# APPENDIX J

# GROUNDWATER CONTAMINATION AND THE POTENTIAL FOR OFFSITE MIGRATION

# APPENDIX J

# GROUNDWATER CONTAMINATION AND THE POTENTIAL FOR OFFSITE MIGRATION

## ABSTRACT

This appendix describes the various geological formations and associated aquifers that direct the flow of groundwater in the environs of the Savannah River Site (SRS). It also discusses the potential for offsite migration of groundwater and associated contaminant transport based on water flow in the aquifers underlying the SRS. Although groundwater contamination from SRS releases may be a potential exposure pathway for the future, the evidence suggests that it did not impact offsite residents before 1992.

## INTRODUCTION

Operations at the SRS have resulted in groundwater contamination at several locations around the Site, including areas below seepage and retention basins. However, the accumulated groundwater monitoring data suggest that the potential for contamination of offsite groundwater is limited. Most of the impacted areas are near the interior of the Site, and the underlying groundwater outcrops at seep lines along the various Site streams eventually traveling offsite to the Savannah River. Surface water release estimates made for the Site streams (discussed in Chapter 5) are based on water concentrations measured at the location where the streams cross Road A. This sampling location is downstream from most of the impacted groundwater below seepage and retention basins at separations and reactor areas. The measurements result in surface water estimates that include potential contributions from the groundwater pathway that may be related to Site activities.

Groundwater below the M-Area, A-Area, D-Area, and TNX is closer to the Site boundary. Measurements made in 1993 indicate the plume of contamination in groundwater below the M-Area and A-Area to be near the Site boundary (Arnett et al. 1994). While this plume may eventually contaminate offsite groundwater, groundwater does not appear to be an exposure pathway to people living offsite before 1992. If this is the case, groundwater contamination is not an important factor in estimating historical dose from past SRS releases, but groundwater data may require further evaluation to estimate potential current or future offsite exposures. Figure J-1 shows the primary operational onsite areas and major Site streams and roads.

## SAVANNAH RIVER SITE GEOLOGY

The geologic and hydrogeologic systems that control groundwater flow in the vicinity of the SRS are complex. Siple (1967) established three roughly separable systems consisting of (1) crystalline basement rocks composed of metamorphic and intrusive igneous rocks, (2) hardened Triassic-aged sediments, and (3) overlapping, weakly consolidated Cretaceous-aged and more recently deposited coastal plain sediments.

