



# Public Health Assessment for

## EVALUATION OF OFF-SITE GROUNDWATER AND SURFACE WATER CONTAMINATION AT THE SAVANNAH RIVER SITE (USDOE)

SAVANNAH RIVER SITE  
AIKEN, SOUTH CAROLINA  
EPA FACILITY ID: SC1890008989  
MARCH 1, 2007

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES  
PUBLIC HEALTH SERVICE

Agency for Toxic Substances and Disease Registry

**Comment Period Ends:**

**APRIL 16, 2007**

## THE ATSDR PUBLIC HEALTH ASSESSMENT: A NOTE OF EXPLANATION

This Public Health Assessment-Public Comment Release was prepared by ATSDR pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) section 104 (i)(6) (42 U.S.C. 9604 (i)(6)), and in accordance with our implementing regulations (42 C.F.R. Part 90). In preparing this document, ATSDR has collected relevant health data, environmental data, and community health concerns from the Environmental Protection Agency (EPA), state and local health and environmental agencies, the community, and potentially responsible parties, where appropriate. This document represents the agency's best efforts, based on currently available information, to fulfill the statutory criteria set out in CERCLA section 104 (i)(6) within a limited time frame. To the extent possible, it presents an assessment of potential risks to human health. Actions authorized by CERCLA section 104 (i)(11), or otherwise authorized by CERCLA, may be undertaken to prevent or mitigate human exposure or risks to human health. In addition, ATSDR will utilize this document to determine if follow-up health actions are appropriate at this time.

This document has previously been provided to EPA and the affected state in an initial release, as required by CERCLA section 104 (i) (6) (H) for their information and review. Where necessary, it has been revised in response to comments or additional relevant information provided by them to ATSDR. This revised document has now been released for a 30-day public comment period. Subsequent to the public comment period, ATSDR will address all public comments and revise or append the document as appropriate. The public health assessment will then be reissued. This will conclude the public health assessment process for this site, unless additional information is obtained by ATSDR which, in the agency's opinion, indicates a need to revise or append the conclusions previously issued.

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Prepared by:

Site and Radiological Assessment Branch  
Division of Health Assessment and Consultation  
Agency for Toxic Substances and Disease Registry

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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.

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## **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  
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## Acronyms

AEC	Atomic Energy Commission
ATSDR	Agency for Toxic Substances and Disease Registry
CAB	Citizens Advisory Board
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
DNAPL	dense non-aqueous phase liquid
DOE	U.S. Department of Energy
DUS	dynamic underground stripping
EPA	U.S. Environmental Protection Agency
ERDA	Energy Research and Development Administration
ESOP	Environmental Surveillance and Oversight Program
GDNR	Georgia Department of Natural Resources
HWMF	Hazardous Waste Management Facility
MCL	maximum contaminant level
NERP	National Environmental Research Park
NIOSH	National Institute of Occupational Safety and Health
NPDES	National Pollutant Discharge Elimination System
NPL	National Priority List
PCB	polychlorinated biphenyls
PCE	tetrachloroethylene
pCi/L	picocurie/liter
PHA	public health assessment
ppb	parts per billion
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
SREL	Savannah River Ecology Laboratory
SRI	Savannah River Natural Resource Management and Research Institute
SRP	Savannah River Plant
SRS	Savannah River Site
SRSHES	Savannah River Site Health Effects Subcommittee
SRTC	Savannah River Technology Center
SRNL	Savannah River National Laboratory
TCE	trichloroethylene
USGS	United States Geological Survey
VOCs	volatile organic compounds
WSRC	Westinghouse Savannah River Company

## Summary

The Savannah River Site (SRS), owned by the U.S. Department of Energy (DOE), is a 310 square mile plant located within portions of Allendale, Aiken, and Barnwell counties in the southwest section of South Carolina. SRS, formerly the Savannah River Plant (SRP) was constructed in 1950, with a mission to support the United States defense program by producing basic materials used in the manufacturing of nuclear weapons. The original plant 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. Between 1953 and 1988, SRP produced plutonium and other radionuclides for military and commercial purposes.

Hazardous materials and wastes were processed, treated, and stored at the site during its operation. Past waste disposal practices include seepage basins for liquids, pits and piles for solids, and landfills for low-level radioactive wastes. Cleanup activities at SRP were initiated by DOE in 1985. In 1989, SRP became SRS, and the site was officially listed on EPA's National Priorities List (NPL) due to chemical (primarily metals and solvents) and radiological contamination of on-site groundwater. Since that time, DOE has addressed many contamination and disposal issues. SRS initiated the Environmental Management Program to help facilitate the evaluation and clean-up of sources of contamination. From 1989 until December 2005, Westinghouse Savannah River Company (WSRC) was the primary contractor at SRS. WSRC's contractual responsibilities included overseeing and managing the environmental cleanup and restoration at SRS. In December 2005, Washington Savannah River Company LLC became the primary contractor for SRS.

In 1992, CDC initiated a Dose Reconstruction Project, conducted in three phases, to examine the release of chemicals and radionuclides from the site during the main operating period from 1954 to 1992. Agency for Toxic Substances and Disease Registry (ATSDR) scientists reviewed the dose reconstruction report findings and agreed with the report's conclusions that the primary historical pathways of concern were through air and surface water releases. This public health assessment (PHA) addresses potential human health hazards associated with off-site groundwater and surface water releases from 1993 to the present, and the potential for future exposures.

**Groundwater Evaluation:** ATSDR's evaluation did not identify any site-related groundwater plumes that have migrated beyond the SRS boundary and impacted off-site private wells. However, the A&M-Area, which is close to the northwest SRS boundary, could potentially impact off-site groundwater resources in the future. This area contains a large groundwater plume primarily consisting of volatile organic compounds (VOCs) and metals, which has migrated close to the boundary. ATSDR reviewed the results of the available on- and off-site groundwater monitoring data. The results show that although site-related contaminants have been detected within about 2,000 feet of the SRS boundary, they have not been detected off site.

During the groundwater evaluation, ATSDR scientists identified two non site-related contaminants (lead and radium) that were detected in municipal drinking water wells at concentrations above ATSDR's health-based comparison values. ATSDR investigated the possible sources of these two contaminants and their potential to cause illness or adverse health effects at the levels reported. ATSDR scientists conclude that the concentrations of lead are not

present at levels that would cause health effects in adults or children. However, radium (which occurs naturally in the Aiken plateau) has consistently been detected above EPA's Safe Drinking Water Standards. When maximum ingestion rates are assumed for chronic ingestion, the potential exposures appear to be at levels of health concern, especially for infants drinking formula and juice mixed with tap water. Studies of large groups of people who chronically consumed radium in drinking water at or slightly above the EPA Safe Drinking Water Standard have conflicting results. Therefore, ATSDR made recommendations to limit potential exposures.

**Surface Water Evaluation:** ATSDR reviewed chemical and radiological surface water data based on samples collected at on- and off-site locations. Chemical contaminants were not detected at levels of concern since 1993 in the Savannah River or in SRS streams or brooks close to the SRS boundary that feed into the river. Since 1993, the greatest potential for human exposure to radioactive contaminants, primarily tritium, in off-site surface water has been at or near the mouth of Four Mile Creek. This sampling location is also slightly downstream from Plant Vogtle's discharge point. Although the source of the tritium is not definitively known, ATSDR calculated the annual committed effective doses based on the maximum annual average concentration for this stretch of surface water. The estimated doses, ranging between 0.5 and 0.9 millirem, are less than ATSDR's health-based comparison value for drinking water of 4 millirems (0.04 millisieverts). Therefore, ATSDR concludes that the surface water releases of tritium and other radioactive contaminants did not pose a health concern since 1993; nor do these contaminants pose a current or future health concern as long as site activities and operations at SRS do not change.

The interpretation, conclusions, and recommendations in this public health assessment are provided on the basis of the data and information referenced herein. Additional data could alter the conclusions and recommendations. The conclusions and recommendations are site-specific and are, therefore, not applicable to any other situation.

## **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 released to onsite groundwater and surface water and transported off site or released to offsite surface water. It does not address occupational exposures of SRS or SRP workers to radioactive or hazardous materials on the site. Concerns about occupational exposures and workplace safety are addressed by the National Institute for Occupational Safety and Health (NIOSH).

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 reported to the CDC in September 1998 for initial review and released as a final report in April 2001. Phase III estimated the radiation doses and associated cancer risks for hypothetical persons living near SRS and performing representative activities on or near the site.

The Agency for Toxic Substances and Disease Registry (ATSDR) scientists reviewed the dose reconstruction report findings and agreed that the primary historical pathways of concern were through air and surface water releases. Due to operational changes at SRS, air and surface water releases and corresponding off-site contaminant concentrations appear to be decreasing. The report also found that groundwater contamination did not present any off-site exposures. In 1984, the closest groundwater contamination was estimated to be approximately 5,000 feet from the site boundary. In 1993, groundwater contamination did not appear to be migrating off site; however, sampling of plume definition wells indicated that site-related groundwater contamination was as close as 2,000 feet from the site boundary (CDC 2001).

Given the relatively close proximity of on-site groundwater plumes to some nearby residential populations, ATSDR focused this public health assessment on groundwater and surface water contamination that could potentially impact off-site drinking water supplies. Although the emphasis of this evaluation is on identifying more recent potential exposure pathways, ATSDR considers any past exposures that may result in long-term health effects of residents.

For additional reference, this document includes a glossary of terms (Appendix A), a list of health-based comparison values used by ATSDR (Appendix B), and an overview of ATSDR's methodology for evaluating potential public health effects (Appendix C).

## Background

### Site Description and Operational History

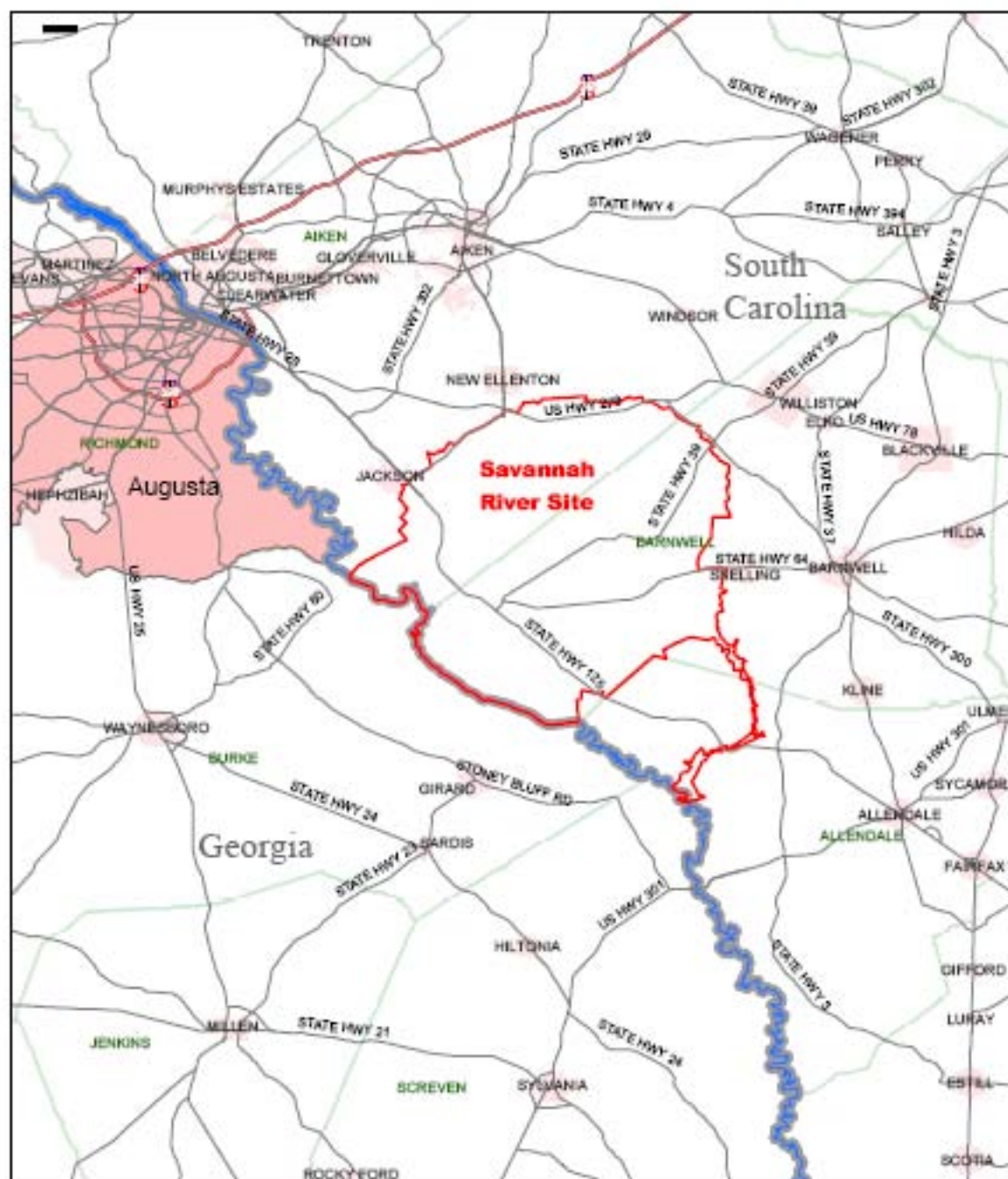
The SRS is a 310 square mile (806 square kilometer) U.S. Department of Energy (DOE) owned and contractor operated facility. It encompasses 198,344 acres (80,000 hectares) in the southeastern coastal area of the United States in the southwest section of South Carolina (WSRC 2005a). The site is located 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. The Aiken Plateau is a relatively flat area that slopes southeastward and is divided by several tributaries of the Savannah River. The Savannah River flows more than 300 miles from the Blue Ridge Mountains in North Carolina to the Atlantic Ocean near Savannah, Georgia and forms the site's 27-mile (43 kilometer) southwestern boundary along the South Carolina and Georgia border (SCDHEC 2005a; USDOE 2005e).

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 includes 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; USFS-SR 2004b; USDOE 2005e).

The former Atomic Energy Commission (AEC) contracted with the E.I. duPont de Nemours and Company, Inc. (DuPont) to construct SRP in 1950 (WSRC 1994b). 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 2005e). 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 (WSRC 2005a; USDOE 2000).

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 1994b). 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 (Gail Whitney, DOE, Personal communication, September 22, 2006). WSRC is responsible for nuclear facility operations; for research and development conducted by the Savannah River National Laboratory (SRNL); for environmental, health, safety and quality assurance issues; and for all administrative functions at the site (WSRC 2005b). SRNL, formerly known as the Savannah River Technology Center (SRTC), conducts research, development, and technical support activities. 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 1994b).

Figure 1. Savannah River Site Area Map



## Savannah River Site

0 3.75 7.5 15  
Miles

Aiken, South Carolina  
EPA Facility ID SC1890008989

Base Map Source: 1:50,000 Scale File  
JAN2000



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:

- **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.
- **Heavy water reprocessing** (*D-Area*), now closed, had facilities for supporting heavy water coolant/moderator for the reactors, heavy water purification facilities, an analytical laboratory, and a powerhouse.
- **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 facilities that tested equipment and developed new designs.
- **Nuclear/radiological facilities:** Fuel/Target Fabrication (*M-Area*) facilities housed the metallurgical/foundry operations for fabricating fuel and target elements for the SRS reactors. This area is undergoing closure activities.
- **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 shutdown 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*.
- **Processing facilities:** *H-Area* facilities 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* of SRS and include tritium loading, unloading and surveillance operations to support the active stockpile. The Tritium Extraction Facility will become 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, 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* (USDOE 2005e, 2006b; WSRC 2001a).

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. Between 1953 and 1988, SRS produced approximately 36 metric tons of plutonium and other radionuclides (WSRC 2005a). 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 released into the ground, surface waters, and air during the period of operation (CDC 2005).

The present mission of SRS includes environmental cleanup and management of nuclear and hazardous wastes; processing and storing nuclear materials in support of the U.S. nuclear non-proliferation efforts; converting and managing excess plutonium to a form that can be used in commercial power reactors; storing domestic and foreign spent research reactor nuclear fuel; and conducting research and development, economic development and technology transfer initiatives (USDOE 2000, 2005e, 2006b; WSRC 2004b).

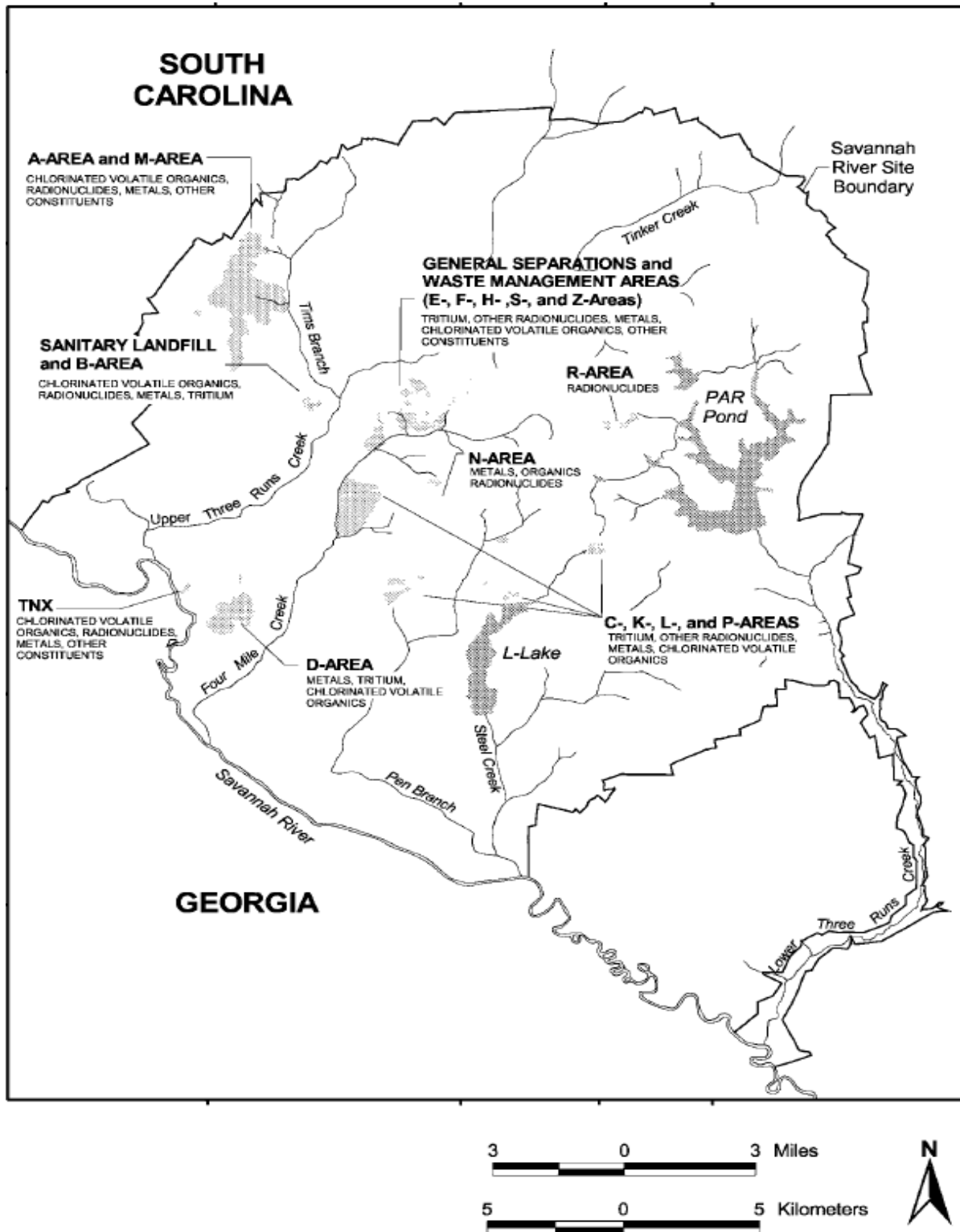
Currently, 12 percent of the site (24,000 acres; 9,712 hectares) is designated for nuclear processing, research and development, and waste management purposes; 9 percent (18,000 acres; 7,284 hectares) is contained within 30 separate ecological set-aside areas; and another 7 percent (14,000 acres; 5,666 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 toward the center of the site. 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 1994b) (see Figure 2).

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 (USFS-SR 2005c; USDOE 2005e). In general, public access to SRS is restricted to environmental/ecological research studies, guided tours, and controlled hunting and fishing activities (CDC 2005). In addition, to address trespassing and easement issues, “no trespassing” and “no fishing” notices are posted along public roads and stream crossings (USFS-SR 2003).

The following organizations also have 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. The SREL is operated by a research branch of the University of Georgia and is funded primarily by DOE’s Environmental Management Division, Savannah River Operations office. The SREL initially conducted baseline ecological studies and later became involved in waste management activities, release studies of various radioactive and non-radioactive elements, thermal effect studies of reactor effluent water on local ponds, and environmental assessments. Today, the SREL provides an independent evaluation of the ecological effects of SRS operations through a program of ecological research, education, and outreach. This program involves utilizing basic and applied environmental research, as well as evaluating the impacts of industrial and land-use activities on the environment (SREL 2001, USDOE 2006b).

- 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 is coordinated by SREL (SREL 1998).
- The United States Forest Service – Savannah River (USFS-SR) works with SREL to conduct research on the basic aspects of ecological and environmental sciences. Research is 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; USFS-SR 2004b). Specifically, USFS-SR conducts research in direct support of threatened, endangered, and sensitive species, as well as examines methods to improve biological diversity (USFS-SR 2005a). USFS-SR cuts and sells timber and conducts annual prescribed burning operations to enhance wildlife habitat and reduce forest fuels (WSRC 2005a; USFS-SR 2005b). An average of 13,326 acres (5,393 hectares) underwent prescribed burning each year from 1995 through 2004 (USFS-SR 2005c). USFS-SR also participates in waste site closure projects, provides aerial photo services, maintains secondary roads and site boundaries, manages soil erosion areas and watersheds, and engages in community outreach. USFS-SR is responsible for developing the SRS Natural Resources Management Plan which encompasses all natural resource operations, including management, education, and research programs (USFS-SR 2005c; USDOE 2005e, 2006b).
- The University of South Carolina Savannah River Archeological Research Program (SRARP) makes recommendations to DOE that facilitate management of cultural resources and assist with compliance activities involving site-use surveys, data recovery, coordination with major land users, and reconstruction of the site's environmental history (WSRC 2001a).

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

Source: WSRC 2002b

## 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, air, and biota. Past waste disposal practices include seepage basins for liquids, pits and piles for solids, and landfills for low-level radioactive wastes (USDOE 2005e).

Initial cleanup activities of seepage basins, pits, piles, and landfills were started by DOE 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 the South Carolina Department of Health and Environmental Control (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, such as pumping and treating groundwater, capping and solidifying various disposal basins and solid waste disposal sites, and removing and treating and/or disposing of hazardous substances (EPA 1989; USDOE 2006b).

In 1989, SRS was officially listed on EPA's National Priorities List (NPL) due to contamination of shallow groundwater with volatile organic compounds (VOCs), heavy metals, and radionuclides. Trichloroethylene (TCE) was detected in numerous on-site monitoring wells and soil. Additionally, the Savannah River Swamp had previously been found to be contaminated with heavy metals and radionuclides that overflowed into the area from an old seepage basin (EPA 1989; USDOE 2006b).

SRS initiated the Environmental Management Program to address the closure of old burial grounds and seepage basins. The program 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 (USDOE 2000).

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, 2002a, 2002b, 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* plans for all inactive waste

units to be remediated and facilities to be deactivated and/or decommissioned unless reused to support other long-range federal missions or designated for historical preservation or economic development. Future land use plans continue to concentrate industrial operations toward the center of the site for the purpose of continuing national security missions. The *SRS End State Vision* plan assumes that the entire site will continue to be owned and controlled by the federal government once the cleanup is complete by 2025, and that off-site repositories will be available for high level radioactive, transuranic, hazardous, and mixed waste (USDOE 2005e). However, some portions of the property that will remain under federal ownership may be managed by the state of South Carolina.

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

As of October 2006, SRS had identified 515 inactive waste units and 1,055 facilities for deactivation and decommissioning. Of the 515 waste units, 496 were surface soil units and 19 were groundwater units. A portion of the surface soil units also have a groundwater component. Six of the groundwater remediations are complete, seven are being assessed, and six are in remediation. SRS groundwater and surface water cleanup strategies are based on meeting EPA's drinking water standards (USDOE 2005e, 2006b).

### **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 land use surrounding SRS includes residential, industrial, commercial, transportation, agricultural, and recreational areas that are owned by both private individuals and companies. 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, Georgia.

A variety of crops are produced on area farms, such as cotton, soybeans, corn, peaches, grapes, and small grains. While some livestock, horse farming, and vegetable farming occurs, most of the land is used to produce forest products, such as pulp and paper, telephone poles, and pine straw (USDOE 2003, 2005a). A few small neighborhoods and individual homes are on the periphery of the site, as well as large plantations such as Creek Plantation (a privately owned land area between the southeast site boundary and Lower Three Runs Creek) and Cowden Plantation (a privately owned land area between the northwest site boundary and the Savannah River) (WSRC 2002b).

