

Use of Geographic Information System to Assess Groundwater Monitoring Well Integrity in a Large Well Network at the Savannah River Site

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Abstract

Groundwater samples taken from wells that lack well construction integrity may produce unreliable data. One of the principal well construction integrity issues is whether the well filter-pack zone breaches an overlying or underlying confining unit. Examining well geophysical logs and related well data to identify wells with screen and filter-pack zones that may breach a confining unit is a time-intensive process. GIS, therefore, was utilized as an inexpensive screening tool to determine which wells at the Savannah River Site's administrative and technical area potentially penetrate into or breach confining units. Three dimensional gridded surfaces representing the interfaces of aquifer and confining units were used in conjunction with well construction data obtained from a relational database in a GIS application written to locate well screen and filter-pack zone top and bottom elevations within the vertical hydrostratigraphy. The application then was used to identify wells with screen and filter-pack zones that potentially breach a confining unit. Use of these software tools enabled the efficient identification of 66 monitoring wells that may breach a confining unit within the Savannah River Site's technical and administrative area. Geophysical logs from these wells will be examined to determine whether they should be removed from service.

Introduction and Background

The Savannah River Site (SRS) is a large federal facility, approximately 325 square miles in size, operated by the Department of Energy (DOE) in South Carolina. The site is located along the Savannah River close to the city of Augusta, Georgia. The location of SRS is illustrated in Figure 1. Land for the facility was acquired in 1950 and through the years various facilities have been operated to support national defense and space exploration. As a result of these activities, there have been inadvertent releases of contaminants to the environment. Many waste materials were disposed of in shallow seepage basins, which was considered a best management practice during those times. Over time, contaminants have leached from the disposal facilities and have been released to the subsurface environment.

In the late 1970's and early 1980's, the awareness of environmental contamination issues began to grow and an extensive environmental monitoring program was implemented at SRS. The groundwater monitoring program is a subset of the environmental monitoring program and is conducted primarily for the purpose of maintaining compliance with the Resource Conservation and Recovery Act (RCRA) and other associated South Carolina regulations.

The groundwater monitoring program has grown dramatically in the last 15 years, with the number of monitoring wells now totaling approximately 2000, of which 570 are located in the A/M Area, which is the technical and administration area of SRS and the focus of this investigation. In addition to monitoring wells that are utilized for routine groundwater monitoring, the well network also includes piezometers, research wells, and other special use wells. The routinely monitored wells are categorized, for regulatory purposes, as either Point of Compliance wells, Background wells, or Plume Definition wells. Each of the different well types have a different sampling frequency and are analyzed for different suites of contaminants. The specific suites of analyses are selected to coincide with contaminants that have been disposed of at nearby waste sites.

Groundwater monitoring wells are installed to allow information to be obtained in specific aquifers. Many wells are part of a network and are routinely sampled to provide monitoring of the groundwater chemistry for specific aquifers. Great care must be taken in the well installation process to ensure that the screen zone is appropriately located within the subsurface sediments to allow monitoring of the groundwater in the desired aquifer. Usually all available information is reviewed prior to installation of a new well. Typical types of information include geophysical logs from other previously installed wells located near the new well location, as well as any descriptive geologic logs from these same wells. At many new well sites, several wells are installed at different depths. The deepest well is typically drilled and installed first to provide a geophysical log that can be used to locate screen elevations for the shallower wells at the same well cluster. After a borehole is drilled, well screen and casing is lowered into place such that the screen zone is located within the aquifer that is to be monitored. A monitoring well screen is typically 5 feet in length. Connected above the screen, and extending to the land surface, is solid casing. Well screens and casing are constructed of Polyvinyl Chloride. Once the well screen and casing are situated, gravel material is placed in the annular space between the casing and the borehole wall. Gravel is filled to an elevation several feet above the screen. An impermeable clay material is placed immediately above the gravel, above which grout is used to back fill the annular region to the land surface. These impermeable annular materials prevent the vertical migration of groundwater immediately adjacent to the well casing, thus allowing samples to be collected from the well which reflect groundwater conditions in the aquifer located adjacent to the screen zone. For various reasons, the construction of wells such that the screen zones and filter-pack material are perfectly located is sometimes a difficult task.

