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AQUIFER PERFORMANCE TEST REPORT

Brunswick Aquifer, Toombs County, Georgia

July 8-July 20, 1998

By

Rex A. Hodges

Department of Natural Resources
Environmental Protection Division
Georgia Geologic Survey

Project Report No. 35

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This report has not been reviewed for conformity with Georgia Geologic Survey editorial standards, stratigraphic nomenclature, and standards of professional practice.

DEPARTMENT OF NATURAL RESOURCES
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Table of Contents

List of Figures

ABSTRACT

As part of the Geologic Survey Branch of the Georgia Environmental Protection Division's "Evaluation of the Miocene Aquifers in the Coastal Area of Georgia Project", the Department of Geological Sciences at Clemson University conducted a pump test at the Georgia Geologic Survey's Toombs County well cluster, located on Horace Sanders farm, Toombs County, Georgia. A test of the Brunswick Aquifer was conducted from July 8 through July 20, 1998 using Toombs County 1 as the pumping well and Toombs County 2 as an observation well. The observation well is located 124.6 feet from the pumping well and the average flowrate during the test was 35.2 gpm. Calculations from observation well data resulted in a storativity (S) of 0.0006 and a transmissivity (T) of 520 ft^2/day. The aquifer was assumed to be fully screened with the screen zone ranging from 110 ft to 350 ft in both the pumping and observation wells. A transmissivity of 290 ft^2/day with a skin factor of 2.8 was calculated from pumping well data. Results from the observation well data are probably more reliable considering well bore effects in the vicinity of the pumping well. Based on the gamma ray log, the aquifer was estimated to have an effective sand thickness (aquifer) of 160 ft giving a hydraulic conductivity of 2.6 ft/day and a permeability of 0.96 darcys (water temperature of 20^{0}C). A decreasing water level trend due to a prolonged drought was removed prior to aquifer property analysis.

INTRODUCTION

Purpose of the Toombs County Miocene Aquifer Performance Test

Due to the hydrologic stress imposed on the Eocene to Oligocene age Upper Floridan aquifer, the principal water source of coastal Georgia, the Geologic Survey Branch of the Georgia Environmental Protection Division is investigating the Miocene aquifers as an additional source of ground water for the region. The test at Toombs County is the third of seven Miocene aquifer tests (Tybee Island and St. Marys were done previously) to be conducted at selected sites in southeast Georgia. Four of the seven test sites will be located in coastal counties, and three of the sites will be located inland where agricultural ground-water use is prevalent. The purpose of the Toombs County test is to estimate the transmissivity and storativity of the Miocene aquifer. The results from each of the seven sites will be analyzed in combination with other geologic data to determine if the Miocene aquifers are viable alternatives to the Upper Floridan aquifer for smaller-demand needs such as community water supply, golf courses, agricultural (lower demand or supplemental), small industries, and non-contact cooling water.

Site Conditions

Location

The Toombs County site is located about 75 miles inland from St. Catherines Island on the southeastern coast of Georgia. The nearest town is Reidsville, about 12 miles east of the site. Figure 1 is a map of Georgia showing the location of the Toombs County test site, St. Marys test site and the Tybee Island test site. The well cluster is located about 12 miles southwest of Reidsville on Horace Sanders farm, Figures 2 and 3.

