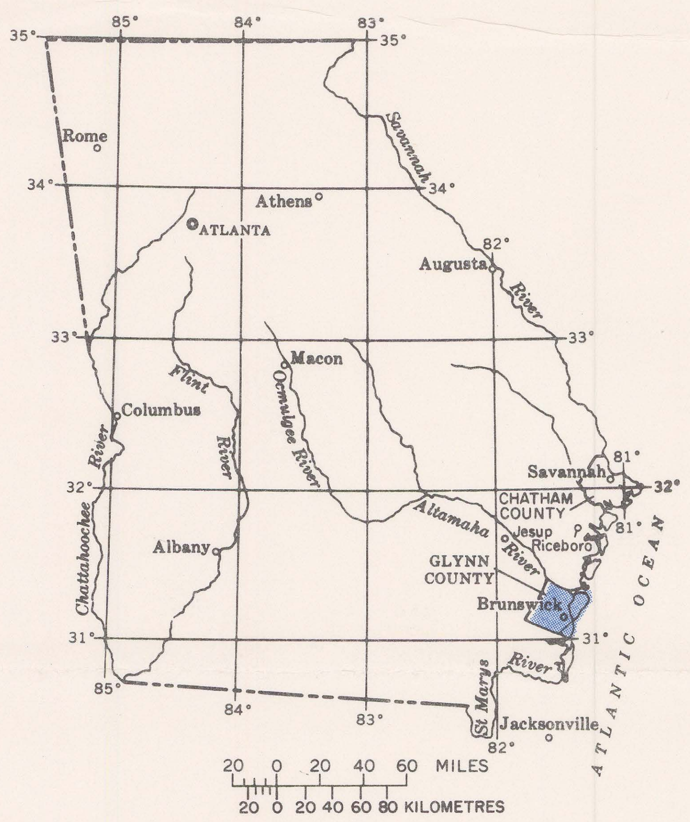
Department of the Interior
United States Geological Survey
V. E. McKelvey, Director

Prepared in cooperation with the
City of Brunswick
Glynn County
Georgia Department of Natural Resources,
Earth and Water Division

WATER RESOURCES INVESTIGATIONS
1-75
OPEN-FILE REPORT
SHEET 1 OF 4

INTRODUCTION



INDEX MAP SHOWING LOCATION OF STUDY AREA

Ground water has been developed in coastal Georgia from the principal artesian aquifer because of its good quality, availability, and relative low cost. Ground-water users in the Brunswick area (See index map for location of study area.) withdraw about 105 Mgal/d (4,600 l/s) of water from the aquifer. This high usage has caused some problems of water-level decline and deterioration of the water quality, as brackish water is moving upward through fractures or solution zones into the aquifer. Because of these problems, a large amount of ground-water data has been collected in Brunswick and Glynn County. Warren (1944), Wait (1965), Krause and Gregg (1972), Wait and Gregg (1973), and Gregg and Zimmerman (1974) have discussed the hydrology and geology of the area, and the reader is referred to these reports for a detailed description of the geology, hydrologic conditions, and history of ground-water development.

With high ground-water usage and the probability of an increase, it is important that this resource be managed wisely. An aid to management is the accurate prediction of the response of the principal artesian aquifer to various hydrologic stresses. A recently developed tool which helps make this prediction possible is the digital model, which is a computer program designed to simulate the response of an aquifer to various hydrologic stresses. The program used herein was developed by Pinder and Bredehoeft (1968), revised by Pinder (1970), further revised by Trescott (1973), and modified by the authors for use in the study area.

The intent of this study was to develop and verify the model, and to show the results by simulating the response of the aquifer to various pumping stresses imposed upon it. The investigation was made by the U. S. Geological Survey in cooperation with the city of Brunswick, Glynn County, and the Georgia Department of Natural Resources, Earth and Water Division.

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

Multiply English Units	By	To obtain SI Units
feet (ft)	0.3048	metres (m)
miles (mi)	1.609	kilometres (km)
gallons (gal)	3.785	litres (l)
gallons per minute (gal/min)	.06309	litres per second (l/s)
million gallons per day (Mgal/d)	43.81	litres per second (l/s)

GEOHYDROLOGIC BACKGROUND

Almost all the fresh water withdrawn in the Glynn County area comes from the principal artesian aquifer, a limestone of middle Eocene to Oligocene age, lying about 550 ft (168 m) below land surface. The aquifer is generally divided into two water-bearing zones. The upper zone consists of the Oligocene Series (although often cased out because of caving tendencies) and the upper part of the Ocala Limestone. The lower zone is the basal part of the Ocala Limestone and the Avon Park Limestone. Underlying the Avon Park Limestone and the lower water-bearing zone is the Lake City Limestone, the upper part of which is a hard dolomite confining unit, separating the aquifer from an underlying brackish-water zone. Most wells tap only the upper zone, which yields more than 70 percent of the total water produced by both zones. Solution cavities in the limestone make it a very productive aquifer, yielding as much as 16 Mgal/d (700 l/s) per well.