A review of the growth management, transportation, and economic development plans for the region indicate that no major changes are anticipated that would affect site missions until 2025. Normal growth is expected in the cities and populated counties around SRS. However, the predominant land uses in the area adjacent to SRS are expected to remain the same (USDOE 2005e).

Except for site facilities, most of the terrestrial land cover at SRS consists of a wide variety of natural vegetation with a minor portion supporting the production areas, roads, and utility corridors. Open fields, pine, and hardwood forests comprise the majority of the site. Forest lands, which dominate land cover in the area, 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, with hardwood/deciduous and cypress/tupelo forests primarily found in stream valleys (USFS-SR 2005c; WSRC 2004b, 2005a). The U.S. Forest Service harvests forest products on the site. The annual volume of SRS forest timber sold has ranged from 3.5 to 7.3 million cubic feet, and pine straw sold has varied from approximately 77 to 449 acres (31 to 182 hectares) (USFS-SR 2004a).

Approximately 7,400 acres of the total area of SRS is covered by surface water. The Savannah River is the largest and most significant regional surface water body near SRS. SRS is approximately 160 river miles<sup>1</sup> from the Atlantic Ocean. Three large upstream reservoirs, Hartwell, Richard B. Russell, and Strom Thurmond/Clarks Hill, moderate the effects of droughts and the impacts of low flows on downstream water quality and fish and wildlife resources in the river. Although the source for most drinking water near and on the site is groundwater, Augusta, Georgia and North Augusta, South Carolina (upstream), and Beaufort/Jasper Counties, South Carolina, and Port Wentworth (Savannah), Georgia (downstream) use water from the Savannah River (WSRC 2005a).

Water from the Savannah River has been used extensively in SRS operations since the 1950s. The Savannah River is navigable from Savannah to Augusta, Georgia at the fall line and has historically served as an important transportation corridor. The Savannah River is used for recreational fishing and boating. Common commercial and/or recreational fish species found in the Savannah River include the American shad, channel catfish, Atlantic sturgeon, sunfish, bream, and striped bass. No commercial fishing is allowed within SRS, but fishing is a common activity along many portions of the Savannah River (USDOE 1995a).

Six main watersheds originate on or pass through SRS before discharging into the Savannah River. These tributaries have received varying amounts of effluent from SRS operations over the years, but they do not serve as commercial water sources. The 100-year flood plain for the main watersheds on SRS is shown in Figure 3 (USDOE 2003, 2005e). 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. 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 streams include Tinker Creek, Meyers Branch, and Tims Branch (Figure 3). Beaver Dam Creek is a small stream that drains D Area and may 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. No development occurs in this area of SRS (USDOE 1995b).

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<sup>1</sup> A river mile is a mile as measured along the navigation channel of a river.

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. The Freshwaters classification, however, imposes a more stringent set of water quality standards (USDOE 1995b).

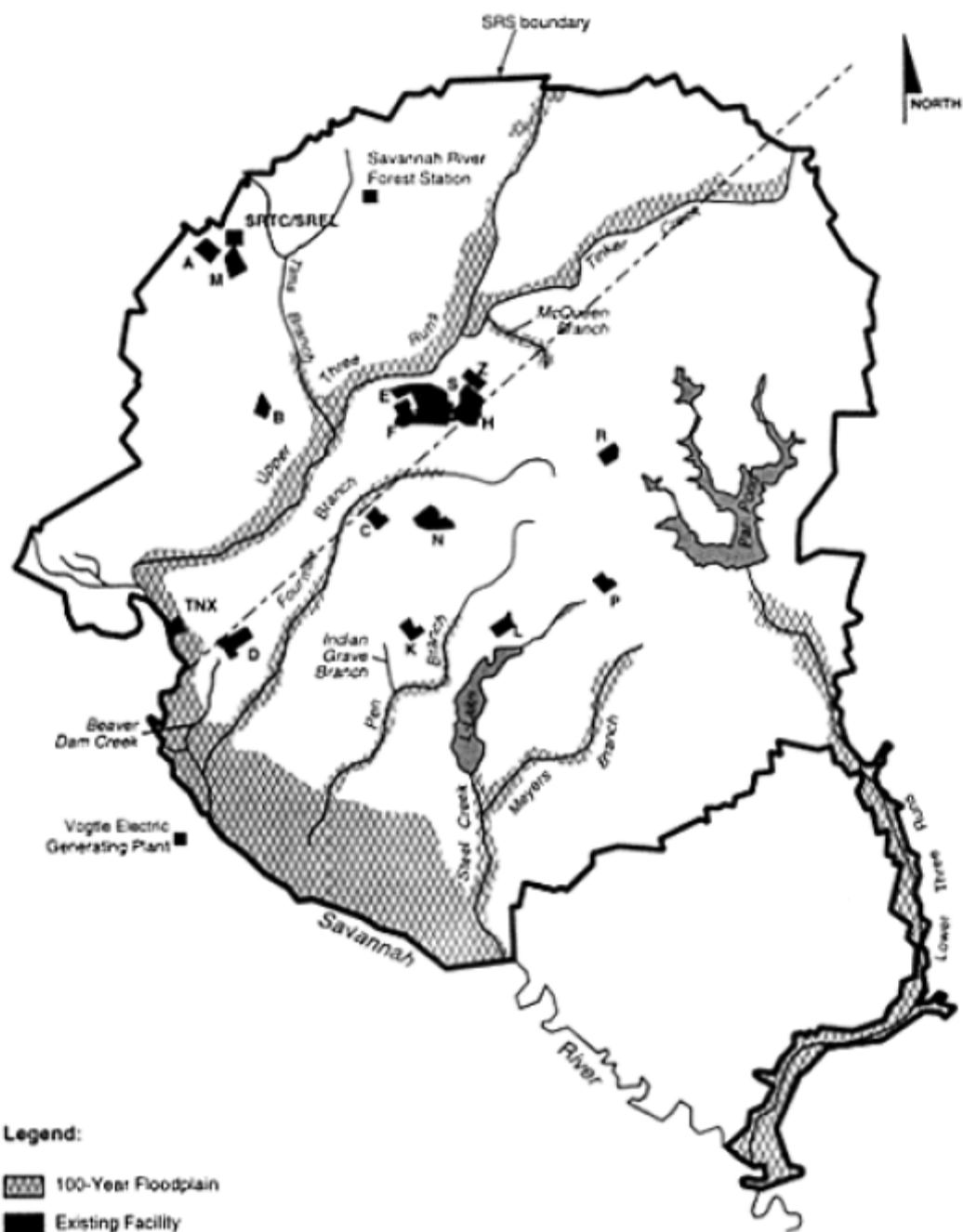
In addition to the Savannah River and the streams and creeks that flow into it, SRS contains many smaller surface water features, including lakes, ponds, and approximately 370 Carolina bays. Carolina bays are unique wetland features of the southeastern United States covering approximately 1,100 acres (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).

About 20 percent of the site (approximately 15,000 acres) is classified as wetlands. The Savannah River Swamp is a 3,020-hectare (about 18.6 square miles) forested wetland along the southwest border of SRS. The swamp runs along the Savannah River for about 10 miles and is approximately 1.5 miles wide. It is separated from the main flow of the Savannah River by a 3-meter-high natural levee along the river bank. At various times, river water overflows the levee and floods the entire swamp area. 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). Twelve dams on SRS support biological, environmental, and ecological research (USFS-SR 2005c; USDOE 2005e; WSRC 2004b, 2005a).

About 64 percent of the wetlands are bottomland hardwood forests that occur primarily along streams and in the Savannah River Swamp and 14 percent of the wetlands consist of Cypress-Tupelo swamp forest, located mostly in the swamp. Scrub and emergent marsh areas are found in the thermal and post-thermal areas where discharge carrying streams enter the swamp (USDOE 1995a; 2000). The Carolina bays on SRS range from a few hundred feet long to four miles in length and exhibit extremely variable hydrology. Some of the bays remain inundated year round while others have dry bottoms in periods of low rainfall. These periodically dry bays frequently have wetland vegetation covering the entire bottom of the bay (USDOE 1995a; 1995b).

In June 1999, DOE designated 11,200 acres (4,532 hectares) in the western section of SRS as a biological and wildlife refuge, called the Crackerneck Wildlife Management Area and Ecological Reserve (CWMAER), which is bordered by Route 125 and Upper Three Runs Creek. The Reserve is managed by the South Carolina Department of Natural Resources (SCDNR) and is open to the public on a controlled and limited basis primarily for hunting and fishing (USNRC 2005; USFS-SR 2005c). The main purpose of the CWMAER is to enhance the wildlife habitat. Another objective of the CWMAER is to provide controlled, quality recreational opportunities, such as hunting, fishing, bird watching, and hiking to the public (USFS-SR 2004a).

Most of SRS has been virtually undisturbed for decades, which has fostered a healthy, diverse ecosystem that is home to an estimated 50 mammal, 100 reptile and amphibian, 80 fish, and 260 bird species (USDOE 2005e; WSRC 2005a). SRS is in the process of restoring native vegetative habitats and species, hardwood habitat, pine-savannahs, and wetlands. In addition, the restoration

**Figure 3. The 100-Year Floodplain Associated with Watersheds at SRS**

Source: USDOE 1995b



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 (USFS-SR 2005c; USDOE 2005).

The climate in the region of SRS is subtropical, characterized by long, warm, humid summers and short, mild winters. The average annual temperature of the area is 64.7°F (18°C) and the average precipitation is 49.5 inches. The driest season is fall with an average monthly rainfall of 3.3 inches. The wettest season is summer with an average monthly rainfall of 5.2 inches. The average relative humidity is 70 percent annually. Winds most frequently blow from the northeast and southwest at an average of 8.5 miles per hour (3.8 meters per second) (CDC 2005; WSRC 2004c).

## Demographics

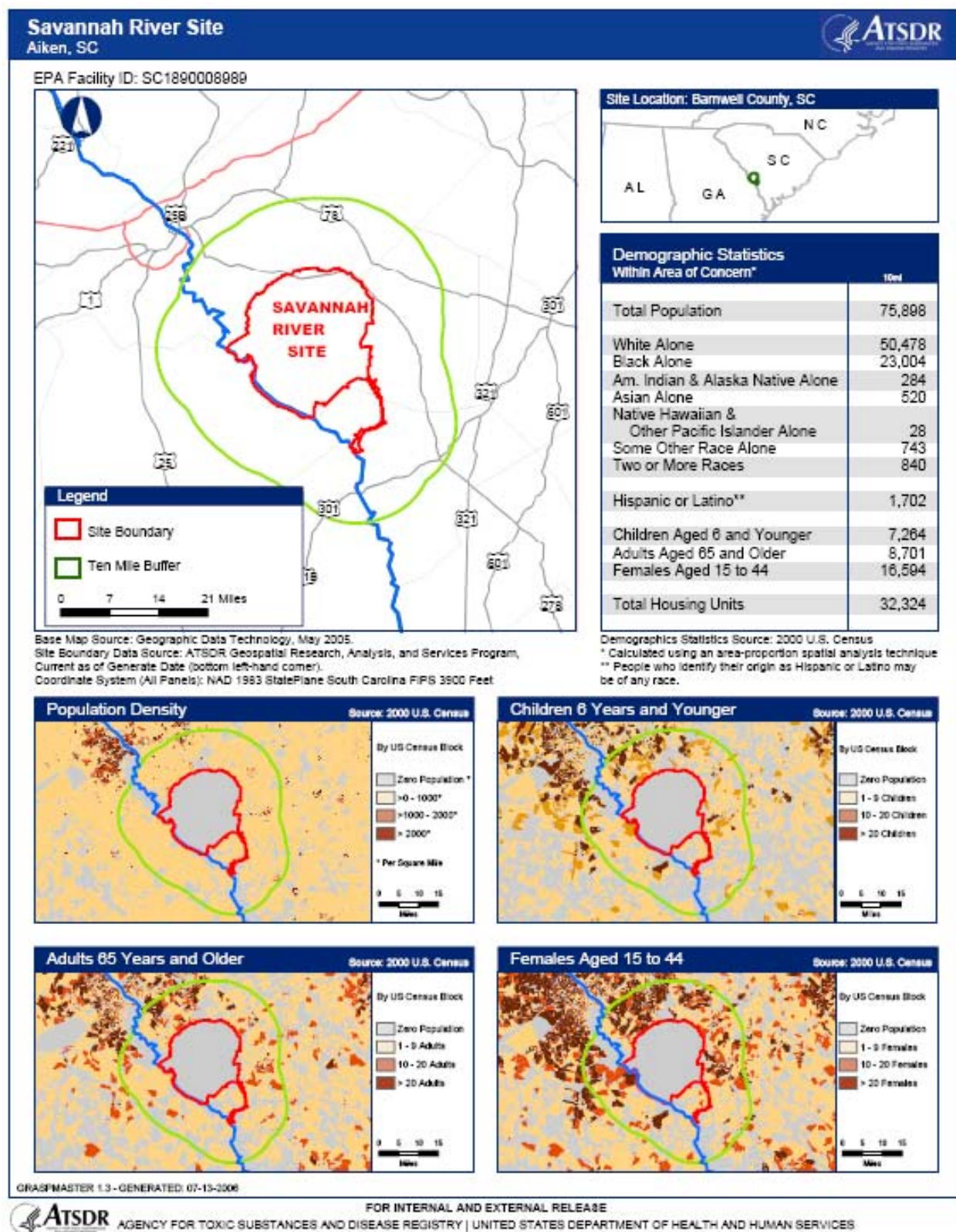
The most densely populated area in proximity to the site is Augusta, Georgia with a population of 195,182. Augusta is within 20 miles of the SRS boundary. The population within ten miles of SRS is 75,898 (see Figure 4) (U.S. Census Bureau 2000; WSRC 2005a). Table 1 presents land area and persons per square mile for counties within 10 miles (16 kilometers) of SRS compared to the land area and persons per square mile for the states of South Carolina and Georgia. Table 2 and 3 present population and demographic data for towns and counties within 10 miles (16 kilometers) of SRS compared to data for the states of South Carolina and Georgia. The total population within one mile of the site is 3,849 (U.S. Census Bureau 2000).

In Aiken, Allendale, and Barnwell Counties in South Carolina, approximately 69 percent of people ages 25 and older have a high school diploma, 75 percent live in owner-occupied housing units which suggest a stable, non-transient population, and the median household income for residents of those counties was approximately \$29,126 in 1999 (U.S. Census Bureau 2000).

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 2005a; WSRC 2004b).

<b>Table 1. Land area and persons per square mile for selected counties within 10 miles of SRS compared to South Carolina and Georgia</b>		
<b>County</b>	<b>Land Area (square miles)</b>	<b>Persons per square mile</b>
Aiken, SC	1,073	133
Allendale, SC	408	28
Barnwell, SC	548	43
State of South Carolina	30,109	133
Burke, GA	830	27
Richmond, GA	324	617
Screven, GA	648	24
State of Georgia	57,906	141
Source: U.S. Census Bureau 2000.		

Figure 4. Demographics Within Ten Miles of SRS Boundary



**Table 2. Demographic data for selected towns within 10 miles of SRS compared to data for the states of South Carolina and Georgia**

Town	Total Persons	Sex		Race			Age Group (years)		
		Male	Female	White	African American	Hispanic	0–4	5-19	65+
Barnwell City, Barnwell County, SC	5,035	47%	53%	50%	47%	1%	8%	23%	15%
Blackville Town, Barnwell County, SC	2,973	47%	53%	24%	76%	1%	7%	25%	12%
Jackson Town, Aiken County, SC	1,625	49%	51%	89%	9%	1%	5%	23%	19%
New Ellenton Town, Aiken County, SC	2,250	48%	52%	61%	36%	2%	6%	22%	16%
Snelling Town, Barnwell County, SC	246	52%	48%	78%	20%	3%	7%	26%	7%
Williston Town, Barnwell County, SC	3,307	47%	53%	51%	48%	1%	7%	23%	16%
State of SC	4,012,012	49%	51%	67%	30%	2%	7%	25%	12%
Girard Town, Burke County, GA	227	50%	50%	57%	41%	2%	12%	24%	12%
State of GA	8,186,453	49%	51%	65%	29%	5%	7%	27%	10%

Source: U.S. Census Bureau 2000.

Note: The percentages in this table were calculated from numbers provided in the 2000 Census data.

**Table 3. Demographic data for selected counties within 10 miles of SRS compared to data for the states of South Carolina and Georgia**

County	Total Persons	Sex		Race			Age Group (years)		
		Male	Female	White	African American	Hispanic	0–4	0-17	65+
Aiken, SC	142,552	48%	52%	71%	26%	2%	7%	26%	13%
Allendale, SC	11,211	52%	48%	27%	71%	2%	7%	27%	13%
Barnwell, SC	23,478	48%	52%	55%	43%	1%	7%	28%	13%
State of SC	4,012,012	49%	51%	67%	30%	2%	7%	25%	12%
Burke, GA	22,243	48%	52%	47%	51%	1%	8%	31%	11%
Richmond, GA	199,775	48%	52%	46%	50%	3%	7%	27%	11%
Screven, GA	15,374	48%	52%	54%	45%	1%	7%	28%	14%
State of GA	8,186,453	49%	51%	65%	29%	5%	7%	27%	10%

Source: U.S. Census Bureau 2000.

Note: The percentages in this table was calculated from numbers provided in the 2000 Census data.

## **Public Health Activities**

### ***ATSDR Involvement***

ATSDR is required by law to conduct a PHA at each of the sites on EPA's NPL. As part of the PHA process, ATSDR conducted a site visit to SRS in September 2005, to collect information necessary to identify any potential public health hazards and health issues or community concerns related to environmental contamination. During the visit, ATSDR staff 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), NIOSH, and ATSDR, on the adequacy of their health research and public activities at SRS. SRSHES was a non-partisan, independent group of citizens comprised of individuals selected to reflect the demographic diversity of the communities impacted by the past and present operations at SRS (CDC 2003). During their final meeting on September 15, 2005, the results of the Phase III Dose Reconstruction Project were presented, which included the estimated radiation doses and associated cancer risks for hypothetical persons living near SRS and engaging in representative activities (e.g., swimming, boating, fishing).

In addition, since 1991, other past ATSDR activities associated with SRS include oral and written consultations on various on-site 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, which was issued in March, 2002.

In a three-phase health education/needs assessment program conducted in 2002, ATSDR worked with community leaders in ten 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 impacted 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 gather 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 2002).

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 2002).

***Savannah River Site Citizens Advisory Board***

SRS Citizens Advisory Board (CAB) was created in February 1994, in response to the Federal Facilities Agreement and Public Participation Plan. The CAB is a non-partisan group comprised of 25 members from South Carolina and Georgia who reflect the cultural diversity of the population affected by SRS. The CAB provides informed and timely recommendations to DOE, concerning decisions that affect environmental restoration and waste management activities at SRS. The two main goals of SRS CAB are to improve mutual communication with SRS impacted communities and to improve the process by which federal facility environmental cleanup decisions are made, such that these decisions reflect the priorities and concerns of all stakeholders (CAB 2001, 2003, 2006; USDOE 2006). For more information, the official Web site for SRS CAB is <http://www.srs.gov/general/outreach/srs-cab/>.

***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. Information was gathered during the SRSHEs and SRSCAB meetings as well as during ATSDR's health education/needs assessment project.

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 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 were established to allow for more direct interaction between the public and SRS management (SRS 1990, 1991).

Community concerns and responses regarding the SRS can be categorized into three groups: environmental restoration, waste management, and health issues. 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 the SRS; groundwater contamination; infant mortality/birth defects; fish contamination; and cancer rates around the SRS (SRS 1990, 1991). The concerns about contamination in drinking water, groundwater, and surface water are addressed in this public health assessment.

## **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. Other data sources include Georgia Department of Natural resources (GDNR), SCDHEC and the city of Jackson.

ATSDR's evaluation included the identification of inconsistencies in reporting detection limits and some data gaps. 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 the data quality reviewed for this PHA is adequate for making public health decisions. However, ATSDR is not confident that the analytical methods adequately address questions regarding detection limits for all the data sets analyzed. ATSDR has identified monitoring data generated by the SCDHEC's Environmental Surveillance and Oversight Program (ESOP) and some of the DOE onsite monitoring data where the detection limit exceeds the corresponding health-based screening value. For the DOE data, the sample results with the most elevated detection limits were understandably from analyses of samples collected near or under waste areas. These contaminants were not detected offsite at levels of health concern with the exception of naturally-occurring radium. The quality of the SCDHEC ESOP data has improved since 1993 (especially since 2003) with a few exceptions. While reliance on such detection limits does not necessarily indicate that the contaminant being monitored exceeds the CV, it does not make it possible to determine whether the concentrations are at levels of potential health concern. However, ATSDR determined that there was adequate information to make public health decisions on potential offsite exposures from 1993 through 2005.



## 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 (see Figure 5). 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 a member of the off-site community. 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.

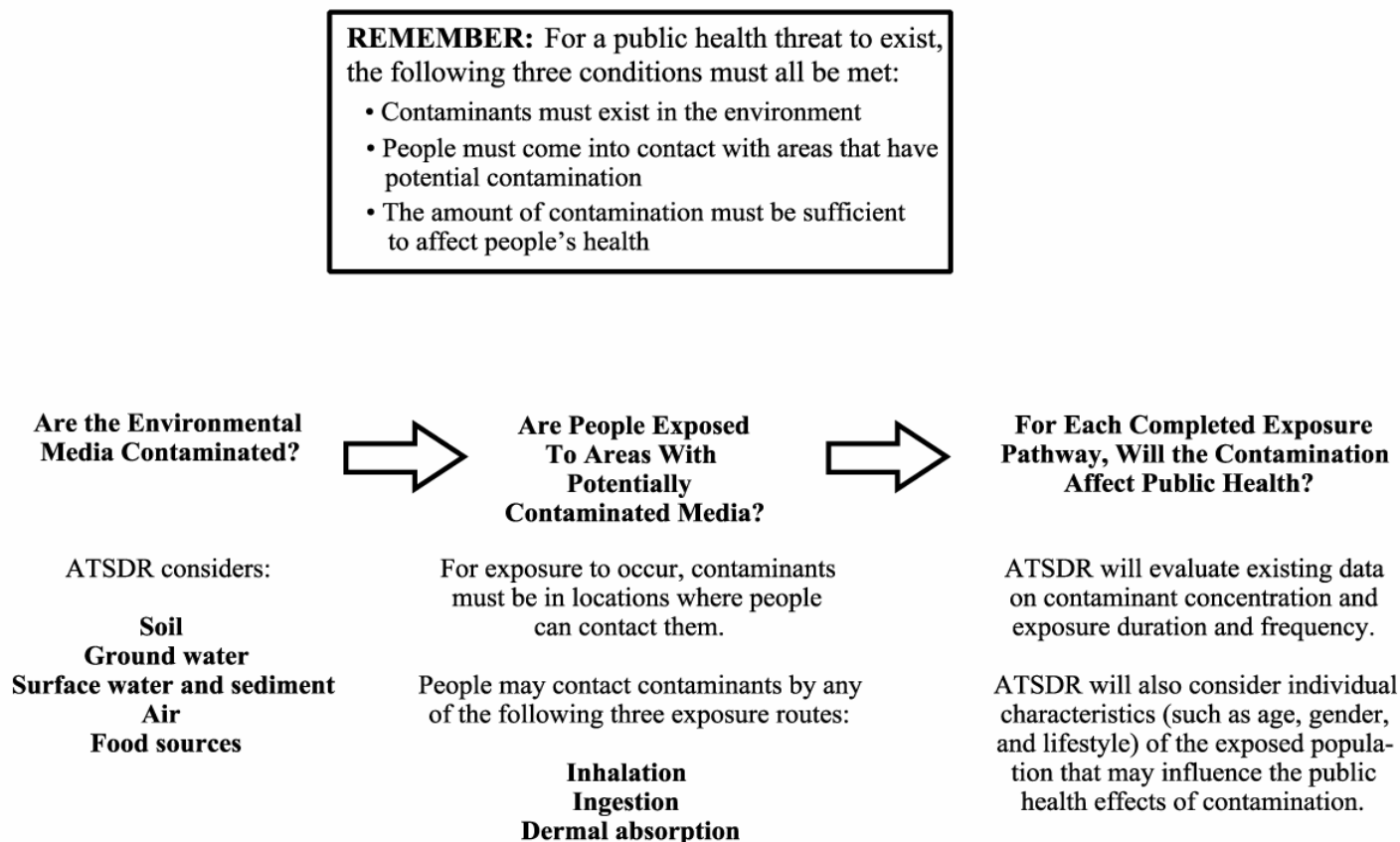
### *How does ATSDR determine which exposure situations to evaluate?*

ATSDR scientists evaluate site conditions to determine if people could have been or could be exposed to site-related contaminants. ATSDR identifies whether exposure to contaminated media (soil, water, air, or biota) has occurred, is occurring, or will occur through ingestion, dermal (skin) contact, or inhalation when evaluating exposure pathways. An exposure pathway could involve air, surface water, groundwater, soil, dust, or even plants and animals. ATSDR identifies an exposure pathway as completed or potential, or eliminates the pathway from further evaluation. Completed exposure pathways exist if all the 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. 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 2005a).

As previously noted, this PHA is focused on human exposure to groundwater and surface water.

