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Florida Power and Light

TURKEY POINT EXPLORATORY DRILLING AND AQUIFER PERFORMANCE TEST PROGRAM

August 19, 2009

HDR

FLORIDA POWER AND LIGHT COMPANY

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AQUIFER PERFORMANCE TEST PROGRAM

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Many Solutions℠

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1.0 INTRODUCTION

Florida Power & Light Company (FPL) further evaluated the use of radial collector wells as one of the potential sources of cooling water for the proposed Turkey Point Units 6 &7.

Radial collector wells consist of a central concrete caisson (up to 20-30 feet in diameter) excavated to a target optimal depth at which well screens project laterally outward in a radial pattern from the bottom of the well. Radial wells are designed to induce infiltration from a nearby surface-water source, combining the desirable features of a groundwater and surface-water supply. Radial wells can provide an abundant, dependable supply of water with constant temperature, low turbidity and filtration of undesirable surface water constituents. The project location at Turkey Point, along with the local and regional boundaries, and several major water control structures are shown in Figure 1.1.

In order to further evaluate the use of a radial collector well system, an exploratory drilling and aquifer testing program was performed on the Turkey Point plant property after planning, consultation with and review by local and state agencies. Drilling was performed on the Turkey Point peninsula, or the "Point" (the landmass extending out into Biscayne Bay) to assess the subsurface lithology and to install a test production well and monitoring wells for an aquifer performance test (APT). There were several goals of the APT. The first goal was to provide information on the potential yield of the shallow water bearing units beneath the Point that could potentially be utilized for a radial well system. The second goal was to provide data for an evaluation of the aquifer characteristics of this shallow permeable interval. The APT was also conducted to allow for an evaluation of potential short term water quality changes under pumping conditions. The final goal of the APT was to provide information for numerical model calibration to assess the performance of radial collector wells. The following sections of this report describe the procedures and results of the drilling and testing program performed on the Point.

2.0 EXPLORATORY DRILLING PROGRAM

The drilling program performed on the Point began on January 5, 2009, and concluded on February 11, 2009. The program consisted of soil borings, rock/soil classification, water quality sampling, and monitoring well and test production well installation for the APT. The drilling included one pilot hole (MW-1) drilled to a depth of 75 feet below land surface (bls) to determine the lithology of the shallow stratigraphic units beneath the Point. The purpose of the pilot hole was to provide information on the subsurface conditions so that the depth of the test production well and monitoring wells for the APT could be selected. Once drilled, the casing was set in the pilot hole, caliper, temperature, gamma, and fluid conductivity geophysical logs were run under static (non-pumping) conditions. A video survey was also conducted in the pilot hole to provide an in-situ visual log of the subsurface at the Point.

Formation samples were collected at four additional boring locations (MW-2 through MW-5) using split-spoon and reverse air methods, as appropriate, from land surface to the maximum depth drilled. Split spoon cores were collected in accordance with ASTM Standard D 1586-84 (Standard Method for Penetration Test and Split-Barrel Sampling of Soils). Split spoon samples were obtained to refusal or mud loss utilizing mud rotary drilling techniques. Formation cuttings were collected continuously during reverse-air drilling. Each formation sample was placed in a sample storage bag on 5-foot intervals and marked with the boring name, date, time, and depth interval of the sample. The boring locations are shown on Figure 2.1.

2.1 Geological Interpretation Methods

The lithologic information collected from each borehole was reviewed in the field during drilling by a geologist registered in the State of Florida. The geologic interpretation of the stratigraphy at the site based on the data obtained during drilling is discussed below.

The upper 75 feet of subsurface material encountered at the site included well defined sequences of sandy limestone, cemented sand, and coralline limestone. In order to characterize this variability in the near surface stratigraphy on the Point, the facies encountered are identified by the primary rock type with the formation name applied based on the similarity to the literature description. Detailed paleontologic or petrographic classification of the facies encountered was outside the scope of the study.

2.2 Regional Conditions

The Turkey Point site is located in the Coastal Marshes and Mangroves physiographic zone of Florida (Davis, 1943). The site is underlain by geologic formations that make up the Biscayne aquifer, named after Biscayne Bay. The aquifer extends along the eastern coast from southern Dade County into coastal Palm Beach County as a wedge-shaped underground reservoir having a thin edge to the west. It underlies the Everglades as far north as northern Broward County.

The Biscayne aquifer is identified by Fish and Stewart (1991) as that part of the surficial aquifer system in southeastern Florida composed of (from land surface downward) the Pamlico Sand, Miami Oolite, Anastasia Formation, Key Largo Limestone, and Fort Thompson Formation (all of Pleistocene age), and contiguous, highly permeable beds of the Tamiami Formation of Pliocene and late Miocene age, where at least 10 feet of the section is very highly permeable (a horizontal hydraulic conductivity of about 1,000 feet/d or more). The Anastasia Formation, the Key Largo Limestone, and the Fort Thompson Formation constitute the bulk of the very highly permeable sediments of the Biscayne aquifer in eastern Dade County. The average hydraulic conductivity of the three formations probably exceeds 10,000 feet/d over much of the area (Fish and Stewart 1991). Figure 2.2 is a stratigraphic section that represents eastern Miami Dade County and the Turkey Point site.

Near the western limit, the base of the aquifer is about 20 feet below sea level and then slopes downward to the east at an average of about 3 to 4 feet/mile, forming a wedge-shaped aquifer. In coastal southeastern Dade County, the base is 110 to 120 feet below sea level, but in coastal northeastern Dade County, a basin or trough reaches a depth of at least 187 feet below sea level (Figure 2.3). In the area of the FPL Turkey Point plant property, the Biscayne aquifer is approximately 115 feet thick (Fish and Stewart 1991), although drilling to the base of the aquifer was not performed for this investigation. The aquifer water quality is saline to saltwater in the area of Turkey Point plant property.

Transmissivity of the Biscayne aquifer varies with the lithology of the geologic formations present and with the thickness of zones with well-developed secondary-solution porosity. The area that has transmissivities greater than 1,000,000 $feet^2/d$ coincides with the thickest sequence of the Fort Thompson Formation or the Key Largo Limestone. The decrease in transmissivity to the west corresponds to the thinning of highly permeable marine beds in the Fort Thompson Formation. The relatively lower transmissivity of northeastern and coastal east-central Dade County corresponds with the predominance of the Anastasia Formation, the Miami Oolite, and the upper part of the Tamiami Formation. This decrease in transmissivity occurs although there is an increase in thickness of the aquifer because sand and calcareous sandstone become the principal lithologies (Fish and Stewart, 1991).

Fish and Stewart (1991) provide an indication of the horizontal hydraulic conductivity of the rocks or sediments that make up the Biscayne aquifer. According to the report, highly transmissive limestone formations are present at depths ranging from approximately land surface to approximately 80 feet below land surface (bls) near the Turkey Point plant property. Other research shows that the porosity and permeability of the aquifer are reported to be highly heterogeneous and anisotropic, and mostly related to secondary porosity due to biogenic activity such as touching-vug macroporosity, which forms tabular-shaped stratiform groundwater flow zones of regional extent. Cunningham et al. (20009), who used data from numerous test core holes, reported that macroporosity associated with burrows is important to groundwater flow in the aquifer formations.

2.3 General Lithologic Section

In the area of the Turkey Point plant site, the literature indicates that the shallow formations in the area consist of, in descending order, the Miami Limestone, the Key Largo Limestone, and the Fort Thompson Formation. The Key Largo is known to form the Florida Keys, but in some areas has encroached on the mainland at some time in the past (Hofmeister, 1974). This is illustrated in Figure 2.4, which shows that the Key Largo Limestone is present in the area of Turkey Point. Deeper formations are not the focus of this study, which is to evaluate the shallow formations for a proposed radial collector well system. Less permeable units of the Tamiami Formation, and the deeper Hawthorn Group (Scott, 1998), form the confining unit between the Biscayne aquifer and the Upper Floridan aquifer (Fish and Stewart, 1991). The units reported to be present at the Point are discussed below.

Miami Limestone

The Miami Limestone was named by Hoffmeister et al. (1967) and is composed of a bryozoan facies and an oolitic facies. During reef growth, carbonate sand banks periodically accumulated behind the reef in environments similar to the Bahamas today. One such lime-sand bank covered the southwestern end of the coral reefs and, when sea level last dropped, the exposed lime-sand or oöid bank formed the Lower Keys. Thickness is variable reaching a maximum thickness of approximately 50 feet. The oolitic facies consists of well-sorted ooids, with varying amounts of skeletal material (corals, echinoids, mollusks, algae) and some quart sand. Hoffmeister et al. (1967) and Perkins (1977). The Miami Limestone grades laterally to the south into the Key Largo limestone (FGS, 1991). Throughout the Lower Keys, the Miami Limestone lies on top of the coralline Key Largo Limestone, and varies from a few feet up to 35 feet in thickness.

Key Largo Limestone

The Key Largo Limestone was named by Sanford (1909), and is a Pleistocene reef limestone that forms the upper Florida Keys. It stretches in the subsurface at least from Miami to the Dry Tortugas, and its thickness, although variable, can be up to 200 feet. About 1.8 million years ago, a shallow sea covered what is now south Florida. From that time to about 10,000 years ago, often called the Pleistocene "Ice Ages," world sea levels underwent many fluctuations of several hundred feet, both above and below present sea level, in response to the repeated growth and melting of the glaciers. Colonies of coral became established in the shallow sea along the rim of the broad, flat Florida Platform. The subtropical climate allowed the corals to grow rapidly and in great abundance, forming reefs. As sea levels fluctuated, the corals maintained footholds along the edge of the platform; their reefs grew upward when sea level rose, and their colonies retreated to lower depths along the platform's rim when sea levels fell. During times of rising sea levels, dead reefs provided good foundations for new coral growth. In this manner, during successive phases of growth, the Key Largo Limestone accumulated from about 75 to 200-feet thick in places. The last major drop in sea level exposed the ancient reefs, which are the present Keys. Exposures of the Key Largo Limestone can be seen in many places along the Keys: in canal cuts, at shorelines, and in construction spoil piles (Schmidt and Lane, 1994).

The Key Largo limestone consists of an organic framework of coral colonies with intra and interbedded calcarenites. In general, the formation contains a large amount of coral in growth position (Hoffmeister, et. al.1967).

Fort Thompson Formation

The Pleistocene Fort Thompson Formation consists of fossiliferous sandy marine limestone and calcareous sandstones interstratified with thin layers of dense freshwater limestone, and is generally highly permeable and produces high water yields. The shell beds are characteristically variably sandy and slightly indurated to unindurated. The sandy limestones present in the Fort Thompson were deposited under both freshwater and marine conditions. The sand present is both fine to medium grained (FGS, 1991).

2.4 Site Stratigraphy

As discussed, in order to characterize the variability in the near surface stratigraphy on the Point, the facies encountered are identified by the primary rock or soil type, with the formation name applied based on the similarity to the literature description. Detailed paleontologic or petrographic classification of the facies encountered was outside the scope of the study. The depths and elevations of the individual facies encountered are included in Table 2.1.

Subsurface materials encountered during drilling at Turkey Point include fill material underlain by peat or muck. The muck indicates native material and was encountered in all borings at approximately 10 feet bls (Table 2.1). Beneath the peat/muck layer is a gray sandy limestone facies. Beneath the sandy limestone is calcareous cemented sand. The sand is fine grained with some shell material, however the sand was not encountered at boring MW-5 to the northwest of the Point, and was only 2-feet thick at boring MW-3. Below the sand layer is a coralline limestone with some gray limestone and shell. Below the coralline limestone is a light gray to white sandy limestone with some shell. Soil boring logs are included in Appendix A. The fill material was placed to form the landmass referred to as the "Point" extending into Biscayne Bay. The fill material extended to depths of eight to nine feet on the Point. The lithofacies encountered below the fill material are described in more detail below. Lithologic cross sections are included as Figures 2.5 and 2.6.

Fill Material

The fill material consists predominantly of limestone boulders and rock fragments approximately 8 to 9 feet thick at the Point.

Peat

The peat layer consists of dark brown to black clayey sand/sandy clay with abundant plant material. The peat (or muck) is wet, and exhibited a strong sulpher odor. The thickness of the peat ranges from 1 foot to 3.5 feet at the Point. Figure 2.7 shows a contour map of the top elevation of the peat layer. As shown, the peat layer dips to the south-southeast at the Point.

Gray Sandy Limestone (Miami Limestone)

A limestone facies consisting of gray sandy limestone with varying amounts of shell (mollusks, gastropod), and some bryozoan fossils were encountered below the peat and extends to depths ranging from 32 to 35 feet bls. Based on the literature, this facies is likely part of the Miami Limestone, although no ooids were noted at the Point, and similar facies have been described as part of the Key Largo Limestone (Hoffmeister, 1967). The limestone appears to fit the classification of a calcarenite, which is a rock that is formed by the percolation of water through a matrix of calcareous shell fragments and sand causing the dissolved lime to cement the mass together. Fossil mollusk percentages can range from 10 percent to 60 percent. At the Point, the percentage of fossils in the rock cuttings based on visual inspection was approximately 10 to 30 percent.

The video survey indicates a moderate to high degree of cavities, channels, tubes, and diverse irregular passageways in this unit as shown on Figure 2.8. A contour map of the top of the sandy limestone layer is included as Figure 2.9, which shows the unit dipping to the southeast. The top elevation ranges from approximately -7 feet to -4 feet NAVD 88.

Calcareous Cemented Sand

The cemented sand consists of light gray to white cemented calcareous sand and fine sand, well sorted, fine grained, some shell material. The cemented sand extends to depths ranging from 36 to 43 feet bls where present. The sand facies was not present at MW-5, and only two feet thick at MW-3. Figure 2.10 shows the top elevation of the cemented sand, which does not dip to the east-southeast, but shows a relatively flat surface varying by approximately 0.5 feet. Figure 2.11 shows an isopach contour map of the thickness of the sand unit, which shows the unit pinching out to the northeast. Video still images of the cemented sand are shown on Figure 2.12. The sand is possibly part of the Miami Limestone as quartz sand is typically present in this facies.

Coralline Limestone

The corraline limestone consists of gray limestone and yellow-brown calcite-replaced coral consistent with descriptions of the Key Largo Limestone (Hoffmeister, et al. (1967). In the pilot hole, the coralline limestone extends to a depth of approximately 58 feet bls. Video survey indicates coralline structure in a limestone matrix, with coralline structure, abundant cavities, channels, tubes, and diverse irregular passageways, as shown on Figure 2.13. A contour map of the top elevation of the coralline limestone is shown on Figure 2.14. As shown, the top elevation ranges from -29 to -40 feet NAVD 88 and dips to the east.

Lt Gray to White Sandy Limestone

This unit consists of light gray to white sandy limestone and moderately fossiliferous limestone. The cuttings were noted to be smaller than the shallower limestone facies. The video survey indicates varying degrees of small channels, tubes, and diverse irregular passageways within the unit. The upper portion of the light gray limestone (approximately 57 to 66 feet bls) appears to be more dense, with little to no well developed burrows and openings as compared to the lower part as illustrated on Figure 2.15. This limestone facies is likely part of the Fort Thompson Formation (Hoffmeister, et al. (1967), with the denser limestone possibly a freshwater limestone layer.

2.5 Geophysical Logging Results

Geophysical logging consisting of caliper, temperature, gamma, and fluid conductivity were run in pilot hole MW-1 under static conditions. The logs are included as Figures 2.16 and 2.17.

The background temperature log shows a decrease in temperature from the base of the casing at 24 feet bls, to about 32 feet bls, where only a slight decrease is observed to the total depth of the borehole. The temperature near the casing at approximately 26 feet bls is shown at 85.5 degrees Fahrenheit(F), decreasing to approximately 79 degrees F at 32 feet bls. The temperature then gradually decreases s to 78.3 degrees F at the base of the borehole (75 feet bls).

The fluid conductivity log shows the measured conductivity just below the casing (depth of 24 feet bls) at 48,000 uS/cm, increasing to approximately 52,500 at a depth of 32 feet bls. The conductivity then gradually increases to 56,000 uS/cm at the bottom of the borehole.

The caliper log indicates a potential zone where the formation consists of cavities and openings, corresponding to a depth interval of 25 to 34 feet bls, which corresponds to the gray sandy limestone (Miami Limestone). The caliper could also indicate some washout due to drilling, however, the zone corresponds to the initial mud losses noted during drilling at about 23 to 24 feet bls. A second zone is noted near the base of the borehole at a depth of 66 to 75 feet bls, corresponding to the lower portion of the light gray limestone (Fort Thomson Formation). The caliper log shows the zone which includes the cemented sand, the coralline Key Largo Limestone, and the upper portion of the light gray limestone with no apparent large cavities or washouts.

Gamma ray logs measure the natural radioactivity in formations and can be used to identify formation or correlate zones. Sandstones and carbonates typically have low concentrations of radioactive material and give low gamma signals. The presence of fine grain clastics would increase the gamma response. The gamma log overall shows low American Petroleum Institute (API) units, varying from approximately 8 to 24 API units. The fill material and the cemented sand show the lowest API units, and the upper portion of the gray sandy limestone (Miami limestone) shows the highest, indicating some silty material may be present in the interval. The upper part of the Miami Limestone was interpreted as less permeable than the lower portion during drilling due to the occurrence of mud losses in the lower part.

3.0 MONITORING WELLS AND SURFACE WATER MONITORING POINTS

The test production well and a series of monitoring/observation wells were installed at the Point for the APT. Two surface water monitoring points were also installed at the site, one in the Industrial Wastewater Facility and one near the mouth of the barge slip. Monitoring wells are completed within the surficial aquifer at various depth intervals, including the production zone, and above and below the production zone. Each monitoring well was given an identification number following installation with the prefix “MW”. All of the wells are constructed of either 6-inch diameter schedule 40 PVC pipe and open hole, or 2-inch diameter PVC and 0.010 inch slotted screen. Construction details for the wells are shown in Table 3.1. Well construction logs are included in Appendix B.

3.1 Pilot Hole MW-1/ Dual Zone Monitoring Well

Based on the data obtained during the drilling of pilot hole MW-1, the depths of the production and monitoring wells were selected. During drilling at the Point with mud rotary techniques, a “mud loss” zone was encountered at approximately 25 to 26 feet bls in the gray sandy limestone (Miami Limestone). The mud loss zone indicates a region of potentially high permeability, so the target casing depth for the wells was determined to be 22 to 24 feet bls. The target production zone was selected to include what appeared to be not only the permeable portion of the Miami Limestone, but also the cemented sand and the upper portion of the Key Largo Limestone to a depth of 46 feet. Further logging and video survey indicated the entire section of borehole from approximately 24-feet bls to 57 feet bls consisted of highly permeable limestone, cemented sand (discontinuous unit), and coralline limestone that was likely in hydraulic connection. The rationale for selecting this production interval was that it would potentially encompass the potential depth interval of RCW laterals. The potential well yield of this shallow portion of the section was determined to be of primary importance in assessing the feasibility of the radial well system. The partial penetration test would also allow the calculation of the equivalent transmissivity of the entire thickness of the aquifer at the Point. Although the cemented sand unit may be less permeable than the limestone, since this unit is discontinuous, the Miami and Key Largo limestones are likely in direct communication in most areas of Turkey Point.

The pilot hole was completed as dual zone well MW-1, and includes completion intervals in and below the production zone (Appendix B). The interval identified as MW1-DZ-PI is the production interval of the dual zone well, and is open to a depth range of 24 to 60 feet bls. The deep interval is designated as MW1-DZ-Deep, and is open to a depth range of 65 to 75 feet bls, which is below a relatively dense light gray limestone encountered at approximately 57 to 66 feet bls..

3.2 Surfical Aquifer Monitoring Wells

Monitoring wells were used to observe the groundwater fluctuations at various distances from the production well as shown on Figure 3.1. In addition to the dual zone well, additional surficial aquifer monitoring wells/observation wells were installed at the Point. Completion details are included in Table 3.1, and well completion diagrams are included in Appendix B. Each well was drilled utilizing mud rotary and reverse air drilling techniques. A 5-inch hole was drilled to obtain rock cuttings and determine the casing depths. Once the casing depth was selected, the hole was reamed to 12-inch diameter and a 6-inch surface casing was installed. The casing was grouted in place and allowed to set at least 12 hours prior to drilling the open hole interval on the well. A 5-inch diameter open hole was drilled using reverse air drilling techniques to the total depth of each well. Monitoring well MW-1 SS was completed using a 2-inch diameter PVC well casing and screen. The screened interval is open to a depth range of 12 to 17 feet bls.

The wells were developed by pumping during the reverse air drilling process after the total depth was reached until conductivity had stabilized. All wells were surveyed by a registered surveyor for location and top of casing elevation. A copy of the survey is included in Appendix C.

3.3 Production Well

The test production well (PW-1) is located on the Point as shown on Figure 3.1. The following summarizes the sequence of the production well permitting and installation activities.

1. Obtained SFWMD well construction permit for the test production well, and monitoring wells prior to initiation of drilling activities.
2. Completed the test production well (PW-1) with 30-inch diameter steel casing set to 22 feet bls, and an open hole interval to 46 feet bls. Lithologic samples were collected during the construction to validate the casing setting depths and to confirm that the selected production interval lithology was similar to that observed at pilot hole MW-1 at the test well location. The pumped interval encompasses the gray sandy limestone facies, the sandstone/sand facies (Miami Limestone), and the upper portion of the coralline facies (Key Largo Limestone). As discussed, the potential well yield of this shallow portion of the section was determined to be of primary importance in assessing the feasibility of the radial well system. The partial penetration test would then allow calculation of the equivalent transmissivity of the entire thickness of aquifer at the Point.

Well development was performed on March 26, 2009 by inserting a 24-inch suction pipe down the well and pumping with an air compressor. The well was pumped at five-foot depth intervals beginning at the bottom of the well. Approximately 63,000 gallons was removed from the well (equivalent to approximately 60 well volumes). The volume pumped was estimated by the number of frac tanks filled during development. Turbidity, conductivity, and temperature were recorded during development and are summarized on Table 3.2. All development water was contained at the site and transported to the Land Use area of the Turkey Point property for disposal at a location selected by FPL and subsequently reviewed by Miami-Dade County Department of Environmental Resources Management (DERM).

3.4 Surface Water Monitoring Stations

Surface water monitoring stations were installed in the Industrial Wastewater Facility and at the barge slip in Biscayne Bay. The Industrial Wastewater Facility monitoring station consists of a 2”x6” treated wood plank bolted to an existing concrete pad on the canal bank. A 2-inch diameter well screen was bolted to the wood plank so that instrumentation could be installed. At the barge slip, a 2-inch diameter PVC well screen and casing was bolted to an existing piling.

The surface water monitoring points were surveyed by a registered surveyor for location and top of casing elevation. A copy of the survey is included in Appendix C.

3.5 Well and Surface Water Monitoring Instrumentation

Water level data collection methods included water level readings utilizing a pressure transducer (In-Situ Level Troll™ 700), and water level/water quality monitoring using an In-Situ Aqua Troll™ 200 capable of monitoring and recording water level, temperature, plus conductivity/salinity.

The Level Troll™ 700 transducers contain a level and temperature sensor, a data logger, and internal power in a 18.3 mm titanium housing. The transducer collects data on a user-specified interval. The readings are relative to a reference level specified by the user; in this case the reference was the pre-pumping depth to water measured manually when the instruments were set in the wells.

In-Situ water level sensors measure the sum of all pressures (atmospheric and hydrostatic) exerted on a pressure transducer and use that data to calculate water levels. Water density contributes to the total hydrostatic pressure. Salt water has a higher specific gravity than fresh water. A standard column of salt water exerts more pressure per square inch (psi) on a transducer than the same column of fresh water. Higher pressure levels are typically interpreted as increasing water levels, but many times are simply due to increasing salinity levels.