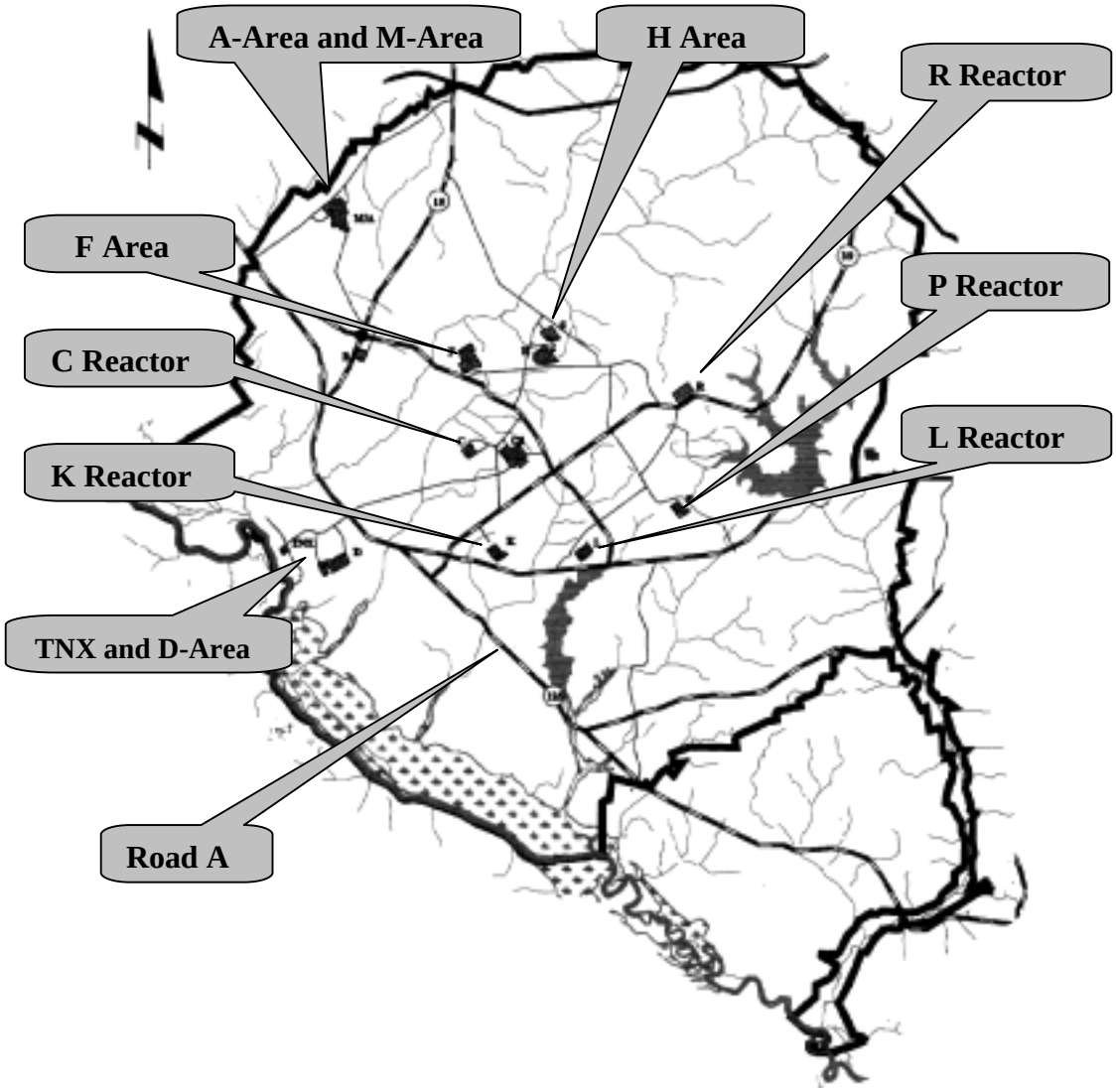


**Figure J-1.** The SRS showing the reactor (C-Area, K-Area, L-Area, P-Area, and R-Area) and processing (F-Area and H-Area) areas, TNX, D-Area, M-Area, and A-Area. The Site occupies approximately 300 $mi^2$ at the boundary of Georgia and South Carolina near Augusta, Georgia, and Aiken, South Carolina.

The permeability of the basement and Triassic-aged rocks is likely low, and test wells have shown that the water they do contain in joints and fractures is geopressured with a high hydraulic head. Marine (1974) attributed this overpressuring to osmotic pressure across the overlying impermeable aquitards, but its origin is uncertain. Overlying the basement and Triassic-aged rocks is a blanket of hardened, poorly sorted clayey sediments that hydraulically separates and isolates the younger, overlying sedimentary materials from the Triassic-aged and basement rocks (Carlton et al. 1993).

The nomenclature for the various aquifers, aquitards, and confining systems has changed significantly within the past 30 years. The layer that separates the older basement and Triassic-aged rocks from the more recently deposited sediments is referred to by Aadland et al. (1992) as the Appleton Confining System, but it has also been called the Cape Fear Formation. The

Cretaceous-aged formations are referred to by Aadland et al. (1992) as the Dublin-Midville Aquifer system. This system includes the deepest aquifers and is the source of most of the pumped groundwater at the SRS. The system includes aquifers in the Peedee, BlackCreek, and Middendorf Formations, which have also been referred to as the Upper and Lower Tuscaloosa Aquifers. Aadland et al. (1992) refers to the upper Tertiary-aged formations as the Floridian Aquifer system, which is separated from the lower system by confining beds of the Black Mingo Group, particularly the New Ellenton Formation. Also included in the upper system are the Tobacco Road, Dry Branch, McBean, Congaree, and Williamsburg Formations. The upper aquifers have historically been referred to as the Hawthorn, Barnwell, and Congaree Aquifers. Figure J-2 shows a geologic cross section of the SRS.

