SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Construction and Aquifer Testing of the Oak Island Site

Osceola County, Florida

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Water Supply Bureau
Water Resources Division

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1
Introduction

The construction and aquifer testing of wells installed at the Oak Island Site in Osceola County, Florida, required Advanced Well Drilling (AWD), the selected contractor, to 1) repair an existing well with an obstruction at the bottom of the casing, 2) drill a new 14-inch diameter production well, and 3) conduct an aquifer performance test (APT) on the upper portion of the Floridan aquifer system (FAS). The Oak Island site is located in northwestern Osceola County, as shown in **Figure 1**. The South Florida Water Management District (SFWMD) provided an on-site geologist during drilling operations to observe the collection of geological or lithological samples, conduct a full-scale APT, and to observe well construction operations for conformance to the Scope of Work.

Figure 1. Oak Island APT site, Osceola County, Florida.

1.1 LOCAL SETTINGS

The Oak Island site is located in northwestern Osceola County, Florida, near the intersection of Highway 27 and Highway 192. The site is located at latitude 28° 20′02.2″ and longitude 81° 38′01.6″, with the elevation of the production well (OSF-108) at 109.33 feet National Geodetic Vertical Datum 1929 (NGVD 29), and the monitor well (OSF-103) at 111.60 feet NGVD 29. The site is a county restoration site, previously a sand and fill mining operation. The site contains wetlands and pine flatwoods. Numerous development projects are located around the test site, and the site is within close proximity to the Disney World development.

Figure 2. Oak Island site layout.

Previous work was performed at this site in order to establish a long-term water level monitoring station. The original site design included two surficial aquifer monitoring sites (OSS-101 and OSS-102), one Upper Floridan aquifer monitor site (OSF-103), and an existing wetland site, as shown in **Figure 2**. The wetland and all monitoring wells were outfitted with a continuous data logger (Campbell CR-10X), allowing for the collection and recording of real-time data.

1.2 SCOPE OF WORK

The Oak Island site was first designed in 2005 as part of the Regional Floridan Aquifer Monitoring Network. This effort established one Upper Floridan aquifer and two surficial aquifer monitoring wells, and a representative wetland monitoring station for the entire site. More recently, the SFWMD's regional groundwater modeling program determined the need for hydrogeological data in the Oak Island area. In 2009, the SFWMD funded the installation of an additional Upper Floridan aquifer production well, as well as the completion of a 96-hour aquifer performance test in order to define necessary modeling parameters.

The scope of work required the Oak Island site to be prepared for an aquifer performance test, the repair of an existing 4-inch diameter PVC monitor well (OSF-103), and the drilling of a large-diameter production well (OSF-108) with a minimum casing diameter of 16 inches. The repair work required removing or clearing an obstruction located at the bottom of the casing in OSF-103 at 70 feet below land surface (bls), and clearing the borehole to a total depth of approximately 150 feet bls. This phase also required AWD to conduct the APT using the aforementioned wells. The total length of time of the APT was 96 hours, consisting of a 72-hour constant-rate drawdown phase and a 24-hour recovery period. AWD was responsible for providing and installing on-site equipment necessary to perform a successful APT.

2

Well Construction

2.1 INSTALLATION OF SHALLOW MONITOR WELLS OSS-101 AND OSS-102

On March 15, 2005, the drilling began for the first two shallow monitoring wells (OSS-101 and OSS-102) at the Oak Island site (**Figure 3**). The drilling contractor, Environmental Drilling Service, Inc. (EDS), used the hollow-stem auger method to install both shallow monitoring wells. The OSS-102 monitor well was drilled first to determine the geology in order to set casing for the shallower well, OSS-101. The boreholes were advanced to predetermined depths, the screen and casing were installed immediately, and a 20/30 grain sand pack was set to two feet above the screen interval. Once the sand settled, a bentonite seal was placed two feet above the sand, followed by neat cement to surface. Once completed, the monitoring wells were developed until the water was clear and free of sediment.

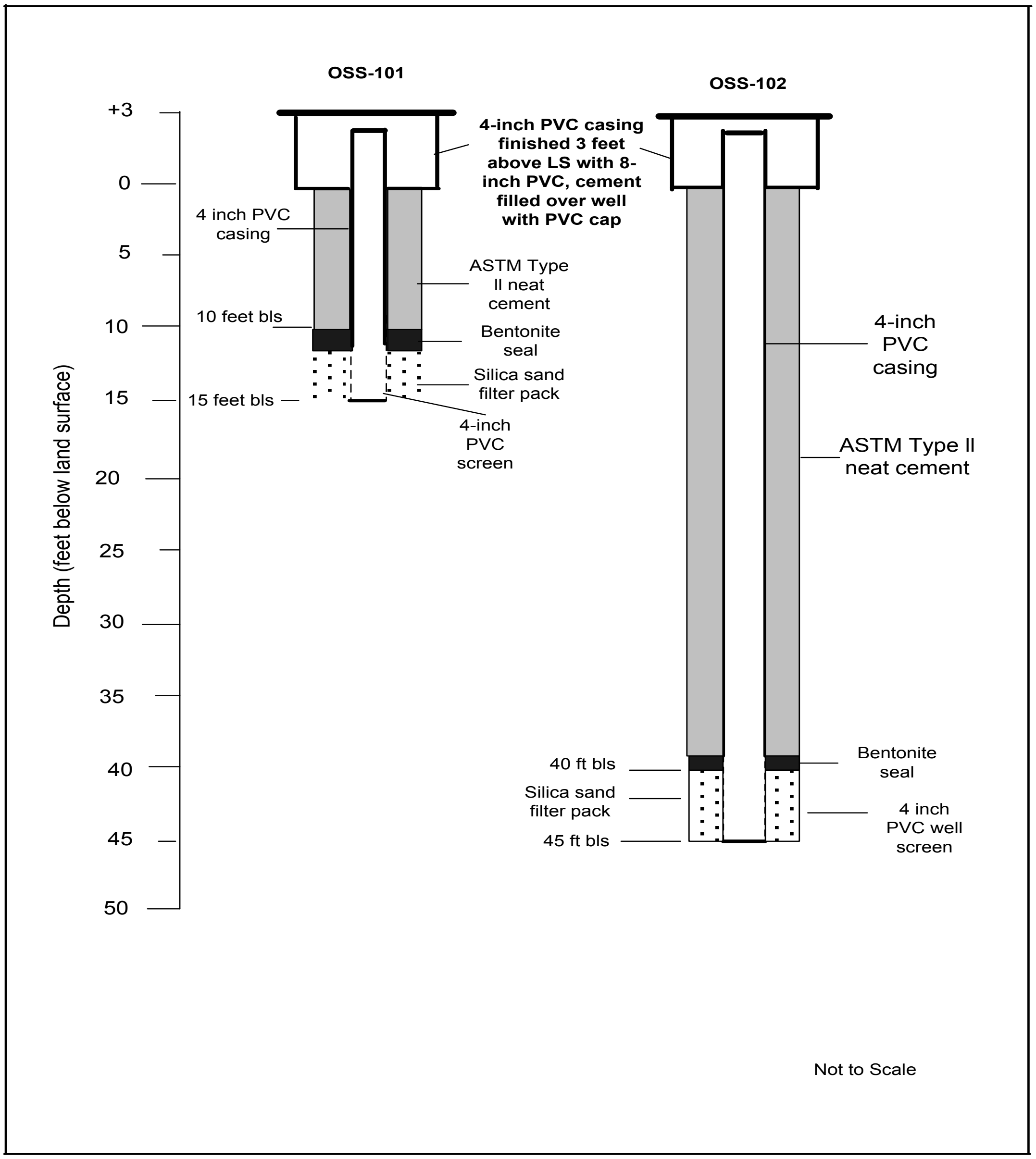

Figure 3. Existing surficial aquifer monitor wells OSS-101 and OSS-102.

2.2 INSTALLATION OF MONITOR WELL OSF-103

Environmental Drilling Service, Inc. (EDS) was contracted to install the Upper Floridan aquifer monitor well OSF-103. Drilling started on March 16, 2005, with 10-inch diameter hollow-stem augers advanced to a depth of 65 feet bls, where a hard layer of limestone was encountered. As the augers advanced, two-foot split-spoon samples were driven every ten feet ahead of the augers (**Appendix A**). The augers were advanced to 67 feet bls to allow for a good casing seat. The 4-inch diameter PVC casing was installed inside the hollow-stem auger to 67 feet bls with a 4-foot riser. Neat cement was pumped to surface and left to set for the rest of the day. On March 17, 2005, EDS arrived on-site and set up for mud-rotary drilling, then mixed the mud and attempted to drill. EDS drilled approximately 6 inches and broke through a hard layer of limestone with immediate loss of the entire amount of mud in the drill hole and mud pit. Circulation could not be maintained for the rest of the day. EDS tried using heavyweight mud, and there was still no return. After drilling to a total depth of 120 feet bls, EDS stopped for the day.