#### **Elements of an Exposure Pathway**

- 1.) The *source* is the place where the chemical or radioactive material was released.
- 2.) The *environmental media* (such as groundwater, soil, surface water, or air) transports 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 5. ATSDR Exposure Evaluation Process**



ATSDR scientists evaluated the potential for contaminants to be transported off the site by reviewing environmental sampling data from DOE, DOE contractors, SCDHEC, and the GDNR. ATSDR scientists then select contaminants for further evaluation by comparing them to media-specific health-based comparison values (CVs). These values are developed by ATSDR<sup>2</sup> from available scientific literature related to exposure and health effects. CVs are derived for each of the different media and reflect an estimated contaminant concentration that is not likely to cause adverse health effects for a given chemical, assuming a standard daily contact rate (e.g., the amount of water consumed) and body weight.

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.

Some of the CVs used by ATSDR scientists include ATSDR's environmental media evaluation guides (EMEGs), reference dose media evaluation guides (RMEGs), and cancer risk evaluation guides (CREGs) and EPA's maximum contaminant levels (MCLs). EMEGs, RMEGs, and CREGs are non-enforceable, health-based CVs developed by ATSDR for screening environmental contamination for further evaluation. MCLs are enforceable drinking water regulations developed to protect public health (See Appendix B).

***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 can experience due to contact with an environmental contaminant depend on the exposure concentration (how much), the frequency (how often) and/or duration (how long) of exposure, the route or pathway of exposure (breathing, eating, drinking, or skin contact), and the multiplicity of exposure (combination of contaminants). Once exposure occurs, characteristics such as age, sex, nutritional status, genetics, lifestyle, and health status of the exposed individual influence how the individual absorbs, distributes, metabolizes, and excretes the contaminant. Together, these factors and characteristics determine the health effects that may occur.

To account for the uncertainty in the precise level of exposure and to be protective of public health, ATSDR scientists typically use worst-case 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, ATSDR performs a more detailed review of the exposure pathway and consults the toxicologic and epidemiologic literature for scientific information about the health effects from exposure to hazardous substances.

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<sup>2</sup> ATSDR may also rely on health-based screening values derived by other state and/or federal public health agencies when no ATSDR CV is available.

## Groundwater Evaluation

### *Site Hydrogeology*

SRS and its nearby surroundings are situated between 90 and 340 feet above mean sea level in a flat landscape that is drained by several tributaries of the Savannah River. The depth to which these streams erode into sediments, the lithology of the sediments (i.e., the characteristics of rocks and mineral formations), and the orientation of the sediment formations are all factors that contribute to the horizontal and vertical movement of the groundwater (USDOE 2003).

Groundwater beneath SRS is separated by layered geologic formations as described below.

- SRS overlays approximately 700 to 1,200 feet of Atlantic Coastal Plain geological strata that consists of unconsolidated and semi-consolidated sediments composed of sandy clays, clayey sands, clay, silt, and calcareous/limestone sediment. In general, the sandy strata are permeable and transport and yield water, whereas the clay strata are less permeable and impede water movement.
- These layers overlay dense crystalline rock or consolidated sediments. The crystalline rocks yield little water except within fracture zones.
- The system of variable permeable geological layers not only contributes to the direction of groundwater flow, but has also generated a complex system of aquifers.

(Sources: USDOE 1995a; WSRC 1991, 2000, 20001a, 2002a, 2002b).

#### **What is an Aquifer?**

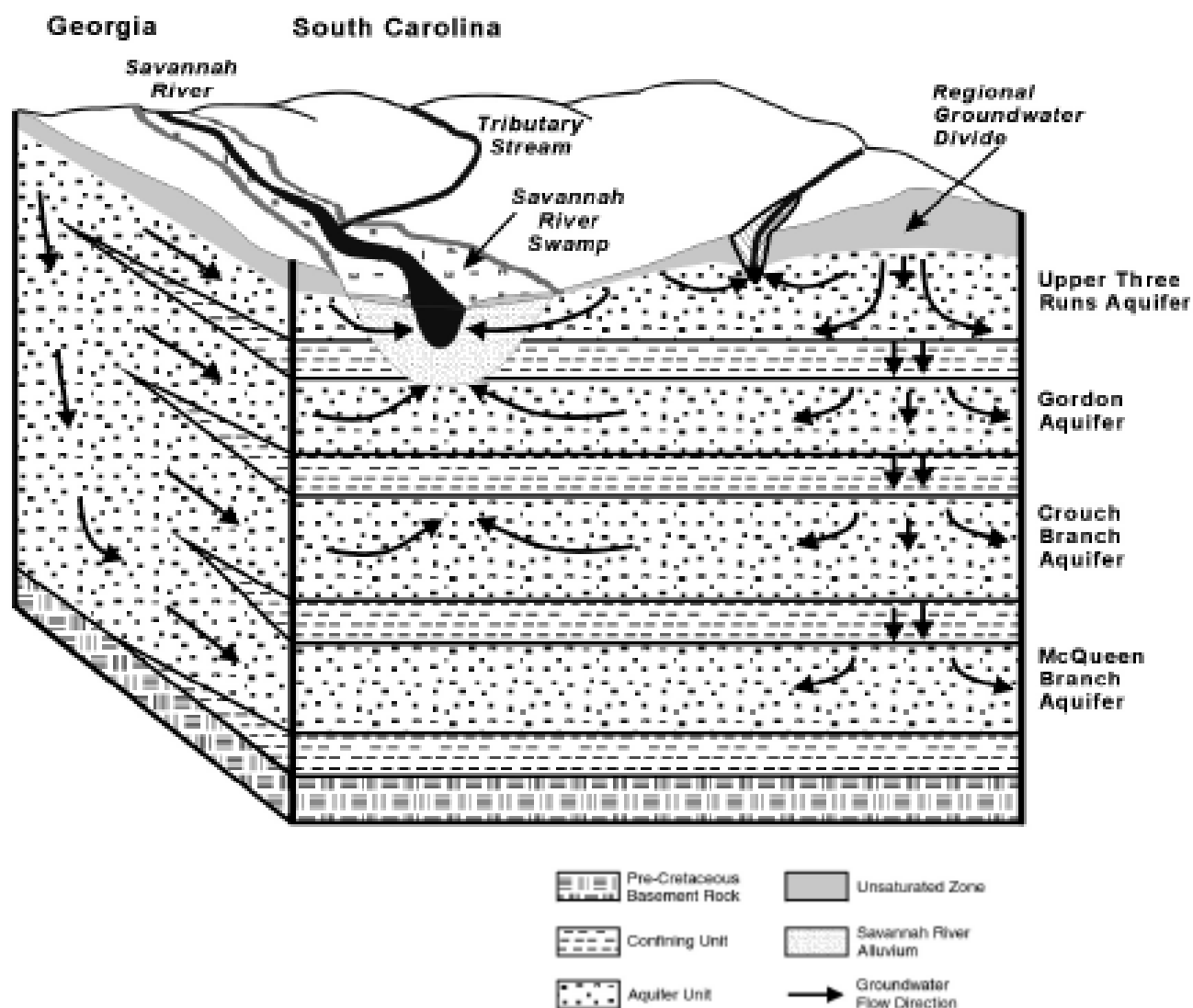
An aquifer is defined as any underground rock or sediment formation that is sufficiently permeable (i.e., allows liquid to filter through different layers) to yield significant quantities of water to wells and springs. Different aquifers can be present at various depths below the ground.

A confined aquifer is a geological formation that is resistant to groundwater flow because of its lower permeability. An aquifer that is confined is less likely to be impacted by surface contamination (WSRC 1999b).

Groundwater moves beneath SRS in the permeable sand layers separated by the less permeable clay layers. The groundwater flows slowly with rates ranging from several inches to feet per year in the clay zones and from tens to several hundreds of feet per year in the sand zones. In general, it flows beneath the on-site waste sites toward the Savannah River, the Savannah River Swamp, and the on-site tributaries of the Savannah River, or migrates into the deeper aquifer systems (WSRC 2000, 2005). Figure 6 illustrates how groundwater travels toward streams and swamps on site and eventually into the Savannah River (WSRC 2000a).

SCDNR and the United States Geological Survey (USGS) have established a hydrostratigraphic (geologic units with the same hydrogeologic properties) classification system for the area (CRESP 2001; SCDNR 1995; USGS 1997, 1998; USDOE 2002; WSRC 2001a). A similar version of this classification system is used by SRS to characterize groundwater contamination beneath the site (Aadland 1995; Smits 1996). A description of the three principle aquifer systems is described after Figure 6. Figures 6 and 7 show the major aquifer units within these systems.

Figure 6. Hydrological Cycle at SRS



The groundwater flow system at SRS consists of four major aquifers separated by confining units. Flow in recharge areas generally migrates downward as well as laterally—eventually either discharging into the Savannah River and its tributaries or migrating into the deeper regional flow system.

Source: WSRC 2002b

- The **Floridan Aquifer System** mainly consists of sand and limestone.
  - South of Upper Three Runs Creek on the site, the Floridan Aquifer System is subdivided into the overlying Upper Three Runs Aquifer Unit and the underlying Gordon Aquifer Unit, separated by the Gordon Confining Unit. North of Upper Three Runs Creek, this aquifer system is collectively referred to as the Steed Pond Aquifer Unit, which is subdivided into the overlying M-Area Aquifer Zone and the underlying Lost Lake Aquifer Zone separated by the Green Clay Confining Zone.
  - The water table aquifer, Upper Three Runs Aquifer/Steed Pond Aquifer, is up to 150 feet deep in the SRS area.
- The **Dublin Aquifer System** consists primarily of sand. This system is equivalent to the Crouch Branch Aquifer Unit and is separated from the Floridan Aquifer System by the Meyers Branch Confining System, also referred to as the Crouch Branch Confining Unit.
- The **Midville Aquifer System** consists primarily of sand and is equivalent to the McQueen Branch Aquifer Unit. It is separated from the Dublin Aquifer System (Crouch Branch Aquifer Unit) by the McQueen Branch Confining Unit.

Figure 7 shows how SRS site documents typically describe the aquifer zones in different areas of SRS. For instance, in the General Separations Area, the aquifer units, from the shallowest to the deepest, include the Upper Three Runs Aquifer, the Gordon Aquifer, the Crouch Branch Aquifer, and the McQueen Branch Aquifer (WSRC 1999b).

The upper aquifer zones collect rainwater that soaks in and infiltrates the soil from the earth's surface. Water in this zone moves either laterally to discharge as surface water or downward into lower groundwater zones. Much of the groundwater at SRS discharges into on-site surface streams, swamps, and eventually into the Savannah River. Surface water runoff and groundwater discharges represent the main pathways for the transport of contaminants to the Savannah River (WSRC 1999b, 2002b). Beneath the upper aquifer zone is a clay layer that inhibits the groundwater from moving downward into the lower zones. In some areas, the clay layer is thick and undisturbed and is effective in preventing the groundwater from moving downward (i.e., confined). In other areas, this clay layer is thin, broken, or missing, and the groundwater can readily move into lower zones (i.e., unconfined) (WSRC 1999b, 2000). Potentially hazardous substances in the soil may dissolve as water is absorbed and moves downward through the soil to the water table. The lateral movement of contaminants in the aquifer zones results in migrating plumes of contaminated groundwater, which may become a health risk to individuals using it (WSRC 2000).

Figure 7. Schematic of SRS Groundwater Aquifers

A&M Areas			General Separations Areas		Reactor Areas
Steed Pond Aquifer Unit (undiff.)	M Area Aquifer Zone		Upper Three Runs Aquifer Unit	D Upper Aquifer Zone – Upper Three Runs Aquifer Unit	D Transmissive Zone – Upper Three Runs Aquifer Unit
				Tan Clay Confining Zone	
				C Middle Aquifer Zone – Upper Three Runs Aquifer Unit	
			Tan Clay Confining Zone – Lower Clay		
			B Lower Aquifer Zone – Upper Three Runs Aquifer Unit		
	Green Clay Confining Zone		Gordon Confining Unit		Gordon Confining Unit
Lost Lake Aquifer Zone (undiff.)	C Upper Lost Lake Aquifer Zone	A	Gordon Aquifer Unit	A	
	B Lower Lost Lake Aquifer Zone				
Crouch Branch Confining Unit – Upper Clay			Crouch Branch Confining Unit		
A Middle Sand Aquifer Zone					
Crouch Branch Confining Unit – Lower Clay			Crouch Branch Aquifer Unit		
Crouch Branch Aquifer Unit					
McQueen Branch Confining Unit			McQueen Branch Confining Unit		
McQueen Branch Aquifer Unit			McQueen Branch Aquifer Unit		McQueen Branch Aquifer Unit
Appleton Confining System			Appleton Confining System		Appleton Confining System
Cape Fear Formation			Cape Fear Formation		Cape Fear Formation

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### ***Groundwater Contamination***

Chemical and radioactive wastes are byproducts of nuclear material production at SRS. These wastes have been treated, stored, and in some cases, disposed at the site, resulting in soil and groundwater contamination. SRS operations have resulted in groundwater contamination primarily by those associated with waste disposal facilities in the central area of the site. The waste sites range in size from a few square yards to tens of acres and include basins, pits, piles, burial grounds, landfills, and tanks. Industrial solvents, radionuclides, metals, and other compounds used or produced by operations at SRS have contaminated groundwater at approximately five to ten percent of the site. Significant groundwater contamination has been identified across several areas at SRS. These areas are described below with groundwater flow based on true north:

- **A-Area and M-Area<sup>3</sup> Plume:** The A&M-Area contains facilities that were used for fabrication of reactor fuel and target assemblies, for support and administrative services, and for laboratory services (WSRC 2003b). The fabrication process used industrial solvents to degrease fuel assemblies and generated electroplating wastes containing toxic metals from the 1950s until August 1982. TCE and tetrachloroethylene (PCE) are the major groundwater contaminants in this plume, which covers approximately 5.5 square miles in the northwestern section of SRS. The plume is migrating towards the south in the direction of Tims Branch and Upper Three Runs Creek and southwest towards the site boundary near Jackson and the Savannah River. The A&M-Area plume has the highest potential to migrate off site and impact drinking water supplies because of its proximity to the SRS boundary. Therefore, the A&M-Area will be evaluated in greater detail in this PHA.
- **B-Area (Sanitary Landfill) Plume:** Groundwater contamination at the sanitary landfill, located northwest of the general separations and waste management areas, consists of VOCs, tritium, metals, and radionuclides. This plume covers a small geographic area and the source of contamination is at least 3 miles from the SRS boundary. Surface water and groundwater flow is to the southeast, toward Upper Three Runs Creek. There is very limited potential for contaminants in the B-Area plume to impact off-site drinking water or surface water sources.
- **D-Area and TNX-Area Plumes:** The D-Area included a large coal-fired power plant and decommissioned heavy water facilities. The TNX-Area had facilities used to test equipment and develop new designs. Shallow contaminated groundwater plumes containing VOCs (primarily TCE), lead, heavy metals, and radionuclides have been identified in the D-Area and TNX-Area in the southwestern part of the site. The contaminated groundwater plume is confined to the Upper Three Runs Aquifer Unit. The Savannah River is the closest SRS boundary, approximately one-quarter mile to the west of the TNX-Area and approximately one mile west of the D-Area. Groundwater contaminants from the TNX-Area are migrating in a plume towards the Savannah River Swamp and the Savannah River; whereas contaminants in the D-Area are migrating toward the Savannah River and a nearby swamp adjacent to Beaver Dam Creek.

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<sup>3</sup>Throughout the remainder of this report this is referred to as the A&M-Area

Although the contaminant plumes are in close proximity to the site boundary, the shallow aquifer discharges to the Savannah River swamp and the Savannah River, and there is limited potential for the plume to impact drinking water supplies west of the Savannah River. Any potential D-Area and TNX-Area plume impacts to the Savannah River and other off-site waterways are addressed within the “Surface Water Evaluation” section of this PHA.

- **N-Area (Central Shops) Plume:** In the Central Shops area (N-Area), located in the center of the site, organic compounds (including TCE) and heavy metals are responsible for groundwater contamination in this location. Groundwater from beneath this area is indirectly discharged to Four Mile Creek and Upper Three Runs Creek from several smaller creeks in close proximity to the N-Area. The groundwater plume associated with the N-Area is relatively small and a long distance (approximately 6 miles) from the closest SRS boundary. This plume is not expected to impact any off-site groundwater or surface water resources.
- **Reactor Area Plumes:** For the centrally located reactor areas (C-Area, K-Area, L-Area, P-Area, and R-Area), tritium and TCE are the major groundwater contaminants with metals, other organics, and other radionuclides also present. These plumes are primarily located across the interior of SRS. The largest groundwater plume is associated with the C-Area. None of the reactor groundwater plumes are close to the SRS boundary and are not expected to impact any off-site groundwater resources.
- **Separations/Waste Management Plumes:** In the general separations and waste management areas (E-Area, F-Area, H-Area, S-Area, and Z-Area), located in the center of the site, the groundwater is contaminated by VOCs (mainly TCE and PCE), radionuclides, metals, and other constituents. These areas comprise many smaller, and in some cases overlapping, groundwater plumes. The shallow groundwater in the southern portion of the E, F, and H-Areas discharges to Four Mile Creek and its tributaries; whereas in the northern portion of these areas shallow groundwater discharges to Upper Three Runs Creek and its tributaries. S and Z-Areas are located on the groundwater divide between Upper Three Runs Creek and its tributaries to the west. As with the other centrally located areas of contamination, the Separations/Waste Management groundwater plumes are not close to the SRS boundary and are not expected to impact any off-site groundwater or surface water resources.

(Sources: WSRC 1999a, 2001a, 2002b, and 2006; USDOE 2006)

SCDHEC's Bureau of Water and Bureau of Land and Waste Management maintain an inventory of groundwater contamination sites by county. In the 2005 inventory, there were no incidents or areas listed for SRS in Allendale County, but there were multiple areas listed in Aiken and Barnwell Counties. The records indicate that several of the groundwater plumes discharge to surface water streams and creeks on site before the contaminants leave DOE property. Most of these streams and creeks discharge to the Savannah River without crossing private property (SCDHEC 2006a).

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## ***Groundwater Monitoring***

Monitoring wells are used extensively to assess the effect of site activities on groundwater quality. These monitoring wells provide valuable information about the nature and extent of groundwater contamination, help determine the flow of the groundwater and groundwater level, and serve to monitor the migration of the contaminant groundwater plume over time. There are over 1,000 groundwater monitoring wells in approximately 80 different locations within the SRS boundary. However, starting in 2003, wells are properly abandoned when they are no longer needed. Additional monitoring wells are installed as needed to redefine the extent of contamination. This groundwater monitoring well network is sampled at various intervals to detect contamination from known and undiscovered locations (WSRC 2005a; USDOE 2006).

## ***Contaminants of Concern***

ATSDR's groundwater evaluation is specifically focused on site-related contaminants that may 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. It is important to emphasize that if people do not come in contact with a contaminant, regardless of its toxicity, it cannot cause harm. Therefore, with respect to exposure pathways, we are most concerned with where people live and the location of municipal and private drinking water supplies relative to where contaminated groundwater plumes exist.

### **Groundwater Contaminants**

ATSDR *focused* on substances detected in on- or off-site groundwater wells at levels that exceed media-specific screening values *and* where exposure to the nearby community is possible.

The on-site groundwater plumes (previously described) are well characterized by extensive groundwater monitoring. Further, remedial activities are being performed by DOE and DOE contractors with regulatory oversight by state and federal environmental agencies (WSRC 2004b).

### ***How did ATSDR evaluate contaminated groundwater at SRS?***

ATSDR's screening process involved multiple steps that allowed a comprehensive review of the available on- and off-site groundwater data at or near SRS. ATSDR scientists conducted a site-wide review of groundwater data, focusing on samples collected since 1992. This timeframe was selected because a review of earlier sampling efforts for radiological and chemical contaminants was conducted as part of the SRS Dose Reconstruction Project and evidence suggested that groundwater contamination had not impacted offsite residents before 1993. The dose reconstruction investigation also concluded that although remedial programs had significantly decreased the amounts of contamination on the site, a potential existed for future off-site groundwater contamination from activities in the A&M-Area (CDC 2001). ATSDR scientists reviewed these reports and applicable data and agreed with these conclusions.

ATSDR evaluated on-site groundwater monitoring well data and identified specific locations within the SRS boundary that might pose an exposure concern. Most areas of groundwater contamination on site were ruled out as posing a potential public health hazard because ATSDR scientists determined that people either are not exposed to harmful levels of contaminants from



groundwater sources at SRS or, in most cases, do not come in contact with the contaminated groundwater plumes. The potential for off-site migration is very limited because of the large distance between most SRS groundwater plumes and the site boundary. Other important factors include documented monitoring of all on-site drinking water supply wells (e.g., ensuring that the results of routine monitoring meets all state and federal drinking water standards) and adequate characterization of the local groundwater hydrogeology (e.g., groundwater flow and proximity of groundwater plumes to drinking water sources and surface water features).

*What criteria were used to select contaminants of concern?*

If a contaminant was not detected above its respective CV in any of the groundwater monitoring wells it was eliminated from further consideration. Contaminant concentrations that are detected below their CVs are not expected to cause adverse health effects. When a substance's maximum concentration exceeded a CV, 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), monitoring well location (contaminants detected in wells closest to the SRS boundary were given the greatest consideration), 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 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.

**Contaminants without CVs**

Most chemical compounds detected in groundwater and surface water have corresponding screening values (i.e., CVs). However, CVs are not always available for every reported compound. In cases where a substance has no corresponding CV, ATSDR reviews the scientific literature and uses the most current information in the scientific literature regarding the chemical's toxicity to determine whether it should be considered as a contaminant of concern.

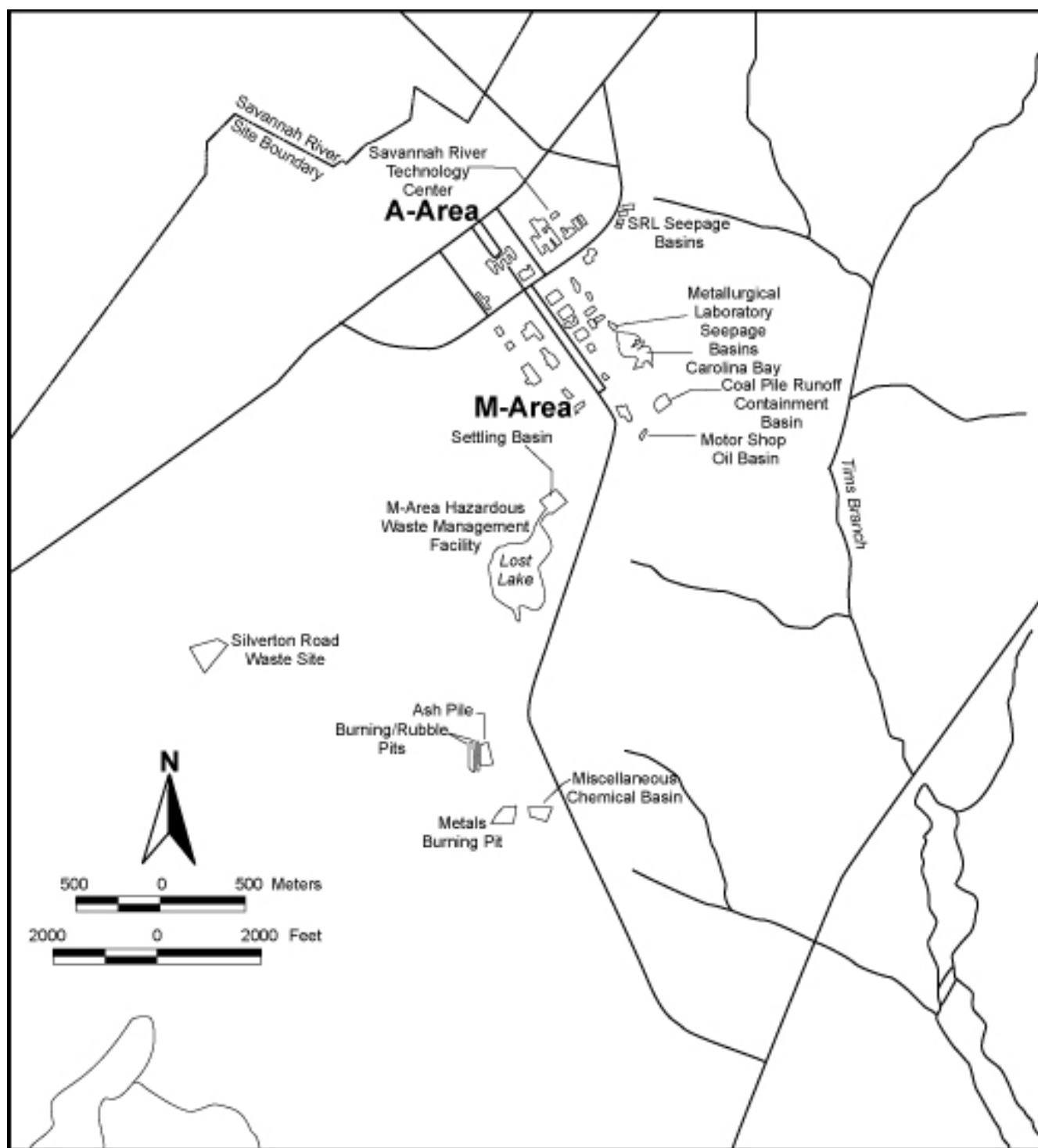
***Areas of Concern Identified at SRS***

During this review, ATSDR did not identify any site-related groundwater plumes that have migrated beyond the SRS boundary and impacted off-site private wells. ATSDR identified one on-site area of contamination, the A&M-Area, that could potentially impact off-site groundwater given the location (it is in close proximity to the northwest site boundary), concentrations detected (solvents such as TCE were detected at very high concentrations), types of contaminants (some chemicals are more mobile than others), and local groundwater hydrogeology. ATSDR looked at the nature and extent of contamination associated with the A&M-Area groundwater plume, focusing on monitoring wells closest to the SRS boundary, and reviewed the results of off-site groundwater sampling efforts conducted by DOE and by the state of South Carolina. A more in depth discussion of the A&M-Area is presented below.