The great majority of wells installed at SRS since the early 1980's have been constructed such that representative samples can be collected from them. However, sample analyses from some wells suggest there may be a well construction problem. If confirmed, such problems might preclude the ability of these wells to obtain groundwater samples representative of the aquifer unit they were intended to monitor. In addition, the understanding of the hydrogeologic system has evolved over the past 15 years as more information has become available. The interpretation of the 3-dimensional configuration of the tops and bottoms of aquifers and confining units has been periodically updated. New interpretations can require the re-assignment of a well to an aquifer unit different than the one it was originally thought to monitor. Monitoring wells with a filter-pack zone which breaches a confining unit provide geochemical and hydrologic data that is not representative of the groundwater in a single aquifer unit. Moreover, wells with filter-pack and screen zones that incise confining units provide a preferential pathway for contaminants in near surface aquifer units to migrate to deeper units where production wells are typically located. Identification and evaluation of such wells is critical to the acquisition of reliable groundwater monitoring data and protection of deeper aquifer units.

This investigation was undertaken with the primary purpose of optimizing the groundwater monitoring program within the A/M Area. The objective was to identify wells which are not providing samples that accurately reflect the groundwater quality in the aquifer the well was installed to monitor. The approach utilized to investigate the A/M Area monitoring well network involved examining historical geochemistry data from individual wells and also comparing well screen and filter-pack elevations with the elevations of hydrostratigraphic unit top and bottom elevations to locate wells that might incise an overlying or underlying confining unit. Specifically, geochemical screenings were conducted to identify patterns of chemical analyses at individual wells which might indicate a problem with well construction, including chronically elevated pH and turbidity levels. Because of the limited space available, this paper addresses only the analysis to identify wells with screen and filter-pack zones that might incise a confining unit.

GIS was used to extract pertinent groundwater quality data from available ORACLE groundwater databases and to display the extracted information spatially. This same technology was also used to

determine the location of well screen and filter-pack zones within the A/M Area hydrostratigraphic units and to identify wells that may breach (extend entirely across) confining units within this system. This approach saved considerable time and monetary resources over traditional methods that have been used at SRS in the past to evaluate monitoring well construction integrity.

Hydrogeologic Model

SRS is located within the Upper Atlantic Coastal Plain Province, which extends from Mississippi to southeastern North Carolina. Beneath the Atlantic Coastal Plain Province is a wedge of seaward dipping, unconsolidated sediments which thicken progressively toward the edge of the continental shelf. In South Carolina, these sediments are more than 1.2 km thick near the coastline.

Beneath SRS, the wedge of sediments range in thickness from 180 to 370 meters and consists of interbedded gravel, sand, silt, and clay with some limestone. These sediments were deposited in near-shore marine environments. Locally, the sediments can be highly heterogeneous and exhibit a significant degree of variability in texture both horizontally and vertically. Layers that are regionally extensive tend to thin in the northwest direction and thicken in the southeastern, or seaward, direction.

The hydrostratigraphic units that occur beneath the A/M Area at SRS are depicted in Figure 2. These units, in descending order, are: the Steed Pond Aquifer, the Crouch Branch Confining Zone, and the Crouch Branch Aquifer. The Steed Pond Aquifer is divided into upper and lower aquifer zones by a confining unit that is somewhat discontinuous beneath the A/M Area. The upper aquifer zone is termed the M-Area Aquifer Zone while the lower aquifer zone is termed the Lost Lake Aquifer Zone. The confining zone is termed the Green Clay Confining Zone. Beneath the Steed Pond Aquifer, the Crouch Branch Confining Zone is also subdivided by a sandy zone, termed the "Middle Sand" Aquifer Zone. The overlying and underlying confining zones are termed the "Upper Clay" Confining Zone and the "Lower Clay" Confining Zone, respectively.

Groundwater moves through this system of layered sediments, proceeding from areas of recharge to areas of discharge. Recharge to the aquifer system results from deep infiltration of precipitation. Most of the recharge at SRS moves through the uppermost aquifer units and discharges locally along the reaches of perennial streams. Some of the recharge water moves into the deeper aquifers and eventually is discharged farther away at the regional discharge locations. Contaminants that leach from surface disposal basins are carried with the infiltrating water and will eventually pass through the system of sediments described above. The rate of groundwater movement is relatively slow and the contaminant plume beneath the A/M Area has not yet reached local discharge zones.

GIS Analysis

Well construction data for the Savannah River Site's network of approximately 2000 groundwater monitoring wells is housed in an ORACLE relational database. The first step in the GIS analysis of determining which wells in the SRS A/M Area might breach or penetrate into a confining unit involved accessing this well construction database to obtain well construction data for the 570 wells included in the study. The well construction database contains information such as well use, well geographic coordinates, depth to the top and bottom of screen and filter-pack zones, and materials descriptions for each filter-pack zone. This information was accessed using Oracle Structured Query Language (SQL) embedded in ArcView Avenue scripts so that the data could be imported directly into ArcView for analysis and display. The resulting well construction data was subsequently used to generate an ArcInfo point coverage with well construction data needed for the study included as attributes.