In environmental monitoring applications, typical water level sensors cannot measure water density variations (due to salinity changes) over the course the monitoring period. The monitoring instruments report all pressure variations as changing water levels. More sophisticated water level sensors can compensate for different water density via input of a fixed, or static, specific gravity value. This compensation method, however, is only effective if the salinity levels do not change during the monitoring period. If not compensated for, changing salinity levels can affect water level accuracy by up to 2%. The Aqua Troll™ 200 automatically and continuously corrects its depth and level parameters for changes in water density due to changes in salinity. This can improve the accuracy of depth and level measurements in estuaries and coastal waters such as Biscayne Bay where tides and rainfall continuously affect the local salinity (www.in-situ.com).

The Level Troll™ and Aqua Troll™ data were downloaded prior, during, and after the APT to a handheld computer in the field. A physical depth to water reading was obtained periodically in the field immediately prior to the downloading to the computer to provide a quality control check of the instrumentation. The Aqua Trolls™ were deployed for background data collection on February 11, 2009 at a logging frequency of one-half hour.

3.6 Seepage Meters

During the review of the APT plan with local and state agencies, the suggestion was made to FPL that the installation of seepage meters might be a possible method to determine the potential effects of the APT on the flow of water between Biscayne Bay and the bay bottom sediments since conventional wells could not be designed, permitted, and installed in the bay within the

APT schedule. Although the technology is largely unproven in tidal and wave dominated environments (Shinn et al, 2002), FPL took the opportunity to install seepage meters near the APT site as a technology that might provide useful results.

Seepage meters are commonly used for the direct measurement of seepage flux. These were initially developed in the 1940s to measure loss of water from irrigation channels and resurrected in the 1970s for use in small lakes and estuaries (McBride and Pfannkuch, 1975; Lee, 1977; Lee and Cherry, 1978). Seepage meters have since been used in numerous studies of seepage fluxes in rivers, the near-shore marine zone, tidal zones (Belanger and Walker, 1990; Robinson et al, 1998), coral reefs, large lakes and water-supply reservoirs (Woessner and Sullivan, 1984). However, it has been reported that seepage meters installed in areas exposed to currents, waves, and ocean swells have not been adequately tested and verified in these environments (Shinn, et al., 2002). Observations and tests indicate that the positive profile of seepage meters, whether conical or constructed of 55-gallon drum ends, create an airfoil (Bernoulli) effect similar to the lift created on an airplane wing. Reversing orbital currents caused by waves can produce even greater advection than unidirectional flow. The Bernoulli effect caused by orbital wave currents passing over the meters every few seconds probably account for most of the water in the collection bags (Shinn, et al, 2002).

Notwithstanding the above limitations, seepage meters were placed in Biscayne Bay near the APT site to attempt to measure any potential effects on the rate of seepage through the bay bottom due to pumping the underlying aquifers. The basic concept of the seepage meter is to cover and isolate part of the sediment-water interface with a chamber open at the base and measure the change in the volume of water contained in a bag attached to the chamber over a measured time interval. The classic design of Lee (1977) consists of a 15-cm end section of a 55-gallon drum, which is inserted into the sediment. A stopper with a tube is inserted into a hole in the top of the drum and a plastic bag is attached to the tube with rubber bands. The time when the bag is connected and when it is subsequently disconnected is recorded, as well as the change in the volume of water in the bag.

The seepage flux (Q) is calculated as:

$$Q=(Vf-V_0)/tA$$

Where: Vo=the initial volume of water in the bag
Vf= is the final volume of water in the bag,
t=the time elapsed between when the bag was connected and disconnected,
A= the surface area of the chamber.

Additional water in the bag (positive seepage) represents upwards (gaining) seepage and water loss from the bag (negative seepage) represents downward (losing) seepage.

The seepage meters for the Point APT were constructed by cutting a 55-gallon drum to form the seepage chamber. The chamber was fitted with a venting valve at the top, and a port attached to the side. Tubing was attached to the side port and connected to 0.5” diameter PVC, on to which a seepage collection bag was attached with a rubber band. The PVC was fitted with a quick release and a valve so that the bag could be removed for monitoring. A total of 12 seepage meters were installed at the locations shown on Figure 3.2. Ten meters were installed in transects on the north side of the Point near the APT site, and two were installed on the south side of the Point.

4.0 AQUIFER TEST PROTOCOLS

The Point APT consisted of three phases: a background period beginning on February 11 and extending to April 3, 2009 to determine the natural water level fluctuations in the aquifer and surface water bodies, especially tidal influences from Biscayne Bay. The background period was followed by a step-drawdown phase, and a constant rate phase. The test protocols are detailed in the "Biscayne Aquifer Exploratory Drilling and Aquifer Performance Test Plan, March 18, 2009", submitted to FPL by HDR under separate cover. All pump test equipment and discharge pipe was installed by the contractor for the project, Diversified Drilling Corp.

The step drawdown test was performed at the Point on April 4, 2009. The purpose of the step drawdown phase was to evaluate the well performance and to select the optimum pumping rate for the long-term portion (7-day duration) of the APT. The pumping rate was set to variable rates ranging from 4,000 to 7,300 gallons per minute (gpm) as shown on Table 4.1. Observing the change in drawdown and specific capacity with increased discharge provided information required to select the optimum pumping rate for the 7-day test. The specific capacity at the various discharge rates was evaluated to confirm the short-term test data. The drawdown in the pumping well at the various pumping rates was also taken into account when selecting the optimum pumping rate for the long-term test, which was determined to be 7,500 gpm.

The 7-day constant rate test began on April 5, 2009 at 1107 hours at a pumping rate of 7,500 gpm. On April 6 at approximately 1440 hours, the pump shut down and could not be restarted. Maintenance was performed on the pump, and the test was re-started on April 8, 2009 (this part of the APT is referred to as Test 2). Similar pump problems began on April 11 when the contractor was forced to reduce the pumping rate to keep the pump operating. A decision was made to stop the pump on April 13, 2009. A new pump was brought to the site and the test re-started on April 16, 2009 (this part of the APT is referred to as Test 3). On April 18, the pump shut down and could not be restarted. A decision was made to get a smaller pump since the larger pumps appeared to be running at idle speed, which is apparently not an optimum condition for these types of engines. A second, smaller flow pump was brought to the site and the test re-started on April 28, 2009 (this part of the APT is referred to as Test 4) at a rate of 7,100 gpm. Test 4 successfully ran for the 7-day period.

Data collection prior to and during the aquifer test consisted of water levels, well discharge rates, and water quality sampling. Hourly monitoring of the fuel tanks on site, and the discharge pipes for leaks was also performed. All test information was recorded by field personnel. The following describes the data collection protocol for each data type.

4.1 Water Level Measurements

The water levels in each well and surface water monitoring point were measured with two pressure transducers (Aqua Troll™ 200, and Level Troll 700™, In-Situ Inc.) in the pumped well and in the monitor wells during the APT. During the test, the Level Troll transducers were set to obtain a data point on an interval of 1 second for the first hour, 10 seconds for the second hour, 30 seconds for the third hour, 1 minute for the fourth hour, and 5 minutes thereafter. The Aqua Troll transducers were installed on February 11, 2009, and collected background data on a 30-minute interval to determine stability of the water levels and tidal influences for the duration of the test. The data were monitored by field personnel during the test to ensure that the instrumentation was working properly. Data was downloaded daily to chart the progress of the test. Water levels were recorded at the same frequencies after the pump was shut down following Test 4 to record the recovery in the pumped well and the monitoring wells for a period of 7 days.

4.2 Discharge Rate Measurements

The test well was pumped with a diesel driven surface (suction lift) well pump. The flow rates were controlled by pump speed by adjusting the throttle of the engine and by varying the opening of an in-line valve installed in the discharge pipe. Discharge rates were measured with an inline flow meter and recorded hourly by field personnel. The flow rates recorded during the APT are included in Appendix D. As shown, the flow meter tended to fluctuate during pumping, however the average rate recorded during the APT was 7097 gpm.

4.3 Water Quality Sampling

Water quality sampling through grab sampling was performed during drilling of the boreholes on site, and periodically through the duration of the APT (Table 4.2 and 4.3). Field water quality data was obtained from the monitoring wells, Biscayne Bay and the Industrial Wastewater Facility using Aqua Trolls (In-Situ Corporation) installed in each well and the surface water bodies on a regular frequency of every half hour.

Grab samples of the monitoring wells, Biscayne Bay and the Industrial Wastewater Facility were obtained for analysis of cations, anions and stable isotopes of water one week prior to starting the test, immediately prior to the start of the test, and on the last day of the test so that this data could be compared to the production well data. Monitoring wells MW-1-DZ-PI through MW-5 were sampled one week prior and one week following the start of the APT. The production well was also sampled for cations, anions, and stable isotopes during the test. A sample collection port was installed on the discharge line of the pumped well to allow grab samples to be obtained at the wellhead. The analytes are consistent with those that will be performed for the FPL Uprate Project to characterize the water within the Industrial Wastewater Facility System (CCS) to better understand the isotopic and ionic “fingerprint” of this water source relative to the surrounding water sources.

The Florida Department of Environmental Protection (FDEP) Standard Operating Procedures (SOPs) for field procedures were followed and are included in DEP-SOP-001/01 (February 1, 2004). The FDEP SOPs comprise minimum requirements under the FDEP Quality Assurance Rule, 62-160, F.A.C. Field procedures for groundwater sampling are included in SOP FS2200. All sample containers were provided by the laboratory. A chain of custody accompanied all samples submitted to the laboratory. Samples were transported on wet ice at 4^{o} Celsius to the laboratory for analysis. Sample preservation was in accordance with FDEP SOPs. Samples were submitted to the laboratory on the same day as collection or via overnight mail the following day.

4.4 Seepage Meters

Seepage meters were placed in Biscayne Bay in an attempt to measure any potential effects on the rate of seepage through the bay bottom due to pumping the underlying aquifers. The seepage meters were measured during pumping periods and during non-pumping periods so that a comparison of the data could be made. The seepage meters were measured during high tide in an effort to remove the tidal effect on the seepage meter results. Seepage meter monitoring began on March 31, 2009 (four days before the start of the APT phase), and was performed daily during the APT. Following the APT from May 16 to May 23, 2009, seepage monitoring was performed at high tide and low tide to determine the seepage relationships to tide without the influence of pumping.

5.0 AQUIFER PERFORMANCE TEST DATA ANALYSIS

The APT at Turkey Point provided water level, water quality, and seepage meter data that were evaluated to determine aquifer properties, to estimate any potential effects of pumping the subsurface aquifer on water levels and water quality, and to provide data for subsequent numerical modeling of radial wells at the Point. Although four test periods were recorded due to pump failures, only the Test 4 data were analyzed since this test provided a complete 7-day data set. The following sub-sections provide a description of the data analysis and results.

5.1 Water Levels and Groundwater Flow

Background water levels were obtained from February 11, 2009 through April 3, 2009 at the wells and surface water monitoring points. At well MW-4, the instrument was inadvertently stopped by the drilling contractor when the well was re-drilled after some caving occurred, therefore only a three-day background period is available for MW-4. The water level elevations were obtained by subtracting the depth to water reading from the surveyed top of casing elevation. The background water level elevations are shown graphically in Figure 5.1. Water levels in shallow well MW-1 SS were corrected to equivalent saltwater heads to account for density differences between the shallow and deep wells. As shown, all of the wells and the barge slip (Bay) show a similar water level pattern, responding to tidal fluctuations. MW-5 background water levels deviates from the pattern exhibited by the other wells and began a general downward trend in mid-February, which overrides the tidal influence. The Industrial Wastewater Facility responds to the major tidal shifts, but is more strongly influenced by cooling water pumping to the power plant. MW-5 does not appear to be influenced by the canal since the downward trend at MW-5 in mid-February is not matched by the Industrial Wastewater Facility. The cause of the water level decline at MW-5 has not been determined.

The groundwater flow pattern in the pumped zone at the site prior to the APT test was evaluated by plotting the groundwater elevation contours on a base map of the site. The water levels on February 25, 2009, representing a high tide and on March 1, 2009 representing low tide are shown in Figures 5.2 and 5.3, respectively. The contour maps show that groundwater flow is to the west toward the shore and the Industrial Wastewater Facility.

The vertical gradient at the site was assessed using the water level elevation data obtained from the nested wells at MW-1. MW-1-SS is completed to a depth of 17 feet bls, MW-1 DZ-PI is open to an interval from 24 to 60 feet bls (production interval) and MW-1 DZ deep is open to an interval of 65 to 75 feet bls. As discussed, water levels in shallow well MW-1 SS were corrected to equivalent saltwater heads (equivalent to the density of the deeper wells) to account for density differences between the shallow and deep wells. A graph of the water level data from the three wells is included as Figure 5.4, with a detailed view in Figure 5.5. These figures show that groundwater elevations in the nested wells are essentially the same, with the heads in the shallow zone slightly higher than the deeper wells. The average water level elevations at the MW-1 nest are as follows:

Groundwater Elevation Summary- Nest MW-1			
	MW-1 SS	MW-1 DZ PI	MW-1 DZ Deep
Maximum	0.51	0.43	0.39
Minimum	-2.17	-2.27	-2.37
Median	-0.99	-1.10	-1.15
Average	-0.96	-1.06	-1.12

The similarity of the water levels at the MW-1 nest, which have a very slight downward hydraulic gradient, indicates that the vertical facies are likely hydraulically interconnected. The Barge Slip/Bay monitoring point is included on the MW-1 well nest graph, and shows that the water elevation in the Bay is generally higher than the groundwater levels (and shows greater tidal fluctuation as expeted), except for a period from about March 18 to April 2, 2009, when the groundwater elevations at MW-1-SS were slightly higher than the Bay. A review of rainfall data at SFWMD gauge S-20F, located just north of Turkey Point, showed approximately 2.5 inches of rainfall occurred during this monitoring period (SFWMD DBHYDRO database). The rainfall hydrograph is shown on Figure 5.6.

A graph of the water level elevations prior to and during the APT for all of the monitoring points is included as Figure 5.7. As shown, the water levels in the Industrial Wastewater Facility and MW-5 show a downward trend during the APT period. The trend at MW-5 does not appear to be related to the Industrial Wastewater Facility since the early part of the MW-5 hydrograph does not match the trend in the canal. The direct cause of the downward trend at MW-5 is unknown at this time. The other wells show typical fluctuation with visible responses to the APT pumping periods noted.

5.2 Statistical Methods for Estimating Aquifer Drawdown

During the APT, the water levels measured in the monitoring wells provides raw data in which the response to pumping, or drawdown, is embedded. Aquifer drawdown measurements can be obscured by a number of factors—particularly tides, regional pumping, recharge events, and barometric pressure. These influences introduce water level fluctuations that may mask any changes in water level brought about through aquifer pumping tests. To estimate drawdown, these compounding influences must first be removed. Simple statistical models, such as the Excel spreadsheet based program developed by the U.S. Geological Survey (USGS) (Halford 2006), have proved to be useful for this purpose. The program utilizes a Time Series approach to extracting the drawdown data from the background “noise”. Time series measures, typically referred to as synthetic water levels, are created by summing multiple series resulting from tidal potential and background water levels. The phase and amplitude of these individual series are then adjusted so that the synthetic water levels match the measured water levels during periods unaffected by an aquifer test. Differences between the synthetic and measured water levels are minimized, frequently using a sum-of-squares objective function. The approach and application of the USGS model to the Turkey Point APT are described in detail below.

5.2.1 Barometric Effects

Atmospherically induced fluctuations can cause water-level changes up to about 0.2 feet on a daily basis while regional storms can cause water-level changes of up to approximately 1 foot or more during a week. Barometric effects may be included in the USGS model by including a time series of atmospheric pressure readings. For the Turkey Point analysis, direct measures of barometric pressure were not included as model fits were generally excellent without including this factor (see below). Additionally, barometric pressure changes should be reflected indirectly in the background water levels since vented instruments were used.

5.2.2 Tidal Effects

Gravitational forces arising from the changing relative positions of the sun, moon, and earth produce tides. The most familiar of these, ocean tides, affect groundwater levels through direct head changes in the aquifer or through loads on the confining unit. For the most part, ocean tides are rhythmic and predictable. Local conditions such as basin morphology and prevailing winds, however, may alter this predictability. Therefore, the most effective way of including the ocean tidal effect is through the inclusion of readings from a nearby tidal gage. For this purpose, data from an Aqua Troll™ (In-Situ Corp) gage mounted at the barge slip was used as an input variable.

Less familiar tidal forces, termed earth tides and gravitational tides, results from the gravitational distortion of the earth's crust. These tides regularly dilate and compress the aquifers surrounding bedrock thereby changing the porosity and causing water-level fluctuations of as much as 0.1 foot or more in certain aquifers. Earth and gravitational tides were included in the Turkey Point analysis by including the two theoretical models as internal functions within the USGS model. Calculation of these tides requires only the latitude, longitude, and elevation of the well location.

5.2.3 Background Water Levels

Recharge events and regional pumping induce aquifer stresses that may affect water elevations over large areas. Such influences are typically non-cyclic and are difficult to predict on a deterministic basis. Water level changes, however, may be modeled using water elevation readings from a location sufficiently outside the region affected by the pump test. In the case of the Turkey Point study, pumping of cooling water for the Turkey Point Units 1-4 results in the intake canal being lower in elevation than the groundwater levels, which would have an influence on nearby groundwater levels. For that reason, water level readings from a gage installed in the Industrial Wastewater Facility were included in the calculation of the synthetic time series.

5.2.4 Estimation of Synthetic Water Levels

Drawdown is represented as the differences between the measured water level in the monitoring/observation well and the synthetic water level derived by the model. The USGS model (Halford, 2006) uses the multiple time series described above to compute the synthetic water levels (SWL) using the following equation:

Eq. 1 $$SWL(t) = C_0 + C_1(t - t_0) + \sum_{i=1}^{n} a_i \; V_i(t + \varphi_i)$$

where:

C_0	offset, L
C_1	slope of water-level change, in LT^{-1}
a_i^n	amplitude multiplier of the i^{th} component of *n* time-series elements
φ_i	phase-shift of the i^{th} component
$V_i(t+\varphi_i)$	value of the i^{th} component at time $t+\varphi_i$ in units of the i^{th} component

Solutions for the various coefficients are found by using the Excel SOLVER add-in to minimize the squared difference between the measured and synthetic water levels over the background period. The coefficients are then used to estimate the synthetic water level series during the APT period. The results of the APT are then obtained from the differences between the measured and synthetic series during the APT period. The USGS spreadsheet model includes additional tools for selecting the background period and analyzing the APT period.

5.2.5 Data Treatment

Data collected for the Turkey Point aquifer performance test was collected in two modes. Prior to the APT, background data were collected using Aqua Troll™ 200 gages recording at 30-minute intervals. During the APT, Level Troll™ 700 gages were used, sometimes recording at intervals as small as 1 per second. In all cases, there was a period of overlap when both gages were employed at each location. For analytical purposes, it was necessary to combine the background and APT data sets. Since the Aqua Trolls correct for density as discussed in Section 3.3, it was decided that the water level readings obtained with the Aqua Trolls were the correct data set. Prior to combining the two data sets, they were checked for comparability by computing the difference in gage readings during the overlap period. In several cases, a slight discrepancy was discovered. In those cases, the average difference was added to or subtracted from the APT readings. These adjustment factors were as follows:

Adjustment Factors for Background Monitoring Gage Data

Well	Adjustment Factor
MW-1-DZ-Deep	-0.40 feet
MW-4	+0.10 feet
MW-5	+0.08 feet

The adjusted data were used in the USGS model to estimate drawdown at each monitoring well.

5.2.6 Model Fitting

Estimation of drawdown first requires the computation of the model coefficients in Equation 1. These coefficients are computed for the background period only. The background period is not subjected to the influence of pumping. Once the coefficients are obtained, they are used to compute the synthetic time series for the APT period. The background period selected for each well is presented in Table 5.1. Typically, the period from 2/11/2009 13:00 to 4/4/2009 09:00 was selected (period prior to pumping). Background data collection did not begin at MW-4 until

4/1/2009 due to problems with the instrumentation. Based on visual inspection, the period 4/19/2009 2300 hrs to 4/28/2009 0600 hrs was selected for model fitting purposes.

For all eight well locations, four independent variables (barge water level, canal water level, earth tide, and gravity tide) were required to obtain the accurate model fit as judged by the root mean square error (RMSE). The sequential improvement with each added variable can be seen in Table 5.1. In general, the full four-parameter model explained approximately 90% or more of the observed variability in observed water elevations. The only exception was MW-5, where unaccounted for influences affected much of the early background period. The overall model fit and model residuals are shown in Appendix E.

5.3 Analysis of Drawdown Data

Drawdown data extracted from the time series model were analyzed for hydraulic properties with well hydraulic equations. The analyses were performed with the AquiferWin32® software package prepared by Environmental Simulations, Inc., AQTESOLV® software package developed by Hydrosolve Inc., and programs developed in Excel (Microsoft Corp). AquiferWin32 allows the analysis of pumping tests by incorporating a wide variety of well hydraulic equations, and optimization and manual curve matching techniques. For the analysis of the data from the APT, well hydraulic equations for unconfined aquifers, confined aquifer with leaky conditions and partial penetration, and recovery data were applied.

As discussed, the drawdown in each well was calculated by subtracting the measured water levels from the synthetic water levels generated with the time series methods discussed above. The difference in the measured and synthetic water levels during the APT test represents the drawdown (Appendix E). Drawdown stabilized at approximately 11 feet bls in the pumped well PW-1 at a pumping rate of 7100 GPM. Once the pumping portion of the test was completed, the rise in the water levels (residual drawdown) to pre-test conditions was also recorded.

The aquifer transmissivity and storage coefficient between the pumped well and the monitoring wells was calculated for the pumping and recovery cycle of the test. The calculated hydraulic parameters would be reflective of the combined thickness of the aquifer at Turkey Point. For a pumping well, the drawdown is affected by well bore storage and head losses; therefore appropriate methods must be applied. In addition, pumping well data do not provide reliable storage coefficient results, so the monitoring/observation wells were relied upon to provide a calculated storage coefficient.

A study of the drawdown pattern in the monitoring wells showed that the pattern deviated from (fell below) the Theis curve and generally formed a straight horizontal line, indicating a leaky or bounded aquifer condition. Time-drawdown data were compared to type curves generated by several analytical models (Hantush (1960), Hantush (1964), Walton (1962), Neuman (1972)). Based on this analysis, the analytical models that appeared to best fit the observed time-drawdown data were Hantush (1964) and Walton (1962). The Hantush (1964) and Walton (1962) solutions simulate the response to pumping an aquifer overlain by a leaky confining unit which is in turn overlain by a constant head source bed. In the case of Turkey Point, the constant head source would be Biscayne Bay. The model also incorporates the effect of partially penetrating wells and various vertical to horizontal anisotropy ratios (Kz/Kr). In addition, the model assumes:

- well discharge is constant
- well is of infinitesimal diameter
- no release of water from storage in the confining bed
- flow of water through the confining unit is vertical
- the initial potentiometric surface of the aquifer and the water table are horizontal and extend infinitely in the radial direction

The Hantush (1964) analytical model is consistent with the conceptualization of the shallow permeable units as a leaky semi-confined aquifer. Due to the relatively large radial distance of most of the observation wells as compared to the thickness and anisotropy of the aquifer, the type curve was insensitive to the affect of partial penetration. For a two aquitard system, AQTESOLV® was used to determine the leakage values B' (for an aquitard above) and B" (for an aquitard below) if this is the case at the site. AQTESOLV® was also used to perform a distance-drawdown analysis. The analysis of recovery data utilized the Theis (1946) recovery method.

