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DEPTH TO THE WATER TABLE IN MISSISSIPPI

INTRODUCTION

Ground water, because of its extensive use in agriculture, industry, and public-water supply, is one of Mississippi's most important natural resources. The Mississippi Department of Environmental Quality, Office of Pollution Control, and the Mississippi Department of Agriculture and Commerce, Bureau of Plant Industry, are developing a program to protect the State's ground water. The U.S. Geological Survey (USGS), in cooperation with these two agencies, is conducting a series of studies to evaluate the susceptibility of water in the major aquifers in Mississippi to contamination from surface sources. The studies are being done by using a geographic information system (GIS) to develop and analyze statewide spatial data layers that contain geologic, hydrologic, physiographic, and cultural information.

The depth-to-water-table information from the map in this report can be used as a measure of the vertical distance a potential contaminant would travel from the land surface to reach the water table. The vertical distance between the land surface and water table is one of the factors used to approximate the travel time of potential contaminants through porous earth materials. This map shows an estimated depth to the water table determined through statistical analysis of water-level and land-surface altitudes for wells completed in the aquifer outcrop. Because water-level data used in the construction of potentiometric-surface maps are mostly from wells completed in confined parts of the aquifer, and data from wells completed in the area of outcrop can be scanty, the construction of potentiometric contours in the area of outcrop may require extrapolation of data. Because the unconfined water table is a subdued replica of the land surface above it (King, 1899), determining the depth to the water table in the area of outcrop by using an analytical technique that transforms a land-surface-altitude model can provide a data product with better accuracy than the extrapolation of elevation heads from the confined part of an aquifer.

SOURCES OF DATA

Data used to prepare the map showing depth to the water table were obtained from the Ground-Water Site Inventory (GWSI) of the USGS. From the approximately 70,000 wells in the GWSI data base for Mississippi, 10,370 wells were selected as being completed in aquifer outcrop areas. Data included latitude and longitude of the well, altitude at the well head top-of-casing, and the measured altitude of the water table. All altitudes presented in this report are given with respect to "sea level" which refers to the National Geodetic Vertical Datum of 1929--a datum derived from a general adjustment of the first order level nets of both the United States and Canada, formerly called the Sea Level Datum of 1929. A generalized aquifer-outcrop map was created from the "Geologic Map of Mississippi" (Bicker, 1969) by selecting, combining, and generalizing the surficially exposed geologic units that are associated with specific aquifer units at depth. A statewide altitude model (grid) was created by combining all of the USGS 1:250,000 Digital Elevation Models (DEM's) for Mississippi. The 1:250,00 DEM's provided the best available source of digital altitude data for the entire State and are based on 1:250,000 quadrangle maps with contour intervals of 50 feet. These DEM's have an interpolated altitude at a 3-arc-second interval, which was resampled to an even 300-foot interval in the construction of the statewide altitude model.

The estimation of depth to the water table for the outcrop area of the Mississippi River alluvial aquifer in northwestern Mississippi, commonly called the "Delta," was made using water-level measurements for spring 1995. Water-level data for more than 450 wells were collected during this period by the Yazoo Mississippi Delta Joint Water Management District and were checked and tabulated by the Mississippi Department of Environmental Quality, Office of Land and Water Resources.

COMPILATION OF THE MAP

Mississippi's land surface generally has little to moderate relief and topographic variability. Therefore, a transformation of a statewide altitude model was done to estimate the depth to the water table. The transformation was based upon a statistical relation between the land-surface altitude and the water-table altitude. However, for the Delta, the determination of depth to the water table for the outcrop area of the Mississippi River alluvial aquifer was made by the direct use of water-level data from more than 450 wells. The decision to use water-level measurement data for the Delta, rather than a transformation of the land surface, was made because of the broad geographic extent of the area; the extensive pumpage from the area (more than 2,000 million gallons per day, Arthur, 1995); the extensive, non-continuous upper confining "hard-pan" clay unit; and the abundance of water-level measurement data for the area. The use of water-level measurements to map the depth to the water table in the Delta makes apparent the areas of drawdown, particularly near pumping centers where extensive use of ground water occurs.

For areas other than the Delta, a statistical technique was used that compares land-surface altitude at a given point (a water well) to localized-mean and outcrop-mean altitude, thus providing a measurement of local and regional land-surface variation. The localized-mean altitude (a filtered version of the statewide altitude model) was created by determining the moving average of the altitudes in the statewide altitude model within a moving rectangular (2,700-foot cell size) region. When differenced from the statewide altitude model, the localized-mean altitude model provides a good measure of local land-surface altitude variation, and this difference indicates whether a given point is located on a local high or low spot (a hill or a valley). The outcrop-mean altitude was determined for each aquifer outcrop area by selecting and averaging only those altitude data from the statewide altitude model that were within the outcrop area of each aquifer. When differenced from the statewide altitude model, the outcrop-mean altitude model provides a good measure of regional land-surface altitude variation, and this difference tells how many feet a given point is above or below the outcrop-mean altitude. Output grids generated by the comparison of the statewide altitude model to the localized-mean and the outcrop-mean altitude models were incorporated into the following procedures that were used to estimate depth to the water table from statewide altitude data.