In order to determine the hydrostratigraphic units where the filter-pack zones are located for each monitoring well included in the study, a gridded hydrostratigraphic model was first required. This model consists of eight surfaces representing the elevations at regularly spaced x,y coordinates of A/M Area hydrostratigraphic interfaces described in the section above. These surfaces were contoured using EarthVision software by Dynamic Graphics, Inc. on a 500 ft. regularly spaced mesh and were converted to ArcInfo Grid coverages as part of this study. Minimum tension gridding was used in EarthVision to provide the best fit to the available hydrostratigraphic picks.

ArcInfo LATTICESPOT was then used to determine the vertical elevation on all eight surfaces corresponding to the x,y location of each well. This process may be visualized by placing a vertical line at each well x,y location such that the line penetrates the surfaces directly underlying the given well as depicted in Figure 3. LATTICESPOT was used to determine the vertical elevation where the vertical line intersects each surface and was used to write these elevations to the ArcInfo coverage containing the well construction data. A total of eight elevation attributes were added to the well construction coverage corresponding to the eight hydrostratigraphic surfaces.

The hydrostratigraphic unit containing the top and bottom of each filter-pack zone was determined using an ARC Macro Language (AML) routine written to compare the tops and bottoms of the filter-pack zone elevations with the corresponding elevations on all eight surfaces at each well x,y coordinate. For each well, attributes were written to the well construction coverage indicating the hydrostratigraphic unit name corresponding to the top and bottom filter-pack elevation.

Well filter-pack zones potentially breaching a confining unit were identified in the AML by comparing the hydrostratigraphic unit containing the top and bottom filter-pack location. A potential confining unit breach was identified if the top and bottom screen location hydrostratigraphic units were different. As a result of this analysis, 66 wells were identified which potentially incise a confining unit. The location of these wells is illustrated on Figure 4 overlaid on top of an aerial photograph of the A/M Area.

Conclusions and Recommendations

This investigation utilized GIS, a 3-D representation of hydrostratigraphic unit interfaces, and an ORACLE well construction database to conduct an automated screening of wells to determine the location of their screens and filter-packs within the hydrostratigraphic system. As a result of this screening, 66 wells have been identified which may have been constructed such that their screens or filter-pack zones extend entirely across a confining unit adjacent to the aquifer they were installed to monitor. These 66 wells represent approximately 11 percent of the wells that were screened.

Considerable time and monetary resources were saved using GIS as a screening tool to locate wells within the A/M Area network, which may have filter-pack zones located across confining units. Geophysical logs from these wells will be examined to determine whether these wells should be evaluated for removal from service.

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Figure 1. Location of the Savannah River Site