The following day, EDS added bentonite chips to new mud and continued to drill. Circulation returned briefly before loss of all mud occurred again. EDS continued to drill in rainy conditions with no drill cutting returns and terminated drilling at 150 feet bls. EDS then tagged the well at a total depth of 150 feet bls with a sounding tape. Based on other existing wells within the surrounding area, the SFWMD's on-site geologist estimated that the interval of 67 to 150 feet bls was within the upper Floridan aquifer and would provide adequate monitoring data. The site was cleaned, and the monitoring well was developed while setting up for a concrete pad. The concrete was poured, and bolsters were set. The finished well design is shown in **Figure 4**.

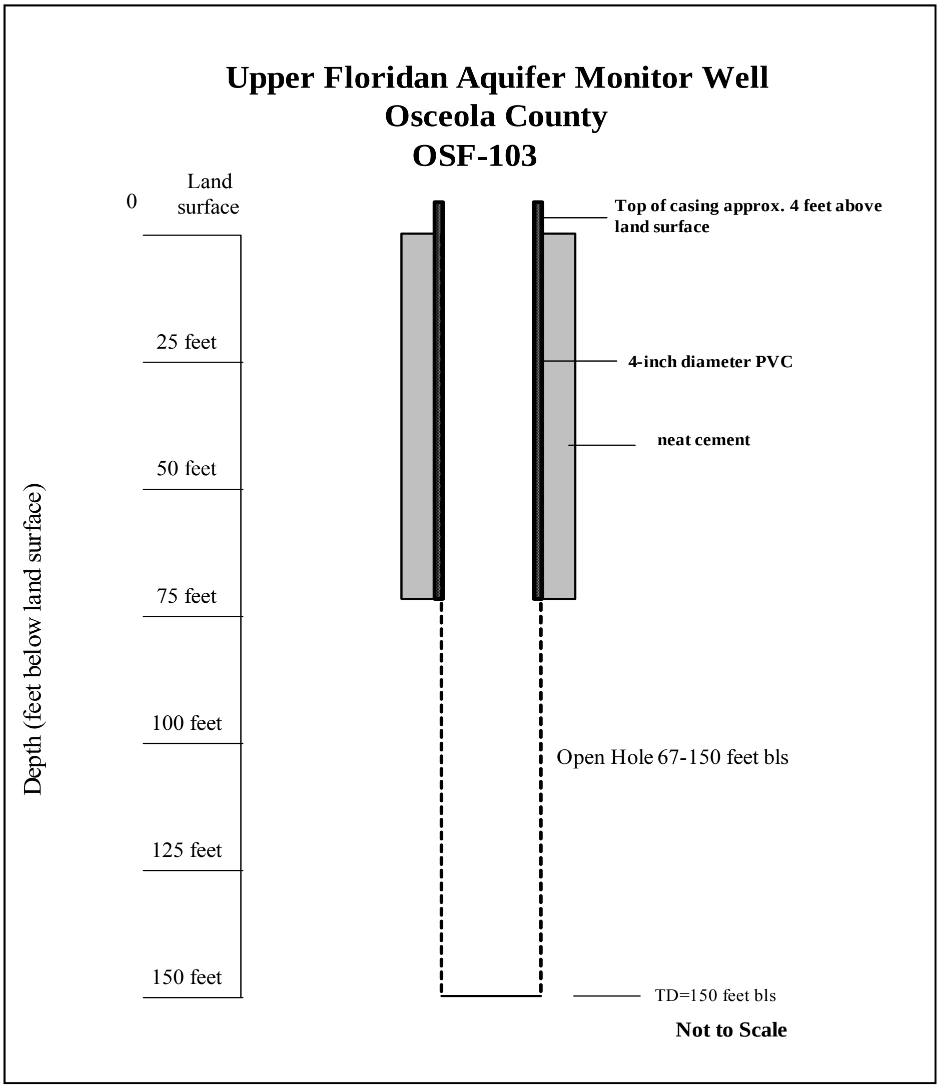

Figure 4. Existing Floridan aquifer monitor well OSF-103.

2.3 INSTALLATION OF PRODUCTION WELL OSF-108

Advanced Well Drilling (AWD) installed a 16-inch diameter, Upper Floridan aquifer system production well to a total depth of 150 feet bls, as shown in **Figure 5**. The work began on June 10, 2009. The well construction first included drilling a pilot hole to casing depth, then reaming a 24-inch diameter mud-rotary borehole to set casing. Based on a review of drill cuttings, the on-site SFMWD geologist determined the depth of the 24-inch diameter hole to be 68 feet bls. The leading bit broke through the hard layer of limestone at or above the Upper Floridan production zone, and all circulation was lost during the reaming phase. This effort was abandoned by filling the hole from bottom to top with neat cement grout, and on June 19, 2009, drilling began for a new production hole. This time the 16-inch diameter carbon steel casing was driven using a pneumatic hammer to a depth of 67 feet bls. Casing installation was completed on June 25, 2009. Reverse-air circulation was used to complete the 16-inch diameter production hole to a total depth of 150 feet bls, with cuttings collected every 10 feet (**Appendix B**). The borehole was cleared of cuttings and developed until it was free of particulate material. A summary of all well construction is included in **Table 1**.

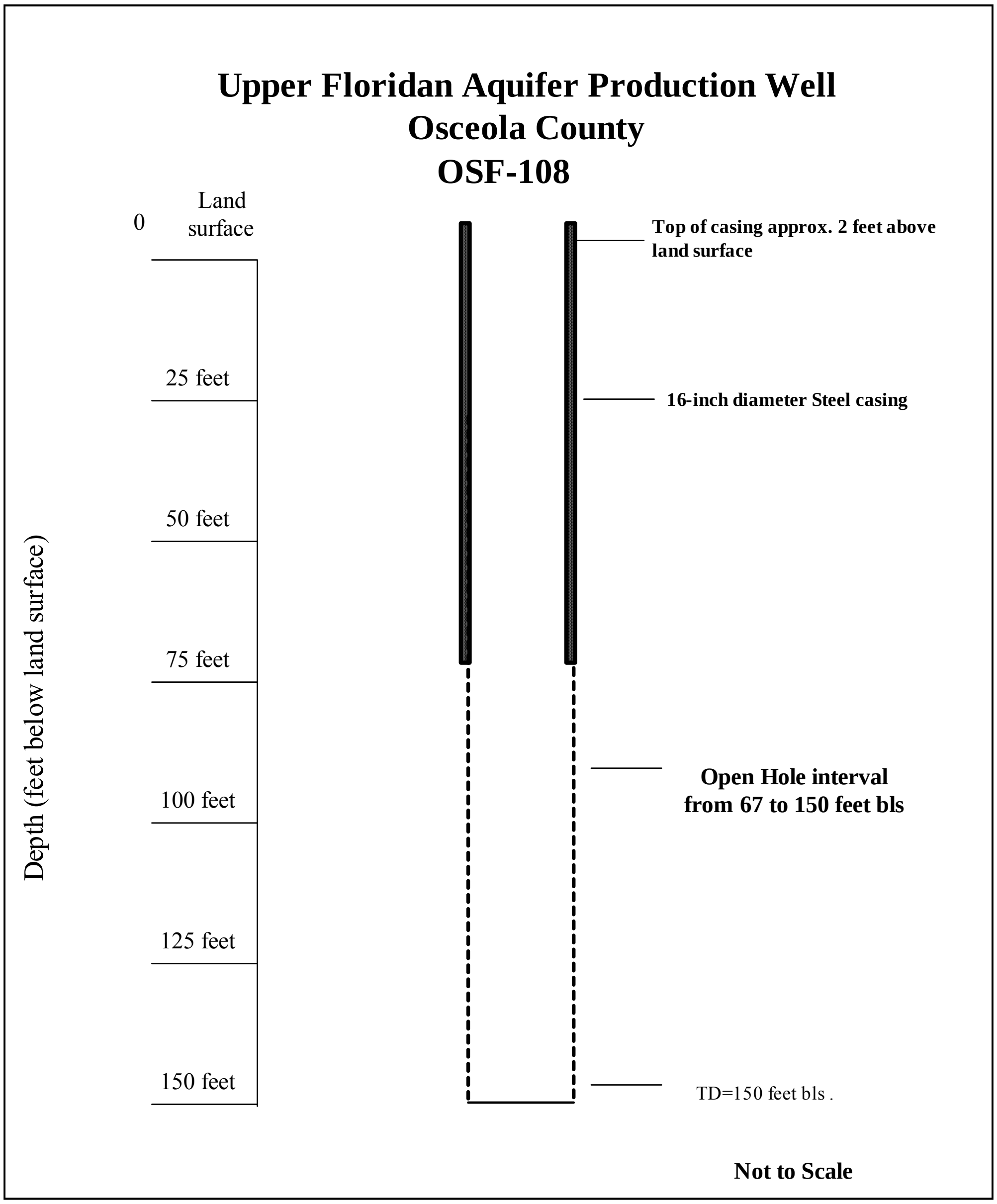

Figure 5. Floridan aquifer production well OSF-108.

