PUBLIC HEALTH ASSESSMENT

Evaluation of Exposures to Contaminants in Biota Originating from the Savannah River Site (USDOE)

Savannah River Site
Aiken, South Carolina
EPA Facility ID: SC1890008989

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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 states regulate the investigation and cleanup 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 scientists from ATSDR and from states with which ATSDR has cooperative agreements. The public health assessment program allows 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. Whatever the form of the public health assessment, the process is not considered complete until public health issues at the site are addressed.

Exposure

As the first step in the evaluation, ATSDR scientists review environmental data to see what chemicals are present, where the chemicals were found, and how people might come into contact with the chemicals. Generally, ATSDR does not collect its own environmental sampling data but reviews information provided by EPA, other government agencies, businesses, and the public. When environmental data does not allow ATSDR to fully evaluate exposure, the report will indicate what further sampling data are 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 exposures may result in harmful effects. ATSDR recognizes that developing fetuses, infants, and children can be more sensitive to exposures than are adults. As a policy, unless data are available to suggest otherwise, ATSDR considers children to be more sensitive and vulnerable than adults. Thus, the health impact to the children is considered first when evaluating exposure and the potential adverse effects to a community. The health impacts to other groups within the community (such as the elderly, chronically ill, and people engaging in high-exposure 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 likelihood of 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. In this case, this report suggests what further public health actions are needed.

Conclusions

This report presents conclusions about the public health threat, if any, posed by a site. Any health threats that have been determined for high-risk groups (such as children, the elderly, chronically ill people, and people engaging in high-risk practices) are summarized in the Conclusions section of the report. Ways to stop or reduce exposure are recommended in the Public Health Action Plan section.

ATSDR is primarily an advisory agency, so its reports usually 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
ATTN: Records Center
4770 Buford Highway, NE (Mail Stop F-09)
Atlanta, GA 30341

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Acronyms and Abbreviations

AEC	Atomic Energy Commission
ATSDR	Agency for Toxic Substances and Disease Registry
CDC	Centers for Disease Control and Prevention
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CV	ATSDR's comparison value
CWMAER	Crackerneck Wildlife Management Area and Ecological Reserve
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ERDA	Energy Research and Development Administration
ESOP	Environmental Surveillance and Oversight Program
GDNR	Georgia Department of Natural Resources
GDNR-EPD	Georgia Department of Natural Resources – Environmental Protection Division
MOX	Mixed Oxide (facility)
NCEH	CDC's National Center for Environmental Health
NERP	National Environmental Research Park
NIOSH	National Institute for Occupational Safety and Health
NNSA	National Nuclear Security Administration
NRMP	Natural Resources Management Plan
NPL	National Priorities List
PCBs	polychlorinated biphenyls
PCDD	polychlorinated dibenzo–p-dioxins
PCDF	polychlorinated dibenzofurans
pCi/g	picocurie/gram
pCi/L	picocurie/liter
PHA	public health assessment
ppm	parts per million
RCRA	Resource Conservation and Recovery Act
SCDHEC	South Carolina Department of Health and Environmental Control
SCDNR	South Carolina Department of Natural Resources
SRARP	Savannah River Archeological Research Program
SREL	Savannah River Ecology Laboratory
SRNL	Savannah River National Laboratory
SRNS	Savannah River Nuclear Solutions
SRP	Savannah River Plant
SRS	Savannah River Site
SRSCAB	Savannah River Site Citizens Advisory Board
SRSHES	Savannah River Site Health Effects Subcommittee
TEF	toxic equivalency factor
TEQ	toxic equivalency
TCE	trichloroethylene
USFS-SR	United States Forest Service – Savannah River
USGS	United States Geological Survey
VOCs	volatile organic compounds
WSRC	Westinghouse Savannah River Company

Summary

Introduction

The Agency for Toxic Substances and Disease Registry (ATSDR) recognizes that people living near or frequenting the area near the Savannah River Site (SRS) have questions about the safety of the environment and the potential for adverse effects on their health. ATSDR's top priority is to ensure that people living in the vicinity of SRS have the best information possible to safeguard their health.

Prior to 1993, when production of radioactive materials for weapons use ceased, hazardous materials and waste were used and stored at SRS which led to releases to the environment. From 1995 through 2005, the Centers for Disease Control and Prevention (CDC) issued three documents addressing the community's past exposures to radioactive materials from 1954 through 1992. This public health assessment covers the time period from 1993 to 2008, which is after production activities ceased, but when waste storage and cleanup continued at the site. It is specifically intended to provide information to the community about radioactive and chemical contaminants in plants and animals, both on and off site, which may be eaten by hunters and community members.

To determine whether a potential for harmful exposures exists, ATSDR reviewed information concerning hunting, fishing, and farming activities in the area and evaluated biota sampling data provided by the U.S. Department of Energy (DOE) and the states of South Carolina and Georgia and obtained in the published scientific literature.

Conclusions

ATSDR reached three main conclusions in this public health assessment:

Conclusion 1

Based on information reviewed by ATSDR, the general population is not exposed to harmful levels of radioactive contaminants if they eat *off-site* crops, livestock, and wild game harvested or produced near SRS.

Basis for conclusion

Using maximum ingestion rates and maximum concentrations of detected radioactive materials, ATSDR estimated hypothetical screening level exposures from various activities. These hypothetical exposures are at levels that will not harm people's health.

Next Steps

DOE should remain informed of and continue to monitor the biota consumed by people both on and off the site until all remediation actions are completed and no old or new sources of contamination remain.

Conclusion 2 Consuming large amounts of largemouth bass, bowfin, and catfish from certain portions of the Savannah River might increase health risks, especially to sensitive populations (e.g., pregnant and nursing mothers and children), due to the level of mercury detected. The levels of other metals in fish from the Savannah River and its tributaries will not harm people's health.

Basis for conclusion Mercury levels are elevated in some species of fish found in the Savannah River and its tributaries. However, some fish from these water bodies can be consumed without harm to people's health if the species-specific fish advisory guidance is followed.

Mercury contamination in fish from the Savannah River, both upstream, along, and downstream of SRS, has been well documented by state agencies. However, the contribution of mercury from SRS-related activities to the river system is not known.

Next Steps People should follow the fish consumption advisories that are issued by South Carolina and Georgia for specific portions of the Savannah River. Species such as bowfin, largemouth bass, and catfish typically accumulate the highest concentrations of mercury.

Conclusion 3 ATSDR cannot make a definitive public health conclusion about non-metal contaminants in biota (e.g., pesticides and polychlorinated biphenyls [PCBs]), some of which have been detected in the ambient environment at SRS.

Basis for conclusion There is very limited fish sampling data for other chemical contaminants. The limited pesticide and PCB fish data that ATSDR reviewed indicates that these chemicals would not pose a health hazard.

Next Steps DOE should include selected pesticides and PCBs using appropriate detection limits as part of their routine chemical analyses.

FOR MORE INFORMATION For further information about this public health assessment, please call ATSDR at 1-800-CDC-INFO and ask for information about the Savannah River Site, Aiken, SC site. If you have concerns about your health, you should contact your health care provider.

Purpose and Scope of Document

This public health assessment (PHA) for the Savannah River Site (SRS), formerly the Savannah River Plant (SRP), primarily addresses the human health hazards from 1993 to the present, and potential future exposure to chemical and radioactive materials in biota. Specifically, exposure evaluations may include information on fish from the Savannah River and site streams or tributaries, farm and agricultural products (e.g., farm-raised animals, milk products, peanuts, cotton, or pecans), local garden crops, natural vegetation, and other wildlife (e.g., game species hunted on or near SRS property).

The Centers for Disease Control and Prevention's (CDC's) Savannah River Site (SRS) Dose Reconstruction Project and Risk-Based Screening of Radionuclide Releases from SRS analyzed the community's past exposures to radioactive materials from 1954 through 1992 (CDC 2005). Phase I of the SRS Dose Reconstruction Project, which involved identifying and retrieving significant documents that could be used for the dose reconstruction task, was completed in June 1995. Phase II of the SRS Dose Reconstruction Project estimated historical releases of chemicals and radioactive materials based on site use inventory or usage estimates, knowledge of processes, information currently required by regulatory agencies, and monitoring data. For chemicals, the monitoring data was limited and was primarily collected from 1980 through 1992. The results of the Phase II study were released as a final report in April 2001. Phase III, released in March 2005, estimated the radiation doses and associated cancer risks for hypothetical persons living near SRS and performing representative activities on or near the site. All Phase III scenarios include ingestion of biota that may have been contaminated from air deposition or water pathways. The radionuclide concentrations in the food chain were estimated for Phase III by using generic models from GENII computer code (Napier et al. 2002). The hypothetical scenario with the largest potential exposure was for a child born in 1955 to an "outdoor family" that ate locally grown food including wild game harvested onsite and fish caught in the Savannah River below Lower Three Runs Creek. The strongest contributors to this hypothetical exposure were eating local beef and drinking local milk. The estimated exposure for a child born in 1964 was greatly reduced (~20% of the 1955 estimate) because air releases had been greatly reduced.

By 1993, site reactors were no longer operating, further reducing the air releases, but sources of potential contamination for biota still exist on the site. For example, potential contaminants in ponds, waste storage areas, stream beds, and groundwater can migrate in the environment and eventually bio-accumulate in plants and animals that can be consumed by humans. Since 1992, an enormous amount of environmental sampling data and information have been compiled by contactors for DOE, by the states of South Carolina and Georgia, and by researchers. CDC's dose reconstruction relied mainly on conservative environmental models; ATSDR's evaluation relies on the evaluation of available sampling data. Both potential radioactive and chemical contaminants will be discussed.

For additional reference, this document includes a glossary of terms (Appendix A) and an overview of ATSDR's methodology for evaluating potential contaminants of concern (Appendix B).

Background

Site Description and Operational History

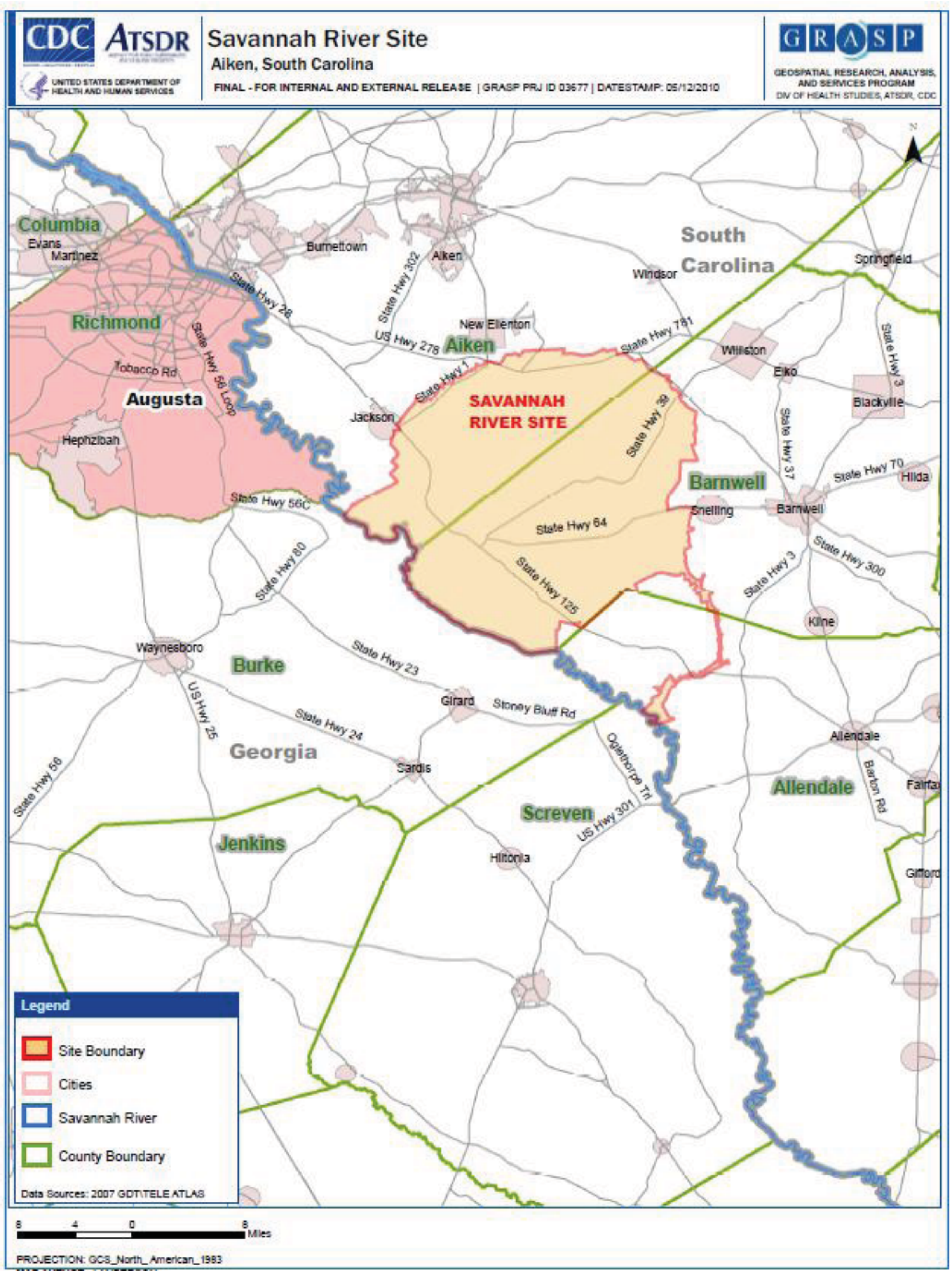
The SRS is a 310-square-mile (806-square-kilometer) U.S. Department of Energy (DOE)-owned and contractor-operated facility. It encompasses 198,344 acres (80,000 hectares) in the southeastern coastal area of the United States in the southwest section of South Carolina (WSRC ND[n]). The site is located on the Aiken Plateau in the Upper Atlantic Coastal Plain about 20 miles southeast of the fall line that separates the Piedmont and Coastal Plain Provinces. SRS is bounded for approximately 27 miles (43 kilometers) on its southwestern border along the South Carolina and Georgia border by the Savannah River (USDOE 2005b).

The closest major population areas to the SRS are Aiken, South Carolina, which is 19.5 miles (31 kilometers) north of the SRS, and Augusta, Georgia, which is 22.5 miles (36 kilometers) northwest of the site. SRS property boundaries include portions of Allendale (4,155 acres; 1,681 hectares), Aiken (72,686 acres; 29,410 hectares), and Barnwell (121,503 acres; 49,170 hectares) counties in South Carolina. In South Carolina, the small towns of Jackson, New Ellenton, and Snelling are adjacent to the northwestern, northern, and eastern site boundaries, respectively (see Figure 1). There are no permanent residents on the site (CDC 2005, USDOE 2005b, USFS-SR 2004).

The former Atomic Energy Commission (AEC) contracted with the E.I. du Pont de Nemours and Company, Inc. (DuPont) to construct SRP in 1950 (WSRC ND[b]). The primary mission of the plant was to support the United States defense program by producing basic materials used in the manufacturing of nuclear weapons (e.g., tritium [hydrogen-3] and plutonium-239) (USDOE 2005b). From 1951 to 1956, DuPont developed, designed, and constructed the SRP, which included five nuclear reactors, two large chemical separation plants, a tritium-processing facility, a heavy-water extraction plant, a uranium fuel-processing facility, a fuel and target fabrication facility, and a waste management facility (USDOE 2000; WSRC ND[m]). In accordance with the Energy Reorganization Act of 1974, the non-regulatory portion of the AEC became the Energy Research and Development Administration (ERDA) in 1975. By 1977, ERDA was replaced by DOE, which is the federal agency that has overseen the site activities since that time (WSRC ND[b]).

DuPont operated the plant until March 31, 1989. On April 1, 1989, Westinghouse Savannah River Company (WSRC) became the primary contractor, and SRP became SRS (WSRC ND[b]). In this document from here on, the site will be referred to as SRS regardless of the referenced time frame. In December 2005, WSRC became Washington Savannah River Company (Whitney 2006). On January 10, 2008, the contract to manage and operate the site for DOE was awarded to Savannah River Nuclear Solutions (SRNS), with SRNS taking over these responsibilities on August 1, 2008 (SRS 2008). This contract runs until December 2012. SRNS is responsible for operating and managing three main SRS areas: the National Nuclear Security Administration (NNSA) activities, operations at the Savannah River National Laboratory (SRNL), and cleanup of environmental contamination. SRNS also handles administrative functions of the site (e.g., SRS infrastructure) (USDOE 2008a).Other contractors at the site are responsible for liquid waste operations, security, construction and operation of the mixed oxide facility, and construction and operation of the salt waste processing facility (SRNS 2010).

Figure 1. Savannah River Site Area Map



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SRS is generally divided into several areas, based on production, land use, and other related characteristics. These areas are shown in Figure 2 and are described below (USDOE 2005b, 2006, 2007, 2008b, 2009, 2010; WSRC ND [i, p]):

- **Administrative facilities:** *A-Area, B-Area,* and part of *H-Area* have primarily administrative facilities that provide office space, training areas, and records storage. Over the last 10 years, most administrative functions have been transferred to *B-Area*. *A-Area*, along with *M-Area* described below, is undergoing some closure activities. The *A-Area* coal-fired steam plant was replaced with a new biomass steam plant, which began operating in September 2008.

- **Heavy water reprocessing** (*D-Area*): This area, now closed, had facilities for supporting heavy water coolant/moderator for the reactors, heavy water purification facilities, an analytical laboratory, and a powerhouse. Demolition of the heavy water extraction and purification facilities was completed in 2006. The *D-Area* coal-fired powerhouse is being replaced with a new biomass unit, which is scheduled to begin operating in 2011.

- **Non-nuclear facilities:** Central Shops (*N-Area*) house construction and craft facilities and the primary facilities for storage of construction materials. The *T-Area* or the *TNX-Area* contained non-nuclear facilities that tested equipment and developed new designs. Completion of all closure activities in this area was accomplished in 2006.

- **Nuclear/radiological facilities:** Fuel/Target Fabrication (*M-Area*) facilities housed the metallurgical/foundry operations for fabricating fuel and target elements for the SRS reactors. All operations have been shut down since the late 1980s. Demolition of most buildings was completed in 2006. Soil and groundwater clean-up activities continued. On October 20, 2010, DOE announced that the M-Area surface clean-up was complete two years ahead of schedule.

- **Reactors:** *C, K, L, P,* and *R Areas* house the C, K, L, P, and R Reactors, respectively. These reactors were used for nuclear production, but are permanently shut down and are being evaluated for deactivation and decommissioning. Fuel storage basins at the L Reactor contain spent nuclear fuel awaiting disposition. Portions of the *K-Area* have been converted to the *K-Area* Material Storage Facility. Decontamination capability has been installed in the *C-Area.* All buildings in the *P-Area* and most buildings in the *R-Area*, except the reactors, have been demolished.

- **Processing facilities:** The facilities in the *H-Area* process, stabilize, separate, and recover nuclear materials. *F-Area* facilities previously performed this work, but primary *F-Area* facilities have been closed. *F-Area* facilities previously contained an analytical laboratory, the Plutonium Metallurgical Building, and the Naval Fuel Facility. The *H-Area* contains the closed Receiving Basin for Off-Site Fuels. The tritium recycling facilities will continue in the *H-Area* and will include tritium loading, unloading, and surveillance operations to support the active stockpile. The Tritium Extraction Facility became operational in 2007. High-level waste tanks are located in the *F-* and *H-Areas*.

- **Waste management facilities:** Solid waste is centrally located in a 195-acre complex in the *G*- and *E-Areas*. These facilities store and dispose of radioactive solid wastes and include the Low Level Radioactive Waste Disposal Facility, the Transuranic Waste Storage Pads, and the Mixed Waste Storage Buildings. *S-Area* facilities house the Defense Waste Processing Facility, which immobilizes the active portion of the high level waste in glass. The Saltstone Processing Facility and the Saltstone Disposal Facility are located in the *Z-Area*.

Historically, irradiated materials were moved from the nuclear reactors to one of two chemical separation plants where the irradiated fuel and target assemblies were chemically processed to separate useful products from waste. Once refined, the useful materials were shipped to other AEC or DOE sites for final application (CDC 2001). The plant also produced radionuclides for nuclear medicine, space exploration, and commercial purposes (USDOE 2000). Liquid and solid radioactive, chemical, and mixed wastes were also created and contaminated surface soil, surface waters, and air during the period of operation (CDC 2005).

The present and future missions of SRS include meeting the needs of the U. S. nuclear weapons stockpile; storing, treating, and disposing of excess nuclear materials safely and securely; treating and disposing of legacy radioactive liquid waste from the Cold War; and cleaning up radioactive and chemical environmental contamination from previous site operations (WSRC ND[p]).

Currently, 12 percent of the site property (24,000 acres; 9,712 hectares) is designated for nuclear processing, research and development, and waste management purposes; 9 percent (18,000 acres; 7,284 hectares) is contained within 30 separate ecological set-aside areas; and another 7 percent (14,000 acres; 5,666 hectares) remains undisturbed to limit the movement of trace radioactive contaminants. The remaining 72 percent of the site (142,000 acres; 57,470 hectares) is forest land (USFS-SR 2005a). The production and support facilities at SRS include buildings, construction areas, and parking lots. The original production facilities occupied less than 10 percent of the total land area, with the major radioactive operations located toward the center of the site (see Figure 2). This layout created a buffer zone aimed at reducing the risk of accidental exposure to the general public and providing security for the site (WSRC ND[b]).

The transportation network at SRS consists of approximately 130 miles (209 kilometers) of primary roads, 1,220 miles (1,963 kilometers) of secondary roads, and 33 miles (53 kilometers) of railroad. Roads serve to provide access for employees; shipment of radioactive and hazardous materials between areas; and access to test wells, utility lines, research sites, and natural resource management activities. The railroad system supports the delivery of foreign fuel shipments, movement of nuclear material and equipment on site, and the delivery of construction materials for new projects (USDOE 2005b, 2005c). In general, public access to SRS has been and is currently restricted to environmental/ecological research studies, guided tours, and controlled hunting and fishing activities (CDC 2005). Controlled hunting and fishing activities are conducted on specified dates and are monitored by SRS personnel and/or the South Carolina Department of Health and Environmental Control (SCDHEC). To address trespassing and easement issues, “no trespassing” and “no fishing” notices are posted along public roads and stream crossings (USFS-SR ND[a]).

The following organizations also have or recently had programs at the site:

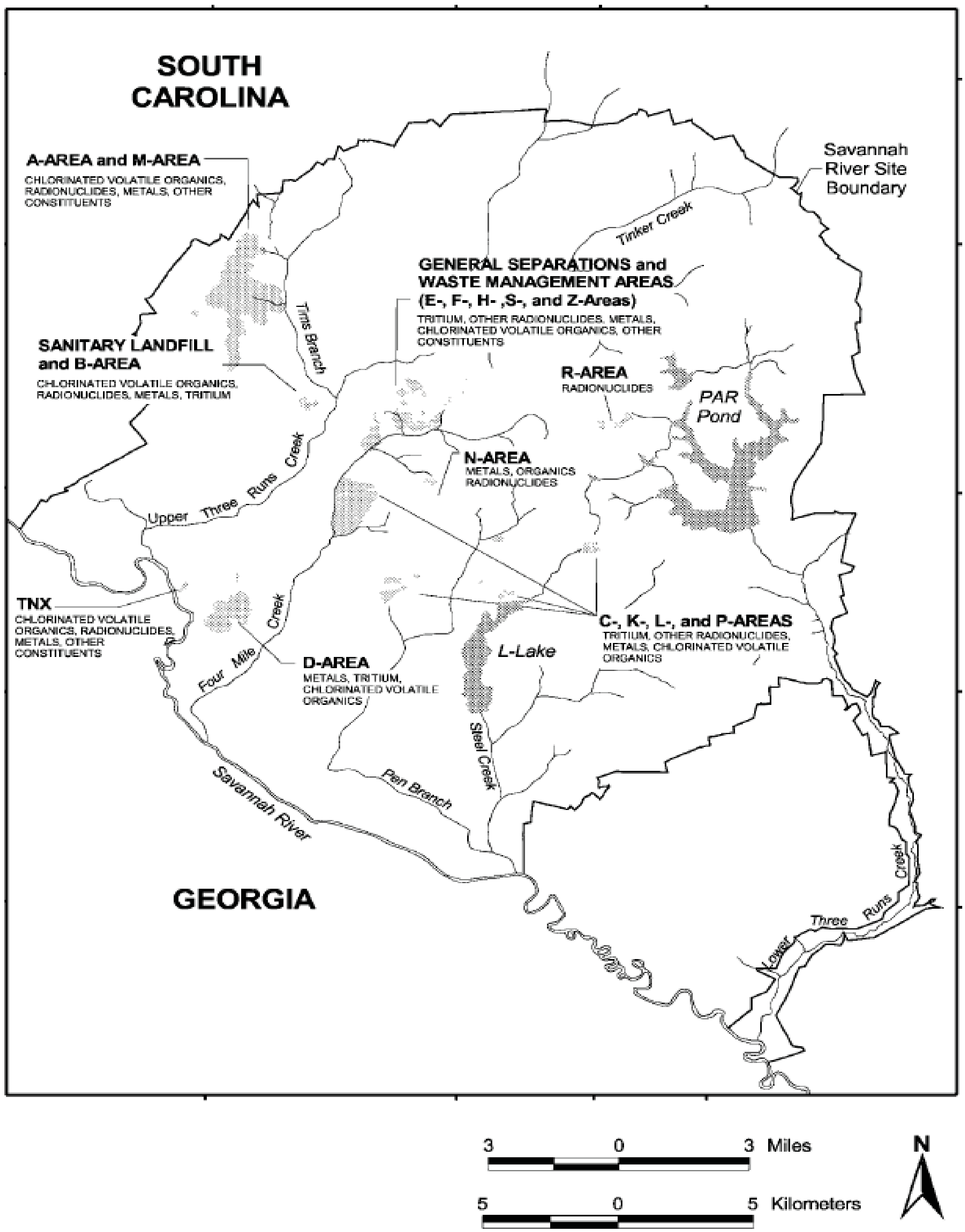
- The Savannah River Ecology Laboratory (SREL), founded in 1951, is located on site and was the first land stewardship program at SRS. SREL is operated by a research branch of the University of Georgia. It has been funded primarily by DOE’s Environmental Management Division, Savannah River Operations Office until 2006 when DOE funding was progressively reduced and exhausted by June 2007. It is now funded largely by specific projects for DOE and Savannah River Nuclear Solutions (SRNS) and by outside projects and grants. SREL conducted initial baseline ecological studies and later became involved in waste management activities, release studies of radioactive and non-radioactive elements, thermal effect studies of reactor effluent water on local ponds, and environmental assessments. SREL has provided independent evaluations of the ecological effects of SRS operations through a program of ecological research, education, and outreach. It has provided knowledge about the behavior of environmental contaminants, especially in aquatic environments like the rivers, streams, and ponds at SRS (SREL 2001, ND; USDOE 2006; UGA 2009).

- In 1972, more than 14,000 acres (5,666 hectares) at SRS were designated as the first National Environmental Research Park (NERP). This designation allowed for ecologists, engineers, and land managers to study the impact of human activities on the environment, to develop methods to estimate or predict the environmental response to human activities, and to evaluate developed methods to minimize any adverse effects human activities may have on the environment. Research conducted by NERP has been coordinated by SREL (SREL 1998).

- The United States Forest Service–Savannah River (USFS-SR) has worked with SREL to conduct research on the basic aspects of ecological and environmental sciences. Research has been focused on studying the fate and effects of contaminants in the environment, examining the biology of native species to improve remediation and restoration activities, and enhancing the management of natural resources (SREL 2001). Specifically, USFS-SR has conducted research in direct support of threatened, endangered, and sensitive species, and has examined methods to improve biological diversity (USFS-SR 2005a). USFS-SR has cut and sold timber and pine straw and has conducted annual prescribed burning operations to enhance wildlife habitat and reduce forest fuels (WSRC ND[n], USFS-SR 2005b). An average of 13,326 acres (5,393 hectares) underwent prescribed burning each year from 1995 through 2004 (USDOE 2005c). USFS-SR has also participated in waste site closure projects, provided aerial photo services, maintained secondary roads and site boundaries, managed soil erosion areas and watersheds, and engaged in community outreach. USFS-SR has been responsible for developing the SRS Natural Resources Management Plan which encompasses all natural resource operations, including management, education, and research programs (USDOE 2005b, 2005c, 2006).

- The University of South Carolina’s Savannah River Archeological Research Program (SRARP) has made recommendations to DOE that facilitate management of cultural resources and has assisted with compliance activities involving site-use surveys, data recovery, coordination with major land users, and reconstruction of the site’s environmental history (WSRC ND[i]).

Figure 2. Location of Major Production Facilities and Reactors at SRS



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Source: WSRC ND[j]

Remedial and Regulatory History

Throughout its operation, large amounts of radioactive, non-radioactive, and mixed hazardous materials and wastes were processed, treated, and stored at SRS. During this time, radioactive and hazardous materials have been released to the groundwater, surface water, soil, sediment, and air, ultimately impacting biota (USDOE 2005b). DOE started initial cleanup activities of seepage basins, pits, piles, and landfills under a Resource Conservation and Recovery Act (RCRA) permit submitted by SRS in 1985 and issued by the U.S. Environmental Protection Agency (EPA) and SCDHEC in 1987. Since that time, DOE has begun action on several RCRA and Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) responses that address contamination and disposal issues (EPA 1989, USDOE 2006).

SRS initiated the Environmental Management Program to address the closure of old burial grounds and seepage basins. The objectives are to contain known contamination at inactive sites, assess the uncertain nature and extent of contamination, and clean up the inactive waste sites. Currently, SRS Environmental Management Program activities include the stabilization of nuclear material and facilities, environmental restoration, and waste management. In 1989, SRS was officially listed on EPA's National Priorities List (NPL) because of contamination of shallow groundwater with volatile organic compounds (VOCs), heavy metals, and radionuclides. Trichloroethylene (TCE) was detected in numerous onsite monitoring wells and soil. Additionally, in the 1960s, failed fuel elements were stored in the P-Area fuel storage basins, which discharged contaminated water to Steel Creek. The Savannah River Swamp between Steel Creek and Little Hell Landing became contaminated with heavy metals and radionuclides when water from Steel Creek flowed across the swamp before entering the Savannah River at Little Hell Landing (EPA 1989, USDOE 2006, WSRC ND[a]).

In 1992, CDC initiated a Dose Reconstruction Project to examine the release of chemicals and radionuclides from SRS during the main operating period from 1954 to 1992. Phase I of the Dose Reconstruction Project included a systematic review of available documentation of potential value to the project. Phase II developed an estimate of the releases of the most significant radionuclides and chemicals from various facilities at SRS from 1954 to 1992. The final phase of the study, Phase III, estimated the radiation doses and associated cancer risks for hypothetical persons (including families and children who were born during the years when the largest quantities of radioactive material were released in the environment) living near SRS and performing representative activities (e.g., swimming, boating, fishing) on or near the site (CDC 2001, 2005).

In 2005, DOE, in collaboration with SRS stakeholders and regulators, developed *SRS End State Vision.* The goal of *SRS End State Vision* is to permanently dispose of all environmental nuclear material and hazardous waste, decommission all environmental management facilities, and remediate all inactive waste units at SRS. The *SRS End State Vision* plan assumes that the entire site will continue to be owned and be the responsibility of the federal government once the cleanup is complete by 2025; however, some portions of the property that will remain under federal ownership might be managed by the state of South Carolina. This plan also assumes that offsite repositories will be available for high-level radioactive, transuranic,

> The future objectives of the SRS call for the site boundaries to remain unchanged and residential use to remain prohibited.

hazardous, and mixed waste and that the site may be used for industrial purposes for future DOE or non-DOE missions; however, residential use will not be allowed (USDOE 2005b).

Land Use and Natural Resources

The majority of the counties close to SRS are primarily rural in nature, except for Richmond County, Georgia, which includes the city of Augusta. The predominant land uses surrounding SRS are forestry and agriculture, with secondary land uses being industry, government operations, residential, and recreational. Major industrial manufacturing facilities in the surrounding area include textile mills; polystyrene foam and paper products; chemical processing facilities; a commercial, low-level radioactive landfill (operated by Chem-Nuclear Systems, LLC) in Barnwell, South Carolina; and a commercial nuclear power plant (Georgia Power's Plant Vogtle) on the Georgia side of the Savannah River near Waynesboro in Burke County, Georgia (USDOE 2005b). Plant Vogtle has two pressurized water reactors that went on line in 1987 and 1989 and is currently seeking approval to build two additional reactors at this location (Southern Company 2010; USNRC 2009). However, the predominant land uses in the area adjacent to SRS are expected to remain as forestry and agriculture through 2025 (USDOE 2005b). For this public health assessment, agricultural, recreational, and forestry activities are of the greatest interest.

Agricultural Activities

ATSDR reviewed the state and county data sets from the 2002 and 2007 Census of Agriculture to identify the extent of livestock and agricultural production near SRS. The Census of Agriculture provides a comprehensive compilation of agriculture statistics on a 5-year cycle at the national, state, county, and zip code level (USDA 2004, 2009). For purposes of this review, ATSDR compared data from the state of South Carolina with data from Aiken, Allendale, and Barnwell Counties in South Carolina, and data from the state of Georgia with data from Burke County in Georgia, directly across the river from the site. The locations of the counties with respect to the site are shown in Figure 1.

Table 1a and 1b present the livestock and agricultural production in Aiken, Allendale, and Barnwell Counties compared with the state of South Carolina, and Table 2a and 2b present the same information for Burke County compared with the state of Georgia.

Although the numbers of beef cattle farms have decreased in South Carolina and Georgia, the numbers in Aiken and Allendale County have been stable, and the number in Barnwell County has increased. However, these are still a small percentage of the state's beef cattle farms. The numbers of dairy farms and hog/pig farms have also decreased in South Carolina and Georgia, which is true of the dairy farms and hog/pig farms in the counties near the site. The numbers of poultry farms have increased both in South Carolina and Georgia as well as in Aiken, Barnwell, and Burke Counties. Aiken County has more livestock farms than the other counties, but Burke County has more dairy farms (USDA 2004, 2009).

Table 1a. Livestock and Agricultural Production for Selected Counties and South Carolina (2002)

Selected Livestock and Crops	South Carolina	Aiken County	Allendale County	Barnwell County
Number of livestock farms (% of state total livestock farms)				
Beef Cattle	8,730	283 (3.2)	22 (<1)	61 (<1)
Milk Cows	326	9 (2.8)	0	4 (<1)
Hogs and Pigs	900	46 (5.1)	3 (<1)	24 (2.7)
Any Poultry	1,959	113 (5.8)	4 (<1)	23 (1.2)
Agricultural crops acreage (% of state total)				
Corn (for grain)	240,085	2,332 (<1)	10,244 (4.3)	4,312 (1.8)
Wheat (for grain)	155,776	1,178 (<1)	9,191 (5.9)	1,144 (<1)
Cotton (all)	208,420	5,027 (2.4)	2,593 (1.2)	4,467 (2.1)
Tobacco	30,241	0	0	0
Soybeans	350,272	2,809 (<1)	13,031 (3.7)	2,697 (<1)
Peanuts	10,344	322 (3.1)	791 (7.6)	1,697 (16.4)
Produce (fruits and nuts) acreage (% of state total)				
Grapes (bearing and non-bearing)	577	34 (5.9)	2 (<1)	NA
Peaches (bearing and non-bearing)	15,069	679 (4.5)	NA	NA
Pecans (bearing and non-bearing)	5,490	251 (4.6)	NA	307 (5.6)

Source: USDA 2004
% = percent; < = less than; NA = not available
Note: All reported data is for 2002.

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Table 1b. Livestock and Agricultural Production for Selected Counties and South Carolina (2007)

Selected Livestock and Crops	South Carolina	Aiken County	Allendale County	Barnwell County
Number of livestock farms (% of state total livestock farms)				
Beef Cattle	8,177	283 (3.5)	23 (<1)	85 (<1)
Milk Cows	106	0	0	2 (<1)
Hogs and Pigs	812	36 (4.4)	3(<1)	8 (<1)
Any Poultry	2,571	143 (5.6)	3 (<1)	33 (1.3)
Agricultural crops acreage (% of state total)				
Corn (for grain)	372,558	5,837 (1.6)	12,970 (4.3)	10,379 (1.8)
Wheat (for grain)	136,766	1,310 (<1)	3,221 (2.4)	1,610 (1.2)
Cotton (all)	158,296	2,536 (1.6)	1,059 (<1)	2,965 (1.9)
Tobacco	20,084	0	0	14 (<1)
Soybeans	442,461	4,051(<1)	10,210 (2.3)	7,876 (1.8)
Peanuts	56,332	NA	2,454 (4.4)	2,909 (5.2)
Produce (fruits and nuts) acreage (% of state total)				
Grapes (bearing and non-bearing)	463	36 (7.8)	NA	NA
Peaches (bearing and non-bearing)	16,160	NA	NA	NA
Pecans (bearing and non-bearing)	4,600	NA	NA	119 (2.6)

Source: USDA 2009
% = percent; < = less than ; NA = not available
Note: All reported data is for 2007; the Census of Agriculture is conducted every 5 years.
The next census will be conducted in 2012, and results will be released in 2014.

Table 2a. Livestock and Agricultural Production for Burke County and Georgia (2002)

Selected Livestock and Crops	Georgia	Burke County
Number of livestock farms (% of state total livestock farms)		
Beef Cattle	21,576	146 (<1)
Milk Cows	841	14 (1.7)
Hogs and Pigs	1,148	18 (1.6)
Any Poultry	4,139	13 (<1)
Agricultural crops acreage (% of state total)		
Corn (for grain)	252,176	5,776 (2.3)
Wheat (for grain)	183,301	41 (<1)
Cotton (all)	1,267,150	27,047 (2.1)
Tobacco	25,060	0
Soybeans	136,138	7,507 (5.5)
Peanuts	467,712	8,813 (1.9)
Produce (fruit and nuts) acreage (% of state total)		
Grapes (bearing and non-bearing)	1,684	NA
Peaches (bearing and non-bearing)	13,242	NA
Pecans (bearing and non-bearing)	128,550	920 (<1)

Source: USDA 2004
% = percent; < = less than; NA = not available
Note: All reported data is for 2002; the Census of Agriculture is conducted every 5 years.

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Table 2b. Livestock and Agricultural Production for Burke County and Georgia (2007)

Selected Livestock and Crops	Georgia	Burke County
Number of livestock farms (% of state total livestock farms)		
Beef Cattle	17,721	121 (<1)
Milk Cows	639	10 (1.6)
Hogs and Pigs	1,111	16 (1.4)
Any Poultry	5,490	40 (<1)
Agricultural crops acreage (% of state total)		
Corn (for grain)	449,007	15,064 (3.4)
Wheat (for grain)	228,959	8,162 (3.6)
Cotton (all)	996,247	22,990 (2.3)
Tobacco	17,989	0
Soybeans	280,202	15,578 (5.6)
Peanuts	518,719	14,103 (2.7)
Produce (fruit and nuts) acreage (% of state total)		
Grapes (bearing and non-bearing)	1,646	NA
Peaches (bearing and non-bearing)	12,356	NA
Pecans (bearing and non-bearing)	114,227	NA

Source: USDA 2009
% = percent; < = less than; NA = not available
Note: All reported data is for 2007; the Census of Agriculture is conducted every 5 years.

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A variety of crops are produced on area farms, such as corn, soybeans, wheat, cotton, peanuts, grapes, peaches, and pecans. Many other crops are grown in the area, which is evident from the biota sampling discussed later. In Aiken County, peanuts, cotton, and corn represent the largest percentage of the state total. However, the total acreage of peanuts harvested in Aiken County is relatively small compared with total acreage for corn, wheat, and soybeans. In all counties considered, the acreage dedicated to growing corn has increased significantly (USDA 2004, 2009).

Allendale County has relatively few farms used for raising livestock; however, it has the most acreage devoted to agricultural crops in the South Carolina counties near the site (predominantly soybeans, corn, and wheat). In Burke County, Georgia, the most acreage is devoted to cotton, but soybeans represent the largest percentage (5.6 percent) of Georgia's total acreage for a single crop compared with the other crops presented (USDA 2004, 2009).

Recreational Activities

Most of SRS has been virtually undisturbed for decades, which has fostered a healthy, diverse ecosystem that is home to an estimated 50 mammalian, 100 reptilian and amphibian, 80 fish, and 260 avian species (USDOE 2005b, WSRC ND[n]). SRS is in the process of restoring native vegetative habitats and species, hardwood habitat, pine-savannahs, and wetlands. In addition, the restoration will protect water quality by stabilizing soil and minimizing industrial area runoff through engineering and vegetative management techniques. The U.S. Forest Service also performs prescribed burning operations to enhance wildlife habitat, facilitate post-timber harvest regeneration, and reduce forest fuels (USDOE 2005c). For many of these reasons, the area near SRS is also ideal for hunting and fishing.

Hunting and fishing are important cultural and traditional activities for many residents of South Carolina and Georgia. Past surveys conducted on populations living near SRS have provided a snapshot of recreational use at SRS (Burger et al. 1997a, 1998).[1] For example, surveys conducted near SRS have found that people spend more time hunting and fishing than expected. A DOE future land-use plan had estimated recreational users would spend a maximum of 14 days a year on the site (the Crackerneck Wildlife Management Area and Ecological Reserve [CWMAER] is considered on site, but separate from the main SRS production and storage areas). However, during the 1995–1996 hunting season, 16 individuals met or exceeded the DOE assumption of 14 days for recreational exposure (Sanchez and Burger 1998).

Figure 3. and 4 present the only available data compiled regarding the frequency of respondents that reported participating in recreational activities near SRS by gender and the average number of days per year respondents reported participating in a specified activity, respectively. It is worth noting that this survey was conducted more than 10 years prior to the release of this public health assessment; therefore, it is possible that the frequency across the types of recreational activities surveyed might have changed. As reported in the survey, men hunt and fish near SRS at considerably greater frequency than women. However, women participate in other activities such as hiking, camping, and bird watching at close to the same frequencies as men (Burger et al.

[1] Researchers conducted interviews in Columbia, South Carolina, in the spring of 1996 with 399 people attending Columbia's Mayfest (May 3-5, 1996) and with 285 hunters and fishermen attending Columbia's Palmetto Sportsman's Classic (March 22–24, 1996).

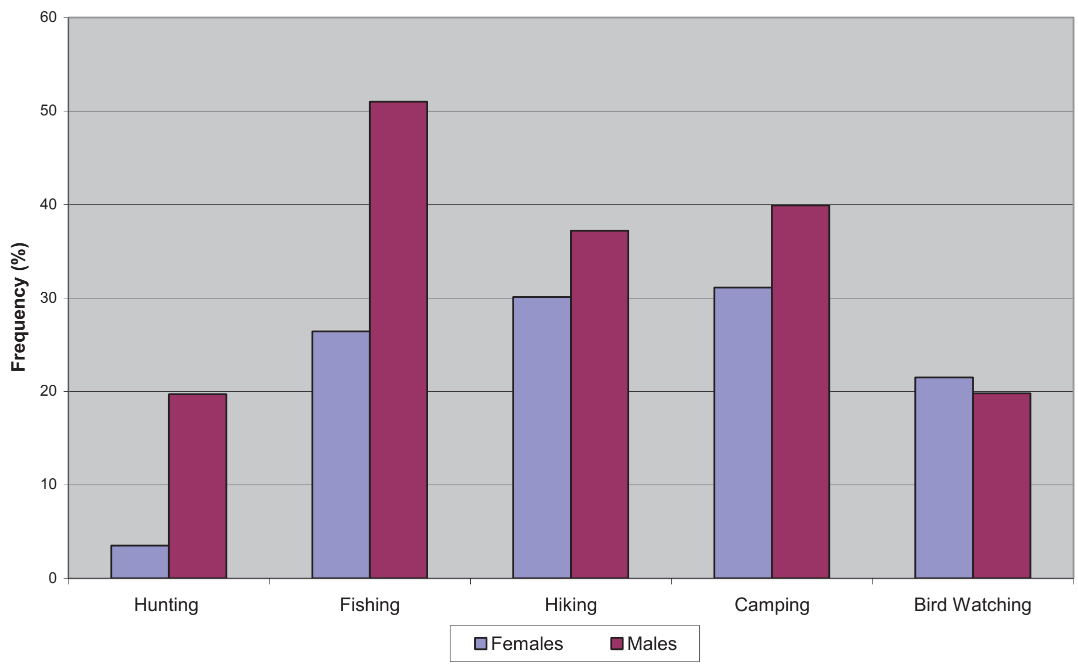
1998). Respondents ranked hunting, fishing, camping, and hiking as high priorities for future land use, which is indicative of the level of interest for these activities in nearby communities. Interestingly, respondents who lived farther from SRS ranked fishing and camping higher than other non-recreational future uses of SRS (e.g., nuclear production and storage) compared with respondents who lived closer to the site (Burger et al. 1997a).

Water Resources and Fishing Activities

Approximately 7,400 acres of the total area of SRS are covered by surface water, predominantly draining into the Savannah River. The Savannah River is the largest and most significant regional surface water body near SRS. Six main watersheds originate on or pass through SRS before discharging into the Savannah River. In addition to the Savannah River and the streams and creeks that flow into it, SRS contains many smaller surface water features, including lakes, ponds, and approximately 370 Carolina bays. Carolina bays are unique wetland features of the southeastern United States covering approximately 1,100 acres (445 hectares) dispersed throughout the uplands of SRS. These bays serve as natural habitats for many species of wildlife on the site. There are also two man-made ponds (Par Pond and L Lake), which cover 2,640 acres (1,068 hectares) and 1,000 acres (405 hectares), respectively, and numerous drainage/seepage basins on SRS (USDOE 1995a, 1995b). Par Pond and L-Lake are formed by the impoundment of the headwaters of Lower Three Runs Creek and Steel Creek, respectively (USDOE 2000) (See Figure 2).

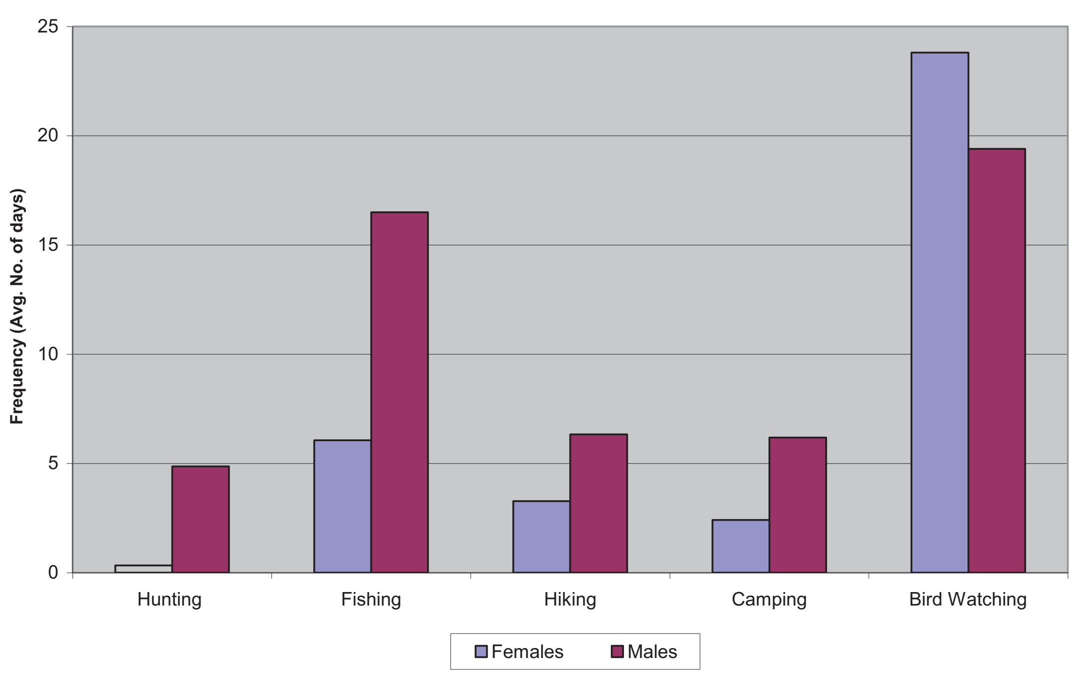
Five major streams from SRS feed into the Savannah River: Upper Three Runs Creek (the largest of the streams that run through SRS), Beaver Dam Creek, Four Mile Creek, Steel Creek and Lower Three Runs Creek (Figure 2). A sixth stream, Pen Branch, does not flow directly into the Savannah River but joins Steel Creek in the Savannah River floodplain swamp. Other main on-site streams include Tinker Creek, Meyers Branch, and Tims Branch. Beaver Dam Creek is a small stream that drains *D-Area* and might have been a seasonal stream prior to SRS operations (USDOE 1995a, 2000). These tributaries drain all of SRS with the exception of a small area on the northeast side, which drains to an unnamed tributary of Rosemary Branch, a tributary of the Salkehatchie River, but no development has occurred in this area of SRS (USDOE 1995b). In 1992, SCDHEC changed the classification of the Savannah River and SRS streams from “Class B waters” to “Freshwaters.” The definitions of Class B waters and Freshwaters are the same; however, the Freshwaters classification imposes a more stringent set of water quality standards (USDOE 1995b).

Figure 3. Frequency of Recreational Activities by Gender Near SRS



Source: Burger et al., 1998
Note: Data was obtained from a survey of 399 people interviewed at the Mayfest celebration held in Columbia, S.C. during weekend of May 3 to 5, 1996

Figure 4. Average Number of Days People Participate in Recreational Activities Near SRS



Source: Burger et al., 1998
Note: Data was obtained from a survey of 399 people interviewed at the Mayfest celebration held in Columbia, S.C. during weekend of May 3 to 5, 1996

Upper Three Runs Creek and the Savannah River form two of the boundaries for the CWMAER. No fishing, boating, or other uses are allowed in Upper Three Runs Creek (SCDNR 2007). Skinface Pond, located within CWMAER, is designated as a fishing pond (USDOE 2005c). The pond water comes from outcrops north of the pond and drains to the Savannah River swamp and the river.

The Savannah River Swamp is 18.6 square miles (3,020-hectares) of forested wetland along the southwest border of SRS and includes private property to the south. The 1.5-mile-wide swamp runs along the Savannah River for about 10 miles. It is separated from the main flow of the river by a 3-meter-high natural levee along the river bank. At times, river water overflows the levee and floods the entire swamp. Three major breaches in the levee allow creek water to flow into the river—the mouths of Beaver Dam Creek, Four Mile Creek, and Steel Creek (IEER 2004).

Fishing is a common activity along many portions of the Savannah River, including the banks of the Savannah River Swamp at Creek Plantation (private property) between the mouth of Steel Creek and Lower Three Runs Creek (USDOE 1995a). There are boat ramps and fishing locations at both Steel Creek Landing and Little Hell Landing (TBRDCNTY 2005). No commercial fishing is allowed within SRS. Recreational fishing is not usually allowed on site except within CWMAER; however, some illegal trespassing and onsite fishing has been reported (Burger et al. 1999). Stream mouths are restricted and posted to warn boaters against trespassing, and SRS security patrols the Savannah River. Lower Three Runs Creek is not on the main site, but USFS-SR maintains “no trespassing” signs along the creek from Patterson Mill Road to the Savannah River (SRNS [ND]). However, fish can migrate from SRS streams to the Savannah River (James Heffner, WSRC, personal correspondence, June 4, 2007). A large variety of fish populate the Savannah River and adjacent streams. Sunfish, shiners, and pirate perch dominate the shallow, relatively narrow upstream areas. The wider, deeper downstream areas are dominated by spotted suckers, largemouth bass, and catfish (USDOE 2003).

A survey of 258 people fishing along a 56-mile (90 km) stretch of the Savannah River, upriver (to Augusta Lock and Dam), along, and downriver (to Barton’s Landing- Highway 301 Bridge) from SRS was conducted between April and November 1997. The results of interviews with mostly male recreational fishermen revealed that their families (i.e., spouses and children) also consumed fish nearly as often as they did, with children starting to eat fish at 3–5 years of age. The most commonly consumed fish species were sunfish (*Lepomis spp.* [locally known as bream]), catfish (*Ictalurus punctatus*), largemouth bass (*Micropterus salmoides*), crappie (*Pomoxis nigromaculatus*), and bowfin (*Amia calva*). On average, respondents consumed 3.2 pounds (1.5 kilograms) of fish per month (approximately 50 grams per day or 18 kilograms per year) and reported fishing on the Savannah River for 24 years, although some had fished the river for over 50 years. Fish consumption also varied by race, with black males consuming almost twice the average amount of fish compared to white males. Women, who were interviewed during this study, consumed much less fish than men, but the differences across race were still evident (see Table 3) (Burger et al. 1999). The average of the 95^{th} percentile adult consumption rate was 135.2 grams per day (approximately 49 kilograms per year).

Table 3. Fish Consumption for Fishermen Interviewed Along the Savannah River

	Mean (g/d)	Median (g/d)	75th % (g/d)	95th % (g/d)
Black Males	70.1	51.8	131.5	187.9
White Males	38.4	18.8	53.4	135.3
Black Females	47.7	35.2	89.4	127.8
White Females	26.1	12.8	36.3	90.0

Source: Burger et al. 1999

g/d = grams per day
Sample size = 258 Fishermen

Freshwater turtles are also harvested for personal consumption and have been harvested as a source of food in South Carolina for commercial sale, both domestically and internationally. In 2003, the South Carolina Natural Resources Board issued an emergency regulation that prohibited the sale or possession of seven native turtles (mainly larger species) for commercial purposes but did not prohibit individual harvesting for personal consumption or the commercial harvesting of other species. This regulation was intended to prevent the depletion of these species in South Carolina. Common snapping turtles and softshell turtles continued to be harvested commercially in large quantities (SCDNR 2003). This emergency regulation was in affect for 180 days.

In 2009, the Center for Biological Diversity petitioned SCDNR and SCDHEC to issue another emergency rule to develop management programs for all turtle species to provide protection across all species and to protect the public from turtle meat products collected from potentially contaminated water and streambeds in South Carolina as well as to issue turtle consumption advisories for streams that have fish advisories (CBD 2009). In response to this petition, SCDNR issued restrictions on turtle harvesting and exporting out of South Carolina of no more than ten turtles twice a year for the larger turtles including snapping turtles and softshell turtles. The restrictions, however, do not limit harvesting of turtles in South Carolina as long as they are not taken out of the state, and no permitting is required. Therefore, no information was available on the harvesting and consumption rates by individuals in South Carolina. Also, no consumption advisories have been issued specifically for turtles (Bennett 2011).

Common Wildlife and Hunting Activities

Game species such as feral hogs, gray squirrels, fox squirrels, white-tailed deer, eastern cottontails, mourning doves, northern bobwhites, and eastern wild turkeys can be found on site. The reptiles and amphibian species of SRS include salamanders, frogs, toads, alligators, turtles, lizards, and snakes. Raccoons, beavers, and otters are relatively common throughout the wetlands of SRS. Waterfowl are common on most SRS wetlands, ponds, and reservoirs, and in the Savannah River swamp (USDOE 1995b; SREL 2009).

In the 1950s, the federal government acquired property in the west–northwest corner of the site (referred to as the Crackerneck reserve) for use as part of the original SRS buffer area. A lawsuit in the early 1970s resulted in the reserve being opened for public recreational use under the management of USFS-SR and the South Carolina Department of Natural Resources (SCDNR). For about 10 years, the site was accessible year-round for various recreational uses, including camping and hunting. However, in the fall of 1984, DOE restricted access to the Crackerneck area out of concern for terrorist attacks. Specifically, DOE eliminated general public use and access, limited hunting and fishing to specific times and required users to obtain special DOE permits (Sanchez and Burger 1998).

In 1995, DOE responded to increased public demand and pressure by SCDNR by doubling the size of the Crackerneck reserve and expanding access on a trial basis. For the 1995–1996 hunting season, the Crackerneck hunting area was doubled to more than 10,000 acres, and DOE permit requirements were rescinded. Although hunters and anglers still needed state permits, public visitors could enter the site freely through an entry gate on Brown Road between Jackson, South Carolina, and the site. People wanting access to the expansive swamp on Crackerneck were expected to register at the Crackerneck entry gate first; however, they could gain unrestricted access to the area by boat from the Savannah River (Sanchez and Burger 1998).

In the fall of 1995 and January 1996, there were 30 days of hunting with more than 2,300 visits made to the Crackerneck reserve. Approximately 80 percent of the visitors originated within 25 miles; 12 percent originated 25–75 miles from the reserve; and 8 percent originated from farther than 75 miles. Approximately 855 visitors spent a maximum stay of more than 15 hours and an average stay of a little more than 6 hours. Persons who traveled the furthest frequented Crackerneck less but spent longer hours per visit on site. Persons living in close proximity normally frequented the site multiple times, which resulted in 51 visitors spending more than 48 hours total on site (Sanchez and Burger 1998).

In June 1999, DOE designated this 11,200 acres (4,532 hectares) in the western section of SRS as a biological and wildlife refuge, called CWMAER, bordered by Route 125, Upper Three Runs Creek, the Savannah River and swamp, and private property. The reserve is managed by SCDNR (USDOE 2005c; USNRC 2005). CWMAER was established to enhance the wildlife habitat and provide controlled recreational opportunities for the public, such as hunting, fishing, bird watching, and hiking (USFS-SR ND[b]).

CWMAER is now open to the public on a controlled and limited basis, primarily for hunting and fishing. All individuals utilizing the reserve are required to sign in prior to entering the area and sign out at the end of the visit. Public access is permitted only during specified dates and times. Fishing is only permitted on Saturdays during September, March, and May, and Fridays and Saturdays from October through February and in April. The reserve allows hunting for deer, hog, raccoon, turkey, quail, dove, coyote, armadillo, duck, squirrel, and rabbit. There are specified days and bag limits for hunting depending on the season and type of game hunted. All harvested fish and game must be checked in at the gate prior to removal from the area (SCDNR 2006, 2007, ND[a]).

Controlled recreational hunting for deer and feral hogs is also allowed on restricted portions of SRS property, primarily during the fall (October and November). Beginning in 2004, controlled wild turkey hunts for the mobility impaired have been conducted annually in April. Controlled hunts for deer and feral hogs vary in number from year to year, but are typically operated about 12 days per year (WSRC ND[b – p]; SRNS [ND]). Locations for the hunts are established each year, and hunting is restricted to those tracts and dates. Hunters' applications are drawn lottery-style to determine who can hunt (Heffner 2007).

In addition to CWMAER and SRS, there are several private hunting areas near the site. In 1995, SCDNR reported that 136 private landowners in Aiken, Barnwell, and Orangeburg counties were approved for antlerless deer harvests and that 21 hunt clubs in Barnwell County had been visited (SCDNR 1995). Some of the private hunting areas are very close to the site, such as Cowden Plantation in Jackson adjacent to CWMAER and Creek Plantation between the main portion of the site south to Lower Three Runs Creek. Their hunting seasons are longer and typically allow more kills than allowed on the site. Deer season in Barnwell County starts in August and ends in January. Turkey season starts in March and ends in May. At Blackwater Hunting Services in Ulmer, a maximum of 16 deer can be hunted by 8 hunters per day, and a maximum of 8 turkeys can be hunted by 4 hunters per day. Tinker Creek Shooting Preserve in Williston also offers turkey, quail, and dove hunts. They limit hunters to 1 gobbler per day or 2 gobblers per stay and 15 quail per day. Cowden Plantation provides hunting for whitetail deer, wild boar/feral hogs, turkeys, waterfowl, dove, and quail (BLKWTR 2007; Jarrett 2009; TBRDCNTRY 2005).

Since 1995, alligator hunting has been allowed on private lands in South Carolina where land owners have a significant alligator habitat. Public alligator hunting seasons in South Carolina began in 2008. The alligator status as a protected species was down-listed in 1987 because of significant increases in the alligator populations. At least 100,000 alligators live in South Carolina (SCDNR 2009a). Alligators live in swampy areas, rivers, streams, lakes and ponds. At SRS, alligators inhabit the Savannah River, its swamp and tributaries, Par Pond, and other reservoirs on the site (SREL 2009). Alligators are hunted for their meat, hides, skulls, and other skeletal parts (SCDNR ND[b]). While the tail meat is the most popular consumable meat of alligators, some people also eat meat from the ribs and legs. The alligator hunting season begins in September and runs into October. In 2008, 362 alligators in South Carolina were taken during the hunting season. Three were taken in Aiken County, three were taken in Barnwell County, and eight were taken in Allendale County.

Forestry Activities

Except for site facilities, most of the terrestrial land cover at SRS consists mainly of old fields, dominated by pine and hardwood forests. Forest lands are distributed among three types: Oak-Hickory-Pine Forest (pine trees are the most dominant), Southern Mixed Forest (cypress trees/tupelo trees), and Southern Floodplain Forest (bottomland hardwood/deciduous trees). The greatest concentration of pine is in the northwest portion of the site. Hardwood/deciduous and cypress/tupelo forests are primarily found in stream valleys (USDOE 2005c; WSRC ND[m]).

Consistent with the U.S. Department of Energy Natural Resources Management Plan (NRMP) for the Savannah River Site (May 2005), the USDA Forest Service Savannah River actively manages approximately 90 percent of the SRS. One objective of the NRMP is to convert stands of non-native slash pine in the Industrial Core Management Area back to native loblolly or longleaf pine. Commercial timber harvesting through competitively bid timber sale contracts is the primary means by which removal of slash pine as well as other forest management activities are accomplished (USDOE 2005c, 2011).

In the 1990s, SRS had been on a sustained timber harvest of about 100,000 cubic meters (m^3) per year and sold approximately 77 to 449 acres (31 to 182 hectares) of pine straw. More recently the annual harvest has increased to nearly 200,000 cubic meters, reflecting that many more timber stands are now reaching maturity. The timber sales are primarily sawtimber and pulpwood, both pine and hardwood. Purchasers may resell the trees that may be used for a number of purposes. Pine straw sales essentially ended in approximately 2006 due to lack of bids. (USFS-SR ND[b], USFS-SR 2004, USDOE 2011).

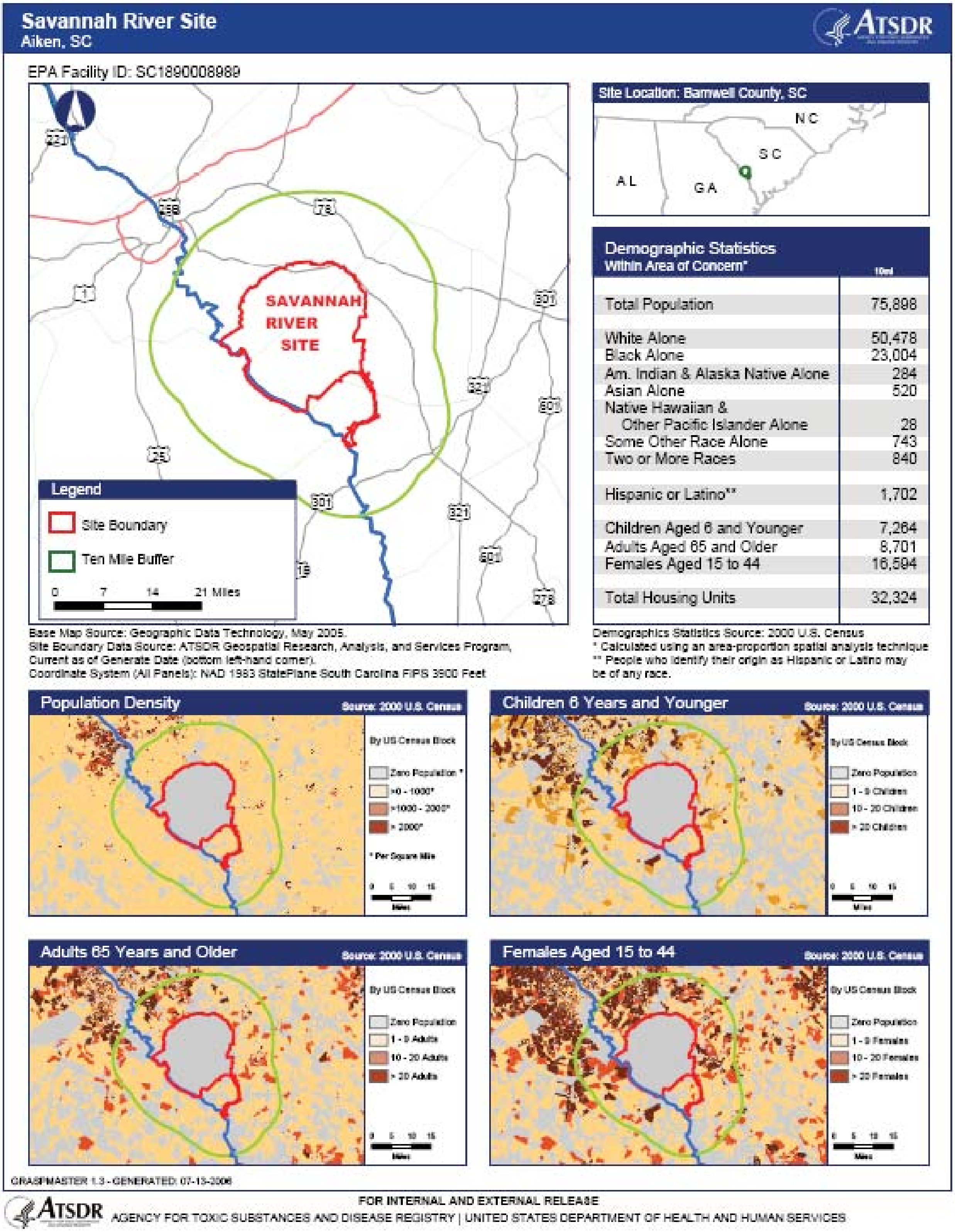
Demographics

According to the 2000 census, the most densely populated area in proximity to the site is Augusta, Georgia, with a population of 195,182. Augusta is within 20 miles of the SRS boundary. The population within 10 miles of SRS is 75,898 (see Figure 5) (U.S. Census Bureau 2000; WSRC ND[n]). The total population within 1 mile of the site is 3,849. In Aiken, Allendale, and Barnwell Counties in South Carolina, approximately 69 percent of people 25 years of age and older have a high school diploma; 75 percent live in owner-occupied housing units, which suggests a stable, non-transient population; and the median household income for residents of those counties was approximately $29,126 in 1999 (U.S. Census 2007). According to the 2000 U.S. Census, Burke County, Georgia, had a population of 22,243. Approximately 38 percent of all households in Burke County had children under 18 years of age living with them. Approximately 65 percent of people 25 years of age and older have a high school diploma; 76 percent live in owner-occupied housing units; and the median household income for residents of those counties was approximately $29,159 in 2004 (U.S. Census 2007).

Manufacturing and government jobs account for the largest portion (44.8 percent) of employment in the region. SRS is the second largest employer in the area with approximately 14,000 employees, and has a large local and regional economic impact. SRS significantly contributes to the economies of South Carolina and Georgia through employment, purchasing, education, research, technology, business development, and community assistance programs (CDC 2005; USDOE 2005b).

