ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

A Summary of ATSDR's Public Health Assessment of X-10 Radionuclide Releases to the Clinch River and the Lower Watts Bar Reservoir via White Oak Creek

MAJOR X-10 PROCESSES AND WASTE DISPOSAL PRACTICES

1943
X-10 "pilot" plant built

1943–1963
Graphite reactor operated

1943
White Oak Dam built across White Oak Creek

1943–1954
White Oak Lake used as a settling pond

1943–present
White Oak Creek carries X-10 discharges to the Clinch River

1943–1949
Radioactive liquid wastes stored in underground gunite tanks

1949–1954
Evaporator used to concentrate liquid wastes

1951–1976
Waste disposal pits and trenches used for liquid wastes

1955
White Oak Lake drained

1956
White Oak Lake floods cause sediment erosion

1957
Process waste water treatment begins

About the X-10 plant and White Oak Creek releases

In 1942, the U.S. government established the Oak Ridge Reservation (ORR) in Anderson and Roane Counties in Tennessee. The reservation was part of the Manhattan Project, a government program to research, develop, and produce radioactive materials for nuclear weapons. Three facilities to enrich uranium were built at the ORR: the Y-12 plant, the K-25 site, and the S-50 site. The X-10 site was created to process plutonium. Following World War II, the role of the ORR (i.e., the Y-12 plant, the K-25 site, and the X-10 site) under the Atomic Energy Commission, which subsequently became part of the Department of Energy (DOE), broadened to include a variety of nuclear research and production projects vital to national security.

Beginning in 1943, some contamination from the ORR entered White Oak Creek (located on the reservation). Most of the radioactive contamination in the creek came from ORR's X-10 facility (known in the past as Clinton Laboratories and now known as the Oak Ridge National Laboratory, or ORNL).

The X-10 site was built in 1943 as a pilot plant to demonstrate plutonium production and separation. The government planned to run the X-10 site for 1 year, but this time frame was made indefinite as operations at the facility expanded. Over time, operations at X-10 grew to include nuclear fission product separation, nuclear reactor safety and development, and radionuclide production for worldwide use in medicine, industry, and research.

Because the government planned to operate X-10 for only 1 year, the initial waste disposal practices quickly proved insufficient for the amount of wastes actually generated at the facility. As a result, some waste products entered White Oak Creek. This creek travels along the X-10 site and through several contaminated areas before flowing into White Oak Lake—used as a final settling basin for radionuclides released from X-10. Wastes that did not settle there continued to travel over White Oak Dam, into the White Oak Creek Embayment, and into the Clinch River. Some contamination eventually reached the Lower Watts Bar Reservoir. As shown in Figure 1, the largest radionuclide releases to White Oak Creek (rates are in arbitrary units) occurred from 1944 to 1963. Most of these releases resulted from early waste disposal practices at X-10. Nevertheless, after significant rainfall in 1956, radioactive waste also entered the Clinch River from the erosion of contaminated sediment in the White Oak Creek Embayment. The release of contaminated sediment from the embayment stopped in the early 1990s, when a coffer cell dam was constructed at the mouth of White Oak Creek to prevent water backflow to the embayment. Please see the photograph in Figure 2 for the areas associated with X-10 radionuclide releases to White Oak Creek.

Figure 1. Radionuclide Releases from White Oak Creek to the Clinch River

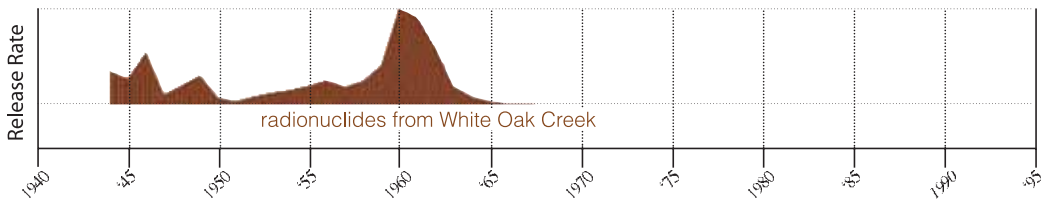


Figure 2. Photograph of Areas Associated with X-10 Radionuclide Releases to White Oak Creek

Who is ATSDR?

What is ATSDR's mission?
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.

The Agency for Toxic Substances and Disease Registry (ATSDR) is the principal federal public health agency charged with evaluating the human **health effects** of **exposure** to hazardous substances in the environment. Congress created ATSDR to implement the health-related sections of the 1980 Superfund law and other laws that protect the public from hazardous waste and from environmental spills of hazardous substances. One of ATSDR's duties is to conduct public health assessments at all sites on the U.S. Environmental Protection Agency's National Priorities List, or NPL. As a result of past releases, the ORR is on the NPL of Uncontrolled Hazardous Waste Sites.

What is ATSDR doing at the Oak Ridge Reservation?