Table 1. Summary of well construction details.

OAK ISLAND SITE, OSCEOLA COUNTY, FLORIDA						
Latitude 28° 20′02.2″ Longitude 81° 38′01.6″						
Well	**Total Depth (feet bls)**	**Interval Depth (feet bls)**	**Screen Type**	**Aquifer**	**Top of Casing (feet) NGVD 29**	**Distance from Production Well OSF-108 (feet)**
OSS-101	15	10-15	Slotted PVC 0.10 inches	SAS	111.60	46.7
OSS-102	45	40-45	Slotted PVC 0.10 inches	SAS	111.46	49.5
OSF-103	150	67-150	Open Hole	FAS	111.55	64.9
OSF-108	150	67-150	Open Hole	FAS	109.33	n/a

Note: No geophysical logs of completed boreholes were run.
SAS = surficial aquifer system
FAS = Floridan aquifer system
bls = below land surface

The OSF-108 well was developed for four hours until the dark orange sediment was removed and clear formation water was apparent. The production well was particularly difficult to develop due to this sediment. Well development was considered to be successful once the sediment was removed, and maximum flow (2,000 gpm) was obtained, as determined by the SFWMD on-site geologist. The discharge water from well development was conveyed on-site to existing wetlands.

3

Hydrogeology

3.1 HYDROGEOLOGIC SETTING

The surficial aquifer system (SAS) in the Oak Island area is predominantly unconsolidated quartz sand and varying amounts of shell, limestone, and clay of late Miocene to Holocene age. The surficial aquifer system is unconfined, and the upper boundary is defined by the water table. The thickness of the aquifer system varies from 30 to 225 feet. The SAS was interpreted to be 45 feet thick at the Oak Island test site, as shown in **Table 2**.

The Hawthorn Group of Miocene age usually contains sediments that consist of unconsolidated shell beds, soft non-indurated clay, silt, and quartz-phosphate sand units. The Hawthorn Group was encountered at this project site at approximately 45 feet bls with the first occurrence of clay; however, the sequence encountered contained predominately sand with moderate phosphate. The Hawthorn Group is regarded as the intermediate confining unit separating the SAS from the FAS, and usually provides good confinement for the Upper Floridan aquifer. The lower portion of the Hawthorn Group contained sandy clay with a hard beige limestone member. Once this dense limestone was penetrated, loss of drilling fluid circulation occurred.

The Ocala Limestone of Upper Eocene age in the Floridan aquifer system was encountered at 70 feet bls, just below a hard, dense layer of limestone at the base of the Hawthorn Group. Once this base of the Hawthorn Group was penetrated, all circulation materials for mud-rotary drilling were lost, and drilling operations had to be converted to the reverse-air drilling method. The Ocala Limestone of Upper Eocene age starts at 70 feet bls, at or below this void. The upper portion of the Floridan aquifer consisted of soft, pale yellowish-orange limestone. As drilling continued, the limestone became a friable calcarenite with shell fragments and corals. The Ocala Limestone was confirmed by index fossils (**Appendix B**) to a depth of 130 feet bls. The scope of this drilling effort was to target the upper portion of the Floridan aquifer system; therefore, drilling efforts were terminated at 150 feet bls, which is consistent with the regional interpretation for the first production zone of the Upper Floridan aquifer.

Table 2. Oak Island stratigraphic and hydrogeologic units.

Geology and Lithology	Series	Stratigraphic Unit	Hydrogeologic Unit	Depth Interval (feet bls)
Undifferentiated sand and shell – surficial deposits	Pleistocene Pliocene	Undifferentiated surficial deposits	surficial aquifer system	0-45
Sandy clay with shell fragements	Miocene	Hawthorn Group	Intermediate Confining unit	45-67
Limestone	Eocene	Ocala Limestone	Upper Floridan aquifer	70-130
Limestone	Eocene	Avon Park Formation	Upper Floridan aquifer	130-150

(Modified from: Barr 1992; O'Reilly and others 2002; Spechler and Kroening 2006)

3.2 AQUIFER TESTING

3.2.1 Background Water Level Data

The SFMWD collected background data in the Floridan aquifer monitoring well and the surficial aquifer monitoring wells at the Oak Island site every ten minutes for four days before the APT, using a HERMIT® 3000 data logger. The water level data for this background monitoring were based on an arbitrary value of zero feet when the data logger started recording. Data was later corrected to the appropriate elevations from a previous survey. The unit recorded the change in water level from this starting value over a four-day period, between July 9 and 13, 2009. **Figure 6** shows the water level fluctuations during the background monitoring period. The shallow surficial aquifer monitor well (OSS-101) is the sole well displayed in the graph, since water levels from both surficial aquifer monitor wells (OSS-101 and OSS-102) were an exact overlay.

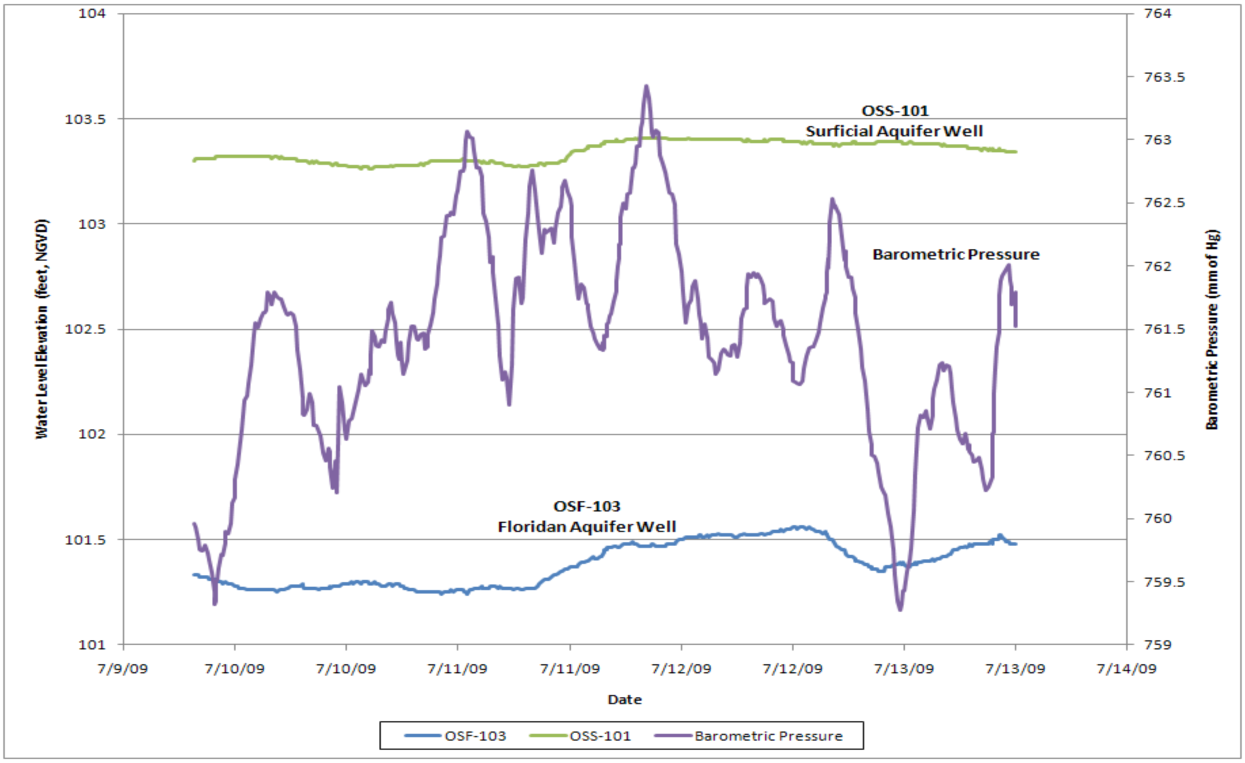

Figure 6. Background water level fluctuations in the surficial and Floridan aquifer wells.

The data do not seem to show any relationship between water levels in the Floridan aquifer system and barometric pressure. As barometric pressure varied over the course of the monitoring, the water level in the Floridan aquifer system did not correspond over the same period (**Figure 6**). This could be due to the relatively thin confining layer between the surficial aquifer and underlying Floridan aquifer system. At this site, the intermediate confining unit (the layer that separates the two aquifers) is only 22 feet thick and consists of sandy clay.