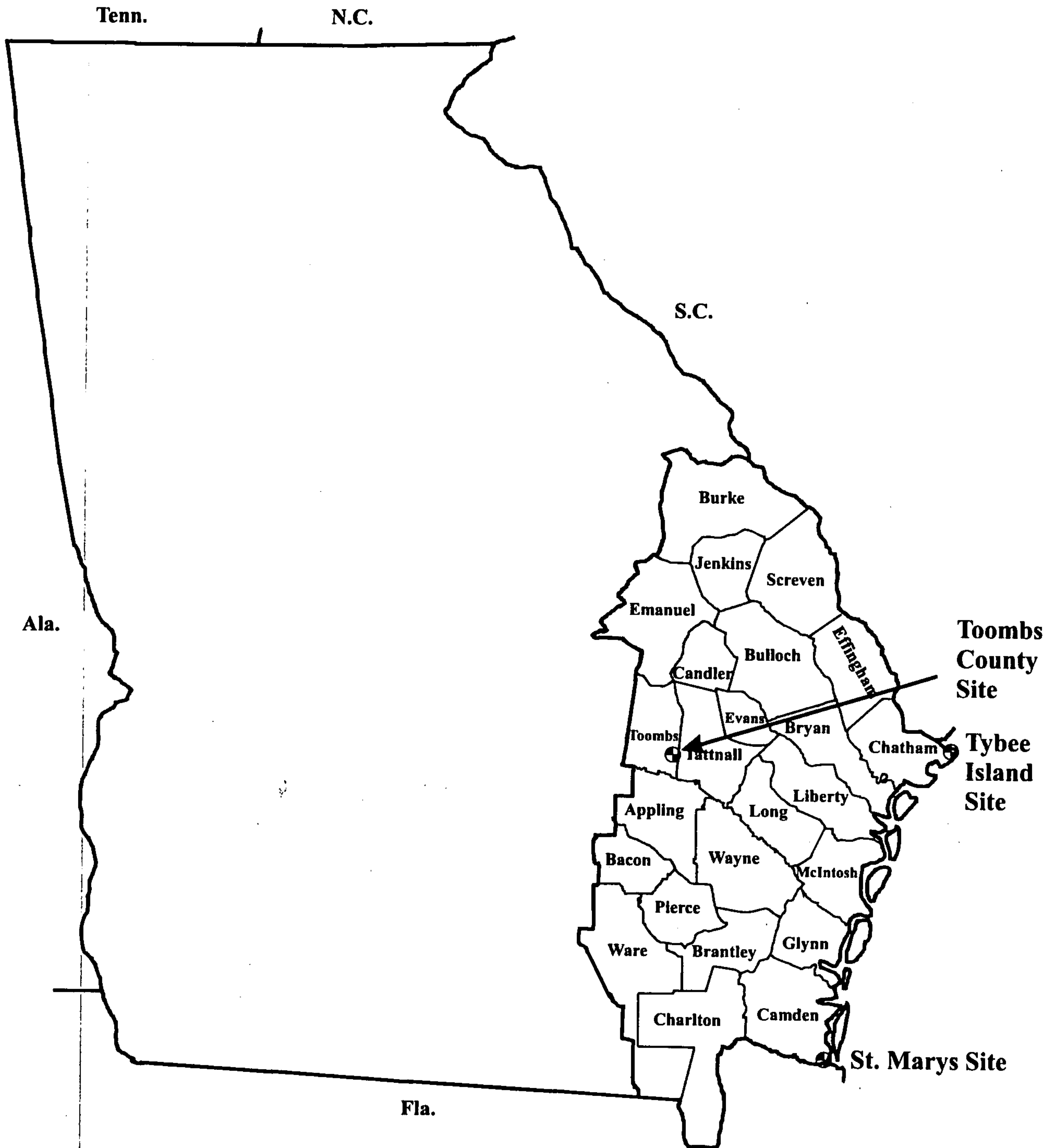


Figure 1: Map of Georgia showing the location of the Toombs County test site.

Figure 2. Map showing the Toombs County test site, about 12 miles SW of Reidsville.

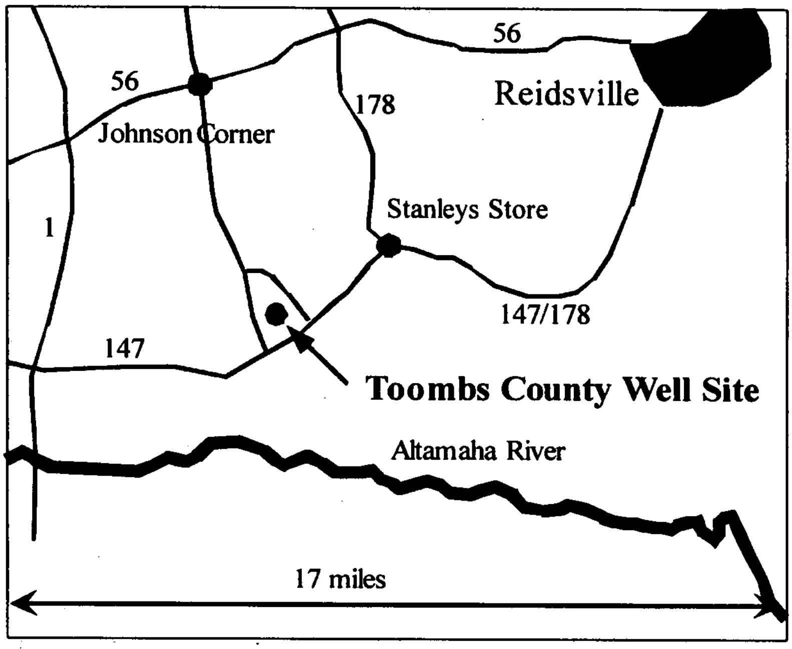
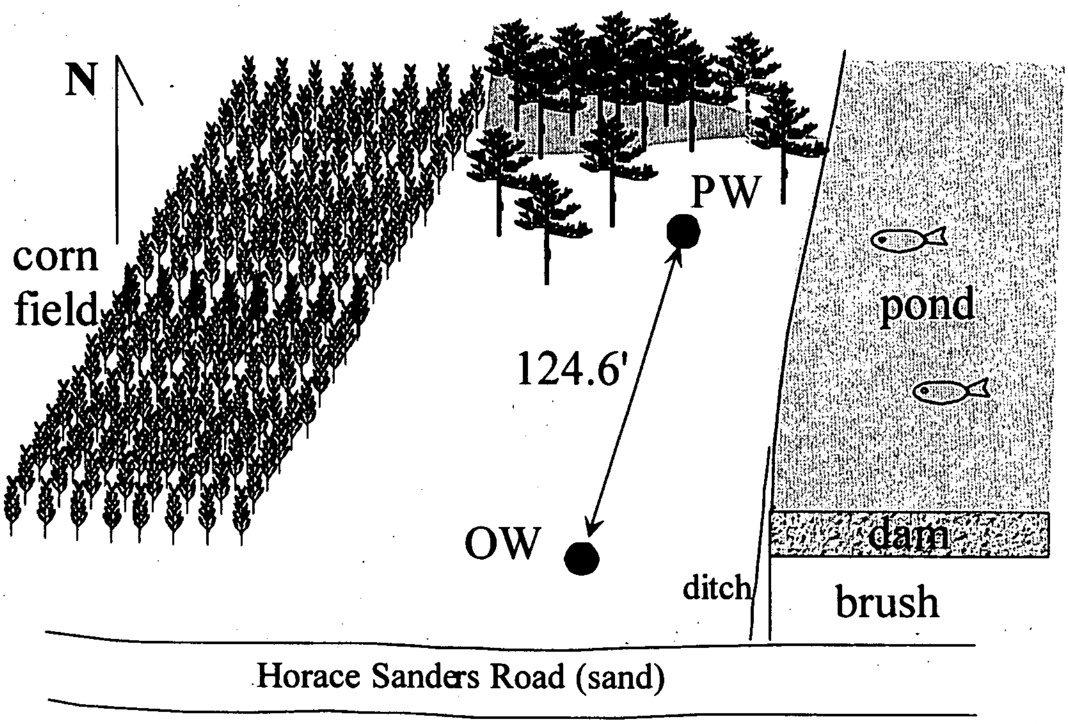


Figure 3. Schematic map of the Toombs County test site showing the relative locations of the pumping well and the observation well.