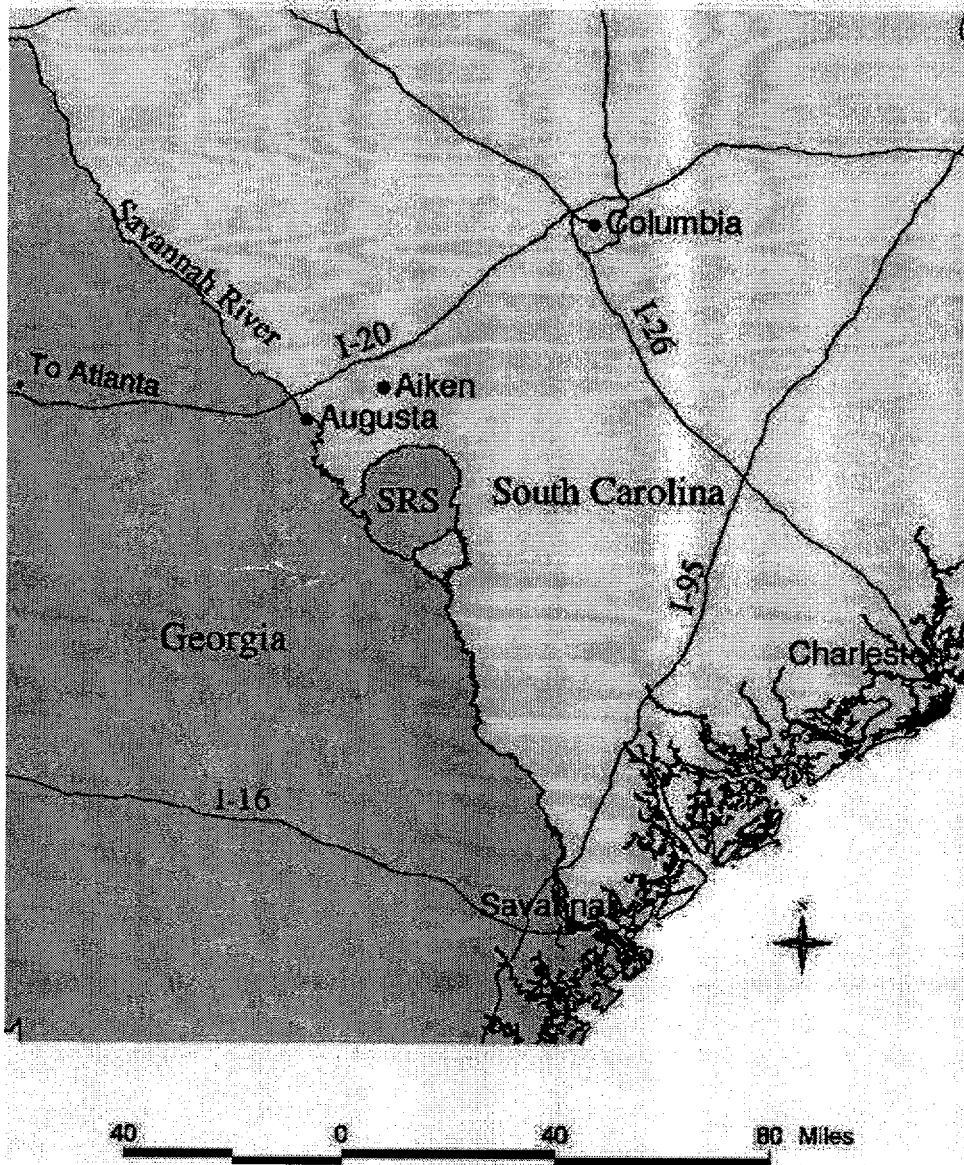


Figure 2. Representation of the Hydrostratigraphy of the A/M Area

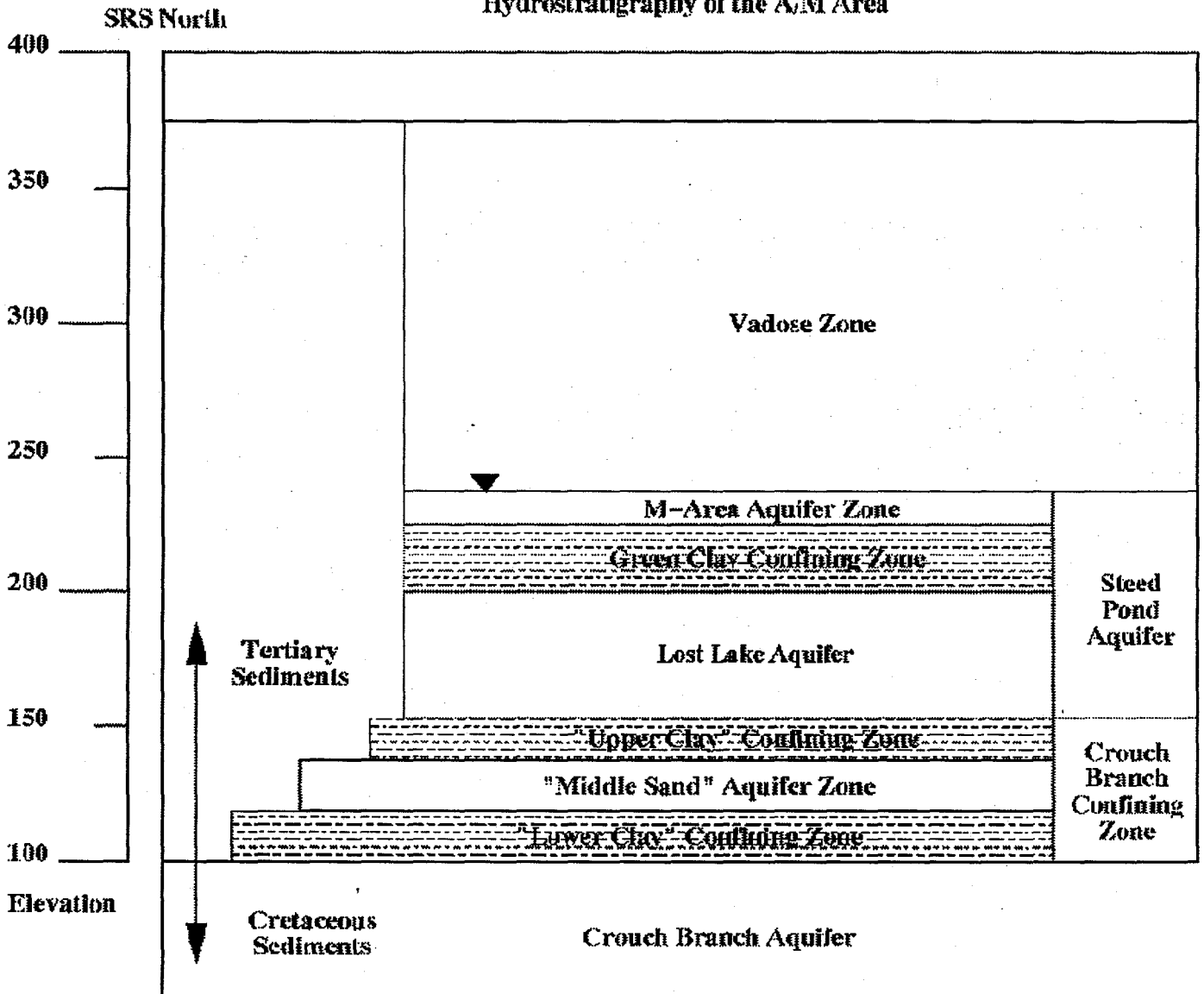


