Groundwater

CHAPTER 7

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Groundwater protection at the Savannah River Site (SRS) has evolved into a program with the following primary components:

- *Protecting groundwater by using best practices in managing groundwater contaminants and implementing sound remediation technologies;*
- *Monitoring groundwater to identify areas of contamination;*
- *Remediating groundwater contamination as needed; and*
- *Conserving groundwater.*

Previous SRS operations have contaminated the groundwater adjacent to and beneath hazardous waste management facilities and operable units. An extensive groundwater monitoring program is in place at SRS and remediation strategies are being implemented. Remediation strategies include closing waste sites to reduce the migration of contaminants into groundwater and actively treating contaminated water.

Groundwater monitoring from wells located off SRS indicate that contaminated groundwater is not migrating off-site.

This chapter describes SRS's groundwater environment and the site-wide programs in place for investigating, monitoring, remediating, and using the groundwater.

Groundwater at SRS

SRS is underlain by sediment of the Atlantic Coastal Plain. The Atlantic Coastal Plain consists of a southeast-dipping wedge of unconsolidated sediment that extends from its contact with the Piedmont Province at the Fall Line to the edge of the continental shelf. The sediment ranges from Late Cretaceous to Miocene in age, and comprises layers of sand, muddy sand, and clay with subordinate calcareous sediments. It rests on crystalline and sedimentary basement rock.

Water flows easily through the sandy layers (aquifers), but is retarded by less permeable clayey beds (confining units). Past SRS operations have resulted in contamination migrating to the groundwater at various site locations, predominantly in the central areas of the site. The continuous movement of water into the subsurface intervals of the aquifer system has the ability to transfer contamination into the groundwater.

The hydrostratigraphy of SRS has been subject to several classifications, as established in Aadland et al. (1995) and Smits et al. (1996). The classifications are used extensively at SRS and regarded as the current site standard. This system is consistent with the U.S. Geological Survey (USGS) standards used in the regional studies that include the area surrounding SRS [Clarke and West 1998]. Figure 7-1 demonstrates the relative position of the SRS hydrostratigraphic units as they relate to their corresponding lithologic units and geologic time scale.

The hydrostratigraphic units beneath SRS are part of the Southeastern Coastal Plain Hydrogeologic Province (figure 7-1). Within this sequence of aquifers/confining units are two principal subcategories: the overlying Floridian Aquifer System and the underlying Dublin-Midville Aquifer System. These systems are separated from each other by the Meyers Branch Confining System. In turn, this system is further subdivided into two aquifers, which are separated by a confining unit. In the northern part of SRS (north of Upper Three Runs), the aquifer system is referred to as the Steed Pond Aquifer and is comprised of the M-Area Aquifer Zone, the Green Clay Confining Zone, and the Lost Lake Aquifer Zone. In the Central and Southern part of SRS, the aquifer system is referred to as the Upper Three Runs and Gordon Aquifers and is comprised