***The A&M-Area history of groundwater contamination***

The A&M-Area covers approximately 350 acres in the northern portion of the site and is located one-third of a mile from the site's boundary (see Figure 8), only a few miles from the nearest population center in Jackson, South Carolina (WSRC 2003a). The area contains facilities that were used for fabrication of reactor fuel and target assemblies, for support and administrative services, and for laboratory services (WSRC 2003b). The fabrication process generated electroplating wastes that contained hydroxide precipitates of aluminum, uranium, nickel, lead, and other metals and could have included either acids or caustics depending on the operating schedule. The process used industrial solvents to degrease fuel assemblies from the 1950s until August 1982 (Pickett et al. 1987).

When fabrication operations started in the M-Area in 1954, process wastewater from all M-Area facilities was released directly to Tims Branch, an on-site surface water stream. In 1958, wastewater from one of the fabrication facilities was directed to a two-acre unlined settling basin (M-Area Settling Basin) through an underground process sewer line. The wastewater that went to the settling basin contained various metals as well as acids, caustics, and chlorinated degreasing solvents (Pickett et al. 1987). The primary contaminants are TCE and PCE, which were used extensively as industrial solvents to degrease fuel assemblies. Organic wastes, metals, radionuclides, and other contaminants were placed into unlined basins that slowly seeped into the groundwater in several of the underlying aquifer zones. Spills and leaking pipes also contributed to contaminating the groundwater. Chlorinated solvent contamination was first discovered in samples collected at the A&M-Area production wells in the M-Area HWMF in 1981. After discovering contamination below the M-Area settling basin in June 1981, an interim groundwater monitoring program was established in 1983 (Jackson et al. 1997).

**Figure 8. A&M-Area Site Map**

Source: WSRC 2000

Solvents evaporate at very low temperatures. However, since solvents and similar compounds are denser than water, they have a tendency to occupy the deeper portions of the settling basin and subsurface soils. Lower concentrations were at the top of the basin due to this stratifying effect, the evaporation of the solvents near the surface, and settling of the metal precipitates. Periodically the basin overflowed to Lost Lake, a natural seepage area and shallow depression approximately 25 acres in size, contaminating soil and groundwater with a lower concentration of metals and solvents than beneath the basin. This area and the M-Area Settling Basin are referred to as the M-Area Hazardous Waste Management Facility (HWMF) (Jackson & Looney 2001). The M-Area Settling Basin was covered with a RCRA cap and closed in 1991. The Metallurgical Laboratory Basin and the Savannah River Laboratory Basins, also used for disposal of liquid wastes, were closed in 1992 and 2001, respectively (USDOE 2006b).

Generally, the upper aquifer zone is the most affected by SRS activities; however, at the A&M-Area, contamination has been identified in the Steed Pond, M-Area, Lost Lake, Crouch Branch, and McQueen Branch Aquifer Zones. The A&M-Area has more than 350 monitoring well locations. This number does not include other wells, such as extraction and injection wells. The number of wells may also vary because wells may be taken out of service or new wells may be constructed (USDOE 2005a, 2006a).

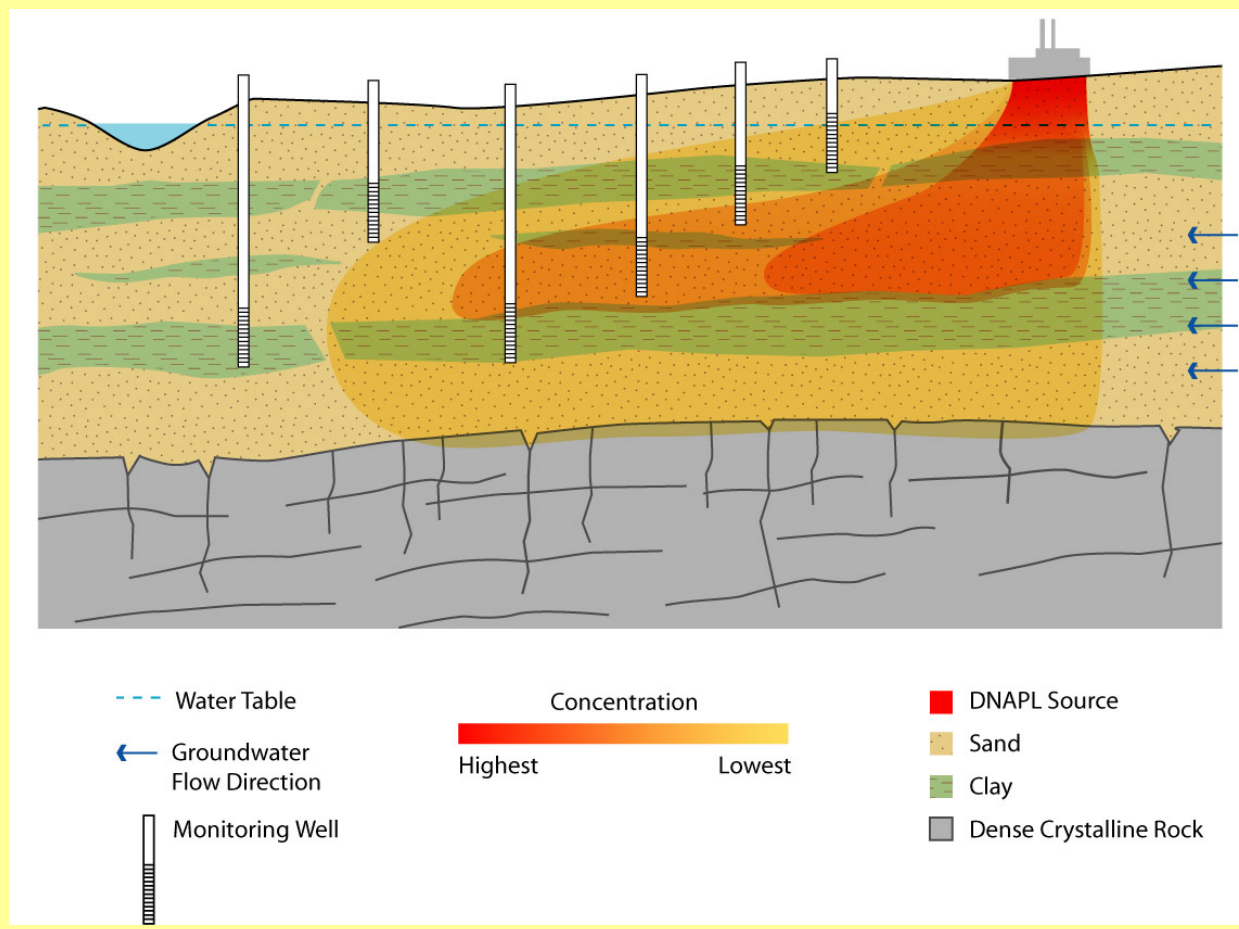
The monitoring well data indicate that the plume is migrating in two predominant directions: south towards Tims Branch and Upper Three Runs Creek and southwest towards the northwest boundary near the city of Jackson and the Savannah River. According to groundwater flow paths in this area, the long-term outcrop is expected to be southwest of the A&M-Area near the CWMAER (Jackson et al. 1997; USDOE 2006).

The industrial solvents, primarily TCE and PCE, formed a dense non-aqueous phase liquid (DNAPL) in subsurface soils beneath the M-Area HWMF, the Solvent Tank Storage Area, the A-014 Outfall Area, and SRNL (formerly SRTC). The relatively high density of the DNAPL caused it to move in a vertical direction following the “path of least resistance” through permeable sand and gravel. Once it encountered a less permeable formation, it spread laterally and served as a source for release of VOCs into the groundwater. The VOCs dissolved in water moved away from the DNAPL in plumes extending in the direction of the groundwater transport (Smits et al. 1998). There are three major impacts on the groundwater (the source zone, the primary contaminant plume, and the dilute fringe), each having different characteristics. The DNAPL has significant contaminant concentrations and continually releases VOCs over a long period of time. Contaminant concentrations in the plume steadily decrease in all directions away from the source area. However, VOC concentrations in groundwater are high enough in some downgradient locations near, but within, the SRS boundary to be of human health concern if exposures were to occur. The dilute fringe contains lower concentrations in large volumes (Jackson & Looney 2001; USDOE 2006).

**DNAPL (dense non-aqueous phase liquid)**

DNAPL plumes exist in the subsurface as a separate fluid phase in the presence of either air or water, and can both vaporize into air and slowly dissolve into flowing groundwater. The fact that DNAPLs are denser than water allows them to migrate to substantial depths below the water table in both unconsolidated deposits and fractured bedrock. Examples include chlorinated solvents, creosote, coal tar, and polychlorinated biphenyl (PCB) oils.

PCE and TCE, the largest DNAPL source at SRS, is heavier than water and has a low solubility (up to one part PCE and TCE per thousand parts of water at room temperature). When present in groundwater, PCE and TCE tend to settle into a layer at the bottom of the aquifer and then continuously dissolve into the groundwater. This may result in high concentrations in the aquifer for many years after the original release of the contaminant has ended. At SRS the DNAPL appears to not only be in the aquifer zones but also in the clay confining units between the zones.



The three main aquifers in the A&M-Area include the shallower Steed Pond aquifer, the Crouch Branch aquifer, and the deeper McQueen Branch aquifer. In part of the A&M-Area there is a variation in the shallower aquifer. The Crouch Branch aquifer is the principal water-producing aquifer at SRS (Smits et al. 1998). However, off-site private wells are drilled into both the Steed Pond and Crouch Branch aquifer zones (SCDHEC 2005c).

#### *Groundwater remediation projects*

As of March 2006, cleanup activities at 325 of the 515 waste units have been completed and billions of gallons of groundwater beneath these closed sites have been treated, with over 1.2 million pounds of solvents removed. Numerous new technologies have been developed at SRS to increase the effectiveness of the remediation efforts. The site Soil and Groundwater Closure Project (formerly Environmental Restoration) is planning on closing entire areas with the priority on peripheral locations (i.e., TNX-Area, D-Area, and the A&M-Area). Although the surface unit closures have occurred or will occur in the near future, the groundwater units will not be completed until later. By 2025, all inactive waste sites posing the greatest risk of future contamination to surface water or groundwater will be cleaned up, and any current contaminated groundwater sources will be remediated or undergoing remediation. Some areas may have waste remain in place but will be under institutional controls and will be inspected, maintained, and monitored (EPA 2006; USDOE 2006).

A program aimed at cleaning up organic solvents from on-site groundwater that has migrated away from the concentrated DNAPL plume was initiated in 1983. A pilot pump-and-treat system was installed to remove VOCs dissolved in the groundwater below the M-Area settling basin (part of the M-Area HWMF), a principal source of groundwater contamination in the A&M-Area. The treated water is discharged through a permitted outfall to a nearby on-site stream. A second, much larger pump-and-treat system was installed in 1985. Eleven wells pumped contaminated groundwater from the shallow aquifer to a stainless steel stripper tower. In 1996, this air stripper was equipped with an off-gas treatment unit to destroy TCE and PCE before they were released to the air (Jackson et al. 1997). The off-gas treatment unit operated about 18 months and was tuned off when the permit and clean-up levels were achieved (USDOE 2006b).

Further analysis indicated that a dissolved plume originating from a source in the northern sector near the SRTC was migrating towards the southwest. In 1992, the prototype pump-and-treat system from the M-Area HWMF was installed in the SRTC area to remove TCE and PCE from the groundwater. In that year, a program was also initiated to remove solvents from the soils above the groundwater in the M-Area HWMF. In 1995, six soil vapor extraction systems, using vacuum extraction, were installed throughout the A&M-Area. By 2003, four of the six units were no longer needed and were retired.

In 1996, another pump-and-treat system connected to six recovery wells was added to the SRTC area. The recovery wells within this northern sector of the A&M-Area served to capture and control groundwater within the Steed Pond Aquifer Unit, minimizing the potential for migration of the groundwater contamination beyond the northern boundary.

In 1997, SRS estimated that the plume in the Crouch Branch aquifer had a total thickness of approximately 50 feet and the expected groundwater outcropping would be in the vicinity of the Crackerneck Swamp, near the Savannah River southwest of the A&M-Area. However, it was also discovered that some monitoring wells were yielding samples above the elevation of the primary plume, resulting in very low or non-detectable concentrations of TCE and PCE at these locations. Beginning in 1997, a series of 12 recirculation wells were installed in the A&M-Area southern sector to treat solvents in the groundwater plume migrating toward Tims Branch Creek (on-site). An in-well stripping technology that removes VOCs in the well without a need to remove, treat, and discharge the wastewater, was used to intercept the leading edge of the plume. This technology proved to be more cost-effective than the traditional pump-and-treat system (Jackson et al. 1997).

Other new techniques have also been used, such as in-situ air-stripping and in-situ bioremediation; however, none of these techniques address the removal of the DNAPL from above and below the water table. After researching and attempting various technologies, SRS selected dynamic underground stripping (DUS) as the preferred method to address DNAPL contamination. The first DUS project at SRS began construction in March 2000, near the M-Area Solvent Storage Tank Area. This process uses continuous injection of steam to vaporize the DNAPL in conjunction with extraction wells that remove the vaporized DNAPL. The full extraction and steaming process in this area occurred from September 2000 to September 2001. A second use of DUS was at the M-Area Settling Basin. This project construction began in September 2003, and the extraction and injection operations began in August 2005 (WSRC 2003b; Jackson & Looney 2001; USDOE 2006). This technique is also being used in the SRTC Area in the northern sector. The project began in August 2005, but the steam injection and extraction process did not begin until December 2005 (Gail Whitney, U. S. Department of Energy, personal communication, January, 2006). ATSDR reviewed the 2005 Annual Groundwater Monitoring and Corrective Action Report for the M-Area and Metallurgical Lab HWMF, but has not reviewed any groundwater monitoring data since the beginning of the DUS process (WSRC 2006). Therefore, ATSDR scientists could not determine if the DUS process will have an effect on off-site wells.

#### *The A&M-Area contaminants of concern*

In 1984, the A&M-Area plume was approximately 5,000 feet from the closest site boundary. However, in 1993, additional sampling of existing and newly installed plume definition wells showed that site-related contaminants had migrated within 2,000 feet of the closest boundary (CDC 2001). According to the 2000 SRS Environmental Monitoring Report, the entire contaminant plume associated with the A&M-Area covered approximately 5.5 square miles and was approximately one-third mile (approximately 1,760 feet) from the nearest SRS boundary north of the A&M-Area (WSRC 2001a). The closest municipal drinking water supply wells are located in the City of Jackson about three miles west of the A&M-Area.

ATSDR reviewed groundwater data from monitoring wells located within the A&M-Area. To determine the potential for off-site migration of contaminants, ATSDR focused on all A&M-Area monitoring wells within one-half mile of the SRS boundary. Using this criterion, a total of 16 monitoring wells were designated “boundary wells.” Figure 9 shows the location of these 16 boundary wells along with the historical maximum TCE concentrations and most recent maximum TCE concentrations detected in these wells. In 2001, TCE was detected in two on-site monitoring wells (JAX1 and JAX2) very close to the SRS boundary, at a maximum concentration of 0.3 parts per billion (ppb), which is below ATSDR’s health-based comparison value of 5 ppb. These monitoring wells are close to the SRS boundary and may represent the furthest extent of the plume. The most recent sampling of these monitoring wells through 2004 has not detected TCE or other organic solvents that could be attributed to the A&M-Area. Therefore, the A&M-Area groundwater plume appears to be contained within the SRS boundary. The contaminants detected in the 16 boundary wells exceeding their CVs or without corresponding CVs are presented below.

Chemical Contaminants in the 11 Boundary Wells — A total of 18 contaminants were detected above their CVs (see Table 4). A brief description of the contaminants that were detected above CVs in these wells is provided below (USDOE 2005a).<sup>4</sup>

*Metals:* Eight metals were detected above their CVs. The source of these metals is not known since most of these elements may occur naturally in the environment. Arsenic and lead were the two metals most frequently detected in A&M-Area boundary wells.

Lead was detected more frequently above its CV than any other metal, with a total of nine of 16 wells having exceeded the EPA action level for lead in drinking water (15 ppb) during at least one sampling round. Lead was detected at a maximum concentration of 113 ppb in well MSB43D, located approximately 2,500 feet from the SRS boundary and more than two miles northeast of the Jackson municipal supply well, the closest drinking water well. There are two monitoring wells in between MSB43 and the Jackson well. Samples collected from the well closest to MSB43 contained lead at a maximum concentration of 27.5 ppb (Well MSB56D) and the samples collected from the well closest to the Jackson supply well (Well JAX1) contained lead in one sample at 10.9 ppb tested in 2001. Samples were collected as recently as 2003 and lead was not detected above the detection limit of 5 ppb.

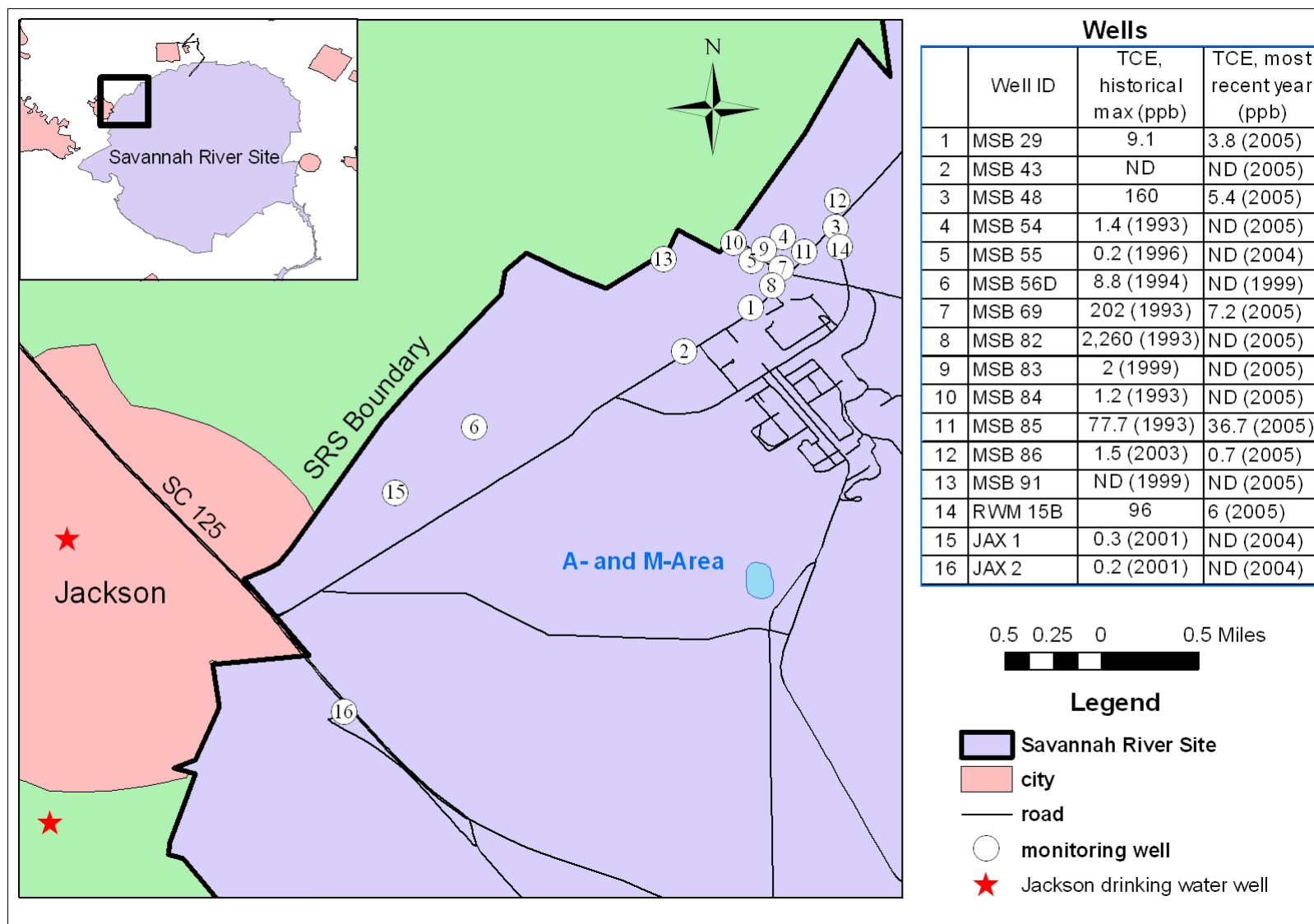
Arsenic was detected above its CV in six boundary wells (Maximum = 4.8 ppb in well MSB29). Other metals that were detected above their CVs in A&M-Area boundary wells include cadmium (287 ppb), copper (159 ppb), fluoride (1,060 ppb), mercury [mercuric chloride] (4.3 ppb), sodium (106,000 ppb), and uranium (97 ppb).

*Volatile Organics:* Seven VOCs were detected above their CVs. The source of most of the detected VOCs is likely from SRS-related activities since VOCs do not occur naturally in the environment. However, some types of VOCs are common laboratory contaminants and could have resulted from the process of analyzing the samples rather than actual contaminants present in the groundwater.

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<sup>4</sup> All values in parentheses represent maximum detected concentrations.



**Figure 9. Location of A&M-Area Boundary Wells and Jackson City Drinking Water Wells**

Methylene chloride was the most frequently detected organic compound in A&M-Area boundary wells. This contaminant was detected above the CV in ten wells at a maximum concentration of 72.9 ppb (well RWM15B). It is possible that the source of this contaminant is attributed to SRS historical releases. However, methylene chloride is also frequently found in laboratory blanks (e.g., soil and water samples) (ATSDR 2000).

The other six organic compounds were detected less frequently in A&M-Area boundary wells. Benzene was detected in one well (3.4 ppb), carbon tetrachloride was detected in two wells (4.9 ppb), 1,4-dioxane was detected in three wells (7.2 ppb), PCE was detected in one well (780 ppb), TCE was detected in seven wells (2,260 ppb), and toluene was detected in one well (614 ppb). The maximum concentration for both PCE and TCE was detected in well MSB82A (see Table 4 for aquifer designation).

*Other compounds:* Three other compounds were detected in A&M-Area boundary wells above their respective CVs. Nitrate and nitrite (reported as one compound) was detected at a maximum concentration of 1,580,000 ppb, phosphorus was detected at a maximum concentration of 2,500 ppb, and sulfate was detected at a maximum concentration of 3,940,000 ppb. Nitrate and nitrite was only detected in two wells. Phosphorus was detected in most of the boundary wells at concentrations above its CV. Sulfate was detected in most of the boundary wells at varying concentrations, but only exceeded its CV in well MSB82.

*Contaminants without screening values:* There are five other compounds that were detected in A&M-Area boundary wells that do not have corresponding CVs. These include carbon, carbonate, chloride, phosphate, and silicon dioxide.