Although SRS's major contractor reduced their workforce by approximately 500 people in fiscal year 2007, DOE employed additional contractors who began construction on the new Mixed Oxide (MOX) Facility at SRS on August 1, 2007 (Shaw Areva 2007), and a new biomass-fueled steam plant replacing a 1950s vintage coal-burning steam plant in the A-Area in August 2007 (USDOE 2007). This biomass-fueled steam plant was completed and started operating in September 2008 (USDOE 2008). Groundbreaking for the construction of another onsite biomass-fueled steam plant in the D-Area occurred on November 30, 2009, with an anticipated completion date of December 2011, providing approximately 800 construction jobs and 125 permanent jobs in plant operations and maintenance and the local forestry and logging industries (USDOE 2009.) Also, in 2009, DOE announced that SRS would receive approximately $1.6 billion in stimulus funds from the 2009 Economic Stimulus Bill to accelerate decommissioning work and create as many as 3,000 jobs (USDOE 2010).

Figure 5. Demographics Within 10 Miles of SRS Boundary



Public Health Activities

ATSDR Involvement

ATSDR is required by law to conduct a Public Health Assessment (PHA) at each site proposed for EPA's NPL. As part of the PHA process, ATSDR visited the site in September 2005 to collect information necessary to identify any potential public health hazards and health issues or community concerns related to environmental contamination. ATSDR staff also met with WSRC and DOE representatives, toured SRS and surrounding areas, and attended the final meeting of the Savannah River Site Health Effects Subcommittee (SRSHES). SRSHES was established to identify the needs of exposed and potentially exposed people and advise the CDC, specifically the National Center for Environmental Health (NCEH), the National Institute for Occupational Safety and Health (NIOSH), and ATSDR, on the adequacy of their health research and public activities at SRS.

Since 1991, other ATSDR activities associated with SRS include oral and written consultations on various onsite remediation projects that included soil contamination at the Acid/Caustic Storage Basins, the unlined trenches of the *D-Area* Seepage Basin, interim actions and remedial alternatives for the Metallurgical Laboratory Hazardous Waste Management Facility and the *M-Area*, and pump-and-treat processes for groundwater in the *A&M-Area*. SRS was also one of the DOE sites included in ATSDR's Health Consultation on Tritium Releases and Potential Off-site Exposures, issued in March, 2002 (ATSDR 2002a).

In 2002, ATSDR conducted a three-phase health education/needs assessment program that involved working with community leaders in 10 Georgia and South Carolina counties potentially affected by SRS activities to assess community environmental health education needs and concerns. Phase 1 focused on collecting information about the demographics, major employers, local medical services, religious institutions, educational centers, and local communication channels for the affected counties. Phase 2 included interviews with local health care providers to gather information on local environmental health concerns. Phase 3 consisted of conducting focus groups in selected communities in both Georgia and South Carolina to collect additional information on community health and other concerns related to SRS, community data needs, and effective communication channels in the communities. As part of this process, ATSDR identified the following community concerns related to potential adverse health effects linked to SRS activities—respiratory illness, cancer, skin diseases, and birth defects (ATSDR 2002b). Focus group members also expressed concern about the extent of environmental degradation resulting from activities conducted at SRS. Those interviewed indicated that they preferred to receive health information relating to SRS from their personal health care providers and other organizations perceived as independent of SRS (ATSDR 2002b).

In March 2005, the final report for the SRS Dose Reconstruction Project was issued (CDC 2005). This report examined releases from SRS from 1954 to the end of 1992. As part of this project, the SRSHES (previously mentioned) was established. Following the dose reconstruction project, ATSDR began working on public health assessments that evaluated potential offsite human exposures to site-related contaminants from the beginning of 1993 forward.

In December 2007, ATSDR released the PHA entitled "Evaluation of Off-Site Groundwater and Surface Water Contamination at the Savannah River Site (USDOE)." ATSDR scientists concluded that according to the information evaluated, under existing and normal operations, SRS currently poses no apparent public health hazard for the surrounding community from exposure to groundwater or surface water (ATSDR 2007a). ATSDR staff has continued to attend DOE's Citizens Advisory Board meetings when possible; to communicate with South Carolina Department of Health and Environmental Control – Environmental Surveillance and Oversight Program (SCDHEC-ESOP) and Georgia Department of Natural Resources – Environmental Protection Division personnel; and to interview some of the citizens living closest to the site in order to understand property usage, hunting and agricultural activities, and site-related health concerns.

Community Concerns Associated With SRS

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 the people who live or work near SRS. ATSDR is particularly interested in hearing from residents of the area, civic leaders, health professionals, and community groups. The SRS Citizens Advisory Board (SRSCAB) is a non-partisan group of SRS community members and non-voting representatives from the facility and government agencies that was established in 1994. The full board meets six times per year with committee meetings held more frequently. Information was gathered during the SRSHES and SRSCAB meetings as well as during ATSDR's health education/needs assessment project and personal interviews with persons living near the site.

WSRC also identified community concerns about SRS operations via public meetings, public hearings, and through the news media. In 1990, SRS representatives conducted 85 interviews with local elected officials, environmentalists, and citizens to identify the public's concerns about the site. The questions and a tabular summary of the interviewee responses are presented in the *Public Participation Plan* (WSRC 1990) as required under CERCLA. WSRC and DOE also held several public meetings in September 1990 and October 1991 to present and obtain feedback on the *1993–1997 Savannah River Site's Site-Specific Environmental Restoration and Waste Management Five-Year Plan*. SRS and DOE management and technical staff presented environmental restoration and waste management activities that were either ongoing or planned at the SRS. A listening post for both "Environmental Restoration" and "Waste Management" issues was established to allow for more direct interaction between the public and SRS management (WSRC 1992). The final document "Environmental Restoration and Waste Management Five-Year Plan, Fiscal years 1994-1998" was published in January 1993 (USDOE 1993a).

Community concerns and responses regarding the SRS can be categorized into three categories: health issues, environmental restoration, and waste management. In general, examples of the types of concerns raised include the following: tritium in drinking water taken from the Savannah River; contamination of game species hunted at or near the SRS; groundwater contamination; infant mortality/birth defects; fish contamination; and cancer rates around the site. The concerns about contamination in biota include fish from the Savannah River and site streams or tributaries, farm and agricultural products (e.g., farm-raised animals, milk products, peanuts, cotton, or pecans), natural vegetation, other wildlife (e.g., game species hunted on or near SRS property), and garden crops near SRS.

Quality Assurance and Quality Control

In preparing this PHA, ATSDR scientists reviewed and evaluated environmental data provided in the referenced documents. The environmental data presented in this PHA come largely from site characterization, remedial investigation, and monitoring reports prepared by DOE and DOE contractors under CERCLA, the Georgia Department of Natural Resources (GDNR), and SCDHEC authorities. Other data sources include research articles published in professional journals and other publicly released documents.

GDNR began their biota sampling program for radioactive contaminants in 1978. This program has continued; however, the number and types of samples collected has been reduced in the past few years due to lower funding. SCDHEC biota sampling program for radioactive contaminants began in 1997; however, sampling specific edible vegetation began in 2000. SCDHEC now collects a wide variety of biota samples from agricultural, fishing, and hunting activities. DOE has collected and analyzed biota samples since SRS began operations. In the past, DOE sampled a wide variety of crops in several locations; however, in 1995, the types of crops sampled and the locations off site were reduced. Currently, beef, fruit, and a green vegetable are collected annually from one location within each of four quadrants extending 25 miles from the perimeter of the site. Since 2005, samples of a secondary crop (e.g., cabbage, wheat) have been collected on a rotating schedule. Milk samples are collected quarterly from dairies within 25 miles of the site perimeter. DOE's data from this program are not used to show direct compliance with dose standards but are used as required to validate dose models and determine environmental trends (WSRC ND[o]).

The validity of analyses and conclusions drawn in this PHA are based on the reliability of the information in the referenced reports. ATSDR has determined that most of the data quality reviewed for this PHA is adequate for making public health decisions. However, some chemical data reviewed by ATSDR do not contain sufficient information regarding detection limits or practical quantitation limits (pqls) to determine whether the contaminants are present at levels of health concern. For example, the State of Georgia analyzed fish samples collected from the Savannah River for many chemical compounds including some chlorinated pesticides and polychlorinated biphenyls (PCBs) with few samples containing detectable concentrations of these analytes. However, the detection limits were too high to be used for purposes of toxicological screening.

Radiological data were not always reported in a consistent manner. Concentrations in biota tissue can be expressed as dry weight or wet weight. Accurate conversions from dry to wet weight are possible if the moisture or water content of the sample is measured and reported for the dry weight sample. The State of Georgia reported several types of biota results in dry weight with the dry-to-wet ratios provided. DOE data were presumed to be reported as wet weight since no other indication was given. The state of South Carolina reported some data as wet weight and some as dry weight without providing dry-to-wet ratio information. Although a rough estimate can be made by assuming dry weight concentrations to be about three times the wet weight values, this is not true across all tissues and species. DOE, WSRC, SCDHEC-ESOP, Georgia Department of

Natural Resources – Environmental Protection Division (GDNR-EPD), Energy Solutions-Barnwell facility (formerly Chem Nuclear Systems), and Plant Vogtle (Southern Nuclear and Georgia Power companies) formed a non-regulatory, technical working group in June 1991 to discuss and resolve many of these data quality issues as well as other technical issues of mutual interest. This group, the Savannah River Radiological Environmental Monitoring Group continues to meet on a regular basis.

ATSDR noticed differences between the maximum on-site deer and feral hog laboratory sampling results compared to maximum cesium-137concentrations measured in the field. All animals harvested have field surveys; however, samples for laboratory analyses are only collected from harvested animals that had elevated field surveys and less than ten percent random samples. The laboratory analyses are usually more sensitive with slightly more elevated results, but occasionally the maximum laboratory analyses are noticeably higher than the maximum field surveys. (Refer to the 1993, 1995, and 2000 results in Table 13.) This is a concern since hunter's doses are calculated based on field surveys. However, for the year when the maximum concentration was reported (1998), the maximum field survey result was essentially the same as the maximum laboratory result.

Evaluation of Environmental Contamination and Potential Exposure Pathways

Introduction

ATSDR's public health assessment process emphasizes the importance of exposure pathways, or the different ways that people can come in contact with environmental contaminants. The release of a chemical or radioactive material into the environment does not always result in human exposure. Human exposure to a substance depends on whether a person comes in contact with the environmental contaminant, for example by breathing, eating, drinking, or touching a substance containing it. If an individual does not come in contact with a contaminant, then exposure and resulting health effects cannot occur. Furthermore, the release of a contaminant from a site does not always mean that the substance will have a negative impact on the health of an individual. However, even if the site is inaccessible to the general public, contaminants can move through the environment to locations where people could come into contact with them. Figure 6 illustrates the various exposure pathways at SRS that could result in accumulation of contaminants in biota. This PHA specifically focuses on the concentrations of radioactive and non-radioactive contaminants measured in the biota (e.g., fish, wildlife, farm animals, agricultural products, or vegetation) around SRS and the potential for people to be exposed at high enough levels to cause health effects.

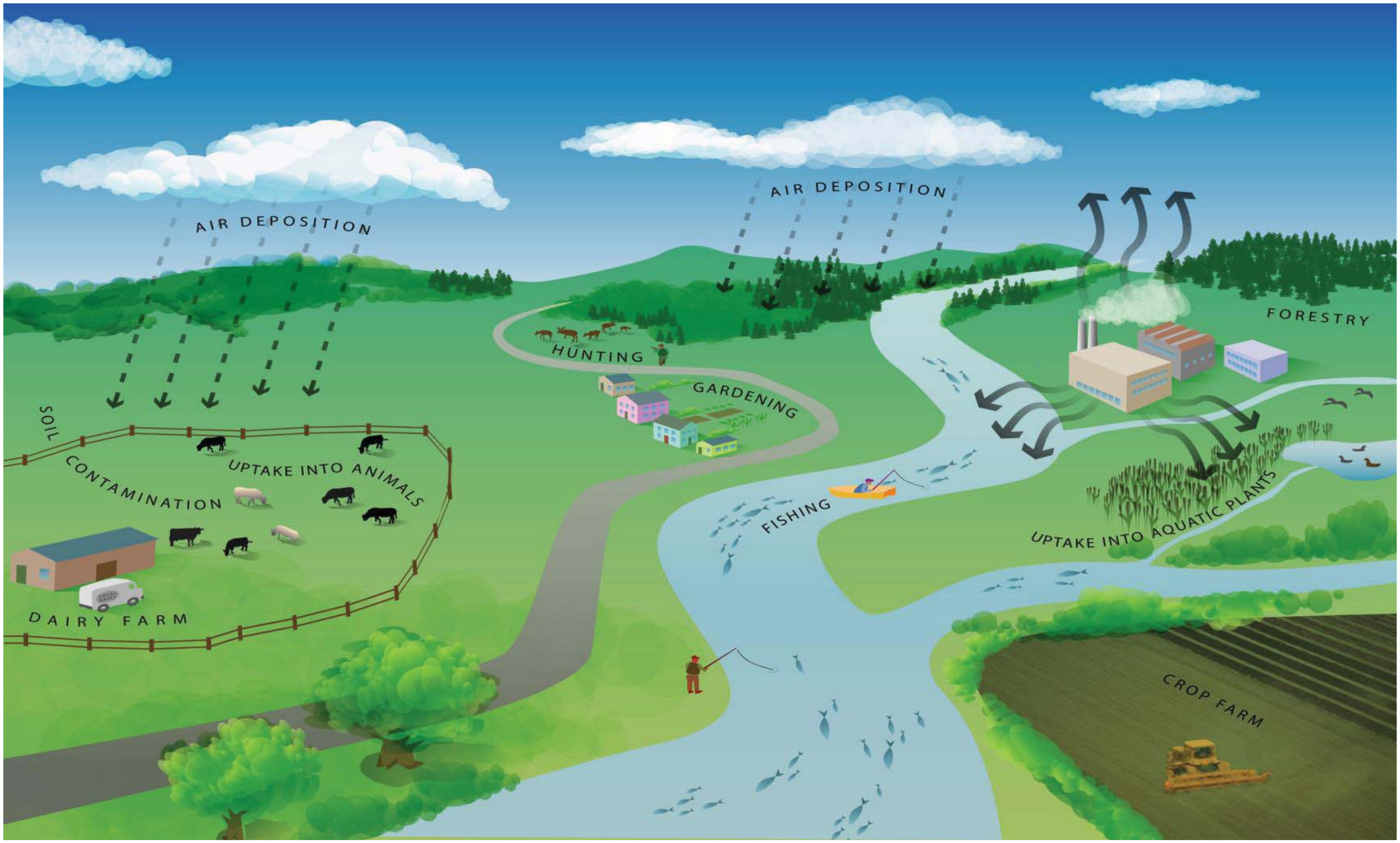
How Does ATSDR Determine Which Exposure Situations to Evaluate?

ATSDR scientists evaluate site conditions to determine if people could have been or could be exposed to site-related contaminants. For this PHA, ATSDR identified whether exposure to contaminants has occurred, is occurring, or might occur in the future through ingestion of biota. ATSDR identifies an exposure pathway as completed or potential, or eliminates the pathway from further evaluation. Completed exposure pathways exist if all five elements of a human exposure pathway are present. A potential exposure pathway exists when one or more of the elements are missing but available information indicates possible human exposure (see Elements of an Exposure pathway Text Box). An incomplete exposure pathway exists when one or more of the elements are missing and available information indicates that human exposure is unlikely to occur (ATSDR 2005).

Elements of an Exposure Pathway

1. The *source* is the place where the chemical or radioactive material is released.
2. The *environmental media* (such as groundwater, soil, surface water, and air) transport the contaminants.
3. The *point of exposure* is the place where people come into contact with the contaminated media.
4. The *route of exposure* (for example, ingestion, inhalation, or dermal contact) is the way the contaminant enters the body.
5. The *receptor population* is a population that is potentially exposed to contaminants at an exposure point.

Figure 6. Potential Pathways of Exposure for Biota



ATSDR evaluated the potential for contaminants to be accumulated in biota by reviewing environmental sampling data from DOE, DOE contractors, SCDHEC, GDNR, and scientific literature. ATSDR scientists focused the evaluation of contaminants that might be a human health hazard for biota exposure pathways. First, analytical data were reviewed and descriptive statistics were generated to determine maximum and/or average concentrations for the chemical contaminants and radionuclides measured in biota tissue.[2]

ATSDR evaluates radioactive contaminants by calculating a potential annual committed effective dose for various age groups under conservative scenarios specific to the site. These estimated total doses from radioactive contaminants are then compared with ATSDR's screening or comparison value (CV) and evaluated for the potential for causing adverse health effects. ATSDR's CVs are not thresholds for adverse health effects. ATSDR establishes CV concentrations many times lower than levels at which no effects were observed in experimental animals or human epidemiologic studies. If contaminant concentrations are above CVs, ATSDR further analyzes exposure variables (for example, duration and frequency of exposure), the toxicology of the contaminant, other epidemiology studies, and the weight of evidence for health effects. For a discussion of ATSDR's CVs, see Appendix B.

Annual Committed Effective Dose

An annual committed effective dose is a dose received over 50 years from an annual intake of a radionuclide and/or the annual dose received from external sources.

If Someone Is Exposed, Will They Get Sick?

Exposure does not always result in harmful health effects. The type and severity of health effects a person might experience due to contact with a contaminant depend on the exposure concentration (how much), the frequency and/or duration of exposure (how often and/or how long), the route(s) or pathway(s) of exposure (breathing, eating, drinking, and/or skin contact), and the multiplicity of exposure (exposure to more than one contaminant). Once exposure occurs, characteristics such as age, sex, nutritional status, genetics, lifestyle, and health status of the individual influence how the contaminant is absorbed, distributed, metabolized, and excreted. Together, these factors and characteristics determine the health effects that may occur.

If quantifiable community-specific exposure information (e.g., ingestion rates, consumption patterns, species of fish or wildlife consumed) is available, ATSDR uses this information to produce realistic estimates of exposure dose. However, this type of information often does not exist for the population being evaluated. To account for the uncertainty in the precise level of exposure and to be protective of public health, ATSDR scientists typically use what are considered "health protective" exposure level estimates as the basis for determining whether adverse (harmful) health effects are possible. These estimates are usually much higher than the actual exposure level received by the individual. If adverse health effects are possible based on these health protective dose estimates, ATSDR performs a more detailed review of the exposure pathway and consults the toxicologic and epidemiologic literature for scientific information pertaining to the contaminants of interest.

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[2] ATSDR has not developed any chemical contaminant screening values specific to biota. However, when appropriate, ATSDR will use health-based screening values derived by other state and/or federal public health agencies (e.g., EPA's risk-based concentrations (RBCs) in fish tissue) when no ATSDR CVs are available.

Evaluation of Biota

> Contaminants released from SRS to air and water can accumulate in plants and animals, which are collectively referred to as *biota.* This section focuses on biota consumed or potentially consumed by people.

Humans rely on plants and animals for their nutrition. When people depend on locally raised or harvested foods rather than store bought foods, which are often obtained from different regions of the country, they are at greater risk for being exposed to local point sources of contamination. As noted earlier in this report (see Recreational Activities), fishing and hunting are popular activities in South Carolina and Georgia. Studies on the ethnic differences for fish consumption rates at SRS indicate that the mean and 95^{th} percentile fish consumption for 258 people who were interviewed while fishing along a 56 mile (90 kilometer) segment of the Savannah River exceeded the national mean and 95^{th} percentile fish consumption rates used by EPA. Fish consumption rates for black males interviewed in the study are closer to EPA's consumption rate estimates for Native Americans and subsistence fishers than to EPA's estimates for freshwater recreational fishers. The lowest fish consumption rates in the study are for white females; however, their fish consumption rates also exceed EPA's mean and 95^{th} percentile rates for recreational freshwater fishers (Burger et al. 1999, EPA 1997). Although turtles are harvested in South Carolina for consumption, consumption rates by individuals near the site are not known.

Deer and wild turkey hunts are very popular in this area; however, other species (e.g., feral hogs, ducks, quail, dove, raccoons) are also hunted and consumed. As mentioned previously, there are several private hunt clubs in the immediate vicinity of the site in addition to CWMAER and the site itself. Also, agriculture and livestock production are an important part of the local land use. Therefore, it is important to evaluate whether biota in proximity to SRS has been affected by site-related activities and, if so, whether residents near SRS are being exposed at levels of human health concern.

The SRS has carried out environmental monitoring activities throughout its history. A preoperational background survey designed to establish *background levels of naturally occurring radionuclides* before plant startup was carried out from June 1951 to January 1953. Selected terrestrial and aquatic animals, vegetation, and food crops were collected and analyzed for alpha-emitting and beta-emitting radioactive materials. Once operations began in 1953, this program was adopted for routine monitoring (CDC 2001). In 1961, SRS began sampling local agricultural products, including collards, plums, peaches, oats, wheat, soybeans, rye, corn, and meat (chicken and beef) for radionuclides at several locations. In 1995 DOE reduced the types of samples and frequency of sampling agricultural products as described in the quality assurance and quality control section (WSRC ND[d]). Routine collection and monitoring of edible and non-edible portions of fish for radioactive contaminants began in 1957 in response to increased releases of reactor effluent to Four Mile Creek, Steel Creek, Lower Three Runs Creek, Pen Branch, and the Savannah River. Before 1957, small numbers of fish were randomly sampled from onsite streams and the Savannah River (CDC 2001). Currently, three composite samples of three to five fish are collected by DOE; typically three species, bass, bream and catfish, are collected from 10 locations on the Savannah River annually. SRS has monitored deer, feral hogs, and turkeys for radioactive contaminants during onsite hunts since the hunts began. Primarily the animals have been monitored for cesium-137. They also have monitored turkeys for radioactive contaminants before relocating them to other wildlife areas. Nuisance game animals have been trapped or hunted, monitored, and disposed of at the site (WSRC ND[b thru p]; SRNS ND).

Also, SCDHEC and GDNR have monitoring programs for sampling biota around the site. They report radionuclides (e.g., cesium-137, strontium-90, and tritium) and chemicals (primarily mercury) in edible and non-edible portions of fish collected from various locations along the Savannah River, and radionuclides in CWMAER and offsite game animals, offsite vegetation, and offsite farm products. These agencies provide independent sources of information.

Researchers from SREL, University of South Carolina, and a variety of other universities have performed multiple research projects and developed models in order to determine vectors of radioactive and chemical contamination at SRS to the human food chain. Many of these studies are referenced in this document.

ATSDR's evaluation process included a review of the available on-site and off-site biota data at or near SRS beginning in 1993. This timeframe was selected because the dose reconstruction performed by CDC evaluated exposure for seven scenarios from ingestion of agricultural products, milk, wild game, and fish from 1953 through 1992. For the dose reconstruction, concentrations of radionuclides in these products were modeled and verified with site-specific sampling data, when available. Most of the ingestion rates were based on information from EPA's Exposure Factors Handbook. However, the ingestion rates used for fish consumption were cited as being from a 1991 research document. Based on currently available information, these rates appear low for a maximum fish ingestion scenario for this site. Although ATSDR agrees with the final results of the dose reconstruction, a more conservative site-specific ingestion rate for fish consumption was used for the ATSDR evaluation. Additionally, biota sampling data were used in lieu of modeling source term information since an abundance of environmental sampling data is available since 1992.

The following sections describe potential sources of contamination that may affect biota near SRS and evaluate radiological and non-radiological monitoring data from biota collected on and off site near SRS from 1993 to the most current year available. Although onsite data are presented for onsite hunting activities and when offsite data are not available or very limited, the focus of this PHA is primarily on offsite human exposures.

SRS Sources of Contamination

Offsite biota can become contaminated in various ways. Fish can accumulate contaminants from surface water and sediment. Wildlife, crops, and farm animals can accumulate contaminants from air deposition either deposited on the soil or directly on the product, and from irrigation using contaminated surface water or groundwater. Wild animals can acquire contaminants by eating vegetation or other animals and drinking water off the site or on the site and then migrating off site (Refer to Figure 6).

Chemical and radioactive wastes have been treated, stored, and in some cases, disposed of at SRS, resulting in soil, surface water and sediment, and groundwater contamination, primarily by facilities in the central area of the site. Disposal practices at SRS have included seepage basins and storage tanks for liquids, pits and piles for solids, and landfills for low-level radioactive wastes. Ducks, turtles, frogs, and salamanders are known to live on or near the seepage basins and have been studied for various contaminants by SREL and SRNL researchers.

Industrial solvents, radionuclides, metals, and other compounds used or produced by operations at SRS have contaminated groundwater at approximately 5 to 10 percent of the site. Shallow ground water on various parts of the site has been contaminated with VOCs, heavy metals (lead, chromium, mercury, and cadmium), radionuclides (tritium, uranium, fission products, and plutonium), and other miscellaneous chemicals (e.g., nitrates) (EPA 1989). Most of the site groundwater discharges to the Savannah River or to site streams that eventually lead to the Savannah River.

Beaver Dam Creek received *thermal effluents* since 1952 from cooling water operations at the heavy water production facility and a coal-fired power plant in D-Area. As a result, this creek received contaminants that included mainly tritium, mercury, and other metals (USDOE 1995b).

Steel Creek received releases from *L-Area* effluents and tritium migration from *P-Area* seepage basins (WSRC ND[c]). In the 1960s, Steel Creek and a portion of the Savannah River Swamp between Steel Creek Landing and Little Hell Landing were contaminated with cesium-137, cobalt-60, and strontium-90 due to releases from the P-reactor (NCRP 2006). In 2007, the predominant contaminant in Steel Creek and the Savannah River Swamp sediment still was cesium-137, and the predominant contaminants in the surface water were low concentrations of tritium and cesium-137 (WSRC ND[p]). The contaminated swamp area extends beyond the SRS boundary to private property known as Creek Plantation. The offsite swamp is not inhabited by humans. However, occasional hunting and fishing occur in this area (WSRS 1992). Steel Creek Landing and Little Hell Landing on the Savannah River are advertised as good fishing areas. Public boat ramps are at both locations (TBRDCNTY 2005).

During SRS operations, Four Mile Creek received process effluent from several areas of the site and groundwater migration from seepage basins causing various radionuclides including cesium-137, strontium-90, plutonium-238, plutonium-239, and tritium to be deposited in Four Mile Creek's stream bed. Surveys conducted in 1991 showed that the predominant contaminant in the sediment was cesium-137 and the predominant contaminants in the creek vegetation were cesium-137 and tritium. The plutonium levels were near background levels at the creek mouth to the Savannah River (WSRC ND[a]). Routine environmental surveys conducted since 1993 show that the predominant contaminant in Four Mile Creek's surface water is tritium; however, cesium-137, strontium-89/90, iodine-129 and technetium-99 can also be detected. In December 1997 and January 1998, SCDHEC reported atypically high concentrations of tritium (~20,000 picocuries per liter [pCi/L]; equivalent to EPA's maximum contaminant level for drinking water) in the weekly surface water grab samples from the Savannah River near Steel Creek Landing. The reasons for the elevated concentration appear to have resulted from incomplete mixing of releases from Four Mile Creek and Pen Branch with river water and a change in sampling location. Normally, the tritium concentrations in surface water in this area range from 1,000 pCi/L to 3,000 pCi/L (WSRC ND[f]). The routine environmental surveys conducted in 2007 show that cesium-137, cobalt-60, strontium-89/90, and plutonium-238 can still be detected in the sediments of Four Mile Creek, and tritium, cesium-137, strontium-89/90, and plutonium-238 can still be detected at low concentrations in the surface water (WSRC ND[p]).

Lower Three Runs Creek receives overflow from Par Pond which received P-reactor effluents; however, before the construction of Par Pond, releases occurred directly to Lower Three Runs Creek which is largely responsible for the contaminated floodplain. In 1963, a failed fuel element resulted in a large release of cesium-137 to Par Pond and subsequently additional releases of cesium-137 to Lower Three Runs Creek (NCRP 2006). In 2007, the predominant radioactive contaminants found in Lower Three Runs Creek surface water include low concentrations of tritium and cesium-137, and the predominant radioactive contaminant found in the sediment is cesium-137(WSRC ND[p]).

A small quantity of depleted uranium was released in January 1984 into Upper Three Runs Creek, according to USDOE (USDOE 2005c). Historically, this creek received uranium primarily from M-Area, and tritium from the Effluent Treatment Facility and the Naval Fuels Facility effluents and from *F-Area* and *H-Area* storm sewers (WSRC ND[d]). Routine surveys conducted since 1993 show that the predominant contaminants in Upper Three Runs Creek sediment are uranium-238 and its decay products along with some cesium-137. The predominant contaminant in Upper Three Runs Creek surface water is tritium (USDOE 2005a). This creek borders CWMAER and flows into the Savannah River at the west-northwest corner of the site.

Chemical and radioactive materials have also been released during plant operations to the air resulting in soil, surface water, and vegetation contamination. The wind directions at this site have been studied over several time periods with the conclusion that there is not a prevailing wind direction at SRS. The winds blow slightly more often from the southwest and northeast. The winds from the southwest blow with the maximum frequency of less than 10 percent of the time (WSRC ND[i]).Therefore, onsite and offsite biota in all directions could have been or could be affected by airborne releases. The air pathway is being addressed in a separate public health assessment.

Potential Exposure Pathways at SRS

As previously noted, Figure 6 characterizes the common pathways of human exposure that might be attributed to consumption of biota. The discussion in this section gives examples of potential biota pathways particular to this site.

Fish and invertebrates can incorporate chemical and radioactive contaminants from the surface water or by ingestion of food. Fish food (free-floating macrophytes such as phytoplankton and algae) can have direct uptake of contaminants from water. Many aquatic plants and animals obtain nutrients from sediments that might contain higher levels of contamination. Also, contaminants in the stream sediments can be released back into the water. This is particularly true for radioactive cesium (Pinder et al. 2006). Freshwater turtles can be exposed to non-volatile contaminants in sediment and surface water (primarily chlorinated organic compounds, metals, and radionuclides). Turtles have long lives and have very slow metabolisms allowing for a longer retention time of contaminants in the tissue and organs (Meyers-Schone and Walton 1990).

Cattails, water lilies, and submerged plants rooted in the sediment can absorb cesium from the water or from the sediment (Pinder et al. 2006). Some animals eat cattails and water lilies. The swamp tupelo, or swamp blackgum, that appear in the Savannah River swamp, the lower reaches of small streams, and the Carolina bays have a significantly greater capacity to remove uranium and thorium from soils and sediments than other tree species; however, they would lower the uranium and thorium soil inventory by only 1 percent over the next 100 years (Hinton et al. 2004).The swamp tupelo is known as a valuable source of food for wildlife and pollen for honeybees (Hinton et al. 2004).

Wild game can become contaminated by what they eat and drink, and by the activities they engage in within their habitats. At SRS, there are more than 50 wild game and furbearing species as well as 260 species of birds, 60 species of reptiles, and 40 species of amphibians (SRNS [ND]). However, the focus in this report will be placed on those species that are known to be consumed by humans. Some additional perspectives on the habitats and lifestyles of these species are provided below:

- *Deer* forage on easily digested plants such as weeds, moss, mushrooms, broadleaf flowering plants leaves, twigs, and tender shoots of plants and vines that might be contaminated in particular with cesium-137 (Buckmanager 2008; NCRP 2006). White-tailed deer are commonly found at SRS in all areas of the site including the highland and swamp areas. Extensive studies have been performed on their breeding patterns, size and location of population clusters, body condition and composition, and radioecology (Cothran et al 1991). Their home range is usually less than 1 square mile; therefore, most onsite deer located near the more contaminated areas of SRS would be unlikely to migrate off the site.

- *Feral hogs* are omnivores, eating both plants and animals, with a diet consisting of grasses and flowering plants, fruits, roots, tubers, acorns, and invertebrates throughout the year. If given the chance, feral hogs (as well as coyotes and bobcats) will prey on young fawns, turkey poults, and eggs of ground-nesting birds like turkey and quail. With an annual home range of over 10 miles, feral hogs can greatly affect food sources for native wildlife over a very large area (Jaworowski 2008). They prefer the swamps and adjacent bottomlands at SRS but can also be found along river bed and open pasture land. Extensive studies have been performed on the feral hogs including studies of contamination distribution and cycling of radioisotopes and heavy metals (Cothran et al 1991).

- *Wild turkeys* are omnivores preferring to eat acorns, nuts, seeds, berries, roots, and insects. Occasionally they eat small animals such as snakes, frogs, or salamanders. Wild turkeys like open areas for feeding, mating and habitat. They use forested areas as cover from predators and for roosting in trees at night. A varied habitat of both open and covered area is essential for wild turkey survival (NWTF 2009). Wild turkeys do not migrate seasonally; however, the home range for a wild turkey flock can range from 350 acres to more than 60,000 acres (USDA 1999).

- The most common *rabbit* found at SRS is the Eastern Cottontail. Eastern cottontails are herbivores, eating different plants including grasses, clover, fruits, and vegetables. In the winter they eat the woody parts of plants like the twigs and the bark of trees. Eastern cottontails are primarily associated with upland areas in both wooded and open habitats at

SRS. Their numbers are low in the sandhills and deep swamp at the site. They are not hunted on the site. Their home range size is estimated to be about 1.5 to 5 acres; therefore, few onsite cottontails would be expected off site (Cothran et al 1991).

- *Raccoons* prefer to live in wooded areas near water and in other natural habitats, have extended home ranges, and have a broadly omnivorous diet. Plant foods include all kinds of fruits, berries, nuts, acorns, corn, and other grains. Animal foods include crayfish, clams, fish, frogs, snails, insects, turtles, rabbits, muskrats, eggs, and ground-nesting birds including waterfowl (Gaines et al., 2005; UCD 2008). Although raccoons are not hunted on site, onsite raccoons can migrate off site especially in search of food or if their habitat has been disturbed.

- Although not hunted on the site, *gray squirrels* are a popular game species. They eat nuts, acorns, buds, fruit, leaves, mushrooms, baby birds and eggs, and insects. At SRS they are most commonly found in the hardwood forest but can also be found in the pinelands. Their territories are small, so few onsite squirrels would be expected to migrate off site (Cothran et al 1991).

- During the fall and winter, migrating *waterfowl* use SRS extensively. SREL has conducted ecological research focusing on SRS waterfowl for more than 25 years in an effort to understand the interactions between waterfowl and environmental contaminants. The site's former reactor cooling ponds are important inland wintering refuges for ducks in the southeast (SREL 1998). The wood duck is one of the site's most common waterfowl found in the forested wetlands along rivers, swamps, marshes, ponds, and lakes. The early diet of ducklings consists largely of high-protein animal material, but ducklings switch to plant foods by 6 weeks of age. Adult wood ducks feed on a variety of nuts and fruits, aquatic plants and seeds, and aquatic insects and other invertebrates. They feed primarily in shallow water areas but will also forage on the forest floor for seeds, acorns, and nuts (USGS 2006). SREL studies indicate that: 1) wood duck females and their eggs contain radiocesium and mercury at levels comparable to those in the environment where they were collected, 2) wood ducks in Steel Creek attain equilibrium levels of radiocesium in only 17 days, 3) wood ducks eliminate radiocesium rapidly after leaving a contaminated environment losing half their body burden every 6 days, and 4) the risks to individual offsite hunters consuming SRS-contaminated waterfowl are low considering harvest patterns, equilibrium levels, and rates of elimination (SREL 1998).

- Freshwater *turtles* are very common at SRS. SREL has conducted ecological research on turtles that has included their usefulness as biological monitors for contaminants. They have long lives and can have long-term exposure to contaminants. Snapping turtles and softshell turtles are likely to have greater levels of aquatic contaminants due to their habit of burrowing and submerging themselves in sediment, which have a tendency to contain higher levels of contaminants than the surrounding water. They appear to be excellent monitors for PCBs, metals (e.g., mercury), and radionuclides. The biological half-life for cesium-137 in turtles is greater than that for birds and other wild animals (Meyers-Schone and Walton 1990).

- American *alligators* prefer freshwater wetlands and have populated cooling reservoirs at SRS for many years. In the earlier years of the site, the warmer portions of the cooling reservoirs attracted large males in the winter. Between 1970 and 1980, the population shifted to include more juveniles (Brisbin et al. 2008). Alligators at SRS also inhabit the Savannah River, its swamp, and its tributaries (SREL 2009). American alligators eat fish, birds, turtles, snakes, mammals, and amphibians. Insects and larvae, snails, spiders, worms, and small fish are included in a hatchling's diet. As they grow, they consume larger fish, mollusks, frogs, and increasingly larger animals. A male alligator's territory can be greater than 2 miles; however, the female's territory is normally smaller. Alligator hunting is not permitted on federal lands or wildlife management areas; however, it is permitted elsewhere in South Carolina (SCDNR ND[b]).

Deer, feral hogs, and wild turkeys are harvested during controlled hunts on site and uncontrolled hunts off site. Hunting of other animals (e.g., duck, dove, quail, rabbit, raccoon, possum) takes place offsite at CWMAER, at private hunt clubs, and on private lands in the area. In the past 2 years, alligator hunting by the public has been permitted by SCDNR (SCDNR ND[b]).

Contaminants of Concern

ATSDR's evaluation of biota is specifically focused on site-related contaminants that might be a potential human health hazard. This means that the contaminant should be present at high enough concentrations and be detected with sufficient frequency to be considered harmful should human exposure occur. With respect to exposure pathways, we are most concerned with how people might be exposed to contaminated biota including consumption of fish, wild game, plants harvested for human consumption or fed to animals that are part of the food chain, and natural vegetation.

What Criteria Were Used to Select Contaminants of Concern?

ATSDR scientists use a screening technique to focus the evaluation only on contaminants that might be a human health hazard for the biota exposure pathway. *First,* analytical data are evaluated to determine maximum and/or average concentrations of contaminants in each type of biota. If a contaminant was not detected above its respective comparison value (CV) or was not detected above an appropriate detection level, it was eliminated from further consideration. Chemical contaminant concentrations below their CVs are not expected to cause adverse health effects. When a substance's maximum concentration exceeded a CV or an appropriate detection level, it was considered as a *possible* contaminant of concern. Other criteria, such as the frequency of detections (single detections are not reliable indicators of contaminant presence), sampling location, and the quality and quantity of environmental sampling data (suspected laboratory contaminants or inappropriate detection levels), were used to make a final determination as to whether additional public health evaluations were necessary. In addition, some chemical contaminants do not have corresponding screening values. For purposes of this evaluation, ATSDR listed the chemicals without CVs and explained the rationale for either considering them as a possible contaminant of concern or, alternatively, why they were eliminated from further consideration. Radioactive contaminants in concentrations above appropriate detection limits and above natural background were considered as *possible* contaminants of concern, but, like chemical contaminants, other criteria were also used to make a final determination as to whether additional public health evaluations were necessary.

The maximum detected concentrations of the selected analytes were routinely used during the initial screening evaluation of the data when available. This is a conservative approach that helps focus on potential contaminants of concern, locations, and exposure time frames. It also helps balance out the relatively small numbers of samples collected from each sampling location during any given sampling period. If the maximum detected concentration does not present a potential health concern, then no further evaluation is presumed necessary.

For purposes of ATSDR's evaluation, only the edible portions of the fish were included in the analyses. This approach might exclude higher concentrations of some contaminants found in parts of a whole fish that would not normally be found in fish fillets; however, the whole fish might have lower concentrations of some contaminants found predominantly in the fillets. As discussed in the next section, ATSDR recognizes that some people cook whole fish and eat part of the skin and fat, and some recipes such as fish cakes and stews might use fish bone.

Not all potential contaminants have been analyzed for each biota type. Overall, there were sufficient data to evaluate the most important radioactive contaminants. However, certain chemical contaminants in fish and other biota could not be adequately evaluated because of the small number of samples or no samples analyzed for the analytes (e.g., PCBs, dioxins). In general, these analytes were not analyzed because they were not considered contaminants of concern at SRS.

Since there were many types of biota sampled, ATSDR grouped similar types into categories, which are presented in Table 4. For some categories with more than one biota type such as vegetables and fruit, ATSDR averaged the maximum concentrations for each type in the category, referred to as average of the maximums.

Table 4. Biota Categories

Biota Category	Possible Biota Types in Category	
Fish	➢ Bass ➢ Bluegill ➢ Bowfin ➢ Bream ➢ Carp	➢ Catfish ➢ Crappie ➢ Mullet ➢ Shad ➢ Sunfish
Wild Game	➢ Deer ➢ Feral hogs ➢ Wild turkeys ➢ Doves ➢ Ducks ➢ Quail	➢ Rabbits ➢ Beavers ➢ Raccoons ➢ Squirrels ➢ Turtles ➢ Alligators
Farm/Domestic Animals and Products	➢ Poultry (chickens) ➢ Eggs ➢ Meat (beef and pork)	
Dairy Products	➢ Milk and milk products	
Agricultural Crops	➢ Fruits (blackberries, cantaloupe, passion fruit, peaches, pears, persimmons, plums, Scuppernong grapes, watermelon) ➢ Vegetables (corn, cucumbers, greens [collard, mustard, turnip], onions, peas, potatoes [white, sweet, yams], rutabagas, squash, tomatoes, turnips) ➢ Nuts and legumes (peanuts, pecans, soybeans, soy products) and grains (unspecified grains and wheat)	

Radioactive Contaminants

The monitoring programs for biota at or near SRS have focused primarily on radioactive contaminants. Biota sampled for radioactive contaminants have included fish and shellfish, game and other wildlife, farm and domestic animals, milk, fruits and vegetables, and other vegetation at different sampling locations near SRS. In total, thousands of biota samples have been collected and analyzed since 1993 as part of routine monitoring of radioactive contamination. Although the analyses included gross alpha and gross beta screening and a wide spectrum of radionuclide screening, some radioactive contaminants had no detectable concentrations in any of the sampling and will not be mentioned. If a contaminant was only detected once in a biota type, this information also was not used. Otherwise, all detectable radioactive contaminants were initially considered as potential contaminants of concern. For a complete summary of the radioactive contaminants detected in certain biota, refer to Table 5 below. No data were reviewed for contaminants in turtles and alligators. A discussion of the reviewed data is presented in the sections that follow.

Table 5. Radionuclides Reported in Biota at or Near SRS From 1993 Through 2008

Radionuclide	Biota Type						
	Fish	Shellfish	Game Animals	Farm/ Domestic Animals	Milk	Agricultural Crops	Other Vegetation (Not Crops)
Gross alpha	X	X		X		X	X
Gross beta	X	X		X		X	X
Americium-241	X					X	
Beryllium-7						X	X
Cesium-134					X		
Cesium-136					X		
Cesium-137	X	X	X	X	X	X	X
Cobalt-60	X	X		X	X	X	X
Curium-244	X						
Iodine-129	X				X		
Plutonium-238	X	X	X	X		X	X
Plutonium-239	X	X	X	X	X	X	X
Potassium-40	X	X	X	X	X	X	X
Strontium-89		X	X	X	X	X	X
Strontium-89/90	X	X		X	X	X	X
Strontium-90	X	X	X	X	X	X	X
Technetium-99	X						
Tritium (hydrogen-3)	X	X	X	X	X	X	X
Uranium-234	X				X		X
Uranium-235	X				X		X
Uranium-238	X				X		X
Uranium/plutonium ratio				X		X	

Sources: Data provided by DOE, GDNR, and SCDHEC electronically or from their annual environmental reports. (WSRC ND[b through p]; SRNS ND; SCDHEC ND[a through j], 2005, 2006a, 2006b, 2010; GDNR 2005; Blackman 2009b)

Fish and Shellfish Monitoring

Approximately 80 species of fish have been identified at SRS; however, only the most prevalent edible fish that potentially contain contaminants are routinely monitored (SRNS [ND]). These species usually include a predator such as bass, a bottom-dweller such as catfish, and a pan fish such as bream. ATSDR evaluated fish monitoring data collected by three different surveillance programs: DOE-SRS, GDNR/EPD, and SCDHEC/ESOP.

Only GDNR/EPD and DOE-SR collected shellfish (crab, oysters, and shrimp) and marine (saltwater) fish samples near Savannah, Georgia. Most radionuclides were either below their analytic limit of detection or slightly above the detection limit. In most cases the detected values were less than concentrations detected in fish upstream closer to the site. Based on ATSDR's initial review of this data, shellfish or marine fish from the Savannah area will not be evaluated further in this PHA.

A brief summary of each program's methods for collecting fish are presented below followed by a summary of the results of freshwater fish tissue radioisotope analyses:

DOE: DOE routinely collects fish samples at nine locations along the Savannah River—from above SRS at Augusta, Georgia, to the mouth of the Savannah River at Savannah, Georgia. Composite samples, made up of three to five fish of a given species, are prepared for each location one to three times per year. Prior to 2006, DOE analyzed samples for cesium-137, cobalt-60, gross alpha, gross beta, plutonium-238, plutonium-239, strontium-89/90, and tritium. Technetium-99, iodine-129, and the actinide series (uranium-234, uranium-235, uranium-238, americium-241, and curium-244) were added to the analyses in 2006 (WSRC ND[p]).

GDNR/EPD: In the past, Georgia's Environmental Protection Division has collected several species of fish including largemouth bass, catfish, and bream from up to 11 locations over a 190-mile stretch of the Savannah River between Augusta and Savannah, Georgia. Samples collected from two locations monitor potential releases from Georgia Power's Plant Vogtle, and one location is a control for Plant Vogtle releases. These locations will not be included in this discussion. During Georgia's DOE contract period (ending in 2004), samples were collected twice a year. Since then, only one species (usually bass) has been collected annually and analyzed for radioisotopes. Five fish are usually included per edible or non-edible composite sample; this might vary to meet the total minimum sample weight requirements. The fish are typically analyzed for alpha and beta radiation, cesium-137, potassium-40, strontium-90, and tritium (Blackman 2009b).

SCDHEC/ESOP: South Carolina's ESOP monitors fish for radioactive materials in largemouth bass and catfish at seven site-related and two upstream sampling locations along the Savannah River and one control location on the Congaree River; all sampling locations are accessible to the public. ESOP typically collects five fish from each species and separates samples into edible and non-edible composite samples. The composites do not contain mixed species of fish or fish from more than one sampling location. Edible composites are analyzed for gamma-emitting isotopes and tritium. Non-edible composites are analyzed for gamma-emitting isotopes and strontium-89/90 (SCDHEC ND[j]).

ATSDR reviewed all available radiological fish sampling data from samples collected by DOE between 1993 and 2008, GDNR between 1993 and 2008, and SCDHEC between 1997 and 2008. The data were reviewed to determine the major contaminants of concern, the sampling locations where fish tissue contained maximum concentrations, and the timeframe when the maximum concentrations were detected. The off-site sampling locations include the Savannah River at the Augusta Lock and Dam (also known as the New Savannah Bluff Lock and Dam); the mouths of Beaver Dam Creek, Four Mile Creek, Lower Three Runs Creek, Steel Creek, and Upper Three Runs Creek; the bridges at Highway 17A and at US Highway 301; and Stokes Bluff Landing (See Figure 7). DOE's control location is on the Edisto River at West Bank Landing, and South Carolina's control is on the Congaree River. The principle fish species sampled include several types of bass, bluegill, bowfin, bream, catfish, crappie, flounder, mullet, shad, and sunfish. Appendix C presents four data tables (2 DOE, 1 GDNR, and 1 SCDHEC) that describe the maximum concentrations for radioactive contaminants found in each species (edible fillets only) at each location. Table 6 summarizes these data.

Cesium-137, strontium-90, and tritium (hydrogen-3) were detected at the highest concentrations among all radionuclides in edible fish samples collected near SRS. All radionuclides detected in fish are included in ATSDR's exposure dose calculations unless rarely detected (i.e., detected in less than 10 percent of samples collected) or there is some other notable reason to exclude in calculating a total dose, which will be documented in ATSDR's methodology. The following discussion of radioactive contaminants will focus on the three radionuclides with the highest concentrations in fish samples. A brief description of each is provided below.

- Cesium-137 is a radioactive metal that emits beta particles and a relatively strong gamma emission. It has a 30.2-year physical half-life and transforms into barium-137m (in a metastable [unstable energy] state), which transforms quickly into stable barium-137. Cesium, which is similar in chemical nature to potassium, moves easily through the environment and accumulates readily in muscle tissue. Potassium is especially important in regulating the activity of muscles and accumulates or is released by muscle activity. At SRS, there is a high and persistent uptake of cesium in vegetation and, consequently, in fish and other animals that consume this vegetation. This cesium uptake by vegetation is largely explained by the sandy, low-clay soils, which are acidic and potassium-depleted. The plant-to-soil, plant-to-water, and fish-to-water concentration ratios for cesium-137 at SRS are some of the highest in the world (NCRP 2006).

- Strontium-90 is also a radioactive metal that emits beta particles and has a physical half-life of 29 years. Chemically, strontium-90 is similar to calcium. It is absorbed along with calcium by fish and primarily deposited in the bones. Predatory fish (such as largemouth bass) typically have higher concentrations of strontium in their muscle tissue compared to other fish. According to a study published in 1996 concerning bioaccumulation factors in fish at SRS, the ratio of strontium-90 bio-accumulating in the bones versus in the flesh of predatory fish is approximately 19:1. The bone to flesh ratio of strontium-90 in bottom-feeders (such as catfish) is approximately 50:1 (Friday 1996).

Figure 7. Savannah River Fish Sampling Locations

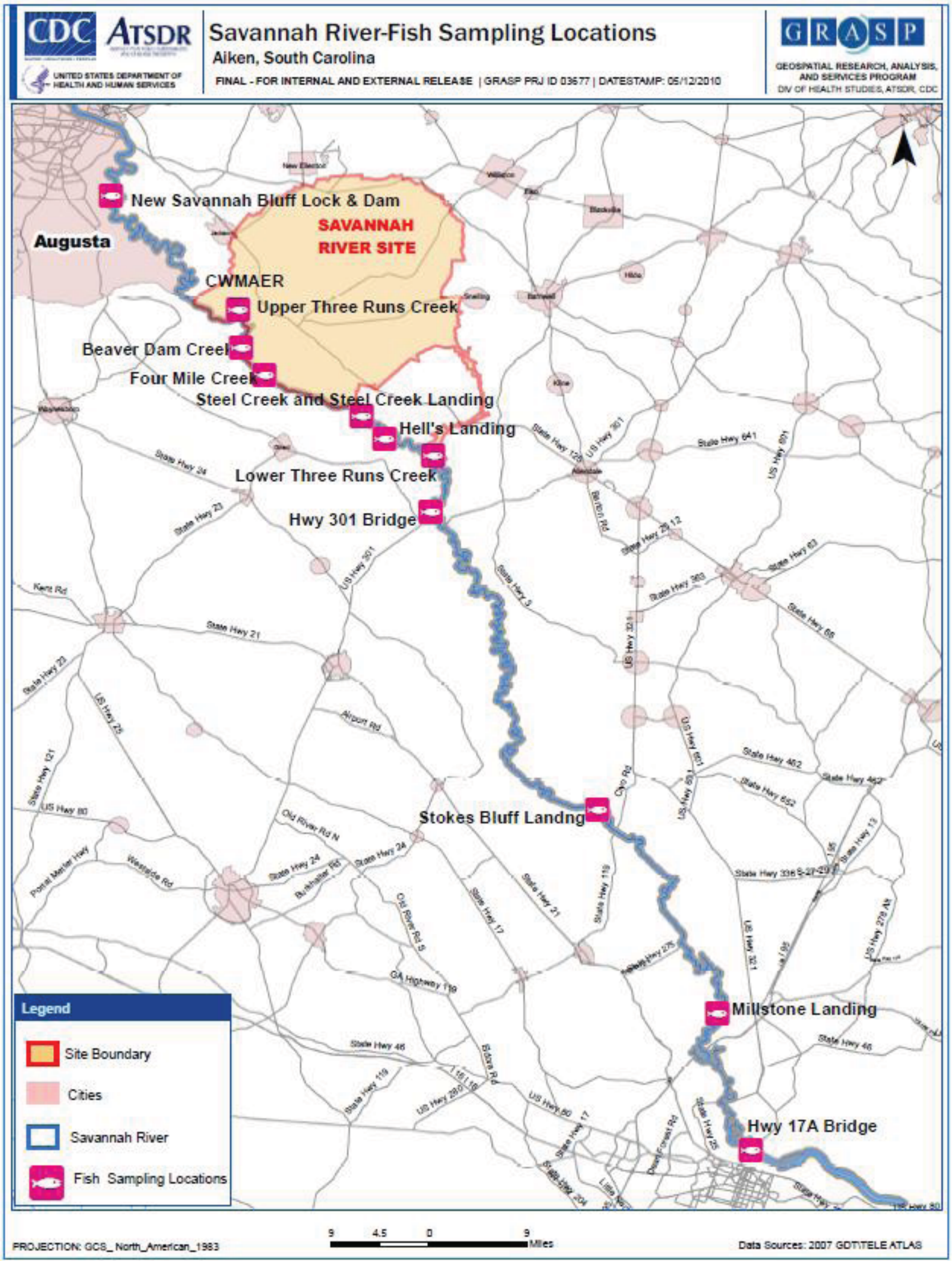

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Table 6. Maximum Radionuclide Concentrations in Edible Portions of Fish from Savannah River Sampling Locations (1993 through 2008)

Radionuclide	*Units in pCi/g (Bq/kg)*										
	Augusta Lock and Dam	*Mouth of Beaver Dam Creek*	*Mouth of Four Mile Creek*	*Highway 17A Bridge Area*	*Highway 301 Bridge Area*	*Mouth of Lower Three Runs Creek*	*Mouth of Steel Creek*	*Stokes Bluff Landing*	*Mouth of Upper Three Runs Creek*	*West Bank Landing (Control)*	*ALL Locations*
Amercium-241	0.00003 (0.0011)	0.00002 (0.0007)	0.00016 (0.0059)	0.00033 (0.0122)	0.00003 (0.0011)	0.00005 (0.0018)	0.00004 (0.0015)	0.00033 (0.0122)	0.00007 (0.0026)	0.00028 (0.0104)	0.00033 (0.0122)
Cesium-137	0.48 (17.8)	1.83 (67.7)	1.37 (50.7	0.56 (20.7)	0.75 (27.8)	3.08 (114.0)	4.40 (162.8)	5.75 (212.8)	0.87 (32.2)	0.25 (9.3)	5.75 (212.8)
Cobalt-60	0.038 (1.41)	0.038 (1.41)	0.038 (1.41)	0.111 (4.11)	0.047 (1.74)	0.044 (1.63)	0.049 (1.81)	0.040 (1.48)	0.035 (1.30)	0.031 (1.15)	0.111 (4.11)
Curium-244	0.00007 (0.0026)	0.00003 (0.0011)	0.00002 (0.0007)	0.00002 (0.0007)	0.00002 (0.0007)	0.00003 (0.0011)	0.00002 (0.0007)	0.00007 (0.0026)	0.00002 (0.0007)	0.00001 (0.0004)	0.00007 (0.0026)
Iodine-129	0.020 (0.74)	0.016 (0.59)	0.007 (0.26)	0.053 (1.96)	0.011 (0.41)	0.052 (1.92)	0.011 (0.41)	0.011 (0.41)	0.021 (0.78)	0.008 (0.30)	0.053 (1.96)
Plutonium-238	0.00039 (0.0144)	0.00134 (0.0496)	0.0005 (0.0185)	0.00514 (0.1903)	0.00019 (0.0070)	0.00041 (0.015)	0.00032 (0.0118)	0.00176 (0.0651)	0.00055 (0.0204)	0.00063 (0.0233)	0.00514 (0.1903)
Plutonium-239	0.00008 (0.0030)	0.00009 (0.0033)	0.00009 (0.0033)	0.00025 (0.0093)	0.00007 (0.0026)	0.00008 (0.0030)	0.00008 (0.0030)	0.00028 (0.0104)	0.00008 (0.0030)	0.00023 (0.0085)	0.00028 (0.0104)
Strontium-90	0.17 (6.30)	0.04 (1.48)	0.35 (12.95)	3.00 (111)	0.04 (1.48)	0.23 (8.33)	0.05 (1.85)	0.37 (13.70)	0.04 (1.62)	0.07 (2.59	0.37 (13.70)
Technetium-99	0.048 (1.78)	0.039 (1.44)	0.147 (5.44)	0.705 (26.11)	0.050 (1.85)	0.069 (2.55)	0.091 (3.37)	0.027 (1.00)	0.121 (4.48)	---	0.705 (26.11)
Tritium (Hydrogen-3)	0.24 (8.9)	1.27 (47)	59.2 (2,193)	1.1 (41)	2.43 (90)	2.22 (82)	9.82 (364)	1.35 (50)	46.97 (1,737.9)	0.1 (4)	59.2 (2,193)
Uranium-234	0.0050 (0.185)	0.0003 (0.011)	0.0265 (0.981)	0.0039 (0.126)	0.0006 (0.022)	0.0003 (0.011)	0.0042 (0.155)	0.0052 (0.192)	0.0004 (0.015)	0.0007 (0.026)	0.0265 (0.981)
Uranium-235	0.00033 (0.0122)	0.00013 (0.0048)	0.00172 (0.0636)	0.00016 (0.0059)	0.00010 (0.0037)	0.00004 (0.0015)	0.00017 (0.0063)	0.00034 (0.0126)	0.00005 (0.0018)	0.00006 (0.0022)	0.00172 (0.0636)
Uranium-238	0.0058 (0.215)	0.0002 (0.007)	0.0255 (0.944)	0.0040 (0.148)	0.0005 (0.018)	0.0003 (0.011)	0.0038 (0.141)	0.0030 (0.111)	0.0005 (0.018)	0.0006 (0.0222)	0.0255 (0.944)

Sources: WSRC ND(b through p); SRNS ND; SCDHEC ND(a through j), 2005, 2006a, 2006b, 2010; GDNR 2005; Blackman 2009b

Table C-1: DOE fish sample data (1993—2000)

Table C-2: DOE fish sample data (2001—2008)

Table C-3: Georgia fish sampling data (1993—2008)

Table C-4: South Carolina fish sampling data (1997—2008)

pCi/g = picocurie per gram of tissue (1 pCi/g = 37 Bq/kg); Bq/kg = becquerel per kilogram of tissue(1 Bq/kg = 0.027 pCi/g); NA = not analyzed

Note: Augusta Lock and Dam is also referred to as New Savannah Bluff Lock and Dam; West Bank Landing is located on the Edisto River.

- Tritium is radioactive hydrogen behaving as natural hydrogen in the environment and readily forming tritiated water when exposed to oxygen. Tritium (with a physical half-life of 12.3 years) emits very low-energy beta particles and transforms to stable helium with no further emissions. Tritium in fish is mainly in the form of tritiated water (HTO) behaving as non-radioactive water. It is taken up by aquatic organisms rapidly and does not bio-accumulate. Concentrations of HTO in fish are closely related to the concentration of tritium in the water where the fish are located. Fish can convert a small fraction of HTO to organically bound tritium (OBT) or can incorporate OBT through ingestion of plants and small organisms. Some of the ingested OBT can decompose to HTO. OBT is released more slowly from fish than HTO; however, OBT is a small component of total tritium in the fish samples. For more information on the behavior of tritium in the environment at SRS, refer to ATSDR's panel of experts report dated March 11, 2002, accessible at http://www.atsdr.cdc.gov/hac/pha/pha.asp?docid=35&pg=0) (ATSDR 2002[a]).

Fish Sampling Near SRS by DOE

Tables C-1 (1993–2000) and C-2 (2001–2008) in Appendix C detail the maximum concentrations of potential radioactive contaminants detected in fillets of various fish species by locations. Table 7 below summarizes the information from these tables for the three major radionuclides at various locations.

Table 7. Summary of DOE Fish Fillet Sampling for Maximum Concentrations of Three Radionuclides at Specified Savannah River Locations

Radionuclide	*1993–2008*			
	pCi/g (Bq/kg)	*Location*	*Year*	*Fish Species*
Cesium-137	5.75 (213)	Stokes Bluff Landing	1993	catfish
	2.99 (110.7)	Mouth of Steel Creek	1996	bass
	1.33 (49.3)	Mouth of Lower Three Runs Creek	1994	catfish
	1.14 (42.2)	Mouth of Four Mile Creek	2004	bass
Strontium-90	0.225 (8.33)	Mouth of Lower Three Runs Creek	1994	panfish (bream)
Strontium-89/90	1.27 (47.04)	Mouth of Four Mile Creek	1994	panfish (bream)
Tritium	26.7 (989)	Mouth of Four Mile Creek	1996, 1997	bass, bream
	5.05 (187)	Mouth of Steel Creek	1996	bream

Source: DOE Annual Environmental Data Reports (1993–2008) (WSRC ND[b through p])
pCi/g = picocuries per gram of tissue (1 pCi/g = 37 Bq/kg);
Bq/kg = bequerels per kilogram of tissue (1 Bq/kg = 0.027 pCi/g)

Cesium-137 in Fish (DOE): Most people who eat fish consume the fillet (i.e., muscle tissue). The radioactive contaminant in fish with the greatest potential health concern is cesium-137 because it readily accumulates in muscle tissue. DOE and GDNR fish data are used to demonstrate the *trend* in maximum cesium-137 concentrations reported for 1993 through 2008. The SCDHEC data are used with other data for exposure evaluations, but not for this discussion because data are not available for the entire timeframe.

With one exception noted in the next paragraph, Table 8 presents the maximum concentrations of cesium-137 measured in edible fish tissue samples collected by DOE between 1993 and 2008 at specified locations above, along, and below SRS and by species. For this discussion, the timeframe is divided into samples collected between 1993 and 2000 and between 2001 and 2008. This is done to highlight the notable decrease in cesium-137 levels in fish observed at many sampling locations in more recent years. The data show that cesium-137 levels vary over time and location, and by fish species.

The maximum cesium-137 concentration in fish at Stokes Bluff Landing is 5.75 picocuries per gram (pCi/g) (213 bequerels per kilogram of tissue [Bq/kg]) detected in a catfish sample collected during 1993; however, this value is not included in the table below. This maximum concentration does not appear to be representative of cesium-137 levels measured at this location. For example, the next highest cesium-137 concentration at this location in 1993 is 0.086 pCi/g (3.2 Bq/kg), more than 50-fold difference. Additionally, the next highest cesium-137 concentration in fish at this location for all other years is 0.30 pCi/g (11 Bq/kg) detected in bream, and the average concentration at this location is less than 0.1 pCi/g (3.7 Bq/kg). Therefore, the maximum cesium-137 concentration in catfish at Stokes Bluff Landing was not used to show concentration trends at major fishing locations as described below.

Table 8. Cesium-137 in Fish Samples by Specified Location and Species (1993—2008)—DOE

Off-site location along the Savannah River	Fish species (edible portions)	Sampling Time-frame	Maximum Concentration in pCi/g (Bq/kg)	Maximum Concentration (year)
Augusta Lock and Dam (aka, New Savannah Bluff Lock & Dam)	Bass	1993-1996-2000	0.42 (15.6)	1993
		2001-2008	0.08 (3.0)	2005
	Bream	1993, 1996-2000	0.48 (17.8)	1997
		2001-2008	0.06 (2.2)	2004
	Catfish	1995-2000	0.08 (3.0)	1999
		2001-2008	0.07 (2.6)	2004
Beaver Dam Creek (BDC) (Mouth)	Bass	1994, 1996-2000	0.94 (34.8)	1994
		2001-2008	0.23 (8.5)	2006
	Bream	1993, 1996-2000	0.71 (26.3)	1993
		2001-2008	0.10 (3.7)	2002
	Catfish	1993-2000	0.11 (4.1)	1995
		2001-2008	0.08 (3.0)	2006
Four Mile Creek (River Mouth)	Bass	1996-2000	1.1 (40.7)	1996
		2001-2008	1.14 (42.2)	2004
	Bream	1993, 1996-2000	0.47 (17.4)	1996
		2001-2008	0.13 (4.8)	2004
	Catfish	1993, 1994, 1996-2000	0.35 (13)	1994
		2001-2008	0.1 (3.7)	2001
Highway 17A (Bridge Area)	Bass (Marine)	1993, 1994, 1996-2000	0.13 (4.8)	1993
		2001-2008	0.42 (15.6)	2002
	Bream	1996-2000	0.18 (6.7)	1998
		2001-2008	0.07 (2.6)	2001
	Catfish	1996-2000	0.11 (4.1)	1996

Table 8. Cesium-137 in Fish Samples by Specified Location and Species (1993—2008)—DOE				
Off-site location along the Savannah River	**Fish species (edible portions)**	**Sampling Time-frame**	**Maximum Concentration in pCi/g (Bq/kg)**	**Maximum Concentration (year)**
		2001-2008	0.2 (7.4)	2002
	Mullet	1993, 1996-2000	0.56 (20.7)	1993
Highway 301 (Bridge Area)	Bass	1993-1994, 1996-2000	0.75 (27.8)	1999
		2001-2008	0.09 (3.3)	2002
	Bream	1993-2000	0.11 (4.1)	1994
		2001-2008	0.04 (1.5)	2001
	Catfish	1993-2000	0.21 (7.8)	2000
		2001-2008	0.06 (2.2)	2001
Lower Three-Runs Creek (Mouth)	Bass	1993-1994, 1996-2000	0.79 (29.3)	2000
		2001-2008	0.65 (24.1)	2002
	Bream	1993,1995-2000	0.80 (29.6)	1994
		2001-2008	0.09 (3.3)	2005
	Catfish	1993-2000	1.33 (49.3)	1994
		2001-2008	0.14 (5.2)	2006
Steel Creek (Mouth)	Bass	1993, 1995-2000	2.99 (110.7)	1996
		2001-2008	0.29 (10.7)	2006
	Bream	1993, 1995-2000	0.73 (27.0)	1996
		2001-2008	0.23 (8.5)	2005
	Catfish	1993-2000	0.49 (18.1)	1996
		2001-2008	0.14 (5.2)	2003
Stokes Bluff Landing	Bass	1993, 1996-2000	0.14 (5.19)	1999
		2001-2008	0.10 (3.7)	2002
	Bream	1993, 1996-2000	0.30 (11.1)	2000

Table 8. Cesium-137 in Fish Samples by Specified Location and Species (1993—2008)—DOE

Off-site location along the Savannah River	Fish species (edible portions)	Sampling Time-frame	Maximum Concentration in pCi/g (Bq/kg)	Maximum Concentration (year)
		2001-2008	0.05 (1.9)	2001
	Catfish	1993, 1994, 1996-2000	0.12 (4.4)[1]	1994
		2001-2008	0.11 (4.1)	2001
Upper Three-Runs Creek (Mouth)	Bass	1996-2000	0.87 (32.2)	1997
		2001-2008	0.17 (6.3)	2005
	Bream	1996-2000	0.12 (4.4)	1996
		2001-2008	0.07 (2.6)	2001
	Catfish	1993-2000	0.13 (4.8)	1996
		2001-2008	0.12 (3.7)	2008
West Bank Landing (background or control location)	Bass	1993	0.25 (9.3)	1993
		2006-2008	0.08 (3.0)	2006
	Bream	2006-2008	0.05 (1.9)	2006
	Crappie	1993	0.045 (16.7)	1993
	Catfish	2006-2008	0.09 (3.3)	2006

Source: US Department of Energy (DOE) annual environmental reports (1993—2008) (WSRC ND[b through p]; SRNS ND)

Units: pCi/g = picocurie per gram of tissue; Bq/kg = Becquerel per kilogram of tissue

Conversions: 1 pCi/g = 37 Bq/kg; 1 Bq/kg = 0.027 pCi/g

[1] This value represents the second highest concentration in catfish at this location. The 1993 maximum value deviates markedly from other values and will not be used for this discussion. Refer to narrative.

Note: If cesium-137 was not detected at all in a fish species, it is not reported in this table.
Samples collected with "unknown" species designation are not included in this table.
Small differences in values may occur due to rounding.

