PUBLIC HEALTH ASSESSMENT
Polychlorinated Biphenyl (PCB) Releases:
Oak Ridge Reservation (USDOE)

Oak Ridge, Anderson County, Tennessee
CERCLIS NO. TN1890090003

March 2009

Prepared by:
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Agency for Toxic Substances and Disease Registry

Foreword

The Agency for Toxic Substances and Disease Registry, ATSDR, was established by Congress in 1980 under the Comprehensive Environmental Response, Compensation, and Liability Act, also known as the *Superfund* law. This law set up a fund to identify and clean up our country's hazardous waste sites. The Environmental Protection Agency, EPA, and the individual state1H2Hs regulate the investigation and clean up of the sites.

Since 1986, ATSDR has been required by law to conduct a public health assessment at each of the sites on the EPA National Priorities List. The aim of these evaluations is to find out if people are being exposed to hazardous substances and, if so, whether that exposure is harmful and should be stopped or reduced. If appropriate, ATSDR also conducts public health assessments when petitioned by concerned individuals. Public health assessments are carried out by environmental and health scientists from ATSDR and from the states with which ATSDR has cooperative agreements. The public health assessment program allows the scientists flexibility in the format or structure of their response to the public health issues at hazardous waste sites. For example, a public health assessment could be one document or it could be a compilation of several health consultations - the structure may vary from site to site. Nevertheless, the public health assessment process is not considered complete until the public health issues at the site are addressed.

Exposure: As the first step in the evaluation, ATSDR scientists review environmental data to see how much contamination is at a site, where it is, and how people might come into contact with it. Generally, ATSDR does not collect its own environmental sampling data but reviews information provided by EPA, other government agencies, businesses, and the public. When there is not enough environmental information available, the report will indicate what further sampling data is needed.

Health Effects: If the review of the environmental data shows that people have or could come into contact with hazardous substances, ATSDR scientists evaluate whether or not these contacts may result in harmful effects. ATSDR recognizes that children, because of their play activities and their growing bodies, may be more vulnerable to these effects. As a policy, unless data are available to suggest otherwise, ATSDR considers children to be more sensitive and vulnerable to hazardous substances. Thus, the health impact to the children is considered first when evaluating the health threat to a community. The health impacts to other high risk groups within the community (such as the elderly, chronically ill, and people engaging in high risk practices) also receive special attention during the evaluation.

ATSDR uses existing scientific information, which can include the results of medical, toxicologic and epidemiologic studies and the data collected in disease registries, to determine the health effects that may result from exposures. The science of environmental health is still developing, and sometimes scientific information on the health effects of certain substances is not available. When this is so, the report will suggest what further public health actions are needed.

Conclusions: The report presents conclusions about the public health threat, if any, posed by a site. When health threats have been determined for high risk groups (such as children, elderly, chronically ill, and people engaging in high risk practices), they will be summarized in the conclusion section of the report. Ways to stop or reduce exposure will then be recommended in the public health action plan.

ATSDR is primarily an advisory agency, so usually these reports identify what actions are appropriate to be undertaken by EPA, other responsible parties, or the research or education divisions of ATSDR. However, if there is an urgent health threat, ATSDR can issue a public health advisory warning people of the danger. ATSDR can also authorize health education or pilot studies of health effects, full-scale epidemiology studies, disease registries, surveillance studies or research on specific hazardous substances.

Community: ATSDR also needs to learn what people in the area know about the site and what concerns they may have about its impact on their health. Consequently, throughout the evaluation process, ATSDR actively gathers information and comments from the people who live or work near a site, including residents of the area, civic leaders, health professionals and community groups. To ensure that the report responds to the community's health concerns, an early version is also distributed to the public for their comments. All the comments received from the public are responded to in the final version of the report.

Comments: If, after reading this report, you have questions or comments, we encourage you to send them to us.

Letters should be addressed as follows:

Agency for Toxic Substances and Disease Registry
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1600 Clifton Road, NE (Mail Stop F-09)
Atlanta, GA 30333

Contents

List of Tables

List of Figures

List of Abbreviations

ABMT	American Board of Medical Toxicology
ALS	amyotrophic lateral sclerosis
AOEC	Association of Occupational and Environmental Clinics
ATSDR	Agency for Toxic Substances and Disease Registry
B.A.	Bachelor of Arts
B.S.	Bachelor of Science
BSCP	Background Soil Characterization Project
CD	Cluster of Differentiation
CDC	Centers for Disease Control and Prevention
CEDR	Comprehensive Epidemiologic Data Resource
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS	CERCLA Information System
cm	centimeter(s)
COPD	chronic obstructive pulmonary disease
CRM	Clinch River mile
DABT	Diplomate of the American Board of Toxicology
DDT	dichlorodiphenyltrichloroethane
DNA	deoxyribonucleic acid
DOE	U.S. Department of Energy
EFPC	East Fork Poplar Creek
EI	exposure investigation
EMEG	environmental media evaluation guide
EPA	U.S. Environmental Protection Agency
ER^-	estrogen receptor negative
ETTP	East Tennessee Technology Park
FACA	Federal Advisory Committee Act
FAMU	Florida Agriculture and Mechanical University
FFA	Federal Facility Agreement
g	gram(s)
g/day	gram(s) per day
g/ml	gram(s) per milliliter
HazDat	Hazardous Substance Release and Health Effects Database
HRSA	Health Resources Services Administration
Ig	immunoglobulin
kg	kilogram
LNT	linear no-threshold
LOAEL	lowest-observed-adverse-effect level
LOD	limit of detection
M.B.A.	Master of Business Arts
MCP	Microsoft Certified Professional
M.D.	Medical Doctor
mg	milligram(s)
mg/day	milligrams per day
mg/kg	milligrams per kilogram

List of Abbreviations (continued)

mg/kg/day	milligrams per kilogram per day
μg/L	micrograms per liter
μg/kg	micrograms per kilogram
$\mu g/m^3$	micrograms per cubic meter
MPH	Master of Public Health
MRL	minimal risk level
MS	multiple sclerosis
M.S.	Master of Science
NA	not applicable
NCEH	National Center for Environmental Health
ng/ml	nanograms per milliliter
NHANES	National Health and Nutrition Examination Survey
NIH	National Institute of Health
NIOSH	National Institute for Occupational Safety and Health
NOAEL	no-observed-adverse-effect level
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
OREIS	Oak Ridge Environmental Information System
ORHASP	Oak Ridge Health Agreement Steering Panel
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
ORRHES	Oak Ridge Reservation Health Effects Subcommittee
PBPK	physiologically based pharmacokinetic
PCB	polychlorinated biphenyl
PCM	Poplar Creek mile
PHA	public health assessment
PHAP	Public Health Action Plan
Ph.D.	Doctor of Philosophy
ppb	parts per billion
ppm	parts per million
RCRA	Resource Conservation and Recovery Act
R.N.C.	Registered Nurse, Certified
TBG	thyroxin-binding globulin
TDEC	Tennessee Department of Environment and Conservation
TDOH	Tennessee Department of Health
TN	Tennessee
TRM	Tennessee River Mile
TSCA	Toxic Substances Control Act
TSH	thyroid stimulating hormone
TVA	Tennessee Valley Authority
TWRA	Tennessee Wildlife Resources Agency
UF_6	uranium hexafluoride
U.S.	United States
USACE	U.S. Army Corps of Engineers

I. Summary

In 1942, the federal government established the Oak Ridge Reservation (ORR) in Anderson and Roane Counties, Tennessee as part of the Manhattan Project to research, develop, and produce special radioactive materials for nuclear weapons. Four facilities were built at that time: the Y-12 plant, the K-25 site, and the S-50 site (now part of the K-25 site) to enrich uranium, and the X-10 site to manufacture and separate plutonium. Since the end of World War II, the role of the ORR (Y-12 plant, K-25 site, and X-10 site) has broadened to include a variety of nuclear research and production projects vital to national security.

During its long history, ORR operations have released polychlorinated biphenyls (PCBs) and generated a variety of other nonradioactive and radioactive wastes, which have been released into the environment and are now present in old waste sites. As a result, in 1989 the U.S. Environmental Protection Agency (EPA) added the ORR to the National Priorities List (NPL). The U.S. Department of Energy (DOE) is conducting cleanup activities at the ORR under a Federal Facility Agreement (FFA) with EPA and the Tennessee Department of Environment and Conservation (TDEC). These agencies are working together to investigate and remediate hazardous wastes generated from past and present site activities.

Since 1992, the Agency for Toxic Substances and Disease Registry (ATSDR) has responded to requests from and addressed health concerns of community members, civic organizations, and other government agencies. ATSDR is the principal federal public health agency charged with evaluating human health effects of exposure to hazardous substances in the environment. To address these concerns and requests, ATSDR has worked extensively, with input and assistance from the community, to determine whether levels of environmental contamination at and near the ORR present a public health hazard to surrounding communities. In the process ATSDR has identified and evaluated several public health issues and has worked closely with many parties. During the 1990s, ATSDR's activities focused on current public health issues related to Superfund cleanup at the site. ATSDR addressed public health issues associated with three off-site areas affected by ORR operations: the East Fork Poplar Creek area, Clinch River/Poplar Creek, and the Lower Watts Bar Reservoir. While ATSDR has evaluated current Superfund issues, the Tennessee Department of Health (TDOH) has conducted the Oak Ridge Health Studies to evaluate whether off-site populations were exposed in the past to site-related contamination.

During the Oak Ridge Health Studies, the TDOH conducted extensive reviews and screening analyses of available information. The TDOH identified four hazardous substances that might have been responsible for adverse health effects: PCBs in fish from East Fork Poplar Creek, Clinch River, and Watts Bar Reservoir; mercury released from the Y-12 plant; iodine from X-10 activities; and radionuclides released to White Oak Creek from X-10 activities. In addition to dose reconstruction studies on these four substances, the TDOH conducted additional screening analyses for releases of uranium, radionuclides, and several other toxic substances.

To expand upon the efforts of the TDOH—but not duplicate them—ATSDR scientists conducted a review and a screening analysis of the department's screening level evaluation of past exposure (1944 to 1990) to identify contaminants requiring further evaluation. Based on this review, ATSDR scientists have completed or are conducting public health assessments (PHAs) on iodine

131 releases from the X-10 site, mercury releases from the Y-12 plant, radionuclide releases from White Oak Creek, uranium releases from the Y-12 plant, uranium and fluoride releases from the K-25 site, and other topics such as contaminant releases from the Toxic Substances Control Act (TSCA) Incinerator and contaminated off-site groundwater. In addition, ATSDR screened current (1990 to 2003) environmental data to identify any other chemicals that require further evaluation. In these PHAs, ATSDR scientists evaluate and analyze the data and findings from previous studies and investigations to assess the public health implications of past and current exposure.

This PHA only evaluates PCB releases from the ORR into nearby off-site waterways, including the East Fork Poplar Creek, Clinch River, Tennessee River, and Lower Watts Bar Reservoir. In this PHA, ATSDR a) assesses past and current PCB exposure for people who use or who live along these waterways; b) addresses the issues related to PCB contamination in the water, to sediment and nearby soil, and to the aquatic food chain associated with the waterways; and c) responds to community concerns associated with these topics.

The PCBs released from the ORR originated from the large electrical energy requirements (in transformers and capacitors) necessary for the production of uranium and plutonium isotopes at K-25, X-10, and Y-12 and from the machining operations (e.g., cutting oils and cooling fluids). During these uses and subsequent waste disposal practices, oily PCB fluids spilled on the ground and entered ponds and creeks that flowed into, or were carried by soil suspended in water to, Poplar Creek, East Fork Poplar Creek, the Clinch River, and the Watts Bar Reservoir. The TDOH documented detailed information about these historical occurrences.

Using the findings of investigations conducted by various agencies, available environmental data, and the results of previous ATSDR studies, ATSDR closely examined the nature and extent of PCB contamination in the ORR's nearby waterways and evaluated potential past and current exposure situations. In the initial ATSDR screening evaluation in Section III (Evaluation of Environmental Contamination and Potential Exposure Pathways), ATSDR concluded that the levels of PCB contamination that entered the water, sediment, and soil of East Fork Poplar Creek, Poplar Creek, the Clinch River, the Tennessee River, and the Lower Watts Bar Reservoir, are in each case too low to cause observable adverse health effects for the people who used or who continue to use these waterways and associated floodplains for drinking, swimming, farming, and gardening. ATSDR based this conclusion on its screening evaluation of the TDOH's Oak Ridge Health Studies' conclusions and on its own evaluation of data of PCB concentrations in various environmental media (i.e., biological and nonbiological). This screening evaluation indicates, however, that some people who ate or continue to eat fish or geese from these waterways may have received higher doses than the ATSDR's screening minimal risk levels (MRLs). Therefore, the health effects of fish and geese consumption are evaluated in more depth in Section IV (Public Health Implications).

Screening Evaluation of Past Exposure (1944–1995)

Using its evaluation of past exposure to PCBs, ATSDR determined that none of the exposure pathways involving intake of PCB-contaminated sediment, airborne PCB contamination, and waterborne PCB contamination are a public health hazard. Nevertheless, ATSDR conducted a more in-depth public health evaluation to determine whether it was safe to eat fish and geese in the past.

ATSDR began the screening evaluation by reviewing Reports of the Oak Ridge Dose Reconstruction (Task 3), *PCBs in the Environment Near the Oak Ridge Reservation, A Reconstruction of Historical Doses and Heath Risks* (ChemRisk 1999a) (referred to as the "Task 3 report"). This conservative (i.e., protective) evaluation stated that the levels of PCBs in the air, in the water in all the waterways, and in the sediment in Poplar Creek, the Clinch River, and the Watts Bar Reservoir are not a public health hazard. The Task 3 team identified 44 potential exposure pathways. Based on a detailed analysis, 13 required further evaluation. For these 13 exposure pathways, ATSDR screened PCB concentrations in the East Fork Poplar Creek sediment and soil separately from PCB concentrations in fish from all the waterways. For nonbiological media, such as sediment or soil, ATSDR compared the distribution of contamination with protective comparison values developed for children and adults exposed for chronic and intermediate durations. For biological media, such as fish and geese, ATSDR compared the distribution of PCB contamination with ORR-specific comparison values developed by ATSDR for this PHA. ATSDR derived these values using consumption data on moderate to high consumers of Watts Bar Reservoir fish and ATSDR's minimal risk level for chronic exposure to PCBs.

> ATSDR delineated the fish-consuming groups from the fish consumption information collected during the Watts Bar Exposure Investigation (ATSDR 1998).

- ATSDR found that no source of sediment below any body of water, at any distance from sediment beds in a floodplain, or taken from any depth (deposited at any time) was sufficiently contaminated with PCBs such that illness could result from any duration of exposure to adults or children. Thus, direct or indirect intake of PCB-contaminated sediment or soil from any of the evaluated waterways did not pose a public health hazard, and was excluded from further evaluation.

- The PCB levels found in some species of fish exceeded the comparison values for some consumption groups under certain exposure conditions. Therefore, eating fish was retained for further in-depth health effects evaluation.

- The median PCB concentration in Canada geese exceeded the comparison values for moderate and high consumption. Therefore, eating geese was retained for further in-depth health effects evaluation.

Screening Evaluation of Current Exposure (1996–2004)

Using its evaluation of current exposure to PCBs, ATSDR determined that no pathway involving intake of PCB-contaminated sediment, airborne PCB contamination, waterborne PCB contamination, or turtle meat is a public health hazard. ATSDR conducted a more in-depth public health evaluation regarding the safety of fish consumption.

- Sediment sampled after 1996 was less contaminated than sediment sampled prior to 1996. PCBs were not detected in most samples, and where PCBs were found, the concentrations were all below ATSDR comparison values. As in the case of earlier samples, ATSDR found no sediment below any body of water or at any distance from sediment beds that was sufficiently contaminated with PCBs such that illness could result from any duration of exposure. Therefore, exposure to sediment is not a public health hazard.

- Waterborne PCB contamination is not a likely source of illness. Given the relative sediment and water solubility of PCBs, the potential maximum PCB concentrations in the water are well below ATSDR's comparison values for drinking water. Further, TDEC's Division of Water Supply regulates drinking water at all public water systems. According to EPA's Safe Drinking Water Information System, the Kingston, Spring City, and Rockwood public water supply systems have not had any significant violations. Recreational exposure (e.g., from swimming or water-skiing) is even less likely to cause illness than drinking the water. Therefore, neither surface water nor groundwater exposure is a public health hazard.

- The ORR does not currently release PCBs into the air. Besides, the air pathway makes less of a contribution to PCB exposure than sediment or water. ATSDR has shown that the sediment and water pathways did not carry sufficient PCB concentrations to be a health hazard. Therefore, the air pathways from 1996 to the present similarly pose no health hazard.

- For the Clinch River, the Tennessee River, and the Lower Watts Bar Reservoir, fish fillets had higher PCB levels than whole fish. Eating fish was eliminated from further evaluation for some consumption groups, but not for all. Therefore, eating fish was retained for further in-depth health effects evaluation.

- Turtle meat (muscle) was not sufficiently contaminated with PCBs to be a likely source of PCB-related illness. Therefore, eating turtle meat does not pose a public health hazard. People should, however, avoid eating turtle fat. Discarding the fat, eggs, and all organs—while only saving the meat for eating—can reduce PCB exposure.

- Serum PCB levels of moderate to high consumers of the Watts Bar Reservoir fish are slightly lower than national norms for total PCBs.

Public Health Implications of Eating Fish and Geese

ATSDR's review of PCB body burdens nationwide found that people occupationally exposed to PCBs have much greater body burdens than do those who consume PCB-contaminated fish. Fish consumers have greater body burdens than the general population, and the difference between fish consumers and nonconsumers has increased over time. Body burdens of people who ate moderate to high amounts of fish from the Watts Bar Reservoir or the Clinch River are below those of people exposed occupationally, above those of nonfish consumers, and within the national norm for those who consume sport fish.

Cancer is an unlikely health outcome from eating PCB-contaminated fish near the ORR. Nevertheless, due to the potential for noncancer health effects, prudent public health practice would recommend limiting high-quantity consumption of *certain fish species* (see Figure 1). ATSDR has therefore categorized the frequent eating of one or more meals a week, over an extended period of time, of *certain species of fish* (catfish, white bass, hybrid bass [striped bass-white bass], striped bass, and largemouth bass) as a public health hazard. But eating any amount of sunfish species or one fish meal per month of other fish species is not a public health hazard. That said, however, given that exposure to PCBs can cause developmental problems, certain sensitive populations such as pregnant women, nursing mothers, and children should be particularly careful to avoid eating *certain species of fish* from Poplar Creek, the Clinch River, the Tennessee River, and the Lower Watts Bar Reservoir.

Catfish

One adult meal of fish is considered to be 8 ounces (227 grams). Children were assumed to eat one-third as much as adults (2.7 ounces).

- Children should eat no more than one fish meal per month from Poplar Creek, the Clinch River, the Tennessee River, and the Lower Watts Bar Reservoir.
- Adults should eat no more than one fish meal per week from Poplar Creek, the Clinch River, the Tennessee River, and the Lower Watts Bar Reservoir.

White Bass, Hybrid Bass (Striped Bass-White Bass), and Striped Bass

- Children should eat no more than one fish meal per month from Poplar Creek, the Clinch River, and the Tennessee River; and no more than one fish meal per week from the Lower Watts Bar Reservoir
- Adults should eat no more than one fish meal per week from Poplar Creek and the Clinch River; and no more than two fish meals per week from the Tennessee River.

Largemouth Bass

- Children should eat no more than one fish meal per week from the Clinch River; and no more than two fish meals per week from the Tennessee River.

Fish is a healthy food that provides many nutritional benefits. Some of the fish from Poplar Creek, the Clinch River, the Tennessee River, and the Lower Watts Bar Reservoir can safely be consumed in lower quantities.

- Sunfish species from Poplar Creek, the Clinch River, the Tennessee River, and the Lower Watts Bar Reservoir are safe to eat in any amount.

- Largemouth bass from Poplar Creek and the Lower Watts Bar Reservoir are safe to eat, even in high amounts. From the Clinch River and the Tennessee River largemouth bass can be safely consumed in moderate to low quantities.

- Low quantities of any species of fish—even catfish—are safe to eat.

- Canada geese are safe to eat in any amount.

If community members are concerned and want to reduce their exposure to PCBs without forfeiting the health benefits gained from eating fish, they can follow these suggestions:

- Eat the less fatty parts of the fish; throw away skin, fat deposits, head, guts, kidneys, and liver.

- Remove the skin and the strip of light-colored fat that remains along the belly flap at the bottom of the fillet as well as any fat that may be present along the sides and the midpoint of the back.

- Grill, broil, or bake fish on a rack to allow fat—and chemicals—to drain away. This helps remove pollutants stored in the fatty parts of the fish. Avoid frying larger, fatty fish.

- Do not reuse cooking liquids or fat drippings from the fish—these liquids retain PCBs.

- Choose to eat younger (or smaller) fish and those lower on the food chain (e.g., sunfish).

CONCLUSIONS

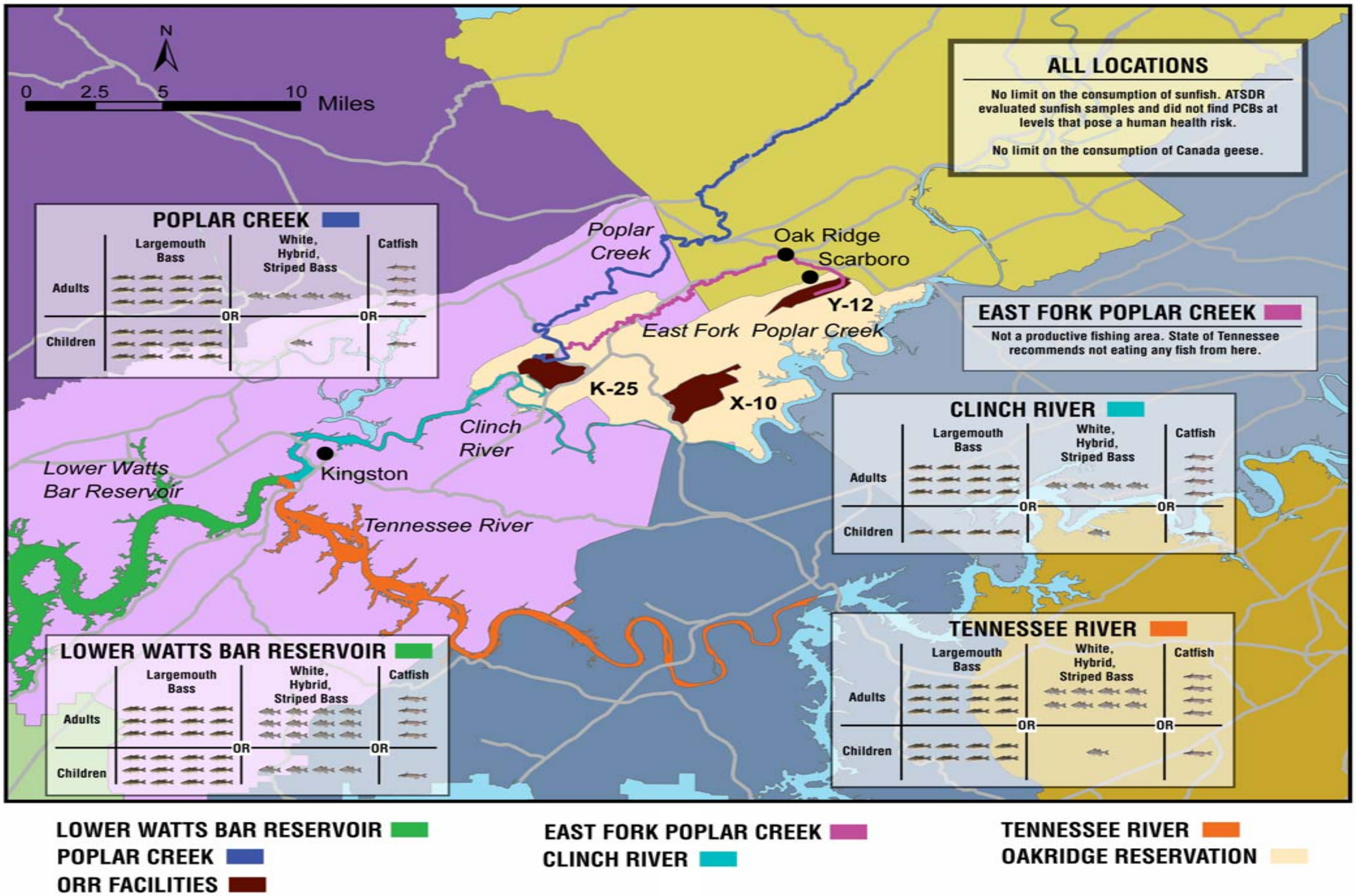
Sunfish species can be safely eaten in any amount.

All fish species can be safely eaten in low amounts (i.e., up to one fish meal per month) from any water body near the ORR.

As a prudent public health practice, eating moderate to high amounts (i.e., one or more meals of fish per week) of certain species of fish (catfish, white bass, hybrid bass [striped bass-white bass], and striped bass) is not recommended due to the levels of PCBs found in the fish. ATSDR recommends that to reduce their exposures to PCBs, people should follow the state fish advisory.

People should avoid eating turtle fat. Discarding the fat, eggs, and all organs—while only saving the meat (muscle) for eating—can reduce exposure to PCB-contaminated fat and tissue.

Figure 1. Maximum Number of Fish Meals That Can Safely Be Eaten per Month



Notes: One adult meal of fish is considered to be 8 ounces (227 grams). Children were assumed to eat one-third as much as adults. Each fish represents one fish meal per month.

II. Background

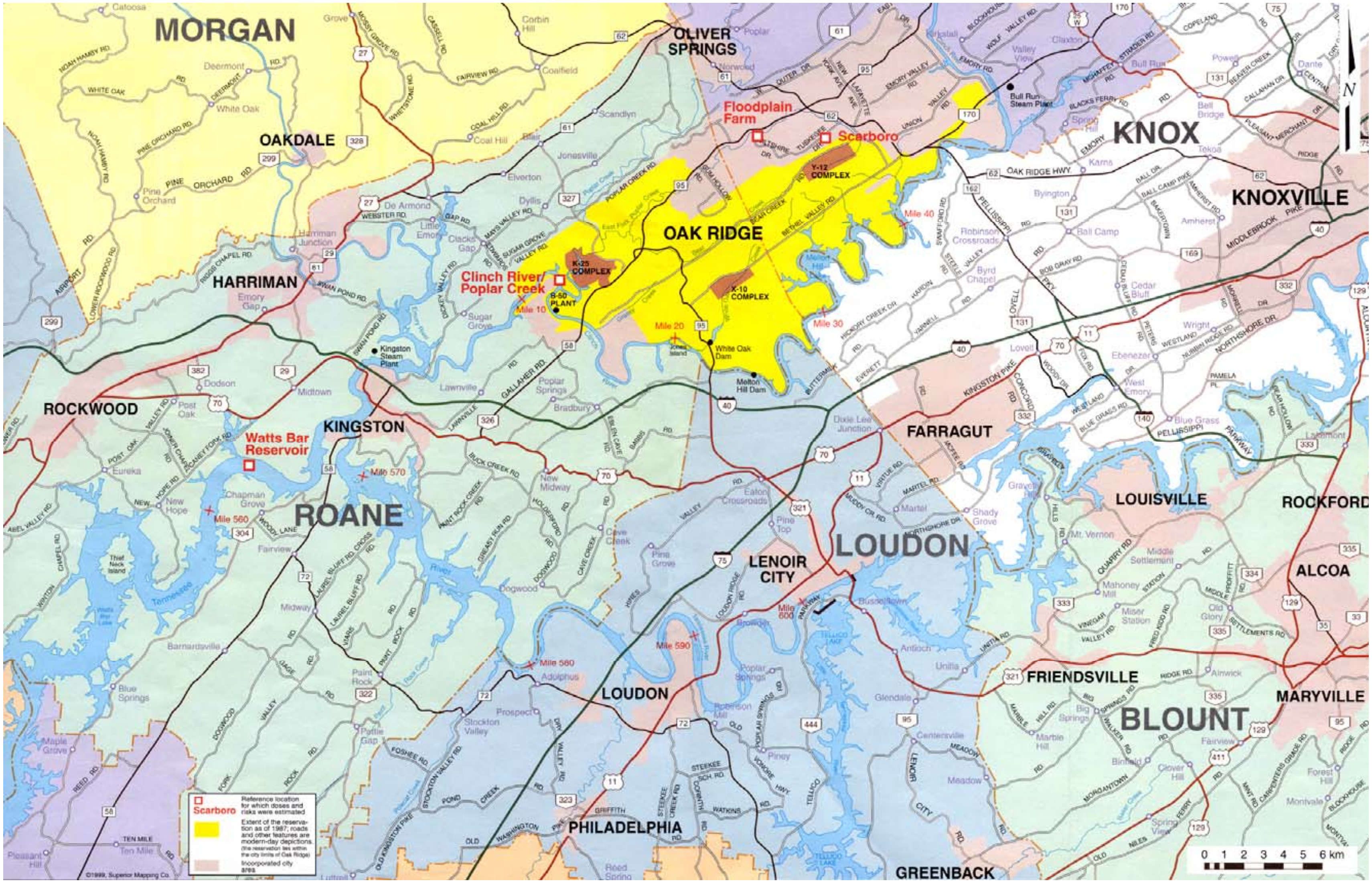
II.A. Site Description

In 1942, shortly after the United States entered World War II, the federal government built the Oak Ridge Reservation (ORR) under the Manhattan Project initiative to manufacture and study nuclear products for nuclear weapons (ChemRisk 1993a; TDOH 2000). The ORR is in the city of Oak Ridge, in eastern Tennessee, about 15 miles west of Knoxville, straddling Roane and Anderson Counties (ChemRisk 1993a; Jacobs Engineering Group Inc 1996; ORNL 2002). The southern and western borders of the ORR are formed by the Clinch River. The city of Oak Ridge forms ORR's northern and eastern borders (see Figure 2) (EUWG 1998; ORNL 2002).

When the federal government acquired the ORR, the reservation occupied 58,575 acres. The federal government has since conveyed away 24,340 of the original 58,575 acres, and the U.S. Department of Energy (DOE) now controls 34,235 acres (Jacobs Engineering Group Inc 1996; ORNL 2002). The rest of the land is managed by other entities (e.g., the city of Oak Ridge and the Tennessee Valley Authority [TVA]) (ORNL 2002).

During the Manhattan Project the government constructed four facilities at the ORR. Three sites, the K-25 site (formerly known as the Oak Ridge Gaseous Diffusion Plant and now referred to as the East Tennessee Technology Park [ETTP]), the Y-12 plant (now known as the Y-12 National Security Complex), and the former S-50 site were developed to manufacture enriched uranium (ChemRisk 1993a; Jacobs Engineering Group Inc 1996; TDEC 2002; TDOH 2000). The X-10 site (formerly known as the Clinton Laboratories and now referred to as the Oak Ridge National Laboratory) was developed to manufacture and separate plutonium.

Figure 2. Location of the Oak Ridge Reservation



Source: ChemRisk 1999a

II.A.1. The K-25 Site (now referred to as the East Tennessee Technology Park)

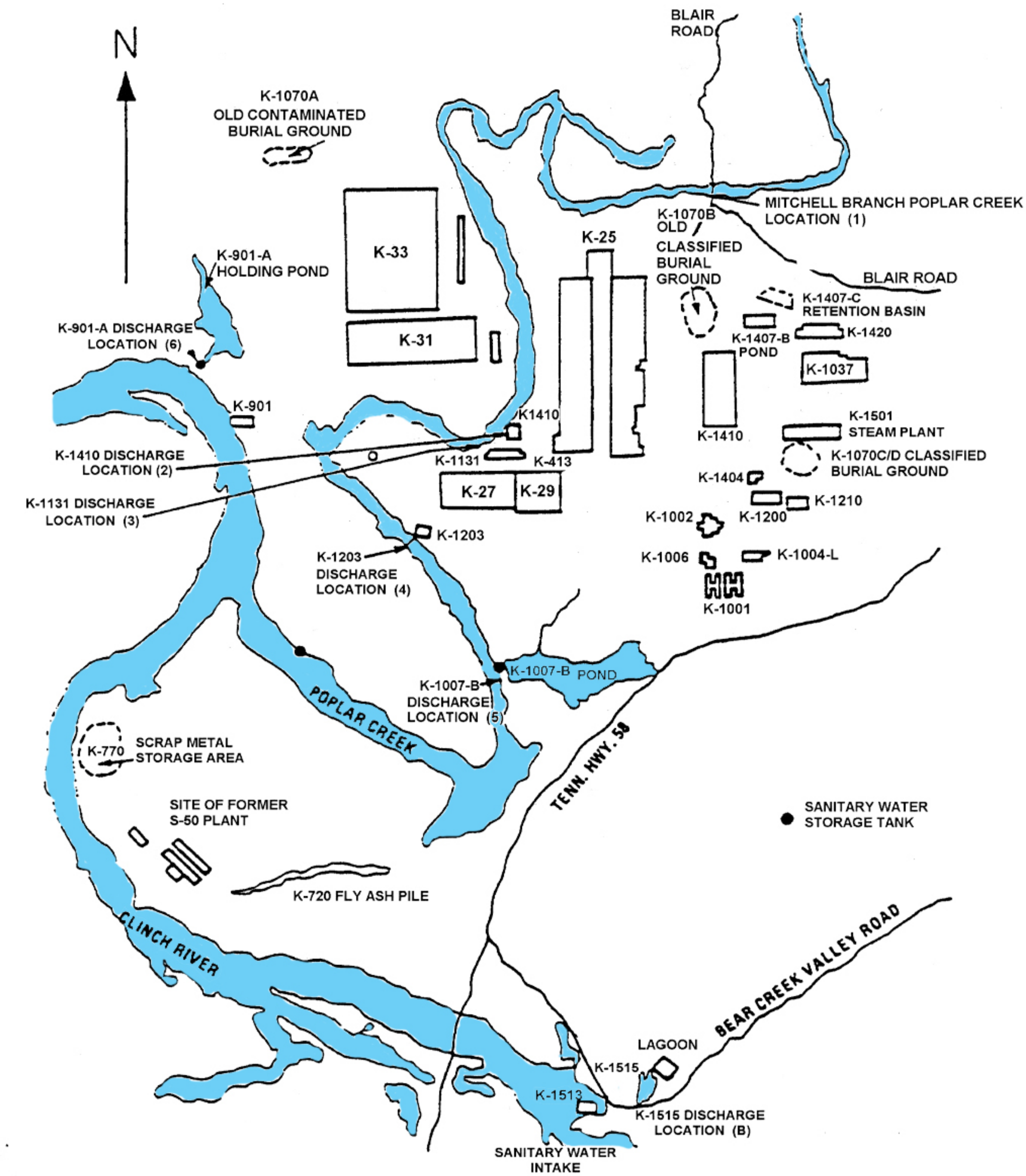
The K-25 site occupies 600 hectares (1,500 acres) within the ORR adjacent to the Clinch River, approximately 21 kilometers (13 miles) west of downtown Oak Ridge, Tennessee (U.S. DOE 1997). The boundaries of the K-25 watershed are Black Oak Ridge to the north, West Pine Ridge to the south, and the Clinch River to the west. The eastern boundary comprises Blair Road, Highway 58, and Highway 95. As shown in Figure 2, downstream of its confluence with East Fork Poplar Creek, Poplar Creek winds through the K-25 area to the Clinch River at the area's southern boundary. The Clinch River then joins the Tennessee River, which flows into the Lower Watts Bar Reservoir.

Historically at the K-25 site uranium isotopes were separated by gaseous diffusion, but site activities have since broadened to include incinerating waste PCBs left over from the electrical system that powered the pumps needed for gaseous diffusion (ChemRisk 1993a). The site is complex, with multiple facilities and disposal sites (ChemRisk 1993a). Gaseous diffusion alone used five buildings in the northern part of the K-25 site. Thermal separation processes took place in three buildings in southwestern K-25, which were later used for incineration, warehousing, and beryllium processing. At least 500 other buildings scattered throughout K-25 housed various support operations. Waste disposal included the use of a sewage treatment plant, a neutralization facility and pits, dilution pits, holding ponds, a retention basin, lagoons, incinerators, drum and other waste storage areas, burn areas, ash piles, burial grounds, and scrap metal dumpsters. Figure 3 shows K-25 area facilities.

II.A.2. The Y-12 Plant (now known as the Y-12 National Security Complex)

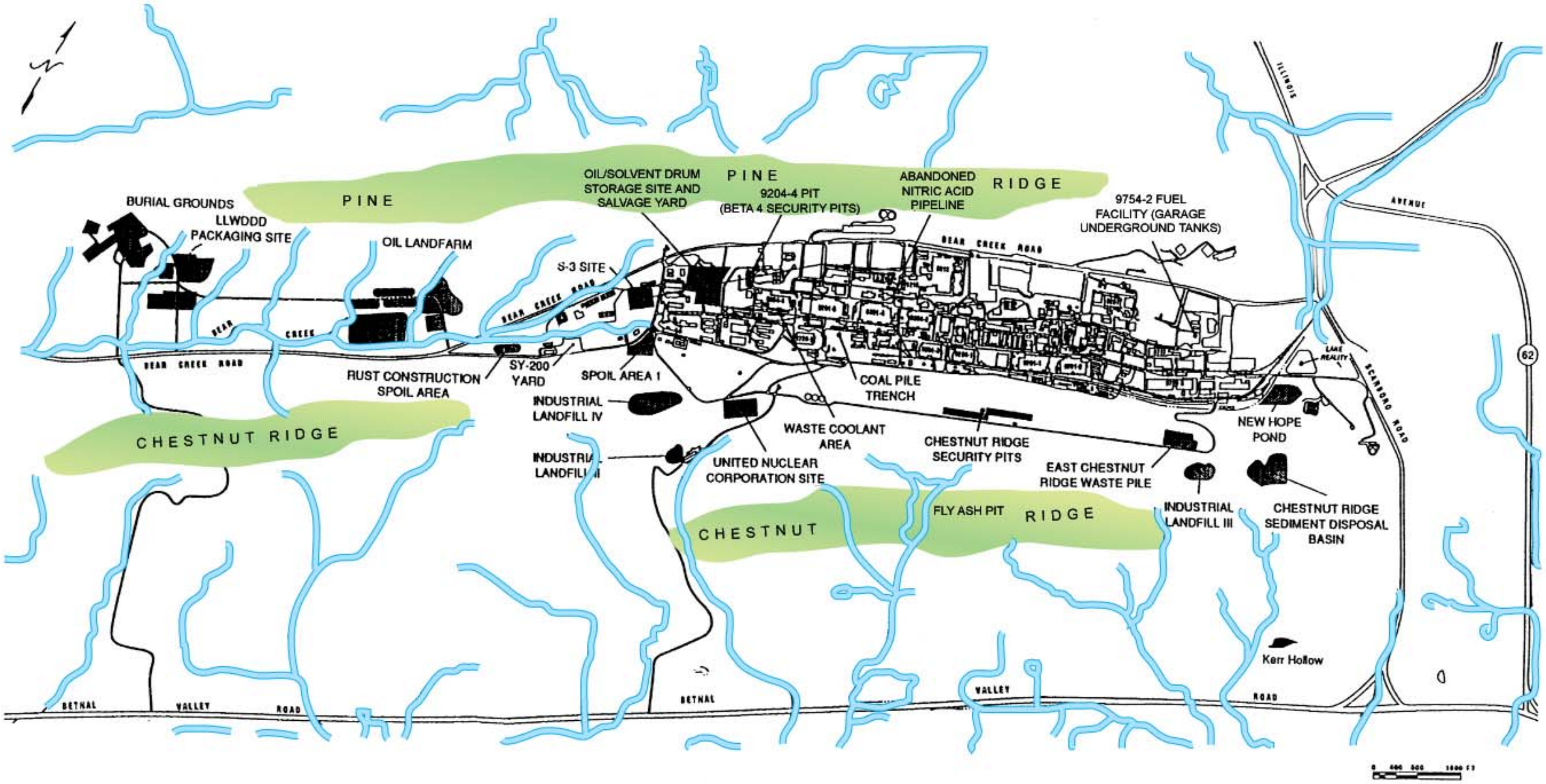
The Y-12 plant is in the eastern end of Bear Creek Valley, about ½ mile from the center of the city of Oak Ridge (ChemRisk 1999c). It is bordered on the south by Chestnut Ridge and on the north by Bear Creek Road and Pine Ridge (ChemRisk 1999a) (see Figure 4). The main Y-12 production area is 0.6 miles wide and 3.2 miles long. The area contains about 240 principal buildings, of which 18 directly processed or stored uranium compounds (ChemRisk 1999c). The 825-acre Y-12 plant is within Oak Ridge corporate limits, 2 miles south of downtown (ChemRisk 1999c; TDOH 2000). Scarboro is less than ½ mile away. Pine Ridge, which rises to about 300 feet above the valley floor, separates Y-12 from most of residential Oak Ridge (TDOH 2000). Bear Creek begins at the west end of Y-12 and flows 8 miles southwest to its confluence with East Fork Poplar Creek (ChemRisk 1999a). The headwaters of East Fork Poplar Creek run through a series of underground pipes extending along the western and southern ends of Y-12. The aboveground part of East Fork Poplar Creek begins along the central portion of the southern boundary of the plant, flows in a northwest direction through a gap in Pine Ridge, and continues through commercially zoned areas in Oak Ridge before meandering west towards its confluence with Poplar Creek (ChemRisk 1999a).