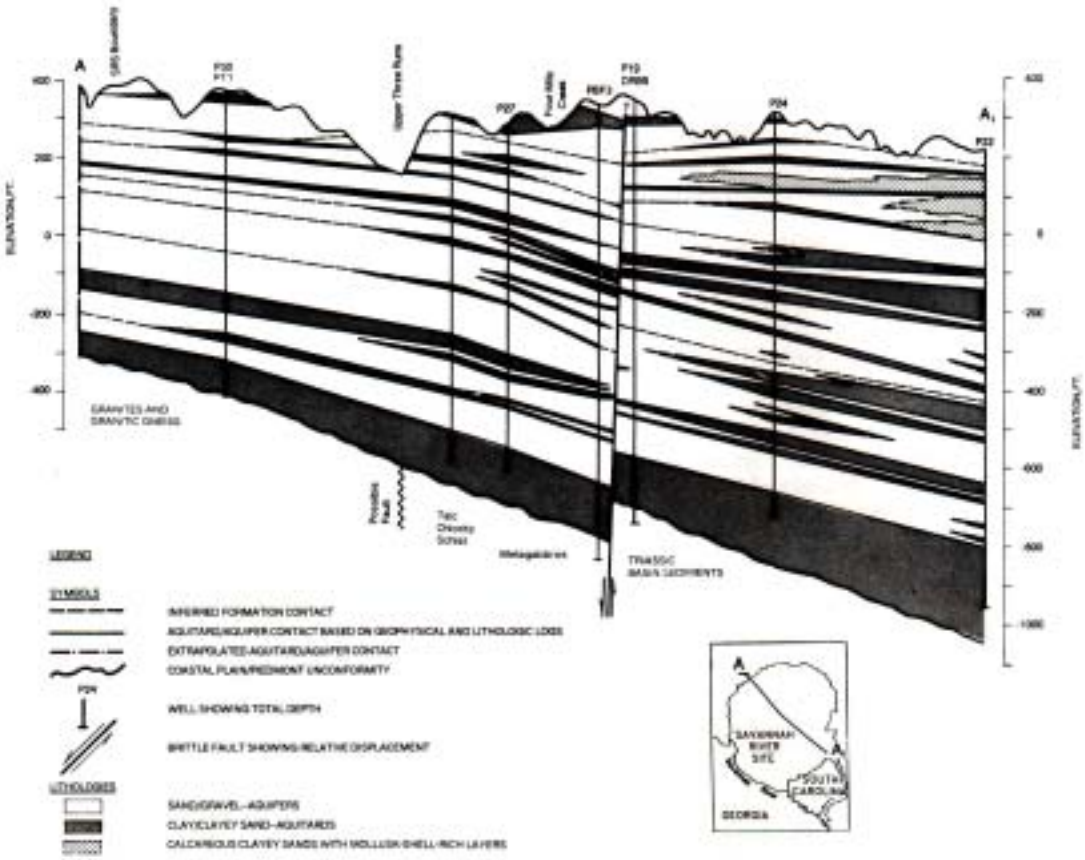


**Figure J-2.** Geologic cross section of the Savannah River Site. Sedimentary deposits of the Upper Coastal Plain near SRS consist primarily of alternating clay- and sand-rich layers with local carbonate-rich horizons. From Cummins et al. (1990).

Groundwater is used as a domestic, municipal, and industrial water supply throughout the Upper Coastal Plain. In Aiken County, municipal and industrial water supplies are primarily developed from the Cretaceous (lower) zone, and most domestic water supplies are developed from the Congaree-Fourmile and upper saturated zones in the Tertiary-aged sediments (Arnett et al. 1994). Potential contamination of surface water drinking supplies is discussed in Chapter 13

and Chapter 18 for radionuclides and chemicals, respectively. Figure J-3 shows the different stratigraphic units at the SRS. The Upper Cretaceous formations include what are know as the Upper and Lower Tuscaloosa Aquifers.

