GIS MAPPING OF GROUND-WATER CONTAMINATION AT THE SAVANNAH RIVER SITE

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Abstract. Numerical simulation models are routinely used to predict the fate and transport of ground-water contaminants. These models rely on estimates of aquifer hydraulic properties instead of historical information because long-term water quality data are generally lacking. The Savannah River Site is unique in that a long-term, water-quality record is available for use in building a spatially explicit water quality model. In this paper we outline a plan to employ Geographic Information System (GIS) mapping techniques to represent the current and historical water quality conditions at two locations (the General Separations Area and the A/M area) at the Savannah River Site. We also propose to identify relationships between water quality parameters, leading to a better understanding of ground-water contamination trends.

INTRODUCTION

The goal of the proposed study is to map ground-water contamination at the Savannah River Site (SRS) located on the border of Georgia and South Carolina. The study employs GIS and methods of multivariate statistics to analyze data collected as part of the SRS well monitoring program. Such mapping provides insight into both the extent and history of ground-water contamination problems at SRS. In addition, these maps help answer the question of future contamination—In what direction is contamination moving, and will this movement pose a threat to public or environmental health? The four main objectives of this study are to:

- Use principal components analysis and factor analysis to segregate aquifers by water quality signature and to group monitoring wells by aquifer.
- Correlate aquifer water quality signatures with trichloroethylene and tritium concentrations to indicate areas of potential contamination.
- Generate maps that depict areas where potential contamination may move through time.
- Evaluate the overall viability of delineating aquifers by water quality signature at SRS.

One of the biggest advantages of the proposed mapping technique is that it utilizes data that have already been collected through the SRS ground-water monitoring program; no additional data collection expenses are necessary. The resulting contaminant maps can be used by SRS researchers to identify important candidate areas for environmental remediation. Finally, state and federal regulators as well as the public can utilize the maps for a rapid estimation of public health risks from ground-water contamination at SRS.

BACKGROUND

The Savannah River Site is a 790 km^2 area operated by the US Department of Energy and located near Aiken, SC on the Georgia-South Carolina border (Figure 1). SRS has manufactured materials for the

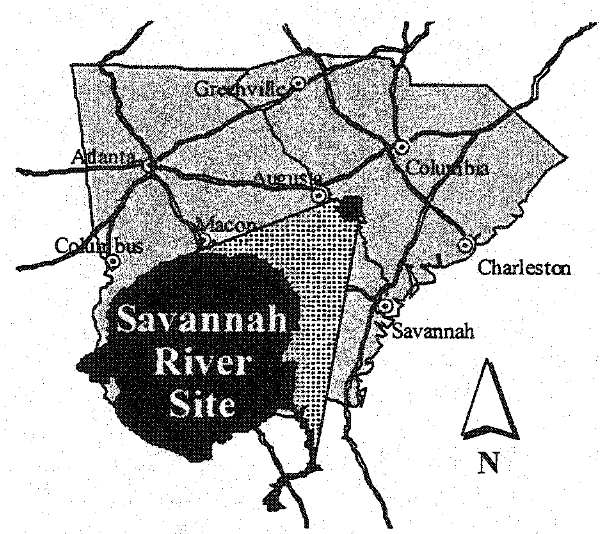

Figure 1. Savannah River Site location.

nation's nuclear defense since the early 1950s. SRS is located in the Upper Atlantic Coastal Plain, a region marked by complex hydrogeology. The sediments underlying SRS form an intricate, stacked lithology deposited by periodic ocean inundation and by river and stream channel migration (Aadland, et al. 1995). Aquifers and aquitards are discontinuous across the site, especially along the Pen Branch Fault Line where significant vertical leakage occurs (Arnett et al. 1992). Ground-water from the surficial aquifers, not lost to deeper formations, ultimately drains into present day streams and the Savannah River (Arnett et al. 1992).

Production wastes from manufacturing efforts at SRS include a variety of radionuclides, such as tritiated water, as well as more common industrial organic by-products such as trichloroethylene (Arnett et al. 1992). Many of these wastes were disposed of in unlined seepage basins or buried in open pits during the first 30 years of production. Resulting groundwater contamination is a significant problem at the site (Bollinger 1999). Ground-water in the surrounding region is the major source of water for human consumption (Arnett et al. 1992). Understanding the potential movement of contaminated ground-water from SRS to aquifers used for water supply is imperative to maintain both public safety and mitigate risk perception. To this end, investigators at SRS installed approximately 2,000 monitoring wells and have maintained a quarterly contaminant sampling program known as GIMS (Arnett et al. 1992) (Figure 2).