Figure 3. A/M Area Hydrostratigraphic Surfaces

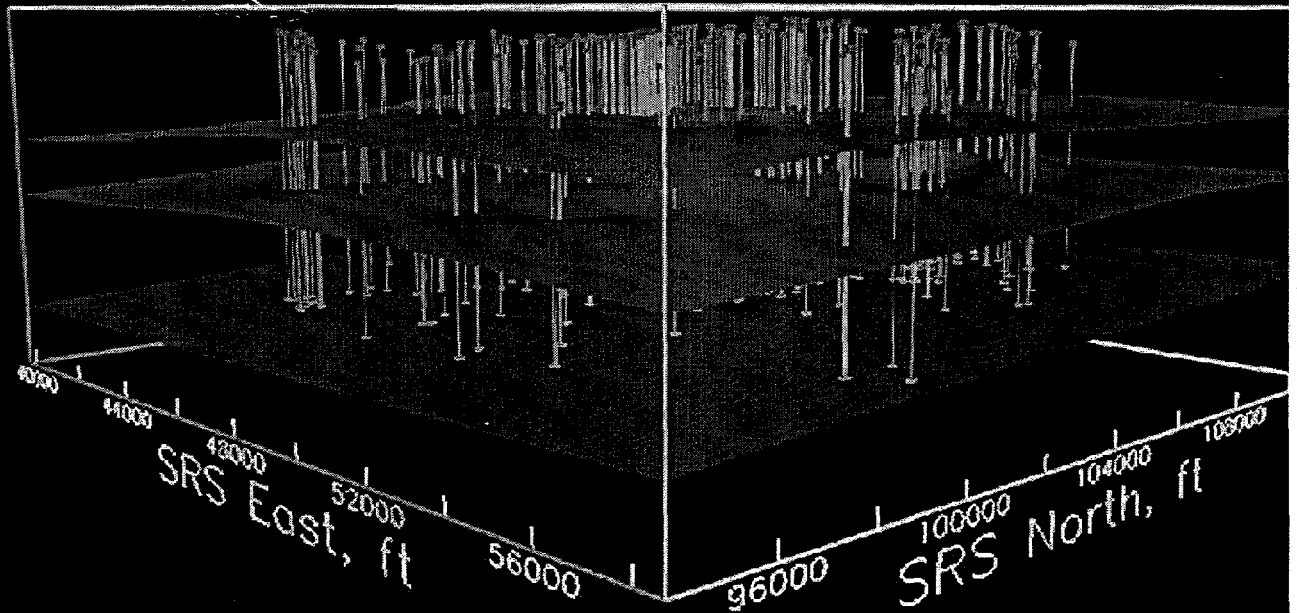


Figure 4. A/M Area Wells that Potentially Breach a Confining Unit



3000 0 3000 6000 Feet

