent public health hazard
A category used in ATSDR's public health assessments for sites where human exposure to contaminated media might be occurring, might have occurred in the past, or might occur in the future, but is not expected to cause any harmful health effects.

Noncancerous effects
Health effects or health endpoints other than cancer, such as cardiovascular disease or genetic effects, that result from exposure to a particular hazardous substance. ATSDR derives health guidelines for noncancerous effects, called minimal risk levels (MRLs), and compares exposure doses to these MRLs. Doses below MRLs are unlikely to cause noncancerous health effects; those above MRLs are evaluated further.

No-observed-adverse-effect level (NOAEL)
The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.

No public health hazard
A category used in ATSDR's public health assessment documents for sites where people have never and will never come into contact with harmful amounts of site-related substances.

NPL
[See National Priorities List for Uncontrolled Hazardous Waste Sites.]

Parent
A radionuclide which, upon disintegration, yields a new nuclide, either directly or as a later member of a radioactive series.

Plume
A volume of a substance that moves from its source to places farther away from the source. *Plumes* can be described by the volume of air or water they occupy and the direction in which they move. For example, a *plume* can be a column of smoke from a chimney or a substance moving with groundwater.

Point of exposure
The place where someone can come into contact with a substance present in the environment [see exposure pathway].

Population
A group or number of people living within a specified area or sharing similar characteristics (such as occupation or age).

ppb
Parts per billion.

ppm
Parts per million.

Prevalence
The number of existing disease cases in a defined population during a specific time period [contrast with incidence].

Prevention
Actions that reduce exposure or other risks, keep people from getting sick, or keep disease from getting worse.

Public comment period
An opportunity for the public to comment on agency findings or proposed activities contained in draft reports or documents. The public comment period is a limited time period during which comments will be accepted.

Public health action plan
A list of steps to protect public health.

Public health advisory
A statement made by ATSDR to EPA or a state regulatory agency that a release of hazardous substances poses an immediate threat to human health. The advisory includes recommended measures to reduce exposure and reduce the threat to human health.

Public health assessment (PHA)
An ATSDR document that examines hazardous substances, health outcomes, and community concerns at a hazardous waste site to determine whether people could be harmed by coming into contact with those substances. The PHA also lists actions that need to be taken to protect public health [compare with health consultation].

Public health hazard
A category used in ATSDR's public health assessments for sites that pose a public health hazard because of long-term exposures (greater than 1 year) to sufficiently high levels of hazardous substances or radionuclides that could result in harmful health effects.

Public health hazard categories
Statements about whether people could be harmed by conditions present at the site in the past, present, or future. One or more hazard categories might be appropriate for each site. The five *public health hazard categories* are no public health hazard, no apparent public health hazard, indeterminate public health hazard, public health hazard, and urgent public health hazard.

Public health statement
The first chapter of an ATSDR toxicological profile. The *public health statement* is a summary written in words that are easy to understand. It explains how people might be exposed to a specific substance and describes the known health effects of that substance.

Public meeting
A public forum with community members for communication about a site.

Quality factor (radiation weighting factor)
The linear-energy-transfer-dependent factor by which absorbed doses are multiplied to obtain (for radiation protection purposes) a quantity that expresses - on a common scale for all ionizing radiation - the approximate biological effectiveness of the absorbed dose.

Rad
The unit of absorbed dose equal to 100 ergs per gram, or 0.01 joules per kilogram (0.01 gray) in any medium [see dose].

Radiation
The emission and propagation of energy through space or through a material medium in the form of waves (e.g., the emission and propagation of electromagnetic waves, or of sound and elastic waves). The term "radiation" (or "radiant energy"), when unqualified, usually refers to electromagnetic *radiation.* Such *radiation* commonly is classified according to frequency, as microwaves, infrared, visible (light), ultraviolet, and x and gamma rays and, by extension, corpuscular emission, such as alpha and beta *radiation,* neutrons, or rays of mixed or unknown type, such as cosmic *radiation.*

Radioactive decay
Transformation of the nucleus of an unstable nuclide by spontaneous emission of charged particles and/or photons.

Radioactive material
Material containing radioactive atoms.

Radioactivity
Spontaneous nuclear transformations that result in the formation of new elements. These transformations are accomplished by emission of alpha or beta particles from the nucleus or by the capture of an orbital electron. Each of these reactions may or may not be accompanied by a gamma photon.

Radioisotope
An unstable or radioactive isotope (form) of an element that can change into another element by giving off radiation.

Radionuclide
Any radioactive isotope (form) of any element.

RBC
Risk-based Concentration, a contaminant concentration that is not expected to cause adverse health effects over long-term exposure.

RCRA
[See Resource Conservation and Recovery Act (1976, 1984).]

Receptor population
People who could come into contact with hazardous substances [see exposure pathway].

Reference dose (RfD)
An EPA estimate, with uncertainty or safety factors built in, of the daily lifetime dose of a substance that is unlikely to cause harm in humans.

Rem
A unit of dose equivalent that is used in the regulatory, administrative, and engineering design aspects of radiation safety practice. The dose equivalent in *rem* is numerically equal to the absorbed dose in rad multiplied by the quality factor (1 *rem* is equal to 0.01 sievert).

Remedial investigation
The CERCLA process of determining the type and extent of hazardous material contamination at a site.

Resource Conservation and Recovery Act (1976, 1984) (RCRA)
This act regulates management and disposal of hazardous wastes currently generated, treated, stored, disposed of, or distributed.

RfD
[See reference dose.]

Risk
The probability that something will cause injury or harm.

Route of exposure
The way people come into contact with a hazardous substance. Three *routes of exposure* are breathing [inhalation], eating or drinking [ingestion], and contact with the skin [dermal contact].

Safety factor
[See uncertainty factor.]

Sample
A portion or piece of a whole; a selected subset of a population or subset of whatever is being studied. For example, in a study of people the *sample* is a number of people chosen from a larger population [see population]. An environmental *sample* (for example, a small amount of soil or water) might be collected to measure contamination in the environment at a specific location.

Screening index
A calculated probability of developing cancer.

Sievert (Sv)
The SI unit of any of the quantities expressed as dose equivalent. The dose equivalent in sieverts is equal to the absorbed dose, in gray, multiplied by the quality factor (1 sievert equals 100 rem).

Solvent
A liquid capable of dissolving or dispersing another substance (for example, acetone or mineral spirits).

Source of contamination
The place where a hazardous substance comes from, such as a landfill, waste pond, incinerator, storage tank, or drum. A *source of contamination* is the first part of an exposure pathway.

Special populations
People who might be more sensitive or susceptible to exposure to hazardous substances because of factors such as age, occupation, gender, or behaviors (for example, cigarette smoking). Children, pregnant women, and older people are often considered *special populations.*

Specific activity
Radioactivity per unit mass of material containing a radionuclide, expressed, for example, as Ci/gram or Bq/gram.

Stakeholder
A person, group, or community who has an interest in activities at a hazardous waste site.

Statistics
A branch of mathematics that deals with collecting, reviewing, summarizing, and interpreting data or information. Statistics are used to determine whether differences between study groups are meaningful.

Substance
A chemical.

Surface water
Water on the surface of the earth, such as in lakes, rivers, streams, ponds, and springs [compare with groundwater].

Surveillance
[See epidemiologic surveillance.]

Survey
A systematic collection of information or data. A *survey* can be conducted to collect information from a group of people or from the environment. *Surveys* of a group of people can be conducted by telephone, by mail, or in person. Some *surveys* are done by interviewing a group of people.

Toxicological profile
An ATSDR document that examines, summarizes, and interprets information about a hazardous substance to determine harmful levels of exposure and associated health effects. A *toxicological profile* also identifies significant gaps in knowledge on the substance and describes areas where further research is needed.

Toxicology
The study of the harmful effects of substances on humans or animals.

Uncertainty factor
A mathematical adjustment for reasons of safety when knowledge is incomplete—for example, a factor used in the calculation of doses that are not harmful (adverse) to people. These factors are applied to the lowest-observed-adverse-effect-level (LOAEL) or the no-observed-adverse-effect-level (NOAEL) to derive a minimal risk level (MRL). *Uncertainty factors* are used to account for variations in people's sensitivity, for differences between animals and humans, and for differences between a LOAEL and a NOAEL. Scientists use *uncertainty factors* when they have some, but not all, the information from animal or human studies to decide whether an exposure will cause harm to people [also sometimes called a safety factor].

Units, radiological

Units	***Equivalents***
Becquerel* (Bq)	1 disintegration per second = 2.7×10^{-11} Ci
Curie (Ci)	3.7×10^{10} disintegrations per second = 3.7×10^{10} Bq
Gray* (Gy)	1 J/kg = 100 rad
Rad (rad)	100 erg/g = 0.01 Gy
Rem (rem)	0.01 sievert
Sievert* (Sv)	100 rem

*International Units, designated (Systeme International [SI])

Urgent public health hazard
A category used in ATSDR's public health assessments for sites where short-term exposures (less than 1 year) to hazardous substances or conditions could result in harmful health effects that require rapid intervention.

Watershed
A watershed is a region of land that is crisscrossed by smaller waterways that drain into a larger body of water.