For the pumped well PW-1, the Cooper-Jacob (1946) straight line method was selected because it utilizes the slope of the drawdown curve instead of the magnitude of the drawdown in the calculation of the aquifer properties. The relatively high head losses in the well and partial penetration have little or no effect on the application of this method. Well losses and partial penetration affect drawdown by a fixed amount that changes very little after a well has been pumping for a sufficient time, as drawdown at later times is controlled mostly by the transmissivity of the aquifer. Therefore the late-time data was utilized for the straight line method for the PW-1 pumping data. The analysis of the recovery data collected from thePW-1 pumping well utilized the Theis recovery method.

The type curve matches for wells MW-1-DZ-PI through MW-4 are presented in Appendix F. Well MW-5 could not be analyzed since the drawdown data could not be extracted due to anomalous water levels in the well. The results are summarized in Table 5.2. A review of the test results indicates the following:

- Calculated transmissivity (T) values using drawdown data range from approximately 368,000 feet^2/day to 1,000,000 feet^2/day. The mean for the calculated T values using drawdown data is approximately 700,000 feet^2/day. The lowest T value was calculated at MW-1 DZ PI near the pumping well, and the higher T values were calculated at far-field wells MW-3 and MW-4 (The mean T value using wells MW-3 and MW-4 is approximately 960,000 feet^2/day). The noted increase in hydraulic conductivity with scale is likely a natural consequence of the aquifer heterogeneity (Rovey, 1998). Over short distances, water converging toward a borehole must generally flow across heterogeneities. Therefore, small-scale tests tend to measure a weighted harmonic mean of the hydraulic-conductivity field. Over a larger area as performed at Turkey Point, however, flow is primarily along high-conductivity heterogeneities. Therefore, large-scale tests approach a weighted arithmetic mean where high-conductivity heterogeneities have a greater influence (Rovey, 1998). In a hydrogeological environment characterized by inhomogeneity elements of a certain size (vugs, cavities, burrows, etc as observed in the Biscayne aquifer) hydraulic conductivity and transmissivity mean values each converge with increasing scale of measurement. Ultimately, as scale of measurement increases, measured values attain essentially the same value irrespective of the location of the test volume (Howard, et al, 2002). As such, the T values obtained at the far-field wells can likely be considered more reliable estimates of T than the values obtained using the closer wells for this test.

- The calculated T value using a distance-drawdown method is 800,000 $feet^2$/day.
- Calculated T values are higher when using recovery data as compared to drawdown data. The calculated T values using recovery data range from approximately 500,000 to over three million $feet^2$/day, with a mean of approximately 2,000,000 $feet^2$/day.
- Storage Coefficient (S) values range from $1x10^{-6}$ to 0.004, with a mean of 0.0014.
- The Hantush (1960) analysis performed in AQTESOLV® indicates a 1/B' value (leakage factor) of 0.01833 ft^{-1} for the upper aquitard, and a 1/B'' of zero for the lower aquitard, possibly indicating lack of confinement immediately below the pumped zone (Appendix F). Therefore in this case, leakage would occur predominantly from the upper portion of the section, which is the combined muck/upper Miami limestone. The analysis may also be affected by partial penetration, which is not accounted for in the Hantush (1960) method.
- Calculated vertical K (K') values ranged from 980 to 4 feet/day. Scale affects appear to impact these calculations, with the highest value in well MW1 DZ PI closest to the pumped well. The average K' without including the highest value is 6 feet/day. The calculated K' is based on a saturated thickness of 17 feet of material from the water table to the bottom of the well casing, which includes the muck layer and the upper portion of the Miami limestone. If only the muck layer is considered to be the leaky "confining" unit (average thickness of 2-feet), then the average calculated K' value is 0.7 feet/day.

The calculated T values using drawdown data from the site are within the range of, with some slightly lower, values reported for this area of Miami-Dade County. Results of aquifer tests in the Biscayne aquifer in southeastern Dade County yielded transmissivity values ranging from 600,000 to over 1,000,000 $feet^2$/day (Fish and Stewart, 1991).

As discussed, there are inconsistencies in the calculated T values for the pumped and recovery cycles for the wells. The analysis of recovery data involves the measurement of the rise in water levels, also referred to as residual drawdowns, following the cessation of a period of pumping at a constant rate. This analytical method is based on the Theis theory and applies to confined aquifers with fully-penetrating wells. The inconsistencies could also be a result of the Theis recovery method being applied to leaky aquifer data and a partially-penetrating well.

5.4 Seepage Meter Data Evaluation

Seepage meter data was recorded during the APT as described in Section 4.0. The measured seepage was recorded as positive (more volume in the bladder as opposed to the start of the monitoring interval), or negative (less volume in the bladder as compared to the volume at the start of the monitoring period). Positive seepage would be indicative of water flowing into the Bay from the Bay bottom sediments, and negative seepage would indicate water leaving the Bay through the Bay bottom sediments.

A summary of the seepage meter operations and data collection is included in Table 5.3. The seepage meter data collected during the pumping test phase are summarized in Table 5.4, and the high tide-low tide comparisons are summarized in Table 5.5. As shown on Table 5.4, the seepage meter data indicate that for most of the meters, a net positive seepage was measured both with no pumping and during the APT pumping periods. The data show that on average, less positive seepage was noted when the pump was on as compared to days when the pump was not operating; Two of the 12 meters (meters 4 and 5) show the average positive seepage to be less when the pump was off than when the pump was operating.

The average positive seepage from all meters for the pump on period was measured at approximately 0.0114 ml/cm^2/hour (39 inches per year), and the average positive seepage during pumping was measured at 0.0102 ml/cm^2/hr (35 inches per year), with a difference of four inches per year. A Mann-Whitney nonparametric statistical analysis of the average seepage data indicate that the differences in non-pumping and pumping positive seepage is not statistically significant (p value= 0.7074).

The source of this apparent positive seepage to Biscayne Bay is not evident from water level data at well nest MW-1, as shown on Figure 5.4. The water level data show no apparent upward vertical gradient in the area of the Point that would provide a source of water to the Bay from the subsurface formations. The horizontal flow of water in the area of the point is from the Bay toward shore as shown on Figures 5.2 and 5.3. In addition, previous studies have shown a similar "positive seepage effect" in similar environments in Florida Bay. Shinn, et.al (2002) determined through flume experiments that advection (i.e., the Bernoulli Effect) was the likely cause of the artificial pumping observed and measured in Florida Bay. The data and the observations and tests indicated that the positive profile of seepage meters, whether conical or constructed of 55-gallon drum ends, created an airfoil (Bernoulli) effect similar to the lift created by an airplane wing. Shinn et al (2002) attributed the Bernoulli Effect caused by orbital wave currents passing over the meters every few seconds as accounting for most of the water in the collection bags. A similar situation could have caused the positive seepage noted at Turkey Point.

The high-tide/low-tide comparisons are summarized in Table 5.5. The data indicate that low tide positive seepage was greater at three of the five meters as compared to high tide (meters pairs 2, 4, and 5). Two of the meters show greater high tide positive seepage than low tide, and one meter pair (meter pair 3) shows fluctuations in high and low tide seepage measurements. Negative seepage was observed at high tide meter 5-G for five of the six days measured. The data do not show a definitive correlation between high and low tide with regards to seepage.

In summary, the seepage meter data indicate that seepage measurements were predominantly net positive and varied considerably from location to location. The seepage data reliability is in question due to the following:

- Water level data in the area of the Point do not indicate an upward hydraulic gradient that would contribute water from the deeper formations to the Bay.
- The horizontal gradient is toward the shore and the Industrial Wastewater Facility, indicating that water would be flowing from the Bay, not toward the Bay from onshore in this area.
- Previous studies in similar environments in Florida Bay show the same “positive net seepage” affect. The studies indicate that wave currents passing over the meters could create a “Bernoulli Effect” and account for most of the water collected in the collection bag. A similar situation could have occurred at the Point.
- Tidal “pumping” could also provide a mechanism for water to be introduced to the collection bags.

Due to the questions regarding the validity of the seepage meter data collected at the Point, the absolute values of the data will not be considered in further studies of radial collector well performance and/or impact to the area. The difference in the seepage values between pumping and non-pumping conditions may still have some validity because the measurements were collected daily at high tide. Therefore, a constant bias (i.e., a constant inflow to the seepage bag over time caused by the Bernoulli Effect) would cancel when the values are subtracted, if wave and current conditions were reasonably constant. Based on these results, alternative methods may be necessary to determine the hydraulic conditions between the bay and the subsurface in this area.

6.0 WATER QUALITY RESULTS

Water quality samples were obtained during drilling, and during the Point APT as described in Section 4.0. Samples were obtained from the test production well (PW-1), Biscayne Bay, the Industrial Wastewater Facility, and the monitoring wells on site. Field measurements of conductivity were also obtained with Aqua Trolls installed at each monitoring point. Laboratory test results are included in Appendix G, and summarized in Table 6.1. The sampling parameters are representative of the major constituents that occur naturally in surface and groundwater. The major and minor constituents in water occur mainly in ionic form and are commonly referred to as ions. Major ions in water include positively charged cations and negatively charged anions. Cations analyzed for the APT include calcium, sodium, magnesium, potassium, and strontium. Anions included chloride, bromide, sulfate, bicarbonate, and boric acid. Stable isotopes of oxygen and hydrogen were also analyzed during the APT test period.

6.1 Borehole Sampling Results

During drilling, water quality samples were obtained at various depth intervals for chloride, TDS, and sulfate. Figure 6.1 shows the analytical results for chloride and TDS. As shown on the figure, both chloride and TDS generally increase with depth at the boring/well locations. The samples at depth were not discreet but a mix of all of the water in the borehole.

Chloride concentrations in the borehole samples ranged from a maximum of 21,400 mg/l at MW-3 (44’) to 17,100 mg/l at MW-1(24’). The average chloride value for all of the borehole samples is 19,563 mg/l. Chloride at depths greater than 40 feet bls exceeded 19,000 mg/l in 85% of the samples obtained (11 of 13 samples). TDS concentrations in the borehole samples range from 37,300 mg/l at MW-3 (44’) to 28,100 mg/l at MW-2 (47’). The average TDS concentration for all of the borehole samples is 33,020 mg/l. Sulfate concentrations also show a slight increase with depth and range from 2,830 mg/l at MW-1(72’) to 2,510 mg/l at MW-4 (30’).

6.2 APT Test Period Laboratory Results

Sampling was performed prior to, during, and after the APT and included monitoring wells (prior and after APT), the test production well (PW-1), Biscayne Bay, and the Industrial Wastewater Facility. The sampling program and sample collection summary are included in Tables 4.3 and 4.4, respectively. Aqua Troll data allowed the collection of field data including conductivity, salinity, TDS, and temperature on a 30-minute time interval. Laboratory analyses were performed to provide additional water quality data. Laboratory results are summarized in Table 6.1, and all laboratory results are included in the tables in Appendix G.

AquaTroll^{TM} Field Water Quality Data

The Aqua Troll results for conductivity and salinity are included graphically as Figure 6.2 and 6.3, respectively. The data show the highest conductivity and salinity at the Industrial Wastewater Facility, and the lowest at monitoring well MW-1-SS (shallow well at nest MW-1). Salinity in the Industrial Wastewater Facility fluctuated between 60 and 70 PSU, which is approximately twice that of seawater. Salinity at well MW-1-SS fluctuated around 20 PSU. Well MW-1SS is set at a depth of 17 feet bls, and represents shallow groundwater at the Point.

The lower salinity water at this depth is likely a result of infiltration of less dense water during rainfall events on the Point landmass. Salinity in the remaining monitoring wells is within the range of approximately 35 to 38 PSU, or roughly that of seawater. The deep well (MW-1 DZ Deep) had the highest measured salinity, while well MW-5 had the lowest measured salinity. In addition, the measured salinity in the bay during the monitoring period shows an increase, which is also noted in well MW-1SS and the Industrial Wastewater Facility. Salinity in the bay and Industrial Wastewater Facility show a drop around March 17 to March 23, 2009. A review of rainfall data at SFWMD gauge S-20F, located just north of Turkey Point, showed near 2.5 inches of rainfall during this period (SFWMD DBHYDRO database, Figure 2.2). The deeper wells do not follow this same increasing trend in salinity but remain fairly constant over the monitoring period. The salinity does show slight drops in concentration at MW-1 SS and MW-1 DZ PI during pumping periods, possibly indicating that the shallower, less saline water from the shallow interval on the Point landmass is being pulled in to the pumping interval (Figure 6.2). Pumping does not appear to have an effect on salinity in the Bay or the Industrial Wastewater Facility.

Laboratory Data

Table 6.1 is a summary of the laboratory data obtained during the APT. Data are also represented graphically in Figure 6.4. The data indicate that concentrations of the constituents measured are generally highest in the Industrial Wastewater Facility as expected, followed by Biscayne Bay, and the groundwater beneath the Point. The concentrations of most of the cations and anions measured in the Industrial Wastewater Facility are observed to be as much as twice that of the Bay and the groundwater beneath the Point. Due to the short time period over which the data were collected and the limited number of data points, evaluating potential trends in the data is likely unreliable, however, linear regression trend lines were plotted on the graphs to provide an indication of possible short-term linear trends in the data during the test period. The R^{-}squared value on the trend line (coefficient of determination) indicates the fit of the trend line, or linear trend model, through the analytical data. The closer its R-squared value is to one, the greater the ability of that model to predict a trend. As values of R-squared depart from 1.0, the fit of the trend model would potentially be less reliable Values of R^{-}squared were used along with visual observations to evaluate short term changes in the parameter concentrations during the APT. Only trendlines with an R-squared of 0.5 or greater are shown on Figure 6.4.

Chloride

The average chloride concentration in the Industrial Wastewater Facility during the test period was 37,400 mg/l, as compared to 22,475 mg/l in the Bay, and 19,407 mg/l at test production well PW-1. Chloride concentrations at PW-1 and the Bay during the APT period are shown graphically in Figure 6.4. As shown on Figure 6.4, the chloride data for PW-1 and the Bay show no indication of a discernible trend in chloride concentrations during the test period. The data do indicate that chloride concentrations in the Bay are generally higher than PW-1 during the latter part of the test period (during Test 4 in late April). Chloride concentration shows a slight decrease in the Industrial Wastewater Facility over the test period.

Total Dissolved Solids

The average Total Dissolved Solids (TDS) in the Bay and at PW-1 during the test period was 41,600 mg/l and 33,931 mg/l, respectively, which is typical of seawater. The average TDS in the

Industrial Wastewater Facility during the test period was 66,167 mg/l. As shown on Figure 6.4, TDS increased in the Industrial Wastewater Facility and the Bay, and showed only a slight increase at PW-1 during the test period.

Sulfate

Sulfate concentrations during the APT were highest in the Industrial Wastewater Facility, with an average concentration of 6,200 mg/l. The average sulfate concentration in the Bay and PW-1 during the test period was 3,288 mg/l and 2,724 mg/l, respectively, which is typical of seawater. As shown on Figure 6.4, sulfate increased during the APT period in the Bay, but remained consistent in PW-1. Sulfate decreased in the Industrial Wastewater Facility over the test period.

Bromide

Bromide concentrations during the APT were highest in the Industrial Wastewater Facility, with an average concentration of 150 mg/l. The average bromide concentration in the Bay and PW-1 during the test period was 102 mg/l and 99 mg/l, respectively, which is typical of seawater. As shown on Figure 6.4, bromide decreased in the Industrial Wastewater Facility and test production well PW-1 during the APT period, and generally shows fluctuating concentrations in the Bay.

Bicarbonate Alkalinity

Bicarbonate alkalinity concentrations during the APT were highest in the Industrial Wastewater Facility, with an average concentration of 184 mg/l. The average bicarbonate alkalinity concentrations in the Bay and PW-1 during the test period were 124 mg/l and 167 mg/l, respectively. As shown on Figure 6.4, bicarbonate alkalinity is higher in the groundwater than in the Bay, and shows decrease in concentration in the Industrial Wastewater Facility, Bay, and PW-1 over the test period. Bicarbonate alkalinity is commonly a dominant anion in shallow groundwater.

Boric Acid

Boric acid concentrations during the APT were highest in the Industrial Wastewater Facility, with an average concentration of 42 mg/l. The average boric acid concentrations in the Bay and PW-1 during the test period were 29 mg/l and 24 mg/l, respectively. As shown on Figure 6.4, boric acid is higher in the Bay than in the groundwater. An increase in concentration over the test is noted during the in the Bay and at PW-1. No discernable trend in boric acid concentrations is indicated in the Industrial Wastewater Facility data during the test period.

Calcium

Calcium concentrations during the APT were highest in the Industrial Wastewater Facility, with an average concentration of 780 mg/l. The average calcium concentrations in the Bay and PW-1 during the test period were 476 mg/l and 427 mg/l, respectively. As shown on Figure 6.4, no linear increases or decreases in calcium concentrations are indicated during the APT period for the Bay, PW-1, or the Industrial Wastewater Facility.

Magnesium

Magnesium concentrations during the APT were highest in the Industrial Wastewater Facility, with an average concentration of 2,367 mg/l. The average magnesium concentrations in the Bay and PW-1 during the test period were 1,790 mg/l and 1,289 mg/l, respectively. As shown on

Figure 6.4, magnesium shows a decrease in the Industrial Wastewater Facility, and no discernable trend at PW-1 or in the Bay during the test period.

Potassium

Potassium concentrations during the APT were highest in the Industrial Wastewater Facility, with an average concentration of 2,367 mg/l. The average magnesium concentrations in the Bay and PW-1 during the test period were 1,790 mg/l and 1,289 mg/l, respectively. As shown on Figure 6.4, potassium increased slightly in the Industrial Wastewater Facility during the APT period. No linear increases or decreases in potassium are indicated during the test period for the Bay or PW-1.

Sodium

Sodium concentrations during the APT were highest in the Industrial Wastewater Facility, with an average concentration of 18,800 mg/l. The average sodium concentrations in the Bay and PW-1 during the test period were 12,275 mg/l and 10,284 mg/l, respectively. As shown on Figure 6.4, sodium increased slightly in the Industrial Wastewater Facility during the APT period. No linear increases or decreases in sodium are indicated during the test period for the Bay or PW-1.

Strontium

Strontium concentrations during the APT were highest in the Industrial Wastewater Facility, with an average concentration of 15.7 mg/l. The average strontium concentrations in the Bay and PW-1 during the test period were 9.3 mg/l and 7.9 mg/l, respectively. As shown on Figure 6.4, a slight decreasing trend is noted in the Industrial Wastewater Facility, with no linear increases or decreases indicated in the Bay or at PW-1.

Monitoring Well Sample Results

The monitoring wells at the Point were sampled prior to and after the APT. The results of the well sampling are included in Figure 6.5. A non-parametric Mann-Whitney test of pre and post-APT samples from MW-1, MW-2, MW-4, MW-5, was performed for some parameters, including TDS, chloride, bicarbonate alkalinity, calcium, strontium and potassium. The test indicates there is no statistical difference in the concentrations of these parameters before and after the APT (i.e. $p > 0.05$). The test statistic p-value indicates the results. If the p-value is less than 0.05 or 5%, then there is significant difference. If the p-value is more than 0.05 or 5%, then there is no significant difference between the pre- and post-APT samples. The Mann-Whitney p-value was above 0.05 for all parameters. Potassium was tested without the outlier value of 825 mg/l on 5/12/09. Other outliers were noted, such as strontium in MW-4 and MW-5, boric acid in MW-4 (values of 46 mg/l, double what was previously detected), and calcium at MW-4 (value of 788 mg/l on 5/12/09).

Stable Isotopes (O18 and Deuterium)

The oxygen and hydrogen that make up water molecules contain a mixture of isotopes of both elements, including the stable isotopes oxygen-18 and deuterium. These isotopes can be fractionated by hydrologic processes such as evaporation. The abundance of these isotopes can help to provide an understanding of the movement or evolution of ground water, including

processes such as recharge and mixing. The objective of the isotope analysis during the APT was to provide data that might help to determine the source of water to the pumping well during the APT (i.e. groundwater, surface water, or Industrial Wastewater Facility water).
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Stable isotopes of oxygen and hydrogen were analyzed during the APT by the University of Miami. The isotope analysis results are shown graphically in Figure 6.6, and are summarized in Appendix G. Oxygen18 (δ18O) shows an increasing concentration in the Industrial Wastewater Facility during the test period. No linear trend in δ18O is indicated in the bay or at PW-1. Hydrogen (deuterium, δD) shows an increase in the Industrial Wastewater Facility and in test production well PW-1, and a decrease in concentration in the Bay.

The monitoring wells were sampled for stable isotopes prior to and following the APT. The results of the monitoring well sampling are shown on Figure 6.7. Based on a paired t-test of samples pre and post-APT from MW-1, MW-3, MW-4, MW-5, there is no statistical difference in the isotopic signature of the water (i.e. $p > 0.05$). A Mann-Whitney non-parametric statistical analysis of δ18O and deuterium isotopes prior to and after pumping also indicate that the differences are not statistically significant (p values of 0.1437 and 0.2963, respectively)

The following additional observations are made with respect to the isotope analysis (personal communication, Sharon Ewe, ENE Inc, July 1, 2009.).

1) PW-1: there is no significant change in water quality based on the δ18O data (δ18O is a more conservative indicator relative to δD);

2) Industrial Wastewater Facility samples on 3/18 /09 and 4/5/09 appear to have some Bay water influence;

3) MW-3 values on 3/18/09 are most likely an error since the salinity is low but the isotopic signature exceeds that even of the Industrial Wastewater Facility.

The water quality results show that during pumping, the concentrations of the cations and anions in the pumping well remained consistent throughout the pumping period, indicating that no apparent changes or degradation of groundwater quality occurred during the APT period at the Point. The isotopic data do not indicate any obvious water quality degradation because of pumping during the APT period. Monitoring well sample results indicate no statistically significant differences from pre to post APT concentrations in the measured parameters.

Long-List Sampling

Sampling was performed for an expanded list of parameters as part of the plant design. The parameters selected were to aid in the design of the cooling water system for the plant expansion. Samples were obtained from well MW-1 DZ PI, pumping well PW-1, and from Biscayne Bay. The analytical reports are included in Appendix H.

7.0 SUMMARY

In order to further evaluate a sub-stratum system under Biscayne Bay, an exploratory drilling and aquifer testing program was performed on Turkey Point. The drilling program performed on the Point began on January 5, 2009, and concluded on February 11, 2009. The program consisted of soil borings, rock/soil classification, water quality sampling, and monitoring well and test production well installation for the APT, seepage meter installation and monitoring, and water quality sampling and analysis. The following is a summary of the findings of the APT program at the Point.

- Subsurface materials encountered during drilling at Turkey Point include fill material underlain by peat or muck. The muck indicates native material and was encountered at all borings to approximately 10 feet bls. Beneath the peat/muck layer is a gray sandy limestone facies. Beneath the sandy limestone is calcareous cemented sand. The sand is fine grained with some shell material; however, the sand pinches out to the northwest. Below the sand layer is a coralline limestone with some gray limestone and shell. Below the coralline limestone is a light gray to white limestone with some shell. The facies encountered all show varying degrees of cavities, channels, tubes, and diverse irregular passageways indicating a high degree of secondary porosity.

- The horizontal groundwater flow pattern at the site prior to the APT was evaluated by plotting the groundwater elevation contours on a base map of the site. The water levels on February 25, 2009, representing a high tide, and on March 1, 2009 representing low tide, show that groundwater flow is generally to the west toward the Industrial Wastewater Facility.

- Vertical gradients at the Point were evaluated by reviewing the water level elevations at the MW-1 well nest. The similarity of the water levels at the MW-1 nest, which have a very slight downward gradient, indicates that the vertical facies are hydraulically interconnected. Less saline water in noted in the shallower portion of the aquifer, and salinity appears to increase slightly with depth.