The aquifer is overlain by sand, silt, clay, and marl of Miocene to Holocene age. A green fuller's earth clay, part of the Hawthorn Formation of Miocene age, acts as the confining layer, retarding upward flow of water from the underlying artesian aquifer.

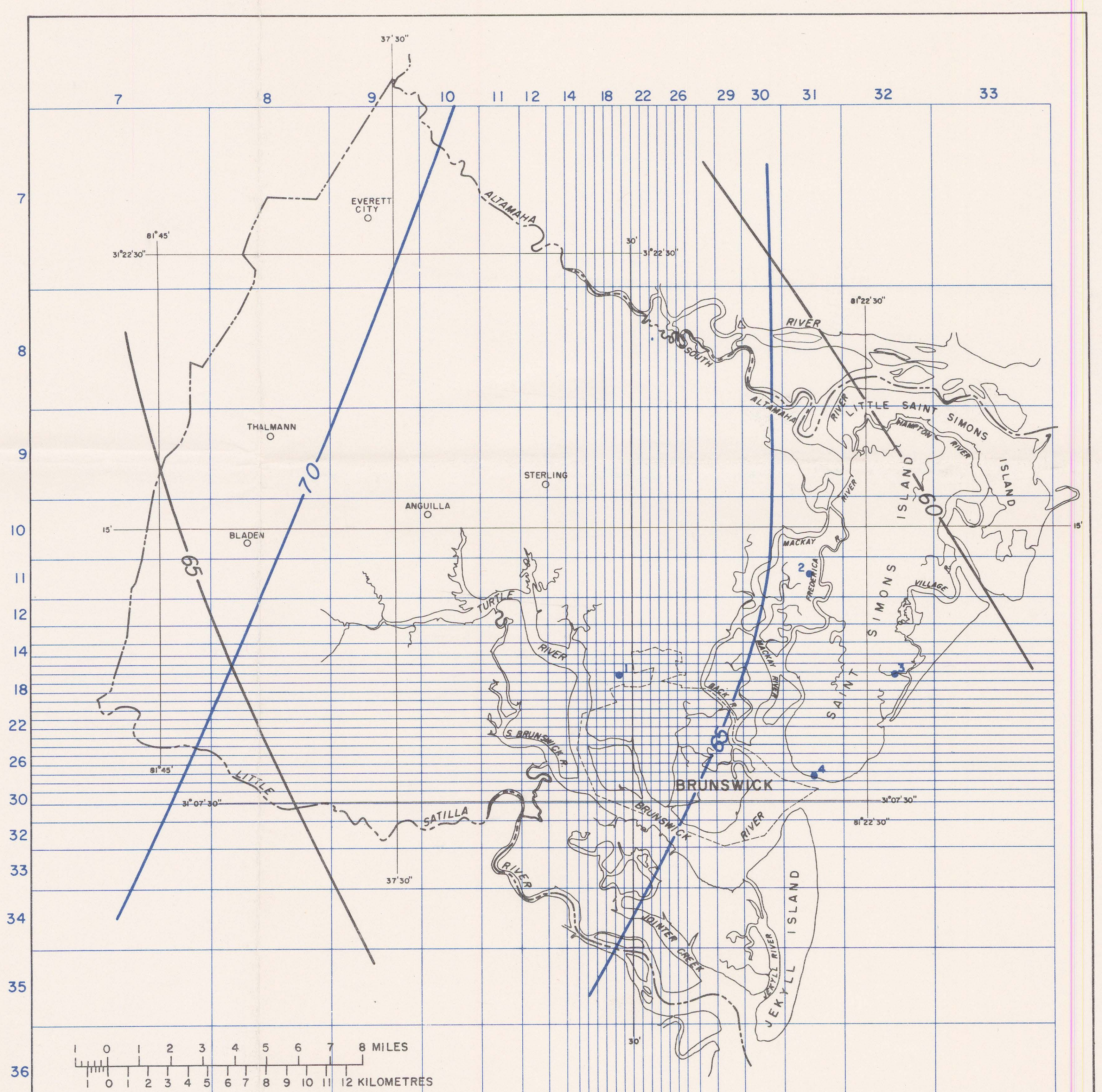
When the aquifer was tapped, the artesian water level was 60 to 70 ft (18 to 21 m) above mean sea level in the Glynn County area (Warren, 1944). See map at right. Ground-water pumpage, now totaling about 105 Mgal/d (4,600 l/s) has lowered the water level 15 to 70 ft (5 to 21 m) below the predevelopment surface (Krause and Gregg, 1972).