Other Glossaries and Dictionaries

Environmental Protection Agency http://www.epa.gov/OCEPAterms/
National Center for Environmental Health (CDC) http://www.cdc.gov/nceh
National Library of Medicine http://www.nlm.nih.gov/medlineplus/mplusdictionary.html

Appendix B. Detailed Remedial Activities Related to the Study Area

Bethel Valley Watershed

The major operations at X-10 take place within the Bethel Valley Watershed. The main plant, key research facilities, primary administrative offices, as well as various forms of waste sites, are situated in Bethel Valley. Over the past 60 years, X-10 releases have contaminated the Bethel Valley Watershed. Mobile contaminants primarily leave the Bethel Valley Watershed via White Oak Creek. These contaminants travel from the Bethel Valley Watershed to the Melton Valley Watershed, where further contaminants enter White Oak Creek. Then, the contaminants that have been discharged to White Oak Creek are released over White Oak Dam and into the Clinch River (USDOE 2001b). The main remedial activities conducted in Bethel Valley are listed below. Please see Figure 10 in Section II.C.1. for a map of Bethel Valley that includes these areas.

- *Corehole 8 Plume*. The Corehole 8 Plume, which was identified at X-10 in 1991, is a plume of groundwater contaminated with Sr 90 (SAIC 2002; USEPA 2002a). In 1994, a remedial action assessment revealed that contaminated groundwater was leaching into X-10's storm drain system and was being released into First Creek. First Creek is a stream that feeds into White Oak Creek and ultimately flows into the Clinch River. Additional evaluation indicated that the contaminated groundwater was seeping into the storm drain system via three catch basins on the western portion of X-10 (SAIC 2002). In November 1994, an action memorandum was approved; by March 1995, a groundwater collection and transmission system at the Corehole 8 Plume prevented groundwater infiltration (SAIC 2002; USEPA 2002a). Through this system, groundwater is treated by X-10's Process Waste Treatment Plant (PWTP) and then released through a National Pollutant Discharge Elimination System (NPDES) outfall. In August 1995, DOE prepared a removal action report that required monthly monitoring of the storm drain outfall close to the joining of First Creek and the Northwest Tributary.

  See Figures 3 and 10 for the location of First Creek and the Northwest Tributary. In addition, based on suggestions from the 1997 remediation effectiveness report (RER), monthly composite samples are taken at this area, as well as at the Corehole 8 sump (SAIC 2002).

  Surface water monitoring in October 1997 revealed elevated levels of Sr 90 and uranium 233 (U 233) in First Creek. In December 1997, further investigation indicated that this contamination was entering the area through two unlined storm drain manholes. As a result, in March 1998, DOE established another interceptor trench that linked to one of the plume's collection sumps. An addendum to the original action memorandum was approved in September 1999. This addendum, which was intended to increase the effectiveness of the initial remedial action, endorsed more groundwater extraction and treatment activities at the

Corehole 8 Plume (SAIC 2002). Composite samples are collected monthly at the First Creek Weir, located above First Creek's confluence with the Northwest Tributary, and at the Corehole 8 sump (SAIC 2004). From spring 1995 through fiscal year 2004, the groundwater collection and transmission system reduced fluxes of Sr 90 within First Creek by more than 80% (SAIC 2005).

- *Gunite and Associated Tanks (GAAT)*. The GAAT are eight underground gunite tanks that were installed at the X-10 site in 1943 and were the primary holding tanks for LLLW at X-10 (SAIC 2002; USDOE 2001c). These inactive tanks are located in two tank farms—the North Tank Farm and the South Tank Farm—that are located in the middle of X-10's central plant area. The North Tank Farm consists of Tanks W-3 and W-4, and the South Tank Farm consists of Tanks W-5 through W-10 (USDOE 2001c). The majority of mixed waste was removed from the GAAT in the 1980s. However, following these removal actions, waste still remained in the tanks (SAIC 2002; USDOE 2001c).

  In September 1997, an Interim Record of Decision (IROD) was signed (SAIC 2002; USDOE 2001c). DOE identified the GAAT cleanup as a priority because of the amount of radiation associated with the tanks, the decaying composition of the tanks, and the considerable risk to X-10 workers and to the environment if a tank leaked or collapsed (USDOE 2001c). The interim action transferred approximately 87,000 gallons of transuranic mixed waste sludge from the GAAT to the Melton Valley Storage Tanks (MVST). The transferred waste was to be treated in the MVST and then shipped to DOE's Waste Isolation Pilot Plant in New Mexico for disposal. This interim action, which removed more than 78,000 curies of waste from the tanks (95% of the contamination), was completed in September 2000. The empty tanks were left in place and grouted (i.e., sealing off the flow of contaminants by pumping cement grout or chemicals into drill holes) in 2001; the remedial action report was approved in October 2001 (SAIC 2002, 2005; USDOE 2001c).

- *Inactive LLLW tanks*. The inactive LLLW tanks are situated in Bethel Valley, within the central plant area of X-10. In April 1999, an Engineering Evaluation/Cost Analysis (EE/CA) suggested removal of these steel tanks, but that a time-critical action was not necessary. In an action memorandum in May 1999, this EE/CA recommendation was approved. The action memorandum focused on 11 tanks holding sludge and residue that presented a risk to public health. The removal operations included the following:

  - extracting the liquid and solid waste from the tanks;
  - moving waste that was not within the waste acceptance criteria (WAC) to suitable treatment facilities;
  - moving liquid waste that was within the WAC to the X-10 LLLW system and moving solid waste to the X-10 solid waste storage facility;
  - isolating vents, piping, and support connections;
  - filling tanks with grout for stabilization;
  - extracting tanks if appropriate storage and removal facilities were available; and
  - using soil to cover unmoved tanks and to fill excavated areas (SAIC 2002).

  In September 1999, an addendum to this action memorandum added 13 tanks to the original removal action (for a total of 24 tanks), but required the same remedial activities as those specified for the initial 11 tanks. The two-phase removal action was finished in September

2001. Once the tanks were emptied, they were filled with grout and stabilized (SAIC 2002, 2005). In October 2001, a removal action report was approved for the first phase of the removal action. As of fiscal year 2005, the action report for the second removal phase was still awaiting final approval. No monitoring activities are required for the stabilized tanks (SAIC 2005).

- *Surface Impoundments Operable Unit*. This OU consists of four impoundments—Impoundments A, B, C, and D—located in the south–central part of the X-10 site (SAIC 2002, USDOE 2005). The impoundments were used to hold liquid low-level radioactive wastes, byproducts of material processing and various experiments at X-10. Impoundments A and B were unlined; Impoundments C and D were lined with clay. Consequently, Impoundments A and B contained a total of 4,560 cubic yards of radioactive-contaminated sediments, whereas Impoundments C and D contained a total of only 40 cubic yards of low-level, radioactive-contaminated sediments (SAIC 2002). A Record of Decision signed in September 1997 outlined the necessary remedial actions for the surface impoundments. A two-phase remedial alternative took place at this OU, with the initial remedial action phase conducted from August to September 1998. During this time, more sediment samples were collected at Impoundments C and D, and sediment, soil, and water were removed from the impoundments (C and D) and placed into Impoundment B. Following the removal, fresh soil was placed into the excavated areas (SAIC 2002). In April 1999, the remedial action report was approved for the initial remedial phase of Impoundments C and D (SAIC 2002, 2005).

  During the next phase, sediment from Impoundment A was moved to Impoundment B, and the excavated area was filled with new soil (SAIC 2002). The sediment in Impoundment B, which contained sediment from all four impoundments, was pumped to an on-site treatment facility, mixed with cement, and placed into a proper shipping container for disposal. In November and December 2002, about 10% of the solidified waste was transported off site for disposal. In spring and summer 2003, the remaining solidified waste was transported to the on-site Environmental Management Waste Management Facility (EMWMF) for disposal. After the sediments were removed, rock and flowable fill were placed into Impoundment B. In May 2004, the remedial action report for Impoundments A and B was approved. No monitoring or institutional controls are required (SAIC 2005).

- *Record of Decision (ROD)*. In May 2002, a ROD was signed to address several interim remedial actions in Bethel Valley. For environmental restoration purposes, Bethel Valley was divided into the following four areas: Central Bethel Valley, East Bethel Valley, West Bethel Valley, and Raccoon Creek. Various remedial activities, such as removal, containment, monitoring, treatment, stabilization, and land use controls, will be implemented under this ROD to address contaminated media, inactive units, and accessible contamination sources. The following will be addressed: underground LLLW tanks, contaminated buildings, decontaminating and decommissioning (D&D) buildings, accessible underground and LLLW transfer pipelines, buried waste, contaminated surface and subsurface soil that is accessible, and contaminated groundwater, sediment, and surface water (SAIC 2004).

  As of fiscal year 2004, three projects had begun under the Bethel Valley ROD: the Bethel Valley Groundwater Engineering Study; the T-1, T-2, and HFIR tank remediation; and the Hot Storage Garden remediation. In fiscal year 2004, the majority of fieldwork projects necessary for the Bethel Valley Groundwater Engineering Study were completed. The projects included installing 235 soil push probes and 199 soil gas sample receptors, and conducting groundwater, storm sewer, surface water, outfall, and process waste system sampling. In fiscal year 2005, an estimated 15 groundwater wells and 48 additional soil push probes will be installed (SAIC 2005).

The HFIR tank at the X-10 site holds radioactive resin and sludge containing transuranic elements, while two inactive underground storage tanks—T-1 and T-2—hold a mixture of transuranic ion-exchange sludge and resin. Grout will stabilize and keep the HFIR tank waste in place. The T-1 and T-2 tank wastes were mixed, and the remaining slurry moved to the X-10 site's LLLW system. Ultimately, the transferred slurry will be solidified at the TRU Waste Processing Facility before off-site disposal at the DOE Waste Isolation Pilot Plant in New Mexico. In January 2004, a remedial design report/remedial action work plan was approved. All three tanks will be filled with grout and subsequently closed. The schedule for completion is fiscal year 2005 (SAIC 2005).