Hydrogeologic Setting

Strata underlying the site dip and thicken to the southeast. The Toombs County well cluster is drilled into Coastal Plain sediments ranging in age from Eocene to Miocene. The hydrostratigraphy penetrated at the site consists principally of two aquifers, the confined (Miocene Brunswick) and the unconfined aquifer. The geophysical well logs are shown in Figure 4.

The Brunswick aquifer at the site, as defined by the screen zone, is 240 ft of sands (~160 ft) with interbedded clays (~80 ft). However, only the sands should be considered as an effective aquifer. The aquifer is confined, though the pressure head is only 11 ft above the aquifer top. Leakage from the adjacent pond to the aquifer is not a factor. The Altamaha River (4 miles to the south and a surface elevation below 60 ft msl) and its associated alluvial valley are a likely discharge sink. Dip of 20 ft/mile from the site to the river would put the top of the aquifer at 30 ft msl, just 30 ft below the river surface, making it likely that the upper sands of the aquifer become unconfined somewhere between the site and the river.

Description of Wells Used for the Test

At the Toombs County test site, two wells, Toombs County #1 (PW, pumping well) and Toombs County #2 (OW, observation well), were drilled and completed in the Brunswick aquifer in early 1998. The wells were drilled to 360 ft (-190 ft msl) and screened over the same interval, 110 to 350 ft (80 to -180 ft msl). A schematic well construction diagram is shown in Figure 5.

Site coordinates: . . . . PW-31°59'52" lat. 82°16'27" long.
PW to OW distance: . . . . 124.6 ft
Date of construction: 02/98
Ground elevation: . . . . 170 ft MSL

Figure 4. Gamma ray and resistivity log from Toombs County

GR [api units] , resistivity [ohm * m].

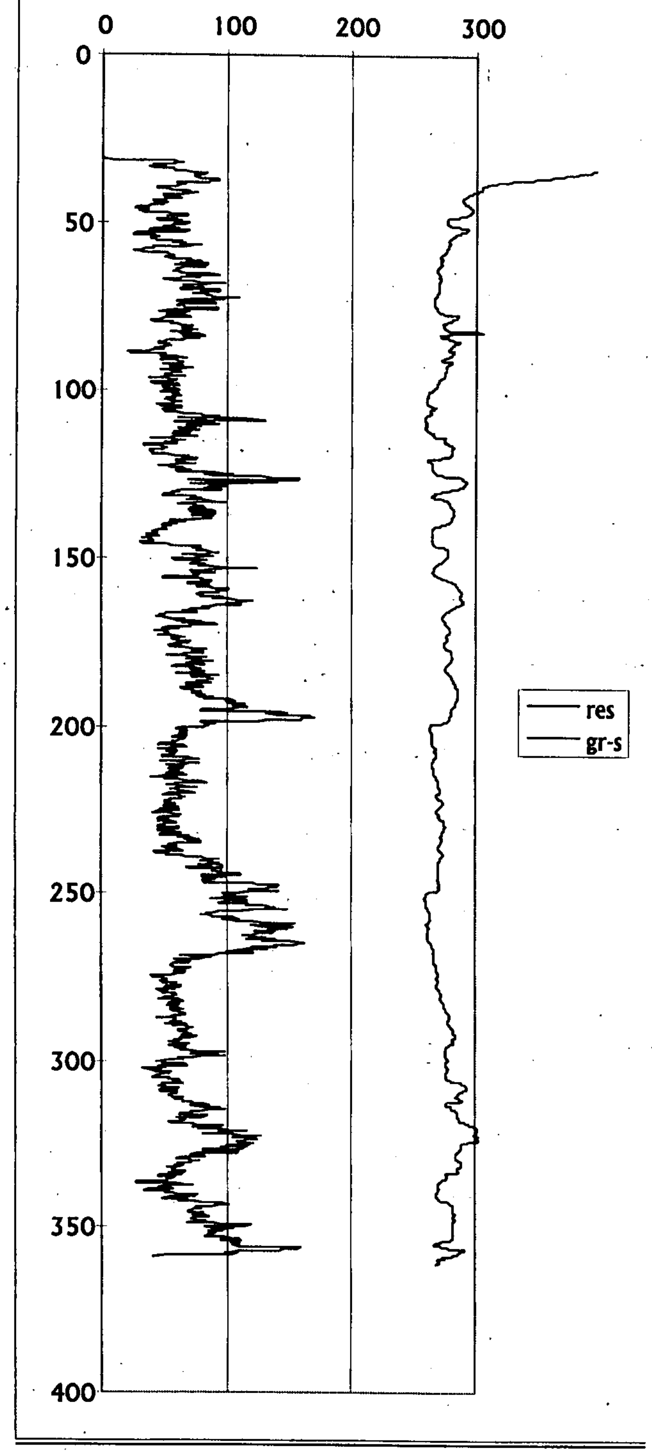
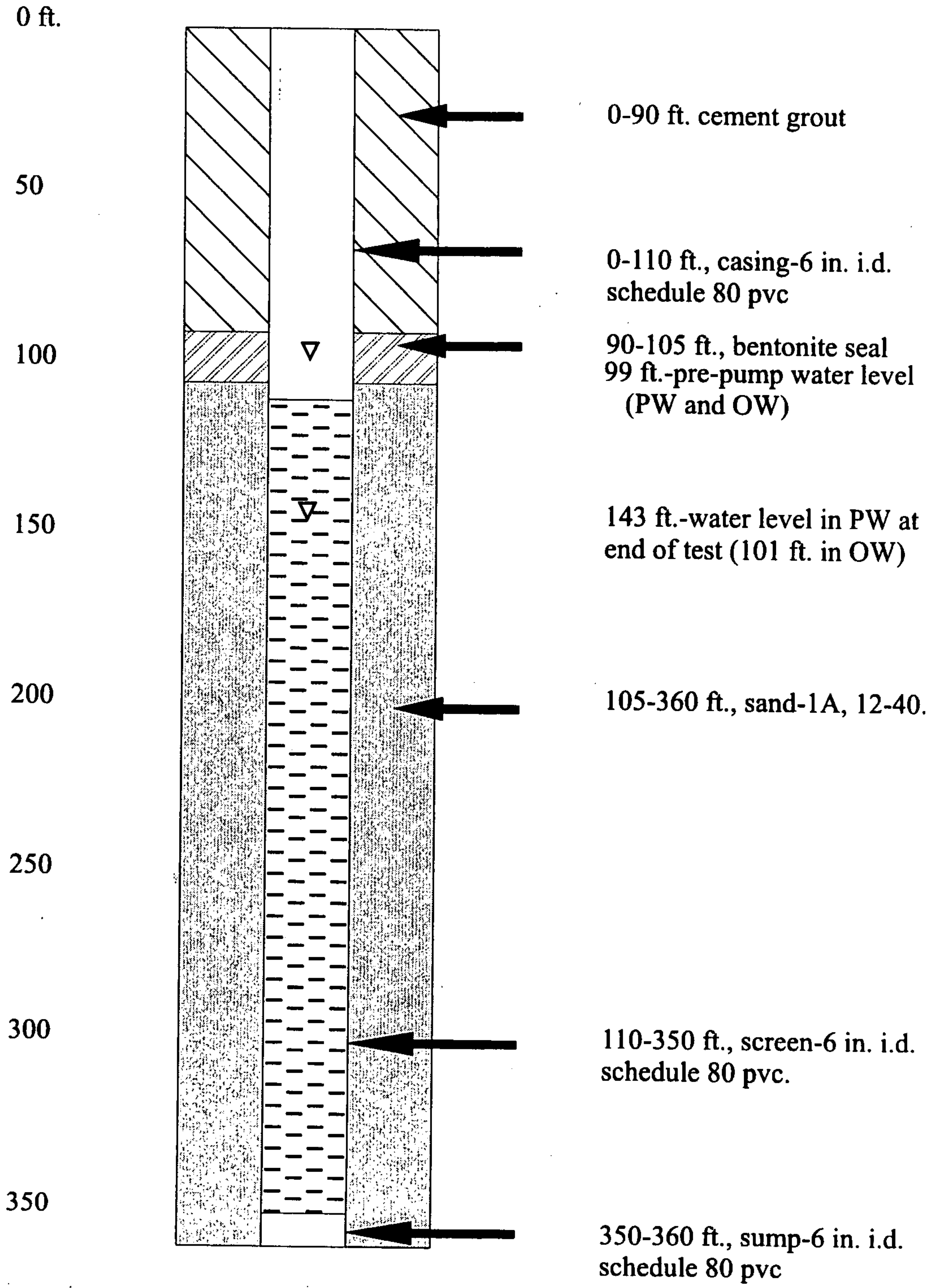


