Southwest Wellfield Hydrologeologic Investigation Highlights Challenges to Water Resource Evaluation in Hernando County

Jeffrey M. Trommer and Christopher Shoemaker

Hernando County has one of the highest growth rates in the state. The population in western Hernando County has grown from 101,000 in 1990 to the current 145,000 and is projected to increase to about 227,000 by 2020. As a result, water use for public supply increased from an average of 14.7 million gallons per day (mgd) in 1990 to 22 mgd in 2003 and is projected to increase to an average of 35 mgd by 2020.

Because of concerns regarding adverse impacts to the groundwater and surface-water resources of the county, Hernando County Utilities and the Southwest Florida Water Management District (SWFWMD) co-funded the Hernando County Water Resource Assessment Project (HCWRAP) in 1995 and HCWRAP 2 in 2001 to evaluate the potential impacts on the water resources due to future groundwater development. Both reports included statements regarding the limited amount of hydrogeologic data available in the county and recommended programs to collect additional data.

As a result, Hernando County Utilities and the SWFWMD developed an aquifer-testing program to be implemented in association with the construction of new wells in the Southwest Hernando Wellfield. The testing activities were funded by the SWFWMD because of the district's need for additional data to support its upcoming Northern District Water Resource Evaluation.

The Hernando County Utilities public supply system consists of two linear wellfields with five or more wells—the West Hernando Linear Wellfield and the Southwest Hernando Wellfield—and 31 other wells in groups of up to three spread across the remainder of the county (Figure 1). Most of these 31 wells were installed to serve individual developments; however, several of the wells in the southwest portion of the county have been interconnected to some extent with the two linear wellfields to form the West Hernando Dispersed Wellfield.

Hernando County recently acquired the Spring Hill water system from a private utility company, which more than doubled the size of the county's public supply system. The Spring Hill system is located in the southwest portion of Hernando County and is surrounded to the north, east, and west by the West Hernando Dispersed Wellfield. Together these two systems represent 90 percent of the total public supply withdrawal in Hernando County.

Many lakes and wetland systems occur in the western portion of the county. Weeki Wachee Spring, a first-magnitude spring with an average discharge of 176 cfs, is located within the West Hernando Dispersed Wellfield area. Also, Hernando County is bordered on the west by the Gulf of Mexico, and the saltwater/freshwater interface lies beneath the coastal portion of the county.

All these hydrologic features are potentially impacted by groundwater withdrawals, which have been the focus of ongoing hydrogeologic studies in the county. This aquifer-testing program was designed to evaluate aquifer characteristics, degree of confinement, and the water-quality profile for the Upper Floridan Aquifer in the area of the Southwest Wellfield.

Previous Studies

Prior to the 1980s, several reports were prepared by the U.S. Geological Survey (USGS) and the Florida Geological Survey, such as Wetterall (1964), Mann and Cherry (1969), Cherry and others (1970), and Mills and Ryder (1977). These were focused on either larger areas, including a portion of Hernando County, or specific topics, such as spring flow or saltwater intrusion. In 1983 the USGS performed a study of the water resources of coastal portions of Hernando, Citrus, and Levy counties (Fretwell, 1983).

The first countywide study of the hydrogeology of Hernando County was performed by the USGS in 1984 (Fretwell, 1985). The

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report provided a description of the topography, surface-water features, geology, aquifer systems, water quality, and water use in the county, and included the results of a groundwater model used to predict potential drawdown impacts from future development.

In the report it was stated that the Upper Floridan Aquifer is generally unconfined in Hernando County with the exception of local areas where the surficial sands are separated from the limestone by thick clay layers. The report also provided a list of seven transmissivity values for the area ranging from 90,000 ft^2/day to over 2 million ft^2/day; however, the aquifer test-derived values were from sites outside Hernando County, while the values within the county were derived from a specific capacity test and flow net analyses. The model presented in the report used transmissivity values ranging from 100,000 ft^2/day in eastern Hernando County to 2 million ft^2/day in the western portion of the county.

The SWFWMD published a *Groundwater Resource Availability Inventory* in 1987 that summarized the information from previous reports, updated with new information available.