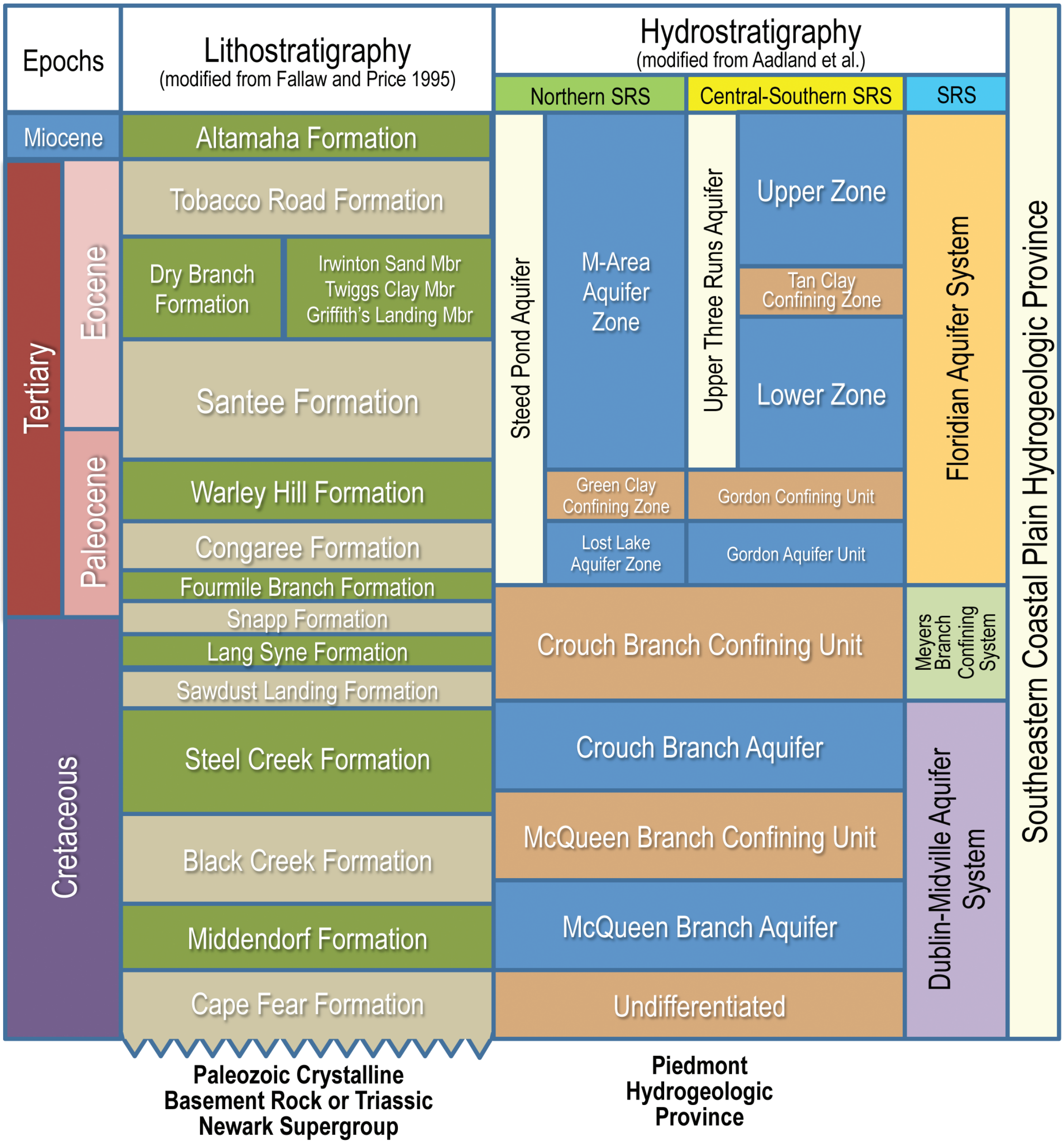


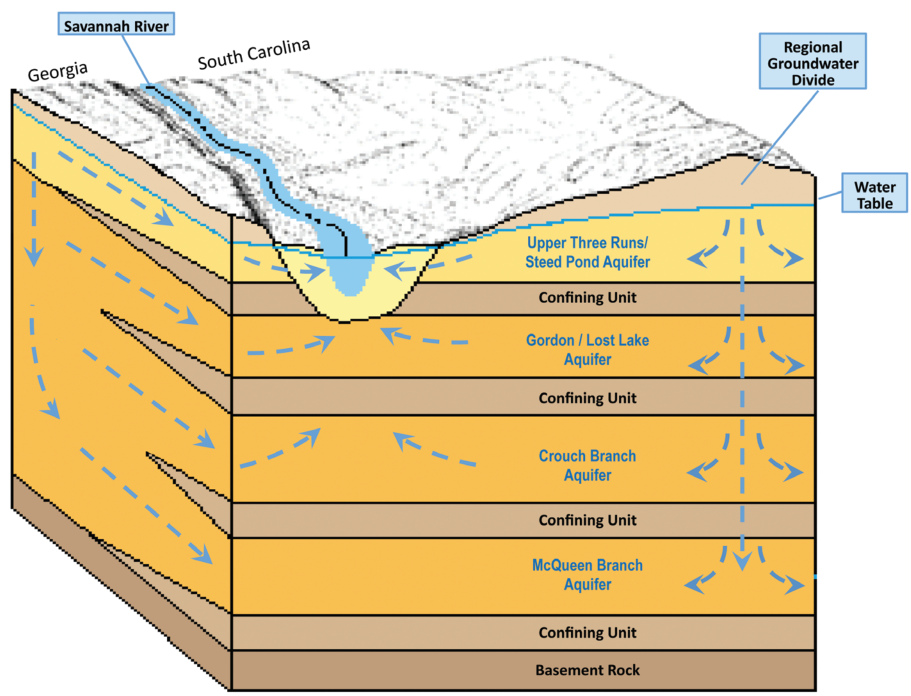
Figure 7–1 Hydrostratigraphic Units at SRS

