Hydrogeology and Aquifer Tests in the Floridan Aquifer System at Selected Sites, Coastal Georgia, 2001

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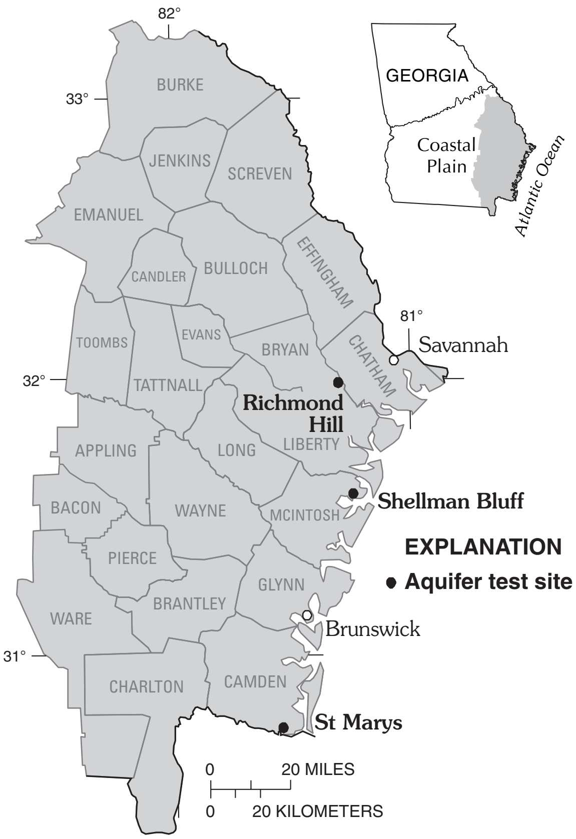
INTRODUCTION

The Floridan aquifer system is one of the most productive ground-water resources in the United States and is the principal source of ground-water supplies in the coastal area of Georgia (Miller, 1986). The aquifer system consists of the Upper and Lower Floridan aquifers throughout most of the aquifer system's distribution in Georgia, South Carolina, Florida, and Alabama. Saltwater encroachment into the Upper Floridan aquifer has degraded the water quality in parts of the coastal area of Georgia, South Carolina, and Florida (Krause and Clarke, 2001).

The U.S. Geological Survey (USGS)—in cooperation with the Georgia Department of Natural Resources, Environmental Protection Division, Georgia Geologic Survey—is investigating the Lower Floridan aquifer as an alternative source of ground water in a 24-county area in coastal Georgia as part of the Coastal Sound Science Initiative. As part of this evaluation, test wells were drilled and completed in the Lower Floridan aquifer at Richmond Hill, Bryan County; Shellman Bluff, McIntosh County; and St Marys, Camden County. Additionally, one well was completed in the Upper Floridan aquifer at Richmond Hill. The USGS planned and completed a single-well aquifer test at each site.



Twenty-four-county study area of the Georgia Coastal Sound Science Initiative and aquifer test sites, Georgia.

General Description of Test Sites

The aquifer-test sites are in the Coastal Plain physiographic province of eastern Georgia (map, to the right). The Richmond Hill site is located in Bryan County, Georgia, approximately 26 miles (mi) west of the Atlantic Ocean and 15 mi southwest of Savannah, Georgia. Land surface altitude is approximately 13 feet (ft) above the National Vertical Datum of 1988 (NAVD 88). A 1- to 2-acre wastewater treatment pond is located approximately 40 ft from the two wells. The pond is partially filled and discharged daily.

The Shellman Bluff site is in McIntosh County, Georgia, approximately 33 mi north of Brunswick and 36 mi south of Savannah, Georgia. Land surface altitude is approximately 10 ft above NAVD 88. An extensive tidal saltwater marsh is present near the well site.

The St Marys site is in Camden County, Georgia, approximately 24 mi north of Jacksonville, Florida, and 51 mi south of Brunswick, Georgia. Land surface altitude is approximately 10 ft above NAVD 88. A large paper mill is present near the site that withdraws water from the Upper and possibly the Lower Floridan aquifers.