- Aquifer drawdown measurements can be obscured by a number of factors—particularly tides, regional pumping, and recharge events. These influences introduce water level fluctuations that may mask any changes in water level brought about through aquifer pumping tests. To estimate drawdown, these compounding influences must first be removed. An Excel spreadsheet based program developed by U.S. Geological Survey (USGS) (Halford, 2006), was used to correct the Point APT data. Time series measures, typically referred to as synthetic water levels, are created by summing multiple series resulting from tidal potential, and background water levels. The phase and amplitude of these individual series are then adjusted so that the synthetic water levels match the measured water levels during periods unaffected by an aquifer test (Background Period). Once a fit is obtained, the model is then used to estimate the synthetic water level series during the APT period. The results of the APT (drawdown data) are then obtained from the differences between the measured and synthetic series during the APT period in each monitoring/observation well. Drawdown ranged from approximately 0.7 feet in the MW-

1 nest (80 feet from the pumped well) wells to 0.15 feet at MW-4 (approximately 2,060 feet from the pumped well).

- The APT drawdown data were analyzed with well hydraulic equations. The data analysis employed various methods to determine the transmissivity and storage coefficient for the Biscayne aquifer. The results of the APT indicate a leaky aquifer with mean T-values in the range of 700,000 to 1,200,000 $feet^2$/day, and a mean storage coefficient of 0.0014. Scale effects are evident in the test results, with the lowest T values in the wells in close proximity to the production well, and the highest T values at the far-field wells. The noted increase in hydraulic conductivity with scale is likely a natural consequence of aquifer heterogeneity, making the far-field well T estimates likely more reliable for this test.

- The seepage meter data indicate that seepage measurements were predominantly net positive and varied considerably from location to location. The seepage data reliability is in question due to the following:

    - Water level data in the area of the Point do not indicate an upward hydraulic gradient that would contribute water from the deeper formations to the Bay.
    - The horizontal gradient is toward the shore and the Industrial Wastewater Facility, indicating that water would be flowing from the Bay, not toward the Bay from onshore in this area.
    - Previous studies in similar environments in Florida Bay show the same "positive net seepage" affect. The studies indicate that wave currents passing over the meters could create a "Bernoulli effect" and account for most of the water collected in the bag. A similar situation could have occurred at the Point.
    - Tidal "pumping" could also provide a mechanism for water to be introduced to the seepage collection bags on the seepage meters.

  Due to the questions regarding the validity of the seepage meter data collect at the Point, the data will not be considered in further studies of radial collector well performance and/or impact to the area.

- The water quality results show that the concentrations of the cations and anions in the pumping well remained consistent throughout the pumping period, indicating that no apparent changes or degradation of groundwater quality occurred because of pumping during the APT period at the Point. The isotopic data do not indicate any obvious water quality degradation as a result of pumping during the APT period. Monitoring well sample results indicate no statistically significant differences from pre-to post-APT concentrations in the measured parameters.

Based on the data obtained during the Point exploratory drilling and aquifer testing program, the site appears to have subsurface characteristics that would be suitable for radial wells. High yields can be obtained from highly transmissive, relatively shallow formations beneath the site. Potential subsurface target zones for the radial wells are the Miami Limestone at depths of approximately 25 to 30 feet bls, and the upper portion of the Key Largo limestone at depths of approximately 39 to 42 feet bls. The highly transmissive Key Largo is presumed to extend regionally beneath Biscayne Bay, where it ultimately forms the base of the upper Keys (Hoffmeister, 1974). Further analysis consisting of numerical modeling will assist in assessing the most effective depth intervals for the radial collector wells.

8.0 REFERENCES

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TABLES

Table 2.1
Florida Power & Light
Turkey Point Exploratory Drilling and Aquifer Performance Test Program
Lithologic Summary

Location	LAT	LONG	Ground Surface Elevation (NAVD 88)	Depth to Bottom of Fill (ft)	Depth to Top of Peat (ft)	Depth to Bottom of Peat (ft)	Elevation Top of Peat (ft NAVD 88)	Thickness of Peat (ft)	Depth to Top of Sandy Limestone(ft)	Depth to Bottom of Sandy Limestone(ft)	Elevation Top of Sandy Limestone (NAVD 88)	Thickness of Sandy Limestone (ft)	Depth to Top of Cemented Sand (ft)	Depth to Bottom of Cemented Sand (ft)	Elevation Top of Cemented Sand (NAVD 88)	Thickness of Cemented Sand (ft)	Depth to Top Coraline LS (Key Largo (ft))	Depth to Bottom Coraline LS (Key Largo (ft))	Elevation Top of Coraline LS (NAVD 88)	Thickness of Coraline Limestone (ft)	Depth to Top Lt Gray Limestone (ft)	Elevation Top of Lt Gray Limestone	Comments
PW-1	25°26'12.7306"	80°19'16.6207"	3.51	9.0	9.0	10.0	-5.5	1.0	10.0	32.0	-6.5	22.0	32.0	43.0	-28.5	11.0	43.0		-39.5				Total Depth 46 feet BLS
MW-1	25°26'12.2359"	80"19'17.3150"	3.00	9.0	9.0	10.0	-6.0	1.0	10.0	32.0	-7.0	22.0	32.0	42.0	-29.0	10.0	42.0	58.0	-39.0	16.0	58.0	-55.0	Total Depth 75 feet BLS
MW-2	25°26'16.9299"	80°19'07.6459"	4.41	9.0	9.0	11.0	-4.6	2.0	11.0	35.0	-6.6	24.0	35.0	44.0	-30.6	9.0	44.0		-39.6				Total Depth 47 feet BLS
MW-3	25°26'10.2903"	80°19'36.8590"	2.87	8.0	8.0	10.0	-5.1	2.0	10.0	34.0	-7.1	24.0	34.0	36.0	-31.1	2.0	36.0		-33.1				Total Depth 44 feet BLS
MW-4	25°26'03.0608	80°19'36.4789"	4.43	8.0	8.0	11.5	-3.6	3.5	11.5	34.0	-7.1	22.5	34.0	43.0	-29.6	9.0	43.0		-38.6				Total Depth 47 feet BLS
MW-5	25°26'22.7708"	80°19'43.9645"	2.86	3.0	3.0	6.5	-0.1	3.5	6.5	32.0	-3.6	25.5	not present	not present	not present	not present	32.0		-29.1				Total Depth 40 feet

Table 3.1
Florida Power and Light
Turkey Point Exploratory Drilling and Aquifer Performance Test Program
APT Monitoring Well and Surface Water Monitoring Details

Monitoring Point ID	Location *	Lat	Long	Casing Depth (feet bls)	Casing Dia (in)	Open Hole Interval (feet bls)	Screened Interval (feet bls)
PW-1	Test production well	25°26’12.7306”	80°19’16.6207”	22	30	22- 46	-
MW-1 DZ-deep	80’ west	25°26’12.2359”	80°19’17.3150”	-	2	-	65-75
MW-1 DZ-PI	80’ west	25°26’12.2359”	80°19’17.3150”	24	6	24-60	-
MW-1-IS	72’ west	25°26’12.3058”	80°19’17.2599”	24	6	24-35	-
MW-1 SS	80’ west	25°26’12.2972”	80°19’17.4014”	12.7	2	-	12.7-17.7
MW-2	925 feet E	25°26’16.9299”	80°19’07.6459”	22	6	22-47	-
MW-3	1876 feet W	25°26’10.2903”	80°19’36.8590”	22	6	22-44	-
MW-4	2065 feet SW	25°26’03.0608	80°19’36.4789”	22	6	22-47	-
MW-5	2704 feet NW	25°26’22.7708”	80°19’43.9645”	22	6	22-41	-
Barge Slip	1748 feet NW	25°26’15.2132”	80°19’35.6518”	-	-	-	-
IWF	2036 feet SW	25°26’05.3186”	80°19’37.3337”	-	-	-	-

*Relative to PW-1
Note: the dual zone monitoring well was the original exploratory hole, and was converted to a well designed to monitor the both the interval below the production interval (65-75’) and the production interval.
Note: Barge Slip and Industrial Wastewater Facility (IWF) are surface water monitoring points

Table 3.2
Florida Power and Light
Turkey Point Exploratory Drilling and Aquifer Performance Test Program
Field Parameters Recorded During Production Well (PW-1) Development
March 26, 2009

Time	Conductivity (mS/cm)	Salinity (ppt)	Turbidity (NTU)	Temperature (DegC)	pH	Approx Gallons Pumped
1052	53.6	35.4	32	26.4	7.51	14,000
1106	53.3	35.2	33	27.1	7.53	21,000
1350	52.9	34.9	15	27.0	7.6	28,000
1410	53.0	35	11	26.9	7.55	35,000
1425	52.9	33.5	6.1	26.5	7.64	49,000
1650	53.1	33.7	7.1	26.6	7.56	56,000
1715	53.3	33.8	6.6	26.4	7.62	63,000

Table 4.1
Florida Power and Light
Turkey Point Exploratory Drilling and Aquifer Performance Test Program
Schedule and Pumping Rates for Turkey Point APT

Test	Start Date	Start Time	Stop Date	Stop Time	Pumping Rate
Step	4/4/09	0930			4,000 gpm
	4/4/09	1200			6,000 gpm
	4/4/09	1350	4/4/09	1530	7,300 gpm
Test 1	4/5/09	1107	4/6/09	1440	7,500 gpm
Test2	4/8/09	1208			7,500 gpm
	4/11/09	0800	rate reduced*		5,500 gpm
			4/13/09	1115	
Test 3	4/16/09	1215	4/18/09	1015	8,000 gpm
Test 4	4/28/09	1045	5/5/09	1032	7,100 gpm

Note: Test 1-3 stopped prematurely due to operational problems with the pump
* Rate reduced due to operational problems with the pump

Table 4.2
Florida Power and Light
Turkey Point Exploratory Drilling and Aquifer Performance Test Program
Water Quality Analytes

Parameter	PW-1 Test Production Well	MW-1, MW-2, MW-3, MW-4, MW-5	Biscayne Bay & Industrial Wastewater Facility
FIELD			
pH	Daily Grab	1 week prior/1 week following test	1 week prior, Grab Day 1, Day 7
Conductivity	Daily Grab/ Aqua Troll	1 week prior/1 week following test/Aqua Troll	1 week prior ,Grab Day 1, Day 7/ Aqua Troll
Temperature	Daily Grab/ Aqua Troll	1 week prior/1 week following test/Aqua Troll	1 week prior ,Grab Day 1, Day 7/ Aqua Troll
Dissolved oxygen	Daily Grab	1 week prior/1 week following test	1 week prior ,Grab Day 1, Day 7
LABORATORY			
Turbidity	Daily Grab	1 week prior/1 week following test	1 week prior ,Grab Day 1, Day 7
Salinity	Daily Grab/ Aqua Troll	1 week prior/1 week following test/Aqua Troll	1 week prior ,Grab Day 1, Day 7
TDS	Daily Grab/ Aqua Troll	1 week prior/1 week following test/Aqua Troll	1 week prior ,Grab Day 1, Day 7
CATIONS			
Calcium (Ca2+)	Grab Day 1, 3, 5 and 7	1 week prior/1 week following test	1 week prior ,Grab Day 1, Day 7
Sodium (Na+)	Grab Day 1, 3, 5 and 7	1 week prior/1 week following test	1 week prior ,Grab Day 1, Day 7
Magnesium (Mg2+)	Grab Day 1, 3, 5 and 7	1 week prior/1 week following test	1 week prior ,Grab Day 1, Day 7
Potassium (K+)	Grab Day 1, 3, 5 and 7	1 week prior/1 week following test	1 week prior ,Grab Day 1, Day 7
Strontium (Sr2+)	Grab Day 1, 3, 5 and 7	1 week prior/1 week following test	1 week prior ,Grab Day 1, Day 7
ANIONS			
Chloride (Cl-)	Daily Grab	1 week prior/1 week following test	1 week prior ,Grab Day 1, Day 7
Bromide (Br-)	Grab Day 1, 3, 5 and 7	1 week prior/1 week following test	1 week prior ,Grab Day 1, Day 7
Sulfate (SO4)	Grab Day 1, 3, 5 and 7	1 week prior/1 week following test	1 week prior ,Grab Day 1, Day 7
Fluoride (F-)	Grab Day 1, 3, 5 and 7	1 week prior/1 week following test	1 week prior ,Grab Day 1, Day 7
Bicarbonate (HCO3-)	Grab Day 1, 3, 5 and 7	1 week prior/1 week following test	1 week prior ,Grab Day 1, Day 7
Borate B(OH3)	Grab Day 1, 3, 5 and 7	1 week prior/1 week following test	1 week prior ,Grab Day 1, Day 7
STABLE ISOTOPES			
hydrogen (δD)	Grab Day 1, 3, 5 and 7	1 week prior/1 week following test	1 week prior ,Grab Day 1, Day 7
oxygen ($\delta^{18}O$)	Grab Day 1, 3, 5 and 7	1 week prior/1 week following test	1 week prior ,Grab Day 1, Day 7

Table 4.3
Florida Power and Light
Turkey Point Exploratory Drilling and Aquifer Performance Test Program
Samples Obtained During Drilling and Testing Program

Date	Sample Point	Analytes
1/9/2009	MW-1 (borehole samples)	CL, Sulfate, TDS
1/14/2009	MW-1 (borehole samples)	CL, Sulfate, TDS
1/22/2009	PW-1 (borehole samples)	CL, Sulfate, TDS
	Bay	CL, Sulfate, TDS
1/28/2009	MW-2 (borehole samples)	CL, Sulfate, TDS
1/30/2009	MW-4 (borehole samples)	CL, Sulfate, TDS
2/3/2009	MW-3 (borehole samples)	CL, Sulfate, TDS
2/6/2009	MW-5 (borehole samples)	CL, Sulfate, TDS
3/17/2009	Bay, MW-1 through MW-5	Cations/Anions/Isotopes
	Industrial Wastewater Facility	Cations/Anions/Isotopes
3/18/2009	Industrial Wastewater Facility	Cations/Anions/Isotopes
	MW-3, MW-4, MW-5	Cations/Anions/Isotopes
4/5/2009	PW-1, Bay	Cations/Anions/Isotopes
	Industrial Wastewater Facility	Cations/Anions/Isotopes
4/6/2009	PW-1	CL, SAL, TDS
4/8/2009	PW-1	CL, SAL, TDS
4/9/2009	PW-1	CL, SAL, TDS
		Cations/Anions/Isotopes
4/10/2009	PW-1	CL, SAL, TDS
		Cations/Anions/Isotopes
4/11/2009	PW-1	CL, SAL, TDS
4/12/2009	PW-1	CL, SAL, TDS
4/13/2009	PW-1	Cations/Anions/Isotopes
4/17/2009	PW-1	CL, SAL, TDS
		Cations/Anions/Isotopes
4/29/2009	PW-1	Cations/Anions/Isotopes
4/30/2009	PW-1	CL, SAL, TDS, Cations/Anions/Isotopes
	Bay	CL, SAL, TDS
5/1/2009	PW-1	Cations/Anions/Isotopes
	Bay	CL, SAL, TDS
5/2/2009	PW-1	CL, SAL, TDS,Cations/Anions/Isotopes
	Bay	CL, SAL, TDS
5/3/2009	PW-1	CL, SAL, TDS,Cations/Anions/Isotopes
	Bay	CL, SAL, TDS
5/4/2009	PW-1	CL, SAL, TDS, Cations/Anions/Isotopes
	Bay	CL, SAL, TDS
5/5/2009	Bay, PW-1,Industrial Wastewater Facility	CL, SAL, TDS, Cations/Anions/Isotopes
5/12/2009	Bay, MW-1 DZ-PI, Industrial Wastewater Facility	CL, SAL, TDS, Cations/Anions/Isotopes
	MW-2 through MW-5	CL, SAL, TDS, Cations/Anions/Isotopes

Table 5.1
Turkey Point Exploratory Drilling and Aquifer Performance Test Program
Aquifer Performance Test Analysis Results
Root Mean Square Error Values for Background (BG) Fitting Periods
Sequential Entry of Independent Variables: Barge Gage, Canal Gage, Earth Tide, and Gravity Tide

	MW-1 DZ-Deep	MW-1 DZ-PI	MW-1 IS	MW-1 SS	MW-2	MW-3	MW-4	MW-5
Period Start	2/11/2009 13:13	2/11/2009 13:13	2/11/2009 13:13	2/11/2009 13:13	2/11/2009 13:13	2/11/2009 13:13	4/19/2009 23:00	2/11/2009 13:13
Period End	4/4/2009 9:00	4/4/2009 9:00	4/4/2009 9:00	4/4/2009 9:00	4/4/2009 9:00	4/4/2009 9:00	4/28/2009 6:00	4/4/2009 9:00
RMSE								
Null Model	0.5025	0.4967	0.4984	0.4975	0.5373	0.4593	0.2244	0.5049
+ Barge	0.1543	0.1500	0.1462	0.1486	0.2162	0.2733	0.1155	0.4483
+ Canal	0.1444	0.1417	0.1401	0.1411	0.1409	0.1459	0.0439	0.3884
+ Earth Tide	0.0954	0.0928	0.0905	0.0915	0.0889	0.0956	0.0304	0.3704
+ Gravity Tide	0.0396	0.0285	0.0202	0.0259	0.0574	0.0344	0.0187	0.3604
Final R^2	0.921	0.943	0.959	0.948	0.893	0.925	0.917	0.286

Table 5.2
Florida Power and Light
Turkey Point Exploratory Drilling and Aquifer Performance Test Program
Aquifer Performance Test Analysis Results

Well	Data	Method	T (ft^2/d)	Storage Coefficient	K' (ft/d) (calculated)
PW-1	Drawdown	Cooper-Jacob	450,000		
	Recovery	Theis Recovery	492,623		
MW1 DZ PI	Drawdown	Walton (1962)	368,000	1.00E-06	980
	Recovery	Theis Recovery	998,360		
MW-2	Drawdown	Hantush (1964)	501,548	0.002	10
		Walton (1962)	517,000		
	Recovery	Theis Recovery	1,826,580		
MW-3	Drawdown	Hantush (1964)	907,296	0.0009	5
		Walton (1962)	977,000	0.0007	
	Recovery	Theis Recovery	2,956,330		
MW-4	Drawdown	Hantush (1964)	925,783	0.001	4
		Walton (1962)	1,030,000	0.004	
	Recovery	Theis Recovery	3,650,000		
ALL	Drawdown	Distance-Drawdown	800,000		
Arithmetic Mean ALL			**1,171,466**	**0.0014**	
Arithmetic Mean Drawdown			**719,625**		
Arithmetic Mean Recovery			**1,984,779**		

Table 5.3
Florida Power and Light
Turkey Point Exploratory Drilling and Aquifer Performance Test Program
Seepage Meter Monitoring and Results Summary

Criteria	All	Pump Off	Pump On	High-Low Tide Monitoring	High-Low Notes
Number of Days	26	12	14	7	
Number of Days (-)	10	5	5	5	
Number of Days (+)	16	7	9	2	
Number of Occurrences (-)	12	6	6	6	5 of the 6 occurrences were during high tide monitoring
Number of Occurrences (+)	300	138	162	77	
Total Occurrences	312	144	168	83	
Number of Stations with at least 1 (-)	7	4	5	2	Station 5-High (500' from well head) accounted for 5 of the 6 occurrences of (-) values. Station 6-Low (900' from well head) had the single (-) occurrence
Number of Stations with all (+)	5	8	7	10*	* One meter in the High-Low monitoring had a minimum seepage value of 0.0
Greatest negative seepage value	-0.0063	-0.0018	-0.0063	-0.0076	
Greatest positive seepage value	0.0431	0.0581	0.0374	0.0419	
Average (-) seepage value	-0.002	-0.0009	-0.0031	-0.0047	
Average (+) seepage value	0.0113	0.0119	0.0107	0.0109	
Average of all seepage values	0.0108	0.0114	0.0102	0.0098	

Table 5.4
Florida Power and Light
Turkey Point Exploratory Drilling and Aquifer Performance Test Program
Seepage Meter Data-APT Phase

		Meter Number											
		11 (S. Array)	**12** (S. Array)	**1**	**3**	**7**	**2**	**4**	**8**	**5**	**6**	**9**	**10**
	Distance from Pump	230'	230'	265'	255'	255'	290'	280'	280'	305'	330'	500 '	900'
7 Day APT Test: Pumping (n=7)	Minimum	-0.0063	0.0103	0.0017	-0.0013	0.0066	0.0084	-0.0025	0.0072	0.0002	0.0000	0.0016	-0.0035
	Maximum	0.0124	0.0314	0.0173	0.0169	0.0305	0.0276	0.0176	0.0251	0.0195	0.0052	0.0047	0.0055
	Average	0.0081	0.0163	0.0051	0.0027	0.0236	0.0167	0.0056	0.0170	0.0078	0.0015	0.0029	0.0019
2 Day Post APT Test: Not Pumping (n2)	Minimum	0.0081	0.0131	-0.0002	0.0002	0.0202	0.0220	0.0069	0.0235	0.0181	0.0006	0.0037	-0.0014
	Maximum	0.0143	0.0174	0.0049	0.0009	0.0256	0.0267	0.0090	0.0305	0.0245	0.0055	0.0055	0.0067
	Average	0.0112	0.0153	0.0024	0.0006	0.0229	0.0243	0.0079	0.0270	0.0213	0.0030	0.0046	0.0026
All Days Active Pumping (n=14)	Minimum	-0.0063	0.0095	-0.0017	-0.0013	0.0066	0.0059	-0.0025	0.0072	0.0002	0.0000	0.0016	-0.0035
	Maximum	0.0132	0.0314	0.0173	0.0214	0.0374	0.0276	0.0176	0.0316	0.0195	0.0055	0.0100	0.0115
	Average	0.0085	0.0165	0.0044	0.0093	0.0253	0.0153	0.0060	0.0198	0.0064	0.0023	0.0046	0.0039
All Days No Pumping (n=12)	Minimum	0.0025	0.0087	-0.0015	0.0002	0.0136	0.0069	0.0025	0.0018	-0.0018	-0.0002	0.0019	-0.0014
	Maximum	0.0146	0.0431	0.0182	0.0227	0.0581	0.0267	0.0126	0.0305	0.0245	0.0097	0.0084	0.0104
	Average	0.0086	0.0210	0.0051	0.0105	0.0288	0.0167	0.0055	0.0221	0.0041	0.0041	0.0047	0.0056
Avg seepage difference(Pumping-No Pumping)		-0.0001	-0.0045	-0.0007	-0.0012	-0.0035	-0.0014	0.0004	-0.0023	0.0023	-0.0018	-0.0001	-0.0017

Seepage units: ml/cm^2/hr

Table 5.5
Florida Power and Light
Turkey Point Exploratory Drilling and Aquifer Performance Test Program
High-Tide/Low-Tide Seepage Meter Data

	Meter Number											
	1-G	**2-G***	**3-G***	**4-G***	**5-G**	**6-G**	**1-P***	**2-P**	**3-P**	**4-P**	**5-P***	**6-P***
Distance from well	**250'**	**280'**	**305'**	**330'**	**500'**	**900'**	**250'**	**280'**	**305'**	**330'**	**500'**	**900'**
Tide	**High Tide Stations**						**Low Tide Stations**					
Minimum	0.0143	0.0016	0.0003	0.0003	-0.0076	0.0033	0.0000	0.0155	0.0039	0.0088	0.0003	-0.0010
Maximum	0.0419	0.0088	0.0167	0.0120	0.0021	0.0189	0.0208	0.0321	0.0180	0.0220	0.0031	0.0174
Average	0.0279	0.0048	0.0096	0.0029	-0.0042	0.0121	0.0067	0.0228	0.0107	0.0167	0.0017	0.0035

* Original meter left in place for the High Tide - Low Tide monitoring.
Seepage units: $ml/cm^2/hr$