3.2.2 Drawdown Test

The SFWMD conducted a drawdown test primarily to determine the maximum sustainable pumping rate for the 72-hour APT. The SFWMD attempted to run three pumping rates in the step-drawdown test, each at a duration of 45 minutes. In a step-drawdown test, a well is pumped at a constant discharge rate until the drawdown in the well stabilizes. The pumping rate is then increased to a higher constant discharge rate and again, the drawdown in the well is allowed to stabilize. This process was to be repeated for a minimum of three steps and a total time of 2 hours, 15 minutes. The discharge of the steps for this test was set using a knife valve, which did not permit proper control of the flow. Therefore, the final 45-minute step, with the valve at full volume, was used to determine a specific capacity value and set the pump at full throttle. The results from the step-drawdown test enabled the SFWMD to determine that a pumping rate of 2,000 gallons per minute was optimal for the 72-hour APT. At this rate, the calculated specific capacity is approximately 149 gallons per minute, per foot of drawdown (gpm/ft) at 45 minutes. Drawdown ratios ranging from less than 100 gpm/ft to over 500 gpm/ft are reported within the Floridan aquifer system within nearby Orange County (Lichtler 1968). However, these reported values include areas of sinkholes where sand has filled solution channels in the aquifer, as well as areas where wells have been drilled into the Lower Floridan aquifer.

3.2.3 Aquifer Test

The SFWMD conducted an APT to determine the hydraulic parameters of the Upper Floridan aquifer interval of 67 to 150 feet bls. This interval included the Ocala Limestone and portions of the Avon Park Formation (**Table 2**). This upper producing zone extends from approximately 67 feet bls to approximately 150 feet bls (Lichtler 1968).

Table 3. Elevations of monitoring wells and initial water levels, Oak Island.

Well Name	Elevation of the Top of Casing (feet NGVD 29)	Initial Water Level below the Top of Casing (07/13/09)
OSS-101	111.60	8.25
OSS-102	111.46	8.04
OSF-103	111.55	9.40
OSF-108	109.33	7.02

Initial water levels were recorded, as shown in **Table 3**, prior to conducting the 72-hour APT. The drawdown phase of the APT consisted of pumping water from the Upper Floridan aquifer via the production well, at a constant rate of 2,000 gpm for 72 hours, while recording water level changes in the production well, the Upper Floridan aquifer monitoring well, and the two shallow aquifer monitoring wells. The 72-hour drawdown phase was followed by a 24-hour recovery period, where pumping stopped and water levels were recorded as they returned to background conditions.

AWD installed a 12-inch diameter, submersible pump in the production well, with the intake elevation set at 65 feet bls. The SFWMD selected this depth to set the pump based on the anticipated drawdown in the production well and the static water level. The wellhead was reinstalled, bolted down, and the wiring of the pump motor was routed to the generator. The discharge had to be directed into the wetland (approximately 150 feet away) that encompasses the entire site, to minimize the impact on the aquifer test. A 10-inch diameter circular orifice weir with an 8-inch diameter fixed orifice plate, along with a small fitting connected to a calibrated monometer tube, was used to measure discharge rates during pumping. A pressure transducer was installed in the orifice weir for continuous data recording. Additional pressure transducers were installed in all monitoring wells: several 10 psi transducers in the shallow monitoring wells, a 30 psi transducer in the Floridan observation well, and a 100 psi transducer in the production well. All were connected to a HERMIT® 3000 data logger using the required electronic connector cables. The transducers and data logger were configured to measure and record water level (pressure) changes at predetermined intervals (logarithmic scale) during the test.

On July 9, 2009, a Goulds 12-inch diameter, single bowl, submersible pump was set at a predetermined rate (2000 gpm), based on pipe diameter and the maximum volume (2000 gpm), that could be reasonably maintained throughout the 72-hour test. A preliminary test was completed, and power output from the generator was recorded in order to run the APT the following week. The site was secured for the weekend, and continuous background water levels were recorded. The pump was set up and run briefly before additional backup data logger equipment was installed in the wells.

On July 13, 2009, the drawdown phase of the APT began, and the discharge rate stabilized at 2,000 gpm after approximately five minutes of pumping. The drawdown phase was monitored by dataloggers that continuously measured and recorded water levels. Additionally, for backup purposes, the water levels were recorded by the SFWMD, using the electronic tape-down method. All measurements were recorded for 72 hours. A time-series plot of the drawdown data for both the production well (OSF-108) and corresponding monitor well (OSF-103) are shown in **Figure 7**. Maximum drawdown in Floridan wells OSF-108 and OSF-103 were 13.4 feet and 6.8 feet, respectively. The surficial aquifer monitor wells (OSS-101 and OSS-102) showed a maximum drawdown of 0.26 feet within the first 24 hours of the test and then began to rise due to rainfall and the discharge water recharging the surficial aquifer and the wetland area.

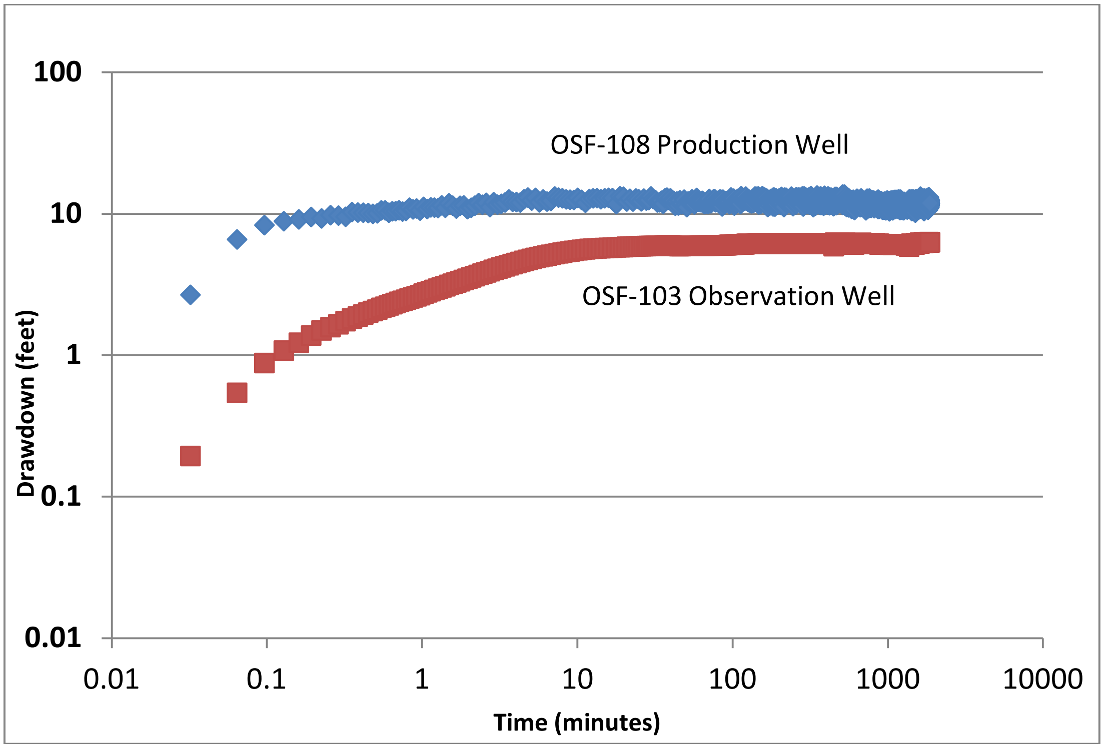

Figure 7. Time-series plot of drawdown data from OSF-108 and OSF-103.

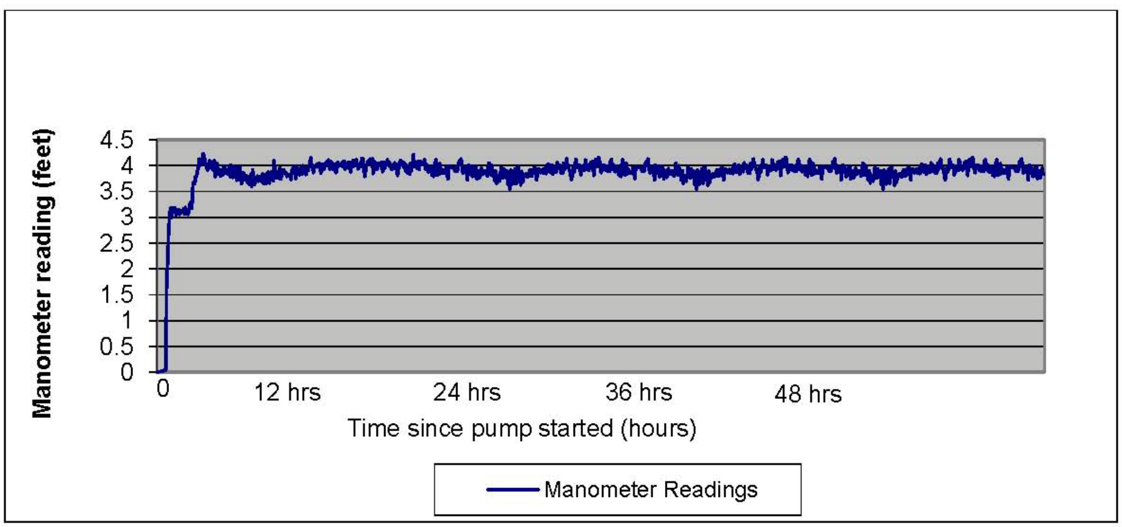

Figure 8. Time-series plot: manometer readings from discharge orifice weir, Oak Island APT.