The Hot Storage Garden, also known as Building 3597, lies in the central plant area of the X-10 site. Radioactive material was historically stored in the building. As a result, traces of radioactive material remain in the facility's old storage wells. Activities at 5 of the 14 wells have been completed. Remedial activities are expected to continue in fiscal year 2005. Due, however, to residual contamination at the facility, the remaining wells will be sealed until initiation of final cleanup efforts, scheduled for 2009 (SAIC 2005).

Melton Valley Watershed

X-10 disposed of its radioactive wastes (liquid and solid) in Melton Valley, and also operated its experimental facilities within this watershed (USDOE 2002a, 2002b). Discharges from Melton Valley's waste areas have produced secondary contamination sources that include sediment, groundwater, and soil contamination. Furthermore, contaminants that are discharged from Melton Valley travel off the reservation through surface water and flow into the Clinch River (SAIC 2002). As a result, the waste sites in the Melton Valley Watershed "…are the primary contributors to off-site spread of contaminants" from the ORR (USDOE 2002b).

The main remedial activities conducted in Melton Valley are detailed below (SAIC 2002; USDOE 2001d; USEPA 2002a). Please see Figure 12 in Section II.C.2. for a map of Melton Valley that includes these areas. Also, please refer to Figure B-1 for the details concerning the completed, current, and future remediation activities in Melton Valley and see Figure B-2 for the Melton Valley projected closure schedule for the current and future activities (USDOE 2003b). The current schedule was accelerated by 9 years to have all closure activities completed by September 2006 (SAIC 2005; USDOE 2003b).

- *Cesium Plots Research Facility*. This facility is located next to and within 50 yards of the Clinch River (SAIC 2002; USEPA 2002a). Eight "experimental" plots were created at X-10's Waste Area Grouping (WAG) 13 to study the fallout from nuclear weapons. Four of these plots were filled with Cs 137. In July 1992, an interim remedial investigation was conducted. This study found that the gamma radiation levels released from the plots were elevated, and that the plots presented a possible threat to public health and to the environment. In October 1992, the IROD was approved (SAIC 2002). Remedial actions were conducted and finished in July 1994 (SAIC 2002; USEPA 2002a). The main aspects of the interim action were

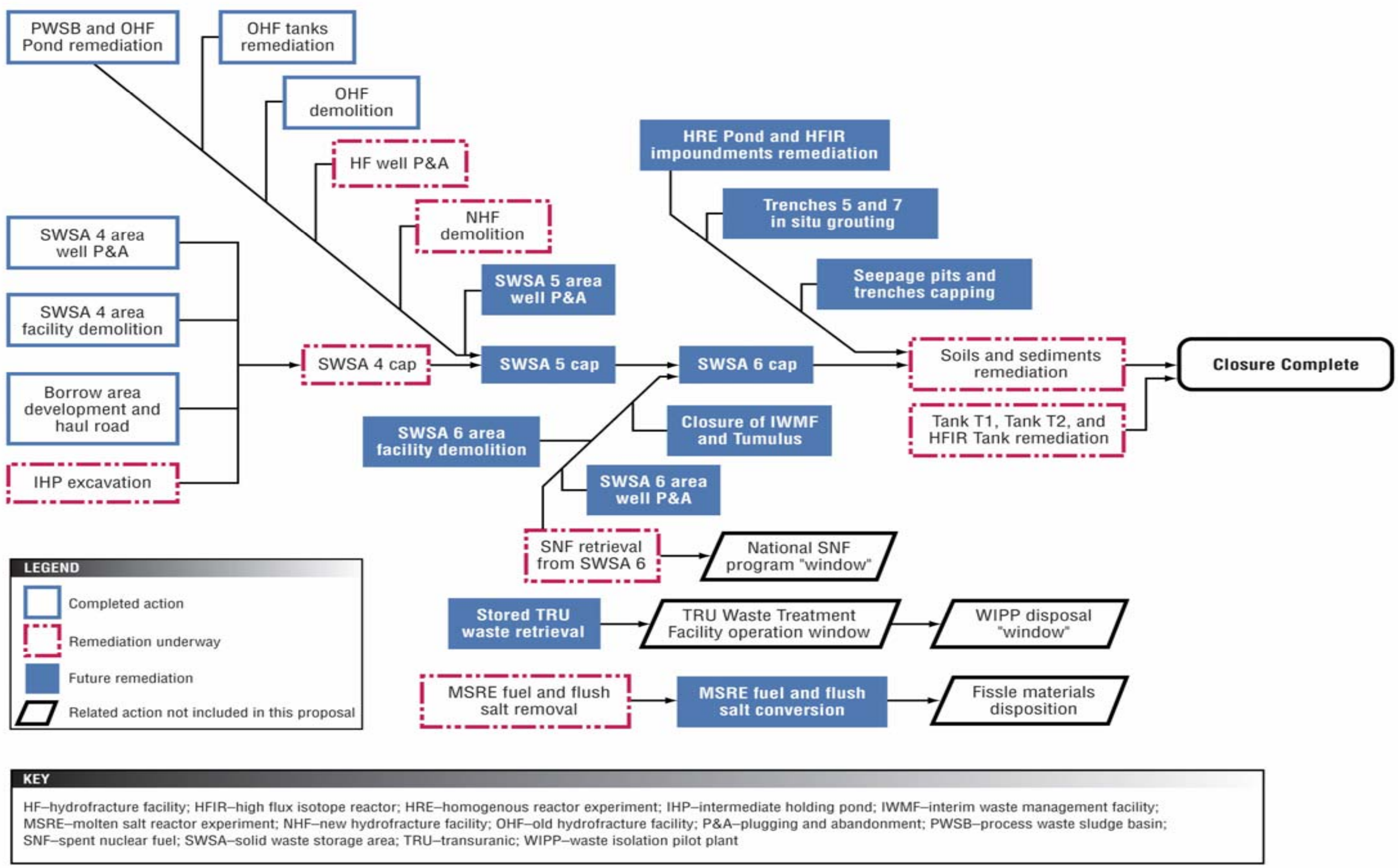
  - excavating soil until contamination was reduced to permissible levels;
  - placing extracted soil into boxes made to store low-level radioactive waste;
  - moving the soil to the low-level waste silos at WAG 6; and
  - placing a porous liner, clean fill material, and a clean top layer of soil over each excavated plot.

  Since the interim action, a fence with many locked gates has enclosed WAG 13. Several signs are posted to notify people that there is on-site soil contamination and restricted access to the site. In addition, the site undergoes surveillance and maintenance inspections on a quarterly basis (e.g., inspecting gates and fences to ensure they are secure) (SAIC 2002, 2005).

- *White Oak Creek Embayment (WOCE)*. From the X-10 site, White Oak Creek flows into White Oak Lake, over White Oak Dam, and into the WOCE before joining the Clinch River at Clinch River Mile (CRM) 20.8 (ChemRisk 1993b, 1999a; TDOH 2000; USDOE 2002a). Thus, the WOCE represents a hydrologic connection between the White Oak Dam and the Clinch River (USDOE 1996c). In 1991, a time-critical removal action was conducted at the WOCE. This action was performed because site-related data suggested that the embayment represented an "uncontrolled" source of sediment-binding substances, including Cs 137 and other contaminants (SAIC 2002).