**Table 4. Chemical contaminants detected in on-site A&M-Area boundary wells above ATSDR's comparison values (CVs)**

Well Number (Well Type) (sampling timeframe)	Contaminant	CV (ppb)	Range (ppb) Includes all aquifers tested	Number of detects/total samples from all aquifers <sup>1</sup>	Number of detects/total samples from selected aquifer <sup>2</sup>	Aquifer where maximum concentration was detected
Well JAX1	Sodium	20,000 (EPA)	41,500	1/1 (1)	1/1 (1)	(CBAU)
Well JAX2	None	NA	NA	NA	NA	(CBAU)
Well MSB29 (Plume definition and background) (1993–2005)	Arsenic 1,4-Dioxane Fluoride (sodium fluoride) Mercury (mercuric chloride) Methylene chloride Phosphorus TCE	0.02 (CREG) 3 (CREG) 500 (EMEG CC) 2 (LTHA) 5 (CREG) 0.1 (LTHA) 5 (MCL)	ND—4.8 ND—3.1 ND—756 ND—4.3 ND—15.6 ND—2,500 ND—9.1	1/90 (1) 1/54 (1) 3/87 (1) 10/124 (1) 8/127 (1) 7/63 (7) 33/176 (7)	1/28 (1) 1/13 (1) 2/25 (1) 1/13 (1) 3/30 (1) 2/17 (2) 31/32 (7)	B (LLLAZ) B (LLLAZ) D (MAAZ) A (MSAZ_CBCU) B (LLAZ) D (MAAZ) TA (CBCU)
Well MSB43 (Background) (1993–2005)	Arsenic Copper Lead <sup>3</sup> Methylene chloride Phosphorus	0.02 (CREG) 100 (EMEG) 15 (EPA) 5 (CREG) 0.1 (LTHA)	ND—2 11.3—119 ND—113 ND—11.1 ND—231	1/77 (1) 26/38 (1) 60/104 (10) 7/106 (2) 12/58 (12)	1/30 (1) 5/5 (1) 16/19 (8) 3/23 (1) 7/20 (7)	A (LLLAZ) D (MAAZ) D (MAAZ) D (MAAZ) A (LLLAZ)
Well MSB48 (Plume definition) (1993–2005)	Arsenic Benzene Methylene chloride Lead <sup>3</sup> Nitrate and Nitrite Phosphorus TCE Uranium	0.02 (CREG) 0.6 (CREG) 5 (CREG) 15 (EPA) 10,000 (MCL) 0.1 (LTHA) 5 (MCL) 30 (MCL)	ND—2.2 ND—3.4 ND—16 5.2—23.5 ND—1,580,000 ND—395 ND—160 ND—97	1/14 (1) 1/79 (1) 9/79 (3) 12/62 (4) 40/41 (1) 10/21 (10) 45/141 (34) 2/16 (1)	1/3 (1) 1/9 (1) 3/18 (1) 5/5 (4) 9/9 (1) 4/5 (4) 33/33 (24) 1/4 (1)	B (LLLAZ) D (ULLAZ) TA (CBAU) D (ULLAZ) TA (CBAU) C (ULLAZ) B (LLLAZ) B (LLLAZ)
Well MSB54 (Plume definition) (1993–2005)	Carbon Tetrachloride 1,4-Dioxane Lead <sup>3</sup> Phosphorus	0.3 (CREG) 3 (CREG) 15 (EPA) 0.1 (LTHA)	ND—4.9 ND—7.2 ND—19.2 ND—240	2/83 (2) 1/21 (1) 17/55 (2) 2/20 (2)	1/22 (1) 1/7 (1) 13/14 (2) 2/5 (2)	TA (CBAU) TA (CBAU) D (ULLAZ) C (LLLAZ)
Well MSB55 (Plume definition) (2003–2005)	Lead <sup>3</sup> Mercury (mercuric chloride) Methylene chloride Phosphorus Sodium	15 (EPA) 2 (LTHA) 5 (CREG) 0.1 (LTHA) 20,000 (EPA)	ND—21 ND—2.1 ND—16.1 ND—268 3,250—28,500	24/73 (5) 3/13 (1) 11/88 (3) 2/26 (2) 55/57 (1)	4/13 (1) 1/13 (1) 2/18 (1) 1/5 (1) 13/13 (1)	HC (ULLAZ) TA (CBAU) B (MSAZ_CBCU) HC (ULLAZ) HC (ULLAZ)
Well MSB56 (Piezometer) (1993–1999)	Copper Lead <sup>3</sup> Phosphorus TCE	100 (EMEG) 15 (EPA) 0.1 (LTHA) 5 (MCL)	6.3—159 ND—27.5 ND—11 ND—8.8	5/5 (1) 11/14 (3) 1/5 (1) 1/17 (1)	5/5 (1) 11/14 (3) 1/5 (1) 1/17 (1)	D (MAAZ) D (MAAZ) D (MAAZ) D (MAAZ)
Well MSB69 (Plume definition) (1993–2005)	Arsenic Lead <sup>3</sup> Phosphorus TCE	0.02 (CREG) 15 (EPA) 0.1 (LTHA) 5 (MCL)	ND—4.5 ND—37.5 ND—150 ND—202	3/12 (3) 19/59 (1) 4/23 (4) 32/120 (32)	1/3 (1) 7/14 (1) 2/6 (2) 32/32 (32)	B (MSAZ_CBCU) D (GCCZ) B (MSAZ_CBCU) C (LLLAZ)
Well MSB82 (Plume definition) (1993–2005)	Cadmium 1,4-Dioxane Lead <sup>3</sup> Methylene chloride Phosphorus Sulfate PCE TCE	7 (EMEG) 3 (CREG) 15 (EPA) 5 (CREG) 0.1 (LTHA) 500,000 (EPA) 5 (MCL) 5 (MCL)	ND—287 ND—4.7 ND—73.8 ND—60 ND—40 ND—3,940,000 ND—780 ND—2,260	3/38 (1) 2/31 (2) 22/79 (3) 6/95 (5) 2/27 (2) 65/77 (1) 12/163 (2) 71/163 (69)	1/11 (1) 2/8 (2) 9/19 (2) 5/23 (5) 1/5 (1) 17/17 (1) 4/37 (1) 37/37 (37)	TA (CBAU) C (LLAZ) A (MSAZ_CBCU) A (MSAZ_CBCU) TA (CBAU) A (MSAZ_CBCU) A (MSAZ_CBCU) A (MSAZ_CBCU)

**Table 4. Chemical contaminants detected in on-site A&M-Area boundary wells above ATSDR's comparison values (CVs)**

Well Number (Well Type) (sampling timeframe)	Contaminant	CV (ppb)	Range (ppb) Includes all aquifers tested	Number of detects/total samples from all aquifers <sup>1</sup>	Number of detects/total samples from selected aquifer <sup>2</sup>	Aquifer where maximum concentration was detected
Well MSB83 (Plume definition) (1993–2005)	Arsenic	0.02 (CREG)	ND—3.3	2/12 (2)	1/3 (1)	B (MSAZ_CBCU)
Well MSB84 (Plume definition) (1993–2005)	Arsenic Fluoride (sodium fluoride) Lead <sup>3</sup> Methylene chloride Phosphorus Sodium	0.02 (CREG) 500 (EMEG CC) 15 (EPA) 5 (CREG) 0.1 (LTHA) 20,000 (EPA)	ND—4.4 ND—1,060 ND—37.5 ND—14 ND—870 1610—106,000	2/9 (2) 2/11 (1) 10/27 (1) 3/34 (2) 3/11 (3) 25/25 (9)	1/5 (1) 2/6 (1) 6/12 (1) 1/18 (1) 3/5 (3) 12/12 (9)	A (MSAZ_CBCU) A (MSAZ_CBCU) A (MSAZ_CBCU) C (LLLAZ) A (MSAZ_CBCU) A (MSAZ_CBCU)
Well MSB85 (Plume definition) (1993–2005)	Lead <sup>3</sup> Methylene chloride Nitrate and Nitrite Phosphorus TCE	15 (EPA) 5 (CREG) 10,000 (MCL) 0.1 (LTHA) 5 (MCL)	ND—15.1 ND—12.6 ND—1,360,000 ND—100 ND—77.7	18/59 (1) 8/75 (6) 30/39 (1) 8/20 (8) 86/132 (42)	11/14 (1) 3/18 (2) 9/9 (1) 3/5 (3) 34/34 (34)	D (MAAZ) B (CBAU) B (CBAU) B (CBAU) C (LLLAZ)
Well MSB86 (Plume definition) (1993–2005)	Methylene chloride Phosphorus	5 (CREG) 0.1 (LTHA)	ND—11.5 ND—210	2/20 (1) 2/5 (2)	2/20 (1) 2/5 (2)	C (LLLAZ) C (LLLAZ)
Well MSB91 (Auxiliary) (1999–2005)	1,4-Dioxane Methylene chloride Toluene	3 (CREG) 5 (CREG) 200 (IEMEG IC)	6.2 ND—7.1 ND—614	1/4 (1) 4/20 (1) 7/20 (2)	1/1 (1) 2/7 (1) 7/13 (2)	TB2 (CBAU) TB2 (CBAU) TB2 (CBAU)
Well RWM15 (Recovery) (1994–2005)	Methylene chloride TCE	5 (CREG) 5 (MCL)	ND—72.9 3.8—96	6/72 (2) 112/112 (111)	6/72 (2) 112/112 (111)	B (LLLAZ_MSAZ_ CBCU)

Source: USDOE 2005a

CREG = cancer risk evaluation guide EMEG = environmental media evaluation guide (CC = chronic, child; IC = intermediate, child);  
LTHA = Lifetime Health Advisory; MCL = EPA's maximum contaminant level; NA = not applicable; ND = not detected; PCE =  
tetrachloroethylene; ppb = parts per billion; TCE = trichloroethylene.

<sup>1</sup> The number in parentheses represents the total number of detected values that exceeded the CV for that contaminant among all aquifers where samples were collected.

<sup>2</sup> The values in this column are only for the aquifer that contained the highest detected concentration of the specified chemical.

<sup>3</sup> In July of 1991, the U.S. Environmental Protection Agency (EPA) established an action level for lead in public drinking water at 15 parts per billion (ppb).

Note: Refer to Figure 9 for the location of the designated boundary wells in the A&M-Area.

#### Aquifer Abbreviations

CBAU = Crouch Branch Aquifer Unit; CBCU = Crouch Branch Confining Unit; GCCZ = Green Clay Confining Zone; LLLAZ = Lower Lost Lake Aquifer Zone; LLLAZ\_MSAZ\_CBCU = Lower Lost Lake Aquifer Zone/Middle Sand Aquifer Zone/ Crouch Branch Confining Unit; MAAZ = M Area Aquifer Zone; MSAZ\_CBCU = Middle Sand Aquifer Zone/ Crouch Branch Confining Unit; ULLAZ = Upper Lost Lake Aquifer Zone.

#### **Contaminants without screening values**

Carbon, carbonate, chloride, phosphate, silicon dioxide.

Radioactive Contaminants in Boundary Wells — Only two radioactive contaminants were detected above their CVs in the 16 boundary wells in the A&M-Area (see Table 5). Most of these wells were only sampled for gross alpha, gross beta, radium, and tritium. A few of these wells were also sampled for two radium isotopes (radium 226 and radium 228) and non-volatile beta emitters. The two wells closest to the city of Jackson, wells JAX1 and JAX2, were analyzed for a variety of radionuclides in 2001. Well MSB91 was not sampled for these radioactive contaminants. A brief description of the two analytes detected above their CVs is provided below (USDOE 2005a):

*Gross alpha:* Gross alpha includes all radioactive contaminants that decay by alpha emission and is not specific for a particular radioactive contaminant. Gross alpha results may include both man-made and naturally occurring radionuclides. Nine samples collected from four of the boundary wells exceeded the gross alpha CV screening level of 15 picocuries per liter (pCi/L). Six of these samples were collected from well MSB29, which also had the highest reported gross alpha concentration (28.5 pCi/L). The other three wells (MSB55, MSB69, and MSB85) had only one sample each that exceeded the CV. However, the average concentration in these wells did not exceed the CV screening level. The two wells closest to the city of Jackson (JAX1 and JAX2) were sampled in 2001, 2002 and 2003 for gross alpha. None of the results exceeded the CV.

*Radium (or total radium):* Radium (or total radium) analyses include radium 226 and radium 228, which are both alpha emitting radionuclides. Thirty-two samples from six boundary wells exceeded the radium CV of 5 pCi/L. Fifteen of these samples were collected from Well MSB29, but the highest concentration of 16.1 pCi/L was detected in Well MSB86. Fourteen of the samples from Well MSB29 were collected from the shallow aquifer (M-Area aquifer zone) with a maximum concentration of 10.1 pCi/L. Well MSB55 had six samples with concentrations above the CV. Well MSB69 had five samples exceeding the CV. Well MSB82 had four samples and MSB83 had one sample that exceeded the CV. In 2001, wells JAX1 and JAX2 were sampled for radium and radium 228. Radium concentrations in samples collected from JAX1 were below the CV. Radium and radium 228 were not detected in samples collected from the JAX2 well.

**Table 5. Radioactive contaminants detected in on-site A&M-Area boundary wells above ATSDR's comparison values (CVs)**

Well Number (sampling timeframe)	Contaminant	MCL <sup>1</sup> (pCi/L)	Range (pCi/L) for all aquifers	Number of detects/total samples from all aquifers <sup>2</sup>	Number of detects/total samples from selected aquifer <sup>3</sup>	Aquifer where maximum concentration was detected
Well MSB29 (1993–2005)	Gross alpha (Total) radium	15 5	ND – 28.5 ND – 10.1	62/92 (6) 70/81 (15)	25/26 (4) 21/21 (14)	D (MAAZ) D (MAAZ)
Well MSB55 (1993–1999)	Gross alpha (Total) radium	15 5	ND – 15.1 ND – 9.5	35/48 (1) 37/47 (6)	8/9 (1) 9/9 (2)	HC (ULLAZ) D (MAAZ)
Well MSB69 (1993–1999)	Gross alpha (Total) radium	15 5	ND – 23.3 ND – 8.4	25/38 (1) 22/39 (5)	9/9 (1) 7/9 (5)	D (MAAZ) D (MAAZ)
Well MSB82 (1993–1999)	(Total) radium	5	ND – 10.5	35/47 (4)	8/10 (4)	B (MSAZ_CBCU)
Well MSB83 (1993–1999)	(Total) radium	5	ND – 5.4	22/36 (1)	8/9 (1)	B (MSAZ_CBCU)
Well MSB85 (1993–1999)	Gross alpha	15	ND – 16.6	16/33 (1)	8/10 (1)	D (MAAZ)
Well MSB86 (1993–2002)	(Total) radium	5	ND – 16.1	6/9 (1)	6/9 (1)	C (LLAZ)

Source: USDOE 2005a

<sup>1</sup> MCL = EPA's maximum contaminant level; based on drinking two liters of water per day.<sup>2</sup> The number in parentheses represents the total number of detected values that exceeded the CV for that contaminant among all aquifers where samples were collected.<sup>3</sup> The values in this column are only for the aquifer that contained the highest detected concentration of the specified chemical.

ND = not detected

pCi/L = picocurie per liter

Note: Refer to Figure 9 for the location of the designated boundary wells in the A&amp;M-Area.

Aquifer AbbreviationsLLLAZ = Lower Lost Lake Aquifer Zone; MAAZ = M Area Aquifer Zone; MSAZ\_CBCU = Middle Sand Aquifer Zone/  
Crouch Branch Confining Unit; ULLAZ = Upper Lost Lake Aquifer Zone

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*Off-site monitoring in close proximity to the A&M-Area*

According to the 2003 Environmental Monitoring Report released by SRS, no off-site wells have been impacted by the migration of contaminated groundwater from SRS (WSRC 2004b). ATSDR scientists reviewed off-site well data collected by DOE and from the ESOP monitoring well network. Most of the off-site groundwater data were collected by ESOP, with only limited off-site groundwater monitoring conducted by DOE. ESOP began monitoring groundwater resources near SRS in 1995 and includes a network of 75 wells (including public supply wells, private wells, irrigation wells and monitoring wells) within 10 miles of the SRS boundary. Samples are collected on a five-year cycle, and analyzed for total and dissolved water quality parameters, priority pollutants, and selected radiological constituents (SCDHEC 2005b). ATSDR reviewed the data for all ESOP wells. However, for purposes of evaluating contaminants that may be specifically associated with releases from the A&M-Area VOC plume, ATSDR focused on ESOP monitoring wells within one mile of the A&M-Area boundary.

Chemical Contaminants — Table 6 presents contaminants detected above ATSDR's CVs<sup>5</sup> in off-site groundwater wells within one mile of the A&M-Area SRS boundary. A brief description of the nature and extent of contamination in these monitoring wells is provided below.

*Metals:* Lead was detected above EPA's action level of 15 ppb in ESOP wells within one mile of the A&M-Area boundary. In 1998, lead was detected at a maximum concentration of 84 ppb in water samples reportedly originating from Well G02141. This is a municipal drinking water well for the city of Jackson. Lead exceeded the EPA action level in this municipal well each year it was sampled between 1997 and 2000 (SCDHEC 2005d, 2006c). In the most recent monitoring data collected in 2005, lead was detected at 6.5 ppb for Well G02141. No other metals exceeded ATSDR's CVs in groundwater monitoring samples collected within one mile of the A&M-Area SRS boundary (SCDHEC 2006b).

*Volatile Organics:* No VOCs were detected above ATSDR's CVs in ESOP wells within one mile of the A&M-Area SRS boundary.

*Contaminants without screening values:* Three compounds without corresponding CVs (bromide, orthophosphate, and silicon) were detected in ESOP wells within one mile of the A&M-Area boundary.

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<sup>5</sup> Table 6 also notes any contaminants that were detected in monitoring wells with no corresponding CVs. ATSDR reviews the toxicological literature and determines whether any of these compounds should be considered contaminants of concern.

**Table 6. Chemical Contaminants Detected Above ATSDR's Screening Values in Off-Site Groundwater Wells Within 1 Mile of the A&M-Area<sup>1</sup>**

Contaminant	CV (ppb)	Number of detects/total number of samples <sup>2</sup>	Range (ppb)	Well ID with maximum detected value	Selected as contaminant of concern (Yes/No)? Explanation of why or why not selected?
Bromide	NA	8/41	20—74	City of Jackson (Well G02141) This well is located approximately 2 miles west south-west of the A&M-Area.	No – Bromide can enter water sources from dissolution of geologic formations, from saltwater intrusion, and by human activities (Cooper 1985). Bromide alone does not pose a human health risk. The frequency of detection and the concentrations detected in the Jackson wells are not expected to be a health concern. However, chlorine and other disinfectants (e.g., ozone and chloramines) can react with bromide in the water to form a range of disinfectant by-products (DBPs).
Lead	15 (EPA) <sup>3</sup>	5/42 (4)	6.5—84	City of Jackson (Well G02141)	Yes – There is no evidence that lead contamination is site-related, but lead was detected at levels above EPA's action level of 15 ppb.
Orthophosphate	NA		ND—830	Well D06004	No – Orthophosphate is a commonly used corrosion inhibitor that is added to drinking water. Orthophosphate works by forming a protective coating inside of pipes in the distribution system and in homes to prevent lead from leaching into drinking water.

Source: SCDHEC 2005d, 2006c

<sup>1</sup> A total of 11 off-site groundwater wells monitored as part of the ESOP monitoring network were identified within one mile of the A&M-Area boundary. Bromide and orthophosphate do not have corresponding CVs. They are presented in this table because they were detected frequently in off-site monitoring wells.

<sup>2</sup> The number in parentheses represents the total number of detected values that exceeded the CV for that contaminant.

<sup>3</sup> EPA's action level for lead in drinking water

ppb = parts per billion

NA = not available

ND = not detected

Notes:

Silicon was detected frequently in most off-site monitoring wells sampled. Silicon is an abundant element and can be found in groundwater as a relatively inert substance.

No screening value is available for this substance, however toxic effects are not expected from ingestion of silicon in groundwater.



Radioactive Contaminants — Very few radioactive analytes were detected in the ESOP network monitoring wells within one mile of the A&M-Area boundary or within one mile of the site boundary in any direction. The few radioactive contaminants that were detected were at concentrations below their respective CVs.

The ESOP program also analyzed drinking water for radioactive contaminants from a network of drinking water wells within 20 miles of the SRS boundary. The only well that had a contaminant above its respective CV was north of the site near North Augusta, South Carolina (well 0210003). The maximum gross alpha result was 61.7 pCi/L in 2002 (the CV for gross alpha is 15 pCi/L). In 2000, this well was tested with results below the reported method detection limit, which were also below the CV. If the results exceed 15 pCi/L for gross alpha, the sample should be checked for specific alpha emitting radioactive contaminants. Although the records indicated that this was done, the detection limits for several alpha-emitting radioactive contaminants exceeded their respective CVs, especially those that are naturally occurring. For instance, the detection limits for radium 226 ranged from 35.6 to 88.9 pCi/L, and the CV for total radium is 5 pCi/L. These elevated detection limits for the radium isotopes appear for most of the well monitoring data reviewed by ATSDR. When the detection limit exceeds the CV, this does not mean that the contaminant exceeds the CV. However, it is not possible to determine from the analyses that were performed whether the concentrations are at levels of potential health concern.

SCDHEC also provided results for chemical and radiological monitoring for the municipal wells in the town of Jackson. In 2003, Jackson's Plant 1 exceeded the gross alpha CV screening level three times. The average concentration at Plant 1 for 2003 was 18 pCi/L. The water from Plant 1 was also tested for uranium, radium, radium 226, and radium 228. Uranium concentrations did not exceed the CV. The radium results exceeded the CV in all tests reviewed by ATSDR scientists. The main contributor appears to be radium 226. For the results reviewed (2001 through 2005), the average annual concentration have varied between 8 pCi/L and 12.1 pCi/L. Tests results for the other municipal well did not exceed its CV (SCDHEC 2006b).

Radium is a naturally occurring radioactive material that is prevalent in this area of South Carolina.

***Exposure Pathways and Potentially Exposed Populations***

ATSDR scientists have not identified any *completed exposure pathways* for off-site groundwater known or believed to be associated with SRS activities. The exposure pathway analysis for groundwater indicates that chemicals and radioactive materials have been released by SRS activities to the environment. There are areas within SRS where groundwater has been significantly impacted by chemical and radioactive contaminants. However, a release of a hazardous substance does not always result in human exposure. ATSDR scientists have reviewed the available on- and off-site monitoring data and it appears most contaminants detected in groundwater have remained within the site boundary. SRS covers a very large area and most of the production facilities, including the reactor areas, waste management areas, and separations areas, where the largest number of releases occurred, are located close to the center of the facility.

There are two source areas that are closer to the site boundary where groundwater plumes have been identified. The TNX area is less than one mile east of the western site boundary and the A&M-Area is near the northwest boundary of SRS. As previously noted, the contaminated groundwater plume in the TNX area is confined to the Upper Three Runs Aquifer Unit. The groundwater flow is toward the Savannah Swamp and the river. The shallow aquifer primarily discharges to the Savannah River and does not impact groundwater west of the river. Extensive groundwater monitoring has shown that contaminants associated with the A&M-Area VOC plume have not migrated beyond the SRS boundary.

ATSDR scientists identified off-site human exposure pathways for past, current, and potential future exposure for lead and radium detected in groundwater. ATSDR does not, however, believe that these contaminants originate from SRS-related activities. Lead concentrations in groundwater were not elevated in monitoring wells between the A&M-Area boundary and the Jackson municipal well. Radium is a naturally occurring substance and levels are known to be elevated in areas surrounding SRS. In this section we discuss only potential health hazards associated with SRS-related contaminants. Table 7 presents the exposure pathways associated with SRS activities and characterizes any potentially exposed populations. ATSDR scientists consider the possible public health impacts from any completed exposure pathways that are identified, regardless of the source. Any potential health effects from lead and radium are addressed in the public health implications section of this report.

***Past exposure (1954 – 1992)***

On-site and off-site groundwater drinking water wells have been monitored for radioactive contaminants since the plant started operations; however, the groundwater monitoring system greatly increased in the 1970s and 1980s. Groundwater monitoring for chemical contaminants at SRS was initiated in 1975. SRS has installed over 1,100 monitoring wells at 85 different locations on site (WSRC 1991). During Phase II of the SRS Dose Reconstruction Project, a review of the groundwater monitoring data through 1992 was conducted. The dose reconstruction investigators concluded that groundwater at SRS did not represent a completed off-site exposure pathway in the past (CDC 2001). ATSDR scientists reviewed the Phase II report and agree with this conclusion of *no past off-site groundwater exposure*.

*Current and future exposure (1993 – present and future)*

ATSDR reviewed groundwater monitoring data for SRS from 1993 through 2005, the most current year available. In most portions of the site ATSDR scientists concluded that since 1993, groundwater contamination does not have the potential to impact residential or municipal drinking water supplies at levels that would constitute a public health hazard. ATSDR identified one portion of SRS, the A&M-Area, where off-site migration of contaminated groundwater was possible. This assessment was based on the presence of a large and previously expanding VOC plume, the proximity of the plume to the SRS boundary, and the general hydrogeology of the area.

A large network of plume definition wells were installed in the A&M-Area after the discovery of contamination in 1981 (WSRC 1991). A close examination of the monitoring data show that although site-related contaminants were detected in monitoring wells close to the SRS boundary, the plume never migrated beyond the SRS boundary. Therefore, ATSDR concludes that current exposure to site-related groundwater contaminants in residential and municipal wells in close proximity to the A&M-Area is not occurring at levels that would constitute a public health hazard.

The A&M-Area groundwater plume presents the most concern for possible future off-site exposure. It is not far from the site boundary. The Jackson municipal wells plus additional private wells are off site, but in the general vicinity of the plume. As of April 2005, there was no indication that the plume was impacting the Jackson wells (SCDHEC 2006b). As of 2004, sampling indicates that the plume has not impacted the wells at Cowden Plantation or CWMAER (SCDHEC 2005b). If on-going remediation efforts to break up and capture the VOCs in the DNAPL are successful, there should not be a future threat to off-site wells; however, close monitoring of these wells should continue until the remedial action is complete and boundary wells do not contain elevated levels of VOCs.

**Table 7. Groundwater Exposure Pathways Associated with SRS Activities and Potentially Exposed Populations**

<i>Potential Pathway</i>	<i>Five Components of a Completed Exposure Pathway</i>					<i>Time Frame for Exposure</i>	<i>Conclusion for Pathway</i>
	<i>1. Source of Contamination</i>	<i>2. Fate and Transport</i>	<i>3. Point of Exposure</i>	<i>4. Route of Exposure</i>	<i>5. Receptor Population</i>		
Coming in contact with contaminated groundwater near the A&M-Area.	The dense non-aqueous phase liquid (DNAPL) groundwater plume in the A&M-Area.	The DNAPL plume has not migrated beyond the site boundary. The groundwater flows primarily to the west-southwest towards the Savannah River.	No past or current exposure.  Future exposure is unlikely, but the plume boundary needs to be monitored carefully to ensure that contaminants are not migrating off site.				Incomplete for past and current exposure.  Potential for future exposure.
Coming in contact with contaminated groundwater from other source areas on site.	Other source areas at SRS, including the TNX, General Separations, Waste Management, and Reactor Areas.	ATSDR identified the source areas for groundwater plumes, reviewed groundwater hydrology, and evaluated on-site groundwater monitoring data. On the basis of this information, ATSDR concludes that none of the on-site groundwater plumes have impacted off-site drinking water wells.	No past, current, or future exposure is expected.				Incomplete

**DNAPL = dense non-aqueous phase liquid**

**Note:** These pathways are for contaminants of concern associated with on-site releases. ATSDR identified two contaminants of concern, lead and radium, in off-site groundwater during its evaluation. These two contaminants were not released as a result of SRS activities. However, any potential public health impacts are addressed in the Public Health Implications section of this report.