People living along and using the Clinch River and the Lower Watts Bar Reservoir want to know if their health could be affected by X-10 radionuclide releases to White Oak Creek. ATSDR conducted a public health assessment to evaluate whether the releases could be harmful for people who use, or who live near, the Clinch River and the Lower Watts Bar Reservoir. ATSDR also worked with the Oak Ridge Reservation Health Effects Subcommittee to ensure that site-specific public health questions of people living in the Oak Ridge Reservation area were answered.

The subcommittee was formed in 1999 under the guidelines of the Federal Advisory Committee Act (FACA) to advise ATSDR and the Centers for Disease Control and Prevention (CDC) on matters related to public health activities and research at the ORR. Members of the subcommittee represented diverse interests, expertise, backgrounds, and communities. The subcommittee, which helped prioritize issues evaluated by ATSDR, gave all people an opportunity to express their concerns and provide comments. The key issues and community concerns identified and evaluated in this public health assessment, as Figure 3 shows, include a) contacting surface water and sediment during recreation, b) consuming game animals, c) consuming fish and turtles, d) eating homegrown vegetables, and e) drinking water and milk.

Radionuclides released from X-10 via White Oak Creek are not a public health hazard for people who lived near or used the Clinch River or Lower Watts Bar Reservoir in the past, who currently do so, or who will in the future.

ATSDR uses the public health assessment process to evaluate previous studies and environmental data describing **contaminated media**. The agency also uses that process to determine whether releases of hazardous substances from the ORR could have affected the health of people in communities near the reservation.

What did ATSDR scientists conclude about health effects related to radionuclides from White Oak Creek?

ATSDR's scientists concluded that some residents living along or visiting the Clinch River and Lower Watts Bar Reservoir had been exposed to **radionuclides** released from ORR's X-10 site via White Oak Creek. The greatest exposure occurred in the 1950s and resulted from frequently eating fish caught near Jones Island, close to the mouth of White Oak Creek. But the **radiation dose** from that exposure was still below levels associated with a health hazard. Therefore, ATSDR does not expect adverse health effects to occur from past, current, and future exposure to the water, sediments, fish, turtles, and geese.

ENVIRONMENTAL HEALTH TERMS

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

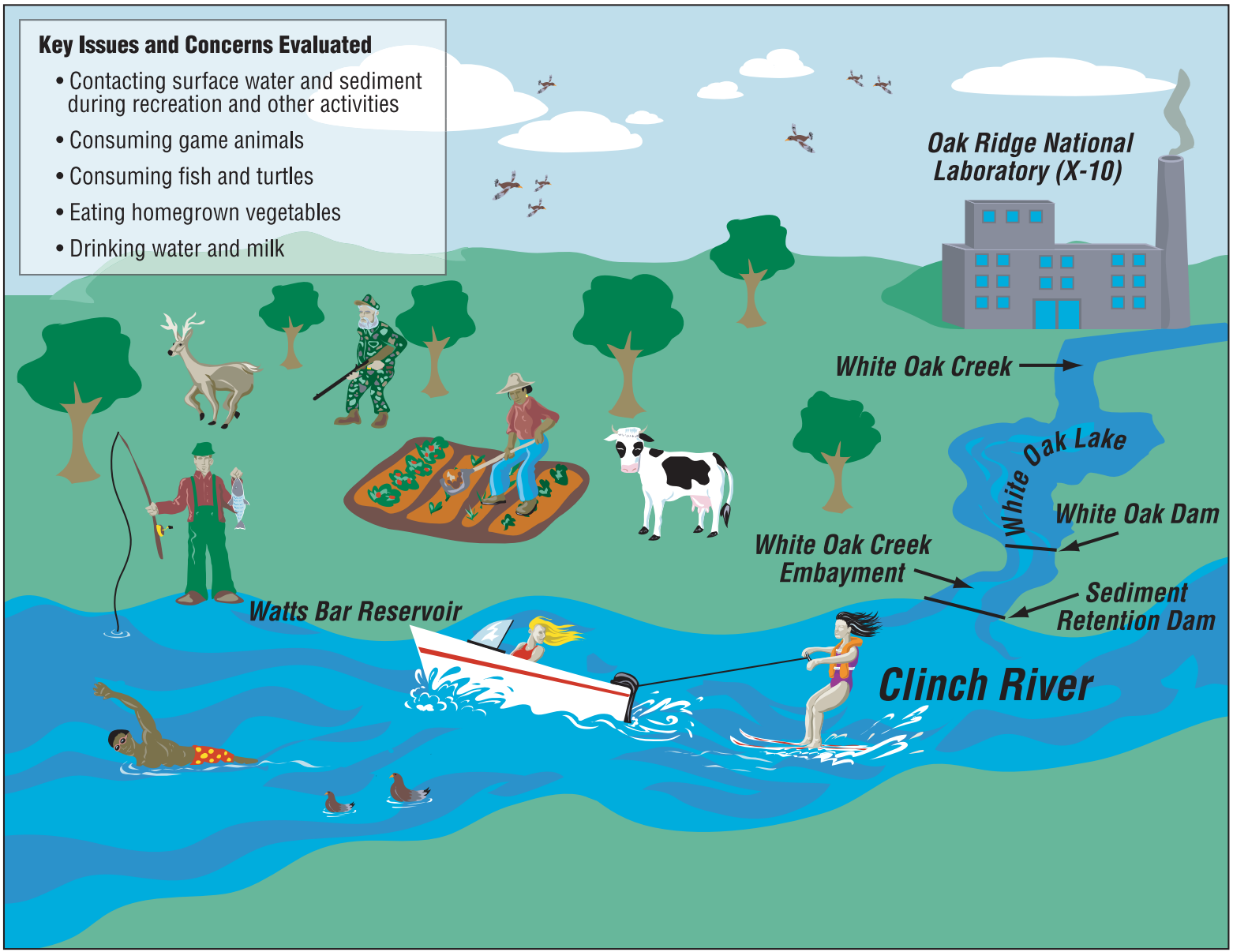
Exposure
Contact with a substance through swallowing it, breathing it, or touching it with the skin or eyes.