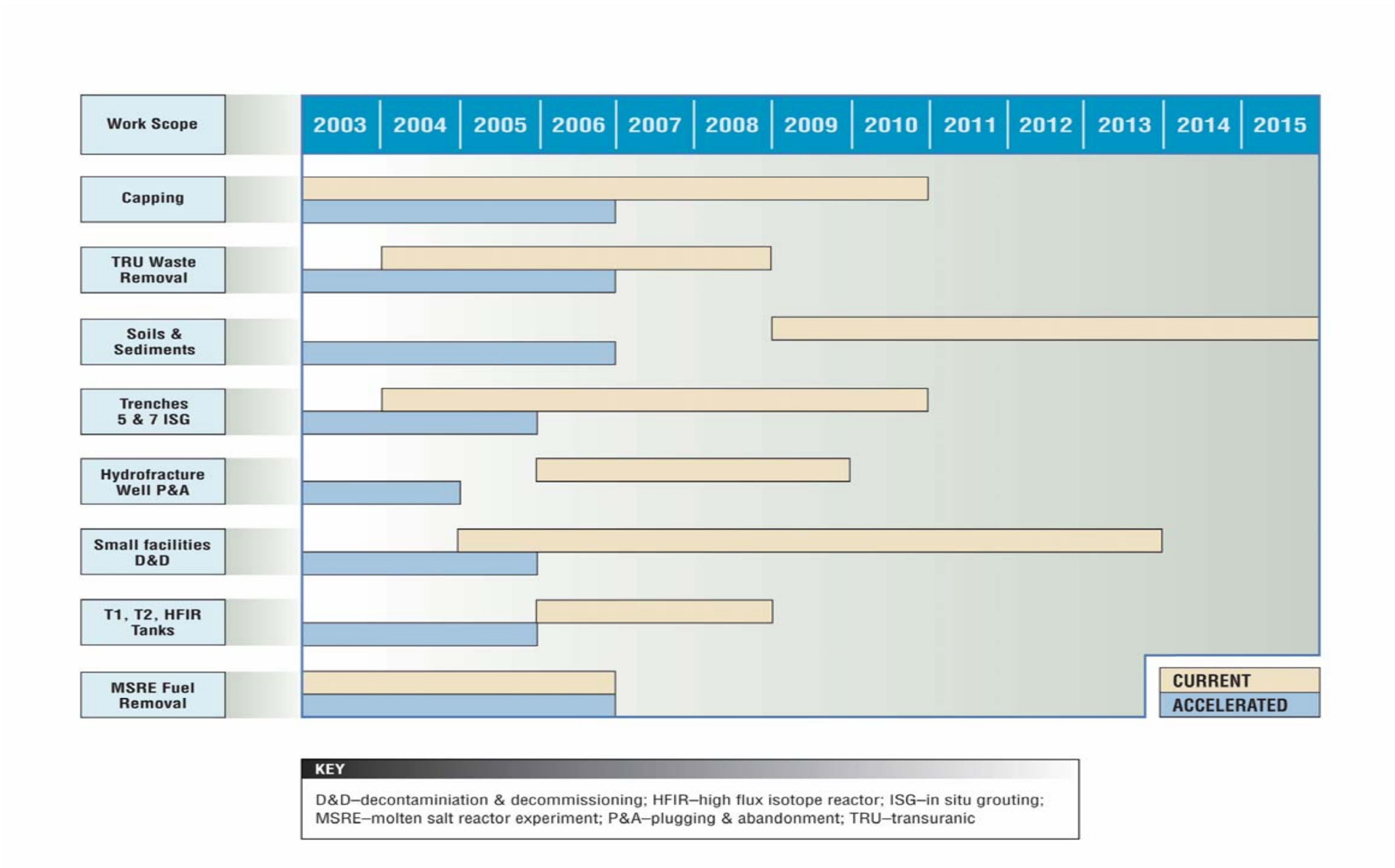
  Between June 1991 and April 1992, a removal action was conducted at the site. This action consisted of building a sediment retention structure (SRS) at the mouth of White Oak Creek to retain the sediments in the lower embayment and reduce the off-site movement of sediments to the Watts Bar Reservoir and to the Clinch River (SAIC 2002; USEPA 2002a). In 2001, the RER suggested the discontinuation of regular water level monitoring in the WOCE and in the Clinch River. This suggestion, which was implemented in fiscal year 2002, was based on about 10 years of information showing that the SRS could sustain sediment water coverage and prevent scouring of the WOCE (SAIC 2002, 2005). Though regular water level monitoring has ceased, monthly inspections of the SRS (e.g., checking warning signs, assessing if excessive debris has built up, and visually inspecting for indications of the dam shifting) continue to take place (SAIC 2005).

Figure B-1. Completed, Current, and Future Remedial Activities in Melton Valley



Source: Adapted from USDOE 2003b

Figure B-2. Melton Valley Closure Schedule



Source: USDOE 2003b
Note: The current Melton Valley closure schedule was accelerated by 9 years to have all closure activities completed by fiscal year 2006.

- *WAG 4*. The WAG 4 seeps area is located at the X-10 site (USDOE 2001e). Data collected at the ORR suggest that releases from WAG 4 have contributed to approximately 25% of the overall Sr 90 that is discharged over White Oak Dam (SAIC 2002). As a result, an action memorandum was prepared in February 1996, and DOE conducted an investigation to identify the X-10 sources that discharged Sr 90 (SAIC 2002; USDOE 2001e). The main contamination source of WAG 4 was found to be SWSA 4, which consists of 23 acres that were used between 1951 and 1974 for industrial and radioactive waste burial (SAIC 2002).

  DOE's investigation revealed that two seeps produced about 70% of the overall Sr 90 that was discharged from WAG 4 (SAIC 2002; USDOE 2001e). Because contaminants from these waste trenches migrated into White Oak Creek, grouting techniques were used to reduce the releases of Sr 90 from these trenches; these activities were completed in October 1996. The removal action report, completed in January 1997, identified five monitoring locations at WAG 4 (SAIC 2002; USEPA 2002a). For 5 years, monthly sampling was conducted at these monitoring stations, and as of 2001, the Sr 90 releases had been reduced by about 33% (SAIC 2002). Monitoring was, however, discontinued; it was superseded by a capping project conducted at SWSA 4 under the Melton Valley ROD (SAIC 2005).

- *WAG 5—Seeps C and D*. In 1994, DOE conducted an assessment and remedial activities at WAG 5 Seeps C and D. The assessment found that Sr 90 was discharged from the X-10 site, and that Seeps C and D were major sources of off-site releases. Seeps C and D are located in the southern portion of WAG 5, which consists of a burial site used for radioactive waste disposal between 1951 and 1959 (SAIC 2002; USDOE 2001f). Since Sr 90 constitutes a significant threat to off-site populations, one of DOE's main goals was to minimize these discharges from WAG 5 into the White Oak Creek system (SAIC 2002; USDOE 2001f; USEPA 2002a). The objective of these remedial activities was to reduce the quantity of Sr 90 in collected groundwater by at least 90% (SAIC 2002; USDOE 2001f).

  - *Seep C*. DOE's investigation in 1994 showed that Seep C was a major source of Sr 90 releases to White Oak Creek (SAIC 2002). Of the strontium detected at White Oak Dam between 1993 and 1994, 20% to 30% was released from Seep C. In March 1994, an action memorandum was approved, and by November 1994, a so-called French drain had been installed at Seep C. The French drain collects the groundwater and directs it to a unit for treatment; this treatment unit consists of drums filled with minerals that filter the Sr 90. Once the groundwater is treated, it is released into Melton Branch. Thus, the primary goal of these remediation activities is to lower the amount of Sr 90 released to Melton Branch and hence to off-site locations (SAIC 2002; USDOE 2001f).

    According to samples taken in 2000 and 2001, the treatment unit has prevented over 99% of the Sr 90 at Seep C from entering Melton Branch (SAIC 2002). The amount of Sr 90 is greater downstream from Seep C than upstream, which suggests that a portion of the Sr 90 from WAG 5 bypasses the treatment unit (SAIC 2002; USDOE 2001f). In 2002, bimonthly sampling and weekly inspections of the treatment unit at Seep C continued to occur (SAIC 2002). Environmental monitoring of the unit was, however, discontinued in September 2003, and the unit was shut down in fiscal year 2004 (SAIC 2004, 2005).

During its operation, the treatment unit at Seep C probably prevented as much as 3 curies of Sr 90 from being released into the Clinch River system (SAIC 2005).

- *Seep D*. DOE's investigation in 1994 revealed that Seep D was also a major source of Sr 90 to the White Oak Creek watershed (SAIC 2002). Of the Sr 90 detected at White Oak Dam between 1993 and 1994, approximately 7% was released from Seep D. In July 1994 an action memorandum was approved, and by November 1994 a groundwater treatment unit was installed and functioning at Seep D. The treatment unit collects groundwater from the bed of Melton Branch and pumps it through a group of mineral-filled columns that filter out Sr 90. Once the groundwater has been treated, it is restored to Melton Branch. Thus, the primary goal of these remediation activities is to decrease the quantity of Sr 90 that is discharged to Melton Branch, and therefore to off-site areas via White Oak Dam (SAIC 2002; USDOE 2001f).

  Data collected in 2000 and 2001 showed that this treatment unit has prevented over 99% of the Sr 90 at Seep D from entering Melton Branch (SAIC 2002). However, the amount of Sr 90 is greater downstream at Seep D than upstream. This suggests that small quantities of Sr 90 going into Melton Branch did not originate from the Seep D pumping location (SAIC 2002; USDOE 2001f). Daily inspections are conducted at Seep D and monthly sampling is performed on the treatment unit, as well as upstream and downstream of Melton Branch (SAIC 2002). In addition, as of fiscal year 2004, stream samples were being collected to identify the entry point of Sr 90 into the stream (SAIC 2004). After the first quarter of 2005, the collection system at Seep D will no longer operate. Remedial activities are not expected to include capping of the Seep D area. Nevertheless, the source of releases captured at the Seep D area will be isolated, and the releases will be piped and treated at a new water treatment plant (SAIC 2005).

- *Old Hydrofracture Facility (OHF) Tanks*. The OHF is located at the Oak Ridge National Laboratory within Melton Valley (SAIC 2002; USDOE 2002c). In 1963, this facility was built for low-level radioactive waste disposal (USDOE 2002c). From 1963 to 1980, the radioactive waste was combined with grout and then injected 1,000 feet below ground by hydraulically fracturing a shale layer and pumping the grouted waste into a thin layer that extended over many acres. The grout would then harden and become a part of the shale formation (SAIC 2002; USDOE 2002c). Five LLLW underground storage tanks were left at the OHF that contained an approximate total of 52,600 gallons (30,000 curies) of radioactive waste and other byproduct waste (e.g., sludge) (SAIC 2002; USDOE 2002c; USEPA 2002a). Because of concerns about the proximity of the tanks to White Oak Creek, the potential threat to environmental receptors, and the possibility of tank leakage, a September 1996 action memorandum authorized the movement and treatment of the tank waste. From June to July 1998, more than 98% of the waste was moved through a pipeline to the MVST, where additional treatment will occur (SAIC 2002; USDOE 2002c).

  In May 1999, another OHF-related action memorandum focused on tank stabilization and on the surface impoundment sediments associated with the OHF. The tank stabilization activities identified in the memorandum included removing the piping system, placing submersible pumps into the tanks, using mixer spool pieces, and grouting the tanks. For the surface impoundment, the remedial activities consisted of applying grout for sediment stabilization, placing grout into standpipes, removing excess water, treating any excess water at the PWTP, and using filler material to replenish the impoundment (SAIC 2002). Upon completion of these remedial activities, a May 2001 removal action report was released (SAIC 2002; USEPA 2002a). Under the Melton Valley ROD, the OHF site will be covered by the SWSA 5 cap (SAIC 2005).