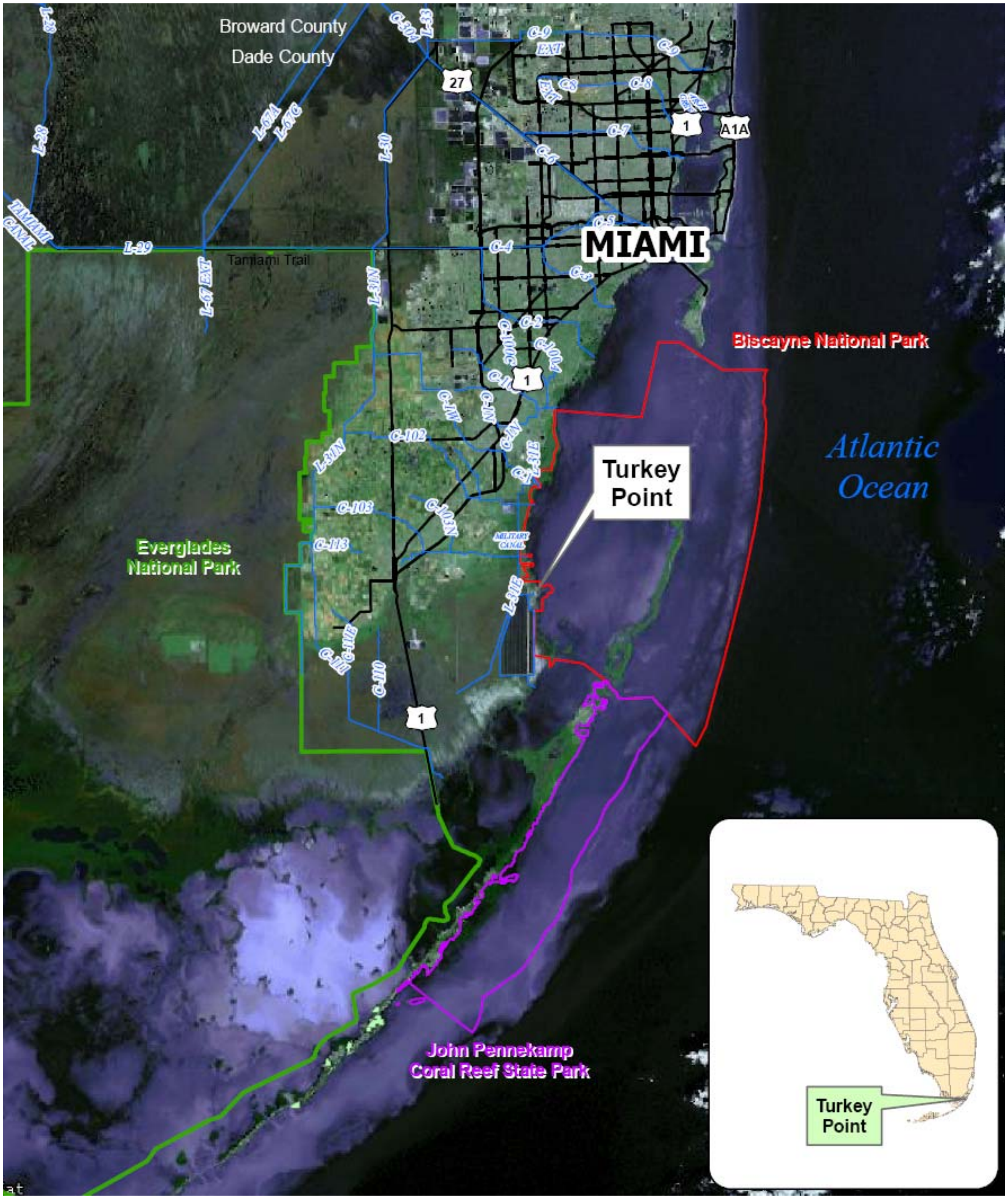
Table 6.1
Florida Power and Light
Turkey Point Exploratory Drilling and Aquifer Performance Test Program
Laboratory Analytical Data Summary

Parameter	Sample Point	Units	Average	Maximum	Minimum	Median		Std Deviation
Total Dissolved Solids	PW-1	mg/l	33931	36400	30400	34300		1561
	Bay		41600	45800	30700	42500		4367
	Industrial Wastewater Facility		66167	66600	65600	66300		513
Chloride	PW-1	mg/l	19407	23300	12300	19600		3051
	Bay		22475	25300	17500	22800		2826
	Industrial Wastewater Facility		37400	39900	35400	37150		2249
Sulfate	PW-1	mg/l	2724	3120	2530	2760		171
	Bay		3400	4200	2470	3465		713
	Industrial Wastewater Facility		6200	7570	5330	5700		1201
Bromide	PW-1	mg/l	99	111	56	105		17
	Bay		98	121	63.4	111		31
	Industrial Wastewater Facility		150	204	101	148		48
Bicarbonate Alkalinity	PW-1	mg/l	167	188	156	162		1
	Bay		120	127	113	120		1
	Industrial Wastewater Facility		184	202	174	181		0
Boric Acid	PW-1	mg/l	24	26	23	24		1
	Bay		29	30	27	29		1
	Industrial Wastewater Facility		42	44	40	43		2
Calcium	PW-1	mg/l	427	457	398	418		17
	Bay		476	493	447	488		4
	Industrial Wastewater Facility		780	824	735	781		9

Parameter	Sample Point	Units	Average	Maximum	Minimum	Median		Std Deviation
Magnesium	PW-1	mg/l	1289	1370	1230	1250		59
	Bay		1545	1570	1520	1545		35
	Industrial Wastewater Facility		2367	2440	2260	2400		95
Potassium	PW-1	mg/l	431	467	408	427		20
	Bay		506	539	457	523		43
	Industrial Wastewater Facility		773	808	731	776		32
Sodium	PW-1	mg/l	10284	11200	9870	10200		415
	Bay		12067	12600	11500	12100		551
	Industrial Wastewater Facility		18800	19000	18400	18900		271
Strontium	PW-1	mg/l	7.9	8.5	7.6	7.8		
	Bay		9.1	9.3	8.9	9.2		0.2
	Industrial Wastewater Facility		15.7	16.0	15.5	15.7		

Note: Fluoride results are either non-detect or between MDL and PQL

FIGURES



FPL Florida Power and Light	HDR Engineering, Inc. 5426 Bay Center Drive Suite 400 Tampa, Florida 33609	**Site Location** Turkey Point Exploratory Drilling and Aquifer Testing Program	DATE 8/19/09 FIGURE 1.1

Boring Location

Source: Data from site drilling program;

FPL Florida Power and Light	HDR HDR Engineering, Inc. 5426 Bay Center Drive Suite 400 Tampa, Florida 33609	**Soil Boring Locations** Turkey Point Exploratory Drilling and Aquifer Testing Program	DATE 8/19/09 FIGURE 2.1

<table>
<tr><th>System</th><th>Series</th><th colspan="2">Stratigraphic Unit</th><th>Hydrogeologic Unit</th></tr>
<tr><td rowspan="5">Quaternary</td><td>Holocene</td><td colspan="2">Undifferentiated sediments</td><td rowspan="5">Surficial Aquifer System</td></tr>
<tr><td rowspan="3">Pleistocene</td><td colspan="2">Miami Limestone</td></tr>
<tr><td colspan="2">Key Largo Limestone</td></tr>
<tr><td colspan="2">Fort Thompson Formation</td></tr>
<tr><td>Pliocene</td><td colspan="2">Tamiami Formation</td></tr>
<tr><td rowspan="7">Tertiary</td><td rowspan="2">Miocene and Late Oligocene</td><td rowspan="2">Hawthorn Group</td><td>Peace River Formation</td><td rowspan="2">Intermediate Confining Unit</td></tr>
<tr><td>Arcadia Formation</td></tr>
<tr><td>Early Oligocene</td><td>Basal Hawthorn/SuwanneeUnit</td><td>Suwanee Limestone</td><td rowspan="4">Floridan Aquifer System</td></tr>
<tr><td rowspan="3">Eocene</td><td colspan="2">Ocala Limestone</td></tr>
<tr><td colspan="2">Avon Park Limestone</td></tr>
<tr><td colspan="2">Oldsmar Formation</td></tr>
</table>

Source: Resse, 2000
Fish and Stewart, 1991

FPL

Florida Power and Light

HDR

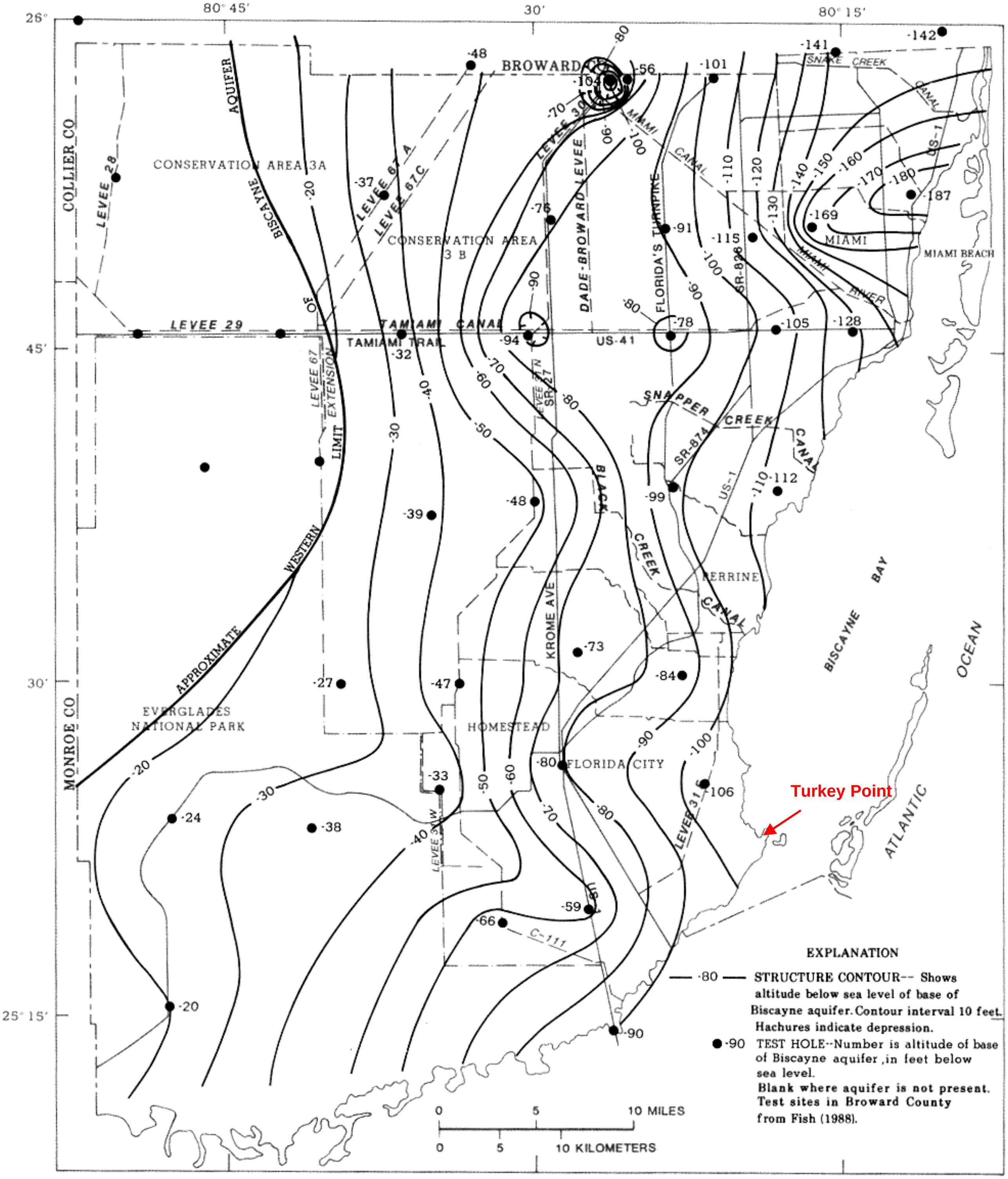
HDR Engineering, Inc.
5426 Bay Center Drive
Suite 400
Tampa, Florida 33609

Regional Stratigraphic Section

Turkey Point Exploratory Drilling and Aquifer Testing Program

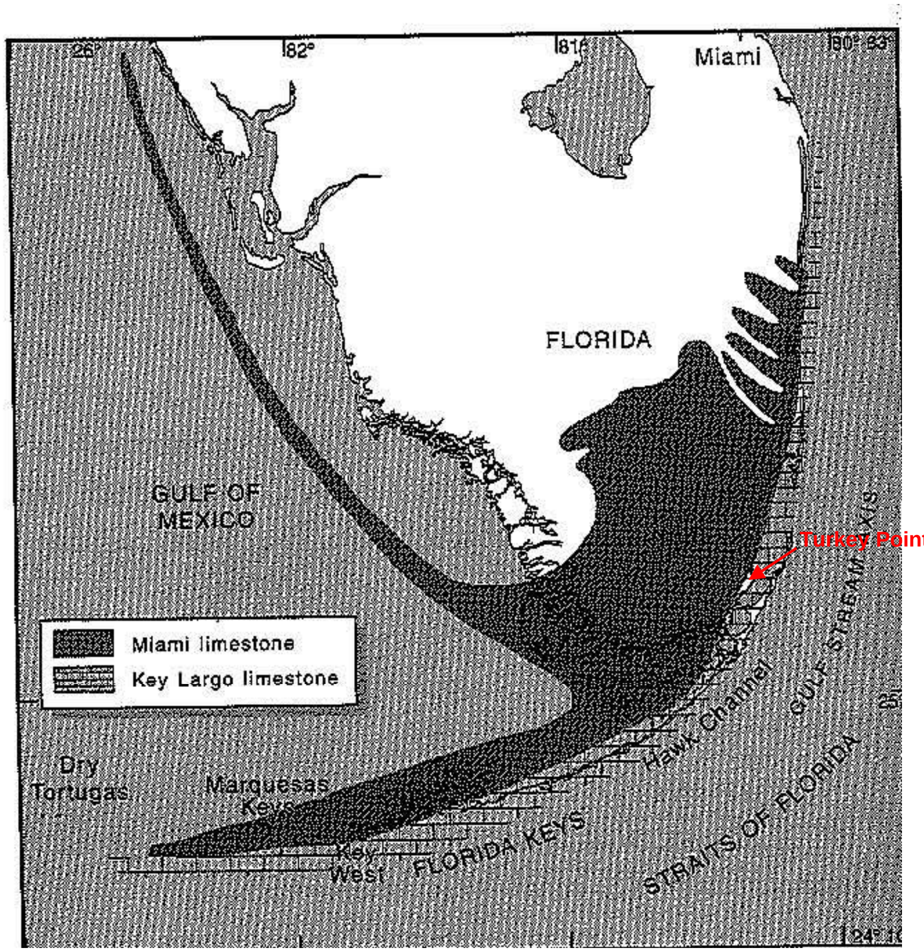
DATE 08/19/09

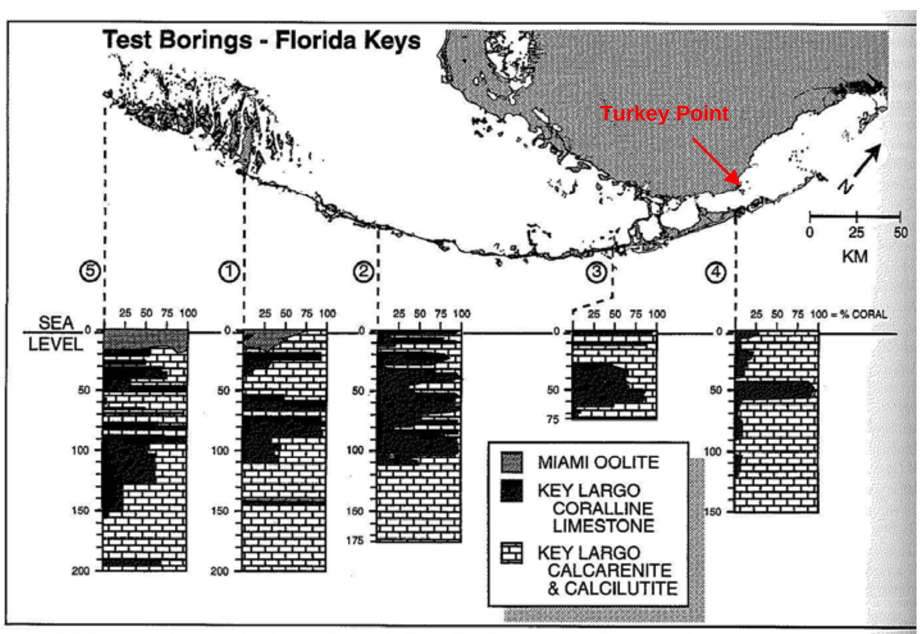
FIGURE 2.2



Source: Fish and Stewart, 1991

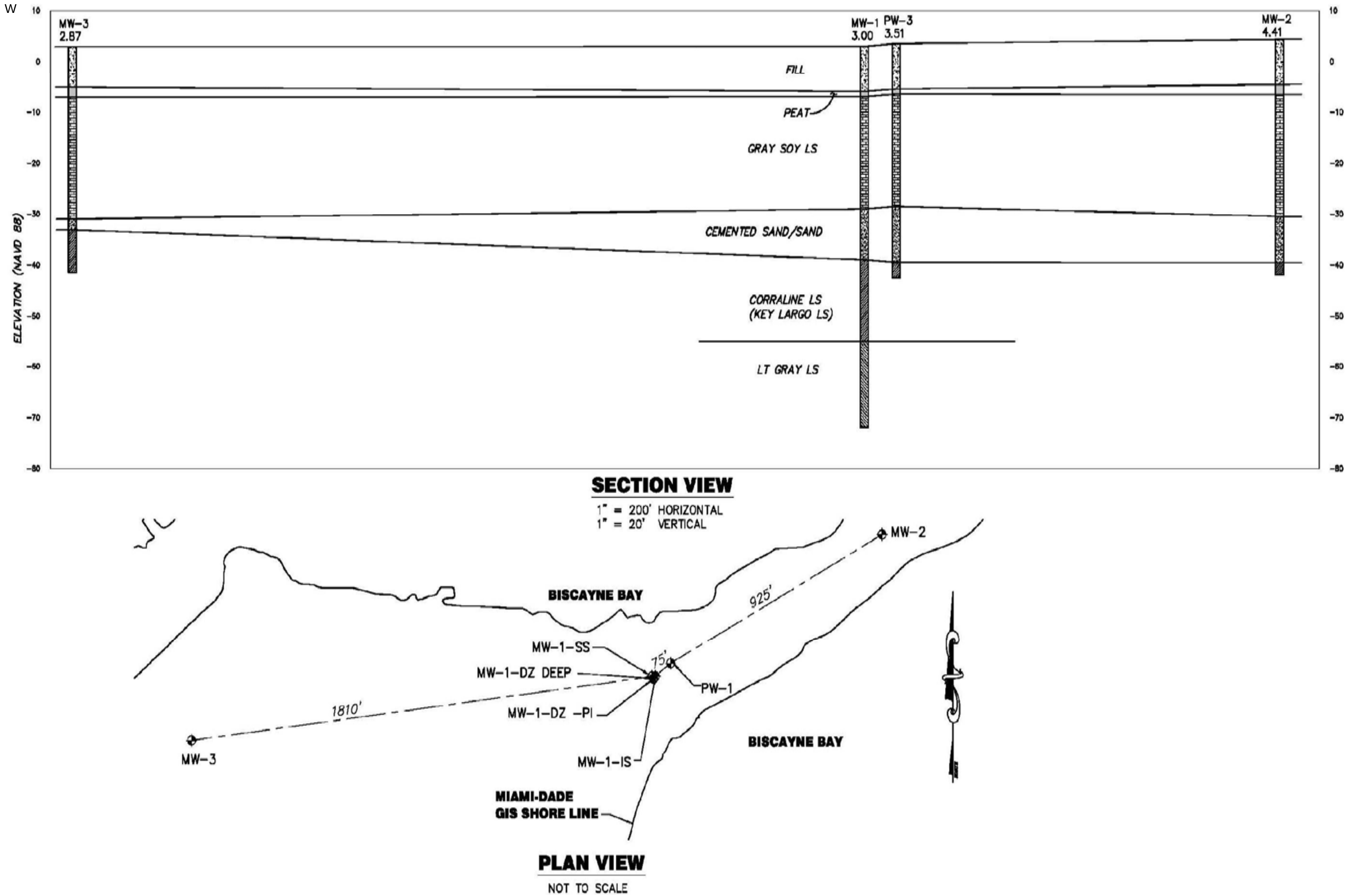
FPL Florida Power and Light	HDR HDR Engineering, Inc. 5426 Bay Center Drive Suite 400 Tampa, Florida 33609	**Base Elevation of the Biscayne Aquifer** Turkey Point Exploratory Drilling and Aquifer Testing Program	DATE 8/19/09 FIGURE 2.3



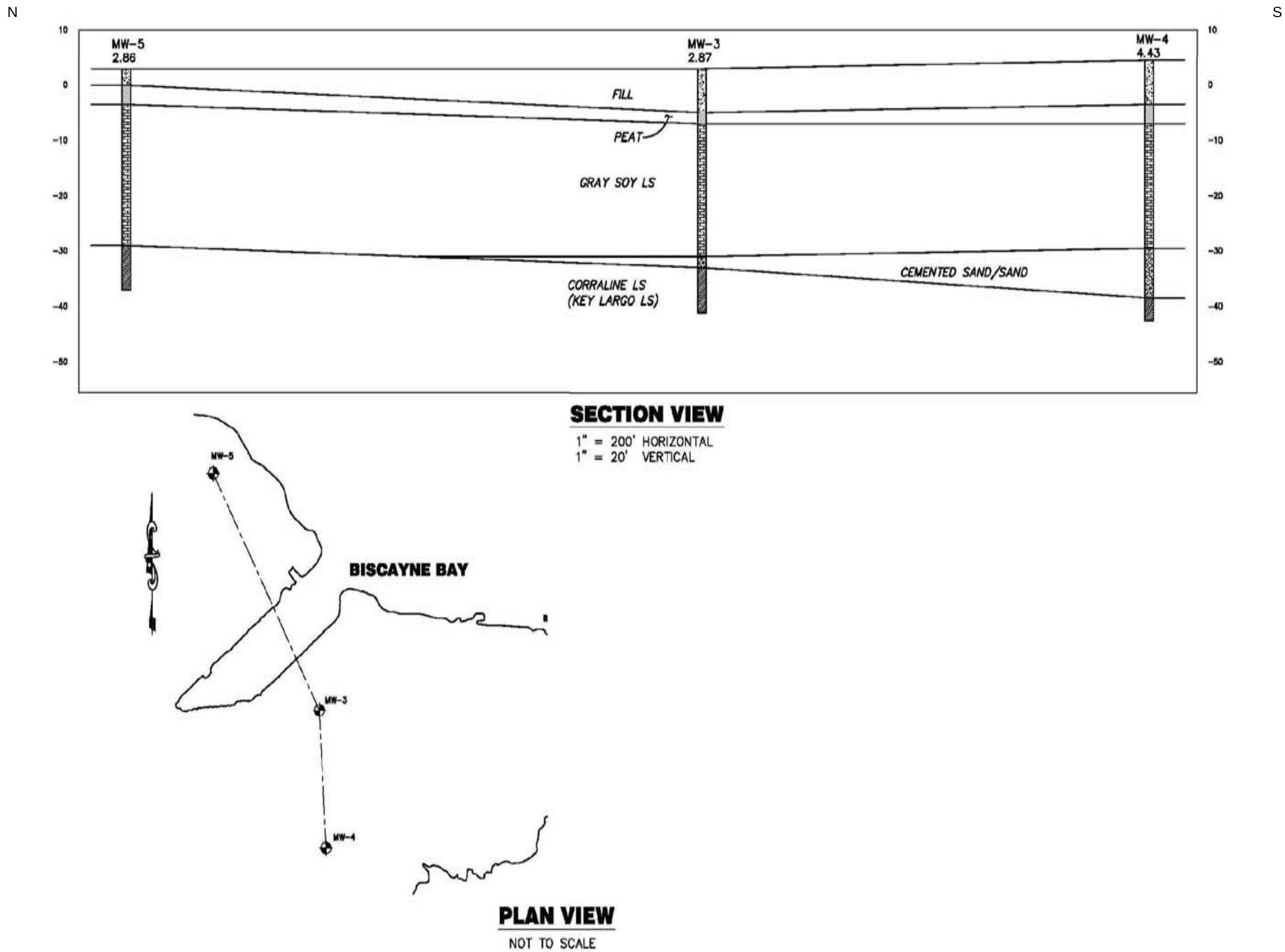


Source: Randazzo and Jones, 1997

FPL Florida Power and Light	HDR HDR Engineering, Inc. 5426 Bay Center Drive Suite 400 Tampa, Florida 33609	**Geologic Map and Boring Data of the Pleistocene Miami and Key Largo Limestones-South Florida** Turkey Point Exploratory Drilling and Aquifer Testing Program	DATE 8/19/09 FIGURE 2.4

