

Construction of a stack-unit map to predict pathways of subsurface contaminants within the A/M Area of the Savannah River Site, SC

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In the mid-1990's, contaminants were detected in the aquifer zone from which the U.S. DOE's Savannah River Site (SRS) in South Carolina produces their potable water. To help delineate the probable pathways of the detected contaminants, the SRS requested an examination of the hydrostratigraphy of the interval overlying the contaminated portion of the aquifer, the Crouch Branch aquifer. A stack-unit mapping approach was used for this problem. This approach utilizes a Geographic Information System (GIS) to integrate subsurface geologic data, soils data and hydrologic data to create a contamination potential map. The interval, which overlies the Crouch Branch aquifer, consists of 10's of meters of vadose and over 100 m of saturated zone with three aquifer and three confining units. A total of 174 borings, all with detailed descriptions, some samples, and precise locations were used within the approximately 20 km² study area (the A / M area).

Computer-drawn isopach maps of the six units were produced using GIS capabilities. First, seven contour line coverages (from the land surface to the top of the Crouch Branch aquifer) were entered by the topogrid interpolation methods for the creation of Digital Elevation Models (DEM). Separate grids for each of the six data layers were generated. All elevation determinations on logs from bore holes were scrutinized carefully by evaluating how well they agreed with known depositional and structural models of the study area. Elevation data that did not agree with trends of data were discarded and elevation contour maps for all units were modified accordingly. Deviant data usually consisted of data from old log descriptions that were not performed under a quality assurance program or the data were determined to be of questionable interpretation by site geologists.

A 5 m resolution was chosen for each grid to capture the total detail. The Arc/Info[®] GRID module was selected for further processing of grids with each of the isopach grids converted into Arc/Info[®] polygon coverages. Elevations from vertically adjacent upper surfaces were "machine-subtracted" to create six isopach maps. It was important to derive computer-drawn isopach maps because the maps revealed previously undisclosed features. However, the subtraction process resulted in many of the computer-drawn maps not appearing geologically plausible. Revised isopach maps then were made for each unit by overlaying individual thickness points on the computer-drawn maps and redrawing the maps. These revised maps retained the original unbiased computer-drawn surfaces, honored specific thickness data points and trends of data, and produced a more geologically sound representation of the three-dimensional geology that was more in keeping with known depositional and structural models.

An additional variable, besides thickness, that was pertinent to the shallowest confining unit, the Green clay, was the presence of sequences with vertical conductivities equaling those of the overlying aquifer unit. These intervals were identified by their high leakance values. Consequently, the stack-unit map created by stacking polygon coverages of the six isopach maps also included a leakance distribution map of the Green clay confining unit.

The “stacking” process in GIS is known as a “*spatial join*” and is accomplished by an overlay procedure that is fundamental to GIS spatial analysis. The attributes for the polygons in the resulting stack-unit map consist of composite attributes from the separate unit maps within the stacked-unit polygon. The unedited stack-unit map of the A/M Area contained 1267 polygons with over 600 unique attribute combinations. After editing to remove sliver polygons (those less than 1000 m²) and dissolving other small polygons into more important adjoining polygons, the final stack-unit map was composed of 341 unique combinations in 455 polygons.

To arrive at a relative contamination potential for the study area, the 341 unique combinations of hydrogeologic sequences and thicknesses were rank ordered, based on their hypothesized potential to retard downward transport of contaminants. The ranking process employed was a logarithmic approach called “utility theory” which assigns each unit an order of magnitude corresponding to its ranked importance. For example, the Green clay confining unit, the most important unit, was assigned a magnitude of 10⁵ and the lowest ranked unit (an aquifer with high vertical conductivity) was assigned a magnitude of 10⁰. For the areas that fell within the zones of high Green clay leakances, the mechanism used to arrive at a logical scoring was multiplying the Green clay score by 10⁻³ which resulted in a numerical ranking with the same magnitude as the overlying aquifer unit (10²).

The distribution of one of the main contaminants, *tetrachloroethylene (PCE)*, within the Crouch Branch aquifer in the A / M area, correlates well with the contamination potential map constructed using the stack-unit mapping approach described above.