HYDROGEOLOGY

At the Richmond Hill site, the Upper Floridan aquifer consists of limestone (Falls and others, 2001). Well 35P110 is open to the aquifer from 315 to 441 ft (table, facing page; well construction diagram, following page) (all depths are reported from land surface). The Lower Floridan aquifer has a porous, permeable zone consisting mostly of limestone with some dolomitic limestone from 950 to 1,076 ft. Strata below the permeable zone consists of fine-grained limestone from 1,076 to 1,293 ft; clay from 1,293 to 1,318 ft; clayey limestone with chert nodules from 1,318 to 1,624 ft; and black marine clay from 1,624 to 1,677 ft. No permeable zone could be identified in the fine-grained lithologies beneath 1,318 ft (Falls and others, 2001). Well 35P109 is open to the

Well location, construction, average pumping rate, aquifer, and calculated transmissivity for aquifer tests
[NAVD 88, National Vertical Datum of 1988]

USGS site name	Site location (map, facing page)	Aquifer	Altitude of land surface (feet above NAVD 88)	Hole depth (feet below land surface)	Well depth (feet below land surface)	Depth of open interval (feet below land surface)	Average pumping rate (gallons per minute)	Calculated transmissivity (feet squared per day)	Date of aquifer test
35P110	Richmond Hill	Upper Floridan	13	441	441	315–441	735	70,000	May 09–10, 2001
35P109	Richmond Hill	Lower Floridan	13	1,677	1,275	1,010–1,275	750	8,300	May 16–17, 2001
35L085	Shellman Bluff	Lower Floridan	10	1,863	1,422	1,144–1,422	700	6,000	June 14–15, 2001
33D073	St Marys	Lower Floridan	10	1,500	1,500	1,360–1,500	710	13,000	July 26–27, 2001

Lower Floridan aquifer from 1,010 to 1,275 ft (table, above; well construction diagram, following page).

At the Shellman Bluff site, the Floridan aquifer system extends from 345 to 1,438 ft with the Lower Floridan aquifer present from 1,196 to 1,438 ft. The Floridan aquifer system consists of limestone that is dolomitic in several intervals; however, beds of dolomite are present only near the contact between the Lower Floridan aquifer and the underlying marl. Well 35L085 is open to the Lower Floridan aquifer from 1,144 to 1,422 (table, above); however, the most permeable zone is from 1,190 to 1,225 ft (well construction diagram, following pages).

At the St Marys site, the Upper Floridan aquifer consists of limestone from 513 to 814 ft and interbedded limestone and dolomite from 814 to 1,115 ft. The Lower Floridan aquifer consists of thick beds of dolomite and interbedded limestone and dolomite (well construction diagram, following pages). Well 33D073 is open to the Lower Floridan aquifer from 1,360 to 1,500 ft (table, above). The base of the Lower Floridan aquifer was not penetrated during drilling (Falls and others, 2001).