of the Upper Zone, Tan Clay Confining Zone, Lower Zone, Gordon Confining Unit, and Gordon Aquifer Zone. Figure 7-2 is a three-dimensional block diagram of the hydrogeologic units at SRS and the generalized groundwater flow patterns within those units. The units from the shallowest to the deepest are: the Upper Three Runs/Steed Pond Aquifer (or water table aquifer), the Gordon/Lost Lake Aquifer, the Crouch Branch Aquifer, and the McQueen Branch Aquifer. Maps of the potentiometric surfaces of these aquifers are presented in figures 19-22, respectively, of the "Environmental Data/Maps - 2011" Appendix located on the accompanying compact disk (CD).

Groundwater recharge is a result of rainwater or other precipitation moving downward through the ground to

the water table. Upon entering the saturated zone at the water table, water moves predominantly in a horizontal direction toward local discharge zones along headwaters and midsections of streams. Additionally some water moves into successively deeper aquifers. The water lost to successively deeper aquifers migrates laterally within those units toward the more distant regional discharge zones. These regional zones are typically located along major streams (e.g., Upper Three Runs or Fourmile Branch), or along the Savannah River itself. Groundwater movement within these units is extremely slow as compared to surface water, with groundwater velocities varying between aquitards and aquifers. At SRS, these velocities can range from several inches to several feet per year in aquitards and from tens to hundreds of feet per year in aquifers.

Monitoring wells are used extensively at SRS to assess the effects of site activities on groundwater quality. Most of the wells monitor the upper groundwater zones (see figure 7-1), although wells are present in the lower zones at the sites with the larger groundwater contamination plumes. Groundwater in some areas contains one or more contaminants at or above the U.S. Environmental Protection Agency (USEPA) drinking water standards (i.e., maximum contaminant levels [MCLs]). These areas can be seen in figure 18 of the “Environmental Data/Maps - 2011” Appendix located on the accompanying CD. Time-versus- concentration plots for selected wells from various contaminated areas are also included on the accompanying CD. The CD also contains all of the 2011 SRS groundwater monitoring data. Well coordinates have been provided in the data tables and can be used in conjunction with figure 25 of the “Environmental Data/Maps - 2011” Appendix located on the accompanying CD to find the location of individual wells.



Modified from Clarke and West, 1998

Figure 7-2 Groundwater at SRS
The groundwater flow system at SRS consists of four major aquifers separated by confining units: Upper Three Runs / Steed Pond, Gordon / Lost Lake, Crouch Branch, and McQueen Branch. Groundwater flow in recharge areas generally migrates downward, as well as laterally, and eventually discharges into the Savannah River and its tributaries or migrates into the deeper regional flow system. Additional information concerning hydraulic heads and flow directions may be found in Figures 19–22 of the “Environmental Data/Maps - 2011” Appendix located on the accompanying CD.

Groundwater Protection Program at SRS

The SRS groundwater protection program is designed to meet federal and state laws/regulations, U.S. Department of Energy (USDOE) orders, and SRS policies and procedures. It contains the following elements:

- Investigating SRS groundwater;
- Using SRS groundwater;
- Protecting SRS groundwater;
- Remediating contaminated SRS groundwater; and
- Monitoring SRS groundwater.

Groundwater monitoring is a key tool used in each of the first four elements, with the results forming the basis for evaluations that are reported to SRS stakeholders.

Investigating SRS Groundwater

An extensive monitoring program is in place at SRS to acquire data and information relating to the groundwater. Groundwater investigations include the collection and analysis of data to understand groundwater conditions on both a regional scale (sitewide) and a local scale (individual waste site) at SRS.

Monitoring efforts at SRS focus on the collection and analysis of data to characterize the groundwater flow and the contaminants present. Characterization efforts at SRS include, but are not limited to, the following activities:

- Collecting soil and groundwater samples using cone penetrometer technology (CPT). Additional information can also be obtained from geologic soil cores or seismic profiles to better delineate subsurface structural features, as warranted;
- Installing wells to allow periodic collection of water level measurements and groundwater samples at strategic locations;
- Developing water table and potentiometric maps to help define the groundwater velocity in the subsurface; and
- Performing various types of tests to obtain in situ estimates of hydraulic parameters in order to estimate groundwater velocities.