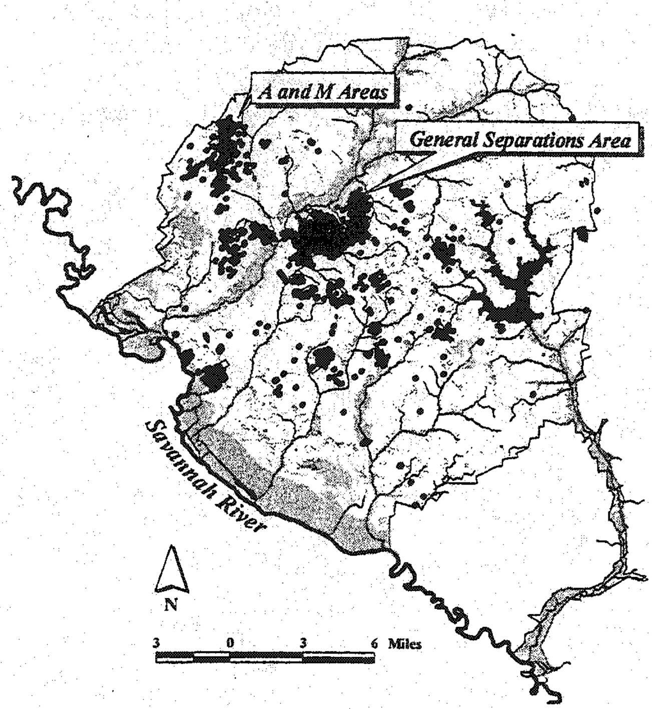

Figure 2. Monitoring wells at SRS.

Recent ground-water modeling studies and monitoring wells on site indicate that most contamination is shallow, and has not reached the deeper aquifers that supply nearby residents with drinking water (Delaimi 1996). The same research has not ruled out the eventual migration of ground-water pollutants offsite and the resulting threat to public safety (Delaimi 1996; Rine, et al. 1998; Arnett et al. 1992).

Promising research by Suk and Lee (1999) offers an alternative approach to the fine-scale hydrogeological characterization required by present methods of contaminant mapping at SRS. Suk and Lee (1999) used multivariate analysis and GIS to correlate contaminant data with ground-water quality parameters for the purpose of identifying contaminant-carrying aquifers. Their analysis operated on the principle that each aquifer has its own unique ground-water quality signature based upon the geochemistry of the sediments that comprise it (Fetter 1994). Ground-water quality measurements from individual wells can thus be statistically grouped using a combination of factor and cluster analyses. Using these methods, researchers have produced accurate maps of aquifer systems (Suk and Lee 1999; Ceron, et al. 2000). Employing these statistical analyses to map ground-water contamination at SRS may be feasible, given that the GIMS database includes measurements of the water quality parameters necessary to describe aquifer signatures.

PLANNED METHODOLOGY

We propose to focus on data from the two most heavily contaminated areas on site—the General Separations Area (GSA), and the Administrative and Manufacturing Areas (A&M Area). These areas are also the most heavily monitored at SRS.

Our analysis of data for SRS largely follows statistical methods employed by Suk and Lee in their study describing ground-water zones through hydrochemical analysis in Incheon, Korea (1999). The initial step in data analysis is a factor analysis testing for correlations among the water quality parameters measured for each well. This step, first utilizing principal components analysis, identifies those parameters that best segregate ground-water from different aquifers (Ochsenkuhn, et al. 1997; Suk and Lee 1999).

Previous studies indicate that dissolved oxygen, calcium, magnesium, chlorine, silicon, and iron concentrations can remain steady for water pumped from the same aquifer but from different well locations (Vidal et al 2000; Ochsenkuhn et al., 1997; Suk and Lee 1999). The correlation analysis for SRS data should indicate correlations among at least some of these constituents. Using weighted least squares and regression methods, we plan to convert the results of the factor analysis to factor scores (Suk and Lee 1999). The A&M Area and the GSA can thus be divided into zones where factor scores are either positive or negative (Suk and Lee 1999).

We intend to perform a cluster analysis on the factor scores to establish relationships between the zones delineated by factor analysis (Suk and Lee 1999). Cluster analysis arranges the different factor score zones in a hierarchical fashion that can be visualized as a dendrogram, or tree diagram. In this way discrete zones can be matched with one another, indicating the vertical and horizontal extents of different aquifers. We plan to compare our statistical delineation of aquifers with existing SRS hydrostratigraphy from Aadland (1995) as a means of coarse verification.

Wells identified by our water-quality signature delineated aquifers are analyzed for contamination levels of two reliably detected analytes, tritium and trichloroethylene (TCE). With information from these wells, their parent aquifers, and contaminant levels, we expect to infer contour maps of contamination using ArcView GIS software, and thus provide insight into current areas at SRS most likely to receive contaminated ground-water. We plan to associate each well with its parent aquifer as described by the factor and cluster analyses. In this way all wells penetrating a particular aquifer at SRS can be grouped together in a single ArcView map layer. Wells can then be color coded according to tritium and trichloroethylene concentrations. Using ArcView's kriging and inverse distance weighting methods of interpolation, contour maps of the contaminant concentrations can be generated. Producing these maps for each year within a five-year period should allow us to infer the movement of contaminated ground-water through time.

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