Prepared in cooperation with the
MISSISSIPPI DEPARTMENT OF ENVIRONMENTAL QUALITY
OFFICE OF POLLUTION CONTROL and the
MISSISSIPPI DEPARTMENT OF AGRICULTURE AND COMMERCE
BUREAU OF PLANT INDUSTRY

THE DETERMINATION OF RELATIVE VERTICAL SERIES HYDRAULIC CONDUCTANCE

Vertical series hydraulic conductance can be analytically determined using soil permeability and soil thickness data, clay thickness data (where available), unsaturated zone and aquifer media data, and depth to the water table in the recharge path from the land surface to the water table. In the evaluation of the susceptibility of ground water to surface and shallow sources of contamination in Mississippi, vertical series conductance is an important factor because it provides a single, integrated value for the capacity of the entire sequence of materials that overlie the saturated zone to transmit water (with or without contaminants) from the land surface to the water table. In essence, the vertical series conductance is a measure of the ease of fluid transmission through the total vertical recharge path.

SOURCES OF DATA

Data used to determine the vertical series hydraulic conductance in the recharge path from the land surface to the water table were obtained from many sources as follows:

- Soil permeability and thickness - the U.S. Department of Agriculture, Natural Resources Conservation Service's (NRCS) State Soil Geographic Data Base (STATSGO) was the primary source of data for the determination of area-weighted harmonic mean soil permeability and soil thickness. STATSGO provides information about soils and individual layers within soils, but does not provide a mapped boundary for each individual soil. The NRCS developed STATSGO to be primarily used as a guide for regional resource planning, management, and monitoring. Soil permeability and thickness information was extracted from STATSGO at the layer level, combined by component, and statistically expanded to cover the entire map unit. The STATSGO data set for Mississippi was used to develop a statewide map of the area-weighted harmonic mean permeability of soils in Mississippi (O'Hara, 1994). Soil permeability values extracted from STATSGO are based on the capacity of the soil to transmit water and are saturated soil permeability rates measured in inches per hour (fig. 4) and converted to feet per day for use in the determination of vertical hydraulic conductance.
- Clay thickness data - the areal extent and vertical thickness of clays in the upper part of the recharge path were used (where available) in the determination of vertical series hydraulic conductance. Clay thickness data for the outcrop area of the Mississippi River alluvial aquifer were obtained from a published map of confining unit thicknesses (Arthur, 1994). Where present, clay units in the upper part of the recharge path significantly deter the downward movement of fluids. The thickness values for clays were taken directly from the published map, whereas the hydraulic conductivity value for the clays used in the determination of the vertical series hydraulic conductance was given as less than 0.01 foot per day. This value may be somewhat higher or lower than actual hydraulic conductivities for the different clay units that occur in the upper part of the Mississippi River alluvial aquifer; however, the value represents a conductivity that is generally high for the clays of the region and, therefore, is a conservatively estimated value.
- Lower unsaturated zone and aquifer media data - the "Geologic Map of Mississippi" compiled by Alvin R. Bicker, Jr. (1969), was modified for use as the geology map for this investigation (fig. 2). The geology map was generalized and modified to determine the general boundaries of aquifer recharge areas. The boundaries of the recharge areas were based on the outcrop areas of the geologic units that generally contain the aquifers and aquifer systems in Mississippi (fig. 3) and are generally referred to [in this report] as aquifer outcrop areas. The areal extent of aquifer outcrop units in Mississippi (fig. 3) was determined by modifying and generalizing the "Geologic Map of Mississippi," (Bicker, 1969) in combination with other map sources (Boswell, 1985 and Wasson, 1986). For the purposes of this investigation, the hydraulic conductivity used for the unsaturated zone [of the aquifer material] is a lateral hydraulic conductivity representing saturated flow conditions. The lateral hydraulic conductivity values, as listed in table 1 for the 14 major aquifers and aquifer systems in Mississippi, were derived from the results published by Slack and Darden (1991).
- Depth to the water table (fig. 5) - was used to determine the total thickness of the unsaturated zone. The study "Depth to the water table in Mississippi," (O'Hara and Reed, 1995) was developed specifically to define the vertical distance from the land surface to the water table in Mississippi. When combined with soil and clay thickness data (where available), the depth to the water table makes it possible to mathematically determine the thickness of each layer from the land surface to the water table.