- *Record of Decision*. In September 2000, a ROD was signed to address several remedial actions in Melton Valley. These actions focus on

    - remediating contaminated structures,
    - significant waste threats,
    - contaminated media, and
    - other main sources of contamination (SAIC 2002, 2005).

    In 2004, the ROD was amended to change the proposed treatment remedy at trenches 5 and 7 from *in situ* vitrification (ISV) to *in situ* grouting (ISG).[17]

    The Melton Valley ROD remedial activities and their status as of fiscal year 2005 are presented below (ORNL et al. 2004, 2005; SAIC 2002, 2004, 2005; USDOE 2004a, 2004b). Please see Figure 8 for the locations of these areas at X-10 and Figure B-2 for the completion schedule for these activities in Melton Valley.

    - Placing multi-layered caps over SWSA 4, SWSA 5 North (the upper four trenches, also referred to as the SWSA 5 North four-trench area), SWSA 5 South, SWSA 6, and sections of the seepage pits and trenches area (Pits 1, 2, 3, and 4; Trench 6). As of fiscal year 2005, cap construction activities were finished at SWSA 4; Pits 1, 2, 3, and 4; Trench 6; and SWSA 5 North four-trench area. In addition, construction had started on the SWSA 5 South cap and tree clearing and cap construction had begun at SWSA 6.
    - Using hydrologic isolation to prevent contaminant migration from the burial grounds (SWSAs 4, 5, and 6) and sections of the seepage pits and trenches area (Pits 1, 2, 3, and 4; Trench 6). When needed, trenches will be used to divert upgradient surface water and stormflow and to intercept downgradient contaminated groundwater. Activities to isolate hydraulically SWSA 4 and Pit 1 began in 2003 and were completed in fiscal year 2005. In 2004, construction of downgradient groundwater interception trenches was finished at SWSA 5 South and at Pits 2, 3, and 4. Remaining hydrologic isolation activities are scheduled for completion in 2006.

[17] *In situ* vitrification (ISV) is a process that applies electrical power to contaminated soil to produce the heat needed to melt and blend the soil and waste into an immobile form (USDOE 1995b). DOE determined, however, that ISV could be problematic because of standing water in the trenches and higher than anticipated expenses related to the process. Thus, in May 2004, DOE issued a proposed plan to amend the Record of Decision by replacing ISV with *in situ* grouting (ISG). ISG involves a low-pressure grouting method to inject Portland cement-based grout throughout the trenches. In addition, a solution grout would be used to treat soil adjacent to the trench walls to close potential seepage pathways (ORSSAB 2004). In September 2004, the proposed requirement for the Record of Decision and the remedial action work plan for ISG of the trenches were approved (ORNL 2005).

- Discarding contaminated soils from 22 trenches in SWSA 5 North, also referred to as the 22-Trench Area. Fieldwork began in fiscal year 2004 and is scheduled for completion in fiscal year 2006.
- Removing contaminated soils and backfill from the homogeneous reactor experiment (HRE) pond. Excavation activities began at the end of fiscal year 2004 and were ongoing as of fiscal year 2005.
- Removing contaminated sediment from the high flux isotope reactor (HFIR) ponds. Excavation activities started in summer 2004 and were mostly completed as of fiscal year 2005.
- Grouting the HRE fuel wells. As of fiscal year 2005, fieldwork was at or near completion.
- Stabilizing, isolating, and removing inactive waste pipelines (as needed). As of fiscal year 2005, planning and construction startup had commenced.
- Using ISG for seepage trench 5 (an estimated 300-foot-long trench containing about 138,000 curies of waste) and trench 7 (an estimated 200-foot-long trench containing about 122,000 curies of waste). As of fiscal year 2005, the trenches had been excavated to depths of 15 to 16 feet and an estimated 10-foot-thick crushed limestone layer was put into the trenches to facilitate percolation. Backfill soil was used to cover the remaining excavated area of the trenches. ISG is scheduled for fiscal year 2005.
- Removing the Intermediate Holding Pond and additional floodplain soil that was contaminated (exposure levels above 2,500 microroentgen per hour [µR/hr]). The remedial action was conducted from June to October 2002. Approximately 24,300 tons of contaminated soil were excavated from the pond and disposed of at the ORR's EMWMF. As of fiscal year 2005, remedial activities to restore the IHP to a wetland area were ongoing.
- Isolating and removing contaminated soils at leak and spill locations, as well as additional locations, if the soils exceeded remedial limits. In fiscal year 2003, planning was initiated for seven additional excavation sites and final planning for the remainder of contaminated soils was in progress. In fiscal year 2004, a remedial design report/remedial action work plan was submitted for the seven additional excavation sites. Once these soils have been removed, they will be disposed of at the ORR's EMWMF or at another approved facility.
- Plugging and abandonment (P&A) of unnecessary wells. From May 2001 through August 2003, a total of 110 of 111 hydrofracture wells were plugged and abandoned. The P&A of one remaining hydrofracture well—the HF-4 injection well at the New Hydrofracture Facility (NHF)—will be completed by the end of fiscal year 2005. P&A of all shallow nonhydrofracture wells (estimated total of 800 wells) was completed as of fiscal year 2005.
- Decontaminating and decommissioning (D&D) buildings. Several D&D activities occurred from fiscal year 2002 to 2004, including D&D activities at the OHF and many small facilities in Melton Valley. D&D activities at the NHF are scheduled for completion in fiscal year 2005. Upcoming D&D activities include various facilities,

such as ancillary buildings for the HRE, LLLW pumping stations, and miscellaneous buildings.

- Conducting groundwater, ecological, and surface water monitoring. A watershed monitoring plan for groundwater and surface water was completed in fiscal year 2002, and implementation of the plan commenced in fiscal year 2003. A first draft of the Melton Valley Ecological Study was submitted in fiscal year 2003 and a second draft in fiscal year 2004.
- Implementing land use controls as appropriate.

Appendix C. Summary of Other Public Health Activities

Summary of ATSDR Activities

Review of clinical information on persons living in or near Oak Ridge. Following a request by William Reid, M.D., ATSDR evaluated the medical histories and clinical data associated with 45 of Dr. Reid's patients. The objective of this review was to assess the clinical data for patients who were tested for heavy metals, and to establish if exposure to metals was related to these patients' various illnesses. ATSDR determined that the case data did not provide sufficient evidence to support an association between these diseases and low levels of metals. The TDOH, which also evaluated the information, reached the same conclusion as did ATSDR. In September 1992, ATSDR provided a copy of its review to Dr. Reid (ATSDR et al. 2000).

Clinical laboratory analysis. In June 1992, William Reid, M.D., an Oak Ridge physician, notified the ORHASP and the TDOH that he believed that about 60 of his patients had been exposed to numerous heavy metals through their occupations or through the environment. Dr. Reid believed that these exposures had caused a number of adverse health outcomes, which included immunosuppression, increased cancer incidence, neurologic diseases, bone marrow damage, chronic fatigue syndrome, autoimmune disease, and abnormal blood clots. Howard Frumkin, M.D., Dr.PH., from the Emory University School of Public Health, requested facilitated clinical laboratory support to evaluate the patients referred by Dr. Reid. As a result of Dr. Frumkin's request, ATSDR and the CDC's NCEH facilitated this laboratory support from 1992 to 1993 through the NCEH Environmental Health Laboratory (ATSDR et al. 2000; ORHASP 1999).

Because of the confidentiality among physicians, as well as the confidentiality between physicians and their patients, the findings of these clinical analyses have not been provided to public health agencies (ATSDR et al. 2000). Nevertheless, in an April 26, 1995, letter to the Commissioner of the Tennessee Department of Health, Dr. Frumkin suggested that one should "not evaluate the patients seen at Emory as if they were a cohort for whom group statistics would be meaningful. This was a self-selected group of patients, most with difficult to answer medical questions (hence their trips to Emory), and cannot in any way be taken to typify the population of Oak Ridge. For that reason, I have consistently urged Dr. Reid, each of the patients, and officials of the CDC and the Tennessee Health Department, not to attempt group analyses of these patients."

Health education. Another essential part of the public health assessment process is designing and implementing activities that promote health and providing information about hazardous substances in the environment.

- *Health professional education on cyanide*. In January 1996, an employee from ETTP (formerly the K-25 facility) requested ATSDR's assistance with occupational cyanide exposure. As a result, in August 1996, ATSDR held a physician health education program in Oak Ridge to teach physicians about health impacts that could result from potential cyanide intoxication. The purpose of the education program was to help community health care providers respond to concerns from ETTP employees. ATSDR gave the following materials to the concerned employee and to the area physicians: the ATSDR public health statement for cyanide, the NIOSH final health hazard evaluation, and the ATSDR Case Studies in Environmental Medicine publication entitled *Cyanide Toxicity*. ATSDR led the environmental health education workshop for physicians at the Methodist Medical Center in Oak Ridge, Tennessee. The session focused on supplying area physicians and other health care providers with information to assist with the diagnosis of acute and chronic cyanide intoxication, and also to assist with answering patients' questions. In addition, ATSDR established a system that area physicians could use to make patient referrals directly to the Association of Occupational and Environmental Clinics (AOEC) (ATSDR et al. 2000).