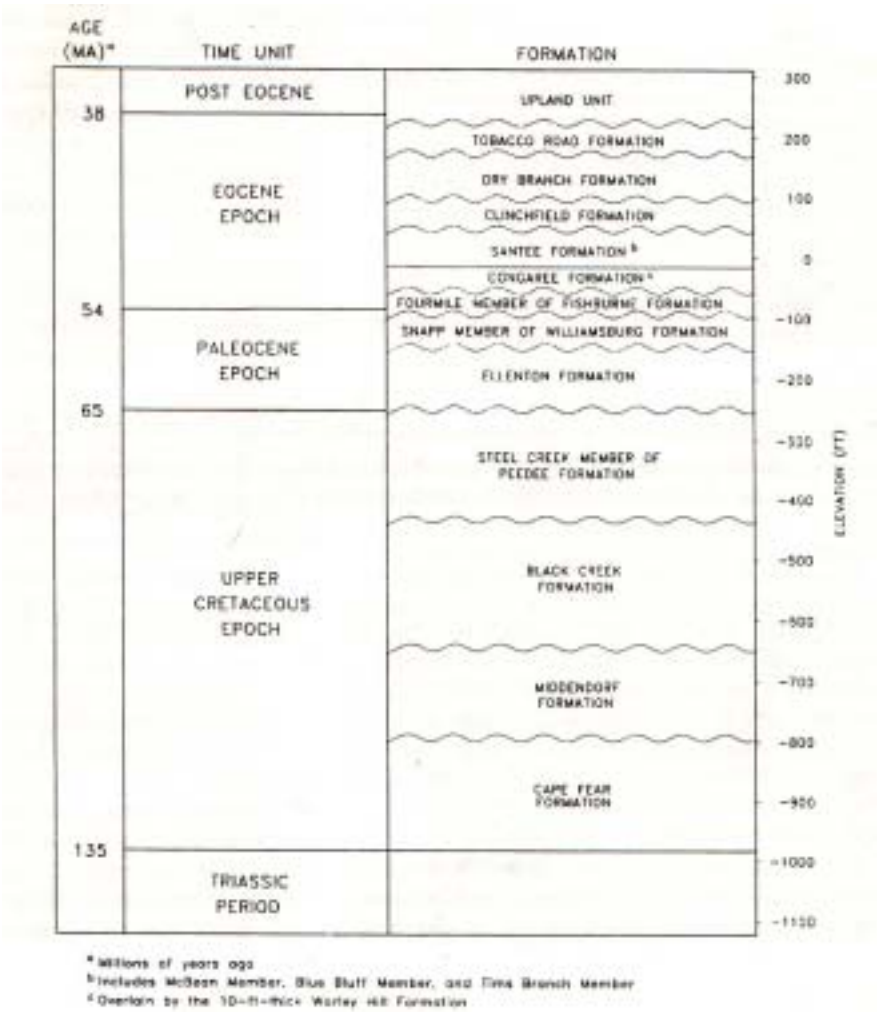


**Figure J-3.** Stratigraphic units at the SRS. Two regionally important aquifers, including the Upper and Lower Tuscaloosa Aquifers, occur in the Upper Cretaceous-age sandy sediments of the Middendorf, Black Creek, and Peedee formations. Aquifers in Eocene-age sediments are locally important but yield lower amounts of water. From Cummins et al. (1990).

The aquifers in the Tertiary-aged sediments receive local recharge, and flow at the water table is toward minor tributaries. Deeper aquifers generally flow toward the major Site streams. The deepest of the aquifers, those in the Cretaceous-aged sediments, including the Upper and Lower Tuscaloosa Aquifers, receive recharge at outcrop areas to the north of the Site, and groundwater flow is generally toward the Savannah River (Carlton et al. 1993).

The direction of vertical groundwater flow, and therefore contaminant transport, at any locality may change or even reverse in successively deeper aquifers. Beneath much of the SRS, hydraulic head decreases with depth, and the vertical flow of water is downward. This is the case

in the A-Area and M-Area, where discontinuous aquitards and downward-decreasing hydraulic head combine to allow water movement from the water table to deeper zones. R, P, and L reactor areas are also located in downward gradient areas, or recharge zones, for the lower aquifers. An upward gradient dominates at other areas, inhibiting downward groundwater flow to the deeper aquifers and directing flow to the upper aquifers in the Tertiary zone. This is the case in the F-Area and H-Area (separations areas), C and K reactor areas, D-Area, and TNX.

A-Area and M-Area, located approximately 0.5 mi from the nearest SRS boundary, are on a watertable mound. Horizontal groundwater flow is east toward Tim's Branch, southwest toward the Savannah River, and north and west toward drainage into lower topographic zones. The D-Area and the TNX are located approximately 0.75 and 0.25 mi from the nearest SRS boundary, respectively, and horizontal groundwater flow in these areas is toward the Savannah River and the nearby swamp. Horizontal groundwater flow at other SRS areas, including F-Area, H-Area, and the five reactor areas, is toward tributary streams draining into the major Site streams and eventually to the Savannah River.

## GROUNDWATER MONITORING

The SRS has been concerned with the potential for radionuclide contamination of groundwater since the early-1950s and began monitoring a number of onsite wells shortly after operations began. During the late 1960s, groundwater monitoring in the vicinity of the F-Area and H-Area seepage basins intensified to determine the impact of the seepage basins on radionuclides, nitrates, and pH in groundwater and in Four Mile Creek, which receives input from groundwater in this area (Fenimore and Horton 1973). The monitoring network has been expanded since then to include about 1200 monitored wells. Monitoring has been most extensive at onsite locations, and groundwater monitoring by the SRS has been limited at offsite locations. Figure J-4 shows the locations of groundwater monitoring wells in the vicinity of the SRS during 1995. Monitoring wells are densely populated around the separations, fabrication, and reactor areas onsite, but offsite wells are significantly less numerous.

The groundwater monitoring program for nonradioactive materials or chemicals (discussed in Chapter 19) was established in 1982 and was rather limited until the mid-1980s when extensive groundwater sampling and analysis began. Much of the groundwater data has been collected to support waste characterization and cleanup activities. Improvements were made to groundwater sampling and sampling preservation techniques in 1983, including better flushing of wells before sampling and sample filtration for metal analysis (Zeigler et al. 1985).