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DOE routinely collects and analyzes three fish species (bass, bream, and catfish) at each off-site sampling location listed in Table 8. Figure 8 shows that between 1993 and 2008, the highest cesium-137 levels were in bass at most sampling locations. Exceptions include bream at Augusta Lock and Dam and Stokes Bluff Landing and catfish at the mouth of Lower Three Runs Creek.

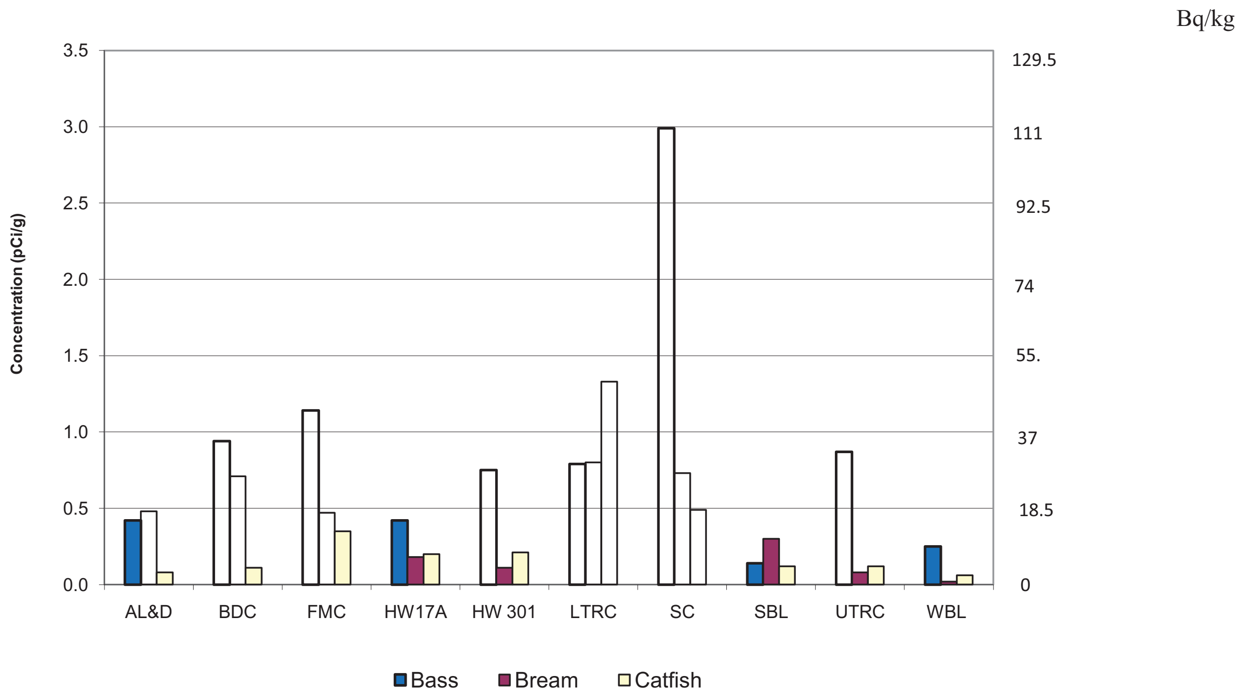
Figure 9 presents the maximum cesium-137 concentrations in three fish species most commonly collected from locations along the Savannah River for two distinct time periods: 1993–2000 and 2001–2008. The decline in the maximum detected cesium-137 concentrations between the earlier and later time periods is most notable at Steel Creek. The maximum cesium-137 concentrations at the mouth of Four Mile Creek have changed little over time.

The locations with the highest off-site concentrations of cesium-137 in fish are at the mouths of Steel Creek, Lower Three Runs Creek, and Four Mile Creek. Higher levels of cesium-137 are expected at Steel Creek and Lower Three Runs Creek compared to other sampling locations because of historical releases. A study performed on SRS fish samples collected from 1972 through 1996 indicated that cesium-137 concentrations in samples from Par Pond and Lower Three Runs Creek increased markedly from 1991 through 1996 during partial draining and refilling of Par Pond. The levels continued to be elevated until 2000 when refilling of the pond was completed (Paller et al. 1999, 2008). Table 8 shows that this was true for the maximum concentrations in bream and catfish, but the maximum concentration in bass at the mouth of Steel Creek from 1993 through 2000 remained more elevated than at the mouth of Lower Three Runs Creek. Over time cesium-137 concentrations in fish have decreased significantly for all locations, even for bass from the mouth of Four Mile Creek. In 2008 the maximum cesium-137 concentration in bass at Four Mile Creek had decreased to 0.07 pCi/g (2.6 Bq/kg).

In each annual SRS environmental reports, DOE calculates an adult dose to the hypothetically maximally exposed individual (WSRC ND [b through p], SRNS ND). As part of this calculation, DOE assumes that someone who lives downstream of SRS (downstream of the bridge at Highway 301) consumes 19 kilograms (or 42 pounds) of Savannah River fish per year and spends the majority of time on or near the river. According to DOE, highway 301 is the location where an individual is likely to receive the maximum exposure to radioactive contaminants from drinking water, consuming fish and from external exposures to surface water. DOE's dose estimate is normally based on annual average cesium-137 concentrations measured directly in fish fillets; however, occasionally a calculated concentration of cesium-137 in fish, estimated from annual effluent releases, is greater than the average cesium-137 concentrations measured in the fish. In this case, DOE used the higher calculated cesium-137 concentration (SRNS ND).

As shown in Figure 8 and in the previous discussion of fish data, the highway 301 bridge area does not appear to be the publicly accessible location with the highest concentrations of radionuclides measured in fish. However, in addition to the above maximally exposed individual dose calculation, DOE samples fish at the mouths of the streams as they enter the Savannah River where public access is possible and calculates a potential dose to a recreational fisherman. The hypothetical dose is based on the scenario that a fisher consumes 19 kg of fish per year caught exclusively from the mouth of the stream that has the highest measured concentrations in fish. As presented in the annual environmental reports, DOE also calculates the lifetime risks from the consumption of SRS creek-mouth fish for 1-year, 30-year, and 50-year exposure durations. For persons who fish at the Savannah River Swamp, DOE also considers external exposure to contaminated soil, incidental ingestion of the soil, and incidental inhalation of re-suspended soil. In the dose calculations for this report, ATSDR uses larger consumption rates for persons who regularly fish and their family members (49.3 kg/yr for adults and 35.4 kg/yr for children) based on a site-specific study for adults (Burger et al. 1999) and 99th percentile ingestion rate for children six to 11 years of age from EPA's Exposure Factor Handbook (EPA 1997). ATSDR also uses the highest concentrations of all measurable radionuclides in fish collected at the mouths of the streams for screening purposes (Appendix D). ATSDR, however, did not factor in other routes of exposure.

Figure 8. Maximum Cesium-137 Concentrations Detected in Three Species of Fish Along the Savannah River (1993–2008)—DOE



Source: DOE annual environmental data reports (1993-2008)

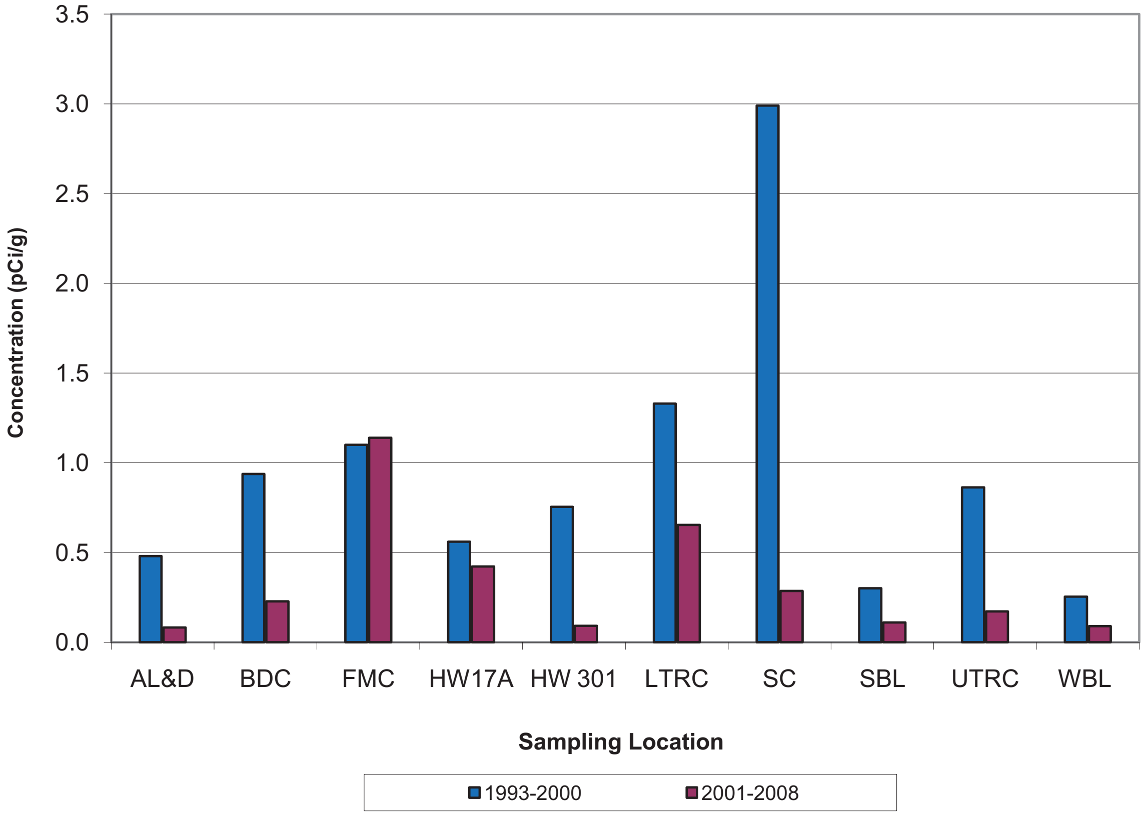
Sampling Location Key: AL&D = Augusta Lock and Dam; BDC = Beaver Dam Creek; FMC = Four Mile Creek; HW17A = Highway 17A; HW301 = Highway 301; LTRC = Lower Three-Runs Creek; SC = Steel Creek; SBL = Stokes Bluff Landing; UTRC = Upper Three-Runs Creek; WBL = West Bank Landing

pCi/g = picocuries per gram of tissue; Bq/kg = Becquerel per kilogram of tissue; samples collected were reported as wet weight.

The results represent the maximum concentration in samples collected at the specified locations between 1993 and 2008.

Note: The cesium-137 value shown for catfish at Stokes Bluff Landing is 0.12 pCi/g (3.7 Bq/kg), which represents the second highest concentration measured at that location. The highest concentration of 5.75 pCi/g (213 Bq/kg) is not representative of measurements taken at that location and is considered an outlier.

Figure 9. Maximum Cesium-137 Detected in Three Fish Species (Bass, Bream, and Catfish) Collected by DOE from Selected Locations Along the Savannah River (1993–2000 and 2001–2008)



Source: US Department of Energy (DOE) annual environmental data reports (1993-2008)

Sampling Location Key: AL&D = Augusta Lock and Dam; BDC = Beaver Dam Creek; FMC = Four Mile Creek; HW 17A = Highway 17A; HW 301 = Highway 301; LTRC = Lower Three-Runs Creek; SC = Steel Creek; SBL = Stokes Bluff Landing; UTRC = Upper Three-Runs Creek; WBL = West Bank Landing (control)

pCi/g = picocuries per gram of tissue; Bq/kg = Becquerel per kilogram of tissue; samples collected were reported as wet weight.

Note: The cesium-137 value shown for the three species at Stokes Bluff Landing is 0.30 pCi/g (11.1 Bq/kg), which represents the second highest concentration measured at that location. The highest concentration of 5.75 pCi/g (213 Bq/kg) is not representative of measurements taken at that location and is considered an outlier.

<u>Other Radionuclides in Fish (DOE):</u> Table 9 shows the maximum concentrations of other radioactive materials in fish collected at the mouths of Steel Creek, Lower Three Runs Creek, and Four Mile Creek for two distinct time periods, 1993-2000 and 2001-2008. With the exception of cesium-137, hydrogen-3 (tritium), and strontium-89/90, fish from these sampling locations contained very low concentrations of the other measured radioactive materials. For all three locations, the maximum cobalt-60 and plutonium-239 concentrations are low and have stayed essentially the same. A few radionuclides (e.g., curium-244, neptunium-237) were included in the reviewed reports, but are not included in Table 9. These radionuclides were not routinely included in the analyses, and the concentrations were very low or not detected in samples.

Changes over time in cesium-137, strontium-89/90, and tritium concentrations at these three locations are demonstrated in Figures 10 (a, b, and c).

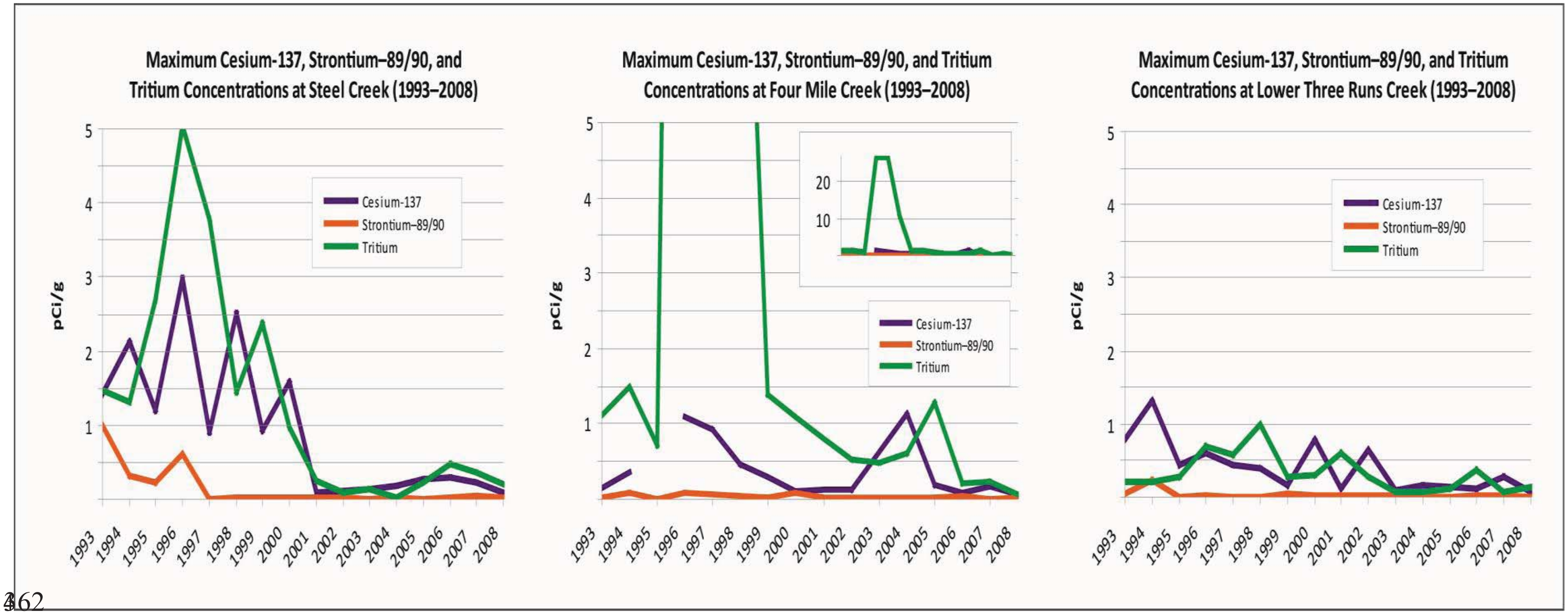
Table 9. Maximum Concentrations of Radioactive Materials in Fish at Mouths of Lower Three Runs Creek, Steel Creek, and Four Mile Creek—DOE

Radioactive Material	*Edible Portions; Units in pCi/g (Bq/kg)[1]*					
	Mouth of Lower Three Runs Creek		*Mouth of Steel Creek*		*Mouth of Four Mile Creek*	
	1993–2000	*2001–2008*	*1993–2000*	*2001–2008*	*1993–2000*	*2001–2008*
Americium-241	NR	0.00005 (0.002)	NR	0.00004 (0.001)	NR	0.00016 (0.006)
Cesium-137	1.33 (49.3)	0.65 (24.1)	2.99 (110.7)	0.29 (10.7)	1.10 (41)	1.14 (42)
Cobalt-60	0.044 (1.63)	0.044 (1.63)	0.049 (1.81)	0.041 (1.52)	0.038 (1.4)	0.038 (1.4)
Hydrogen-3	0.99 (36.7)	0.60 (22.2)	5.05 (187)	0.47 (17.4)	26.7 (989)	1.29 (48)
Plutonium-238	0.00041 (0.015)	0.00041 (0.015)	0.00011 (0.004)	0.00032 (0.012)	0.00011 (0.004)	0.00050 (0.019)
Plutonium-239	0.00008 (0.003)	0.00005 (0.002)	0.00008 (0.003)	0.00008 (0.003)	0.00006 (0.002)	0.00009 (0.004)
Strontium-89/90	0.225 (8.33)[2]	0.017 (0.63)	0.027 (1.00)	0.040 (1.48)	0.075 (2.78)[2]	0.032 (1.19)
Technetium-99	NR	0.069 (2.56)	NR	0.091 (3.37)	NR	0.147 (5.44)
Uranium-234	NR	0.00028 (0.010)	NR	0.00416 (0.154)	NR	0.0265 (0.98)
Uranium-235	NR	0.00004 (0.001)	NR	0.00017 (0.006)	NR	0.00172 (0.06)
Uranium-238	NR	0.00027 (0.010)	NR	0.00378 (0.140)	NR	0.0255 (0.94)

Source: US DOE annual environmental data reports (1993–2008) (WSRC ND[b through p]; SRNS ND)

[1] Concentrations are expressed as activities per wet weight.
[2] This is the maximum concentration for strontium-90 reported for 1994.
NR = not reported; pCi/g = picocuries per gram of tissue (1 pCi/g = 37 Bq/kg); Bq/kg = becquerel per kilogram of tissue (1 Bq/kg = 0.027 pCi/g)

Figure 10. Maximum Concentrations of Cesium-137, Strontium−89/90, and Tritium in Edible Fish for Specified Locations



Source: WSRC ND 9b through p; SRNS ND

Note: For this analysis, strontium-89/90 also includes analyses for strontium-90.

Fish Sampling Near SRS by GDNR/EPD

ATSDR reviewed all available fish sampling data collected by GDNR/EPD between 1993 and 2008. Table C-3 in Appendix C details the maximum concentrations of potential radioactive contaminants detected in fish fillets by location, time period, and species. Table 10 summarizes the information for the three major radionuclides.

Table 10. Summary of GDNR/EPD Fish Fillet Sampling for Maximum Concentrations of Three Radionuclides at Specified Savannah River Locations

Radionuclide	***Maximum Concentrations (1993–2008)***			
	Units in pCi/g (Bq/kg)[1]	***Locations***	***Year***	***Fish Species***
Cesium-137	4.40 (163)	Mouth of Steel Creek	1999	Bass
	3.08 (114)[2]	Mouth of Lower Three Runs	1995	Bass
Strontium-90	0.35 (13)	Mouth of Four Mile Creek	2003	Sucker fish
Tritium	59.2 (2190)	Mouth of Four Mile Creek	1995	Sunfish
	46.97 (1738)[2]	Mouth of Upper Three Runs Creek	2000	Bowfin

Source: Data received from GDNR-EPD (GDNR 2005; Blackman 2009b)

[1]The results are per wet weight of fish tissue.
[2]The next highest concentration reported with year and location.

GDNR/EPD = Georgia Department of Natural Resources/Environmental Protection Division; pCi/g = picocuries per gram; Bq/kg = becquerels per kilogram (1 pCi/g = 37 Bq/kg)

As with the DOE sampling data, the maximum concentrations of cesium-137 in samples collected by GDNR/EPD were detected in bass from the mouth of Steel Creek and Lower Three Runs Creek. The maximum concentrations of strontium-90 and tritium were detected in fish from Four Mile Creek and Upper Three Runs Creek.

<u>Cesium-137 in Fish (GDNR/EPD)</u>: Table 11 shows the maximum levels of cesium-137 detected in different species of fish by location. The two timeframes (1993–2000 and 2001–2008) used for the DOE data are also used for the Georgia data. The table shows that the highest cesium-137 concentration of 4.40 pCi/g (163 Bq/kg) was detected in bass during 1999 at the mouth of Steel Creek, followed by a bass sample collected in 1995 from the mouth of Lower Three Runs Creek at 3.08 pCi/g (114 Bq/kg).

The highest cesium-137 concentrations in other fish species (i.e., excluding bass) were detected in spotted sucker fish collected from Steel Creek in 1993 (1.01 pCi/g [37 Bq/kg]) and from Lower Three Runs Creek in 1993 (0.90 pCi/g [33 Bq/kg]). Cesium-137 concentrations usually were higher in bowfin (max = 0.73 pCi/g [27 Bq/kg]) than catfish, pan fish, and sunfish at all locations. Generally, as demonstrated in Table 11, cesium-137 concentrations have been decreasing at all sampling locations.

Table 11. Cesium-137 Detected in Fish Samples by Location and Species (1993—2008) GDNR/EPD

Location Along the Savannah River	*Fish Species*	*Sampling Timeframe*	*Maximum Concentration pCi/g (Bq/kg)*	*Maximum Concentration (Year)*
300 Augusta Lock and Dam	Bass	1995–2000	0.03 (1.11)	1995
		2001–2007	0.04 (1.48)	2004
	Bowfin	1993–2000	0.06 (2.22)	1993
		2001–2008	0.02 (0.74)	2002
	Catfish	1995–2000	0.04 (1.48)	1995
		2001–2004	0.03 (1.11)	2002
	Pan fish	1995–2000	0.16 (5.92)	1995
		2002–2004	0.13 (4.81)	2003
	Sunfish	1995–1996	0.01 (0.37)	1995
		2001	0.01 (0.37)	2001
330 Upper Three Runs Creek Mouth (SRS)	Bass	1995–1999	0.46 (17.02)	1999
		2001–2007	0.37 (13.69)	2002
	Bowfin	1993 and 2000	0.23 (8.51)	2000
	Catfish	1994–1999	0.13 (4.81)	1997
		2001–2004	0.06 (2.22)	2002
	Pan fish	1995–2000	0.10 (3.70)	1995
		2002–2004	0.20 (7.40)	2002
	Sucker fish	1993	0.08 (2.96)	1993
		2002	0.03 (1.11)	2002
	Sunfish	1995	0.22 (8.14)	1995
		2001	0.03 (1.11)	2001
350 Beaver Dam Creek Mouth (SRS)	Bass	1995–2000	1.83 (67.71)	2000
		2001–2008	0.07 (2.59)	2002
	Bowfin	1993	0.73 (27.01)	1993
	Catfish	1994–1999	0.13 (4.81)	1998
		2001–2004	0.05 (1.85)	2003
	Pan fish	1995–2000	0.03 (1.11)	1999
		2002–2004	0.07 (2.59)	2003
	Spotted Sucker	1993	0.03 (1.11)	1993
	Sucker fish	2002	0.02 (0.74)	2002
	Sunfish	1996	0.01 (0.37)	1996
		2001	0.01 (0.37)	2001
365 Four Mile Creek Mouth	Bass	1995–1997, 2000	1.37 (50.69)	1995
		2001–2007	0.33 (12.21)	2004
	Bowfin	1993–1999	0.36 (13.32)	1998
		2002	0.12	2002
	Catfish	1994–1999	0.11 (4.07)	1997
		2001–2004	0.25 (9.25)	2002
	Pan fish	1997–2000	0.10 (3.70)	1998
		2002–2004	0.06 (2.22)	2002
	Sucker fish	1993	0.03 (1.11)	1993
		2002– 2003	0.17 (6.29)	2002
	Sunfish	1995–1996	0.24 (8.88)	1995
		2001	0.07 (2.59)	2001
366 Downstream of Plant Vogtle and Four Mile Creek	Bass	1998–1999	0.88 (32.56)	1999
		2001–2008	0.22 (8.14)	2006
	Catfish	1998–1999	0.07 (2.59)	1999
		2003, 2006, 2008	0.05 (1.85)	2003

Table 11. Cesium-137 Detected in Fish Samples by Location and Species (1993—2008) GDNR/EPD				
Location Along the Savannah River	***Fish Species***	***Sampling Timeframe***	***Maximum Concentration pCi/g (Bq/kg)***	***Maximum Concentration (Year)***
410 Steel Creek Mouth (SRS)	Bass	1995–1997, 1999	4.40 (162.80)	1999
		2001–2007	0.64 (23.68)	2001
	Bowfin	1993 and 1998	0.61 (22.57)	1998
	Catfish	1994–2000	0.37 (13.69)	1995
		2001–2004	0.17 (6.29)	2003
	Pan fish	1995–2000	0.42 (15.54)	1998
		2002–2004	0.14 (5.18)	2003
	Spotted sucker	1993	1.01 (37.37)	1993
	Sucker fish	2002	0.05 (1.85)	2002
	Sunfish	1996	0.48 (17.76)	1996
		2001	0.01 (0.37)	2001
440 Lower Three Runs Creek Mouth (SRS)	Bass	1995–2000	3.08 (113.96)	1995
		2001–2007	0.46 (17.02)	2002
	Bowfin	1993	0.67 (24.79)	1993
	Catfish	1994–2000	0.42 (15.54)	1995
		2002–2004	0.25 (9.25)	2002
	Pan fish	1995–2000	0.39 (14.43)	1999
		2002–2004	0.08 (2.96)	2003
	Spotted sucker	1993	0.90 (33.30)	1993
	Sucker fish	2000	0.06 (2.22)	2000
	Sunfish	1995	0.43 (15.91)	1995
		2001	0.02 (0.74)	2001
460 US 301 Bridge	Bass	1994–2000	0.08 (2.96)	1999
		2001–2007	0. 10(3.70)	2002
	Bowfin	1993, 2000	0.06 (2.22)	1993
	Catfish	1994–2000	0.10 (3.70)	1995
		2001–2004	0.05 (1.85)	2003
	Pan fish	1994–2000	0.04 (1.48)	1994
		2002–2004	0.05 (1.85)	2002
	Spotted sucker	1993	0.03 (1.11)	1993
	Sucker fish	2002	0.04 (1.48)	2002
	Sunfish	1995–1996	0.03 (1.11)	1995

Source: Data provided by Georgia Dept. of Natural Resources/ Environmental Protection Division (GDNR 2005; Blackman 2009b).

pCi/g = picocuries per gram of tissue (1 pCi/g = 37 Bq/kg);
Bq/kg = becquerels per kilogram of tissue (1 Bq/kg = 0.027 pCi/g)

All samples are edible, and converted to wet weight samples.

Fish species labeled as “unknown” or with no detectable cesium-137 are not included in this table.

<u>Other Radioactive Contaminants in Fish (GDNR/EPD)</u>: ATSDR also reviewed Georgia's fish sampling data for other radionuclides besides cesium-137. Other than gross alpha and beta screenings, the analyses primarily included tritium, strontium-89, strontium-90, plutonium-238, and plutonium-239. No detectible quantities of strontium-89, plutonium-238, or plutonium-239 were reported for any of the sampling locations.

What are alpha and beta measurements used for?
Gross alpha and beta analyses are screening tools that are not radionuclide specific, but can identify whether there are radionuclides present that need further evaluation.

Tritium concentrations were more elevated in fish samples prior to 2001 and most consistently in samples collected from Four Mile Creek. The maximum tritium concentration (63.5 pCi/g [2,349 Bq/kg]) was detected in sunfish collected at the mouth of Four Mile Creek in 1995. The maximum reported tritium concentration measured in bass and catfish at this location was 13.8 and 13.7 pCi/g (511 and 507 Bq/kg) in 1997 and 1995, respectively. The second most elevated tritium fish sample (49.6 pCi/g [1,835 Bq/kg]) was collected from Upper Three Runs Creek in 2000, but normally the tritium concentrations in fish from Upper Three Runs Creek, Steel Creek and Lower Three Runs Creek were lower than the concentrations in fish from Four Mile Creek.

The maximum strontium-90 concentration (0.35 pCi/g [13 Bq/kg]) was reported for sunfish collected at the mouth of Four Mile Creek in 2003. The highest strontium-90 concentration detected in bass at this location was 0.33 pCi/g (12 Bq/kg) during 2003.

Fish Sampling Near SRS by SCDHEC/ESOP

ATSDR reviewed all available fish sampling data collected by SCDHEC/ESOP between 1997 and 2008. Table C-4 in Appendix C provides the maximum concentrations of detected radionuclides in fish fillets by location, time period, and species. Table 12 summarizes this information for the three major radionuclides.

The highest concentrations of cesium-137 have been detected in bass samples collected at the mouth of Steel Creek and Lower Three Runs Creek. Additionally, the South Carolina data are consistent with DOE data showing that the maximum concentrations were detected before 2000 and have been decreasing since then.

South Carolina data show that the most elevated tritium concentrations have been detected in bass fillets at the mouths of Four Mile Creek and Upper Three Runs Creek, and in catfish fillets at the mouth of Steel Creek. These values are generally lower than the maximum concentrations reported by GDNR/EPD; however, the locations with maximum tritium concentrations in fish fillets are similar.

The data also show that the most elevated strontium-90 concentrations were detected during 1997 in catfish fillets and bass fillets at the mouths of Lower Three Runs Creek and Four Mile Creek, respectively. Even though strontium-90 measurements were only reported for fish samples collected in 1997 and 1998, the results are consistent with the DOE data. DOE data indicate that the highest strontium-90 concentrations in fish were detected at the mouths of Lower Three Runs Creek and Four Mile Creek between 1994 and 2000. Georgia's data indicate that the maximum strontium-90 concentrations were detected in fish samples collected from the mouth of Four Mile Creek in 2003, somewhat later than what is observed from the DOE and South Carolina data sets.

Table 12. Summary From SCDHEC/ESOP Fish Fillet Sampling of Most Elevated Concentrations of Three Radionuclides at Specified Savannah River Locations

Radionuclide	*Maximum Concentrations (1997–2008)*[1]		*Year*	*Fish Species*
	Units in pCi/g (Bq/kg)	*Location*		
Cesium-137 (1997–2008)	2.56 (94.7)	Mouth of Steel Creek	1999	Bass
	1.89 (69.9)[2]	Mouth of Steel Creek	1998	Bass
	1.77 (65.4)[2]	Mouth of Steel Creek	1997	Bass
	1.29 (47.7)[2]	Mouth of Lower Three Runs Creek	1997	Bass
Strontium-90 (1997–1998)	0.20 (7.40)	Mouth of Lower Three Runs Creek	1997	Catfish
	0.03 (1.11)[2]	Mouth of Four Mile Creek	1997	Bass
Tritium (1997–2008)	16.8 (622)	Mouth of Four Mile Creek	1999	Bass
	13.7 (507)[2]	Mouth of Steel Creek	1999	Catfish
	13.5 (500)[2]	Mouth of Upper Three Runs Creek	1999	Bass

Source: SCDHEC/ESOP data (SCDHEC ND[a through j], 2005, 2006 [a, b], 2010)

[1]The concentrations listed in this table were either reported as wet weight or were converted to wet weight assuming a 0.25 dry-to-wet conversion.
[2]Next highest concentrations reported with year and location.

pCi/g = picocuries per gram;
Bq/kg = becquerels per kilogram (1 pCi/g = 37 Bq/kg)

Conclusions from the Review of the Fish Sampling Programs

Any comparison of fish data between the three sampling programs should be made with caution because there is inherent variability in sampling methodology that can influence the results. It is encouraging, however, that most of the fish sampling data from all three agencies have consistently demonstrated that concentrations of radioactive materials in fish collected from 1993 through 2008 are lower than concentrations reported prior to 1993, and have continued to decline since 2000.

A comparison of locations and time frames when maximum concentrations in fish were detected generally shows consistency between the three data sources. The highest cesium-137 concentrations in fish were usually reported for fish caught at the mouth of Steel Creek in the late 1990s. DOE and SCDHEC/ESOP reported the maximum concentrations of strontium-89/90 (or strontium-90) in fish from the mouth of Lower Three Runs Creek in 1994 and 1997, respectively. The highest tritium concentrations in fish, across all sampling programs, were found at the mouth of Four Mile Creek in the mid to late 1990s.

Common Game Species and Other Wildlife Monitoring

ATSDR evaluated radiological monitoring data in wild game samples collected by DOE, SCDHEC/ESOP, and GDNR/EPD. ATSDR also reviewed the South Carolina Deer Harvest, Turkey Harvest, and Public Alligator Hunting Season reports to determine the number of deer, feral hogs, turkeys, and alligators harvested per year in the three counties where the site is located and to determine the weight of the deer and hogs captured. A summary of the monitoring program activities are presented below.

Wildlife Monitoring at SRS by DOE

All animals (deer, hogs, and wild turkeys) harvested on site are surveyed by site personnel for cesium-137 using portable sodium iodide detectors before they are released to a hunter. The number of animals harvested by an individual, the weight of the animal, the location where the animal was harvested, and the cesium-137 concentrations detected in the animals are recorded. The potential exposure dose from consumption of the animal or multiple animals is estimated from the field survey, and each hunter's potential cumulative dose is monitored to ensure compliance with recommended dose limits.

On January 7, 1993, DOE Order 5400.5 was revised to require that no member of the public receive a radiation exposure from all routine DOE activities of more than 100 mrem (1 mSv) in a year (USDOE 1993b). This annual limit for the general population includes the sum of the effective dose from external exposures plus the committed effective dose from radionuclides taken into the body. Prior to 2006, DOE used a dose limit for *hunters* of 100 millirem per year (mrem/yr) (1 millisievert per year [mSv/yr]). However, taking into account that the dose from ingestion of the harvested animals may be only one exposure pathway for these hunters, DOE revised their administrative dose limit for hunters from ingestion of the harvested animals to 30 mrem/year (0.3 mSv/year) in 2006 (SRNS [ND]; USDOE 2011).

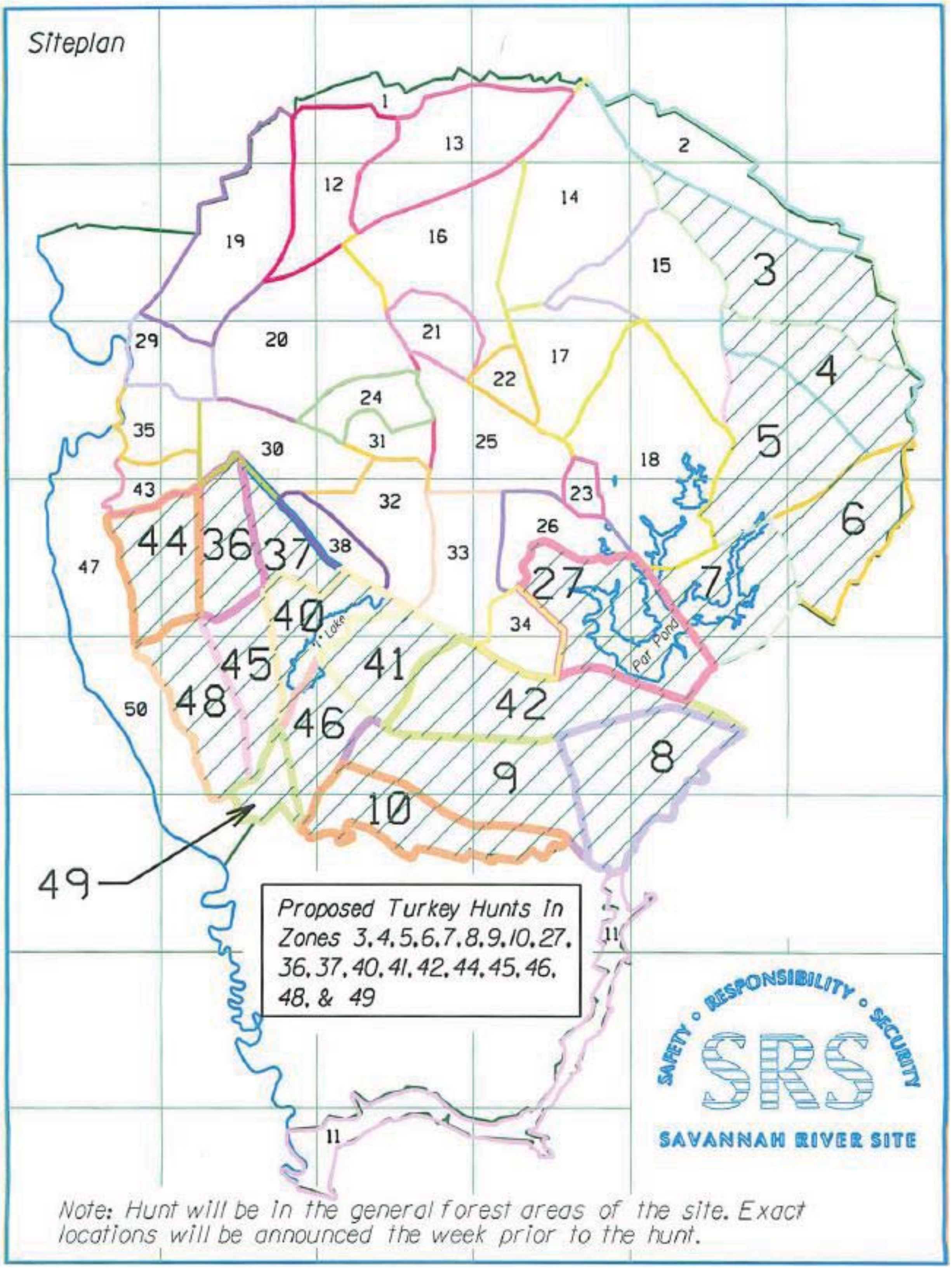
For calculating off-site exposures from hunting, DOE uses the average concentrations detected in on-site deer and assumes that the deer can migrate off site. In 1993 and 1994, DOE monitored off-site deer within a 50-mile radius of SRS in order to verify their assumptions. The off-site deer survey results are presented later in this section. Potential doses and dose calculations will be discussed in the Exposure Pathways and Potentially Exposed Populations section of this report.

Deer (on site): Controlled deer hunts began in 1965 due to the rapid increase in the population of the white-tailed deer on the site. SRS schematically divides the site into 50 zones to plan areas where hunts will occur (Figure 11). The site is divided into clusters of zones for the hunters to report to a designated location to have their harvested animals surveyed. Most of the zones are utilized. It appears from our review that the zones not used include the Lower Three Runs Creek zone (11), the perimeter zones on the northern boundary (1 and 2), the zones closest to the Savannah River (47 and 50), and a few of the zones in the center of the site.

Table 13 presents the maximum concentrations from DOE on-site deer sampling at controlled public hunts. Field surveys are performed on all harvested animals, and the results are used to estimate a hunter's potential dose from consuming the edible portions. Muscle and bone samples are collected from approximately 10 percent of the harvested animals and from all harvested animals with elevated results from the preliminary field survey. These samples are selected for more sensitive analyses by the laboratory (WSRC ND[i]). Each sample analyzed in the laboratory is from an individual deer. The analyses mainly include sampling of deer muscle for cesium-137. A subset of deer muscle and/or bone is also analyzed for strontium-89/90. Occasionally the samples are analyzed for other radionuclides such as cobalt-60, plutonium-238, and plutonium-239. Table 13 only includes the results from deer muscle samples since deer bones are not typically consumed by humans.

As previously noted, not all deer harvested on site were sampled for more sensitive laboratory analysis. Although the laboratory analyses would be expected to be more sensitive than field surveys resulting in slightly higher results, ATSDR noticed that occasionally the maximum concentrations reported from the laboratory analyses were significantly higher than the maximum field survey results (Table 13). If these samples were collected from animals with maximum field surveys, the estimated dose for the hunter may have been too low. However, for the year the most elevated concentration was reported (1998), the field survey and the laboratory results were essentially the same.

1514 **Figure 11. SRS Hunting Zones**



1516 Source: DOE

1518

Table 13. Maximum Concentrations of Cesium-137, Strontium-89/90, and Cobalt-60 from DOE On-Site Deer Muscle Samples at Controlled Public Hunts (1993-2008)

Year	# hunt days	# deer harvested	Radionuclide	# deer samples analyzed in laboratory	Units in pCi/g (Bq/kg)		Zone with laboratory maximum
					Maximum field concentrations	Maximum laboratory concentrations	
1993	14	1,553	Cesium-137	169	43 (1591)	57.68 (2134)	NR
			Strontium-89/90	31	NA	0.049 (1.81)	NR
1994	14	1,591	Cesium-137	178	29 (1073)	28.86 (1068)	NR
			Strontium-89/90	40	NA	0.098 (3.63)	NR
1995	12	1,152	Cesium-137	114	39.9 (1476)	45.3 (1676)	NR
			Strontium-89/90	28	NA	0.02 (0.74)	NR
1996	14	1,685	Cesium-137	167	confiscated–166 (6142)	149 (5513)	NR
			Cesium-137	166	Allowed–21(777)	16.4 (607)	NR
			Strontium-89/90	22	NA	0.05 (1.85)	NR
1997	14	1,363	Cesium-137	130	22 (814)	NR	NR
			Strontium-89/90	17	NA	<0.095 (<3.52)	NR
1998	12	1,293	Cesium-137	129	77 (2849)	76 (2812)	NR
			Strontium-89/90	42	NA	0.022 (0.81)	NR
1999	12	1,003	Cesium-137	107	Not reported	21 (777)	8
			Strontium-89/90	21	NA	0.012 (0.44)	44
			Cobalt-60	107	NA	0.0535 (1.98)	48
2000	14	294[1]	Cesium-137	30	57 (2109)	67.77 (2510)	8
			Strontium-89/90	5	NA	<0.01 (0.28)	18
2001	5	79[2]	Cesium-137	35	2 (74)	4.06 (150)	48
			Strontium-89/90	0	NA	Not analyzed	NA
2002	6	1,218	Cesium-137	56	28 (1036)	8.86 (328)	*unknown*
			Strontium-89/90	0	NA	Not analyzed	NA
2003	19	1,128	Cesium-137	109	17.1 (633)	11.4 (422)	33
			Strontium-89/90	10	NA	0.008 (0.29)	27
			Cobalt-60	109	NA	0.065 (2.4)	unknown
2004	19	817	Cesium-137	100	48.3 (1787)	32.2(1191)	*18*
			Strontium-89/90	35	NA	20.0[3] (740)	3
			Strontium-89/90		NA	2nd max. 1.13 (41.9)	43
2005	10	215	Cesium-137	17	8.1 (300)	5.9 (218)	48
			Strontium-89/90	19	NA	5.7 (211)	2
2006	11	324	Cesium-137	56	9.1 (337)	11.7 (433)	27
			Strontium-89/90	56	NA	0.022 (0.81)	29
2007	12	388	Cesium-137	55	8.7 (322)	10.0 (370)	8
			Strontium-89/90	55	NA	0.005 (0.19)	17
2008	NR	432	Cesium-137	NR	12.65 (469)	8.53 (316)	NR
			Strontium-89/90	NR	NA	4.35 (161)	NR

Sources: Savannah River Site Environmental Reports for 1993 through 2008 (WSRC ND[b – p],SRNS [ND])

[1]Number of deer is low because hunts were restricted to bucks only.
[2]Number of deer is low because hunts were not allowed in the fall after September 11, 2001.
[3]This result appears to be an outlier (~three times higher than next highest and ~20 times higher than the average).

pCi/g = picocurie per gram of tissue (1 pCi/g = 37 Bq/kg); Bq/kg = becquerel per kilogram of tissue (1 Bq/kg = 0.027 pCi/g); NR = not reported; NA = not analyzed

Note: This table does not include bone samples analyzed by the SRS laboratory or deer harvested at Crackerneck Wildlife Management Area and Ecological Reserve and at off-site locations.

Deer (off site): In 1993 and 1994 some off-site deer from hunt clubs within a 50-mile radius of the site were also monitored by DOE or their contractors. Table 14 lists the maximum and average cesium-137 concentrations detected in the deer muscle sampled from hunt clubs in the southeast, southwest, northeast, and northwest quadrants around the site. In 1994, 25 of the 33 samples collected from the northeast quadrant were below the detection limit. The maximum off-site cesium-137 concentration was reported in 1993 for deer harvested in the northwest quadrant and in 1994 for deer harvested in the southeast quadrant. All maximum concentrations in Table 14 were less than the estimated average concentrations for deer harvested on the site for these two years.

Table 14. Maximum Cesium-137 Concentrations Detected in Off-site Deer Muscle Samples from Hunt Clubs Within 50 Miles of SRS (1993–1994)—DOE

Year	*Location (Quadrant)*	*# of Deer Sampled (Muscle)*	*Radioactive Material*	*Maximum Concentration pCi/g (Bq/kg)*	*Average Concentration pCi/g (Bq/kg)*
1993	Southeast	22	Cesium-137	0.91 (33.7)	0.28 (10.4)
	Northwest	7	Cesium-137	1.76 (65.2)	0.78 (28.9)
1994	Southeast	30	Cesium-137	4.48 (165.9)	1.09 (40.4)
	Southwest	30	Cesium-137	3.58 (132.6)	0.73 (27)
	Northeast	33	Cesium-137	1.89 (70)	<0.2 (<7.4)
	Northwest	18	Cesium-137	2.38 (88.1)	1.23 (45.6)

Source: Savannah River Site Environmental Reports for 1993 and 1994 (WSRC ND[b, c])
pCi/g = picocuries per gram;
Bq/kg = becquerels per kilogram (1 pCi/g = 37 Bq/kg)

Feral hogs (on site): Feral hogs are harvested during the on-site deer hunts, but typically in smaller numbers than deer. The hogs are also surveyed in the field before the hunter is allowed to leave the site, and the results are used to estimate a hunter's exposure dose from consumption of the edible meat. Some feral hog are sampled for analysis by the laboratory but not as frequently as deer. Table 15 describes the number of feral hogs harvested each year and the concentrations of radioactive contaminants detected in muscle samples. As with the deer sampling results, the maximum concentrations of samples analyzed by the laboratory can exceed the most elevated field survey results; however, in 2003, the maximum laboratory result for cesium-137 (21.3 pCi/g) significantly exceeded the maximum field survey result (3.1 pCi/g) which may have resulted in an underestimated ingestion dose for the hunter.

1540

Table 15. Maximum Concentrations of Cesium-137, Strontium-89/90, and Cobalt-60 From DOE On-site Feral Hog Muscle Samples at Controlled Public Hunts

Year	*# Hunt Days*	*# Hogs Harvested*	*Radionuclide*	*# Hogs Analyzed in Laboratory*	*Units in pCi/g (Bq/kg)*	
					Maximum Field Survey Concentration	*Maximum Laboratory Concentration*
1993	14	147	Cesium-137	14	26 (962)	34.05 (1260)
			Strontium-89/90	7	NA	0.076 (2.81)
1994	14	106	Cesium-137	6	6 (222)	1.57 (58)
			Strontium-89/90	2	NA	<0.095 (<3.52)
1995	12	47	Cesium-137	2	7 (259)	3.62 (134)
			Strontium-89/90	0	NA	NA
1996	14	109	Cesium-137	2	16 (592)	14.70 (544)
			Strontium-89/90	2	NA	<0.095 (<3.52)
1997	14	85	Cesium-137	NR	8 (296)	NR
			Strontium-89/90	1	NA	<0.095 (<3.52)
1998	12	61	Cesium-137	NR	12 (444)	NR
			Strontium-89/90	0	NA	NA
1999	12	45	Cesium-137	5	30 (1110)	48.06 (1778)
			Strontium-89/90	5	NA	0.01 (0.37)
			Cobalt-60	5	NA	0.04 (1.48)
2000	14	38	Cesium-137	NR	17 (629)	NR
			Strontium-89/90	0	NA	NA
2001	12	102	Cesium-137	NR	6 (222)	NR
			Strontium-89/90	0	NA	NA
2002	NR	163	Cesium-137	0	17 (629)	NA
			Strontium-89/90	0	NA	NA
2003	6	106	Cesium-137	7	3.1 (115)	21.3 (786)
			Strontium-89/90	0	NA	NA
			Cobalt-60	7	NA	0.03 (1.15)
2004	18	213	Cesium-137	NR	25.1 (929)	NR
			Strontium-89/90	0	NA	NA
2005	10	33	Cesium-137	NR	5.2 (192)	NR
			Strontium-89/90	0	NA	NA
2006	11	92	Cesium-137	NR	19 (703)	17.2 (636)
			Strontium-89/90	0	NA	NA
2007	12	84	Cesium-137	NR	6.89 (255)	NR
			Strontium-89/90	NR	NA	0.007 (0.26)
2008	NR	110	Cesium-137	NR	8.53 (316)	NR
			Strontium-89/90	NR	NA	0.016 (0.6)

Sources: Savannah River Site Environmental Reports for 1993 through 2008 (WSRS ND[b-p], SRNS [ND])

pCi/g = picocurie per gram of tissue (1 pCi/g = 37 Bq/kg);
Bq/kg = becquerel per kilogram of tissue (1 Bq/kg = 0.027 pCi/g)
NR = not reported; NA = not analyzed

Note: This table does not include bone samples, feral hogs harvested at Crackerneck Wildlife Management Area and Ecological Reserve, hogs trapped and disposed of on-site by USFS-SRS and their contractors for additional forestry management activities, and hogs harvested off site.

Wild turkeys (on site): From 1993 through 2001, wild turkeys were captured on site, monitored in the field for cesium-137, and relocated to other South Carolina game areas with a few sent out of the state. The number of turkeys captured and relocated per year and the corresponding maximum cesium-137 concentrations in whole turkeys are presented in Table 16.

Table 16. Maximum Cesium-137 Concentrations in Wild Turkeys at SRS (1993–2001)

Year	*Number Captured/ Relocated*	*Maximum Concentration*
1993	33	5 pCi/g (185 Bq/kg)
1994	82	10 pCi/g (370 Bq/kg)
1995	16	1 pCi/g (37 Bq/kg)
1996	68	5 pCi/g (185 Bq/kg)
1997	108	6 pCi/g (222 Bq/kg)
1998	36	5 pCi/g (185 Bq/kg)
1999	29	4 pCi/g (148 Bq/kg)
2000	43	5 pCi/g (185 Bq/kg)
2001	12	4 pCi/g (148 Bq/kg)

Sources: Savannah River Site Environmental Reports for 1993 through 2001 (WSRC ND[b – j])

pCi/g = picocurie per gram;
Bq/kg = becquerel per kilogram (1 pCi/g = 37 Bq/kg)

No turkey monitoring data were reported for 2002 and 2003. Since 2004, SRS has accommodated the National Wild Turkey Federation's hunt for the mobility impaired (NWTF 2009). The harvested turkeys from this annual turkey hunt held in April have been monitored for cesium-137 prior to leaving the site. The number harvested per year and the average cesium-137 concentrations detected in whole turkeys are presented in Table 17.

Table 17. Average Cesium-137 Concentrations in Wild Turkeys at SRS (2004–2009)

Year	**Number Harvested**	**Average Concentration**
2004	13	NR
2005	11	NR
2006	23	1.0 pCi/g (37 Bq/kg)
2007	5	1.3 pCi/g (48.1 Bq/kg)
2008	17	1.3 pCi/g (48.1 Bq/kg)
2009	27	NR

Source: Savannah River Site Environmental Reports for 2004 through 2009 (WSRC ND[m-p];SRNS ND)

pCi/g = picocurie per gram;
Bq/kg = becquerel per kilogram (1 pCi/g = 37 Bq/kg);
NR = not reported

Note: The maximum concentrations were not reported

Other Wild Game (on site): The on-site beaver population has been controlled by trapping the beavers and disposing of them in the Savannah River Sanitary Landfill after being monitored. According to information reviewed by ATSDR, these beavers were monitored for cesium-137 by the site's environmental sampling program from 1993 through 1998, 2000, and 2006. However, since they are not being consumed, ATSDR did not analyze the monitoring results further. Also, beavers tend to be non-migratory.

Since 2009, on-site deer and hog hunters have been encouraged to harvest coyotes because they are overrunning the area and killing fawns. The harvested coyotes are surveyed by the site personnel, properly disposed of, and not consumed by humans (USDOE 2011).

Wildlife Monitoring at SRS by SCDHEC/ESOP

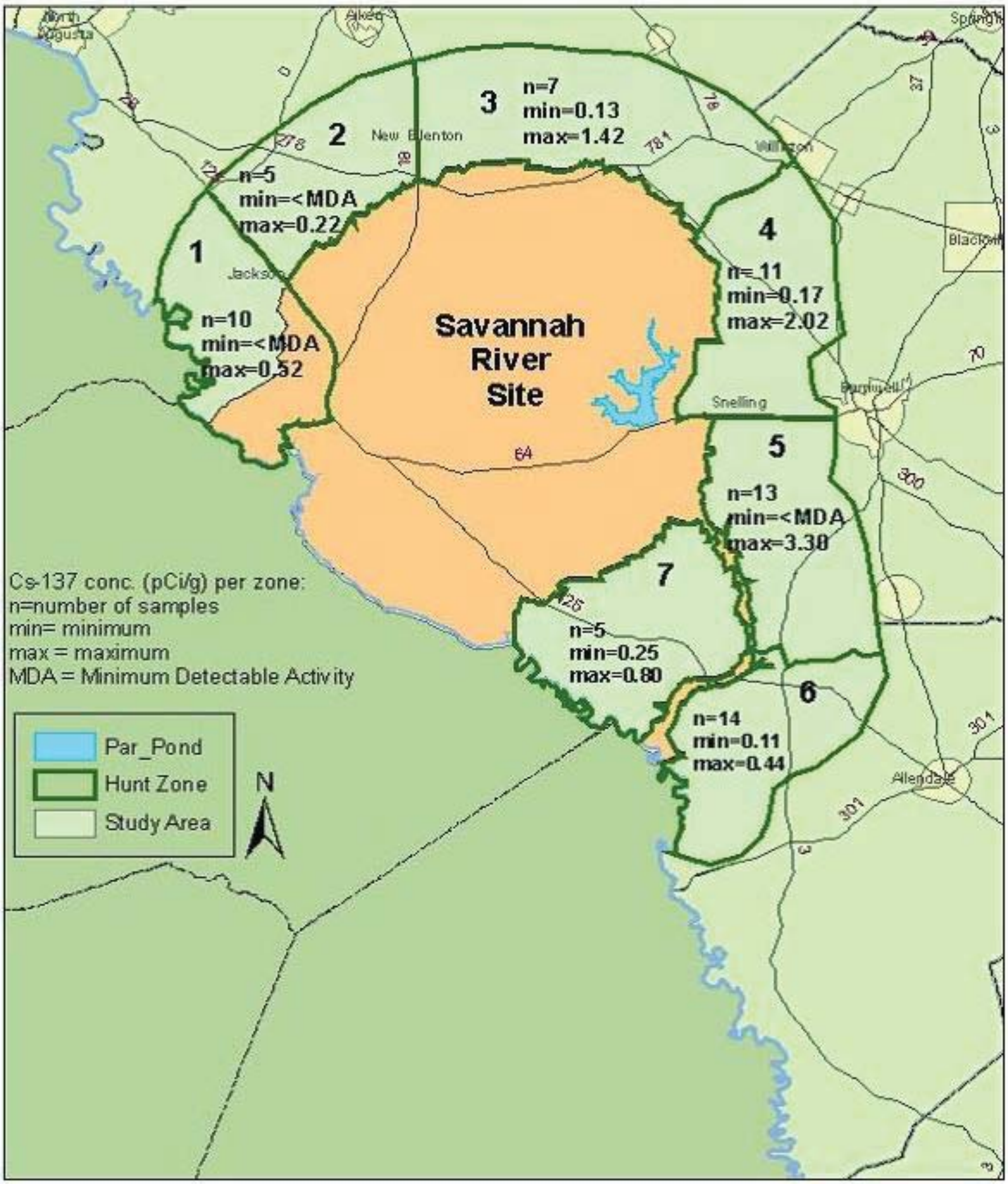
Hunting takes place at CWMAER and on private lands near the site. In 1998, SCDHEC/ESOP began analyzing flesh and bone samples from game animals for radioactive materials by utilizing samples harvested and donated by local hunters within a 5-mile radius of the site including CWMAER and several hunting zones (SCDHEC [NDa]) (Figure 12). Muscle samples from wild game are analyzed predominantly for cesium-137 (Table 18). The percentage of deer and feral hogs harvested in this area and sampled for radiological analyses is unknown; however, the percentage sampled appears quite small. (SCDHEC 2010; SCDNR 2009b).

Turkeys are also harvested within a 5-mile radius of the site but no turkeys were sampled and analyzed for radioactive contaminants by SCDHEC/ESOP (SCDNR 2009c). South Carolina limits a hunter to five turkeys per season, which is a limit set for CWMAER as well as private land (SCDNR 2009c).

CWMAER is open annually to the public for dove hunting. The bag limits are 15 mourning doves per day and no limit for Eurasian collared doves (SCDNR 2009d). Only one dove sample was collected in 1999 and analyzed for cesium-137. It was not specified whether the sample was the whole bird or the edible portion. The result was less than the detection limit.

Duck hunting is a popular sport in South Carolina. Although several types of ducks are hunted in the area, the majority harvested at CWMAER are wood ducks (SCDNR ND[d], ND[e]). SCDHEC/ESOP has collected five duck samples (edible portions) for radiological analyses: one sample in 1998 and four samples in 1999. The maximum cesium-137 concentration was 0.66 pCi/g (24 Bq/kg) reported in 1998. Two samples in 1999 were below the cesium-137 detection limit (SCDHEC ND[a], ND[b]).

Figure 12. South Carolina Monitoring of Game Animals at SRS



Source: SCDHEC/ESOP 2008 Data Report (SCDHEC 2010)

No additional radiological sampling results were located or reviewed for other species. Table 18 summarizes the maximum radioactive material concentrations detected in the muscle (edible portion) of off-site game sampled by SCDHEC/ESOP.

Table 18. Maximum Radioactive Material Concentrations From South Carolina Off-site* Game Animals Sampling

Year	*Species*	*Radioactive Material*	*Number of Samples Collected*	*Maximum Concentration pCi/g (Bq/kg)*	*Location of Maximum Concentration*
1998	Deer	Cesium-137	2	3.7 (137)	Zone 3 (NNE)
		Strontium-89	2	12.5 (463)	Zone 3 (NNE)
	Duck	Cesium-137	1	0.7 (24)	Zone 1 (WNW)
1999	Deer	Cesium-137	2	7.3 (270)	Zone 3 (NNE)
	Feral hog	Strontium-89	2	0.01 (0.4)	Zone 1 (WNW)
	Wood duck	Cesium-137	1	0.3 (11.1)	Zone 1 (WNW)
	Ringneck	Cesium-137	1	<0.013 (<0.5)	Zone 1 (WNW)
	Dove	Cesium-137	1	<0.018 (<0.7)	Zone 1 (WNW)
2000	Deer	Cesium-137	45	6.9 (255)	Zone 5 (SE)
	Feral hog	Cesium-137	5	1.5 (56)	Zone 7 (S)
2001	Deer	Cesium-137	40	4.1 (152)	Zone 7 (S)
2002	Deer	Cesium-137	61	8.9 (328)	Zone 4 (E)
	Feral hog	Cesium-137	4	7.2 (266)	Zone 4 (E)
2003	Deer	Cesium-137	57	5.8 (214)	Zone 4 (E)
2004	Deer	Cesium-137	65	4.6 (170)	Zone 4 (E)
2005	Deer	Cesium-137	81	4.3 (159)	Zone 5 (SE)
2006	Deer	Cesium-137	128	3.9 (144)	Zone 7 (S)
2007	Deer	Cesium-137	85	3.3 (122)	Zone 5 (SE)
2008	Deer	Cesium-137	51	4.6 (170)	Zone 5 (SE)

Source: SCDHEC/ESOP 1997/1998 to 2008 environmental data (SCDHEC ND[a through j], 2005, 2006[a, b], 2010)
*Off-site is within five miles of SRS boundary.
Zone locations shown in Figure 12.
pCi/g = picocurie per gram of tissue (1 pCi/g = 37 Bq/kg); Bq/kg = becquerel per kilogram of tissue (1 Bq/kg = 0.027 pCi/g)
NNE = north-northeast; WNW = west-northwest; SE = southeast; S = south; E = east
Note: This table does not include bone samples; number of samples includes background samples.

A comparison of the maximum cesium-137 concentrations in deer muscle between SCDHEC/ESOP samples and on-site DOE samples from 1998 through 2008 are shown in Table 19. When the maximum result for on-site deer is quite elevated, the off-site SDHEC/ESOP results were significantly lower, but for years when the on-site maximum levels were not as elevated the SCDHEC/ESOP results were similar. It appears from the data that the deer with the maximum concentrations are remaining on the site.

Table 19. Comparison of Cesium-137 in Deer Muscle From DOE On-Site and SCDHEC Off-Site Sampling (1998–2008)

Year	*Units in pCi/g (Bq/kg)*			
	Maximum DOE On-site Lab Results	*Average DOE On-Site Used for Off-site*	*Maximum SCDHEC Off-site Lab Results*	*Average SCDHEC Off-site Results*
1998	76 (2812)	3.85 (142)	3.7 (137)	2.01 (74)
1999	20.98 (777)	3.24 (120)	7.3 (270)	4.8 (178)
2000	67.77 (2510)	2.4 (89)	6.9 (255)	1.03 (38)
2001	4.06 (150)	1.13 (42)	4.1 (152)	1.31(49)
2002	8.86 (328)	4 (148)	8.9 (328)	1.78 (66)
2003	11.4 (422)	1.3 (48)	5.8 (214)	1.31 (49))
2004	32.2 (1191)	5.26 (195)	4.6 (170)	1.49 (55)
2005	5.9 (218)	2.32 (86)	4.3 (159)	0.85 (32)
2006	11.7 (433)	2.65 (98)	3.9 (144)	1.19 (44)
2007	10.0 (370)	1.46 (54)	3.3 (122)	0.54 (20)
2008	8.53 (316)	2.4 (89)	4.6 (170)	0.72 (27)

Sources: SCDHEC/ESOP annual environmental reports (SCDHEC website) and SCDHEC 2010 (SCDHEC ND[a through j], 2010), and DOE Savannah River Site Environmental Reports for 1998 through 2008 (WSRC ND[g – p], SRNS [ND])

pCi/g = picocurie per gram; Bq/kg = becquerel per kilogram (1 pCi/g = 37 Bq/kg)

Wildlife Monitoring at SRS by GDNR/EPD.

GDNR/EPD conducted deer monitoring from four zones in Georgia across the Savannah River from the site until 2004. Deer samples were collected through a voluntary donation program from hunters. Individual deer samples were analyzed for gamma-emitting radionuclides including cesium-137 and naturally occurring potassium-40. Composite samples from each zone were analyzed for tritium, gamma-emitters, strontium-89/90, plutonium-238, and plutonium-239. ATSDR reviewed data from 1996 through 2004. Cesium-137 and tritium were the only man-made radionuclides detected in the deer meat. As shown in Table 20 below, the other radionuclides were at or below the analytical detection limits.

Table 20. Maximum Radionuclide Concentrations From Georgia's Deer Muscle Sampling Program (1996–2004)

Radionuclide	Maximum Concentration (wet weight)	Year
Cesium-137	3.12 pCi/g (115 Bq/kg)	2004
Tritium (Hydrogen-3)	0.55 pCi/g (20 Bq/kg)	1996
Plutonium-238	≤0.00062 pCi/g (0.02294 Bq/kg)	1996–2003
Plutonium-239	≤0.00062 pCi/g (0.02294 Bq/kg)	1996–2003
Strontium-89	≤0.023 pCi/g (0.85 Bq/kg)	2002–2003
Strontium-90	≤0.012 pCi/g (0.44 Bq/kg)	1996–2003

Source: GDNR data in Excel file received February 1, 2005 (GDNR 2005)

pCi/g = picocurie per gram of tissue (1 pCi/g = 37 Bq/kg);
Bq/kg = becquerel per kilogram of tissue (1 Bq/kg = 0.027 pCi/g)

Conclusions from the Review of Game Species and Other Wildlife

The state agencies rely on sample donations from the hunters, which can limit the numbers and types of samples and the sample locations. Ideally samples should be collected from a variety of biota harvested and consumed, from locations near the site where harvesting occurs, and at various times of the year. When activities and operations change on the site, the analyses of the samples should be expanded or adjusted to include any new potential contaminants. Table 21 summarizes the type of game and the maximum concentrations reported by each of the three monitoring programs.

Table 21. Wild Game Maximum Radioactive Contaminant Summary Data

Agency	*Game Type*	*Contaminant*	*Maximum Concentration*	*Year*
DOE on site (1993–2008)	Deer muscle	Cesium-137	77 pCi/g (2849 Bq/kg)	1998
		Strontium-89/90	5.7 pCi/g (211 Bq/kg)	2005
	Feral hog muscle	Cesium-137	48.06 pCi/g (1778 Bq/kg)	1999
		Strontium-89/90	<0.095 pCi/g (<3.52 Bq/kg)	1994, 1996, 1997
	Wild turkeys	Cesium-137	10 pCi/g (370 Bq/kg)	1994
DOE off site (1993–1994)	Deer muscle	Cesium-137	4.48 pCi/g (166 Bq/kg)	1994
South Carolina off site (1998–2008)	Deer muscle	Cesium-137	8.86 pCi/g (328 Bq/kg)	2002
		Strontium-89	12.5 pCi/g (463 Bq/kg)	1998
	Feral hog muscle	Cesium-137	7.19 pCi/g (266 Bq/kg)	2002
	Duck	Cesium-137	0.66 pCi/g (24 Bq/kg)	1998
	Dove	Cesium-137	<0.018 (<0.7)	1999
Georgia off site (1996–2004)	Deer	Cesium-137	3.12 pCi/g (115 Bq/kg)	2004
		Tritium	0.55 pCi/g (20 Bq/kg)	1996

Source: Annual environmental reports and data submitted by DOE, SCDHEC/ESOP, and GDNR/EPD (WSRC ND[b thru p]; SRNS ND; SCDHEC ND[a thru j], 2010; GDNR 2005)
DOE = U.S. Department of Energy;
SCDHEC/ESOP = South Carolina Department of Health and Environmental Control/ Environmental Surveillance and Oversight Program;
GDNR/EPD = Georgia Department of Natural Resources/Environmental Protection Division;
pCi/g = picocurie per gram of tissue (1 pCi/g = 37 Bq/kg);
Bq/kg = becquerel per kilogram of tissue (1 Bq/kg = 0.027 pCi/g)

Farm/Domestic Animals and Products Monitoring

This category includes poultry (chickens), eggs, beef, and pork. A foodstuff survey based primarily on 1994 statistics compiled by South Carolina and Georgia provides some perspective as to the annual production of the above-specified items within approximately an 80-kilometer radius (50-mile radius) of SRS (Twining et al. 2000):

- Poultry ─ 50 million kg (110 million pounds)
- Eggs ─ 200 million kg (440 million pounds)
- Beef ─ 113,000 kg (248,600 pounds)
- Domestic pork ─ 123,000 kg (270,600 pounds)

These amounts approximately match the consumption of these products by the population in this area (Hamby 1991). Therefore, ATSDR has conservatively assumed that persons in this area consumed locally produced poultry, eggs, beef, and pork.