Contaminated media
Soil, water, air, or food containing contaminants.

Radionuclide
An element that is unstable and emits radiation.

Radiation dose
The amount of energy from radiation that is actually absorbed by the body.

Figure 3. Key Issues and Concerns Evaluated



ATSDR public health assessment process

ATSDR scientists analyzed the information from previous studies to determine whether the radionuclide releases might pose a public health hazard for **past exposures**, **current exposures**, or **future exposures**. ATSDR's evaluation considered the amount of radionuclides released, the level of contamination present, the extent to which individuals could come in contact with radionuclides, and the estimated doses to individuals coming in contact with the radionuclides under different exposure scenarios. As shown in Figure 4, ATSDR studied the Watts Bar Reservoir area from the Melton Hill Dam to the Watts Bar Dam.

Evaluation of past exposures (1944–1991)

ATSDR scientists concluded that past exposures to radionuclides released from White Oak Creek to the Clinch River were too low to cause observable health effects and were not a public health hazard.

Because most radionuclides do not remain in the body for long periods of time, assessing exposure of people along the Clinch River since 1944 by measuring the current amount of radionuclides in people is not feasible. Instead, ATSDR used the data from a study conducted in 1996–1997 by the Tennessee Department of Health (TDOH) entitled *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, Task 4*. In the study, the TDOH Task 4 team conducted a dose reconstruction to estimate past exposures to radionuclides released from X-10 into the Clinch River via White Oak Creek. (Access the complete project at *www2.state.tn.us/health/CEDS/OakRidge/ORidge.html*.) The Task 4 team's efforts and ATSDR's reevaluation of past exposures are discussed in this section.

The Task 4 screening analysis: identifying radionuclides and exposure pathways

Early in its evaluation, the Task 4 team identified those radionuclides of potential concern that historical X-10 processes had released to White Oak Creek. The team then determined all possible past exposure pathways. This preliminary work identified 24 radionuclides released to the creek from 1944 through 1991, along with potential exposure pathways. To help focus its efforts on the *most important* radionuclides and the ways people could have been exposed to X-10 releases via White Oak Creek, the Task 4 team conducted a **screening analysis**. The team screened radionuclides and pathways using a risk-based process to calculate human health risk estimates for people and for their target organs, assuming that the exposure occurred during the study period of 1944 through 1991 (a period of up to 48 years).

As a result of the screening analysis, 16 radionuclides and four pathways received a low priority because their estimated screening human health risk indices were below the **minimal level of concern**. Eight radionuclides and five pathways were identified for further evaluation. Additional screening determined that four of those eight radionuclides (cesium 137, cobalt 60, ruthenium 106, and strontium 90) were the most likely to cause adverse health effects to exposed off-site populations. The results of the screening results are shown in Figure 5.

ENVIRONMENTAL HEALTH TERMS

For the White Oak Creek evaluation:

Past exposure
An exposure occurring between 1944 and 1991.

Current exposure
An exposure occurring from 1988/1989 to 2003.

Future exposure
An exposure occurring after 2003.

Screening analysis
A preliminary analysis used to determine which radionuclides and exposure pathways are not a health hazard and which require further evaluation.