The Environmental Monitoring Section (EMS) of the Environmental Protection Department maintains the monitoring program, which includes wells at various onsite locations, particularly around waste disposal areas and seepage and retention basins. The EMS currently maintains both a radioactive and nonradioactive monitoring program. Two additional SRS organizations also monitor groundwater: the Raw Materials Engineering and Technology Department monitors for volatile organics in A-Area and M-Area, and the Interim Waste Technology Division of the Savannah River Laboratory monitors selected burial ground wells (Murphy et al. 1991).

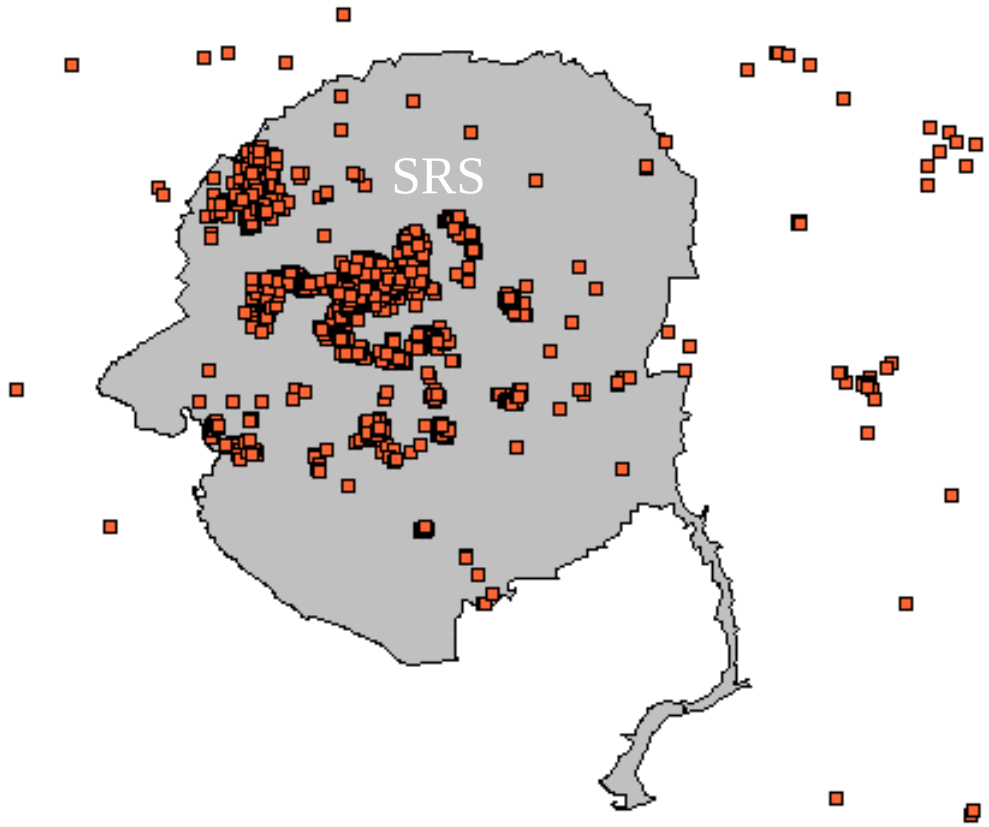


**Figure J-4.** Locations of SRS-maintained groundwater monitoring wells during 1995. These data are part of the Geographic Information System (GIS) coverages that are described in detail in Appendix F.

The EMS samples groundwater as part of the ongoing routine groundwater monitoring program or in response to specific requests from SRS personnel. The routine program schedules wells to be sampled semiannually, annually, or biannually, but requests by personnel outside the EMS result in monthly or quarterly sampling for many wells. New wells added to the program are initially sampled for four consecutive quarters for a comprehensive list of constituents. Sampling for this comprehensive list of constituents is also carried out for all active wells biannually (except for several older wells not properly constructed for such extensive sampling). Those wells with measured constituent concentrations exceeding a certain level are routinely sampled either annually or semiannually depending on the measured concentrations. All active wells are monitored quarterly for pH, temperature, specific conductance, alkalinity, and water level (Cummins et al. 1991).

## PLUME DEFINITION WELLS

In addition to the network of routine groundwater monitoring wells, the SRS has established numerous plume definition wells to track the movement of contaminant plumes in the A-Area and M-Area, the F-Area and H-Area, and the TNX. Contaminant plumes in these areas are discussed in the following three sections.