Figure 5. Schematic well construction diagram of Toombs County wells.



METHODS

Test Logistics

The test took place from July 8 to July 20, 1998. The Brunswick aquifer was pumped using Toombs County 1 and monitored using Toombs County 2. A 3 hp pump was installed in Toombs County 1 on July 8. On Friday, July 10, a short 30 minute trial pump test was conducted to determine the optimum flow rate (Q) for the actual test. A Q of 35 gpm produced a drawdown of 38 ft in 30 minutes, and projecting forward, a 3-day test would draw down 42 to 45 feet. This rate was selected for the long test even though pumping would lower the water level in the pumping well to 30 ft below the top of the screen (and aquifer). The aquifer is composed of many separate sands and only the upper sands in the near vicinity of the well bore would be affected. A flowrate of 10 gpm or less would be required to avoid drawdown into the aquifer and would not be consistent with the overall purpose of the study, to determine the potential of the Brunswick aquifer as a source of water.

Background water level data were collected in Toombs County 1 from March 4, 1998 until the test to detect water level trends. Pumping began at 11:57 a.m. on Monday July 13 and continued for 71 hours until the pump was turned off at 11:00 a.m. on Thursday, July 16. The average flow rate for the test was 35.2 gpm. Recovery data were recorded for 100 hours until the pump was pulled on Monday, July 20 at 3:00 p.m.

Background:	March 4 to July 13, 1998
Pumping:	11:57 July 13 to 11:00 July 16 (71 hours)
Recovery	11:00 July 16 to 15:00 July 20 (100 hours)
Average Q:	35.2 gpm
PW to OW distance:	124.6 ft

Data Acquisition Methods

Water level readings are recorded as pressure changes in meters of water relative to an initial equilibrium static water level condition. For the duration of the pump test (background through recovery), In Situ, Inc. "TROLL" transducers were used to measure and record water level changes in the pumping well and observation wells. Pressure readings were recorded as frequently as 1 second at pump-on and pump-off times to as infrequently as every 5 minutes when water level changes were small. A 100 psi "TROLL" transducer/data recorder was positioned 15 ft above the pump in the PW and a 30 psi "TROLL" was placed 25 ft below the water level in the observation well.

A 3 hp submersible pump was installed below 10.5 joints (~220 ft) of 2" pipe, placing it about 120 ft. below the initial static water level. Discharge was monitored by a portable Omega inline flow meter. Flow readings were recorded manually and are shown in the following table.

Table of flow rate readings taken during the Toombs County test.

time (hrs) (since pump on)	Q (gpm)	
0.02	36	
0.03	35.8	
0.05	35.6	
0.07	35.5	
0.08	35.3	
0.12	35.2	average of readings after 10 minutes
0.17	35.3	
0.25	35.1	
1.10	35.2	
2.0	35.2	
3.5	35.2	
5	35.4	
23.0	35.3	
70.0	35.1	

Analysis Methods

Atmospheric Pressure Corrections

The TROLL transducers are vented to the surface (atmosphere) and record gage pressure, not absolute pressure. No atmospheric pressure corrections are required.