Minimal level of concern
The Task 4 screening value was 1×10^{-5}. The same value can be presented in different ways:

1.0×10^{-5}

1.0E-05

0.00001

1/100,000

one in one hundred thousand

Figure 4. Map of the White Oak Creek Public Health Assessment Study Area

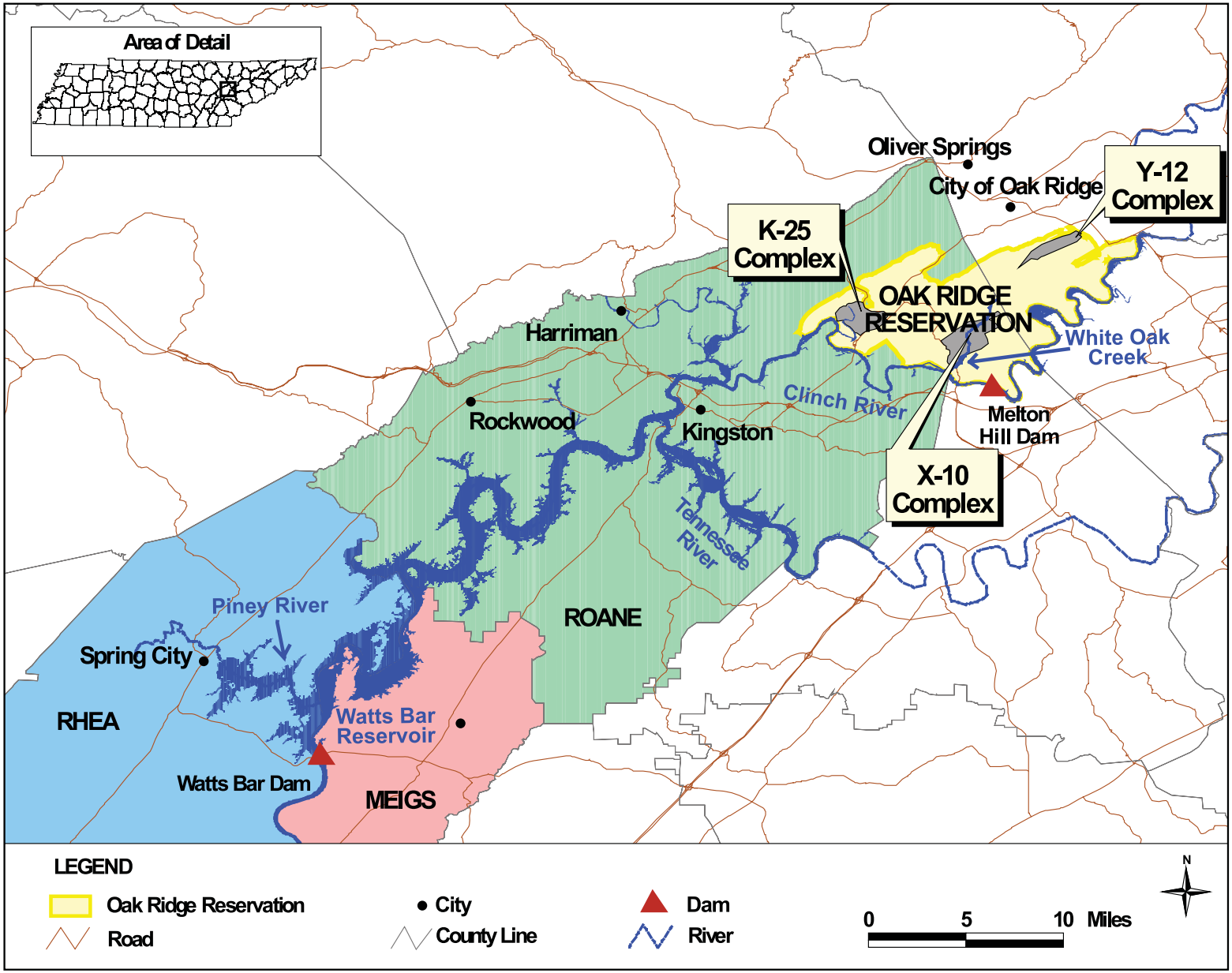


Figure 5. Task 4 Screening Analysis Results

Task 4 Initial Screening		
Low Priority: Not of Health Concern Am 241, Ba 140, Eu 154, H 3, La 140, Nd 147, P 32, Pm 147, Pr 143, Pu 239/240, Sm 151, Sr 89, Th 232, U 235, U 238, and Y 91	**24 radionuclides** 	**High Priority: Selected for Further Study** Ce 144, Co 60, Cs 137, I 131, Nb 95, Ru 106, Sr 90, and Zr 95
Swimming Irrigation Eating local produce Contact with dredged sediment	**9 exposure pathways** 	Eating fish Eating meat Drinking water Drinking milk Walking along the shoreline

The Task 4 dose reconstruction for past exposures

As a central part of reconstructing past exposures to creek surface water and sediment for the eight radionuclides, the Task 4 team needed reliable concentration estimates. To establish these estimates, the team first calculated the amount of radionuclides released from X-10 from 1944 through 1991 by using waste production and release estimates, and reported measurements. The team then performed mathematical modeling to estimate the annual average peak concentrations of the eight radionuclides in surface water (except when actual measurements in water were available to calculate doses) and sediment at certain places downstream from White Oak Creek. Because of **remedial actions** and preventive measures at X-10, physical movement of sediments from the area, and radiological decay, the radionuclide concentrations in the surface water and sediment have substantially decreased over time.