Figure 3. Map of the Oak Ridge Gaseous Diffusion Plant



Source: ChemRisk 1999a

Figure 4. Map of the Y-12 Plant



Source: ChemRisk 1999a

II.A.3. The X-10 Site (now referred to as the Oak Ridge National Laboratory)

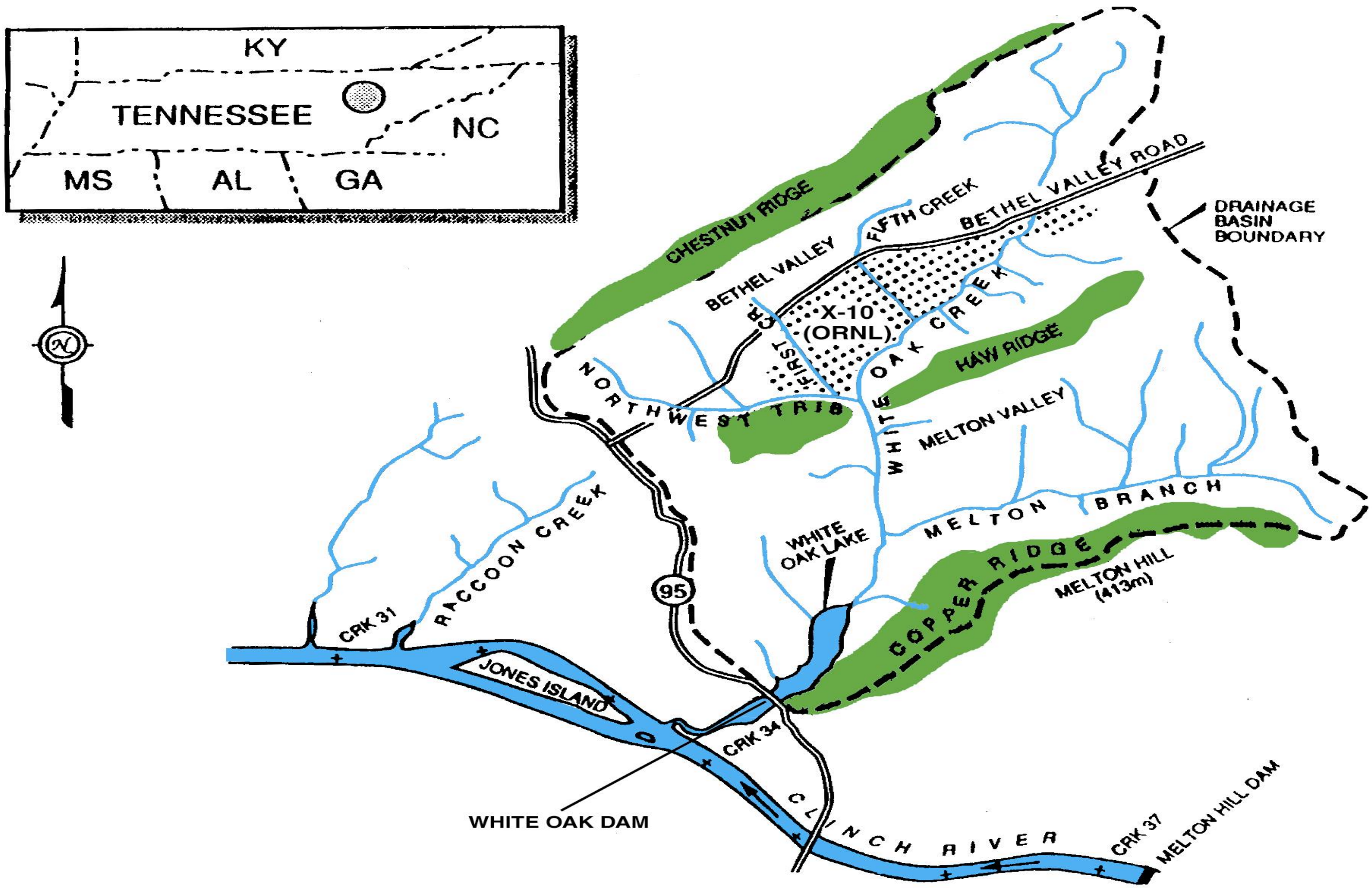
The original X-10 site is part of the Oak Ridge National Laboratory (ORNL), which encompasses 26,580 acres. The main operations at the ORNL take place on about 4,250 acres, in the area of the original X-10 site (Bechtel Jacobs Company LLC et al. 1999; ORNL et al. 1999; TDEC 2002). The remaining acreage is divided between the Oak Ridge National Environmental Research Park (21,980 acres) and the Solway Bend area, which is used for environmental monitoring (350 acres) (ORNL et al. 1999). Originally a laboratory dedicated to nuclear technology research and development, X-10 presently includes multidisciplinary efforts in nonnuclear technologies and sciences (ChemRisk 1999a).

X-10 is on the southern border of the ORR, 10 miles southwest of the Oak Ridge city center. The main laboratory at X-10 is on Bethel Valley Road, within Bethel Valley (ChemRisk 1999b; ORNL et al. 1999). The site also contains remote facilities and waste storage areas in Melton Valley (ORNL et al. 1999). The valley floor is highly developed within the central site area, and the surrounding terrain is wooded. X-10 is surrounded by heavily forested ridges that include Chestnut Ridge, Haw Ridge, and Copper Ridge (ChemRisk 1999b; TDOH 2000).

The X-10 facility discharges to two small streams on site, First and Fifth Creeks, which in turn discharge to White Oak Creek. White Oak Creek passes south of the developed area, leaves the valley through a gap in Haw Ridge, and then enters Melton Valley. There White Oak Creek flows into White Oak Lake, which was formed by White Oak Lake Dam, built by the TVA in 1943. The dam is 1.7 miles upstream from the confluence of White Oak Creek and the Clinch River, at Clinch River mile (CRM) 20.8. White Oak Creek Embayment lies between White Oak Lake and the Clinch River (ChemRisk 1999a). See Figure 5 for a detailed map of the X-10 area and Figure 6 for a detailed map of the surface waters associated with the ORR.

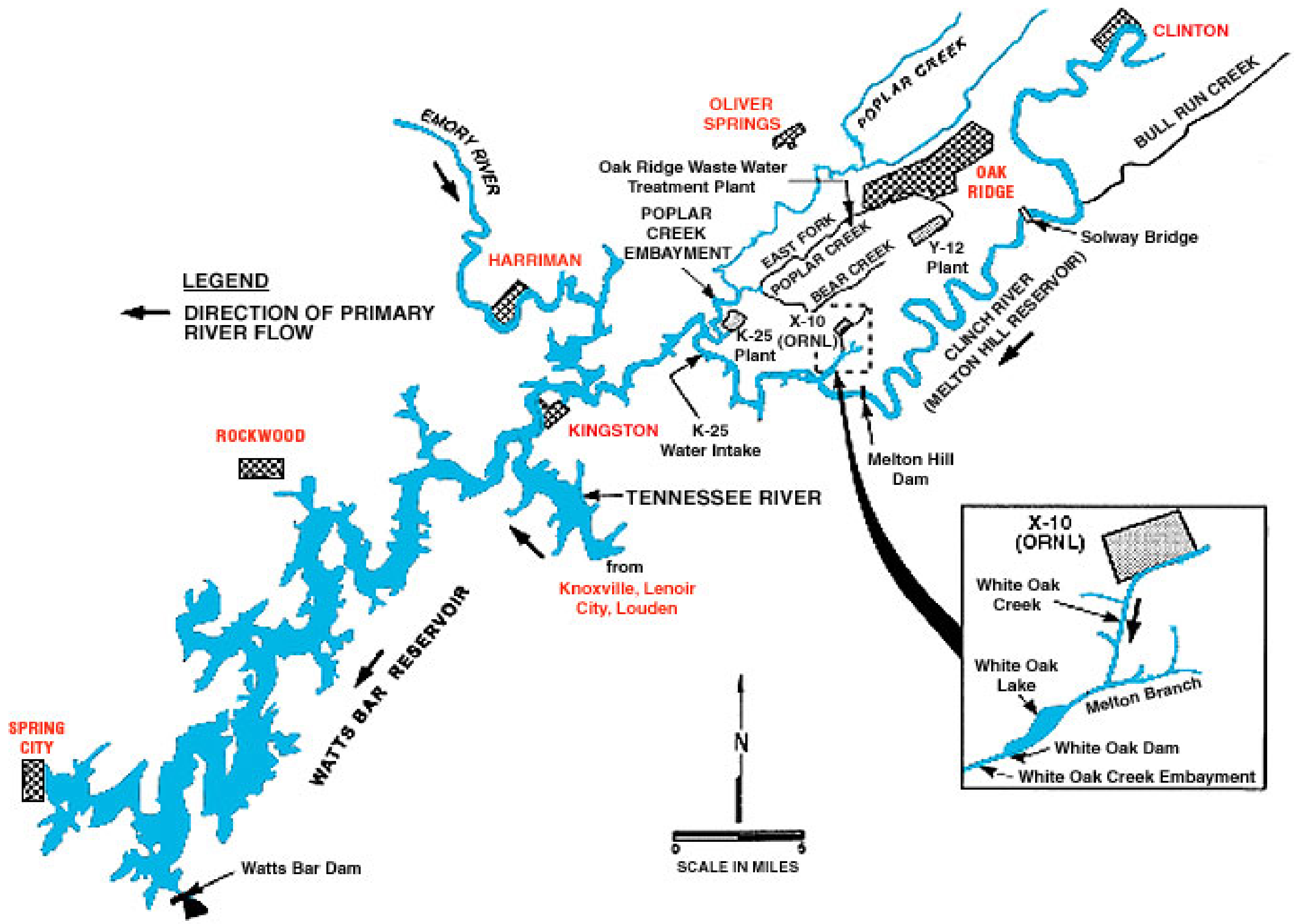
> Public access to the ORR is restricted. Consequently, people do not have access to substances carried down the creek and through the lake and embayment until those substances reach the confluence with the Clinch River.

Figure 5. Detailed Map of the X-10 Area



Source: ChemRisk 1999b

Figure 6. Surface Waters Associated with the ORR



Source: ChemRisk 1993a (with modifications)

II.B. Operational History

II.B.1. The K-25 Site

The federal government began building the K-25 uranium enrichment facility in 1943, and it was operating by January 1945. The K-25 site used gaseous diffusion to enrich uranium into its U-235 component and then feed this slightly enriched uranium to the uranium enrichment facilities at Y-12 (ChemRisk 1999a). After World War II, Y-12 needed less enriched uranium; and as a result, K-25 began providing it elsewhere. By the 1950s, K-25 supplied all enriched uranium used in the United States for commercial and military purposes (ChemRisk 1999a). Between 1945 and 1954, four additional gaseous diffusion process buildings (K-27, K-29, K-31, K-33) were erected, and the K-25 site was renamed the Oak Ridge Gaseous Diffusion Plant (ChemRisk 1993a; ORHASP 1999).

The K-25 site operated as a weapons-grade uranium enrichment facility until 1964 (EUWG 1998). At this time, because the military requirements had been fulfilled, buildings K-25 and K-27 were closed (ChemRisk 1993a). Between 1965 and 1985, when the facility manufactured commercial-grade uranium, the manufacturing process incorporated uranium hexafluoride (UF_6). From the 1960s until 1985, centrifuge enrichment processes took place on the K-25 site (EUWG 1998). Activities at the remaining gaseous diffusion process buildings were discontinued in 1985, and the buildings were officially closed in 1987 (ChemRisk 1993a; ORHASP 1999; U.S. DOE 2003b). At this time, the site name was reverted back to the K-25 site from Oak Ridge Gaseous Diffusion Plant (ORHASP 1999). Currently, K-25 is primarily the headquarters for waste storage treatment and disposal at the ORR (ChemRisk 1999a).

K-25 used PCBs (see the text box below) in the gaseous diffusion process of uranium enrichment. The chief use of PCBs at the K-25 site was in electrical transformers and capacitors in the electrical power system for the gaseous diffusion cascades. From 1945 to 1984 these transformers and capacitors held a total estimated volume of 125,000 gallons of PCBs. Between 1989 and 1991 most of these PCBs were incinerated off site. During plant operations, incidental releases might have migrated off site via surface runoff and storm sewer discharge (ChemRisk 1999a).

What Are PCBs?

PCBs are a group of man-made chlorinated organic compounds that contain up to 209 individual chemicals (congeners) with varying abilities to cause harmful effects. No known natural sources of PCBs occur in significant quantities in the environment, although traces of naturally occurring congeners can exist in some microorganisms (Falch et al. 1995). PCBs are oily liquids and solids that range from colorless to light yellow and are tasteless and odorless. As they are difficult to burn, they made good insulators. Please see Appendix E for additional information.

PCBs also could have migrated off site from sources other than electrical equipment. For example, although most PCBs in burial grounds, burn areas, holding ponds, switchyards, and outside storage areas would have been contained on site, some might have migrated off site via surface runoff, wastewater discharges, and volatilization to air. Reported incidents at K-25 included an explosion and fire in 1951 near the K-31 process area, and two accidental spills at K-25. One spill consisted of 40 to 50 gallons of PCB fluids that leaked in 1991 from a storage drum being stored on site in a diked area at K-711, some of which migrated to the Clinch River via stormwater drains. The second spill consisted of about 2,000 gallons of PCB-contaminated mineral oil from an equipment failure at the K-732 switchyard, which released the oil via a storm drain to Poplar Creek (ChemRisk 1999a).

II.B.2. The Y-12 Plant

Since the early 1940s, large quantities of uranium were processed on the ORR for enrichment into uranium-235, which was used in nuclear weapons components, in commercial nuclear reactors, and in various research and development projects (ChemRisk 1993a). Although the gaseous-diffusion method yields considerable uranium-235, larger amounts of the isotope were produced electromagnetically at Oak Ridge (Coker 1999).

From 1944 to 1947, the Y-12 plant was used to enrich uranium electromagnetically. By 1952, however, the facilities were converted to fabricate nuclear weapon components (ChemRisk 1999c). During the Cold War the government built and operated a column-exchange process (Colex) that used large quantities of mercury as an extraction solvent to enrich the lithium in lithium 6 (TDOH 2000). At the end of the Cold War, the Y-12 missions were curtailed. In 1992, the major focus of the Y-12 plant was the remanufacture of nuclear weapon components and the dismantling and storage of strategic nuclear materials from retired nuclear weapons systems. In October 2000, oversight of the Y-12 plant was changed from the DOE Oak Ridge Operations to the DOE National Nuclear Security Administration. The National Nuclear Security Administration currently uses the Y-12 National Security Complex as the primary storage site for highly enriched uranium.

PCB contamination at Y-12 resulted from several sources, including the electrical systems (i.e., transformers and capacitors), the use of PCB-containing cutting oils, and the Z-oil system for cooling the electromagnetic separation process. PCBs were also used in hydraulic systems throughout Y-12. Once environmental regulations on the use, storage, and disposal of PCB-contaminated equipment went into effect in the 1980s, Y-12 engineers began to identify and remove PCB-containing electrical equipment. Much of the equipment currently in place is original; therefore, recently measured concentrations are similar to historical PCB levels in the transformers and capacitors (ChemRisk 1999a).

Y-12 activities generated thousands of gallons of waste oils. Much of the waste oils from Y-12 contained no PCBs; only mineral oils, water soluble coolants, antifreeze, motor oils, and specialized products were present in the majority of waste oils. Most PCB-contaminated waste oils generated at Y-12 came from machining of enriched uranium (M-Wing coolant), hydraulic systems, and electrical transformers (ChemRisk 1999a).

Early records suggest, but do not document, that Y-12 liquid wastes generated before 1950 were discarded at burial facilities at X-10. Starting in the early 1950s, Y-12 sent most of its liquid waste to the Bear Creek Disposal Area. The three principal disposal sites at Bear Creek were the S-3 ponds, the burial grounds, and the oil landfarm (ChemRisk 1999a).

Oils with high PCB content were not burned at the burial grounds because they were nonflammable. From 1955 to 1961 waste oils with low-level PCBs or non-PCB-bearing fluids were poured over solid waste and burned at Burial Ground A's burn pit. In 1961 a burn tank installed in Burial Ground A collected flammable waste oils and coolants; nonflammable liquids were drained into adjacent trenches. Although small amounts of transformer oils and hydraulic fluids (both of which had low PCB content) might have been burned, significant quantities of PCBs were not burned at Burial Ground A. Oils with high PCB levels came from M-Wing coolants, discarded 2 years after oil burning ended (ChemRisk 1999a).

In the late 1970s two tanks were installed at the Salvage Yard/Solvent Drum Storage Area in the northwest part of the Y-12 area to store 11,000 gallons of PCB-contaminated oils. Any spills were released to the storm drain system (ChemRisk 1999a). After 1982, waste oils were stored at Y-12 tank farms until undergoing incineration at the K-25 Toxic Substances Control Act (TSCA) incinerator. The oils were separated by PCB content; waste oils with greater than 5 parts per million (ppm) PCBs were kept separate from those with lower PCB levels. In 1987 this concentration limit was decreased to 2 ppm. Some waste oils below the concentration limits were sent off site for commercial disposal. From 1982 to 1991, 150,000 gallons of PCB-waste oils had accumulated at Y-12. In 1991, when the K-25 incinerator began operations, these oils were sent to the K-25 incinerator; by 1995, most of these oils had been burned (ChemRisk 1999a).

II.B.3. The X-10 Site

The X-10 site was built in 1943 as a "pilot plant" to demonstrate the manufacture and chemical separation of plutonium (ChemRisk 1993a, 1999b; TDOH 2000). After World War II, the facility also engaged in nonweapons-related activities (e.g., physical and chemical division of nuclear products, creation and assessment of nuclear reactors, and manufacture of a range of radionuclides for global use in medicine, industry, and research) (ChemRisk 1993a; Jacobs Engineering Group Inc 1996). In the 1950s and 1960s, X-10 became a worldwide research center for the study of nuclear energy and to investigate physical and life sciences related to nuclear energy. Following the establishment of DOE in the 1970s, research at X-10 was extended to include the study of energy transmission, conservation, and production (UT-Battelle 2003). Today, ORNL receives worldwide recognition as a facility for extensive research and development in several areas of science and technology. In addition, X-10 manufactures numerous radioactive isotopes that have significant uses in medicine and research (TDEC 2002).

The main activities potentially associated with off-site releases of contaminants from X-10 include: 1) production of radioactive lanthanum (1944 to 1956), 2) Thorex processing of short-decay irradiated thorium (approximately 1954 to 1960), 3) graphite reactor operations (1943 to 1963), 4) processing of graphite reactor fuel for plutonium recovery (1943 to 1945), and 5) waterborne and airborne waste disposal (1943 to present). These historical activities at X-10 required equipment such as capacitors, transformers, pumps, and electric motors. Lubricating and cooling oils associated with this equipment probably contained PCBs. The primary use of PCBs at X-10 was in the form of dielectric oils in electrical transformers at concentrations ranging from <5 to 1 million ppm. Because the government had originally planned to run the X-10 site for only 1 year, minimal waste had been expected from the facility's chemical separation processes (ChemRisk 1993a, 1999b; Jacobs Engineering Group Inc 1996). As a result, the intended waste disposal practices proved insufficient for the wastes generated at X-10. Disposal of wastes in the early years was mainly documented for radioactive substances. Therefore, the extent to which radionuclide wastes were separated from organic wastes, such as PCB-contaminated oils, is unknown.

When X-10 began operating in 1943, liquid wastes were put into several underground gunite (i.e., sprayed concrete) tanks located in Bethel Valley. Each gunite tank held 170,000 gallons, but wastes quickly filled them to capacity. To dispose of the liquid wastes, the sludges were kept in the gunite tanks; the wastes that did not settle, however, were held until enough radioactivity was lost through decay that liquids (combined with diluting water) could be released to White Oak Creek (ChemRisk 1993a, 1999b; Jacobs Engineering Group Inc 1996; ORHASP 1999; U.S. DOE 1997). The creek received this wastewater and stormwater drainage as it flowed through the X-10 facilities, before it emptied into the Clinch River at the site's southern boundary. Some of the waste released into White Oak Creek reached the Clinch River. This waste includes radionuclides, but whether PCBs from discarded transformer oils were mixed in with the radioactive wastes is unclear.

Historically, X-10 wastes were disposed of in on-site tanks, burial grounds, and surface impoundments. No information has been located on the disposal of PCBs at these sites before environmental regulations were in place (ChemRisk 1999a). The lack of information on PCB waste disposal at X-10 probably resulted from of the lack of awareness of the potential hazards associated with PCBs prior to the 1970s. Despite the absence of records about early PCB disposal, most of the contaminant releases to White Oak Creek are associated with former operations at X-10. Since the late 1970s, PCB releases have been handled according to federal regulations and ORR policies. During the 1970s, 1980s, and 1990s, surveys of PCBs in environmental media found low-level contamination near and downstream of X-10. Releases from the facility are negligible since the 1970s, but PCBs remain in White Oak Creek Embayment and White Oak Lake. Thus, PCBs were released either before the late 1970s or from ongoing low-level releases. These waterways are, however, on site at the ORR. Public access to the embayment and the lake is restricted. The contaminants from X-10 could potentially reach the public when creek water and its suspended sediment flow past the White Oak Creek's confluence with the Clinch River, or when fish from the creek swim into the river.

For more details on operational history and use of PCBs, please see Task 3 of the Reports of the Oak Ridge Dose Reconstruction, *PCBs in the Environment Near the Oak Ridge Reservation, A Reconstruction of Historical Doses and Heath Risks* (ChemRisk 1999a) (referred to as the "Task 3 report") and the *Oak Ridge Health Studies Phase 1 Report: Volume II—Part A—Dose Reconstruction Feasibility Study, Tasks 1 & 2, A Summary of Historical Activities on the Oak Ridge Reservation with Emphasis on Information Concerning Off-Site Emission of Hazardous Material* (ChemRisk 1993a).

II.C. Remedial and Regulatory History

> The Federal Facility Agreement was implemented at the ORR on January 1, 1992. This is a legally binding agreement used to establish schedules, procedures, and documentation for remedial activities at the ORR (EUWG 1998). The Federal Facility Agreement is available online at http://www.bechteljacobs.com/ettp_ffa.shtml.

On November 21, 1989, the U.S. Environmental Protection Agency (EPA) listed ORR on the final National Priorities List (NPL) as a result of several on-site processes that released nonradioactive and radioactive wastes into the environment (EUWG 1998; U.S. DOE 2002a). DOE is performing remediation activities at the reservation under a Federal Facility Agreement (FFA), which is an interagency agreement between DOE, the EPA, and the Tennessee Department of Environment and Conservation (TDEC). EPA and TDEC, along with the public, help DOE select the details for remedial actions at the ORR (ATSDR and ORREHS 2000; U.S. DOE 2003b). These parties collaborate to ensure there is adequate remediation and a complete study of hazardous waste related to previous and current ORR activities (ATSDR and ORREHS 2000; U.S. DOE 1996, 2003b). DOE is conducting its investigations of the ORR under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), a program requiring an FFA be established for all NPL sites owned by the federal government (EUWG 1998). In addition, DOE is incorporating response procedures designated by CERCLA, with mandatory actions from the Resource Conservation and Recovery Act (RCRA) (U.S. DOE 1995).

Many old disposal sites at the ORR contain waste material. These waste sites constitute 5 to 10 percent of the reservation. Leaching caused by abundant rainfall, high water tables, and the resulting floods have contributed to the PCB contamination of surface water, groundwater, soil, sediments, and fish at the ORR (EUWG 1998). The *1994 DOE Remedial Investigation for the Lower Watts Bar Reservoir* and the *1995 DOE Remedial Investigation for the Clinch River/Poplar Creek* found ingestion to be the most significant exposure pathway (Jacobs Engineering Group Inc 1996; U.S. DOE 1994).

The ORR's activities historically required electrical components to supply and satisfy a large energy need. From the mid-1950s through the 1970s, the fluids in these electrical components often contained high PCB concentrations. Lower concentrations were also contained in fluids used for cooling during machining operations or for hydraulic lifting. Before the 1970s, toxicological information about PCBs and related regulatory requirements did not demand, or even suggest, a need for caution in management and disposal of these fluids. During these times, and to a diminishing extent over the next 10 to 20 years, PCBs were routinely released into the environment, contaminating water and sediment in nearby waterways.

In 1979, EPA issued final regulations banning the manufacture of PCBs and phasing out most PCB uses in the United States. The regulations prohibited the manufacture, processing, distribution in commerce, and "non-enclosed" (i.e., open to the environment) uses of PCBs unless specifically authorized or exempted by EPA (e.g., research and development samples). "Totally enclosed" uses (i.e., contained, therefore making exposure to PCBs unlikely) were allowed to continue for the life of the equipment. Under controlled conditions, the regulations allowed use and servicing of most existing large electrical equipment containing PCBs for the life of the equipment. The manufacture of new PCB electrical equipment (transformers and capacitors) was entirely prohibited. The regulations phased out or reduced PCB uses in mining machinery, in hydraulic and heat transfer systems, and in paints and pigments. The ban on manufacturing, processing, distributing, and using PCBs, as well as the PCB disposal and marking regulations, were issued under authority of the Toxic Substances Control Act (TSCA) (U.S. EPA 1979).

In 1986, DOE began remedial actions at the ORR under a RCRA permit. Since then, DOE started about 50 response activities under the FFA that address waste disposal and contamination issues at the ORR (U.S. DOE 2002a). These early response activities were made on single sites or projects (SAIC 2004). To facilitate the investigation and remediation of contamination related to the ORR, the contaminated areas on the ORR were separated into five large tracts of land that are typically associated with the major hydrologic watersheds (EUWG 1998; SAIC 2004). This watershed approach to remediation addresses the cumulative impact of all contamination sources and associated contaminated media on environmental conditions within the watershed.

II.C.1. Watersheds Associated With the PCB Study Area

The ETTP watershed encompasses 2,200 acres, including the former K-25 site. The ETTP watershed is bounded by the Black Oak Ridge on the north, West Pine Ridge on the southeast, and the Clinch River on the southwest. Contaminants are transported from the site via Poplar Creek, which bisects the main plant area and flows through the watershed to the Clinch River; the Clinch River joins the Tennessee River, which then flows into the Lower Watts Bar Reservoir (ChemRisk 1999a; SAIC 2004).

The Upper East Fork Poplar Creek watershed encompasses all of theY-12 complex and drains about 1,170 acres (SAIC 2004). Y-12 contamination flows into the Upper East Fork Poplar Creek, which originates from a spring beneath the Y-12 plant and flows through the Y-12 plant along Bear Creek Valley. The creek flows north from the Y-12 complex off site into Lower East Fork Poplar Creek, which goes into the city of Oak Ridge through a gap in Pine Ridge. Lower East Fork Poplar Creek flows through residential and business sections of Oak Ridge to join Poplar Creek, which flows to the Clinch River (SAIC 2004).

The Bear Creek watershed extends from the west end of the Y-12 complex westward to Highway 95. Contaminants from waste areas within Bear Creek Valley are captured by Pine Ridge tributaries and Bear Creek, which confluence with the Lower East Fork Poplar Creek, and then flow to the Clinch River (SAIC 2004).

X-10 is located within two watersheds—Bethel Valley and Melton Valley (ORNL et al. 1999; U.S. DOE 2001b). However, the major operations at X-10 take place within the Bethel Valley Watershed. 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 (U.S. DOE 2001b).

X-10 disposed of its radioactive wastes (liquid and solid) in Melton Valley and also operated its experimental facilities within this watershed (U.S. DOE 2002a, 2002b). Discharges from Melton Valley's waste areas have produced secondary contamination sources for on-site sediment, groundwater, and soil. 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 offsite spread of contaminants" from the ORR (U.S. DOE 2002b).

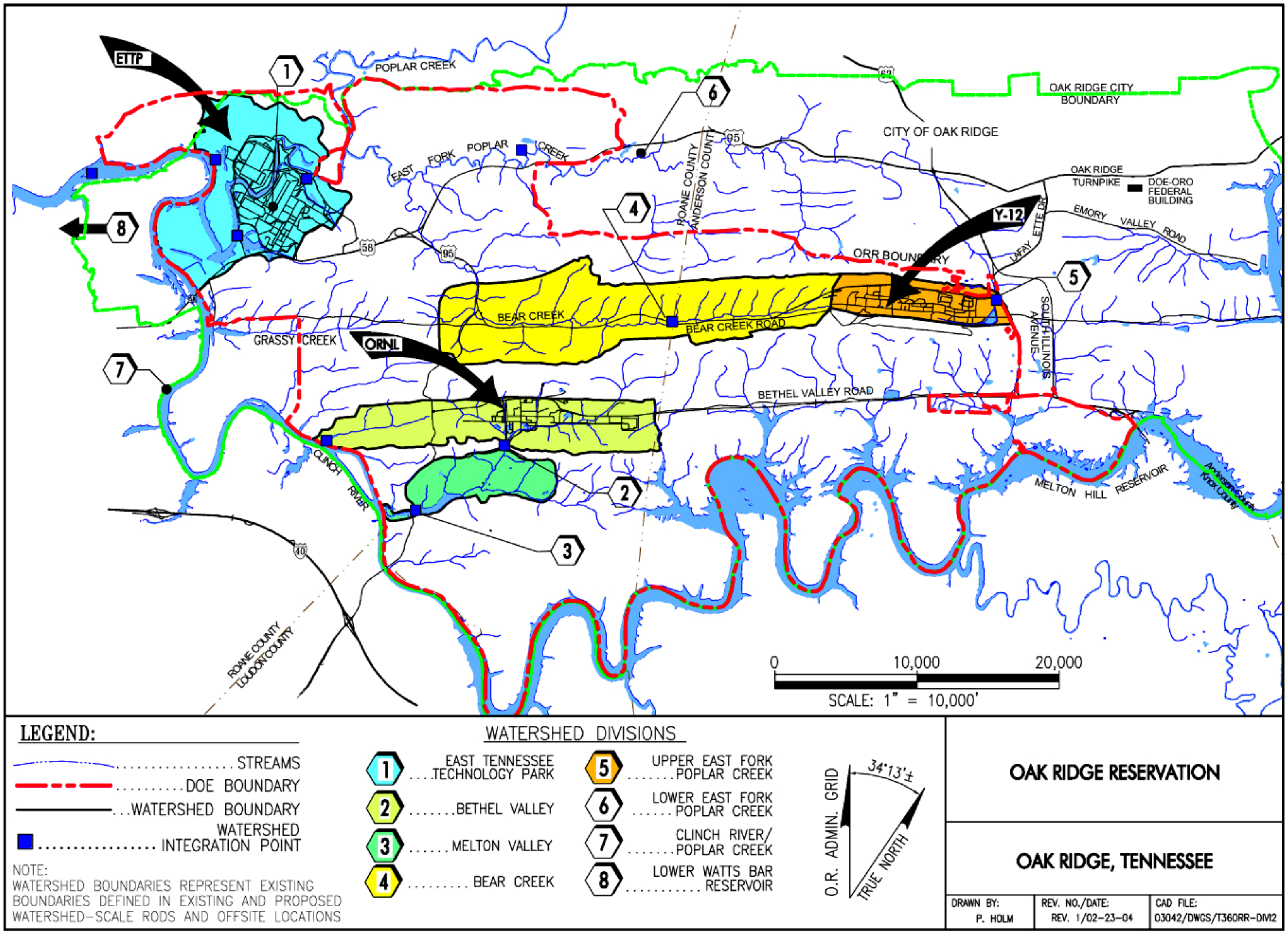
See Figure 7 and Figure 8 for the locations of these watersheds within the ORR and the surface water flow from these watersheds. The investigations and remedial actions described in the next sections pertain to three off-site locations that were affected by contaminant releases from these on-site watersheds located at K-25, Y-12, and X-10.

II.C.2. Lower East Fork Poplar Creek

Lower East Fork Poplar Creek flows north from the Y-12 plant off site into the city of Oak Ridge through a gap in Pine Ridge. The creek flows through residential and business sections of Oak Ridge to join Poplar Creek, which flows to the Clinch River. Starting in the early 1950s, Lower East Fork Poplar Creek was contaminated by releases of mercury and other contaminants.

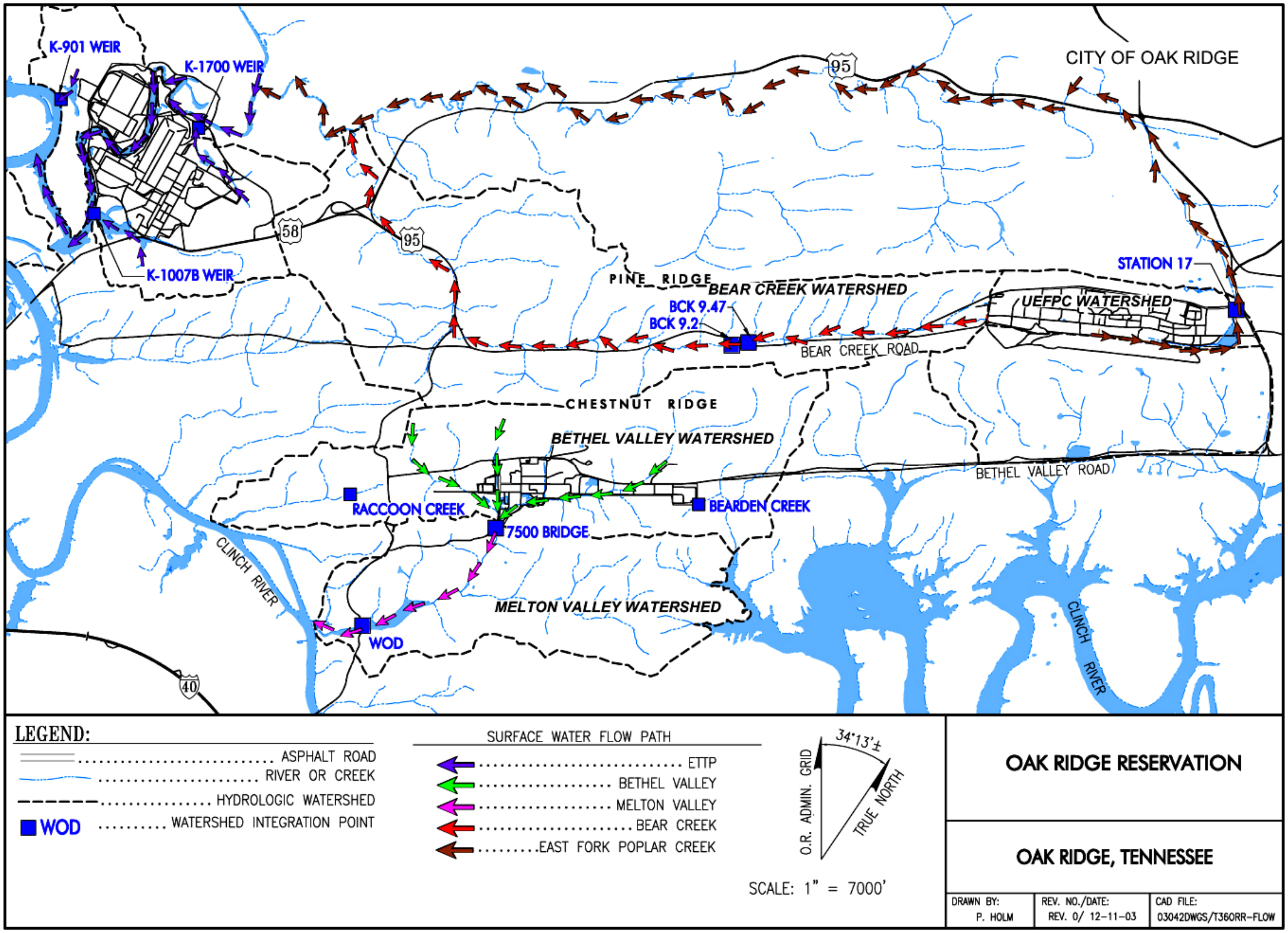
The remedial investigation/feasibility study for Lower East Fork Poplar Creek was completed in 1994. The Record of Decision was approved in September 1995, and remediation field activities began in June 1996 (ATSDR and ORRHES 2000). The remedial investigation and proposed plan ultimately led to the decision to a) excavate floodplain soils containing mercury levels higher than 400 ppm b) ensure that all mercury above this level had been removed, and c) conduct periodic monitoring (U.S. DOE 2001a). The Agency for Toxic Substances and Disease Registry (ATSDR) evaluated the public health impacts of the 400-ppm cleanup level and concluded that it was protective of public health (ATSDR 1996). During the remediation, several pockets of radiologically contaminated soils (>250 counts per minute gross beta-gamma) were located, excavated, placed in containers, and stored at the ETTP site (U.S. DOE 2002a).

Figure 7. Watersheds within the Oak Ridge Reservation



Source: SAIC 2004

Figure 8. Surface Water Flow at the Oak Ridge Reservation



Source: SAIC 2004

II.C.3. Clinch River/Poplar Creek

The Clinch River/Poplar Creek operable unit consists of the biota and sediments in the Melton Hill Reservoir and the Watts Bar Reservoir from CRM 0.0 (where the Tennessee and Clinch Rivers join) to CRM 43.7, upstream of Melton Hill Dam. In addition, the operable unit contains the Poplar Creek embayment from the mouth of Poplar Creek along the Clinch River (at CRM 12.0) to its joining with East Fork Poplar Creek (at Poplar Creek mile [PCM] 5.5). All of the Poplar Creek sections of the operable unit are within the borders of the ORR (SAIC 2002; U.S. DOE 2001a).

In 1996 a remedial investigation/feasibility study examined the past and present releases to off-site surface water to determine whether remedial action was necessary (ATSDR and ORRHES 2000). The study concluded that the Clinch River/Poplar Creek operable unit presented two main risks by exposure to 1) fish tissue that contained chlordane, mercury, PCBs, and arsenic; and to 2) deep sediments in the primary river channel that contained arsenic, mercury, cesium 137, and chromium (Jacobs EM Team 1997b; Jacobs Engineering Group Inc 1996; SAIC 2002; U.S. DOE 2001a). The largest concentrations of radionuclides that have been detected are buried between 8 and 32 inches into the deep sediments (Jacobs EM Team 1997b).

A subsequent baseline risk assessment suggested that consumption of certain fish contaminated with PCBs posed the greatest risk to public health. In addition, fish contaminated with chlordane, mercury, and arsenic presented a possible chance of causing health effects. The assessment also determined that the consumption of any type of fish from Poplar Creek posed a health risk, as well as bass from the Clinch River below Melton Hill Dam. Furthermore, the risk assessment determined that contaminants in deep-water sediments would only present a health risk if they were dredged; no exposure pathway currently exists to the deep-water sediments (Jacobs EM Team 1997b).

In September 1997, DOE issued a Record of Decision for the Clinch River/Poplar Creek operable unit. EPA and TDEC—supportive agencies for this response action—agree with the remedial actions selected for this operable unit. The chosen actions, which comply with federal and state requirements, were undertaken to protect human health and the environment in the present and future. The following remedial actions were selected for the operable unit:

- Yearly monitoring to assess fluctuations in concentration levels and contaminant dispersion.
- Implementation of fish consumption advisories.
- Surveys to gauge the usefulness of the fish advisories.
- Institutional controls to restrict activities that could unsettle the sediment (Jacobs EM Team 1997b; SAIC 2002; U.S. DOE 2001a).