In 1995 Hernando County and the

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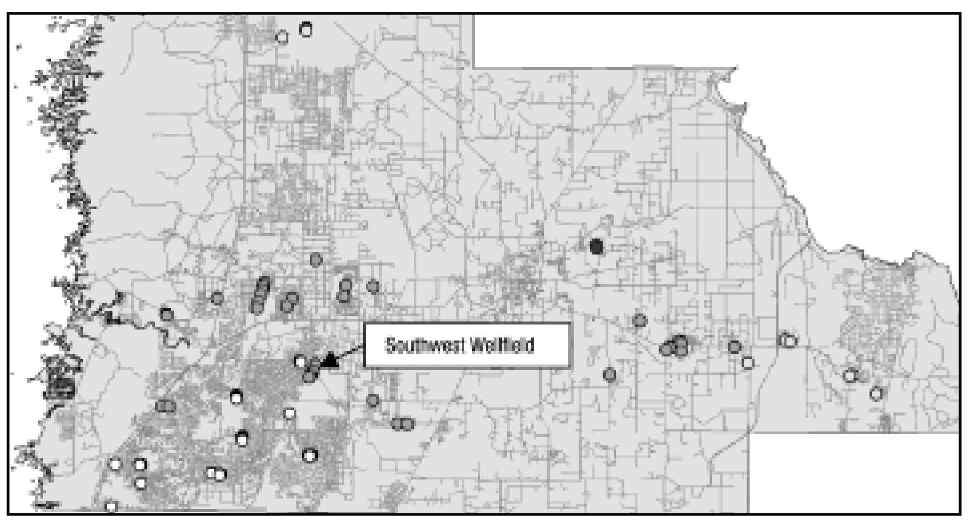

Figure 1: Locations of Hernando County Utilities Public Supply Wells

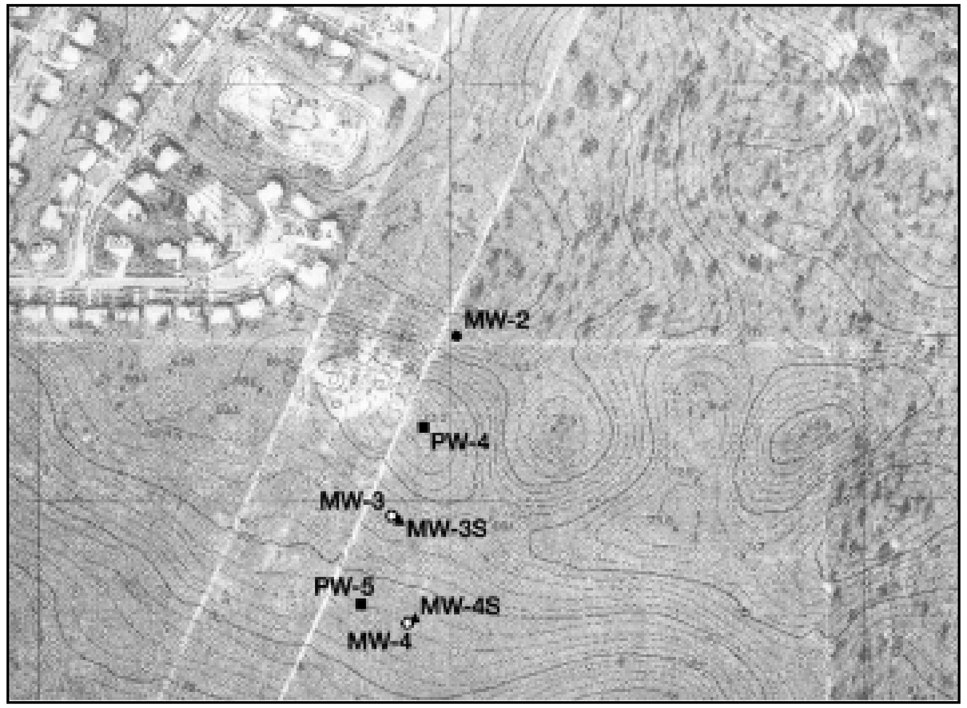

Figure 2: Locations of New Wells in the Southwest Hernando Wellfield

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SWFWMD co-funded the HCWRAP. The project included collection and compilation of available hydrogeologic, water-use, and climatologic data that were used to develop a groundwater flow model to evaluate potential impacts to groundwater levels in the Upper Floridan and Surficial aquifers, spring flow, and flow in the Withlacoochee River as a result of projected groundwater withdrawals to the year 2030.