## M-Area and A-Area

The plume definition wells at A-Area and M-Area were installed after volatile organic contamination of the underlying groundwater was discovered in June 1981. The principal sources of contamination appear to be the solvent storage tank area, the M-Area settling basin, and the A-14 sewer outfall (Marine and Bledsoe 1984). The contamination plume, defined as water with contaminant concentrations above the primary drinking water standard (which consists primarily of trichloroethylene and, to a lesser extent, tetrachloroethylene and other chlorinated solvents), extended to wells within approximately 2000 ft of the nearest SRS boundary in 1993 (Arnett et al. 1994). Based on data provided by Marine and Bledsoe (1984), concentrations of trichloroethylene and tetrachloroethylene above the drinking water standard extended to wells within approximately 5000 ft from the plant boundary in 1984. This suggests that the contaminant plume moved toward the Site boundary at a rate of more than 250 ft $y^{-1}$ between 1984 and 1993. It should be noted that reported distances from the leading edge of the contaminant plume to the nearest plant boundary appear to be general approximations, and this report does not make conclusions about their accuracy. Marine and Bledsoe (1984) reports a horizontal flow velocity of 20 to 25 ft $y^{-1}$, which is more than an order of magnitude lower based on flow velocity, water table gradient, effective porosity, and hydraulic conductivity.

The offsite wells (Figure J-4) are positioned too far from the SRS boundary to determine conditions near the boundary. However, recently installed wells close to the Site boundary near Green Pond Road are located between the leading edge of the contaminant plume and the Site boundary and do not show contamination at the Site boundary (Heffner 1998). Additionally, the residences nearest the Site boundary were connected to the New Ellenton municipal water system some time ago. Therefore, they do not rely on water supplied from the underlying aquifers, which may be impacted by the contaminant plume (Heffner 1998).

Changes in analyte concentration over time are also difficult to interpret because of groundwater remedial activities, which have significantly impacted groundwater flow in this area (Arnett et al. 1994). A groundwater remediation program has been in place at A-Area and M-Area since April 1985, and approximately 300,000 lb of solvents had been removed from nearly 1.75 billion gallons of groundwater as of September 1993 (Arnett et al. 1994). Groundwater contamination by chlorinated solvents resulting from M-Area operations and subsequent remedial air stripping are also addressed in Chapter 17.

Groundwater contamination extended vertically downward to the aquitard separating the upper aquifer system (Tertiary-aged formations) from the lower aquifer system (Cretaceous-aged formations) in 1984 based on M-Area well monitoring (Marine and Bledsoe 1984). Contamination extending into the lower system (frequently referred to as the Tuscaloosa Aquifer) was not evident, but the potential for downward migration exists because of the downward hydraulic head gradient in this area. Arnett et al. (1994) reported that trichloroethylene was detected above the drinking water standard (0.005 mg $L^{-1}$) in two wells in the Black Creek Unit, which is part of the Cretaceous-aged formations. Therefore, there is some indication that contamination is migrating downward into the lower aquifer system (Tuscaloosa Aquifer). The aquitards separating the lower aquifers of the upper aquifer system do, however, retard downward migration into the upper aquifers of the lower aquifer system. Additionally, the remedial efforts at M-Area and A-Area in the upper aquifer system have likely reduced the hydraulic drive toward

the deeper formations, as well as helped direct the lateral flow away from the Site boundary (Marine and Bledsoe 1984).

Although some contamination of the lower aquifer system does apparently exist, the leading edge of the contaminant plume, as discussed previously, was positioned approximately 2000 ft from the Site boundary in 1993. Furthermore, recently installed wells close to the Site boundary do not indicate local groundwater contamination (Heffner 1998). Therefore, it does not appear to represent an exposure pathway to members of the public before 1992.

### Separations Areas

A number of plume definition wells were installed in the F-Area and H-Area (separations areas) in 1951 and 1952. These wells historically were used to monitor for radioactive constituents, and they were monitored for chemical constituents for the first time in 1993 (Arnett et al. 1994). Groundwater in the southern portion of these areas discharges to Four Mile Creek and its tributaries; in the northern portion of these areas, groundwater discharges to Upper Three Runs Creek and its tributaries (Cummins et al. 1991).

Vertical flow of groundwater contaminants is restricted by an aquitard, commonly referred to as the "green clay," and is generally confined to the shallower aquifers in the upper aquifer system. Additionally, the upward hydraulic head gradient in this area inhibits contaminant migration to the lower aquifer system. Both sets of seepage basins are on the slopes of the water table, and underlying groundwater is directed by the horizontal flow pattern toward Four Mile Creek, so the potential for offsite groundwater contamination is low.

### TNX

TNX groundwater has been designated as a Resource Conservation and Recovery Act/Comprehensive Environmental Response, Compensation and Liability unit because of a contaminant plume consisting primarily of volatile organics that extends toward the Savannah River. Based on data from plume definition wells, the trichloroethylene plume in the Savannah River swamp extended to within approximately 500 ft of the Savannah River in 1990 (Cummins et al. 1991). Groundwater in this area discharges to the Savannah River and the nearby swamp.