A 1991 document indicates that the diet of beef cattle raised near SRS consisted of approximately 75 percent pasture grass and 25 percent stored grass (Hamby 1991). The 1994 foodstuff survey found that some beef cattle are raised close enough to the site that using potential radiation doses calculated at the site boundary would be appropriate for estimating the radiological dose from consuming beef (Twining et al. 2000). Pasture grasses consumed by cattle this close to the site potentially contain radioactive materials. Therefore, beef cattle present a potential pathway for human exposure. The 1991 document indicates that domestic hogs and chickens raised for profit were fed imported commercial feed, and chickens were housed in covered shelters (Hamby 1991). Therefore, domestic hogs, chickens, and chicken eggs are less likely to be a potential pathway for human exposure.

Only DOE monitored chickens, eggs, domestic pork, and beef samples off site for radioactive contaminants. Chicken, egg, and domestic pork samples were only collected in the early 1990s. Although data are limited for domestic hogs and chickens, ATSDR used this information along with radiological samples from on- and off-site deer, feral hogs, and wild turkeys as another indicator of the amount of radioactive contaminants that could potentially accumulate in the muscle of locally consumed animals. Table 22 presents the maximum concentrations for beef, domestic pork, chicken, and chicken eggs. (Data for deer, feral hogs, and wild turkeys are discussed under the previous section on wild game).

Table 22. Maximum Radionuclide Concentrations in Edible Portions of Beef, Domestic Pork, Chicken, and Chicken Eggs - DOE

Radionuclide	*Units in pCi/g (Bq/kg)*			
	Beef[1]	*Domestic Pork*[2]	*Chicken*[3]	*Chicken Eggs*[3]
Hydrogen-3 (tritium)	0.49 (18.1)	0.0255 (0.94)	0.343 (12.7)	0.248 (9.19)
Cesium-137	0.132 (4.9)	ND	0.0285 (1.06)	ND
Cobalt-60	0.0281 (1.0)	ND	ND	ND
Strontium-90	0.0043 (0.16)	ND	ND	ND
Neptunium 237[4]	0.00005 (0.002)	NA	NA	NA
Plutonium-238	0.00155 (0.057)	0.00005 (0.002)	0.00076 (0.03)	NA
Plutonium-239	0.00006 (0.002)	NA	ND	NA
Uranium-234	0.00026 (0.01)	NA	NA	NA
Uranium-235	0.00003 (0.001)	NA	NA	NA
Uranium-238	0.00027 (0.01)	NA	NA	NA

Sources: Savannah River Site Environmental Reports for 1993,1994,1996.1999—2008 (WSRC ND[b, c, i thru p] ; SRNS [ND]).

[1] Beef samples were collected in 1993, 1994, 1996, and 1999 through 2008.
[2] Domestic pork samples were collected in 1993.
[3] Chicken and chicken egg samples were collected in 1993 and 1994.
[4] Neptunium 237 was only sampled in beef in 2008.
pCi/g = picocurie per gram (1 pCi/g = 37 Bq/kg); Bq/kg = becquerel per kilogram (1 Bq/kg =0.027 pCi/g)
NA = not analyzed; ND = not detected

Dairy Monitoring

This category includes milk and milk products. Consumption of milk can be an important human exposure pathway for radioactive materials released to the environment, especially for radioiodine. CDC's dose reconstruction project reviewed AEC/DOE's early results of radioiodine sampling in milk. After 1973, the measured concentrations were frequently below the laboratory's analytical detection limits (CDC 2001). Since 1993, milk samples have been collected mainly from local dairies by DOE, SCDHEC, GDNR, or their contractors. DOE, GDNR and SCDHEC have continued to monitor for radioiodine in milk, but no detectable concentrations have been reported from 1993 through 2008. Therefore, radioiodine will not be discussed further.

DOE: From 1993 through August 1995, DOE collected monthly milk samples in South Carolina and Georgia at five dairies within 25 miles and four dairies within 50 miles of the site, and from locally produced inventories by a major distributor. The samples were analyzed for gamma-emitting radionuclides, cesium-137, iodine-131, and tritium. Samples were also collected quarterly at the locations within 25 miles of the site and analyzed for strontium-90. In 1996, DOE began analyzing milk samples for cobalt-60. After August 1995, DOE collected samples only from dairies within 25 miles of SRS and the major distributor. In 2002, sampling frequency was changed to quarterly, and no samples were collected from the major distributor. Dairies having milk samples analyzed fairly consistently from 1993 through 2008 were located in Denmark, South Carolina; Girard, Georgia; Gracewood, Georgia; and Waynesboro, Georgia.

SCDHEC/ESOP: Beginning in 1997, SCDHEC has collected and analyzed milk samples at five South Carolina dairies within 50 miles of the site and two background locations. SCDHEC collected monthly samples until 2003 when the frequency was changed to quarterly. Fresh milk is collected in two containers from each dairy—one analyzed for tritium and the other for gamma-emitting radionuclides, cesium-137, and iodine 131. A composite sample from the two containers is analyzed for radioactive strontium (SCDHEC 2010). These samples were usually collected from cow's milk; however, in 2003 and 2004, SCDHEC sampling included goat's milk. ATSDR reviewed the South Carolina milk sampling data results from 1997 through 2008.

GDNR/EPD: GDNR has sampled milk at three dairies in Georgia since 1982 and continues to analyze milk samples on a monthly basis for gamma-emitting radionuclides, cesium-137, iodine-131, and tritium. Samples were also analyzed for strontium-89/90 on a quarterly basis until June 2006 when this analysis was discontinued. One gallon of fresh milk is collected monthly by either personnel from the Georgia Department of Agriculture or from Georgia Power Plant Vogtle and analyzed by the GDNR/EPD laboratory (Blackman 2009a). ATSDR reviewed the Georgia milk sampling data results from 1993 through 2008.

Table 23 shows the maximum contaminant concentrations reported between 1993 and 2008 by DOE, SCDHEC, or GDNR. The maximum tritium, cesium-137, and cobalt-60 concentrations in milk samples were reported for dairies in Georgia. The maximum strontium-89 and strontium-90 concentrations in milk samples were reported for dairies in South Carolina.

Table 23. Maximum Radionuclide Concentrations in Milk (1993–2008)—DOE, SCDHEC, GDNR

Dairy Locations by State	*Units in pCi/L (Bq/L)*				
	Hydrogen-3 (Tritium)	*Cesium-137*	*Cobalt-60*	*Strontium-89*	*Strontium-90*
Georgia	4,810 (178.2)	10 (0.37)	6.21 (0.23)	8.1 (0.3)	3.0 (0.11)
South Carolina	1,170 (43.3)	7.87 (0.29)	ND	229 (8.48)	12.9 (0.48)

Sources: DOE, GDNR-EPD, SCDHEC-ESOP data (WSRC ND[b through p]; SRNS ND; GDNR 2005; Blackman 2009a; SCDHEC ND[a through j], 2010)

ND = non-detect;
pCi/L = picocurie per liter (1 pCi/L = 0.037 Bq/L);
Bq/L = becquerel per liter (1 Bq/L = 27 pCi/L)

The maximum tritium concentration (4, 810 pCi/L [178.2 Bq/L]) was detected in a milk sample collected by DOE in Waynesboro, Georgia in 1998. This concentration was significantly greater than any other DOE result for that year. All concentrations of tritium in milk reported by GDNR/EPD for 1998 were less than or equal to 200 pCi/L (≤ 7.4 Bq/L). GDNR/EPD reported their maximum tritium concentration (3,400 pCi/L [125.9 Bq/L]) detected in milk in 1993. These maximum concentrations for tritium were all in Georgia.

GDNR/EPD reported the maximum cesium-137 concentration (10 pCi/L [0.37 Bq/L]) in milk in 1993. This concentration was only slightly higher than the maximum cesium-137 concentrations reported for other years.

The maximum concentrations for strontium-89 (229 pCi/L[8.48 Bq/L]), strontium-90 (12.9 pCi/L[0.48 Bq/L]), and strontium-89/90 (22.7 pCi/L[0.84 Bq/L]) in milk were detected in South Carolina by DOE and SCDHEC. SCDHEC also collected goat's milk samples in 2003 and 2004 and analyzed them for strontium-90. The maximum strontium-90 concentration in goat's milk reported for both years was 11 pCi/L (0.41Bq/L). This concentration is slightly greater than the cows' milk concentrations for those years, but less than the maximum concentration reported in cow's milk (12.9 pCi/L [0.48 Bq/L]) in 1996.

Agricultural Crop Monitoring

The monitoring of agricultural crops in the vicinity of SRS includes a variety of fruits, vegetables, nuts and legumes, and grains that are consumed by humans.

DOE: Since 1953, SRS has sampled vegetation (mainly grass) at various locations both on and off site. They began sampling local agricultural products in 1961. This document focuses on SRS's biota sampling results beginning in 1993. Samples of agricultural products are collected during harvest seasons, which are usually during the summer and fall. The information below provides a summary of DOE's monitoring program and reports notable changes in the monitoring of agricultural crops since 1993.

- In 1993, the SRS environmental sampling program for biota was improved by the use of a global positioning system (GPS) and geographic information system (GIS) technology to identify and map sampling locations. The terrestrial food products program expanded to include sampling points along a 50-mile radius from the center of the site in each of the northeast, northwest, southeast, and southwest quadrants. SRS also continued to collect food crops from locations near the site perimeter and approximately 25 miles from the site.

  The samples are analyzed for gamma-emitting radionuclides, uranium isotopes, plutonium-238 and 239, strontium-89/90, and tritium. The crops that have been sampled by SRS include a variety of greens, corn, grains (wheat, barley, oats, and rye), peanuts, soybeans, cantaloupe, watermelon, and other fruits (WSRC ND[b]).

- In 1995, the site cut back on the types and locations for crop sampling. Only one variety of fruit and one variety of green vegetable were being collected routinely. The sampling locations were in four quadrants approximately 9 miles from the site perimeter. Samples were collected annually from each quadrant and from a background location (WSRC ND[d]).

- In 1996, food samples were analyzed for the presence of gamma-emitting radionuclides, tritium, strontium-89/90, plutonium-238, and plutonium-239. Samples were no longer analyzed for uranium (WSRC ND[e]).

- The food product monitoring program expanded in 2005 to include secondary crops on a rotating schedule and analyses for additional radionuclides (WSRC ND[n]). For example, wheat and cabbage were sampled in 2007, and peanuts and pecans were sampled in 2008 (WSRC ND[p] ; SRNS ND).

- Samples typically are analyzed for gamma-emitting radionuclides, tritium, strontium-89/90, uranium-234, uranium-235, uranium-238, plutonium-238, plutonium-239, americium-241, curium-244, gross alpha, and gross beta. A fifth sample location was added approximately 25 miles to the southeast of the site.

Data from the DOE food product monitoring program are not used to show direct compliance with any dose standard. DOE uses the data to verify dose models and determine environmental trends (SRNS ND). ATSDR used the data to supplement the data reported by SCDHEC and GDNR.

SCDHEC/ESOP: SCDHEC/ESOP began sampling agricultural crops in 2003; however, vegetation (mainly Bermuda grass) was collected both on and off site and analyzed for tritium and gamma-emitting radionuclides prior to 2003 (SCDHEC ND[b], ND[c]). SCDHEC/ESOP sampled a wide variety of food crops (e.g., green leafy vegetables, squash, fruit, potatoes, cucumbers) twice a year from areas in the vicinity of the site and at a background location 110 miles from the site. In 2008, sampling frequency was reduced to once per year, with random collection of samples from January through November. The locations for collecting these samples are determined by the availability of the crops, the population density, and the proximity to the perimeter of the site. The samples are analyzed for tritium and gamma-emitting radionuclides (SCDHEC ND[j], SCDHEC 2010).

GDNR/EPD: GDNR/EPD began sampling grass and food crops in Georgia near the site in 1978. Until 2005, they sampled and analyzed a wide variety of fruits, vegetables, and nuts and legumes annually. The crop that was most frequently sampled was corn (from 1993 through 1997, 2002, and 2003). The samples were analyzed for gross alpha and beta, gamma-emitting radionuclides, tritium, cesium-137, strontium-89/90, plutonium-238, and plutonium-239. GDNR/EPD has continued collecting and analyzing grass samples.

For Table 24, ATSDR used the average of the maximum concentrations of each radionuclide detected in each type of vegetable, fruit, nuts, and grains. Hydrogen-3 (tritium), cesium-137, and strontium-90 are the most prevalent radioactive contaminants in agricultural crops at this site. This is not surprising since they are more water soluble than the other potential contaminants and easily taken up by plants (cesium and strontium are chemically similar to essential plant nutrients).

Table 24. Maximum Radionuclide Concentrations in Agricultural Crops from 1993 Through 2008

Radionuclide	*Average of the Maximums—Units in pCi/g (Bq/kg)*			
	Total Vegetable	*Total Fruit*	*Peanuts/Pecans*	*Grains*
Americium-241	0.0028 (0.102)	0.0001 (0.003)	0.0027 (0.101)	0.00002 (0.001)
Cesium-137	0.116 (4.29)	0.026 (0.96)	0.07 (2.6)	0.02 (0.74)
Cobalt-60	0.022 (0.80)	0.004 (0.15)	0.004 (0.16)	<0.003 (<0.1)
Hydrogen-3 (tritium)	0.45 (16.65)	1.22 (45.12)	0.24 (8.74)	<0.20 (<7.56)
Plutonium-238	0.00154 (0.06)	0.00222 (0.08)	0.00212 (0.08)	0.00024 (0.009)
Plutonium-239	0.00039 (0.01)	0.00005 (0.00)	0.00168 (0.06)	0.00007 (0.003)
Strontium-90	0.584 (21.61)	0.025 (0.93)	0.079 (2.93)	0.047 (1.74)
Uranium-234	0.0085 (0.32)	0.0001 (0.001)	0.0058 (0.21)[1]	0.0004 (0.01)[1]
Uranium-235	0.0014 (0.05)	0.0001 (0.001)[1]	0.0006 (0.02)	0.003 (0.11)
Uranium-238	0.0058 (0.22)	0.0002 (0.007)	0.0010 (0.04)[1]	0.0004 (0.01)[1]

Source: DOE, GDNR-EPD, SCDHEC-ESOP data (WSRC ND[b through p]; SRNS ND; GDNR 2005; SCDHEC ND[a through j], 2010)

[1] Only have 2008 data for these values.
pCi/g = picocurie per gram (1 pCi/g = 37 Bq/kg); Bq/kg = becquerel per kilogram (1 Bq/kg = 0.027 pCi/g)
Note: Background was not subtracted.

Non-Radioactive Contaminants

The monitoring programs for biota at or near SRS have focused mainly on radioactive contaminants. The SRS monitoring of non-radioactive contaminants in biota has primarily involved sampling of mercury in fish (see text box for additional information about mercury), both on site and at off-site locations along the Savannah River. As noted previously, the Savannah River is also monitored by SCDHEC and GDNR. Both state agencies routinely monitor for mercury contamination in fish, with other contaminants monitored less frequently or not at all.

What Is Mercury?

- Mercury is a naturally occurring metal which has several forms.
- Inorganic mercury (metallic mercury and inorganic mercury compounds) enters the air primarily from industrial sources.
- Mercury combines with carbon to make organic mercury compounds. The most common one, methylmercury, is produced mainly by microscopic organisms in the water and soil.
- Methylmercury builds up in the tissues of fish. Larger and older fish tend to have the highest levels.

SRS routinely monitors chemical contaminants in surface water (on-site streams and the Savannah River), drinking water, sediment, and groundwater. Water quality monitoring data indicate that the amounts of chemicals (including most metals, pesticides, polychlorinated biphenyls (PCBs), nitrates, and solvents) introduced in the Savannah River from SRS streams have been either non-detectable or below levels of concern (CDC 2001). The absence of elevated levels of most chemicals in surface water samples collected by SRS is reassuring in that surface water contaminants alone are unlikely to result in harmful levels of contamination in aquatic biota. However, many aquatic plants and animals obtain nutrients from sediments that may contain higher levels of contamination, especially in close proximity to point sources on site. Additionally, terrestrial biota may also accumulate chemical contaminants from soil and sediments near seepage basins or other point sources on site.

ATSDR has reviewed and evaluated data from SRS, SCDHEC, and GDNR, as well as conducted searches in the scientific literature to identify investigations of chemical contaminants in biota at or near SRS conducted since 1993. The findings for those chemical contaminants measured in biota that have no detectable concentrations will not be discussed in this report. If a contaminant was detected less than ten percent of the time in a given biota type, it was not used to calculate dose. Otherwise, all detectable chemical contaminants were initially considered as potential contaminants of concern. Table 25 summarizes the chemical contaminants detected in edible portions of specified biota. A discussion of the reviewed data is presented in the sections that follow.

Table 25. Chemical Contaminants Analyzed in Biota at or Near SRS From 1993 Through 2008							
Contaminant	***Biota Type***						
	Fish	***Shellfish***	***Game Animals***	***Farm/ Domestic Animals***	***Milk***	***Agricultural Crops***	***Other Vegetation (not crops)***
Metals							
Antimony	X						
Arsenic	X		X				
Cadmium			X				
Chromium	X		X				
Copper	X						
Lead	X		X				
Manganese			X				
Mercury	X	X	X				X[1]
Selenium			X				
Strontium	X		X				
Thalium	X						
Persistent Organic Pollutants							
Dieldrin	X						
HCB	X						
PCBs	X						
PCDDs			X				
PCDFs			X				

Sources: DOE, GDNR, and SCDHEC, and published articles from scientific literature

[1] Sampling of vegetation for non-radioactive contaminant at SRS was very limited and because of a lack of specificity about what type of vegetation was sampled the data are not presented in this report.
HCB = hexachlorobenzene; PCDDs = polychlorinated dibenzo-dioxins; PCDFs = polychlorinated dibenzo-furans

Fish Monitoring

Metals: In July 1971, SRS began monitoring fish collected from on-site ponds and streams and the Savannah River for mercury. This program has consistently monitored both on- and off-site locations, and large numbers of fish and numerous species have been analyzed for mercury content (CDC 2001). ATSDR reviewed fish tissue data beginning in 1993 through 2008.

Table 26 presents the maximum mercury concentrations detected in fish by location and species. As reported in the sampling time frame column, some species were not sampled every year or might have only been collected during a single sampling event. Bass consistently contain the highest mercury concentration of all species sampled between 1993 and 2008. Mercury levels in bowfin are also consistently elevated, but were only sampled by SRS during 1998. Mercury was detected in bass in nearly 100 percent of the samples collected, whereas mercury was only detected in panfish about 40 percent of the time.

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Table 26. Mercury Detected in Fish Samples (Edible Portions) by Species and Specified Locations (1993–2008)—DOE

Location Along the Savannah River	*Fish Species*	*Sampling Timeframe*	*Maximum Concentration (ppm)*	*Maximum Concentration (Year)*
Augusta Lock and Dam	Bass	1993–2008	1.03	1996
	Bream	1993–2008	0.39	2008
	Catfish	1995–2008	0.57	1996
	Panfish	1995–1997	0.93	1996
Mouth of Beaver Dam Creek	Bass	1993–2008	1.30	1998
	Bream	1993–2008	0.69	1994
	Catfish	1993–2008	0.90	1993
	Panfish	1996–1997	0.57	1996
Mouth of Four Mile Creek	Bass	1993–2008	1.20	1993
	Bowfin	1998	1.03	1998
	Bream	1993–2008	0.87	1998
	Catfish	1993–2008	1.47	1999
	Panfish	1996–1997	0.53	1996
	Shad	1999	0.8	1999
	Suckerfish	1998	0.5	1998
Highway 17A Bridge	Bass	1993–2008	2.32	2004
	Bream	1993–2008	1.33	2004
	Catfish	1993–2008	1.15	2004
	Mullet	1997–2008	0.74	2004
	Panfish	1996	0.47	1996
	Red Drum	2006–2007	0.30	2007
	Trout	2006	0.92	2006
Highway 301 Bridge	Bass	1995–2008	1.21	2008
	Bowfin	1998	1.27	1998
	Bream	1995–2008	0.85	2008
	Catfish	1995–2008	1.71	2004
	Panfish	1996–1997	0.37	1996
	Sucker	1998	0.47	1998
Mouth of Lower Three-Runs Creek	Bass	1993–2008	1.24	2004
	Bream	1993–2008	0.92	2004
	Catfish	1993–2008	1.02	2004
	Crappie	1994–1995	0.17	1994
	Panfish	1995–1997	1.24	1997
Mouth of Steel Creek	Bass	1993–2008	1.75	2004
	Bowfin	1998	1.27	1998
	Bream	1993–2008	0.54	2004
	Catfish	1993–2008	0.80	2005
	Crappie	1993–1995	1.27	1993
	Panfish	1996–1997	0.47	1996
	Shad	1999	0.27	1999
	Sucker	1998	0.53	1998
Stokes Bluff Landing	Bass	1993–2008	2.09	2004
	Bream	1993–2008	2.49	2004
	Catfish	1993–2008	1.10	2004
	Panfish	1996–997	0.73	1996
Mouth of Upper Three-Runs Creek	Bass	1993–2008	1.02	2004
	Bream	1993–2008	0.34	2008
	Catfish	1993–2008	0.42	2008

Table 26. Mercury Detected in Fish Samples (Edible Portions) by Species and Specified Locations (1993–2008)—DOE

Location Along the Savannah River	*Fish Species*	*Sampling Timeframe*	*Maximum Concentration (ppm)*	*Maximum Concentration (Year)*
	Crappie Panfish	1995 1995–1997	0.87 0.68	1995 1997

Source: USDOE annual environmental reports (1993—2008) (WSRC ND[b through p]; SRNS ND)

ppm = parts per million; small differences in the values may occur due to rounding

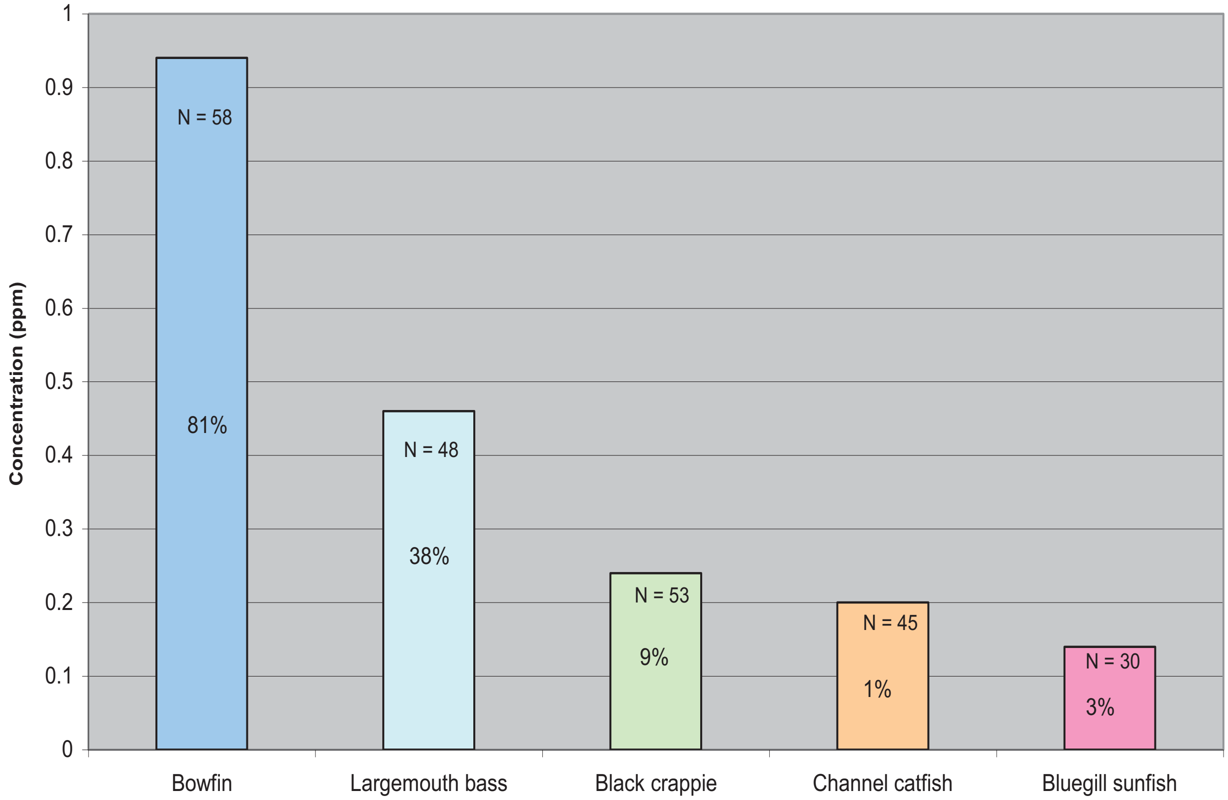
A separate non-SRS fish sampling effort conducted in 1997 along the Savannah River, between Augusta Lock & Dam and the Highway 301 Bridge, reported the highest average mercury concentrations in the edible portion of bowfin (mean = 0.94 parts per million [ppm]), with the mean mercury concentration in largemouth bass (*Micropterus salmoides*) (mean = 0.46) only about one-half that of the bowfin samples.

Figure 13 presents the average mercury concentrations and percent of samples that exceeded 0.5 ppm of mercury for five commonly consumed fish species collected from the Savannah River for the same study. This study suggests notable differences in how mercury is accumulated by these edible fish species. For example, 81 percent of all bowfin samples and almost 40 percent of all largemouth bass samples collected contained more than 0.5 ppm[3] of mercury; whereas only 1 percent of channel catfish contained more than 0.5 ppm of mercury (Burger et al. 2001).

The results of fish monitoring along the Savannah River conducted by SCHEC (1993-2008) and GDNR (1993-2007) are presented in Table 27 and Table 28. South Carolina has only monitored for mercury levels in fish from the Savannah River. However, GDNR has also analyzed for other contaminants (metals, common pesticides, PCBs, and other organic/chlorinated compounds) that are known to accumulate in biological tissues.

[3] Burger et al. (2001) present the percentages of each fish species that exceeded 0.5 ppm and 1.0 ppm mercury. ATSDR has not developed a comparison (i.e., screening) value for mercury in fish tissue. According to Burger et al. (2001), most public health agencies are in agreement that people should avoid consuming fish containing mercury exceeding 0.5 ppm. It is important to emphasize that ATSDR does not consider 0.5 ppm to be a benchmark value for developing adverse health effects. The percentage of samples reported above 0.5 ppm is presented to provide the reader with additional perspective about the data.

Figure 13. Average Reported Mercury[1] Concentration and Percentage of Samples With Mercury Levels Greater Than 0.5 ppm[2] in Edible Portions of Selected Fish Species From the Savannah River



Source: Burger et al. 2001

[1] Mercury concentrations are reported in parts per million (ppm) on a wet weight basis.
Note: Fish samples were collected between April 3 and November 22, 1997.
[2] ATSDR does not consider 0.5 ppm to be a benchmark value for developing adverse health effects. The percentage of samples reported above 0.5 ppm is presented to provide the reader with additional perspective about the data (refer to footnote 3 on page 76 for additional information regarding the public health significance of this value).

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Table 27. Mercury Detected in Fish Tissue Along Savannah River (1993–20087)—South

Contaminant	*Species (Max)*	*Maximum Concentration (ppm)*	*Max. Conc. (Year)*	*Location (Max)/Source*
Mercury	Bass (largemouth)	2.6	2000	SV-687 (Savannah River at Stokes Bluff)
	Black crappie	1.3	2005	SV-805 (Savannah River at Millstone)
	Bluegill	1.6	2005	SV-805 (Savannah River at Millstone)
	Bowfin	3.2	2001	SV-687 (Savannah River at Stokes Bluff)
	Catfish (blue)	1.1	2001	SV-687 (Savannah River at Stokes Bluff)
	Catfish (channel)	1.3	1995	SV-687 (Savannah River at Stokes Bluff)
	Perch (yellow)	0.52	2007	SV-687 (Savannah River at Stokes Bluff)
	Pickeral (chain)	1.2	2006	SV-687 (Savannah River at Stokes Bluff)
	Redbreast	2.4	1999	SV-209
	Sunfish (redear)	1.5	2006	SV-687 (Savannah River at Stokes Bluff)
	Warmouth	0.50	2005	SV-805 (Savannah River at Millstone)

Source: SCDHEC 2006, 2010 (Mercury concentrations in fish: 1993–2008)

Table 28. Metals Detected in Fish Tissue Along Savannah River (1993–2007)—Georgia

Contaminant[1]	*Species (Max)*	*Historical Max Conc. (ppm)*	*Max Conc. Year*	*Location (Max)/Source*
Antimony	Mullet (striped)	2.1	2004	SR–Below New Savannah Bluff Lock and Dam
Arsenic	Mullet (striped–roe)	1.4	2004	SR–U.S. Hwy 17 to Chatham County
Mercury	Bass (striped)	2.5	2004	SR–U.S. Hwy 17 to Chatham County
Thallium	Sunfish (redbreast)	1.1	2004	SR–US Hwy 119 to Effingham County

Source: GDNR 2006 (State of GA Environmental Protection Division fish tissue contaminant database – 1993-2005)

SR = Savannah River
[1] Only contaminants that exceed EPA's risk-based concentrations (RBCs) for fish tissue are reported.

Notes:
RBC for antimony (0.54 ppm), arsenic (0.0021 ppm), methylmercury (0.14 ppm), and thallium (0.095 ppm).
Small differences in the values may occur due to rounding.

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The South Carolina and Georgia fish mercury data are consistent with mercury concentrations reported in different species of fish by SRS and those reported by Burger et al. The highest mercury concentrations were detected in bowfin (max = 3.2 ppm) and largemouth bass (max = 2.6 ppm). The fish species that consistently had the lowest mercury concentrations were yellow perch (max = 0.52 ppm) and warmouth (max = 0.5 ppm). The locations of the maximum concentrations varied somewhat, but higher concentrations were frequently detected in fish collected from the Stokes Bluff and Millstone portions of the Savannah River. It is important to note, however, that not all species were collected along every sampling station along the river. Therefore, it is not always possible to make reliable inferences about mercury concentrations by sampling location across all species (GDNR 2006; SCDHEC 2006).

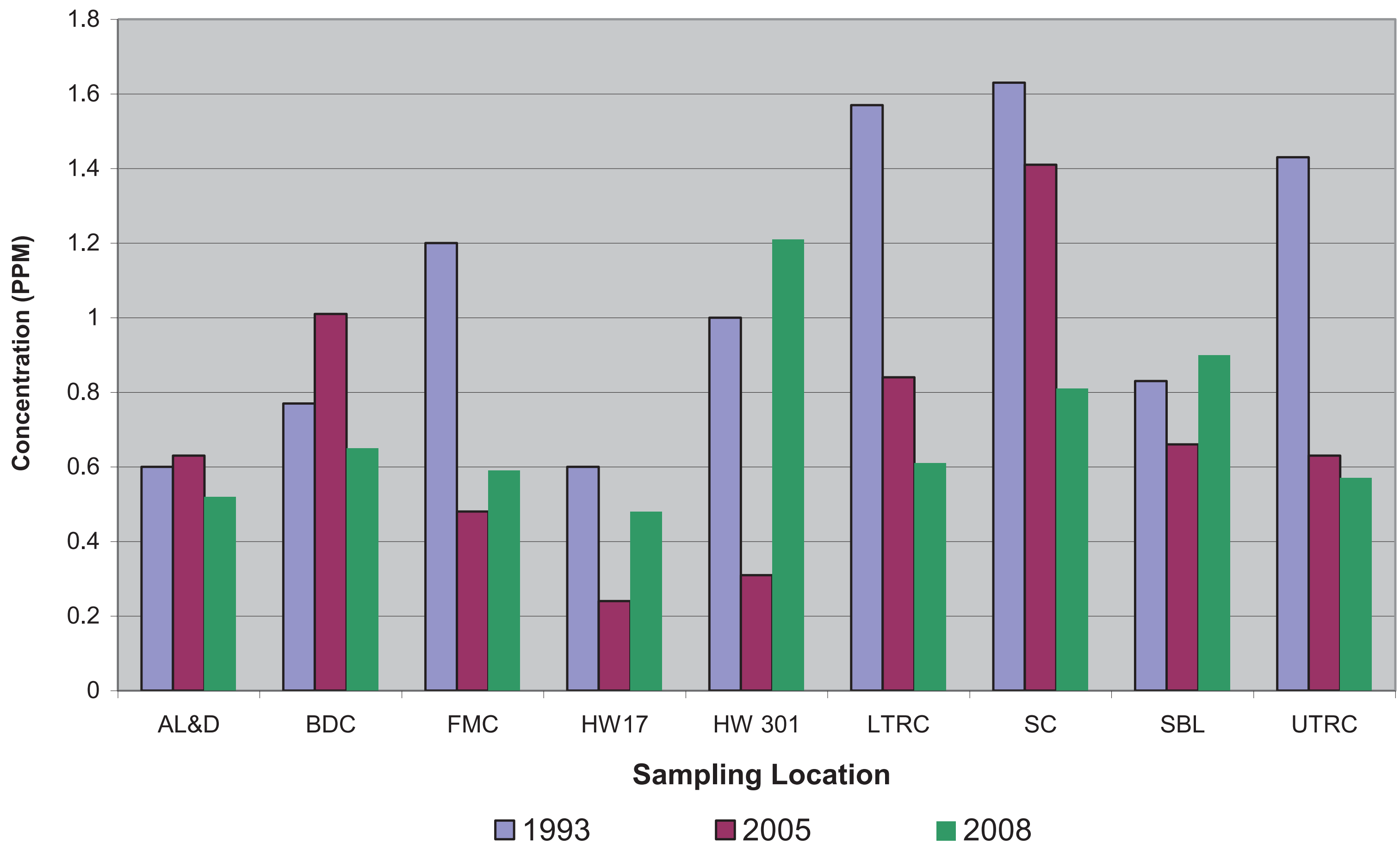
An examination of the SRS fish sampling data over time indicates that mercury levels in fish from some SRS streams and portions of the Savannah River are increasing. For example, a comparison of maximum mercury concentrations detected in samples of bass collected in 2005 versus samples collected in 1993 at specified on- and off-site locations shows a notable increase in the maximum mercury concentrations across most of the sampling locations. Figure 14 presents the maximum mercury concentrations in bass samples during 1993, 2005, and 2008 (the most current reporting period). The magnitude of difference in maximum mercury concentrations between 1993 and 2008 was highest at Lower Three Runs creek and Upper Three Runs Creek; where there was nearly a 2.5-fold difference in the mercury levels (DOE).

Although mercury levels in fish tissue from a few sampling locations (i.e., Highway 301 and Stokes Bluff Landing) appear to have increased since 1993, the sources, and especially the contribution from each source, are not well characterized. Figure 15 displays mercury levels in three common edible fish species from samples collected above SRS, along SRS, and below SRS. For largemouth bass, a clear increase in mercury concentration is evident the further downstream samples are collected. Although sunfish samples were not available for areas below SRS, a similar pattern is observed for portions of the river above and along SRS. This would suggest that the largest contribution of mercury in fish is coming from areas in close proximity to SRS. However, the same pattern is not evident in the bowfin samples collected along similar portions of the river. The data suggest that upstream mercury sources may contribute to mercury levels in bowfin and perhaps other fish species as well.

In addition to mercury, three other metals (antimony, arsenic, and thallium) were detected above EPA's risk-based concentrations (RBCs) in fish tissue samples collected by GDNR between 1993 and 2005 (See Table 28). The RBCs are often used as an initial tool for screening chemical contaminants in certain environmental media. Arsenic was detected most frequently (26 percent), followed by antimony (6 percent) and thallium (4 percent) in fish tissue samples[4] (GDNR 2006). Figure 16 shows the arsenic levels detected in three fish species and American eel from three different locations along the Savannah River. The highest arsenic levels are clearly found in the bowfin and the levels appear to be highest upstream and downstream from SRS (Burger et al. 2002a).

[4] The analyte-specific practical quantitation limits (pqls) for arsenic used by the state of Georgia were adequate. However, the PQLs for the other two metals, antimony (pql range: 1–5 ppm) and thallium (pql range: 1–5 ppm), were above their corresponding Region III RBCs.

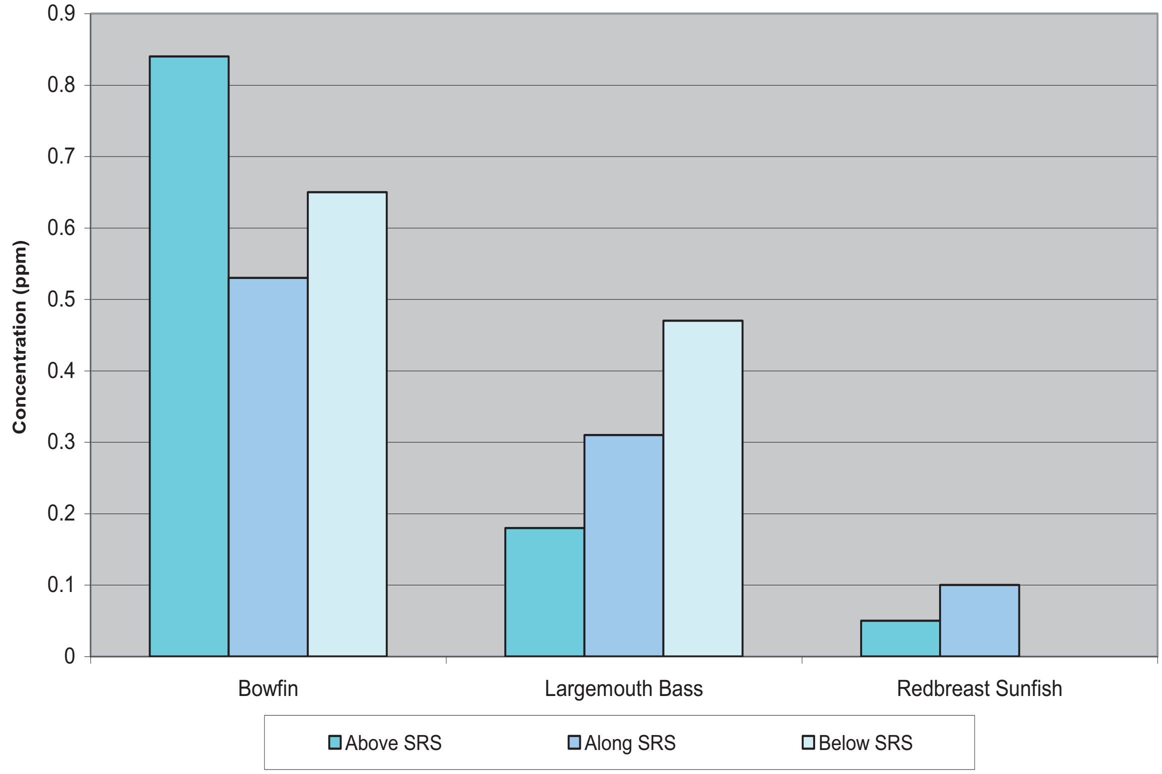
Figure 14. Maximum Mercury Concentrations in Bass From Selected Locations (1993, 2005, and 2008)



Source: DOE monitoring data 1993–2008

Sampling Location Key: AL&D = Augusta Lock and Dam; BDC = Mouth of Beaver Dam Creek; FMC = Mouth of Four Mile Creek; HW 17A - Highway 17A; HW 301 = Highway 301; LTRC = Mouth of Lower Three-Runs Creek; SC = Mouth of Steel Creek; SBL = Stokes Bluff Landing; UTRC = mouth of Upper Three-Runs Creek; ppm = parts per million
Note: Samples collected were reported as wet weight.

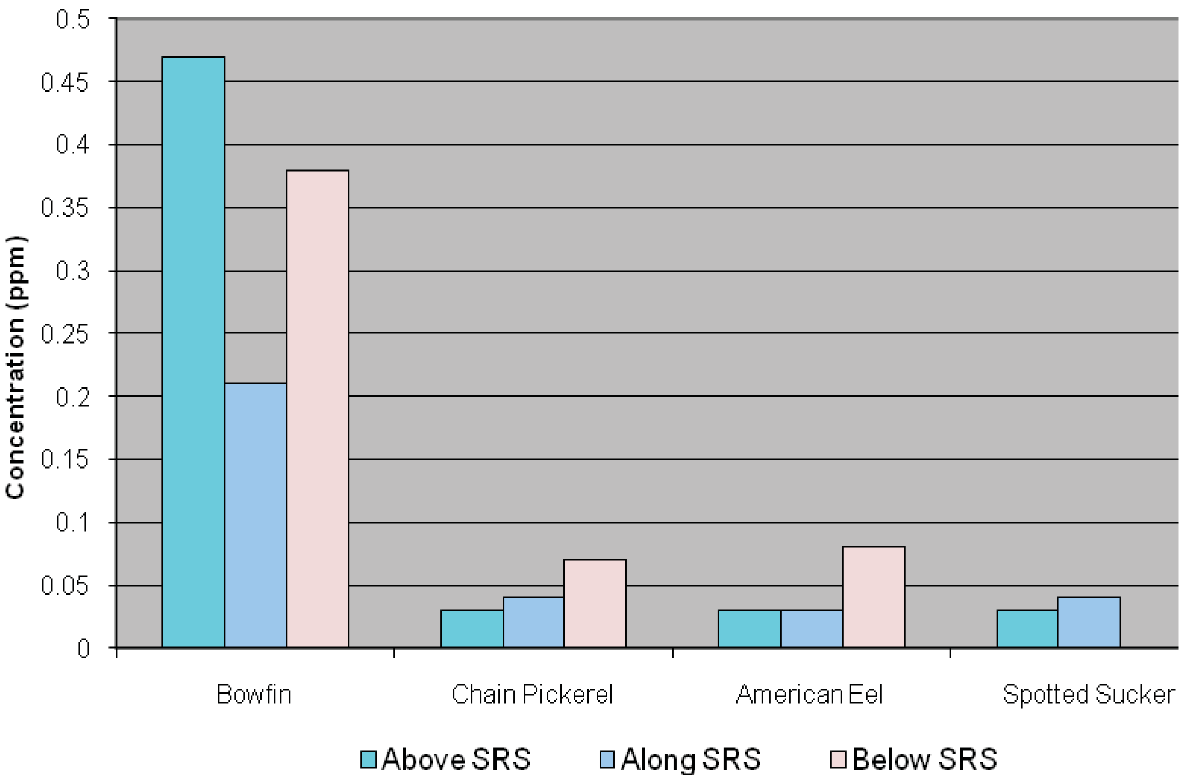
Figure 15. Mercury Levels in Common Edible Fish Species From Above, Along, and Below SRS



Source: Burger et al., 2002a

Mercury concentrations are arithmetic means reported in parts per million (ppm) on a wet weight basis. Sunfish samples were not collected downstream (i.e., below) of SRS.
Note: Fish samples were collected in 1997.

Figure 16. Arsenic Levels in Selected Fish Species and Eel From Above, Along, and Below SRS



Source: Burger et al. 2002a

Arsenic concentrations are arithmetic means reported in parts per million (ppm) on a wet weight basis. Fish samples were collected in 1997.

ATSDR identified a recent investigation that analyzed metals in 11 fish species from the Savannah River (Burger et al. 2002a). The results showed that metal levels were quite variable among different species, with the highest levels of mercury, arsenic, chromium, and copper typically found in the species highest on the food chain (i.e., higher trophic level). Specifically, bowfin had some of the highest levels of arsenic, chromium, copper, and mercury of all the species sampled. However, it had nearly the lowest level of strontium. The findings also showed that the sampling location with respect to SRS was not very important for many of the species along the Savannah River. For example, concentrations of arsenic, lead, manganese, and mercury, were highest in bowfin collected above SRS than either along or below SRS. Cadmium concentrations in channel catfish were also generally higher above SRS than along or below SRS. However, higher levels of mercury were found in largemouth bass collected along and below SRS compared with those collected above SRS. The authors concluded that the levels of most metals in fish from the Savannah River were similar to, or lower than, those found across the United States.

Other Contaminants: SRS and SCDHEC have primarily monitored mercury in fish samples collected from SRS streams and the Savannah River. Beginning in 2007, SRS began analyzing other metal compounds besides mercury in fish samples. GDNR includes other non-radioactive contaminants besides metals in their monitoring program. Table 28, discussed previously, presented the GDNR data for metals. ATSDR reviewed all contaminant data from samples collected between 1993 and 2005. During this time period, three non-metal contaminants, dieldrin, hexachlorobenzene (HCB), and PCBs, were detected above EPA's Region III RBCs in fish tissue (Table 29). None of the three contaminants were detected more than one time between 1993 and 2005. The analytical detection limits were not available.

Table 29. Non-Metal Contaminants Detected in Fish Tissue Along Savannah River (1993–2005)

Contaminant[1]	*Species (Max)*	*Historical Max. Conc. (ppm)*	*Max. Conc. Year*	*Location (Max.)/Source*
Dieldrin	Bass (striped)	0.01	2004	SR–U.S. Hwy 17 to Chatham County
HCB	Bass (striped)	0.09	2004	SR–US Hwy 17 to Chatham County
PCBs (Total)	Bass (striped)	0.21	2005	SR–below New Savannah Bluff Lock and Dam

Source: Georgia Department of Natural Resources (GDNR) Fish Tissue Contaminant Database (1993-2005).

1 Only contaminants that exceed EPA's risk-based concentrations (RBCs) for fish tissue are reported
HCB = hexachlorobenzene; SR = Savannah River; ppm = parts per million
RBC for dieldrin = 0.0004 ppm; FDA action level for aldrin and dieldrin for edible fish tissue = 0.3 ppm
RBC for HCB = 0.002; RBC for PCBs (total) = 0.0016
Note: 47 samples were analyzed for dieldrin and HCB; 45 samples were analyzed for PCBs from 1993 to 2005.

Common Game Species and Other Wildlife Monitoring

Numerous studies have been conducted at or near SRS. These investigations have typically been conducted to monitor mercury levels in various tissues of animals. However, metals and some organics have also been measured in the tissues of common wildlife species in the areas surrounding SRS or on SRS property. Although the report focuses on off-site contaminants in biota, a review of on-site investigations when available is provided for additional perspective and for purposes of comparison.

Mercury: Table 30 presents mercury concentrations measured in tissues of different wildlife species collected on SRS property or off-site locations usually in close proximity to SRS. Both terrestrial and aquatic wildlife species have been monitored for mercury contamination and a summary of the findings are presented below. Comparisons of wildlife species cannot always be made because some of the studies did not collect both on- and off-site samples. All results were reported on a wet weight basis unless otherwise noted.[5]

[5] The results of mercury and other metals in tissues can be expressed on a dry or wet weight basis. Accurate comparisons between wet and dry weights are possible if the moisture or water content of the sample is measured. A very rough estimate can be made by assuming that dry weight results are about three times the wet weight value. However, this is not uniformly true across different tissues and different species and any data based on this standard conversion should be used with caution.

On Site: In 1998, a bald eagle nestling was collected on site and parts of the carcass were analyzed for mercury content. The nestling contained the highest concentrations of mercury of any of the wildlife species sampled on SRS property. The highest mercury levels were measured in feathers (mean = 45.9 ppm [dry weight basis]), followed by liver (mean = 36.6 ppm), down (mean = 36.2 ppm [dry weight basis]), and muscle tissue (mean = 9.4 ppm) (Jagoe et al. 2002). It is important to note that although the mercury concentrations detected in this bald eagle nestling collected on site were elevated, only one bird was sampled. It is not possible to make any general conclusions about mercury levels in bald eagle nestlings found on SRS property based on this one observation. Mercury in the tissues of alligators was measured at two on-site locations (Par Pond and L-Lake) at SRS. The highest mercury concentrations were found in the liver (mean = 17.7 ppm), tail scute (mean = 5.1 ppm), and muscle (mean = 4.8 ppm) (Yanochko et al. 1997; Jagoe et al. 1998). Raccoons also contained relatively high levels of mercury in the liver (max = 6.1 ppm) and kidney (max = 3.95 ppm) (Burger et al. 2002b; Gaines et al. 2002; Lord et al. 2002). Mercury was also detected in the muscle tissue of cottonmouth snakes (mean = 0.9 ppm) collected from Steeds Pond and Tims Branch on SRS property (Burger et al. 2006). Mercury was not detected in hair samples collected from deer or in the feathers, muscle, or liver of mourning doves (Burger et al. 1997b; Carl 2006).

Off Site: The levels of mercury measured in different tissues of wildlife species collected off SRS property were, in general, considerably lower than those measured in wildlife species collected on SRS property. For example, bald eagle nestlings collected off site contained the highest levels of mercury of any of the wildlife species sampled. However, mercury levels were about one order of magnitude (i.e., 10 times) lower in the feathers (max = 6.7 ppm) and down (max = 5.1 ppm) compared to the levels found in the bald eagle nestling collected on SRS property. The maximum blood mercury level in the eagle nestlings was reported to be 0.25 ppm—this was the only wildlife species where mercury was measured in blood (Jagoe et al. 2002). The next highest mercury concentration detected in offsite wildlife species was in the muscle tissue of raccoons (max = 0.14 ppm). The highest mercury concentration detected in the liver was just under 3 ppm from a raccoon (Lord et al. 2002).

Table 30. Mercury Concentrations Detected in Different Wildlife Species

Species	*Tissue*	*Range (ppm)*	*Average (ppm)*	*Location*	*Source*
Alligators[1]	Liver Muscle Tail Scute	NS	17.73 4.08 4.58	SRS (Par Pond)	Yanochko et al. 1997
	Muscle Liver Kidney Tail Scute Claw	NS	4.83 14.9 ND 5.14 ND	SRS (Par Pond and L-Lake	Jagoe et al. 1998
Bass (largemouth) (Micropterus salmoides)	Tissue	0.19–1.40 0.04–0.57 0.03–0.81 0.12–0.54 0.56–2.01	0.69 0.28 0.30 0.25 1.13	L-Lake (SRS) Lake Marion (SC Reservoir) Lake Russell (SC Reservoir) Lake Thurmond Par Pond (SRS)	Peles et al. 2006
Asiatic Clams (*Corbicula fluminea*)					
	Tissue (wet weight)	NS	0.044[2]	Discharge Plumes of S.R. Tributaries.	Paller et al. 2003
		NS	0.017[2]	S.R. Upstream from tributary mouths	
Deer					
	Hair	NS	ND	SRS	Carl 2006
	Hair	NS	ND	Upstream (off site)	
Wood Duck Eggs (wet weight)					
	Albumin Yolk Shell	NS NS NS	0.22 (0.2[2]) 0.04 (0.03[2]) 0.03 (0.03[2])	SRS (Pond B) (1991–1992) N = 132 samples	Kennamer et al. 2005
Bald Eagle	Feathers[1] Down[1] Blood	0.61–6.67 0.50–5.05 0.02–0.25	2.49 (1998) 3.67 (1999) 2.50 (1998) 2.43 (1999) 0.12 (1998) 0.09 (1999)	South Carolina (1998–1999) N = 34 Samples were collected from live nestlings.	Jagoe et al. 2002
	Feathers[1] Down[1] Muscle Liver	NA NA NA NA	45.9 36.2 9.4 36.6	SRS (adult eagle found dead on site) December 1998 N = 1	Jagoe et al. 2002
Mourning Doves					
	Feathers Muscle Liver	ND ND ND	ND ND ND	SRS	Burger et al. 1997b
Possums					
	Hair	NS	1.19	SRS	Carl 2006
	Hair	NS	1.44	Upstream (off site)	
Raccoons (wet weight)					
	Kidney Liver Muscle Hair[1]	0.28–3.95 0.13–6.11 0.02–1.10 0.39–12.05	1.64[2, 3] 1.35[2, 3] 0.33[2, 3] 1.65[2, 3]	SRS-On Site Four locations (Steel creek delta, Upper Three Runs Creek, Pond B, and Ash basins	Lord et al. 2002

Table 30. Mercury Concentrations Detected in Different Wildlife Species

Species	*Tissue*	*Range (ppm)*	*Average (ppm)*	*Location*	*Source*
	Kidney Liver Muscle	0.08–0.99 0.19–2.99 0.06–0.14	0.40[2] 0.55[2] 0.02[2]	SC (Savanna River) Off Site (n = 25)	
	Liver Kidney	NS NS NS NS	1.45 (on site) 0.67 (off site) 1.18 (on site) 0.46 (off site)	SC (SRS-area) On site and off site near SRS (n = 46 on-site) and (n = 25 off site)	Burger et al. 2002b
	Muscle	ND–0.36 0.02–0.60 0.16–1.10 0.10–1.07 ND–0.14	0.13 (n = 12) 0.28 (n = 9) 0.47 (n = 10) 0.44 (n = 12) 0.05 (n = 25)	SRS (Ash basins[4]) Pond B Steel Creek Upper 3-Runs Creek Off Site	Gaines et al. 2002
Snakes[1]					
Banded Brown Cottonmouth	Muscle Muscle Muscle	NS NS NS	0.6 0.7 0.9	SRS Steed's Pond/ Tim's Branch	Burger et al. 2006

[1] Concentrations are expressed as dry weight

[2] Value is reported as a geometric mean

[3] The average represents the highest average concentration reported at any of the four on-site sampling locations

[4] Ash basins were created by discharges from the coal-fired power plant

NA = Not applicable; ND = Not detected; NS = Not specified; ppm = parts per million

Notes: Concentrations reported in this table may differ slightly with the original citation because of rounding to nearest significant figure. Data are presented from different studies and may use different sampling methodologies, quality assurance and quality control procedures, and laboratory analyses.

1992

Other Metals: In addition to mercury, levels of other common metals were measured in wildlife tissues and reported for locations on SRS property and some nearby offsite locations. A study by Burger et al. measured eight metal compounds (arsenic, cadmium, chromium, lead, manganese, selenium, and strontium) in various tissues (i.e., heart, kidney, muscle, spleen, and liver) of raccoons collected at four areas on SRS property and from public hunting areas within approximately 9 miles (15 kilometers of SRS). Other than mercury (see previous discussion) and manganese in liver (4.57 versus 0.05 ppm, on- and off -site, respectively), there were no consistent notable differences between on-site and off-site metal concentrations across the different tissues of raccoons. However, for specific metals, some small differences were apparent in certain tissues. For example, average lead levels in raccoon kidney and liver collected off site were slightly higher than levels from the four on-site sampling locations. In contrast, selenium levels were generally higher in most raccoon tissue samples from on-site locations (Burger et al. 2002b).

Levels of metals were also measured in mourning doves on SRS property and in off-site locations, approximately 6 miles west (Jackson) and 16 miles southeast (Barnwell) of Par Pond. Levels of metals were not consistently higher in on-site locations and varied considerably between on and off site depending on the metal and tissue sampled (Burger et al. 1997b). In mourning doves, the highest levels of metals were generally found in the feathers (means: lead = 2.0, cadmium = 0.12, selenium = 0.59, manganese = 5.2, and chromium = 0.63 ppm) and liver (means: lead = 0.81, cadmium = 0.28, selenium = 0.46, manganese = 4.9, and chromium = 0.19 ppm), whereas the lowest levels were measured in the muscle tissue (means: lead = 0.14, cadmium = 0.01, selenium = 0.23, manganese = 0.55, and chromium = 0.07 ppm).[6]

Non-Metal Compounds: ATSDR identified one investigation that measured non-metal contaminants in the tissues of wildlife on SRS property. Blood of adult and juvenile black and turkey vultures was analyzed for the presence of polychlorinated dibenzo-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), and dioxin-like PCBs.Toxic equivalency (TEQs)[7]concentrations ranged from 1.8 to 8.4 picograms (pg) TEQ/milliliter (ml) in black vultures and 3.2–20 pg TEQ/ml in turkey vultures (Table 31). The authors reported concentrations of TEQs contributed by 2,3,7,8-PCDD/DFs and dioxin-like PCBs in blood collected from vultures were lower than threshold values reported for human toxic effects in the scientific literature (Senthil Kumar et al. 2003).

[6] The values presented are the means reported at either Jackson or Barnwell off-site locations, whichever was higher.

[7] Dioxins and dioxin-like compounds, including certain PCBs and furans, are evaluated based on total toxicity equivalency factors (TEFs) as related to the most toxic dioxin, 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD). The resulting TEQ is used to evaluate concentrations and exposures. There are two main sets of TEFs, the International TEFs (I-TEFs), which is used by EPA, and the World Health Organizations TEFs (WHO-TEFs). Both of these methods are protective. One of the primary differences between the two methods is that the WHO method uses TEFs for dioxin-like PCB congeners. The TEFs are based on known toxicological information for each compound. A total equivalency (TEQ) is calculated by multiplying the chemical concentration by the TEF, and then summing all the values.

Table 31. Concentrations of Dioxins/PCB Contaminants Detected in Vultures

Species	*Tissue*	*Contaminant*	*Concentration PPT Wet wt (Fat Weight Basis[1])*	*Location*	*Source*
Black Vultures	Blood	TEQ[2]	1.8–8.4 (46–360)	SRS (near center) All samples collected during 2000–2001	Senthil Kumar et al. 2003
		2,3,7,8-PCDDs	11–31 (400–770)		
		2,3,7,8-PCDFs	1.6–6.7 (42–170)		
		Dioxin-like PCBs[2]	815–4,627 (28,500–150,900)		
		di-ortho PCBs	1,415–10,325 (45,000–370,000)		
Turkey Vultures		TEQ[2]	3.2–20 (140–650)		
		2,3,7,8-PCDDs	6.1–31 (380–1,000)		
		2,3,7,8-PCDFs	2.6–8.3 (160–350)		
		Dioxin-like PCBs[3]	753–3,611 (41,730–150,500)		
		di-ortho PCBs	663–7,500 (41,000–270,000)		

[1] PCBs and dioxins are typically found in the highest concentrations in fat tissue; therefore, these contaminants are often measured as the amount of chemical per specified quantity of fat tissue (e.g. picograms PCB per gram of fat).

[2]Toxic equivalents (TEQ) concentrations are based on 17 2,3,7,8-substituted PCDD/DF congeners and 12 dioxin-like PCBs. Two di-ortho PCBs were not included because World Health Organization (WHO) toxicity equivalent factors (TEFs) were not available for these two congeners.

[3] Dioxin-like PCBs include the sum of non-ortho and mono-ortho PCBs.

Note: TEQ concentrations are well below toxic threshold values reported for chickens, pheasants, or Caspian tern eggs

PPT = parts per trillion; 1 pg/ml = 1 part per trillion (ppt)

Vegetation Monitoring

SRS has generally not analyzed for non-radioactive contaminants in vegetation on or near the site. In 1999, SRS began the sediment surveillance program, which helps determine the deposition, movement, and accumulation of non-radioactive contaminants in nearby stream systems (WSRC ND[p]). Although sediment data are not an ideal proxy for predicting the levels of chemical contaminants that may accumulate in vegetation, the findings can be used to assess the potential for elevated levels of non-radioactive contamination to accumulate in aquatic, and to a lesser extent terrestrial, vegetation. Sediment samples are collected annually from 10 designated surface water locations near SRS. The samples were analyzed for metals and selected pesticides. The metal concentrations were generally very low. Mercury was not detected in any samples collected during 2006 or 2007. Pesticides were not detected in any sediment samples collected between 1999 and 2007 (WSRC ND[p]).

Exposure Pathways and Potentially Exposed Populations

For this PHA, ATSDR evaluated biota exposure pathways surrounding SRS between 1993 and 2008; however, past findings from the SRS Dose Reconstruction Project will also be mentioned. As previously noted, an exposure pathway is only considered complete when all of the following five elements are present: 1) a source of contamination, 2) an environmental medium through which the contaminant is transported, 3) a point of human exposure, 4) a route of human exposure, and 5) an exposed population. A potential exposure pathway exists when one or more of the elements are missing, but available information indicates that human exposure is possible. An incomplete exposure pathway exists when one or more of the elements are missing and available information indicates that human exposure is unlikely.

Child Health Considerations

ATSDR recognizes that the fetus, breast-feeding infants and children may be more sensitive to exposures than adults in communities with contamination in water, soil, air, or food. This sensitivity is the result of a number of factors. Children are more likely to be exposed because they play outdoors and they often bring food into contaminated areas. Children are also smaller, potentially resulting in higher doses of chemical exposure per unit body weight. The developing body systems of children can sustain permanent damage if toxic exposures occur during critical growth stages.

Children's metabolic pathways, especially in the first months after birth, are less developed than those of adults. In some cases, children are better able than adults to deal with environmental toxins, but in others, they are less able and more vulnerable. Some chemicals that are not toxins for adults are highly toxic to infants. Fetuses, nursing infants, and young children are more sensitive to mercury than adults. Mercury in the mother's body passes to the fetus and may accumulate there. Children grow and develop rapidly in the first months and years of life. Some organ systems, especially the nervous and respiratory systems, can experience permanent damage if exposed to high concentrations of certain contaminants during this period. However, children’s diets and ingestion rates change dramatically as they develop. Many forms of edible biota are not ingested in significant quantities within the first few years of life. For instance, children are not expected to begin eating fish until they are three to five years old (Burger 1999), but infants are assumed to be ingesting milk from birth.

When evaluating exposure and potential health concerns from exposure to radioactive materials, ATSDR uses age-specific biokinetic models as recommended by the International Commission on Radiological Protection (ICRP). These models take the above factors into consideration.

It is important to learn about and follow wildlife and fish advisory guidance from your public health or natural resources department. Following the recommended guidance minimizes exposure to harmful contaminants such as mercury.

Most importantly, children depend completely on adults for risk identification and management decisions, housing decisions, and access to medical care. Therefore, ATSDR is committed to evaluating their special interests at sites such as SRS as part of the ATSDR Child Health Initiative.

Past Exposure (1954–1992)

Radioactive Contaminants

The purpose of the SRS Dose Reconstruction Project was to determine the total cumulative effective radiation dose to the populations surrounding SRS from 1954 through 1992, as well as evaluate possible exposures to any known chemical contaminants. During Phase III of the Dose Reconstruction, investigators estimated the cumulative effective doses and associated cancer risk for seven hypothetical families, each comprised of four individuals (an adult female, an adult male, a male child born in 1955, and a male child born in 1964) who lived near the site and performed differing activities (CDC 2005). Standard bioaccumulation models were used to determine contaminant uptake by edible biota from air and liquid releases. Standard models were also used to determine the hypothetical individuals' internal and external doses and cancer risk estimations.

Some of the major conclusions from the Dose Reconstruction are listed below (CDC 2005):

- For the hypothetical person who ate fish from the Savannah River or Lower Three Runs Creek, fish ingestion was the most significant pathway. The radioactive contaminants contributing the most to the dose were cesium-137, phosphorus-32, and strontium-90.
- For the hypothetical person who did not eat fish from these locations, ingestion of water, milk, and beef (and venison) were the most significant. The radioactive contaminants contributing the most to the dose were iodine-131 and tritium.
- A large fraction of the total dose was received during the years 1955 through 1961.
- Doses caused by ingesting fish from Lower Three Runs Creek were significantly higher than doses caused by ingesting fish from the Savannah River.

Although the doses would be expected to be much higher during the years of peak operation of the facilities, significant legacy waste is still present at the site. As time progresses, the more mobile contaminants are more likely to surface and be incorporated into biota which is potentially ingested by humans. However, radioactive contaminants with shorter half-lives (such as phosphorus-32 with a 14-day half-life and iodine-131 with an 8-day half-life) should not be significant after 1992.

Non-Radioactive Contaminants

Mercury and chromium were the only non-radioactive contaminants evaluated in the Phase II Dose Reconstruction Investigation. Chromium has been ruled out as a contaminant of concern in fish tissue (See Table 34) and will not be discussed further. A brief summary of the Phase II Dose Reconstruction findings for mercury in fish samples collected from the Savannah River are presented below.

According to the findings from the Phase II Dose Reconstruction Report, mercury was discharged to the seepage basins at SRS. It was concluded, however, that the total inventory of mercury in the *F-Area* and *H-Area* seepage basin (about 4,500 pounds) had not migrated significantly out of the basins, and the rate of mercury transport into Four Mile Creek and the Savannah River was relatively small. In June 1973, a monitoring program for mercury in water, sediment, and fish in on-site streams and Par Pond was established to document whether or not SRS operations were contributing significant amounts of mercury to the Savannah River (CDC 2001). A report published by DOE in 1994 concluded that no significant releases of mercury to the Savannah River were likely to have occurred, and any smaller releases would have been well below the SCDHEC standard (CDC 2001; Kvartek et al. 1994).

Additionally, according to the dose reconstruction investigators, “SRS activities did not result in measurable mercury releases to the Savannah River” between 1971 and 1991. The author’s conclusion was largely based on the similarity of mercury measured in fish collected from the Savannah River at locations above, adjacent to, and below the SRS (CDC 2001). Fish were the only biota evaluated for non-radioactive contamination.

The Phase II Dose Reconstruction investigators reviewed three sets of SRS (DOE) annual environmental monitoring reports spanning the years 1971 through 1991 to summarize mercury concentrations in fish collected from locations on or in the vicinity of the SRS. The average mercury concentrations for the Savannah River from 1971 through 1991 were reported for bass (0.54 ppm), bream (0.25 ppm), and catfish (0.30 ppm) (CDC 2001). These earlier data are very comparable to the most recent (2007 and 2008) DOE sampling data analyzed for mercury in bass (0.47 ppm), bream (0.31 ppm), and catfish (0.35 ppm).

Current (1993–present) and Future Exposure

Radioactive Contaminants

ATSDR evaluated potential radiation exposures to the general population in the SRS vicinity from consumption of agricultural and farm products, fish, and on- and off-site wild game. Since 1993, the greatest potential for human exposure to radioactive contaminants in biota has been to the avid sportsman who lives near the site, hunts onsite or offsite, and/or routinely fishes at the mouths of Steel Creek, Lower Three Runs Creek and Four Mile Creek.

In order to evaluate if potential exposures to radioactive contaminants could be of health concern, ATSDR compared a hypothetical exposure dose to a health-based comparison value. A dose above a comparison value does not indicate that an adverse health effect will occur, but no adverse health effect would be expected for a dose below a comparison value. ATSDR's comparison values for ionizing radiation include minimal risk levels (MRLs). These MRLs are based on the potential risk of radiation-induced fatal cancers and serious genetic effects and are consistent with the recommendations of the ICRP and their risk-based system for determining the potential for adverse human health effects over 70 years following exposure. For acute exposure, ATSDR's MRL is 4 millisieverts per year (4 mSv/yr) or 400 millirems per year (400 mrem/yr) above background. For chronic exposure, ATSDR's MRL is 1 mSv/yr (100 mrem/yr) above background from all pathways (ATSDR 1999a). Exposure from ingestion of biota is assumed to be chronic and is only one potential exposure pathway. Others include ingestion of water, inhalation, and external exposure. Since this PHA only involves exposure from the consumption of biota, ATSDR used the default radiation dose limit (30 mrem/yr [0.3 mSv/yr]) used by RESRAD's family of computer codes for this pathway. (RESRAD also is based on a total dose limit to the general public of 100 mrem/yr [1 mSv/yr].)[8]

For an initial screening, ATSDR estimated a hypothetical exposure screening level for an adult and a child (6 to 11 years) using the equation for calculating annual committed effective doses (see text box below). ATSDR either used the maximum concentrations or the average of the maximum concentrations of samples collected from any of the years between 1993 and 2008 within a biota category or type, and applied the specified ingestion rates shown in Table 32. This *hypothetical exposure screening level* is only used for screening purposes and considered to be even more health protective than a maximally exposed individual scenario. (A "maximally exposed individual scenario" is a hypothetical situation, corresponding to a set of "reasonable" assumptions about human needs and activities. People who have unusual habits are not considered. Several ATSDR assumptions would not be considered "reasonable". For example, an individual consuming all their annual meat intake from game hunted on the site with maximum cesium-137 concentrations or that someone fished in one location and consumed fish containing maximum concentrations of radioactive contaminants would not be considered for a "reasonable maximally exposed individual.")

