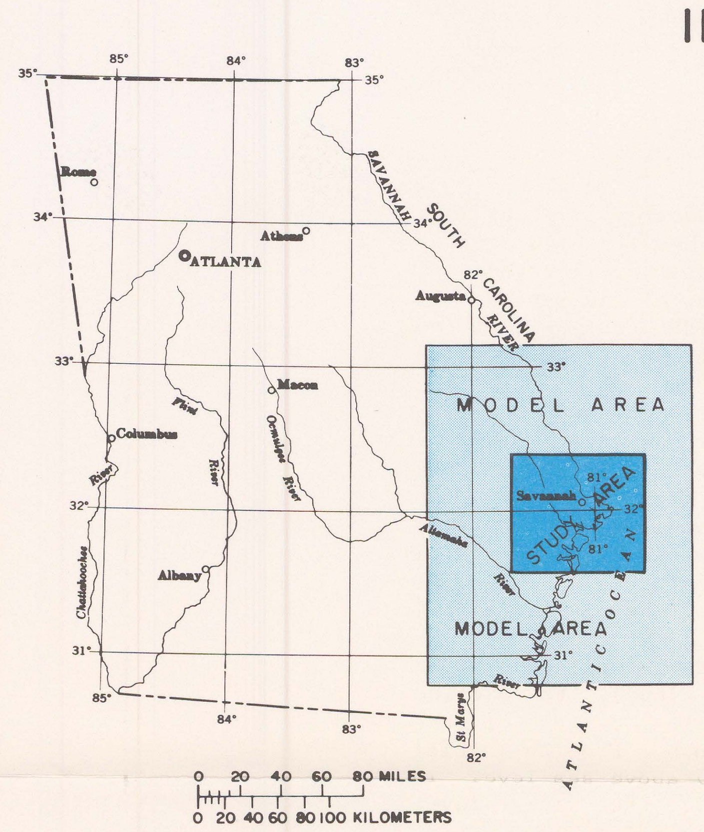
Department of the Interior
United States Geological Survey
V. E. McKelvey, Director

Prepared in cooperation with the
City of Savannah
Chatham County
Georgia Department of Natural Resources
Geologic and Water Resources Division

WATER RESOURCES INVESTIGATIONS
76-133
OPEN-FILE REPORT

INTRODUCTION



SAVANNAH STUDY AREA AND TOTAL AREA MODELED

The principal artesian aquifer is the most productive, widespread, and heavily used aquifer in Georgia. (See map at left for location of the study area.) Development of the aquifer in the Savannah area began in 1885, and by 1970 an average of about 75 Mgal/d (3,300 L/s) was being pumped.

The presence of salt water in the lower part of the aquifer northeast of Savannah and the widespread decline in the water level in the Savannah area are important factors in the continued utilization of this aquifer. The further development of this major water resource will require an adequate management plan. A powerful tool to aid in the management is the digital model.

Heavy pumpage has caused the potentiometric surface, or artesian water level, to decline markedly in the aquifer at the center of the cone of depression in Savannah. From an initial height of about 35 ft (11 m) above sea level in 1880 (See map at right.), the water level declined to a depth of 110 ft (34 m) below sea level in 1957, and to about 150 ft (46 m) below sea level in 1970.

The purpose of this study was: (1) to develop and calibrate a model that would simulate the response of the principal artesian aquifer in the Savannah area to various pumping rates, and (2) to demonstrate the usefulness of the model as a management tool for evaluating and predicting water-level changes in the aquifer to 2000.

The model used in this study was developed by Pinder and Bredehoeft (1968), revised by Pinder (1970), and further developed by Trescott (1973). It was modified by the authors for use in the study area.