These institutional controls are developed under an interagency agreement established in February 1991 by DOE, EPA, TVA, TDEC, and the U.S. Army Corps of Engineers (USACE). The interagency agreement allows these agencies to work cooperatively through the Watts Bar

Interagency Agreement to review permitting and other activities that could result in disturbing the sediment (for example, building a dock or erecting a pier) (ATSDR 1996; Jacobs EM Team 1997b; U.S. DOE 2003a). For more details see pages 3–12 of the Clinch River/Poplar Creek Record of Decision at http://www.epa.gov/superfund/sites/rods/fulltext/r0497075.pdf. For additional information on institutional controls to prevent sediment-disturbing activities, see *Rules of the Tennessee Department of Environment and Conservation, Chapter 1200-4-7, Aquatic Resource Alteration Permit Process; Section 26A of the Tennessee Valley Authority Act of 1933; and Section 10 of the Rivers and Harbors Act of 1910 (U.S.A.C.E.)* (Jacobs EM Team 1997b).

In February 1998 a remedial action report was approved. This report recommended that monitoring be conducted for surface water, fish, sediment, and turtles in the Clinch River/Poplar Creek operable unit (ATSDR and ORRHES 2000). Since this time, annual surface water sampling, sediment monitoring, and fish and turtle sampling have been conducted at the Clinch River/Poplar Creek operable unit (SAIC 2002; U.S. DOE 2001a). Institutional controls examine activities that could result in movement of the sediments, and the Tennessee Wildlife Resources Agency (TWRA) prints fish consumption advisories in its *Tennessee Fish Regulations* (SAIC 2002).

II.C.4. Lower Watts Bar Reservoir

The Lower Watts Bar Reservoir operable unit is downstream of the ORR, extending from the confluence of the Clinch and Tennessee Rivers to the Watts Bar Dam (ATSDR 1996). All surface water and sediment released from the ORR enters the Lower Watts Bar Reservoir operable unit (SAIC 2002; U.S. DOE 2001a, 2003c). In 1995, a remedial investigation/feasibility study was conducted to assess the level of contamination in the Watts Bar Reservoir, to create a baseline risk analysis based on the contaminant levels, and to determine whether remedial action was necessary (ATSDR and ORRHES 2000). The remedial investigation/feasibility study revealed that discharges of radioactive, inorganic, and organic pollutants from the ORR have contributed to biota, water, and sediment contamination in the Lower Watts Bar Reservoir (ATSDR and ORRHES 2000; SAIC 2002; U.S. DOE 2001a, 2003b). The baseline risk analysis indicated that standards for environmental and human health would not be reached if deep channel sediments with cesium 137 were dredged and placed in a residential area, and if people consumed moderate to high quantities of specific fish that contained increased levels of PCBs (ATSDR and ORRHES 2000; Environmental Sciences Division et al. 1995).

In September 1995, DOE issued a Record of Decision for the Lower Watts Bar Reservoir operable unit. EPA and TDEC, support agencies for this response action, agree with the remedial actions selected for this operable unit. The chosen actions were undertaken to protect human health and the environment in the present and future and to comply with federal and state requirements. The following contaminants of concern were identified at the operable unit: 1) mercury, arsenic, PCBs, chlordane, and aldrin in fish; 2) mercury, chromium, zinc, and cadmium in dredged sediments and sediments used for growing food products; and 3) manganese through ingestion of surface water (ATSDR and ORRHES 2000; SAIC 2002; U.S. DOE 2001a, 2003b). The greatest threat to public health from the Lower Watts Bar Reservoir is related to the consumption of PCB-contaminated fish (SAIC 2002; U.S. DOE 2001a, 2003b). The Record of

Decision concluded that if the deep sediments were kept in place, then "…these sediments do not pose a risk to human health because no exposure pathway exists" (U.S. DOE 1995).

The remedial activities selected for the Lower Watts Bar Reservoir have included 1) preexisting institutional controls to decrease contact with contaminated sediment, 2) fish consumption advisories printed in the *Tennessee Fish Regulations*; and 3) yearly monitoring of biota, sediment, and surface water (ATSDR and ORRHES 2000; SAIC 2002; U.S. DOE 1995, 2001a, 2003b). The February 1991 interagency agreement established by DOE, EPA, TVA, TDEC, and USACE allows these agencies to work cooperatively through the Watts Bar Interagency Agreement to review permitting and all other activities that could result in disturbing the sediment, such as building a dock or erecting a pier (ATSDR 1996; Jacobs EM Team 1997b; U.S. DOE 2003a). According to the interagency agreement, DOE is required to take action if an institutional control is not effective or if a sediment-disturbing activity could cause harm (Jacobs EM Team 1997b; U.S. DOE 2003a). See pages 3–5 of the Lower Watts Bar Reservoir Record of Decision at http://www.epa.gov/superfund/sites/rods/fulltext/r0495249.pdf. For additional information on institutional controls to prevent sediment-disturbing activities, see *Rules of the Tennessee Department of Environment and Conservation, Chapter 1200-4-7, Aquatic Resource Alteration Permit Process; Section 26A of the Tennessee Valley Authority Act of 1933; and Section 10 of the Rivers and Harbors Act of 1910 (U.S.A.C.E.)* (Jacobs EM Team 1997b).

II.D. Land Use and Natural Resources

With its 1942 ORR acquisition, the federal government reserved a section (about 14,000 acres out of the total of approximately 58,575) for housing, businesses, and support services (ChemRisk 1993b; ORNL 2002). In 1959, that section became the independent city of Oak Ridge. This self-governing area has parks, homes, stores, schools, offices, and industrial areas (ChemRisk 1993b).

The majority of residences in Oak Ridge are located along the northern and eastern borders of the ORR (Bechtel Jacobs Company LLC et al. 1999). Since the 1950s, however, the urban population of Oak Ridge has grown toward the west. As a result of this expansion, the property lines of many homes in the city's western section border the ORR property (ChemRisk 1993b). Apart from these urban sections, areas close to the ORR have historically been and continue to be mostly rural (Bechtel Jacobs Company LLC et al. 1999; ChemRisk 1993b). The closest homes to X-10 are near Jones Island, about 2.5 to 3 miles southwest of the main facility (ChemRisk 1993b).

In 2002, the ORR comprised 34,235 acres, which include the three main DOE facilities: Y-12, X-10, and K-25 (ORNL 2002). These DOE facilities constitute approximately 30 percent of the reservation. In 1980 the remaining 70 percent was turned into a National Environmental Research Park. This park was created to protect land for environmental education and research and to demonstrate the compatibility between energy technology development and a quality environment (EUWG 1998). Over several decades a large amount of land at the ORR has become fully forested. Sections of this land contain "deep forest" areas that include flora and fauna considered ecologically important, and portions of the reservation are regarded as biologically rich (SAIC 2002).

Historically, forestry and agriculture (beef and dairy cattle) have constituted the primary land use in the area around the reservation. These activities are currently in decline. For several years, milk produced in the area was bottled for local distribution, whereas beef cattle from the area were sold, slaughtered, and nationally distributed. In addition, tobacco, soybeans, corn, and wheat were the primary crops grown in the area. Small game and waterfowl are regularly hunted in the ORR area, and deer are hunted annually during specific time periods (ChemRisk 1993b). During the annual deer hunts, radiological monitoring is conducted on all deer prior to their release to the hunters. Monitoring is conducted to ensure that none of the animals contain quantities of radionuclides that could cause "significant internal exposure" to the consumer (Teasley 1995).

The southern and western boundaries of the ORR are formed by the Clinch River; Poplar Creek and East Fork Poplar Creek drain the ORR to the north and west (Jacobs EM Team 1997b). 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 CRM 20.8 (ChemRisk 1993b, 1999a; TDOH 2000; U.S. DOE 2002a). Ultimately, every surface water system on the reservation drains into the Clinch River (ChemRisk 1993b). The Lower Watts Bar Reservoir is situated downstream of the ORR, extending from the confluence of the Clinch and Tennessee Rivers to the Watts Bar Dam (ATSDR 1996). As a result, the Clinch River and the Lower Watts Bar Reservoir have received contaminants associated with ORR operations (Jacobs EM Team 1997b; U.S. DOE 1995, 2001a).

The majority of land around the Clinch River and the Lower Watts Bar Reservoir is undeveloped and wooded. Other than activities at the ORR, minimal industrial development has occurred in these surrounding areas, but residential growth has been fairly steady. The public has access to the Clinch River and to the Lower Watts Bar Reservoir, which it uses for recreational purposes such as boating, swimming, fishing, water skiing, and shoreline activities (U.S. DOE 1996d, 2001b, 2003b).

Kingston, Spring City, and Rockwood maintain public water supplies in the vicinity of the Oak Ridge Reservation. 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 affected by ORR contaminants (Hutson and Morris 1992; G. Mize, TDEC, Drinking Water Program, personal communication, 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, 2006; TVA 1991). Still, only reverse flow conditions could potentially affect any of these three intakes (ATSDR 1996).

Under the authority of the Safe Drinking Water Act, since 1974 the EPA has set health-based standards for substances in drinking water and has specified treatments for providing safe drinking water (U.S. EPA 1999b). The public water supplies for Kingston, Spring City, and Rockwood are continually monitored for these regulated substances, which include 15 inorganic contaminants, 51 synthetic and volatile organic contaminants, and four radionuclides. For EPA's monitoring schedules, see http://www.epa.gov/safewater/pws/pdfs/qrg_smonitoringframework.pdf (U.S. EPA 2004a).

According to EPA's Safe Drinking Water Information System, the Kingston, Spring City, and Rockwood public water supply systems have not experienced any notable violations (U.S. EPA 2004b). To access information related to these and other public water supplies, visit EPA's Local Drinking Water Information Web site at http://www.epa.gov/safewater/dwinfo.htm. To find additional information related to these water supplies or additional water supplies in the area, 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.

II.E. Demographics

The study area of the PCB PHA consists of the off-site area along Lower East Fork Poplar Creek, Poplar Creek, the Clinch River, and the Tennessee River from the Melton Hill Dam to the Watts Bar Dam (see Figure 9). Parts of four counties and five principal cities fall within this area. Figure 10 and Figure 11 show the population demographics and distribution for the entire PCB study area.

Figure 9. Map of the PCB Study Area

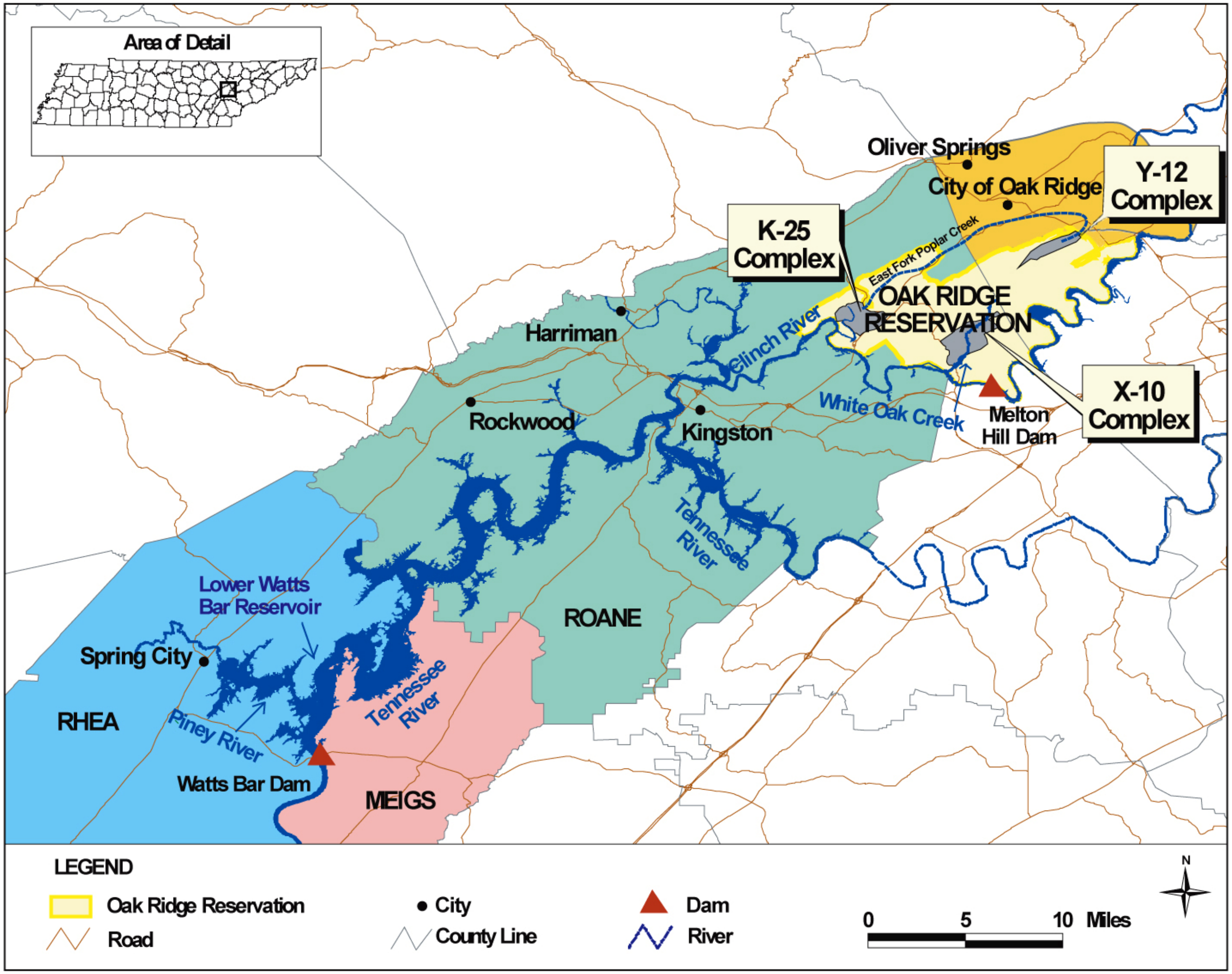
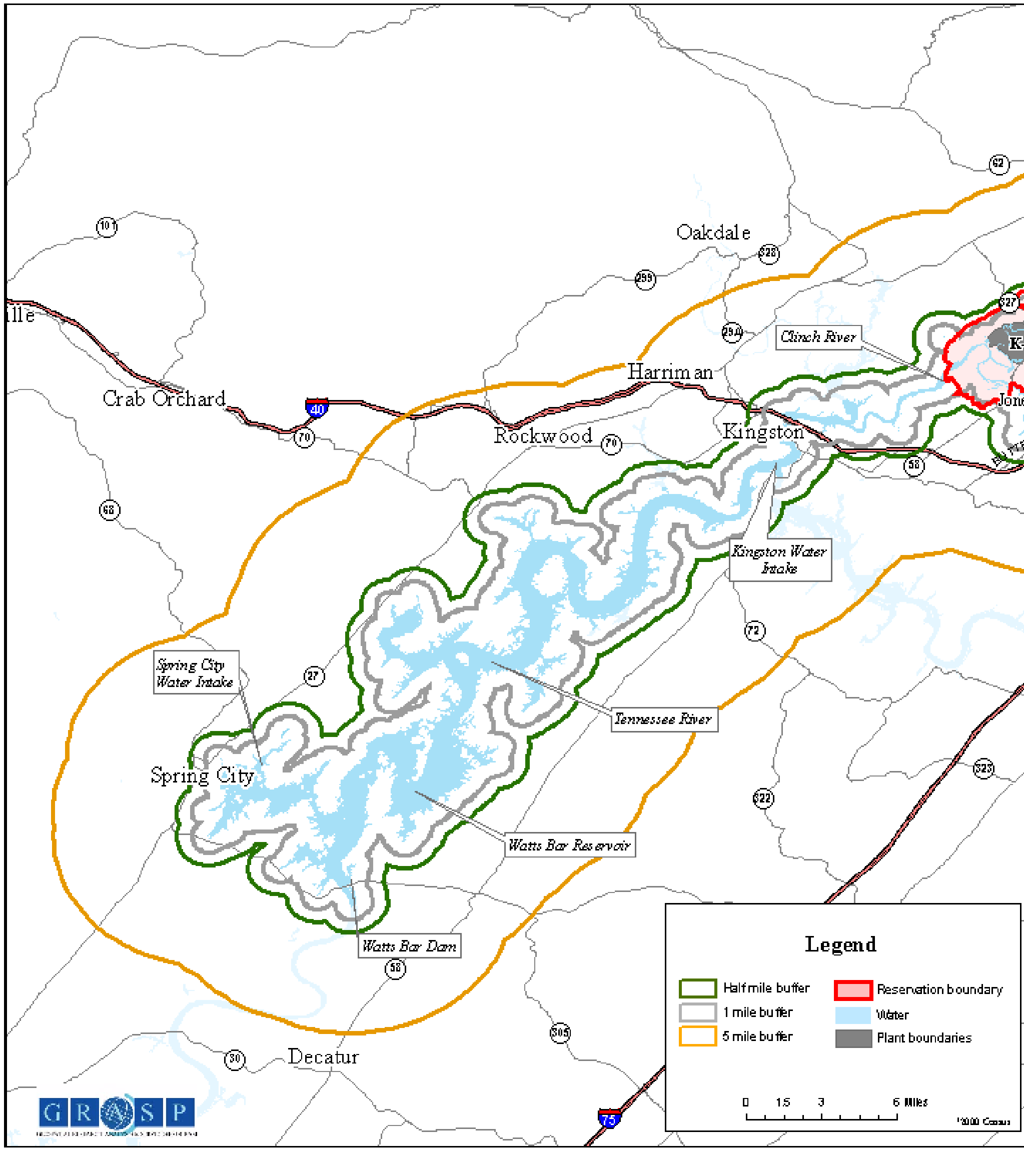
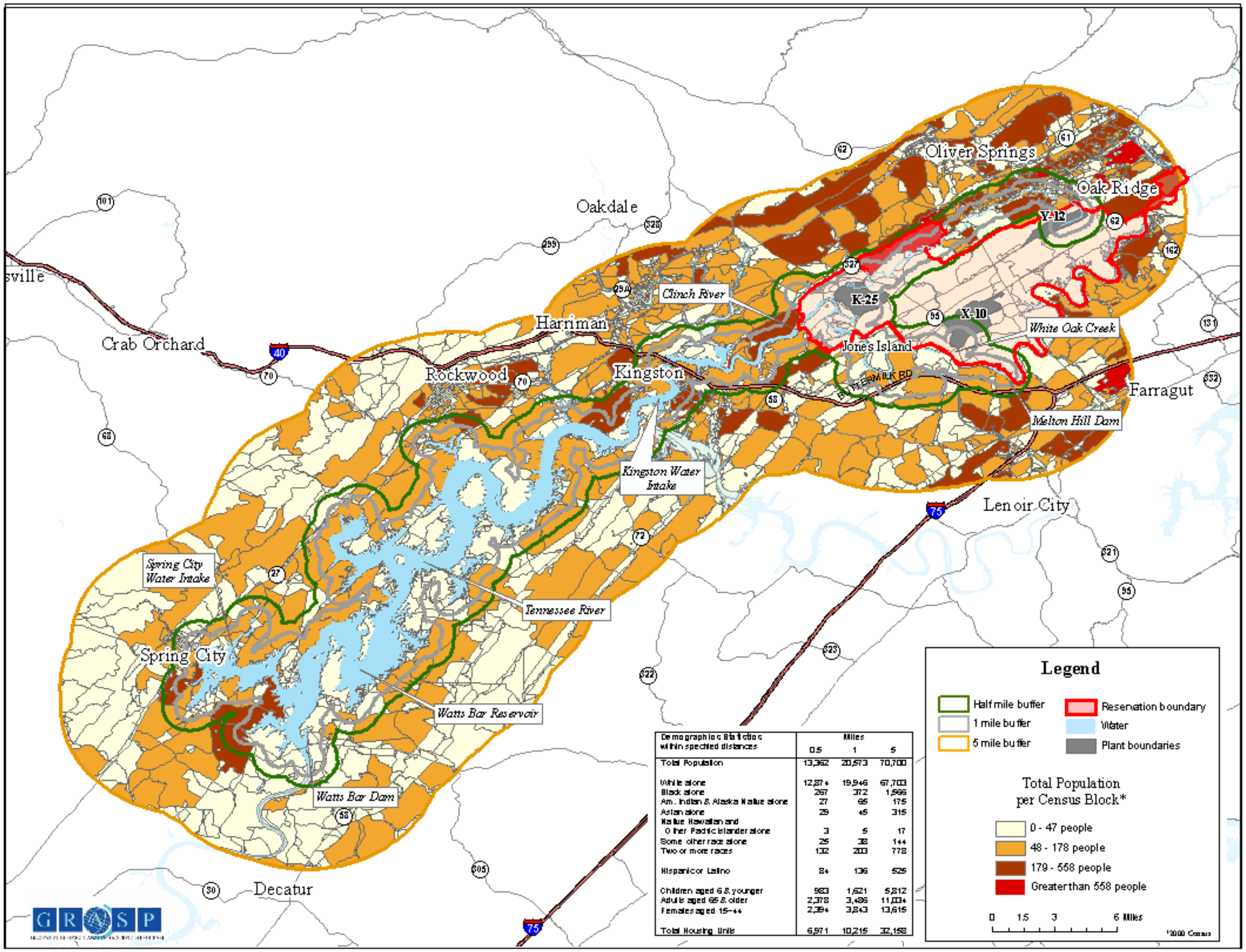


Figure 10. Population Demographics



Demographics Statistics within specified distances	Miles 0.5	Miles 1	Miles 5
Total Population	20,092	34,707	106,631
White alone	18,493	31,612	99,840
Black alone	997	1,947	3,975
Am. Indian & Alaska Native alone	48	112	281
Asian alone	198	359	855
Native Hawaiian and Other Pacific Islander alone	6	10	23
Some other race alone	88	181	356
Two or more races	262	485	1,301
Hispanic or Latino	234	457	1070
Children aged 6 & younger	1,526	2,703	8,534
Adults aged 65 & older	3,649	6,121	17,981
Females aged 15–44	3,617	6,440	20,335
Total Housing Units	10,407	17,255	49,207

Figure 11. Population Distribution



Demographic Statistics within specified distances	Miles 0.5	1	5
Total Population	13,362	20,573	70,700
White alone	12,874	19,946	67,703
Black alone	267	372	1,966
Am. Indian & Alaska Native alone	27	65	175
Asian alone	29	45	315
Native Hawaiian and Other Pacific Islander alone	3	5	17
Some other race alone	25	38	144
Two or more races	132	203	778
Hispanic or Latino	84	136	525
Children aged 6 & younger	983	1,621	5,812
Adults aged 65 & older	2,378	3,486	11,034
Females aged 15–44	2,394	3,843	13,615
Total Housing Units	6,971	10,215	32,158

II.E.1 Counties within the Study Area

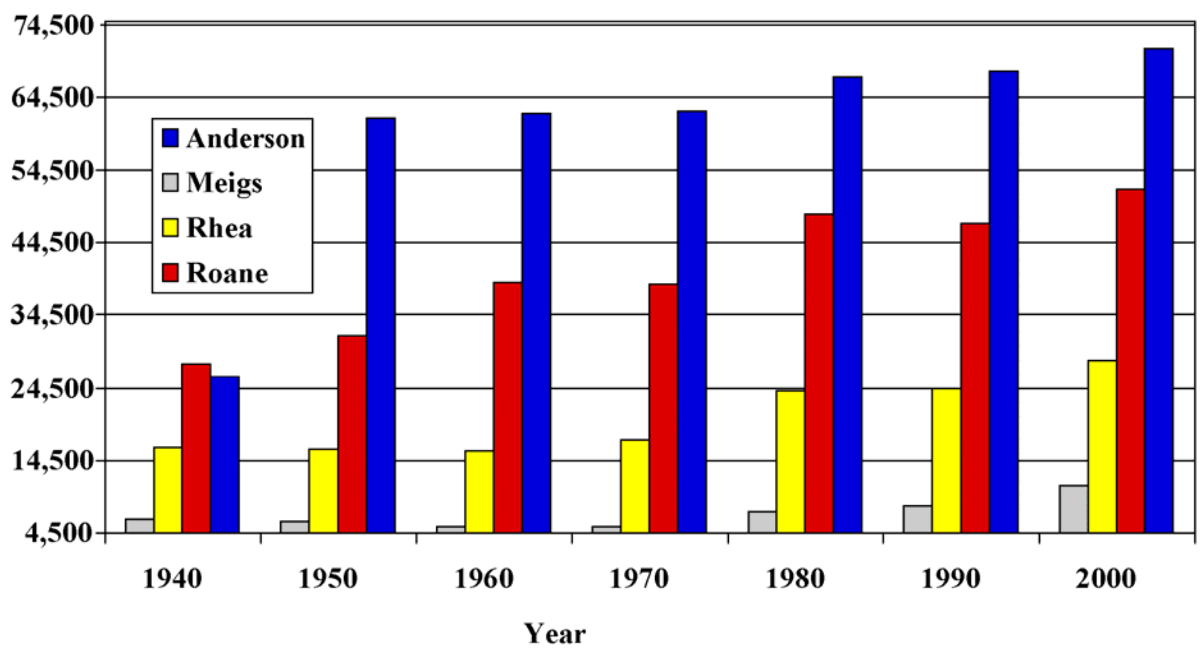
Since 1940, the populations of Anderson, Meigs, Rhea, and Roane Counties have all grown by more than 50 percent (U.S. Census Bureau 1993, 2000). Table 1 shows the population for these counties over 60 years, and Figure 12 shows the population distribution for the counties over time.

Table 1. Populations of Anderson, Meigs, Rhea, and Roane Counties from 1940 to 2000

County	*1940*	*1950*	*1960*	*1970*	*1980*	*1990*	*2000*
Anderson County	26,504	59,407	60,032	60,300	67,346	68,250	71,330
Meigs County	6,393	6,080	5,160	5,219	7,431	8,033	11,086
Rhea County	16,353	16,041	15,863	17,202	24,235	24,344	28,400
Roane County	27,795	31,665	39,133	38,881	48,425	47,227	51,910

Source: U.S. Census Bureau 1993, 2000

Figure 12. Population Distribution of Anderson, Meigs, Rhea, and Roane Counties from 1940 to 2000



Source: U.S. Census Bureau 1993, 2000

Anderson County

From 1940 to 1950, the population of Anderson County more than doubled from 26,504 to 59,407 as families arrived to build and operate the new Y-12 facilities. After that initial increase, the county grew steadily at a more modest rate of 20 percent over the next 50 years to 71,330 in the year 2000 (U.S. Census Bureau 1993, 2000). Figure 12 shows the pattern of growth. As of 2000, most residents worked in management, professional, and related fields. Anderson County is home to 66,593 Caucasians, 2,766 African Americans, and 828 persons of other races. Most residents are between 40 and 44 years old, with a median age of 39.9 years (U.S. Census Bureau 2000).

Meigs County

Between 1940 and 1960, the population of Meigs County decreased. The population has, however, nearly doubled since then—from 5,160 to 11,086 (46.5 percent) (see Table 1 and Figure 12). The largest percentage increase in population occurred between 1970 and 1980, when the number of residents grew from 5,219 to 7,431 (42.4 percent). Since 1940, the population of Meigs County has grown by almost 60 percent (U.S. Census Bureau 1993, 2000). As of 2000, most residents worked in the manufacturing industry. The Meigs County population comprises 10,826 Caucasians, 138 African-Americans, and 122 persons of other races. Also, most residents are between the ages of 35 and 44 years, and the median age is 36.7 years (U.S. Census Bureau 2000).

Rhea County

Between 1940 and 1960 the population of Rhea County declined but has since increased steadily (see Table 1 and Figure 12). The largest increase (40.9 percent) was between 1970 and 1980, when the number of residents went from 17,202 to 24,235. Over the past 60 years, the population of Rhea County has increased by nearly 75 percent (U.S. Census Bureau 1993, 2000). As of 2000, most residents worked in the manufacturing industry. Rhea County has 27,097 Caucasians, 580 African-Americans, and 723 persons of other races. Most residents are between the ages of 35 and 44 years, with a median age of 37.2 years (U.S. Census Bureau 2000).

Roane County

Over this 60-year period, the population of Roane County has grown by 86.8 percent, as shown in Table 1 (U.S. Census Bureau 1993, 2000). The population declined slightly from 1960 to 1970, and between 1980 and 1990 (East Tennessee Development District 1995; U.S. Census Bureau 1993, 2000). The county population grew during the remaining time and reached a population of 51,910 in 2000. Figure 12 shows the population distribution of the county over time (East Tennessee Development District 1995; U.S. Census Bureau 1993, 2000).

Most of Roane County's residents are Caucasian (49,440); the rest are African-American (1,409) and other races (1,061) (U.S. Census Bureau 2000). Since the 1970s, the median age of Roane County residents has increased from 32.1 to 40.7 years, suggesting that the county population is aging (East Tennessee Development District 1995; U.S. Census Bureau 1993, 2000). The X-10 site and the K-25 site are both within Roane County (East Tennessee Development District 1995; Jacobs EM Team 1997a). Primarily because of these two facilities, between 1940 and 1990 manufacturing was the predominant occupation for Roane County residents (East Tennessee Development District 1995; U.S. Census Bureau 1993).

II.E.2. Cities within the Study Area

Five principal cities fall within the study area—part of one city (Oak Ridge) and three other cities (Harriman, Kingston, and Rockwood) are in Roane County, the remainder of Oak Ridge is in Anderson County, and one city (Spring City) is in Rhea County. Table 2 shows the populations of these five cities between 1940 and 2000, and Figure 13 shows the population distribution during that time period.

Table 2. Populations of Spring City, Kingston, Rockwood, Harriman, and Oak Ridge from 1940 to 2000

City	1940	1950	1960	1970	1980	1990	2000
Spring City	1,569	1,725	1,800	1,756	1,951	2,199	2,025
Kingston	880	1,627	2,010	4,142	4,561	4,552	5,264
Rockwood	3,981	4,272	5,345	5,259	5,695	5,348	5,774
Harriman	5,620	6,389	5,931	8,734	8,303	7,119	6,744
Oak Ridge	3,000*	30,229	27,169	28,319	27,662	27,310	27,387

* Combined population on land that was established as Oak Ridge in 1942, with 13,000 initial residents (Convention and Visitors Bureau 2003).

Sources: ChemRisk 1993b; City of Oak Ridge 1989; Convention and Visitors Bureau 2003; U.S. Census Bureau 1940, 1950, 1960, 1970, 1980, 1993, 2000

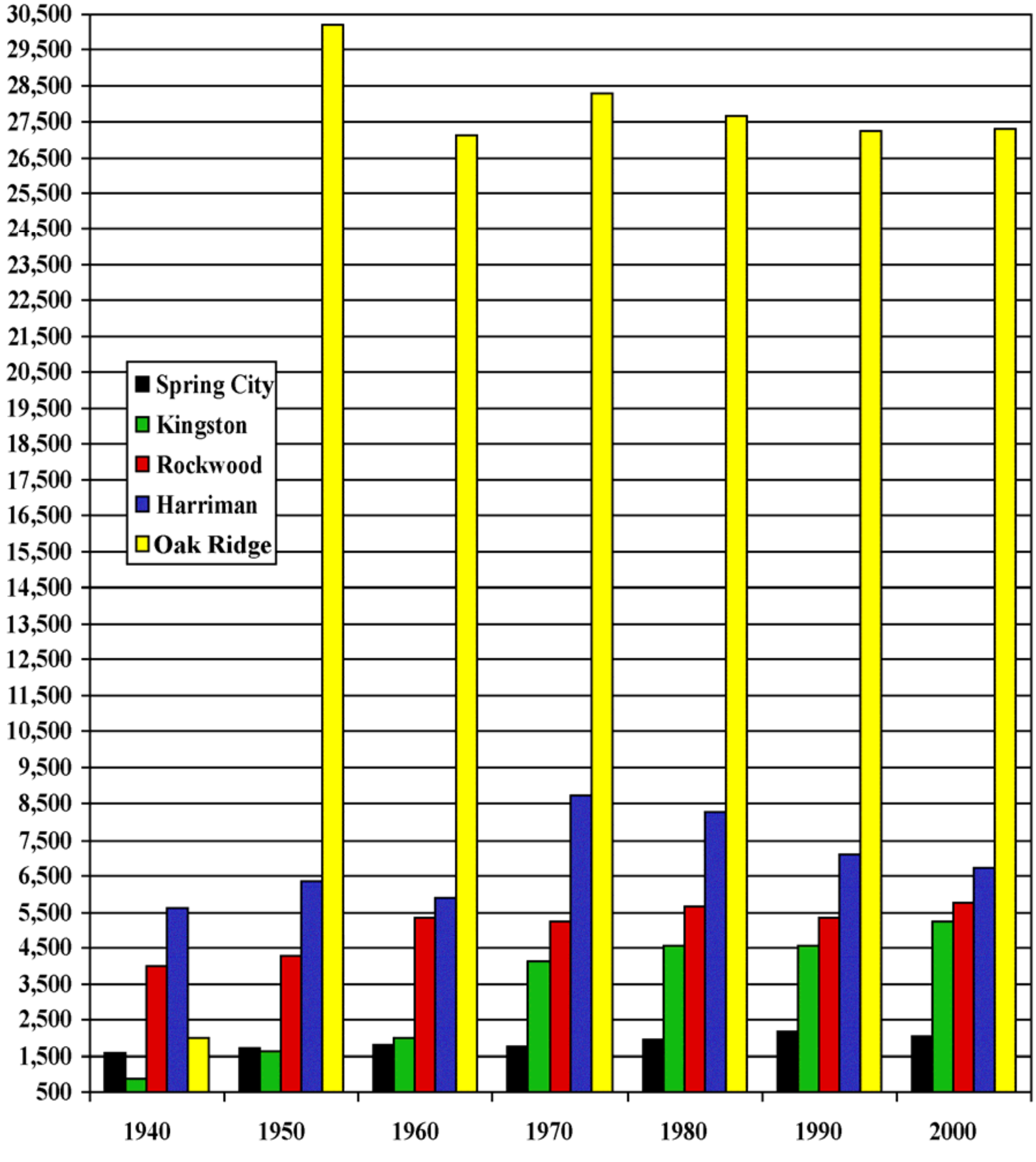
Oak Ridge

In 1942, Oak Ridge was established in Anderson County for the 13,000-strong labor force anticipated at the ORR (Friday and Turner 2001). To present decade-by-decade size comparisons for the available census intervals, Table 2 and Figure 13 understate the city's dramatic population growth and its contrast with the growth of its neighbors. By July 1944, the population of Oak Ridge had in fact increased to 50,000. The population peaked at 75,000 in 1945, decreased to 30,229 by 1950, and to 27,169 by 1960, but remained relatively stable thereafter (see Table 2 and Figure 13) (City of Oak Ridge 1989). In 1959, about 14,000 acres within the city of Oak Ridge became self-governing (ChemRisk 1993b). Almost since its establishment, the city of Oak Ridge has been one of the largest population centers in eastern Tennessee (ChemRisk 1993b).

Spring City

Spring City is approximately 50 miles southwest of the ORR (see Figure 9) (MapQuest 2007). Between 1940 and 2000, the population of Spring City continually fluctuated, as shown in Table 2 and Figure 13. During this time, the number of residents increased between 1940 and 1960 and between 1970 and 1990. The population declined from 1960 to 1970, and from 1990 to 2000. The largest percentage increase in population was seen between 1980 and 1990, followed by the largest decrease between 1990 and 2000 (U.S. Census Bureau 1940, 1950, 1960, 1970, 1980, 1993, 2000). As of 2000, the largest percentage (31.6 percent) of residents worked in the manufacturing industry. The population consists of 1,914 Caucasians, 91 African-Americans, and 20 persons of other races. The highest percentage of the population is between the ages of 35 and 44 years, and the city's median age is 44 years (U.S. Census Bureau 2000).

Figure 13. Population Distribution of Spring City, Kingston, Rockwood, Harriman, and Oak Ridge from 1940 to 2000



Note: Population for Oak Ridge in 1940 is the combined population on land that was established as Oak Ridge in 1942 with 13,000 initial residents (Convention and Visitors Bureau 2003).

Sources: ChemRisk 1993b; City of Oak Ridge 1989; Convention and Visitors Bureau 2003; U.S. Census Bureau 1940, 1950, 1960, 1970, 1980, 1993, 2000

Kingston

The city of Kingston is located at the confluence of the Clinch River and the Tennessee River (see Figure 9), and is about 20 miles southwest of the ORR (MapQuest 2007). As shown in Table 2 and Figure 13, the population of Kingston has grown steadily from 1940 to 2000, except for a 0.2 percent decrease between 1980 and 1990 (East Tennessee Development District 1995, U.S. Census Bureau 1993, 2000). In 1969, the city of Kingston had one manufacturing plant; by 1990, 6 of the 35 manufacturing plants in Roane County were in Kingston (East Tennessee Development District 1995). Since 1990, the greater number of residents has been employed in the professional services field (East Tennessee Development District 1995; U.S. Census Bureau 2000). In 2000, the population consisted of 4,935 Caucasians, 187 African-Americans, and 142 persons of other races. The majority of Kingston residents are between the ages of 45 and 54 years; the median age is 41.6 years (U.S. Census Bureau 2000).

Rockwood

The city of Rockwood is about 30 miles southwest of the ORR (see Figure 9) (MapQuest 2007). As Table 2 and Figure 13 show, the population of Rockwood fluctuated from 1940 to 2000. The city experienced steady growth between 1940 and 2000, except for slight declines that occurred between 1960 and 1970, and between 1980 and 1990 (East Tennessee Development District 1995; U.S. Census Bureau 1993, 2000). In 1969, 10 out of 29 manufacturing plants in Roane County were in Rockwood. By 1990, Rockwood had 13 out of the 35 manufacturing plants in the county (East Tennessee Development District 1995). The largest percentage of residents is employed in the manufacturing field. As of 2000, the Rockwood population consisted of 5,362 Caucasians, 314 African-Americans, and 98 persons of other races. The median age is 42 years, and the greatest portion of individuals is between the ages of 45 and 54 years (U.S. Census Bureau 2000).

Harriman

The city of Harriman is about 20 miles west of the ORR (see Figure 9) (MapQuest 2007). As Table 2 and Figure 13 show, the population of Harriman peaked between 1970 and 1980 and has continued to decline since that time (East Tennessee Development District 1995; U.S. Census Bureau 1993, 2000). In 1969, 18 of the 29 manufacturing plants in Roane County were located in the city of Harriman. By 1990, Roane County had 35 manufacturing plants, but the number in Harriman had fallen to 15 (East Tennessee Development District 1995). Still, as of 2000, manufacturing remains the leading source of employment for Harriman residents. In 2000, the population consisted of 6,077 Caucasians, 501 African-Americans, and 166 persons of other races. Most residents are between the ages of 45 and 54 years, with a median age of 40.5 years (U.S. Census Bureau 2000). As of 1990, Harriman had more minority residents than any other city in Roane County (East Tennessee Development District 1995).

II.F. Summary of Public Health Activities Pertaining to PCB Releases

This section describes the public health activities that pertain to PCB releases from the Y-12, K-25, and X-10 sites to the Clinch River, East Fork Poplar Creek, and White Oak Creek, and thence to the Watts Bar Reservoir. ATSDR, the Tennessee Department of Health (TDOH), and other agencies have conducted additional ORR-related public health activities, which are described in Appendix B. Summary of Other Public Health Activities.

II.F.1. ATSDR

Since 1992, ATSDR has worked extensively to determine whether levels of environmental contamination at and near the ORR present a public health hazard to nearby communities. During this time, ATSDR identified and evaluated several public health issues and has worked closely with community members, physicians, and several federal, state, and local health and environmental agencies. While TDOH conducted the Oak Ridge Health Studies to determine whether off-site populations could have experienced exposures in the *past,* to avoid duplication of the state's efforts ATSDR's activities have focused on *current* public health issues. The following paragraphs highlight major public health activities conducted by ATSDR health scientists and health educators to address current public health issues that pertain to PCB releases into the East Fork Poplar Creek, Clinch River, and the Watt Bar Reservoir.

Public Health Consultation on the Y-12 Weapons Plant Chemical Releases Into East Fork Poplar Creek, Oak Ridge, Tennessee, April 1993. This health consultation provided DOE with advice on current public health issues related to past and present chemical releases into the creek from the Y-12 plant. Before finalizing its remedial investigation on East Fork Poplar Creek, DOE implemented many of ATSDR's recommendations. The East Fork Poplar Creek Phase I data evaluated for this health consultation indicate that the creek's soil, sediment, groundwater, surface water, air, and fish are contaminated with various chemicals. Consequently, ATSDR drew the following public health conclusions.

- Soil and sediments in certain locations along the East Fork Poplar Creek floodplain are contaminated with levels of mercury that might be sufficient to affect human health.
- Fish in the creek contain levels of mercury and PCBs that could pose a moderately increased risk of adverse health effects to people—if they eat fish frequently over long periods of time.
- Shallow groundwater in a few areas along the East Fork Poplar Creek floodplain contains metals at levels that might be sufficient to affect people's health if they drink the water; the groundwater in this area is, however, too shallow to support productive drinking water wells.