Analysis of groundwater characteristics on the regional scale is needed to provide a comprehensive understanding of SRS groundwater movement in order to better understand the migration of contaminants at the local scale (i.e., near individual waste units).

Surface water flow characteristics are also determined on the regional scale at SRS in order to ascertain contaminant risk to perennial streams since they are the receptors of groundwater discharge. Because the SRS boundary does not represent a groundwater boundary, regional studies are useful in understanding the movement of groundwater into SRS from surrounding areas and vice versa.

Groundwater modeling has been used extensively at SRS as an analytical tool for regional and local groundwater investigations. Models have been used to (1) define regional groundwater flow patterns on and off SRS; (2) enhance understanding of contaminant migration in the subsurface; (3) support remedial designs; and (4) provide predictive performance assessments of waste disposal facilities. At SRS, major groundwater modeling efforts have been conducted on A/M-Areas, D/TNX-Areas, F/H Areas, the Burial Ground Complex, and C-, K-, L-, P-, and R-Reactor Areas.

In order to gain a better understanding of the fate and transport processes in groundwater, research is being conducted on many topics, including attenuation processes for inorganics and radionuclides, physical interactions of contaminants with porous media matrices, and biogeochemical factors that influence microbial degradation of organic contaminants in groundwater. Research to address relevant issues at SRS is often conducted through cooperative studies with public universities and private companies or by SRS employees exclusively. Published papers describing the results of the specific research projects may be found at DOE s Office of Scientific and Technical Information website, http://www.osti.gov, and in various technical journals.

Using SRS Groundwater

SRS manages its own drinking and process water supply from groundwater located beneath the SRS. SRS domestic and process water systems are supplied from a network of approximately 40 production wells in widely scattered locations across the site, of which eight wells supply the primary drinking water system for the SRS (figure 14 of the “Environmental Data/Maps - 2011” Appendix found on the accompanying CD). The production wells are the water supply wells that provide water for all the facility operations including domestic water systems. In 1983, SRS began reporting its water usage annually to the South Carolina Water Resources Commission, and later to the South Carolina Department of Health and Environmental Control (SCDHEC). Since that time, the amount of groundwater pumped for SRS

Sample Scheduling and Collection

Approximately 2,000 wells and numerous direct-push holes are sampled each year. Most of the wells are sampled semiannually, but many are sampled quarterly or annually. These groundwater samples provide data for reports required by federal/state regulations, internal monitoring reports, and research projects. The results, which contain over 193,000 lines of data, are included with the CD that accompanies this document.

Nonradioactive constituents that may be required for analysis due to permit or regulatory document requirements include metals, field parameters, herbicides, pesticides, volatile organic compounds (VOCs), and others as needed. Likewise, radioactive constituents that may be required for analysis include gross alpha and nonvolatile beta indicators, gamma emitters, iodine-129, strontium-90, radium isotopes, uranium isotopes, and other alpha and beta emitters.

Groundwater samples are typically collected via pumps or bailers that are dedicated to each individual well to prevent cross-contamination between the wells. Portable sampling equipment can also be used if decontamination procedures are implemented between wells.

Sampling and shipping equipment and procedures are consistent with USEPA, SCDHEC, and U.S. Department of Transportation guidelines. USEPA-recommended preservatives and sample-handling techniques are employed for sample storage and transportation to onsite and offsite analytical laboratories. Potentially radioactive samples are screened for total activity prior to shipment to determine appropriate packaging and labeling requirements. Deviations from scheduled sampling and analysis for 2011 (caused by dry wells, inoperative pumps, etc.) were entered into the SRS groundwater database and issued in appropriate reports.

usage has dropped by more than two thirds from 10.8 million gallons per day during 1983-1986 to 3.3 million gallons per day in 2011. The majority of this decrease is attributed to the consolidation of the SRS domestic water systems, which was completed in 1997. Thirteen separate water systems, each with its own high-capacity supply wells, were consolidated in 1997 into three systems which are located in A-, D-, and K-Areas. In 2009, these three systems were further consolidated into two systems located in A- and D-Areas. This consolidation greatly reduced the amount of excess water being pumped to waste. Site facility shutdowns and reductions in population have also been contributing factors to the decrease in water usage. An increase from 2.7 million gallons per day in 2009 to the 3.3-million gallons per day in 2011 was likely due to the American Recovery and Reinvestment Act that accelerated many SRS projects and required an increase in the workforce through 2011.