The project also included solute-transport modeling to assess potential movement of the saltwater/freshwater interface, based on predicted heads from the flow model. The models were based largely on existing hydrogeologic data from the previous referenced reports, as little new additional data had been collected in the 10 years since those reports had been published. As with previous models of Hernando County, transmissivity values in the WRAP model ranged from 60,000 ft^2/day in eastern Hernando County to over 2 million ft^2/day in the western portion of the county and were approximately 400,000 ft^2/day in the area of the Southwest Hernando Wellfield.

The HCWRAP report (HydroGeologic, 1997) concluded with a list of recommendations for data collection and monitoring programs needed to improve future model updates. These included:

1) Develop a saltwater interface monitoring well network.
2) Establish a program to monitor water levels and water quality in all existing municipal production wells.
3) Establish a monitoring well program in each wellfield to better define cones of depression.
4) Design and implement an aquifer test program to better define aquifer characteristics, the locations of producing zones, and the relationship of the Surficial and Upper Floridan aquifers in existing and planned wellfield areas.

HCWRAP 2 was performed in 2001 as an update to the HCWRAP. The databases used in the HCWRAP were updated, and the groundwater flow and transport models were updated. The sharp-interface cross-section model used in the HCWRAP was replaced by incorporating variable-density solute-transport modeling in the MODFLOW model using MODFLOW-SURFACT. Although the model was updated and recalibrated, no additional aquifer characteristics data were available, since the HCWRAP model and the same range in aquifer transmissivity were used.

AQUIFER TEST PROGRAM

The Southwest Hernando Wellfield is a linear wellfield located adjacent to a Progress Energy Florida power line right-of-way between State Road 50 and Spring Hill Boulevard. The area is underlain by relic sand dunes, characterized by a gently rolling topography with elevations ranging from 60 feet to 100 feet NGVD. The wellfield currently has three operating 16-inch diameter production wells that produce an average of 750,000 to 815,000 gallons per day each, and up to 1 mgd each for peak-month use. These wells are located adjacent to the Progress Energy Florida power line right-of-way to the north of Elgin Boulevard.

Beginning in 2002, a project was started to add up to four additional production wells adjacent to the right-of-way south of Elgin Boulevard, as shown on Figure 2. The test program portion of the project included the installation of two Upper Floridan Aquifer monitoring wells, two surficial aquifer monitoring wells, and an exploratory boring to the base of the Upper Floridan Aquifer.

Well Construction

Monitoring Wells

The well-drilling program was started with the construction of Monitoring Well No. 3 (MW-3), constructed with 12-inch diameter steel casing to a depth of 186 feet below land surface (bls), and six-inch diameter PVC casing to a depth 250 feet bls. A nominal six-inch diameter borehole was drilled to a depth of 550 feet bls.

Monitoring Well No.4 (MW-4) was constructed with 12-inch diameter steel casing to a depth of 130 feet bls and six-inch diameter PVC casing to a depth of 255 feet bls. A nominal six-inch diameter borehole was drilled to a depth of 530 feet bls.

A shallow Surficial Aquifer monitoring well was constructed adjacent to MW-3 and MW-4. The wells were installed using a hollow stem auger. MW-3S was constructed with two-inch diameter PVC screen from 38 feet bls to 68 feet bls and PVC casing to land surface. MW-4S was constructed with two-inch diameter PVC screen from 50 to 80 feet bls and PVC casing to land surface.

Exploratory Boring

Upon completion of MW-3 to a depth of 550 feet bls, the six-inch diameter exploratory borehole was continued from 550 feet bls to 1,004 feet bls. Lithologic samples indicated that the bottom of the Upper Floridan Aquifer was reached at about 860 to 900 feet bls, based on the presence of interstitial evaporites in the dolomite.

Specific capacity tests were performed at 50-foot intervals during reverse air drilling of the open borehole section of the well and exploratory borehole, starting at 300 feet bls. Samples were collected during the specific capacity tests and analyzed in the field for conductivity, pH, temperature, and chloride. Samples were also analyzed by a laboratory for chloride, sulfate, and total dissolved solids (TDS).