Trend Effect Corrections

The Toombs County # 1 well was instrumented with a transducer/water level recorder on March 4, 1998 providing over 4 months of background data. The extended period was the result of delays in performing the test which was originally scheduled for mid to late March. Background data are collected in order to recognize any long-term trends in water levels, such as those caused by extended rainy or dry periods. Water level changes not related to pumping are filtered prior to analysis.

Well Analysis Methods

Analysis of data from an observation well screened in the same aquifer as the pumping well is the best method for calculating aquifer properties, storativity and transmissivity. Data from the pumping well are also used, but an additional variable, the head loss caused by water being pumped through the screen and altered formation near the well bore (skin factor effects), makes the pumping well data analysis problematic. If one of the three variables is known or can be estimated, the other two can be calculated. The skin factor of the pumping well is unknown and could be highly variable depending on well installation. The storativity of the aquifer is less sensitive than the transmissivity. It is estimated from analysis of observation well data or from average storativity values of similar aquifers if no observation well is present. This storativity value is then used in the analysis of the pump well data.

Variable rate curve matching of drawdown data from the observation well yields a transmissivity and a storativity value for the aquifer. Analysis of pumping well data gives a separate transmissivity value for the aquifer (to compare with the one calculated from OW data) and a skin factor for the pumping well. Both methods employ the superposition of the Theis solution (1935) or Jacob straight-line method (Cooper and Jacob, 1946) for variable flow rates, modified for the skin factor analysis of Van Everdingen (1953) for confined aquifers with fully penetrating wells. The skin factor of the observation well is assumed to be zero because of the much lower water velocity away from the pumped well. For partial penetrating wells, data are analyzed using the Hantush (1961, 1964) solution for partial penetrating wells modified to account for the skin factor and multiple flow rate. The long screen zones at Toombs County are considered to be fully penetrating. Hydraulic conductivity is determined by dividing the transmissivity by the effective aquifer thickness. Permeability can then be calculated by multiplying the hydraulic conductivity in m/sec by a factor of 104,000 to convert to darcys (at 20^0 C water temperature; Fetter, 1988).

RESULTS

Water Level Readings

A total of 6596 data points were recorded in the PW. During the test period (3586 data points) were recorded as frequently as every 1 second at times of rapidly changing water levels (i.e. at the beginning and end of pumping phase of the test), decreasing to every 5 minutes when water level changes were relatively small. During the extended background phase, 3010 data points were recorded, one each hour. In the OW, a total of 2046 data points were recorded during the test.

Water Level Change During the Test

A maximum drawdown of 14.24 meters (46.7 ft) was observed in the pumping well Toombs County 1 after 71.0 hours of pumping (Figure 6). A maximum drawdown of approximately 1.865 meters (6.12 ft) was seen in the observation well Toombs County 2 (Figure 7), 15 seconds after the pump was shut off. Figures 6 and 7 are graphs of the water level in the PW and OW before and during the test. Note the drawdown caused by the pre-test to determine optimum flowrate on July 10.

Figure 6 Graph of water level data in the PW, July 8 through July 20.

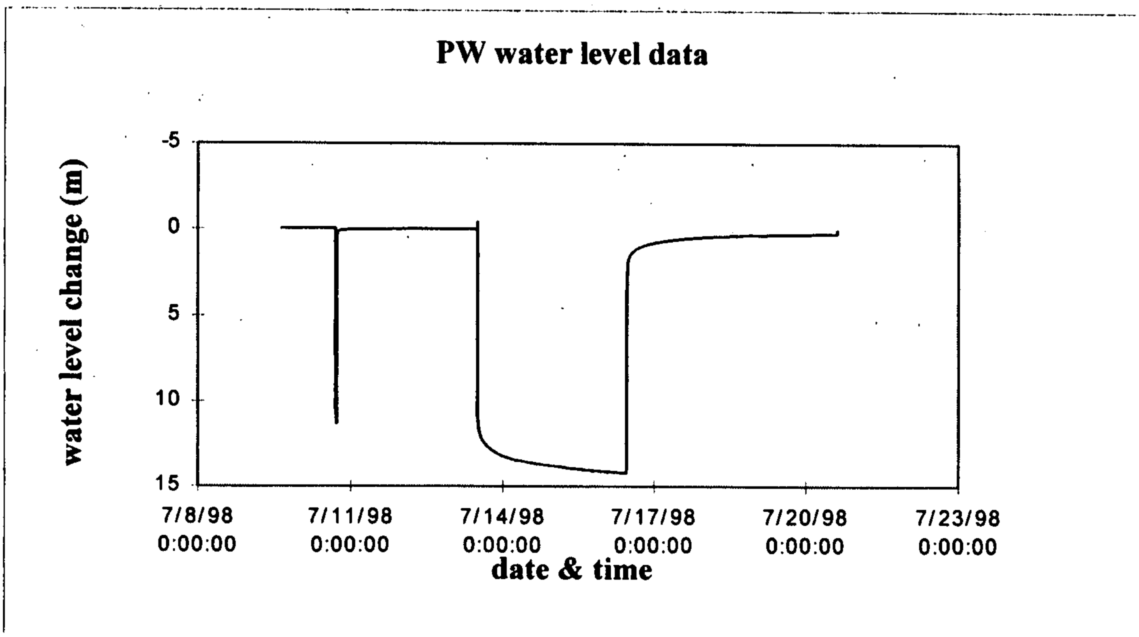
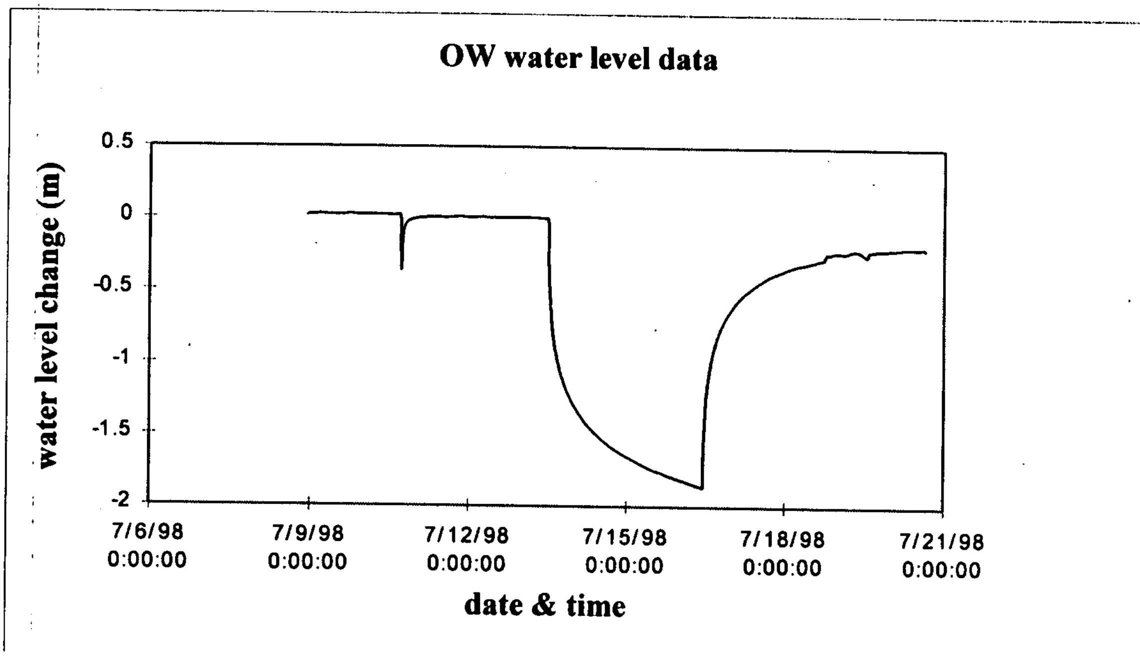