The depth to the water table used as length of flow path, grid-cell area (of the GIS raster data) used as cross-section area of flow, and hydraulic conductivity values for all intervals (soil, clay, and balance of the unsaturated zone) are used to determine vertical series hydraulic conductance from the land surface to the water table.

COMPILATION OF THE MAP

Hydraulic conductance was determined through the combined use of GIS spatial data layers that provided data about soil permeability and soil thickness, lower unsaturated zone and aquifer media data, and the depth to the water table (used as the total thickness of the unsaturated zone). Where available, the reported thickness of clay units in the upper part of the outcrop was used as supplemental data in determining the hydraulic conductance.

Hydraulic Conductance (C) - the product of hydraulic conductivity (K) and cross-sectional area (A) of flow divided by the length (L) of the flow path (McDonald and Harbaugh, 1988). Hydraulic conductance represents the transmitting capability of a block of earth material (Franke and others, 1990) and is used in this investigation as a measurement of the capacity of the materials in the soil zone and the unsaturated zone overlying the unconfined aquifer to transmit water (with or without contaminants) from the land surface to the water table. Hydraulic conductance (C) is expressed in a formula as follows:

$$C = (K \times A)/L \qquad (1)$$

In a multi-layered hydrologic system, the following figure and equation are used to define vertical series hydraulic conductance:

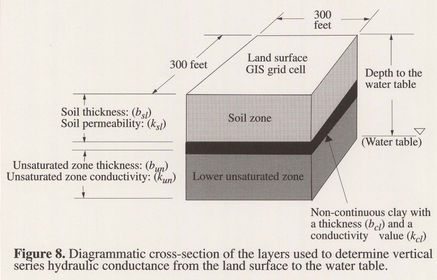

Figure 8. Diagrammatic cross-section of the layers used to determine vertical series hydraulic conductance from the land surface to the water table.

$$Ceq = \frac{Area}{\frac{b_{sl}}{k_{sl}} + \frac{b_{cl}}{k_{cl}} + \frac{b_{un}}{k_{un}}} \qquad (2)$$

where C_{eq} = the equivalent vertical series conductance from the land surface to the water table, and

$Area$ = the area of the GIS grid cell that is used to define the area of cross-sectional flow.

The analytical technique detailed above was performed by using customized GIS data bases and Arc Macro Language (AML) programs all done within the ArcInfo environment.[1] Most of the procedures discussed above were done in the GRID module of ArcInfo.

The results of the determination of vertical series hydraulic conductance (VSHC) are shown in figure 9. Values for vertical series hydraulic conductance are shown in relative ranges of conductance from lowest to highest. The numerical values for the relative ranges of VSHC are listed in table 2. VSHC ranges are displayed in gray- and blue-shaded intervals with decreasing gray and increasing blue indicating an increase in VSHC. The statewide VSHC map shows areas of "lowest" VSHC in the interior of the Delta. Some of the highest values in the State are found along the eastern margin of the bluff hills in the area that is generally considered the alluvial fan margin of the Delta. Throughout the rest of the State, VSHC values range from "low to moderate" to "highest." In any specific location, the actual VSHC may be greater or less than indicated on the map due to local factors which could not be considered. In parts of the State, areas of outcrop have localized confining conditions within the outcrop due to hardpan or noncontinuous clay sediments. Areas where aquifer conditions are locally confined but occur in the area of outcrop of an aquifer are treated the same as the rest of the aquifer outcrop region. Areas shown in dark gray-brown as "confining units outcrop" are in the outcrop of units that consist of materials such as massive clays and chalks and are not aquifer outcrop areas.

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[1]The use of trade, product, or firm names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Government.