AQUIFER TESTS

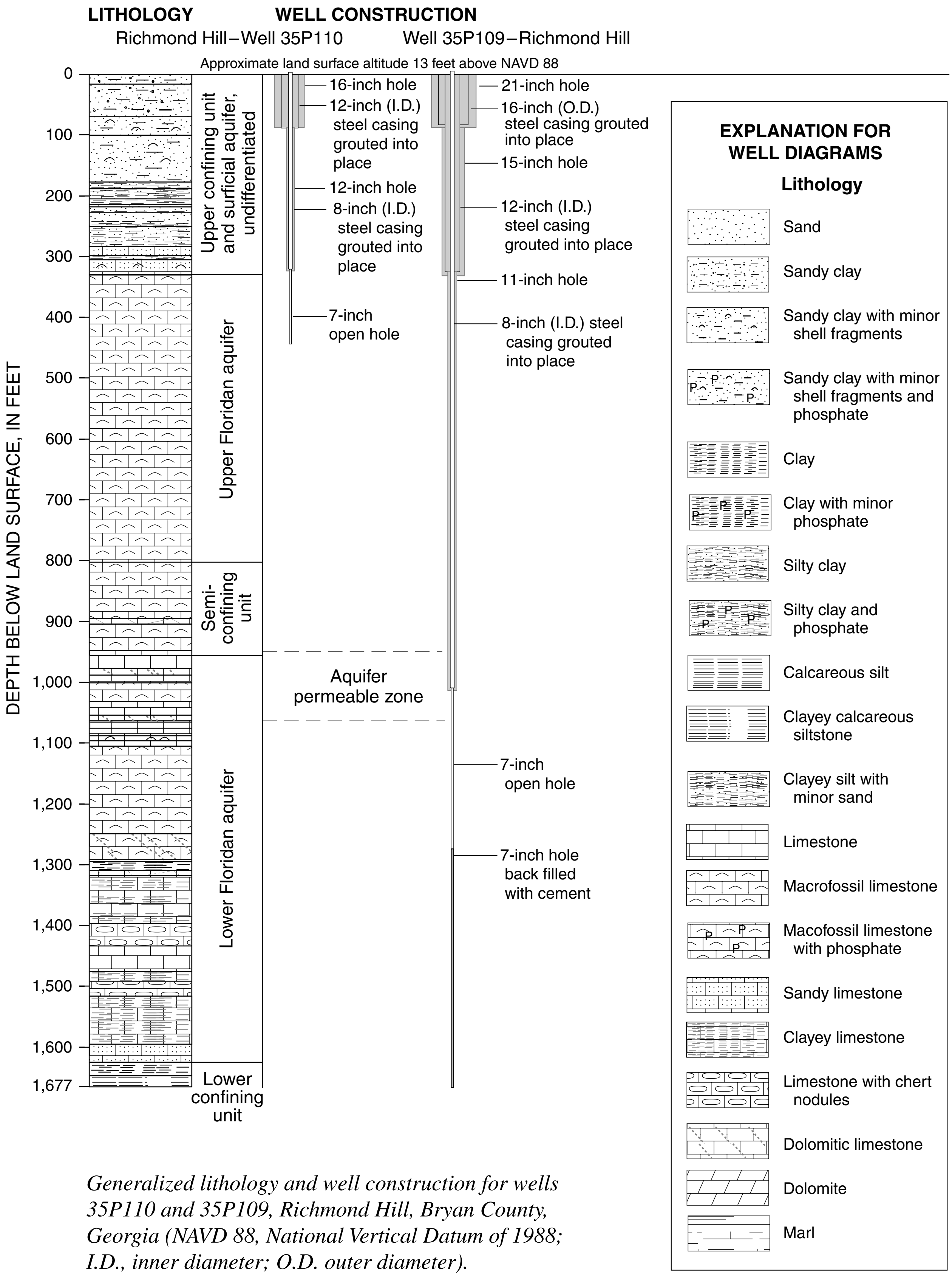
Each single-well aquifer test was designed to provide a reliable estimate of transmissivity. The aquifer tests consisted of four phases. Ideally, the four phases were as follows:

1. A 4-hour (hr) pre-test pumping was done to ensure that each well was fully developed prior to the pumping test. During the pretest, discharge was monitored to verify that a constant discharge could be maintained. Water levels were monitored to ensure that drawdown in the well would not exceed the depth of the pump intake or pressure transducer.
2. A 24-hr pretest (background) monitoring of the atmospheric pressure and water levels in the well(s) was conducted to investigate the water-level fluctuations caused by changes in atmospheric pressure, loading by external forces, regional ground-water withdrawals, and tidal cycles.
3. The well was pumped for 24 hrs while concurrently monitoring ground-water discharge, water level, and atmospheric pressure.
4. Following completion of pumping, the atmospheric pressure and water levels were monitored for 24 hrs.