Other contaminants found in soil, sediment, surface water, and fish were not detected at levels that could make people ill. In summary, among other recommendations, ATSDR advised continuation of the East Fork Poplar Creek fish advisory with posting of signs, especially at the confluence of Poplar Creek. This public health consultation can be accessed at http://www.atsdr.cdc.gov/HAC/pha/efork1/y12_toc.html. A brief summarizing the health consultation is provided in Appendix F. Summary Briefs and Fact Sheets.

Health Consultation on the Lower Watts Bar Reservoir, February 1996. In March 1995, DOE proposed a plan to address contaminants in the Lower Watts Bar Reservoir. Local residents requested that ATSDR assess the health hazards associated with contaminants in the Lower Watts Bar Reservoir to ensure DOE's proposed remedial actions and controls were adequate for protecting human health. In response to this request, ATSDR conducted a health consultation.

ATSDR reviewed environmental sampling data from the 1980s and 1990s compiled by DOE, TVA, their consultants, and TVA's 1993 and 1994 Annual Radiological Environmental Reports for the Watts Bar nuclear plant. ATSDR screened the data for contaminant levels that exceeded health-based comparison values.

During the public health assessment process, ATSDR uses comparison values as conservative screening tools.

Using conservative risk modeling, ATSDR estimated that frequent and long-term consumption of reservoir fish, if high levels entered and remained in the bodies of the consumers, could moderately increase a person's risk of cancer. In addition, ATSDR concluded that mothers who regularly consumed these fish while nursing or during pregnancy and acquired large quantities of the PCBs in their bodies might increase the risk of having a child with developmental anomalies (ATSDR and ORRHES 2000). For more specific details on ATSDR's health consultation, see the document at http://www.atsdr.cdc.gov/HAC/PHA/efork3/hc_toc.html. A brief summarizing the health consultation is provided in Appendix F. Summary Briefs and Fact Sheets.

ATSDR determined that current contaminant levels in the reservoir sediment and in surface water were not a public health concern. The reservoir was safe for recreational activities such as skiing, swimming, and boating; the municipal water was also safe to drink. Further, ATSDR concluded that DOE's chosen remedial actions were protective of public health. These actions included

- ongoing environmental monitoring,
- continuing fish consumption advisories,
- offering community and physician education concerning PCB contamination, and
- applying institutional controls to prevent resuspension, removal, disruption, or disposal of contaminated sediment (ATSDR and ORRHES 2000).

Given these findings, and because the level of PCB contamination in the bodies of people who already had consumed large amounts of fish or turtles was not known, ATSDR made the following recommendations:

- To minimize PCB exposure, the Lower Watts Bar Reservoir fish advisory should remain in effect.

- ATSDR and the state of Tennessee should implement a community health education program regarding the Lower Watts Bar Reservoir fish advisory and the potential health effects of PCB exposure.

- Evaluate the likelihood of health effects from consumption of turtles in the Lower Watts Bar Reservoir. The evaluation should investigate turtle consumption patterns and PCB levels in edible portions of turtles.

- Do not disturb, remove, or dispose of surface and subsurface sediments.

- Continue sampling of municipal drinking water at regular intervals. In addition, if a significant release of contaminants from the ORR is discharged into the Clinch River at any time, DOE should notify the municipal water systems and should monitor surface water intakes.

Community and Physician Education on PCBs in Fish, September 1996. As a follow up to the recommendations in the Lower Watts Bar Reservoir Health Consultation, ATSDR created a program to educate the community and its physicians on PCBs in Lower Watts Bar Reservoir fish. On September 11, 1996, Daniel Hryhorczuk, MD, MPH, ABMT, from the Great Lakes Center at the University of Illinois at Chicago, spoke on health risks related to the consumption of PCBs in fish. Dr. Hryhorczuk made his presentation to about 40 area residents at the community health education meeting in Spring City, Tennessee. In addition, on September 12, 1996, an educational meeting for health care providers in the Watts Bar Reservoir area was held at the Methodist Medical Center in Oak Ridge, Tennessee. Furthermore, ATSDR collaborated with local residents, associations, and state officials to create a brochure informing the public about TDEC's fish consumption advisories for the Lower Watts Bar Reservoir (ATSDR and ORRHES 2000).

Watts Bar Reservoir Exposure Investigation, March 1998. Before this exposure investigation, studies on the Watts Bar Reservoir and on the Clinch River reviewed several contaminants, but the only one suspected to be capable of causing illness was PCBs in Watts Bar Reservoir fish. These studies include DOE's 1994 remedial investigation on the Lower Watts Bar Reservoir and on the Clinch River/Poplar Creek (Jacobs Engineering Group Inc 1996), as well as ATSDR's 1993 Public Health Consultation on the Y-12 Weapons Plant Chemical Releases into East Fork Poplar Creek (ATSDR 1993) and its 1996 Health Consultation on the Lower Watts Bar Reservoir (ATSDR 1996). The studies based their findings on estimated PCB exposure doses and conservatively modeled increases of cancer likelihood after consuming large amounts of fish over extended time periods, assuming all the fish contamination was taken up and remained in the bodies of the consumers. ATSDR conducted this exposure investigation because of the uncertainties associated with estimating exposure doses and with estimating increases in cancer likelihood from ingestion of reservoir fish and turtles. In addition, these past investigations did not confirm that people were actually being exposed or that sufficient amounts of the chemicals had accumulated in their bodies to result in elevated blood levels. Also, a TDOH contractor

> Exposure investigations are one of the tools ATSDR uses to develop a better characterization of past, present, or possible future human exposure to hazardous substances in the environment. These investigations only evaluate exposure—they do not assess whether exposure levels result in adverse health effects.

suggested conducting an extensive region-wide evaluation to assess the relevant exposures and health effects in counties surrounding the Watts Bar Reservoir. ATSDR believed, however, that before any agency conducted extensive investigations, it should determine whether mercury and PCBs were elevated in individuals who consumed large amounts of fish and turtles from the reservoir.

The exposure investigation evaluated exposures at one time point. Historical exposures were estimated from these modern results by looking at changes in PCBs as they were deposited in river sediments over time. ATSDR focused its evaluation on individuals who consumed moderate to high amounts of fish and turtles from the Watts Bar Reservoir. Participants were recruited through newspaper, radio, and television announcements, as well as through posters and flyers placed at various fishing-related locations (e.g., bait shops). ATSDR interviewed more than 550 volunteers, 116 of whom ate enough fish or turtles for inclusion in the investigation. These 116 participants supplied a high-end estimate of exposure doses resulting from fish consumption.

The results of this investigation were released via a mailing and a public forum. Participants' serum PCB and blood mercury levels turned out to be similar to those in the general population. A brief summary of the exposure investigation is provided in Appendix F. Summary Briefs and Fact Sheets. The major findings are (ATSDR and ORREHS 2000; ORHASP 1999)

- The investigation participants' serum PCB levels and blood mercury levels were very close to levels seen in the general population.

- Of the 116 people tested, only five (4 percent) had serum PCB levels above 20 micrograms per liter (µg/L) or parts per billion (ppb)—the level regarded as elevated for total serum PCBs. Four of the five participants who exceeded 20 µg/L had levels between 20 and 30 µg/L. The remaining participant, who spent 2 months of each year in Tennessee and 10 months of each year in Florida, had a serum PCB level that measured 103.8 µg/L—above the distribution the agency observed in the population in the Tennessee Watts Bar Reservoir area or in the U.S. population in general. Follow-up counseling was given to study participants with elevated PCB blood levels. Through this counseling, researchers were able to investigate other potential past exposure routes and to recommend behaviors that could reduce future exposure. It should be noted that, although these five participants represented 4 percent of the highest Watts Bar Reservoir fish consumers, they were less than 1 percent of those surveyed for fish consumption (i.e., over 550 volunteers interviewed).

- One investigation participant (1 percent of the highest fish consumers and 0.2 percent of those surveyed for fish consumption) had a total blood mercury level above 10 µg/L—a level considered to be elevated. The other participants had mercury blood levels below 10 µg/L, a level likely to be seen in the general population. Follow-up counseling was also given to this person.

Coordination with Other Parties and Establishment of the ORR Public Health Working Group and the Oak Ridge Reservation Health Effects Subcommittee (ORRHES). Since 1992, ATSDR has consulted regularly with representatives of other parties involved with the ORR. In 1998, under a collaborative effort with the DOE Office of Health Studies, ATSDR and the Centers for Disease Control and Prevention (CDC) developed credible, coherent, and coordinated agendas for public health activities and health studies at each DOE site. ATSDR coordinated its efforts with TDOH, TDEC, the National Center for Environmental Health (NCEH), the National Institute for Occupational Safety and Health (NIOSH), the Health Resources Services Administration (HRSA), and DOE. In February 1999, ATSDR became the lead agency to improve communication. In cooperation with other agencies and to gather input from local organizations and individuals about creating a public health forum, in 1999 ATSDR established the ORR Public Health Working Group. After consideration of community input, ATSDR and CDC determined that establishing the ORRHES was the most effective way to meet the community's needs. Also, ATSDR provided some assistance to TDOH in its study of past public health issues (ATSDR and ORREHS 2000).

Oak Ridge Reservation Health Effects Subcommittee. In 1999, ATSDR and CDC, under authority of the Federal Advisory Committee Act (FACA), established the ORRHES as a subcommittee of the U.S. Department of Health and Human Services' Citizens Advisory Committee on Public Health Service Activities and Research at DOE sites. The subcommittee consisted of people with diverse interests, expertise, backgrounds, and communities, as well as liaison members from federal and state agencies. It became a forum for communication and collaboration between the citizens and those agencies that evaluate public health issues and conduct public health activities at the ORR. To help ensure citizen participation, the meetings of the subcommittee's work groups were open to the public; everyone was invited to attend and present their ideas and opinions. The subcommittee

- Served as a citizen advisory group to CDC and ATSDR and made recommendations on matters related to public health activities and research at the ORR.
- Allowed citizens to collaborate with agency staff members and to learn more about the public health assessment process and other public health activities.
- Helped to prioritize the public health issues and community concerns evaluated by ATSDR.

ATSDR Field Office. From 2001 to 2005, ATSDR maintained a field office in the city of Oak Ridge. The office was opened to promote collaboration between ATSDR and the communities surrounding the ORR by providing community members with opportunities to become involved in ATSDR's public health activities at the ORR.

How to Obtain More Information on ATSDR's Activities at Oak Ridge

ATSDR has conducted several additional analyses that are not documented here or in Appendix B, as have other agencies involved with this site. Community members can find more information on ATSDR's past activities by the following three ways:

1. *Visit one of the records repositories.* Copies of ATSDR's publications on the ORR, along with publications from other agencies, can be viewed in records repositories at the DOE Information Center, Harriman Public Library, Kingston City Library, Oak Ridge Public Library, Roane State Community College, and the Rockwood Public Library.

2. *Visit the ATSDR Web site.* ATSDR's Oak Ridge Reservation Web site is at http://www.atsdr.cdc.gov/HAC/oakridge. This Web site includes our past publications and other materials. The most comprehensive summary of past activities can be found at http://www.atsdr.cdc.gov/HAC/oakridge/phact/c_toc.html.

3. *Contact ATSDR directly.* Residents can contact representatives from ATSDR directly by dialing the agency's toll-free number, 1-800-CDC-INFO (1-800-232-4636).

II.F.2. Tennessee Department of Health (TDOH)

Oak Ridge Health Studies. In 1991, DOE and the state of Tennessee entered into the Tennessee Oversight Agreement, which allowed TDOH to undertake a two-phase independent state research project to determine whether past environmental releases from ORR operations could have harmed people who lived nearby (ORHASP 1999). All of the technical reports produced for the TDOH Oak Ridge Health Studies are accessible at http://cedr.lbl.gov.

Phase I. Phase I of the Oak Ridge Health Study is a dose reconstruction feasibility study. This feasibility study evaluated all past releases of hazardous substances and operations at the ORR. The objective was to determine the quantity, quality, and potential uses of the available information and data on these past releases and subsequent exposure pathways. Phase I of the health studies began in May 1992, and was completed in September 1993 (ATSDR and ORREHS 2000). A brief summarizing the Phase I Feasibility Study is provided in Appendix F. Summary Briefs and Fact Sheets.

During the health study process the state reviewed thousands of documents and interviewed knowledgeable parties to assess the possibility of creating a dose reconstruction, and to examine historical releases from the ORR that posed the greatest threat to public health. The state reviewed documents related to the three major facilities (X-10, Y-12, and K-25), the former S-50 site, and for several off-site areas associated with ORR contamination (ChemRisk 1993a, 1993b). In the feasibility study, the state

1. evaluated historical activities at each facility on the ORR,
2. compiled an inventory of environmental sampling and research data for use in dose reconstruction,
3. identified activities with the highest potential to release substantial quantities of contaminants to off-site populations,

4. determined the potential the released contaminants had to affect public health,
5. identified important environmental media and exposure pathways through which off-site populations could be exposed,
6. compiled a list of contaminants to evaluate those that needed further evaluation,
7. examined whether a completed exposure pathway existed, and
8. assessed which pathways contributed significantly to the potential health risks for off-site populations.

Through this extensive process ChemRisk, TDOH's contractor, attempted to identify the contaminants and pathways having the greatest likelihood of causing adverse health effects. For information on other activities conducted during the feasibility study, see ChemRisk's 1993 *Oak Ridge Health Studies* (ChemRisk 1993a, 1993b).

The findings of the Phase I Dose Reconstruction Feasibility Study indicated that a significant amount of information was available to reconstruct the past releases and potential off-site exposure doses for four hazardous substances that might have been responsible for adverse health effects. These four substances include 1) radioactive iodine releases associated with radioactive lanthanum processing at X-10 from 1944 through 1956; 2) mercury releases associated with lithium separation and enrichment operations at the Y-12 plant from 1955 through 1963; 3) PCBs in fish from East Fork Poplar Creek, the Clinch River, and the Watts Bar Reservoir; and 4) radionuclides from White Oak Creek associated with various chemical separation activities at X-10 from 1943 through the 1960s (ATSDR and ORREHS 2000).

Phase II (also referred to as the Oak Ridge Dose Reconstruction). Phase II of the Oak Ridge health studies began in mid-1994 and was completed in early 1999. Phase II primarily consisted of a dose reconstruction study focusing on past releases of radioactive iodine, radionuclides from White Oak Creek, mercury, and PCBs. In addition to the full dose reconstruction analyses, the Phase II effort included detailed screening analyses for releases of uranium and several other toxic materials that had not been fully characterized in Phase I. The significant findings for each of the substances evaluated, as well as the significant findings of the additional screening analyses in the Task 7 report, are summarized here.

- Radioactive iodine releases were associated with radioactive lanthanum processing at X-10 from 1944 through 1956. Results indicate that children who were born in the area in the early 1950s and who drank milk produced by cows or goats living in their yards had the highest theoretical increased risk of developing thyroid cancer. The results suggest that a female born in 1952 at Bradbury, Tennessee, would have the highest risk of developing thyroid cancer from the radioactive iodine releases.

- The study evaluated mercury releases associated with lithium separation and enrichment operations at the Y-12 plant from 1955 through 1963. Results indicate that during the mid-1950s farm families living along East Fork Poplar Creek and children playing in the creek may

EPA defines a reference dose as an "estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime."

have received annual average doses of mercury exceeding the EPA reference dose. The results also suggest that fetuses of pregnant women who ate significant quantities of fish from the Clinch River or Poplar Creek in the late 1950s and early 1960s are at the highest risk from methylmercury exposure.

- Additional studies were conducted on PCBs in fish from East Fork Poplar Creek, the Clinch River, and the Watts Bar Reservoir. TDOH concluded that persons who consumed large amounts of fish from the Clinch River and the Lower Watts Bar Reservoir were at risk from noncancer effects of PCBs. They also concluded that three or fewer cases of cancer could have resulted from eating Clinch River and Watts Bar Reservoir fish. Because, however, the estimates and modeling are conservative, "the actual risks and expected number of cases are likely to be smaller and could be zero" (ChemRisk 1999a). TDOH also made recommendations for further study to reduce uncertainty. A brief summarizing the PCB dose reconstruction (Task 3) is provided in Appendix F. Summary Briefs and Fact Sheets.

- Radionuclides associated with various chemical separation activities at the X-10 site from 1943 through the 1960s, were released into White Oak Creek. Eight radionuclides (cesium 137, ruthenium 106, strontium 90, cobalt 60, cerium 144, zirconium 95, niobium 95, and iodine 131) deemed more likely to carry significant risks were studied. The results indicate that the releases caused small increases in the radiation dose over background for individuals who consumed fish from the Clinch River, near the mouth of White Oak Creek. The dose reconstruction scientists estimated that a man who ate up to 130 meals of fish from the mouth of White Oak Creek every year for 50 years (worst-case scenario) had the highest theoretical increase risk of developing cancer. The risk from eating fish declines proportionately for people who eat fewer fish and for people who eat fish caught farther downstream.

- Uranium was released from various large-scale uranium operations, primarily uranium processing and machining operations at the Y-12 plant and uranium enrichment operations at the K-25 and S-50 plants. Because uranium was not initially given high priority as a contaminant of concern, a Level II screening assessment for all uranium releases was performed. Preliminary screening indices for Y-12 and K-25 were below the Oak Ridge Health Agreement Steering Panel (ORHASP) decision guide of one chance in 10,000 (1×10^{-4}).

- The *Screening-Level Evaluation of Additional Potential Materials of Concern* was conducted to determine whether contaminants other than those identified in the *Oak Ridge Dose Reconstruction Feasibility Study* warranted further evaluation to assess their potential to cause health effects to off-site populations. Three methods—a qualitative screening, a quantitative screening, and a threshold quantity approach—were used to evaluate the potential for 25 materials or groups of materials to cause off-site health effects. A review of the screening results disclosed that five materials used at the K-25 plant and 14 materials used at the Y-12 plant warranted no further study. Three materials used at the K-25 plant (copper powder, nickel, and technetium 99), three materials used at the Y-12 plant (beryllium compounds, lithium compounds, and technetium 99), and one material used at the ORR (chromium VI) were determined to be potential candidates for further study. High-priority candidates for further study included one material used at the K-25 plant (arsenic) and two materials used at the Y-12 plant (arsenic and lead).

- *The Oak Ridge Health Agreement Steering Panel (ORHASP).* A panel consisting of experts and local citizens was appointed to direct and oversee the Oak Ridge Health Studies and provide liaison with the community. Using the findings of the Oak Ridge Health Studies and what is generally known about the health risks posed by exposures to various toxic chemicals and radioactive substances, ORHASP concluded that "past releases from the Oak Ridge Reservation were likely to have harmed some people." Two groups most likely to have been harmed were 1) local children who drank milk produced by a backyard cow or goat in the early 1950s and 2) fetuses of women who routinely ate fish from contaminated creeks and rivers downstream of the ORR in the 1950s and early 1960s. For additional information on the ORHASP findings, please see the final report of the ORHASP titled *Releases of Contaminants from Oak Ridge Facilities and Risks to Public Health* at http://health.state.tn.us/CEDS/OakRidge/ORHASP.pdf (ORHASP 1999).

II.F.3. Tennessee Department of Environment and Conservation (TDEC)

Watts Bar Reservoir and Clinch River Turtle Sampling Survey, May 1997. TDEC conducted this survey to assess PCB body burdens in snapping turtles in the Clinch River and in the Watts Bar Reservoir. Fish advisories had been in effect for several years because of PCB contamination, and TDEC was concerned that people who consumed turtles from these water sources might also be exposed to PCBs. TDEC concluded that PCBs and additional contaminants accumulate in turtles from the Clinch River and the Watts Bar Reservoir. TDEC reviewed data used to formulate the fish advisories and found that the PCB concentrations in turtle tissue were detected at levels such that, if the tissue were consumed by people and the PCBs accumulated in their bodies, it might make them ill. Most PCB contamination was, however, in the fat tissue of the turtles, as is the case in fish. Thus food preparation techniques, particularly tissue selection and draining away fat, can significantly influence the quantities of PCBs consumed with turtle meat (ATSDR and ORREHS 2000). A brief summarizing the turtle sampling is provided in Appendix F. Summary Briefs and Fact Sheets.

Fish Advisories. The fish advisory for East Fork Poplar Creek was originally issued in 1982. The fish advisories for the Tennessee River and the Clinch River were issued a decade later, in 1992 (G. Denton, TDEC, personal communication, February 2005.). In February 2004, the following fish advisories were in place for waterways near the ORR (TDEC 2004). For the advisory, go to http://www.state.tn.us/environment/wpc/publications/advisories.pdf.

- Given the levels of mercury and PCBs detected in the East Fork of Poplar Creek, including Poplar Creek Embayment, fish taken from these waters should not be eaten and water contact should be avoided.

- For the Tennessee River portion of the Watts Bar Reservoir, a review of PCB levels shows that catfish, striped bass, and hybrid bass (striped bass-white bass) should not be eaten. Children, pregnant women, and nursing mothers should not consume white bass, sauger, carp, smallmouth buffalo, or largemouth bass, but other people can consume one meal per month of these fish.

- For the Clinch River, detected PCB levels indicate that striped bass should not be eaten. Children, pregnant women, and nursing mothers should not consume sauger, carp, smallmouth buffalo, or largemouth bass, but other people can consume one meal per month of these fish.

Sampling of Public Drinking Water Systems in Tennessee. For 30 years, under the Safe Drinking Water Act of 1974 (http://www.epa.gov/safewater/sdwa/index.html), EPA has set health-based standards and specified treatments for substances in public drinking water systems. 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 program requirement all public water systems in Tennessee individually monitor their water supply for EPA-regulated contaminants and report monitoring results to TDEC. The public water supplies for Kingston, Spring City, Rockwood, and other supplies in Tennessee are monitored for 15 inorganic contaminants, 51 synthetic and volatile organic contaminants, and four radionuclides (EPA 2004a). According to EPA's Safe Drinking Water Information System, the Kingston, Spring City, and Rockwood public water supply systems have not had any notable violations (U.S. EPA 2004b). For EPA's monitoring schedules for each contaminant, go to http://www.epa.gov/safewater/pws/pdfs/qrg_smonitoringframework.pdf. TDEC submits quarterly the individual water supply data to EPA's Safe Drinking Water Information System (TDEC 2003c). To look up information and sampling results for public water supplies in Tennessee, visit EPA's Local Drinking Water Information Web Site at http://www.epa.gov/safewater/dwinfo/tn.htm.

> EPA's Environmental Radiation Ambient Monitoring System program was established to provide radiological monitoring for public water supplies located close to U.S. nuclear facilities.

In addition, in 1996 TDEC's DOE Oversight Division began participation in EPA's Environmental Radiation Ambient Monitoring System. As part of this Oak Ridge program, TDEC collects samples from five facilities on the ORR and in its vicinity. These public water suppliers include the 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). Under the Oak Ridge Environmental Radiation Ambient Monitoring System, 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. Please 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 drinking water sampling results. TDEC has also conducted filter backwash sludge sampling at Spring City—radioactive contaminants from the reservation 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 find additional information related to either of these water supplies or additional 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.

II.F.4. U.S. Department of Energy (DOE)

Watts Bar Interagency Agreement, February 1991. DOE, EPA, TVA, TDEC, and USACE comprise the Watts Bar Reservoir Interagency Working Group. This group works collaboratively through the Watts Bar Interagency Agreement, which established guidelines related to any dredging in Watts Bar Reservoir. Through this agreement, these agencies review permitting and all other activities that could possibly disturb the sediment of Watts Bar Reservoir, such as erecting a pier or building a dock (ATSDR 1996; Jacobs EM Team 1997b; U.S. DOE 2003a). The agreement also establishes guidelines for reviewing potential sediment-disturbing activities in the Clinch River below Melton Hill Dam, including Poplar Creek (Jacobs EM Team 1997b). According to the interagency agreement, DOE is required to take action if an institutional control is ineffective or if a sediment-disturbing activity could cause harm (U.S. DOE 2003a).

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 the presence of any DOE-related 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 (Jacobs EM Team 1997b). If dredging is necessary in an area with contaminated sediments, DOE will assume any financial and waste management responsibility over and above the costs that would normally be incurred (Jacobs EM Team 1997b). For more details, please see the Clinch River/Poplar Creek Operable Unit Record of Decision at http://www.epa.gov/superfund/sites/rods/fulltext/r0497075.pdf and the Lower Watts Bar Reservoir Record of Decision at http://www.epa.gov/superfund/sites/rods/fulltext/r0495249.pdf (Jacobs EM Team 1997b; U.S. DOE 1995).

Oak Ridge Environmental Information System (OREIS), April 1999. Over the years an abundance of ORR-related environmental data has accumulated. To process this data DOE created an electronic management system to integrate all of the data into one database. This database now facilitates public and governmental access to ORR environmental operations data, while at the same time maintaining data quality. DOE’s objective was to ensure that the database had long-term retention of the environmental data and provided useful ways to access the information. OREIS contains data on compliance, environmental restoration, and surveillance activities. Information from all key surveillance activities and environmental monitoring efforts is entered into OREIS. Such information includes, but is not limited to, studies of the Clinch River embayment and the Lower Watts Bar Reservoir, as well as annual site summary reports. As new studies are completed, the environmental data are entered as well (ATSDR and ORREHS 2000).

Comprehensive Epidemiologic Data Resource (CEDR). CEDR is a public-use database that contains information pertinent to health-related studies performed at the ORR and other DOE sites. DOE provides this easily accessible, public-use repository of data (without personal identifiers) collected during occupational and environmental health studies of workers at DOE facilities and of nearby community residents. This large resource organizes the electronic files of data and documentation collected during these studies and makes them accessible on the Internet at http://cedr.lbl.gov. Most of CEDR's large data collection pertains to about 50 epidemiological studies of workers at various DOE sites. Of particular interest to Tennessee residents is an additional feature of CEDR (available at http://cedr.lbl.gov/DR/ordr.html) that provides searchable text for about 1,800 original government documents (now declassified) used by the TDOH scientists for the Oak Ridge Dose Reconstruction. Also available through CEDR at http://cedr.lbl.gov are all of the technical and summary reports produced by this study. For the first time, this complex information is easily accessible in a concise, uncluttered, and easily understood manner. In addition, CEDR now provides images in slideshow format that give estimated concentrations, doses, and risk values for three contaminants (iodine, mercury, and uranium) in air at locations studied in TDOH's Dose Reconstruction.

III. Evaluation of Environmental Contamination and Potential Exposure Pathways

III.A. Introduction

In 2001, ATSDR scientists conducted a review and an analysis of the Phase I and Phase II screening evaluation of TDOH's Oak Ridge Health Studies to identify contaminants requiring further public health evaluation. In the Phase I and Phase II screening evaluation, TDOH performed extensive reviews of available information and conducted qualitative and quantitative analyses of past (1944–1990) releases and off-site exposures to hazardous substances from the entire ORR. Having reviewed and analyzed Phase I and Phase II screening evaluations, ATSDR scientists determined that past releases of uranium, mercury, iodine-131, fluorides, radionuclides from White Oak Creek, and PCBs required further public health evaluation. The public health assessment (PHA) is the primary public health process ATSDR uses to evaluate these contaminants further.

ATSDR scientists have completed or are conducting PHAs on the following ORR-related releases: Y-12 uranium releases, Y-12 mercury releases, X-10 iodine-131 releases, and K-25 uranium and fluoride releases. PHAs were also conducted on other issues of concern such as the TSCA incinerator and off-site groundwater. In addition, ATSDR screened current (1990 to 2003) environmental data to identify any other chemicals that required further evaluation. The completed PHAs can be found at http://www.atsdr.cdc.gov/HAC/oakridge/phact/index.html.

In this PHA, ATSDR scientists evaluate PCB releases from the ORR (specifically, from X-10, Y-12, and K-25) that have reached off-site areas, such as East Fork Poplar Creek, the Clinch River, and Watts Bar Reservoir, and assess whether people who use or live along these waterways are being exposed to harmful levels of ORR-related PCBs.

III.A.1. Exposure Evaluation Process

A release of a contaminant from a site does not always mean the substance will impact negatively on an off-site community member. For a substance to pose a potential health problem, exposure must first occur. Human exposure to a substance depends on whether a person comes in contact with the contaminant—by, for example, breathing, eating, drinking, or touching a substance containing it. If no one comes into contact with a contaminant, no exposure occurs, thus no health effects can occur. That said, however, even if the site is inaccessible to the public, contaminants can move through the environment to locations where people could come into contact with them.

> The five elements of an exposure pathway are
> 1) source of contamination,
> 2) environmental media,
> 3) point of exposure,
> 4) route of human exposure, and
> 5) receptor population.
>
> The *source of contamination* is where the chemical or radioactive material was released. The *environmental media* (e.g., groundwater, soil, surface water, air) transport the contaminants. The *point of exposure* is where people come in contact with the contaminated media. The *route of exposure* (e.g., ingestion, inhalation, dermal contact) is how the contaminant enters the body. The people actually exposed are the *receptor population.*

ATSDR evaluates site conditions to determine whether people could have been, are currently, or could be in the future exposed to site-related

> Biota refers to plants and animals in the environment. The biota evaluated by ATSDR includes fish, turtles, and geese.

contaminants. When evaluating exposure pathways, ATSDR identifies whether exposure to contaminated media (soil, water, air, waste, or biota) has occurred, is occurring, or will occur through ingestion, dermal (skin) contact, or inhalation. ATSDR also identifies an exposure pathway as *completed* or *potential*, or *eliminates the pathway from further evaluation*. Completed exposure pathways exist if all elements of a human exposure are present. A potential pathway is one that ATSDR is unable to rule out because one or more of the pathway elements cannot be definitely proved or disproved. A pathway is eliminated if one or more of the elements are definitely absent.

More information about the ATSDR evaluation process can be found in ATSDR's Public Health Assessment Guidance Manual at http://www.atsdr.cdc.gov/HAC/PHAManual/toc.html. An interactive program that provides an overview of the process ATSDR uses to evaluate whether people will be harmed by hazardous materials is available at http://www.atsdr.cdc.gov/training/public-health-assessment-overview/html/index.html. Appendix A. ATSDR Glossary of Environmental Health Terms is provided to acquaint the reader with terminology and methods used in this PHA.

III.A.2. Exposure and Health Effects

As stated, exposure does not always result in harmful health effects. The type and severity of health effects a person can experience depend on the amount of exposure (or dose), which in turn is based on age at exposure**,** the exposure rate (how much of the substance is taken into the body), the frequency (how often) or duration (how long) of exposure, the route or pathway of exposure (breathing, eating, drinking, or skin contact), and the multiplicity of exposure (the combination of contaminants and pathways involved). Sometimes it is also possible to measure the amount of the substance that remains in the body (body burden) after exposure. Given an exposure and a resulting body burden, characteristics such as age, sex, nutritional status, genetics, lifestyle, and health status of the exposed person influence how the person absorbs, distributes, metabolizes, and excretes the contaminant. The likelihood that adverse health outcomes will actually occur depends on site-specific conditions, individual lifestyle, and genetic factors that affect the route, magnitude, and duration of actual exposure. Together, those factors and characteristics determine the health effects that might result from the exposure. An environmental concentration alone will not cause an adverse health outcome.

Equally important is that the true level of exposure (or dose) to environmental contamination can never be exactly determined. There is considerable uncertainty in the factors (exposure rate, frequency, duration, route) used to estimate exposure. To account for the uncertainty and yet protect public health, ATSDR scientists typically use worst-case exposure level estimates to determine whether adverse health effects might be *possible*. This stage of the evaluation is known as "screening." In the public health assessment process, similar techniques to those of the quantitative risk assessment methods (i.e., generating quantitative "risk estimates") are used primarily as a screening tool to determine which exposure pathways are clearly not public health hazards (and need no further evaluation), and which exposure pathways require further public health evaluation. The estimated worst-case doses are much

> *Screening* is a process to identify potential pathways that are *not* a health concern. It also identifies pathways that need further in-depth health evaluation.

higher than the doses to which people are in fact exposed. If the estimated exposure dose is lower than one or more media-specific comparison value (dose-based comparison values or quantitative risk estimates), then the specific exposure pathway is not a public health hazard and is eliminated from further evaluation. If, however, the worst-case dose for an exposure pathway exceeds one or more media-specific comparison values, the public health assessment process proceeds with a more in-depth health effects evaluation of that specific exposure pathway.

ATSDR scientists conduct a thorough health effects evaluation. They carefully examine site-specific parameters and exposure conditions about actual or likely exposures. They conduct a critical review of available toxicological, medical, and epidemiological information to ascertain the substance-specific toxicity characteristics (levels of significant human exposure). They also compare an estimate of the amount of chemical exposure to which people might frequently encounter at a site (i.e., dose) to situations that in the past have been associated with disease and injury. This health effects evaluation involves a balanced review and integration of site-related environmental data, site-specific exposure factors, and toxicological, radiological, epidemiological, medical, and health outcome data to assist in determining whether exposure to contaminant levels might result in harmful effects. The goal of the health effects evaluation is to decide whether harmful effects might be possible in the exposed population by weighing the scientific evidence and by keeping site-specific doses in perspective. The output is a qualitative description of whether site exposure doses are of sufficient nature and magnitude to trigger a public health action that will limit, eliminate, or study further any potentially harmful exposures.

III.A.3. Possible Exposure Situations

During the 1970s, PCBs were found to persist and to bioaccumulate in the environment. Traces can be found in the tissues of wildlife, domestic animals, and people. These background levels of PCBs in the environment have been declining since EPA, because of concern for human health, banned PCB production in 1978 (ATSDR 2000; Kimbrough et al. 1999).

Although PCBs are no longer made nationally, people in the United States are still exposed to them. Many older transformers and capacitors still contain PCBs. For instance, those present in old electrical appliances can overheat, leak PCBs, and contaminate inside air. Discarded capacitors and transformers can also release PCBs into the environment from landfills. Before the 1970s, heavy electrical power consumers and industrial facilities such as the ORR were major releasers of environmental PCBs. Since the 1980s, however, the ORR has been under strict regulations by the state and the EPA (ChemRisk 1999a).

Major operations that produced PCBs at the ORR took place from the mid-1940s into the 1970s, within the Bear Creek Valley, Upper East Fork Poplar Creek, and Bethel Valley Watersheds. Generally, contamination left the areas either as direct releases to the waterways or as indirect releases to soil, which then washed into the waterways and settled into the sediment. In addition, occasional flooding spread smaller amounts into soil adjacent to the waterways (ChemRisk 1993a; U.S. DOE 1998).

DOE restricts public use of on-site waterways (e.g., sport or subsistence fishing is not allowed on site); therefore, ATSDR considered contamination that traveled to off-site waterways. An overview of the historical uses and disposal of PCBs reveals that potential off-site exposures probably originated from PCB contamination in sediments and biota of East Fork Poplar Creek and the Clinch River. Thus the primary off-site regions requiring investigation are Lower East Fork Poplar Creek, the Clinch River, and Watts Bar Reservoir. People could potentially contact PCBs along these waterways through dermal and oral exposure to contaminated water and sediments during recreational activities and by consumption of contaminated fish and other biota. The key issues and concerns evaluated in this PHA are depicted in Figure 14.

ATSDR identified the most critical pathway for evaluation as consumption of Clinch River and Lower Watts Bar Reservoir fish and turtles. Oak Ridge residents reported that fishing was a relatively common activity and that many of the fish caught were consumed (ChemRisk 1999a). Local anglers, however, told ATSDR that East Fork Poplar Creek is not a very productive fishing location, and very few people actually eat fish from it.

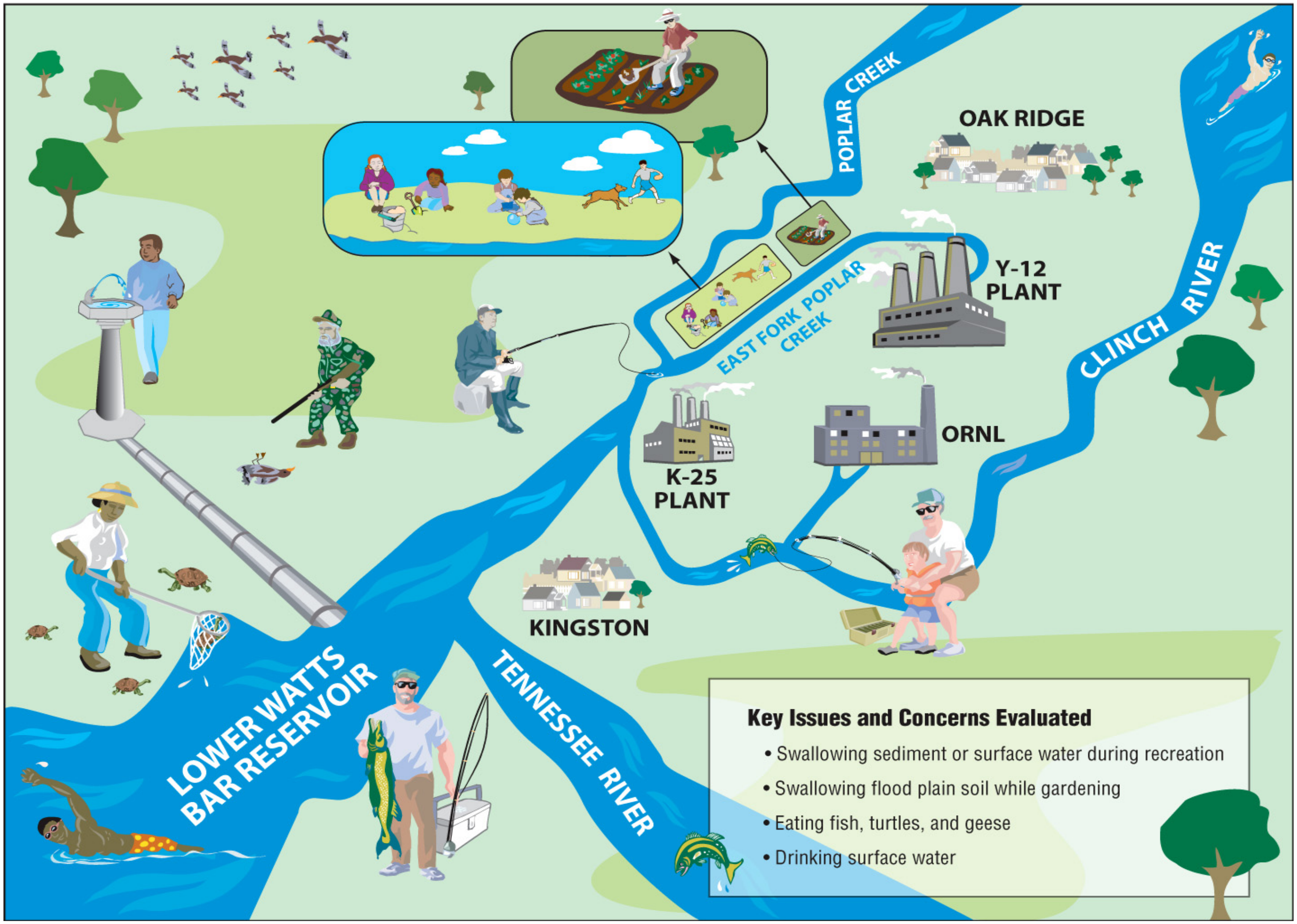
PCBs from sediment enter bottom-feeding species (e.g., worms and invertebrates). These prey become PCB sources to bottom-feeding fish, which then become prey to larger fish and to turtles. Birds and land predators—including humans—then eat the fish (and eat the birds, such as geese), and can build up body burdens of PCBs. At each step in this food web, PCBs that accumulated in the fatty tissues of prey animals can appear in greater concentrations (bio-magnification of PCB levels) in predator species that eat them. Unlike nonbiologic media (e.g., sediment), which is recurrently covered by new material, biologic media recirculates persistent contaminants such as PCBs. For example, as dead fish decompose, live fish eat the decaying matter. As a result, contaminant levels in the fish may change little over time (see Appendix C. Examples of Various Aquatic Food Webs).

After confirming previous findings that PCBs are not significantly present in surface water or groundwater (see text box), ATSDR analyzed PCB contamination data for sediment and biota to determine whether the levels detected could have the potential for past, current, or future public health hazards. When evaluating these media, ATSDR assessed the level of contamination present in the sediment and biota, the extent to which individuals come in contact with the contamination directly (e.g., by eating fish and turtles or by inadvertently ingesting soil or sediment) or indirectly (e.g., from sediment eaten by fish and turtles), and whether this contact would result in harmful health effects. Again, estimating the amount of PCBs that could have reached a person's body from the amount of PCBs in sediment or fish is inherently uncertain. To reduce some of that uncertainty, ATSDR in this PHA used PCB serum levels (a measure of the PCB level accumulated in a person's body) from people who ate moderate to large amounts of fish from the Clinch River and Watts Bar Reservoir.