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

The Task 4 team then further considered exposure pathways. For each exposure pathway, reference populations were identified with varying characteristics and sizes. For example, to account for possible variability in exposure situations due to 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 1 contains location and exposure situations evaluated for the four segments of the Clinch River included in the Task 4 report. Eating fish, drinking milk, consuming meat, and external exposures to shoreline sediment were the exposure pathways of interest in all four segments. The drinking water pathway, however, was also evaluated at three of the segments (river water was not used as a drinking water source at Jones Island). For the fish consumption pathway, three categories of fish consumption patterns were assessed.

ENVIRONMENTAL HEALTH TERMS

Remedial actions
Implementation of cleanup activities at a Superfund site.

ENVIRONMENTAL HEALTH TERMS

Critical organ
The organ receiving the highest radiation dose following intake of radioactive material. This is the most important organ in terms of radiation protection.

Internal radiation dose
The dose from radioactive substances taken into the body through breathing or eating. Exposure continues after the initial intake, even if no additional radionuclides are ingested or inhaled.

Radiation dose equivalent
An equivalent dose to organs that will be received from intake of radioactive material by an individual. This is over a 50-year period after the intake for adults, and from age of the intake to 70 years for children.

External radiation dose
A dose from radiation sources outside the body, such as radiation emitted from contaminated sediment. These external sources can sometimes penetrate the human skin. Exposure stops when the source is removed.

Table 1. Past Exposure Scenarios for the Clinch River Area

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

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

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

The Task 4 authors estimated the radiation doses for each pathway of interest to approximate the amount of radiation that a potentially exposed person might have received. The Task 4 team used the International Commission on Radiological Protection (ICRP) **critical organ** concept to derive **internal radiation doses** for people eating contaminated food or drinking contaminated water or milk. The team applied this concept in deriving **radiation dose equivalents** for 22 organs. The **external radiation doses** were then calculated for exposures to radionuclides in sediment. Whether an exposure contributed to a person's external or internal exposure depended primarily on the type of radiation—that is, alpha or beta particles or gamma rays—to which a person was exposed. Most radionuclides released from X-10 delivered internal radiation doses in the form of beta or gamma radiation from particles ingested (e.g., with contaminated food, water, or milk) or inhaled.

ATSDR's evaluation of the Task 4 findings

For community members who had past exposures over a maximum 48-year exposure period, ATSDR reevaluated the Task 4 estimated radiation doses to radionuclides (cesium 137, ruthenium 106, strontium 90, cobalt 60, iodine 131, cerium 144, zirconium 95, and niobium 95). The internal exposures came through consumption of fish, meat, milk, and water; the external radiation exposures came from walking on shoreline sediment. 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 and Tennessee Rivers (CRM 0) near the city of Kingston.

For the specified exposures, ATSDR derived both the whole-body dose (annual and **committed effective dose** over a 70-year duration) and total lifetime organ dose (**committed equivalent dose** over a 70-year duration) for the bone, lower large intestine, red bone marrow, skin, and female breast. ATSDR derived these doses by using the organ-specific doses presented in the Task 4 report (specifically, the 50th percentile of the uncertainty distribution, also known as the central value). Table 2 contains ATSDR's derived doses for past radiation exposures. These are below the levels likely to cause observable health effects. More specifically, ATSDR's findings are as follows:

- ***Estimated radiation dose to the whole body.*** A person exposed to the radionuclides in Clinch River water, fish, shoreline sediment, meat, and milk was expected over a 70-year duration to receive a committed effective dose to the whole body of less than 300 **millirem (mrem)**. This whole-body dose is well below (18 times less than) ATSDR's **radiogenic cancer comparison value** of 5,000 mrem over a 70-year duration. Furthermore, the annual whole-body dose (derived by combining the organ doses of 4 mrem/year) is 25 times less than ATSDR's **radiogenic minimal risk level (MRL)** of 100 mrem/year. The 100 mrem/year value is also the maximum dose constraint for members of the public as recommended by the ICRP, the U.S. Nuclear Regulatory Commission (NRC), DOE, and the National Council on Radiation Protection and Measurements (NCRP).
- ***Estimated radiation dose to individual organs.*** The bone received the highest estimated total committed equivalent dose over a lifetime (70 years) of exposure to the radionuclides along the Clinch River. Even so, 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 exposed to radiation.
- ***Pathway(s) of greatest radiation exposure.*** Eating fish from the Clinch River resulted in the highest estimated organ dose to the bone. Primarily, the organ dose depended on how often people ate fish and where in the Clinch River the fish were collected. The highest cumulative organ doses (1944–1991) were for people 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. Organ doses for people eating fish caught near Kingston were eight times less than organ doses for people eating fish caught near Jones Island. Also, organ doses for people who walked along the shore, drank water and milk, and ate meat were at least six times less than organ doses from eating fish. Nonetheless, ATSDR determined that estimated doses from fish consumption—and all other exposure pathways—for past exposure to radionuclides released by X-10 to the Clinch River via White Oak Creek are lower than ATSDR's comparison values (CVs). These estimated doses are also below those reported in radiologic and epidemiologic studies associated with adverse effects.