Only formations in the upper aquifer system between elevations (above sea level) of about 150 and 100 ft have the potential for contamination, which is confined to the immediate vicinity of the basins. The upward hydraulic head gradient in this area prohibits downward migration of groundwater, and the potential for contamination of the deeper sediments is extremely low (Marine and Bledsoe 1984). The nearest Site boundary, the Savannah River, is approximately 1000 ft to the west of TNX, and contaminant migration through the intervening Savannah River swamp appears to be slow.

## OTHER POTENTIAL SOURCES OF CONTAMINATION NEAR THE SRS BOUNDARY

The Savannah River Laboratory (SRL) seepage basins are located east of the A-Area, approximately 4000 ft southeast of the nearest Site boundary. Groundwater sampling indicates low-level contamination in the upper aquifer system, and, as in A-Area, the potential for

downward contaminant migration exists because of the downward hydraulic head gradient in this area. Based on water table elevations, horizontal movement appears to be toward the Site boundary. The relatively flat water table in this area results in a small horizontal gradient, however, and horizontal movement is likely slow (Marine and Bledsoe 1984).

The Silverton Road waste site is located about 1.5 mi west of M-Area, approximately 3200 feet from the nearest Site boundary (on U.S. Forest Service land). However, the nearest boundary down the groundwater gradient is approximately 10,500 ft to the southwest. Monitoring indicates volatile organic contamination in the upper aquifer system, and, as in M-Area, the potential for downward migration exists. The horizontal groundwater gradient at this location is toward the Site boundary, so there is potential for eventual offsite migration. However, the rate of migration is likely slow because of the relatively flat water table (Marine and Bledsoe 1984).

## AVAILABLE DATA

A number of groundwater-related datasets are available and are being provided to the Centers for Disease Control and Prevention with this report, including several geographic information system coverages that are described in detail in Appendix F. The SRS groundwater monitoring locations shown in Figure J-4 are examples of the types of data that are available.

Additionally, coverages are being provided for U.S. Geological Survey groundwater quality data and water table elevation contours. Figure J-5 shows U.S. Geological Survey groundwater monitoring well locations in the vicinity of the SRS. The wells are clustered most heavily along the eastern edge of the Site, and there are relatively few wells in the vicinity of TNX, D-Area, M-Area, and A-Area.

## CONCLUSIONS

Although groundwater contamination from SRS releases may be a potential exposure pathway for the future, the evidence suggests that it did not impact offsite residents before 1992. Most of the groundwater flow in contaminated areas at the SRS is toward Site streams and eventually the Savannah River. It does not appear that the groundwater monitoring data could be used to increase the accuracy of our surface water release estimates. These estimates, which are based on water concentrations measured in Site streams at Road A, include possible contributions from contaminated groundwater in the separations and reactor areas.

A potential exists for future contamination of offsite groundwater resulting from activities in A-Area and M-Area. As of 1993, the contamination plume beneath these areas, characterized by chlorinated solvent concentrations above the primary drinking water standard, extended to wells within about 2000 ft of the nearest Site boundary. However, remedial programs have significantly decreased the amounts of contamination, and the plume does not appear to have reached the Site boundary. However, evidence suggests that the contaminant plume is migrating downward into the lower aquifer system. There is also the potential for the contaminant plume in groundwater below the TNX to eventually extend and discharge to the Savannah River, and groundwater below the SRL seepage basins and the Silverton Road waste site appears to be migrating toward the Site boundary.