Figure 7 Graph of water level data in the OW, July 8 through July 20. Note the expanded scale vs the PW graph.



Trend Corrections

Background water level data was taken for over 4 months prior to the test in Toombs County 1 (Figure 8). Two long term trend changes were observed. First, there was an overall increasing water level through the end of April. The probable cause was an extremely wet late winter and spring and has no effect on the test. However, a drought from May through the test caused a reversal of the trend, with water levels falling. For the month prior to the test, water levels were decreasing at the average rate of 6 mm/day. Test data for both wells (the wells were screened over the same zone) were corrected for this effect, shown in Figure 9.

Figure 8 Graph of water level data in the PW, March 4 through July 20.

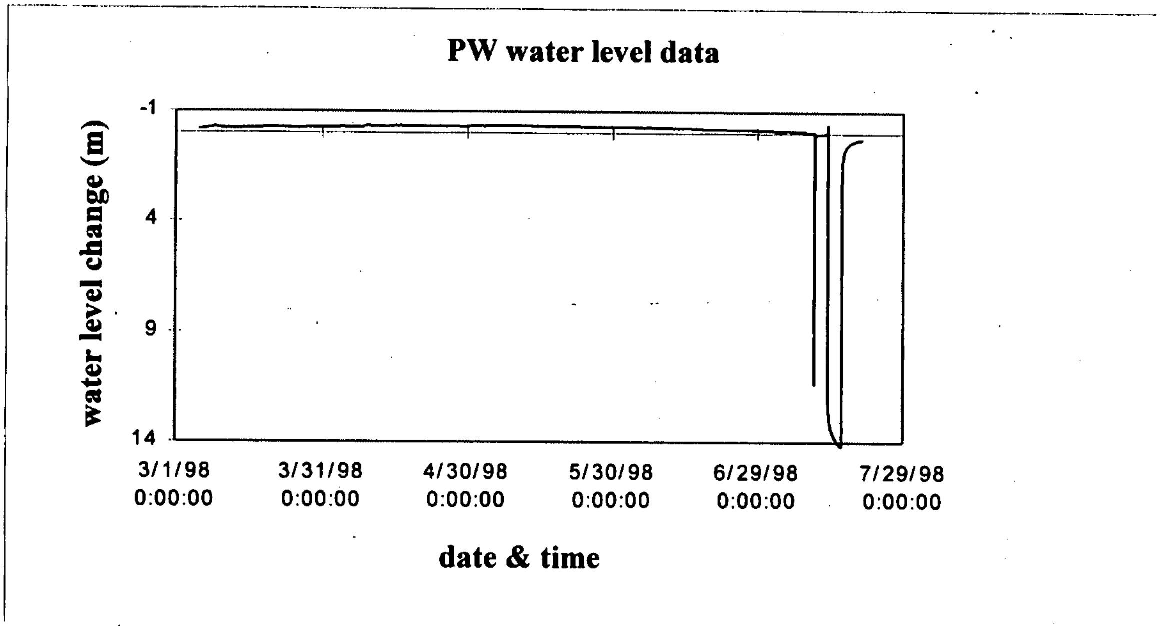
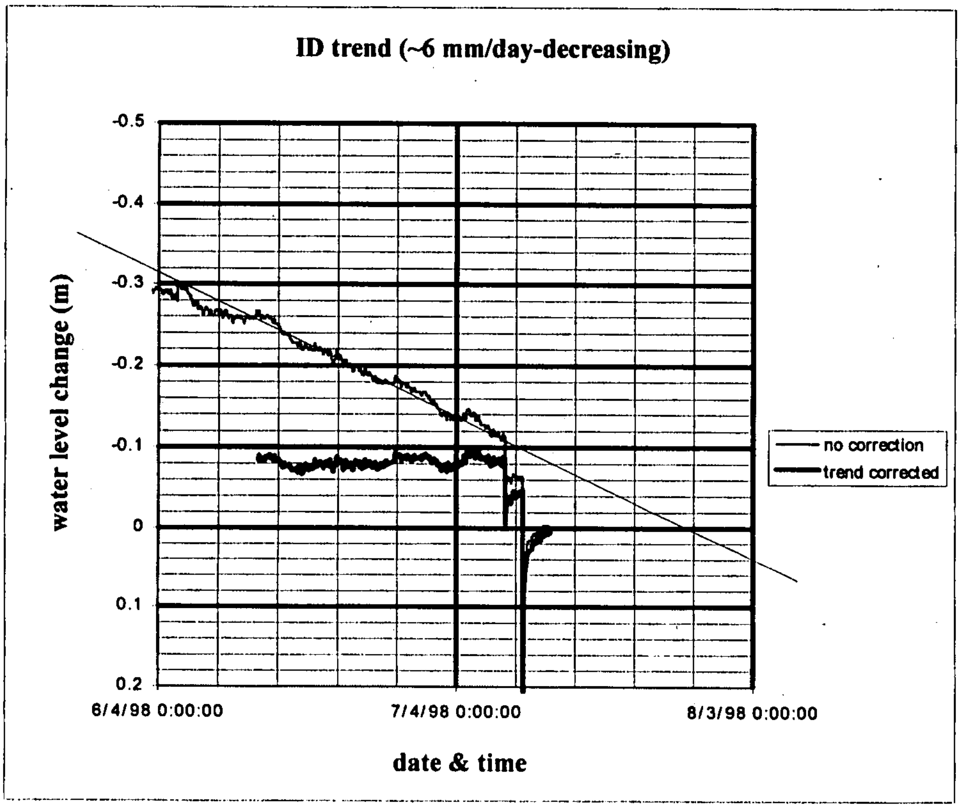