Treated water is supplied to the larger SRS facilities by the A-Area and D-Area domestic water systems. Each system is comprised of a treatment plant, distribution piping, elevated storage tanks, and a well network. The wells range in capacity from 200 to 1,500 gallons per minute. The SRS domestic water systems meet state and federal drinking water quality standards. The two systems supply water to site drinking fountains, lunchrooms, restrooms, and showering facilities. The systems are sampled quarterly for chemical analyses by SCDHEC. The A-Area water system is monitored monthly for bacteriological analyses; the D-Area water system is sampled quarterly. SCDHEC performs sanitary surveys every two years on the A-Area and D-Area systems. The much smaller systems are inspected by SCDHEC every three years. All 2011 water samples were in compliance with SCDHEC and EPA water quality standards. Additional information is provided in the Safe Drinking Water Act section of Chapter 3, “Environmental Compliance.”

The process water systems are located in A-, F-, H-, K-, L-, and S-Areas and meet SRS’s demands for boiler feedwater, equipment cooling water, facility washdown water, and makeup water for cooling towers, fire storage tanks, chilled-water-piping loops, and site test facilities. These systems are supplied from dedicated process water wells ranging in capacity from 100 to 1,500 gallons per minute. In K-Area, the process water system is supplied from the domestic water wells. At some locations, the process water wells pump to ground level storage tanks, where the water is treated for corrosion control. At other locations, the wells directly pressurize the process water distribution piping system without supplemental treatment.

Protecting SRS Groundwater

SRS is committed to protecting the groundwater resources beneath the site. A variety of activities that contribute to this endeavor, include:

- Construction, waste management, and monitoring efforts to prevent or control sources of groundwater contamination;
- Groundwater and surface water monitoring programs to detect contamination; and
- A successful groundwater cleanup program that is managed by Environmental Compliance & Area Completion Projects (EC&ACP).

The main objective of the groundwater monitoring program is to protect potential offsite receptors from groundwater and or surface water contamination that originated at SRS. Monitoring the groundwater around SRS facilities and known waste disposal sites provides the best means to detect and keep track of groundwater contamination so that the appropriate remedial or corrective actions can be implemented before the contamination travels offsite. The majority of SRS's groundwater contamination is located in its central areas. However, the potential for offsite migration does exist. The consequences of offsite contamination occurring are serious enough to warrant a comprehensive groundwater monitoring program.

The SRS groundwater monitoring program also collects groundwater data to determine the effects of site operations on groundwater quality. The program:

- Supports SRS in complying with environmental regulations and USDOE directives;
- Provides contaminant data to evaluate the current status of groundwater plumes;
- Provides water quality data necessary for evaluating the suitability of a new facility location; and
- Supports basic and applied research projects.

The SRS groundwater monitoring program includes two primary components: (1) waste site monitoring associated with remediation, and (2) groundwater surveillance monitoring.

Groundwater monitoring data are evaluated on a regulatory-approved frequency to identify whether new groundwater contamination exists or if current monitoring programs need to be modified in order to maintain an overall optimal monitoring program.

Monitoring wells and production wells that are no longer beneficial are abandoned with approval from SCDHEC, following SRS procedures. A typical abandonment involves placing a smaller diameter pipe ("tremie pipe") near the bottom of the well and pumping cement grout through the tremie pipe until the well is full of grout. This method ensures that grout reaches the bottom of the well. SRS abandoned seven wells in 2011. The Z-Area Saltstone Disposal Facility is planning to abandon seven monitoring wells in 2012.

Remediating Contaminated SRS Groundwater

SRS has maintained an environmental remediation and monitoring effort for more than 20 years. EC&ACP currently manages the remediation and monitoring of contaminated groundwater associated with Resource Conservation and Recovery Act (RCRA) hazardous waste management facilities, Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) waste sites and other hazardous waste sites as specified in the *Savannah River Site Federal Facility Agreement* (FFA) (FFA 1993). The purpose of the FFA is to ensure that

- Schedules for environmental agreements are consistently met;
- Usage of financial and technological resources is continually improved; and
- Overall risk of contamination to human health and ecological receptors from SRS sources is eliminated or reduced.