Water-table altitudes in the outcrop area of confined-aquifer units in Mississippi vary little with time or season and generally are not affected by pumpage from the confined part of the aquifer (Mallory, 1993). By referencing point data for water-table altitudes to the outcrop-mean altitude, the variation in the water-table altitude with respect to the average land-surface altitude in the outcrop region was quantified. With sufficient samples of water-table altitude and land-surface altitude, the variation in the water-table altitude can be related statistically to variation in the land-surface altitude (Williams and Williamson, 1989). In this study, the variation in the water-table altitude was determined and related (by regression analysis) to variation in the local and regional land-surface altitude by the following method:

- Wells were selected from the GWSI data base for each aquifer that crops out in the State. A subgroup of these wells was selected by using the boundary of a generalized aquifer outcrop map to determine which of the wells for a specific aquifer are completed in the outcrop area of that aquifer. Wells completed in the outcrop areas were tested for accuracy of data with final selection criteria being the reported depth to water (less than 150 feet), well-construction depth (less than 200 feet), and the difference between the DEM altitude and the reported altitude of the well head top-of-casing (less than 100 feet), reducing the selected set of wells to 3,948;
- The measured water-table altitude at each well was referenced to the outcrop-mean altitude to provide a relative datum for the water-table-altitude surface within the outcrop (d1);
- The altitude of the land surface at each well was compared to the outcrop-mean altitude to determine variation in the regional land-surface altitude (d2);
- The altitude of the land surface at each well was compared to the local-mean altitude to determine variation in the local land-surface-altitude (d3); and
- A multiple-regression analysis was done for each aquifer unit to quantify the relation between the variation in the water-table altitude (d1) in the outcrop to variation in the regional (d2) and local (d3) land-surface altitudes.

After the regression analysis was performed for each aquifer unit, the results were used to generate an analytical surface representing the depth to water (DTW) for each aquifer outcrop area at the same resolution as that of the statewide digital altitude model (a 300-foot grid cell size). The process used is summarized in the following steps:

- Determination (by aquifer unit) of coefficients (c1 and c2) and intercept (constant k) from the multiple-regression analysis;
- The generation of a transformation formula using the following:

$$d1 = (h_{wt} - h_{rm})$$
$$d2 = (Z - h_{rm})$$
$$d3 = (Z - h_{lm})$$

where

h_{wt} = water-table altitude;
h_{rm} = outcrop-mean altitude;
Z = land-surface altitude; and
h_{lm} = local-mean altitude.

The regression formula is expressed as follows:

$$d1 = c1 \times d2 + c2 \times d3 + k$$
$$(h_{wt} - h_{rm}) = c1(Z - h_{rm}) + c2(Z - h_{lm}) + k$$

Simple algebraic rearrangement of terms yielded the following formula which was used to determine the water-table altitude:

$$h_{wt} = c1(Z - h_{rm}) + c2(Z - h_{lm}) + h_{rm} + k$$

The depth to the water table was determined by subtracting the water-table altitude from the land-surface altitude as follows:

$$DTW = Z - h_{wt}$$

Table 1. Results of regression analysis showing values determined by aquifer unit

Aquifer	Coefficient c1	Coefficient c2	Constant (k)	Number of selected wells	Root-mean square error	Adjusted R-squared
Citronelle	0.899	0.041	-38.58	997	18.696	0.9871
Cockfield	.885	-.012	-33.97	93	16.665	.9509
Coffee	.923	.110	-33.72	98	19.196	.8995
Eutaw-McShan	..908	.301	-33.29	553	20.326	.9713
Miocene	.864	-.009	-46.68	1,400	28.909	.8845
Oligocene	.910	.140	-51.16	123	29.460	.8932
Paleozoic and Tuscaloosa	.930	.151	-37.94	39	21.091	.9605
Wilcox	.873	.032	-52.51	276	28.707	.8988
Winona-Tallahatta	.938	.064	-45.92	132	29.529	.8801
Ripley	1.043	.226	-47.23	33	30.362	.8561
Sparta	.981	.190	-53.51	204	32.516	.8196

The analytical technique detailed above was performed by using customized GIS data bases, Arc Macro Language (AML) programs, and Fortran language programs all done within the ArcInfo environment.[1] Most of the procedures discussed above were done in the GRID module of ArcInfo. The coefficients and intercept values in table 1 were used in a GRID AML program to transform the statewide altitude model by aquifer outcrop area into a statewide DTW surface.