A suite of geophysical logs were completed in the exploratory borehole, including:

1) under static conditions, a) caliper, b) temperature, c) gamma, d) short and long normal resistivity, e) fluid resistivity, and f) fluid velocity
2) under pumping conditions, a) temperature, b) fluid resistivity, and c) fluid velocity

Packer tests were performed to obtain hydraulic and water-quality data from specific intervals in the Upper Floridan Aquifer. The intervals were based on changes in water quality observed in the samples collected from the reverse air discharge during drilling, changes in fluid resistivity log response, and suitable borehole diameter for packer sets as determined from the caliper log.

Tests were performed in the following intervals: 480 to 500 feet; 580 to 630 feet; 790 to 810 feet; 880 to 900 feet; and 984 to 1,004 feet. Drawdown and pumping rate were used to calculate the specific capacity of each interval. Water samples were analyzed in the field for conductivity, pH, temperature, and chloride, and in a laboratory for chloride, sulfate, and total dissolved solids (TDS).

Production Wells

Production Well No. 4 (PW-4) was constructed upon completion of the construction and testing of MW-3 and exploratory boring. PW-4 was constructed with 24-inch diameter steel casing to a depth of 130 feet bls and 16-inch diameter steel casing to a depth 250 feet bls. A 16-inch diameter borehole was drilled to a depth of 508 feet bls.

Production Well No. 5 (PW-5) was constructed with 24-inch diameter steel casing to a depth of 112 feet bls and 16-inch diameter steel casing to a depth 255 feet bls. A 16-inch diameter borehole was drilled to a depth of 530 feet bls.

Specific capacity tests were performed at 50-foot intervals during reverse air drilling of the open borehole section of both wells starting at 300 feet bls. Samples were collected during the specific capacity tests and analyzed in the field for conductivity, pH, temperature, and chloride. The suite of geophysical logs referenced previously was performed in both production wells.

Aquifer Testing

Aquifer tests were performed separately on wells PW-4 and PW-5. Each test was performed with a pumping period of 24 hours, which was preceded by 24 hours of background data collection and followed by 24 hours of recovery data collection.

Aquifer Test Procedures

Water levels were recorded with pressure transducer dataloggers in seven wells for the test at PW-4. These wells included the pumping well PW-4; monitoring wells MW-2 (an existing monitoring well), MW-3, MW-3S, MW-4, and MW-4S; and production well PW-5. Monitoring well MW-2 is located approximately 238 feet northeast of production well PW-4. Monitoring well MW-3 is

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approximately 228 feet southwest of PW-4.

Monitoring well MW-4 is 478 feet south of PW-4, and PW-5 is approximately 458 feet southwest of production well PW-4. Shallow monitoring wells MW-3S and MW-4S are adjacent to monitoring well MW-3 and MW-4, respectively. The approximate locations of these wells are shown on Figure 2. PW-4 was pumped at an average rate of 1,466 gallons per minute (gpm).

Water levels were recorded in four wells for the test at PW-5. These wells included the pumping well PW-5, monitoring wells MW-4 and MW-3, and production well PW-4. Monitoring well MW-4, as previously indicated, is approximately 126 feet east of production well PW-5. Monitoring well MW-3 is approximately 230 feet north of production well PW-5, and PW-4 is approximately 458 feet north of PW-5.

The shallow monitoring wells were not installed at the time of the test at PW-5. The approximate locations of these wells are shown on Figure 2. PW-5 was pumped at an average rate of 928 gpm.

<u>Aquifer Test Analysis</u>

Maximum sustained drawdown in the pumping well during the PW-4 aquifer test was approximately 15.0 feet, resulting in a specific capacity of 98 gpm/ft of drawdown. The maximum drawdowns in wells MW-2, MW-4, and PW-5 were approximately 0.3 feet. The maximum drawdown in monitoring well MW-3 was approximately 0.9 feet.

Maximum drawdown in the pumping well during the PW-5 aquifer test was approximately 43.3 feet, resulting in a specific capacity of approximately 22 gpm/ft. Maximum drawdown in monitoring well MW-4 was approximately 1.7 feet. The maximum drawdown in MW-3 was approximately 1.5 feet. The maximum drawdown in the previously constructed production well PW-4 was approximately 0.17 feet.