## Surface Water Evaluation

Surface water bodies at SRS have been used for the discharge of effluent from SRS operations since the early 1950s. Consequently, thermal, biological, chemical, and radiological effects have been observed in SRS streams. All of the major surface water streams on or adjacent to SRS flow directly or indirectly, via wetlands, into the Savannah River. About 200 Carolina bays are scattered throughout the site, but they have not been used for effluent discharge (IEER 2004). Two man-made ponds (Par Pond and L Lake) received cooling effluent from reactors in the past, as did Ponds C and B. Currently, levels of radioactivity are relatively low, and no effluent is being discharged into these ponds. Most of the radioactive isotopes have partitioned to the sediments and shoreline soils of these sites (USDOE 1995b).

The primary sources associated with SRS that could adversely impact the Savannah River include radioactive and chemical wastes that were disposed of in shallow trenches and pits, radiological and chemical wastes in tanks that have not been retrieved, and contaminated soils and sediments that could be transported to surface waters during heavy rain events. Contaminated water that is flowing from on-site streams will eventually feed into the Savannah River and potentially impact water quality (IEER 2004). However, water from the Savannah River is routinely monitored at downstream drinking water supplies by SRS and the States of South Carolina and Georgia (USDOE 2006b).

### ***SRS Discharges to SRS streams and the Savannah River***

Historically, major on-site streams have received varying amounts of effluent from SRS operations that have had a significant environmental impact on some of the on-site streams. For example, Pen Branch and Four Mile Creek have a normal flow rate of about 5 to 10 cubic feet per second (cfs). When they received discharges from reactors in the past, the flow was recorded to be 10 to 12 times above the average rate along with water temperatures 95 degrees Fahrenheit above normal. Each of the streams that feed the Savannah River has received discharges from various SRS operations, with Four Mile Creek having received the greatest quantity most recently. These streams are not used as drinking water sources; however, they are tributaries to the Savannah River which is used downstream as a drinking water source (USDOE 1995a).

A brief description of each of the six major on-site streams that have been impacted at SRS, and the principle discharges to these surface water bodies related to SRS activities are presented below:

- *Upper Three Runs Creek:* This creek discharges to the Savannah River in the northern part of SRS. It drains an area approximately 545 square kilometers (210 square miles). It is approximately 40 kilometers (25 miles) long, with its lower 28 kilometers (17 miles) within the boundaries of SRS. This creek receives more water from underground sources than other SRS streams. Upper Three Runs is the only major tributary on SRS that has not received thermal discharges. It receives surface water runoff and water from permitted discharges in A-, E-, F-, H-, M-, S-, and Z-Areas (USDOE 1995b). It has received alpha- and non-volatile beta-emitting radioactive contaminants as well as tritium (WSRC 2005b).

- *Beaver Dam Creek*: This creek is approximately 5 kilometers (3.1 miles) long and drains approximately 2.2 square kilometers (approximately 1 square mile). Beaver Dam Creek originates at the effluent canal of D-Area and flows to the south, parallel to Four Mile Creek. Some of the discharges of Four Mile and Beaver Dam Creeks mix in the Savannah River floodplain swamp before entering the Savannah River. Prior to SRS operations, Beaver Dam Creek had only intermittent or low flow (USDOE 1995b).

Beaver Dam Creek has received thermal effluents since 1952, as a result of the cooling water operations from the heavy water production facility (shut down in 1982) and a coal-fired power plant in D-Area. The power plant is operated by South Carolina Electric and Gas and will remain in service after remediation of the area (WSRC 2005b). Beaver Dam Creek has also received condenser cooling water from the coal-fired power plant, neutralization wastewater, sanitary wastewater treatment effluent, ash basin effluent waters, and various laboratory wastewaters. Water from the Savannah River is added to the D-Area powerhouse condenser discharges during the summer months to maintain the temperature of the stream below 90 degrees Fahrenheit. D-Area contaminants include mainly tritium, mercury, and other metals (USDOE 1995b).

- *Four Mile Creek* (also referred to as Fourmile Branch): This creek originates near the center of SRS and follows a southwesterly route for approximately 24 kilometers (15 miles). It drains an area of about 57 square kilometers (21 square miles), receiving effluents from F- and H-Areas. Although it received C-Reactor effluent until the reactor was placed on shutdown status in 1987, thermal discharges ceased in 1985. Although the use of F- and H-Area seepage basins was discontinued in 1988, Four Mile Creek continued to receive large quantities of tritium, strontium 90, cesium 137, and cesium 134 migrating from these seepage basins and the Radioactive Waste Burial Grounds. Most of the water from the creek discharges into the Savannah River at river mile 152.1, however, a small portion of the creek flows west and enters Beaver Dam Creek (USDOE 1995b).
- *Pen Branch*: This stream along with its tributary, Indian Grave Branch, drains an area of about 55 square kilometers (21 square miles). Pen Branch is about 24 kilometers (15 miles) long and follows a southwesterly path from its headwaters about 3.2 kilometers (2 miles) east of K-Area to the Savannah River Swamp. At the swamp, it flows parallel to the Savannah River for about 8 kilometers (5 miles) before it enters and mixes with the waters of Steel Creek (USDOE 1995b).

Until K-Reactor shut down in 1988, Indian Grave Branch, a tributary of Pen Branch, received thermal effluent from the reactor. Pen Branch receives non-thermal effluents (e.g., non-process cooling water, ash basin effluent waters, and sanitary wastewater) from K-Area and sanitary effluent from the Central Shops (N-Area) (USDOE 1995b).

Between December 22 and 25, 1991, a large unplanned release of tritium occurred at the K-Reactor, releasing contaminated primary cooling water to Pen Branch. The primary contaminant was tritium, which traveled down Pen Branch, through the Savannah River Swamp to the mouth of Steel Creek, and down the Savannah River. This incident was well monitored (Hamby et. al.1993).

- *Steel Creek:* The headwaters of Steel Creek originate near P-Reactor. The creek flows southwesterly about 3 kilometers (approximately 2 miles) before it enters the headwaters of L-Lake. Flow from the outfall of L-Lake travels about 5 kilometers (3 miles) before entering the Savannah River Swamp and then another 3 kilometers (approximately 2 miles) before entering the Savannah River. Meyers Branch, the main tributary of Steel Creek, flows approximately 10 kilometers (6.2 miles) before entering Steel Creek downstream of the L-Lake dam and upstream of SRS Road A. The total area drained by the Steel Creek-Meyers Branch system is about 91 square kilometers (35 square miles) (USDOE 1995b).

In 1954 (before the construction of L-Lake or Par Pond), Steel Creek started to receive effluents from L- and P-Reactors. In the 1960s, failed fuel elements leaked radioactivity (mainly cesium 137 and cobalt 60) into the P-Area Storage Basin which occasionally discharged to Steel Creek. During periods of high river flow Steel Creek flowed along the lowlands entering the Savannah River at Little Hell Landing and contaminating private property (Creek Plantation) along the river (WSRC 1995). In 1964, all P-Reactor effluent was diverted to Par Pond, and in 1968 L-Reactor was put on standby. In 1981, DOE initiated activities to restart L-Reactor. L-Lake was constructed in 1985, along the upper reaches of Steel Creek to cool the heated effluent from L-Reactor. Since the construction of L-Lake, there was a notable decrease in the concentration of radioactive contaminants in Steel Creek below the lake. The lake received these effluents for several years until L-Reactor was shut down in 1988 (USDOE 1995b; CDC 2001). In addition to receiving the cooling water from L-Reactor, Steel Creek also received ash basins runoff, non-process cooling water, powerhouse wastewater, reactor process effluents, sanitary treatment plant effluents, and vehicle wash waters. Steel Creek has also received other radionuclides (mainly tritium) from the P-Area Seepage Basin (USDOE 1995b; CDC 2001).

- *Lower Three Runs Creek:* The SRS property includes Lower Three Runs Creek and its floodplain from Par Pond to the river. This creek drains about 460 square kilometers (286 square miles) of SRS, with a 10-square kilometer (2,500-acre) manmade impoundment, Par Pond, located at the head of the creek. From the Par Pond dam, Lower Three Runs flows about 39 kilometers (24 miles) before entering the Savannah River (USDOE 1995b). Lower Three Runs Creek received some discharge from the R-Reactor Area before 1958, when Par Pond opened. Par Pond was created to receive cooling water from the P- and R-Reactors (IEER 2004). Par Pond also received sludge from the Central Shops Sludge Lagoon in the N-Area, and elevated levels of cesium-137 and mercury have been detected in the pond. The overflow from Par Pond to Lower Three Runs carried runoff from the northeast portion of the plant, sewage treatment effluent, water treatment chemicals added to P-Reactor cooling water, and any materials leaking to the cooling water (CDC 2001).

In 1991, Par pond was partially drained by two-thirds of its volume for safety reasons. This process exposed 1,340 acres of radioactively contaminated sediments, caused the loss of 10 square miles of wetland vegetation, and released contamination to the Savannah River. This resulted in EPA listing Par Pond as a Comprehensive Environmental Restoration Conservation and Liability Act (CERCLA) site subject to remediation (USDOE 1995b).

***Surface water resources and uses***

The Savannah River receives sewage treatment plant effluents from Augusta, Georgia; North Augusta, Aiken, and Horse Creek Valley, South Carolina; and from a variety of SRS operations through permitted stream discharges (USDOE 1995a, 1995b). SCDHEC regulates the physical properties and concentrations of chemicals and metals in SRS effluents under the National Pollutant Discharge Elimination System (NPDES) program. SCDHEC also regulates chemical and biological water quality standards for SRS waters (USDOE 1995b).

All site streams, except Upper Three Runs Creek, Tinker Creek, and Meyer's Branch, have received thermal effluents from SRS operations in the past. The effects of these discharges have diminished over time and most large thermal discharges have been eliminated. All drainages, however, receive radioactive and non-radioactive effluents from NPDES-permitted discharges and significant sediment transport due to erosion of upland areas and channel degradation. These effluents are sampled at NPDES outfalls and reported in a monthly report to SCDHEC (WSRC 1999b; USDOE 2000). In 2004, SRS discharged water into site streams and the Savannah River under two NPDES permits: one for industrial wastewater and one for storm water runoff (industrial discharge). A third permit does not require sampling unless requested by SCDHEC to address specific discharge issues at a given construction site; SCDHEC did not request such sampling in 2004 (WSRC 2005b).

*Water Supplies:* The Savannah River is used as a drinking water supply for some residents upstream and downstream of SRS as described below:

- Immediately upstream of SRS, the Savannah River supplies domestic and industrial water to Augusta, Georgia, and North Augusta, South Carolina.
- The Chelsea Water Treatment Plant (also referred to as the Beaufort-Jasper Water Treatment Plant) in South Carolina, is approximately 120 river miles downstream from SRS (at river mile 39.2) and provides drinking water to about 148,000 people (IEER 2004, WSRC 2004b, USDOE 2006).
- The Savannah Industrial and Domestic Water Treatment Plant (formerly known as the Cherokee Hill Plant) in Port Wentworth, Georgia, is approximately 130 river miles downstream from SRS and a few miles upstream of Savannah, Georgia (at river mile 29). This plant provides water largely for industrial and manufacturing purposes, but also provides potable water for approximately 11,000 people (IEER 2004; WSRC 2004b; USDOE 2006).

*Recreational and Commercial Activities:* The Savannah River and its associated off-site tributaries are also used for fishing, boating, swimming, and other recreational activities. There is no known use of the river for irrigation by farming operations downriver of the site (WSRC 2004b).



### ***Surface Water Monitoring***

Surface water monitoring for radiological contamination of SRS streams and the Savannah River has been routinely conducted by DOE since 1953 (CDC 2001). Routine monitoring for non-radiological contaminants has also been conducted since 1967. Initially these samples were analyzed primarily for pesticides (e.g. dieldrin) and herbicides (CDC 2001). The frequency of sample collection and type of analyses performed is determined by previous monitoring results and the type of radionuclides or chemical contaminants likely to be present in the water at the monitoring station. Samples analyzed for chemicals are collected on a monthly schedule from five Savannah River and 11 SRS stream surface water locations (WSRC 2000; WSRC 2001a). Samples analyzed for radionuclides are collected from five Savannah River and 21 onsite stream locations (USDOE 2006b). Savannah River sampling stations are located up river of, adjacent to, and down river from SRS to compare the site's contribution of pollutants with background levels from natural sources and from contaminants produced by municipal sewage plants, medical facilities, and other industrial facilities up stream (WSRC 2000). The site also collects and analyzes samples from downstream public water supply plants (USDOE 2006b).

In addition to the DOE surface water monitoring program, the states of Georgia and South Carolina conduct surface water monitoring. Since 1978, GDNr has been collecting samples at approximately 25 locations along the Savannah River that are analyzed for radioactive contaminants. Alpha- and non-volatile beta-emitting radionuclides, tritium, cesium 137, and iodine 131 are analyzed for either once or twice per month. Strontium 89 and strontium 90 are analyzed for monthly or quarterly, and plutonium 238 and plutonium 239 are analyzed for on a quarterly or bi-annual basis. The GDNr, Environmental Protection Division, regularly monitors drinking water from the Savannah Industrial and Domestic Water Treatment Plant for radioactive contaminants (GDNr 2005).

SCDHEC collects surface water samples from seven locations that are monitored on a monthly basis for certain water quality parameters (e.g., pH, temperature, dissolved oxygen, conductivity); on a quarterly basis for heavy metals, VOCs, and other organic compounds; and on an annual basis for pesticides and polychlorinated biphenyls (PCBs). Monthly composites are gathered from nine areas and analyzed for gamma-emitting radionuclides and gross alpha and beta activity. Five creek mouth locations are sampled monthly for tritium. Surface water samples are collected weekly from 13 locations and analyzed for tritium (SCDHEC 2005b). An enhanced tritium monitoring program was developed to provide advance notice of an SRS release (CDC 2002c).

SCDHEC also collects monthly raw drinking water samples from water treatment plants that use the lower portion of the Savannah River as a source, as well as quarterly grab samples from selected municipal and large community drinking water systems (mainly from groundwater wells) within 30 miles of SRS. Samples are analyzed for gross alpha, non-volatile beta, and beta-gamma emitting radionuclides, and tritium. (SCDHEC 2005b).

ATSDR scientists evaluated all available chemical and radiological monitoring data collected by DOE between 1993 and 2004. This includes routine monitoring, special survey and project monitoring, and DOE surface water samples collected for the purposes of monitoring the impacts of remedial activities at SRS. ATSDR also evaluated surface water data collected by DOE for

upstream and downstream portions of the Savannah River. ATSDR scientists reviewed Georgia's surface water monitoring results from 1978 through 2004, and surface water data collected as part of ESOP by the state of South Carolina between 1997 and 2004. A summary of the data are presented below.

### *Chemical contaminants*

SRS streams receive treated wastewater and rainwater runoff from site facilities. Stream locations are sampled for water quality at monthly and quarterly frequencies by the conventional grab-collection technique. Each grab sample shows the water quality at the time of sampling only (WSRC 2002b). ATSDR scientists reviewed chemical contaminant monitoring data from DOE and SCDHEC.

*On Site:* ATSDR reviewed all DOE non-radiological (i.e., chemical) contaminant data from 1993 through 2004. The highest chemical contaminant concentrations detected in surface water during DOE sampling events were generally found close to the center of SRS. Most contaminants were not detected at levels above ATSDR's CVs at surface water stations near the Savannah River. Although surface water is clearly impacted in SRS streams near the points of release of chemical effluent discharges, the contaminants generally appear to either be significantly diluted or are not transported in high concentrations to the SRS boundary.

The on-site surface water monitoring conducted by SRS serves several purposes. Some samples are collected near contaminated seeps, lagoons, and small tributaries near source areas to evaluate the nature and extent of contamination prior to mixing and significant dilution. As expected, these samples are often found to contain the highest contaminant concentrations in surface water on SRS property. Other samples are collected from the larger on-site surface water streams, both near the industrial facilities and also close to the SRS boundary where streams flow off site. The concentrations in these samples are typically much lower due to mixing, dilution, volatilization, or deposition.

In general, VOCs were detected infrequently or detected at low levels in the streams across the site. The highest, most frequent VOC concentrations in surface water were found in the A-Area. However, samples collected from Tim's Branch (A-Area) from 2002 through 2004 did not contain VOC concentrations above ATSDR's CVs. Also, samples collected from Upper Three Runs Creek from 1997 through 2004 did not contain VOC concentrations above ATSDR's CVs. Few off-site surface water samples were analyzed for VOCs; however, elevated concentrations would not be expected because these compounds volatilize quickly and disperse into the air. Samples collected in 1999 and in 2001 from the Savannah River had no detectable TCE, and few samples had detectable concentrations of PCE, which were all below its corresponding CV.

Metals and other notable surface water contaminants detected in SRS streams include beryllium (maximum = 72 ppb), lead (maximum = 471 ppb), manganese (maximum = 12,600 ppb), and nitrate plus nitrite (maximum = 246,000 ppb). Beryllium was detected close to the SRS boundary near the TNX Area and in Upper Three Runs Creek; however, beryllium has not been detected in the Savannah River. The highest lead concentration occurred at an unspecified on-site sampling location in 2001. The next highest concentration (378 ppb) was reported for a sample collected in Upper Three Runs Creek in 2001. Upper Three Runs also had elevated lead concentrations in

1996 and 2000. In 2004, lead was detected in several grab samples collected at storm water outfalls across SRS. Outfall N-03 contained the highest detected lead concentration (88 ppb) during this sampling period. Manganese was detected in most of the streams across the site. The highest concentrations were reported for samples collected on September 27, 2002 at an outfall in the D-Area. This outfall was only sampled on this one day, and no off-site samples were collected on or close to that date. In 2000, manganese concentrations were elevated in Lower Three Runs Creek; however, all analyses for samples collected from the Savannah River at the mouth of Lower Three Runs in 2000 were below ATSDR's CVs. Although nitrates and nitrites were detected at elevated concentrations in some onsite areas, none of the detected concentrations in the Savannah River exceeded ATSDR's CVs.

During 2001 DOE sampling, aluminum, cadmium, chromium, copper, iron, manganese, nickel, and zinc were detected in surface waters at all river and stream locations at levels below ATSDR's CVs. One pesticide, beta BHC, was found in 2001 near the quantitation limit in Four Mile Creek, approximately 2 miles from the Savannah River, and in the Savannah River (at River Miles 150.4, 141.5, 129.1, and 118.8). No herbicides were detected during 2001 (WSRC 2002b).

One other compound, di(2-ethylhexyl)phthalate, was detected at a concentration of 163 ppb at the mouth of Steel creek where it empties into the Savannah River. This sample result was reported by the DOE remediation program in 1999. However, a duplicate sample was analyzed and the compound was not detected (the detection limit was 4.95 ppb) (USDOE 2005a, 2005b). Di(2-ethylhexyl)phthalate is a common laboratory contaminant and it is possible that the high concentration was a result of laboratory contamination and not a true measure of what was in the water sample.

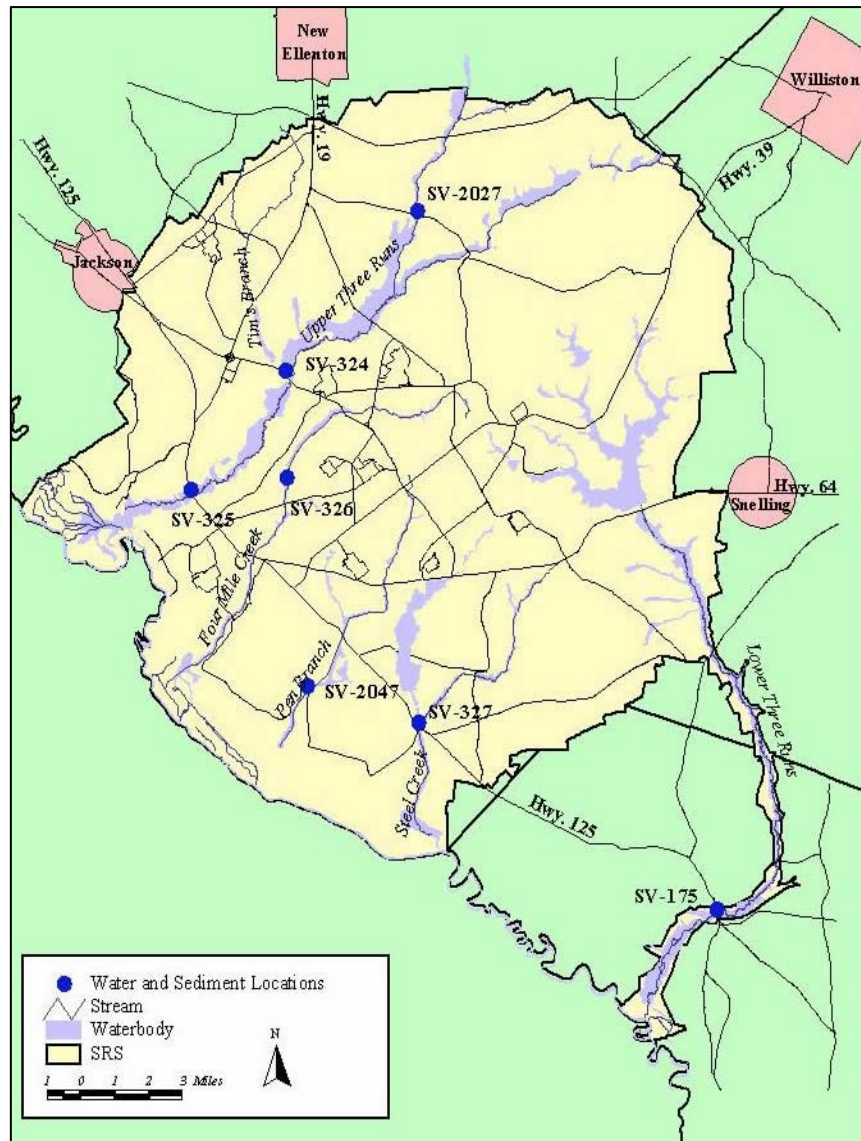
Most of the surface water samples analyzed for chemical contaminants as part of SCDHEC-ESOP were collected from the on-site streams that flow into the Savannah River. Figure 10 displays the locations of the DOE and ESOP surface water monitoring stations at or near SRS. The most recent data available from the ESOP 2004 Water Monitoring Report do not indicate elevated levels of chemical contaminants in these streams (SCDHEC 2005b).

*Off Site:* Much of the chemical contaminant monitoring in surface water is conducted at on-site streams, so that contaminant levels can be measured prior to being transported to off-site locations. DOE does monitor water quality along the Savannah River, both upstream and downstream, to evaluate potential impacts from SRS. In general, routine monitoring has not detected high concentrations of chemical contaminants in off-site surface water near SRS.