ENVIRONMENTAL HEALTH TERMS

Committed effective dose
This dose, associated with internal exposure, is the sum of the weighting factors applicable to each body organ or tissue that is irradiated over a 50-year duration after the intake for an adult and from the age of intake to 70 years for a child.

Committed equivalent dose
The dose to an organ that an individual will receive from an intake of radioactive material over a 50-year period following the intake for adults and over a 70-year period following the intake for children.

Millirem (mrem)
A unit of measurement of radiation dose. It is 1,000 times less than the rem ("roentgen equivalent man").

Radiogenic cancer comparison value
A screening level—5,000 mrem over 70 years—used during the public health assessment process. Doses below this value are not expected to result in observable health effects and are not evaluated further. Doses greater than this value are selected for further evaluation.

Radiogenic minimal risk level (MRL)
An estimate of daily human exposure to a radionuclide that is unlikely to result in noncancer health effects over a specified duration.

Table 2. Past (1944–1991) Radiation Doses for the Area Along the Clinch River

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 (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 who lived near, the Clinch River and Lower Watts Bar Reservoir.
	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)	
Female 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.*

† *See the discussion related to Table 11 in the public health assessment for an explanation on the derivations of the past radiation doses.*

‡ *ATSDR's minimal risk level (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 that are unlikely to result in noncancer health effects over a specified duration. The ICRP-, NCRP-, and NRC-recommended value of 100 mrem/year for the public considers both noncancer and cancer health effects.*

§ *Based on studies of atomic bomb survivors.*

¶ *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.*

** *Based on studies of atomic bomb survivors.*

†† *Based on studies of patients irradiated for the treatment of ringworm.*

Evaluation of current and future exposures

ATSDR scientists concluded that the levels of radionuclides in the Clinch River and Lower Watts Bar Reservoir are below levels associated with a public health hazard.

For exposures to radionuclides in the Clinch River and Lower Watts Bar Reservoir from 1988 through 2003 (current exposures), ATSDR scientists evaluated data on current contaminant levels in the water, sediment, and fish, as well as turtles and geese in the Clinch River. The scientists then estimated radiation doses using **conservative exposure scenarios**. For future exposures (exposures occurring after 2003), ATSDR scientists evaluated the institutional controls that are in place to monitor contaminants in the Clinch River and Lower Watts Bar Reservoir, including the public drinking water systems. ATSDR's evaluation shows that current and potential future exposures to even the highest detected concentrations of radionuclides in the surface water, sediment, and fish from the Clinch River and Lower Watts Bar Reservoir, as well as turtles and geese from the Clinch River, will result in radiation doses too low to be considered a health hazard. ATSDR's evaluation is discussed in detail in the sections that follow.

ATSDR scientists also evaluated drinking water data collected from the Kingston, Rockwood, and Spring City public water suppliers that receive water from the Tennessee River system. The Kingston water supply has an intake on the Tennessee River in Watts Bar Lake. Spring City obtains its water from an intake on the Piney River branch of Watts Bar Lake, and the city of Rockwood receives its water from an intake on the King Creek branch of Watts Bar Lake. All the water samples were below the U.S. Environmental Protection Agency's maximum contaminant levels. Accordingly, now and in the future ATSDR considers this water safe for consumption and for other potable uses.

ATSDR's identification of exposure pathways

The current environmental sampling data indicate that radioactive materials released from the ORR are still present in the Lower Watts Bar Reservoir and Clinch River sediments and, to a lesser extent, in surface waters. To select likely ways in which people might come in contact with radionuclides in these waterways, ATSDR scientists assessed possible recreational and domestic uses of the reservoir and river. Table 3 summarizes the current (and future) exposure pathways, potentially exposed people, and exposure situations that ATSDR evaluated. As noted in the table, ATSDR assessed conservative hypothetical exposure scenarios for people living along and using the Lower Watts Bar Reservoir. These people were exposed to radionuclides while contacting surface water (via swimming, drinking, or showering), eating fish, or contacting surface sediment or dredged sediment from the deep river channel. For the Clinch River, ATSDR assessed hypothetical exposures for people exposed to radionuclides while contacting shoreline sediment during recreational activities, contacting surface water via drinking or swimming, or eating fish, turtles, or geese.

ENVIRONMENTAL HEALTH TERMS

Conservative exposure scenarios Hypothetical exposure scenarios with worst-case exposure assumptions that are protective of public health in essentially all situations. The resulting estimated radiation doses are usually much higher—that is, more conservative—than the levels to which people are really exposed.