The time-drawdown data obtained from the wells monitored during each test were used in the aquifer test analysis program AquiferWin 32 by Environmental Simulations Inc. to calculate transmissivity, storativity, and leakance. Drawdown data from the wells were analyzed using the Cooper and Jacob Method for confined aquifers, the Hantush and Jacob Method for leaky aquifers, and the Neuman Method for unconfined aquifers. Recovery data from monitoring and pumping wells were analyzed using the Theis Recovery Method.

SITE HYDROGEOLOGY

Site Geology

The subsurface stratigraphy consisted of fine-grained sand to a depth ranging from 100 feet bls at PW-4, PW-5, and MW-4 to 183 feet bls at MW-3. This surficial sand layer contained interbedded clayey-sand to sandy-clay layers from 40 feet to 100 feet bls in PW-4, and from 100 feet to 183 feet bls in MW-3. These clayey-sand layers were not present at PW-5 or MW-4.

The surficial sand layer is underlain by Suwannee Limestone, which is a tan to cream color, sandy, soft to moderately hard, fossiliferous limestone. The base of the Suwannee Limestone, as marked by an abrupt decrease in activity on the gamma log, ranged from 170 feet bls at PW-4 to 220 feet bls at PW-5 and MW-4.

The Suwannee Limestone is underlain by Ocala Limestone, which is a tan to light-gray, soft to very hard, fossiliferous limestone that extends to a depth of approximately 400 feet bls in MW-3 and PW-4, and to 470 feet at MW-4 and PW-5. The lower portion of the Ocala Limestone contains layers of dolomitic limestone.

The Ocala Limestone is underlain by Avon Park Limestone The top of the Avon Park Limestone is marked by a significant increase in the electrical resistivity log. The Avon Park Limestone consists of tan to brown, crystalline, dolomitic limestone.

The first occurrence of evaporites was observed in the exploratory boring at 860 feet bls. Interstitial evaporites in the dolomite of the lower Avon Park Limestone mark the base of the Upper Floridan Aquifer. This interval is marked by an increase in the electrical resistivity log.

Flow Producing Zones

Flow-producing zones in the Upper Floridan Aquifer at the site were identified from the specific capacity values obtained from drill stem tests during drilling and the geophysical logs. The increase in specific capacity in MW-3 from 8.2 gpm/ft at 450 feet bls to 32 gpm/ft at 500 feet bls indicates the primary producing zone in MW-3 is between 450 and 500 feet bls. The caliper log shows a cavity from 486 to 492 feet bls. The pumping flow log indicates that most of the productivity is from the interval of 480 to 550 feet bls.

The specific capacity in PW-4 increased from 21.4 gpm/ft at 400 feet bls to 110 gpm/ft at 450 feet bls and then to 263 gpm/ft at 500 feet bls, which indicates that the primary producing zone in PW-4 is between 400 and 500 feet bls. The caliper log shows a cavity from 500 to 505 feet bls. Analysis of the pumping flow log indicates that approximately 63 percent of the water is produced from 430 to 500 feet bls.

The pumping flow log performed in the exploratory borehole section of MW-3 (550 to 1,000 feet bls) indicated that virtually no additional flow is contributed to the well below 570 feet bls. The specific capacity values obtained from the straddle packer tests decreased from 5 gpm/ft in the 480-to-500-foot interval to 2 gpm/ft in the 580-to-600-foot interval to 1.4 x 10^{-3} gpm/ ft in the 880-to-900-foot interval.

The specific capacity in PW-5 increased from 10 gpm/ft at 450 feet bls to 22 gpm/ft at 500 feet bls, and then only to 30 gpm/ft at 530 feet, which indicates that the primary producing zone in PW-5 is between 450 and 530 feet bls. A review of the caliper log did not indicate the presence of apparent cavities or other significant fractures zones within this production zone. Evaluation of the pumping flow log further suggests that water is produced consistently throughout the open-hole portion of the well, and in fact there appears to be a slight decrease in flow below a depth of approximately 510 feet bls. This generally agrees with the findings from MW-3 that little flow is contributed below a depth of approximately 570 feet bls.

Aquifer Characteristics

The test at PW-4 was analyzed with the Cooper-Jacob Method for confined aquifers using time-drawdown data from MW-2, MW-3, MW-4, and PW-5, and with the Hantush-Jacob Method for leaky aquifers using time-drawdown data from MW-3. Time-drawdown data from MW-2, MW-4, and PW-5 produced similar aquifer characteristics using the Cooper-Jacob Method, with transmissivity values of 740,000 ft^2/day, 720,000 ft^2/day, and 900,000 ft^2/day, respectively. The transmissivity value calculated from MW-3 (the closest monitoring well) was significantly lower at 145,000 ft^2/day.