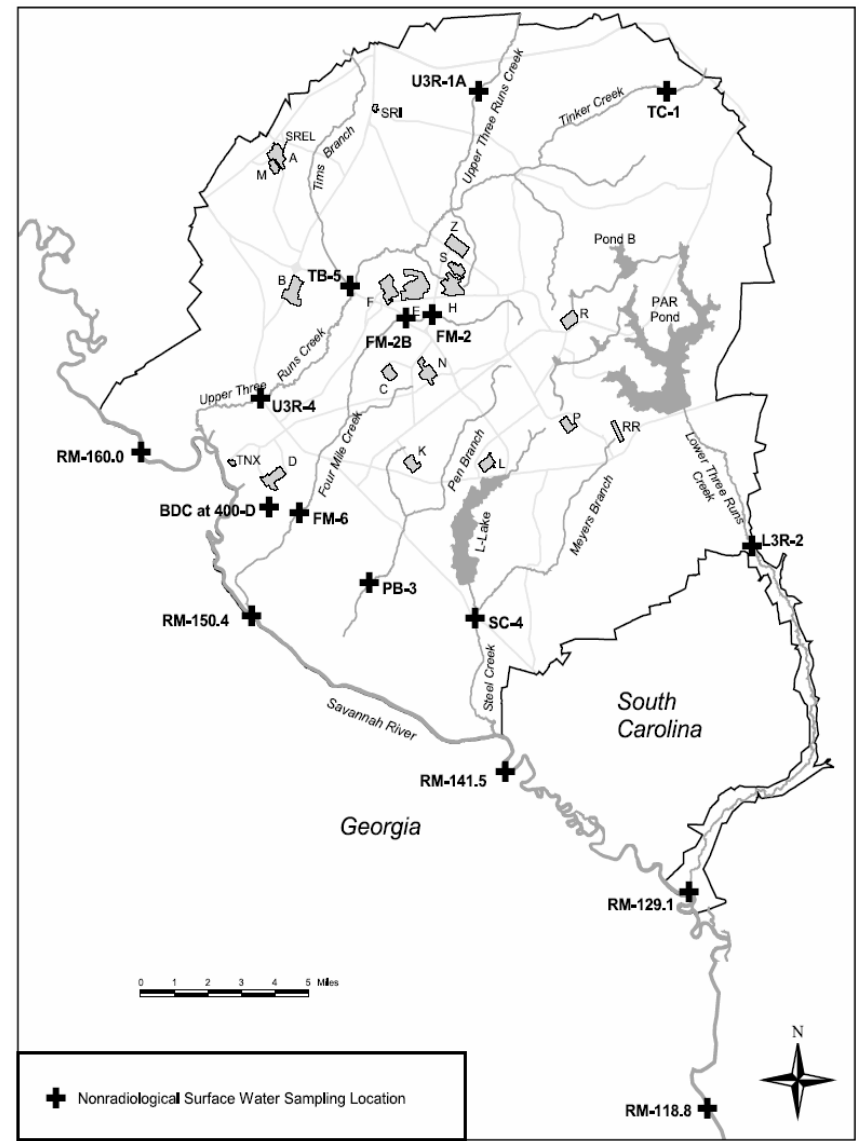
Table 8 presents contaminant levels in Savannah River water samples collected upstream and downstream of SRS during 1993. This serves as a useful baseline year because all the SRS reactors had been shut down by this time. These results show little difference between upstream and downstream chemical concentrations. It is important to note that the analysis only included a small number of chemical constituents. For example, VOCs and pesticides were not included in the water quality monitoring. However, these compounds were not detected in streams near the SRS boundary and, therefore, would not likely have been transported to the Savannah River from on-site locations

**Figure 10. Non-radiological Surface Water Sampling Locations**

SCDHEC ESOP Sampling Locations



DOE Sampling Locations



**Table 8. Non-radiological contaminants detected in the Savannah River upstream and downstream from SRS (1993).**

Contaminant <sup>1</sup>	Units	CV	Upstream		Downstream	
			Minimum	Maximum†	Minimum	Maximum
Aluminum	mg/L	0.05-0.2 <sup>2</sup>	0.174	0.946	0.182	0.838
Cadmium	mg/L	0.005 <sup>3</sup>	ND	ND	ND	ND
Chloride	mg/L	250 <sup>2</sup>	4	13	4	12
Chromium	mg/L	0.1 <sup>3</sup>	ND	ND	ND	ND
Copper	mg/L	1.3 <sup>4</sup>	ND	ND	ND	ND
Iron	mg/L	0.3 <sup>2</sup>	0.41	1.39	0.516	1.15
Lead	mg/L	0.015 <sup>4</sup>	ND	0.002	ND	0.003
Magnesium	mg/L	NA	1.08	1.38	1.11	1.34
Manganese	mg/L	0.05 <sup>2</sup>	0.067	0.088	0.04	0.064
Mercury	mg/L	0.002 <sup>3</sup>	ND	ND	ND	ND
Nickel	mg/L	0.1 <sup>3</sup>	ND	ND	ND	ND
Nitrite/Nitrate (as nitrogen)	mg/L	10 <sup>3</sup>	0.17	0.31	0.18	0.31
Phosphate	mg/L	NA	ND	ND	ND	ND
Sulfate	mg/L	250 <sup>2</sup>	4.0	8.0	4.0	9.0
Zinc	mg/L	5 <sup>2</sup>	ND	ND	ND	0.012

Source: WSRC 1994a; USDOE1995b

CV = comparison value

mg/L = milligrams per liter;

NA = Not available

ND = Not detected

&lt; DL indicates concentration below analyses detection limit (DL).

<sup>1</sup> DOE routinely measures these parameters as a regulatory requirement or as part of ongoing monitoring programs.<sup>2</sup> Secondary maximum contaminant level (SMCL), EPA National Secondary Drinking Water Regulations (40 CFR Part 143).<sup>3</sup> Maximum Contaminant Level (MCL), EPA National Primary Drinking Water Standards (40 CFR Part 141).<sup>4</sup> Action level for lead and copper.

† The maximum listed concentration is the highest single result found during one sampling event.

From 1993 through 2001, samples were collected in the Savannah River at the locations closest to the site and analyzed for chemical contaminants, including metals and organics. Except for lead, contaminants were not detected at concentrations above ATSDR's health-based CVs (WSRC 2002b; USDOE 2005a, 2005b, 2005c; SCDHEC 2005d, 2006c). Of the 30 Savannah River samples analyzed for lead, 15 had detectable concentrations of lead ranging from 2 to 30 ppb. Seven samples had concentrations (20 to 30 ppb) that exceeded EPA's action level of 15 ppb for lead in drinking water. Since upstream samples had concentrations as high as 20 ppb, the majority of the lead appears to be coming from a source upstream.

*Radiological contaminants*

ATSDR scientists reviewed radiological monitoring data from DOE, GDNR, and SCDHEC. Figure 11 displays the locations of the DOE and ESOP surface water monitoring stations at or near SRS. As discussed earlier, all of the major streams on site have been impacted by releases of radioactive materials, primarily tritium. Since there is sufficient off-site data for the Savannah River from routine environmental monitoring and from testing of municipal water supplies downstream from SRS, there was no need to analyze the concentrations of radioactive contaminants on the site, other than to know what contaminants might be released to the Savannah River from each stream.

The Savannah River is used for drinking water downstream of Highway 301 only. In general, a comparison of the upstream concentrations above the site and downstream concentrations below Highway 301 shows little impact from SRS discharges on the water quality of the Savannah River, except for an increase in the tritium concentration (USDOE 1995b). From ATSDR's data review, it appears that the tritium concentrations fluctuated significantly between 1993 and 2001; however, none exceeded ATSDR's CV at or below Highway 301 (USDOE 2005b, 2005c). When you compare maximum upstream and downstream concentrations reported by GDNR, SCDHEC, and DOE (Table 9), tritium and cesium-137 concentrations increase; however, none of these concentrations exceed ATSDR's CVs.

Prior to 1993, GDNR's data showed samples that exceeded ATSDR's CV for tritium in December 1991 (GDNR 2005). These elevated samples were a result of a well documented release of tritium. The water treatment plants downstream were notified at the time of the release. One plant shut down for nine days and the other modified its pumping schedule to minimize intake of tritium into their system. This incident was closely monitored by DOE, SCDHEC, and GDNR (Hamby et al. 1993). No one was exposed through drinking water to levels that would have caused adverse health effects. The average annual concentrations of tritium at Highway 301 and at the downstream water treatment plants for 1991 were well below ATSDR's health-based CV.

Although radioactive contaminants do not normally exceed ATSDR's CVs at Highway 301 and points further downstream, some samples collected in the river closer to the site (an unrestricted area that is available to the public for recreational activities) did contain radioactive contaminants that exceeded ATSDR's CVs. Members of the public could be exposed to contaminants through occasional incidental ingestion and/or dermal absorption of the river water while fishing, boating, swimming, or other shoreline activities (CDC 2005).

In 2001, DOE reported a gross beta analysis of 333 pCi/L, which exceeded ATSDR's CV screening level of 50 pCi/L, for a sample collected at RM-150 (just below the river confluence with Four Mile Creek). This was the only DOE sample that exceeded the screening level out of 608 gross beta analyses performed on samples collected at or near this location from August 1993 through April 2001 (USDOE 2005b, 2005c).

In 1995, DOE also reported a gross beta analysis level of 59.5 pCi/L at RM-141.5, just below Steel Creek. Most of the samples collected at this location are well below the ATSDR screening level. The samples were also analyzed for individual radionuclides. No individual radionuclide was detected above its CV; however, not all major beta-emitting radionuclides (such as strontium 90) were included in these analyses (USDOE 2005b, 2005c).

In 1998, DOE reported elevated concentrations of tritium at or near Four Mile Creek in three samples (USDOE 2005b, 2005c). South Carolina's surface water monitoring results from 1997 through 2004 also showed that tritium exceeded ATSDR's CV at or near the mouth of Four Mile Creek, Steel Creek and Little Hell Boat Landing. Tritium concentrations at the mouth of Four Mile Creek, 30 feet downstream, and 150 feet downstream exceeded ATSDR's screening level for all years that the data were reviewed (SCDHEC 2005d, 2006c). ATSDR scientists' review of GDNr's surface water data showed that only tritium exceeded ATSDR's CV at or near the confluence of some of the SRS streams with the Savannah River. Tritium concentrations exceeded the screening level at the mouth of Upper Three Runs Creek four times in 2000 and five times in 2002; however, the average annual concentrations for these years were less than ATSDR's CV. Tritium concentrations also exceeded the screening level at the mouth of Four Mile Creek in 1998, 1999, 2000, and 2002. The average annual concentrations exceeded ATSDR's CV in 1999 and 2000. Tritium has not been detected in samples from the mouth of Steel Creek at levels above ATSDR's CV since January 1992, which was shortly after the tritium incident that occurred at the end of 1991 (GDNr 2005). Table 10 includes the annual average and maximum tritium concentrations reported by DOE, South Carolina, and Georgia for areas where ATSDR's CV for tritium was exceeded. Since tritium exceeded its health-based screening value of 20,000 pCi/L during multiple sampling events, ATSDR did further evaluation to determine whether people have been or are being exposed at levels of health concern.

South Carolina data also showed elevated concentrations of cesium 137 at the mouths of Upper Three Runs Creek, Steel Creek, and Lower Three Runs Creek in August 1997; however, these locations were only sampled once in 1997. Three of the locations were only sampled this once and not again, and one location was sampled 25 times in other years with no detectable concentrations of cesium 137 (SCDHEC 2005d, 2006c). GDNr and DOE data did not indicate that cesium 137 was at a level of health concern at these locations during this period (GDNr 2005; USDOE 2005b, 2005c). Therefore, ATSDR's review of the data collected from 1992 through 2004 shows that this was an unusual occurrence and that cesium 137 was not released to off-site surface water at levels of health concern during this time period.

**Table 9. Radioactive contaminants detected in the Savannah River upstream, at either the Augusta Lock and Dam or at Jackson Boat Landing, and downstream from the SRS at Highway 301 (1993 through 2004)**

Contaminant	Units	ATSDR's CV	Upstream		Down Stream	
			Minimum	Maximum <sup>1</sup>	Minimum	Maximum <sup>1</sup>
Gross alpha radioactivity	pCi/L	15 <sup>2</sup>	<DL	3.0 (GA)	<DL	5.0 (GA)
Nonvolatile (dissolved) beta radioactivity	pCi/L	50 <sup>2</sup>	<DL	18.6 (DOE)	<DL	8.0 (GA)
Cesium-137	pCi/L	200 <sup>2</sup>	<DL	1.3 (DOE)	<DL	130 (SC)
Plutonium-238	pCi/L	6.4 <sup>3</sup>	<DL	<DL (DOE, SC)	<DL	0.0146 (DOE)
Plutonium-239	pCi/L	5.4 <sup>3</sup>	<DL	0.000921 (DOE)	<DL	0.0012 (DOE)
Strontium-90	pCi/L	8 <sup>2</sup>	<DL	<DL (DOE, SC)	<DL	0.83 (DOE)
Tritium	pCi/L	20,000 <sup>2</sup>	<DL	2,400 (GA)	<DL	6,027 (SC)

Source: USDOE 2005b, 2005c; GDNr 2005; SCDHEC 2005d, 2006c

CV = comparison value

DOE = Department of Energy (datasets 3,4,5)

GA = Georgia (dataset 1)

pCi/L = picocuries (i.e., one trillionth of a curie) per liter

SC = South Carolina (dataset 2)

< DL indicates concentration below analyses detection limit (DL).

<sup>1</sup> The maximum listed concentration is the highest single result found during one sampling event. The agency collecting the sample is in parentheses.

<sup>2</sup> Maximum contaminant level (MCL), EPA National Primary Drinking Water Standards (40 CFR Part 141).

<sup>3</sup> ATSDR's derived concentration based on International Commission Radiological Protection Report No. 72 dose conversion factors and the EPA drinking water MCL of 4 millirem per year (0.04 millisievert per year).



**Table 10. Tritium concentrations exceeding ATSDR's Comparison Value (CV) in the Savannah River at or near the mouths of SRS streams (1993 through 2004)**

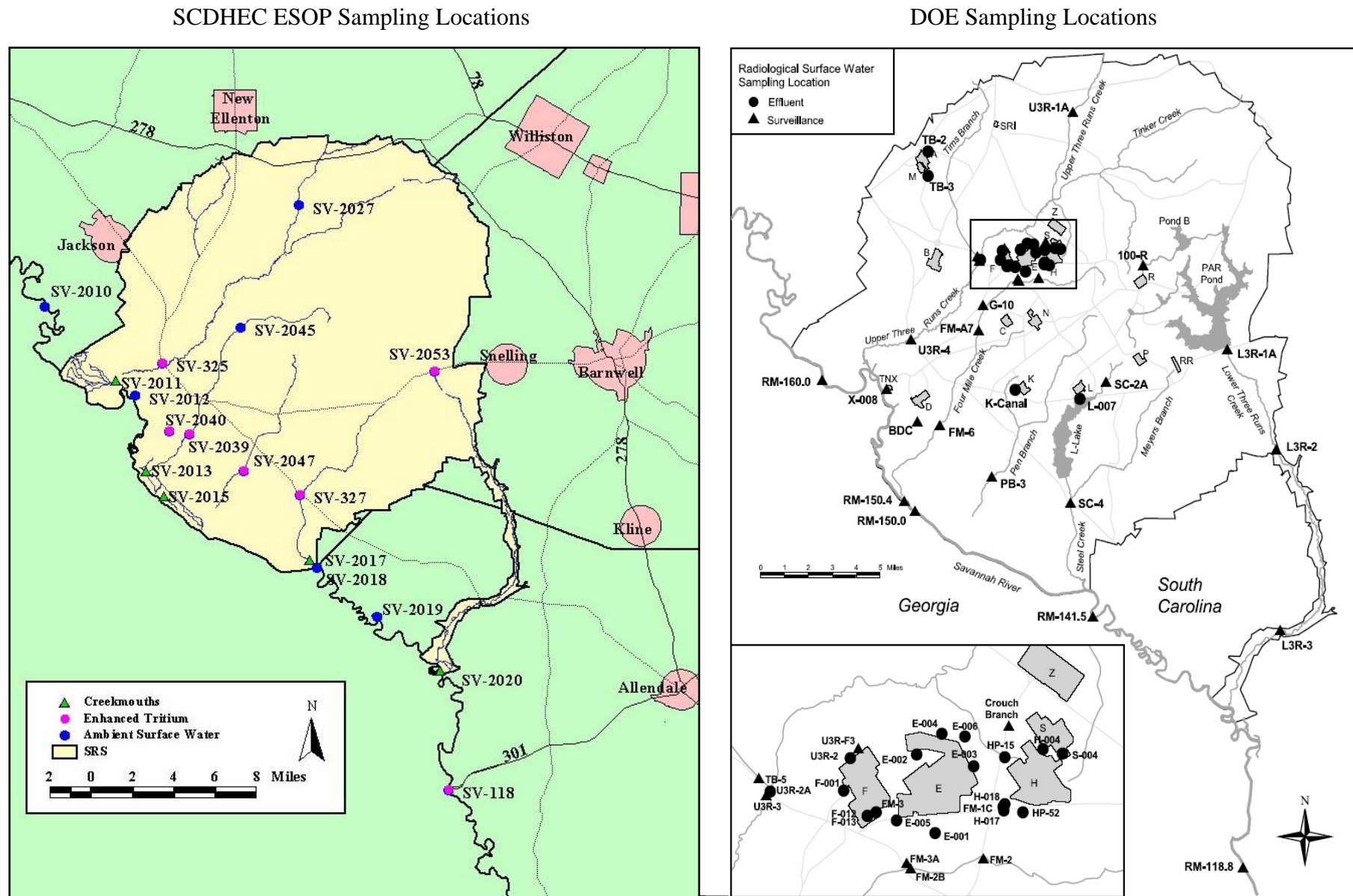
Data source (Record dates)	Location	Year with concentration above CV	# of detects > CV/ # of detects	Maximum concentration (pCi/L <sup>1</sup> )	Annual average (mean) detected concentration (pCi/L)
DOE (1993—1996 and 1998—2000; no data for 1997)	Near Plant Vogtle and Four Mile Creek (River Mile 150.4)	1998	3/44	72,200	< CV (20,000) <sup>2</sup>
South Carolina (1997—2004)	Four Mile Creek (mouth) (SV-2015)	1997	2/3	219,159	105,719
		1998	6/9	235,060	125,984
		1999	12/12	213,646	176,767
		2000	12/12	188,909	164,377
		2001	12/12	92,174	69,162
		2002	11/11	66,751	57,937
		2003	7/11	80,909	42,023
		2004	10/11	88,718	55,105
(1998—2004)	Four Mile Creek (30 ft. downstream)	1998	2/2	217,160	130,456
		1999	12/12	206,764	127,599
		2000	12/12	178,915	111,227
		2001	11/11	88,851	53,325
		2002	9/11	67,012	39,591
		2003	4/10	65,640	23,528
		2004	6/7	78,738	36,223
(1998—2004)	Four Mile Creek (150 ft. downstream)	1998	2/2	83,300	61,508
		1999	11/12	132,286	57,722
		2000	8/8	119,582	69,248
		2001	8/11	63,202	35,464
		2002	6/11	53,600	26,538
		2003	1/10	35,675	< CV
		2004	4/10	56,009	< CV
(1997—2004)	Steel Creek (mouth) (SV-2017 and SV-2018)	1997	2/51	24,287	< CV
		1998	11/59	30,374	< CV
		1999	3/64	34,466	< CV
		2000	1/64	22,501	< CV
(1997—2004)	Little Hell Landing (SV-2019)	1998	1/51	23,879	< CV
Georgia (1993—2004)	Upper Three Runs Creek (mouth) (330)	2000	4/13	36,000	< CV
		2002	3/28	35,000	< CV
(1993—2004)	Four Mile Creek (mouth) (365)	1998	1/13	210,000	< CV
		1999	4/13	220,000	26,679
		2000	7/13	43,000	21,562
		2002	2/27	24,000	< CV

Source: USDOE 2005b, 2005c; GDNr 2005; SCDHEC 2005d, 2006c

&lt; CV = less than ATSDR's CV for tritium

pCi/L = picocuries (i.e., one trillionth of a curie) per liter

<sup>1</sup> The maximum concentration is the highest single result reported for that year.<sup>2</sup> ATSDR's CV for tritium is the maximum contaminant level (MCL) for tritium listed in EPA's National Primary Drinking Water Standards (40 CFR Part 141).

**Figure 11. Radiological Surface Water and Sediment Sampling Locations**

***Exposure Pathways and Potentially Exposed Populations***

ATSDR scientists identified off-site human exposure pathways for past, current, and potential future exposure to tritium detected in the Savannah River bordering SRS. No chemical contaminants were detected in off-site surface water at levels of health concern. It is important to keep in mind that an exposure pathway is *only* considered complete if all five elements discussed in the Environmental Contamination, Exposure Pathways, and Potentially Exposed Populations Section link the contaminant source to a receptor population. A potential pathway exists when one or more of the elements are missing but exposure could have occurred in the past, could be occurring now, or could occur in the future.

***Past Exposure (1954 – 1992)***

Phase II Dose Reconstruction investigators reviewed a large amount of effluent and environmental monitoring data related to measured chemical concentrations in surface water at SRS. On the basis of these data, the report concluded that SRS-related activities have not resulted in measurable off-site impacts associated with chemical contaminant releases. Localized areas (such as seepage basin water and sediments; coal and ash pile runoff areas; several seep-line areas; and, to some extent, on-site surface water) have been affected by various routine and accidental site activities. However, the data suggest that impacts to surface water extending beyond the site boundary are not measurable (CDC 2001).

Previous water quality monitoring data suggest that chemicals (including heavy metals, pesticides, PCBs, nitrates, and solvents) from SRS streams were generally not detected in the Savannah River. Chemical concentrations upstream were typically the same or greater than levels downstream of the site, or the concentrations were at or below detection limits. The Phase II Dose Reconstruction investigators concluded that although large chemical releases to seepage basins and site streams occurred, the impacts to surface water extending beyond the site boundary did not appear to be measurable (CDC 2001).

Past exposures to radioactive contaminants in the Savannah River were also investigated during CDC's Dose Reconstruction project. ATSDR scientists reviewed the Phase II portion of the project and agree with the findings (CDC 2001). Tritium and cesium-137 were the main radionuclides of concern from past releases to surface streams that eventually reached the Savannah River; however, other radionuclides were also released. These releases were highest in the early to middle 1960s. The measured and estimated annual average concentrations of radionuclides at downstream water treatment plants did not exceed the EPA's current MCLs; however, these concentrations were significantly higher closer to the site. The concentration of tritium measured at the downstream location (Highway 301) in March 1963 was similar to the concentration measured more recently at the mouth of Four Mile Creek (See discussion below). Maximum concentrations at the mouth of the streams and during various incidents may have been higher for shorter periods of time. For the tritium incident in 1991, since the release occurred at the end of December, it is unlikely that anyone would have been recreating (swimming) in the area and; therefore, would not have received excessive exposures.

*Current (1993 – present) and Future Exposure*

Since 1993, the greatest potential for human exposure to radioactive contaminants in off-site surface water has been at or near the mouth of Four Mile Creek. ATSDR used the “maximum exposure times” for recreating in the river, which were previously agreed upon by the SRS/HES for CDC’s Dose Reconstruction. However, ATSDR did not agree with the location of exposure selected by the dose reconstruction investigators. Instead of assuming that all radiation exposure associated with recreational activities at the Savannah River (e.g., boating, swimming, and/or shoreline fishing) occurred at a location below the confluence of the river with Lower Three Runs Creek, ATSDR scientists believe that the maximum exposure to tritium would be more likely to occur at or near the mouth of Four Mile Creek. Since tritium is a very weak beta-emitter that will not penetrate a layer of clothing or skin, boating and external exposure is not considered a pathway of concern. Incidental ingestion of water from swimming, wading, or fishing in the river was the primary pathway of concern. Surface water in this area is not used as a drinking water source and, therefore, was not considered a pathway. Although it is unlikely that a person would swim near the mouth of Four Mile Creek on a regular basis, this area is unrestricted (see Table 11).

Annual committed effective doses based on the maximum annual average concentration were calculated for all age groups. The formula and ATSDR’s assumptions are presented in the following text box. The calculated doses (ranging between 0.5 and 0.9 millirem) are less than ATSDR’s CV for drinking water (EPA’s Safe Drinking Water Standards) of 4 millirems (0.04 millisieverts). Therefore, tritium is not considered a contaminant of concern and is not discussed in the Public Health Implications section of this report.

**Calculating Annual Committed Effective Dose**

*Equation:*  $CED = C_w \times I \times CF$

Where;

CED = Annual committed effective dose for tritium

$C_w$  = Concentration in surface water [picocuries (pCi) or becquerels (Bq) per liter (L); 1 Bq = 27 pCi]

$I$  = Incidental ingestion rate (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 ICRP Report 72 were used (ICRP 1995).

*Assumptions:*

1. Ingestion: For incidental ingestion ATSDR scientists assumed that a person could ingest 0.5 liter of river water per exposure [0.5 L/day (incidental) x 91 days/year].
2. CDC’s Dose Reconstruction assumed for a “Near River Family” that any member of the family could spend one hour/day swimming during the summer (91 days).

As long as on-site processes remain similar to current operations and no major incidents occur, future off-site releases to the Savannah River should continue at or below current levels. If on-site activities and operations change, then the potential for off-site exposures from surface water releases should be re-evaluated.

**Table 11. Surface Water Exposure Pathways Associated with SRS Activities and Potentially Exposed Populations**

<i>Potential Pathway</i>	<i>Five Components of a Completed Exposure Pathway</i>					<i>Time Frame for Exposure</i>	<i>Conclusion for Pathway</i>
	<i>1. Source of Contamination</i>	<i>2. Fate and Transport</i>	<i>3. Point of Exposure</i>	<i>4. Route of Exposure</i>	<i>5. Receptor Population</i>		
Coming in contact with contaminated surface water near the mouth of Four Mile Creek.	F-Area and H-area seepage basins and Radioactive Waste Burial Grounds	Groundwater contamination from seepage basins discharging to Four Mile Creek on-site. Four Mile Creek empties into the Savannah River near River Mile 152.	Maximum exposure estimated to be within 150 feet of the mouth of Four Mile Creek in the Savannah River.	Incidental ingestion while swimming or recreating in the area.	A "near river family" who frequents the river during the summer months (as described by the SRS Health Effects Subcommittee in CDC's Dose Reconstruction study).	Past, Present, Future	<b>Complete:</b> This exposure pathway is only for off-site contaminants of concern determined during ATSDR's initial screening <sup>1</sup> . Although this pathway is complete, the doses from incidental ingestion of water at this location from 1993 through 2004 were less than ATSDR's drinking water screening level of 4 millirem per year.

<sup>1</sup> For surface water, the initial screening level was based on surface water used as a drinking water source. However, surface water at this location is not used as a drinking water source. Therefore, only recreational activities (e.g., fishing, swimming, and boating) in the Savannah River were considered.