[8] RESRAD is a family of computer codes developed by Argonne National Laboratory to assist in determining clean-up levels and to provide a tool for evaluating human health risk at sites contaminated with radioactive residues. RESRAD is used widely in the United States and abroad and has been approved by the U.S. Nuclear Regulatory Commission and the U.S. Department of Energy. Ref: http://www.ead.anl.gov/resrad/documents/ or document ANL-EAD-4.

Calculating Annual Committed Effective Dose

Equation: $CED = C_B \times I \times CF$

Where;

CED = Annual committed effective dose

C_B= Concentration in biota [picocuries per gram (pCi/gm) or becquerels per kilogram (Bq/kg), except for milk in pCi or Bq per liter (L); 1 Bq = 27 pCi]

I = Ingestion rate (kilograms per year or liters per year)

CF = Dose conversion factor: Converts Bq (or pCi) to Sv (or rem) for various age groups. For whole body committed effective dose, dose conversion factors from International Commission on Radiological Protection (ICRP) Report 72 were used (ICRP 1995).

Table 32. Upper Bound Ingestion Rates for Adults and Children[1]

Product	Adult (18 years and over)	Child (6 through 11 years)
Total vegetables	306 kg/yr	87 kg/yr
Total fruits	304 kg/yr	102 kg/yr
Nuts	0.88 kg/yr	0.95 kg/yr
Grains	0.67 kg/yr	0.28 kg/yr
Milk[2]	440 L/yr	374 L/yr
Beef	78.1 kg/yr	18.6 kg/yr
Pork	47.8 kg/yr	13.5 kg/yr
Chicken	68.26 kg/yr	18.25 kg/yr
Eggs	44.9 kg/yr	14.2 kg/yr
Fish	49 kg/yr[3]	35.4 kg/yr
Onsite deer and feral hogs	78 kg/yr	18.6 kg/yr
Onsite turkeys[4]	10 kg/yr	6.2 kg/yr
Offsite deer and feral hogs	78 kg/yr	18.6 kg/yr
Offsite birds and ducks	51 kg/yr	13.7 kg/yr

[1] The 99th percentile ingestion rates from EPA's Exposure Factor Handbook (EPA 1997) are presented unless otherwise noted.
[2] The 99th percentile milk ingestion rate from EPA's Exposure Factor Handbook (EPA 1997) is presented for adults; the 95th percentile ingestion rates from EPA's Child-Specific Exposure Factors Handbook (EPA 2008) are presented for a teen (374 L/yr), a 6 through 11 tear old child (374 L/yr), and a 1 through 5 year old child (377 L/yr)
[3] Mean of 95th percentile rates for Savannah River fishermen interviewed by Burger et al. 1999.
[4] Ingestion rate is based on number of turkeys allowed to be harvested per year, average weight, and edible portion after cleaned and cooked (refer to page 100).
kg/yr = kilograms per year; L/yr = liters per year

Consumption of Savannah River Fish

Fish samples collected from the Savannah River and its tributaries were the largest source of radiological data available for ATSDR's review. ATSDR employed a health-protective methodology for the initial maximum exposure screening levels for fish. Because of the large amount of data available, this included using the maximum concentration of each radionuclide analyzed in fish fillets at each sampling location for each year from 1993 through 2008 (Appendix C). Additional assumptions regarding fish consumption are presented below:

- For children six to 11 years, ATSDR used the ingestion rate for the 99th percentile from EPA's Exposure Factor Handbook of 97 g/d or 35.4 kg/yr (EPA 1997).
- For adult consumption rates, ATSDR used the mean of the 95th percentile adult ingestion rates (135.2 grams per day [g/d]) reported by Burger et al (1999; 2001), which examined consumption patterns for individuals fishing along the Savannah River. This rate would be equivalent to consuming approximately 49 kg/yr. (108 pounds per year). In the SRS annual environmental reports, the exposure to a hypothetical maximally exposed individual assumes a maximum fish consumption rate of 19 kg/yr (42 pounds/yr) based on a regional survey published in 1991 (Hamby 1991). After reviewing the basis for this regional survey, ATSDR concluded that the Burger study is site-specific and more appropriate for our screening purposes.
- Table 33 shows the estimated upper bound annual exposure screening level for an adult and a child for each location and for the specified time frame. Refer to Appendix D for ATSDR's calculated estimates for each year at each location. The maximum hypothetical adult exposure from consuming fish (10.58 mrem/yr, 0.106 mSv/yr) would be for fish caught at Steel Creek in 1999, and the maximum hypothetical child exposure (10.5 mrem/yr, 0.105 mSv/yr) would be for fish caught at Four Mile Creek in 1994. Both hypothetical estimates by themselves are lower than ATSDR's adjusted comparison value (30 mrem/yr).

Consumption of Wild Games Harvested On and Off Site

Hunting for wild game has included both on and off site hunting for deer, feral hogs, and turkeys. Off-site hunting also includes a variety of other animals. (Refer to Appendix D for details considered by ATSDR for the evaluation of potential radiation exposures to hunters on and off site.)

- For *on-site deer and feral hogs*, DOE surveys all harvested deer and feral hogs in the field for cesium-137. From 1993 (and before) through 2008, DOE has calculated potential exposures for all on-site hunters tracking multiple kills and hunts per year and assuming that one individual eats all edible portions of their kills. This ingestion rate is often larger than the 99th percentile meat ingestion rate for adults reported in EPA's Exposure Factor Handbook (EPA 1997). EPA's 99th percentile ingestion rate for total meat is approximately 78 kg/yr. For children, the 99th percentile ingestion rate for total meat is 18.6 kg/yr.

DOE estimated that the maximum potential hunter's exposure (77 mrem or 0.77 mSv) occurred in 1999, assuming one individual consumed 121 kg (267 lbs) of harvested meat in that year. According to EPA's Exposure Factor Handbook (EPA 1997), this ingestion rate is not considered realistic. ATSDR used the EPA 99^{th} percentile ingestion rates for total meat consumption and estimated that the adult adjusted exposure could be 50 mrem (0.5 mSv) and a child's exposure could be 9 mrem (0.09 mSv) if their total meat consumption consisted of harvested game. The ATSDR adjusted estimate of 50 mrem (0.5 mSv) will be used as the hypothetical maximum exposure screening levels. This scenario will be discussed further in the Health Implications section of this report.

- For *on-site turkeys*, ATSDR applied the maximum cesium-137 concentration reported for monitoring on-site turkeys that were being relocated to other wildlife management areas (10 pCi/g [370 Bq/kg]), and estimated hypothetical maximum exposure levels by assuming five male turkeys (state hunting limit) were captured and consumed per year. The estimated adult ingestion rate for the edible portions is 10 kg/yr (22 lbs/yr) resulting in 4.8 mrem/yr (0.048 mSv/yr), and the estimated child ingestion rate is 6.2 kg/yr (13.6 lbs/yr) resulting in 2.3 mrem/yr (0.023 mSv/yr). Both hypothetical estimates by themselves are less than ATSDR's adjusted comparison value (30 mrem/yr [0.3 mSv/yr]).

- For *off-site deer and feral hogs,* DOE calculates a hypothetical off-site hunter dose by using the average of the concentrations reported for on-site deer and hogs and an adult consumption rate of 81 kg/yr (slightly higher than the EPA 99^{th} percentile of 78 kg/yr).The consumption rate assumes all meat consumption consists of deer and/or feral hog meat. The concentrations used by DOE are similar to the concentrations observed in off-site deer and hog samples collected by SCDHEC-ESOP from 2000 through 2008 when averaged over all SCDHEC-ESOP hunt zones. (Refer to Appendix D for more detail.)

  However, when compared to individual hunt zones, the average concentrations (and thus the estimated exposure dose) were slightly higher in some of the zones. ATSDR used the maximum concentrations reported for cesium-137 in off-site deer and feral hogs (8.86 pCi/g [328 Bq/kg] in deer) sampled in 2002 by SCDHEC-ESOP for the hypothetical maximum screening exposure levels. Assuming their total meat ingestion consisted of deer meat containing the maximum concentrations detected, the adult hypothetical maximum screening exposure level would be 33 mrem/yr (0.33 mSv/yr) and the child hypothetical screening exposure level would be 6.1 mrem/yr (0.06 mSv/yr). This scenario will be discussed further in the Health Implications section of this report.

- For *off-site bird and duck* hunters, ATSDR used the maximum concentration of cesium-137 (0.7 pCi/g [24 Bq/kg]) reported in a duck sample in 1998 and maximum ingestion rates for avid bird hunters (51kg/yr for an adult and 13.7 kg/yr for a child). The hypothetical maximum screening exposure levels are 1.6 mrem/yr (0.016 mSv/yr) for an adult and 0.3 mrem (0.003 mSv/yr) for a child, both well below ATSDR's adjust comparison value (30 mrem/yr [0.3 mSv/yr]).

Consumption of Agricultural and Farm Products

ATSDR assumed that all consumed food was locally grown, raised, or produced. Agricultural products (vegetables, fruits, nuts, and grains) and milk sampling occurred fairly consistently from 1993 through 2008 by DOE, GDNR-EPD, and/or SCDHEC-ESOP.

- Since each year the types of vegetables and fruits sampled and the radionuclides included in the analyses varied, the average value of the maximum concentrations from each type of vegetable or fruit from all sampled years were used to determine a hypothetical maximum exposure screening level for an adult and a child.
- Since nuts were not sampled every year and samples were analyzed for additional radionuclides in 2006 and 2008, the average of the maximum concentrations for peanuts and pecans from all sampled years were used to determine the hypothetical maximum exposure screening level for an adult and a child.
- Since grains were not sampled every year, the maximum concentrations from all sampled years were used to determine the hypothetical maximum exposure screening level for an adult and a child.
- For milk samples, the maximum concentrations from all sampled years were used to determine the hypothetical maximum exposure screening level. These levels, presented in Table 33 were calculated for four age groups consuming milk from South Carolina dairies. The hypothetical maximum screening levels for all four age groups consuming milk from Georgia dairies were less than 0.01 mSv/yr (< 1.0 mrem/yr). (Strontium-90 concentrations detected in milk from dairies in South Carolina resulted in higher exposure screening levels in South Carolina than in Georgia.)

Farm products (beef, domestic pork, chicken, and eggs) were sampled at various times.

- As mentioned previously in this report, beef cattle graze in open fields in areas near SRS. The maximum concentrations from all sampled years were used to determine a hypothetical maximum exposure screening level for an adult and a child.
- Chickens (including egg producers) and domestic pigs are generally housed and fed imported feed so they would be less likely to contain contaminants from the site. The maximum concentrations from all sampled years were used to determine a hypothetical maximum exposure screening level for an adult and a child.

The adult and child hypothetical maximum exposure screening levels from consumption of agricultural and farm products combined (27 mrem/yr and 14.3 mrem/yr, respectively) are less than ATSDR's adjusted comparison value (30 mrem/yr) but will be included in the discussion in the Health Implication section of this report for persons living in the area who may also consume their total meat intake from locally harvested deer and feral hogs.

Calculations for determining the upper bound hypothetical exposure screening levels in Table 33 are described in Appendix D.

Table 33. Upper Bound Hypothetical Exposure Screening Levels for Biota

	Adults (18 yrs and over) mrem/yr (mSv/yr)	Teen (12 thru 17 yrs) mrem/yr (mSv/yr)	Child (6 thru 11 yrs) mrem/yr (mSv/yr)	Young Child (1 thru 5 yrs) mrem/yr (mSv/yr)
Agricultural Crops (years sampled)				
Vegetables (1993 – 2008)	10.5 – 22.5* (0.11 – 0.23)	NC	4.9 - 11.6* (0.05 – 0.12)	NC
Fruits (1993 – 2008)	1.85 (0.02)	NC	0.88 (0.01)	NC
Nuts (1993-1996, 2001,2003,2005,2006,2008)	0.02 (0.00)	NC	0.01 (0.00)	NC
Grains (1993, 1994, 2006-2008)	0.00 (0.00)	NC	0.00 (0.00)	NC
Milk (South Carolina) (1993-2008)	1.81 (0.02)	2.91 (0.03)	3.12 (0.03)	3.92 (0.04)
Farm Products				
Beef (1993, 1994, 1996, 1999-2008)	0.68 (0.01)	NC	0.15 (0.00)	NC
Pork (1993)	0.00 (0.00)	NC	0.00 (0.00)	NC
Chicken (1993, 1994)	0.15 (0.00)	NC	0.03 (0.00)	NC
Eggs(1993, 1994)	0.00 (0.00)	NC	0.00 (0.00)	NC
TOTAL (GENERAL POPULATION)	15 (0.15) – 27 (0.27)	milk only – 2.9 (0.03)	9.15 (0.09) – 15.9 (0.16)	milk only – 3.92 (0.04)
SPORTMAN'S EXPOSURE Game Animals (hunters and their families)** (years sampled)				
On-site deer & feral hogs (1993-2008)	50 (0.50)	NC	9 (0.09)	NC
On-site turkeys (1993-2001,2006-2008)	4.8 (0.05)	NC	2.3 (0.02)	NC
Off-site deer and feral hogs (1993 – 2008)	33 (0.33)	NC	6.1 (0.06)	NC
Off-site birds and ducks (1998-1999)	1.6 (0.02)	NC	0.3 (0.00)	NC
Fish (fisherpersons and their families) – maximum annual estimate at each location				
Augusta Lock & Dam	1.22 (0.01)	NC	1.47 (0.01)	NC
Upper Three Runs Creek	2.29 (0.02)	NC	1.48 (0.01)	NC
Beaver Dam Creek	4.83 (0.05)	NC	3.15 (0.03)	NC
Four Mile Creek	7.34 (0.07)	NC	10.50 (0.11)	NC
Steel Creek	10.58 (0.11)	NC	6.00 (0.06)	NC
Lower Three Runs Creek	7.41 (0.07)	NC	4.91 (0.05)	NC
Bridge at Highway 301	2.00 (0.02)	NC	1.33 (0.01)	NC

*The strontium-89/90 concentration in greens (the maximum concentration in vegetables) was detected in only one sample and is an order of magnitude higher than other maximum results at other locations.
**Based on cesium-137 results.
yrs = years; mrem/yr = millirem per year; mSv/yr = millisievert per year (1 mSv/yr = 100 mrem/yr)
NC = not calculated

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From the results in Table 33, which are based on maximum concentrations and ingestion rates, ATSDR has concluded that hypothetical exposures to individuals, who live in the area, consume all of their agricultural crops and farm products locally, and fish occasionally in the Savannah River near the site, would not be exposed to levels that would cause adverse health effects. For the hypothetical avid adult sportsperson who consumes all edible portions of several animals harvested on site (50 mrem/yr [0.50 mSv/yr]) or off site (33 mrem/yr [0.33 mSv/yr]), consumes large quantities of fish from the mouth of Steel Creek (11 mrem/yr [0.11 mSv/yr]), and consumes only local farm products and locally grown crops (mainly greens with maximum concentrations of strontium-90) (27 mrem/yr), ATSDR's adjusted comparison value for consumption of biota would be exceeded. This scenario and the potential for adverse health effects will be discussed in the Health Implications section of this report.

Non-Radioactive Contaminants

Fish: DOE has routinely analyzed mercury in fish tissue between 1993 and 2008. Beginning in 2007 and 2008, other metals (i.e., antimony, arsenic, cadmium, and manganese) were included in DOE's fish tissue analyses. Table 34 presents ATSDR's screening evaluation findings for metals detected in fish tissue from the Savannah River.

Mercury was the only non-radioactive contaminant identified at levels of possible health concern in fish. Although it is unlikely that arsenic in fish poses a health concern for consumers, arsenic will also be evaluated because suitable screening values are not currently available for organic arsenic in fish tissue. The following section "Public Health Implications" will provide additional health perspective for both of these contaminants.

Other Biota: The monitoring programs at SRS have characterized the nature and extent of both radioactive and non-radioactive contaminants released directly into the environment during the operation of the facility. Although radioactive isotopes have also been routinely measured in a variety of biota (e.g., fish, deer, hogs, milk, beef), non-radioactive contaminants have not been routinely characterized in the biota at SRS and in surrounding areas of the site. This is, in large part, because the monitoring of chemical contaminants in other media (e.g., soil, sediment, surface water) did not indicate that site-related chemicals (e.g., chromium, lead, mercury, VOCs) were migrating off site. During its evaluation of groundwater and surface water, ATSDR confirmed that groundwater plumes did not extend beyond the site boundaries and surface water in on-site tributaries did not contain elevated levels of chemical contamination.

During this evaluation of biota, ATSDR conducted a literature search for any sampling programs or research efforts conducted for non-radioactive contaminants near SRS. The search identified a small number of research studies (See Table 30) that reported levels of mercury and a few other contaminants in biota near or on SRS property. With the exception of a few studies, most of the samples were not for common edible species. Although most of the environmental sampling on SRS property would indicate that migration of non-radioactive contaminants has not occurred off site, ATSDR cannot make a definitive conclusion about accumulation of chemical contaminants in the wildlife that inhabit SRS and the surrounding area. Edible wildlife species (e.g., duck, deer, turtles, and possibly alligators) might feed from contaminated locations on SRS property and then move off site where they could be hunted by residents.

Table 34. Screening Table for Metals Detected in Common Edible Fish Tissue from Savannah River

Compound	Species	Average Concentration[1] (ppm)	Screening Value[2] (ppm)	Further Evaluation (Yes/No)	Rationale
Arsenic* (Total)	Bowfin Bass Channel Catfish Y. Perch	0.32 0.03 0.09 0.05	NA	Yes	No suitable screening value available for organic arsenic. Most arsenic in fish tissue is organic; this is much less toxic than inorganic arsenic.
Antimony	Bass Catfish Bream	----- (0.38)[3] ----- (0.37)[3] ----- (0.41)[3]	0.54	No	Below screening value.
Cadmium	Bowfin Bass Bream Catfish (mixed) Y. Perch	0.01 0.01 (ND)[3] ----- (0.80)[3] 0.01 (0.30)[3] 0.01	1.4	No	Below screening value.
Chromium	Bowfin Bass Ch. catfish Y. Perch	0.32 0.21 0.33 0.32	4.1 [Cr-VI]	No	Below screening value.
Copper	Bowfin Bass Ch. catfish Y. Perch	0.32 0.26 0.36 0.36	54	No	Below screening value.
Manganese	Bowfin Bass Channel Catfish Y. Perch	0.24 0.13 0.26 0.79	27	No	Below screening value.
Mercury (Total)	Bowfin Bass Bream Catfish (mixed) Y. Perch	0.64 0.33 (0.47)[3] ----- (0.31)[3] 0.16 (0.35)[3] 0.18	0.14 0.3 **	Yes	Exceeds screening value.
Strontium [Stable Isotope]	Bowfin Bass Channel Catfish Y. Perch	0.26 0.66 0.36 0.88	810	No	Below screening value.

Source: Burger et al. 2002a; WSRC ND(p); SRNS ND

Notes: Results reported as wet weight values; ppm = parts per million; Cr-VI = Hexavalent chromium; NA = not available.

[1] The concentrations presented for metals screening were collected in 1997 and are representative of fish found along the Savannah River between Augusta Lock and Dam (above SRS) downstream to the Route 301 Bridge (below SRS). ATSDR also reviewed Department of Energy (DOE), South Carolina Department of Health and Environmental Control (SCDHEC), and Georgia Department of Natural Resources (GDNR) data to evaluate concentrations of mercury in fish tissue.
[2] Unless otherwise noted, all screening values are based on U.S. EPA's Region III Risk-based concentrations for fish tissue.
[3] Values in parentheses represent the average concentration detected in the specified species during the most current 2-year sampling period (2007–2008). These samples were collected by DOE at selected locations along the Savannah River for bass (n=132), bream (n=210), and catfish (n=154). Samples reported below the limit of detection were not included in the calculation of the average.

*Arsenic was analyzed in fish tissue samples collected by DOE in 2007 and 2008; however, average concentrations were not presented because fewer than 5 percent of the samples were reported above the analytical limit of detection (limit of detection ranged from 0.37 to 0.50 ppm).
** EPA human health criterion for methyl mercury in fish.

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Table 35. Biota Exposure Pathways Associated With SRS Activities and Potentially Exposed Populations

Potential Pathway	*Five Components of a Completed Exposure Pathway*					*Time Frame for Exposure*	*Conclusion for Pathway*
	1. Source of Contamination	*2. Fate and Transport*	*3. Point of Exposure*	*4. Route of Exposure*	*5. Receptor Population*		
Exposure to mercury from eating fish from the Savannah River	Unknown (Multiple potential sources of contamination exist upstream of SRS; SRS may also contribute to the mercury sediment load of the Savannah River.)	Some mercury has migrated from *F-Area* and *H-Area* seepage basins into the groundwater and might contribute to mercury in fish from the Savannah River and tributaries.	Highly variable	Ingestion	Recreational anglers or subsistence anglers	Past, present, future	**Complete:** This is a completed exposure pathway. It is important to emphasize, however, that the source of mercury contamination is not fully known. There is no evidence that SRS has contributed significantly to the mercury that has accumulated over time in the Savannah River watershed.
Exposure to radioactive contaminants (mainly cesium-137) from eating edible wild game from on-site and off-site hunts, fishing at the mouths of on-site creeks feeding into the Savannah River, and eating only locally grown produce and farm products.	Past plant operations and waste disposal activities that released contaminants to surface water, soil, and air that have been transported in the environment, taken up by plants and ingested by animals.	Radioactive contaminants (mainly cesium-137, tritium, and strontium-90) can be found in many locations on site: creeks, ponds, settling basins, waste sites, vegetation, and in animals.	Highly variable but mainly from on-site hunting	Ingestion	Avid sportsmen (avid recreational or subsistence deer/hog hunters and anglers)	Past and present Future	**Complete (past and present):** This was/is a completed exposure pathway for avid sportsperson especially for those living in the area consuming locally produced agricultural and farm products **Potential (future)**: Although concentrations of radioactive materials have been decreasing in biota on and near the site, exposure to these materials may continue for some time after clean-up operations on the site are complete. Clean-up operations are on-going but this site will continue to be active for the foreseeable future.

Public Health Implications

This section evaluates the likelihood of health effects from exposure to contaminants of concern for potentially affected populations. If a completed or potential exposure pathway is identified, ATSDR estimates an individual's exposure dose using available site-specific data. In these evaluations, ATSDR considers the frequency and duration of the estimated exposures using health-protective dose assumptions when information about specific activities (e.g., fish or wildlife consumption rates) is not available. This section places the potential for health effects from each contaminant of concern identified into perspective given the exposure situations identified. Table 35 provides a summary of the biota exposure pathways associated with SRS activities and potentially exposed populations.

Radioactive Contaminants

Radioactive contaminants have been detected at varying concentrations in biota, with some types of biota (e.g., on-site deer and hogs) being impacted more than others. Table 33 presents the estimated upper bound hypothetical exposure screening levels for adults and children. These levels were based on chronic ingestion of maximum concentrations (or averages of maximum concentrations) in biota at the 95th or 99th percentile ingestion rates and were compared to ATSDR's adjusted comparison value (30 mrem/yr [0.3 mSv/yr]). The only screening levels that exceeded ATSDR's adjusted comparison value were for an avid onsite hunter (50 mrem/yr [0.50 mSv/yr]) in 1999 and an avid off-site hunter (33 mrem/yr [0.33 mSv/yr]) in 2002. These hypothetical screening levels by themselves would not be at a level of health concern. In the calculations, it was assumed that these individuals' entire meat consumptions for the year were from on- and off-site deer and feral hogs (78 kg/yr, or 172 lbs/yr). Although these calculations are based only on cesium-137 concentrations, the calculations included very conservative assumptions. The limited sampling for other radionuclides indicated very low concentrations that would not add appreciably to these estimates. (Refer to Appendix D)

Human data and the results of animal experiments indicate that soluble compounds of cesium-137 are rapidly and almost completely absorbed in the gastrointestinal tract and behave similar to potassium after entering the bloodstream, distributing to all body tissues. Slightly higher concentrations of cesium-137 are found in muscle tissue. In 1989, researchers measured the uptake of cesium-137 in 10 volunteers after they consumed venison contaminated as a result of the Chernobyl accident[9]. The absorption rate of cesium-137 from this food intake varied from 56 to 90 percent (mean 78%) indicating that the uptake of cesium-137 was not always complete. However, since there is insufficient data on the uptake of cesium-137 incorporated in various foods, the assumption is made in the ICRP models (used in our calculations) that cesium-137 in food is soluble and almost completely absorbed (ICRP 1989). This assumption adds another layer of conservatism to the dose estimates.

Like potassium, cesium is excreted from the body fairly quickly. In an adult, 10% is excreted with a biological half-life of 2 days, and the rest leaves the body with a biological half-life of 110 days. Its clearance from the body is somewhat quicker for children and adolescents. This means

[9] The **Chernobyl disaster** was a nuclear accident that occurred on 26 April 1986, at the Chernobyl Nuclear Power Plant in Ukraine (then in the Ukrainian Soviet Socialist Republic, part of the Soviet Union).

that if someone is exposed to radioactive cesium and the source is removed, much of it will readily clear the body within several months (ANL 2005).

If the avid on-site hunter also lived in the area near the site in 1999, this individual could also receive an exposure from consumption of other biota.

- Depending on the fishing location and the assumption that someone ingests 49 kg/yr (108 lbs/yr) of fish with maximum concentrations mainly of cesium-137, this hypothetical individual could have received an additional dose between 0.5 mrem/yr (0.005 mSv/yr) and 11 mrem/yr (0.11 mSv/yr) in 1999. (Refer to Appendix D). The total screening level dose for this hypothetical avid on-site hunter who also consumes 49 kg/yr of fish from the Savannah River would not exceed 100 mrem/yr (1 mSv/yr) and would not be expected to cause adverse health effects.
- If this person also consumed all their produce and farm products from local sources, based on maximum concentrations in 1999, the hypothetical individual could receive an additional dose of less than 15mrem/yr (<0.15 mSv/yr). The total screening level dose for this hypothetical avid on-site hunter who also consumes 49 kg/yr of fish from the Savannah River and only local produce and farm products with maximum concentrations would not exceed 100 mrem/yr (1 mSv/yr) and would not be expected to cause adverse health effects.
- Any doses received by persons living in the area who occasionally hunt or fish and eat locally grown produce and farm products would not result in any adverse health effects.

Non-Radioactive Contaminants

Mercury: The exposure pathway analysis for biota in the previous section of this PHA indicates that mercury is present in some fish samples at levels of health concern. It is not possible to determine how much of the mercury accumulating in fish sampled from the Savannah River is a result of SRS-related activities. Other sources of mercury are known to exist upstream of SRS and have contributed to the total inventory of mercury in the Savannah River watershed. Regardless of the source, however, levels have not trended appreciably in any one direction since Phase II of CDC's Dose Reconstruction Project was released in 2001.

Fish Advisories

For more information about the most current fish advisories for the Savannah River and other popular fishing areas near SRS go to the following URLs:

South Carolina: http://www.scdhec.net/environment/water/fish/advisories.htm

Georgia: http://www.gaepd.org/Documents/fish_guide.html

Based on the data ATSDR reviewed, it is possible to identify where the highest concentrations of mercury in fish have occurred since 1993 and what commonly consumed species contain the highest levels of mercury. SCDHEC and GDNR have issued fish advisories warning people against consuming certain species known to be contaminated with mercury along portions of the river. ATSDR concurs with the information provided in the fish advisory for the specified species and designated sections of the Savannah River. Given that mercury in fish from the Savannah River is already known to be elevated and fish advisories are currently posted (see text box), the primary focus of this section is to provide some perspective on the toxicity of mercury, and to provide additional guidance, based on data trends, to people who consume fish from locations where elevated mercury concentrations were measured in fish.

Contaminants are not evenly distributed in all fish species, and concentrations can vary considerably from the same water body. Levels depend on both uptake and accumulation. Species that eat other animals are exposed to higher levels of pollutants than plant-eating fish, and fish that eat larger animals are exposed to higher levels than those that eat smaller animals. Moreover, accumulation depends to some extent on size (usually highly correlated to age): larger, carnivorous fish accumulate higher concentrations than smaller fish of the same species. Contaminant levels are likely to be lowest in small, fast-growing herbivores such as perch. Predatory fish such as bass and many species of bottom-dwelling fish typically accumulate higher concentrations of mercury than other species. Table 36 presents typical mercury levels commonly detected in fish and shellfish across the U.S. As reported in the table, most fresh water fish from uncontaminated water bodies typically have lower levels of mercury compared to saltwater species.

Table 36. Average Mercury Concentrations in Fish Reported Across the United States

Species	*Average Mercury Concentration (ppm)*	*Source of Data*
Fresh Water Fish		
Bass	0.36 (spotted bass) 0.27 (striped bass)	EPA—National Fish and Wildlife Contamination Program (NFWCP) 1987-2003
Carp (similar to Bream)	0.14	EPA—NFWCP 1987-2003
Catfish	0.05	FDA 1990-2004
Perch	0.14	FDA SURVEY 1990-2002
Trout	0.07 0.16 (Brown trout)	FDA 2002-2004 U.S. EPA—NFWCP
Salt Water Fish		
Swordfish	0.98	FDA 1990-2004
Tuna (Fresh/Frozen, Bigeye)	0.64	FDA 2002-2004
Tuna (Canned, Fresh/Frozen, Albacore)	0.36	FDA 2002-2004
Halibut	0.25	FDA 1990-2004
Salmon (Canned, Fresh/Frozen)*	ND–0.01	FDA 1990-2002

Source: US FDA. Mercury Levels in Commercial Fish and Shellfish. http://www.fda.gov/Food/FoodSafety/Product-SpecificInformation/Seafood/FoodbornePathogensContaminants/Methylmercury/ucm115644.htm [FDA ND]

U.S. EPA. National Fish and Wildlife Contamination Program (NFWCP).
US EPA National Listing of Fish and Wildlife Advisory (NLFWA) fish tissue database, October 2003.
URL: http://www.epa.gov/waterscience/fish/advice/tissue-slide.pdf [EPA ND]

Notes: Mercury was measured as total Mercury except only methylmercury was analyzed for species with an (*);
ND = Mercury concentration below detection level.

Accumulation of mercury in fish is generally greatest in the liver, kidney, and muscle tissue. Unlike many of the chlorinated pesticides and PCBs, mercury is stored in the muscle tissue rather than the fat. A 1992 study by EPA generally found higher mercury concentrations in fillet samples compared to whole body samples; however, this was not uniformly the case at all sampling locations. These inconsistent findings might be due to a number of factors, including species variability and stomach content, which can include contaminated sediments (CDC 2001).

The nature of mercury toxicity differs with the chemical form. Ingestion of *inorganic* mercury in laboratory animals has produced toxicity in the kidney. However, the majority (80 to 99 percent) of mercury found in fish tissue is *organic* in the form of methylmercury (see "What is Mercury" Text Box). Methylmercury is accumulated in biological tissues more readily than inorganic forms. It has the ability to be absorbed by the digestive tract and enter the blood stream, possibly causing damage to the nervous system as well as developmental toxicity in fetuses, breastfeeding infants whose mothers ingested contaminated biota, and younger children over time (ATSDR 1999b).

EPA established a chronic oral reference dose (RfD) of 0.0001 milligrams per kilograms per day (mg/kg-day) for methylmercury. ATSDR derived a chronic oral Minimum Risk Level (MRL) of 0.0003 mg/kg-day for methylmercury based on information from human populations. Although not identical to EPA's RfD, the ATSDR MRL (a level likely to be without appreciable risk of adverse non-cancer health effects) has been peer reviewed and is widely accepted (ATSDR 1999b). Estimated mercury doses are based on average mercury concentrations measured in samples collected for bass, bream, bowfin, catfish, and perch along the Savannah River. As shown in Table 37, the estimated child and adult dose for each of the species is at or exceeds ATSDR's chronic oral MRL. Refer to Appendix D for ATSDR's methodology of how dose is calculated and for additional estimates of dose by species and location along the Savannah River.

Table 37. Estimated Mercury Doses from Ingestion of Fish from the Savannah River

	Estimated Child Dose	***Estimated Adult Dose***	***Reference Dose***
Bass	0.0023	0.0008	0.0003 (ATSDR's chronic oral minimum risk level)
Bream	0.0015	0.0005	
Bowfin	0.0032	0.001	
Catfish	0.0017	0.0006	
Perch	0.0009	0.0003	

Units: mg/kg/day
Dose estimates are for non-cancer health effects and based on average mercury concentrations.
Data supplied to ATSDR did not indicate if the mercury was methylmercury; however, in order to be cautious, ATSDR assumed that it could be.

According to the South Carolina Department of Health and Environmental Control' s fish advisory, bluegill, sunfish, catfish, and black crappie from the Savannah River along SRS should be limited to one meal (8 ounces or 227 grams) a week (1.14 ounces/day), while largemouth bass and bowfin from the Savannah River along SRS should not be consumed at all. This is based on the mercury content of the fish, and not on the radionuclide levels.

As more general guidance, FDA recommends that people consuming fish with methylmercury levels greater than 1 ppm should limit their intake to 7 ounces (200 grams) per week, and people consuming fish with methylmercury levels around 0.5 ppm should limit their intake to 14 ounces (400 grams per week). This is based on an individual weighing 70 kilograms (154 pounds) representing a dose of 0.0004 mg/kg/day (Burger et al. 2001).

Arsenic: Arsenic, a naturally occurring element, typically has no smell or distinctive taste. Although elemental arsenic sometimes occurs naturally, arsenic is usually found in the environment in two forms—inorganic (arsenic combined with oxygen, chlorine, and sulfur) and organic (arsenic combined with carbon and hydrogen). Most simple organic forms of arsenic are less harmful than the inorganic forms (ATSDR 2007b). Once arsenic is in the environment, it cannot be destroyed; it can only change forms or become attached to or separated from particles (e.g., by reacting with oxygen or by the action of bacteria in soil). Some forms of arsenic may be so tightly attached to particles or embedded in minerals that they are not taken up by plants and animals.

Arsenic has been detected in fish tissue samples collected from the Savannah River and its tributaries. The maximum arsenic concentration (1.5 ppm) was detected in a redfish in the mouth of the Savannah River during 2008 sampling by DOE. The highest arsenic concentration measured in bass (1.5 ppm) was at Augusta Lock and Dam during 2007 sampling by DOE. Although arsenic may accumulate in fish tissues, most of this arsenic is in an organic form called arsenobetaine (commonly called "fish arsenic") that is much less harmful (ATSDR 2007b). The fish sampling data for the Savannah River is presented as total arsenic and does not distinguish between organic and inorganic arsenic. While there is no way to ascertain the inorganic arsenic fraction in the fish samples that have already been analyzed, the general consensus is that greater than 90 percent of the arsenic in the edible parts of fish and shellfish is organic arsenic and that approximately 10 percent is comprised of inorganic arsenic (EPA 2003). Given the low toxicity potential for organic arsenic, it is very unlikely that the total arsenic levels reported in fish sampled from the Savannah River are of health concern.

The specific form of arsenic present in the environment is not generally determined. Therefore, it is not always known what form of arsenic a person may be exposed to.

Conclusions

This PHA addresses the potential for human exposure from consuming or coming in contact with biota that are collected at or in close proximity to SRS. The evaluation emphasized the period of time following the CDC Dose Reconstruction Project (from 1993 through the foreseeable future).

Based on the most currently available information and as discussed in the Public Health Implications section, no past, current, or future public health hazards are associated with consuming *off-site* biota potentially contaminated from SRS-related activities. As long as harvested *on-site* wild game are monitored for radioactive contaminants, restrictions on contamination levels remain, and animals containing above these levels are confiscated, wild game harvested in approved hunting areas on SRS property do not present a public health hazard. Some fish species in the Savannah River do contain elevated levels of mercury. The source of mercury in the Savannah River and associated tributaries is not known, but there are likely multiple sources. Although SRS might be a contributing source, there is no current evidence to suggest it is the primary contributor. ATSDR's conclusions regarding the potential exposure pathways evaluated are described below:

- Based on information reviewed by ATSDR, the general population exposures to radioactive contaminants in *off-site* biota near the Savannah River Site would not be at a level to produce adverse health effects.

- With the exception of mercury (see below), the levels of metals in fish from the Savannah River and its tributaries do not pose a public health hazard.

- There is very limited fish sampling data for other chemical contaminants (e.g., pesticides, PCBs, dioxins/furans). The limited pesticide and PCB fish data that ATSDR reviewed does not indicate that these chemicals would pose a health hazard. However, since the sampling is limited for these types of chemicals, ATSDR cannot make a public health conclusion.

- Mercury contamination in fish from the Savannah River, both upstream, along, and downstream of SRS, has been well documented by state agencies. However, the contribution of mercury from SRS-related activities to the river system is not known. Although mercury levels are elevated in some species of fish, these levels do not pose a public health hazard if the species-specific fish advisory guidance issued by South Carolina and Georgia are followed.

- If subsistence fishers do not follow the recommended consumption guidance, consuming large amounts of fish, especially species that typically accumulate mercury such as largemouth bass, bowfin, and catfish, from certain portions of the Savannah River might increase health risks associated with mercury exposure, especially to sensitive populations (e.g., fetuses and nursing infants whose mother ingests mercury-contaminated fish).

Recommendations

On the basis of information reviewed for this site, ATSDR recommends the following:

- DOE should continue to monitor all types of biota consumed by humans both on and off the site until all remediation actions are completed and no old or new sources of contamination remain.
- DOE should keep informed of the types of biota consumed by humans and provide adequate monitoring for those types that may be contaminated by site activities. There were limited or no data reviewed on some animals potentially consumed by humans, such as alligators, rabbits, squirrel, ducks, turtles, and other small animals.
- DOE should periodically review potential differences in environmental monitoring results between all agencies and programs involved. This comparison should include the on-site field surveys performed on harvested animals and laboratory sampling results.
- Largemouth bass and bowfin have typically accumulated the highest concentrations of mercury. Currently, the state of South Carolina recommends not eating these two species if collected from portions of the Savannah River between Highway 119 in Jasper County to U.S. Highway 17 near Savannah, Georgia.
- DOE should consider routine environmental sampling of turtles for aquatic contaminants, especially for those chemical and radioactive contaminants found predominantly in pond and stream sediment.

Public Health Action Plan

The public health action plan for SRS contains a description of actions taken at the site and those to be taken at the site following the completion of this public health assessment. The purpose of the public health action plan is to ensure that this document not only identifies potential and ongoing public health hazards, but also provides a plan of action designed to mitigate and prevent adverse human health effects resulting from exposure to harmful substances in the environment. The following public health actions at SRS are completed, ongoing, or planned:

Completed Actions

DOE and the States of South Carolina and Georgia have independent environmental monitoring programs to detect radioactive contaminants in off-site biota. They have also formed a group of scientists from each agency that discusses differences in sampling techniques, compares their results and strives to improve the quality of the data.

Ongoing Actions

It is important that all biota consumed by humans is monitored until demonstrated that it does not present a health concern. Along with the state monitoring programs, the Savannah River Ecology Laboratory's research projects also provides another independent source of monitoring biota. DOE's Savannah River National Laboratory also performs biota monitoring.

DOE has several ongoing studies that focus on obtaining contaminant data for on-site locations including; *Reptiles as Long-lived Receptors for Ecological Risk Assessment on the SRS*; *Contaminant Bioaccumulation and Trophic Relationships in Beaver Dam Creek Biota from the D-Area Coal Combustion Waste Plume*; and *Support of the SRS Trophic Transfer Modeling Effort*.

DOE and the State of South Carolina present their annual environmental sampling reports to the Savannah River Site Citizens Advisory Board for questions and comments. They also issue a public release and press announcement for these reports encouraging public responses.

Planned Actions

DOE plans to continue their current environmental monitoring program and evaluate other biota for inclusion in the routine environmental monitoring program (USDOE 2011). The State of Georgia has not received any funds from DOE for off-site monitoring since 2004; therefore the future involvement of Georgia in the SRS monitoring programs is unclear.

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APPENDICES

Appendix A. ATSDR Glossary of Terms

The Agency for Toxic Substances and Disease Registry (ATSDR) is a federal public health agency with headquarters in Atlanta, Georgia, and 10 regional offices in the United States. ATSDR's mission is to serve the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposures and diseases related to toxic substances. ATSDR is not a regulatory agency, unlike the U.S. Environmental Protection Agency (EPA), which is the federal agency that develops and enforces environmental laws to protect the environment and human health. This glossary defines words used by ATSDR in communications with the public. It is not a complete dictionary of environmental health terms. If you have questions or comments, call ATSDR's toll-free telephone number, 1-888-42-ATSDR (1-888-422-8737).

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

Ambient
Surrounding (for example, ambient air).

Analyte
A substance measured in the laboratory. A chemical for which a sample (such as water, air, or blood) is tested in a laboratory. For example, if the analyte is mercury, the laboratory test will determine the amount of mercury in the sample.

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

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

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

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

Carcinogen
A substance that causes cancer.

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

Chronic
Occurring over a long time [compare with acute].

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

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

Completed exposure pathway [see exposure pathway].

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

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

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

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

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

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

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

DOE
United States Department of Energy.

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

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

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

EPA
United States Environmental Protection Agency.

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

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

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

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

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

Half-life ($t_{1/2}$)
The time it takes for half the original amount of a substance to disappear. In the environment, the

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

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

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

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

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

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

mg/kg
Milligram per kilogram.

Migration
Moving from one location to another.

Minimal risk level (MRL)
An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse) health effects [see reference dose].

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

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

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

NPL [see National Priorities List for Uncontrolled Hazardous Waste Sites]

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

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

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

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

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

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

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

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

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

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

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

Radionuclide
Any radioactive isotope (form) of any element.

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

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

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

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

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

RfD [see reference dose]

Risk
The probability that something will cause injury or harm.

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

SARA [see Superfund Amendments and Reauthorization Act]

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

Sample size
The number of units chosen from a population or an environment.

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

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

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

Substance
A chemical.

Superfund [see Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and Superfund Amendments and Reauthorization Act (SARA)]

Superfund Amendments and Reauthorization Act (SARA)
In 1986, SARA amended the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and expanded the health-related responsibilities of ATSDR. CERCLA and SARA direct ATSDR to look into the health effects from substance exposures at hazardous waste sites and to perform activities including health education, health studies, surveillance, health consultations, and toxicological profiles.

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

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

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

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

Tritium
A common name for radioactive hydrogen

Volatile organic compounds (VOCs)
Organic compounds that evaporate readily into the air. VOCs include substances such as benzene, toluene, methylene chloride, and methyl chloroform.

Other glossaries and dictionaries:
Environmental Protection Agency (http://www.epa.gov/OCEPAterms/)
National Center for Environmental Health (CDC) (http://www.cdc.gov/nceh/dls/report/glossary.htm)
National Library of Medicine (NIH) (http://www.nlm.nih.gov/medlineplus/mplusdictionary.html)

Appendix B. ATSDR's Methodology for Evaluating Contaminants of Concern

ATSDR scientists select contaminants for further evaluation by comparing the maximum environmental contaminant concentrations or potential radiation doses against health-based comparison values (CVs). The CVs are developed by ATSDR from available scientific literature related to exposure and health effects. CVs reflect an estimated contaminant concentration or radiation dose that is *not likely* to cause adverse health effects, assuming a standard daily contact rate (e.g., an amount of water or soil consumed or an amount of air breathed) and representative body weight. ATSDR's CVs represent contaminant concentrations that are many times lower than levels at which no adverse health effects were observed in studies on experimental animals or in human epidemiologic studies and are considered protective of public health in essentially all exposure scenarios. Thus, chemical concentrations or radiation doses below ATSDR's CVs are not considered for further evaluation. For radioactive materials, the comparison value is based on a potential radiation dose from one or more radioactive substances via multiple pathways.

ATSDR comparison values are used as screening values in the preliminary identification of site-specific "contaminants of concern." The latter term should not be misinterpreted as an indication of "hazard." As ATSDR uses the phrase, a "contaminant of concern" is a chemical or radioactive substance detected at the site in question and selected by the health assessor for further evaluation of potential health effects. Generally, a chemical or a radioactive material is selected as a "contaminant of concern" because its maximum concentration in air, water, or soil at the site or the resulting potential radiation dose exceeds one of ATSDR's comparison values.

Nevertheless, it must be emphasized that comparison values are not thresholds of toxicity. Although concentrations at or below the relevant comparison values could reasonably be considered safe, it does not automatically follow that any environmental concentration that exceeds a comparison value would be expected to produce adverse health effects. The principal purpose behind conservative, health-based standards and guidelines is to enable health professionals to recognize and resolve potential public health hazards before they become actual public health consequences. Thus comparison values are designed to be preventive-rather than predictive-of adverse health effects. The probability that such effects will actually occur does not depend on environmental concentrations alone, but on a unique combination of site-specific conditions and individual lifestyle and genetic factors that affect the route, magnitude, and duration of actual exposure.

If the chemical or radioactive material is selected as a "contaminant of concern", then ATSDR further analyzes the site-specific exposure variables (such as exposure locations and duration and frequency of exposures) and the scenario similarity to the toxicologic research for the contaminant and the epidemiologic studies. This analysis is discussed in the Public Health Implications section of the main report.

Listed and described below are the various comparison values that ATSDR uses to select chemicals or radioactive substances for further evaluation, as well as other non-ATSDR values that are sometimes used to put environmental concentrations into perspective.

CREG	=	Cancer Risk Evaluation Guides
MRL	=	Minimal Risk Level
EMEG	=	Environmental Media Evaluation Guides
RMEG	=	Reference Dose Media Evaluation Guide
RfD	=	Reference Dose
RfC	=	Reference Dose Concentration
RBC	=	Risk-Based Concentration
MCL	=	Maximum Contaminant Level

Cancer Risk Evaluation Guides (CREGs) are estimated contaminant concentrations expected to cause no more than one excess cancer in a million persons exposed over a lifetime. CREGs are calculated from EPA's cancer slope factors, or cancer potency factors, using default values for exposure rates. That said, however, neither CREGs nor cancer slope factors can be used to make realistic predictions of cancer risk. The true risk is always unknown and could be as low as zero.

Minimal Risk Levels (MRLs) are estimates of daily human exposure to a chemical (doses expressed in mg/kg/day) or radioactive material (doses expressed as mrem/yr, or mSv/yr) that are unlikely to be associated with any appreciable risk of deleterious non-cancer effects over a specified duration of exposure. MRLs are calculated using data from human and animal studies and are reported for acute (first to 14 days), intermediate (15 through 364 days), and chronic (365 or more days) exposures. MRLs for specific chemicals are published in ATSDR toxicological profiles.

Environmental Media Evaluation Guides (EMEGs) are concentrations that are calculated from ATSDR minimal risk levels by factoring in default body weights and ingestion rates.
They factor in body weight and ingestion rates for acute exposures (Acute EMEGs — those occurring for 14 days or less), for intermediate exposures (Intermediate EMEGs — those occurring for more than 14 days and less than 1 year), and for chronic exposures (Chronic EMEGs — those occurring for 365 days or greater).

Reference Dose Media Evaluation Guide (RMEG) is the concentration of a contaminant in air, water or soil that corresponds to EPA's RfD for that contaminant when default values for body weight and intake rates are taken into account.

Reference Dose (RfD) is an estimate of the daily exposure to a contaminant unlikely to cause noncarcinogenic adverse health effects. Like ATSDR's MRL, EPA's RfD is a dose expressed in mg/kg/day.

Reference Concentrations (RfC) is a concentration of a substance in air that EPA considers unlikely to cause noncancer adverse health effects over a lifetime of chronic exposure.

Risk-Based Concentrations (RBC) are media-specific concentrations derived by Region III of the Environmental Protection Agency from RfDs, RfCs, or EPAs cancer slope factors. They represent concentrations of a contaminant in tap water, ambient air, fish, or soil (industrial or residential) that are considered unlikely to cause adverse health effects over a lifetime of chronic exposure. RBCs are based either on cancer or non-cancer effects.

Maximum Contaminant Levels (MCLs) represent contaminant concentrations in drinking water that EPA deems protective of public health (considering the availability and economics of water treatment technology) over a lifetime (70 years) at an exposure rate of 2 liters of water per day.

Appendix C. Fish Sampling Data Tables

The largest amount of biota sampling data for fish was collected in the Savannah River near the site. This appendix contains *radioactive contaminant* summary tables for the fish sampling data for the timeframe from 1993 through 2008.

- Table C-1 contains a summary of data from DOE for 1993 through 2000.
- Table C-2 contains a summary of data from DOE for 2001 through 2008.
- Table C-3 contains a summary of data from the State of Georgia for 1993 through 2008.
- Table C-4 contains a summary of data from the State of South Carolina for 1997 through 2008.

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3460 (The data does not include samples marked non-edible. Samples are freshwater unless otherwise indicated.)

Table C-1: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (1993-2000) —DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
Augusta Lock and Dam	Bass	1993,1994, 1996—2000	Gross Alpha	5/18	0.264	1998
		1993,1994, 1996—2000	Gross Beta	18/18	2.99	1999
		1993, 1996—2000	Cesium-137	15/17	0.42	1993
		1996—2000	Cobalt-60	6/15	0.028	1997
		1993, 1996—2000	Plutonium-238	8/16	0.00012	1997
		1993, 1996—2000	Plutonium-239	6/16	0.00004	1998
		1996—2000	Strontium-89/90	11/14	0.018	1999
		1993—1994	Strontium-90	2/4	0.029	1993
		1993, 1994, 1996—2000	Tritium (Hydrogen-3)	15/19	0.13	1996
	Bream	1993,1995—2000	Gross Alpha	10/19	0.136	1999
		1993,1995—2000	Gross Beta	19/19	2.83	1998
		1993, 1996—2000	Cesium-137	16/17	0.48	1997
		1996—2000	Cobalt-60	5/15	0.022	1997
		1993, 1995—2000	Plutonium-238	8/18	0.00030	1996
		1995—2000	Plutonium-239	3/18	0.00008	1998
		1995—2000	Strontium-89/90	15/17	0.034	1999
		1993	Strontium-90	1/3	0.020	1993
		1993, 1995—2000	Tritium (Hydrogen-3)	16/20	0.12	1993
	Freshwater Catfish	1995—2000	Gross Alpha	7/18	0.155	1996
		1995—2000	Gross Beta	18/18	2.98	1995
		1995—2000	Cesium-137	15/17	0.08	1999
		1996—2000	Cobalt-60	7/15	0.027	2000
		1995—2000	Plutonium-238	4/18	0.00004	1995
		1995—2000	Plutonium-239	6/18	0.00003	1995

Table C-1: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (1993-2000) —DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
		1995—2000	Strontium-89/90	18/18	0.014	1999
		1995—2000	Tritium (Hydrogen-3)	18/18	0.19	1998
	Shad	1999	Gross Beta	3/3	2.19	1999
			Cesium-137	3/3	0.06	1999
			Cobalt-60	1/3	0.034	1999
			Plutonium-238	3/3	0.00001	1999
			Plutonium-239	1/3	0.00003	1999
			Strontium-89/90	3/3	0.011	1999
			Tritium (Hydrogen-3)	3/3	0.05	1999
	Sucker	1998	Gross Alpha	1/3	0.137	1998
			Gross Beta	3/3	2.71	1998
			Cesium-137	3/3	0.03	1998
			Cobalt-60	1/3	0.016	1998
			Plutonium-238	1/3	0.00006	1998
			Plutonium-239	2/3	0.00001	1998
			Strontium-89/90	3/3	0.010	1998
			Tritium (Hydrogen-3)	3/3	0.15	1998
	Bowfin	1998	Gross Alpha		0.04	1998
			Gross Beta		2.71	1998
			Cesium-137		0.16	1998
			Cobalt-60		0.015	1998
			Plutonium-238		0.00002	1998
			Plutonium-239		0.00004	1998
			Strontium-89/90		0.004	1998
			Tritium (Hydrogen-3)		0.06	1998
	Crappie	1995	Gross Alpha	1/1	0.101	1995
			Gross Beta	1/1	2.98	1995

Table C-1: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (1993-2000) —DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
			Plutonium-238	1/1	0.00006	1995
			Plutonium-239	1/1	0.00003	1995
			Strontium-89/90	1/1	0.008	1995
			Tritium (Hydrogen-3)	1/1	0.02	1995
Beaver Dam Creek (River Mouth)	Bass	1994, 1996–2000	Gross Alpha	3/16	0.072	1999
		1994, 1996–2000	Gross Beta	16/16	3.11	1996
		1994, 1996–2000	Cesium-137	16/16	0.94	1994
		1996–2000	Cobalt-60	13/15	0.037	2000
		1996–2000	Plutonium-238	3/15	0.00007	1996
		1996–2000	Plutonium-239	7/15	0.00009	1996
		1996–2000	Strontium-89/90	12/14	0.023	2000
		1994	Strontium-90	1/1	0.007	1994
		1994, 1996–2000	Tritium (Hydrogen-3)	16/16	0.11	1996
	Bream	1993, 1996—2000	Gross Alpha	7/16	0.247	1997
		1993, 1996—2000	Gross Beta	16/16	3.17	1998
		1993, 1996—2000	Cesium-137	13/15	0.71	1993
		1996—2000	Cobalt-60	8/15	0.032	2000
		1993, 1996—2000	Plutonium-238	9/15	0.00022	1996
		1993, 1996—2000	Plutonium-239	7/15	0.00008	1996
		1996—2000	Strontium-89/90	11/15	0.034	1999
		1993	Strontium-90	1/1	0.039	1993
		1993, 1996—2000	Tritium (Hydrogen-3)	16/16	0.16	1999
	Freshwater Catfish	1993—2000	Gross Alpha	8/24	0.375	1999
		1993—2000	Gross Beta	24/24	3.13	1994
		1993—2000	Cesium-137	17/24	0.11	1995
		1996—2000	Cobalt-60	8/15	0.038	2000
		1993—2000	Plutonium-238	7/23	0.00134	1995

Table C-1: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (1993-2000) —DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
		1993—2000	Plutonium-239	8/24	0.00002	1999
		1995—2000	Strontium-89/90	12/17	0.015	2000
		1993—1994	Strontium-90	1/5	0.004	1993
		1993—2000	Tritium (Hydrogen-3)	24/24	0.76	1994
Four Mile Creek (River Mouth)	Bass	1996 – 2000	Gross Alpha	5/15	0.073	1996
		1996 – 2000	Gross Beta	15/15	4.93	2000
		1996 – 2000	Cesium-137	15/15	1.10	1996
		1996 – 2000	Cobalt-60	10/15	0.019	1998
		1996 – 2000	Plutonium-238	9/15	0.00002	1999
		1996 – 2000	Plutonium-239	4/15	0.00002	1999
		1996 – 2000	Strontium-89/90	15/15	0.089	1996
		1996 - 2000	Tritium (Hydrogen-3)	15/15	26.7	1996
	Bream	1993, 1996 – 2000	Gross Alpha	6/18	0.172	1993
		1993, 1996 – 2000	Gross Beta	18/18	5.15	1993
		1993, 1996 – 2000	Cesium-137	12/18	0.47	1996
		1996 – 2000	Cobalt-60	8/15	0.028	2000
		1993, 1996 – 2000	Plutonium-238	7/17	0.00010	1997
		1993, 1996 – 2000	Plutonium-239	7/17	0.00006	2000
		1996 – 2000	Strontium-89/90	15/15	0.059	1997
		1993	Strontium-90	3/3	0.014	1993
		1993, 1996 - 2000	Tritium (Hydrogen-3)	18/18	26.7	1997
	Freshwater Catfish	1993 – 2000	Gross Alpha	6/22	0.161	1993
		1993 – 2000	Gross Beta	22/22	4.52	1993
		1993, 1994, 1996 – 2000	Cesium-137	20/21	0.35	1994
		1996 – 2000	Cobalt-60	11/15	0.038	1999
		1993 – 2000	Plutonium-238	8/22	0.00011	1995
		1993 – 2000	Plutonium-239	12/21	0.00006	1996

Table C-1: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (1993-2000) —DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
		1994 – 2000	Strontium-89/90	16/18	0.017	1997
		1993, 1994	Strontium-90	6/6	0.063	1994
		1993 – 2000	Tritium (Hydrogen-3)	22/22	6.34	1997
	Shad	1999	Gross Alpha	1/3	0.213	1999
			Gross Beta	3/3	2.33	1999
			Cesium-137	3/3	0.29	1999
			Cobalt-60	1/3	0.023	1999
			Plutonium-238	1/3	0.00011	1999
			Plutonium-239	2/3	0.00001	1999
			Strontium-89/90	3/3	0.024	1999
			Tritium (Hydrogen-3)	3/3	0.78	1999
	Sucker	1998	Gross Alpha	1/3	0.072	1998
			Gross Beta	3/3	3.02	1998
			Cesium-137	3/3	0.08	1998
			Cobalt-60	2/3	0.012	1998
			Strontium-89/90	3/3	0.019	1998
			Tritium (Hydrogen-3)	3/3	1.29	1998
	Bowfin	1998	Gross Alpha	2/3	0.05	1998
			Gross Beta	3/3	2.42	1998
			Cesium-137	3/3	0.31	1998
			Cobalt-60	2/3	0.008	1998
			Plutonium-239	2/3	0.00004	1998
			Strontium-89/90	3/3	0.004	1998
			Tritium (Hydrogen-3)	3/3	1.45	1998
	Panfish	1994	Gross Alpha	1/3	0.148	1994
			Gross Beta	3/3	3.13	1994
			Cesium-137	1/1	0.21	1994

Table C-1: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (1993-2000) —DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
			Plutonium-238	1/2	0.00001	1994
			Plutonium-239	1/2	0.00006	1994
			Strontium-89/90	3/3	1.27	1994
			Strontium-90	3/3	0.075	1994
			Tritium (Hydrogen-3)	3/3	1.40	1994
Highway 17A (Bridge Area)	Bass	1993, 1994, 1996—2000	Gross Alpha	3/20	0.116	1998
		1993, 1994, 1996—2000	Gross Beta	20/20	4.38	1994
		1993, 1994,1996—2000	Cesium-137	16/16	0.13	1993
		1996, 1998—2000	Cobalt-60	9/12	0.044	1999
	Bream	1996—2000	Gross Alpha	5/15	0.125	1997
		1996—2000	Gross Beta	15/15	3.17	1998
		1996, 1998—2000	Cesium-137	12/12	0.18	1998
		1996, 1998—2000	Cobalt-60	10/12	0.020	1996
	Catfish	1994, 1996—2000	Gross Alpha	6/21	0.112	1998
		1994, 1996—2000	Gross Beta	20/20	3.98	1994
		1996, 1998—2000	Cesium-137	15/15	0.11	1996
		1996, 1998—2000	Cobalt-60	10/15	0.030	1999
	Panfish	1994	Gross Alpha	1/3	0.086	1994
			Gross Beta	3/3	2.78	1994
	Mullet (marine)	1993, 1995—2000	Gross Alpha	9/19	0.241	1993
		1993, 1995—2000	Gross Beta	19/19	2.60	1995
		1993, 1996—2000	Cesium-137	14/18	0.56	1993
		1996—2000	Cobalt-60	6/15	0.041	1996
	Red Fish, Drum (marine)	1997—2000	Gross Alpha	2/11	0.140	1999
		1997—2000	Gross Beta	11/11	3.07	1998
		1997—2000	Cesium-137	9/11	0.06	1997, 2000
		1997—2000	Cobalt-60	6/11	0.033	1999

Table C-1: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (1993-2000) —DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
	Sea Trout (marine)	1996, 1999	Gross Alpha	1/4	0.073	1996
		1996, 1999	Gross Beta	2/4	1.93	1999
		1996, 1999	Cesium-137	3/4	0.04	1996
		1996, 1999	Cobalt-60	3/4	0.011	1999
Highway 301 (Bridge Area)	Bass	1993,1994,1996—2000	Gross Alpha	7/18	0.132	2000
		1993, 1994,1996—2000	Gross Beta	18/18	3.29	2000
		1993, 1994, 1996—2000	Cesium-137	16/18	0.75	1999
		1996 — 2000	Cobalt-60	11/15	0.024	1998
		1993, 1994, 1996—2000	Plutonium-238	9/18	0.00008	1997
		1993, 1996—2000	Plutonium-239	8/17	0.00002	1999
		1996—2000	Strontium-89/90	15/15	0.012	2000
		1993, 1994	Strontium-90	2/3	0.009	1993
		1993, 1994, 1996 —2000	Tritium (Hydrogen-3)	18/18	0.41	1998
	Bream	1993,1995—2000	Gross Alpha	4/21	0.252	1993
		1993, 1995—2000	Gross Beta	21/21	3.50	1997
		1993, 1995—2000	Cesium-137	19/21	0.09	1995
		1996 — 2000	Cobalt-60	9/15	0.047	1996
		1993, 1995—2000	Plutonium-238	10/21	0.00019	1997
		1993, 1995—2000	Plutonium-239	8/21	0.00007	1998
		1995—2000	Strontium-89/90	15/17	0.025	2000
		1993	Strontium-90	3/3	0.009	1993
		1993, 1995 —2000	Tritium (Hydrogen-3)	21/21	0.49	1998
	Freshwater Catfish	1993 – 2000	Gross Alpha	4/22	6.03	1993
		1993 – 2000	Gross Beta	22/22	3.36	1997
		1993 – 2000	Cesium-137	21/22	0.21	2000
		1996 – 2000	Cobalt-60	6/15	0.015	2000
		1993 – 2000	Plutonium-238	10/22	0.00007	1996

Table C-1: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (1993-2000) —DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
		1993 – 2000	Plutonium-239	5/22	0.00004	1996
		1994 – 2000	Strontium-89/90	17/19	0.011	1997
		1993, 1994	Strontium-90	3/4	0.013	1994
		1993 – 2000	Tritium (Hydrogen-3)	22/22	0.49	2000
	Shad	1999	Gross Alpha	1/3	0.107	1999
			Gross Beta	3/3	2.46	1999
			Cesium-137	3/3	0.05	1999
			Cobalt-60	1/3	0.009	1999
			Plutonium-238	1/3	0.00010	1999
			Strontium-89/90	3/3	0.016	1999
			Tritium (Hydrogen-3)	3/3	0.26	1999
	Sucker	1998	Gross Alpha	1/3	0.048	1998
			Gross Beta	3/3	2.38	1998
			Cesium-137	3/3	0.13	1998
			Cobalt-60	1/3	0.017	1998
			Plutonium-238	1/3	0.00002	1998
			Plutonium-239	2/3	0.00000	1998
			Strontium-89/90	3/3	0.019	1998
			Tritium (Hydrogen-3)	3/3	0.15	1998
	Bowfin	1998	Gross Alpha	3/3	0.343	1998
			Gross Beta	3/3	3.50	1998
			Cesium-137	3/3	0.11	1998
			Cobalt-60	3/3	0.015	1998
			Plutonium-239	1/3	0.00002	1998
			Strontium-89/90	1/3	0.005	1998
			Tritium (Hydrogen-3)	3/3	0.92	1998
	Panfish	1994	Gross Beta	4/4	3.78	1994

Table C-1: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (1993-2000) —DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
			Cesium-137	2/2	0.11	1994
			Plutonium-238	1/2	0.00000	1994
			Plutonium-239	1/3	0.00000	1994
			Strontium-89/90	1/4	0.036	1994
			Tritium (Hydrogen-3)	4/4	0.08	1994
Lower Three Runs Creek (River Mouth)	Bass	1993,1994,1996—2000	Gross Alpha	6/17	0.146	2000
		1993, 1994,1996—2000	Gross Beta	17/17	3.57	1997
		1993, 1994, 1996—2000	Cesium-137	17/17	0.79	2000
		1996 — 2000	Cobalt-60	12/17	0.027	1997
		1994, 1996—2000	Plutonium-238	5/16	0.00005	1997
		1994, 1996—2000	Plutonium-239	7/16	0.00008	1996
		1996—2000	Strontium-89/90	15/15	0.017	1996
		1993, 1994	Strontium-90	2/2	0.005	1993
		1993, 1994, 1996 —2000	Tritium (Hydrogen-3)	17/17	0.99	1998
	Bream	1993, 1995 – 2000	Gross Alpha	2/19	0.127	1998
		1993, 1995 – 2000	Gross Beta	19/19	3.15	1997
		1993, 1995 – 2000	Cesium-137	19/19	0.80	1994
		1996 – 2000	Cobalt-60	10/15	0.030	1999
		1993, 1996 – 2000	Plutonium-238	5/18	0.00015	1993
		1993, 1996 – 2000	Plutonium-239	7/18	0.00007	1996
		1996 – 2000	Strontium-89/90	11/16	0.047	1999
		1993	Strontium-90	3/3	0.045	1993
		1993, 1996 - 2000	Tritium (Hydrogen-3)	19/19	0.85	1998

Table C-1: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (1993-2000) —DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
	Freshwater Catfish	1993 – 2000	Gross Alpha	9/23	0.141	1997
		1993 – 2000	Gross Beta	23/23	4.70	1994
		1993 – 2000	Cesium-137	23/23	1.33	1994
		1996 – 2000	Cobalt-60	7/15	0.044	1998
		1993 – 2000	Plutonium-238	11/21	0.00004	1997
		1993 – 2000	Plutonium-239	10/21	0.00007	1996
		1995 – 2000	Strontium-89/90	11/16	0.013	2000
		1993, 1994	Strontium-90	6/6	0.024	1994
		1993 – 2000	Tritium (Hydrogen-3)	23/23	0.71	1998
	Panfish	1994	Gross Alpha	2/4	0.098	1994
			Gross Beta	4/4	4.70	1994
			Cesium-137	4/4	0.80	1994
			Plutonium-238	1/4	0.00004	1994
			Plutonium-239	1/4	0.00006	1994
			Strontium-89/90	1/2	0.704	1994
			Strontium-90	4/4	0.225	1994
			Tritium (Hydrogen-3)	4/4	0.07	1994
Lower Three Runs Creek at Patterson Mill Road (DOE now considers this an on-site sample location; however, it was not originally part of the site)	Bass	1993,1997—2000	Gross Alpha	2/14	0.539	1999
		1993, 1997—2000	Gross Beta	14/14	13.6	1993
		1993, 1997—2000	Cesium-137	15/15	7.22	1997
		1997—2000	Cobalt-60	5/12	0.033	1998
	Bream	1993, 1997—1999	Gross Alpha	6/14	0.449	1993
		1993, 1997—1999	Gross Beta	14/14	8.84	1993
		1993, 1997—1999	Cesium-137	14/14	3.45	1993
		1997—1999	Cobalt-60	5/12	0.043	1999
	Crappie	1993	Gross Alpha	1/1	0.45	1993
			Gross Beta	1/1	8.16	1993

Table C-1: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (1993-2000) —DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
			Cesium-137	1/1	2.68	1993
Steel Creek (Mouth)	Bass	1993—2000	Gross Alpha	7/20	0.100	1997
		1993—2000	Gross Beta	20/20	4.97	1996
		1993, 1995 —2000	Cesium-137	18/18	2.99	1996
		1996—2000	Cobalt-60	12/15	0.049	1998
		1993, 1995—2000	Plutonium-238	8/18	0.00011	1993
		1993, 1995—2000	Plutonium-239	8/18	0.00005	1993
		1995—2000	Strontium-89/90	16/16	0.021	1999
		1993, 1994	Strontium-90	4/4	0.027	1993
		1993—2000	Tritium (Hydrogen-3)	20/20	4.70	1996
	Bream	1993, 1995 – 2000	Gross Alpha	7/19	0.320	1993
		1993, 1995 – 2000	Gross Beta	19/19	4.69	1993
		1993, 1995 – 2000	Cesium-137	17/18	0.73	1996
		1996 – 2000	Cobalt-60	12/15	0.031	2000
		1993, 1995 – 2000	Plutonium-238	9/19	0.00009	1998
		1993, 1995 – 2000	Plutonium-239	7/19	0.00008	2000
		1995 – 2000	Strontium-89/90	15/17	0.024	1999
		1993	Strontium-90	2/2	0.011	1993
		1993, 1995 - 2000	Tritium (Hydrogen-3)	20/20	5.05	1996
	Freshwater Catfish	1993 – 2000	Gross Alpha	4/23	0.126	1998
		1993 – 2000	Gross Beta	23/23	5.09	1995
		1993 – 2000	Cesium-137	23/23	0.49	1996
		1996 – 2000	Cobalt-60	10/15	0.023	1998
		1993 – 2000	Plutonium-238	8/23	0.00007	1998
		1993 – 2000	Plutonium-239	11/21	0.00005	1998
		1994 – 2000	Strontium-89/90	19/19	0.092	1994
		1993, 1994	Strontium-90	5/5	0.025	1994

Table C-1: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (1993-2000) —DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
		1993 – 2000	Tritium (Hydrogen-3)	23/23	4.26	1996
	Shad	1999	Gross Alpha	1/3	0.132	1999
			Gross Beta	3/3	1.69	1999
			Cesium-137	3/3	0.13	1999
			Cobalt-60	2/3	0.014	1999
			Strontium-89/90	3/3	0.013	1999
			Tritium (Hydrogen-3)	3/3	0.54	1999
	Sucker	1998	Gross Beta	3/3	2.82	1998
			Cesium-137	3/3	0.33	1998
			Cobalt-60	1/3	0.011	1998
			Plutonium-238	1/1	0.00002	1998
			Strontium-89/90	3/3	0.027	1998
			Tritium (Hydrogen-3)	3/3	0.82	1998
	Bowfin	1998	Gross Alpha	1/3	0.234	1998
			Gross Beta	3/3	2.84	1998
			Cesium-137	3/3	0.44	1998
			Plutonium-238	1/3	0.00001	1998
			Strontium-89/90	1/3	0.005	1998
			Tritium (Hydrogen-3)	3/3	0.59	1998
Stokes Bluff Landing	Bass	1993, 1996—2000	Gross Alpha	10/18	0.462	1996
		1993, 1996—2000	Gross Beta	18/18	3.42	1998
		1993, 1996—2000	Cesium-137	18/18	0.14	1999
		1996—2000	Cobalt-60	9/15	0.024	1999
	Bream	1993, 1996—2000	Gross Alpha	6/16	0.734	1999
		1993, 1996—2000	Gross Beta	16/16	4.36	1993
		1993, 1996—2000	Cesium-137	15/17	0.30	2000
		1996—2000	Cobalt-60	8/14	0.038	1997

Table C-1: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (1993-2000) —DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
	Freshwater Catfish	1993, 1996—2000	Gross Alpha	5/16	0.140	1999
		1993, 1996—2000	Gross Beta	16/16	3.66	1998
		1993, 1996—2000	Cesium-137	15/16	5.75	1993
		1996—2000	Cobalt-60	3/13	0.023	2000
Upper Three Runs Creek (River Mouth)	Bass	1996—2000	Gross Alpha	4/15	0.008	1996
		1996—2000	Gross Beta	15/15	3.82	1997
		1996—2000	Cesium-137	15/15	0.87	1997
		1996—2000	Cobalt-60	10/15	0.018	2000
		1996—2000	Plutonium-238	5/15	0.00013	1996
		1996—2000	Plutonium-239	10/15	0.00007	1996
		1996—2000	Strontium-89/90	13/15	0.036	1997
		1996—2000	Tritium (Hydrogen-3)	14/15	1.02	1998
	Bream	1996—2000	Gross Alpha	3/15	0.447	1999
		1996—2000	Gross Beta	15/15	3.54	1998
		1996—2000	Cesium-137	15/15	0.12	1996
		1996—2000	Cobalt-60	9/15	0.035	1999
		1996—2000	Plutonium-238	10/15	0.00032	1997
		1996—2000	Plutonium-239	5/15	0.00026	2000
		1996—2000	Strontium-89/90	13/15	0.029	1997
		1996—2000	Tritium (Hydrogen-3)	15/15	1.07	1998
	Freshwater Catfish	1993—2000	Gross Alpha	5/23	0.249	1993
		1993—2000	Gross Beta	23/23	3.64	1999
		1993—2000	Cesium-137	20/21	0.13	1996
		1996—2000	Cobalt-60	7/15	0.029	1997
		1993—2000	Plutonium-238	7/22	0.00015	1998
		1993—2000	Plutonium-239	9/23	0.00006	1999
		1994—2000	Strontium-89/90	14/20	0.013	1998

Table C-1: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (1993-2000) —DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
		1994	Strontium-90	4/4	0.019	1994
		1993—2000	Tritium (Hydrogen-3)	23/23	0.28	1999
West Bank Landing	Bass	1993	Cesium-137	1/1	0.25	1993
			Plutonium-239	1/1	0.00003	1993
	Bream	1993	Gross Beta	1/1	2.12	1993
			Strontium-90	1/1	0.007	1993
	Crappie	1993	Gross Alpha	1/2	0.227	1993
			Gross Beta	2/2	2.71	1993
			Cesium-137	1/2	0.45	1993
			Plutonium-238	1/1	0.00002	1993
			Plutonium-239	1/1	0.00003	1993
			Strontium-90	3/3	0.067	1993

Source: Savannah River Environmental Data Reports for 1993 through 2000 (WSRC ND[b through i]).

pCi/g = picocuries per gram
Small differences in the values may occur due to rounding

Note: If a specific radiological contaminant was not detected at all in a fish species, it is not reported in this table.