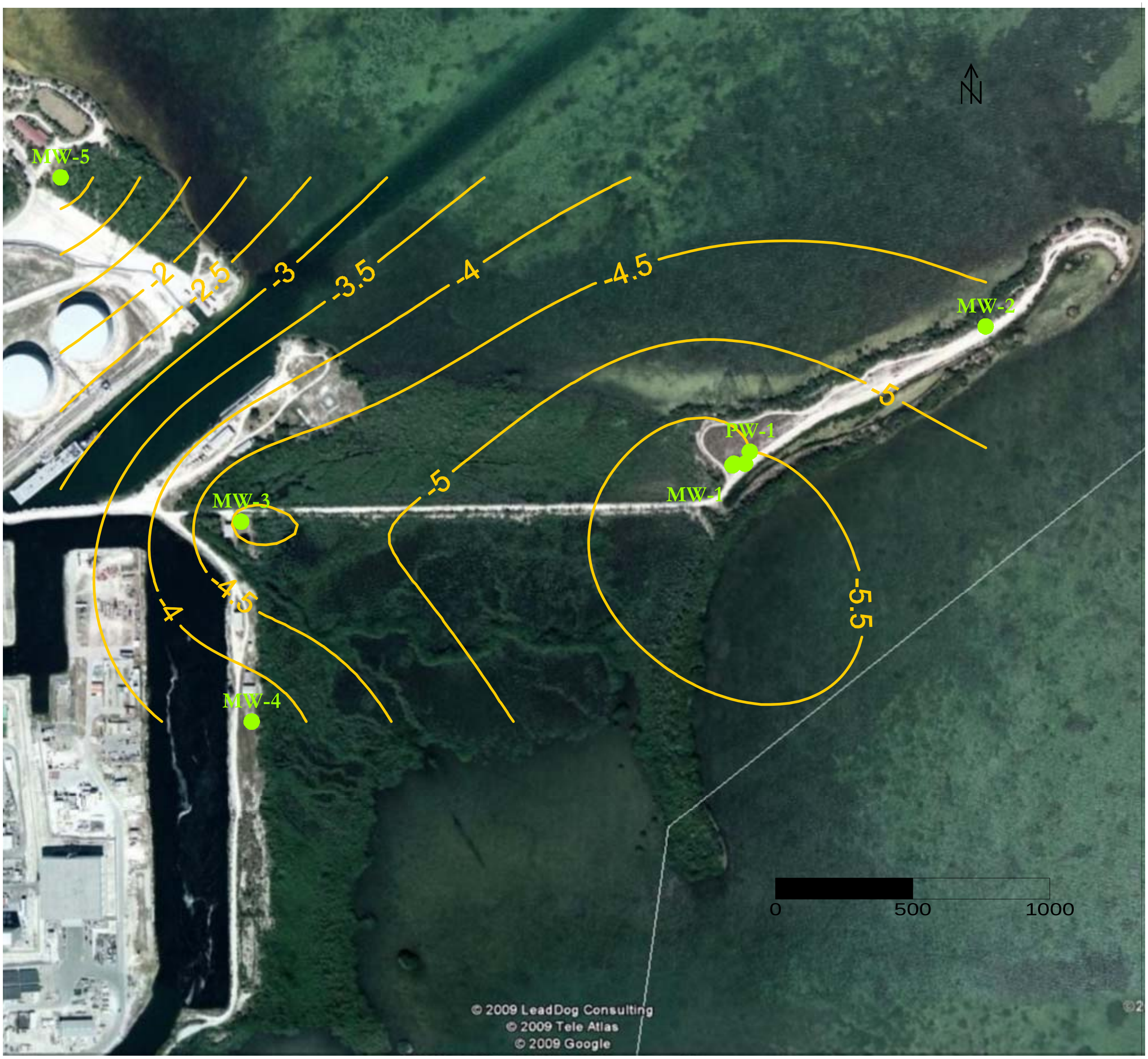


FPL Florida Power and Light	HDR HDR Engineering, Inc. 5426 Bay Center Drive Suite 400 Tampa, Florida 33609	**West to East Geologic Cross Section** Turkey Point Exploratory Drilling and Aquifer Testing Program	DATE 8/19/09 FIGURE 2.5



Source: water levels obtained during APT program

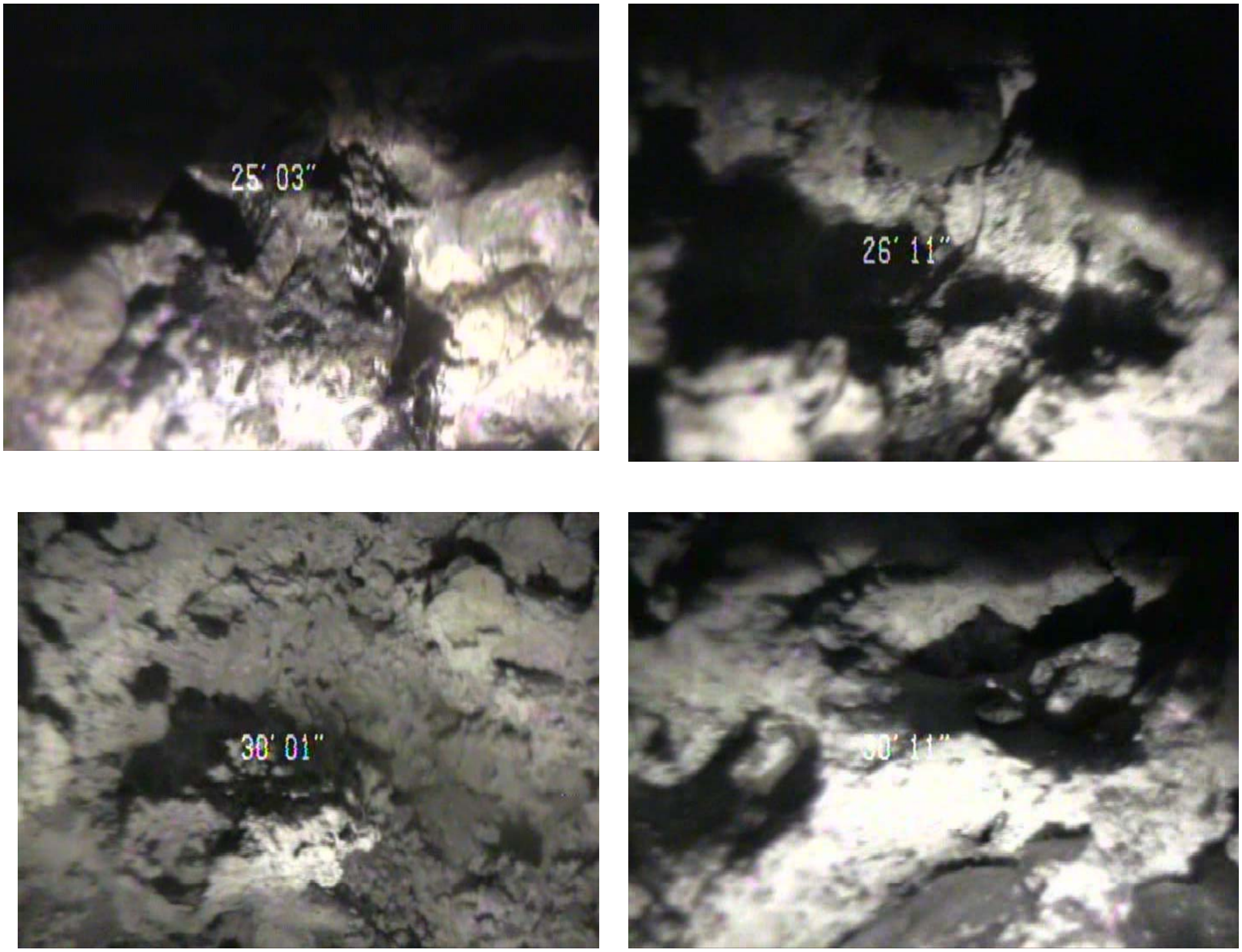
FPL Florida Power and Light	HDR Engineering, Inc. 5426 Bay Center Drive Suite 400 Tampa, Florida 33609	**North to South Geologic Cross Section** Turkey Point Exploratory Drilling and Aquifer Testing Program	DATE 8/19/09 FIGURE 2.6



Source: Lithologic data from site drilling program;

Contour Interval 0.5 Feet

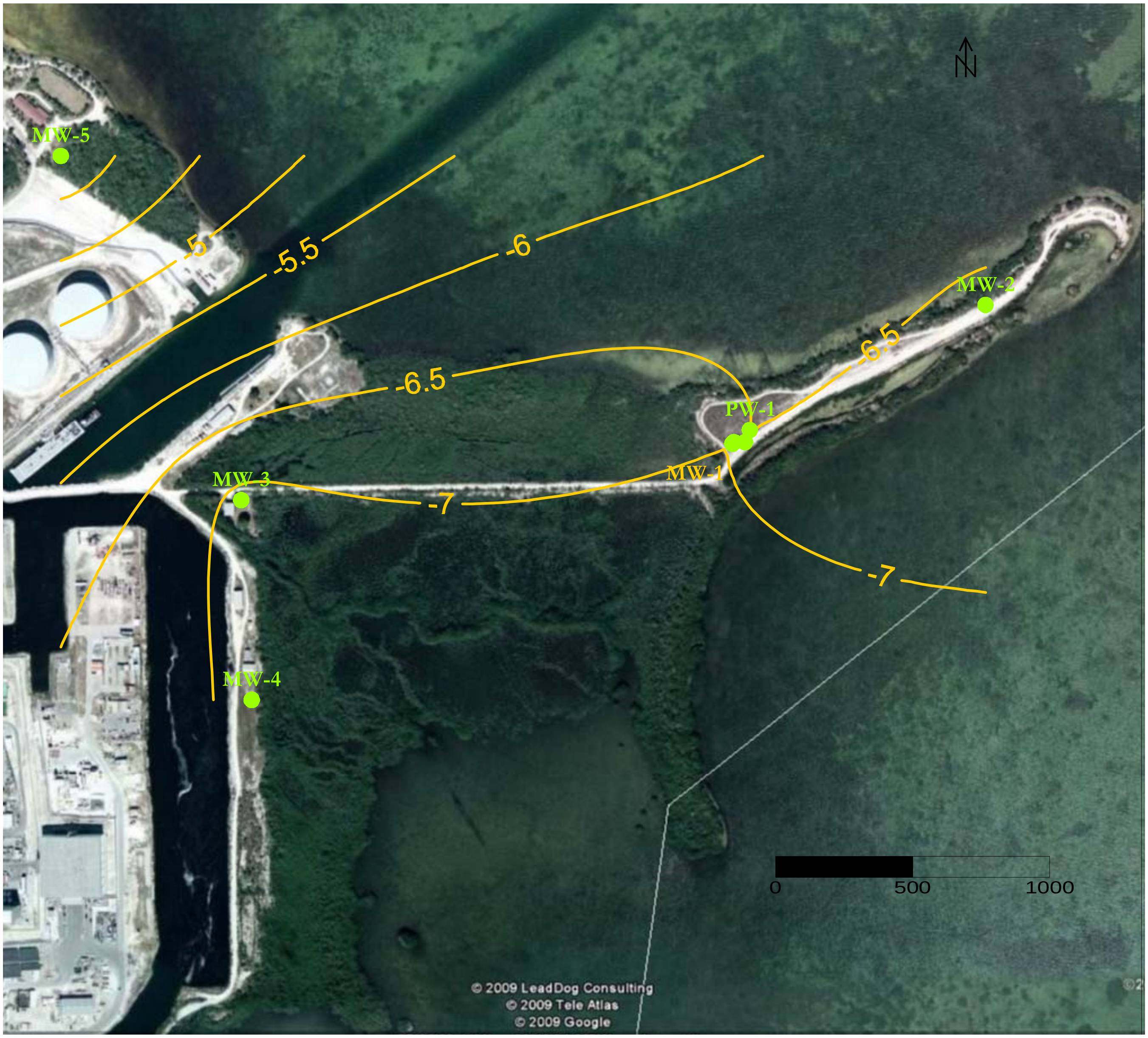
FPL Florida Power and Light	HDR HDR Engineering, Inc. 5426 Bay Center Drive Suite 400 Tampa, Florida 33609	**Top Elevation of the Peat/Muck Layer (Ft NAVD 88)** Turkey Point Exploratory Drilling and Aquifer Testing Program	DATE 8/19/09	FIGURE 2.7



Source: Video Survey of MW-1 pilot hole at site
(MV Geophysical, Inc.);

Note: Depth approximately 1' less than shown

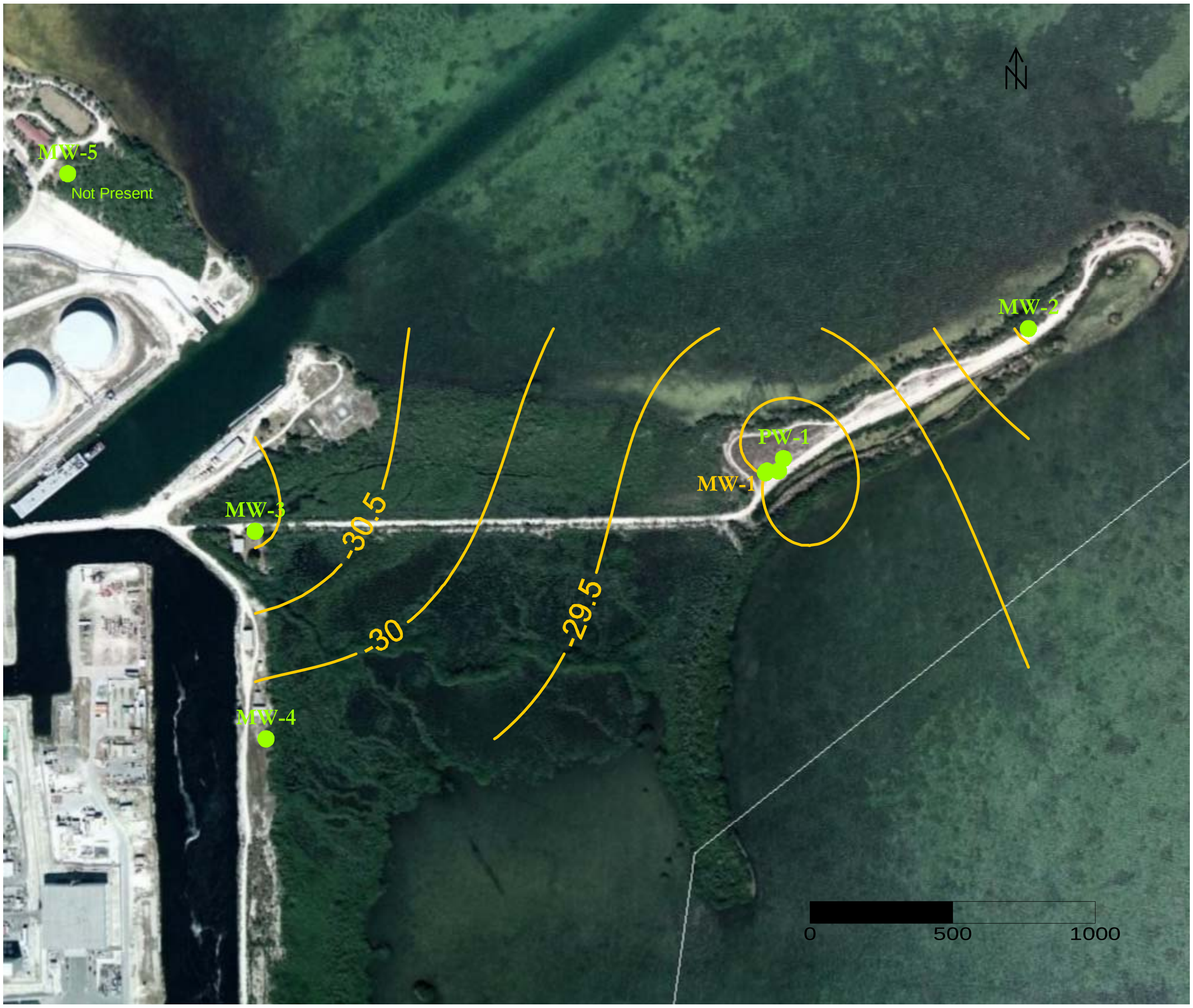
FPL Florida Power and Light	HDR HDR Engineering, Inc. 5426 Bay Center Drive Suite 400 Tampa, Florida 33609	**Video Still- Gray Sandy Limestone** **(Miami Limestone)** Turkey Point Exploratory Drilling and Aquifer Testing Program	DATE 8/19/09 FIGURE 2.8



Source: Data from site drilling program

Contour Interval=0.5 Feet

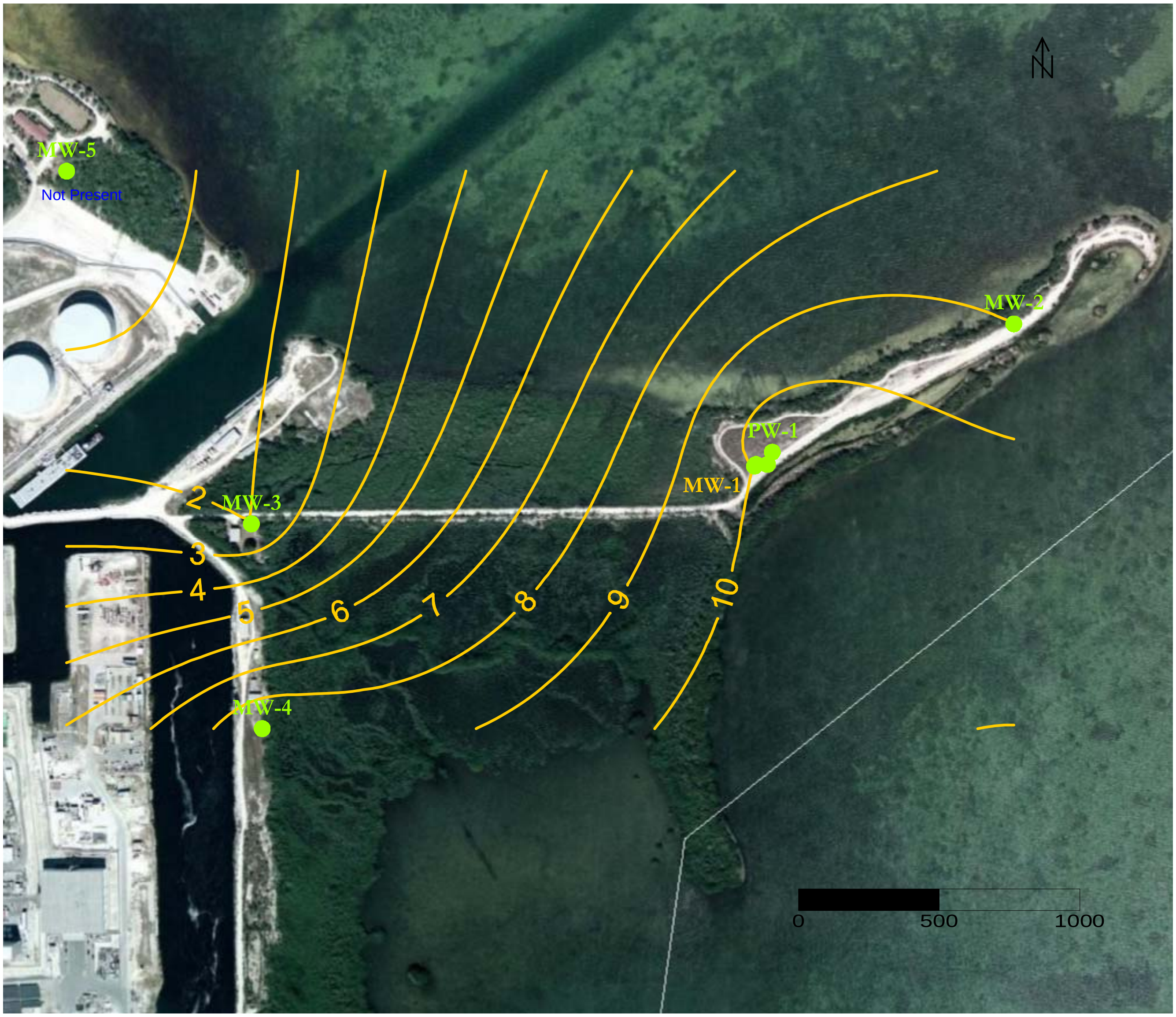
FPL Florida Power and Light	HDR HDR Engineering, Inc. 5426 Bay Center Drive Suite 400 Tampa, Florida 33609	**Top Elevation** **Gray Sandy Limestone** **(Ft NAVD 88)** Turkey Point Exploratory Drilling and Aquifer Testing Program	DATE 8/19/09 FIGURE 2.9



Source: Data from site drilling program;

Contour Interval 0.5 Feet

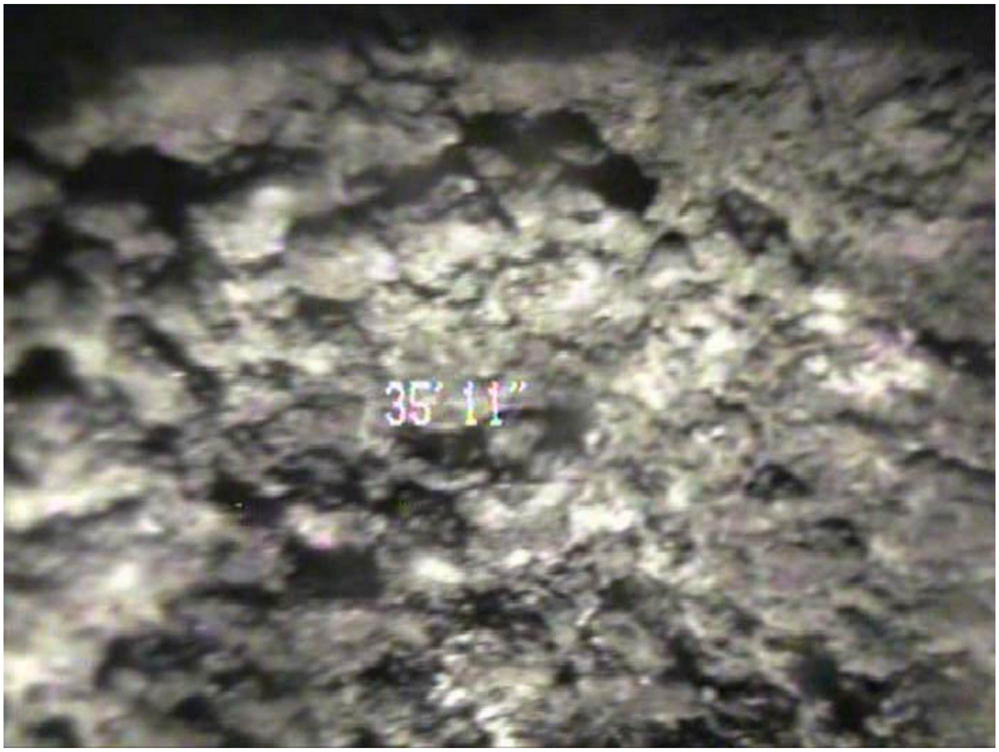
FPL Florida Power and Light	HDR HDR Engineering, Inc. 5426 Bay Center Drive Suite 400 Tampa, Florida 33609	**Top Elevation of the Cemented Sand Layer (Ft NAVD 88)** Turkey Point Exploratory Drilling and Aquifer Testing Program	DATE 8/19/09 FIGURE 2.10