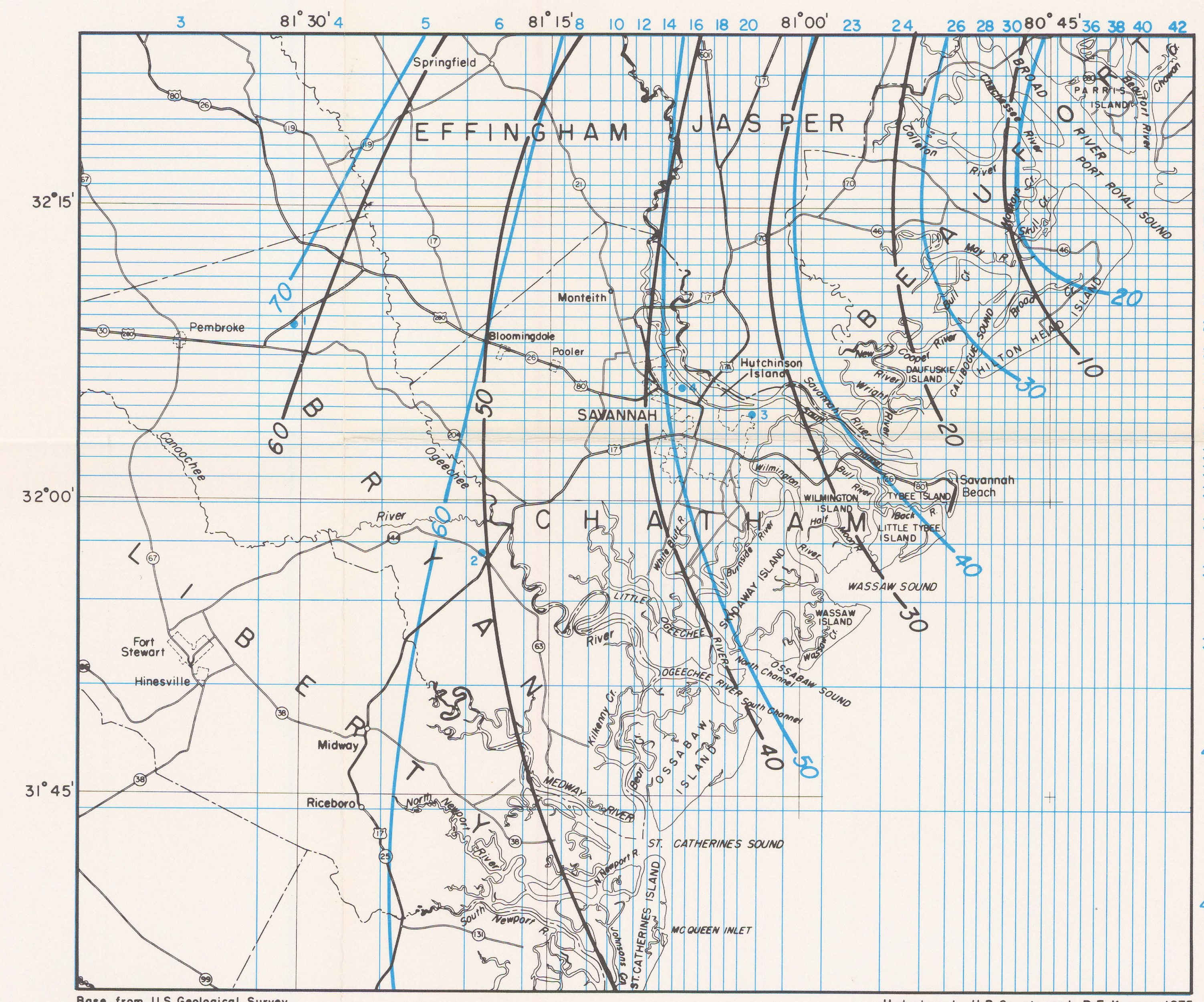
Information used in the model came from a series of ground-water investigations made from about 1937 to 1944, and from 1953 to 1975. These reports are listed in the selected references.

This study was made by the U.S. Geological Survey in cooperation with Chatham County, the city of Savannah, and the Georgia Department of Natural Resources, Geologic and Water Resources Division.

FACTORS FOR CONVERTING ENGLISH UNITS TO INTERNATIONAL SYSTEM (SI) UNITS

Multiply English Units	By	To Obtain SI Units
feet (ft)	0.3048	meters (m)
miles (mi)	1.609	kilometers (km)
gallons (gal)	3.785	liters (L)
gallons per minute (gal/min)	.06309	liters per second (L/s)
million gallons per day (Mgal/d)	43.81	liters per second (L/s)
hydraulic conductivity feet per day (ft/d)	.3048	meters per day (m/d)
transmissivity feet squared per day (ft^2/d)	.0929	meters squared per day (m^2/d)

THE MODEL



Base from U.S. Geological Survey 1:250,000 quadrangles

Hydrology by H. B. Counts and R. E. Krause, 1975
Observed water-level contours from Warren (1944)

0 10 20 30 MILES
0 10 20 30 40 KILOMETERS

EXPLANATION

—50— OBSERVED WATER-LEVEL CONTOUR—Shows altitude of artesian water level. Contour interval 10 feet (3 meters); datum is mean sea level

—60— COMPUTED WATER-LEVEL CONTOUR—Shows altitude of computed artesian water level. Contour interval 10 feet (3 meters); datum is mean sea level

6 / 8 MODEL GRID—Numbers 3-42 (left to right) indicate columns; 6-41 (top to bottom) indicate rows

•2 WELL—Number is identification number referred to on hydrographs

MODEL GRID, OBSERVED (1880) AND COMPUTED STEADY-STATE WATER LEVEL OF THE PRINCIPAL ARTESIAN AQUIFER

GEOHYDROLOGIC CONDITIONS

The Savannah area is underlain by several thousand feet of unconsolidated sediments and consolidated sedimentary rocks, chiefly of marine origin, which range in age from Late Cretaceous to Holocene (Cooke, 1943). The sedimentary rocks dip seaward and thicken, generally, in that direction. A very permeable and extensive part of this rock sequence is a highly productive water-bearing unit known as the principal artesian aquifer.