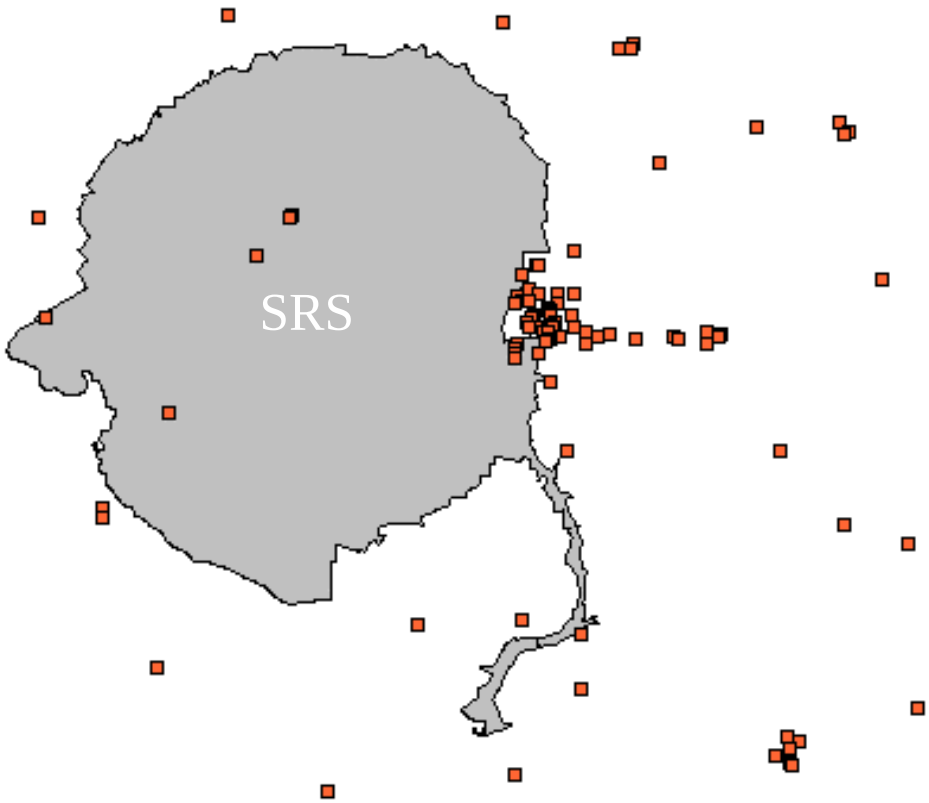


**Figure J-5.** Locations of groundwater monitoring wells maintained by the U.S. Geological Survey.

Additional groundwater data may be necessary to thoroughly examine the potential for current or future public exposure. However, it does not appear that these data are necessary for establishing historical offsite exposure through contaminated groundwater, which does not appear to have been a complete pathway during the 1953–1992 period covered by this historical dose reconstruction study.

## REFERENCES

Aadland, R.K., P.A. Thayer, and A.D. Smits. 1992. "Hydrostratigraphy of the Savannah River Site Region, South Carolina and Georgia." *Geological Investigations of the Central Savannah Area, South Carolina and Georgia*. Edited by Wallace Fallaw and Van Price. Carolina Geological Society Field Trip Guide Book, South Carolina Geological Survey, Columbia, South Carolina. November 13–15. OpenLit.

Arnett, M.W., L.K. Karapatakis, and A.R. Mamatey. 1994. *Savannah River Site Environmental Report for 1993*. WSRC-TR-94-075. Westinghouse Savannah River Company. SRS Phase II Database KRM199710132.

Carlton, W.H., A.G. Evans, L.A. Geary, C.E. Murphy, Jr., J.E. Pinder, and R.N. Strom. 1993. *Assessment of Plutonium in the Savannah River Site Environment*. WSRC-RP-92-879, Rev. 1. Westinghouse Savannah River Company, Savannah River Technology Center. SRS Phase II Database MJC199405138.

Cummins, C.L., D.K. Martin, and J.L. Todd. 1991. *Savannah River Site Environmental Report. Annual Report for 1990. Volume I, Environmental Monitoring Compliance and Research, Volume II, Groundwater Monitoring.* WSRC-IM-91-28. Westinghouse Savannah River Company. SRS Phase II Database MOL1993120613 and MOL1993120614.

Fenimore, J.W. and J.H. Horton. 1973. *Operating History and Environmental Effects of Seepage Basins in Chemical Separations Areas of the Savannah River Plant*. DPST-72-548. SRS Phase II Database HRM199308315.

Heffner, J. 1998. Westinghouse Savannah River Company. Personal Communication with J. Mohler, Consultant to *Radiological Assessments Corporation*. Subject: Information Regarding Location of M-Area Solvent Plume. SRS Phase II Database Interview 32. August 24.

Marine, I.W. 1974. "Geohydrology of the Buried Triassic Basin at the Savannah River Site, South Carolina." *American Association of Petroleum Geologists Bulletin* 58: 1825–1837. OpenLit.

Marine, I.W. and H.W. Bledsoe. 1984. *M-Area Groundwater Investigation: Supplemental Technical Data Summary*. DPSTD-84-112. SRS Phase II Database SKR1993093014. October.

Murphy, C.E., Jr., L.R. Bauer, D.W. Hayes, W.L. Marter, C.C. Zeigler, D.E. Stephenson, D.D. Hoel, and D.M. Hamby. 1991. *Tritium in the Savannah River Site Environment*. WSRC-RP-90-424-1. SRS Phase II Database MJC1994051310. May.

Siple, G.E. 1967. *Geology and Ground Water of the Savannah River Site and Vicinity*. South Carolina U.S. Geological Survey Water Supply Paper 1841. U.S. Government Printing Office, Washington, D.C. OpenLit.

Zeigler, C.C., I.B. Lawrimore, and W.E. O'Rear. 1985. *Environmental Monitoring at the Savannah River Plant, Annual Report 1984*. DPSPU-85-302. Health Protection Department, Savannah River Plant, Du Pont. SRS Phase II Database MJC1994051722. June.