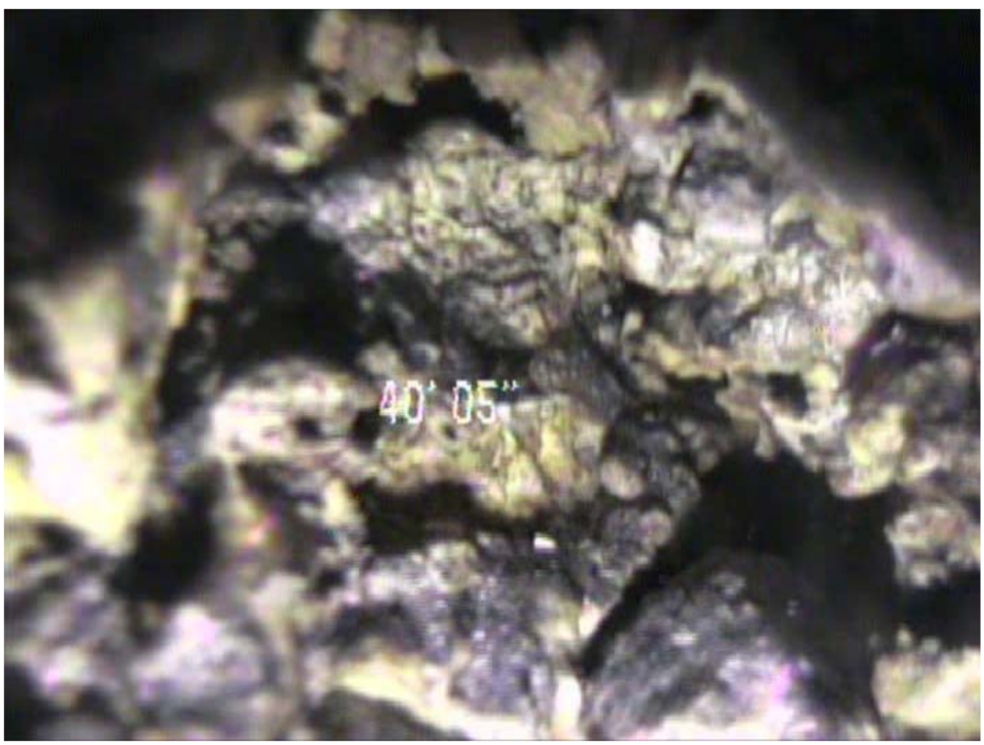


Source: Data from site drilling program

Contour Interval=1.0 Feet

FPL Florida Power and Light	HDR HDR Engineering, Inc. 5426 Bay Center Drive Suite 400 Tampa, Florida 33609	**Thickness of the Cemented Sand Layer (ft)** Turkey Point Exploratory Drilling and Aquifer Testing Program	DATE 8/19/09 FIGURE 2.11

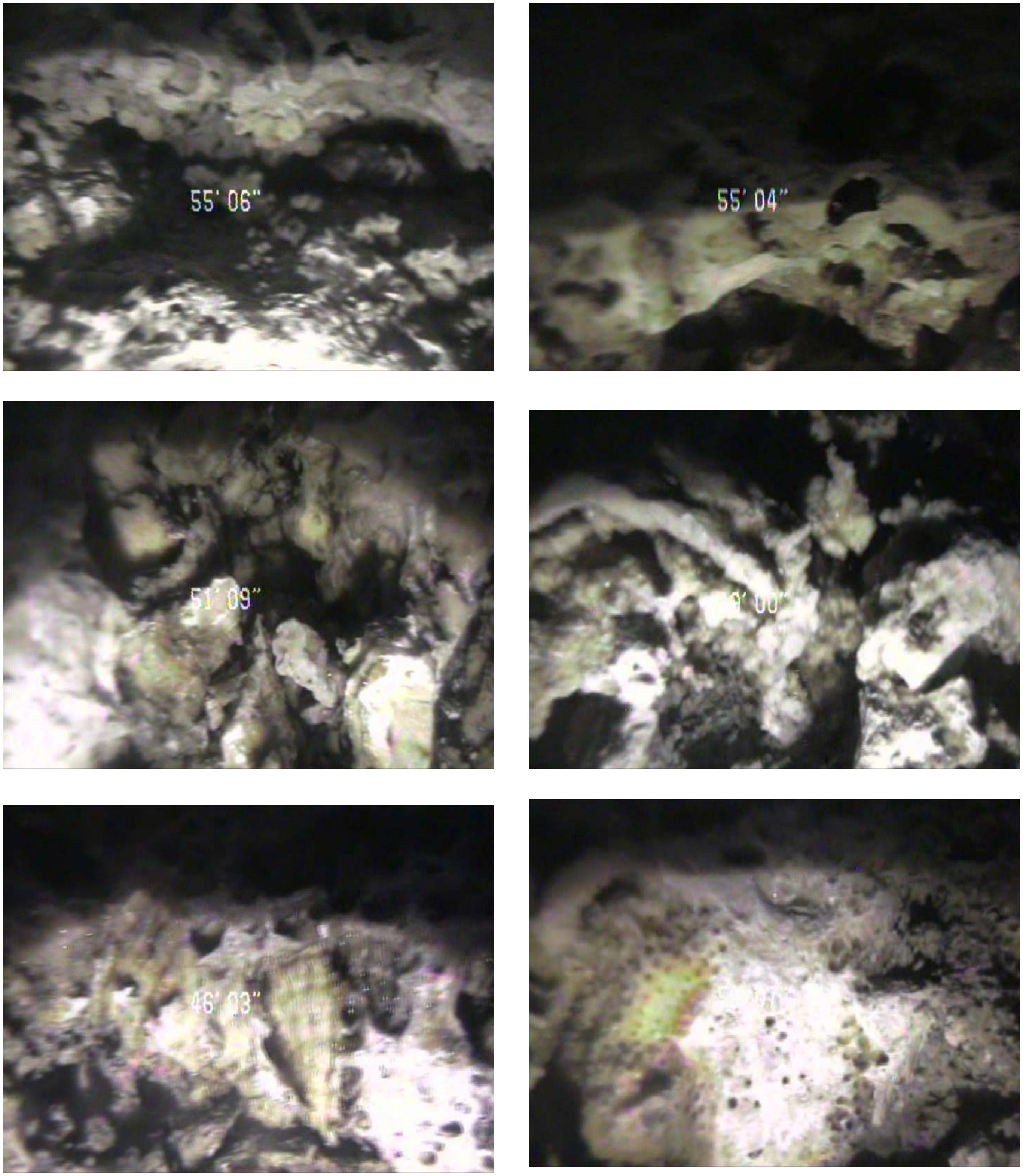




Source: Video Survey of MW-1 pilot hole at site
(MV Geophysical, Inc.);

Note: Depth approximately 1' less than shown

FPL Florida Power and Light	HDR HDR Engineering, Inc. 5426 Bay Center Drive Suite 400 Tampa, Florida 33609	**Video Still- Cemented Calcareous Sand** Turkey Point Exploratory Drilling and Aquifer Testing Program	DATE 8/19/09 FIGURE 2.12

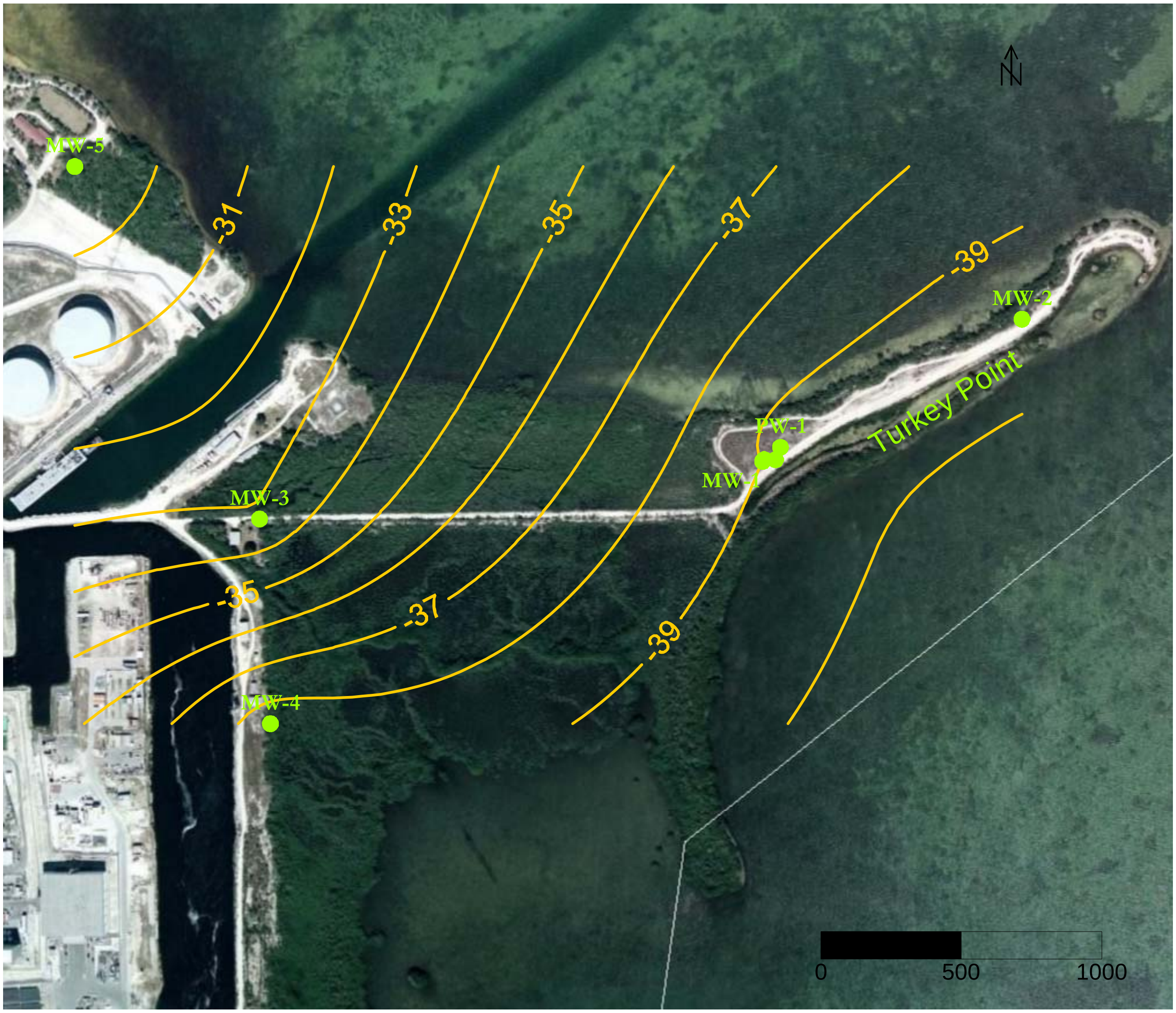


Coral structure, yellow calcite crystals noted

Source: Video Survey of MW-1 pilot hole at site
(MV Geophysical, Inc.)

Note: Depth approximately 1' less than shown

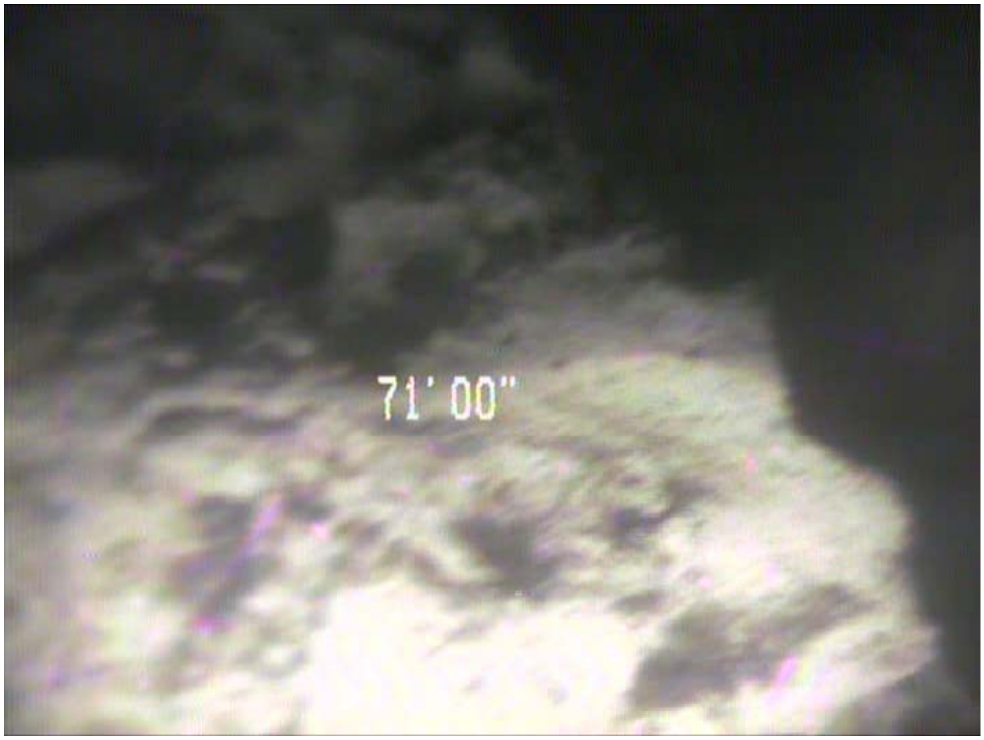
FPL — Florida Power and Light	HDR Engineering, Inc. 5426 Bay Center Drive Suite 400 Tampa, Florida 33609	**Video Still- Coralline Limestone (Key Largo Limestone)** Turkey Point Exploratory Drilling and Aquifer Testing Program	DATE 8/19/09 FIGURE 2.13



Source: Data from site drilling program

Contour Interval=0.5 Feet

FPL Florida Power and Light	HDR Engineering, Inc. 5426 Bay Center Drive Suite 400 Tampa, Florida 33609	**Top Elevation Key Largo Limestone (Ft NAVD 88)** Turkey Point Exploratory Drilling and Aquifer Testing Program	DATE 8/19/09 FIGURE 2.14



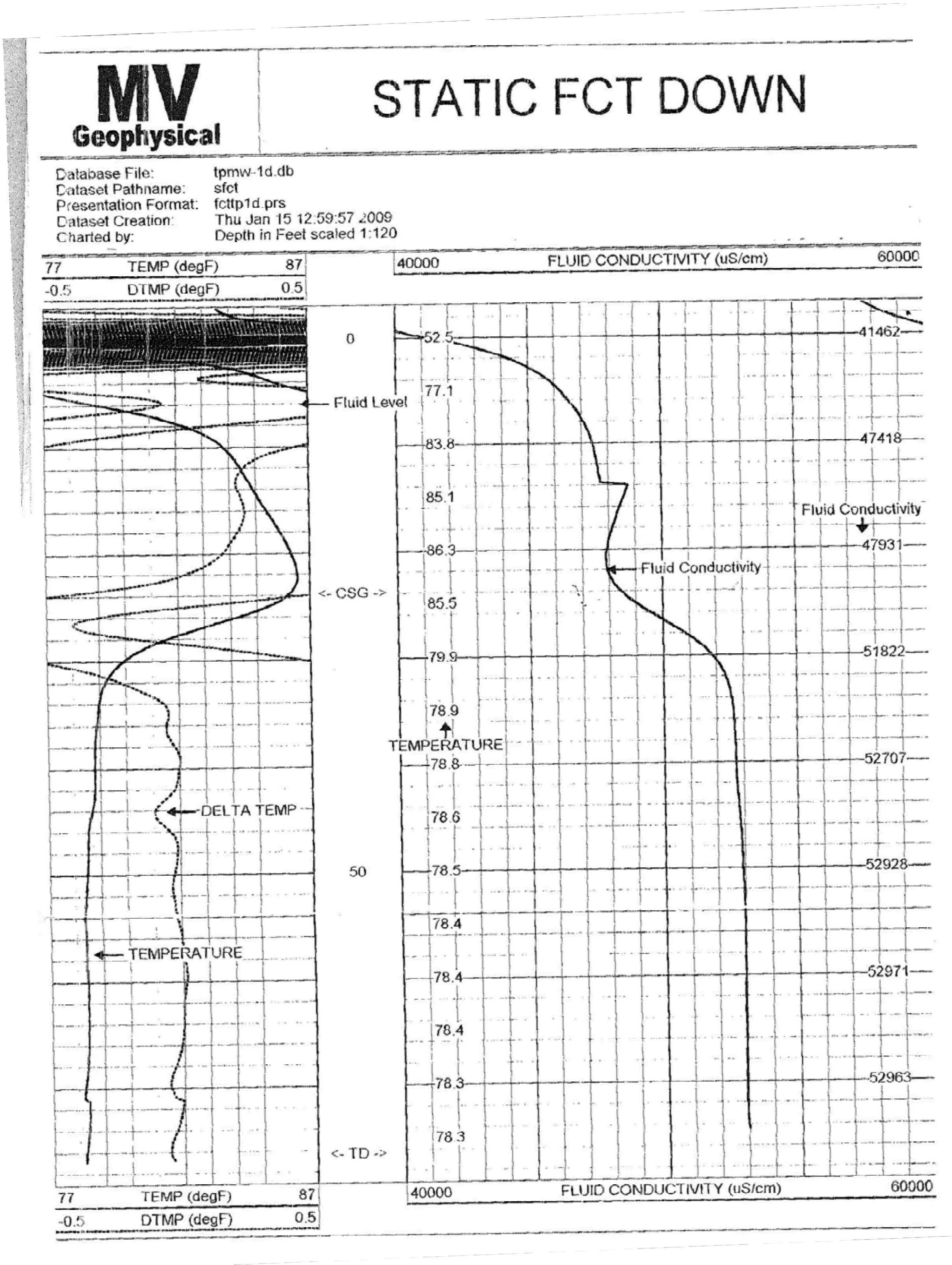
Lower portion of Light gray to White limestone

Upper portion of Light gray to White limestone

Source: Video Survey of MW-1 pilot hole at site
(MV Geophysical, Inc.);

Note: Depth approximately 1' less than shown

FPL	Florida Power and Light	HDR HDR Engineering, Inc. 5426 Bay Center Drive Suite 400 Tampa, Florida 33609	**Video Still - Light Gray Limestone** Turkey Point Exploratory Drilling and Aquifer Testing Program	DATE 8/19/09 FIGURE 2.15



Source: Geophysical logging of MW-1 pilot hole at site (MV Geophysical, 2009)

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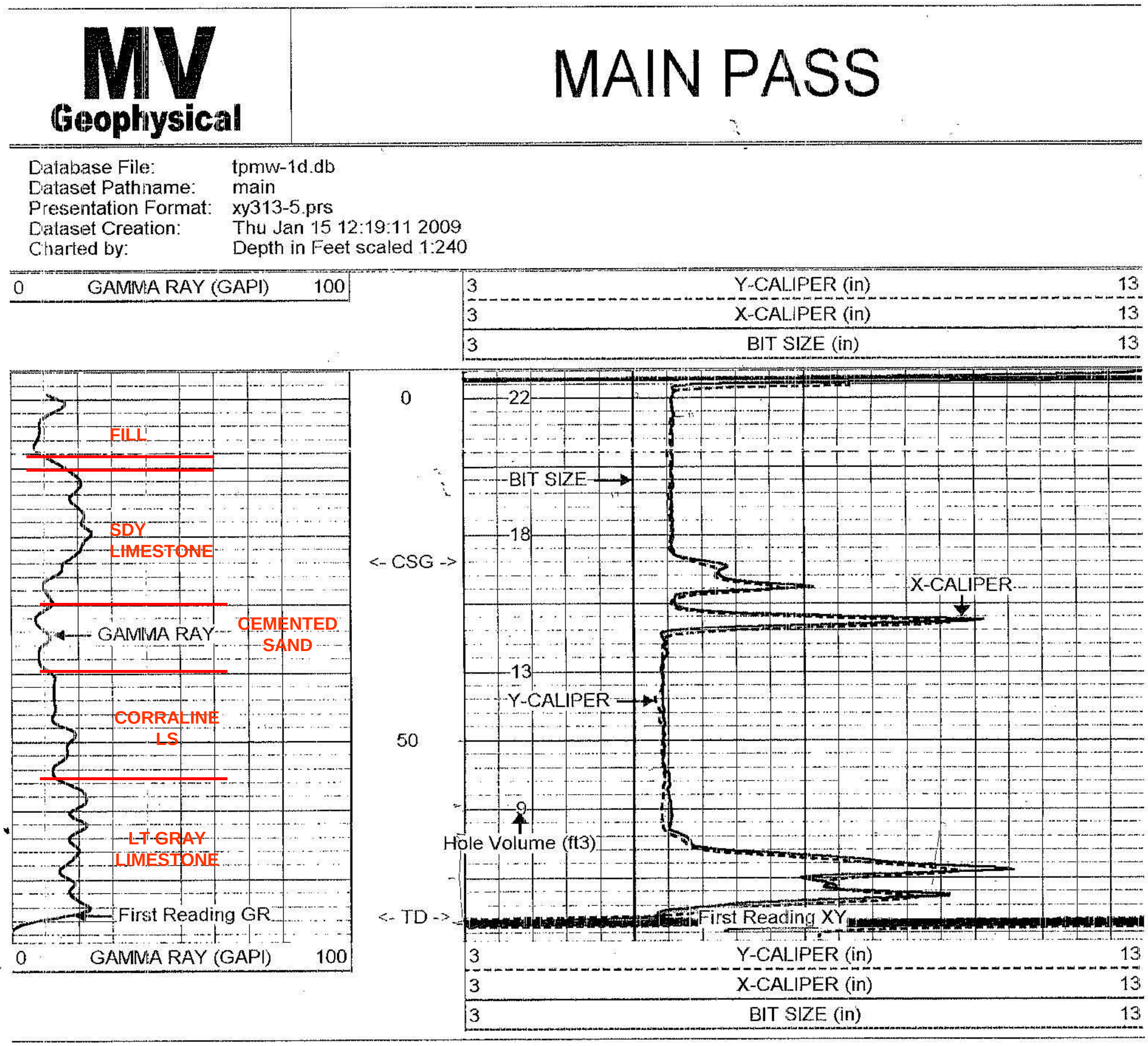
Fluid Conductivity and Temperature Log