Surface water itself is not a major source of exposure—PCBs are not readily water soluble. These oils, when directly spilled into water, are quickly absorbed by underlying sediments and nearby soils. Therefore, it is not surprising that historical and recent data show PCBs were nearly all below levels of detection in surface water (ChemRisk 1999a; OREIS).

Although groundwater often received releases of waste PCBs deposited in the soil, it could not transport significant quantities of the poorly soluble oils. By depositing PCBs onto the surrounding (mostly inaccessible) on-site surface soils, groundwater, as well as inaccessible subsurface soil, became barriers to migration (ChemRisk 1999a).

Figure 14. Possible Exposure Situations along ORR Waterways



III.A.4. Deriving Comparison Values

ATSDR maintains a database of standard health-based comparison values for soil, drinking water, and ambient air. ATSDR does not, however, have standard comparison values for biota such as fish, geese, and turtles. Instead ATSDR developed protective comparison values based on site-specific information about biota consumption. The Task 3 report indicated that cancer was not a likely outcome based on its evaluation of exposures to ORR-related PCB releases. Therefore, ATSDR developed comparison values for this PHA based on noncancer health effects.

ATSDR derived fish, geese, and turtle comparison values using the chronic minimal risk level (MRL) of 0.02 micrograms PCBs per kilogram body weight per day (µg/kg/day). The MRL is an estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. The chronic MRL for PCBs is based on a study in which immunological effects were observed in monkeys. MRLs have built-in uncertainty, or safety factors, making them considerably lower than doses at which health effects have been observed in human and animal studies. See ATSDR's Toxicological Profile for PCBs (ATSDR 2000) for additional information about the study on which the MRL is based.

> 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 health effects.

Fish

Comparison values for fish were generated using the fish consumption study in ATSDR's Watts Bar Reservoir Exposure Investigation (ATSDR 1998). Over 550 local fish consumers responded to the invitation to participate in this fish consumption study. About 79 percent of the volunteers ate too few fish or turtles to be eligible to participate in the study, however. The remaining 116 people, or 21 percent, ate at least six fish meals annually, with a mean of 66.5 grams per day (g/day) and a 95th percentile of 108 g/day. From this information, ATSDR derived three ranges of consumption.

> ATSDR uses comparison values to screen chemicals that require additional evaluation.

- "Low fish consumers" were defined based on the 79 percent of volunteers (and nonvolunteers, who include a higher proportion of people who did not eat any local fish) who ate too few fish to be eligible to participate in the study. They consumed between zero and six 8-ounce meals of fish a year. The midpoint equates to 1.95 g/day, or about one 8-ounce meal of fish every 4 months.

- "High fish consumers" were defined by the 95th percentile (top 5 percent) of the people eligible to participate in the study, which represents about 1 percent of the volunteers. Their mean adult consumption rate was 108 g/day, which equates to about three 8-ounce meals of fish per week.

- "Moderate fish consumers" represent the mean consumption of the group between the 79 percent of those ineligible to participate and the 1 percent who were high consumers.

Their consumption rate was 66.5 g/day, which equates to slightly more than two 8-ounce fish meals per week. This group represents about 20 percent of fish and nonfish consumers.

To screen the fish exposure pathway, ATSDR derived comparison values for PCB concentrations in fish for each consumption range by dividing the permitted PCB intake[1] (1.4 µg/kg/day for a 70-kg adult and 0.2 µg/kg/day for a 10-kg child) by the amount of fish eaten daily (in kilograms; therefore, the ingestion rates presented above are divided by 1,000). Adults were assumed to weigh 70 kilograms (150 pounds) and children were assumed to weigh 10 kilograms (22 pounds, which represents the weight of a 1-year-old child). Children were assumed to eat about one-third the amount of adults. The results are presented in Table 3.

Table 3. ORR-Specific Comparison Values for Screening PCB Concentrations in Fish

Consumption Level	*Child Comparison Value (ppb)*	*Adult Comparison Value (ppb)*
High (3 meals/week)	6	10
Moderate (2 meals/week)	9	20
Low (3 meals/year)	300	700

Comparison values are rounded.

Canada Geese

ATSDR conservatively assumed hunters might consume as much as 10 kilograms (about 22 pounds) of goose muscle per year. This amount averages to about one 6 to 8 ounce serving per week, or 27 g/day. When ATSDR surveyed fish consumers, sufficient information was obtained to assign adults to high, moderate, and low consumption groups in the ratio of 108 / 66.5 / 1.9 g/day of fish. If similar consumption ratios hold true for geese, then the amount and ratios for the three 70-kilogram adult goose consumer groups would be 27 / 17 / 0.5 g/day of goose meat. If, as assumed for the fish, 10-kilogram children eat one-third the portion sizes that adults eat, their consumption levels would be in the ratios of 9 / 5.6 / 0.16 g/day[2] of goose meat.

To derive comparison values for PCB concentrations in geese for each consumption range, ATSDR divided the permitted PCB intake[1] (1.4 µg/kg/day for a 70-kg adult and 0.2 µg/kg/day for a 10-kg child) by the amount of goose eaten daily (in kilograms; therefore, the ingestion rates presented above are divided by 1,000). Adults were assumed to weigh 70 kilograms (150 pounds) and children were assumed to weigh 10 kilograms (22 pounds, which represents the weight of a 1-year-old child) (see Table 4).

[1] The permitted PCB intake is calculated by multiplying the chronic MRL of 0.02 µg/kg/day by 70 kg for adults and 10 kg for children.
[2] The numbers do not divide evenly due to rounding for the adult group ratios.

Table 4. ORR-Specific Comparison Values for Screening PCB Concentrations in Canada Geese

Consumption Level	*Child Comparison Value (ppb)*	*Adult Comparison Value (ppb)*
High (1 meal/week)	22	52
Moderate (2 meals/month)	36	82
Low (1 meal/year)	1,250	2,800

Turtle Meat

ATSDR evaluated three turtle meat consumption levels. From the exposure investigation and interviews with its author, ATSDR learned that moderate consumers eat about 100 grams of turtle meat a year (or 0.27 g/day). High consumers eat turtle meat twice as often as moderate consumers (0.55 g/day), and low consumers eat one-sixth the amount that moderate consumers eat (about 0.05 g/day, with rounding) (ATSDR 1998).

To derive comparison values for PCB concentrations in turtle meat for each consumption range, ATSDR divided the permitted PCB intake[3] (1.4 µg/kg/day for a 70-kg adult and 0.2 µg/kg/day for a 10-kg child) by the amount of turtle meat eaten daily (in kilograms). Adults were assumed to weigh 70 kilograms (150 pounds) and children were assumed to weigh 10 kilograms (22 pounds, which represents the weight of a 1-year-old child) (see Table 5).

Table 5. ORR-Specific Comparison Values for Screening PCB Concentrations in Turtle Meat

Consumption Level	*Child Comparison Value (ppb)*	*Adult Comparison Value (ppb)*
High (2 meals/year)	500	2,500
Moderate (1 meal/year)	1,000	5,000
Low (1 meal/6 years)	6,000	30,000

Comparison values are rounded.

[3] The permitted PCB intake is calculated by multiplying the chronic MRL of 0.02 µg/kg/day by 70 kg for adults and 10 kg for children.

III.B. Exposure Evaluation of PCBs

ATSDR evaluated past and current exposure to PCB contamination in East Fork Poplar Creek, Poplar Creek, Clinch River, Tennessee River, and the Lower Watts Bar Reservoir. The screening evaluation confirmed that eating biota (fish, turtles, and geese) is the main exposure pathway to PCBs released from the ORR. ATSDR also evaluated the body-burden of PCBs in the most frequent fish and turtle consumers. As a result of the screening evaluation, the potential for human health effects from eating fish and geese was further evaluated in Section IV. Public Health Implications.

ATSDR used the following time periods and information in its evaluation.

Past Exposure: "Past" refers to the period from 1942 through 1995. To begin evaluating past exposures, ATSDR reviewed the Task 3 report (*PCBs in the Environment near the Oak Ridge Reservation—A Reconstruction of Historical Doses, and Health Risks*) and associated documents. The complete project can be accessed through TDOH's Web site at www2.state.tn.us/health/CEDS/OakRidge/ORidge.html, and a brief summarizing the Task 3 report is provided in Appendix F. Summary Briefs and Fact Sheets. For in-depth analysis of environmental data, ATSDR compiled data from DOE's OREIS, TVA, and TDEC.

Current Exposure. "Current" refers to the period from 1996 to 2004. To evaluate current exposures and doses, ATSDR used data presented in its 1996 Health Consultation entitled *Health Consultation for U.S. DOE Oak Ridge Reservation: Lower Watts Bar Reservoir Operable Unit*, its 1998 Exposure Investigation entitled *Serum PCB and Blood Mercury Levels in Consumers of Fish and Turtles from Watts Bar Reservoir*, and data from OREIS and TDEC. Briefs summarizing the Health Consultation and Exposure Investigation are provided in Appendix F. Summary Briefs and Fact Sheets.

III.B.1. Past Exposure (1942–1995)

Tennessee Department of Health's Task 3 Study

From 1992 to 1995, TDOH conducted the Task 3 study to assess whether persons visiting or living in the areas along East Fork Poplar Creek and the Watts Bar Reservoir contacted harmful levels of PCBs in the past. The wastes generated by Y-12, K-25, and X-10 during the time frame covered in the Task 3 report, 1942 through 1991, included PCBs used in electrical components and in cutting oils.

Drawing on various sources of data for ORR contamination and analogous contamination elsewhere, TDOH made conservative assumptions about the total sample PCB content and sample typicality, the access to various contamination levels present in different environmental media, the frequency of activities leading to occupational or recreational contact with these media, the amount of contamination in media that entered and remained in human bodies following exposures, and the level of resulting toxicity. To select potential pathways and ensure those deemed most harmful were identified, the first, or screening, quantitative risk assessment evaluation of exposures was highly conservative. In the second quantitative risk assessment more refined modeling was carried out, and a third level analysis described uncertainties in the process.

The Task 3 report estimated exposure intakes using quantitative risk assessment methods to combine conservative exposure point concentrations with equally conservative assumptions about exposure, exposure duration, and fraction of time exposed. Using these conservative assumptions, TDOH determined the following exposure pathways are not a public health hazard and eliminated them from further consideration for both adults and children. In addition, the screening values for ingestion of turtles exceeded the screening criteria, but were not retained for further analysis (ChemRisk 1999a).

East Fork Poplar Creek

- Dermal contact with sediment
- Dermal contact with surface water
- Incidental ingestion of surface water
- Inhalation of dust
- Eating beef from cattle that:
  - Breathed airborne PCBs
  - Ate pasture with PCBs deposited by the air
  - Drank PCBs from the water
- Drinking milk from cows that:
  - Breathed airborne PCBs
  - Drank PCBs from the water
- Eating vegetables with PCBs deposited by the air

Scarboro

- Breathing airborne PCBs

Poplar Creek

- Dermal contact with sediment
- Dermal contact with surface water
- Incidental ingestion of sediment
- Incidental ingestion of surface water

Clinch River

- Dermal contact with sediment
- Dermal contact with surface water
- Incidental ingestion of sediment
- Incidental ingestion of surface water
- Ingestion of drinking water
- Ingestion of turtles
- Breathing airborne PCBs

Watts Bar

- Dermal contact with sediment
- Dermal contact with surface water
- Incidental ingestion of sediment
- Incidental ingestion of surface water
- Ingestion of drinking water

- Ingestion of turtles

Sale of Waste Oil

- Dermal contact with soil
- Ingestion of soil
- Inhalation of dust

The Task 3 report kept 13 potential pathways for further evaluation. In general, ingested media provided greater doses than did inhaled or touched media. The main exposure pathway with the highest potential for exposure was the consumption of locally caught fish. Following are the remaining locations and exposure pathways that Task 3 kept for further evaluation.

East Fork Poplar Creek

- Incidental ingestion of sediment
- Incidental ingestion of soil
- Dermal contact with soil
- Eating locally caught fish
- Eating beef from cattle that:
  - Incidentally ingested soil
  - Ate pasture contaminated by soil
- Drinking milk from cows that:
  - Incidentally ingested soil
  - Ate pasture contaminated by soil
  - Breathed airborne PCBs and the products of burning them
- Eating vegetables containing PCBs from soil

Poplar Creek

- Eating locally caught fish

Clinch River

- Eating locally caught fish

Watts Bar

- Eating locally caught fish

After reviewing the Task 3 quantitative risk assessment, TDOH concluded that people who consumed large amounts of fish from the Clinch River and the Lower Watts Bar Reservoir were at risk from the noncancer effects of PCBs. Only three or fewer cases of cancer, however, could have resulted from eating Clinch River and Watts Bar Reservoir fish. Because the estimates and modeling are conservative, "the actual risks and expected number of cases are likely to be smaller and could be zero" (ChemRisk 1999a). Because TDOH indicated there was minimal, if any, chance of cancer risk from ORR-related PCB releases, ATSDR only evaluated noncancerous effects. See Appendix F. Summary Briefs and Fact Sheets for a summary of the Task 3 study.

ATSDR reviewed the Task 3 report and determined that the exposure pathways it eliminated could safely be removed from further consideration. Due to TDOH's robust conservatism in the

Task 3 quantitative risk assessment (i.e., exposure point estimates), ATSDR agrees that the exposure pathways eliminated by the Task 3 report are not a public health hazard and do not require further evaluation. Because of this same conservatism, however, ATSDR determined that it should perform an independent screening evaluation of the 13 pathways retained by Task 3. Also, because the Task 3 quantitative risk assessment estimated the cancer risk to be less than three cancer cases in the population eating Clinch River and Watts Bar Reservoir fish, ATSDR only evaluated noncancer health effects in the screening evaluation of these 13 pathways. See Appendix D. ATSDR's Validation of Task 3 Screening Results for further details.

ATSDR's Evaluation of the Pathways Retained by Task 3

In this section of the PHA, ATSDR screens contaminant concentrations against conservative comparison values. Comparison values are calculated concentrations of a substance in air, water, food, or soil that are unlikely to cause harmful health effects in exposed people.

> ATSDR uses comparison values as conservative screening tools during the public health assessment process. Comparison values are set much lower than the lowest amount shown to affect health. Substances found in amounts greater than their comparison values are selected for further in-depth evaluation. Contaminants detected at concentrations above comparison values do not necessarily cause adverse health effects. Comparison values are used to help ATSDR determine which contaminants need to be evaluated more closely.

Screening is a process to eliminate from consideration those exposures very unlikely to cause illness. Because ATSDR intentionally chooses comparison values that are much too low to cause disease, exposures that are not eliminated require further in-depth evaluation to determine whether that exposure is likely to cause illness. Once the elimination process is completed, ATSDR conducts a more in-depth health evaluation for those retained exposures (see Section IV. Public Health Implications).

> Oily contaminants, such as PCBs, partition between water and soil or sediment particles. Soil and sediment particles pick up oily PCBs millions of times more readily than does water (ATSDR 2000), and become the principal means for carrying this contamination off site.

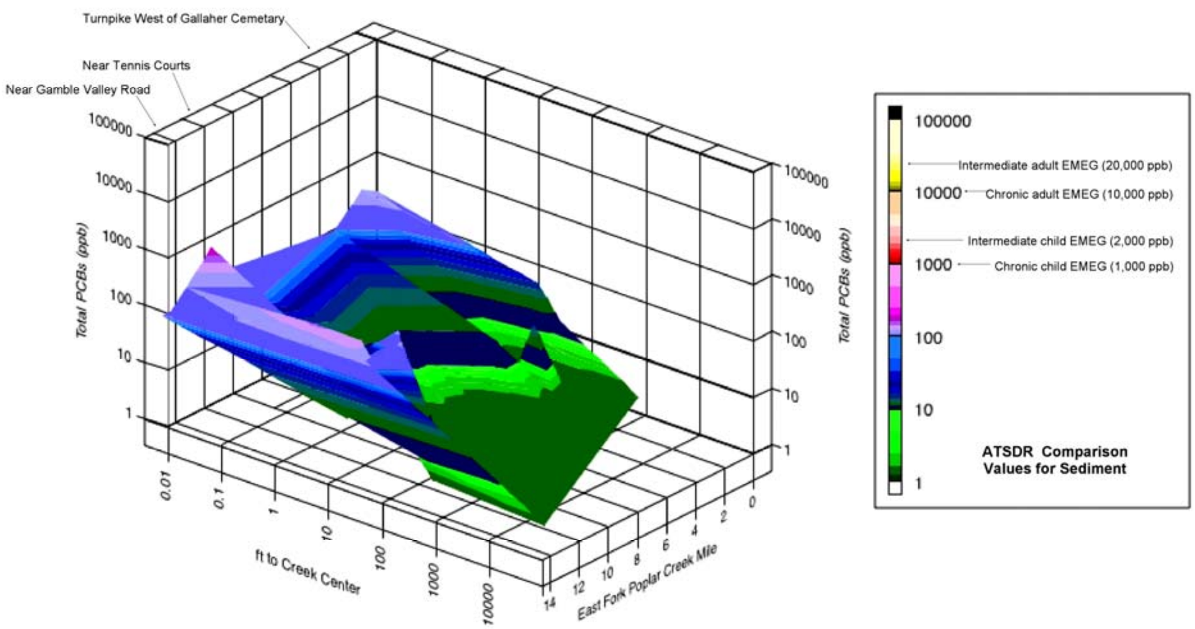
East Fork Poplar Creek Floodplain Soil and Sediment

East Fork Poplar Creek is of concern to residents in the city of Oak Ridge. The creek originates and flows through the Y-12 plant and winds through the city of Oak Ridge, flowing past residents' backyards. Children play on the creek banks and have contact with East Fork Poplar Creek floodplain sediment and soil, although not on a daily basis. The Task 3 report retained pathways carrying PCBs to floodplain soil, from which PCBs were taken up by local produce and its consumers, such as milk cows, beef cattle, and local gardeners, and transferred to consumers of local beef and milk.

ATSDR collected 1978 data from the OREIS database for East Fork Poplar Creek miles 0 through 14.8 that was tabulated in the Phase I report (ChemRisk 1993a) and 1991 to 1992 data. These data were collected from the creek bed and the floodplain. ATSDR totaled the seven aroclors (commercial mixtures of PCBs) detected in 75 samples from 63 stations. For samples indicating no PCBs were found, ATSDR assumed that the PCB concentration for that sample was midway between zero and the lowest detected concentration.

To explore the influence of position (creek mile and perpendicular distance from the creek bed center) on the level of PCB contamination, ATSDR plotted sediment/soil sampling results to display a surface representing the three-dimensional relationship between creek mile, feet from the bed center, and sediment/soil PCB concentrations in ppb (see Figure 15). Creek mile places contamination near the facilities flanking East Fork Poplar Creek. Distance away from the bed center shows the proportion of creek-bed contamination that has been carried into the floodplain and beyond. ATSDR's comparison values for soil/sediment (e.g., 1,000 ppb is the chronic child environmental media evaluation guide [EMEG]) are also illustrated along the PCB concentration axis in Figure 15. For a more direct illustration of the distribution of sampling, see Figure 16, a map of East Fork Poplar Creek and its sediment sampling points.

Figure 15. PCBs Detected* in East Fork Poplar Creek Sediment



*Samples with no detected PCBs are shown as having one half the lowest detected concentration of Aroclor 1254 (■)

To understand Figure 15, begin by picturing a large flat surface, such as the ground. On this large flat area lies a conventional two-dimensional graph. The x-axis indicates mile markers along East Fork Poplar Creek. The y-axis indicates the distance from the center of the creek bed to the exact location where the samples were taken. Next, imagine driving some stakes into the ground at different heights, which indicate the PCB concentration in each of the samples, at each of their creek-mile/distance markers. Now throw a bed sheet over the stakes so that it drapes over them, like a tent. What you arrive at is a three-dimensional depiction of PCB concentrations at different mile markers along the creek at different locations within the creek bed, deviating right or left from the center.

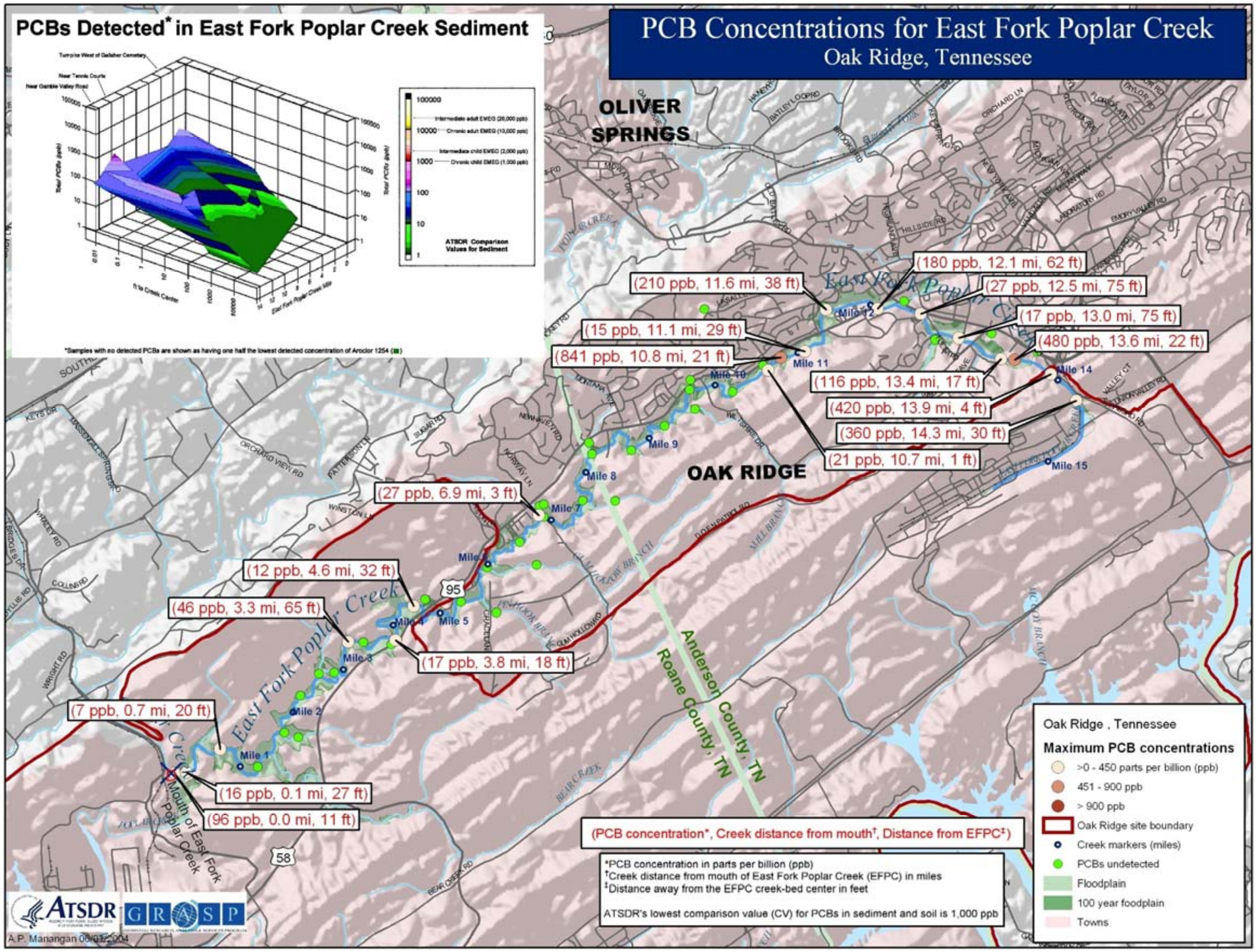
Figure 15 shows that both on site and off site detected contaminant levels in the East Fork Poplar Creek bed sediment are below the lowest sediment comparison value for PCBs (1,000 ppb). Moreover, these low levels decline still further as they are carried from the creek bed into the floodplain. Exposure to East Fork Poplar Creek sediment or floodplain soil PCB levels does not pose a public health hazard. This means that gardening or farming the soil, eating the resulting produce, and eating beef or drinking milk from cattle that grazed the floodplain are all unlikely to cause harmful health effects. Therefore, the following nine East Fork Poplar Creek pathways are not a public health hazard and can safely be eliminated from further evaluation:

> Comparison values are conservative health-based values developed by ATSDR from available scientific literature concerning exposure and health effects. Comparison values are media-specific and reflect an estimated contaminant concentration that is not expected to cause harmful health effects for a given contaminant, assuming a standard daily contact rate (for example, the amount of water or soil consumed or the amount of air breathed) and representative body weight. Because they reflect concentrations that are much lower than those that have been observed to cause adverse health effects, comparison values are protective of public health in essentially all exposure situations. As a result, **concentrations detected at or below ATSDR's comparison values are <u>not</u> considered to be a public health hazard**.

<u>East Fork Poplar Creek</u>

- Incidental ingestion of sediment
- Incidental ingestion of soil
- Dermal contact with soil
- Eating beef from cattle that:
  - Incidentally ingested soil
  - Ate pasture contaminated by soil
- Drinking milk from cows that:
  - Incidentally ingested soil
  - Ate pasture contaminated by soil
  - Breathed airborne PCBs and the products of burning them
- Eating vegetables containing PCBs from soil

Figure 16. Map of PCB Sediment Sampling Stations Along East Fork Poplar Creek



Eating Fish from East Fork Poplar Creek, Lower Watts Bar Reservoir, Clinch River, Tennessee River, and Poplar Creek

Water and sediment in the waterways in and near the ORR do not themselves contain sufficient PCB contamination to result in harmful health effects. But surface water and sediment present opportunities for increased human exposure via biomagnification of PCB levels. Sediment particles bear decaying biomatter that feed small aquatic species. These species are food sources for bottom-feeding fish, such as catfish and gizzard shad. Small predator fish feed on these, and larger, second order predators feed on the smaller ones.

> Food chains occur among terrestrial species also. But the effect on human exposure is greater through the aquatic chain because people are more likely to consume the meat of higher-order aquatic predators (e.g., large fish, turtles, and waterfowl) than land predators (e.g., mountain lions and hawks). See Appendix C for examples of various aquatic food chains.

Residents living along or visiting the waterways in and near the ORR have expressed concerns about their consumption of PCB-contaminated fish and turtles. The Task 3 team conducted a quantitative risk assessment on fish consumption, but not on turtle consumption. The Task 3 report based its conclusions about fish on screening assumptions, and conservatively assumed 100 percent efficiency of uptake of PCBs from aquatic biota into the human body. In ATSDR's reevaluation of the fish and turtle pathway, it intensively reviewed nearly 53,000 biota records, concentrating on species in the aquatic food chain—fish, turtles, and Canada geese.

The data were analyzed to compare Aroclor totals versus congener totals of PCBs. Aroclor totals overstate contamination whereas congener totals may understate it. In every analysis, total PCBs summed from Aroclors exceeded those from the individual congeners, making total PCB estimates based on Aroclor analyses the more conservative (though potentially less accurate) approach for screening. Appendix E. PCBs Measured as Total Congeners or Total Aroclors discusses this analysis in more detail.

East Fork Poplar Creek

In 1993, ATSDR evaluated a summary of the 1990 and 1991 fish data from East Fork Poplar Creek, which was compiled by the DOE Biological Monitoring and Abatement Program (ATSDR 1993). The concentrations of PCBs in fish fillet samples ranged from less than 10 to 3,860 ppb. While these levels are above the fish comparison values presented in Table 3, ATSDR eliminated East Fork Poplar Creek fish consumption as a potential exposure pathway because East Fork Poplar Creek is not a very productive fishing location and people do not frequently eat East Fork Poplar Creek fish over a prolonged period of time. Most local fish are caught from the Clinch River and the Watts Bar Reservoir, with some from Poplar Creek, especially near its confluence with East Fork Poplar Creek, but very few fish are actually caught and consumed from East Fork Poplar Creek.

Lower Watts Bar Reservoir Fish

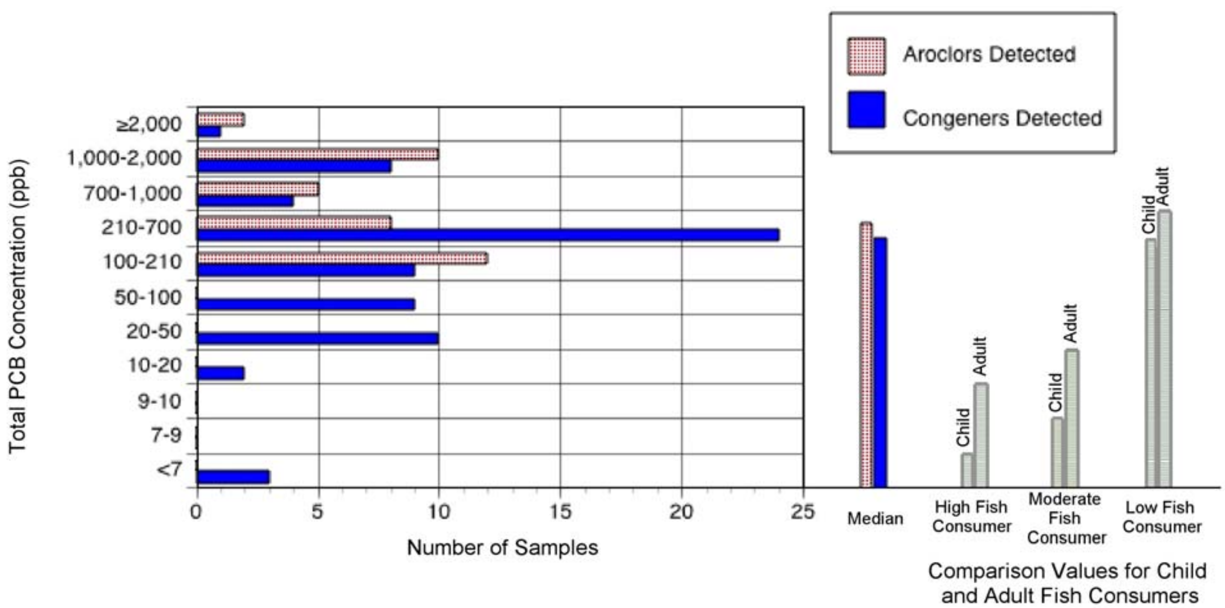
ATSDR evaluated the PCB concentrations in fish from the Lower Watts Bar Reservoir—the area of the Tennessee River extending from the city of Kingston to the Watts Bar Dam. Figure 17 shows histograms of the levels of PCBs found in Lower Watts Bar Reservoir fish as total

Aroclors and total congeners, with their respective medians compared to the PCB comparison values derived in Table 3. The median concentrations for adults in the low fish consumption group are below the PCB comparison value. Therefore, adults eating three fish meals per year or less eat too few fish for the PCB contamination in the reservoir to be a public health hazard. The median PCB concentrations, however, exceed not only the PCB comparison values for children in the low fish consumption group, they also exceed the comparison values for both adults and children in the moderate and high fish consumer groups. Therefore, eating fish from Lower Watts Bar Reservoir is further evaluated in Section IV (Public Health Implications).

Presentation of Fish Data

To illustrate the distribution of fish contamination, as well as the number of samples in each range, ATSDR generated histograms from fish data. The histograms show the number of samples with PCB concentrations in a series of ranges selected for comparison to the fish comparison values shown in Table 3. Numbers of samples, rather than the percentages, are presented so that readers can see the numerical strength of the underlying data. Each histogram figure is coupled with additional bars representing median concentration and fish comparison values drawn in proportion to the range limits in the histogram.

Figure 17. PCBs in Fish Taken from the Lower Watts Bar Reservoir Before 1996



● Above CV
○ Below CV

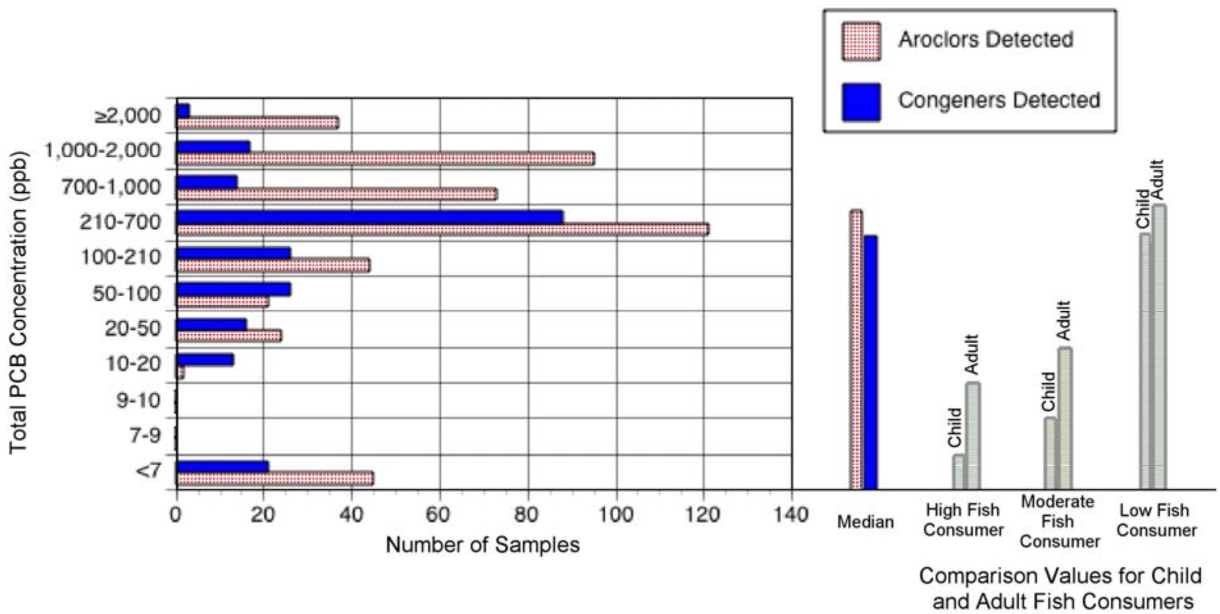
Median Concentration	High Fish Consumer Comparison Values		Moderate Fish Consumer Comparison Values		Low Fish Consumer Comparison Values	
	Child (6 ppb)	Adult (10 ppb)	Child (9 ppb)	Adult (20 ppb)	Child (300 ppb)	Adult (700 ppb)
Aroclors (500 ppb)	●	●	●	●	●	○
Congeners (305 ppb)	●	●	●	●	●	○

Clinch River Fish

ATSDR evaluated the PCB concentrations in fish from the Clinch River—the area from the Melton Hill Dam to the confluence with the Tennessee River near the city of Kingston.

Figure 18 shows that adults in the low fish consumption group eat too few fish for the PCB contamination in the river to be a public health hazard (i.e., the median concentrations for adults eating about three fish meals a year or less are below the PCB comparison value). However, the median PCB concentrations exceeded the PCB comparison values for children in the low fish consumption group as well as both adults and children in the moderate and high fish consumer groups. Therefore, eating fish from the Clinch River is further evaluated in Section IV (Public Health Implications).

Figure 18. PCBs in Fish Taken from the Clinch River Before 1996



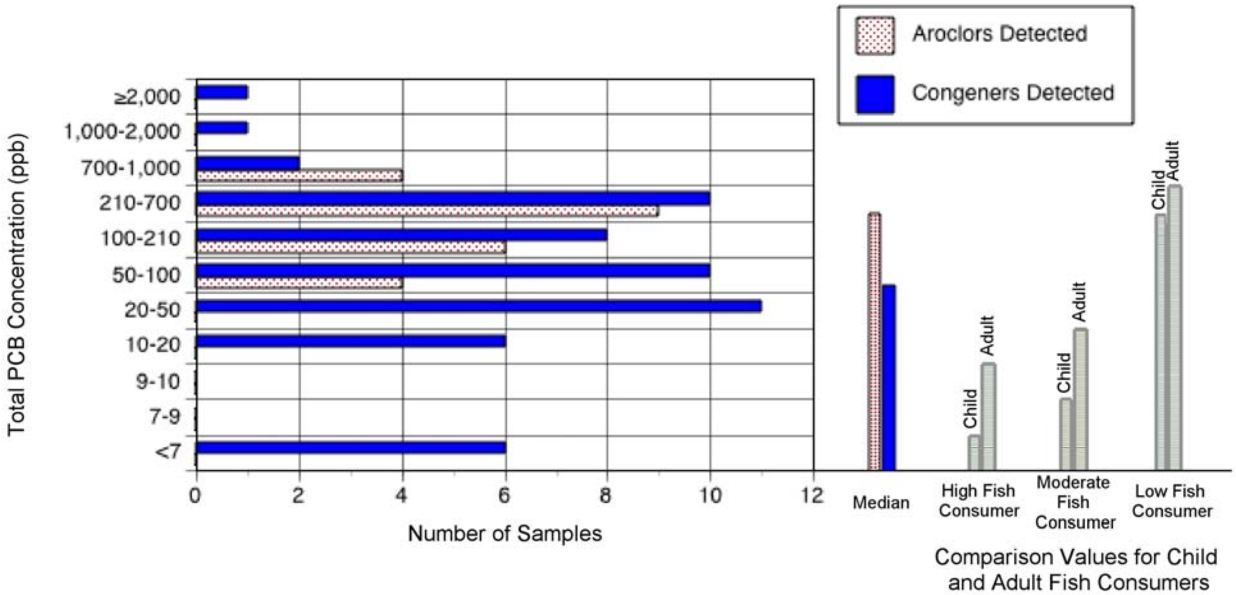
● Above CV		
○ Below CV		

Median Concentration	High Fish Consumer Comparison Values		Moderate Fish Consumer Comparison Values		Low Fish Consumer Comparison Values	
	Child (6 ppb)	Adult (10 ppb)	Child (9 ppb)	Adult (20 ppb)	Child (300 ppb)	Adult (700 ppb)
Aroclors (595 ppb)	●	●	●	●	●	○
Congeners (257 ppb)	●	●	●	●	○	○

Tennessee River Fish

ATSDR evaluated the PCB concentrations in fish from the Tennessee River from Loudon Dam to the confluence with the Clinch River near the city of Kingston. As shown in Figure 19, the median concentrations for adults in the low fish consumption group are below the PCB comparison value. Therefore, adults eating three fish meals per year or less eat too few fish for the PCB contamination in the river to be a public health hazard. However, the median PCB concentrations exceeded the PCB comparison values for children in the low fish consumption group, as well as the comparison values for both adults and children in the moderate and high fish consumer groups. Therefore, eating fish from the Tennessee River is further evaluated in Section IV (Public Health Implications).

Figure 19. PCBs in Fish Taken from the Tennessee River Before 1996



Legend
● Above CV
○ Below CV

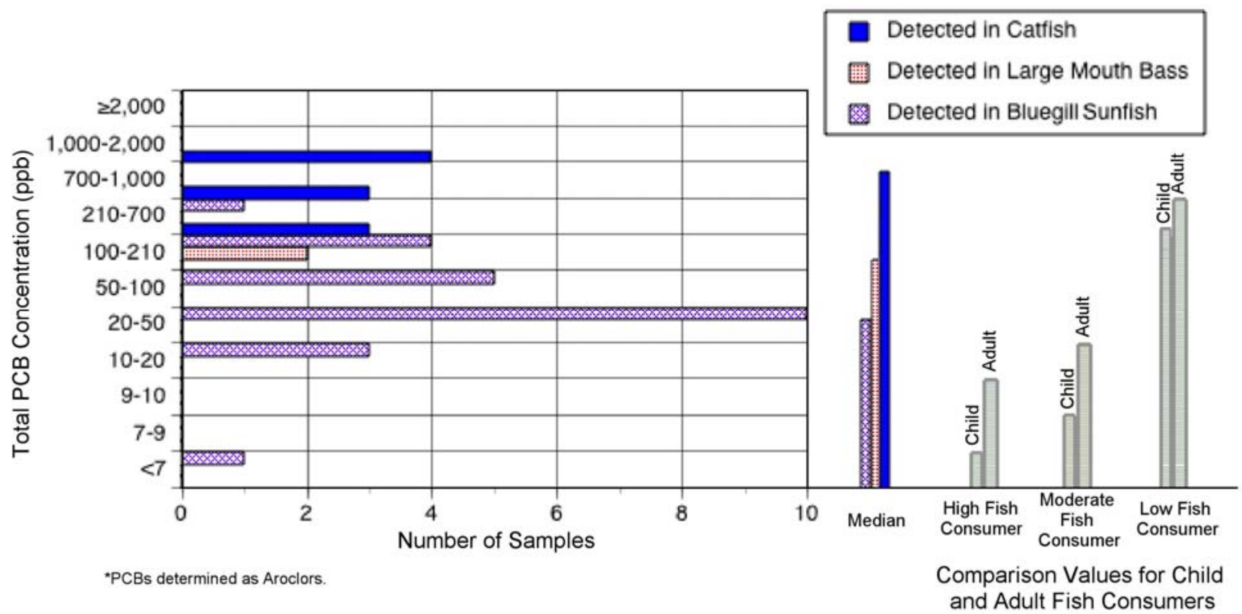
Median Concentration	High Fish Consumer Comparison Values		Moderate Fish Consumer Comparison Values		Low Fish Consumer Comparison Values	
	Child (6 ppb)	Adult (10 ppb)	Child (9 ppb)	Adult (20 ppb)	Child (300 ppb)	Adult (700 ppb)
Aroclors (300 ppb)	●	●	●	●	●	○
Congeners (60 ppb)	●	●	●	●	○	○

Off-site Poplar Creek Fish

Few PCB fish data are available from off-site Poplar Creek, and fewer still from its East Fork Poplar Creek confluence. Ten catfish and two largemouth bass were sampled from the confluence. Twenty-four sunfish[4] were taken upstream. Data were reported as Aroclors (see Figure 20). The median PCB concentration for catfish exceeded the PCB comparison values for all fish consumption groups. Eating largemouth bass or sunfish three or fewer times a year will not result in harmful health effects for adults or children (i.e., the PCB concentrations were below the comparison values for low fish consumers). The median PCB concentrations of largemouth bass and sunfish exceeded, however, the comparison values for both moderate and high consumption groups. Therefore, eating fish from Poplar Creek is further evaluated in Section IV (Public Health Implications).