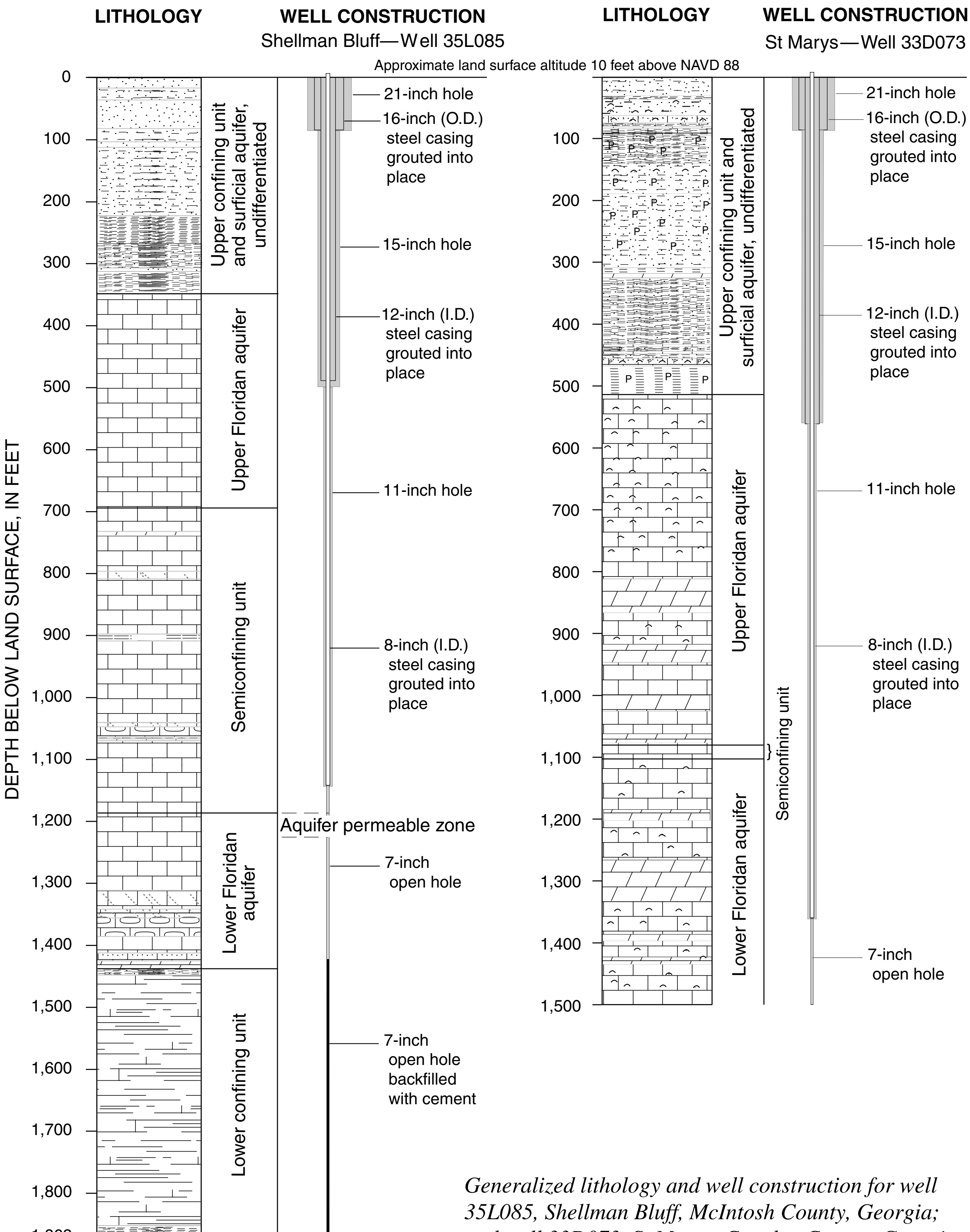
In general, each aquifer test followed the same procedure and used comparable equipment. A 30- or 100-pound-per-square-inch pressure transducer was installed into a 0.75-inch polyvinylchloride pipe in the well. An internal pressure sensor in the data logger measured atmospheric pressure. The data logger was programmed to collect data in logarithmic sample intervals with a maximum sample interval of 5 or 10 minutes. This method allowed for rapid collection of data during the initial period of the 24-hr aquifer and recovery tests. During each test, water levels were measured periodically with a steel or electric tape and compared to pressure transducer readings to verify the accuracy of the pressure transducer.