For each groundwater project, the following actions occur: (1) the appropriate regulatory framework is developed with the regulatory agencies (USEPA and SCDHEC) and USDOE; (2) the degree and extent of contamination is determined through characterization efforts; and, if warranted, (3) a strategy for remediating the contaminated groundwater to its original beneficial use is decided.

Remedial actions are often applied to the groundwater contamination source. For instance, soil vapor extraction (SVE), which is pulling contaminated soil vapor from the subsurface, is widely used at SRS to remove VOCs from the unsaturated (vadose) zone. Other remedial technologies that have been recently deployed to the vadose zone include heating (steam or electrical resistance), chemical oxidation, and enhancing natural biodegradation through nutrient additions. Heating has also been used to volatilize tritium that has sorbed to concrete slabs.

Groundwater remedial technologies that have been and are being implemented at SRS include pump and treat systems, in situ pH adjustments, steam injection, phytoremediation, biodegradation, natural attenuation, and subsurface barriers construction. These

technologies are implemented with the intent of managing contaminant flux and reducing contaminant exposure risk to human health and ecological receptors.

Monitoring SRS Groundwater

The objective of the SRS groundwater monitoring program is to ensure that groundwater contamination is not being released offsite. SRS groundwater discharges into various site streams and/or the Savannah River. To date, no offsite wells have been contaminated by groundwater from SRS. Additionally, the majority of the SRS groundwater plumes are located in the center of SRS and do not pose a risk of offsite contamination. A/M Area is the site of a significant VOC plume. The groundwater monitoring program for A/M Area utilizes more than 150 wells for monitoring the plume. Some of these monitoring wells lie within a half-mile of SRS's northwestern boundary. While it is known that the major component of groundwater flow in the area parallels the site boundary, groundwater flow direction can fluctuate. For this reason, particular attention is paid to the groundwater results from the wells located along the site boundary and between A/M Area and the nearest population center, Jackson, South Carolina (figure 23 of the "Environmental Data/Maps - 2011" Appendix located on the accompanying CD).

In 2009, trichloroethylene (TCE) was detected at well MSB91 at a concentration of 1.6 µg/L which is below the drinking water standard (maximum concentration limit [MCL] is 5 µg/L). As a result, MSB91 was sampled quarterly during 2010. The second quarter groundwater sample had a detection of TCE at 3.92 µg/L, still below the MCL. The other three quarterly samples had results that were below the TCE detection limit (0.25 µg/L). Furthermore, the 2011 sampling events continue to indicate that TCE concentrations are below the detection limit.

Since the early 1990s, considerable effort has been directed at assessing the likelihood of trans-river flow from South Carolina to Georgia. Forty-four wells were drilled by the U.S. Geological Survey (USGS) and the Georgia Department of Natural Resources (figure 24 of the "Environmental Data/Maps - 2011" Appendix located on the accompanying CD). A groundwater model developed by the USGS indicates there is no mechanism by which trans-river flow could contaminate Georgia wells [Cherry 2006]. Despite the model results, SRS continues to maintain and sample the Georgia monitoring wells on an annual basis. The 2011 sampling results for tritium confirm that none of the Georgia wells are exceeding a concentration of 1,000 pCi/L. Tritium concentrations of 1000 pCi/L or less are consistent with aquifer recharge from rainfall in the SRS area. The MCL for tritium is 20,000 pCi/L.

Although most of the contaminated groundwater plumes at SRS do not approach the site boundary, the potential to impact site streams does exist. Therefore, extensive monitoring is conducted adjacent to and near SRS waste sites and operating facilities, regardless of their proximity to the boundary.

Table 7-1 presents a general summary of the most contaminated groundwater conditions at SRS, based on 2011 monitoring data. The selected wells are from the large plumes at A/M-Area, F/H-Area Seepage Basins, and at the Mixed Waste Management Facility (E Area). The table shows the 2011 maximum concentrations for major constituents in SRS areas that have contaminated groundwater and compares these values to the appropriate drinking water standards. As shown in the table, the two major contaminants of concern in the groundwater are common degreasers (TCE and tetrachloroethylene [PCE]) and radionuclides (tritium, gross alpha, and nonvolatile beta emitters).