- *Workshops on epidemiology*. Following requests from ORRHES members, ATSDR conducted two epidemiology workshops for the subcommittee. The first session took place at the ORRHES meeting in June 2001. During this meeting, Ms. Sherri Berger and Dr. Lucy Peipins of ATSDR's Division of Health Studies presented an overview of the science of epidemiology. Dr. Peipins also presented at the second epidemiology workshop, which was held at the ORRHES meeting in December 2001. The purpose of this second session was to help the ORRHES members build the skills that are required for analyzing scientific reports (ATSDR et al. 2000). In addition, at the EEWG (formerly known as PHAWG) meeting on August 28, 2001, Dr. Peipins demonstrated the systematic and scientific approach of epidemiology by guiding the group as they critiqued a report by Joseph Mangano titled *Cancer Mortality Near Oak Ridge, Tennessee* (International Journal of Health Services, Volume 24:3, 1994, page 521). Based on the EEWG critique, the ORRHES made the following conclusions and recommendations to ATSDR.

    1. The Mangano paper is not an adequate, science-based explanation of any alleged anomalies in cancer mortality rates of the off-site public.

    2. The Mangano paper fails to establish that radiation exposure from the ORR is the cause of any such alleged anomalies of cancer mortality rates in the general public.

    3. The ORRHES recommends to ATSDR that the Mangano paper be excluded from consideration in the ORR public health assessment process (ATSDR et al. 2000).

Coordination with other parties. Since 1992 and continuing to the present, ATSDR has consulted regularly with representatives of other parties involved with the ORR. Specifically, ATSDR has coordinated its efforts with TDOH, TDEC, NCEH, NIOSH, and DOE. These efforts led to the establishment of the Public Health Working Group in 1999, which then led to the establishment of the ORRHES. In addition, ATSDR provided some assistance to TDOH in its study of past public health issues. ATSDR has also obtained and interpreted studies prepared by academic institutions, consulting firms, community groups, and other parties.

Establishment of the ORR Public Health Working Group and the ORRHES. In 1998, under a collaborative effort with the DOE Office of Health Studies, ATSDR and CDC embarked on a process to develop credible, coherent, and coordinated agendas for public health activities and for health studies at each DOE site. In February 1999, ATSDR was given the responsibility to lead the interagency group's efforts to improve communication at the ORR. In cooperation with other agencies, ATSDR established the ORR Public Health Working Group to gather input from local organizations and individuals regarding the creation of a public health forum. After careful consideration of the input gathered from community members, ATSDR and CDC determined that the most appropriate way to meet the needs of the community would be to establish the ORRHES.

Exposure investigations, health consultations, and other scientific evaluations. In addition to the Watts Bar Reservoir, ATSDR health scientists have addressed current public health issues and community health concerns related to other areas affected by ORR operations.

Following are summaries of other ATSDR public health activities involving EFPC:

- *Health consultation on Y-12 Weapons Plant chemical releases into East Fork Poplar Creek, April 1993*. As a result of community concerns, ATSDR conducted this health consultation to examine the potential health effects that could result from exposure to contaminants discharged into EFPC from the Y-12 plant (past and present). The Phase IA data assessed for this consultation suggest that the sediment, surface water, soil, fish, groundwater, and air in EFPC are contaminated with various chemicals. However, the only levels of public health concern are PCBs and mercury detected in fish, and mercury detected in soil and sediment. Based on these data, ATSDR made the following conclusions.

    1. Sediments and soil in specific areas along the EFPC floodplain are contaminated with mercury levels that present a public health concern.

2. Fish in EFPC have mercury and PCB levels that present a moderately increased risk of adverse health effects for people who consume fish regularly over extended time periods.
3. Shallow groundwater along the EFPC floodplain has metals that are at levels of public health concern; however, the shallow groundwater along EFPC is not utilized for drinking water or for other domestic purposes.
4. Other contaminants, including radionuclides found in soil, sediment, surface water, and fish, were not detected at levels of public health concern (ATSDR et al. 2000).

- *ATSDR science panel meeting on the bioavailability of mercury in soil, August 1995*. Based on an evaluation of the DOE studies conducted on mercury, ATSDR concluded that outside expertise was needed to assess technical details related to mercury. As a result, a science panel was created that consisted of experts from various government agencies (e.g., EPA), private consultants, and other individuals with experience in metal bioavailability research. The panel's goal was to select procedures and strategies that could be used by health assessors to create site-specific and data-supported estimates with regards to the bioavailability of inorganic mercury and other metals (e.g., lead) from soils. ATSDR applied the data from the panel to its assessment of the mercury clean up level in the EFPC soil. In 1997, the International Journal of Risk Analysis (Volume 17:5) published three technical papers and an ATSDR overview paper that detailed this meeting's results (ATSDR et al. 2000).

- *Health consultation on proposed mercury cleanup levels, January 1996*. Following a request from community members and the city of Oak Ridge, ATSDR prepared a health consultation to assess DOE's cleanup levels for mercury in the EFPC floodplain soil. The final health consultation, which was released in January 1996, concluded that DOE's clean up levels of 180 milligrams per kilogram (mg/kg) and 400 mg/kg would protect public health and would not present a health risk to adults or to children (ATSDR et al. 2000).

- *Health consultation on the assessment of cancer incidence in counties adjacent to the Oak Ridge Reservation, March 2006*. Some area residents expressed concerns about the number of cancer cases in communities around the Oak Ridge Reservation. To address these concerns, the Oak Ridge Reservation Health Effects Subcommittee requested ATSDR conduct an assessment of cancer incidence to evaluate cancer rates in these communities. For the assessment, ATSDR obtained cancer incidence data—data on newly diagnosed cases of cancer—from the Tennessee Cancer Registry for 42 different cancer types. Data from 1991–2000 were obtained for the eight-county area surrounding the Oak Ridge Reservation: Anderson, Blount, Knox, Loudon, Meigs, Morgan, Rhea, and Roane Counties. To analyze the data and identify any increases in cancer incidence, ATSDR compared the number of observed cases in each of the eight counties to the expected number of cases in the state of Tennessee. The findings indicated that when compared to the cancer incidence rates in the state, in some of the counties both higher and lower rates of certain cancers appeared. But no consistent pattern of cancer occurrence was identified, and the reasons for the increases and decreases of cancer occurrence remain unknown. For more information, the assessment of cancer incidence (released for public comment in 2006) is available from http://www.atsdr.cdc.gov/HAC/oakridge/phact/cancer_oakridge/index.html.

Summary of U.S. Department of Health and Human Services Activities

U.S. Department of Health and Human Services' evaluation of data in an article from The Tennessean*, September 29, 1998.* In a November 2, 1998 letter, the Honorable William H. Frist, M.D., United States Senator, requested that Donna E. Shalala, Secretary of the Department of Health and Human Services (DHHS), have the CDC, ATSDR, and the National Institutes of Health (NIH) evaluate the data that the article in *The Tennessean* describes as reporting a pattern of illnesses among residents living near nuclear plants, including the DOE ORR.

In particular, Senator Frist requested the following:

- Assess the quality and usefulness of the data on which the report is based.
- Examine the data for any patterns of illness and assess whether there is sufficient data to establish a relationship to the nuclear plants.
- Summarize the DHHS studies that are currently underway at the 11 sites.
- Estimate how the key questions raised by the newspaper article could be addressed in a potential study.
- Describe any existing programs at the three agencies that may help address the medical needs of people living near nuclear plants.

In a letter dated February 22, 1999, Donna E. Shalala, Secretary of DHHS, responded to Senator Frist's request. DHHS evaluated the article in *The Tennessean* and responded to Senator Frist's five specific issues. DHHS concluded the following:

1. The data in the article from *The Tennessean* were not compiled from an epidemiologic study and thus have many limitations. It is impossible to calculate rates for the reported illnesses or to determine whether rates of the illnesses were abnormal. It is also difficult to relate excess illnesses to specific nuclear plants because primary exposures differ among the plants.
2. Epidemiologically, it is neither acceptable to tabulate data collected in an unstandardized manner, nor to assess illnesses and symptoms based on limited diagnostic information. Thus, it is not possible to determine if data in this report represent a new or unusual occurrence of symptoms in this population.
3. DHHS has a significant number of ongoing studies that seek to analyze environmental exposure at each of the 11 sites rather than focusing on general medical evaluations of the populations near the sites. However, clinical data from the Fernald Medical Monitoring Program and the Scarboro, Tennessee, survey focus on respiratory illnesses in children and, although quite limited, are most relevant to the issues raised by the report.

4. Sound data using standardized information is essential in order to establish increased prevalence of a disease and linkage to the nuclear plants.
   - First, the occurrence of a single, definable illness would have to be assessed.
   - Second, studies including structured population surveys would need to be developed for general health and illness data in well-defined population groups near the nuclear sites. The findings would then be compared to results from other well-defined populations living elsewhere.
   - Third, any attempt to determine a causal relationship between disease or illness rates in these populations and exposures to hazards would be difficult since historic exposures are difficult to identify and measure.
5. CDC, ATSDR, and NIH are working with DOE to plan appropriate public health follow-up activities to address the concerns of communities and workers regarding the nuclear weapons complexes. Embarking on such a comprehensive program will require considerable resource, planning, and evaluation. Please note that CDC, ATSDR, and NIH do not provide direct primary medical services to communities. However, where possible, CDC, ATSDR, and NIH will continue to support community leaders and existing medical care systems to address public health concerns of communities that are near nuclear plants.