The results of the transformation of the statewide altitude model are shown on the DTW map on which values for DTW range from 0 to 96 feet. DTW is displayed in color-shaded intervals with increasing intensity of blue indicating increasing DTW. The depth-to-water-table map shows generalized, estimated values for the predevelopment depth to water (except in the Delta where the effects of drawdown in the outcrop are apparent) for assumed water-table conditions. The map shows estimated shallow water-table conditions along the coast, in areas where the topography is extensively dissected by stream drainage, and in the Delta. Deep water-table conditions are shown in the hills and uplands of aquifer outcrops which have large overall relief across the outcrop.

In areas other than the Delta, the values for DTW shown on the map result from an analytical estimation of water-table altitudes during unpumped conditions based on a statistical analysis of land-surface and water-table altitudes, and DTW values displayed do not show the localized effects of drawdown. In any specific location, the actual depth to the water table 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 brown as "outcrop of confining units" 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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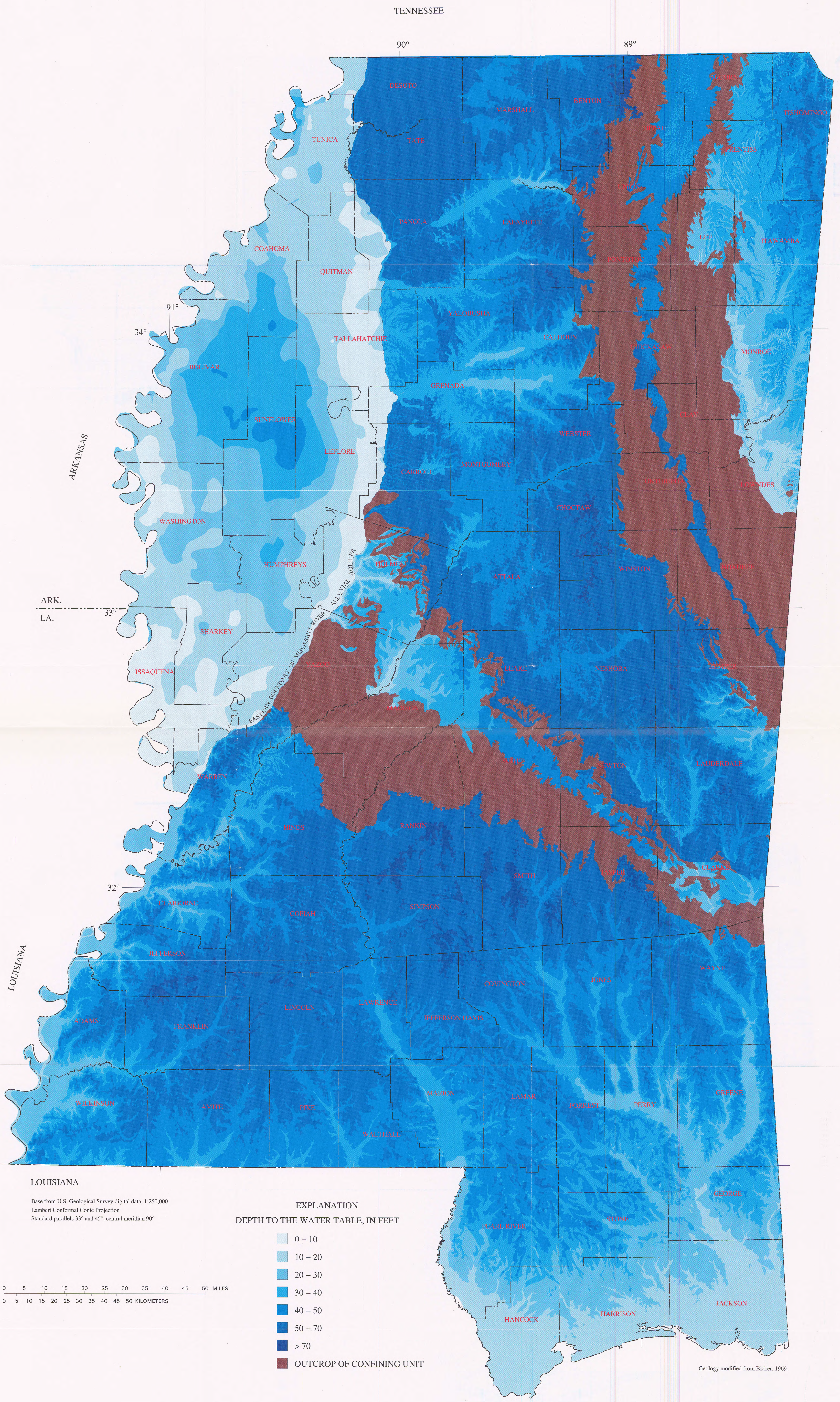
[1]The use of trade, product, or firm names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Government.



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