The rapid departure of the time-drawdown data from the straight-line slope for all these wells suggests that groundwater in the lower portion of the surficial sand unit may be slightly hydraulically separated from the Upper Floridan by the sandy-clay layer, resulting in leaky or perhaps unconfined conditions.

The Hantush-Jacob Method for leaky aquifers produced a transmissivity value of 90,200 ft^2/day from MW-3. The leakance value was 1.3 x 10^{-1} d^{-1}. This very high leakance value suggests that there is very little hydraulic separation between the limestone and overlying sand, and the surficial sand is actually the upper portion of an unconfined Upper Floridan Aquifer in this area. The recovery data from MW-3 yielded a transmissivity value that was slightly higher but still consistent with those from the drawdown data (190,000 ft^2/day and 143,000 ft^2/day, respectively).

The test at PW-5 was analyzed using time drawdown data from MW-3, MW-4, and PW-4. Aquifer characteristics were calculated using the Cooper-Jacob Method for confined aquifers, Hantush-Jacob Method for leaky aquifers, and the Neuman Method for unconfined aquifers.

The results using these methods with the data from MW-3 and MW-4 were consistent. The Cooper-Jacob Method produced transmissivity values of 45,000 ft^2/day and 42,000 ft^2/day from MW-3 and MW-4, respectively; however, the time-drawdown data from PW-4 produced a transmissivity value of approximately 1 million ft^2/day.

The Hantush-Jacob Method for leaky aquifers produced transmissivity values of 42,000 ft^2/day and 40,000 ft^2/day from MW-3 and MW-4, respectively. Leakance values were 1.1 x 10^{-2} d^{-1} and 2.2 x 10^{-2} d^{-1}, respectively.

The Neuman Method for unconfined aquifers yielded a similar value of transmissivity (39,000 ft^2/day), but the test was not long enough to determine if the time-drawdown data matched the late time portion of the curve. If the late-time portion of the curve had been matched, it would have indicated that the Upper Floridan Aquifer was unconfined and not a leaky aquifer. The recovery data from MW-3 and MW-4 yielded transmissivity values that were slightly lower, but still consistent with those from the pumping data (37,000 ft^2/day and 31,000 ft^2/day, respectively).

Transmissivity was also evaluated using data collected from the pumping wells during each test. Recovery data collected from PW-5 resulted in transmissivity that was significantly lower (1,300 ft^2/day to 10,000 ft^2/day) than that calculated from the monitoring wells. Recovery data were not available from the pumping well during the PW-4 pumping test; however, solution of the Jacob Equation using the specific capacity of 98 gpm/ft resulted in a transmissivity of approximately 25,000 ft^2/day, which is significantly lower than the values calculated from the monitoring well data.

There are three sources of variability in the results from these tests. The first is the difference in transmissivity values between the PW-5 test (42,000 ft^2/day) and the PW-4 test (500,000 ft^2/day). Lithologic and geophysical data suggested that PW-4 intercepts a fracture or conduit system that the other wells in the area do not intercept. As a result, water pumped from PW-4 is produced preferentially from the fracture or conduit system, and less drawdown is conveyed to wells MW-2 and MW-3, which do not intercept the fracture system. As a result, time-drawdown data from these wells results in an anonymously high value of transmissivity.

In the case of the PW-5 test, neither the pumped well (PW-5) or monitoring wells MW-3 and MW-4 appear to intercept this fracture system; therefore, more drawdown is conveyed to the monitoring wells and transmissivity is lower. The effect of the fracture system on drawdown in the PW-5 test is shown, however, in the time-drawdown data collected from PW-4, which is open to the fracture system. Drawdown in PW-4 was less than 0.2 feet, while drawdown in MW-3 was 1.5 feet, resulting in a transmissivity of 1 million ft^2/day from PW-4 data and 45,000 ft^2/day from MW-3 data.

The second source of variability is that between transmissivity values calculated from pumping-well drawdown data and those from monitoring-well drawdown data. Transmissivity calculated from the pumping well is often slightly lower than that calculated from observation-well data because of drawdown due to well losses in the pumped well; however, the amount of drawdown in the pumped well for both tests is disproportionately greater than the amount of drawdown measured in the monitoring wells to be due to well losses.