Discharge data from the 10-inch diameter (8x10) circular orifice weir acquired during the 72-hour pumping phase of the APT are shown in **Figure 8**. Minor fluctuations in the pumping rate (less than +/-5 percent) were present during the course of the APT. These fluctuations were small enough to be considered inconsequential to the overall test results.

As the end of the drawdown phase of the APT came to a close, the data logger was programmed to collect recovery data. The drilling contractor stopped the pump, and water levels were recorded for 24 hours as the well returned to static conditions. The recovery data for the pumped well and the observation well are shown in **Figure 9**. Electronic copies of the original drawdown, recovery, and orifice weir (pump rate) data for the APT are archived and available for review at the SFWMD headquarters in West Palm Beach, Florida.

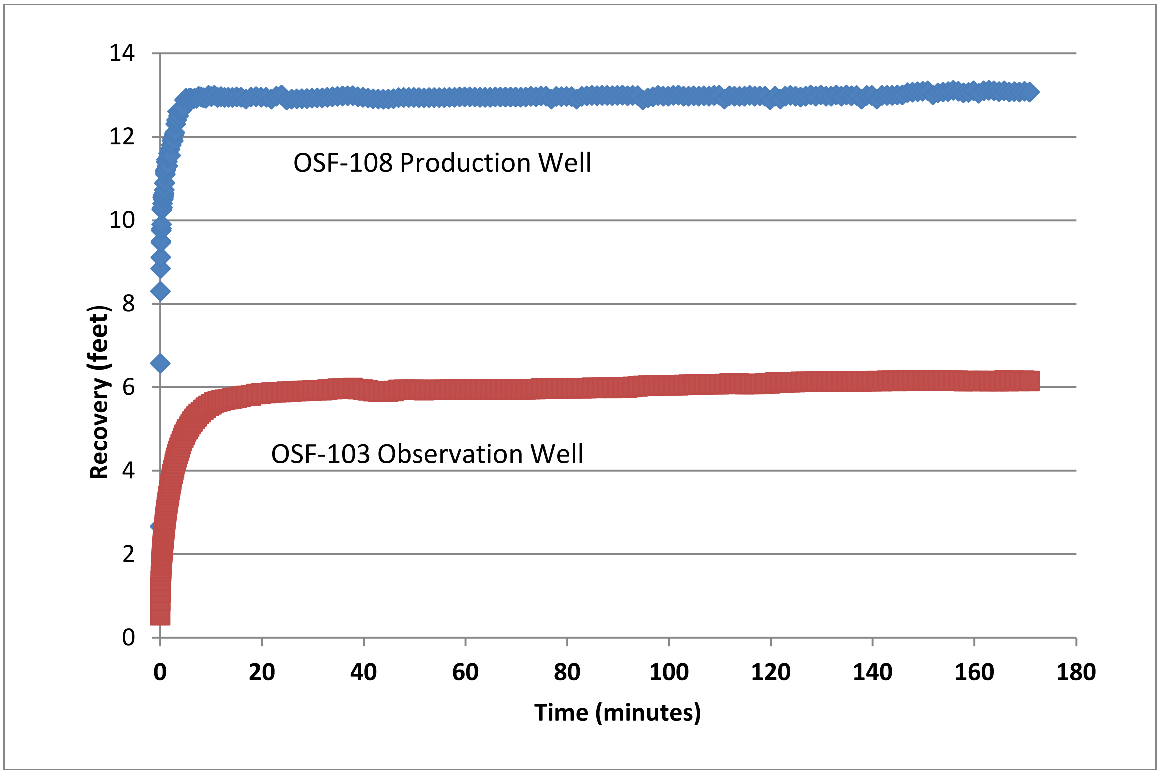

Figure 9. Time-series plot of recovery data from Oak Island APT.

3.2.4 Aquifer Test Analysis

A number of semi-confined analytical models were applied to the drawdown data collected during the APT to determine the hydraulic properties of the aquifer and aquitard(s). The analytical models included those developed by Hantush-Jacob (1955), Neuman-Witherspoon (1969), and Moench (1985).

Figures 10, **11**, and **12** are log/log plots of drawdown versus time for the Floridan aquifer monitoring well located 65 feet from the production well. The shape of the drawdown curve is indicative of a leaky-type aquifer, where the late-time drawdown remains relatively flat. A leaky (semi-confined) aquifer is one that loses or gains water (depending on the pressure gradients) through the semi-confining units (aquitards). **Figures 10**, **11**, and **12** show the analyses performed using the

Hantush-Jacob, Neuman-Witherspoon, and Moench methods, respectively. The overlying and underlying semi-confining units are composed of interbedded deposits of sand, silt, and clay above, and porous limestone and crystalline dolomite below. Both of these semi-confining units may provide water to the pumping well, indicating a leaky-type aquifer.

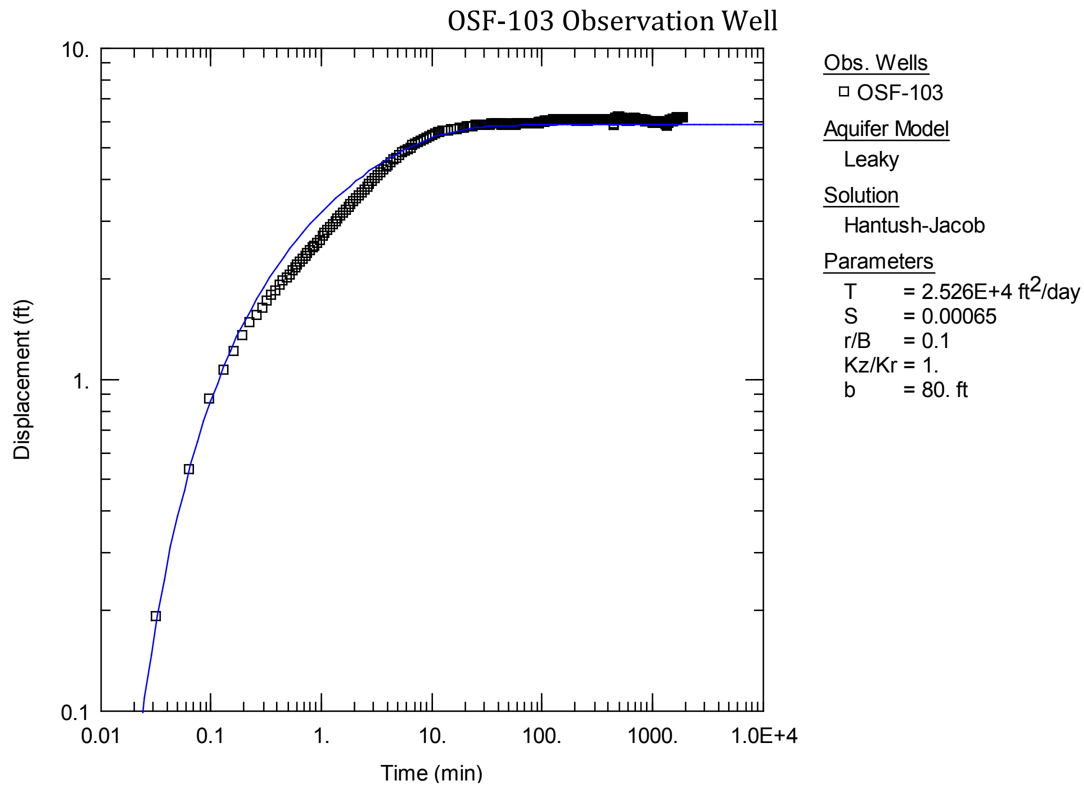

Figure 10. Hantush-Jacob solution, Oak Island APT.