## 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., drinking water consumption, frequency and duration of swimming, boating, or other recreational activities) is not available. This section places the potential for health effects from each contaminant of concern identified into perspective given the past, current, and future exposure situations identified.

The exposure pathway analysis for surface water and groundwater in the previous section of this public health assessment indicates that chemical and radioactive contaminants have been released to on-site groundwater and surface water streams in the past and, to a lesser extent, continue to be currently released. Releases at or below the levels that have been reported during recent monitoring events are expected to continue in the near future. However, it has been determined that due to the locations of these releases since 1993 (primarily near the center of the site) and the limited potential for people to be exposed, site-related contaminants do not present an off-site health hazard. Tritium released to the Savannah River was evaluated in the previous section. The potential doses were not at levels that would cause adverse health effects. Therefore, tritium in surface water will not be discussed further. During the groundwater review, two contaminants not related to the site were detected at levels that exceeded ATSDR's CVs: lead and radium. Since these contaminants were collected from a municipal water supply system, ATSDR considers drinking water a completed pathway for all age groups and discusses the potential health implications of exposure to these two substances in this section.

*Lead:* Lead is a naturally occurring element found in the earth's crust. It is used in a variety of products and industrial processes. Lead can be introduced to soil through leaded paint or paint chips or through application of a variety of lead-containing products.

Lead is strongly adsorbed to soil, usually in the upper layers of soil, and does not leach appreciably into the subsoil and groundwater (ATSDR 2005b). Therefore, any lead in groundwater migrating off-site from SRS would not be expected to migrate much beyond the site boundary. A total of 11 ESOP monitoring wells were identified within one mile of the SRS boundary (SCDHEC 2005d, 2006c). Lead was only detected in one off-site monitoring well above EPA's action level of 15 ppb, a municipal well that supplies potable water to the city of Jackson and Aiken County. Monitoring data show that this well contained lead levels that were more than five times EPA's action level. ATSDR evaluated the potential for lead in drinking water to cause adverse health effects, especially in infants and young children. The following discussion provides some background information about lead and provides perspective regarding the health risks associated with lead at the levels detected in the Jackson city municipal well.

As previously noted, there is no evidence that SRS activities are responsible for the higher lead concentrations observed in this well. These higher concentrations of lead do not appear to be occurring naturally in the groundwater. In general, very low concentrations of lead are typically found in groundwater used to supply the public with drinking water. However, wells or pipes

that transport water to distribution tanks or to homes may contain lead. Lead from lead pipe or solder may be released into water when the water is acidic or “soft” (ATSDR 2005b).

Well G02141 is one of several wells that the city of Jackson uses to supply potable water to approximately 3,600 people in Aiken County. The highest lead concentration detected in the Jackson municipal drinking water supply was 84 ppb, collected in June 1998. Several other samples since that time have exceeded EPA’s action level of 15 ppb. More recently, in January 2005, a water sample collected from Well G02141 contained 3.6 ppb of lead, well below EPA’s action level.

The reason for the variability in lead concentration in the data was investigated further by ATSDR scientists. According to an SCDHEC representative, the high lead concentrations that were reported in 1998 and in some subsequent samples were not collected at the point of distribution (i.e., well G02141). The samples were collected at specific residences that obtain their water from the Jackson municipal supply. A closer examination of the samples collected at the well head did not contain elevated concentrations of lead. Therefore, the lead found in the samples appears to be associated with lead piping or other sources closer to the end of the distribution line rather than at the point of distribution (Personal communication, Bruce Bleau, SCDHEC, September 14, 2006).

It has long been known that lead exposure can have harmful effects. Young children and fetuses have been the main focus of health effects research, since they are the most sensitive individuals; however, adults exposed to lead can also experience adverse health effects. Infants and children receive higher doses from any given level of environmental lead than do adults because they have a greater absorption capacity for lead than adults. Therefore, age is an important determinant of exposure dose for a given concentration of lead in drinking water. ATSDR reviewed the toxicological literature pertaining to human and animal exposures to various doses of lead. In general, exposure doses below 0.001 mg/kg/day do not harm humans or animals. Exposure doses between 0.001 and 0.01 mg/kg/day produce minor changes in blood cells. Harmful effects in animals are observed when doses reach and exceed 0.01 mg/kg/day (ATSDR 2005b).

The highest levels of lead detected in the Jackson municipal drinking water system was 84 ppb. Assuming that an individual was always exposed to the highest concentration reported, the highest estimated dose that correlates with this maximum concentration is less than 0.01 mg/kg/day. This dose would not be expected to result in adverse health effects. However, this could be a concern if other exposures were occurring at the same time (e.g., a child also exposed to lead paint or dust in the home). It should be reassuring to any resident who obtains their drinking water from the Jackson municipal system that the groundwater is not the source of lead contamination, nor is it likely that the Jackson supply wells at the point of distribution are a significant source of lead.

For humans, there is a generally consistent correlation between the levels of lead in blood and the harmful effects that may be seen. Blood levels of lead can be elevated by sustained exposure to contaminated soil, food, air, or drinking water. Neurological effects are the most important health effects from exposure in childhood or during gestation (i.e., in the uterus). Changes in blood cells serve as indicators of exposure. CDC considers a child to have an elevated blood lead

level if the amount of lead in his or her blood is 10 micrograms per deciliter (ug/dL) or higher (CDC 1991).

*Radium:* Radium is a naturally occurring radioactive metal that exists in several isotopic forms, radium 226 and radium 228 being the most common. It is formed when naturally occurring uranium and thorium decay in the environment. Radium is found in low concentrations in soil, water, rocks, coal, plants, and food. The amount of radium varies in different geological regions of the United States. The amount of radium in groundwater drinking wells is caused by erosion of natural deposits and varies by the proximity of the well to certain geological formations and the chemistry of the water (ATSDR 1990).

The predominant isotopes of radium found in the environment decay primarily by releasing alpha particles that travel short distances and cannot travel through your skin; however, alpha particles can cause damage when they are ingested (ATSDR 1990). EPA's Safe Drinking Water Standard for total radium in municipal water supplies is 5 pCi/L (EPA 2000). Levels of radium in public drinking water are usually less than 1 pCi/L (ATSDR 1990), although it is not uncommon to find higher levels of radium in the groundwater along the coastal ridge line in South Carolina and other areas of the country.

The Jackson municipal well (plant location B02001) has exceeded the 5 pCi/L annual average for all years reviewed (2001 through January 2006) (SCDHEC 2006b). Based on the results reviewed, the concentrations in this well have been fairly consistent and were probably similar in the past. There is no indication that these concentrations are associated with SRS, but rather are naturally occurring. As seen in Table 12, the main contributor to the total radium concentration is radium 226; however, radium 228 produces proportionately more radiation dose to an individual than radium 226.

<b>Table 12. Jackson City Municipal Well – Plant 1</b>			
	Total radium	Radium 226	Radium 228
Annual average - 2001	8.4 pCi/L	5.8 pCi/L	2.6 pCi/L
Annual average - 2002	12.1 pCi/L	9.5 pCi/L	2.6 pCi/L
Annual average - 2003	9.0 pCi/L	6.5 pCi/L	2.5 pCi/L
Annual average - 2004	8.0 pCi/L	6.0 pCi/L	2.0 pCi/L
Annual average - 2005	8.0 pCi/L	6.5 pCi/L	1.5 pCi/L
01/09/2006	7.9 pCi/L	6.2 pCi/L	1.7 pCi/L
Source: SCDHEC 2006b			
pCi/L = picocuries per liter of water			

Using conservative assumptions for the amount of water consumed and daily exposure, ATSDR's evaluation shows that current exposures to the maximum annual average concentrations range from 12 to 170 millirem per year depending on the age of the person (EPA's Safe Drinking Water Standards are derived from an exposure of four millirem per year for this pathway). ATSDR scientists believe that past exposures would have been similar. The hypothetical maximum exposure rate is for an infant 0 to 12 months old that drinks formula and juice mixed with tap water only. Typically, children of this age will also drink other liquids not made from tap water, and their corresponding exposure dose would be less.



Most adverse health effects seen from exposure to radium have been observed at very high levels of exposure, such as that received by radium dial painters and therapeutic applications. Health studies performed to determine potential health effects at low levels in drinking water are contradictory. The National Research Council's BEIR IV report cites three studies where adverse health effects were observed at levels found in drinking water resources that contain naturally occurring radium at or above the drinking water standards. The control groups for these studies were from a different community and drank well water containing less than one pCi/L of radium. One study found elevated deaths due to malignant neoplasm involving bone, a second study found elevated incidences of bladder and lung cancer in males and lung and breast cancer in females with increases in concentrations above 5 pCi/L, and the third study found elevated rates of leukemia. When individuals in one of these communities who drank surface water not containing radium were compared to persons drinking the well water, there was no significant difference. In a follow-up report, the author of one study concluded that "no significant difference could be detected between the osteosarcoma mortality rate in towns with water supplies having elevated levels of radium 226 and matched control towns." (NCR 1988).

However, precautions can easily be taken to prevent or minimize exposure. Radium can be removed by using water softeners. If persons are concerned about their tap water, they should have their water supply tested. Also, very young children should drink prepared formula, bottled juices, etc.

## **Child Health Considerations**

ATSDR recognizes that 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 shorter than adults, which mean they breathe dust, soil, and heavy vapors close to the ground. 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. 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.

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.

ATSDR's evaluation indicates that contaminants released into groundwater beneath SRS have not migrated off site. Therefore, children have not come in contact with and are not being adversely impacted by site-related contaminants. Furthermore, it is unlikely that children have come in contact with contaminants migrating off-site via surface water at levels that would be harmful. However, during the evaluation of non site-related contaminants (i.e., lead and radium), exposures to children were taken into consideration.

## Conclusions

This focused PHA addresses off-site migration of hazardous substances released to the groundwater and surface water from SRS activities and any potential health effects to community members from exposure to those substances. The evaluation emphasized the period of time since the end of the CDC Dose Reconstruction (1992) through the present, and focused on any potential future exposures. Our evaluation had several components: 1) we identified the specific chemical and radioactive substances released from SRS; 2) we evaluated the nature and extent of contamination in areas where off-site migration to receptor populations could have occurred in the past, may be occurring now, or potentially could occur in the future; 3) we determined whether any people or groups were exposed, how they may have been exposed, and the length of exposure; and 4) if a completed exposure pathway was identified, we estimated contaminant specific doses for each type of exposure, then compared those doses to the most currently available medical and health information to determine if the doses are likely to produce any adverse health effects in the exposed community.

On the basis of the most currently available information, there are no past, current, or future public health hazards associated with contaminants in groundwater or surface water from SRS-related activities. ATSDR conclusions regarding the potential exposure pathways evaluated are described below:

- According to the information evaluated by ATSDR, under existing conditions and normal operations, SRS currently *poses no apparent public health hazard* for the surrounding community from exposure to groundwater or surface water.

There is no evidence of historical migration of off-site groundwater and the monitoring data evaluated since 1993 shows that the groundwater plumes have not migrated beyond the site boundaries. No future off-site groundwater exposure is anticipated if the DUS remedial action in the A&M-Area successfully captures the DNAPL and related dissolved VOCs and ongoing groundwater monitoring continues to show that the primary plume is not progressing toward the site boundary.

“No apparent public health hazard” means that people may be exposed to contaminated media (surface water close to the mouth of the on-site streams), but that exposure is not expected to cause any adverse health effects.

- Unless on-site processes change and begin releasing additional chemical or radioactive substances, off-site surface water exposures should remain the same or be lower as on-site remedial projects are completed.
- Two contaminants not related to the site were identified in a municipal well in close proximity to the SRS boundary. This exposure was identified as a completed pathway for all age groups in the community. Concentrations of lead in the Jackson drinking water supply are not currently at levels believed to cause adverse health effects. Concentrations of radium may be levels of concern for infants drinking formula and juices mixed with tap water. Based on exposure calculations, these levels are not expected to cause adverse health effects in other age groups. Health studies of large populations who chronically

consumed radium in drinking water at or near these concentrations have conflicting results. Therefore, precautions should be taken.

## Recommendations

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

### *For site-related issues:*

1. DOE should continue to monitor the “boundary wells” in the A&M-Area for VOCs until monitoring results demonstrate that groundwater plume remedial activities are successful and site-related contaminants no longer have the potential to impact off-site wells.
2. SCDHEC and DOE should use adequate detection limits for the analysis of all environmental monitoring data. Detection limits above the contaminant-specific screening levels do not allow for adequate public health evaluations since there is no way to quantitatively determine whether the concentrations are at levels of health concern.
3. DOE, GDNR, and SCDHEC should continue to monitor potential contaminant concentrations in the Savannah River at or near the mouth of the streams that flow through or originate at SRS. The types and frequencies of activities by the general public in the Savannah River near these locations should also be monitored periodically to assure that exposures to off-site populations are kept well below the levels that could cause adverse health effects. Several agencies have used concentrations in the river at or below Highway 301 for their calculation of potential off-site exposure dose; however, concentrations can be greater at the mouths of the SRS streams, which are unrestricted to the public. ATSDR recommends that the concentrations at or near the mouths of the streams be considered when estimating potential off-site exposures.

### *For non-site-related issues:*

1. The elevated radium concentration in the Jackson well appears to be naturally occurring and not site-related. However, the State of South Carolina and/or the City of Jackson should pursue a method of reducing these radium concentrations in the drinking water. According to the National Research Council’s Committee on the Biological Effects of Ionizing Radiation, water-softening devices remove radium from water (NRC 1988).
2. ATSDR encourages residents who are concerned about lead or radium in their drinking water to have their water tested. Information regarding lead in drinking water is available by contacting SCDHEC's Bureau of Water at (803) 898-4300. As a general precaution, EPA recommends running your tap for 30 seconds to 2 minutes before using the tap water. For radium, infants should consume prepared liquids such as pre-mixed formula, juices, and bottled water. You may contact EPA’s Safe Drinking Water Hotline by calling 1-800-426-4791 or accessing their web site on the internet at: <http://www.epa.gov/safewater/drinklink.html>.

## 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

- In 1985, DOE initiated on-site remedial activities to reduce and/or eliminate releases of chemicals and radioactive contaminants to the groundwater and surface water streams and eventually to the Savannah River.
- The M-Area Settling Basin was covered with a RCRA cap and closed in 1991. The Metallurgical Laboratory Basin and the Savannah River Laboratory Basins, also used for disposal of liquid wastes, were closed in 1992 and 2001, respectively
- From September 2000 to September 2001, the Dynamic Underground Stripping (DUS) technique was successfully used to remove dense non-aqueous liquid phase (DNAPL) volatile organic compounds (VOCs) from below the M-Area Solvent Storage Tank Area in the A&M-Area.
- By October 2006, SRS had completed 325 out of 495 surface soil remediation projects and 6 out of 19 groundwater remediation projects.
- Since 1991, ATSDR has provided both oral and written consultations on various on-site remediation projects at SRS.
- In 2002, ATSDR completed a three-phase health education/needs assessment program for off-site communities potentially impacted by SRS.

### Ongoing Actions

- On-site remedial activities are ongoing which include surface units and groundwater units. Priority is being placed on peripheral locations, such as the A&M-Area, D-Area and T-Area.
- DUS operations began in August 2005 to remove VOCs from below and near the M-Area Settling Basin in the A&M-Area. As of October 2006, 250,000 pounds of DNAPL source had been removed.
- The remediation activities associated with the M-Area closure, which impact groundwater quality, are scheduled for completion by 2010. This does not include the groundwater remediation efforts in the A&M-Area, which will take longer.
- SCDHEC is continuing to monitor various media around and on the SRS site for chemical and radioactive contaminants.
- GDNR is continuing to monitor various media near the SRS site for monitoring radioactive contaminants.

**Planned Actions**

- SCDHEC and DOE will continue to monitor groundwater quality in or near the A&M-Area of the site and nearby off-site wells.
- SCDHEC and DOE will continue to monitor SRS streams that are tributaries to the Savannah River.
- GDNR, SCDHEC, and DOE will continue to monitor drinking water from the water treatment plants downstream of the site.
- DOE, SCDHEC and GDNR will continue to have emergency procedures that will be activated during unplanned or excessive releases of radioactive and/or chemical contaminants.

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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 prevention**

Measures used to prevent a disease or reduce its severity.

**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.

**Environmental media and transport mechanism**

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

**EPA**

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-dose reconstruction**

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

**Exposure 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.

**Health investigation**

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

**Indeterminate public health hazard**

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

**Incidence**

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

**Ingestion**

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

**Inhalation**

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

**Intermediate duration exposure**

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

**Lowest-observed-adverse-effect level (LOAEL)**

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

**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].

**Morbidity**

State of being ill or diseased. Morbidity is the occurrence of a disease or condition that alters health and quality of life.

**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.

**No-observed-adverse-effect level (NOAEL)**

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

**No public health hazard**

A category used in ATSDR's public health assessment documents for sites where people have never and will never come into contact with harmful amounts of site-related substances.

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

**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 health hazard categories**

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

**Public health statement**

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

**Public health surveillance**

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

**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].

**Safety factor** [see uncertainty factor]

**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].

**Surveillance** [see public health surveillance]

**Survey**

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

**Toxic agent**

Chemical or physical (for example, radiation, heat, cold, microwaves) agents that, under certain circumstances of exposure, can cause harmful effects to living organisms.

**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

**Tumor**

An abnormal mass of tissue that results from excessive cell division that is uncontrolled and progressive. Tumors perform no useful body function. Tumors can be either benign (not cancer) or malignant (cancer).

**Urgent public health hazard**

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

**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>)

**For more information on the work of ATSDR, please contact:**

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## Appendix B. List of Comparison Values used by ATSDR

### Comparison Values

ATSDR scientists select contaminants for further evaluation by comparing them against health-based comparison values (CVs). These are developed by ATSDR from available scientific literature related to exposure and health effects. CVs are derived for each of the different media and reflect an estimated contaminant concentration that is *not likely* to cause adverse health effects for a given chemical, assuming a standard daily contact rate (e.g., an amount of water or soil consumed or an amount of air breathed) and body weight.

ATSDR comparison values are media-specific concentrations that are considered to be safe under default conditions of exposure. They are used as screening values in the preliminary identification of site-specific “contaminants of concern.” The latter term should not be misinterpreted as an implication of “hazard.” As ATSDR uses the phrase, a “contaminant of concern” is a chemical substance detected at the site in question and selected by the health assessor for further evaluation of potential health effects. Generally, a chemical is selected as a “contaminant of concern” because its maximum concentration in air, water, or soil at the site 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.

Listed and described below are the various comparison values that ATSDR uses to select chemicals 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 (MRL)** are estimates of daily human exposure to a chemical (doses expressed in mg/kg/day) 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 ( $\leq 14$  days), intermediate (15-364 days), and chronic ( $\geq 365$  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 one year [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 RfD's, RfC's, or EPA's 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 ("c") or noncancer ("n") 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.

More information about the ATSDR evaluation process can be found in ATSDR's Public Health Assessment Guidance Manual at <http://www.atsdr.cdc.gov/HAC/HAGM/>. A hard copy can be obtained by contacting the ATSDR information line toll-free at (888) 422-8737.

## Appendix C. Overview of ATSDR's Methodology for Evaluating Potential Public Health Effects

### Methodology

#### *Comparing Environmental Data to Comparison Values*

For this public health assessment, ATSDR selected contaminants for further evaluation by comparing the maximum environmental contaminant concentrations against conservative health-based comparison values. Comparison values are developed by ATSDR from

available scientific literature concerning exposure and health effects. Comparison values are derived for each environmental media (water, soil, and air) and reflect an estimated contaminant concentration that is not expected to cause harmful health effects, assuming a standard daily

contact rate (for example, the amount of water or soil consumed) and representative body weight. Because the concentrations reflected in comparison values are much lower than those that have been observed to cause adverse health effects, comparison values are protective of public health in essentially all exposure situations. As a result, concentrations detected at or below ATSDR's comparison values are not considered for further evaluation.

A comparison value is used by ATSDR to screen chemicals that require additional evaluation.

ATSDR uses the term "conservative" to refer to values that are protective of public health in essentially all situations. Values that are likely to be overestimated are considered to be conservative.

ATSDR's comparison values include the cancer risk evaluation guides (CREGs), environmental media evaluation guides (EMEGs), and reference dose media evaluation guides (RMEGs). These are nonenforceable, health-based comparison values developed for screening environmental contamination for further evaluation. The U.S. Environmental Protection Agency's (EPA) risk-based concentration (RBC) is a health-based comparison value developed to screen sites not yet on the National Priorities List, respond rapidly to citizens' inquiries, and spot-check formal baseline risk assessments.

Essential nutrients (e.g., calcium, magnesium, phosphorous, potassium, and sodium) are important minerals that maintain basic life functions; therefore, certain doses are recommended on a daily basis. Because these chemicals are necessary for life, screening guidelines do not exist for them. They are found in many foods, such as milk, bananas, and table salt.

While concentrations at or below the relevant comparison value can reasonably be considered safe, it does not automatically follow that any environmental concentration exceeding a comparison value would be expected to produce adverse health effects. Comparison values are not thresholds for harmful health effects. ATSDR comparison values represent contaminant concentrations that are many times lower than levels at which no effects were observed in studies on experimental animals or in

human epidemiologic studies. The likelihood that adverse health outcomes will actually occur depends on site-specific conditions, individual lifestyle, and genetic factors that affect the route, magnitude, and duration of actual exposure. An environmental concentration alone will not cause an adverse health outcome. If contaminant concentrations are above comparison values, ATSDR further analyzes exposure variables (such as site-specific exposure, duration, and frequency) for health effects, including the toxicology of the contaminant and other epidemiology studies.

### ***Comparing Estimated Doses to Health Guideline Values***

If chemical concentrations are above comparison values, ATSDR further evaluates the chemical and potential exposure. ATSDR does this by calculating exposure doses and comparing the doses to protective health guideline values, including ATSDR's minimal risk levels (MRLs) and EPA's

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

reference doses (RfDs). Estimated exposure doses that are less than health guideline values are not considered to be of health concern. ATSDR's MRLs and EPA's RfDs are estimates of the daily human exposure to hazardous substances that are likely to be without appreciable risk of adverse noncancer health effects over a specified duration of exposure.

When estimating exposure doses, health assessors evaluate chemical concentrations to which people could have been exposed, together with the length of time and the frequency of exposure. Collectively, these factors influence an individual's physiological response to chemical exposure and potential outcomes. Where possible, ATSDR used site-specific information regarding the frequency and duration of exposures. When site-specific information was not available, ATSDR employed several conservative assumptions to estimate exposures.

MRLs and RfDs are generally based on the most sensitive end point considered to be of relevance to humans. While estimated doses that are less than these values are not considered to be of health concern, exposure to levels above the MRL or RfD does not automatically mean that adverse health effects will occur. To maximize human health protection, they have built-in uncertainty or safety factors, making these values considerably lower than levels at which health effects have been observed. The result is that even if a dose is higher than the health guideline, it does not necessarily follow that harmful health effects will occur. Rather, it is an indication that ATSDR should further examine the harmful effect levels reported in the scientific literature and more fully review exposure potential.

In addition, to screen for cancer effects, estimated chronic-exposure doses were multiplied by EPA's cancer slope factors (CSFs) to measure the relative potency of carcinogens. This calculation estimates a theoretical excess cancer risk expressed as the proportion of a population that may be affected by a carcinogen during a lifetime of exposure. For example, an estimated cancer risk of  $1 \times 10^{-6}$  predicts the probability of one additional cancer over background levels in a population of 1 million. Because conservative models are used to derive CSFs, the doses associated with these estimated hypothetical risks may be orders of magnitude lower than doses reported in the toxicology literature to cause carcinogenic effects. As such, a low cancer risk estimate (risk estimates less than  $1 \times 10^{-5}$ ) indicates that the toxicology literature would support a finding that no excess cancer risk is likely. A higher cancer risk estimate, however, indicates that ATSDR should carefully review the toxicology literature before making conclusions about potential cancer risks.

***Comparing Estimated Doses to Health Effects Levels***

If the MRLs or RfDs are exceeded, ATSDR examines the health effects levels discussed in the scientific literature and more fully reviews exposure potential. ATSDR reviews available human studies as well as experimental animal studies. This information is used to describe the disease-causing potential of a particular chemical and to compare site-specific dose estimates with doses shown in applicable studies to result in illness (known as the margin of exposure). This process enables ATSDR to weigh the available evidence in light of uncertainties and offer perspective on the plausibility of harmful health outcomes under site-specific conditions.

***Sources for Health-based Guidelines***

By Congressional mandate, ATSDR prepares toxicological profiles for hazardous substances found at contaminated sites. These toxicological profiles were used to evaluate potential health effects at SRS. ATSDR's toxicological profiles are available on the Internet at <http://www.atsdr.cdc.gov/toxpro2.html> or by contacting the National Technical Information Service (NTIS) at 1-800-553-6847. EPA also develops health effects guidelines, and in some cases, ATSDR relied on EPA's guidelines to evaluate potential health effects. These guidelines are found in EPA's Integrated Risk Information System (IRIS)—a database of human health effects that could result from exposure to various substances found in the environment. IRIS is available on the Internet at <http://www.epa.gov/iris>. For more information about IRIS, please call EPA's IRIS hotline at 202-566-1676 or e-mail at [Hotline.IRIS@epa.gov](mailto:Hotline.IRIS@epa.gov).