A 30-horsepower submersible pump with a 5-inch (internal diameter) riser pipe was used to produce ground-water discharge. The pump was set at approximately 100 ft below land surface. A foot valve was installed in the riser pipe just above the submersible pump to prevent backflow into the well. Power for the submersible pump was provided by a trailer-mounted, diesel-powered, electric generator.

Ground-water discharge was determined by using an inline totalizing flowmeter. An inline gate valve was installed downstream of the flowmeter. The gate valve was shut in at approximately 55 percent of maximum flow permitting the pumping discharge to be maximized while applying sufficient backpressure to minimize pump-related water-level fluctuations.



Generalized lithology and well construction for wells 35P110 and 35P109, Richmond Hill, Bryan County, Georgia (NAVD 88, National Vertical Datum of 1988; I.D., inner diameter; O.D. outer diameter).



Generalized lithology and well construction for well 35L085, Shellman Bluff, McIntosh County, Georgia; and well 33D073, St Marys, Camden County, Georgia (NAVD 88, National Vertical Datum of 1988; I.D., inner diameter; O.D., outer diameter).

ANALYTICAL SOLUTIONS

During each aquifer test, the magnitude of water-level fluctuation produced by changes in atmospheric pressure, local pumping, or tidal oscillation was minor in comparison with the amount of drawdown induced by the pump. Therefore, drawdown data used in the analysis of these aquifer tests were not corrected for atmospheric pressure, local pumping, or tidal fluctuations.

Initial estimates of transmissivity were derived using the Cooper and Jacob (1946) modified nonequilibrium equation. Additionally, digital analytical models were used to analyze these aquifer-test data including Theis (1935) nonequilibrium equation, Cooper and Jacob (1946) modified nonequilibrium equation, and Hantush (1961) nonequilibrium equation for a partially penetrating well. The Hantush (1961) method was used in the data analysis of partial penetration for wells 35P110, 35P109, and 33D073. Vertical to horizontal conductivity (Kz/Kr) ratios of 0.01, 0.1, and 1.0 were applied to the data set for aquifer tests. For each aquifer test, the estimated transmissivity derived by the various analytical methods provided similar results.

Atmospheric and water-level recovery data were analyzed using the Jacob (1963) analysis for water-level recovery data. This method produced lower estimates of transmissivity than was calculated using the pumping (drawdown) water levels. For each of the aquifer tests, the intercept line did not pass through the origin of the semi-log graph as it should if all conditions governing the model were met. Jacob (1963) indicated that transmissivity values calculated from an aquifer test with a partially penetrating well may underestimate the true transmissivity of the aquifer. For this reason, reported transmissivity estimates reflect analysis of drawdown data.

Richmond Hill Test

Two 24-hr aquifer tests were conducted at the Richmond Hill site—well 35P110, completed in the Upper Floridan aquifer, was tested May 9–10, 2001; and well 35P109, completed in the Lower Floridan aquifer, was tested May 16–17, 2001. Water levels in both of these wells respond to regional pumping, as indicated on long-term hydrographs collected at the site (Michael F. Peck, U.S. Geological Survey, written commun., September 17, 2001).

Upper Floridan Aquifer

During May 8–9, 2001, pretest water-level and atmospheric pressure data were collected in well 35P110. During this period, the water level in the well rose about 0.3 ft. The water level changed from 30.84 to 31.27 ft below land surface (total change was 0.43 ft). During this time, atmospheric pressure fluctuated from 30.28 to 30.45 inches (mercury), or 34.3 to 34.5 ft (water). Assuming a barometric efficiency of 50 percent for the Upper Floridan aquifer, the barometric effect would be less than 0.1 ft. The effect of tidal cycles were observed in the water level for well 35P110. Amplitude for tidally induced water-level fluctuations was about 0.2 ft.