> Aside from spurious variation inherent in small numbers, the variation in contamination levels in the Poplar Creek fish could have resulted either from the location where the sample was taken, or from the feeding habits of the different species.

Figure 20. PCBs* in Fish Taken from Poplar Creek Before 1996



● Above CV
○ Below CV

Median Concentration	High Fish Consumer Comparison Values		Moderate Fish Consumer Comparison Values		Low Fish Consumer Comparison Values	
	Child (6 ppb)	Adult (10 ppb)	Child (9 ppb)	Adult (20 ppb)	Child (300 ppb)	Adult (700 ppb)
Catfish (920 ppb)	●	●	●	●	●	●
Largemouth Bass (130 ppb)	●	●	●	●	○	○
Sunfish (40 ppb)	●	●	●	●	○	○

[4] References to sunfish include the bluegill species.

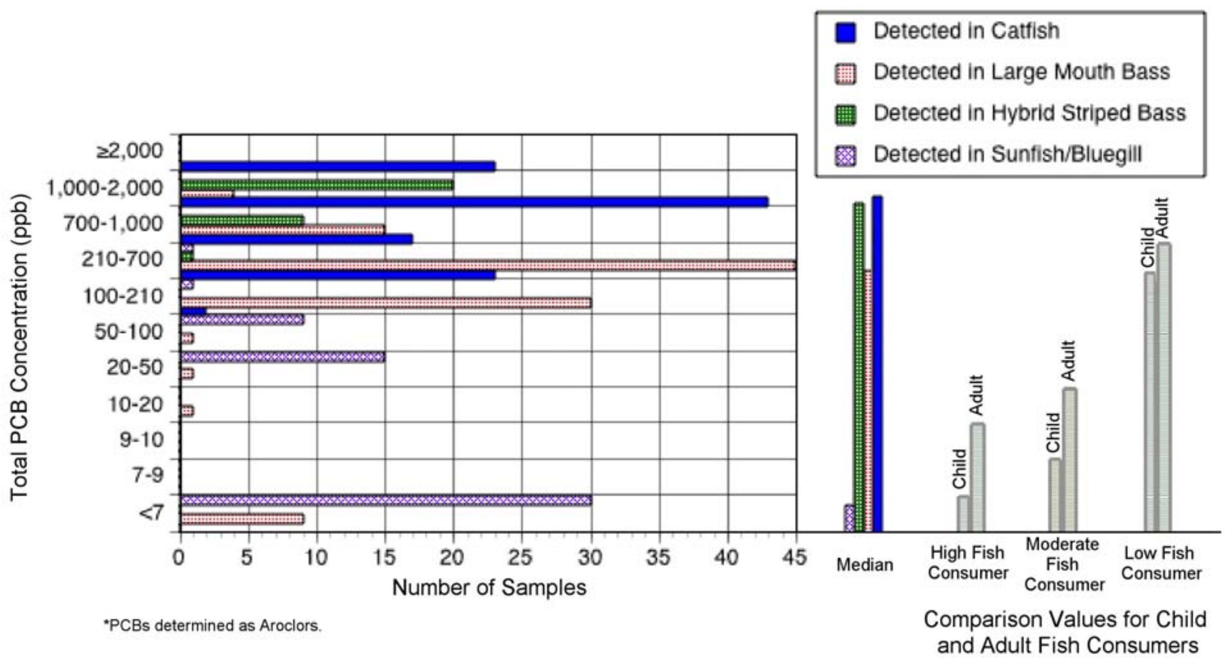
PCB Contamination in Watts Bar Reservoir Fish, by Species

Figure 21 shows PCB distribution by species, available in the sampling database for the entire Watts Bar Reservoir. The total numbers of sunfish, largemouth bass, striped bass, and catfish were 60, 106, 30, and 56 samples, respectively. The concentrations of PCBs in sunfish are much less than the concentrations in other fish species. The largemouth bass are less contaminated than the striped bass and channel catfish. Note also that the striped bass found in the Watts Bar Reservoir have about the same PCB concentrations, on average, as do the catfish.

These differences in PCB concentrations are to be expected from the species' order of predation, or trophic levels (i.e., who feeds on whom). Medium-sized striped bass and channel catfish feed on sunfish. Catfish, being bottom-feeders, also consume decaying matter from the river bed. Larger catfish and striped bass feed on the smaller predator fish, including some largemouth bass (see Appendix C. Examples of Various Aquatic Food Webs).

> Contamination in fish increases from prey, to predator, to prey again, and so on. Each fish biomagnifies fat-soluble PCBs in the fatty tissues of its food into its own fatty tissues, which then become biomagnified in its predator's fat.

Figure 21. PCBs* in Fish Taken from Watts Bar Reservoir Before 1996



● Above CV	○ Below CV

Median Concentration	High Fish Consumer Comparison Values		Moderate Fish Consumer Comparison Values		Low Fish Consumer Comparison Values	
	Child (6 ppb)	Adult (10 ppb)	Child (9 ppb)	Adult (20 ppb)	Child (300 ppb)	Adult (700 ppb)
Catfish (1,250 ppb)	●	●	●	●	●	●
Largemouth Bass (300 ppb)	●	●	●	●	●	○
Hybrid Bass (1,050 ppb)	●	●	●	●	●	●
Sunfish (5 ppb)	○	○	○	○	○	○

Figure 21 shows that consumption of sunfish from the Watts Bar Reservoir is safe because the median PCB concentration is well below all PCB comparison values for adults and children. The median PCB concentrations for catfish and hybrid bass (striped bass-white bass) exceed, however, the comparison values for all consumption groups. The median PCB concentration for largemouth bass exceeds the adult comparison values for moderate and high consumption and the child comparison values for all three consumption groups. Therefore, eating fish from Watts Bar Reservoir is further evaluated in Section IV (Public Health Implications).

Eating Canada Geese

As an example of a high-order predator in the aquatic food chain, ATSDR chose Canada Geese, which feed on all sizes of fish in waterways in and near the ORR. Data were available for goose liver and muscle. PCBs were undetected in the goose liver samples, but Aroclors were found close to the limit of quantitation of 40 to 80 ppb in all goose muscle samples. The median concentration of all the Aroclors in each of the 10 goose muscle samples was 320 ppb.

Table 6. PCB Levels for Canada Geese Compared to ORR-Specific Comparison Values

Consumption Level	*Child Comparison Value (ppb)*	*Adult Comparison Value (ppb)*	*Goose Muscle PCBs (ppb)*
High (1 meal/week)	22	52	320
Moderate (2 meals/month)	36	82	320
Low (1 meal/year)	1,250	2,800	320

Table 6 shows that the median PCB concentration reported for goose muscle exceeds the PCB comparison values for adults and children who eat moderate to high levels of Canada geese. Therefore, eating Canada geese is further evaluated in Section IV (Public Health Implications).

Summary of ATSDR's Screening Evaluation of Past Exposure (Before 1996)

ATSDR began the evaluation by validating the Task 3 scientists' elimination of the media and exposure pathways deemed unlikely to cause illness. For the 13 pathways not eliminated by the Task 3 team and for the consumption of geese, ATSDR screened concentrations in each exposure pathway separately. For nonbiological media, such as sediment and soil, ATSDR compared the distribution of actual PCB contamination with estimated protective PCB comparison values developed for children and adults exposed for chronic and intermediate durations. For biological media, such as fish and geese, ATSDR compared the distribution of PCB contamination with ORR-specific PCB comparison values developed based on self-reported consumption values and conservative assumptions about the relative intake levels of adults and children.

- ATSDR found that no source of sediment below any body of water or at any distance from sediment beds into a floodplain, or taken from any depth (deposited at any time) was sufficiently contaminated with PCBs such that illness could result from any duration of exposure to adults or children. Thus, all pathways based on direct or indirect intake of PCB-contaminated sediment are not a public health hazard and were therefore eliminated from further health effects evaluation.

- The median PCB concentrations for some of the fish species in some consumption groups exceeded the ATSDR comparison values for both adults and children. Therefore, consumption of fish was retained for further in-depth health effects evaluation (see Section IV. Public Health Implications).

- The median PCB concentration for goose muscle exceeded the PCB comparison values for adults and children who eat moderate to high levels of Canada geese. Therefore, eating Canada geese was retained for further in-depth health effects evaluation (see Section IV. Public Health Implications).

- Table 7 presents a brief summary of pre-1996 screening results. All retained exposure media and pathways are further evaluated in Section IV (Public Health Implications).

Table 7. Summary of ATSDR's Screening Evaluation of Past Exposure to PCBs Before 1996

Medium	*Source/Species*	*Eliminated Not of Public Health Hazard*	*Retained for Further Health Effects Evaluation*
Sediment	East Fork Poplar Creek creek bed	All	None
	East Fork Poplar Creek floodplain	All	None
Fish	East Fork Poplar Creek	All	None
	Lower Watts Bar Reservoir	Low consuming adults	Moderate to high consuming adults & all children
	Clinch River	Low consuming adults	Moderate to high consuming adults & all children
	Tennessee River	Low consuming adults	Moderate to high consuming adults & all children
	Catfish	None	All
	Poplar Creek largemouth bass	Low consumers	Moderate to high consumers
	Poplar Creek sunfish	Low consumers	Moderate to high consumers
	Watts Bar Reservoir largemouth bass	Low consuming adults	Moderate to high consuming adults & all children
	Watts Bar Reservoir hybrid bass	None	All
	Watts Bar Reservoir sunfish	All	None
Geese	All	Low consumers	Moderate to high consumers

III.B.2. Current Exposures (1996–2004)

Since 1996, TDEC and DOE have continued to collect environmental samples in and near the ORR and to analyze them for PCBs. ATSDR compiled site-related environmental data on PCBs and other contaminants from areas surrounding the ORR (mainly from OREIS and TDEC). For the evaluation of current exposures, ATSDR reviewed ORR data from 1996 to 2004.

ATSDR also reviewed the data published in the ATSDR exposure investigation report on serum PCB levels in consumers of fish and turtles from Watts Bar Reservoir (ATSDR 1998), interviewed the author for additional unpublished observations, and presented the results of additional analysis of the data from the blood samples. ATSDR conducted the exposure investigation because of the uncertainties associated with the quantitative risk assessment methods used in previous studies to evaluate the contaminants in the Clinch River and the Watts Bar Reservoir. The previous investigations evaluated many contaminants in the Watts Bar Reservoir and the Clinch River, but identified only PCBs in reservoir fish as a possible contaminant posing a health hazard. This finding by the previous studies was based on 1) an estimation of PCB exposure doses and conservative modeled increases of cancer likelihood after consuming large amounts of fish over an extended period of time, and 2) an assumption that all the PCBs in the fish were taken up into and remained in the bodies of the consumers. These previous studies only estimated and did not confirm that people were actually being exposed or that sufficient amounts of PCBs had accumulated in the people. The ATSDR exposure investigation measured the actual PCB body-burden (PCBs in the serum) of people who ate moderate to large amounts of fish and turtles from the Watts Bar Reservoir. ATSDR also interviewed the anglers about how they prepared their fish and turtles for consumption, and how much and how often they ate fish and turtles.

Sediment

Contamination from oily PCBs persists in the particles of sediment and soil for many years after release into the environment. But the contamination becomes less bioavailable over time:

- The oil slowly seeps from the particle surfaces inward towards the particle centers, from which it not easily extracted by the intestines of fish, animals, and people.
- Contaminated particles become overlain with uncontaminated particles carried by wind and water.

<u>East Fork Poplar Creek Sediment</u>

In Section III.B.1., ATSDR showed East Fork Poplar Creek floodplain sediment contamination before 1996, was most frequent between East Fork Poplar Creek Mile 14.5 (Williams Bend), where the creek emerges from Y-12, and East Fork Poplar Creek Mile 10.5, near Louisiana Avenue (see Figure 15 and Figure 16). Sediment in East Fork Poplar Creek at Williams Bend was sampled 11 times from January 1996 to May 2001. PCBs were not detected in any samples. Therefore, PCBs in the East Fork Poplar Creek floodplain are not a public health hazard for people who live near and visit the area, and will not be evaluated further.

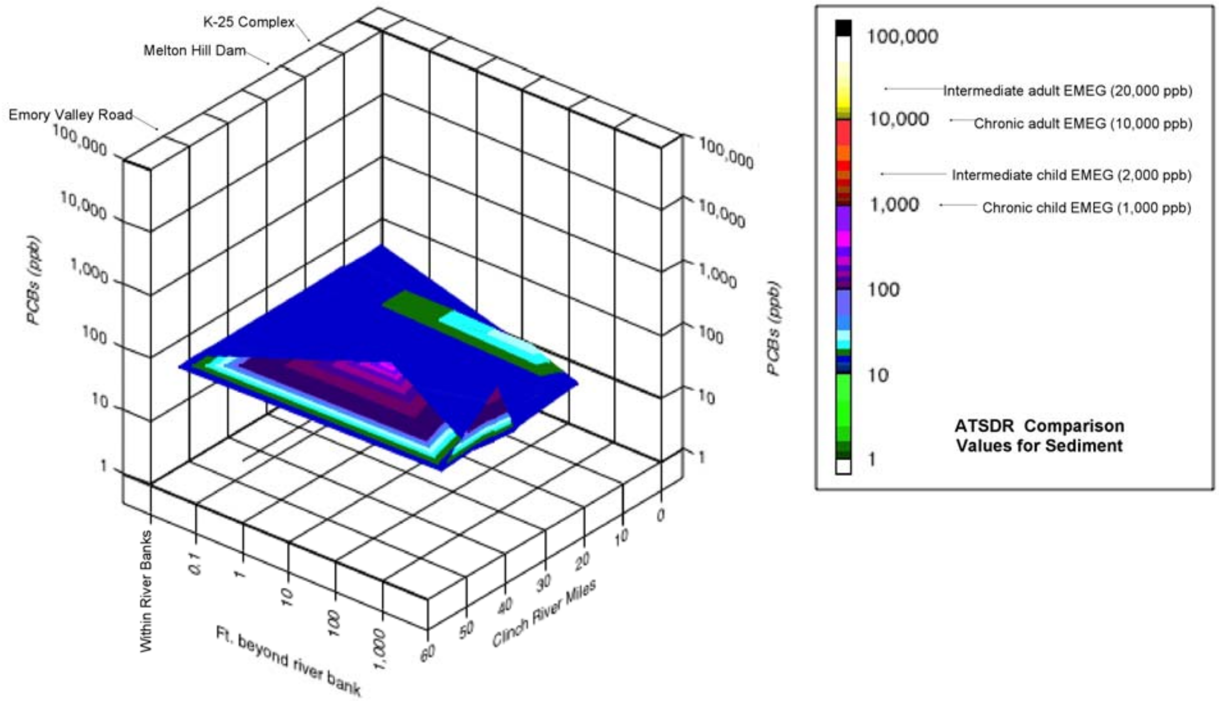
Clinch River Sediment

PCB contamination of Clinch River sediment was primarily in subsurface layers deposited during the years 1950 to 1970, when the ORR used PCBs heavily and discarded them into the environment. Most contamination was detected near the mouth of the Clinch River where the Clinch joins the Tennessee River and in the core sample at CRM 9.5, which was about 40 centimeters deep and deposited around 1960. Since 1996, 189 Clinch River surface sediment samples were collected from 28 stations along the river. PCBs were detected at three sampling stations:

- At CRM 14.4 (on site, west of Grassy Creek), PCBs were detected once in 1997, but not in six subsequent sampling events up to 2001.
- At CRM 37.8 (near McCoy Branch), three nondetect samples in 1997 and 1998, were followed by a positive detection in 2000.
- At CRM 51.1 (near Anderson, upstream from the ORR), the one sample from the embayment was positive for PCBs in 2000.

To display positive samples amidst many negative ones at the same station, negative data points were suppressed in the figure below (Figure 22). Figure 22 shows the resulting three-dimensional surface plot relating Clinch River mile and distance from the riverbed center to the sediment PCB concentrations detected. The color key to the side of the surface plot displays ATSDR's PCB comparison value for soil (e.g., the chronic child EMEG is 1,000 ppb), showing that all samples were below ATSDR PCB comparison values. Thus, directly or indirectly swallowing or touching PCB-contaminated sediment in the Clinch River is not a public health hazard for people visiting or living near the river. Exposure pathways related to sediment were not retained for further evaluation.

Figure 22. PCBs Detected* in Clinch River Sediment Since 1996



*Samples with no detected PCBs are shown as having one half the lowest detected concentration of Aroclor 1260 (■)

Surface Water and Groundwater

Because PCBs are poorly soluble, surface water is not a major source of exposure. Thus ATSDR eliminated surface water as a potential exposure pathway. These oils, when directly spilled into water, drift down to and are absorbed by underlying sediments and nearby soils. That historical and recent data indicated PCBs in surface water were nearly all below levels of detection is not surprising (ChemRisk 1999a; OREIS). ATSDR identified trace PCB levels in the surface water (OREIS). PCBs in the water, however, could not have been higher than 0.0003 ppb—total sediment PCB concentrations never exceeded 929 ppb (this determination is based on the log octanol-water coefficients for Aroclors 1254 and 1260 (ATSDR 2000; ChemRisk 1999a)). The highest possible surface water concentration (0.0003 ppb) is 667 to 2,333 times less than ATSDR's PCB comparison values for chronic drinking water by adults and children (0.7 and 0.2 ppb, respectively). These PCB comparison values assume children and adults drink one and two liter(s) of water a day, respectively. For recreational water use (e.g., swimming and water-skiing), the average daily water intake is much less (e.g., 0.15 liters represents the amount of water ingested during a 3-hour swimming event) (U.S. EPA 1997). Therefore, PCBs in the surface water are not a public health hazard. Both drinking and recreational use of surface water from 1996 onward are eliminated from further consideration. Further, on-site groundwater often received releases of waste PCBs (see Section II. Background), but could not transport significant quantities because of the off-site soils' limited solubility. On-site groundwater thus became a barrier to migration by depositing the waste PCBs instead onto (largely inaccessible) on-site surface soil and subsurface soil (ChemRisk 1999a). ATSDR addressed exposures to off-site groundwater in a separate PHA.

In addition, TDEC's Division of Water Supply regulates drinking water at all public water systems. According to EPA's Safe Drinking Water Information System, the Kingston, Spring City, and Rockwood public water supply systems have not had any significant violations (U.S. EPA 2004b).

Air

PCBs are not currently being released from the ORR into the air. The air pathway makes less of a contribution to PCB exposure than sediment or water. ATSDR has shown that the sediment and water pathways did not carry sufficient PCB concentrations to be a health hazard. Therefore, the air pathways from 1996 onward are also not a health hazard and will not be retained for further investigation.

Fish

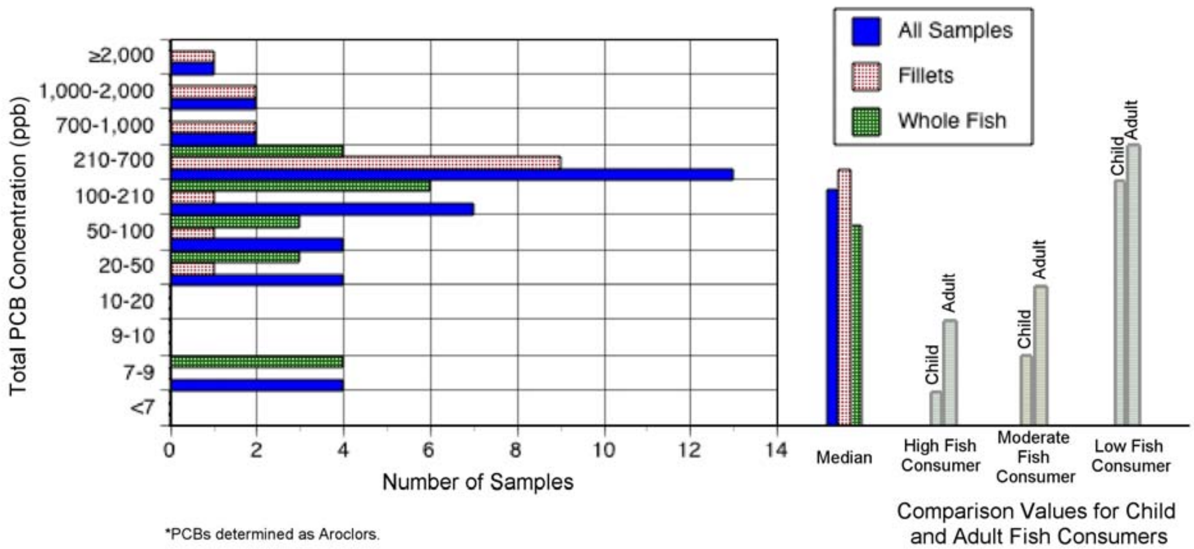
ATSDR evaluated fish data collected from 1996 to 2004 and compared the PCB concentrations to ATSDR's PCB comparison values shown in Table 3. The data are again presented as histograms and medians to show the distribution and central tendencies of the contamination. Because total Aroclors provide more conservative estimates of fish contamination, these measurements were used to assess samples taken from 1996 to 2004.

The OREIS database contains PCB concentrations for both fillets and whole fish samples in the Lower Watts Bar Reservoir, the Clinch River, and the Tennessee River. Some people, especially subsistence and ethnic consumers, might prefer whole fish, while others might prepare and serve fillets almost exclusively. PCBs collect in fat; fillet muscle dissected away from the skin would have lower fat (and PCB) content than would whole fish served with skin and internal organs intact. But if only the fins, heads, tails, and innards are removed, the fillets would retain the fat under the skin and could have higher PCB concentrations than whole fish, whose inner organs might have less fat. To evaluate the most conservative PCB concentrations for fish sampled in these waterways, ATSDR compared both types of samples.

<u>Lower Watts Bar Reservoir Fillet and Whole Fish</u>

Figure 23 displays the distribution of PCBs in Lower Watts Bar Reservoir fillets and whole fish. Fillets contain higher PCB concentrations than do whole fish. The median concentrations for adults in the low fish consumption group are below the PCB comparison value. Therefore, adults eating three fish meals per year or less eat too few fish for the PCB contamination in the reservoir to be a public health hazard. That said, the median PCB concentrations did exceed the PCB comparison values for both adults and children in the moderate and high fish consumer groups, and for children eating fillets in the low consumer group. Consequently, eating fish from the Lower Watts Bar Reservoir is further evaluated in Section IV (Public Health Implications).

Figure 23. PCBs* in Lower Watts Bar Reservoir Fish Since 1996



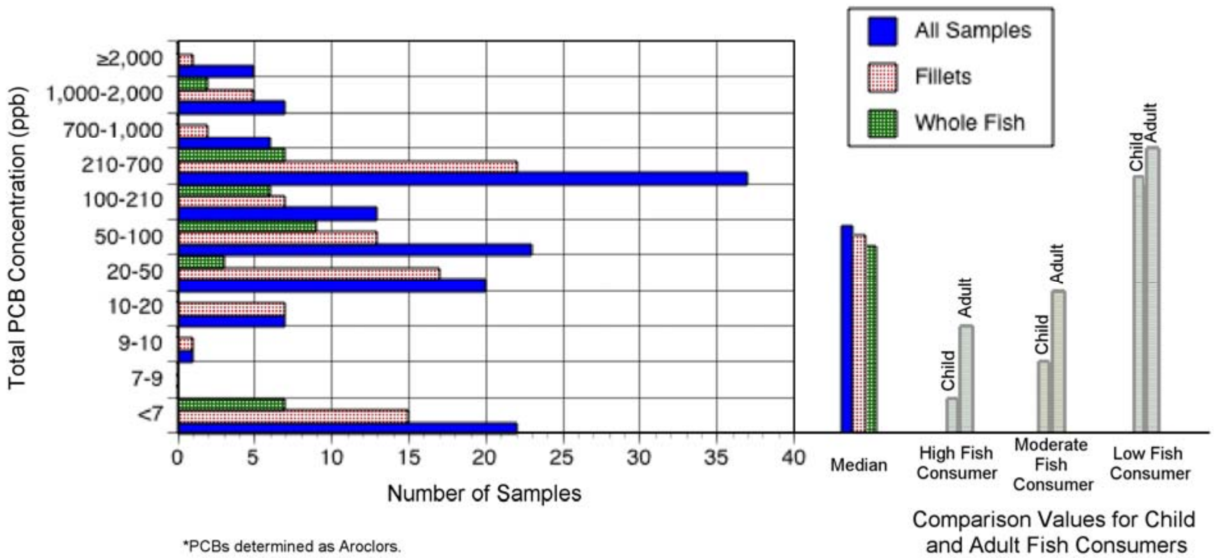
Legend
● Above CV
○ Below CV

Median Concentration	High Fish Consumer Comparison Values		Moderate Fish Consumer Comparison Values		Low Fish Consumer Comparison Values	
	Child (6 ppb)	Adult (10 ppb)	Child (9 ppb)	Adult (20 ppb)	Child (300 ppb)	Adult (700 ppb)
All Samples (190 ppb)	●	●	●	●	○	○
Fillets (320 ppb)	●	●	●	●	●	○
Whole Fish (88 ppb)	●	●	●	●	○	○

<u>Clinch River Fillet and Whole Fish</u>

Figure 24 shows a qualitatively similar pattern for fillets and whole fish taken from the Clinch River, although the difference between fillets and whole fish is less pronounced. Adults and children eating three fish meals per year or less eat too few fish for the PCB contamination in the river to be a public health hazard (i.e., the median concentrations for adults and children in the low fish consumption group are below the PCB comparison values). The median PCB concentrations did, however, exceed the PCB comparison values for both adults and children in the moderate and high fish consumer groups. Therefore, eating fish from the Clinch River is further evaluated in Section IV (Public Health Implications).

Figure 24. PCBs* in Clinch River Fish Since 1996



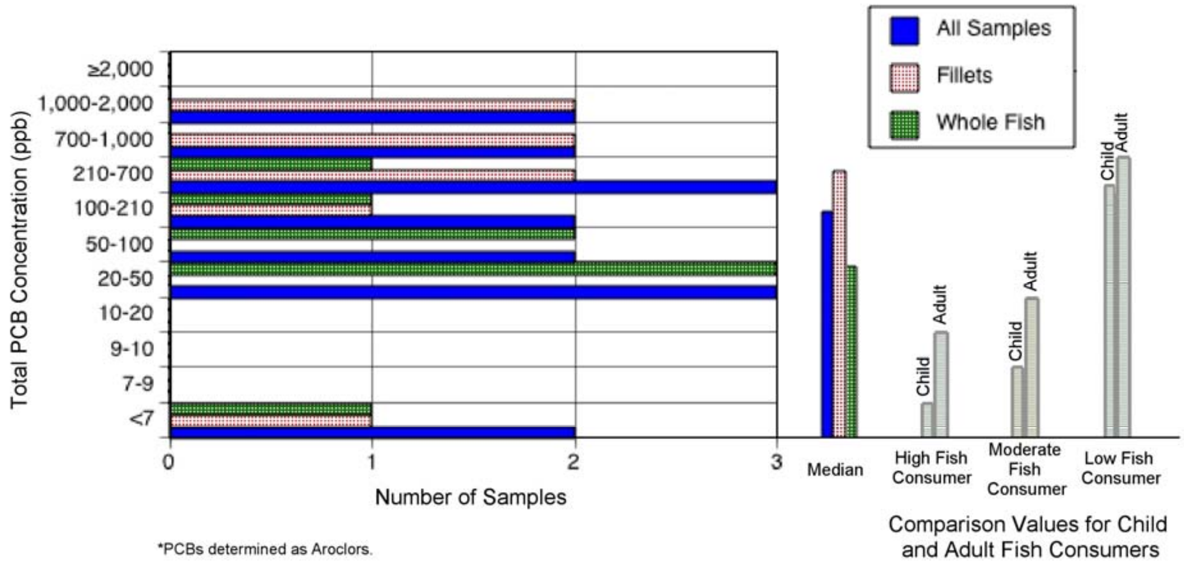
● Above CV
○ Below CV

Median Concentration	High Fish Consumer Comparison Values		Moderate Fish Consumer Comparison Values		Low Fish Consumer Comparison Values	
	Child (6 ppb)	Adult (10 ppb)	Child (9 ppb)	Adult (20 ppb)	Child (300 ppb)	Adult (700 ppb)
All Samples (91 ppb)	●	●	●	●	○	○
Fillets (62 ppb)	●	●	●	●	○	○
Whole Fish (77 ppb)	●	●	●	●	○	○

Tennessee River Fillet and Whole Fish

Figure 25 shows that distribution of PCB contamination of fillets and whole fish in the Tennessee River is more like that in the Lower Watts Bar Reservoir than in the Clinch River. Again, fillets contain higher PCB concentrations than do whole fish. The median concentrations for adults in the low fish consumption group are below the PCB comparison value. Therefore, adults eating three fish meals per year or less eat too few fish for the PCB contamination in the river to be a public health hazard. The median PCB concentrations did, however, exceed the PCB comparison values for both adults and children in the moderate and high fish consumer groups, and for children eating fillets in the low consumer group. Thus eating fish from the Tennessee River is further evaluated in Section IV (Public Health Implications).

Figure 25. PCBs* in Tennessee River Fish Since 1996



● Above CV
○ Below CV

Median Concentration	High Fish Consumer Comparison Values		Moderate Fish Consumer Comparison Values		Low Fish Consumer Comparison Values	
	Child (6 ppb)	Adult (10 ppb)	Child (9 ppb)	Adult (20 ppb)	Child (300 ppb)	Adult (700 ppb)
All Samples (150 ppb)	●	●	●	●	○	○
Fillets (500 ppb)	●	●	●	●	●	○
Whole Fish (46 ppb)	●	●	●	●	○	○

Turtle Meat

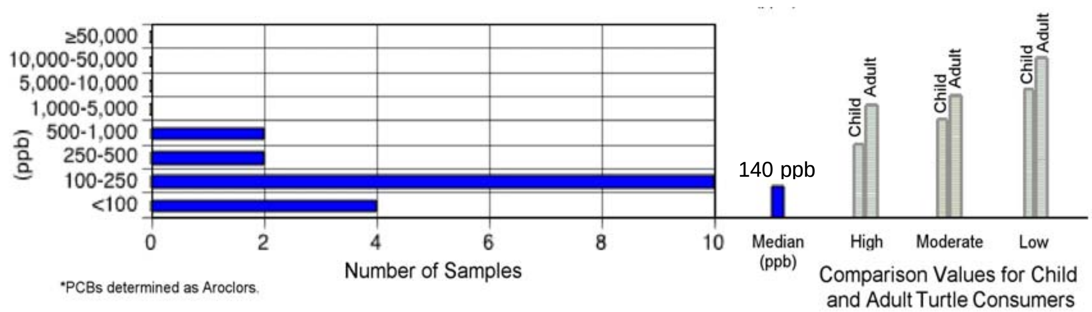
- **High consumption**
  two meals of turtle per year
- **Moderate consumption**
  one meal of turtle per year
- **Low consumption**
  one meal of turtle every 6 years

Studies conducted by DOE and TVA documented elevated levels of PCBs in certain species of fish in the Watts Bar Reservoir and the Clinch River. As a result, TDEC issued several consumption advisories on fish. Although anglers are known to harvest turtles from the Watts Bar Reservoir, TDEC did not issue any consumption advisories on turtles. Moreover, little information is available on contaminant levels in turtles. Because of these fish advisories, community members have also expressed concern that their consumption of turtle meat could cause illness. To respond to this concern, in the 1996 Health Consultation of the Lower Watts Bar Reservoir ATSDR recommended sampling of turtles for PCBs—previous studies from other states indicated that snapping turtles have a propensity to bioaccumulate PCBs. In the exposure investigation, ATSDR also included questions on turtle meat preparation and consumption patterns.

To evaluate levels of contaminants in turtles, in 1996 TDEC collected and analyzed the meat, fat, and eggs of 25 snapping turtles collected from 10 sampling stations in the Watts Bar Reservoir and the Clinch River. ATSDR generated ORR-specific PCB comparison values for turtle meat (see Table 5) and used them in a histogram to show Watts Bar Reservoir PCB contamination of turtle meat, its distribution, and the median.

The PCB concentrations are listed as Aroclors in Figure 26. The median PCB concentration for turtle meat (140 ppb) is displayed alongside the ATSDR PCB comparison values. Turtle meat is well below ATSDR's PCB comparison values for children and adults at all three turtle consumption levels. Because of the conservative considerations built into the PCB comparison values (e.g., the 300-fold safety factor, the sensitive species [monkeys] used in the study it is based on, and the consumption levels) eating turtle meat is not a public health hazard, and the turtle PCB pathway was eliminated from further consideration.

Figure 26. Total PCB* Concentrations in Watts Bar Reservoir Turtle Meat Since 1996



PCBs in turtles are mostly stored in body fat. The median PCB concentration detected in turtle fat (44,000 ppb) is much higher than the median PCB concentrations detected in any other biota species (see Table 11). Therefore, people should avoid eating turtle fat. Discarding the fat, eggs, and all organs—while only saving the meat (muscle) for eating—can reduce exposure to PCB-contaminated fat and tissue.

Exposure Investigation of ORR Fish Consumers

Previous investigations of the Watts Bar Reservoir and the Clinch River evaluated many contaminants but identified only PCBs in reservoir fish as a possible contaminant posing a health hazard. These previous investigations did not, however, confirm that people are actually being exposed or that they have elevated levels of PCBs.

The purpose of the exposure investigation was to determine whether people consuming moderate to large amounts of fish and turtles from the Watts Bar Reservoir are accumulating high PCB body burdens. ATSDR invited local anglers to participate in an exposure investigation; over 550 people volunteered for the exposure investigation and were screened for eligibility to participate. To be included as participants, within the previous year the volunteers had to eat at least one or more turtle meals, six or more meals of catfish and striped bass, nine or more meals of white bass, hybrid bass, or small mouth bass, or 18 or more meals of largemouth bass, sauger, or carp. They also had to be willing to submit blood samples. About one-fifth of the volunteers (116 people) met these criteria; for each participant, interviews were conducted and serum samples were collected. The 116 participants in the exposure investigation lived in eight Tennessee counties and several other states (e.g., Kentucky, Ohio, and Florida). One participant lived (and fished) the Watts Bar Reservoir 2 months per year and spent the rest of his time living and fishing in Miami, Florida. Appendix F. Summary Briefs and Fact Sheets contains a summary of ATSDR's exposure investigation (ATSDR 1998).

To collect information about fish consumption patterns of people who eat moderate to large amounts of fish, interviewers questioned participants about species consumed, how servings were prepared, how often they ate Watts Bar Reservoir fish and turtles, and how large the servings were. After reviewing their answers, ATSDR estimated the average consumption rate to be 66.5 g/day for moderate consumers of fish and 108 g/day for high consumers (the mean U.S. adult daily consumption rate of fish is 20 g/day; U.S. EPA 1997).

ATSDR analyzed the participants' serum samples for PCBs. Of the 116 samples, serum PCB concentrations were below 20 µg/L in 112 samples (97 percent), between 20 and 30 µg/L in three samples, and at 103.8 µg/L in one sample from the person who lived and fished 10 months of the year in Miami, Florida. The median PCB concentration in the serum samples of ORR's highest 20 percent of fish and turtle consumers was 4.3 µg/L. Although serum PCB levels corresponded poorly with fish consumption, those same levels matched up well with the ages of participants: no child was in the top 25 percent (less than 10 µg/L). The laboratory report included the statement: "Population-based studies by the Centers for Disease Control and Prevention (CDC) demonstrate that most people without occupational exposure have serum PCB levels in the µg/L range, with a median between 5 and 7 µg/L." By this measure, the median serum PCB levels for moderate to high consumers of Watts Bar Reservoir fish (4.3 µg/L) are slightly below the median for people without occupational exposure to PCBs (between 5 and 7 µg/L).

> These investigations only evaluate exposure—they do not assess whether exposure levels result in adverse health effects.

Summary of Screening Results From 1996 to 2004

ATSDR reviewed environmental samples collected from 1996 to 2004. As before, ATSDR screened nonbiological and biological exposure media separately. ATSDR also reevaluated data used for the 1998 exposure investigation. For nonbiological exposures, as well as for fish, ATSDR used the same PCB comparison values developed and discussed in the evaluation of past exposure. For turtle meat, ATSDR derived additional site-specific PCB comparison values based on the information provided during the Watts Bar Reservoir exposure investigation.

- Sediment samples taken from 1996 to 2004 were less contaminated than sediment sampled earlier. PCBs were not detected in most samples, and where PCBs were found, the concentrations were all below the ATSDR PCB comparison values for soil/sediment. As in the case of earlier samples, ATSDR found no sediment below any body of water or at any distance from sediment beds was sufficiently contaminated with PCBs that illness could result from any duration of exposure. Therefore, exposure to sediment is not a public health hazard and was not further evaluated.

- PCBs are not currently being released from the ORR into the air. The air pathway makes less of a contribution to PCB exposure than sediment or water. ATSDR has shown that the sediment and water pathways did not carry sufficient PCB concentrations to be a public health hazard. Therefore, the air pathway from 1996 onward is also not a public health hazard and was not further evaluated.

- Waterborne PCB contamination is not a likely source of illness. Using the relative sediment and water solubility of PCBs, the potential maximum concentrations in the water are well below ATSDR's PCB comparison values for drinking water. Further, TDEC's Division of Water Supply regulates drinking water at all public water systems. According to EPA's Safe Drinking Water Information System, the Kingston, Spring City, and Rockwood public water supply systems have not had any significant violations (U.S. EPA 2004b). Recreational exposure (e.g., from swimming or water-skiing) is even less likely to cause illness than drinking the water. On-site groundwater often received releases of waste PCBs, but could not transport significant quantities because of the off-site soils' limited solubility. Therefore, surface water and groundwater are not a public health hazard and were not further evaluated.

- Fillets were more contaminated than whole fish for the Clinch River, the Tennessee River, and the Lower Watts Bar Reservoir. The median PCB concentrations exceeded the ATSDR comparison values for both adults and children in the moderate and high consumption groups. Therefore, consumption of fish was retained for further in-depth health effects evaluation (see Section IV. Public Health Implications).

- Turtle meat was not sufficiently contaminated to be a likely source of PCB-related illness. Because, however, PCBs in turtles are mostly stored in fat, people should avoid eating turtle fat.

- Serum PCB levels from moderate to high consumers of Watts Bar Reservoir fish are slightly below national norms for total PCBs.

Table 8 presents a brief summary of screening results of ATSDR's evaluation of current exposure to PCBs. All retained exposure media and pathways were further evaluated in Section IV (Public Health Implications).

Table 8. Summary of ATSDR's Screening Evaluation of Current Exposure to PCBs (1996–2004)

Medium	*Source*	*Eliminated Not a Public Health Hazard*	*Retained for Further Health Effects Evaluation*
Sediment	East Fork Poplar Creek creek bed	All	None
	Clinch River riverbed	All	None
	≤4,393 ft. from Clinch River	All	None
Water	Used for drinking	All	None
	Recreational use	All	None
Air	All	All	None
Fish	Lower Watts Bar Reservoir fish fillets	Low consuming adults	Moderate to high consuming adults & all children
	Lower Watts Bar Reservoir whole fish	Low consuming adults & children	Moderate to high consuming adults & children
	Clinch River fish fillets	Low consuming adults& children	Moderate to high consuming adults & children
	Clinch River whole fish	Low consuming adults& children	Moderate to high consuming adults & children
	Tennessee River fish fillets	Low consuming adults	Moderate to high consuming adults & all children
	Tennessee River whole fish	Low consuming adults& children	Moderate to high consuming adults & children
Turtle Meat[5]	All	All	None

[5] The median PCB concentration detected in turtle fat is much higher than the median PCB concentrations detected in any other biota species. Therefore, people should avoid eating turtle fat. Discarding the fat, eggs, and all organs—while only saving the meat (muscle) for eating—can reduce exposure to PCB-contaminated fat and tissue.