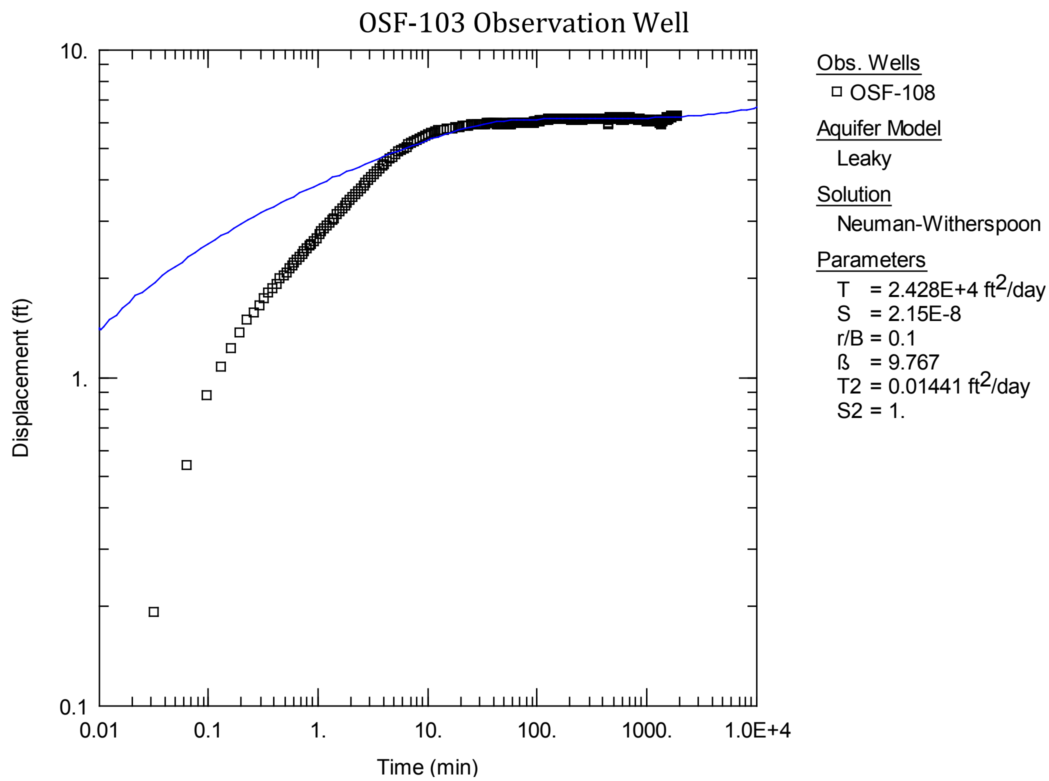

Figure 11. Neuman-Witherspoon solution, Oak Island APT.

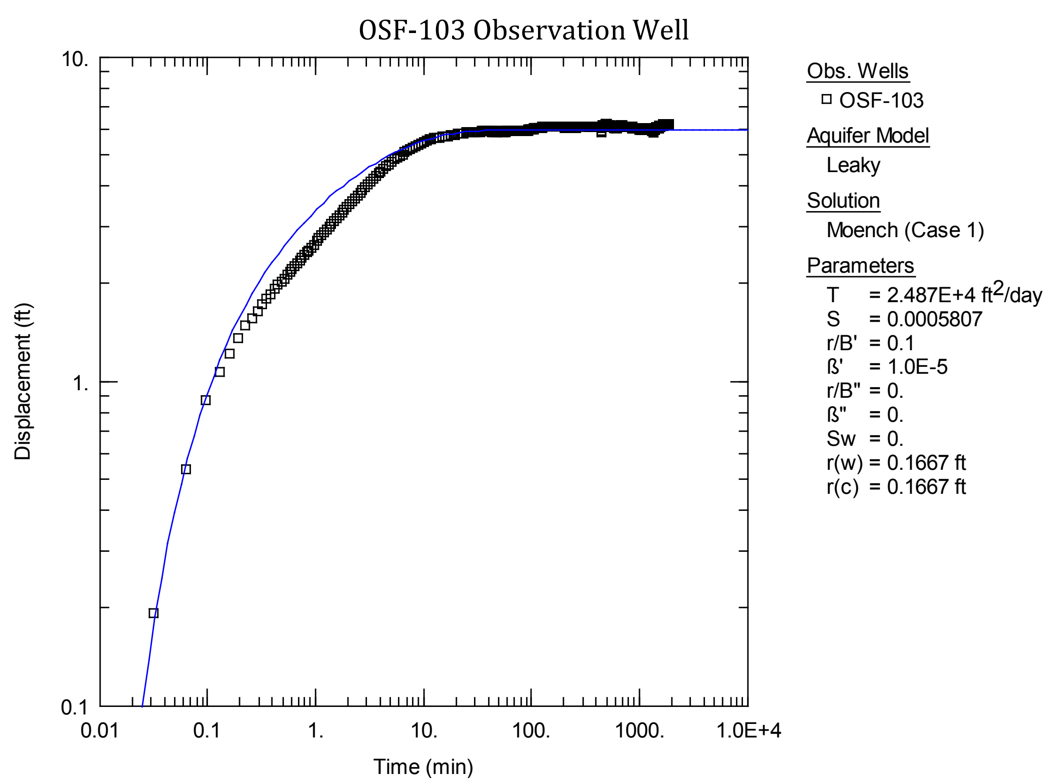

Figure 12. Moench (Case 1) solution, Oak Island APT.

The results obtained from each method are presented in **Table 4**. In general, drawdown data from a single observation well (OSF-103) provides an estimate of aquifer characteristics based on various assumptions and best-fit curve matching by using each of these methods.

Table 4. Leaky analytical model results for Oak Island APT Drawdown data.

Analytical Method	Transmissivity (ft^2/day)	Storativity	r/B	K (ft/day)	K′ (ft/day)	b (feet)	b′ (feet)	L (gpd/ft^3)
Hantush-Jacob	25,260	6.50 $X10^{-04}$	0.1	316	1.32	80	22	.058
Neuman-Witherspoon	24,280	2.15 $X10^{-08}$	0.1	304	1.26	80	22	0.057
Moench (Case1)	24,870	5.82 $X10^{-04}$	0.1	311	1.30	80	22	0.059

Legend:
T Transmissivity in square feet per day
S Storativity (dimensionless)
r/B Characterizes leakance across semi-confining units (dimensionless)
K Hydraulic conductivity in feet per day
K′ Hydraulic conductivity of the aquitard for vertical flow in feet per day
b Aquifer thickness in feet
b′ Aquitard thickness in feet
L Leakage value in gallons per day per cubic foot

The results that were derived from the different testing methods indicate a close fit for the three solutions. The Hantush-Jacob (1955) model was selected because it presented an important modification of the theory of leaky, semi-confined aquifers in which the storage of water in the semipervious confining beds is taken into account (Lohman 1979). The Neuman-Witherspoon model was selected since the Floridan aquifer production and monitoring wells fully penetrated the first flow zone of the Upper Floridan aquifer, and because a monitoring well was installed above the top portion of the aquitard. Moench (1985) was selected as an analytical solution since it provided the best fit and was derived for predicting water level displacements in response to pumping a large diameter well (14-inch production well) that takes into account well bore storage in a leaky confined aquifer and assumes storage in the aquitard(s) and wellbore skin effects. Moench (1985) also builds on several previously established analytical solutions, such as Hantush (1960). Based on these analytical considerations and the site-specific hydrogeological data collected during drilling and aquifer testing, the Hantush-Jacob analytical model appears to best represent the conditions present at this site. A transmissivity value of 25,260 ft^2/day, a storage coefficient of 6.50 x 10^{-4}, and an r/B value of 0.1 were determined using the Hantush-Jacob solution. The dimensionless parameter r/B characterizes the leakage across the aquitard(s) to the pumped aquifer, and from this value, a leakance factor of 0.06 gpd/ft^3 was calculated (Walton 1960). The leakance value is calculated by determining the vertical hydraulic conductivity (K′) through the semi-confining layer (**Equation 1**).

$$B = \sqrt{\frac{Tb'}{K'}}$$

Equation 1

Where:

B = Leakage factor calculated from r/B = 0.1

T = Transmissivity of the tested aquifer (ft^2/day)

b′ = Thickness of the semi-confining bed (ft)

K′ = Vertical hydraulic conductivity of the semi-confining bed (ft/day)

Equation 1 is rearranged as follows (**Equation 2**) to calculate K′:

Equation 2

$$K' = \frac{Tb'}{B^2}$$

The vertical hydraulic conductivity calculated from the APT data was 1.32 ft/day. K′ was calculated using **Equation 2**, and the transmissivity value determined from the Hantush-Jacob (1955) solution, assuming a semi-confining unit thickness of 22 feet in OSF-108. Using K′, the leakance coefficient of 0.060 was calculated using Equation 3:

Equation 3

$$\eta = \frac{K'}{b'}$$

Where:

η = Leakage coefficient (gpd/ft^3)

After the drawdown data were analyzed, the recovery data were plotted and analyzed for comparison with the drawdown data. The log/log plots of the recovery data versus time for the observation well were used to compare the drawdown data versus time for the observation well, and produced similar hydraulic results. The solutions analyzed are presented in **Appendix C.** The transmissivity values derived from the Oak Island test of the upper portion of the Floridan aquifer (25,260 ft^2/day) compared favorably with previous tests performed on the upper Floridan aquifer at OSF-70 (26,870 ft^2/day), located 20 miles to the southeast, and POF-26 (26,350 ft^2/day), located 50 miles to the south-southeast. The various methods referenced within this analysis section are based on various assumptions, and interested readers should refer to the original articles for further details.

Table 5. Leaky analytical model results for Oak Island APT Recovery data.