This difference in drawdown is also greater than that normally observed in tests performed at other locations. For example, a pumping test recently performed in northeastern Pasco County at a pumping rate of 1,465 gpm resulted in 7.5 feet of drawdown in the pumping well and 2.2 feet of drawdown in a monitoring well at a distance of 380 feet (Leggette, Brashears & Graham, Inc., 2002). In comparison, the PW-5 test resulted in 43 feet of drawdown in the pumped well and 1.5 feet of drawdown at a distance of 230 feet. The PW-4 test resulted in 15 feet of drawdown in the pumped well and 0.3 feet in one well and 0.9 feet in another well both approximately 230 feet from the pumped well.

This difference in relative amounts of drawdown and resulting differences in transmissivities between the observation-well and pumping-well data from both tests suggest that the data are influenced by other factors, most likely heterogeneity due to the influence of fracture flow in the Upper Floridan Aquifer in this area.

The third source of variability is specific to the test performed at PW-4. This variability is the difference in transmissivity values calculated with data from MW-2 (741,000 ft^2/day), MW-4 (720,500 ft^2/day), and PW-5 (906,000 ft^2/day), compared with that from MW-3 (198,000 ft^2/day). These differences may also be due to heterogeneity in the Upper Floridan Aquifer, which essentially results in an asymmetric cone of depression around the pumping well.

Degree of Confinement

Groundwater elevations at the site were evaluated using monitoring wells MW-3, MW-3S, MW-4, and MW-4S. Groundwater elevations measured on three dates in March 2003 showed that the water level in MW-3 was 0.7 feet higher that in MW-3S, and the water level in MW-4 was 0.3 feet higher than that in MW-3S. The higher water-level elevations observed in the deeper wells could be due to a slight hydraulic separation of the Surficial and Upper Floridan aquifers.

Also, the hydrographs generated during the performance of the 72-hour pumping test using production well PW-4 were compared to evaluate water-level differentials during pumping conditions. The static water-level elevations in the deeper monitoring wells

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WE'VE MOVED!

On October 1, the Journal editorial office moved to 1402 Emerald Lakes Drive, Clermont, Florida 34711. Our new telephone number is 352-241-6006, and the new fax number is 352-241-6007. The editor's e-mail address remains editor@fwrj.com, and the e-mail address for display and classified advertising remains ads@fwrj.com.

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(MW-3 and MW-4) were slightly higher than those in the shallow monitoring wells (MW-3S and MW-4S) prior to the start of pumping. During the pumping test at PW-4, the maximum drawdown in shallow monitoring well MW-3S was approximately 0.2 feet, compared to 0.9 feet in MW-3. The maximum drawdown in MW-4S was less than 0.1 feet, compared to 0.3 feet in MW-4.

The difference in the amount of drawdown resulted in the water levels in the shallow and deep monitoring wells being at approximately the same elevation. This suggests that the aquifer units are hydraulically connected and tend to act as a single, unconfined hydrogeologic unit or a highly leaky aquifer system, which is consistent with the interpretation of the time-drawdown data from the APTs.

Water Quality

Results from water-quality samples collected at 50-foot intervals during reverse-air drilling and analyzed for chloride, sulfate, and TDS indicated that chloride concentration remained less than 10 mg/l to the bottom of the exploratory borehole at 1,000 feet bls; however, sulfate concentration increased from 22 mg/l at 550 feet bls to 130 mg/l at 600 feet bls, and TDS increased from approximately 140 mg/l to 300 mg/l over the same interval.

The concentration derived from the reverse air samples represents a composite of the water being pumped from the entire open borehole; therefore, the results are weighted to the quality of water from the primary producing zone. The packer test results provide the depth-interval-specific water quality. Chloride increased from 6 mg/l at 480 to 500 feet bls to 38 mg/l at 580 to 600 feet, and reached a maximum concentration of 260 mg/l at 880 to 900 feet bls.

The most significant change in water quality was the increase in sulfate and TDS concentration from 40 mg/l and 190 mg/l respectively at 480 to 500 feet bls to 1,900 mg/l and 2,000 mg/l respectively at 580 to 600 feet bls. Sulfate concentration remained relatively constant from 600 feet to 1,000 feet bls, but TDS increased to 3,400 mg/l at 900 feet bls.