Samples collected with “unknown” species designation are not included in this table.

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SRS FISH SAMPLING 2001— 2008 [off-site edible]
3464 (The data does not include samples marked non-edible)

Table C-2: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (2001-2008)—DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
Augusta Lock and Dam	Bass	2006—2008	Americium-241	5/9	0.0000164	2008
		2001—2008	Cesium-137	20/24	0.08	2005
		2006—2008	Curium-244	4/8	0.00000873	2006
		2001—2008	Cobalt-60	12/24	0.0282	2003
		2001—2008	Gross Alpha	6/24	0.115	2004
		2001—2008	Gross Beta	24/24	4.41	2004
		2001—2008	Hydrogen-3 (tritium)	15/24	0.13	2006
		2001—2008	Plutonium-238	13/23	0.00011	2007
		2001—2008	Plutonium-239	11/23	0.0000166	2008
		2001—2008	Strontium-89/90	23/24	0.00865	2001
		2006—2008	Technetium-99	4/9	0.0481	2008
		2006—2008	Uranium-234	9/9	0.000214	2006
		2006—2008	Uranium-235	7/9	0.0000384	2008
		2006—2008	Uranium-238	9/9	0.000168	2008
	Bream	2006—2008	Americium-241	7/9	0.0000247	2007
		2001—2008	Cesium-137	13/24	0.06	2004
		2006—2008	Curium-244	4/9	0.0000376	2007
		2001—2008	Cobalt-60	15/24	0.0301	2003
		2001—2008	Gross Alpha	4/24	0.125	2004
		2001—2008	Gross Beta	24/24	4.51	2004
		2001—2008	Hydrogen-3 (tritium)	19/24	0.12	2006
		2006—2008	Iodine-129	3/9	0.0151	2007
		2001—2008	Plutonium-238	15/22	0.000233	2007
		2001—2008	Plutonium-239	12/22	0.0000622	2007

Table C-2: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (2001-2008)—DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
		2001—2008	Strontium-89/90	21/24	0.0134	2002
		2006—2008	Technetium-99	7/9	0.0419	2008
		2006—2008	Uranium-234	9/9	0.000354	2007
		2006—2008	Uranium-235	6/9	0.00011	2007
		2006—2008	Uranium-238	9/9	0.000215	2008
	Catfish	2006—2008	Americium-241	7/9	0.0000254	2007
		2001—2008	Cesium-137	19/24	0.07	2004
		2006—2008	Curium-244	5/9	0.00007	2006
		2001—2008	Cobalt-60	14/24	0.0375	2001
		2001—2008	Gross Alpha	13/24	0.395	2002
		2001—2008	Gross Beta	24/24	42.9	2002
		2001—2008	Hydrogen-3 (tritium)	18/24	0.08	2006
		2006—2008	Iodine-129	5/9	0.0199	2007
		2001—2008	Plutonium-238	18/23	0.000389	2006
		2001—2008	Plutonium-239	12/23	0.0000703	2006
		2001—2008	Strontium-89/90	21/24	0.0134	2006
		2006—2008	Technetium-99	3/9	0.033	2008
		2006—2008	Uranium-234	9/9	0.00497	2006
		2006—2008	Uranium-235	9/9	0.00033	2006
		2006—2008	Uranium-238	9/9	0.00581	2006

Table C-2: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (2001-2008)—DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
Beaver Dam Creek [BDC] [Mouth]	Bass	2006—2008	Americium-241	3/9	0.0000199	2007
		2001—2008	Cesium-137	24/24	0.23	2006
		2006—2008	Curium-244	6/9	0.0000276	2007
		2001—2008	Cobalt-60	18/24	0.0314	2005
		2001—2008	Gross Alpha	7/24	0.0554	2004
		2001—2008	Gross Beta	23/23	3.38	2004
		2001—2008	Hydrogen-3 (tritium)	21/23	0.377	2006
		2006—2008	Iodine-129	4/9	0.0083	2006
		2001—2008	Plutonium-238	14/22	0.000132	2007
		2001—2008	Plutonium-239	14/22	0.0000286	2007
		2001—2008	Strontium-89/90	22/24	0.0159	2001
		2006—2008	Technetium-99	3/9	0.00105	2007
		2006—2008	Uranium-234	9/9	0.000159	2006
		2006—2008	Uranium-235	7/9	0.0000816	2008
		2006—2008	Uranium-238	9/9	0.00021	2006
	Bream	2006—2008	Americium-241	4/9	0.0000158	2008
		2001—2008	Cesium-137	19/24	0.10	2002
		2006—2008	Curium-244	2/9	0.0000084	2006
		2001—2008	Cobalt-60	18/24	0.03	2007
		2001—2008	Gross Alpha	7/24	0.211	2007
		2001—2008	Gross Beta	24/24	3.76	2004
		2001—2008	Hydrogen-3 (tritium)	21/24	0.887	2006
		2006—2008	Iodine-129	7/9	0.0162	2006
		2001—2008	Plutonium-238	17/24	0.000153	2002
		2001—2008	Plutonium-239	15/24	0.0000362	2007
		2001—2008	Strontium-89/90	24/24	0.0371	2002
		2006—2008	Technetium-99	6/9	0.00905	2008

Table C-2: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (2001-2008)—DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
		2006—2008	Uranium-234	9/9	0.000257	2007
		2006—2008	Uranium-235	6/9	0.000126	2008
		2006—2008	Uranium-238	9/9	0.000234	2008
	Catfish (FW)	2006—2008	Americium-241	6/9	0.0000175	2007
		2001—2008	Cesium-137	22/24	0.08	2006
		2006—2008	Curium-244	3/9	0.0000265	2006
		2001—2008	Cobalt-60	9/24	0.0205	2007
		2001—2008	Gross Alpha	9/24	0.258	2003
		2001—2008	Gross Beta	24/24	3.15	2001
		2001—2008	Hydrogen-3 (tritium)	17/24	0.20	2006
		2006—2008	Iodine-129	3/9	0.00957	2008
		2001—2008	Plutonium-238	15/24	0.0000959	2007
		2001—2008	Plutonium-239	11/24	0.0000730	2007
		2001—2008	Strontium-89/90	23/24	0.00593	2003
		2006—2008	Technetium-99	7/9	0.0386	2006
		2006—2008	Uranium-234	9/9	0.000234	2007
		2006—2008	Uranium-235	8/9	0.0000641	2008
		2006—2008	Uranium-238	9/9	0.000221	2006

Table C-2: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (2001-2008)—DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
Four Mile Creek (River Mouth)	Bass	2006–2008	Americium-241	7/9	0.000131	2006
		2001–2008	Cesium-137	24/24	1.14	2004
		2006–2008	Curium-244	3/9	0.00000816	2007
		2001–2008	Cobalt-60	15/24	0.0293	2001
		2001–2008	Gross Alpha	11/24	0.188	2008
		2001–2008	Gross Beta	24/24	4.6	2003
		2001–2008	Hydrogen-3 (tritium)	21/24	1.29	2005
		2006–2008	Iodine-129	3/9	0.00681	2006
		2001–2008	Plutonium-238	17/23	0.000176	2006
		2001–2008	Plutonium-239	14/23	0.0000405	2007
		2001–2008	Strontium-89/90	24/24	0.0322	2006
		2006–2008	Technetium-99	8/9	0.147	2006
		2006–2008	Uranium-234	9/9	0.000646	2006
		2006–2008	Uranium-235	5/9	0.000163	2006
		2006–2008	Uranium-238	9/9	0.00083	2006
	Bream	2006–2008	Americium-241	7/9	0.0000389	2006
		2001–2008	Cesium-137	20/24	0.13	2004
		2006–2008	Curium-244	3/9	0.0000189	2006
		2001–2008	Cobalt-60	15/24	0.0259	2002
		2001–2008	Gross Alpha	9/24	0.181	2001
		2001–2008	Gross Beta	24/24	3.86	2004
		2001–2008	Hydrogen-3 (tritium)	20/21	0.79	2001
		2006–2008	Iodine-129	7/12	0.00632	2008
		2001–2008	Plutonium-238	16/24	0.000397	2007
		2001–2008	Plutonium-239	12/24	0.0000865	2007
		2001–2008	Strontium-89/90	23/24	0.0148	2004
		2006–2008	Technetium-99	2/9	0.0441	2006

Table C-2: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (2001-2008)—DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
		2006—2008	Uranium-234	9/9	0.000386	2007
		2006—2008	Uranium-235	5/9	0.0000681	2007
		2006—2008	Uranium-238	9/9	0.0003030	2007
	Catfish	2006—2008	Americium-241	5/9	0.000159	2006
		2001—2008	Cesium-137	20/24	0.1	2001
		2006—2008	Curium-244	6/9	0.0000092	2007
		2001—2008	Cobalt-60	16/24	0.0383	2001
		2001—2008	Gross Alpha	8/24	0.187	2002
		2001—2008	Gross Beta	24/24	3.08	2005
		2001—2008	Hydrogen-3 (tritium)	20/24	0.36	2001
		2006—2008	Iodine-129	3/9	0.00751	2007
		2001—2008	Plutonium-238	15/24	0.000497	2006
		2001—2008	Plutonium-239	9/24	0.0000419	2006
		2001—2008	Strontium-89/90	21/24	0.0276	2006
		2006—2008	Technetium-99	6/9	0.0148	2006
		2006—2008	Uranium-234	9/9	0.0265	2006
		2006—2008	Uranium-235	7/9	0.00172	2006
		2006—2008	Uranium-238	9/9	0.0255	2006

Table C-2: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (2001-2008)—DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
Highway 17A (Bridge Area)	Bass	2006–2008	Americium-241	3/12	0.00033	2007
		2001–2008	Cesium-137	25/27	0.42	2002
		2006–2008	Curium-244	5/12	0.0000641	2006
		2001–2008	Cobalt-60	15/27	0.051	2002
		2001–2008	Gross Alpha	10/27	0.211	2001
		2001–2008	Gross Beta	27/27	3.24	2007
		2001–2008	Hydrogen-3 (tritium)	10/12	0.121	2008
		2006–2008	Iodine-129	5/12	0.00446	2008
		2001–2008	Plutonium-238	12/12	0.00514	2007
		2001–2008	Plutonium-239	7/12	0.000234	2006
		2001–2008	Strontium-89/90	12/12	3.00	2007
		2006–2008	Technetium-99	11/12	0.705	2006
		2006–2008	Uranium-234	13/13	0	2006
		2006–2008	Uranium-235	9/12	0.00261	2006
		2006–2008	Uranium-238	12/12	0.000357	2007
					0.004	
	Bream	2006–2008	Americium-241	5/12	0.00007	2008
		2001–2008	Cesium-137	15/24	0.07	2001
		2006–2008	Curium-244	6/12	0.000108	2006
		2001–2008	Cobalt-60	14/24	0.111	2003
		2001–2008	Gross Alpha	8/24	0.155	2006
		2001–2008	Gross Beta	24/24	3.57	2004
		2001–2008	Hydrogen-3 (tritium)	11/12	0.07	2007
		2006–2008	Iodine-129	6/12	0.0532	2007
		2001–2008	Plutonium-238	12/12	0.000565	2006
		2001–2008	Plutonium-239	8/12	0.000152	2006
		2001–2008	Strontium-89/90	12/12	0.136	2006

Table C-2: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (2001-2008)—DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
		2005--2008	Technetium-99	10/12	0.164	2005
		2006—2008	Uranium-234	12/12	0.00338	2006
		2006—2008	Uranium-235	10/12	0.000266	2006
		2006—2008	Uranium-238	12/12	0.00219	2006
	Catfish	2006—2008	Americium-241	5/12	0.000214	2006
		2001—2008	Cesium-137	27/27	0.20	2002
		2006—2008	Curium-244	9/12	0.0000859	2006
		2001—2008	Cobalt-60	21/27	0.0466	2001
		2001—2008	Gross Alpha	13/27	0.256	2007
		2001—2008	Gross Beta	27/27	3.08	2004
		2001—2008	Hydrogen-3 (tritium)	12/12	0.13	2007
		2006—2008	Iodine-129	6/12	0.0139	2007
		2001—2008	Plutonium-238	12/12	0.000261	2006
		2001—2008	Plutonium-239	12/12	0.000249	2006
		2001—2008	Strontium-89/90	12/12	0.102	2006
		2005--2008	Technetium-99	8/12	0.0266	2005
		2005—2008	Uranium-234	12/12	0.00248	2005
		2005--2008	Uranium-235	5/12	0.0000346	2008
		2006—2008	Uranium-238	12/12	0.00212	2006

Table C-2: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (2001-2008)—DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
Highway 301 (Bridge Area)	Bass	2006–2008	Americium-241	3/9	0.000009	2007
		2001–2008	Cesium-137	24/24	0.09	2002
		2006–2008	Curium-244	6/9	0.0000109	2006
		2001–2008	Cobalt-60	13/24	0.0179	2004
		2001–2008	Gross Alpha	9/24	0.212	2008
		2001–2008	Gross Beta	24/24	3.24	2005
		2001–2008	Hydrogen-3 (tritium)	22/24	0.6	2001
		2006–2008	Iodine-129	3/9	0.0047	2007
		2001–2008	Plutonium-238	17/24	0.000135	2007
		2001–2008	Plutonium-239	10/24	0.0000443	2007
		2001–2008	Strontium-89/90	22/24	0.0118	2001
		2006–2008	Technetium-99	8/9	0.0495	2006
		2006–2008	Uranium-234	9/9	0.000557	2006
		2006–2008	Uranium-235	6/9	0.0000354	2006
		2006–2008	Uranium-238	9/9	0.000519	2006
	Bream	2006–2008	Americium-241	3/9	0.0000327	2007
		2001–2008	Cesium-137	17/24	0.04	2001
		2006–2008	Curium-244	4/9	0.0000222	2007
		2001–2008	Cobalt-60	12/24	0.0116	2008
		2001–2008	Gross Alpha	6/24	0.0741	2006
		2001–2008	Gross Beta	24/24	4.08	2004
		2001–2008	Hydrogen-3 (tritium)	20/24	0.57	2001
		2006–2008	Iodine-129	4/9	0.0111	2007
		2001–2008	Plutonium-238	15/23	0.000189	2007
		2001–2008	Plutonium-239	8/23	0.0000668	2006
		2001–2008	Strontium-89/90	24/24	0.0289	2005
		2006–2008	Technetium-99	6/9	0.0324	2006

Table C-2: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (2001-2008)—DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
		2006–2008	Uranium-234	9/9	0.000273	2007
		2006–2008	Uranium-235	9/9	0.0000992	2006
		2006–2008	Uranium-238	9/9	0.000349	2006
	Catfish	2006–2008	Americium-241	4/9	0.0000156	2007
		2001–2008	Cesium-137	24/24	0.06	2001
		2006–2008	Curium-244	7/9	0.0000181	2007
		2001–2008	Cobalt-60	20/24	0.0178	2003
		2001–2008	Gross Alpha	12/24	0.113	2007
		2001–2008	Gross Beta	24/24	4.03	2004
		2001–2008	Hydrogen-3 (tritium)	20/24	0.543	2001
		2006–2008	Iodine-129	4/9	0.00484	2007
		2001–2008	Plutonium-238	16/24	0.0001	2007
		2001–2008	Plutonium-239	9/24	0.0000161	2006
		2001–2008	Strontium-89/90	22/24	0.0122	2001
		2006–2008	Technetium-99	6/9	0.0422	2008
		2006–2008	Uranium-234	9/9	0.000349	2008
		2006–2008	Uranium-235	4/9	0.0000695	2006
		2006–2008	Uranium-238	9/9	0.000322	2008

Table C-2: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (2001-2008)—DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
Lower 3-Runs Creek (River Mouth)	Bass	2006—2008	Americium-241	4/9	0.0000524	2007
		2001—2008	Cesium-137	24/24	0.65	2002
		2006—2008	Curium-244	5/9	0.0000327	2007
		2001—2008	Cobalt-60	15/24	0.0276	2004
		2001—2008	Gross Alpha	11/24	0.276	2007
		2001—2008	Gross Beta	24/24	3.11	2004
		2001—2008	Hydrogen-3 (tritium)	24/24	0.597	2001
		2006—2008	Iodine-129	6/9	0.013	2006
		2001—2008	Plutonium-238	16/23	0.0000962	2007
		2001—2008	Plutonium-239	9/23	0.0000392	2007
		2001—2008	Strontium-89/90	24/24	0.0119	2006
		2006—2008	Technetium-99	5/9	0.0597	2006
		2006—2008	Uranium-234	9/9	0.000261	2006
		2006—2008	Uranium-235	3/9	0.0000182	2006
		2006—2008	Uranium-238	9/9	0.000243	2006
	Bream	2006—2008	Americium-241	3/9	0.0000196	2008
		2001—2008	Cesium-137	20/24	0.09	2005
		2006—2008	Curium-244	5/9	0.00000878	2006
		2001—2008	Cobalt-60	16/24	0.0338	2005
		2001—2008	Gross Alpha	11/24	0.205	2004
		2001—2008	Gross Beta	24/24	3.19	2004
		2001—2008	Hydrogen-3 (tritium)	21/24	0.585	2001
		2006—2008	Iodine-129	6/9	0.0519	2006
		2001—2008	Plutonium-238	15/24	0.000405	2007
		2001—2008	Plutonium-239	6/24	0.000053	2007
		2001—2008	Strontium-89/90	23/24	0.0174	2002
		2006—2008	Uranium-234	9/9	0.000256	2008

Table C-2: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (2001-2008)—DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
		2006—2008	Uranium-235	6/9	0.0000295	2007
		2006—2008	Uranium-238	9/9	0.00021	2008
	Catfish	2006—2008	Americium-241	4/9	0.000018	2008
		2001—2008	Cesium-137	24/24	0.14	2006
		2006—2008	Curium-244	4/9	0.0000267	2007
		2001—2008	Cobalt-60	18/24	0.0436	2003
		2001—2008	Gross Alpha	11/24	0.267	2004
		2001—2008	Gross Beta	24/24	2.68	2004
		2001—2008	Hydrogen-3 (tritium)	21/24	0.368	2006
		2006—2008	Iodine-129	5/9	0.00689	2008
		2001—2008	Plutonium-238	20/24	0.000139	2007
		2001—2008	Plutonium-239	10/24	0.0000236	2007
		2001—2008	Strontium-89/90	18/24	0.0104	2001
		2006—2008	Technetium-99	4/9	0.0692	2006
		2006—2008	Uranium-234	9/9	0.000278	2008
		2006—2008	Uranium-235	6/9	0.0000438	2008
		2006—2008	Uranium-238	9/9	0.000265	2008
Lower 3-Runs Creek	Bream	2006	Cesium-137	2/3	0.0306	2006
[Patterson Mill Road]		2006	Cobalt-60	3/3	2.24	2006
Designated as on-site by DOE		2006	Gross Alpha	1/3	0.232	2006
		2006	Gross Beta	3/3	3.9	2006

Table C-2: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (2001-2008)—DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
Steel Creek (River Mouth)	Bass	2006–2008	Americium-241	4/9	0.00000846	2006
		2001–2008	Cesium-137	24/24	0.29	2006
		2006–2008	Curium-244	5/9	0.0000164	2008
		2001–2008	Cobalt-60	10/24	0.0319	2002
		2001–2008	Gross Alpha	11/24	0.182	2002
		2001–2008	Gross Beta	24/24	3.89	2004
		2001–2008	Hydrogen-3 (tritium)	22/24	0.473	2006
		2006–2008	Iodine-129	1/9	0.0112	2006
		2001–2008	Plutonium-238	23/24	0.000114	2008
		2001–2008	Plutonium-239	10/24	0.0000289	2007
		2001–2008	Strontium-89/90	20/24	0.0101	2006
		2006–2008	Technetium-99	4/9	0.0914	2006
		2006–2008	Uranium-234	9/9	0.000319	2006
		2006–2008	Uranium-235	4/9	0.0000202	2006
		2006–2008	Uranium-238	9/9	0.000311	2006
	Bream	2006–2008	Americium-241	6/9	0.0000365	2006
		2001–2008	Cesium-137	22/24	0.23	2005
		2006–2008	Curium-244	23/24	0.0000183	2008
		2001–2008	Cobalt-60	14/24	0.0146	2002
		2001–2008	Gross Alpha	7/24	0.217	2001
		2001–2008	Gross Beta	24/24	3.54	2008
		2001–2008	Hydrogen-3 (tritium)	23/24	0.368	2007
		2006–2008	Iodine-129	4/9	0.0043	2007
		2001–2008	Plutonium-238	18/24	0.00021	2008
		2001–2008	Plutonium-239	15/24	0.0000814	2006
		2001–2008	Strontium-89/90	21/24	0.0397	2007
		2006–2008	Technetium-99	6/9	0.0589	2006

Table C-2: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (2001-2008)—DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
		2006—2008	Uranium-234	8/9	0.000253	2007
		2006—2008	Uranium-235	4/9	0.0000484	2008
		2006—2008	Uranium-238	9/9	0.000538	2006
	Catfish	2006—2008	Americium-241	4/9	0.000043	2007
		2001—2008	Cesium-137	24/24	0.14	2003
		2006—2008	Curium-244	4/9	0.0000195	2006
		2001—2008	Cobalt-60	16/24	0.0408	2001
		2001—2008	Gross Alpha	6/24	0.135	2006
		2001—2008	Gross Beta	24/24	3.27	2007
		2001—2008	Hydrogen-3 (tritium)	23/24	0.262	2001
		2006—2008	Iodine-129	3/9	0.00589	2008
		2001—2008	Plutonium-238	17/23	0.000324	2005
		2001—2008	Plutonium-239	11/23	0.0000722	2006
		2001—2008	Strontium-89/90	22/24	0.0164	2006
		2006—2008	Technetium-99	5/9	0.0657	2008
		2006—2008	Uranium-234	9/9	0.00416	2006
		2006—2008	Uranium-235	8/9	0.000167	2006
		2006—2008	Uranium-238	9/9	0.00378	2006

Table C-2: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (2001-2008)—DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
Stokes Bluff Landing	Bass	2006—2008	Americium-241	6/12	0.00033	2007
		2001—2008	Cesium-137	23/27	0.10	2002
		2006—2008	Curium-244	3/12	0.0000659	2006
		2001—2008	Cobalt-60	17/27	0.0401	2001
		2001—2008	Gross Alpha	8/27	0.468	2004
		2001—2008	Gross Beta	27/27	4.15	2003
		2001—2008	Hydrogen-3 (tritium)	11/12	0.157	2008
		2006—2008	Iodine-129	6/12	0.00959	2008
		2001—2008	Plutonium-238	12/12	0.00176	2007
		2001—2008	Plutonium-239	6/12	0.000284	2007
		2001—2008	Strontium-89/90	12/12	0.37	2007
		2006—2008	Technetium-99	4/12	0.021	2006
		2002, 2006--2008	Uranium-234	12/12	0.00524	2007
		2006—2008	Uranium-235	5/12	0.000343	2007
		2002, 2006--2008	Uranium-238	11/12	0.00246	2007
	Bream	2006—2008	Americium-241	6/12	0.00005	2008
		2001—2008	Cesium-137	16/24	0.05	2001
		2006—2008	Curium-244	4/12	0.0000316	2007
		2001—2008	Cobalt-60	15/27	0.0378	2004
		2001—2008	Gross Alpha	7/27	0.0949	2003
		2001—2008	Gross Beta	27/27	3.59	2004
		2001—2008	Hydrogen-3 (tritium)	11/12	0.195	2006
		2006—2008	Iodine-129	6/12	0.0106	2008
		2001—2008	Plutonium-238	11/12	0.000819	2002
		2001—2008	Plutonium-239	9/12	0.000188	2001
		2001—2008	Strontium-89/90	12/12	0.187	2001
		2001, 2006--2008	Technetium-99	6/12	0.0768	2001

Table C-2: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (2001-2008)—DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
		2001, 2006--2008	Uranium-234	12/12	0.00176	2001
		2001, 2006--2008	Uranium-235	7/12	0.0000965	2001
		2002, 2006--2008	Uranium-238	11/12	0.00177	2002
	Catfish	2002, 2006--2008	Americium-241	4/12	0.0000228	2002
		2001—2008	Cesium-137	24/27	0.11	2001
		2001, 2006--2008	Curium-244	5/12	0.00007	2006 ,2001
		2001—2008	Cobalt-60	17/27	0.0385	2002
		2001—2008	Gross Alpha	8/27	0.219	2003
		2001—2008	Gross Beta	26/27	3.89	2003
		2001—2008	Hydrogen-3 (tritium)	8/12	0.02	2006, 2001
		2001, 2006--2008	Iodine-129	4/12	0.00854	2008
		2001—2008	Plutonium-238	11/12	0.000411	2002
		2001—2008	Plutonium-239	7/12	0.00007	2006, 2002
		2001—2008	Strontium-89/90	12/12	0.131	2002
		2001, 2006--2008	Technetium-99	9/12	0.0541	2001
		2001, 2006--2008	Uranium-234	12/12	0.00649	2001
		2002, 2006--2008	Uranium-235	10/12	0.000438	2002
		2002, 2006--2008	Uranium-238	12/12	0.006	2002

Table C-2: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (2001-2008)—DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
Upper 3-Runs Creek (Mouth)	Bass	2006–2008	Americium-241	5/9	0.0000684	2006
		2001–2008	Cesium-137	23/24	0.17	2005
		2006–2008	Curium-244	7/9	0.0000222	2006
		2001–2008	Cobalt-60	15/24	0.0181	2002
		2001–2008	Gross Alpha	11/24	0.403	2005
		2001–2008	Gross Beta	24/24	4.22	2004
		2001–2008	Hydrogen-3 (tritium)	22/24	0.542	2001
		2006–2008	Iodine-129	5/9	0.0209	2006
		2001–2008	Plutonium-238	17/24	0.000551	2006
		2001–2008	Plutonium-239	12/24	0.0000849	2006
		2001–2008	Strontium-89/90	23/24	0.0167	2006
		2006–2008	Technetium-99	7/9	0.0351	2008
		2006–2008	Uranium-234	9/9	0.000424	2006
		2006–2008	Uranium-235	7/9	0.0000446	2007
		2006–2008	Uranium-238	9/9	0.000468	2006
	Bream	2006–2008	Americium-241	5/9	0.0000349	2008
		2001–2008	Cesium-137	13/24	0.07	2001
		2006–2008	Curium-244	3/9	0.0000168	2006
		2001–2008	Cobalt-60	12/24	0.0226	2007
		2001–2008	Gross Alpha	7/24	0.235	2007
		2001–2008	Gross Beta	24/24	3.43	2004
		2001–2008	Hydrogen-3 (tritium)	21/24	0.17	2001
		2006–2008	Iodine-129	7/9	0.0164	2006
		2001–2008	Plutonium-238	13/24	0.000234	2007
		2001–2008	Plutonium-239	7/24	0.0000373	2008
		2001–2008	Strontium-89/90	24/24	0.0204	2001
		2006–2008	Technetium-99	7/9	0.121	2006

Table C-2: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (2001-2008)—DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
		2006–2008	Uranium-234	9/9	0.000266	2008
		2006–2008	Uranium-235	7/9	0.0000446	2008
		2006–2008	Uranium-238	9/9	0.000226	2008
	Catfish	2006–2008	Americium-241	5/9	0.0000101	2008
		2001–2008	Cesium-137	21/24	0.12	2008
		2006–2008	Curium-244	5/9	0.0000193	2008
		2001–2008	Cobalt-60	21/24	0.029	2002
		2001–2008	Gross Alpha	7/24	0.106	2002
		2001–2008	Gross Beta	24/24	3.57	2007
		2001–2008	Hydrogen-3 (tritium)	16/24	0.114	2002
		2006–2008	Iodine-129	5/9	0.0175	2006
		2001–2008	Plutonium-238	16/24	0.000128	2007
		2001–2008	Plutonium-239	9/24	0.0000563	2001
		2001–2008	Strontium-89/90	19/24	0.00697	2001
		2006–2008	Technetium-99	5/9	0.0489	2008
		2006–2008	Uranium-234	9/9	0.000236	2006
		2006–2008	Uranium-235	9/9	0.0000229	2007
		2006–2008	Uranium-238	9/9	0.000209	2006

Table C-2: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (2001-2008)—DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
West Bank Landing	Bass	2006 — 2008	Americium-241	3/9	0.000278	2007
		2006 — 2008	Cesium-137	10/10	0.08	2006
		2006 — 2008	Curium-244	2/9	0.0000171	2006
		2006 —2008	Cobalt-60	8/10	0.0211	2006
		2006 —2008	Gross Alpha	4/11	0.308	2007
		2006 —2008	Gross Beta	10/10	9.76	2006
		2006 —2008	Hydrogen-3 (tritium)	5/10	0.0281	2007
		2006, 2008	Iodine-129	3/9	0.00824	2006
		2006 —2008	Plutonium-238	6/10	0.00144	2007
		2006--2008	Plutonium-239	6/10	0.000159	2006
		2006--2008	Strontium-89/90	10/10	0.15	2006
		2006, 2008	Technetium-99	6/9	0.0638	2006
		2006, 2008	Uranium-234	10/10	0.00214	2006
		2006, 2008	Uranium-235	7/9	0.000132	2006
		2006--2008	Uranium-238	10/10	0.0022	2006
	Bream	2006, 2008	Americium-241	3/5	0.0000654	2006
		2006, 2008	Cobalt-60	2/5	0.0311	2006
		2006—2008	Cesium-137	5/6	0.05	2006
		2006, 2008	Gross Alpha	5/9	0.232	2008
		2006, 2008	Gross Beta	5/5	3.14	2008
		2006, 2008	Hydrogen-3 (tritium)	4/5	0.104	2008
		2008	Iodine-129	1/3	0.00359	2008
		2006, 2008	Plutonium-238	5/5	0.000241	2006
		2006, 2008	Plutonium-239	4/5	0.000077	2008
		2006, 2008	Strontium-89/90	5/5	0.161	2006
		2006, 2008	Technetium-99	3/5	0.125	2006
		2006, 2008	Uranium-234	5/5	0.00241	2006

Table C-2: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (2001-2008)—DOE

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)*	*Maximum Concentration (year)*
		2008	Uranium-235	1/3	0.00005	2008
		2006, 2008	Uranium-238	5/5	0.00177	2006
	Catfish	2006--2008	Americium-241	7/12	0.0000805	2007
		2006- 2008	Cesium-137	12/12	0.09	2006
		2006--2008	Curium-244	5/12	0.00007	2006
		2006--2008	Cobalt-60	7/12	0.025	2008
		2006--2008	Gross Alpha	9/18	0.167	2007
		2006--2008	Gross Beta	12/12	2.45	2008
		2006--2008	Hydrogen-3 (tritium)	4/12	0.0535	2006
		2006--2008	Iodine-129	5/12	0.00668	2006
		2006--2008	Plutonium-238	12/12	0.000608	2007
		2006--2008	Plutonium-239	10/12	0.000227	2006
		2006--2008	Strontium-89/90	10/12	0.0716	2006
		2006 —2008	Technetium-99	10/12	0.123	2006
		2006 —2008	Uranium-234	12/12	0.0023	2006
		2006--2008	Uranium-235	10/12	0.000147	2006
		2006--2008	Uranium-238	12/12	0.00357	2006

Source: Savannah River Site Environmental Data Reports for 2001 through 2008 (WSRC ND[j through p]; SRNS ND).
pCi/g = picocuries per gram
Note: If a specific radiological contaminant was not detected at all in a fish species, it is not reported in this table.
Samples collected with "unknown" species designation are not included in this table. Small differences in the values may occur due to rounding.
Values in parentheses represent samples designated as "on-site edible"

STATE OF GEORGIA FISH SAMPLING 1993— 2008 (off-site edible wet)

(The data does not include samples marked "non-edible wet," "unknown wet," or "whole wet". If results were reported in dry weight, the concentrations were converted to wet weight.)

Table C-3: Radioactive Contaminants Detected in Fish Samples by Locations and Species (1993-2008) — Georgia

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration pCi/g (Bq/kg)*	*Maximum Concentration (year)*
Augusta Lock and Dam	Bass (largemouth)	1995—2000	Alpha radiation	4/7	0.09 (3.33)	1995
		1993—2000	Beta radiation	7/7	4.41 (163.17)	1996
		1995—2007	Cesium-137	14/14	0.05 (1.85)	2005
		1995—2005	Strontium-90	3/12	0.04 (1.54)	2003
		1995—2007	Tritium	1/14	0.08 (2.81)	1995
	Bowfin	1993	Beta radiation	1/1	3.57 (132.09)	1993
		1993 and 2008	Cesium-137	2/2	0.06 (2.22)	1993
		1993 and 2002	Tritium	2/2	0.24 (8.88)	1993 and 2002
	Catfish	1995—1999	Alpha radiation	1/4	0.02 (0.85)	1995
		1995—2000	Beta radiation	5/5	4.4 (162.8)	1995
		1995—2004	Cesium-137	9/11	0.04 (1.48)	1995
		1995—2003	Strontium-90	2/9	0.01 (0.41)	1997
		1995—2003	Tritium	1/9	0.1 (3.7)	1995
	Sunfish	1995, 1996, and 2001	Cesium-137	2/6	0.01 (0.37)	1996
	Panfish (assorted)	1995, 1997-2000, 2002— 2004	Alpha radiation	3/5	0.47 (17.32)	2000
			Beta radiation	5/5	3.36 (124.32)	1997
			Cesium-137	9/10	0.13 (4.81)	2003
			Strontium-90	7/7	0.17 (6.16)	2000
Upper Three Runs Creek Mouth (SRS)	Bass (largemouth)	1996—1999	Alpha radiation	3/5	0.09 (3.26)	1996
		1996—1999	Beta radiation	5/5	4.4 (162.8)	1996
		1999—2007	Cesium-137	14/14	0.46 (17.02)	1999
		1995—2003	Strontium-90	4/11	0.04 (1.62)	2003

Table C-3: Radioactive Contaminants Detected in Fish Samples by Locations and Species (1993-2008) — Georgia

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration pCi/g (Bq/kg)*	*Maximum Concentration (year)*
		1995—2007	Tritium	11/14	0.55 (20.5)	1999
	Bowfin	1993	Beta radiation	1/1	3.75 (138.75)	1993
		1993 and 2000	Cesium-137	2/2	0.23 (8.51)	2000
		1993 and 2000	Tritium	2/2	46.97 (1737.9)	2000
	Catfish	1994—1999	Alpha radiation	3/6	0. 0.09 (3.26)	1995
		1994—1999	Beta radiation	5/5	3.08 (113.96)	1997
		1994—2004	Cesium-137	10/11	0.13 (4.81)	1997
		1994—2003	Strontium-90	3/11	0.01 (0.40)	2003
		1994—2004	Tritium	6/10	0.78 (28.9)	1994
	Panfish (assorted)	1995,1997—2004	Alpha radiation	2/4	0.23 (8.66)	1997
			Beta radiation	4/4	3.51 (129.87)	1995
			Cesium-137	8/8	0.27 (9.84)	1995
			Tritium	6/8	19.5 (721.5)	2000
	Sucker fish	1993	Beta radiation	1/1	1.33 (49.21)	1993
		1993, 2002	Cesium-137	2/2	0.08 (2.88)	1993
		2002	Strontium-90	1/1	0.02 (0.59)	2002
		1993	Tritium	1/1	1.05 (39.0)	1993
Beaver Dam Creek Mouth (SRS)	Bass (largemouth)	1996—1999	Alpha radiation	3/4	0.08 (3.11)	1999
		1996—1999	Beta radiation	4/4	4.41 (163.2)	1996
		1995—2008	Cesium-137	12/13	1.83 (67.71)	2000
		1996—2005	Strontium-90	5/12	0.04 (1.48)	2003
		1995—2005	Tritium	7/13	0.86 (31.7)	2000
	Bowfin	1993	Beta radiation	1/1	5.72 (211.6)	1993
			Cesium-137	1/1	0.73 (27.01)	
			Strontium-90	1/1	0.01 (0.33)	
			Tritium	1/1	0.31 (11.5)	

Table C-3: Radioactive Contaminants Detected in Fish Samples by Locations and Species (1993-2008) — Georgia

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration pCi/g (Bq/kg)*	*Maximum Concentration (year)*
	Catfish	1994—1998	Beta radiation	5/5	4.20 (155.4)	1994
		1994—2004	Cesium-137	11/11	0.13 (4.81)	1998
		1994—2003				
		1994—2004	Strontium-90	4/10	0.02 (0.67)	1999
			Tritium	7/10	0.62 (22.8)	2002
	Panfish (assorted)	1995-2000, 2002-2004	Cesium-137		0.07 (2.59)	2003
	Spotted Sucker and Sucker fish	1993, 2002	Beta radiation	1/1	2.52 (93.2)	1993
			Cesium-137	2/2	0.03 (1.11)	
			Tritium	1/1	0.32 (11.7)	
	Sunfish	1996, 2001	Cesium-137	2/2	0.01 (0.37)	1996, 2001
Four Mile Creek Mouth	Bass (largemouth)	1995—1997	Beta radiation	3/3	4.18 (154.7)	1996
		1995—1997, 2000—2007	Cesium-137	12/12	1.37 (50.69)	1995
		1995—2005	Strontium-90	5/9	0.08 (2.93)	2003
		1995—2007	Tritium	13/13	13.1 (484.3)	1997
	Bowfin	1993—1999	Beta radiation	3/3	3.36 (124.3)	1993
		1993—1999, 2002	Cesium-137	4/4	0.36 (13.32)	1998
		1993—2002	Strontium-90	1/4	0.01 (0.44)	1993
		1993—2002	Tritium	3/3	4.9 (179.5)	1999
	Catfish	1994—2000	Beta radiation	6/6	5.04 (186.5)	1995
		1994—2004	Cesium-137	12/12	0.25 (9.25)	2002
		1994—2003	Strontium-90	6/11	0.03 (1.22)	1994
		1994—2004	Tritium	11/11	12.9 (478.0)	1995
	Panfish (assorted)	1997—1999, 2002	Alpha radiation	1/3	0.14 (5.33)	1997
			Cesium-137	1/1	0.10 (3.70)	2002

Table C-3: Radioactive Contaminants Detected in Fish Samples by Locations and Species (1993-2008) — Georgia

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration pCi/g (Bq/kg)*	*Maximum Concentration (year)*
			Strontium-90	1/1	0.02 (0.62)	2002
			Tritium	1/1	7.0 (260.1)	2002
	Spotted sucker and sucker fish	1993, 2002, 2003	Beta radiation	1/1	3.80 (140.6)	1993
			Cesium-137	3/3	0.17 (6.29)	2002
			Strontium-90	3/3	0.35 (13.0)	2003
			Tritium	2/2	2.2 (82.9)	1993
	Sunfish	1995—1996, 2001	Alpha radiation	1/2	0.08 (2.78)	1996
			Cesium-137	3/3	0.24 (8.88)	1995
			Tritium	3/3	59.2 (2190.4)	1995
Downstream of Vogtle and Four Mile Creek	Bass (largemouth)	1998	Beta radiation	1/1	3.15 (116.6)	1998
		1998—2008	Cesium-137	12/12	0.91 (33.74)	2006
		1998	Strontium-90	1/1	0.01 (0.44)	1998
		1998—2008	Tritium	10/11	2.5 (92.4)	1999
	Catfish (channel)	1998, 1999, 2003, 2006—2008	Cesium-137	5/6	0.13 (4.63)	2006
			Tritium	6/6	1.2 (44.4)	2007
Steel Creek Mouth (SRS)	Bass (largemouth)	1995—1999	Alpha radiation	2/5	0.11 (3.89)	1995
		1995—1999	Beta radiation	5/5	4.62 (170.9)	1996
		1995 —2007	Cesium-137	14/14	4.40 (162.80)	1999
		1995 —2003	Strontium-90	3/10	0.04 (1.45)	2003
		1995—2007	Tritium	15/15	8.7 (321.5)	1995
	Bowfin	1993 and 1998	Alpha radiation	1/2	0.0.6 (2.15)	1998
			Beta radiation	2/2	4.37 (161.7)	1993
			Cesium-137	2/2	0.61 (22.57)	1998
			Strontium-90	1/2	0.01 (0.34)	1993
			Tritium	1/1	7.9 (293.4)	1993
	Catfish	1995	Alpha radiation	1/1	0.07 (2.44)	1995

Table C-3: Radioactive Contaminants Detected in Fish Samples by Locations and Species (1993-2008) — Georgia

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration pCi/g (Bq/kg)*	*Maximum Concentration (year)*
		1994—1999	Beta radiation	5/5	3.99 (147.6)	1994
		1994—2004	Cesium-137	12/121/9	0.37 (13.69)	1995
		1994—2003	Strontium-90	10/11	0.05 (1.71)	1994
		1994—2003	Tritium		3.1 (115.4)	1995
	Panfish	1995—2000,	Alpha radiation	2/5	0.08 (2.78)	1995
		2002—2004	Beta radiation	5/5	4.78 (176.1	1995
			Cesium-137	9/9	0.42 (15.54)	1998
			Tritium	10/10	7.9 (293.0)	1995
	Spotted sucker	1993	Beta radiation	1/1	3.57 (132.1)	1993
			Cesium-137	1/1	1.01 (37.37)	
			Tritium	1/1	8.7 (321.5)	
	Sucker fish	1994, 2002	Cesium-137	1/1	0.05 (1.85)	2002
			Strontium-90	1/1	0.01 (0.31)	2002
			Tritium	1/1	0.7 (26.3)	1994
	Sunfish	1996, 2001	Alpha radiation	1/1	0.08 (2.78)	1996
			Cesium-137		0.48 (17.76)	1996
Lower Three Runs Creek Mouth (SRS)	Bass (largemouth)	1996—2000	Alpha radiation	2/5	0.0.07 (2.66)	1997
		1996—2000	Beta radiation	5/5	4.84 (179.1)	1996
		1995—2007	Cesium-137	15/15	3.08 (113.96)	1995
		1995—2003	Strontium-90	1/11	0.04 (1.33)	2003
		1995—2007	Tritium	11/15	1.4 (50.6)	2003
	Bowfin	1993	Beta radiation	1/1	6.90 (255.3)	1993
			Cesium-137	1/2	0.67 (24.79)	
			Strontium-90	1/1	0.01 (0.34)	
			Tritium	1/1	0.6 (23.3)	
	Catfish	1994—2000	Beta radiation	7/7	4.62 (170.9)	1995
		1994—2004	Cesium-137	2/12	0.42 (15.54)	1995

Table C-3: Radioactive Contaminants Detected in Fish Samples by Locations and Species (1993-2008) — Georgia

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration pCi/g (Bq/kg)*	*Maximum Concentration (year)*
		1994—2003	Strontium-90	2/9	0.02 (0.65)	1995
		1994—2004	Tritium	12/12	2.22 (82)	1999
	Panfish	1995—2004	Alpha radiation	2/5	0.27 (9.99)	1997
			Beta radiation	5/5	3.12 (115.4)	1999
			Cesium-137	1/1	0.39 (14.43)	1999
			Tritium	9/9	1.3 (47.1)	2003
	Spotted sucker	1993	Beta radiation	1/1	3.74 (138.4)	1993
			Cesium-137	1/1	0.90 (33.30)	
			Tritium	1/1	0.5 (17.3)	
	Sucker fish	2000	Cesium-137	1/1	0.06 (2.22)	2000
	Sunfish	1995, 2001	Cesium-137	1/1	0.043 (15.91)	1995
US 301 Bridge	Bass	1993—1999	Alpha radiation	4/6	0.11 (4.00)	1995
		1993—1999	Beta radiation	6/6	4.40 (162.8)	1996
		1993—2007	Cesium-137	15/15	0.10 (3.70)	2002
		1999, 2003, 2005	Strontium-90	3/12	0.04 (1.60)	1999
		1993—2007	Tritium	11/15	2.0 (75.0)	1996
	Bowfin	1993 and 2000	Beta radiation	2/2	4.14 (153.2)	2000
		1993, 2000, 2006	Cesium-137	4/4	0.06 (2.22)	1993
		1993, 2000, 2006	Tritium	3/3	1.3 (46.6)	2000
	Catfish	1994—2000	Alpha radiation	2/7	0.09 (3.40)	1994
		1994—1999	Beta radiation	6/6	3.24 (119.9)	1999
		1994—2004	Cesium-137	12/12	0.10 (3.70)	1995
		1994—2003	Strontium-90	5/10	0.02 (0.80)	1999
		1994—2004	Tritium	11/11	1.4 (52.6)	2003
	Panfish (assorted)	1994—2000,	Alpha radiation	3/7	0.08 (3.00)	1995
		2002—2004	Beta radiation	1/1	9.7 (358.9)	2004
			Cesium-137	1/1	0.05 (1.85)	2002

Table C-3: Radioactive Contaminants Detected in Fish Samples by Locations and Species (1993-2008) — Georgia

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration pCi/g (Bq/kg)*	*Maximum Concentration (year)*
			Strontium-90	1/1	0.03 (1.11)	1994
			Tritium		1.5 (56.9)	2000
	Spotted sucker	1993	Beta radiation	1/1	2.99 (110.6)	1993
			Cesium-137	1/1	0.03 (1.85)	
			Tritium	1/1	1.1 (39.9)	
	Sucker fish	2002	Cesium-137	1/1	0. 04 (1.48)	2002
			Strontium-90	1/1	0.01 (0.28)	
	Sunfish	1995—1996	Cesium-137		0. 03 (0.93)	1995
					0.012 (4.35)	1996

Source: GDNR/EPD (State of Georgia)
pCi/g = picocuries per gram; Bq/kg = becquerels per kilogram (1 pCi/g = 37 Bq/kg)
Notes:
Small differences in the values may occur due to rounding
Note: If a specific radiological contaminant was not detected at all in a fish species, it is not reported in this table.
Samples collected with “unknown” species designation are not included in this table.

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(Edible: The data does not include samples marked "non-edible," "unknown," or "whole". Some concentrations were reported as dry weight, some as wet weight, and some did not specify.)

Table C-4: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (1997-2008) —South Carolina

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)**	*Maximum Concentration (year)*
Upstream of SRS (includes Stevens Creek and Augusta Lock & Dam locations) [mixed dry and wet weight]	American Shad	2001	Hydrogen-3 (tritium)	1/1	0.16 (wet)	2001
	Bass	1997—2008	Cesium-137	7/17	0.63 (dry)	1998
		1998 and 2001	Lead-212	2/2	0.08 (dry)	1998
		1997, 1998, 2008	Lead-214	4/4	0.41 (dry)	1998
		1997	Strontium-90	1/1	0.03 (dry)	1997
		1998—2006, 2008	Hydrogen-3 (tritium)	1/4	0.33 (dry)	2002
	Carp	2006	Hydrogen-3 (tritium)	1/1	(188 pCi/L)	2006
	Catfish	1999—2008	Cesium-137	3/7	0.04 (wet)	1999
		1997	Cesium-137	1/1	0.16 (dry)	1997
		1998,2001,2002,2008	Lead-214	4/7	0.11 (wet)	2002
		1998—2003, 2008	Hydrogen-3 (tritium)	4/16	9.91(dry)	1998
	Redear Sunfish	2000	Lead-214	1/1	0.08 (wet)	2000
Upper Three Runs Creek Mouth [mixed dry and wet weight]	Bass	1997 and 1998	Actinium-228	1/3	0.30 (dry)	1997
		1997—1999	Cesium137	5/5	2.21 (dry)	1997
		2000—2008	Cesium-137	7/9	0.87 (wet)	2000
		1997	Europium155	1/1	0.06 (dry)	1997
		1998	Lead-212	1/2	0.06 (dry)	1998
		1997, 1998, 2008	Lead-214	4/5	0.28 (dry)	1998
					0.11 (wet)	2008
		1997	Strontium-90	1/1	0.06 (dry)	1997
		1998,1999,2000, 2003, 2008	Hydrogen-3 (tritium)	8/9	13.47 (wet)	1999

Table C-4: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (1997-2008) —South Carolina

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)**	*Maximum Concentration (year)*
	Bowfin	2002	Cesium-137	1/1	0.23	2002
	Catfish	1997 and 1998	Actinium-228	1/2	0.36 (dry)	1997
		1997—2008	Cesium-137	5/8	0.16 (wet)	1999
		2001 and 2007	Lead-212	1/2	0.02 (wet)	2001
		2008	Lead-214	1/1	0.05 (wet)	2008
		1998	Plutonium-238	1/1	0.00003 (dry)	1998
		1998	Plutonium-239	1/1	0.00006 (dry)	1998
		1998 and 1999	Hydrogen-3 (tritium)	3/3	3.93 (dry)	1998
		2008	Hydrogen-3 (tritium)	1/1	(278 pCi/L)	2008
	Striped Mullet	2004	Hydrogen-3 (tritium)	1/1	0.95 (wet)	2004
Beaver Dam Creek Mouth [wet weight basis]	Bass	2000—2008	Cesium-137	10/11	0.23	2001
		2001	Lead-214	1/1	0.06	2001
		2000—2008	Hydrogen-3 (tritium) Hydrogen-3 (tritium)	5/7	0.72 (359 pCi/L)	2002 2007
	Bluegill	2005	Cesium-137	1/1	0.21	2005
			Hydrogen-3 (tritium)	1/1	(264 pCi/L)	2005
	Carp	2006	Hydrogen-3 (tritium)	1/1	(358 pCi/L)	2006
	Catfish	2001—2008	Cesium-137	3/7	0.18	2001
		2001	Lead-212	1/1	0.08	2001
		2001	Lead-214	1/1	0.08	2001
		1999, 2006	Hydrogen-3 (tritium)	6/8	1.27 (469 pCi/L)	1999 2006
	Chain Pickerel	2007	Strontium-89/90	1/1	0.03	2007
Four Mile Creek Mouth [mixed dry and wet weight]	Bass	1997—2008	Cesium-137	15/15	3.46 (dry)	1997
		1998 and 2001	Lead-212	2/4	0.12 (dry)	1998

Table C-4: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (1997-2008) —South Carolina

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)**	*Maximum Concentration (year)*
		1997, 1998, 2001	Lead-214	4/4	0.6 (dry)	1998
		1998	Plutonium-239	1/1	0.00002 (dry)	1998
		1997	Strontium-90	1/1	0.11 (dry)	1997
		1998—2008	Hydrogen-3 (tritium)	11/12	16.83 (wet)	1999
					(2930 pCi/L)	2007
	Bluegill	2005	Cesium-137	1/1	0.053	2005
			Hydrogen-3 (tritium)	1/1	(4,468 pCi/L)	2005
	Carp	2006	Hydrogen-3 (tritium)	1/1	(1,335 pCi/L)	2006
	Catfish	1997—2008	Cesium-137	10/11	0.33 (dry)	1997
					0.34 (wet)	2007
		1997—2001	Lead-214	6/7	0.40 (dry)	1997
		1998—2008	Hydrogen-3 (tritium)	8/9	3.76 (wet)	2004
					(507 pCi/L)	2008
		1997	Zinc 65	1/1	0.22 (dry)	1997
	Chain Pickerel	2008	Cesium-137	1/1	0.48 (wet)	2008
Steel Creek Mouth [mixed dry and wet weight]	Bass	1997—2007	Cesium-137	11/11	7.27 (dry)	1998
		2008	Cesium-137	1/1	0.70 (wet)	2008
		1998	Strontium-90	1/2	0.00003 (dry)	1998
		1997—2002, 2008	Hydrogen-3 (tritium)	9/9	117 (dry)	1998
					(954 pCi/L)	2008
	Catfish	1997—2007	Cesium-137	10/10	0.73 (dry)	1997
		2008	Cesium-137	2/2	0.03 (wet)	2008
		2001	Lead-212	1/3	0.03 (wet)	2001
		1997	Lead-214	1/3	0.5 (dry)	1997
		2008	Lead-214	1/1	0.06 (wet)	2008
		1998	Plutonium-239	1/1	0.00009 (dry)	1998

Table C-4: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (1997-2008) —South Carolina

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)**	*Maximum Concentration (year)*
		1997 and 1998 1998—2004, 2008	Strontium-90 Hydrogen-3 (tritium)	1/3 868	0.03 (dry) 14.4 (dry) (256)	1997 1998 2008
	Chain Pickerel	2007	Cesium-137 Strontium-89/90	1/1 1/1	0.071 0.006 (wet)	2007
	Common Carp	2006	Cesium-137 Hydrogen-3 (tritium)	1/1 1/1	0.063 (2,879 pCi/L)	2006
	Crappie/ Bluegill	2005	Cesium-137 Hydrogen-3 (tritium)	1/1 1/1	0.16 (625 pCi/L)	2005
	Redear Snfish	2000	Hydrogen-3 (tritium)	1/1	9.82 (wet)	2000
	Spotted Sucker	2003	Hydrogen-3 (tritium)	1/1	0.90 (wet)	2003
Lower Three Runs Creek Mouth [mixed dry and wet weight]	Bass	1997—2007 2008 1998 2008 1997 1998—2008	Cesium-137 Cesium-137 Lead-214 Lead-214 Strontium-90 Hydrogen-3 (tritium)	12/12 1/1 1/2 1/1 1/1 10/10	4.96 (dry) 0.43 (wet) 0.37 (dry) 0.18 (wet) 0.02 (dry) 0.83 (dry) (518 pCi/L)	1997 2008 1998 2008 1997 1998 2007
	Bowfin	2002	Hydrogen-3 (tritium)	1/1	0.36 (wet)	2002
	Catfish	1998— 20081998 1997 1997— 2008	Cesium-137 Lead-214 Strontium-90 Hydrogen-3 (tritium)	9/102/3 1/1 11/11	2.68 (dry) 0.54 (dry) 0.76 (dry) 1.51 (dry) (484 pCi/L)	1998 1998 1997 1997 2007

Table C-4: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (1997-2008) —South Carolina

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)**	*Maximum Concentration (year)*
	Chain Pickerel	2007	Cesium-137	1/1	0.102 (dry?)	2007
			Lead-214	1/1	0.14 (wet)	
	Common Carp	2006	Cesium-137	1/1	0.088	2006
			Hydrogen-3 (tritium)	1/1	(619 pCi/L)	
	Redbreast Sunfish	2005	Hydrogen-3 (tritium)	1/1	(302 pCi/L)	2005
Near Highway 301 Bridge	Bass	2000—2008	Cesium-137	7/8	0.08	2000
		1997-1999	Cesium-137	3/3	0.29 (dry)	1997
		2001	Lead-212	1/1	0.01	2001
		2001	Lead-214	1/1	0.04	2001
		1998	Lead-214	1/1	0.12 (dry)	1998
		2001 and 2007	Hydrogen-3 (tritium)	6/6	2.43	2004
		1998	Hydrogen-3 (tritium)	1/1	1.38 (dry)	1998
		2006 - 2008	Hydrogen-3 (tritium)	3/3	(454 pCi/L)	2006
	Black Crappie	2001	Hydrogen-3 (tritium)	1/1	0.56	2001
	Bluegill	2005	Cesium-137	1/1	0.09	2005
	Catfish	2003—2008	Cesium-137	1/5	0.043	2003
		1998	Cesium-137	1/1	0.15 (dry)	1998
		1998, 2008	Lead-214	2/2	0.44 (dry)	1998
					0.08 (wet)	2008
		2002,2007, 2008	Hydrogen-3 (tritium)	4/6	1.15	2002
					(621 pCi/L)	2007
		1998, 1999	Hydrogen-3 (tritium)	2/2	0.85 (dry)	1998
	Chain Pickerel	2007	Cesium-137	1/1	0.03	2007
	Common Carp	2006	Hydrogen-3 (tritium)	1/1	(400 pCi/L)	2006
	Spotted Sucker	2003	Hydrogen-3 (tritium)	1/1	0.88	2003

Table C-4: Radiological Contaminants Detected in Fish Samples by Specified Locations and Species (1997-2008) —South Carolina

Location along the Savannah River	*Fish species*	*Sampling Time-frame*	*Contaminant*	*# detects/ # samples analyzed*	*Maximum Concentration (pCi/g)**	*Maximum Concentration (year)*
Stokes Bluff (downstream of site) [mixed dry and wet weight]	Bass	1997—2008	Cesium-137	7/9	0.27	1997 (dry)
		1997	Lead-214	1/1	0.17	1997 (dry)
		1998—2008	Hydrogen-3 (tritium)	9/9	1.35 (477 pCi/L)	2002 (wet) 2007
	Catfish	1997—2008	Cesium-137	5/9	0.14	1997 (dry)
		1998 and 2001	Lead-212	1/2	0.01	2001 (wet)
		1998 and 2000	Lead-214	1/2	0.73	1998
		1998—2008	Hydrogen-3 (tritium)	6/7	0.90 (396 pCi/L)	1998 2007
	Common Carp	2006	Hydrogen-3 (tritium)	1/1	(218 pCi/L)	2006
	Spotted Sucker	2003	Cesium-137	1/1	0.04	2003
			Hydrogen-3 (tritium)	1/1	0.45	

Source: Data provided by State of South Carolina

pCi/g = picocuries per gram; pCi/L = picocuries per liter (liquid only)
*Values in ( ) are tritium concentrations in liquid extracted from fish samples
Small differences in the values may occur due to rounding.
Samples collected with “unknown” species designation are not included in this table.

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Appendix D. Dose calculations for upper bound exposure screening levels

Calculations for hypothetical exposure screening levels from radionuclides (fish, wild game, and agricultural and farm products)

ATSDR calculated a hypothetical exposure screening level for each type of biota potentially ingested using the maximum concentrations detected in samples collected from any of the years between 1993 and 2008 within a biota category or type. For screening purposes, ATSDR often uses the maximum contaminant concentration detected in a specific medium at the site to identify contaminants requiring specific exposure evaluations. With one exception, the dose calculations were performed for an adult and a child (6 to 11 years) using the equation for calculating annual committed effective doses (see text box below) and the International Commission on Radiological Protection's (ICRP's) models and methodology (ICRP 1995). For milk ingestion, calculations were also performed for a young child and a teenager. For this public health assessment, ATSDR used the specified ingestion rates shown in Table D-1 below. Also, each of the following exposure tables will indicate the intake rates used for the type of biota and the age group. Table D-2 presents the whole body committed effective dose conversion factors in Sv/Bq (sievert/becquerel) from the International Commission on Radiological Protection (ICRP) Report 72 (ICRP 1995).

Calculating Annual Committed Effective Dose

Equation: $CED = C_B \times I \times CF$

Where;

CED = Annual committed effective dose

C_B= Concentration in biota [picocuries per gram (pCi/gm) or becquerels per kilogram (Bq/kg), except for milk in pCi or Bq per liter (L); 1 Bq = 27 pCi]

I = Ingestion rate (kilograms per year or liters per year)

CF = Dose conversion factor: Converts Bq (or pCi) to Sv (or rem) for various age groups. For whole body committed effective dose, dose conversion factors from International Commission on Radiological Protection (ICRP) Report 72 were used (ICRP 1995).

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Table D-1. Upper bound ingestion rates for adults and children[1]

Product	Adult (18 years and over)	Child (6 through 11 years)
Total vegetables	306 kg/yr	87 kg/yr
Total fruits	304 kg/yr	102 kg/yr
Nuts	0.88 kg/yr	0.95 kg/yr
Grains	0.67 kg/yr	0.28 kg/yr
Milk[2]	440 L/yr	374 L/yr
Beef	78.1 kg/yr	18.6 kg/yr
Pork	47.8 kg/yr	13.5 kg/yr
Chicken	68.26 kg/yr	18.25 kg/yr
Eggs	44.9 kg/yr	14.2 kg/yr
Fish	49.3 kg/yr[3]	35.4 kg/yr
Onsite deer and feral hogs	78 kg/yr	18.6 kg/yr
Onsite turkeys[4]	10 kg/yr	6.2 kg/yr
Offsite deer and feral hogs	78 kg/yr	18.6 kg/yr
Offsite birds and ducks	51 kg/yr	13.7 kg/yr

[1] The 99th percentile ingestion rates from EPA's Exposure Factor Handbook (EPA 1997) are presented unless otherwise noted.
[2] The 99th percentile ingestion rates from EPA's Exposure Factor Handbook (EPA 1997) are presented for adults; the 95th percentile ingestion rates from EPA's Child-Specific Exposure Factors Handbook (EPA 2008) are presented for a teen (374 L/yr), a 6 through 11 tear old child (374 L/yr), and a 1 through 5 year old child (377 L/yr)
[3] Mean of 95th percentile rates for Savannah River fishermen interviewed by Burger et al. 1999.
[4] Rate based on number of turkeys allowed for harvest yearly, average weight, and edible portion.
kg/yr = kilograms per year; L/yr = liters per year

Table D-2: Whole body committed effective dose conversion factors in Sv/Bq (sievert/becquerel)

Radioactive material	Adult (18 years and over)	Child (6 through 11 years)
Americium-241	2.00E-07	2.00E-07
Cesium-137	1.30E-08	1.00E-08
Cobalt-60	3.40E-09	1.10E-08
Iodine-129	1.10E-07	1.90E-07
Plutonium-238	2.30E-07	2.40E-07
Plutonium-239	2.50E-07	2.70E-07
Strontium-90	2.80E-08	6.00E-08
Hydrogen-3 (tritium)	1.80E-11	5.70E-11
Uranium-234	4.90E-08	7.40E-08
Uranium-235	4.70E-08	7.10E-08
Uranium-238	4.50E-08	6.80E-08
Curium-244	1.20E-07	1.40E-07
Technetium-99	6.40E-10	1.30E-09
Neptunium 237	1.10E-07	1.10E-07

Source: ICRP Report 72 (ICRP 1995)

Hypothetical exposure screening levels for ingestion of fish

Due to the amount of fish data available and the differences in radionuclide analyses and maximum concentrations reported for the major sampling locations along the Savannah River, screening level dose calculations were performed for the maximum concentrations reported for each year from 1993 through 2008 at each location. (Tables D-3 through D-9 are for separate locations.) These screening levels are more conservative than for a maximally exposed individual and are used for screening purposes only. The assumption was made that all fish consumed that year came from one location with all consumed fish containing the maximum detected concentrations for that year.