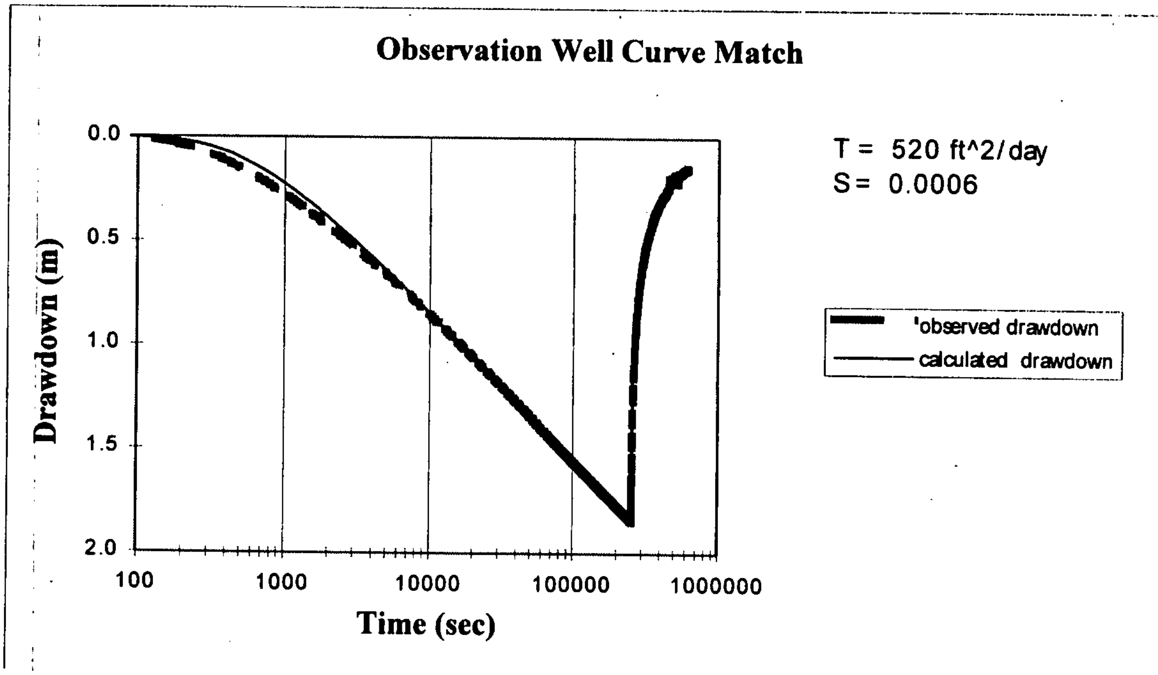
Figure 9 Identification of trend and applied correction. Note that the small data breaks that occur at the time of pump installation on July 8.



Calculated Aquifer Properties

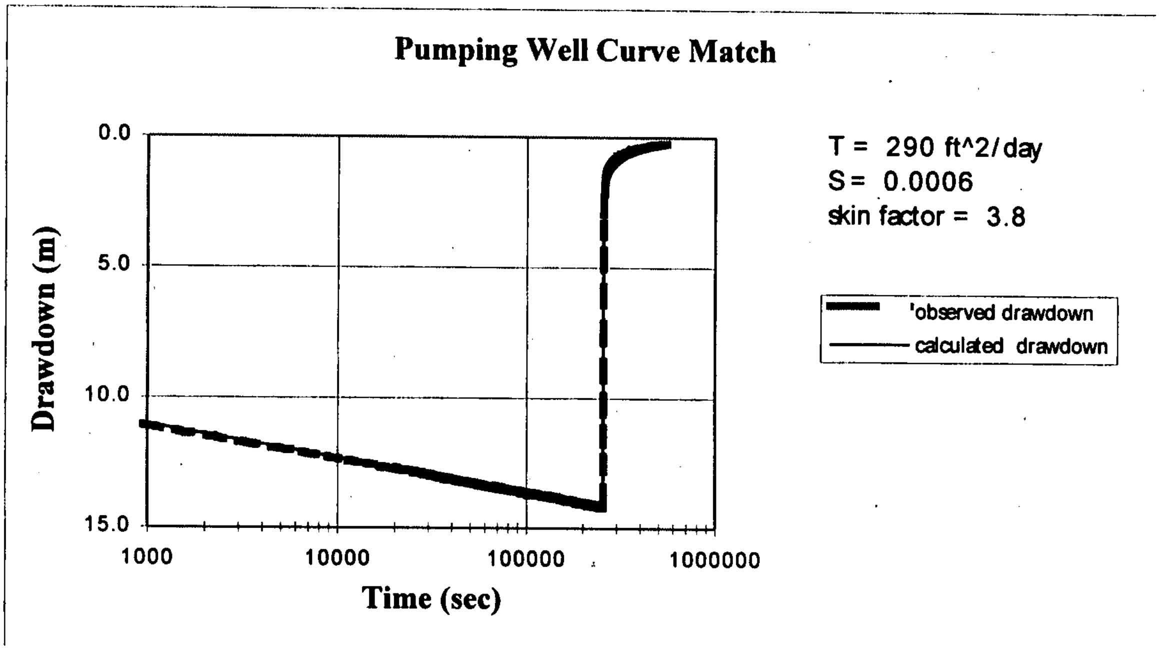
Data from the OW were used to calculate a storativity of 0.0006 and a transmissivity of 520 ft^2/day for the Brunswick aquifer. Calculated drawdown was based on a flow rate of 35.2 gpm and a PW distance of 124.6 ft. Hydraulic conductivity and permeability values of 2.6 ft/day and 0.96 darcys were calculated based on an estimated effective aquifer thickness of 160 ft. The match is excellent for 100 minutes into the pumping phase of the test through the recovery period (Figure 10). The anomalous blips during the latter stages of the recovery coincide with a thunderstorm.