IV. Public Health Implications

IV.A. Introduction

In the previous section on evaluating contamination and potential exposure pathways, ATSDR conducted a screening evaluation of the PCB levels in each of the media found in the off-site waterways surrounding the ORR. This screening evaluation compared the measured concentration of PCB in each media to ATSDR's PCB comparison values and analyzed the measured PCB body-burden (serum PCB) of participants in the Watts Bar Reservoir exposure investigation. This screening evaluation allowed ATSDR scientists to confidently eliminate from further evaluation pathways not expected to cause adverse health effects. Most of the exposure pathways were eliminated, including direct and indirect exposures to the sediment, drinking and recreational use of the surface water, inhalation of the air, and consumption of turtle meat.[6] Eating fish and geese exposure pathways were, however, retained for further in-depth health evaluation.

In this section on public health implications, the fish and geese ingestion pathways—which were not eliminated in the screening evaluation—undergo a more in-depth health evaluation. ATSDR scientists compared the measured PCB body burdens from the exposure investigation to those found in the general population. ATSDR also conducted a critical review of available toxicological, medical, and epidemiological information to ascertain the PCB toxicity levels from occupational exposures and animal studies (to determine levels of significant human exposure), and compared the estimated PCB doses from eating fish and geese to PCB doses that have been associated with disease and injury in humans and animals.

This health effects evaluation involves a balanced review and integration of site-related environmental data, site-specific exposure factors, and toxicological, epidemiological, and medical data. Its purpose is to help determine whether exposure to PCBs in fish and geese might result in harmful effects. ATSDR also reviewed the scientific literature for consistency and the probability of noncancerous and cancerous effects being caused by the estimated doses. The goal of the health effects evaluation is to decide whether harmful effects might be possible in the exposed population by weighing the scientific evidence. The result is a qualitative discussion of whether site-related exposures are of sufficient nature and magnitude to trigger a public health action to limit, eliminate, or further study any potential harmful exposures.

ATSDR compared estimated exposure doses to the lowest toxicity values at which health effects have been observed in humans or animals exposed to PCBs. For noncancerous effects, ATSDR reviewed toxicological and epidemiological literature to evaluate the weight-of-evidence for adverse effects under site-specific conditions. ATSDR used the literature to find the PCB levels that represent no-observed-adverse-effect levels (NOAELs) and lowest-observed-adverse-effect levels (LOAELs) in the most sensitive species for the most sensitive outcome.

The NOAEL is the highest tested dose of a substance in a study that has been reported to have no harmful (adverse) health effects on people or animals.
The LOAEL is the lowest tested dose of a substance in a study that has been reported to cause harmful (adverse) health effects in people or animals.

[6] People should avoid eating turtle fat. Discarding the fat, eggs, and all organs—while only saving the meat (muscle) for eating—can reduce exposure to PCB-contaminated fat and tissue.

The conclusions and recommendations are based on the professional knowledge and judgment of the health assessment team members. Because, however, of uncertainties regarding exposure conditions and adverse effects associated with environmental levels of exposures and body burdens, definitive answers are not possible on whether health effects will actually occur. Nevertheless, providing a framework that puts site-specific exposures and the potential for harm in perspective is possible. This is one of the primary goals of the public health assessment process.

IV.B. PCB Body Burdens

Previous investigations of the Watts Bar Reservoir and the Clinch River evaluated many contaminants, but identified only PCBs in reservoir fish as a possible contaminant posing a health hazard. However, these previous investigations only estimated the amount of PCB exposure from fish; they did not measure the levels in people, or determine whether the levels of PCBs were elevated. Because of the uncertainties in these previous investigations involving the estimated exposure doses and excess cancer risk, ATSDR conducted an exposure investigation to determine the body burden, or the actual amount of PCBs at a specific time, in the bodies of people who ate moderate to large amounts of fish and turtles. This investigation only evaluated exposure—it did not assess whether exposure levels resulted in adverse health effects.

Serum samples were drawn from the 116 highest fish consumers who volunteered for the study (ATSDR 1998). Serum PCB concentrations were below 20 µg/L in 112 samples, were between 20 and 30 µg/L in three samples, and one level was 103.8 µg/L in a person who lived and fished 10 months per year in Miami, Florida. The median serum PCB concentration for the highest 20 percent of fish and turtle consumers was 4.3 µg/L, with 95 percent of the samples detecting levels less than 17 µg/L. The laboratory report included the following statement: “Population-based studies by the Centers for Disease Control and Prevention (CDC) demonstrate that most people without occupational exposure have serum PCB levels in the µg/L range, with a median between 5 and 7 µg/L.” Table 9 compares the median serum PCB levels from the Watts Bar Reservoir exposure investigation to those reported in other studies.

> PCBs have been found at more than 500 hazardous waste sites and are present in all environmental media. Food consumption is the major contributor to body burden of PCBs in the general population (ATSDR 2000).

Table 9. Median Serum PCB Levels (ppb or ng/g lipid) in “Fish-eaters”

Year	*Male*	*Female*
1973–1974	17.0	11.0
1979–1982	22.9	14.5
1989–1993	21.1	13.5
	Male/Female	
2000–2001	5.95	
WBR Exposure Investigation[a]	4.3	

Sources: ATSDR 1998; He et al. 2001; Schwartz 2000–2001
[a] Median serum PCB concentration for the highest 20% of fish and turtle consumers (ATSDR 1998).

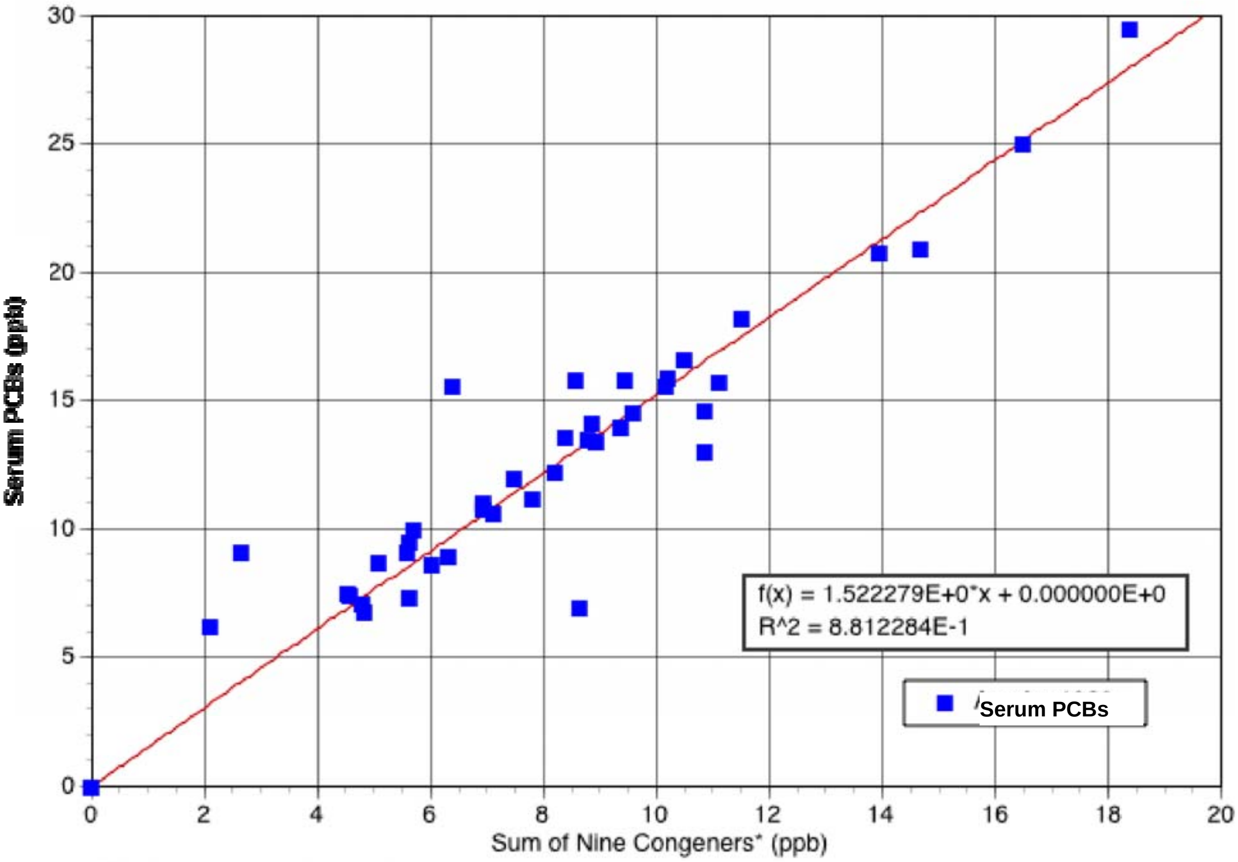
For comparison purposes, ATSDR compiled PCB data from studies available in ATSDR's *Toxicological Profile for PCBs* (ATSDR 2000). The studies were presented in three tables: 1) serum samples of persons not occupationally exposed who *did not* consume contaminated fish, 2) serum samples of persons not occupationally exposed who *did* consume contaminated fish, and 3) serum samples of persons who were *occupationally exposed*. ATSDR reviewed the original studies in the toxicological profile for additional details, and obtained the most recent laboratory data file from the National Center for Health Statistics on PCBs in the serum samples of the general U.S. population (NHANES 2005).

> The National Health and Nutrition Examination Survey (NHANES) is a nationally representative survey of the health and nutritional status of the United States population. Detailed interviews, clinical, laboratory, and radiological examinations are conducted as part of the survey.

Although the National Health and Nutrition Examination Survey (NHANES) data (1999–2000) listed the serum concentration of individual PCB congeners, equivalent data that would allow comparison to exposure investigation participants were not provided. Nine of the congeners measured in the serum samples of the participants were included in the NHANES data. ATSDR plotted the sum of the serum concentrations of these nine congeners against serum PCB concentrations. ATSDR did this for each participant for which both congener and serum PCB information was available, with the exception of the one outlier. (The outlier's serum PCB levels differed from the mean of the others by more than 17 times their standard deviation. This serum belonged to the person who fished in Miami, Florida, 10 months per year.) Figure 27 shows the plot, the best straight line passing through zero and the plotted points (called a linear regression), and the equation describing the straight line.

Using this equation, ATSDR assigned an equivalent, ORR-specific level to each serum sample in the NHANES data. This technique allowed ATSDR to compute measures of central tendency such as the median, mode, and arithmetic and geometric means for the NHANES data in the same way as the data for the Watts Bar Reservoir exposure investigation participants.

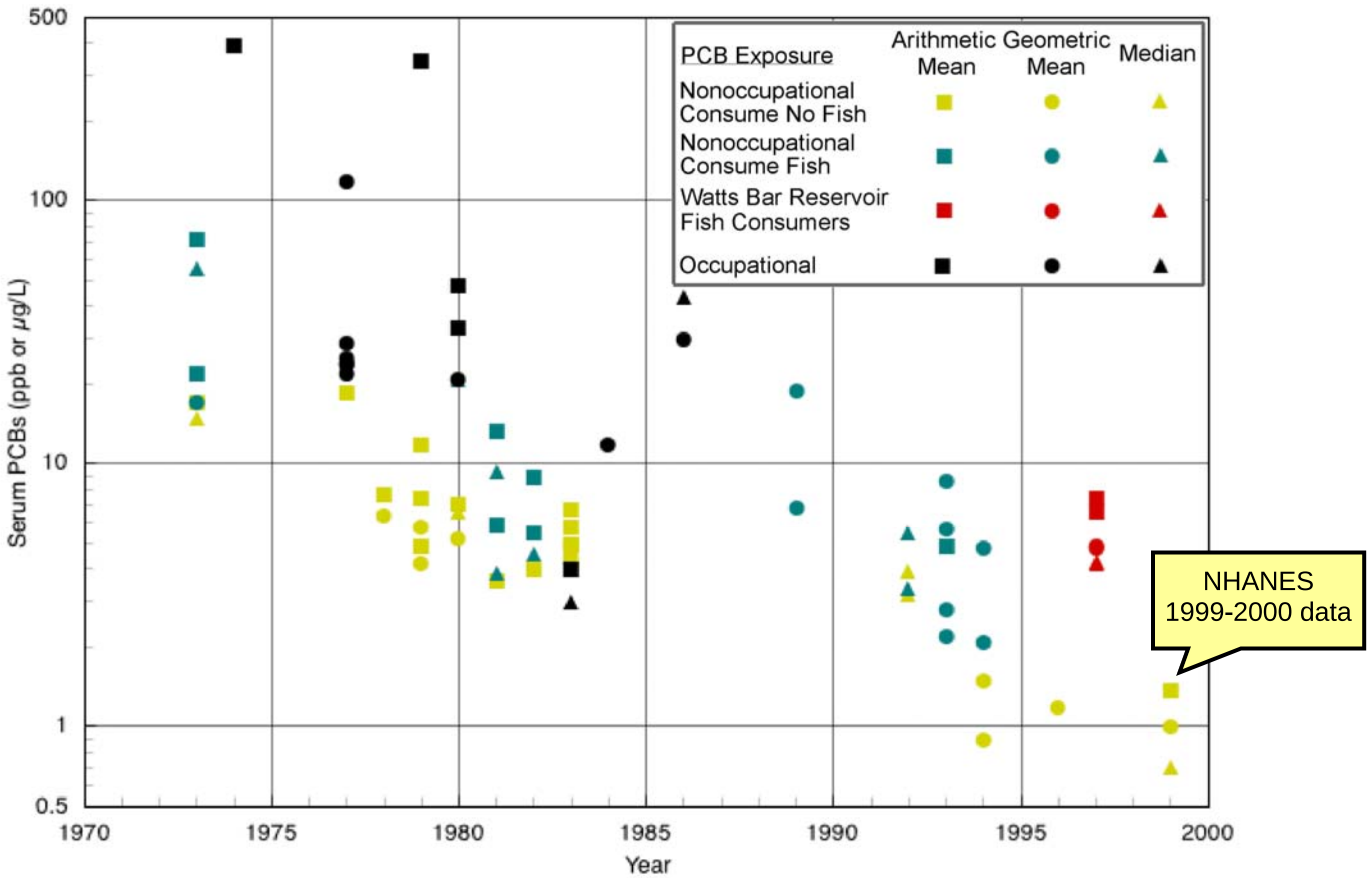
Figure 27. Linear Regression of ORR Serum PCBs vs. Congener Sums



*PCBs 74, 99, 118, 138, 153, 156, 170, 180, and 187.

ATSDR plotted measures of central tendency for serum PCBs from the toxicological profile, other selected studies, the NHANES data, and the exposure investigation in Figure 28 (ATSDR 1998, 2000; Chase et al. 1982; Fait et al. 1989; Maroni et al. 1981; NHANES 2005; Ouw et al. 1976; Sahl et al. 1985; Schwartz et al. 1983; Smith et al. 1982; Stehr-Green et al. 1986; Wolff et al. 1982). Figure 28 shows that people occupationally exposed to PCBs have greater body burdens of PCBs than people who consume PCB-contaminated fish. Fish consumers have greater body burdens than the general population, and the difference between fish consumers and nonconsumers has increased over time. Body burdens of Watts Bar Reservoir moderate to high fish consumers are below people exposed occupationally, above nonfish consumers, and within the range for people who consume sport fish.

Figure 28. Comparison of Watts Bar Reservoir Fish Consumers to Exposed and Unexposed People Nationwide



The vertical axis representing serum PCB concentration is shown in logarithmic scale because of the disparity between body burdens resulting from occupational and non-occupational exposure.

IV.C. Health Evaluation

For the screening evaluation in Section III, ATSDR derived conservative ORR-specific PCB comparison values based on ATSDR's MRLs and consumption levels from the exposure investigation. As a result of this evaluation, eating fish and geese was retained for further in-depth evaluation, but eating turtle meat[7] was eliminated as a potential health hazard. In this section, ATSDR estimates exposure doses (see text box for definition) and compares them to health effects levels reported in the toxicological literature.

> A dose, expressed in milligrams per kilogram per day (mg/kg/day), represents the amount of contaminant that an individual is estimated to ingest (in milligrams), divided by the body weight of the individual (in kilograms) each day.

IV.C.1. Noncancerous Health Effects

ATSDR reviewed the scientific literature for noncancerous effects from exposure to PCBs. Ingestion of PCBs at high exposure doses has been shown to cause skin irritations, such as chloracne and rashes. The doses required to produce such effects are, however, quite high—daily occupational exposure doses ranging from 0.07 to 0.14 mg/kg/day failed to produce adverse health effects in workers (ATSDR 2000). Immunological effects were observed in female Rhesus monkeys chronically exposed to the LOAEL of 0.005 mg/kg/day of Aroclor 1254. Neurobehavioral effects were observed in infant monkeys exposed to 0.0075 mg/kg/day. A summary of the effects levels is presented in Table 10. See Chapter 3 of ATSDR's Toxicological Profile for Polychlorinated Biphenyls (http://www.atsdr.cdc.gov/toxprofiles/tp17-c3.pdf) for additional information.

Generally, humans appear to be less sensitive to the toxic effects of PCBs than do other animals. In laboratory animals, PCBs have been shown to produce skin effects (similar to those seen in people exposed at high doses) as well as effects on the thyroid, immune system, liver, toenails, and eyelids. Of the laboratory animals tested (i.e., rabbits, minks, mice, rats, ferrets, and monkeys), the rhesus monkey appears to be the most sensitive. PCBs have been shown to impair the monkey's immune system (in addition to producing skin, fingernail, and toenail effects), at doses as low as 0.005 mg/kg/day (Arnold et al. 1993; Tryphonas et al. 1989, 1991). This dose is 28 times lower than the dose shown not to harm people.

Table 10. Summary of Noncancerous Effect Levels Associated With PCB Exposure

Literature on Effect Levels				
	Human, Occupational		Monkeys	
	Chloracne		Immunological	Neurobehavioral
	NOAEL	LOAEL	LOAEL	LOAEL
Estimated Dose (mg/kg/day)	0.14	No data available	0.005	0.0075

Source: ATSDR 2000
NOAEL = no-observed-adverse-effect level
LOAEL = lowest-observed-adverse-effect level

[7] People should avoid eating turtle fat. Discarding the fat, eggs, and all organs—while only saving the meat (muscle) for eating—can reduce exposure to PCB-contaminated fat and tissue.

IV.C.2. Cancerous Effects

Overall, human studies provide suggestive evidence that PCBs are carcinogenic (ATSDR 2000). In contrast to human studies, conclusive evidence supports the view that commercial PCB mixtures are carcinogenic in animals (e.g., rats) based on induction of tumors in the liver and thyroid (ATSDR 2000). Scientists studying cancer effects of PCBs have only been able to show PCB-induced cancer in rats, which means that cancer did not develop in other animal species. The Department of Health and Human Services (DHHS) has concluded that PCBs may reasonably be anticipated to be carcinogenic in humans, whereas both EPA and the International Agency for Research on Cancer (IARC) have determined that PCBs are probably carcinogenic to humans.

Using data reviewed for this health assessment and estimated exposure doses, ATSDR concludes cancer is an unlikely health outcome for people exposed to PCBs released from the ORR. The highest estimated exposure doses (calculated for people eating the most contaminated fish species at the "high" consumption rate) are 300 to 1,600 times below the levels proven to cause cancer in animals (cancer effect levels). All other estimated exposure doses are even lower. See Chapter 3 of ATSDR's Toxicological Profile for Polychlorinated Biphenyls (http://www.atsdr.cdc.gov/toxprofiles/tp17-c3.pdf) for further discussion.

> The occupational exposure studies strongly suggest that animal-based linear no-threshold estimates of cancer substantially overestimate the risk due to PCB exposures (ChemRisk 1999a; Kimbrough et al. 1999, 2003; Laden et al. 2001b; Loomis et al. 1997; Moysich et al. 2002; Negri et al. 2003).

The occupational studies examining the cancer-causing effect of PCBs often have methodological limitations and have shown a lack of consistency across multiple studies (ATSDR 2000; U.S. EPA 2005). A small excess risk of liver-related cancer was found in studies of workers from two capacitor manufacturing plants in New York (2,567 workers) and Massachusetts (1,599 workers). A 1999 study of more than 7,000 capacitor workers employed at least 3 months and followed an average of more than 30 years described exposures up to 1,500 micrograms per cubic meter ($\mu g/m^3$) of PCBs in workplace air. The study found no excess liver cancers and could not verify findings of increased incidence of cancers in other organs suggested by previous smaller studies (Kimbrough et al. 1999). The overall cancer rate among women in the Kimbrough et al. (1999) study was unchanged from the general population, while the rate among men was significantly *lower* (by 19 percent) than expected. A 5-year follow up of this study of industrial exposures confirmed the earlier results (Kimbrough et al. 2003).

Kimbrough's studies (Kimbrough et al. 1999, 2003) are not the only ones to look for cancer in general or in specific tissues of people exposed to PCBs at their workplaces—ATSDR found numerous studies (e.g., Bertazzi et al. 1987; Bosetti et al. 2003; Brown 1987; Brown and Jones 1981; Charles et al. 2003; Faroon et al. 2001; Golden et al. 2003; Gustavsson and Hogstedt 1997; Gustavsson et al. 1986; Hardell et al. 2003; Loomis et al. 1997; Ritchie et al. 2003; Sinks et al. 1992; Wong 1995; and Yassi et al. 1994). Studies with the most subjects were the least likely to find increased cancer rates, suggesting that those that found increased cancer rates were picking up variabilities inherent in small populations or study groups. One study of more than 138,000 utility workers found significantly decreased rates for cancer overall and for cancers of the liver, rectum, pancreas, and respiratory tract. Cancers of blood components were not significantly affected (Loomis et al. 1997). Similarly, the recent scientific literature of breast cancer studies do not support increased risk of breast cancer among women with environmental exposure to PCBs.

A technique known as physiologically based pharmacokinetic (PBPK) modeling incorporates information about how a substance and its degradation products are absorbed, chemically modified, moved within the body, and eliminated. When PBPK was used to compare how different species treat PCBs and their metabolites, many inconsistencies were found, making cross-species predictions highly uncertain (ATSDR 2000). These differences might explain the absence of cancer in animals (other than rats) and humans following exposure.

IV.C.3. Dose Estimation

ATSDR reviewed more than 52,000 records of PCBs in ORR biota. Median PCB concentrations ranged from 22 ppb for sunfish fillets from the Clinch River to 1,270 ppb for catfish fillets taken from the Lower Watts Bar Reservoir (see Table 11). Fillet samples had higher concentrations of PCBs than whole fish (see Section III for more details). In addition, total PCBs summed from total Aroclors exceeded those from the individual congeners (see Appendix E. PCBs Measured as Total Congeners or Total Aroclors for more details). The median PCB concentration in goose muscle was 320 ppb.

Table 11. Median PCB* Concentrations (ppb) in Biota

Species†	*Poplar Creek*	*Clinch River*	*Tennessee River*	*Lower Watts Bar Reservoir*
Sunfish species	40	22	NS	NS
Largemouth Bass	130	400	300	200
White, Striped, & Hybrid Bass	NS	1,000	730	440
Catfish species	920	900	1,240	1,270
Goose muscle	320 (site-wide)			

*PCBs measured as total Aroclors.
†Includes fillet and muscle samples of known fish species only.
NS = not sampled

During the screening evaluation (see Section III), ATSDR estimated doses from consuming high, moderate, and low amounts of the different species of fish from Poplar Creek, the Clinch River, the Tennessee River, and the Lower Watts Bar Reservoir. To give fish consumers some additional perspective and to determine a safe consumption rate, ATSDR estimated five levels of fish consumption (see text box) during the in-depth evaluation. The following equation was used to estimate ingestion of PCBs:

Fish Consumption Rates

- **High consumption**
  three meals of fish per week
- **Moderate consumption**
  two meals of fish per week
  one meal of fish per week
- **Low consumption**
  one meal of fish per month
  three meals of fish per year

One adult meal of fish is considered to be 8 ounces (227 grams). Children were assumed to eat one-third as much as adults.

$$\text{Estimated exposure dose} = \frac{C \times CR \times IR \times EF \times ED}{BW \times AT}$$

where:

C = Concentration (mg/kg): see Table 11
CR = Cooking Reduction (unitless): 0.7 for fish*
IR = High Consumption: 0.108 kg/day for adults; 0.036 kg/day for children**
Moderate Consumption: 0.0665 kg/day for adults; 0.0222 kg/day for children**
0.032 kg/day for adults; 0.011 kg/day for children
Low Consumption: 0.00195 kg/day for adults; 0.0025 kg/day for children**
0.0074 kg/day for adults; 0.0222 kg/day for children
EF = Exposure Frequency: 365 days/year
ED = Exposure Duration: 30 years for adults; 6 years for children
BW = Body Weight: 70 kg for adults; 10 kg for children
AT = Averaging Time: 10,950 days for adults; 2,190 days for children

* For fish, ATDSR assumed a 30% skinning/trimming/cooking loss associated with PCBs. Several studies have reported PCB reductions ranging from 14 to 80% due to skinning, trimming, and cooking fish (U.S. EPA 2000).

** The consumption rates are based on information collected during the fish consumption study in ATSDR's Watts Bar Reservoir Exposure Investigation (ATSDR 1998). Please see Section III.A.4. Deriving Comparison Values for additional information.

ATSDR used the following equation to estimate doses from consuming high, moderate, and low amounts of Canada geese:

Goose Consumption Rates

- **High consumption**
  one meal of goose per week
- **Moderate consumption**
  two meals of goose per month
- **Low consumption**
  one meal of goose per year

One adult meal of goose is between 6 and 8 ounces. Children were assumed to eat one-third as much as adults.

$$\text{Estimated exposure dose} = \frac{C \times CR \times IR \times EF \times ED}{BW \times AT}$$

where:

C = Concentration (mg/kg): see Table 11
CR = Cooking Reduction (unitless): 1.0 for geese*
IR = High Consumption: 0.027 kg/day for adults; 0.009 kg/day for children**
Moderate Consumption: 0.017 kg/day for adults; 0.0056 kg/day for children**
Low Consumption: 0.0005 kg/day for adults; 0.00016 kg/day for children**
EF = Exposure Frequency: 365 days/year
ED = Exposure Duration: 30 years for adults; 6 years for children
BW = Body Weight: 70 kg for adults; 10 kg for children
AT = Averaging Time: 10,950 days for adults; 2,190 days for children

* No cooking reduction was assumed for geese.

The following highlight the most noteworthy results (see Table 12, Figure 29, and Figure 30).

- Due to their lower body weights, children's exposures are slightly higher than are adult exposures.
- None of the calculated exposure doses for either fish or geese are higher than the LOAEL of 0.005 mg/kg/day.
- The worst-case fish consumption scenario assumes people exclusively eat catfish fillets from the Lower Watts Bar Reservoir (1,270 ppb) at the high consumption rate. The calculated PCB doses for this scenario are 2 to 4 times below the LOAEL. The calculated doses are more than 100 times less than the PCB doses shown to cause cancer in rats.
- The doses from eating catfish from all four water bodies one or more times a week for children and two or more times a week for adults, are within an order of magnitude of the LOAEL.
- Eating sunfish from Poplar Creek or the Clinch River at the high consumption rate would result in child and adult exposure doses that are well below (more than 50 times less than) the LOAEL.[8]
- The estimated exposure doses from low consumption of all species of fish from all four water bodies are well below (86 to 12,000 times less than) the LOAEL.
- Eating Canada geese at high, moderate, or low consumption rates is estimated to result in exposure doses below (at least 17 times less than) the LOAEL.

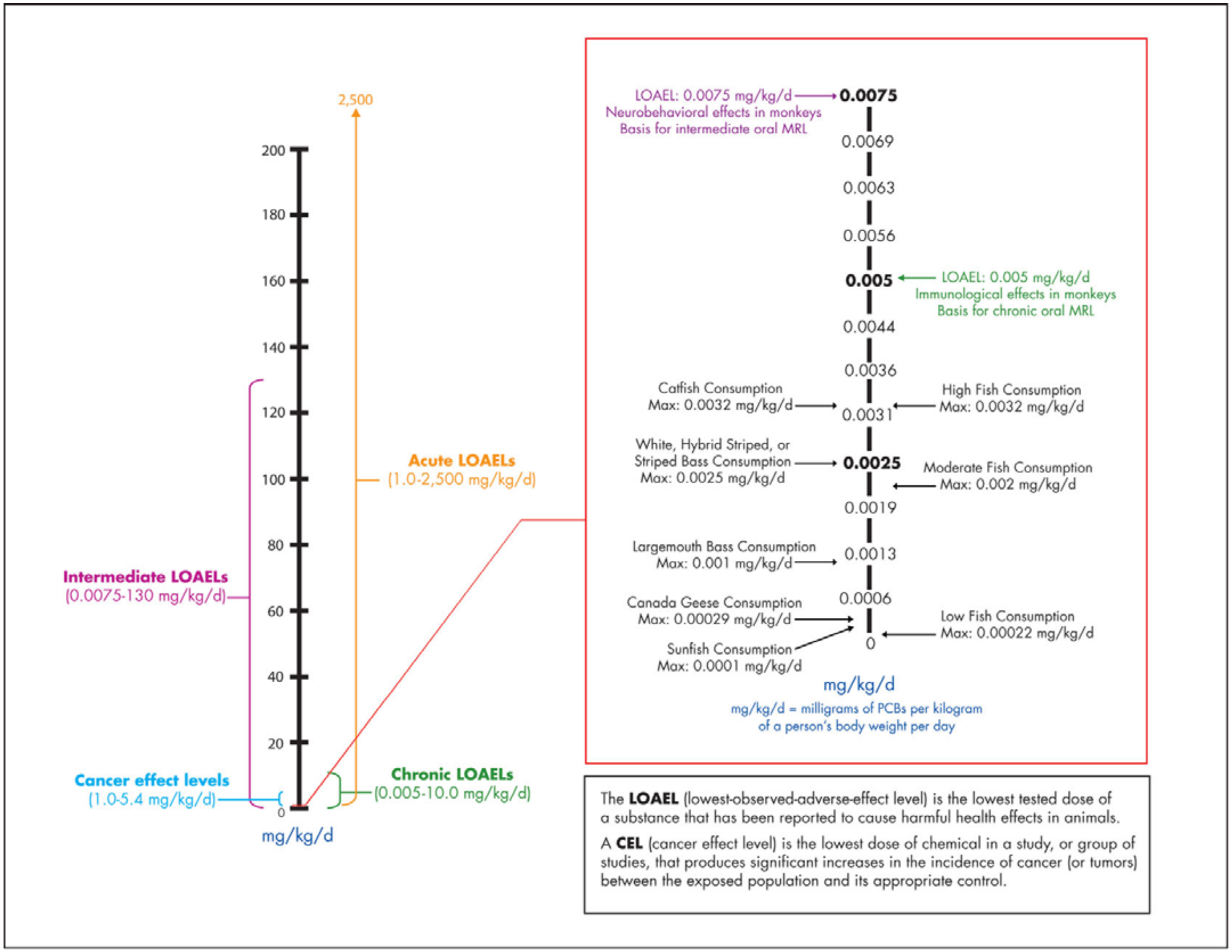
[8] Sunfish, however, were not sampled in the Tennessee River or the Lower Watts Bar Reservoir. After reviewing the levels detected in sunfish from Poplar Creek and the Clinch River and their trophic level in the aquatic food chain, ATSDR does not expect high PCB concentrations in sunfish from either water body.

Table 12. Summary of Estimated PCB Doses for Consumers of Fish and Geese

Location and Species	*High Consumer Doses (mg/kg/day) 3 meals/week*		*Moderate Consumer Doses (mg/kg/day)*				*Low Consumer Doses (mg/kg/day)*			
			2 meals/week		*1 meal/week*		*1 meal/month*		*3 meals/year*	
	Child	*Adult*	*Child*	*Adult*	*Child*	*Adult*	*Child*	*Adult*	*Child*	*Adult*
Poplar Creek										
Sunfish	1.0E-04	4.3E-05	6.2E-05	2.7E-05	3.1E-05	1.3E-05	7.0E-06	3.0E-06	1.8E-06	7.8E-07
Largemouth Bass	3.3E-04	1.4E-04	2.0E-04	8.6E-05	1.0E-04	4.2E-05	2.3E-05	9.6E-06	5.9E-06	2.5E-06
White, Striped, & Hybrid Bass	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Catfish	**2.3E-03**	**9.9E-04**	**1.4E-03**	**6.1E-04**	**7.1E-04**	2.9E-04	1.6E-04	6.8E-05	4.2E-05	1.8E-05
Clinch River										
Sunfish	5.5E-05	2.4E-05	3.4E-05	1.5E-05	1.7E-05	7.0E-06	3.9E-06	1.6E-06	1.0E-06	4.3E-07
Largemouth Bass	**1.0E-03**	4.3E-04	**6.2E-04**	2.7E-04	3.1E-04	1.3E-04	7.0E-05	3.0E-05	1.8E-05	7.8E-06
White, Striped, & Hybrid Bass	**2.5E-03**	**1.1E-03**	**1.6E-03**	**6.7E-04**	**7.7E-04**	3.2E-04	1.8E-04	7.4E-05	4.6E-05	2.0E-05
Catfish	**2.3E-03**	**9.7E-04**	**1.4E-03**	**6.0E-04**	**6.9E-04**	2.9E-04	1.6E-04	6.7E-05	4.1E-05	1.8E-05
Tennessee River										
Sunfish	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Largemouth Bass	**7.6E-04**	3.2E-04	4.7E-04	2.0E-04	2.3E-04	9.6E-05	5.3E-05	2.2E-05	1.4E-05	5.9E-06
White, Striped, & Hybrid Bass	**1.8E-03**	**7.9E-04**	**1.1E-03**	4.9E-04	**5.6E-04**	2.3E-04	1.3E-04	5.4E-05	3.3E-05	1.4E-05
Catfish	**3.1E-03**	**1.3E-03**	**1.9E-03**	**8.2E-04**	**9.5E-04**	4.0E-04	2.2E-04	9.2E-05	5.6E-05	2.4E-05
Lower Watts Bar Reservoir										
Sunfish	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Largemouth Bass	**5.0E-04**	2.2E-04	3.1E-04	1.3E-04	1.5E-04	6.4E-05	3.5E-05	1.5E-05	9.1E-06	3.9E-06
White, Striped, & Hybrid Bass	**1.1E-03**	4.8E-04	**6.8E-04**	2.9E-04	3.4E-04	1.4E-04	7.7E-05	3.3E-05	2.0E-05	8.6E-06
Catfish	**3.2E-03**	**1.4E-03**	**2.0E-03**	**8.4E-04**	**9.8E-04**	4.1E-04	2.2E-04	9.4E-05	5.8E-05	2.5E-05
Site Wide	*High (1 meal/week)*		*Moderate (2 meals/month)*				*Low (1 meal/year)*			
Canada Geese	2.9E-04	1.2E-04	1.8E-04		7.8E-05		5.1E-06		2.3E-06	

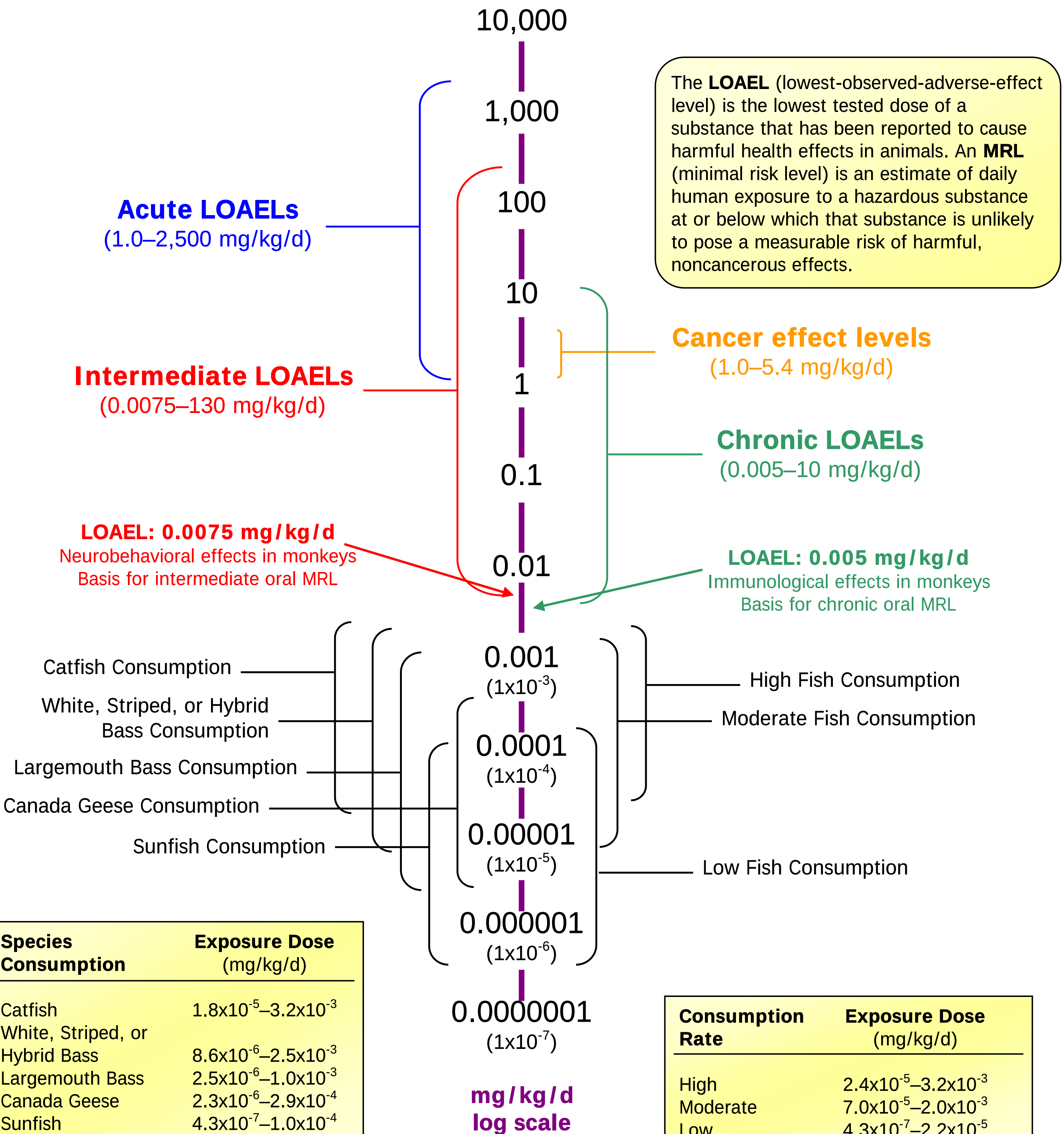
ATSDR assumed a 30% reduction of PCBs from skinning, trimming, and cooking the fish. No reduction was applied for eating geese.
PCBs measured as total Aroclors.
Includes fillet and muscle samples of known fish species only.
Bold text indicates that the dose *approaches* the LOAEL of 5.0E-03 mg/kg/day (ATSDR 2000) (i.e., are within an order of magnitude). None of the calculated exposure doses are higher than the LOAEL.
mg/kg/day = milligrams per kilogram per day NS = not sampled

Figure 29. PCB Effect Levels* and Estimated Oral Exposure Doses (linear scale)



*All effect levels were observed in laboratory animals (e.g., rats and monkeys).

Figure 30. PCB Effect Levels* and Estimated Oral Exposure Doses (log scale)



Species Consumption	Exposure Dose (mg/kg/d)
Catfish	1.8×10^{-5}–3.2×10^{-3}
White, Striped, or Hybrid Bass	8.6×10^{-6}–2.5×10^{-3}
Largemouth Bass	2.5×10^{-6}–1.0×10^{-3}
Canada Geese	2.3×10^{-6}–2.9×10^{-4}
Sunfish	4.3×10^{-7}–1.0×10^{-4}

Consumption Rate	Exposure Dose (mg/kg/d)
High	2.4×10^{-5}–3.2×10^{-3}
Moderate	7.0×10^{-5}–2.0×10^{-3}
Low	4.3×10^{-7}–2.2×10^{-5}

mg/kg/d = milligrams of PCBs per kilogram of a person's body weight per day

*All effect levels were observed in laboratory animals (e.g., rats and monkeys).