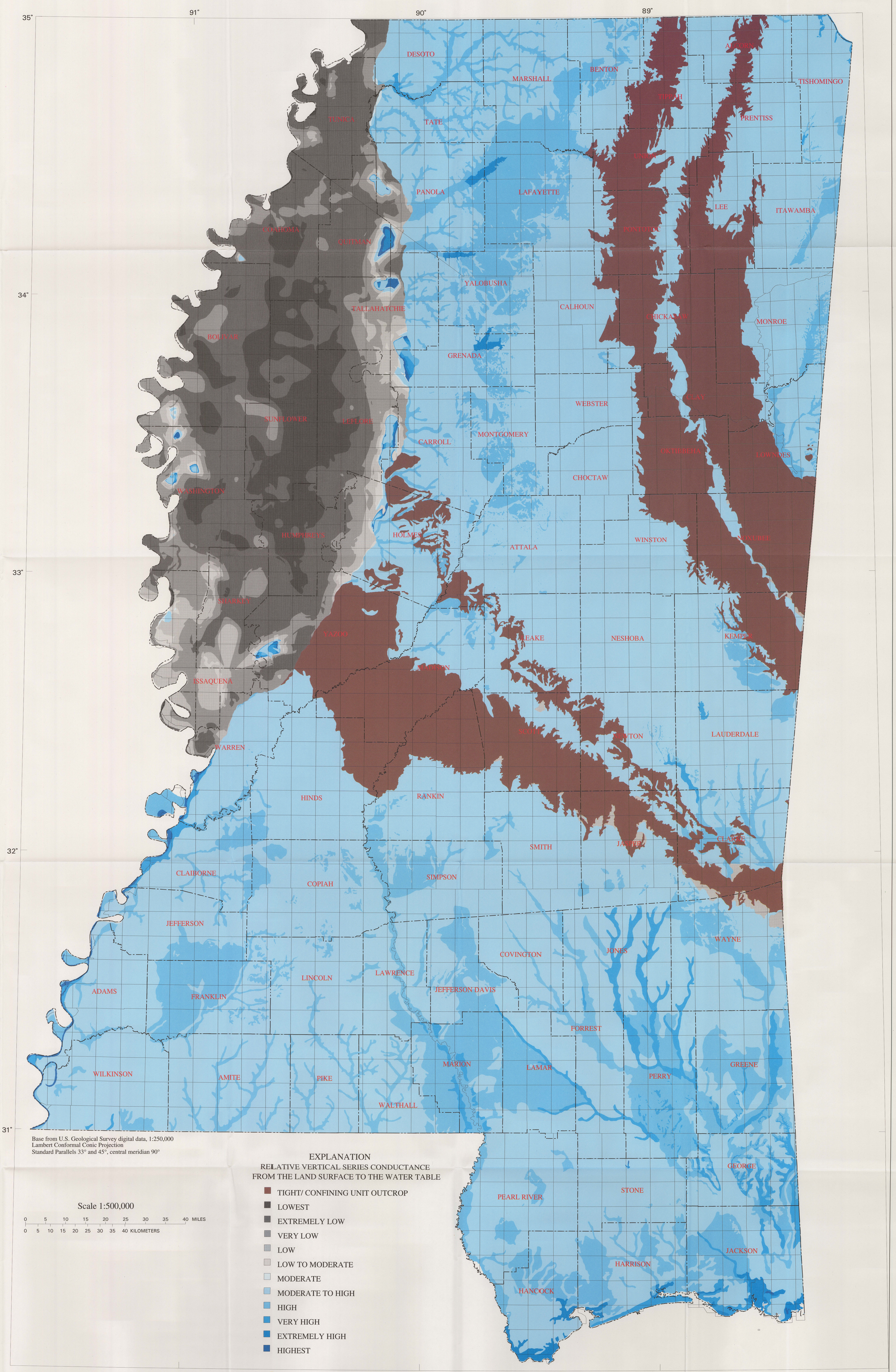

Figure 9. Relative vertical series hydraulic conductance in Mississippi.

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SUSCEPTIBILITY OF GROUND WATER TO SURFACE AND SHALLOW SOURCES OF CONTAMINATION IN MISSISSIPPI

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