Summary of TDOH Activities

Pilot survey. In the fall of 1983, TDOH established an interim soil mercury level to use for making environmental management decisions. CDC evaluated the methodology for this mercury level, and advised the TDOH to conduct a pilot survey to determine if populations with the greatest risk for mercury exposure had elevated mercury body burdens. Between June and July 1984, TDOH and CDC conducted a pilot survey to record the inorganic mercury levels of Oak Ridge residents who had the greatest risk of being exposed to mercury-contaminated fish and soil. In addition, the survey assessed if exposure to mercury through contaminated fish and soil represented an immediate health hazard for the Oak Ridge community. In October 1985, the findings of the pilot study were released; these results indicated that people who lived and worked in Oak Ridge, Tennessee, were unlikely to have a greater risk for significantly high mercury levels. Further, concentrations of mercury detected in hair and urine samples were lower than levels associated with known health effects (ATSDR et al. 2000).

Health statistics review. In June 1992, William Reid, M.D., an Oak Ridge physician, informed the ORHASP and the TDOH that he believed that about 60 of his patients had been exposed to numerous heavy metals through their occupation or through the environment. Dr. Reid felt that these exposures had caused a number of adverse health outcomes that included immunosuppression, increased cancer incidence, neurologic diseases, bone marrow damage, chronic fatigue syndrome, autoimmune disease, and abnormal blood clots. In 1992, TDOH conducted a health statistics review that evaluated the cancer incidence rates for the counties around the reservation between 1988 and 1990, and compared these rates to the state rates for Tennessee. The health statistics review determined that some of the counties' rates were low and some were high when compared to the state's rates; however, the review was unable to distinguish any patterns associated with the site. More detailed findings of the review can be found in a TDOH memorandum dated October 19, 1992, from Mary Layne Van Cleave to Dr. Mary Yarbrough. In addition, the handouts and minutes from Ms. Van Cleave's presentation at the ORHASP meeting on December 14, 1994, are available through TDOH (ATSDR et al. 2000).

Health statistics review. In 1994, area residents reported that there were several community members who had amyotrophic lateral sclerosis (ALS) and multiple sclerosis (MS). TDOH consulted with Peru Thapa, M.D., M.P.H., from the Vanderbilt University School of Medicine, to perform a health statistics review of mortality rates for ALS and MS within certain counties in Tennessee. TDOH also received technical support for the health statistics review from ATSDR (ATSDR et al. 2000).

Because ALS and MS are not reportable, TDOH determined that it was impossible to calculate reliable incidence rates for these diseases. Mortality rates for counties surrounding the ORR were analyzed for the time period between 1980 and 1992, and then compared with mortality rates for the state of Tennessee. The review found that the mortality rates did not differ significantly from the rates in the rest of Tennessee (ATSDR et al. 2000). The following results were reported by TDOH at the ORHASP public meeting on August 18, 1994.

- There were no significant differences in ALS mortality in any of the counties in comparison with the rest of the state.
- For Anderson County, the rate of age-adjusted deaths from chronic obstructive pulmonary disease (COPD) was significantly higher than rates in the rest of the state, but the rates for total deaths, deaths from stroke, deaths from congenital anomalies, and deaths from heart disease were significantly lower for 1980–1988. There were no significant differences in the rates of deaths due to cancer, for all sites, in comparison to rates for the rest of the state.

Rates of deaths from uterine and ovarian cancer were significantly higher than the rates in the rest of the state. The rate of death from liver cancer was significantly lower in comparison with the rest of the state.

- For Roane County, the rates of total deaths and deaths from heart disease were significantly lower than the rates in the rest of the state for 1980–1988. Although the total cancer death rate was significantly lower than the rate in the rest of the state, the rate of deaths from lung cancer was significantly higher than the rate in the rest of the state. Rates of deaths from colon cancer, female breast cancer, and prostate cancer were also significantly lower than the rates in the rest of the state.

- For Knox County, the rates for total deaths and deaths from heart disease were significantly lower than the rates in the rest of the state. There was no significant difference in the total cancer death rate in comparison to the rest of the state.

- There were no significant exceedances for any cause of mortality studied in Knox, Loudon, Rhea, and Union Counties in comparison to the rest of the state.

- Rates of total deaths were significantly higher in Campbell, Claiborne, and Morgan Counties in comparison to the rest of the state.

- Cancer mortality was significantly higher in Campbell County in comparison to the rest of the state. The excess in number of deaths from cancer appeared to be attributed to the earlier part of the time period (1980 to 1985); the rate of deaths from cancer was not higher in Campbell County in comparison to the rest of the state for the time periods from 1986 to 1988 and 1989 to 1992.

- Cancer mortality was significantly higher in Meigs County in comparison with the rest of the state from 1980 to 1982. This excess in cancer deaths did not persist from 1983 to 1992.

Knowledge, attitudes, and beliefs study. TDOH coordinated a study to evaluate the attitudes, beliefs, and perceptions of residents living in eight counties around Oak Ridge, Tennessee. The purpose of the study was to (1) investigate public perceptions and attitudes about environmental contamination and public health problems related to the ORR, (2) ascertain the public's level of awareness and assessment of the ORHASP, and (3) make recommendations for improving public outreach programs. The report was released in August 1994 (ATSDR et al. 2000; Benson et al. 1994). Following is a summary of the findings (Benson et al. 1994):

- A majority of the respondents regard their local environmental quality as better than the national environmental quality. Most rate the quality of the air and their drinking water as good or excellent. Almost half rate the local groundwater as good or excellent.

- A majority of the respondents think that activities at the ORR created some health problems for people living nearby and most think that activities at the ORR created health problems for people who work at the site. Most feel that researchers should examine the actual occurrence of disease among Oak Ridge residents. Twenty-five percent know of a specific local environmental condition that they believe has adversely affected public health, but many of these appear to be unrelated to the ORR. Less than 0.1% have personally experienced a health problem that they attribute to the ORR.

- About 25% have heard of the Oak Ridge Health Study and newspapers are the primary source of information about the study. Roughly 33% rate the performance of the study as good or excellent and 40% think the study will improve public health. Also, 25% feel that communication about the study has been good or excellent.

Health assessment. The East Tennessee Region of TDOH conducted a health assessment on the eastern region of Tennessee. The purpose of this health assessment was to review the health status of the population, to evaluate the accessibility and utilization of health services, and to develop priorities for resource allocation. The East Tennessee Region released its first edition of *A Health Assessment of the East Tennessee Region* in December 1991; this edition generally contained data from 1986 to 1990. The second edition, which was released in 1996, generally included data from 1990 to 1995. A copy of the document can be obtained from the East Tennessee Region of TDOH (ATSDR et al. 2000).

Presentation. On February 16, 1995, Dr. Joseph Lyon of the University of Utah gave a TDOH-sponsored presentation at an ORHASP public meeting. The purpose of the presentation was to inform the public and the ORHASP that several studies had been conducted on the fallout from the Nevada Test Site, including the study of thyroid disease and leukemia (ATSDR et al. 2000).

Other Agencies

Assessment reports, environmental studies, health investigations, remedial investigation/ feasibility studies, and sampling validation studies. Other agencies have also addressed community health concerns and public health issues through studies and investigations. Two areas that have been investigated by other agencies—Scarboro and Lower East Fork Poplar Creek (LEFPC)—are discussed below.

Following are summaries of investigations related to the Scarboro community:

- *Scarboro Community Assessment Report*. Since 1998, the Joint Center for Political and Economic Studies (with the support of DOE’s Oak Ridge Operations) has worked with the Scarboro community to help residents express their economic, environmental, health, and social needs. In 1999, the Joint Center for Political and Economic Studies conducted a survey of the Scarboro community to identify the residents' environmental and health concerns. The surveyors attempted to elicit responses from the entire community, but achieved an 82% response rate. Because Scarboro is a small community, the community assessment provided new information about the area and its residents that would not be available from sources that evaluate more populated areas, such as the Bureau of the Census. In addition, the assessment identified Scarboro's strengths and weaknesses, and illustrated the relative unimportance of environmental and health issues among residents in comparison to other community concerns. The assessment showed that environmental and health issues were not a priority among Scarboro residents, as the community was more concerned about crime, security, children, and economic development. The Joint Center for Political and Economic Studies recommended an increase in active community involvement in city and community planning (Friday and Turner 2001).

- *Scarboro Community Environmental Study*. In May 1998, soil, sediment, and surface water samples were taken in the Scarboro community to address residents' concerns about previous environmental monitoring in the Scarboro neighborhood (i.e., validity of past measurements). The study was designed to integrate input from the community, while also fulfilling the requirements of an EPA-type evaluation. The Environmental Sciences Institute of Florida Agriculture and Mechanical University (FAMU), along with its contractual partners at the Environmental Radioactivity Measurement Facility at Florida State University and the Bureau of Laboratories of the Florida Department of Environmental Protection, as well as DOE subcontractors in the Neutron Activation Analysis Group at the ORNL, conducted the analytical element of this study. These results were compared with findings from an October 1993 report by DOE, titled *Final Report on the Background Soil Characterization Project (BSCP) at the Oak Ridge Reservation, Oak Ridge, Tennessee*. In general, mercury was detected within the range that was seen in the BSCP, which was between 0.021 mg/kg and 0.30 mg/kg. The radionuclide findings were within the predicted ranges, including concentrations of total uranium. However, about 10% of the soil samples indicated an enrichment of uranium 235. Alpha-chlordane, gamma-chlordane, heptachlor, and heptachlor epoxide exceeded the detection limits in one sample. This same sample also had concentrations of lead and zinc that were twice as high as those found in the BSCP. On September 22, 1998, the final Scarboro Community Environmental Study was released (ATSDR et al. 2000).