In the Savannah area, the principal artesian aquifer consists of about 600 ft (183 m) of soft, granular, commonly very porous, crystalline limestone that also includes beds of sand and marl and sandy, clayey, cherty, and dolomitic limestone (Counts and Donsky, 1959, table 1). The aquifer includes a basal unit of middle Eocene age; the Ocala Limestone of late Eocene age; a section of undifferentiated rocks of Oligocene age; and an upper limestone unit of Miocene age.

The aquifer is confined below by relatively impermeable clayey marl and dense limestone of middle Eocene age, and above by clayey deposits of Miocene age. The top of the aquifer is 210 ft (64 m) below sea level at Savannah.

The aquifer crops out about 110 mi (177 km) northwest of Savannah where it is recharged by infiltration of precipitation. The top of the aquifer is also exposed in deep scoured areas of Skull Creek, Beaufort River, and Port Royal Sound in the Hilton Head Island area in South Carolina. (See map at right.) These were areas of discharge before the aquifer was developed. Now they are intake areas for salt water.

Other natural boundaries of the aquifer are outside the modeled area which was extended far beyond the study area to minimize effects of those boundaries. (See map at left.)

The reader is referred to Counts and Donsky (1963) for a detailed description of the hydrologic system.

The model represents a finite-difference simulation of the movement of ground water in the aquifer. A computer program solves for hydraulic-head (water-level) distribution in the principal artesian aquifer.

The computed water level is compared to head measurements from wells in the field. The comparison provides a measure of the adequacy of the conceptualization used to develop the model. Finally, the model can be used to predict the effects of various pumping patterns, increases and/or decreases in pumping on the principal artesian aquifer system in the Savannah area.

The map at right shows how an irregular block-centered grid was positioned over the base map, dividing it into rectangles. The spacing between grids is variable and represents a minimum of 4,000 ft (1,220 m).

The grid is smallest in the immediate Savannah and Hilton Head Island area, 4,000 ft (1,220 m) on each side, giving weighted importance to the area where most of the water is pumped. The center of each rectangle, regardless of its size, is called a node in the computation network. Data values are assigned to each node and are punched on cards and used as input to the model. The following physical and hydrologic data were used.

1. Transmissivity (the rate at which water is transmitted through a unit width of the aquifer under a unit hydraulic gradient).
2. Storage coefficient (the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head).
3. Pumping rate at those nodes where significant discharge from wells is located.
4. Thickness of a semi-permeable confining bed.
5. Water level in the overlying water-table aquifer.
6. Initial artesian water level in the aquifer.
7. Dimensions of the rectangular grid.
8. Hydraulic conductivity of the confining bed (in the vertical).
9. Specific storage of the confining bed.

Data values used in the model to simulate conditions in the aquifer were obtained by contouring known data points on a base map of the Savannah area. The grid was then positioned over the base map and data values interpolated for each node.

The data used for the model were taken from a variety of sources. Values for initial artesian water level were obtained from Warren's map of the 1880 potentiometric surface (Warren, 1944). Storage coefficient and transmissivity data were estimated from aquifer test data. The storage coefficient used was 0.0001 (dimensionless) and transmissivity ranged from 9,500 ft^2/d (880 m^2/d) to 121,000 ft^2/d (11,200 m^2/d). Estimates of the hydraulic conductivity (permeability) and the specific storage of the confining bed were derived from laboratory analyses of well cores; these were included as single values which apply to all nodes. The thickness of the confining bed was obtained from geologic and geophysical logs. The altitude of the water table was determined, primarily, by water-level measurements and supplemented by estimates of the depths to water-level based on land-surface altitude from topographic maps. The average rate of pumping for each pumping period is included for each grid block. If more than one well is located in a grid block, the total rate of pumping for all wells in the block is used.

Hydraulic boundaries of the aquifer are beyond the modeled area except for the northwest and southwest corners, and in the Parris and Hilton Head Islands area where recharge enters the system. Constant-head boundaries were used in those areas. A no-flow boundary was used around the border of the model as a computational expedient.

Cartography by W. G. Hester

DIGITAL MODEL ANALYSIS OF THE PRINCIPAL ARTESIAN AQUIFER, SAVANNAH, GEORGIA AREA

By
H. B. Counts and R. E. Krause

1976