During May 9–10, 2001, a 24-hr aquifer test was conducted with an average discharge of 735 gallons per minute (gal/min), which varied by about +/– 0.3 percent. The total amount of ground water withdrawn from the Upper Floridan aquifer during the test was about 1,092,000 gallons. The drawdown resulting from the 24 hrs of pumping was about 17 ft. During May 11–12, 2001, 24 hrs of recovery water-level and atmospheric pressure data were collected. Estimated transmissivity of the Upper Floridan aquifer was 70,000 feet squared per day (ft^2/d) at the Richmond Hill site.

Lower Floridan Aquifer

During May 11–16, 2001, pretest water-level and atmospheric pressure data were collected in well 35P109. A slight water-level decline of 0.04 ft was observed during this period. The water level changed from 31.82 to 32.16 ft below land surface (total change was 0.34 ft). During this time, atmospheric pressure fluctuated from 30.10 to 30.34 inch (mercury), or 34.10 to 34.38 ft (water). Assuming a barometric efficiency of 50 percent for the Lower Floridan aquifer, the barometric effect would be less than 0.14 ft. Amplitudes for tidally induced water-level fluctuations were about 0.2 ft.

During May 16–17, 2001, a 24-hr aquifer test was conducted for the Lower Floridan aquifer using well 35P109. During the test, the average discharge was 750 gal/min and varied by about +/- 0.1 percent. The total amount of ground water withdrawn from the Lower Floridan aquifer during the aquifer test was about 1,091,000 gallons. The overall drawdown resulting from the 24 hrs of pumping was about 45 ft. During May 17–18, 2001, 24 hrs of recovery water-level and atmospheric pressure data were collected. Estimated transmissivity of the Lower Floridan aquifer was 8,300 ft^2/d.

Shellman Bluff Test

During June 6–11, 2001, atmospheric pressure and background water-level data were collected in well 35L085. The water level in the well changed from 22.81 to 23.23 ft below land surface (total change was 0.42 ft). During this time, barometric pressure fluctuated from 30.04 to 30.3 inches (mercury), or 34.04 to 34.33 ft (water). Assuming a barometric efficiency of 50 percent for the Lower Floridan aquifer, the barometric effect would be less than 0.15 ft. Amplitude for tidally induced water-level fluctuations was about 0.3 ft.

During June 14–15, 2001, a 24-hr aquifer test was conducted for the Lower Floridian aquifer using well 35L085. During the test, the average discharge was 700 gal/min and varied by about +/– 6.69 percent. The total amount of ground water withdrawn from the Lower Floridan aquifer during the test was about 1,016,000 gallons. The overall drawdown resulting from the 24-hrs of pumping was about 60 ft. During June 15–18, 2001, 69.5 hrs of recovery water-level and atmospheric pressure data were collected. Estimated transmissivity of the Lower Floridan aquifer was 6,000 ft^2/d.

St Marys Test

During July 25–26, 2001, atmospheric pressure and background water-level data were collected in well 33D073, which flows above land surface. The water level in the well changed from 0.9 to 2.6 ft above land surface (total change of 1.7 ft). During this time, barometric pressure fluctuated from 30.38 to 30.22 inches (mercury) or 34.42 to 34.24 ft (water). Assuming a barometric efficiency of 50 percent for the Lower Floridan aquifer, the barometric effect would be less than 0.01 ft. Amplitude for tidally induced water-level change was about 0.5 ft.

During July 26–27, 2001, a 24-hr aquifer test was conducted for the Lower Floridian aquifer using well 33D073. During the test, the average discharge was 710 gal/min and varied by approximately +/–1.15 percent. The total amount of ground water withdrawn from the Lower Floridan aquifer during the test was about 1,021,000 gallons. The overall drawdown resulting from the 24 hrs of pumping was about 82 ft. During July 27–28, 2001, 24-hrs of recovery water level and atmospheric pressure data were collected. Estimated transmissivity of the Lower Floridan aquifer was 13,000 ft^2/d.

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