HYDROLOGIC INPUT DATA

Data used in the model for solving the ground-water flow equations were determined by contouring known data points on a base map of Glynn County. A rectangular grid with variable cell dimensions was superimposed, as shown on the map at right, and values assigned by interpolation for each node (the center of each rectangle of the grid). The grid is smallest in the immediate Brunswick area, 1,500 ft (457 m) on each side, giving weighted importance to the area where most of the water is pumped.

The following parameters are put in the model as individual values for each node: 1) the height above mean sea level of the predevelopment hydraulic head or artesian water level (contours shown on map at right); 2) the storage coefficient and transmissivity of the aquifer; 3) the height above mean sea level of the unconfined water table; 4) the thickness of the clay bed confining the aquifer; and 5) the discharge from or recharge to the aquifer. The storage coefficient and transmissivity are aquifer parameters that denote the amount of water released from or taken into storage, and the rate at which water is transmitted through the aquifer, respectively. Specific storage and hydraulic conductivity of the confining layer, which denote the ability of the confining bed to store and transmit water, are included as single values. The artesian water-level data were taken from Warren's map of the predevelopment (1880) potentiometric surface (1944). Storage coefficient and transmissivity data are from aquifer tests, and thickness of confining layer is derived from well logs—lithologic, driller's, and geophysical. The data for the unconfined water-table altitude are from water-level measurements, and are also estimated from land-surface altitudes taken from topographic maps. The average rate of pumping for each pumping period is included for each node. If more than one well is located in a node, the total rate of pumping for all wells in the node is used.

STEADY-STATE MODEL



Hydrology by R.E.Krause, 1973
Observed water-level contours from Warren (1944)

EXPLANATION

—65— OBSERVED WATER-LEVEL CONTOUR—Shows altitude of artesian water level. Contour interval 5 feet (1.5 metres); datum is mean sea level

—70— COMPUTED WATER-LEVEL CONTOUR—Shows altitude of computed artesian water level. Contour interval 5 feet (1.5 metres); datum is mean sea level

10 / 9 MODEL GRID—Numbers 7—33 (left to right) indicate columns; 7-36 (top to bottom) indicate rows.

•2 WELL—Number is identification number referred to on figure 5

MAP SHOWING MODEL GRID, OBSERVED (1880) AND COMPUTED (1980) STEADY-STATE WATER-LEVEL CONFIGURATION OF THE PRINCIPAL ARTESIAN AQUIFER

Hydrologic modeling is merely the solving by computer of a series of complex equations that describe the flow of water in an aquifer. Equations are solved for the water level or head value at each node of the grid. When values for the entire matrix have been calculated, time is increased incrementally by a factor of 1.5 times and the entire operation is repeated until the total time has been simulated. A simulation time of 100 years was used, so the final computed steady-state water level would be for 1980. A mass balance of the total water inflow and outflow in the modeled area is also determined. For this steady-state modeling, only natural recharge and discharge are used in the flow equations; pumpage is not included. The hydrologic system is in equilibrium when there are no changes in the water level with time. Therefore, the steady-state water level calculated by the model without pumpage should ideally match the water level found in the late 1880's, when the aquifer was first tapped by wells.

The steady-state model was improved by adjusting some hydrologic parameters. Confining-bed thickness was adjusted somewhat because it was not known how effective the confinement should be throughout its thickness. A better model was achieved using a thinner section of less permeable material (the green clay found in Glynn County), than by using total overburden thickness of more permeable material. The hydraulic conductivity (permeability) of the confining bed, a parameter which denotes the ability of the confining layer to leak water, and for which there were no real data, was adjusted for model refinement.

The map above shows the predevelopment artesian water level and the water level computed by the steady-state model. A reasonable match was achieved, indicating that the hydrologic data used in the model were reliable. Although the model used the water-level data of Warren (1944), computations were based on other and later hydrologic data which produced a configuration slightly different from Warren's. The computed configuration may more closely represent the water level before the aquifer was tapped, whereas much of Warren's data was from estimates and measurements obviously made after the aquifer was tapped and water discharged, especially in Chatham County, which could cause a deflection of contours in Glynn County. Also, the computed contours parallel the coast—possibly a more logical configuration than Warren's.

Cartography by W. G. Hester

DIGITAL MODEL ANALYSIS OF THE PRINCIPAL ARTESIAN AQUIFER, GLYNN COUNTY, GEORGIA

By

R. E. Krause and H. B. Counts

1975