Analytical Method	Transmissivity (ft^2/day)	Storativity	r/B	K (ft/day)	K′ (ft/day)	b (feet)	b′ (feet)	L (gpd/ft^3)
Hantush-Jacob	24,540	$7.68\ X10^{-04}$	0.1	307	1.28	80	22	.058
Neuman-Witherspoon	24,280	$2.15\ X10^{-08}$	0.1	304	1.26	80	22	.057
Moench (Case1)	22,500	$4.90\ X10^{-04}$	0.1	281	1.17	80	22	.053

Legend:
T Transmissivity in square feet per day
S Storativity (dimensionless)
r/B Characterizes leakance across semi-confining units (dimensionless)
K Hydraulic conductivity in feet per day
K′ Hydraulic conductivity of the aquitard for vertical flow in feet per day
b Aquifer thickness in feet
b′ Aquitard thickness in feet
L Leakage value in gallons per day per cubic foot

3.2.5 Water Quality Testing

Field water quality data were collected from OSF-108 at two-hour intervals during the first 24 hours of the 72-hour aquifer test. After baseline data were established, water quality data were collected every four hours. The field data were collected from the discharge orifice pipe used for the APT. A composite sample was collected using a bucket, and the YSI probe was submerged in the sample. These field data are displayed in **Figure 13**. Since the field samples from the Upper Floridan aquifer were not analyzed for dissolved-solids concentrations, these values were estimated by multiplying specific conductance by 0.55 to 0.65, yielding a reasonable approximation of the dissolved-solids concentration (Spechler and Kroening 2006). The field data indicate that the water quality in the Upper Floridan aquifer at this site in Osceola County meets U.S. Environmental Protection Agency (2000) established secondary drinking water standards of 500 milligrams per liter for dissolved-solids concentrations.

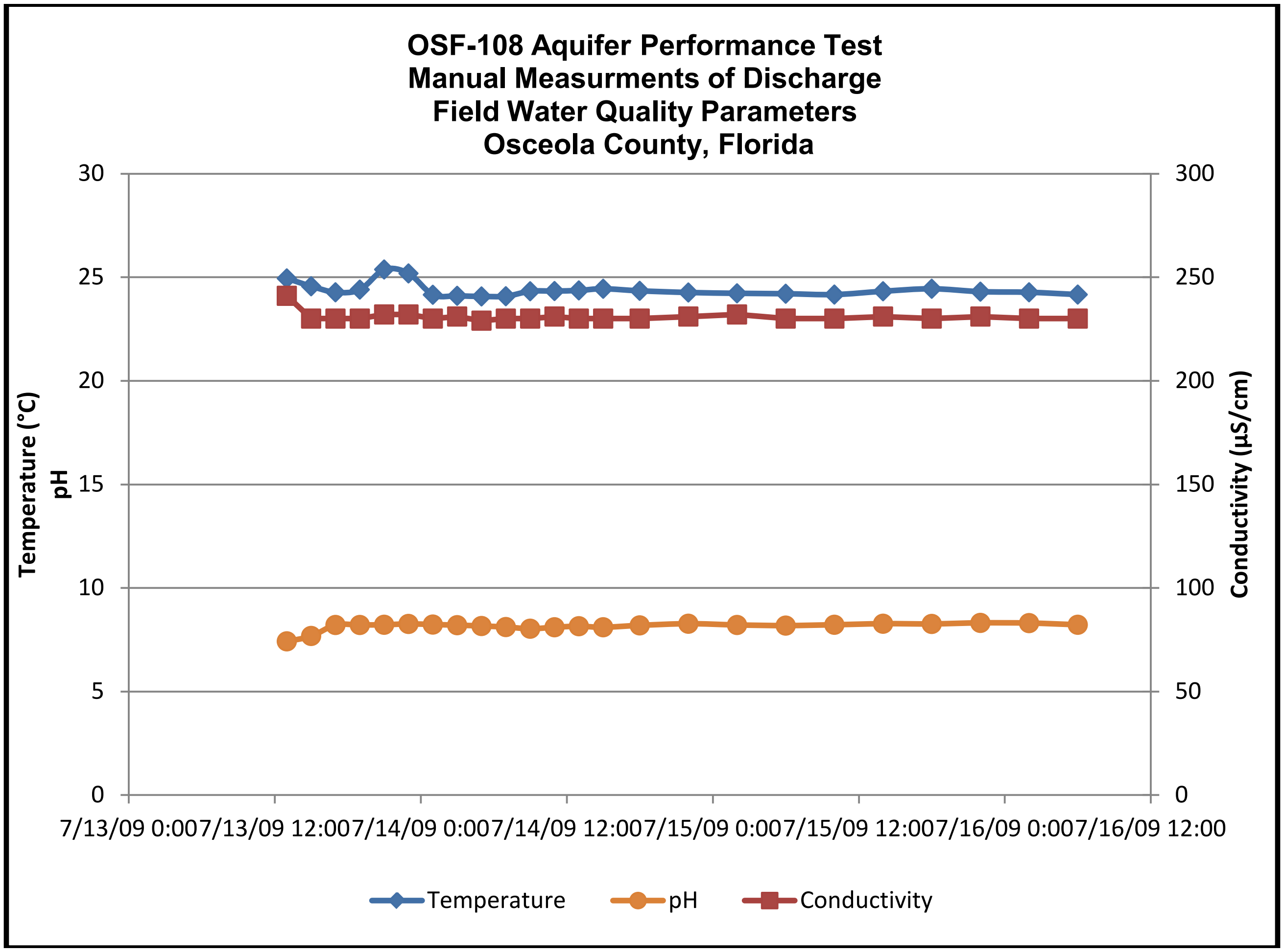

Figure 13. Field water quality data from the production well.

4

Summary and Conclusions

1. The top of the Upper Floridan aquifer occurs at a depth of 70 feet bls, with the first occurrence of the semi-permeable limestone unit of the Ocala Limestone just below the void encountered. This first occurrence of a yellowish-orange limestone was encountered and marked by the characteristic cavernous unit.
2. The specific capacity and aquifer performance test both indicate a production capacity of at least 2,000 gallons per minute from the Upper Floridan aquifer at the site.
3. The Upper Floridan production zone from these test wells yielded a transmissivity value of 25,260 feet squared per day, a storage coefficient of 6.50×10^{-4}, and a leakance value of 0.060 gpd/ft^3.
4. The transmissivity values derived from the Oak Island test of the upper portion of the Floridan aquifer compared favorably with previous test at OSF-70 (26,870 ft^2/day), located 20 miles to the southeast, and POF-26 (26,350 ft^2/day), located 50 miles to the south-southeast.
5. The aquifer testing at the Oak Island site indicates that hydraulic connections between the surficial aquifer system, Hawthorn Group or intermediate confining unit, and the Upper Floridan aquifer exist as evidenced by water level fluctuations that occurred within the first five hours of the test. The fluctuations in the lower and upper surficial aquifer monitoring wells, 0.26 feet and 0.21, respectively, indicate the semi-confining nature of the aquitard.
6. The field data indicate that the water quality in the Upper Floridan aquifer at this site in Osceola County meets the U.S. Environmental Protection Agency (2000) secondary drinking water standards of 500 milligrams per liter for dissolved-solids concentrations.

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Appendix A

GENERALIZED LITHOLOGIC LOG, OSF-103 FLORIDAN MONITOR WELL

INTERVAL (feet bls)	DESCRIPTION
10 - 20	SAND; MEDIUM-TO FINE-GRAINED, LIGHT BROWN TO TAN
20 - 30	SAND; FINE-GRAINED, LIGHT TO MODERATE BROWN
30 - 40	SAND; FINE-GRAINED, CLEAN, LIGHT TAN SAND
40 - 50	CLAY AND SAND; LIGHT GRAY TO LIGHT GREEN
50 - 65	CLAY; DARK GRAY/LIGHT GREEN, LOW PERMEABILTY, MINOR SHELL
65 - 67	HARD DRILLING, LIGHT TAN/BEIGE LIMESTONE, LOW PERMEABILITY
67 - 70	LOSS OF CIRCULATION, VOID
70 - 80	LIMESTONE WITH MUD; SOFT DRILLING, LIGHT BEIGE, POOR RETURN
80 - 90	LIMESTONE; LIGHT BEIGE, POOR RETURN
90 - 100	LIMESTONE; LIGHT BEIGE, MINOR WHITE SAND, POOR RETURN
100 - 110	NO RETURN
110 - 120	NO RETURN, SOFT DRILLING
120 - 130	NO RETURN, SOFT DRILLING
130 - 140	NO RETURN, SLIGHTLY HARDER DRILLING
140 - 150	NO RETURN, SAME AS ABOVE