- *Scarboro Community Health Investigation*. In November 1997, a Nashville newspaper published an article that described various illnesses seen among children who lived in the Scarboro community—a neighborhood located close to the ORR's nuclear weapons facility. The article stated that the Scarboro residents experienced high rates of respiratory illness, and that there were 16 children who repeatedly had "severe ear, nose, throat, stomach, and respiratory illnesses." The reported respiratory illnesses included asthma, sinus infections, hay fever, ear infections, and bronchitis. The article implied that these illnesses were caused by exposure to the ORR, especially because of the proximity of these children's homes to the ORR facilities (ATSDR et al. 2000; Johnson et al. 2000).

  In response to this article, on November 20, 1997, the Commissioner of TDOH requested that the CDC assist the TDOH with an investigation of the Scarboro community. TDOH coordinated the *Scarboro Community Health Investigation* to examine the reported excess of pediatric respiratory illnesses within the Scarboro community. The investigation consisted of a community health survey of parents and guardians, and a follow-up medical examination for children younger than 18 years of age. Both of these components (survey and exam) were essentially designed to measure the rates of common respiratory illnesses among Scarboro children, compare these rates to national rates for pediatric respiratory illnesses, and determine if these illnesses had any unusual characteristics. The investigation was not, however, designed to determine the cause of the illnesses (ATSDR et al. 2000; Johnson et al. 2000).

In 1998, CDC and TDOH were assisted by the Scarboro Community Environmental Justice Oversight Committee to develop a study protocol. After the protocol was created, a community health survey was administered to members of households in the Scarboro neighborhood. The purpose of the survey was to assess if the rates of specific diseases were higher in Scarboro when compared to the rest of the United States, and to determine if exposure to different factors increased the Scarboro residents' risk for health problems. In addition, the survey collected information from adults about their occupations, occupational exposures, and general health concerns. The health investigation survey had an 83% response rate, as 220 out of 264 households were interviewed; this included 119 questionnaires about children and 358 questionnaires about adults in these households (ATSDR et al. 2000; Johnson et al. 2000).

In September 1998, CDC released its initial findings from the survey. For children in Scarboro, the asthma rate was 13%; this was compared to nationally estimated rates of 7% for children between the ages of 0 and 18, and 9% for African American children between the ages of 0 and 18. Still, the Scarboro rate fell within the range of rates (6% to 16%) found in comparable studies across the United States. The wheezing rate was 35% for children in Scarboro, which was compared to international estimates that fell between 1.6% and 36.8%. With the exception of unvented gas stoves, the study did not find any statistically significant link between exposure to typical environmental asthma triggers (e.g., pests, environmental tobacco smoke) or possible occupational exposures (i.e., living with an adult who works at the ORR) and asthma or wheezing illness (ATSDR et al. 2000; Johnson et al. 2000).

After review of information obtained in the health investigation survey, 36 children were invited to have a physical examination; this number included the children who were discussed in the November 1997 newspaper article. In November and December 1998, these medical examinations were conducted to verify the community survey results, to evaluate if the children with respiratory illnesses were receiving necessary medical care, and to confirm if the children detailed in the newspaper actually had those reported respiratory medical problems. The children who were invited to have medical examinations had one or more of the following conditions: 1) severe asthma, which was defined as more than three wheezing episodes or going to an emergency room as a result of these symptoms; 2) severe undiagnosed respiratory illness, which was defined as more than three wheezing episodes and going to an emergency room as a result of these symptoms; 3) respiratory illness and no source for regular medical care; or 4) identified in newspaper reports as having respiratory illness. Out of the 36 children invited, 23 participated in the physical examination. A portion of the eligible children had moved away from Scarboro, whereas others were unavailable or opted not to participate (ATSDR et al. 2000; Johnson et al. 2000).

During the physical examinations, nurses asked the participating children and their parents a series of questions about the health of the children; volunteer physicians evaluated the findings from the nurse interviews and examined the children. In addition to these physical examinations, the children were given blood tests and a special breathing test. The examining physician sometimes took an x-ray of the child, but this was determined on a case-by-case basis. All of the tests, examinations, and transportation to and from the examinations were provided without charge (Johnson et al. 2000).

As soon as the examinations were completed, the results were evaluated to see if any children required immediate intervention, but none of the children needed urgent care. Several laboratory tests revealed levels that were either above or below the normal range, which included blood hemoglobin level, blood calcium level, or breathing test abnormality. After a preliminary review of the findings, laboratory results were conveyed to the parents of the children and their doctors by letter or telephone. If the parents did not want their child's results sent to a physician, then the parents received the results over the telephone. The parents of children who had any health concern identified from the physical examination were sent a personal letter from Paul Erwin, M.D., of the East Tennessee Regional Office of the TDOH, that informed the parents that follow-up was needed with their medical provider. If the children did not have a medical provider, the parents were advised to contact Brenda Vowell, R.N.C., a Public Health Nurse with the East Tennessee Regional Office of the TDOH, for help locating a provider and about possibly receiving TennCare or Children's Special Service (ATSDR et al. 2000; Johnson et al. 2000).

On January 5, 1999, a group of physicians from the CDC, TDOH, the Oak Ridge medical community, and the Morehouse School of Medicine, conducted a thorough review of the findings from the community health survey, the physical examinations, the laboratory tests, and the nurse interviews. From the 23 children who were physically examined, 22 of these children had evidence of some type of respiratory illness, which was discovered during the nurse interviews or during the doctor's physical examinations. Overall, the children seemed to be healthy and no problems requiring immediate assistance were identified. Many of the children had mild respiratory illnesses at the time of their examination, but only one child was found to have a lung abnormality during the examination. In addition, none of the children experienced wheezing at the time of their examination. The examinations did not indicate an unusual illness pattern among children in the Scarboro community. The illnesses that were identified from these examinations were not more severe than would be expected, and they were characteristic of illnesses that could be found in any community. Basically, the results of these examinations validated the results from the community health survey. On January 7, 1999, the results from this team review were presented at a Scarboro community meeting. In July 2000, the final report was released (ATSDR et al. 2000; Johnson et al. 2000).

Three months after the letters had been sent to the parents and to the physicians about the results, efforts were made to telephone the parents of the children who had been examined. Eight of the parents were contacted successfully. Since some of the parents had more than one child who participated in the examination, the questions for the eight parents were applied to 14 children. Despite many attempts on different days, the parents of nine children could not be contacted by telephone (Johnson et al. 2000).

Out of the 14 children whose parents had been contacted, seven of the children had been to a doctor since the examinations. For the most part, the health of the children was about the same. However, since the examinations, one child had been in the hospital because of asthma and another child's asthma medication had been strengthened due to worsening asthma. In addition, several parents reported that their children had nasal allergies, and many parents noted problems with obtaining medicines because of the expense and the lack of coverage by TennCare for the specific medicines. Subsequently, TDOH nurses have helped these parents obtain the needed medicines (Johnson et al. 2000).

- *Scarboro Community Environmental Sampling Validation Study*. In 2001, EPA's Science and Ecosystem Division Enforcement Investigation Branch collected soil, sediment, and surface water samples from the Scarboro community to respond to community concerns, identify data gaps, and validate the sampling performed by FAMU in 1998 (FAMU 1998). All samples were subjected to a full analytical scan, including inorganic metals, volatile organic compounds, semi-volatile organic compounds, radiochemicals, organochlorine pesticides, and PCBs. In addition, EPA collected uranium core samples from two locations in Scarboro and conducted a radiation walkover of the areas selected for sampling to determine whether radiation existed above background levels (USEPA 2003b).

  The level of radiation was below background levels and the radionuclide analytical values did not indicate a level of health concern. Uranium levels in the core soil samples were also below background levels. EPA concluded that the results support the sampling performed by FAMU in 1998, and that there is not an elevation of chemical, metal, or radionuclides above a regulatory health level of concern. The residents of Scarboro are not currently being exposed to harmful levels of substances from the Y-12 plant. The report stated that "based on EPA's results, the Scarboro community is safe. Therefore, additional sampling to determine current exposure is not warranted." A final report was released in April 2003 (USEPA 2003b).

Following is a summary of a remedial investigation/feasibility study (RI/FS) for LEFPC:

- *Lower East Fork Poplar Creek Remedial Investigation/Feasibility Study*. Under the Federal Facility Agreement, DOE, EPA, and TDEC performed an RI/FS at Lower East Fork Poplar Creek (LEFPC) that was completed in 1994. The study was conducted to evaluate the floodplain soil contamination in LEFPC, which has resulted from Y-12 plant discharges since 1950. The goals of the study were to 1) establish the degree of floodplain contamination, 2) prepare a baseline risk assessment according to the level of contaminants, and 3) determine if remedial action was necessary. The findings of the investigation suggested that sections of the floodplain were contaminated with mercury, and that floodplain soil with mercury concentrations above 400 parts per million (ppm) represented an unacceptable risk to human health and to the environment. As a result of this conclusion, a ROD was approved in September 1995 that requested remedial action at LEFPC. Remedial activities began in June 1996 and were completed in October 1997. The activities consisted of the following: 1) excavating four sections of floodplain soil that had mercury concentrations above 400 ppm, 2) recording the removal by taking confirmatory samples during excavation, 3) disposing of contaminated soil at a Y-12 plant landfill, 4) re-filling the excavated areas with soil, and 5) providing a new vegetative cover over the excavated areas (ATSDR et al. 2000).