Table D-3: Maximum adult and child screening levels for fish ingestion at Augusta Lock and Dam

Year	Radioactive material	Maximum Concentration in fish pCi/g (Bq/kg)	Adult Screening Level mrem/year (Sv/year))	Child Screening Level mrem/year (Sv/year)
1993	Cesium-137	0.421 (15.58)	1.00 (1.00E-05)	5.52E-01 (5.52E-06)
	Plutonium-239	0.00001 (0.0004)	4.57E-04 (4.57E-09)	3.54E-04 (3.54E-09)
	Strontium-90	0.029 (1.07)	1.48E-01 (1.48E-06)	2.28E-01 (2.28E-06)
	Hydrogen-3 (tritium)	0.24 (8.89)	7.90E-04 (7.90E-09)	1.79E-03 (1.79E-08)
	TOTAL		**1.15 (1.15E-05)**	**0.78 (7.82E-06)**
1994	Strontium-90	0.006 (0.22)	3.07E-02 (3.07E-07)	4.72E-02 (4.72E-07)
	Hydrogen-3 (tritium)	0.04 (1.48)	1.32E-04 (1.32E-09)	2.99E-04 (2.99E-09)
	TOTAL		**0.03 (3.08E-07)**	**0.05 (4.75E-07)**
1995	Cesium-137	0.04 (1.48)	9.50E-02 (9.50E-07)	5.25E-02 (5.25E-07)
	Plutonium-238	0.00017 (0.006)	7.15E-03 (7.15E-08)	5.35E-03 (5.35E-08)
	Plutonium-239	0.00003 (0.001)	1.37E-03 (1.37E-08)	1.06E-03 (1.06E-08)
	Strontium-90	0.019 (0.70)	9.72E-02 (9.72E-07)	1.49E-01 (1.49E-06)
	Hydrogen-3 (tritium)	0.1 (3.7)	3.29E-04 (3.29E-09)	7.47E-04 (7.47E-09)
	TOTAL		**0.20 (2.01E-06)**	**0.21 (2.09E-06)**
1996	Cesium-137	0.07 (2.59)	1.66E-01 (1.66E-06)	9.18E-02 (9.18E-07)
	Cobalt-60	0.011 (0.41)	6.84E-03 (6.84E-08)	1.59E-02 (1.59E-07)
	Plutonium-238	0.0003 (0.011)	1.26E-02 (1.26E-07)	9.44E-03 (9.44E-08)
	Strontium-90	0.008 (0.30)	4.09E-02 (4.09E-07)	6.29E-02 (6.29E-07)
	Hydrogen-3 (tritium)	0.13 (4.81)	4.28E-04 (4.28E-09)	9.72E-04 (9.72E-09)
	TOTAL		**0.23 (2.27E-06)**	**0.18 (1.81E-06)**
1997	Cesium-137	0.48 (17.76)	1.14 (1.14E-05)	6.29E-01 (6.29E-06)
	Cobalt-60	0.028 (1.04)	1.74E-02 (1.74E-07)	4.04E-02 (4.04E-07)
	Plutonium-238	0.00012 (0.004)	5.04E-03 (5.04E-08)	3.78E-03 (3.78E-08)
	Plutonium-239	0.00003 (0.001)	1.37E-03 (1.37E-08)	1.06E-03 (1.06E-08)
	Strontium-90	0.01 (0.37)	5.12E-02 (5.12E-07)	7.87E-02 (7.87E-07)
	Hydrogen-3 (tritium)	0.13 (4.81)	4.28E-04 (4.28E-09)	9.72E-04 (9.72E-09)
	TOTAL		**1.22 (1.22E-05)**	**0.75 (7.54E-06)**
1998	Cesium-137	0.19 (7.042.59)	4.51E-01 (4.51E-06)	2.49E-01 (2.49E-06)
	Cobalt-60	0.021 (0.78)	1.30E-02 (1.30E-07)	3.03E-02 (3.03E-07)
	Plutonium-238	0.00006 (0.0022)	2.52E-03 (2.52E-08)	1.89E-03 (1.89E-08)
	Plutonium-239	0.00008 (0.003)	3.66E-03 (3.66E-08)	2.83E-03 (2.83E-08)
	Strontium-90	0.013 (0.48)	6.65E-02 (6.65E-07)	1.02E-01 (1.02E-06)
	Hydrogen-3 (tritium)	0.19 (7.03)	6.25E-04 (6.25E-09)	1.42E-03 (1.42E-08)
	TOTAL		**0.54 (5.381E-06)**	**0.39 (3.88E-06)**
1999	Cesium-137	0.08 (2.96)	1.90E-01 (1.90E-06)	1.05E-01 (1.05E-06)
	Cobalt-60	0.034 (1.26)	2.11E-02 (2.11E-07)	4.90E-02 (4.90E-07)
	Plutonium-238	0.00004 (0.0015)	1.68E-03 (1.68E-08)	1.26E-03 (1.26E-08)
	Plutonium-239	0.00003 (0.0011)	1.37E-03 (1.37E-08)	1.06E-03 (1.06E-08)
	Strontium-90	0.034 (1.26)	1.74E-01 (1.74E-06)	2.68E-01 (2.68E-06)

Table D-3: Maximum adult and child screening levels for fish ingestion at Augusta Lock and Dam

Year	Radioactive material	Maximum Concentration in fish pCi/g (Bq/kg)	Adult Screening Level mrem/year (Sv/year))	Child Screening Level mrem/year (Sv/year)
	Hydrogen-3 (tritium)	0.05 (1.85)	1.64E-04 (1.64E-09)	3.74E-04 (3.74E-09)
	TOTAL		**0.39 (3.88E-06)**	**0.42 (4.24E-06)**
2000	Cesium-137	0.07 (2.59)	1.66E-01 (1.66E-06)	9.18E-02 (9.18E-07)
	Cobalt-60	0.027 (1.00)	1.68E-02 (1.68E-07)	3.89E-02 (3.89E-07)
	Plutonium-238	0.00003 (0.0011)	1.26E-03 (1.26E-08)	9.44E-04 (9.44E-09)
	Plutonium-239	0.00005 (0.0019)	2.28E-03 (2.28E-08)	1,77E-03 (1.77E-03)
	Strontium-90	0.17 (6.16)	8.70E-01 (8.70E-06)	1.34E+00 (1.34E-05)
	Hydrogen-3 (tritium)	0.08 (2.96)	2.63E-04 (2.63E-09)	5.98E-04 (5.98E-09)
	TOTAL		**1.06 (1.06E-05)**	**1.47 (1.47E-05)**
2001	Cesium-137	0.1 (3.7)	2.38E-01 (2.38E-06)	1.31E-01 (1.31E-06)
	Cobalt-60	0.038 (1.41)	2.36E-02 (2.36E-07)	5.48E-02 (5.48E-07)
	Plutonium-238	0.000005 (0.0002)	2.10E-04 (2.10E-09)	1.57E-04 (1.57E-09)
	Plutonium-239	0.000006 (0.0002)	2.74E-04 (2.74E-09)	2.12E-04 (2.12E-09)
	Strontium-90	0.009 (0.33)	4.61E-02 (4.61E-07)	7.08E-02 (7.08E-07)
	Hydrogen-3 (tritium)	0.16 (5.92)	5.26E-04 (5.26E-09)	1.20E-03 (1.20E-08
	TOTAL		**0.31 (3.08E-06)**	**0.26 (2.58E-06)**
2002	Cesium-137	0.057 (2.11)	1.35E-01 (1.35E-06)	7.47E-02 (7.47E-07)
	Cobalt-60	0.025 (0.93)	1.55E-02 (1.55E-07)	3.61E-02 (3.61E-07)
	Plutonium-238	0.000024 (0.0009)	1.01E-03 (1.01E-08)	7.55E-04 (7.55E-09)
	Plutonium-239	0.000032 (0.0012)	1.46E-03 (1.46E-08)	1.13E-03 (1.13E-08)
	Strontium-90	0.013 (0.48)	6.65E-02 (6.65E-07)	1.02E-01 (1.02E-06)
	Hydrogen-3 (tritium)	0.24 (8.88)	7.90E-04 (7.90E-09)	1.79E-03 (1.79E-08)
	TOTAL		**0.22 (2.21E-06)**	**0.22 (2.17E-06)**
2003	Cesium-137	0.13 (4.81)	3.09E-01 (3.09E-06)	1.70E-01 (1.70E-06)
	Cobalt-60	0.03 (1.11)	1.86E-02 (1.86E-07)	4.33E-02 (4.33E-07)
	Plutonium-238	0.000035 (0.0013)	1.47E-03 (1.47E-08)	1.10E-03 (1.10E-08)
	Plutonium-239	0.000001 (0.00004)	4.57E-05 (4.57E-10)	3.54E-05 (3.54E-10)
	Strontium-90	0.04 (1.54)	2.05E-01 (2.05E-06)	3.15E-01 (3.15E-06)
	Hydrogen-3 (tritium)	0.02 (0.74)	6.58E-05 (6.58E-10)	1.49E-04 (1.49E-09)
	TOTAL		**0.53 (5.34E-06)**	**0.53 (5.30E-06)**
2004	Cesium-137	0.07 (2.59)	1.66E-01 (1.66E-06)	9.18E-02 (9.18E-07)
	Cobalt-60	0.019 (0.70)	1.18E-02 (1.18E-07)	2.74E-02 (2.74E-07)
	Plutonium-238	0.000059 (0.0022)	2.48E-03 (2.48E-08)	1.86E-03 (1.86E-08)
	Plutonium-239	0.000013 (0.0005)	5.94E-04 (5.94E-09)	4.60E-04 (4.60E-09)
	Strontium-90	0.008 (0.30)	4.09E-02 (4.09E-07)	6.29E-02 (6.29E-07)
	Hydrogen-3 (tritium)	0.03 (1.11)	9.87E-05 (0.87E-10)	2.24E-04 (2.24E-09)
	TOTAL		**0.22 (2.22E-06)**	**0.19 (1.85E-06)**
2005	Cesium-137	0.081 (3.00)	1.92E-01 (1.92E-06)	1.06E-01 (1.06E-06)
	Cobalt-60	0.002 (0.07)	1.24E-03 (1.24E-08)	2.88E-03 (2.88E-08)
	Plutonium-238	0.000059 (0.0022)	2.48E-03 (2.48E-08)	1.86E-03 (1.86E-08)
	Plutonium-239	0.00001 (0.0004)	4.57E-04 (4.57E-09)	3.54E-04 (3.54E-09)
	Strontium-90	0.008 (0.30)	4.09E-02 (4.09E-07)	6.29E-02 (6.29E-07)
	Hydrogen-3 (tritium)	0.05 (1.85)	1.64E-04 (1.64E-09)	3.74E-04 (3.74E-09)
	TOTAL		**0.24 (2.38E-06)**	**0.18 (1.75E-06)**
2006	Americium-241	0.000021 (0.0008)	7.68E-04 (7.68E-09)	5.51E-04 (5.51E-09)
	Cesium-137	0.052 (1.92)	1.24E-01 (1.24E-06)	6.82E-02 (6.82E-07)
	Cobalt-60	0.019 (0.70)	1.18E-02 (1.18E-07)	2.74E-02 (2.74E-07)
	Iodine-129	0.009 (0.33)	1.81E-01 (1.81E-06)	2.24E-01 (2.21E-06)
	Plutonium-238	0.00039 (0.0144)	1.64E-02 (1.64E-07)	1.22E-02 (1.22E-07)
	Plutonium239	0.00007 (0.0026)	3.20E-03 (3.20E-08)	2.48E-03 (2.48E-08)
	Strontium-90	0.013 (0.48)	6.65E-02 (6.65E-07)	1.02E-01 (1.02E-06)
	Hydrogen-3 (tritium)	0.13 (4.81)	4.28E-04 (4.28E-09)	9.72E-04 (9.72E-09)
	Uranium-234	0.005 (0.185)	4.48E-02 (4.48E-07)	4.85E-02 (4.85E-07)
	Uranium235	0.0003 (0.011)	2.58E-03 (2.58E-08)	2.79E-03 (2.79E-08)
	Uranium238	0.0058 (0.215)	4.77E-02 (4.77E-07)	5.17E-02 (5.17E-07)

Table D-3: Maximum adult and child screening levels for fish ingestion at Augusta Lock and Dam

Year	Radioactive material	Maximum Concentration in fish pCi/g (Bq/kg)	Adult Screening Level mrem/year (Sv/year))	Child Screening Level mrem/year (Sv/year)
	Curium-244	0.00007 (0.0026)	1.54E-03 (1.54E-08)	1.29E-03 (1.29E-08)
	Technetium-99	0.0265 (0.98)	3.10E-03 (3.10E-08)	4.52E-03 (4.52E-08)
	TOTAL		**0.50 (5.03E-06)**	**0.44 (4.38E-06)**
2007	Americium-241	0.000025 (0.0009)	9.28E-04 (9.28E-09)	6.56E-04 (6.56E-09)
	Cesium-137	0.04 (1.48)	9.50E-02 (9.50E-07)	5.25E-02 (5.25E-07)
	Cobalt-60	0.02 (0.74)	1.24E-02 (1.24E-07)	2.88E-02 (2.88E-07)
	Iodine-129	0.02 (0.74)	4.02E-01 (4.02E-06)	4.98E-01 (4.98E-06)
	Plutonium-238	0.00023 (0.0085)	9.67E-03 (9.67E-08)	7.24E-03 (7.24E-08)
	Plutonium239	0.00006 (0.0022)	2.74E-03 (2.74E-08)	2.12E-03 (2.12E-08)
	Strontium-90	0.004 (0.15)	2.05E-02 (2.05E-07)	3.15E-02 (3.15E-07)
	Hydrogen-3 (tritium)	0.04 (1.48)	1.32E-04 (1.32E-09)	2.99E-04 (2.99E-09)
	Uranium-234	0.0004 (0.0148)	3.58E-03 (3.58E-08)	3.88E-03 (3.88E-08)
	Uranium235	0.00011 (0.0041)	9.45E-04 (9.45E-09)	1.02E-03 (1.02E-08)
	Uranium238	0.0004 (0.0148)	3.29E-03 (3.29E-08)	3.57E-03 (3.57E-08)
	Curium-244	0.00004 (0.00148)	8.77E-04 (8.77E-09)	7.34E-04 (7.34E-09)
	Technetium-99	0.0017 (0.06)	1.99E-04 (1.99E-09)	2.90E-04 (2.90E-09)
	TOTAL		**0.55 (5.52E-06)**	**0.62 (6.21E-06)**
2008	Americium-241	0.000024 (0.0009)	8.77E-04 (8.77E-09)	6.29E-04 (6.29E-09)
	Cesium-137	0.03 (1.11)	7.13E-02 (7.13E-07)	3.93E-02 (3.93E-07)
	Cobalt-60	0.016 (0.59)	9.94E-03 (9.94E-08)	2.31E-02 (2.31E-07)
	Iodine-129	0.008 (0.30)	1.61E-01 (1.61E-06)	1.99E-01 (1.99E-06)
	Plutonium-238	0.00013 (0.0048)	5.46E-03 (5.46E-08)	4.09E-03 (4.09E-08)
	Plutonium239	0.00003 (0.0011)	1.37E-03 (1.37E-08)	1.06E-03 (1.06E-08)
	Strontium-90	0.008 (0.30)	4.09E-02 (4.09E-07)	6.29E-02 (6.29E-07)
	Hydrogen-3 (tritium)	0.09 (3.33)	2.96E-04 (2.96E-09)	6.73E-04 (6.73E-09)
	Uranium-234	0.0004 (0.0148)	3.58E-03 (3.58E-08)	3.88E-03 (3.88E-08)
	Uranium235	0.00005 (0.0019)	4.30E-04 (4.30E-09)	4.66E-04 (4.66E-09)
	Uranium238	0.0003 (0.0111)	2.47E-03 (2.47E-08)	2.68E-03 (2.68E-08)
	Curium-244	0.00001 (0.0004)	2.19E-04 (2.19E-09)	1.84E-04 (1.84E-09)
	Technetium-99	0.048 (1.78)	5.61E-03 (5.61E-08)	8.18E-03 (8.18E-08)
	Neptunium 237	0.00005 (0.0019)	1.01E-03 (1.01E-08)	7.21E-04 (7.21E-09)
	TOTAL		**0.30 (3.04E-06)**	**0.33 (3.31E-06)**

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Table D-4: Maximum adult and child screening levels for fish ingestion at mouth of Beaver Dam Creek				
Year	Radioactive material	Maximum Concentration in fish pCi/g (Bq/kg)	Adult Screening Level mrem/year (Sv/year))	Child Screening Level mrem/year (Sv/year)
1993	Cesium-137	0.73 (27.01)	1.73E+00 (1.73E-05)	9.56E-01 (9.56E-06)
	Plutonium-238	0.00004 (0.0015)	1.68E-03 (1.68E-08)	1.26E-03 (1.26E-08)
	Strontium-90	0.039 (1.44)	2.00E-01 (2.00E-06)	3.07E-01 (3.07E-06)
	Hydrogen-3 (tritium)	0.32 (11.84)	1.05E-03 (1.05E-08)	2.39E-03 (2.39E-08)
	TOTAL		**1.94 (1.94E-05)**	**1.27 (1.27E-05)**
1994	Cesium-137	0.94 (34.78)	2.23E+00 (2.23E-05)	1.23E+00 (1.23E-05)
	Plutonium-239	0.00001 (0.0004)	4.57E-04 (4.57E-09)	3.54E-04 (3.54E-09)
	Strontium-90	0.039 (1.44)	2.00E-01 (2.00E-06)	3.70E-01 (3.70E-06)
	Hydrogen-3 (tritium)	0.76 (28.12)	2.50E-03 (2.50E-08)	5.68E-03 (5.68E-08)
	TOTAL		**2.44 (2.44E-05)**	**1.55 (1.55E-05)**
1995	Cesium-137	0.13 (4.81)	3.09E-01 (3.09E-06)	1.70E-01 (1.70E-06)
	Plutonium-238	0.00134 (0.0496)	5.63E-02 (5.63E-07)	4.22E-02 (4.22E-07)
	Plutonium-239	0.00001(0.0004)	4.57E-04 (4.57E-09)	3.54E-04 (3.54E-09)
	Strontium-90	0.002 (0.07)	1.02E-02 (1.02E-07)	1.57E-02 (1.57E-07)
	Hydrogen-3 (tritium)	0.4 (14.8)	1.32E-03 (1.32E-08)	2.99E-03 (2.99E-08)
	TOTAL		**0.38 (3.77E-06)**	**0.23 (2.32E-06)**
1996	Cesium-137	0.43 (15.91)	1.02E+00 (1.02E-05)	5.64E-01 (5.64E-06)
	Cobalt-60	0.028 (1.04)	1.74E-02 (1.74E-07)	4.04E-02 (4.04E-07)
	Plutonium-238	0.00048 (0.0178)	2.02E-02 (2.02E-07)	1.51E-02 (1.51E-07)
	Plutonium-239	0.00009 (0.0033)	4.11E-03 (4.11E-08)	3.19E-03 (3.19E-08)
	Strontium-90	0.005 (0.19)	2.56E-02 (2.56E-07)	3.93E-02 (3.93E-07)
	Hydrogen-3 (tritium)	0.32 (11.84)	1.05E-03 (1.05E-08)	2.39E-03 (2.39E-08)
	TOTAL		**1.09 (1.09E-05)**	**0.66 (6.64E-06)**
1997	Cesium-137	1.15 (42.55)	2.73E+00 (2.73E-05)	1.51E+00 (1.51E-05)
	Cobalt-60	0.032 (1.18)	1.99E-02 (1.99E-07)	4.62E-02 (4.62E-07)
	Plutonium-238	0.00005 (0.0019)	2.10E-03 (2.10E-08)	1.57E-03 (1.57E-08)
	Plutonium-239	0.00007(0.0026)	3.20E-03 (3.20E-08)	2.48E-03 (2.48E-08)
	Strontium-90	0.024 (0.89)	1.23E-01 (1.23E-06)	1.89E-01 (1.89E-06)
	Hydrogen-3 (tritium)	0.16 (5.92)	5.26E-04 (5.26E-09)	1.20E-03 (1.20E-08)
	TOTAL		**2.88 (2.88E-05)**	**1.75 (1.75E-05)**
1998	Cesium-137	0.63 (23.31)	1.50E+00 (1.50E-05)	8.26E-01 (8.26E-06)
	Cobalt-60	0.022 (0.81)	1.37E-02 (1.37E-07)	3.17E-02 (3.17E-07)
	Plutonium-238	0.00002 (0.0007)	8.41E-04 (8.41E-09)	6.29E-04 (6.29E-09)
	Plutonium-239	0.00002 (0.0007)	9.14E-04(9.14E-09)	7.08E-04 (7.08E-09)
	Strontium-90	0.022 (0.81)	1.13E-01 (1.13E-06)	1.73E-01 (1.73E-06)
	Hydrogen-3 (tritium)	0.15 (5.55)	4.93E-04 (4.93E-09)	1.12E-03 (1.12 E-08)
	TOTAL		**1.63 (1.63E-05)**	**1.03 (1.03E-05)**
1999	Cesium-137	0.25 (9.25)	5.94E-01 (5.94E-06)	3.28E-01 (3.28E-06)
	Cobalt-60	0.029 (1.07)	1.80E-02 (1.80E-07)	4.18E-02 (4.18E-07)
	Plutonium-238	0.00011(0.0041)	4.62E-03 (4.62E-08)	3.46E-03 (3.46E-08)
	Plutonium-239	0.00003 (0.0011)	1.37E-03 (1.37E-08)	1.06E-03 (1.06E-08)
	Strontium-90	0.039 (1.44)	2.00E-01 (2.00E-06)	3.07E-01 (3.07E-06)
	Hydrogen-3 (tritium)	1.27 (47)	4.18E-03 (4.18E-08)	9.49E-03 (9.49E-08)
	TOTAL		**0.82 (8.22E-06)**	**0.69 (6.91E-06)**
2000	Cesium-137	1.83 (67.71)	4.35 E+00 (4.35 E-05)	2.40E+00 (2.40E-05)
	Cobalt-60	0.038 (1.41)	2.36E-02 (2.36E-07)	5.48E-02 (5.48E-07)
	Plutonium-238	0.00004 (0.0015)	1.68E-03 (1.68E-08)	1.26E-03 (1.26E-08)
	Plutonium-239	0.00003 (0.0011)	1.37E-03 (1.37E-08)	1.06E-03 (1.06E-08)
	Strontium-90	0.023 (0.85)	1.18E-01 (1.18E-06)	1.81E-01 (1.81E-06)
	Hydrogen-3 (tritium)	0.14 (5.18)	4.61E-04 (4.61E-09)	1.05E-03 (1.05E-08)
	TOTAL		**4.49 (4.49E-05)**	**2.64 (2.64E-05)**

Table D-4: Maximum adult and child screening levels for fish ingestion at mouth of Beaver Dam Creek

Year	Radioactive material	Maximum Concentration in fish pCi/g (Bq/kg)	Adult Screening Level mrem/year (Sv/year))	Child Screening Level mrem/year (Sv/year)
2001	Cesium-137	0.23 (8.51)	5.46E-01 (5.46E-06)	3.02E-01 (3.02E-06)
	Cobalt-60	0.021 (7.77)	1.30E-02 (1.30E-07)	3.03E-02 (3.03E-07)
	Plutonium-238	0.00004 (0.0015)	1.68E-03 (1.68E-08)	1.26E-03 (1.26E-08)
	Plutonium-239	0.000009 (0.0003)	4.11E-04 (4.11E-09)	3.19E-04 (3.19E-09)
	Strontium-90	0.016 (0.59)	8.19E-02 (8.19E-07)	1.26E-01 (1.26E-06)
	Hydrogen-3 (tritium)	0.44 (16.28)	1.45E-03 (1.45E-08)	3.29E-03 (3.29E-08)
	TOTAL		**0.65 (6.45E-06)**	**0.46 (4.63E-06)**
2002	Cesium-137	0.16 (5.92)	3.80E-01 (3.80E-06)	2.10E-01 (2.10E-06)
	Cobalt-60	0.013 (0.48)	8.08E-03 (8.08E-08)	1.88E-02 (1.88E-07)
	Plutonium-238	0.00015 (0.0056)	6.31E-03 (6.31E-08)	4.72E-03 (4.72E-08)
	Plutonium-239	0.00002 (0.0007)	9.14E-04 (9.14E-09)	7.08E-04 (7.08E-09)
	Strontium-90	0.037 (1.37)	1.89E-01 (1.89-06)	2.91E-01 (2.91E-06)
	Hydrogen-3 (tritium)	0.89 (32.93)	2.93E-03 (2.93E-08)	6.65E-03 (6.65E-08)
	TOTAL		**0.59 (5.88E-06)**	**0.53 (5.32E-06)**
2003	Cesium-137	0.13 (4.81)	3.07E-01 (3.07E-06)	1.69E-01 (1.69E-06)
	Cobalt-60	0.023 (0.85)	1.43E-02 (1.43E-07)	3.32E-02 (3.32E-07)
	Plutonium-238	0.0001 (0.0037)	4.20E-03 (4.20E-08)	3.15E-03 (3.15E-08)
	Plutonium-239	0.00001 (0.0004)	4.57E-04 (4.57E-09)	3.54E-04 (3.54E-09)
	Strontium-90	0.016 (0.59)	8.19E-02 (8.19E-07)	1.26E-01 (1.26E-06)
	Hydrogen-3 (tritium)	0.3 (11.1)	9.87E-04 (9.87E-09)	2.24E-03 (2.24E-08)
	TOTAL		**0.41 (4.08E-06)**	**0.33 (3.34E-06)**
2004	Cesium-137	0.12 (4.33)	2.78E-01 (2.78E-06)	1.53E-01 (1.53E-06)
	Cobalt-60	0.023 (0.85)	1.43E-02 (1.43E-07)	3.32E-02 (3.32E-07)
	Plutonium-238	0.00002 (0.0007)	8.41E-04 (8.41E-09)	6.29E-04 (6.29E-09)
	Strontium-90	0.006 (0.22)	3.07E-02 (3.07E-07)	4.72E-02 (4.72E-07)
	Hydrogen-3 (tritium)	0.15 (5.55)	4.93E-04 (4.93E-09)	1.12E-03 (1.12E-08)
	TOTAL		**0.32 (3.24E-06)**	**0.24 (2.36E-06)**
2005	Cesium-137	0.13 (4.88)	3.14E-01 (3.14E-06)	1.73E-01 (1.73E-06)
	Cobalt-60	0.031(1.15)	1.93E-02 (1.93E-07)	4.47E-02 (4.47E-07)
	Plutonium-238	0.00009 (0.0033)	3.78E-03 (3.78E-08)	2.83E-03 (2.83E-08)
	Plutonium-239	0.00001 (0.0004)	4.57E-04 (4.57E-09)	3.54E-04 (3.54E-09)
	Strontium-90	0.014 (0.52)	7.16E-02 (7.16E-07)	1.10E-01 (1.10E-06)
	Hydrogen-3 (tritium)	0.05 (1.85)	1.64E-04 (1.64E-09)	3.74E-04 (3.74E-09)
	TOTAL		**0.41 (4.09E-06)**	**0.33 (3.32E-06)**
2006	Americium-241	0.00002 (0.0007)	7.31E-04 (7.31E-09)	5.25E-04 (5.25E-09)
	Cesium-137	0.228 (8.44)	5.42E-01 (5.42E-06)	2.99E-01 (2.99E-06)
	Cobalt-60	0.017 (0.63)	1.06E-02 (1.06E-07)	2.45E-02 (2.45E-07)
	Iodine-129	0.016 (0.592)	3.22E-01 (3.22E-06)	3.99E-01 (3.99E-06)
	Plutonium-238	0.00008 (0.0030)	3.36E-03 (3.36E-08)	2.52E-03 (2.52E-08)
	Plutonium239	0.00002 (0.0007)	9.14E-04 (9.14E-09)	7.08E-04 (7.08E-09)
	Strontium-90	0.011 (0.407)	5.63E-02 (5.63E-07)	8.65E-02 (8.65E-07)
	Hydrogen-3 (tritium)	0.89 (32.85)	2.92E-03 (2.92E-08)	6.65E-03 (6.65E-08)
	Uranium-234	0.0002 (0.0074)	1.79E-03 (1.79E-08)	1.94E-03 (1.94E-08)
	Uranium235	0.00001 (0.0004)	8.59E-05 (8.59E-10)	9.31E-05 (9.31E-10)
	Uranium238	0.0002 (0.0074)	1.64E-03 (1.64E-08)	1.78E-03 (1.78E-08)
	Curium 244	0.00003 (0.0011)	6.58E-03 (6.58E-08)	5.51E-04 (5.51E-09)
	Technetium-99	0.039 (1.44)	4.56E-03 (4.56E-08)	6.65E-03 (6.65E-08)
	TOTAL		**0.94 (9.41E-06)**	**0.83 (8.30E-06)**
2007	Americium-241	0.00002 (0.0007)	7.31E-04 (7.31E-09)	5.25E-04 (5.25E-09)
	Cesium-137	0.12 (4.29)	2.76E-01 (2.76E-06)	1.52E-01 (1.52E-06)
	Cobalt-60	0.03 (1.11)	1.86E-02 (1.86E-07)	4.33E-02 (4.33E-07)
	Iodine-129	0.011(0.407)	2.21E-01 (2.21E-06)	2.74E-01 (2.74E-06)
	Plutonium-238	0.00013 (0.0048)	5.46E-03 (5.46E-08)	4.09E-03 (4.09E-08)
	Plutonium239	0.00007(0.0026)	3.20E-03 (3.20E-08)	2.48E-03 (2.48E-08)
	Strontium-90	0.03 (1.11)	1.54E-01 (1.54E-06)	2.36E-01 (2.36E-06)

Table D-4: Maximum adult and child screening levels for fish ingestion at mouth of Beaver Dam Creek

Year	Radioactive material	Maximum Concentration in fish pCi/g (Bq/kg)	Adult Screening Level mrem/year (Sv/year))	Child Screening Level mrem/year (Sv/year)
	Hydrogen-3 (tritium)	0.07 (2.59)	2.30E-04 (2.30E-09)	5.23E-04 (5.23E-09)
	Uranium-234	0.0003 (0.0111)	2.69E-03 (2.69E-08)	2.91E-03 (2.91E-08)
	Uranium235	0.00003 (0.0011)	2.58E-04 (2.58E-09)	2.79E-04 (2.79E-09)
	Uranium238	0.0002 (0.0074)	1.64E-03 (1.64E-08)	1.78E-03 (1.78E-08)
	Curium-244	0.00003 (0.0011)	6.58E-04 (6.58E-09)	5.51E-04 (5.51E-09)
	Technetium-99	0.002 (0.07)	2.34E-04 (2.34E-09)	3.41E-04 (3.41E-09)
	TOTAL		**0.68 (6.78E-06)**	**0.72 (7.19E-06)**
2008	Americium-241	0.00002 (0.0007)	7.31E-04 (7.31E-09)	5.25E-04 (5.25E-09)
	Cesium-137	0.05 (1.99)	1.28E-01 (1.28E-06)	7.08E-02 (7.08E-07)
	Cobalt-60	0.026 (0.96)	1.62E-02 (1.62E-07)	3.75E-02 (3.75E-07)
	Iodine-129	0.01 (0.37)	2.01E-01 (2.01E-06)	2.49E-01 (2.49E-06)
	Plutonium-238	0.00012 (0.0044)	5.04E-03 (5.04E-08)	3.78E-03 (3.78E-08)
	Plutonium239	0.00003 (0.0011)	1.37E-03 (1.37E-08)	1.06E-03 (1.06E-08)
	Strontium-90	0.008 (0.30)	4.09E-02 (4.09E-07)	6.29E-02 (6.29E-07)
	Hydrogen-3 (tritium)	0.08 (2.96)	2.63E-04 (2.63E-09)	5.98E-04 (5.98E-09)
	Uranium-234	0.0002 (0.0074)	1.79E-03 (1.79E-08)	1.94E-03 (1.94E-08)
	Uranium235	0.00013 (0.0048)	1.12E-03 (1.12E-08)	1.21E-03 (1.21E-08)
	Uranium238	0.0002 (0.0074)	1.64E-03 (1.64E-08)	1.78E-03 (1.78E-08)
	Technetium-99	0.01 (0.37)	1.17E-03 (1.17E-08)	1.70E-03 (1.70E-08)
	Neptunium 237	0.00004 (0.0015)	8.04E-04 (8.04E-09)	5.77E-04 (5.77E-09)
	TOTAL		**0.39 (3.93E-06)**	**0.43 (4.34E-06)**

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Table D-5: Maximum adult and child screening levels for fish ingestion at mouth of Four Mile Creek

Year	Radioactive material	Maximum Concentration in fish pCi/g (Bq/kg)	Adult Screening Level mrem/year (Sv/year))	Child Screening Level mrem/year (Sv/year)
1993	Cesium-137	0.26 (9.62)	6.18E-01 (6.18E-06)	3.41E-01 (3.14E-06)
	Plutonium-238	0.00001 (0.0004)	4.20E-04 (4.20E-09)	3.15E-04 (3.15E-09)
	Plutonium-239	0.00001 (0.0004)	4.57E-04 (4.57E-09)	3.54E-04 (3.54E-09)
	Strontium-90	0.014 (0.52)	7.16E-02 (7.16E-07)	1.10E-01 (1.01E-06)
	Hydrogen-3 (tritium)	2.28 (84.36)	7.50E-03 (7.50E-08)	1.70E-02 (1.70E-07)
	TOTAL		**0.70 (6.98E-06)**	**0.47 (4.69E-06)**
1994	Cesium-137	0.35 (12.95)	8.32E-01 (8.32E-06)	4.59E-01 (4.59E-06)
	Plutonium-238	0.00001 (0.0004)	4.20E-04 (4.20E-09)	3.15E-04 (3.15E-09)
	Plutonium239	0.00006 (0.0022)	2.73E-03 (2.73E-08)	2.12E-03 (2.12E-08)
	Strontium-90	1.27 (46.99)	6.50E+00 (6.50E-05)	9.99E+00 (9.99E-05)
	Hydrogen-3 (tritium)	9.36 (346.32)	3.08E-02 (3.08E-07)	7.00E-02 (7.00E-07)
	TOTAL		**7.36 (7.36E-05)**	**10.5 (1.05E-04)**
1995	Cesium-137	1.37 (50.69)	3.26E+00 (3.26E-05)	1.80E+00 (1.80E-05)
	Plutonium-238	0.00011 (0.0041)	4.62E-03 (4.62E-08)	3.46E-03 (3.46E-08)
	Plutonium-239	0.00001 (0.0004)	4.57E-04 (4.57E-09)	3.54E-04 (3.54E-09)
	Strontium-90	0.036 (1.33)	1.84E-01 (1.84E-06)	2.83E-01 (2.83E-06)
	Hydrogen-3 (tritium)	59.2 (2193)	1.95E-01 (1.95E-06)	4.42E-01 (4.42E-06)
	TOTAL		**3.64 (3.64E-05)**	**2.53 (2.53E-05)**
1996	Cesium-137	1.1 (40.7)	2.61E+00 (2.61E-05)	1.44E+00 (1.44E-05)
	Cobalt-60	0.02 (0.74)	1.24E-02 (1.24E-07)	2.88E-02 (2.88E-07)
	Plutonium-238	0.00011 (0.0041)	4.62E-03 (4.62E-08)	3.46E-03 (3.46E-08)
	Plutonium-239	0.00006 (0.0022)	2.74E-03 (2.74E-08)	2.12E-03 (2.12E-08)
	Strontium-90	0.089 (3.29)	4.55E-01 (4.55E-06)	7.00E-01 (7.00E-06)
	Hydrogen-3 (tritium)	26.7 (987.9)	8.78E-02 (8.78E-07)	2.00E-01 (2.00E-06)
	TOTAL		**3.18 (3.18E-05)**	**2.38 (2.38E-05)**
1997	Cesium-137	0.92 (34.04)	2.19E+00 (2.19E-05)	1.21E+00 (1.21E-05)
	Cobalt-60	0.021 (0.78)	1.30E-02 (1.30E-07)	3.03E-02 (3.03E-07)
	Plutonium-238	0.0001 (0.0037)	4.20E-03 (4.20E-08)	3.15E-03 (3.15E-08)
	Plutonium-239	0.00005 (0.0019)	2.28E-03 (2.28E-08)	1.77E-03 (1.77E-08)
	Strontium-90	0.059 (2.18)	3.02E-01 (3.02E-06)	4.64E-01 (4.64E-06)
	Hydrogen-3 (tritium)	26.7 (987.9)	8.78E-02 (8.78E-07)	2.00E-01 (2.00E-06)
	TOTAL		**2.60 (2.60E-05)**	**1.91 (1.91E-05)**
1998	Cesium-137	0.47 (17.39)	1.12E+00 (1.12E-05)	6.16E-01 (6.16E-06)
	Cobalt-60	0.019 (0.70)	1.18E-02 (1.18E-07)	2.74E-02 (2.74E-07)
	Plutonium-238	0.00002 (0.0007)	8.41E-04 (8.41E-09)	6.29E-04 (6.29E-09)
	Plutonium-239	0.00004 (0.0015)	1.83E-03 (1.83E-08)	1.42E-03 (1.42E-08)
	Strontium-90	0.035 (1.30)	1.79E-01 (1.79E-06)	2.75E-01 (2.75E-06)
	Hydrogen-3 (tritium)	10.6 (392.2)	3.49E-02 (3.49E-07)	7.92E-02 (7.92E-07)
	TOTAL		**1.35 (1.35E-05)**	**1.00 (1.00E-05)**
1999	Cesium-137	0.3 (11.1)	7.13E-01 (7.13E-06)	3.93E-01 (3.93E-06)
	Cobalt-60	0.038 (1.41)	2.36E-02 (2.36E-07)	5.48E-02 (5.48E-07)
	Plutonium-238	0.00011 (0.0041)	4.62E-03 (4.62E-08)	3.46E-03 (3.46E-08)
	Plutonium-239	0.00002 (0.0007)	9.14E-04 (9.14E-09)	7.08E-04 (7.08E-09)
	Strontium-90	0.03 (1.11)	1.54E-01 (1.54E-06)	2.36E-01 (2.36E-06)
	Hydrogen-3 (tritium)	4.85 (179.45)	1.60E-02 (1.60E-07)	3.63E-02 (3.63E-07)
	TOTAL		**0.91 (9.11-06)**	**0.73 (7.25E-06)**
2000	Cesium-137	0.11 (4.07)	2.61E-01 (2.61E-06)	1.44E-01 (1.44E-06)
	Cobalt-60	0.03 (1.11)	1.86E-02 (1.86E-07)	4.33E-02 (4.33E-07)
	Plutonium-238	0.00004 (0.0015)	1.68E-03 (1.68E-08)	1.26E-03 (1.26E-08)
	Plutonium-239	0.00006 (0.0022)	2.74E-03 (2.74E-08)	2.12E-03 (2.12E-08)
	Strontium-90	0.091 (3.37)	4.66E-01 (4.66E-06)	7.16E-01 (7.16E-06)

Table D-5: Maximum adult and child screening levels for fish ingestion at mouth of Four Mile Creek				
Year	Radioactive material	Maximum Concentration in fish pCi/g (Bq/kg)	Adult Screening Level mrem/year (Sv/year))	Child Screening Level mrem/year (Sv/year)
	Hydrogen-3 (tritium)	3.69 (136.53)	1.21E-02 (1.21E-07)	2.76E-02 (2.76E-07)
	TOTAL		**0.76 (7.62E-06)**	**0.93 (9.34E-06)**
2001	Cesium-137	0.16 (5.92)	3.80E-01 (3.80E-06)	2.10E-01 (2.10E-06)
	Cobalt-60	0.038 (1.41)	2.36E-02 (2.36E-07)	5.48E-02 (5.48E-07)
	Plutonium-238	0.00004 (0.0015)	1.68E-03 (1.68E-08)	1.26E-03 (1.26E-08)
	Plutonium-239	0.00001 (0.0004)	4.57E-04 (4.57E-09)	3.54E-04 (3.54E-09)
	Strontium-90	0.014 (0.52)	7.16E-02 (7.16E-07)	1.10E-01 (1.10E-06)
	Hydrogen-3 (tritium)	0.79 (29.23)	2.60E-03 (2.60E-08)	5.90E-03 (5.90E-08)
	TOTAL		**0.48 (4.80E-06)**	**0.38 (3.82E-06)**
2002	Cesium-137	0.22 (8.14)	5.23E-01 (5.23E-06)	2.88E-01 (2.88E-06)
	Cobalt-60	0.03 (1.11)	1.86E-02 (1.86E-07)	4.33E-02 (4.33E-07)
	Plutonium-238	0.00001 (0.0004)	4.20E-04 (4.20E-09)	3.15E-04 (3.15E-09)
	Plutonium-239	0.00001 (0.0004)	4.57E-04 (4.57E-09)	3.54E-04 (3.54E-09)
	Strontium-90	0.012 (0.44)	6.14E-02 (6.14E-07)	9.44E-02 (9.44E-07)
	Hydrogen-3 (tritium)	7.03 (260.11)	2.31E-02 (2.31E-07)	5.25E-02 (5.25E-07)
	TOTAL		**0.63 (6.27E-06)**	**0.48 (4.79E-06)**
2003	Cesium-137	0.62 (22.94)	1.47E+00 (1.47E-05)	8.13E-01 (8.13E-06)
	Cobalt-60	0.017 (0.63)	1.06E-02 (1.06E-07)	2.45E-02 (2.45E-07)
	Plutonium-238	0.00014 (0.0052)	5.89E-03 (5.89E-08)	4.41E-03 (4.41E-08)
	Plutonium-239	0.00001 (0.0004)	4.57E-04 (4.57E-09)	3.54E-04 (3.54E-09)
	Strontium-90	0.018 (0.67)	9.21E-02 (9.21E-07)	1.42E-01 (1.42E-06)
	Hydrogen-3 (tritium)	1.13 (41.81)	3.72E-03 (3.72E-08)	8.45E-03 (8.45E-08)
	TOTAL		**1.59 (1.59E-05)**	**0.99 (9.92E-06)**
2004	Cesium-137	1.14 (42.18)	2.71E+00 (2.71E-05)	1.49E+00 (1.49E-05)
	Cobalt-60	0.017 (0.63)	1.06E-02 (1.06E-07)	2.45E-02 (2.45E-07)
	Plutonium-238	0.00004 (0.0015)	1.68E-03 (1.68E-08)	1.26E-03 (1.26E-08)
	Plutonium-239	0.00001 (0.0004)	4.57E-04 (4.57E-09)	3.54E-04 (3.54E-09)
	Strontium-90	0.016 (0.59)	8.19E-02 (8.19E-07)	1.26E-01 (1.26E-06)
	Hydrogen-3 (tritium)	1.01 (37.37)	3.32E-03 (3.32E-08)	7.55E-03 (7.55E-08)
	TOTAL		**2.81 (2.81E-05)**	**1.65 (1.65E-05)**
2005	Cesium-137	0.55 (20.35)	1.31E+00 (1.31E-05)	7.21E-01 (7.21E-06)
	Cobalt-60	0.018 (0.67)	1.12E-02 (1.12E-07)	2.60E-02 (2.60E-07)
	Plutonium-238	0.0001 (0.0037)	4.20E-03 (4.20E-08)	3.15E-03 (3.15E-08)
	Plutonium-239	0.00002 (0.0007)	9.14E-04 (9.14E-09)	7.08E-04 (7.08E-09)
	Strontium-90	0.013 (0.48)	6.65E-02 (6.65E-07)	1.02E-01 (1.02E-06)
	Hydrogen-3 (tritium)	9.64 (356.68)	3.17E-02 (3.17E-07)	7.21E-02 (&.21E-07)
	TOTAL		**1.42 (1.42E-05)**	**0.93 (9.25E-06)**
2006	Americium-241	0.00016 (0.0059)	5.85E-03 (5.85E-08)	4.20E-03 (4.20E-08)
	Cesium-137	0.36 (13.32)	8.55E-01 (8.55E-06)	4.72E-01 (4.72E-06)
	Cobalt-60	0.019 (0.70)	1.18E-02 (1.18E-07)	2.74E-02 (2.74E-07)
	Iodine-129	0.007 (0.259)	1.41E-01 (1.41E-06)	1.74E-01 (1.74E-06)
	Plutonium-238	0.0005 (0.0185)	2.10E-02 (2.10E-07)	1.57E-02 (1.57E-07)
	Plutonium239	0.00006 (0.0022)	2.74E-03 (2.74E-08)	2.12E-03 (2.12E-08)
	Strontium-90	0.032 (1.18)	1.64E-01 (1.64E-06)	2.52E-01 (2.52E-06)
	Hydrogen-3 (tritium)	0.21 (7.77)	6.91E-04 (6.91E-09)	1.57E-03 (1.57E-08)
	Uranium-234	0.0265 (0.9805)	2.37E-01 (2.37E-06)	2.57E-01 (2.57E-06)
	Uranium235	0.0017 (0.0629)	1.46E-02 (1.46E-07)	1.58E-02 (1.58E-07)
	Uranium238	0.0255 (0.9435)	2.10E-01 (2.10E-06)	2.27E-01 (2.27E-06)
	Curium-244	0.00002 (0.0007)	4.39E-04 (4.39E-09)	3.67E-04 (3.67E-09)
	Technetium-99	0.147 (5.44)	1.72E-02 (1.72E-07)	2.51E-02 (2.51E-07)
	TOTAL		**1.20 (1.20E-05)**	**1.47 (1.47E-05)**
2007	Americium-241	0.00002 (0.0007)	7.31E-04 (7.31E-09)	5.25E-04 (5.25E-09)
	Cesium-137	0.47 (17.39)	1.12E+00 (1.12E-05)	6.16E-01 (6.16E-06)
	Cobalt-60	0.019 (0.703)	1.18E-02 (1.18E-07)	2.74E-02 (2.74E-07)
	Iodine-129	0.008 (0.30)	1.61E-01 (1.61E-06)	1.99E-01 (1.99E-06)

Table D-5: Maximum adult and child screening levels for fish ingestion at mouth of Four Mile Creek

Year	Radioactive material	Maximum Concentration in fish pCi/g (Bq/kg)	Adult Screening Level mrem/year (Sv/year))	Child Screening Level mrem/year (Sv/year)
	Plutonium-238	0.0004 (0.0148)	1.68E-02 (1.68E-07)	1.26E-02 (1.26E-07)
	Plutonium239	0.00009 (0.0033)	4.11E-03 (4.11E-08)	3.19E-03 (3.19E-08)
	Strontium-90	0.005 (0.19)	2.56E-02 (2.56E-07)	3.93E-02 (3.93E-07)
	Hydrogen-3 (tritium)	0.24 (8.88)	7.90E-04 (7.90E-09)	1.79E-03 (1.79E-08)
	Uranium-234	0.0004 (0.0148)	3.58E-03 (3.58E-08)	3.88E-03 (3.88E-08)
	Uranium235	0.00007 (0.0026)	6.01E-04 (6.01E-09)	6.52E-04 (6.52E-09)
	Uranium238	0.0003 (0.0111)	2.47E-03 (2.47E-08)	2.68E-03 (2.68E-08)
	Curium-244	0.00001 (0.0004)	2.19E-04 (2.19E-09)	1.84E-04 (1.84E-09)
	Technetium-99	0.003 (0.11)	3.51E-04 (3.51E-09)	5.11E-04 (5.11E-09)
	TOTAL		**1.34 (1.34E-05)**	**0.91 (9.08E-06)**
2008	Americium-241	0.00002 (0.0007)	7.31E-04 (7.31E-09)	5.25E-04 (5.25E-09)
	Cesium-137	0.48 (17.76)	1.14E+00 (1.14E-05)	6.29E-01 (6.29E-06)
	Cobalt-60	0.024 (0.89)	1.49E-02 (1.49E-07)	3.46E-02 (3.46E-07)
	Iodine-129	0.006 (0.22)	1.21E-01 (1.21E-06)	1.49E-01 (1.49E-06)
	Plutonium-238	0.00013 (0.0048)	5.46E-03 (5.46E-08)	4.09E-03 (4.09E-08)
	Plutonium239	0.00003 (0.0011)	1.37E-03 (1.37E-08)	1.06E-03 (1.06E-08)
	Strontium-90	0.0047 (0.0329)	2.41E-02 (2.41E-07)	3.70E-02 (3.70E-07)
	Hydrogen-3 (tritium)	0.06 (2.22)	1.97E-04 (1.97E-09)	4.48E-04 (4.48E-09)
	Uranium-234	0.0002 (0.0074)	1.79E-03 (1.79E-08)	1.94E-03 (1.94E-08)
	Uranium235	0.00002 (0.0007)	1.72E-04 (1.72E-09)	1.86E-04 (1.86E-09)
	Uranium238	0.0002 (0.0074)	1.64E-03 (1.64E-08)	1.78E-03 (1.78E-08)
	Curium-244	0.00001 (0.0004)	2.19E-04 (2.19E-09)	1.84E-04 (1.84E-09)
	Technetium-99	0.027 (1.00)	3.16E-03 (3.16E-08)	4.60E-03 (4.60E-08)
	Neptunium 237	0.00005 (0.0019)	1.01E-03 (1.01E-08)	7.21E-04 (7.21E-09)
	TOTAL		**1.31 (1.31E-05)**	**0.87 (8.65E-06)**

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Table D-6: Maximum adult and child screening levels for fish ingestion at Highway 301 Bridge Area

Year	Radioactive material	Maximum Concentration in fish pCi/g (Bq/kg)	Adult Screening Level mrem/year (Sv/year))	Child Screening Level mrem/year (Sv/year)
1993	Cesium-137	0.15 (5.55)	3.56E-01 (3.56E-06)	1.97E-01 (1.97E-06)
	Plutonium-238	0.00001 (0.0004)	4.20E-04 (4.20E-09)	3.15E-04 (3.15E-09)
	Plutonium-239	0.00001 (0.0004)	4.57E-04 (4.57E-09)	3.54E-04 (3.54E-09)
	Strontium-90	0.009 (0.33)	4.61E-02 (4.61E-07)	7.08E-02 (7.08E-07)
	Hydrogen-3 (tritium)	1.08 (39.96)	3.55E-03 (3.55E-08)	8.07E-03 (8.07E-08)
	TOTAL		**0.41 (4.07E-06)**	**0.28 (2.76E-06)**
1994	Cesium-137	0.11 (4.07)	2.61E-01 (2.61E-06)	1.44E-01 (1.44E-06)
	Plutonium-238	0.00001 (0.0004)	4.20E-04 (4.20E-09)	3.15E-04 (3.15E-09)
	Strontium-90	0.03 (1.11)	1.54E-01 (1.54E-06)	2.36E-01 (2.36E-06)
	Hydrogen-3 (tritium)	1.23 (45.51)	4.05E-03 (4.05E-08)	9.19E-03 (9.19E-08)
	TOTAL		**0.42 (4.19E-06)**	**0.39 (3.90E-06)**
1995	Cesium-137	0.1 (3.7)	2.38E-01 (2.38E-06)	1.31E-01 (1.31E-06)
	Plutonium-238	0.00003 (0.0011)	1.26E-03 (1.26E-08)	9.44E-04 (9.44E-09)
	Plutonium-239	0.00004 (0.0015)	1.83E-03 (1.83E-08)	1.42E-03 (1.42E-08)
	Strontium-90	0.009 (0.33)	4.61E-02 (4.61E-07)	7.08E-02 (7.08E-07)
	Hydrogen-3 (tritium)	1.06 (39.22)	3.49E-03 (3.49E-08)	7.92E-03 (7.92E-08)
	TOTAL		**0.29 (2.90E-06)**	**0.21 (2.12E-06)**
1996	Cesium-137	0.09 (3.33)	2.14E-01 (2.14E-06)	1.18E-01 (1.18E-06)
	Cobalt-60	0.047 (1.74)	2.92E-02 (2.92E-07)	6.78E-02 (6.78E-07)
	Plutonium-238	0.00008 (0.0030)	3.36E-03 (3.36E-08)	2.52E-03 (2.52E-08)
	Plutonium-239	0.00004 (0.0015)	1.83E-03 (1.83E-08)	1.42E-03 (1.42E-08)
	Strontium-90	0.01 (0.37)	5.12E-02 (5.12E-07)	7.87E-02 (7.87E-07)
	Hydrogen-3 (tritium)	2.03 (75.11)	6.68E-03 (6.68E-08)	1.52E-02 (1.52E-07)
	TOTAL		**0.31 (3.06E-06)**	**0.28 (2.84E-06)**
1997	Cesium-137	0.08 (2.96)	1.90E-01 (1.90E-06)	1.05E-01 (1.05E-06)
	Cobalt-60	0.009 (0.33)	5.59E-03 (5.59E-08)	1.30E-02 (1.30E-07)
	Plutonium-238	0.00019 (0.0070)	7.99E-03 (7.99E-08)	5.98E-03 (5.98E-08)
	Plutonium-239	0.00002 (0.0007)	9.14E-04 (9.14E-09)	7.08E-04 (7.08E-09)
	Strontium-90	0.011 (0.41)	5.63E-02 (5.63E-07)	8.65E-02 (8.65E-07)
	Hydrogen-3 (tritium)	1.05 (38.85)	3.45E-03 (3.45E-08)	7.85E-03 (7.85E-08)
	TOTAL		**0.26 (2,64E-06)**	**0.22 (2.19E-06)**
1998	Cesium-137	0.16 (5.92)	3.80E-01 (3.80E-06)	2.10E-01 (2.10E-06)
	Cobalt-60	0.024 (0.89)	1.49E-02 (1.49E-07)	3.46E-02 (3.46E-07)
	Plutonium-238	0.0001 (0.0037)	4.20E-03 (4.20E-08)	3.15E-03 (3.15E-08)
	Plutonium-239	0.00007 (0.0026)	3.20E-03 (3.20E-08)	2.48E-03 (2.48E-08)
	Strontium-90	0.019 (0.70)	9.72E-02 (9.72E-07)	1.49E-01 (1.49E-06)
	Hydrogen-3 (tritium)	0.98 (36.26)	3.22E-03 (3.22E-08)	7.32E-03 (7.32E-08)
	TOTAL		**0.50 (5.03E-06)**	**0.41 (4.07E-06)**
1999	Cesium-137	0.75 (27.75)	1.78E+00 (1.78E-05)	9.83E-01 (9.83E-06)
	Cobalt-60	0.011 (0.41)	6.84E-03 (6.84E-08)	1.59E-02 (1.59E-07)
	Plutonium-238	0.0001 (0.004)	4.20E-03 (4.20E-08)	3.15E-03 (3.15E-08)
	Plutonium-239	0.00002 (0.0007)	9.14E-04 (9.14E-09)	7.08E-04 (7.08E-09)
	Strontium-90	0.04 (1.48)	2.05E-01 (2.05E-06)	3.15E-01 (3.15E-06)
	Hydrogen-3 (tritium)	1.22 (45.14)	4.01E-03 (4.01E-08)	9.12E-03 (9.12E-08)
	TOTAL		**2.00 (2.00E-05)**	**1.35 (1.35E-05)**
2000	Cesium-137	0.21 (7.77)	4.99E-01 (4.99E-06)	2.75E-01 (2.75E-06)
	Cobalt-60	0.015 (0.56)	9.32E-03 (9.32E-08)	2.16E-02 (2.16E-07)
	Plutonium-238	0.00005 (0.0019)	2.10E-03 (2.10E-08)	1.57E-03 (1.57E-08)
	Plutonium-239	0.00005 (0.0019)	2.28E-03 (2.28E-08)	1.77E-03 (1.77E-08)
	Strontium-90	0.025 (0.93)	1.28E-01 (1.28E-06)	1.97E-01 (1.97E-06)

Table D-6: Maximum adult and child screening levels for fish ingestion at Highway 301 Bridge Area

Year	Radioactive material	Maximum Concentration in fish pCi/g (Bq/kg)	Adult Screening Level mrem/year (Sv/year))	Child Screening Level mrem/year (Sv/year)
	Hydrogen-3 (tritium)	1.8 (66.60)	5.92E-03 (5.92E-08)	1.35E-02 (1.35E-07)
	TOTAL		**0.65 (6.47E-06)**	**0.51 (5.11E-06)**
2001	Cesium-137	0.06 (2.22)	1.43E-01 (1.43E-06)	7.87E-02 (7.87E-07)
	Cobalt-60	0.013 (0.48)	8.08E-03 (8.08E-08)	1.88E-02 (1.88E-07)
	Plutonium-238	0.00004 (0.0015)	1.68E-03 (1.68E-08)	1.26E-03 (1.26E-08)
	Plutonium-239	0.00003 (0.0011)	1.37E-03 (1.37E-08)	1.06E-03 (1.06E-08)
	Strontium-90	0.017 (0.63)	8.70E-02 (8.70E-07)	1.34E-01 (1.34E-06)
	Hydrogen-3 (tritium)	0.87 (32.19)	2.86E-03 (2.86E-08)	6.50E-03 (6.50E-08)
	TOTAL		**0.24 (2.44E-06)**	**0.24 (2.40E-06)**
2002	Cesium-137	0.1 (3.7)	2.38E-01 (2.38E-06)	1.31E-01 (1.31E-06)
	Cobalt-60	0.012 (0.44)	7.46E-03 (7.46E-08)	1.73E-02 (1.73E-07)
	Strontium-90	0.017 (0.63)	8.70E-02 (8.70E-07)	1.34E-01 (1.34E-06)
	Hydrogen-3 (tritium)	0.78 (28.86)	2.57E-03 (2.57E-08)	5.83E-03 (5.83E-08)
	TOTAL		**0.34 (3.35E-06)**	**0.29 (2.88E-06)**
2003	Cesium-137	0.07 (2.59)	1.66E-01 (1.66E-06)	9.18E-02 (9.18E-07)
	Cobalt-60	0.018 (0.67)	1.12E-02 (1.12E-07)	2.60E-02 (2.60E-07)
	Plutonium-238	0.00016 (0.0059)	6.73E-03 (6.73E-08)	5.04E-03 (5.04E-08)
	Strontium-90	0.007 (0.26)	3.58E-02 (3.58E-07)	5.51E-02 (5.51E-07)
	Hydrogen-3 (tritium)	1.42 (52.54)	4.67E-03 (4.67E-08)	1.06E-02 (1.06E-07)
	TOTAL		**0.23 (2.25E-06)**	**0.19 (1.88E-06)**
2004	Cesium-137	0.05 (1.85)	1.19E-01 (1.19E-06)	6.56E-02 (6.56E-07)
	Cobalt-60	0.018 (0.67)	1.12E-02 (1.12E-07)	2.60E-02 (2.60E-07)
	Plutonium-238	0.00002 (0.0007)	8.41E-04 (8.41E-09)	6.29E-04 (6.29E-09)
	Plutonium-239	0.00002 (0.0007)	9.14E-04 (9.14E-09)	7.08E-04 (7.08E-09)
	Strontium-90	0.021 (0.78)	1.07E-01 (1.07E-06)	1.65E-01 (1.65E-06)
	Hydrogen-3 (tritium)	2.43 (90)	7.99E-03 (7.99E-08)	1.82E-02 (1.82E-07)
	TOTAL		**0.25 (2.47E-06)**	**0.28 (2.76E-06)**
2005	Cesium-137	0.05 (1.85)	1.19E-01 (1.19E-06)	6.56E-02 (6.56E-07)
	Cobalt-60	0.16 (5.92)	9.94E-03 (9.94E-08)	2.31E-02 (2.31E-07)
	Plutonium-238	0.00012 (0.0044)	5.04E-03 (5.04E-08)	3.78E-03 (3.78E-08)
	Plutonium-239	0.00004 (0.0015)	1.83E-03 (1.83E-08)	1.42E-03 (1.42E-08)
	Strontium-90	0.029 (1.07)	1.48E-01 (1.48E-06)	2.28E-01 (2.28E-06)
	Hydrogen-3 (tritium)	0.55 (20.35)	1.81E-03 (1.81E-08)	4.11E-03 (4.11E-08)
	TOTAL		**0.29 (2.86E-06)**	**0.33 (3.26E-06)**
2006	Americium-241	0.00003 (0.0011)	1.10E-03 (1.10E-08)	8.65E-04 (8.65E-09)
	Cesium-137	0.03 (1.11)	7.13E-02 (7.13E-07)	3.93E-02 (3.93E-07)
	Cobalt-60	0.01 (0.37)	6.21E-03 (6.21E-08)	1.44E-02 (1.44E-07)
	Iodine-129	0.002 (0.074)	4.02E-02 (4.02E-07)	4.98E-02 (4.98E-07)
	Plutonium-238	0.00008 (0.0030)	3.36E-03 (3.36E-08)	2.52E-03 (2.52E-08)
	Plutonium239	0.00007 (0.0026)	3.20E-03 (3.20E-08)	2.48E-03 (2.48E-08)
	Strontium-90	0.016 (0.59)	8.19E-02 (8.19E-07)	1.26E-01 (1.26E-06)
	Hydrogen-3 (tritium)	0.39 (14.43)	1.28E-03 (1.28E-08)	2.92E-03 (2.92E-08)
	Uranium-234	0.0006 (0.0222)	5.37E-03 (5.37E-08)	5.82E-03 (5.82E-08)
	Uranium235	0.00001 (0.0004)	8.59E-05 (8.59E-10)	9.31E-05 (9.31E-10)
	Uranium238	0.0005 (0.0185)	4.11E-03 (4.11E-08)	4.46E-03 (4.46E-08)
	Curium-244	0.00002 (0.0007)	4.39E-04 (4.39E-09)	3.67E-04 (3.67E-09)
	Technetium-99	0.049 (1.81)	5.73E-03 (5.73E-08)	8.35E-03 (8.35E-08)
	TOTAL		**0.21 (2.07E-06)**	**0.24 (2.37E-06)**
2007	Americium-241	0.00003 (0.0011)	1.21E-03 (1.21E-08)	8.65E-04 (8.65E-09)
	Cesium-137	0.03 (1.11)	7.13E-02 (7.13E-07)	3.93E-02 (3.93E-07)
	Cobalt-60	0.006 (0.02)	3.73E-03 (3.73E-08)	8.65E-03 (8.65E-08)
	Iodine-129	0.011 (0.41)	2.21E-01 (2.21E-06)	2.74E-01 (2.74E-06)
	Plutonium-238	0.00019 (0.0070)	7.99E-03 (7.99E-08)	5.98E-03 (5.98E-08)
	Plutonium239	0.00005 (0.0019)	2.28E-03 (2.28E-08)	1.77E-03 (1.77E-08)
	Strontium-90	0.012 (0.44)	6.14E-02 (6.14E-07)	9.44E-02 (9.44E-07)

Table D-6: Maximum adult and child screening levels for fish ingestion at Highway 301 Bridge Area

Year	Radioactive material	Maximum Concentration in fish pCi/g (Bq/kg)	Adult Screening Level mrem/year (Sv/year))	Child Screening Level mrem/year (Sv/year)
	Hydrogen-3 (tritium)	0.08 (2.96)	2.63E-04 (2.63E-09)	5.98E-04 (5.98E-09)
	Uranium-234	0.0003 (0.0111)	2.69E-03 (2.69E-08)	2.91E-03 (2.91E-08)
	Uranium235	0.00002 (0.0007)	1.72E-04 (1.72E-09)	1.86E-04 (1.86E-09)
	Uranium238	0.0003 (0.0111)	2.47E-03 (2.47E-08)	2.68E-03 (2.68E-08)
	Curium-244	0.00002 (0.0007)	4.39E-04 (4.39E-09)	3.67E-04 (3.67E-09)
	Technetium-99	0.002 (0.07)	2.34E-04 (2.34E-09)	3.41E-04 (3.41E-09)
	TOTAL		**0.37 (3.68E-06)**	**0.43 (4.25E-06)**
2008	Americium-241	0.00001 (0.0004)	3.66E-04 (3.66E-09)	2.88E-04 (2.88E-09)
	Cesium-137	0.07 (2.59)	1.66E-01 (1.66E-06)	9.18E-02 (9.18E-07)
	Cobalt-60	0.012 (0.44)	7.46E-03 (7.46E-08)	1.73E-02 (1.73E-07)
	Iodine-129	0.005 (0.185)	1.01E-01 (1.01E-06)	1.25E-01 (1.25E-06)
	Plutonium-238	0.00011 (0.0041)	4.62E-03 (4.62E-08)	3.46E-03 (3.46E-08)
	Plutonium239	0.00002 (0.0007)	9.14E-04 (9.14E-09)	7.08E-04 (7.08E-09)
	Strontium-90	0.01 (0.37)	5.12E-02 (5.12E-07)	7.87E-02 (7.87E-07)
	Hydrogen-3 (tritium)	0.02 (0.74)	6.58E-05 (6.58E-10)	1.49E-04 (1.49E-09)
	Uranium-234	0.0003 (0.0111)	2.69E-03 (2.69E-08)	2.91E-03 (2.91E-08)
	Uranium235	0.00007 (0.0026)	6.01E-04 (6.01E-09)	6.52E-04 (6.52E-09)
	Uranium238	0.0003 (0.0111)	2.47E-03 (2.47E-08)	2.68E-03 (2.68E-08)
	Curium-244	0.00001 (0.0004)	2.19E-04 (2.19E-09)	1.84E-04 (1.84E-09)
	Technetium-99	0.042 (1.55)	4.91E-03 (4.91E-08)	7.16E-03 (7.16E-08)
	Neptunium 237	0.00007 (0.0026)	1.41E-03 (1.41E-08)	1.01E-03 (1.01E-08)
	TOTAL		**0.33 (3.31E-06)**	**0.32 (3.17E-06)**

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Table D-7: Maximum adult and child screening levels for fish ingestion at mouth of Lower Three Runs Creek