Figure 10 Theis-Jacob curve match for OW, Toombs County 2.



Data from the pumping well were also used to calculate transmissivity. Early time data (from 1 to 1000 seconds) were not used in the curve match because of well bore storage effects. Calculated drawdown was based on a flow rate of 35.2 gpm and a well radius of 3 inches. A storativity of 0.0006, based on OW analysis, was used and the well was assumed to be fully screened over the entire thickness of the aquifer. The curve match (Figure 11) for the pumping well yielded a transmissivity of 290 ft^2/day and a skin factor of 3.8. Hydraulic conductivity and permeability values of 1.45 ft/day and 0.53 darcys were calculated based on an estimated effective aquifer thickness of 160 ft. The poor match of the recovery phase is due to a leak above the check valve, causing the well to recover faster than would be predicted.

Figure 11 Theis-Jacob curve match for PW, Toombs County 1.



Specific Capacity

An average flow rate of 35.2 gpm created a 46.7 ft drawdown after 71 hours of pumping. This equates to a specific capacity of 0.754 gpm/ft.

DISCUSSION

Test Logistics

An intermediate flow rate (35.2 gpm) was selected for the test despite the fact that it would cause drawdown into the upper sands of the aquifer. In order to avoid any de-watering of the aquifer, a flowrate of less than 10 gpm would be necessary. In order to test the aquifers potential as a water supply, a low flow test over 240 ft of screen did not seem reasonable. Additionally, the aquifer is comprised of several sands separated by interbedded clays. The intermediate flow rate only begins to de-water the upper-most sands within a 10 ft radius of the PW based on the transmissivity calculated from the OW data. It is believed that the drawdown into the screen at the PW does reduce the reliability of the transmissivity calculated from PW data.

Analysis

The observation well analysis yielded reasonable values for both storativity and transmissivity. The S of 0.0006 is consistent with that of a confined aquifer. The permeability of only about a darcy is not promising for producing significant quantities of water but is adequate for small demands, such as a household. The wells are not sufficient to supply water for irrigation purposes except for limited periods. A flow rate of 150 gpm (probably less due to induced relative permeability problems) for 3 days would lower the water level in the PW to the base of the aquifer and the water level in the OW would be lowered 27 ft. For the two wells at the Toombs County site, a 5 hp pump capable of 50 gpm could be set in one well for emergency drought conditions and a 1 hp pump capable of 10-15 gpm could be used on a regular basis to fill the adjacent pond. The pond could then be used as a source of irrigation water. Any prolonged pumping at high rates will allow air into the de-watering formation, reducing the relative permeability of water, thereby reducing future yields. This occurs because not all of the air will be displaced when pumping stops and the aquifer is fully saturated. Small amounts will remain in the formation and occupy space, shrinking pore throats used for water flow.

Analysis of pumping well data yielded a transmissivity value significantly lower than the OW (290 vs 520 ft^2/day). Although this degree of variability is not without precedence, the value from the PW data is suspect because of the drawdown into the upper sands of the aquifer.

REFERENCES

Cooper, H. H., and Jacob, C. E., 1946, A generalized graphical method for evaluating formation constants and summarizing well field history, Transactions of the American Geophysical Union, v. 27., pp. 526-534.

Earlougher, Robert C., 1977, Advances in Well Test Analysis, Millet the Printer, Inc., Dallas, Texas, 264 p.

Fetter, C. W., 1988, Applied Hydrogeology, Macmillan, Inc., New York, NY, 691 p.

Freeze, Allan R., Cherry, John A., 1979, Groundwater, Prentice-Hall, Inc., Englewood Cliffs, NJ, 604 p.

Hantush, M. S., 1961, Drawdown around a partially penetrating well, Journal of the Hydrualics Division, Proceedings of the American Society of Civil Engineers, pp. 83-98.

Hantush, M. S., 1964, Hydraulics of wells: Advances in hydrosciences, v.1., Academic Press, New York, pp. 281-432.

Jacob, C. E., 1940, On the flow of water in an elastic artesian aquifer, American Geophysical Union Transactions, part 2, pp. 574-586.

Theis, C.V., 1935. The relation between lowering of the piezometric surface and the rate and duration of the discharge of a well using groundwater storage. Transactions of the American Geophysical Union, Vol. 2., pp. 519-524.

Van Everdingen, A. F., 1953. The skin effect and its influence on the productive capacity of a well. Petroleum Transactions, Vol. 198, pp. 171-176.

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