IV.C.4. Benefits from Fish Consumption

A healthy diet that includes lean sources of protein (such as grilled, broiled, and baked fish) can provide health benefits. Much of the research regarding beneficial effects of consuming fish surrounds species with higher levels of omega-3 fatty acids (e.g., sardines, mackerel, tuna, herring, trout, and salmon). The scientific literature regarding the health benefits from eating freshwater species is not as robust as with saltwater species. The following text provides suggestive evidence that fish consumption provides 1) beneficial developmental effects, 2) decreased incidence of and mortality from cancer, and 3) improvements in heart health.

- *Developmental Effects*. Higher developmental scores were reported in children at 15 months of age from women eating fish (omega-3 rich) one to four times per week compared to those of women who seldom ate fish. The children were tested for social activity, vocabulary, and language; all improved with increased maternal fish consumption (Daniels et al. 2004).

- *Cancer*. Observations of protection against breast cancer among fisherman's wives in Norway date back at least a decade (Lund and Bonaa 1993). Larsson et al. (2004) reviewed studies showing that omega-3 fatty acid (fish) consumption protects against breast cancer by several mechanisms. The incidence of both breast and colorectal cancer is decreased proportionally to the amounts of omega-3 rich fish consumed (Caygill et al. 1996; de Deckere 1999).

- *Heart Disease*. One of the most serious complications of diabetes is increased risk of mortality from coronary artery disease. But fish (omega-3 rich) intake shows significant protection, at least in women, against atherosclerosis (Connor 2004; Erkkila et al. 2004), as well as against coronary heart disease and total mortality (Hu et al. 2003). Fish intake (tuna and other broiled or baked fish, but not fried fish) also lowers the incident risk of atrial fibrillation (Mozaffarian et al. 2004).

IV.C.5. Conclusions

All of the estimated exposure doses that ATSDR calculated are below the lowest health effect level reported in the scientific literature (LOAEL of 0.005 mg/kg/day). Eating moderate to high amounts (i.e., one or more meals per week for children and two or more meals per week for adults) of catfish, white bass, hybrid bass (striped bass-white bass), or striped bass from Poplar Creek,[9] the Clinch River, the Tennessee River, and the Lower Watts Bar Reservoir are, however, less than an order of magnitude below this dose (LOAEL). The doses for children eating moderate to high amounts (two or more times a week) of largemouth bass from the Clinch River and the Tennessee River are also within an order of magnitude of the LOAEL.

[9] White bass, hybrid bass, and striped bass were not sampled in Poplar Creek.

Estimated exposure doses within an order of magnitude of the LOAEL are of potential health concern and warrant further consideration because of the uncertainties in the toxicity studies. This LOAEL is reported in a study in which female Rhesus monkeys were chronically exposed to Aroclor 1254 (Tryphonas et al. 1989, 1991). The effects were measurable, but whether the clinical relevance of the effects from the study has been demonstrated is the subject of some debate. Interpretation of the adversity of the reported effects is "complicated by a lack of data on immunocompetence and the essentially inconclusive findings in the other tested end points" (ATSDR 2000). Therefore, it is unclear whether the reported levels would actually cause adverse health effects.

> Cancer is not expected to result from eating PCB-contaminated fish near the ORR. The highest estimated exposure doses are hundreds of times below the levels proven to cause cancer.

Due to the uncertainties involved in the toxicity studies and the estimated exposure doses, it is prudent public health practice to limit consumption of *certain species of fish* from Poplar Creek, the Clinch River, the Tennessee River, and the Lower Watts Bar Reservoir, due to the level of PCBs detected (see Table 13 and Figure 1). Certain sensitive populations, such as children, pregnant women, and nursing mothers, should be particularly careful to avoid eating *certain species of fish* from these water bodies, because exposure to PCBs might cause developmental problems.

- Children should avoid eating moderate to high amounts (one or more 2.7-ounce meals of fish per week) of catfish, white bass, striped bass, or hybrid bass from Poplar Creek,[10] the Clinch River, the Tennessee River, and the Lower Watts Bar Reservoir.

- Adults should avoid eating moderate to high amounts (two or more 8-ounce meals of fish per week) of catfish, white bass, striped bass, or hybrid bass from Poplar Creek,[10] the Clinch River, and the Tennessee River.

- Children should avoid eating moderate (two or more 2.7-ounce meals of fish per week) to high (three or more 2.7-ounce meals of fish per week) quantities of largemouth bass from the Clinch River and the Tennessee River, respectively.

- Pregnant women and nursing mothers should avoid eating catfish, white bass, striped bass, hybrid bass, or largemouth bass from Poplar Creek,[10] the Clinch River, the Tennessee River, and the Lower Watts Bar Reservoir.

ATSDR's chief mission in conducting a PHA is to address issues of public health, not simply to assess toxicity levels. Fish is a healthy food—often more so than food that might be substituted for it. Eating fewer fish than necessary to protect oneself from contaminants means receiving less of the nutritional benefits. Therefore, it is also important to point out what species of fish are safe to eat and from where those species may safely be taken.

- Sunfish species are safe to eat in any amount from Poplar Creek, the Clinch River, the Tennessee River,[11] and the Lower Watts Bar Reservoir.[11]

[10] White bass, hybrid bass, and striped bass were not sampled in Poplar Creek, however, based on the levels detected in the other water bodies, children and adults would be well advised to limit their consumption from Poplar Creek as well.

- Largemouth bass from Poplar Creek and the Lower Watts Bar Reservoir are safe to eat, even in high amounts (three 8-ounce meals of fish per week). Adults can also safely consume high amounts of largemouth bass from the Clinch River and the Tennessee River. Children can safely consume moderate amounts (one 2.7-ounce meal of fish per week from the Clinch River and two 2.7-ounce meals of fish per week from the Tennessee River) of largemouth bass.

- Low quantities (i.e., up to one fish meal per month) of any species of fish are safe to eat, even catfish.

- Canada geese are safe to eat in any amount.

Of course whenever possible, exposure to environmental contamination should be reduced. If concerned community members wish to reduce their exposure to PCBs without forfeiting the healthy benefits from eating fish, they can follow the suggestions in EPA and ATSDR's *A Guide to Healthy Eating of the Fish You Catch* (see Appendix F. Summary Briefs and Fact Sheets):

- Eat the less fatty parts of the fish; throw away skin, fat deposits, head, guts, kidneys, and liver.

- Remove the skin and the strip of light-colored fat that remains along the belly flap at the bottom of the fillet as well as any fat that may be present along the sides and the midpoint of the back.

- Grill, broil, or bake fish on a rack to allow fat—and chemicals—to drain away. This helps remove pollutants stored in the fatty parts of the fish. Avoid frying for larger, fatty fish.

- Do not reuse cooking liquids or fat drippings from the fish because these liquids retain PCBs.

- Choose to eat younger (or smaller) fish and those lower on the food chain (e.g., sunfish).

- People should avoid eating turtle fat. Discarding the fat, eggs, and all organs—while only saving the meat (muscle) for eating—can reduce exposure to PCB-contaminated fat and tissue.

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[11] Sunfish were not sampled in the Tennessee River or the Lower Watts Bar Reservoir. Nevertheless, given the levels detected in sunfish from Poplar Creek and the Clinch River and their trophic level in the aquatic food chain, ATSDR does not expect high PCB concentrations in sunfish from either water body.

Table 13. Recommended Number of Fish and Geese Meals, Based on Levels of PCBs Detected

Species	*Child Consumption*					*Adult Consumption*					Location
	High	*Moderate*		*Low*		*High*	*Moderate*		*Low*		
	1/week	*2/month*		*1/year*		*1/week*	*2/month*		*1/year*		
Canada Geese	○	○		○		○	○		○		Site-wide
	High	*Moderate*		*Low*		*High*	*Moderate*		*Low*		
	3/week	*2/week*	*1/week*	*1/month*	*3/year*	*3/week*	*2/week*	*1/week*	*1/month*	*3/year*	
Sunfish species	○*	○*	○*	○*	○*	○*	○*	○*	○*	○*	LWBR
	○	○	○	○	○	○	○	○	○	○	Poplar Creek
	○	○	○	○	○	○	○	○	○	○	Clinch River
	○*	○*	○*	○*	○*	○*	○*	○*	○*	○*	Tennessee River
Largemouth Bass	○	○	○	○	○	○	○	○	○	○	LWBR
	○	○	○	○	○	○	○	○	○	○	Poplar Creek
	●	●	○	○	○	○	○	○	○	○	Clinch River
	●	○	○	○	○	○	○	○	○	○	Tennessee River
White, Hybrid, Striped Bass	●	●	○	○	○	○	○	○	○	○	LWBR
	●*	●*	●*	○*	○*	●*	●*	○*	○*	○*	Poplar Creek
	●	●	●	○	○	●	●	○	○	○	Clinch River
	●	●	●	○	○	●	○	○	○	○	Tennessee River
Catfish species	●	●	●	○	○	●	●	○	○	○	LWBR
	●	●	●	○	○	●	●	○	○	○	Poplar Creek
	●	●	●	○	○	●	●	○	○	○	Clinch River
	●	●	●	○	○	●	●	○	○	○	Tennessee River

○	Safe to eat
●	Limit Consumption[§]

*Not sampled
[§]It would be prudent public health practice to limit consumption.

One adult meal of fish is considered to be 8 ounces (227 grams). One adult meal of goose is between 6 and 8 ounces. Children were assumed to eat one-third as much as adults.

LWBR = Lower Watts Bar Reservoir

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, 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. 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 in that they provide additional information about human health effects and they are useful in that they 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 a plausible, reasonable expectation emerges of adverse health effects associated with the observed levels of exposure to contaminants. In this PHA on PCB releases, ATSDR scientists determined that people eating *certain species of fish* from Poplar Creek, the Clinch River, the Tennessee River, and the Lower Watts Bar Reservoir could be exposed to PCBs.

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 PHA.

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 PHA, ATSDR sufficiently documented completed exposure pathways from eating fish and turtles. ATSDR conducted an exposure investigation to determine the body burden, or the actual amount of PCBs at a specific time, in the bodies of people who ate moderate to large amounts of fish and turtle. The results of this investigation showed that body burdens of Watts Bar Reservoir moderate to high fish consumers are below those of people exposed occupationally, above nonfish consumers, and within the range for people who consume sport fish. ATSDR also calculated estimated exposure doses and found that all of the calculated doses are below levels associated with health effects. Because the estimated doses are not expected to cause *observable* health effects, no further analysis of health outcome data is appropriate. Further, fish consumption provides beneficial developmental effects, decreased incidence of and mortality from cancer, and improvements in heart health. 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 is not feasible, the requirement to consider analysis of site-related health outcome data on the basis of exposure is complete.

> As a conservative measure, ATSDR determined prudent public health practice would limit consumption of *certain species of fish* from Poplar Creek, the Clinch River, the Tennessee River, and the Lower Watts Bar Reservoir because some of the doses approached (but did not exceed) the health effects level.

Responding to Community Concerns

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

Area residents have also voiced concerns about cancer. Citizens living in the communities surrounding the ORR have 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 percent 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 of cancer incidence is a descriptive epidemiologic analysis that provides a general picture of the occurrence of cancer in each of the eight counties. The purpose of conducting this evaluation was to provide citizens living in the ORR area with information regarding cancer rates in their county compared with those in the state of Tennessee as a whole. This 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 with cancer incidence rates for the state of Tennessee. No consistent pattern of cancer occurrence was, however, identified. Given the large number of statistical analyses conducted in this assessment, it is not unusual to find some increases and some decreases in cancer occurrence. The reasons for the increases and decreases are unknown. The increases could simply be the result of heightened awareness and screening in particular areas. The document 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 ORR. 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

Responding to community health concerns is an essential part of ATSDR's overall mission and commitment to public health. 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 is addressing these community health concerns in the ORR PHAs 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 2001–2005, ATSDR compiled more than 3,000 community health concerns obtained from 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 PHA are those concerns in the ATSDR Community Health Concerns Database related to PCB releases from the ORR. Table 14 contains the actual comments and ATSDR's responses. These concerns and responses are sorted by category (concerns about PCBs, concerns about fish and turtles that could be related to their PCB contamination, and PCB-related concerns about the Clinch River and East Fork Poplar Creek).

Table 14. Community Health Concerns from the Oak Ridge Reservation Community Health Concerns Database

	Actual Comment	*ATSDR's Response*
Concerns about PCBs		
1	The multiple exposure problem-There is no coefficient for this phenomenon. It is not possible to assess the toxicity of all known compounds, never mind of their combinations. The most obviously suspicious cases were exposures to PCBs and mercury, in which similar symptoms occurred elsewhere in the country. All interactions in the body have not been studied and understood, but he felt that they were not likely.	ATSDR could find only one such peer-reviewed study in which Oswego, New York children exposed in the womb to the highest levels of highly chlorinated PCBs were said to be more sensitive to the effect of exposures to mercury on cognitive development, although levels of mercury exposure did not affect sensitivity to PCBs (Stewart, et al. 2003). The difference in performance of the exposure groups was, however, within the internal consistency and reliability expected of the test used, and the difference seen at age 38 months was gone at age 54 months, when one of the sub tests showed better performance in the highest PCB group than in the group for which PCBs were not detected. The authors considered their results inconclusive until they could be repeated by other scientists. Although the Watts Bar Reservoir Exposure Investigation (EI) found total serum PCBs in ORR fish consumers to be higher than in unexposed people, but similar to other fish consumers nationally, ATSDR did not find the proportion of highly chlorinated PCBs to be higher in the ORR sera than in that of unexposed people. So the Stewart et al. (2003) study, if its results can be replicated in the future, might not have relevance to ORR fish/biota consumers. The commenter is probably correct about the likelihood of harmful interactions among site-related contaminants. It is true that many medicines, intentionally prescribed at doses high enough to have an effect, will interact with other medicines. Doctors commonly ask their patients for lists of all their drugs and doses to avoid harmful interactions among the effects the different medicines can cause. But exposures to environmental pollutants are commonly at doses near their MRLs or reference doses, which are usually hundreds to thousands of times less than those observed to cause effects (ATSDR 2004, 2005; U.S. EPA 2005). Pollution levels need to be orders of magnitude higher than these standards to have any effect, or to be able to cause interactions (Groten et al. 1997; Jonker et al. 1993). Hazardous sites rarely release that much pollution to the areas where people live (see our Web site http://www.atsdr.cdc.gov/). Therefore we do not usually expect toxic interactions in such environments, including residential areas near the ORR.

	Actual Comment	ATSDR's Response
2	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? A public health study takes the exposure data and health outcome data and tries to find a correlation between them. "Study" in this sense is a very specific term and should not be taken lightly. It should not be confused with "investigations" such as the one at Watts Bar. 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? So finding one or two people that were in the high risk category might be pretty misleading, if indeed the study didn't really reflect how-I mean stored PCBs in people. 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 the Watts Bar Reservoir EI in March 1998. The EI evaluated the levels of PCBs (and mercury) in people who consumed moderate to large quantities of turtles and fish from the Watts Bar Reservoir. The EI reported: (1) the participants' serum levels are slightly below national norms for total PCBs and (2) of the 116 people tested, only 5 (4%) had a serum PCB level above the level that is regarded as elevated for total PCBs, and only 1 participant had a serum PCB level that was above the distribution seen in the general population. In this PHA's additional extensive review of the scientific literature, ATSDR found that body burdens of Watts Bar Reservoir moderate to high fish consumers are below those of people exposed occupationally, above those of nonfish consumers, and within the national norm for those who consume sport fish (see Figure 28). Follow-up counseling was provided for participants with elevated PCB blood levels. PCBs are persistent organic pollutants and remain in the environment or in the body for a long time. After a fish meal, blood PCB levels are elevated for 24–48 hours, until the PCBs equilibrate into the tissues. If they are ingested repeatedly, they accumulate. That is why the oldest participants in the EI had the highest body burdens. By comparing ORR body burdens to those nationwide and researching the scientific literature about effects of body burden levels, ATSDR took this age-related effect into account. TDEC is the state agency responsible for issuing these public health advisories. They may be seen at http://www.state.tn.us/environment/wpc/publications/advisories.pdf. ATSDR recommends that the advisories be followed as a prudent public health practice. To lower PCB exposure, ATSDR recommends that people should skin fillets, remove belly fat from fish, and cut away excess fat from turtles and geese taken near the ORR. Fish and turtles should be prepared by methods that permit fat to drain away. Under the Tennessee Oversight Agreement, TDEC established a DOE Oversight Division office in Oak Ridge, Tennessee. This division conducts annual monitoring of chemical and radioactive substances released from the ORR to assure that the levels of contaminants do not pose a public health hazard. DOE publishes its findings in an annual report that is accessible to the public at http://www.state.tn.us/environment/doeo/active.shtml. Given these findings, TDEC may or may not issue public health advisories. Monitoring data and additional information are available from the Oak Ridge office at 761 Emory Valley Road, Oak Ridge, TN. For more information about Oak Ridge advisories, call John Owsley at 865-481-0995. Visit http://www.state.tn.us/environment/doeo/ for details about this division (TDEC 2003b). This PHA found that at the consumption levels reported in the EI, eating turtle meat does not expose people to levels of PCBs sufficient to cause illness. People should not, however, eat the turtle fat.

	Actual Comment	ATSDR's Response
3	Uranium, mercury, iodine, and PCBs have been detected in Scarboro. 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.	In addition to this evaluation of PCBs from the ORR, ATSDR scientists have completed or are conducting PHAs on the following ORR-related releases: Y-12 uranium releases, Y-12 mercury releases, X-10 iodine-131 releases, and K-25 uranium and fluoride releases. PHAs were also conducted on other issues of concern such as the TSCA incinerator and off-site groundwater. ATSDR also screened current (1990 to 2003) environmental data to identify any other chemicals that required further evaluation. The completed PHAs can be found at http://www.atsdr.cdc.gov/HAC/oakridge/phact/index.html. In 1998, the Florida Agriculture and Mechanical University (FAMU) collected soil and sediment from Scarboro and analyzed 10 percent of the samples for 150 organic and inorganic chemicals (FAMU 1998). ATSDR evaluated these data and determined that none of the chemicals detected (over 100 chemicals were not detected) were at concentrations that would cause harmful health effects from exposure to the soil or sediment. In this PHA, ATSDR found that PCBs in East Fork Poplar Creek (EFPC) sediment and associated floodplain soil near the Scarboro region (which is elevated 40 feet above EFPC) were at levels too low to affect the most sensitive residents, who are the children playing there on a daily basis (see Figure 15 and Figure 16).
4	There is one other very important thing in the 1990s. I believe about 1993 or 1994 is when the most concern was raised about the TSCA Incinerator and PCBs.	From the dose reconstruction, "Based upon the data collected, it is unlikely that oils containing high concentrations of PCBs were incinerated. Waste oils containing high concentrations of PCBs are nonflammable and would have been disposed in burial pits. In addition, the only documented wastes with high concentrations of PCBs (the cutting fluids) were disposed in the 1970s after the practice of burning waste oils had been discontinued. It is possible, however, that wastes containing lower concentrations of PCBs (up to several hundred parts per million) could have been burned at the facility, potentially resulting in PCB levels in ambient air and also causing the formation of low levels of chlorinated dioxins and furans" (ChemRisk 1999a). The authors of the dose reconstruction considered air transport a less significant source of the total PCB dose than transport via water, sediment, and fish. Direct air pathways were eliminated as sources of illness by the dose reconstruction. In this PHA, ATSDR validated and accepted pathway elimination by the dose reconstruction because the dose reconstruction used conservatively estimated and modeled environmental concentrations even when actual concentration data were lower than those modeled.

	Actual Comment	ATSDR's Response
5	The dose reconstruction missed a lot of PCBs that came from the lab, and there are no records of what came from White Oak Creek. 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.	The dose reconstruction said, "Although records of the last 15 years indicate that releases from [X-10] have been negligible, measurable levels of PCBs exist in White Oak Creek Embayment and White Oak Lake. This suggests that PCBs have been released from X-10 operations. It is not clear whether these observed levels have resulted from releases that occurred prior to the late 1970s or from ongoing low level releases. . . It should be noted that PCBs likely entered the Clinch River from White Oak Creek. This contribution was included in the evaluation of exposures from the consumption of Clinch River Fish" (ChemRisk 1999a). Because White Oak Creek is located on site and there are signs and a barrier, ATSDR did not evaluate eating fish from White Oak Creek. If people were to fish in White Oak Creek it would most likely be in the area of the confluence with the Clinch River since the sediment retention dam prevents people from entering White Oak Creek from the Clinch River. Fish in this area are likely to contain levels of PCBs similar to those in the Clinch River, which ATSDR did evaluate. Therefore, ATSDR recommends that adults and children avoid eating moderate to high amounts of largemouth bass, white bass, hybrid bass, striped bass and catfish from this area as well.
6	Has physician training on polychlorinated biphenyls and cyanide had any benefit and if the referrals were helpful.	Yes, it resulted in counseling patients about their exposures and in providing referrals to specialists.
7	What about area contamination sources? Can ATSDR estimate the contamination resulting from ORR operations?	The Task 3 team investigated historical uses and releases of PCBs at the ORR. They also identified more than 22 additional facilities that managed PCB-containing wastes upstream from the ORR. They noted that "it is difficult…to discern what fraction of the PCBs in fish in the vicinity of the ORR may have been contributed by these other facilities" (ChemRisk 1999a). Please see Section 3.1 and 3.2 in the Task 3 report for additional details.
8	Do plants uptake PCBs?	PCBs are strongly sorbed by soil organic matter and clay, which inhibits the uptake of PCBs in plants through the roots (Bacci and Gaggi 1985; Chu et al. 1999; Gan and Berthouex 1994; Paterson et al. 1990; Strek et al. 1982b; Webber et al. 1994; Ye et al. 1992a). Plant bioconcentration factors of PCBs from soil are estimated to be <0.02 for most terrestrial plant species (Cullen et al. 1996; O'Connor et al. 1990; Pal et al. 1980). PCBs adhere to the outer surfaces of plants, especially root crops such as carrots. To remove PCBs from such crops, especially when they are grown in contaminated soil, peel before eating.
Concerns about Fish and Turtles that Could Be Related to their PCB Contamination		
9	The units are confusing and meaningless in mg/kg/day, could the expression use so many sized fish consumed per day? People in the area consume a lot of local fish and locally grown foods so there should be site-specific intake rate values.	Please see Figure 1 for ATSDR's recommended maximum number of fish meals that can safely be eaten from the waterways near the ORR. One adult meal is considered to be 8 ounces (227 grams). Children were assumed to eat one-third as much as adults.

	Actual Comment	***ATSDR's Response***
10	They fish out of the local lakes and streams and the streams are contaminated for a hundred miles. Having grown up along lakes and creeks, I'd like to point out that people were not limited to one area, fishing people went everywhere. Because of this, it is difficult to pinpoint one single location. What about the levels of PCBs in the fish? Since vegetables and fish are the dominant pathways, are people who live downstream at higher risk?	In this PHA, ATSDR evaluated levels of PCBs in fish in the local lakes and streams (all along the three arms of the Watts Bar Reservoir, including the Clinch and Tennessee Rivers), and Poplar Creek. ATSDR made the following conclusions: • Sunfish species can safely be eaten in any amount. • All fish species can safely be eaten in low amounts from any water body near the ORR. • Eating moderate to high amounts of certain species of fish (catfish, white bass, hybrid bass, and striped bass) is not recommended. ATSDR recommends that people follow the fish advisory to reduce their exposures. • People should avoid eating turtle fat. Discarding the fat, eggs, and all organs—while only saving the meat (muscle) for eating—can reduce exposure to PCB-contaminated fat and tissue. Please see Figure 1 for ATSDR's recommended maximum number of fish meals that can safely be eaten from the waterways near the ORR.
11	Concentrations of PCB in fish of upper East Fork Poplar Creek are not decreasing.	ATSDR eliminated East Fork Poplar Creek fish consumption as a pathway posing a potential health hazard. East Fork Poplar Creek is not a productive fishing location, and very few people actually eat fish from this creek. Most local fish are caught from the Clinch River and the Watts Bar Reservoir. Further, in 1996 and 1997, 34,220 loose cubic meters of mercury-contaminated soils were removed from the floodplain near the NOAA Atmospheric Diffusion Laboratory off Illinois Avenue and across the Oak Ridge Turnpike from the Bruner's Shopping Center on the Wayne Clark Property. PCB-contaminated soils in these areas would also have been removed during this remediation.
12	Since the contamination from fish ingestion will not necessarily be measurable in the blood stream 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 medical tests that measure the level of PCBs in the body by analyzing blood, body fat, and breast milk. These are not routine 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 amount of exposure, the type of PCBs, or if adverse health effects will occur. Thus, these tests do not enable physicians to provide better care for their patients (ATSDR 2000). For more information on PCBs, visit http://www.atsdr.cdc.gov/toxprofiles/phs17.html.

	Actual Comment	ATSDR's Response
13	I'm very concerned/interested in how ATSDR addresses PCBs in turtles in the final report. We sample turtles every 5 years and find PCBs significantly higher then in fish. There is no consumption advisory on turtles and this seems to be a contradiction. It must be based on a lower intake of turtle flesh per year. It would be great if ATSDR could address this head on in their PHA and state very clearly whether there is any risk from consuming turtles and if not why.	The median PCB concentration detected in turtle meat (140 ppb) is about equal to the median PCB concentration detected in largemouth bass from Poplar Creek (130 ppb); that is higher than the concentrations in sunfish (22–40 ppb) and lower than the concentrations in white bass, striped bass, hybrid bass, and in catfish species (440–1,270 ppb). The median PCB concentration detected in turtle fat (44,000 ppb) is much higher than the median PCB concentrations detected in any other biota species (see Table 11). In this PHA, ATSDR evaluated three turtle meat consumption levels—eating two meals of turtle per year, eating one meal of turtle per year, and eating one meal of turtle every 6 years. These consumption rates were established from the information gathered during ATSDR's exposure investigation. ATSDR's evaluation determined that eating turtle meat up to twice a year does not pose a public health hazard. Because, however, the level of PCBs detected in turtle fat (44,000 ppb) is so much higher than turtle meat and all the other fish species, people should avoid eating turtle fat. Discarding the fat, eggs, and all organs—while only saving the meat (muscle) for eating—can reduce exposure to PCB-contaminated fat and tissue.
14	What is the national PCB average in fish?	EPA's National Study of Chemical Residues in Fish reported an arithmetic mean of 1.89 ppm (wet weight) for total PCBs (U.S. EPA 1999a). EPA Region 5 and the Upper Mississippi River Conservation Committee compiled a database of fish tissue data collected throughout the Upper Mississippi River from 1970 through 1998 (U.S. EPA 2002a). For additional perspective on PCB levels in fish, please see their report at the following Web site: http://www.epa.gov/region5/water/umr_wq_assess.htm.
15	Do species that are higher on the food chain contain higher PCB levels?	Yes. PCBs bioaccumulate through the aquatic food chain. Species that are higher on the food chain typically contain higher PCB concentrations. See Appendix C. Examples of Various Aquatic Food Webs.
16	Is it safe to eat carp?	Due to their high lipid content, carp are a suitable species for assessing PCB contamination and would closely mirror the levels found in ORR catfish. Therefore, ATSDR recommends following the same advisory for carp as catfish (i.e., children should avoid eating more than one carp meal per month and adults should avoid eating more than one carp meal per week).
17	Is it safe to eat crappie?	Crappie are members of the sunfish family, Centrarchidae. Therefore, it is likely that some crappie were captured and reported as "sunfish spp.," which were among the species evaluated during this health assessment. The concentrations of PCBs detected in sunfish spp. were below levels posing a health hazard. Therefore, ATSDR presumes that it is also safe to eat crappie based on the PCB levels found in sunfish.
18	What is the lifespan of catfish?	According to FishBase, Channel catfish (*Ictalurus punctatus*) can live a maximum of 16 years, flathead catfish (*Pylodictis olivaris*) can live a maximum of 20 years, and blue catfish (*Ictalurus furcatus*) can live a maximum of 21 years (www.fishbase.org).

	Actual Comment	ATSDR's Response
PCB-Related Concerns about the Clinch River		
19	What is the probability of a clinic for residents closely associated and who live close by incinerators and the Clinch River and East Fort Poplar Creek?	On August 27, 2002, ORRHES determined that discussion of public health activities related to establishment of a clinic, clinical evaluations, medical monitoring, health surveillance, health studies, and biological monitoring is premature. The ORRHES recommended postponing formal consideration of these issues until the ATSDR PHA process identifies and characterizes an exposure of an off-site population at levels presenting a health hazard. ATSDR scientists generally consider recommending follow-up public health activities that are service- or research-oriented (e.g., medical monitoring, health studies, health surveillance, or research) when there is a plausible, reasonable expectation of adverse health effects associated with the observed levels of exposure to contaminants. In this PHA on PCB releases, ATSDR scientists determined that people eating certain species of fish from Poplar Creek, the Clinch River, the Tennessee River, and the Lower Watts Bar Reservoir could be exposed to PCBs. The results of ATSDR's exposure investigation on people who ate moderate to large amounts of fish and turtles from the Watts Bar Reservoir investigation showed, however, that body burdens of Watts Bar Reservoir moderate to high fish consumers are below people exposed occupationally, above nonfish consumers, and within the range for people who consume sport fish. ATSDR also calculated estimated exposure doses and found that all of the calculated doses are below levels associated with health effects. Because the estimated doses are not expected to cause health effects, analysis of health outcome data, medical monitoring, or surveillance is not appropriate. Further public health activities are 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 further public health activities on the basis of exposure is complete. But as a conservative measure, ATSDR determined prudent public health practice would limit consumption of *certain species of fish* from Poplar Creek, the Clinch River, the Tennessee River, and the Lower Watts Bar Reservoir; some of the doses approached (but did not exceed) the health effects level. Therefore, ATSDR recommends people follow the TDEC's fish consumption advisories for Poplar Creek, the Clinch River, the Tennessee River, and the Lower Watts Bar Reservoir. The advisory is available at the following Web site: http://www.state.tn.us/environment/wpc/publications/advisories.pdf. ATSDR will also develop health education materials to help community members understand the fish consumption advisory and ways to minimize exposure to PCBs in fish.
20	Are the impacts of solid waste storage areas on groundwater considered in any of the PHAs? Today's Knoxville newspaper reported on the impacts on the Clinch River and downstream reservoir of solid waste storage areas.	ATSDR evaluated exposures to off-site groundwater in a pathway-specific PHA. It was released final in 2006, and can be accessed at http://www.atsdr.cdc.gov/HAC/pha/oakridge_gw_7-06/gor_toc.html.

	Actual Comment	ATSDR's Response
21	There was more PCBs coming down the Tennessee River than the Clinch River.	That was the result modeled by the dose reconstruction: loading to the riverbed and fish for these two rivers deposited more PCBs to the Tennessee River. It also seemed logical because the ORR would have been the primary contributor to Clinch River pollution, while multiple sources released PCBs to the Tennessee River. The only sediment core with detectible PCBs was, however, one taken from the Clinch River at CRM 9.5 (see Figure 15 and Figure 16). From the more than 52,000 records of biota ATSDR reviewed for this document, the median PCB levels in fish taken before 1996 from the LWBR (a part of the Tennessee River widened by the Watts Bar Dam) and the Tennessee River were about half that taken from fish in the Clinch River (see the distribution graphs in Figure 17, Figure 18, and Figure 19). Because of regulatory oversight, the ORR began to remediate sources of PCBs as early as the 1970s, and that may have been earlier than other facilities were able to begin. Based on samples collected 1996 and after, Clinch River fish PCB medians were 20–25 percent of the medians from the LWBR and the Tennessee River (see Figure 23, Figure 24, and Figure 25).
PCB-Related Concerns about East Fork Poplar Creek (EFPC)		
22	Lower EFPC flows through the Scarboro community; so does Scarboro Creek.	Scarboro is located at an elevation of about 40 feet higher than EFPC and avoided direct contact with discharges of waterborne Y-12 contaminants (such as the PCBs carried by EFPC sediment). In 1998, FAMU collected soil and sediment from Scarboro and analyzed 10 percent of the samples for 150 organic and inorganic chemicals (FAMU 1998). ATSDR evaluated these data and determined that none of the chemicals detected (over 100 chemicals were not detected) were at concentrations that would cause harmful health effects from exposure to the soil or sediment.
23	East Fork Poplar creek has been identified by TDEC as the most contaminated creek in Tennessee according to the Oak Ridger newspaper.	In this PHA, ATSDR mapped PCB contamination in the sediment under EFPC and the floodplain alongside (Figure 16) and graphically showed that PCB contamination of EFPC sediment and associated floodplain soil is all below comparison values (Figure 15). Thus, for PCBs the EFPC is not the most contaminated creek in Tennessee.

VII. Child Health Considerations

ATSDR recognizes that infants and children can be more sensitive to environmental exposure than are adults in communities faced with contamination of their water, soil, air, or food. This sensitivity is a result of 1) children's higher probability of exposure to certain media (for example, soil or surface water) because they play and eat outdoors; (2) children's shorter height, which means that they can breathe dust, soil, and vapors close to the ground; and (3) children's generally smaller stature, which means childhood exposure will result 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. As part of ATSDR's Child Health Initiative, ATSDR is committed to evaluating the special interests of children at sites such as the ORR.

Children can be exposed to PCBs both prenatally and from breast milk. PCBs are stored in the mother's body and can be released during pregnancy, cross the placenta, and enter fetal tissues. Because PCBs dissolve readily in fat, they can accumulate in breast milk fat and be transferred to babies and young children. In one study of women exposed to relatively high concentrations of PCBs in the workplace during pregnancy, their babies weighed slightly less at birth than babies born to women exposed to lower concentrations of PCBs. Studies of women who consumed high amounts of fish contaminated with PCBs and other chemicals also had babies that weighed less than babies from women who did not eat PCB-contaminated fish. Babies born to women who ate fish contaminated with PCBs before and during pregnancy showed abnormal responses to tests of infant behavior. Some of these behaviors, such as problems with motor skills and a decrease in short-term memory, persisted for several years. However, in these studies, the women may have been exposed to other chemicals. Other studies suggest that the immune system may be affected in children born to and nursed by mothers exposed to increased levels of PCBs (ATSDR 2000).

> A study by Gladen et al. (1988), however, did not demonstrate any effect on infant psychomotor response associated with exposure through breastfeeding.

Animal studies have shown harmful effects in the behavior of very young animals exposed to PCBs in the womb or through breast milk. In addition, some animal studies suggest that exposure to PCBs causes an increased incidence of prenatal death and changes in the immune system, thyroid, and reproductive organs. Studies in monkeys showed that young animals developed skin effects after nursing from mothers who were exposed to PCBs. Some studies indicate that very high doses of exposure to PCBs *in utero* may cause structural birth defects in animals (ATSDR 2000).

Children could have been exposed to PCBs in the womb during their mothers' pregnancies and while nursing if their mothers ate fish from the creeks and rivers near the ORR. As they were weaned and began eating food from their parents' plates, they could have been exposed to PCBs in the fish their parents ate. ATSDR estimated that the youngest, most vulnerable children could have eaten as much as one-third the amount of the adults. In addition, children living near the ORR could have been exposed to small amounts of PCBs if they played in the sediment and soil along the Watts Bar Reservoir. From the exposure scenarios considered, however, the highest doses would have come from fish consumption—still, these doses are not expected to have caused harm. Further, in most cases, the benefits of breast-feeding outweigh any risks from exposure to PCBs in mother's milk. "With full regard for the uncertainty over the toxic effects of organochlorines in human milk, the known benefits of breastfeeding are extensive and serve as a strong rationale for advising mothers to continue to breast feed their newborns unless cautioned by their local health care worker to reduce or stop" (Van Oostdam et al. 1999). ATSDR recommends you consult your health care provider if you have any concerns about PCBs and breast-feeding.

> The advantages of breast-feeding include improved nutrition, increased resistance to infection, protection against allergies, and better parent-child relationships.

VIII. Conclusions and Recommendations

Having evaluated the release of PCBs from the ORR and the potential past and current exposure to PCBs, ATSDR has reached the following conclusions:

- Past, present, and future exposure to PCBs in the sediment, soil, surface water, turtle meat, and geese pose ***no apparent public health hazard***. The levels of PCBs released to off-site waterways such as East Fork Poplar Creek, Popular Creek, the Clinch River, the Tennessee River, and the Lower Watts Bar Reservoir, or their associated sediment and nearby soils, are not expected to cause harmful health effects to people who live or visit near these waterways, and who engage in recreational activities, drink the water, garden in the soil, consume turtle meat, or eat geese.

> ATSDR's category of *no apparent public health hazard* means that people were, are, or could be exposed, but the level of exposure would not be likely to cause harm to people's health.

- ATSDR's review of PCB body burdens nationwide found that body burdens of people who ate moderate to high amounts of fish from the Watts Bar Reservoir or the Clinch River are below those of people exposed occupationally, above those of nonfish consumers, and within the national range for those who consume sport fish.

- Frequent eating of moderate to large amounts (one or more meals a week for an extended period of time) of certain fish species (catfish, white bass, hybrid bass [striped bass-white bass], striped bass, and largemouth bass) is potentially a ***public health hazard***. Noncancer health effects (immunological and developmental) have been observed in animals exposed to amounts similar to those ATSDR estimated for people who frequently eat large amounts of these fish. Certain sensitive populations, such as pregnant women, nursing mothers, and children, should be particularly careful and limit intake of certain species.

> ATSDR's *public health hazard* category means that long-term exposures (greater than 1 year) to a substance could result in harmful health effects.

  Given these findings, ATSDR believes prudent public health practice would limit consumption of certain species of fish. The agency recommends people follow the TDEC's fish consumption advisories for Poplar Creek, the Clinch River, the Tennessee River, and the Lower Watts Bar Reservoir. The advisory is available at the following Web site: http://www.state.tn.us/environment/wpc/publications/advisories.pdf.

  Fish is a healthy food that provides many nutritional benefits. People can safely (i.e., **not** a public health hazard) eat any amount of sunfish species. Children can safely eat largemouth bass up to once a week; adults can safely eat any amount of largemouth bass. People can without undue risk eat small amounts (up to one fish meal a month) of catfish, white bass, hybrid bass, and striped bass. If community members wish to reduce their exposure to PCBs without forfeiting the benefits from eating fish, they can follow these suggestions:

- Eat the less fatty parts of the fish; throw away skin, fat deposits, head, guts, kidneys, and liver.
- Remove the skin and the strip of light-colored fat that remains along the belly flap at the bottom of the fillet as well as any fat that may be present along the sides and the midpoint of the back.
- Grill, broil, or bake fish on a rack to allow fat—and chemicals—to drain away. This helps remove pollutants stored in the fatty parts of the fish. Avoid frying for larger, fatty fish.
- Do not reuse cooking liquids or fat drippings from the fish because these liquids retain PCBs.
- Choose to eat younger (or smaller) fish and those lower on the food chain (e.g., sunfish).

- In 1996 PCBs in turtle fat were found at extremely high concentrations in the turtles collected from the Watts Bar Reservoir and the Clinch River. Care should be taken to avoid eating turtle fat. ATSDR recommends the following precautions to reduce your exposure to contaminants that may be present in turtle fat:

ATSDR's evaluation of PCBs indicates that it is safe for people to eat turtle meat.

- Lay the turtle on its back shell (carapace).
- Remove the shell that faces you (the plastron) by carefully cutting through the two bony ridges (on both sides of the turtle) between the fore and hind limbs.
- Remove carefully and discard any fat and eggs present, and all organs, such as the liver and kidneys. Save only the muscle (meat) for eating.
- Remove claws from the fore and hind limbs.
- Remove skin from the neck, tail, and fore and hind limbs.
- Combine all meat portions you wish to save.

IX. Public Health Action Plan

The public health action plan (PHAP) for the ORR describes the actions to be taken by ATSDR and other government agencies at the vicinity of the site after the completion of this PHA. The purpose of the PHAP is to ensure that the PHA not only identifies potential public health hazards, but that it also provides a plan of action designed to mitigate and/or prevent adverse human health effects potentially resulting from exposure to harmful substances in the environment. If additional information about ORR releases to nearby waterways—especially those that could affect the biota therein—becomes available, that could change this PHA's conclusions. If that occurs, then human exposure pathways should be reevaluated and these conclusions and recommendations should be amended, as necessary, to protect public health.

Upon request from the public, ATSDR will develop and implement additional environmental health education materials to help community members understand the findings and implications of this PHA.

Please see Section II.F. for a summary of public health activities pertaining to PCB releases and Appendix B for a summary of additional public health activities.

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