The packer test results indicate that chloride concentrations remain less than 40 mg/l above the base of the Upper Floridan Aquifer and increase to over 200 mg/l within the evaporite zone comprising the base of the aquifer. Sulfate and TDS concentrations increase significantly at about 580 feet bls and then remain relatively consistent to the bottom of the exploratory borehole. This increase is marked on the static and pumping fluid resistivity logs as an increase in fluid resistivity between 480 and 520 feet bls. Chloride, sulfate, and TDS concentrations from the sample collected from PW-4 and analyzed for Primary and Secondary Drinking Water Standard analysis were 5.7 mg/l, 9.1 mg/l, and 160 mg/l respectively.

Considerations for Future Water Resource Evaluations And Development

The purpose of this testing program was to evaluate aquifer characteristics, the degree of confinement, and the water-quality profile for the Upper Floridan Aquifer in the area of the Southwest Wellfield. Overall, the test results indicated that:

1) Transmissivity of the Upper Floridan is highly variable, ranging from 40,000 to 1,000,000 ft^2/day.
2) The primary producing zone occurs between 450 and 500 feet bls.
3) The Upper Floridan and Surficial aquifers are hydraulically well connected, with the Upper Floridan Aquifer acting as a highly leaky or unconfined aquifer.
4) Water quality is not limited by chloride, but by sulfate, which increases from 40 to 1,900 mg/l at a depth of 580 feet bls.

Here are some observations on how these test results should be considered in planning future water-resource evaluations:

- Groundwater flow in the Upper Floridan Aquifer in Hernando County is controlled by karst-related fracture zones and conduits, resulting in extreme heterogeneity compared with conditions to the south in Pasco and Hillsborough counties. Transmissivity values may vary by more than an order of magnitude between wells located a few hundred feet apart.
- The high transmissivity zone in the upper portion of the Avon Park Limestone is not laterally extensive as it is in much of the area to the south, but is confined to discrete cavities or fracture zones.
- Single-well pumping tests do not provide transmissivity values that are consistent with values calculated with monitoring-well data from multiple-well tests. Results from aquifer tests performed at sites in Pasco and Hillsborough counties indicated that transmissivity values from pumped-well data were consistent with those from monitoring-well data. This difference is due to the heterogeneous nature of the Upper Floridan Aquifer in Hernando County.
- Although monitoring-well data shows that there is a small head differential between the Surficial Aquifer and the Upper Floridan Aquifer, the rapid response to pumping shown in the Surficial Aquifer monitoring well indicates that the degree of hydraulic connection is such that the surficial sand layer is the top of an unconfined Upper Floridan Aquifer. The apparent leaky-aquifer response shown in the time-drawdown data is probably due to a delayed release of water from the sand layer through the clayey-sand beds; however, it appears that the groundwater flow system in Hernando County can probably be modeled as a two-aquifer system separated with a high leakance value in the areas where the Upper Floridan Aquifer is unconfined.
- Maximum depth of wells in Hernando County is limited by water quality and the depth of the primary producing zone. In the area of the Southwest Hernando Wellfield, the primary producing zone is reached by 500 feet bls. Very little additional production is provided below this depth, and water quality deteriorates by 580 feet bls due to high sulfate concentrations.
- The karstic nature of the groundwater flow system in Hernando County is problematic for groundwater modeling. High transmissivity values across the county may be effective to calibrate potentiometric surface elevations and spring flows in a regional model, but use of these high transmissivity values in a local drawdown model may underestimate local drawdown impacts in areas where the wells do not intercept high transmissivity zones. Likewise, drawdown impact models that use well-specific lower values of transmissivity may tend to overestimate drawdown impacts as the distance from the pumping wells increases. Also, transmissivity values from existing regional groundwater flow models may not be appropriate for evaluating the locations proposed for groundwater withdrawals.
- The county's wellhead protection area zone map was created using a groundwater flow/particle tracking model that was based on the high transmissivity values from the HCWRAP regional model, resulting in wellhead protection zones that were long, narrow zones oriented along the regional flow direction in the Upper Floridan Aquifer. These long, narrow zones may not be suitable for wells producing from lower transmissivity zones, which have a more radial cone of depression.