Appendix B

LITHOLOGIC LOG, OSF-108 FLORIDAN AQUIFER PRODUCTION WELL

INTERVAL (feet bls)		DESCRIPTION
0 - 10	SAND:	VERY LIGHT GRAY N8, VERY FINE-GRAINED, WELL SORTE
10 - 20	SAND:	YELLOWISH GRAY 5GY 8/1, VERY-FINE GRAINED, MODERATELY TO WELL SORTED, MODERATE SHELL FRAGMENTS
20 - 30	SAND:	YELLOWISH GRAY 5GY 8/1, VERY FINE-GRAINED, MODERATELY TO WELL SORTED, MINOR SHELL FRAGMENTS
30 - 40	SAND:	YELLOWISH GRAY 5GY 8/1, VERY FINE-GRAINED, MODERATELY TO WELL SORTED, MINOR SHELL FRAGMENTS
40 - 45	SAND:	YELLOWISH GRAY 5GY 8/1, VERY FINED-GRAINED, WELL SORTED, MINOR SHELL FRAGMENTS
45 - 50	SAND (50%):	VERY LIGHT GRAY N8, VERY FINE-GRAINED; AND CLAY (50%): LIGHT OLIVE GRAY 5Y 6/1, SOFT, MODERATELY LOW PLASTICITY
50 - 60	SAND (70%):	VERY LIGHT GRAY N8, VERY FINE-GRAINED; AND CLAY (30%): LIGHT OLIVE GRAY 5Y 6/1, SOFT
60 - 70	CLAY:	OLIVE GRAY 5Y 4/1, SOFT, MODERATELY LOW PLASTICITY, LOW PERMEABILITY, SILTY
70 - 80	LIMESTONE:	PALE YELLOWISH ORANGE 10YR 8/6, MICRITIC, MODERATE TO WELL INDURATED, TRACES OF SILT
80 – 90	LIMESTONE:	VERY PALE ORANGE 10YR 8/2, MICRITIC, MODERATELY HARD TO FRIABLE

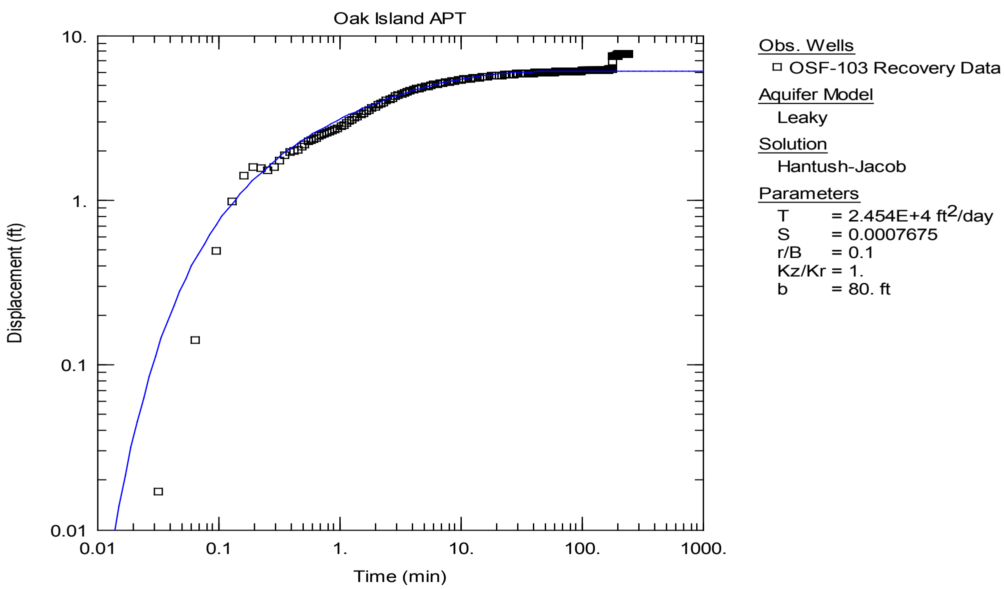
.

LITHOLOGIC LOG, OSF-108 FLORIDAN AQUIFER PRODUCTION WELL

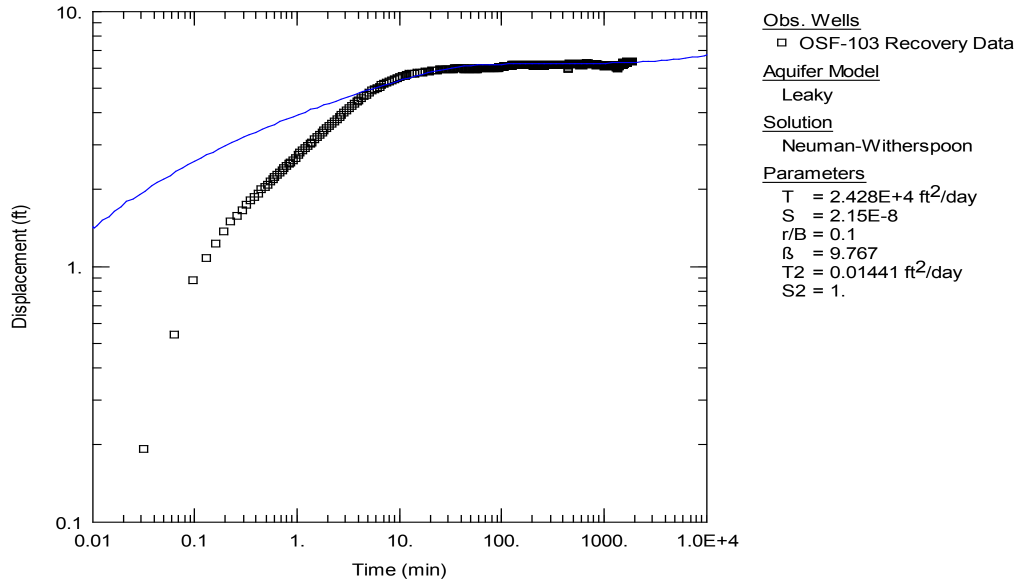
INTERVAL (feet bls)	DESCRIPTION	
90 - 100	LIMESTONE:	VERY PALE ORANGE 10YR 8/2, MICRITIC, MODERATELY HARD TO FRIABLE, MODERATE MOLDIC PERMEABILITY, SOME SHELL FRAGMENTS
100 - 110	LIMESTONE:	PALE YELLOWISH ORANGE 10YR 8/6, CALCARENITIC, FRIABLE, MODERATE MOLDIC AND INTERGRANULAR PERMEABILITY, SOME SHELL FRAGMENTS AND TRACES OF CORAL
110 - 120	LIMESTONE:	PALE YELLOWISH ORANGE 10YR 8/6, CALCARENITIC, FRIABLE, ABUNDANT BIVALVES AND CORAL; MINOR IRON-STAINED LIMESTONE: DARK YELLOWISH ORANGE 10YR 6/6
120 – 130	LIMESTONE:	DARK YELLOWISH ORANGE 10YR 8/6, BIOGENIC, FRIABLE, ABUNDANT BIVALVES AND CORAL, FIRST OCCURRENCE OF OLIGOPYGUS WETHERBYI DE LORIOL (OCALA LIMESTONE – CRYSTAL RIVER FORMATION)
130 – 140	LIMESTONE:	DARK YELLOWISH ORANGE 10YR 8/6, SAME AS ABOVE BUT SOFTER
140 - 150	LIMESTONE:	DARK YELLOWISH ORANGE 10YR 8/6, SOFT, HOLE WILL NOT STAY OPEN

Appendix C

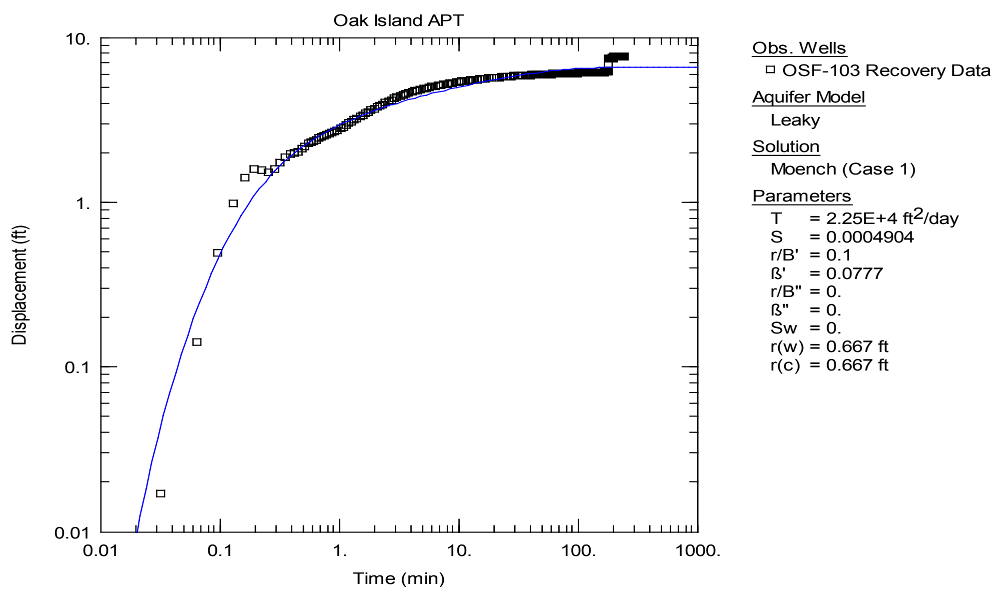
ANALYTICAL SOLUTIONS USED FOR RECOVERY DATA , OSF-103 FLORIDAN AQUIFER MONITOR WELL



Hantush-Jacob solution, Oak Island APT



Neuman-Witherspoon solution, Oak Island APT



Moench (Case 1), Oak Island APT