Year	Radioactive material	Maximum Concentration in fish pCi/g (Bq/kg)	Adult Screening Level mrem/year (Sv/year))	Child Screening Level mrem/year (Sv/year)
1993	Cesium-137	0.9 (33.3)	2.14E+00 (2.14E-05)	1.18E+00 (1.85E-05)
	Plutonium-238	0.00015 (0.0056)	6.31E-03 (6.31E-08)	4.72E-03 (4.72E-08)
	Strontium-90	0.045 (1.67)	2.30E-01 (2.30E-06)	3.54E-01 (3.54E-06)
	Hydrogen-3 (tritium)	0.69 (25.53)	2.27E-03 (2.27E-08)	5.16E-03 (5.16E-08)
	TOTAL		**2.38 (2.38E-05)**	**1.54 (1.54E-05)**
1994	Cesium-137	1.33 (49.21)	3.16E+00 (3.16E-05)	1.74 E+00 (1.74E-05)
	Plutonium-238	0.00004 (0.0015)	1.68E-03 (1.68E-08)	1.26E-03 (1.26E-08)
	Plutonium-239	0.00006 (0.0022)	2.74E-03 (2.74E-08)	2.12E-03 (2.12E-08)
	Strontium-90	0.225 (8.33)	1.15E+00 (1.15E-05)	1.77E+00 (1.77E-05)
	Hydrogen-3 (tritium)	2.18 (80.66)	7.17E-03 (7.17E-08)	1.63E-02 (1.63E-07)
	TOTAL		**4.32 (4.32E-05)**	**3.53 (3.53E-05)**
1995	Cesium-137	3.08 (113.96)	7.32E+00 (7.32E-05)	4.04E+00 (4.04E-05)
	Plutonium-238	0.00004 (0.0015)	1.68E-03 (1.68E-08)	1.26E-03 (1.26E-08)
	Plutonium-239	0.00002 (0.0007)	9.14E-04 (9.14E-09)	7.08E-04 (7.08E-09)
	Strontium-90	0.018 (0.67)	9.21E-02 (9.21E-07)	1.42E-01 (1.42E-06)
	Hydrogen-3 (tritium)	0.91 (33.67)	2.99E-03 (2.99E-08)	6.80E-03 (6.80E-08)
	TOTAL		**7.42 (7.42E-05)**	**4.19 (4.19E-05)**
1996	Cesium-137	0.6 (22.2)	1.43E+00 (1.43E-05)	7.87E-01 (7.87E-06)
	Cobalt-60	0.037 (1.37)	2.30E-02 (2.30E-07)	5.34E-02 (5.34E-07)
	Plutonium-238	0.00005 (0.0019)	2.10E-03 (2.10E-08)	1.57E-03 (1.57E-08)
	Plutonium-239	0.00008 (0.0030)	3.66E-03 (3.66E-08)	2.83E-03 (2.83E-08)
	Strontium-90	0.017(0.63)	8.70E-02 (8.70E-07)	1.34E-01 (1.34E-06)
	Hydrogen-3 (tritium)	1.09 (40.33)	3.59E-03 (3.59E-08)	8.15E-03 (8.15E-08)
	TOTAL		**1.54 (1.54E-05)**	**0.99 (9.86E-06)**
1997	Cesium-137	0.44 (16.28)	1.05E+00 (1.05E-05)	5.77E-01 (5.77E-06)
	Cobalt-60	0.028 (1.04)	1.74E-02 (1.74E-07)	4.04E-02 (4.04E-07)
	Plutonium-238	0.00005 (0.0019)	2.10E-03 (2.10E-08)	1.57E-03 (1.57E-08)
	Plutonium-239	0.00005 (0.0019)	2.28E-03 (2.28E-08)	1.77E-03 (1.77E-08)
	Strontium-90	0.007 (0.26)	3.58E-02 (3.58E-07)	5.51E-02 (5.51E-07)
	Hydrogen-3 (tritium)	0.91 (33.67)	2.99E-03 (2.99E-08)	6.80E-03 (6.80E-08)
	TOTAL		**1.11 (1.11E-05)**	**0.68 (6.83E-06)**
1998	Cesium-137	0.39 (14.43)	9.27E-01 (9.27E-06)	5.11E-01 (5.11E-06)
	Cobalt-60	0.04 (1.48)	2.49E-02 (2.49E-07)	5.77E-02 (5.77E-07)
	Plutonium-238	0.00002 (0.0007)	8.41E-04 (8.41E-09)	6.29E-04 (6.29E-09)
	Plutonium-239	0.00006 (0.0022)	2.74E-03 (2.74E-08)	2.12E-03 (2.12E-08)
	Strontium-90	0.01 (0.37)	5.12E-02 (5.12E-07)	7.87E-02 (7.87E-07)
	Hydrogen-3 (tritium)	0.99 (36.63)	3.26E-03 (3.26E-08)	7.40E-03 (7.40E-08)
	TOTAL		**1.01 (1.01E-05)**	**0.66 (6.58E-06)**
1999	Cesium-137	0.33 (12.21)	7.84E-01 (7.84E-06)	4.33E-01 (4.33E-06)
	Cobalt-60	0.044 (1.63)	2.73E-02 (2.73E-07)	6.35E-02 (6.35E-07)
	Plutonium-238	0.00008 (0.0030)	3.36E-03 (3.36E-08)	2.52E-03 (2.52E-08)
	Plutonium-239	0.00004 (0.0015)	1.83E-03 (1.83E-08)	1.42E-03 (1.42E-08)
	Strontium-90	0.047 (1.74)	2.41E-01 (2.41E-06)	3.70E-01 (3.70E-06)
	Hydrogen-3 (tritium)	2.22 (82.14)	7.30E-03 (7.30E-08)	1.66E-02 (1.66E-07)
	TOTAL		**1.06 (1.06E-05)**	**0.89 (8.87E-06)**
2000	Cesium-137	0.79 (29.23)	1.88E+00 (1.88E-05)	1.04E+00 (1.04E-05)
	Cobalt-60	0.021 (0.78)	1.30E-02 (1.30E-07)	3.03E-02 (3.03E-07)
	Plutonium-238	0.00002 (0.0007)	8.41E-04 (8.41E-09)	6.29E-04 (6.29E-09)
	Plutonium-239	0.00003 (0.0011)	1.37E-03 (1.37E-08)	1.06E-03 (1.06E-08)
	Strontium-90	0.031 (1.15)	1.59E-01 (1.59E-06)	2.44E-01 (2.44E-06)
	Hydrogen-3 (tritium)	1.23 (45.51)	4.05E-03 (4.05E-08)	9.19E-03 (9.19E-08)
	TOTAL		**2.06 (2.06E-05)**	**1.32 (1.32E-05)**

Table D-7: Maximum adult and child screening levels for fish ingestion at mouth of Lower Three Runs Creek				
Year	Radioactive material	Maximum Concentration in fish pCi/g (Bq/kg)	Adult Screening Level mrem/year (Sv/year))	Child Screening Level mrem/year (Sv/year)
2001	Cesium-137	0.40 (14.80)	9.50E-01 (9.50E-06)	5.25E-01 (5.25E-06)
	Cobalt-60	0.025 (0.93)	1.55E-02 (1.55E-07)	3.61E-02 (3.61E-07)
	Plutonium-238	0.00002 (0.0007)	8.41E-04 (8.41E-09)	6.29E-04 (6.29E-09)
	Strontium-90	0.016 (0.59)	8.19E-02 (8.19E-07)	1.26E-01 (1.26E-06)
	Hydrogen-3 (tritium)	0.60 (22.20)	1.97E-03 (1.97E-08)	4.48E-03 (4.48E-08)
	TOTAL		**1.05 (1.05E-05)**	**0.69 (6.92E-06)**
2002	Cesium-137	0.72 (26.64)	1.71E+00 (1.71E-05)	9.44E-01 (9.44E-06)
	Cobalt-60	0.037 (1.37)	2.30E-02 (2.30E-07)	5.34E-02 (5.34E-07)
	Plutonium-238	0.00004 (0.0015)	1.68E-03 (1.68E-08)	1.26E-03 (1.26E-08)
	Plutonium-239	0.00001 (0.0004)	4.57E-04 (4.57E-09)	3.54E-04 (3.54E-09)
	Strontium-90	0.017 (0.63)	8.70E-02 (8.70E-07)	1.34E-01 (1.34E-06)
	Hydrogen-3 (tritium)	0.32 (11.84)	1.05E-03 (1.05E-08)	2.39E-03 (2.39E-08)
	TOTAL		**1.82 (1.82E-05)**	**1.14 (1.14E-05)**
2003	Cesium-137	0.1 (3.7)	2.38E-01 (2.38E-06)	1.31E-01 (1.31E-06)
	Cobalt-60	0.044 (1.63)	2.73E-02 (2.73E-07)	6.35E-02 (6.35E-07)
	Plutonium-238	0.00006 (0.0022)	2.52E-03 (2.52E-08)	1.89E-03 (1.89E-08)
	Plutonium-239	0.00002 (0.0007)	9.14E-04 (9.14E-09)	7.08E-04 (7.08E-09)
	Strontium-90	0.013 (0.48)	6.65E-02 (6.65E-07)	1.02E-01 (1.02E-06)
	Hydrogen-3 (tritium)	1.61 (59.57)	5.30E-03 (5.30E-08)	1.20E-02 (1.20E-07)
	TOTAL		**0.34 (3.40E-06)**	**0.31 (3.12E-06)**
2004	Cesium-137	0.57 (21,09)	1.35E+00 (1.35E-05)	7.47E-01 (7.47E-06)
	Cobalt-60	0.028 (1.04)	1.74E-02 (1.74E-07)	4.04E-02 (4.04E-07)
	Plutonium-238	0.00003 (0.0011)	1.26E-03 (1.26E-08)	9.44E-04 (9.44E-09)
	Strontium-90	0.011 (0.41)	5.63E-02 (5.63E-07)	8.65E-02 (8.65E-07)
	Hydrogen-3 (tritium)	0.31 (11.47)	1.02E-03 (1.02E-08)	2.32E-03 (2.32E-08)
	TOTAL		**1.43 (1.43E-05)**	**0.88 (8.78E-06)**
2005	Cesium-137	0.28 (10.36)	6.65E-01 (6.65E-06)	3.67E-01 (3.67E-06)
	Cobalt-60	0.034 (1.26)	2.11E-02 (2.11E-07)	4.90E-02 (4.90E-07)
	Plutonium-238	0.0001 (0.0037)	4.20E-03 (4.20E-08)	3.15E-03 (3.15E-08)
	Plutonium-239	0.00001 (0.0004)	4.57E-04 (4.57E-09)	3.54E-04 (3.54E-09)
	Strontium-90	0.007 (0.26)	3.58E-02 (3.58E-07)	5.51E-02 (5.51E-07)
	Hydrogen-3 (tritium)	0.11 (4.07)	3.62E-04 (3.62E-09)	8.22E-04 (8.22E-09)
	TOTAL		**0.73 (7.27E-06)**	**0.48 (4.76E-06)**
2006	Americium-241	0.00001 (0.0004)	3.66E-04 (3.66E-09)	2.88E-04 (2.88E-09)
	Cesium-137	1.51 (55.87)	3.59E+00 (3.59E-05)	1.98E+00 (1.98E-05)
	Cobalt-60	0.018 (0.67)	1.12E-02 (1.12E-07)	2.60E-02 (2.60E-07)
	Iodine-129	0.052 (1.92)	1.05E+00 (1.05E-05)	1.30E+00 (1.30E-05)
	Plutonium-238	0.00012 (0.0044)	5.04E-03 (5.04E-08)	3.78E-03 (3.78E-08)
	Plutonium239	0.00003 (0.0011)	1.37E-03 (1.37E-08)	1.06E-03 (1.06E-08)
	Strontium-90	0.012 (0.44)	6.14E-02 (6.14E-07)	9.44E-02 (9.44E-07)
	Hydrogen-3 (tritium)	0.37 (13.69)	1.22E-03 (1.22E-08)	2.77E-03 (2.77E-08)
	Uranium-234	0.0003 (0.0111)	2.69E-03 (2.69E-08)	2.91E-03 (2.91E-08)
	Uranium235	0.00002 (0.0007)	1.72E-04 (1.72E-09)	1.86E-04 (1.86E-09)
	Uranium238	0.0002 (0.0074)	1.64E-03 (1.64E-08)	1.78E-03 (1.78E-08)
	Curium-244	0..00001 (0.0004)	2.19E-04 (2.19E-09)	1.84E-04 (1.84E-09)
	Technetium-99	0.069 (2.55)	8.07E-03 (8.07E-08)	1.18E-02 (1.18E-07)
	TOTAL		**4.71 (4.71E-05)**	**3.40 (3.40E-05)**
2007	Americium-241	0.00005 (0.0019)	1.83E-03 (1.83E-08)	1.44E-03 (1.44E-08)
	Cesium-137	0.72 (26.64)	1.71E+00 (1.71E-05)	9.44E-01 (9.44E-06)
	Cobalt-60	0.021 (0.78)	1.30E-02 (1.30E-07)	3.03E-02 (3.03E-07)
	Iodine-129	0.004 (0.15)	8.04E-02 (8.04E-07)	9.97E-02 (9.97E-07)
	Plutonium-238	0.00041 (0.0152)	1.72E-02 (1.72E-07)	1.29E-02 (1.29E-07)
	Plutonium239	0.00005 (0.0019)	2.28E-03 (2.28E-08)	1.77E-03 (1.77E-08)
	Strontium-90	0.014 (0.52)	7.16E-02 (7.16E-07)	1.10E-01 (1.10E-06)
	Hydrogen-3 (tritium)	0.39 (14.43)	1.28E-03 (1.28E-08)	2.92E-03 (2.92E-08)

Table D-7: Maximum adult and child screening levels for fish ingestion at mouth of Lower Three Runs Creek

Year	Radioactive material	Maximum Concentration in fish pCi/g (Bq/kg)	Adult Screening Level mrem/year (Sv/year))	Child Screening Level mrem/year (Sv/year)
	Uranium-234	0.0002 (0.0074)	1.79E-03 (1.79E-08)	1.94E-03 (1.94E-08)
	Uranium235	0.00003 (0.0011)	2.58E-04 (2.58E-09)	2.79E-04 (2.79E-09)
	Uranium238	0.0002 (0.0074)	1.64E-03 (1.64E-08)	1.78E-03 (1.78E-08)
	Curium-244	0.00003 (0.0011)	6.58E-04 (6.58E-09)	5.51E-04 (5.51E-09)
	Technetium-99	0.002 (0.07)	2.34E-04 (2.34E-09)	3.41E-04 (3.41E-09)
	TOTAL		**1.90 (1.90E-05)**	**1.20 (1.20E-05)**
2008	Americium-241	0.00002 (0.0007)	7.31E-04 (7.31E-09)	5.77E-04 (5.77E-09)
	Cesium-137	0.43 (15.91)	1.02E+00 (1.02E-05)	5.64E-01 (5.64E-06)
	Cobalt-60	0.018 (0.67)	1.12E-02 (1.12E-07)	2.60E-02 (2.60E-07)
	Iodine-129	0.007 (0.26)	1.41E-01 (1.41E-06)	1.74E-01 (1.74E-06)
	Plutonium-238	0.00013 (0.0048)	5.46E-03 (5.46E-08)	4.09E-03 (4.09E-08)
	Plutonium239	0.00004 (0.0015)	1.83E-03 (1.83E-08)	1.42E-03 (1.42E-08)
	Strontium-90	0.01 (0.37)	5.12E-02 (5.12E-07)	7.87E-02 (7.87E-07)
	Hydrogen-3 (tritium)	0.13 (4.81)	4.28E-04 (4.28E-09)	9.72E-04 (9.72E-09)
	Uranium-234	0.0003 (0.0111)	2.69E-03 (2.69E-08)	2.91E-03 (2.91E-08)
	Uranium235	0.00004 (0 0015)	3.44E-04 (3.44E-09)	3.72E-04 (3.72E-09)
	Uranium238	0.0003 (0.0111)	2.47E-03 (2.47E-08)	2.68E-03 (2.68E-08)
	Curium-244	0.00001 (0.0004)	2.19E-04 (2.19E-09)	1.84E-04 (1.84E-09)
	Technetium-99	0.048 (1.78)	5.61E-03 (5.61E-08)	8.18E-03 (8.18E-08)
	Neptunium 237	0.00009 (0.0033)	1.81E-03 (1.81E-08)	1.30E-04 (1.30E-09)
	TOTAL		**1.23 (1.23E-05)**	**0.85 (8.49E-06)**

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Table D-8: Maximum adult and child screening levels for fish ingestion at mouth of Steel Creek

Year	Radioactive material	Maximum Concentration in fish pCi/g (Bq/kg)	Adult Screening Level mrem/year (Sv/year))	Child Screening Level mrem/year (Sv/year)
1993	Cesium-137	1.42 (52.54)	3.37E+00 (3.37E-05)	1.86E+00 (1.86E-05)
	Plutonium-238	0.00011 (0.0041)	4.62E-03 (4.62E-08)	3.46E-03 (3.46E-08)
	Plutonium-239	0.00005 (0.0019)	2.28E-03 (2.28E-08)	1.77E-03 (1.77E-08)
	Strontium-90	0.027 (1.00)	1.38E-01 (1.38E-06)	2.12E-01 (2.12E-06)
	Hydrogen-3 (tritium)	1.47 (54.39)	4.84E-03 (4.84E-08)	1.10E-02 (1.10E-07)
	TOTAL		**3.52 (3.52E-05)**	**2.09 (2.09E-05)**
1994	Cesium-137	2.12 (78.44)	5.04E+00 (5.04E-05)	2.78E+00 (2.78E-05)
	Plutonium-238	0.00001 (0.0004)	4.20E-04 (4.20E-09)	3.15E-04 (3.15E-09)
	Plutonium-239	0.00001 (0.0004)	4.57E-04 (4.57E-09)	3.54E-04 (3.54E-09)
	Strontium-90	0.046 (1.70)	2.35E-01 (2.35E-06)	3.62E-01 (3.62E-06)
	Hydrogen-3 (tritium)	1.31 (48.47)	4.31E-03 (4.31E-08)	9.79E-03 (9.79E-08)
	TOTAL		**5.28 (5.28E-05)**	**3.15 (3.15E-05)**
1995	Cesium-137	2.28 (84.36)	5.42E+00 (5.42E-05)	2.99E+00 (2.99E-05)
	Plutonium-238	0.00002 (0.0007)	8.41E-04 (8.41E-09)	6.29E-04 (6.29E-09)
	Plutonium-239	0.00001 (0.0004)	4.57E-04 (4.57E-09)	3.54E-04 (3.54E-09)
	Strontium-90	0.02 (0.74)	1.02E-01 (1.02E-06)	1.57E-01 (1.57E-06)
	Hydrogen-3 (tritium)	8.69 (321.53)	2.86E-02 (2.86E-07)	6.50E-02 (6.50E-07)
	TOTAL		**5.55 (5.55E-05)**	**3.21 (3.21E-05)**
1996	Cesium-137	2.99 (110.63)	7.10E+00 (7.10E-05)	3.92E+00 (3.92E-05)
	Cobalt-60	0.03 (1.11)	1.86E-02 (1.86E-07)	4.33E-02 (4.33E-07)
	Plutonium-238	0.00003 (0.0011)	1.26E-03 (1.26E-08)	9.44E-04 (9.44E-09)
	Plutonium-239	0.00003 (0.0011)	1.37E-03 (1.37E-08)	1.06E-03 (1.06E-08)
	Strontium-90	0.016 (0.59)	8.19E-02 (8.19E-07)	1.26E-01 (1.26E-06)
	Hydrogen-3 (tritium)	6.32 (233.84)	2.08E-02 (2.08E-07)	4.72E-02 (4.72E-07)
	TOTAL		**7.23 (7.23E-05)**	**4.14 (4.14E-05)**
1997	Cesium-137	2.04 (75.48)	4.85E+00 (4.85E-05)	2.68E+00 (2.68E-05)
	Cobalt-60	0.007 (0.26)	4.35E-03 (4.35E-08)	1.01E-02 (1.01E-07)
	Plutonium-238	0.00003 (0.0011)	1.26E-03 (1.26E-08)	9.44E-04 (9.44E-09)
	Plutonium-239	0.00004 (0.0015)	1.83E-03 (1.83E-08)	1.42E-03 (1.42E-08)
	Strontium-90	0.011 (0.41)	5.63E-02 (5.63E-07)	8.65E-02 (8.65E-07)
	Hydrogen-3 (tritium)	3.78 (139.86)	1.24E-02 (1.24E-07)	2.83E-02 (2.83E-07)
	TOTAL		**4.92 (4.92E-05)**	**2.80 (2.80E-05)**
1998	Cesium-137	2.52 (93.24)	5.99E+00 (5.99E-05)	3.30E+00 (3.05E-05)
	Cobalt-60	0.049 (1.81)	3.04E-02 (3.04E-07)	7.07E-02 (7.07E-07)
	Plutonium-238	0.00009 (0.0033)	3.78E-03 (3.78E-08)	2.83E-03 (2.83E-08)
	Plutonium-239	0.00005 (0.0019)	2.28E-03 (2.28E-08)	1.77E-03 (1.77E-08)
	Strontium-90	0.027 (1.00)	1.38E-01 (1.38E-06)	2.12E-01 (1.49E-06)
	Hydrogen-3 (tritium)	1.44 (53.28)	4.74E-03 (4.74E-08)	1.08E-02 (1.08E-07)
	TOTAL		**6.17 (6.17E-05)**	**3.60 (3.60E-05)**
1999	Cesium-137	4.40 (162.8)	1.05E+01 (1.05E-04)	5.77E+00 (5.77E-05)
	Cobalt-60	0.016 (0.59)	9.94E-03 (9.94E-08)	2.31E-02 (2.31E-07)
	Plutonium-238	0.00003 (0.0011)	1.26E-03 (1.26E-08)	9.44E-04 (9.44E-09)
	Plutonium-239	0.00002 (0.0007)	9.14E-04 (9.14E-09)	7.08E-04 (7.08E-09)
	Strontium-90	0.024 (0.89)	1.23E-01 (1.23E-06)	1.89E-01 (1.89E-06)
	Hydrogen-3 (tritium)	2.38 (88.06)	7.83E-03 (7.83E-08)	1.78E-02 (1.78E-07)
	TOTAL		**10.6 (1.06E-04)**	**6.00 (6.00E-05)**
2000	Cesium-137	1.58 (58.46)	3.75E+00 (3.75E-05)	2.07E+00 (2.07E-05)
	Cobalt-60	0.031 (1.15)	1.93E-02 (1.93E-07)	4.47E-02 (4.47E-07)
	Plutonium-238	0.00001 (0.0004)	4.20E-04 (4.20E-09)	3.15E-04 (3.15E-09)
	Plutonium-239	0.00008 (0.0030)	3.66E-03 (3.66E-08)	2.83E-03 (2.83E-08)
	Strontium-90	0.019 (0.70)	9.72E-02 (9.72E-07)	1.49E-01 (1.49E-06)
	Hydrogen-3 (tritium)	9.82 (364)	3.23E-02 (3.23E-07)	7.34E-02 (7.34E-07)

Table D-8: Maximum adult and child screening levels for fish ingestion at mouth of Steel Creek

Year	Radioactive material	Maximum Concentration in fish pCi/g (Bq/kg)	Adult Screening Level mrem/year (Sv/year))	Child Screening Level mrem/year (Sv/year)
	TOTAL		**3.91 (3.91E-05)**	**2.34 (2.34E-05)**
2001	Cesium-137	0.82 (30.34)	1.95E+00 (1.95E-05)	1.08E+00 (1.08E-05)
	Cobalt-60	0.041 (1.52)	2.55E-02 (2.55E-07)	5.91E-02 (5.91E-07)
	Plutonium-238	0.00007 (0.0026)	2.94E-03 (2.94E-08)	2.20E-03 (2.20E-08)
	Plutonium-239	0.00006 (0.0022)	2.74E-03 (2.74E-08)	2.12E-03 (2.12E-08)
	Strontium-90	0.014 (0.52)	7.16E-02 (7.16E-07)	1.10E-01 (1.10E-06)
	Hydrogen-3 (tritium)	1.4 (51.8)	4.61E-03 (4.61E-08)	1.05E-02 (1.05E-07)
	TOTAL		**2.06 (2.06E-05)**	**1.26 (1.26E-05)**
2002	Cesium-137	0.26 (9.62)	6.18E-01 (6.18E-06)	3.41E-01 (3.41E-06)
	Cobalt-60	0.032 (1.18)	1.99E-02 (1.99E-07)	4.62E-02 (4.62E-07)
	Plutonium-238	0.00003 (0.0011)	1.26E-03 (1.26E-08)	9.44E-04 (9.44E-09)
	Plutonium-239	0.00002 (0.0007)	9.14E-04 (9.14E-09)	7.08E-04 (7.08E-09)
	Strontium-90	0.012 (0.44)	6.14E-02 (6.14E-07)	9.44E-02 (9.44E-07)
	Hydrogen-3 (tritium)	0.79 (29.23)	2.60E-03 (2.60E-08)	5.90E-03 (5.90E-08)
	TOTAL		**0.70 (7.04E-06)**	**0.49 (4.89E-06)**
2003	Cesium-137	0.19 (7.03)	4.51E-01 (4.51E-06)	2.49E-01 (2.49E-06)
	Cobalt-60	0.018 (0.67)	1.12E-02 (1.12E-07)	2.60E-02 (2.60E-07)
	Plutonium-238	0.0002 (0.0074)	8.41E-03 (8.41E-08)	6.29E-03 (6.29E-08)
	Plutonium-239	0.00004 (0.0015)	1.83E-03 (1.83E-08)	1.42E-03 (1.42E-08)
	Strontium-90	0.012 (0.44)	6.14E-02 (6.14E-07)	9.44E-02 (9.44E-07)
	Hydrogen-3 (tritium)	0.74 (27.38)	2.43E-03 (2.43E-08)	5.53E-03 (5.53E-08)
	TOTAL		**0.54 (5.37E-06)**	**0.38 (3.83E-06)**
2004	Cesium-137	0.23 (8.51)	5.46E-01 (5.46E-06)	3.02E-01 (3.02E-06)
	Cobalt-60	0.008 (0.30)	4.97E-03 (4.97E-08)	1.15E-02 (1.15E-07)
	Plutonium-238	0.00007 (0.0026)	2.94E-03 (2.94E-08)	2.20E-03 (2.20E-08)
	Plutonium-239	0.00001 (0.0004)	4.57E-04 (4.57E-09)	3.54E-04 (3.54E-09)
	Strontium-90	0.021 (0.78)	1.07E-01 (1.07E-06)	1.65E-01 (1.65E-06)
	Hydrogen-3 (tritium)	0.9 (33.3)	2.96E-03 (2.96E-08)	6.73E-03 (6.73E-08)
	TOTAL		**0.67 (6.65E-06)**	**0.49 (4.88E-06)**
2005	Cesium-137	0.27 (9.99)	6.42E-01 (6.42E-06)	3.54E-01 (3.54E-06)
	Cobalt-60	0.031 (1.15)	1.93E-02 (1.93E-07)	4.47E-02 (4.47E-07)
	Plutonium-238	0.00003 (0.0011)	1.26E-03 (1.26E-08)	9.44E-04 (9.44E-09)
	Plutonium-239	0.00032 (0.012)	1.46E-02 (1.46E-07)	1.13E-02 (1.13E-07)
	Strontium-90	0.01 (0.37)	5.12E-02 (5.12E-07)	7.87E-02 (7.87E-07)
	Hydrogen-3 (tritium)	1.64 (60.68)	5.40E-03 (5.40E-08)	1.23E-02 (1.23E-07)
	TOTAL		**0.73 (7.33E-06)**	**0.50 (5.02E-06)**
2006	Americium-241	0.00004 (0.0015)	1.46E-03 (1.46E-08)	1.15E-03 (1.15E-08)
	Cesium-137	0.63 (23.31)	1.50E+00 (1.50E-05)	8.26E-01 (8.26E-06)
	Cobalt-60	0.008 (0.30)	4.97E-03 (4.97E-08)	1.15E-02 (1.15E-07)
	Iodine-129	0.011 (0.41)	2.21E-01 (2.21E-06)	2.74E-01 (2.74E-06)
	Plutonium-238	0.0002 (0.0074)	8.41E-03 (8.41E-08)	6.29E-03 (6.29E-08)
	Plutonium239	0.00008 (0.0030)	3.66E-03 (3.66E-08)	2.83E-03 (2.83E-08)
	Strontium-90	0.019 (0.70)	9.72E-02 (9.72E-07)	1.49E-01 (1.49E-06)
	Hydrogen-3 (tritium)	0.47 (17.39)	1.55E-03 (1.55E-08)	3.51E-03 (3.51E-08)
	Uranium-234	0.00042 (0.0155)	3.76E-03 (3.76E-08)	4.08E-03 (4.08E-08)
	Uranium235	0.00017 (0.0063)	1.46E-03 (1.46E-08)	1.58E-03 (1.58E-08)
	Uranium238	0.00378 (0.1400)	3.11E-02 (3.11E-07)	3.37E-02 (3.37E-07)
	Curium-244	0.00002 (0.0007)	4.39E-04 (4.39E-09)	3.67E-04 (3.67E-09)
	Technetium-99	0.091 (3.37)	1.06E-02 (1.06E-07)	1.55E-02 (1.55E-07)
	TOTAL		**1.83 (1.83E-05)**	**1.27 (1.27E-05)**
2007	Americium-241	0.00004 (0.0015)	1.46E-03 (1.46E-08)	1.15E-03 (1.15E-08)
	Cesium-137	1.41 (52.17)	3.35E+00 (3.35E-05)	1.85E+00 (1.85E-05)
	Cobalt-60	0.015 (0.56)	9.32E-03 (9.32E-08)	2.16E-02 (2.16E-07)
	Iodine-129	0.01 (0.37)	2.01E-01 (2.01E-06)	2.49E-01 (2.49E-06)
	Plutonium-238	0.00016 (0.0059)	6.73E-03 (6.73E-08)	5.04E-03 (5.04E-08)

Table D-8: Maximum adult and child screening levels for fish ingestion at mouth of Steel Creek

Year	Radioactive material	Maximum Concentration in fish pCi/g (Bq/kg)	Adult Screening Level mrem/year (Sv/year))	Child Screening Level mrem/year (Sv/year)
	Plutonium239	0.00003 (0.0011)	1.37E-03 (1.37E-08)	1.06E-03 (1.06E-08)
	Strontium-90	0.04 (1.48)	2.05E-01 (2.05E-06)	3.15E-01 (3.15E-06)
	Hydrogen-3 (tritium)	0.37 (13.69)	1.22E-03 (1.22E-08)	2.77E-03 (2.77E-08)
	Uranium-234	0.0003 (0.0111)	2.69E-03 (2.69E-08)	2.91E-03 (2.91E-08)
	Uranium235	0.00002 (0.0007)	1.72E-04 (1.72E-09)	1.86E-04 (1.86E-09)
	Uranium238	0.0003 (0.0111)	2.47E-03 (2.47E-08)	2.68E-03 (2.68E-08)
	Curium-244	0.00002 (0.0007)	4.39E-04 (4.39E-09)	3.67E-04 (3.67E-09)
	Technetium-99	0.001 (0.04)	1.17E-04 (1.17E-09)	1.70E-04 (1.70E-09)
	TOTAL		**3.77 (3.77E-05)**	**2.44 (2.44E-05)**
2008	Americium-241	0.00001 (0.0004)	3.66E-04 (3.66E-09)	2.88E-04 (2.88E-09)
	Cesium-137	0.7 (25.9)	1.66E+00 (1.66E-05)	9.18E-01 (9.18E-06)
	Cobalt-60	0.021 (0.78)	1.30E-02 (1.30E-07)	3.03E-02 (3.03E-07)
	Iodine-129	0.006 (0.22)	1.21E-01 (1.21E-06)	1.49E-01 (1.49E-06)
	Plutonium-238	0.00021 (0.0078)	8.83E-03 (8.83E-08)	6.61E-03 (6.61E-08)
	Plutonium239	0.00003 (0.0011)	1.37E-03 (1.37E-08)	1.06E-03 (1.06E-08)
	Strontium-90	0.014 (0.52)	7.16E-02 (7.16E-07)	1.10E-01 (1.10E-06)
	Hydrogen-3 (tritium)	0.2 (7.4)	6.58E-04 (6.58E-09)	1.49E-03 (1.49E-08)
	Uranium-234	0.0003 (0.0111)	2.69E-03 (2.69E-08)	2.91E-03 (2.91E-08)
	Uranium235	0.00002 (0.0007)	1.72E-04 (1.72E-09)	1.86E-04 (1.86E-09)
	Uranium238	0.00003 (0.0111)	2.47E-03 (2.47E-08)	2.68E-03 (2.68E-08)
	Curium-244	0.00002 (0.0007)	4.39E-04 (4.39E-09)	3.67E-04 (3.67E-09)
	Technetium-99	0.001 (0.04)	1.17E-04 (1.17E-09)	1.70E-04 (1.70E-09)
	Neptunium 237	0.00004 (0.0015)	8.04E-04 (8.04E-09)	5.77E-05 (5.77E-10)
	TOTAL		**1.88 (1.88E-05)**	**1.22 (1.22E+00)**

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Table D-9: Maximum adult and child screening levels for fish ingestion at mouth of Upper Three Runs Creek

Year	Radioactive material	Maximum Concentration in fish pCi/g (Bq/kg)	Adult Screening Level mrem/year (Sv/year))	Child Screening Level mrem/year (Sv/year)
1993	Cesium-137	0.1 (3.7)	2.38E-01 (2.38E-06)	1.31E-01 (1.31E-06)
	Strontium-90	0.004 (0.15)	2.05E-02(2.05E-07)	3.15E-02 (3.15E-07)
	Hydrogen-3 (tritium)	1.05 (38.85)	3.45E-03 (3.45E-08)	7.85E-03 (7.85E-08)
	TOTAL		**0.26 (2.62E-06)**	**0.17 (1.70E-06)**
1994	Cesium-137	0.07 (2.59)	1.66E-01 (1.66E-06)	9.18E-02 (9.18E-07)
	Strontium-90	0.019 (0.70)	9.72E-02 (9.72E-07)	1.49E-01 (1.49E-06)
	Hydrogen-3 (tritium)	0.78 (28.86)	2.57E-03 (2.57E-08)	5.83E-03 (5.83E-08)
	TOTAL		**0.27 (2.66E-06)**	**0.25 (2.47E-06)**
1995	Cesium-137	0.35 (12.95)	8.32E-01 (8.32E-06)	4.59E-01 (4.59E-06)
	Plutonium-238	0.00001 (0.0004)	4.20E-04 (4.30E-09)	3.15E-04 (3.15E-09)
	Plutonium-239	0.00001 (0.0004)	4.57E-04 (4.57E-09)	3.54E-04 (3.54E-09)
	Strontium-90	0.004 (0.148)	2.05E-02 (2.05E-07)	3.15E-02 (3.15E-07)
	Hydrogen-3 (tritium)	1.61 (59.57)	5.30E-03 (5.30E-08)	1.20E-02 (1.20E-07)
	TOTAL		**0.86 (8.58E-06)**	**0.50 (5.03E-06)**
1996	Cesium-137	0.24 (8.88)	5.70E-01 (5.70E-06)	3.15E-01 (3.15E-06)
	Cobalt-60	0.022 (0.81)	1.37E-02 (1.37E-07)	3.17E-02 (3.17E-07)
	Plutonium-238	0.00013 (0.0048)	5.46E-03 (5.46E-08)	4.09E-03 (4.09E-08)
	Plutonium-239	0.00007 (0.0026)	3.20E-03 (3.20E-08)	2.48E-03 (2.48E-08)
	Strontium-90	0.01 (0.37)	5.12E-02 (5.12E-07)	7.87E-02 (7.87E-07)
	Hydrogen-3 (tritium)	0.31 (11.47)	1.02E-03 (1.02E-08)	2.32E-03 (2.32E-08)
	TOTAL		**0.65 (6.45E-06)**	**0.43 (4.34E-06)**
1997	Cesium-137	0.87 (32.19)	2.07E+00 (2.07E-05)	1.14E+00 (1.14E-05)
	Cobalt-60	0.029 (1.07)	1.80E-02 (1.80E-07)	4.18E-02 (4.18E-07)
	Plutonium-238	0.00032 (0.0118)	1.35E-02 (1.35E-07)	1.01E-02 (1.01E-07)
	Plutonium-239	0.00011 (0.0041)	5.03E-03 (5.03E-08)	3.89E-03 (3.89E-08)
	Strontium-90	0.036 (1.33)	1.84E-01 (1.84E-06)	2.83E-01 (2.83E-06)
	Hydrogen-3 (tritium)	0.32 (11.84)	1.05E-03 (1.05E-08)	2.39E-03 (2.39E-08)
	TOTAL		**2.29 (2.29E-05)**	**1.48 (1.48E-05)**
1998	Cesium-137	0.15 (5.55)	3.56E-01 (3.56E-06)	1.97E-01 (1.97E-06)
	Cobalt-60	0.021 (0.78)	1.30E-02 (1.30E-07)	3.03E-02 (3.03E-07)
	Plutonium-238	0.00015 (0.0056)	6.31E-03 (6.31E-08)	4.72E-03 (4.72E-08)
	Plutonium-239	0.00011 (0.0041)	5.03E-03 (5.03E-08)	3.89E-03 (3.89E-08)
	Strontium-90	0.013 (0.48)	6.65E-02 (6.65E-07)	1.02E-01 (1.02E-06)
	Hydrogen-3 (tritium)	1.07 (39.59)	3.52E-03 (3.52E-08)	8.00E-03 (8.00E-08)
	TOTAL		**0.45 (4.51E-06)**	**0.35 3.46E-06)**
1999	Cesium-137	0.46 (17.02)	1.09E+00 (1.09E-05)	6.03E-01 (6.03E-06)
	Cobalt-60	0.035 (1.30)	2.17E-02 (2.17E-07)	5.05E-02 (5.05E-07)
	Plutonium-238	0.00005 (0.0019)	2.10E-03 (2.10E-08)	1.57E-03 (1.57E-08)
	Plutonium-239	0.00006 (0.0022)	2.74E-03 (2.74E-08)	2.12E-03 (2.12E-08)
	Strontium-90	0.011 (0.41)	5.63E-02 (5.63E-07)	8.65E-02 (8.65E-07)
	Hydrogen-3 (tritium)	0.55 (20.35)	1.81E-03 (1.81E-08)	4.11E-03 (4.11E-08)
	TOTAL		**1.18 (1.18E-05)**	**0.75 (7.48E-06)**
2000	Cesium-137	0.23 (8.51)	5.46E-01 (5.46E-06)	3.02E-01 (3.02E-06)
	Cobalt-60	0.22 (8.14)	1.37E-01 (1.37E-06)	3.17E-01 (3.17E-06)
	Plutonium-238	0.00004 (0.0015)	1.68E-03 (1.68E-08)	1.26E-03 (1.26E-08)
	Plutonium-239	0.00026 (0.0096)	1.19E-02 (1.19E-07)	9.21E-03 (9.21E-08)
	Strontium-90	0.016 (0.59)	8.19E-02 (8.19E-07)	1.26E-01 (1.26E-06)
	Hydrogen-3 (tritium)	46.97 (1,737.89)	1.55E-01 (1.55E-06)	3.51E-01 (3.51E-06)
	TOTAL		**0.93(9.33E-06)**	**1.11 (1.11E-05)**
2001	Cesium-137	0.24 (8.88)	5.70E-01 (5.70E-06)	3.15E-01 (3.15E-06)
	Cobalt-60	0.016 (0.59)	9.94E-03 (9.94E-08)	2.31E-02 (2.31E-07)
	Plutonium-238	0.00001 (0.0004)	4.20E-04 (4.20E-09)	3.15E-04 (3.15E-09)

Table D-9: Maximum adult and child screening levels for fish ingestion at mouth of Upper Three Runs Creek

Year	Radioactive material	Maximum Concentration in fish pCi/g (Bq/kg)	Adult Screening Level mrem/year (Sv/year))	Child Screening Level mrem/year (Sv/year)
	Plutonium-239	0.00006 (0.0022)	2.74E-03 (2.74E-08)	2.12E-03 (2.12E-08)
	Strontium-90	0.02 (0.74)	1.02E-01 (1.02E-06)	1.57E-01 (1.57E-06)
	Hydrogen-3 (tritium)	1.33 (49.21)	4.38E-03 (4.38E-08)	9.94E-03 (9.94E-08)
	TOTAL		**0.69 (6.90E-06)**	**0.51 (5.08E-06)**
2002	Cesium-137	0.37 (13.69)	8.79E-01 (8.79E-06)	4.85E-01 (4.85E-06)
	Cobalt-60	0.029 (1.07)	1.80E-02 (1.80E-07)	4.18E-02 (4.18E-07)
	Plutonium-238	0.00001 (0.0004)	4.20E-04 (4.20E-09)	3.15E-04 (3.15E-09)
	Strontium-90	0.006 (0.22)	3.07E-02 (3.07E-07)	4.72E-02 (4.72E-07)
	Hydrogen-3 (tritium)	0.31 (11.47)	1.02E-03 (1.02E-08)	2.32E-03 (2.32E-08)
	TOTAL		**0.93 (9.29E-06)**	**0.58 (5.77E-06)**
2003	Cesium-137	0.06 (2.22)	1.43E-01 (1.43E-06)	7.87E-02 (7.87E-07)
	Cobalt-60	0.025 (0.93)	1.55E-02 (1.55E-07)	3.61E-02 (3.61E-07)
	Plutonium-238	0.00005 (0.0019)	2.10E-03 (2.10E-08)	1.57E-03 (1.57E-08)
	Plutonium-239	0.00001 (0.0004)	4.57E-04 (4.57E-09)	3.54E-04 (3.54E-09)
	Strontium-90	0.012 (0.44)	6.14E-02 (6.14E-07)	9.44E-02 (9.44E-07)
	Hydrogen-3 (tritium)	0.22 (8.14)	7.24E-04 (7.24E-09)	1.64E-03 (1.64E-08)
	TOTAL		**0.22 (2.23E-06)**	**0.21 (2.13E-06)**
2004	Cesium-137	0.07 (2.59)	1.66E-01 (1.66E-06)	9.18E-02 (9.18E-07)
	Cobalt-60	0.017 (0.63)	1.06E-02 (1.06E-07)	2.45E-02 (2.45E-07)
	Plutonium-238	0.00003 (0.0011)	1.26E-03 (1.26E-08)	9.44E-04 (9.44E-09)
	Plutonium-239	0.00001 (0.0004)	4.57E-04 (4.57E-09)	3.54E-04 (3.54E-09)
	Strontium-90	0.012 (0.44)	6.14E-02 (6.14E-07)	9.44E-02 (9.44E-07)
	Hydrogen-3 (tritium)	0.14 (5.18)	4.61E-04 (4.61E-09)	1.05E-03 (1.05E-08)
	TOTAL		**0.24 (2.40E-06)**	**0.21 (2.13E-06)**
2005	Cesium-137	0.21 (7.77)	4.99E-01 (4.99E-06)	2.75E-01 (2.75E-06)
	Cobalt-60	0.025 (0.93)	1.55E-02 (1.55E-07)	3.61E-02 (3.61E-07)
	Plutonium-238	0.00007 (0.0026)	2.94E-03 (2.94E-08)	2.20E-03 (2.20E-08)
	Plutonium-239	0.00002 (0.0007)	9.14E-04 (9.14E-09)	7.08E-04 (7.08E-09)
	Strontium-90	0.012 (0.44)	6.14E-02 (6.14E-07)	9.44E-02 (9.44E-07)
	Hydrogen-3 (tritium)	0.12 (4.44)	3.95E-04 (3.95E-09)	8.97E-04 (8.97E-09)
	TOTAL		**0.58 (5.80E-06)**	**0.41 (4.10E-06)**
2006	Americium-241	0.00007 (0.0026)	2.56E-03 (2.56E-08)	2.02E-03 (2.02E-08)
	Cesium-137	0.15 (5.55)	3.56E-01 (3.56E-06)	1.97E-01 (1.97E-06)
	Cobalt-60	0.021 (0.78)	1.30E-02 (1.30E-07)	3.03E-02 (3.03E-07)
	Iodine-129	0.021 (0.78)	4.22E-01 (4.22E-06)	5.23E-01 (5.23E-06)
	Plutonium-238	0.00055 (0.0204)	2.31E-02 (2.31E-07)	1.73E-02 (1.73E-07)
	Plutonium239	0.00008 (0.0063)	3.66E-03 (3.66E-08)	2.83E-03 (2.83E-08)
	Strontium-90	0.017 (0.63)	8.70E-02 (8.70E-07)	1.34E-01 (1.34E-06)
	Hydrogen-3 (tritium)	0.16 (5.92)	5.26E-04 (5.26E-09)	1.20E-03 (1.20E-08)
	Uranium-234	0.0004 (0.0148)	3.58E-03 (3.58E-08)	3.88E-03 (3.88E-08)
	Uranium235	0.00003 (0.0011)	2.58E-04 (2.58E-09)	2.79E-04 (2.79E-09)
	Uranium238	0.0005 (0.0185)	4.11E-03 (4.11E-08)	4.46E-03 (4.46E-08)
	Curium-244	0.00002 (0.0007)	4.39E-04 (4.39E-09)	3.67E-04 (3.67E-09)
	Technetium-99	0.121 (4.48)	1.42E-02 (1.42E-07)	2.06E-02 (2.06E-07)
	TOTAL		**0.91 (9.06E-06)**	**0.91 (9.05E-06)**
2007	Americium-241	0.00003 (0.0011)	1.10E-03 (1.10E-08)	8.65E-04 (8.65E-09)
	Cesium-137	0.13 (4.81)	3.09E-01 (3.09E-06)	1.70E-01 (1.70E-06)
	Cobalt-60	0.023 (0.85)	1.43E-02 (1.43E-07)	3.32E-02 (3.32E-07)
	Iodine-129	0.004 (0.148)	8.04E-02 (8.04E-07)	9.97E-02 (9.97E-07)
	Plutonium-238	0.00023 (0.0085)	9.67E-03 (9.67E-08)	7.24E-03 (7.24E-08)
	Plutonium239	0.00003 (0.0011)	1.37E-03 (1.37E-08)	1.06E-03 (1.06E-08)
	Strontium-90	0.01 (0.37)	5.12E-02 (5.12E-07)	7.87E-02 (7.87E-07)
	Hydrogen-3 (tritium)	0.24 (8.88)	7.90E-04 (7.90E-09)	1.79E-03 (1.79E-08)
	Uranium-234	0.0002 (0.0074)	1.79E-03 (1.79E-08)	1.94E-03 (1.94E-08)
	Uranium235	0.00004 (0.0015)	3.44E-04 (3.44E-09)	3.72E-04 (3.72E-09)

Table D-9: Maximum adult and child screening levels for fish ingestion at mouth of Upper Three Runs Creek

Year	Radioactive material	Maximum Concentration in fish pCi/g (Bq/kg)	Adult Screening Level mrem/year (Sv/year))	Child Screening Level mrem/year (Sv/year)
	Uranium238	0.0002 (0.074)	1.64E-03 (1.64E-08)	1.78E-03 (1.78E-08)
	Curium-244	0.00001 (0.0004)	2.19E-04 (2.19E-09)	1.84E-04 (1.84E-09)
	Technetium-99	0.001 (0.04)	1.17E-04 (1.17E-09)	1.70E-04 (1.70E-09)
	TOTAL		**0.47 (4.67E-06)**	**0.39 (3.92E-06)**
2008	Americium-241	0.00003 (0.0011)	1.10E-03 (1.10E-08)	8.65E-04 (8.65E-09)
	Cesium-137	0.14 (5.18)	3.33E-01 (3.33E-06)	1.84E-01 (1.84E-06)
	Cobalt-60	0.021 (0.78)	1.30E-02 (1.30E-07)	3.03E-02 (3.03E-07)
	Iodine-129	0.009 (0.33)	1.81E-01 (1.81E-06)	2.24E-01 (2.24E-06)
	Plutonium-238	0.00016 (0.0059)	6.73E-03 (6.73E-08)	5.04E-03 (5.04E-08)
	Plutonium239	0.00004 (0.0015)	1.83E-03 (1.83E-08)	1.42E-03 (1.42E-08)
	Strontium-90	0.012 (0.44)	6.14E-02 (6.14E-07)	9.44E-02 (9.44E-07)
	Hydrogen-3 (tritium)	0.02 (0.74)	6.58E-05 (6.58E-10)	1.49E-04 (1.49E-09)
	Uranium-234	0.0003 (0.0111)	2.69E-03 (2.69E-08)	2.91E-03 (2.91E-08)
	Uranium235	0.00004 (0.0015)	3.44E-04 (3.44E-09)	3.72E-04 (3.72E-09)
	Uranium238	0.0002 (0.0074)	1.64E-03 (1.64E-08)	1.78E-03 (1.78E-08)
	Curium-244	0.00002 (0.0074)	4.39E-04 (4.39E-09)	3.67E-04 (3.67E-09)
	Technetium-99	0.058 (2.15)	6.78E-03 (6.78E-08)	9.89E-03 (9.89E-08)
	Neptunium 237	0.00004 (0.0015)	8.04E-04 (8.04E-09)	5.77E-05 (5.77E-10)
	TOTAL		**0.60 (5.97E-06)**	**0.54 (5.39E-06)**

Hypothetical exposure screening levels for ingestion of harvested wild game

The hypothetical exposure screening levels for ingestion of harvested wild animals were estimated using radiological sampling data provided to ATSDR by DOE, South Carolina and Georgia. ATSDR's review concentrated on data from the edible portions of the animals. The main radionuclide of concern and the most data reported were for cesium-137.

Sampling data from DOE consisted of infield surveys and periodic laboratory analyses of harvested animal samples from on-site hunts. All animals harvested on-site are surveyed for cesium-137 in the field prior to release. DOE's offsite sampling of deer in 1993 and 1994 was used to verify an environmental model. DOE assumes that the cesium concentration in off-site deer and feral hogs does not exceed the average concentration in on-site deer.

From 1993 (and before) through 2008, DOE has calculated potential exposures for all *on-site* hunters tracking multiple kills and hunts per year and assuming that one individual eats all edible portions of their kills. This ingestion rate is often larger than the 99th percentile meat ingestion rate for adults reported in EPA's Exposure Factor Handbook (EPA 1997). EPA's 99th percentile adult ingestion rate for total meat is 78 kg/yr, and, for children, the rate is 18.6 kg/yr.

Most of the off-site wild game sampling data was reported by the states of South Carolina and Georgia. The states rely on hunters to voluntarily donate samples for analyses.

The ingestion rates used by ATSDR are as follows:

Maximum ingestion rates used for ingestion of wild game[1]		
Species and location	*Adult*	*Child*
Onsite deer and feral hogs	78 kg/yr	18.6 kg/yr
Onsite turkeys[2]	10 kg/yr	6.2 kg/yr
Offsite deer and feral hogs	78 kg/yr	18.6 kg/yr
Offsite birds and ducks	51 kg/yr	13.7 kg/yr

[1] The 99th percentile rates for ingestion of meat from EPA's Exposure Factor Handbook (EPA 1997) was used for ingestion of deer and feral hogs.
[2] Ingestion rate for turkeys is based on the number of turkeys allowed to be harvested per year, average weight, and edible portion after cleaning and cooked.

Table D-10. Wild Game Maximum Radioactive Contaminant Summary Data

Type of Wild Game (Location)	Radioactive material	Maximum Concentration in wild game, pCi/g (Bq/kg)	Adult Screening Level mrem/year (Sv/year))	Child Screening Level mrem/year (Sv/year)
Deer & feral hog muscle (on-site)	Cesium-137	13.33 (493)	50 (5.0E-04)	9 (9.0E-05)
Wild turkeys (on-site)	Cesium-137	10 (370)	4.8 (4.8E-05)	2.3 (2.3E-05)
Deer & feral hog muscle (off-site)	Cesium-137	8.86 (328)	33 (3.3E-04)	6.1 (6.1E-05)
Birds & ducks (off-site)	Cesium-137	0.7 (24)	1.6 (1.6E-05)	0.3 (3.3E-06)

Source: Annual environmental reports and data submitted by DOE, SCDHEC/ESOP, and GDNR/EPD
pCi/g = picocurie per gram of tissue (1 pCi/g = 37 Bq/kg);
Bq/kg = becquerel per kilogram of tissue (1 Bq/kg = 0.027 pCi/g)
mrem = millirem (1 mrem = 1E-05 Sv); Sv = sievert (1 Sv = 1E+05 mrem)

Hypothetical exposure screening levels for ingestion of agricultural and farm products

The hypothetical exposure screening levels for ingestion of agricultural and farm products were estimated for vegetables, fruits, nuts, grains, milk, beef, domestic pork, chicken, and eggs. ATSDR assumed that all consumed food was locally grown, raised, or produced.

Since each year the types of vegetables and fruits sampled and the radionuclides included in the analyses varied, the average value of the maximum concentrations from each type of vegetable or fruit from all sampled years were used to determine a hypothetical maximum exposure screening level for an adult and a child. The average of the maximum concentrations for peanuts and pecans from all sampled years were also used to determine the hypothetical maximum exposure screening level for an adult and a child.

For grain and milk samples, the maximum concentrations from all sampled years were used to determine the hypothetical maximum exposure screening level. The hypothetical maximum screening levels for ingestion of milk were estimated for four age groups.

Farm products (beef, domestic pork, chicken, and eggs) were sampled at various times. For beef , domestic pork, chicken and eggs, maximum concentrations were used to determine the hypothetical maximum screening levels for an adult and a child.

ATSDR used the following ingestion rates:

Maximum ingestion rates used for ingestion of agricultural and farm products except milk		
Type of product	*Adult*	*Child*
Total vegetables	306 kg/yr	87 kg/yr
Total fruits	304 kg/yr	102 kg /yr
Nuts	0.88 kg/yr	0.95 kg/yr
Grain	0.67kg/yr	0.28 kg/yr
Beef	78 kg/yr	18.6 kg/yr
Domestic Pork	47.8 kg/yr	13.5 kg/yr
Chicken	68.3 kg/yr	18.25 kg/yr
Eggs	45 kg/yr	14.2 kg/yr
Source: The 99th percentile ingestion rates from EPA's Exposure Factor Handbook (EPA 1997) are presented unless otherwise noted. kg/yr = kilogram per year		

Maximum ingestion rates used for ingestion of milk				
Milk	Adult	Teenager (13 – 17 yrs)	Child (6 – 12 yrs)	Young child (2 – 5 yrs)
	440 L/yr	374 L/yr	374 L/yr	377 L/yr
Source: Adult (EPA 1997); teenager, 6-12 yr child, and 1 – 5 yr child (EPA 2008) L/yr = liters per year yrs = years				

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Table D-11: Maximum adult and child screening levels for ingestion of agricultural and farm products

Product	Radioactive material	Maximum Concentration in agricultural and farm products, pCi/g (Bq/kg)	Adult Screening Level mrem/year (Sv/year))	Child Screening Level mrem/year (Sv/year)
Vegetables	Hydrogen-3 (tritium)	0.45 (16.65)	2.17E-02 (2.17E-07)	8.26E-03 (8.26E-08)
	Cesium-137	0.12 (4.29)	1.71E+00 (1.71E-05)	3.73E-01 (3.73E-06)
	Cobalt-60	0.022 (0.80)	8.32E-02 (8.32E-07)	7.66E-02 (7.66E-07)
	Strontium-90*	0.584 (21.61)*	1.85E+01 (1.85E-04)	1.13E+01 (1.13E-04)
		0.21 (7.72) *	6.61E+00 (6.61E-05)	3.69E+00 (3.69E-05)
	Plutonium-238	0.00154 (0.057)	4.01E-01 (4.01E-06)	1.19E-01 (1.19E-06)
	Plutonium-239	0.00039 (0.014)	1.07E-01 (1.07E-06)	3.29E-02 (3.29E-07)
	Uranium-234	0.0085 (0.316)	4.74E-01 (4.74E-06)	2.03E-01 (2.03E-06)
	Uranium-235	0.0014 (0.052)	7.48E-02 (7.48E-07)	3.21E-02 (3.21E-07)
	Uranium-238	0.0058 (0.215)	2.96E-01 (2.96E-06)	1.27E-01 (1.27E-06)
	Americium-241	0.0028 (0.102)	6.24E-01 (6.24E-06)	1.95E-01 (1.95E-06)
	Curium-244	0.00108 (0.04)	1.47E-01 (1.47E-06)	5.57E-02 (5.57E-07)
	TOTAL		**10.5 to 22.5* (1.05E-04 to 2.25E-04)**	**4.9 to 11.6* (4.9E-05 to 1.16E-04)**
Fruit	Hydrogen-3 (tritium)	1.22 (45.12)	5.76E-02 (5.76E-07)	2.62E-02 (2.62E-07)
	Cesium-137	0.026 (0.96)	3.79E-01 (3.79E-06)	9.79E-02 (9.79E-07)
	Cobalt-60	0.004 (0.15)	1.55E-02 (1.55E-07)	1.68E-02 (1.68E-07)
	Strontium-90	0.025 (0.93)	7.92E-01 (7.92E-06)	5.22E-01 (5.22E-06)
	Plutonium-238	0.00222 (0.0821)	5.59E-01 (5.59E-06)	1.96E-01 (1.96E-06)
	Plutonium-239	0.00005 (0.0019)	1.52E-02 (1.52E-07)	5.51E-03 (5.51E-08)
	Uranium-234	0.0001 (0.0037)	5.52E-03 (4.47E-08)	2.79E-03 (2.79E-08)
	Uranium-235	0.0001 (0.0037)	5.29E-03 (5.29E-08)	2.68E-03 (2.68E-08)
	Uranium-238	0.0002 (0.0074)	8.21E-03 (8.21E-08)	4.16E-03 (4.16E-08)
	Americium-241	0.0001 (0.0037)	1.82E-02 (1.82E-07)	6.73E-03 (6.73E-08)
	TOTAL		**1.85 (1.85E-05)**	**0.88(8.81E-06)**
Nuts	Hydrogen-3 (tritium)	0.24 (8.74)	3.23E-05 (3.23E-10)	4.73E-05 (4.73E-10)
	Cesium-137	0.07 (2.59)	2.96E-03 (2.96E-08)	2.46E-03 (2.46E-08)
	Cobalt-60	0.004 (0.16)	4.79E-05 (4.79E-10)	1.67E-04 (1.67E-09)
	Strontium-90	0.079 (2.93)	7.22E-03 (7.22E-08)	1.61E-03 (1.61E-08)
	Plutonium-238	0.00212 (0.0784)	1.59E-03 (1.59E-08)	1.79E-03 (1.79E-08)
	Plutonium-239	0.00168 (0.0622)	1.37E-03 (1.37E-08)	1.60E-03 (1.60E-08)
	Uranium-234	0.0058 (0.2146)	9.25E-04 (9.25E-09)	1.51E-03 (1.51E-08)
	Uranium-235	0.0006 (0.0222)	9.18E-05 (9.18E-10)	1.50E-04 (1.50E-09)
	Uranium-238	0.0010 (0.0370)	1.47E-04 (1.47E-09)	2.39E-04 (2.39E-09)
	Americium-241	0.0027 (0.101)	1.78E-03 (1.78E-08)	2.11E-03 (2.11E-08)
	TOTAL		**0.02 (1.62E-07)**	**0.01 (1.17E-07)**
Grain	Hydrogen-3 (tritium)	0.10(3.78)	1.06E-05 (1.06E-10)	6.03E-06 (6.03E-11)
	Cesium-137	0.02 (0.74)	6.45E-04 (6.45E-09)	2.07E-04 (2.07E-09)
	Cobalt-60	0.002 (0.05)	1.14E-05 (1.14E-10)	1.54E-05 (1.54E-10)
	Strontium-90	0.047 (1.74)	3.26E-03 (3.26E-08)	2.68E-03 (2.68E-08)
	Plutonium-238	0.00024 (0.0089)	1.39E-04 (1.39E-09)	6.05E-05 (6.05E-10)
	Plutonium-239	0.00007 (0.0026)	5.03E-05 (5.03E-10)	2.27E-05 (2.27E-10)
	Uranium-234	0.0004 (0.0148)	1.31E-06 (1.31E-11)	8.29E-07 (8.29E-12)
	Uranium-235	0.003 (0.1110)	3.46E-04 (3.46E-09)	2.19E-04 (2.19E-09)
	Uranium-238	0.0004 (0.0148)	1.21E-06 (1.21E-11)	7.62E-07 (7.62E-12)
	Americium-241	0.00002 (0.0007)	1.34E-05 (1.34E-10)	6.16E-06 (6.16E-11)
	TOTAL		**0.004 (4.48E-08)**	**0.003 (3.22E-08)**
Beef	Hydrogen-3 (tritium)	0.49 (18.1)	5.94E-03 (5.94E-08)	1.92E-03 (1.92E-08)
	Cesium-137	0.132 (4.9)	4.98E-01 (4.98E-06)	9.12E-02 (9.12E-07)
	Cobalt-60	0.028 (1.0)	2.66E-02 (2.66E-07)	2.05E-02 (2.05E-07)
	Strontium-90	0.0043 (0.16)	3.50E-02 (3.50E-07)	1.73E-03 (1.73E-08)
	Plutonium-238	0.00155 (0.0574)	1.02E-01 (1.20E-06)	2.55E-02 (2.55E-07)
	Plutonium-239	0.00006 (0.0022)	3.91E-03 (3.91E-08)	1.01E-03 (1.01E-08)
	Uranium-234	0.00026 (0.0096)	3.83E-03 (3.83E-08)	1.38E-03 (1.38E-08)
	Uranium-235	0.00003 (0.0011)	3.67E-04 (3.67E-09)	1.32E-04 (1.32E-09)

Table D-11: Maximum adult and child screening levels for ingestion of agricultural and farm products

Product	Radioactive material	Maximum Concentration in agricultural and farm products, pCi/g (Bq/kg)	Adult Screening Level mrem/year (Sv/year))	Child Screening Level mrem/year (Sv/year)
	Uranium-238	0.00027 (0.01)	3.51E-03 (3.51E-08)	1.27E-03 (1.27E-08)
	TOTAL		**0.68 (6.80E-06)**	**0.15 (1.45E-06)**
Domestic Pork	Hydrogen-3 (tritium)	0.03 (0.94)	1.89E-04 (1.89E-09)	7.24E-05 (7.24E-10)
	Plutonium-238	0.00005 (0.0022)	2.20E-03 (2.20E-08)	6.48E-04 (6.48E-09)
	TOTAL		**0.00 (2.39E-08)**	**0.00 (7.21E-09)**
Chicken	Hydrogen-3 (tritium)	0.34 (12.7)	3.64E-03 (3.64E-08)	1.32E-03 (1.32E-08)
	Cesium-137	0.03 (1.06)	9.41E-02 (9.41E-07)	1.93E-02 (1.93E-07)
	Plutonium-238	0.00076 (0.0281)	4.71E-02 (4.71E-07)	1.31E-02 (1.31E-07)
	TOTAL		**0.15 (1.45E-06)**	**0.03 (3.38E-07)**
Chicken Eggs	Hydrogen-3 (tritium)	0.25 (9.19)	1.73E-03 (1.73E-08)	7.46E-04 (7.46E-09)
	TOTAL		**0.00 (1.73E-08)**	**0.00 (7.46E-09)**

*The first strontium-90 concentration is the maximum reported; however, it is an order of magnitude higher than any other strontium-90 result. The second concentration is the next highest and is more consistent with other results.

pCi/g = picocuries per gram; Bq/kg = becquerels per kilogram (1 pCi/g = 37 Bq/kg)
mrem/yr = millirem per year; Sv/yr = sieverts per year (1 mrem/yr = 10^{-5} Sv/yr)

Table D-12: Maximum adult and child screening levels for ingestion of milk

Radioactive material	Maximum Concentration in milk, pCi/L (Bq/L)	Adult (18 yrs and over) screening level, mrem/yr (Sv/yr)	Teenager 13 to 18 yrs) screening level, mrem/yr (Sv/yr)	Child (6 to 13 yrs) screening level, mrem/yr (Sv/yr)	Young child (2 to 6 yrs) screening level. mrem/yr (Sv/yr)
Hydrogen-3 (tritium)	1,170 (43.3)	8.01E-02 (8.01E-07)	6.80E-02 (6.80E-07)	9.24E-02 (9.24E-07)	1.19E-01 (1.19E-06)
Cesium-137	7.87 (0.29)	1.66E-01 (1.66E-06)	1.41E-01 (1.41E-06)	1.08E-01 (1.08E-06)	1.05E-01 (1.05E-06)
Strontium-89	229 (8.48)	9.70E-01 (9.70E-06)	1.27E+00 (1.27E-05)	1.84E+00(1.84E-05)	2.85E+00 (2.85E-05)
Strontium-90	12.9 (0.48)	5.91E-01 (5.91E-06)	1.44E+00 (1.44E-05)	1.08E+00 (1.08E-05)	8.51E-01 (8.51E-06)
TOTAL		**1.81 (1.81E-05)**	**2.91 (2.91E-05)**	**3.12 (3.12E-05)**	**3.92 (3.92E-05)**

pCi/L = picocuries per liter; Bq/L = becquerels per liter (1 pCi/L = 0.037 Bq/L)

mrem/yr = millirem per year; Sv/yr = sievert per year (1 mrem/yr = 10^{-5} Sv/yr)

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Estimated exposure dose calculations for mercury in fish from the Savannah River

ATSDR calculated a hypothetical exposure screening dose for fish using the average (species-specific) and maximum (for bass by location along the Savannah River) concentrations detected in samples collected from any of the years between 1993 and 2008. The dose calculations were estimated for an adult and a child (6 to 11 years) using the equation for calculating exposure doses (see text box below). Table D-13 presents ATSDR's assumptions used to calculate exposure dose. These assumptions are very conservative (i.e., health-protective) and most exposure scenarios are likely to result in lower exposure doses.

Calculating Exposure Dose

Equation: $$\text{Exposure Dose} = \frac{C_f \times IR \times EF \times ED}{BW \times AT}$$

Where;

C_f = Concentration in fish tissue [milligrams per kilogram (mg/kg)

IR = Ingestion rate (kilograms per day) ;

EF = Exposure Frequency;

ED – Exposure Duration

BW = Bodyweight;

AT = Averaging Time

Table D-13: Dose Assumptions: Exposure to Fish			
Parameter	**Abbreviation**	**Child**	**Adult**
Chemical Concentration in Fish[1]	C	Concentration	Concentration
Ingestion Rate[2]	IR	67.5 g/day (i.e., 0.0675 kg/day)	13 5 g/day (i.e., 0.135kg/day)
Exposure Frequency	EF	350 days/year	350 days/year
Exposure Duration	ED	6 years	30 years
Body Weight	BW	13 kg (29 pounds)	79 kg (174 pounds)
Averaging Time Non-carcinogens	AT	365 days x 6 years	365 days x 30 years

Notes:

[1] ATSDR used the average mercury concentration detected in fish from five common edible species (bowfin, bass, bream, channel catfish, and yellow perch) collected along the Savannah River (see Table D-14). ATSDR also estimated dose using the maximum concentrations detected in largemouth bass between 1993 and 2008 at specified locations along the Savannah River (see Table D-15).

[2] ATSDR's ingestion rate assumptions for adults are based on the mean value (95th percentile) of Burger et al. 2001 ingestion rates for fishermen interviewed along the Savannah River. [Black males – 187.9, white males – 135.3, black females – 127.8, and white females – 90.0]. ATSDR assumes children's ingestion rates are one half of the adult value used.

g = grams; kg = kilograms

Table D-14. Estimated Mercury Doses from Ingestion of Fish from the Savannah River

	Estimated Child Dose	***Estimated Adult Dose***	***Reference Dose***
Bowfin	0.0032	0.0011	0.0003
Bass	0.0023	0.0008	
Bream	0.0015	0.0005	
Catfish	0.0017	0.0006	
Yellow Perch	0.0009	0.0003	

Units: mg/kg/day

Dose estimates are for non-cancer health effects based on average concentrations detected in the selected species during the following time periods; bowfin -1997, bass, 2007-2008, bream, 2007-2008, catfish – 2007-2008, and perch – 1997.

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Table D-15. Estimated Mercury Doses from Ingestion of Largemouth Bass from selected locations along the Savannah River

	Estimated Child Dose	*Estimated Adult Dose*	*Reference Dose*
Augusta Lock and Dam	0.0026	0.0009	0.0003
Beaver Dam Creek	0.0032	0.0011	
Four Mile Creek	0.0029	0.0010	
Highway 17	0.0024	0.0008	
Highway 301	0.0060	0.0020	
Lower Three Runs Creek	0.0030	0.0010	
Steel Creek	0.0040	0.0013	
Stokes Bluff Landing	0.0045	0.0015	
Upper Three Runs Creek	0.0028	0.009	

Units: mg/kg/day
Dose estimates are for non-cancer health effects based on maximum concentrations detected in bass at each sampling location between 1993 and 2008.

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