Table 3. Current and Future Exposure Scenarios

Area and Time Frame	Pathway	Most Likely Exposed Population
Lower Watts Bar Reservoir (from 1988)	Contact with surface sediment during recreational activities	Child
	Contact with subsurface sediment dredged from the deep-river channel	Child
	Drinking, showering with, and swimming in reservoir water	Child
	Eating fish	Adult and child
Clinch River (from 1989)	Contact with sediment during recreational activities	Adult
	Drinking and swimming in river water	Adult
	Eating fish, turtles, and goose liver and muscle	Adult, teenager, and child

ATSDR's estimation of current and future radiation doses

To estimate the amount of radiation a potentially exposed person might receive from current and future exposures, ATSDR scientists derived radiation doses for each pathway of interest. Table 4 contains the estimated doses for the Lower Watts Bar Reservoir and the Clinch River exposure scenarios. The possible health effects of these estimated doses are discussed below.

- ***Lower Watts Bar Reservoir.*** ATSDR's estimated committed effective dose to the whole body for all the worst-case exposure scenarios 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. Furthermore, the estimated annual whole-body dose is less than 30 mrem—below ATSDR's screening CV, NRC's and DOE's regulatory value, and below ICRP's and NCRP's recommended limit for the public of 100 mrem/year.
- ***Clinch River.*** ATSDR's estimated committed effective dose to the whole body for all the conservative exposure scenarios combined is less than 236 mrem to 70 years of age—21 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, about 30 times below the recommended limit of 100 mrem/year.

ATSDR also derived organ-specific doses for Clinch River exposures by using data obtained for 1989 to 2003 from the Oak Ridge Environmental Information System (OREIS, detailed in the public health assessment). For the target organs evaluated, ATSDR estimated that over a lifetime (to age 70) the bone receives the highest total committed equivalent dose of exposure to those radionuclides detected along the Clinch River. The highest committed equivalent doses to the bone were associated with a 15-year-old ingesting goose muscle or liver and fish over a 55-year period. (These were the highest doses because of the accelerated bone growth in that age group.)

The dose estimate to the bone from all pathways combined—less than 218 mrem over 50 years—is based on exposures for adults. Estimates suggest that this dose to the bone is 1,788 times less than the doses of 390,000 to 620,000 mrem associated with bone cancers in radium dial workers. Much lower doses were associated with other pathways, such as ingestion of Clinch River water and external exposures from walking on sediment and swimming. Following 50 years of exposure for adults, the committed equivalent dose to the lower large intestine of 270 mrem for all pathways combined was about 18 times less than ATSDR's radiogenic cancer 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, which is 1,500 times below the value of 9,000 mrem based on the Biological Effects of Ionizing Radiation (BEIR) V report of patients irradiated for the treatment

Table 4. Current and Future 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-present)	Whole body	Annual	Less than 30 mrem	100 mrem (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 in the present or in the future. Current releases of radioactive material from White Oak Creek are **not a public health hazard** for current and future users of these waterways and for people who live near the Clinch River and Lower Watts Bar Reservoir.††
		Committed effective dose or lifetime	Less than 1,900 mrem	5,000 mrem§	Below (2.5 times less)	
Clinch River (1989-present)	Whole body	Annual	Less than 3.4 mrem	100 mrem‡	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 duration for the Lower Watts Bar Reservoir 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 and committed equivalent doses, the dose for a pathway was adjusted for a 70-year exposure for the Lower Watts Bar Reservoir 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. MRLs are estimates of daily human exposures to substances that are unlikely to result in noncancer health effects over a specified duration. The ICRP-, NCRP-, and NRC-recommended limit of 100 mrem/year for the public considers both noncancer and cancer health effects.*