All groundwater monitoring results collected during 2011 are included in data table 7-1 of the "Environmental Data/Maps-2011" Appendix located on the accompanying CD. Though it is impractical to provide maps of all wells; Universal Transverse Mercator (UTM) coordinates for each well are included and can be used in conjunction with figure 25 of the "Environmental Data/Maps - 2011" Appendix located on the accompanying CD to find the approximate locations of the wells. Time-versus-concentration plots for representative wells and contaminants are shown in figure 7-3. The selected wells are from the plumes in A/M-Area, F/H-Areas, and K-Area. As shown in the plots, contaminant concentrations in these wells has decreased through time due to the remedies in place and/or the attenuation process occurring.

TCE contaminant plumes are shown in figures 26-28 of the "Environmental Data/Maps - 2011" Appendix located on the accompanying CD for various aquifers in A/M-Area. Likewise, tritium contaminant plumes for E- and F/H-areas are shown in figures 29-31 of the "Environmental Data/Maps - 2011" Appendix located on the accompanying CD. Details concerning groundwater monitoring and conditions at individual sites are discussed in SRS site-specific documents, such as RCRA corrective action reports or RCRA/CERCLA facility investigation/remedial investigation reports.

Table 7-1 Summary of Maximum Well Monitoring Results for Major Areas within SRS (2011)

Location	Major Contaminant	Units	2011 Maximum Concentration	Well	MCL[a]	Likely Discharge Point
A/M Area	Trichloroethylene	µg/L	54,000	RWM 1	5	Tims Branch/Upper Three Runs in Swamp in West
	Tetrachloroethylene	µg/L	41,000	MSB101B	5	
C Area	Trichloroethylene	µg/L	2,320	CRW020D	5	Fourmile Branch and Castor Creek
	Tetrachloroethylene	µg/L	25	CRW020D	5	
	Tritium	pCi/mL	2,970	CDB 1	20	
CMP Pits	Tetrachloroethylene	µg/L	643	CMP 10C	5	Pen Branch
	Trichloroethylene	µg/L	707	CMP 10C	5	
	Lindane	µg/L	1.95	CMP 35D	0.2	
D Area	Trichloroethylene	µg/L	286	DCB 62	5	Savannah River Swamp
	Tritium	pCi/mL	231	DCB 26AR	20	
E Area	Tritium	pCi/mL	64,700	BSW 4D2	20	Upper Three Runs/ Crouch Branch in North; Fourmile Branch in South
	Trichloroethylene	µg/L	400	BSW 4D2	5	
F Area	Tritium	pCi/mL	60.6	FSL 15D	20	Upper Three Runs/ Crouch Branch in North; Fourmile Branch in South
	Trichloroethylene	µg/L	37.9	FGW005 C	5	
	Gross Alpha	pCi/L	1,830	FGW005 C	15	
	Nonvolatile Beta	pCi/L	707	FGW005 C	4 mrem/yr[b]	
F-Area Seepage Basin	Tritium	pCi/mL	3,520	FSB 94C	20	Fourmile Branch
	Gross Alpha	pCi/L	652	FSB 94C	15	
	Nonvolatile Beta	pCi/L	1,490	FSB 94C	4 mrem/yr[b]	
H Area	Trichloroethylene	µg/L	6.1	HGW 3D	5	Upper Three Runs/ Crouch Branch in North; Fourmile Branch in South
	Gross Alpha	pCi/L	6.11	HR3 16DU	15	
	Nonvolatile Beta	pCi/L	65.5	HAA 15A	4 mrem/yr[b]	
H-Area Seepage Basin	Tritium	pCi/mL	1,980	HSB70C	20	Fourmile Branch
	Gross Alpha	pCi/L	44.8	HSB102D	15	
	Nonvolatile Beta	pCi/L	648	HSB116D	4 mrem/yr[b]	
K Area	Tritium	pCi/mL	980	KDB 2	20	Indian Grave Branch
	Tetrachloroethylene	µg/L	16.1	KRP 9	5	
	Trichloroethylene	µg/L	16.4	KRP 9	5	
L Area	Trichloroethylene	µg/L	9.65	LAC 8DL	5	L-Lake
	Tetrachloroethylene	µg/L	43.1	LSW 25DL	5	
	Tritium	pCi/mL	642	LSW 25DL	20	
P Area	Tritium	pCi/mL	18,000	PSB011DL	20	Steel Creek
	Tetrachloroethylene	µg/L	400	PGW029DL	5	
	Trichloroethylene	µg/L	5,200	PGW026DL	5	
R Area	Trichloroethylene	µg/L	15.9	RAG008DL	5	Mill Creek in Northwest; Tributaries of PAR Pond
	Tritium	pCi/mL	1,500	RPS004C	20	
	Strontium-90	pCi/L	26.9	RPC 11DU	8	
Sanitary Landfill	Trichloroethylene	µg/L	7.44	LFW 32	5	Upper Three Runs
	Tetrachloroethylene	µg/L	5.71	LFW 59D	5	
	Vinyl Chloride	µg/L	91.9	LFW 21	2	
TNX	Trichloroethylene	µg/L	130	TRW 3	5	Savannah River Swamp