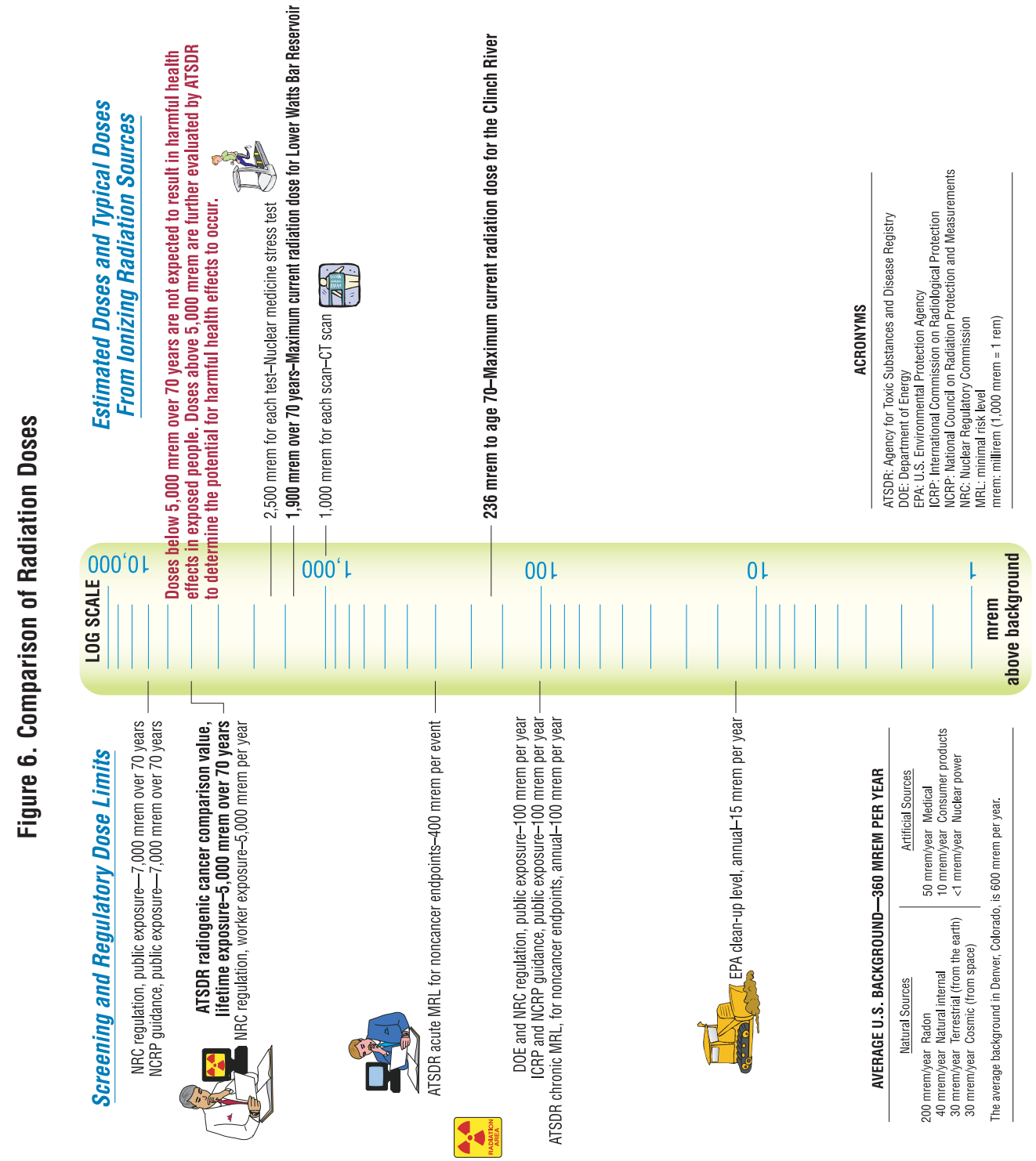
§ *Based on studies of atomic bomb survivors.*

¶ *A review of human radium dial workers suggests that a threshold for radium-induced bone cancers is between 390,000 and 620,000 mrem.*

** *Based on studies of patients irradiated for the treatment of ringworm.*

†† *ATSDR assessed the estimated current doses in its evaluation of future exposures.*

Figure 6 shows a comparison of the estimated current whole-body radiation doses (on the right side) to screening and regulatory dose limits (on the left side). This comparison illustrates that past and current exposure doses, even when based on the highest detected concentrations of radionuclides in the Lower Watts Bar Reservoir and the Clinch River, are below recommended dose limits. Radiation doses below these values are not expected to pose health hazards. Therefore, people who have used these waterways or who have lived near them—or who continue to do so—are not expected to develop observable health effects.



Evaluation of health outcome data

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, and 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. ATSDR scientists generally consider health outcome data evaluation when they identify a plausible, reasonable expectation of adverse health effects associated with the observed levels of exposure to contaminants.

In this public health assessment, 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 allowable 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 in the past, and they are not currently being exposed to harmful levels of radionuclides released to White Oak Creek from the X-10 site. 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. Because the estimated radiation doses are not expected to cause health effects, no further analysis of health outcome data is appropriate.

What other issues is ATSDR evaluating at the Oak Ridge Reservation?

In addition to the public health assessment on radionuclide releases from the X-10 site to White Oak Creek, ATSDR scientists are conducting public health assessments on the following issues related to the Oak Ridge Reservation:

- Mercury releases from the Y-12 plant
- Contaminant releases from the TSCA Incinerator
- Uranium releases from the Y-12 plant
- Contaminated off-site groundwater
- Screening for current chemical exposures
- Polychlorinated biphenyl (PCB) releases from the X-10 site, the Y-12 plant, and the K-25 site
- Uranium and fluoride releases from the K-25 site
- Iodine 131 releases from the X-10 site

Where can I get more information?

For more information on ionizing radiation, see ATSDR's toxicological profile for ionizing radiation on the Internet at *http://www.atsdr.cdc.gov/toxprofiles/tp149.pdf*. In addition, you can get more detailed information from ATSDR's Web site at *http://www.atsdr.cdc.gov/* or by contacting ATSDR headquarters toll free at 1-888-42ATSDR (1-888-422-8737). You may also contact Paul Charp, Jack Hanley, or Marilyn Palmer.

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