[a] MCL = Maximum Contaminant Level

[b] The activity (pCi/L) equivalent to 4 mrem/yr varies according to which specific beta emitters are present in the sample.

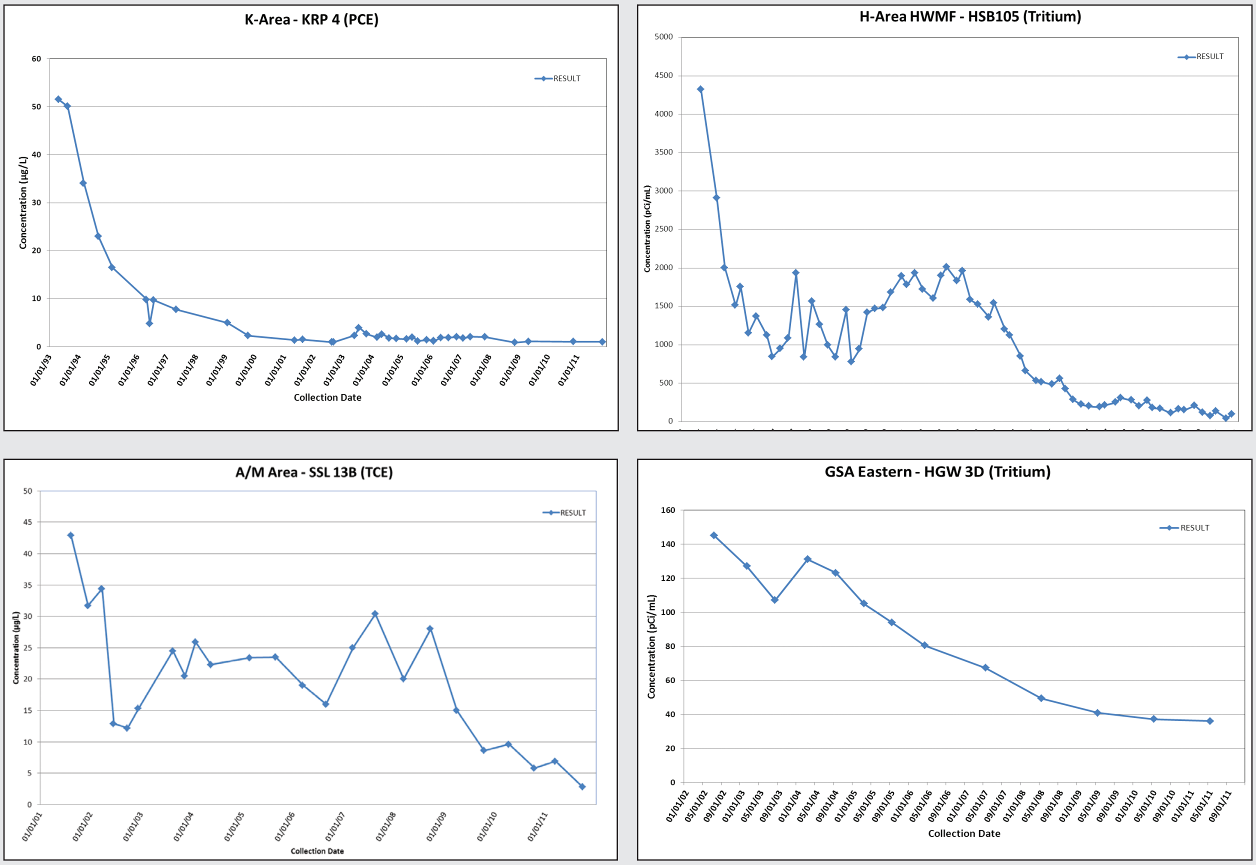


Figure 7-3 Concentration verses Time Plots for Representative Wells at SRS