Turkey Point Exploratory Drilling and Aquifer Testing Program

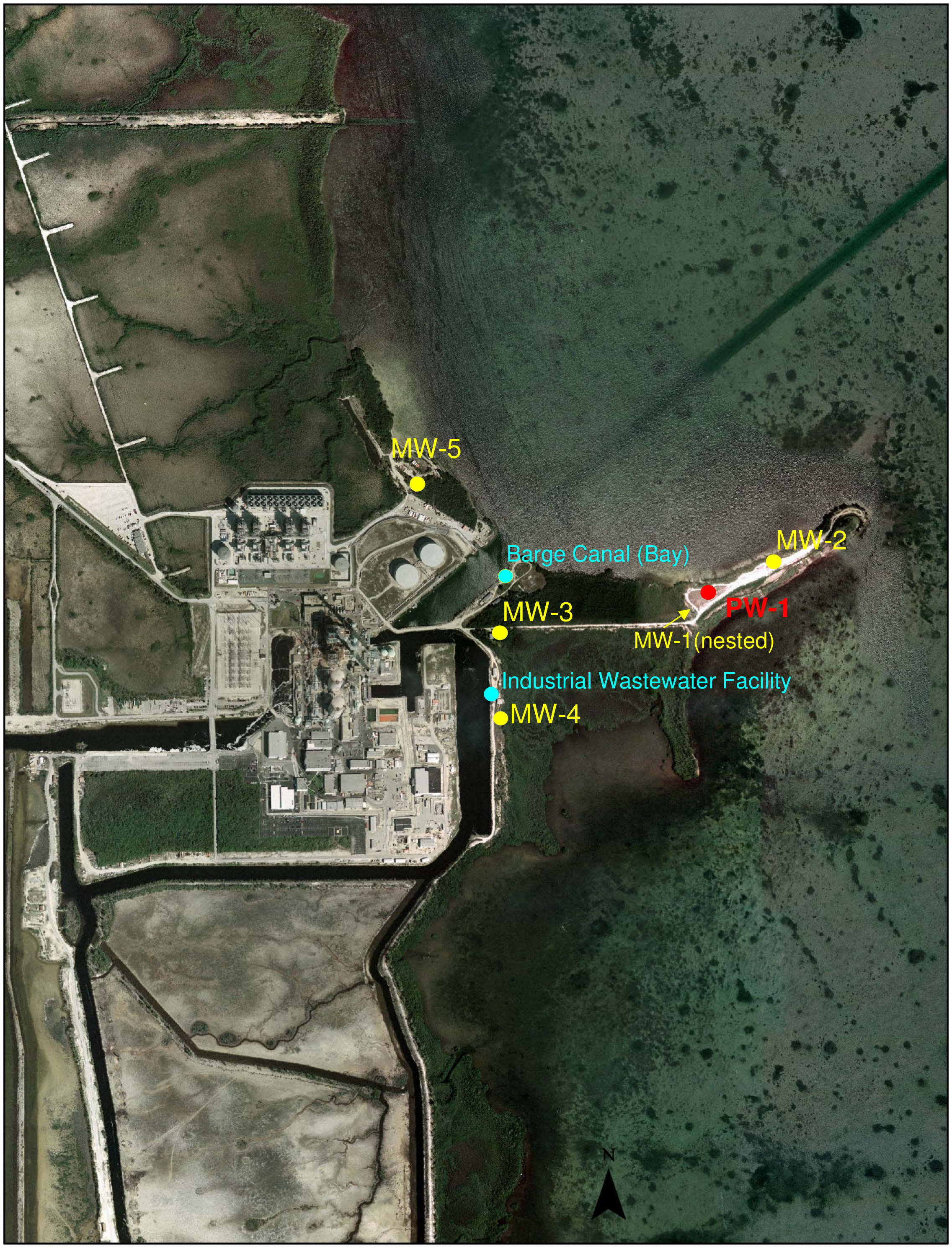
DATE 8/19/09

FIGURE 2.16



Source: Geophysical logging of Pilot hole MW-1 at site; MV Geophysical Inc, 2009

FPL Florida Power and Light	HDR HDR Engineering, Inc. 5426 Bay Center Drive Suite 400 Tampa, Florida 33609	**Gamma-Caliper Log MW-1** Turkey Point Exploratory Drilling and Aquifer Testing Program	DATE 8/19/09 FIGURE 2.17



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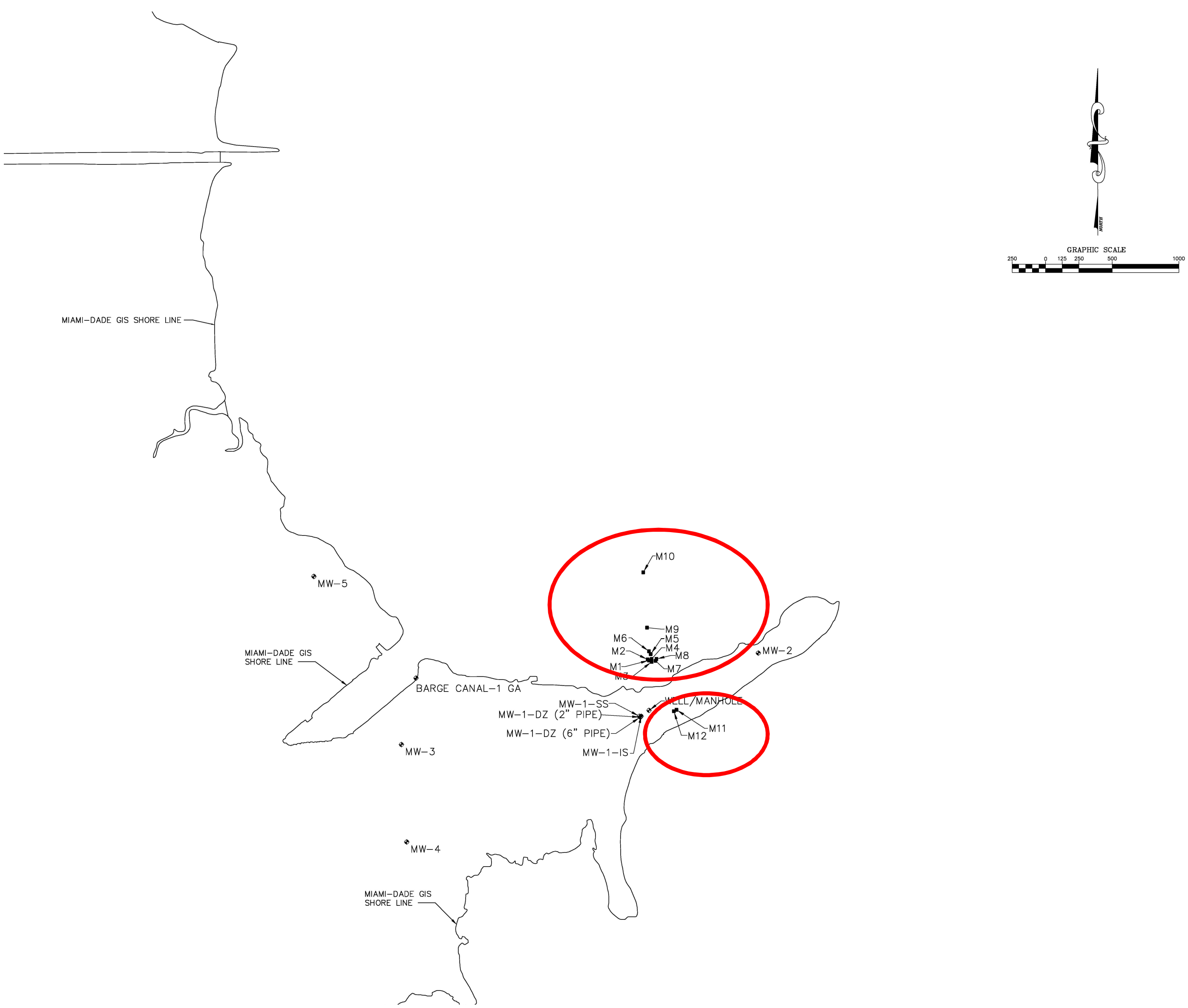
Location of Wells and Surface Water Monitoring Points

Turkey Point Exploratory Drilling and Aquifer Testing Program

DATE
8/19/09

FIGURE
3.1



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Seepage Meter Locations

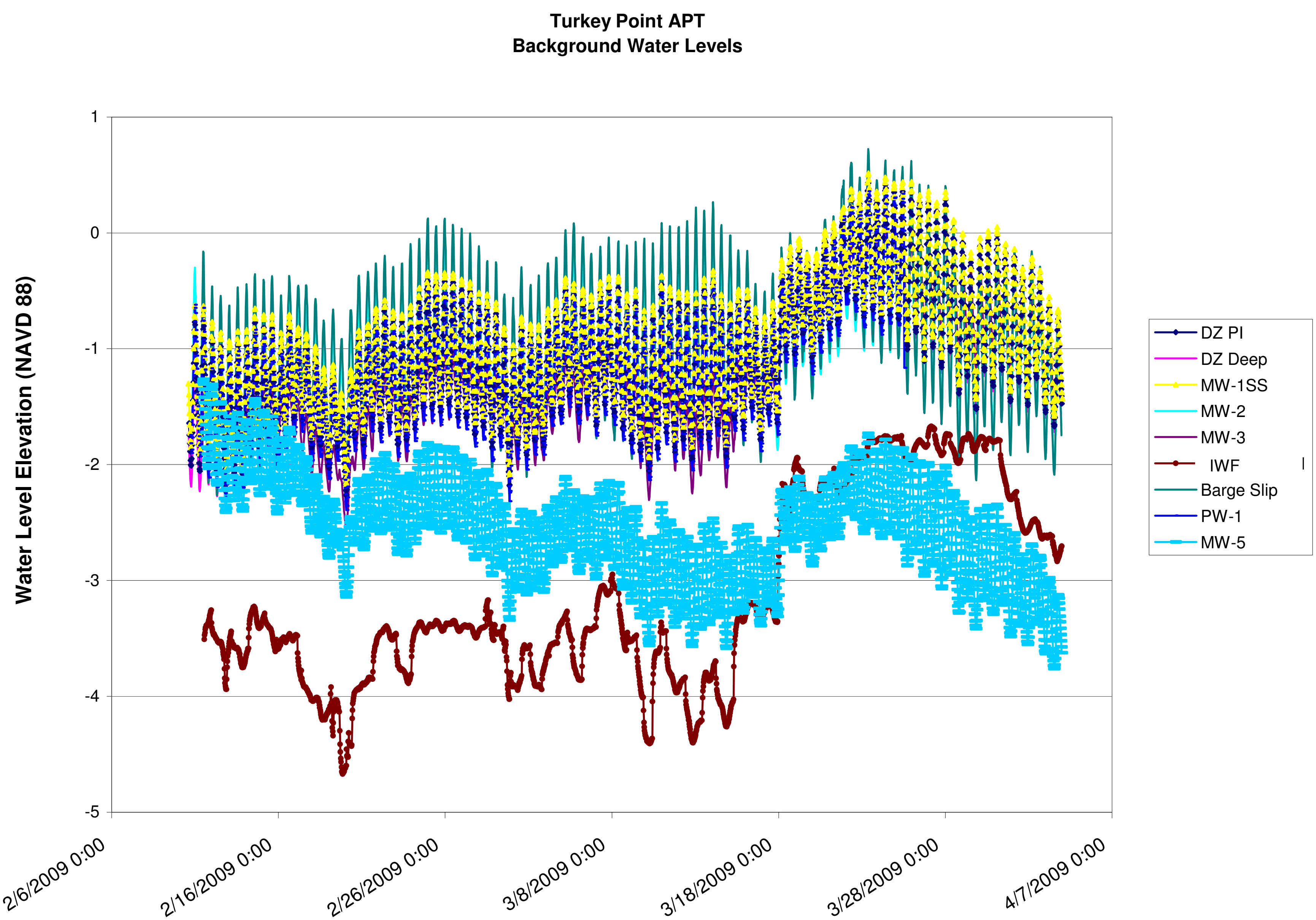
Turkey Point Exploratory Drilling and Aquifer Testing Program

DATE

8/19/09

FIGURE

3.2



Source: site water levels

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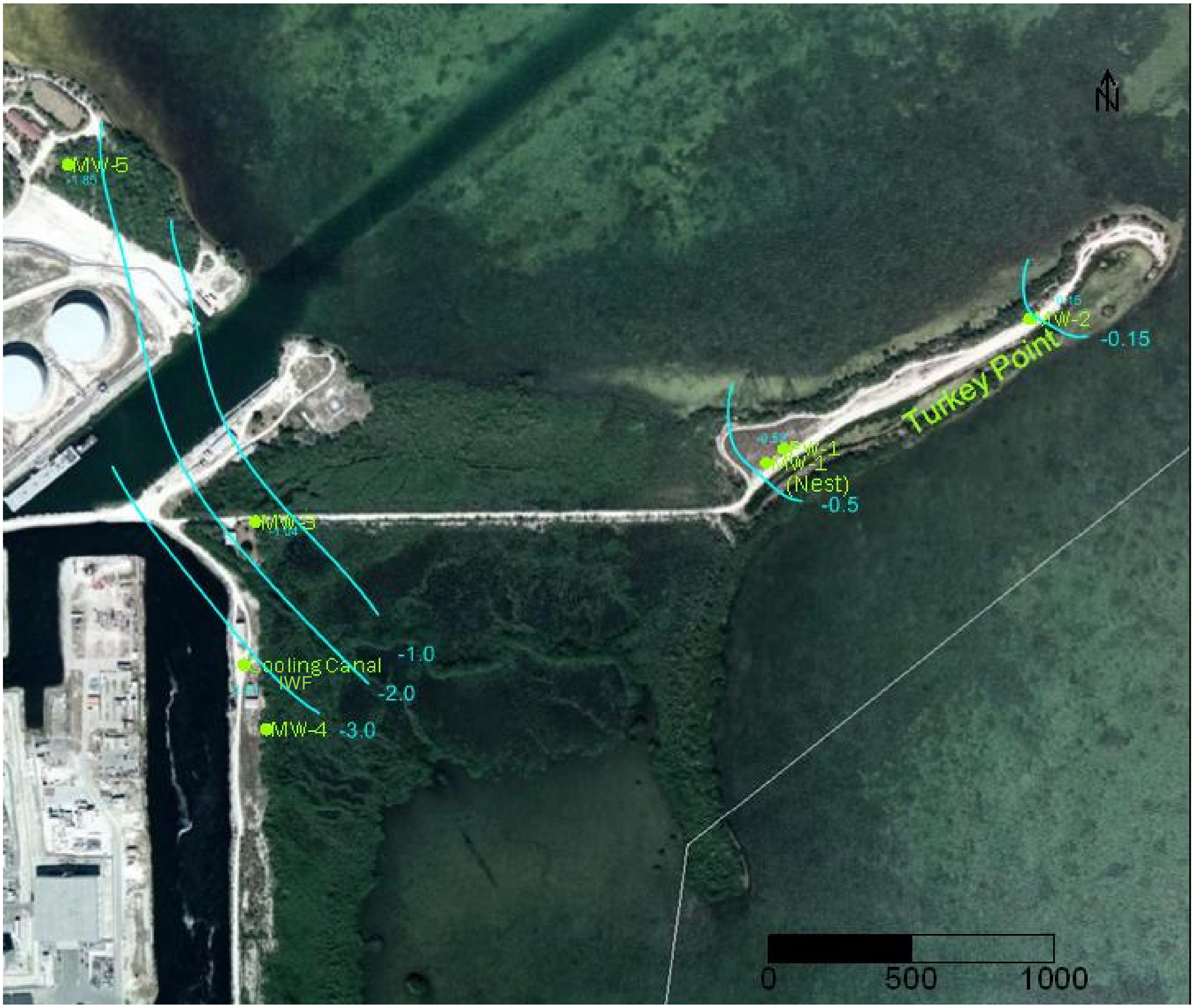
Background Water Levels

Turkey Point Exploratory Drilling and Aquifer Testing Program

DATE 8/19/09

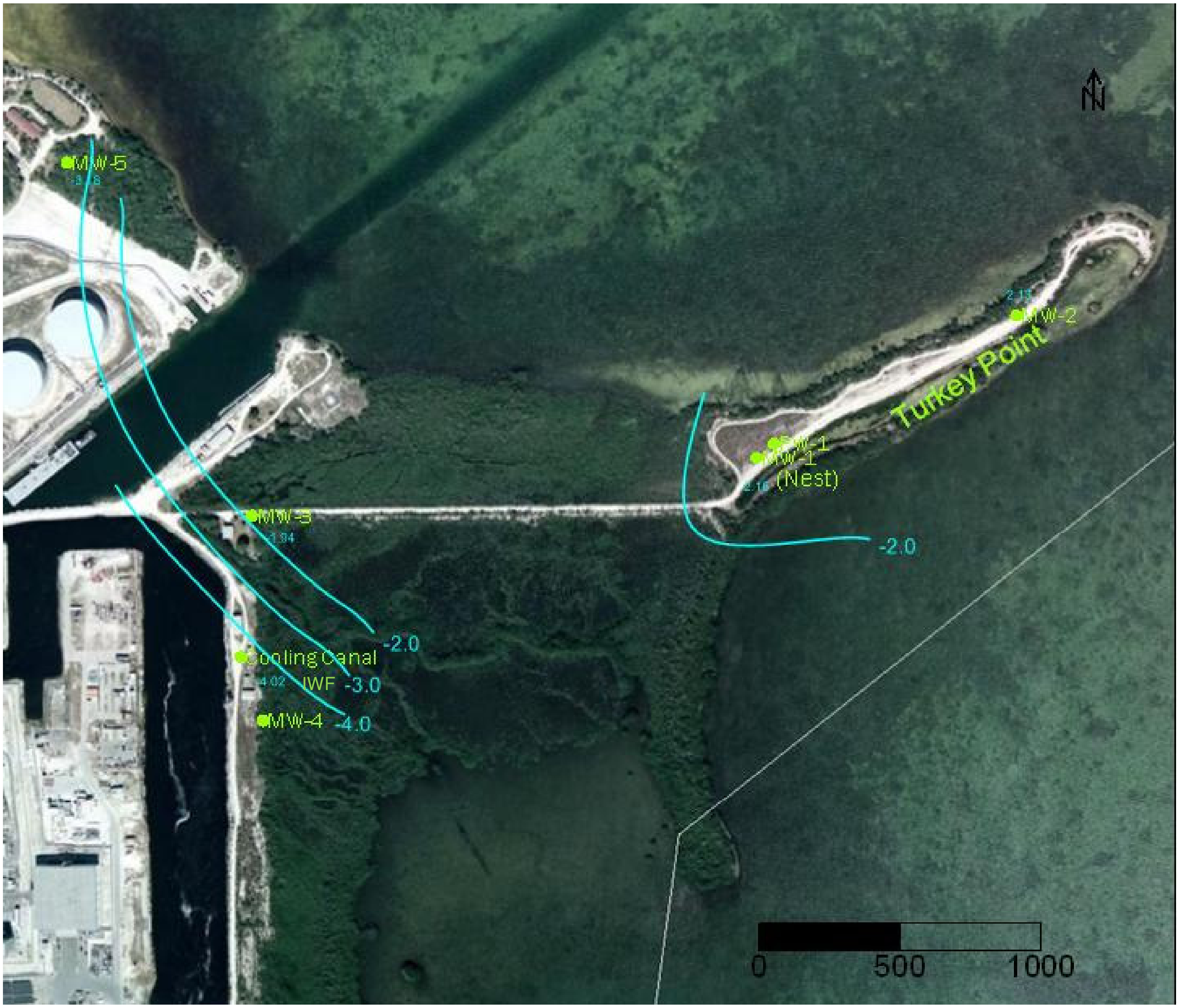
FIGURE 5.1



Source: Groundwater Levels measured at site

Contour Interval= 1.0 feet; supplemental contours at 0.15 and 0.5 feet

Florida Power and Light	HDR Engineering, Inc. 5426 Bay Center Drive Suite 400 Tampa, Florida 33609	**Groundwater Elevation Contours** **February 25, 2009 (high tide)** Turkey Point Exploratory Drilling and Aquifer Testing Program	**DATE** 8/19/09	**FIGURE** 5.2



Source: Groundwater Levels measured at site;

Contour Interval 1.0 Feet

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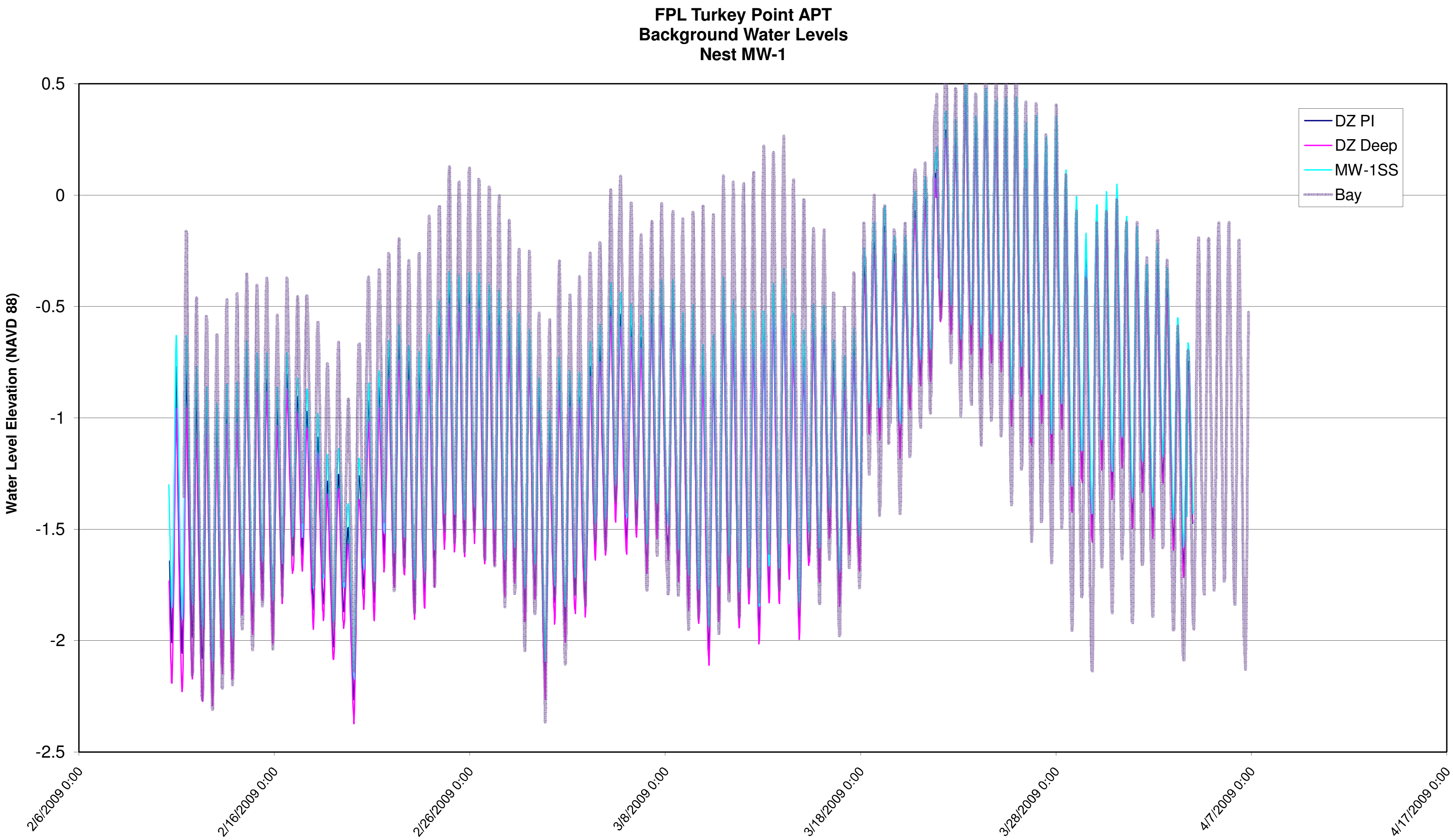
Groundwater Elevation Contours

March 1, 2009 (low tide, NAVD 88)

Turkey Point Exploratory Drilling and Aquifer Testing Program

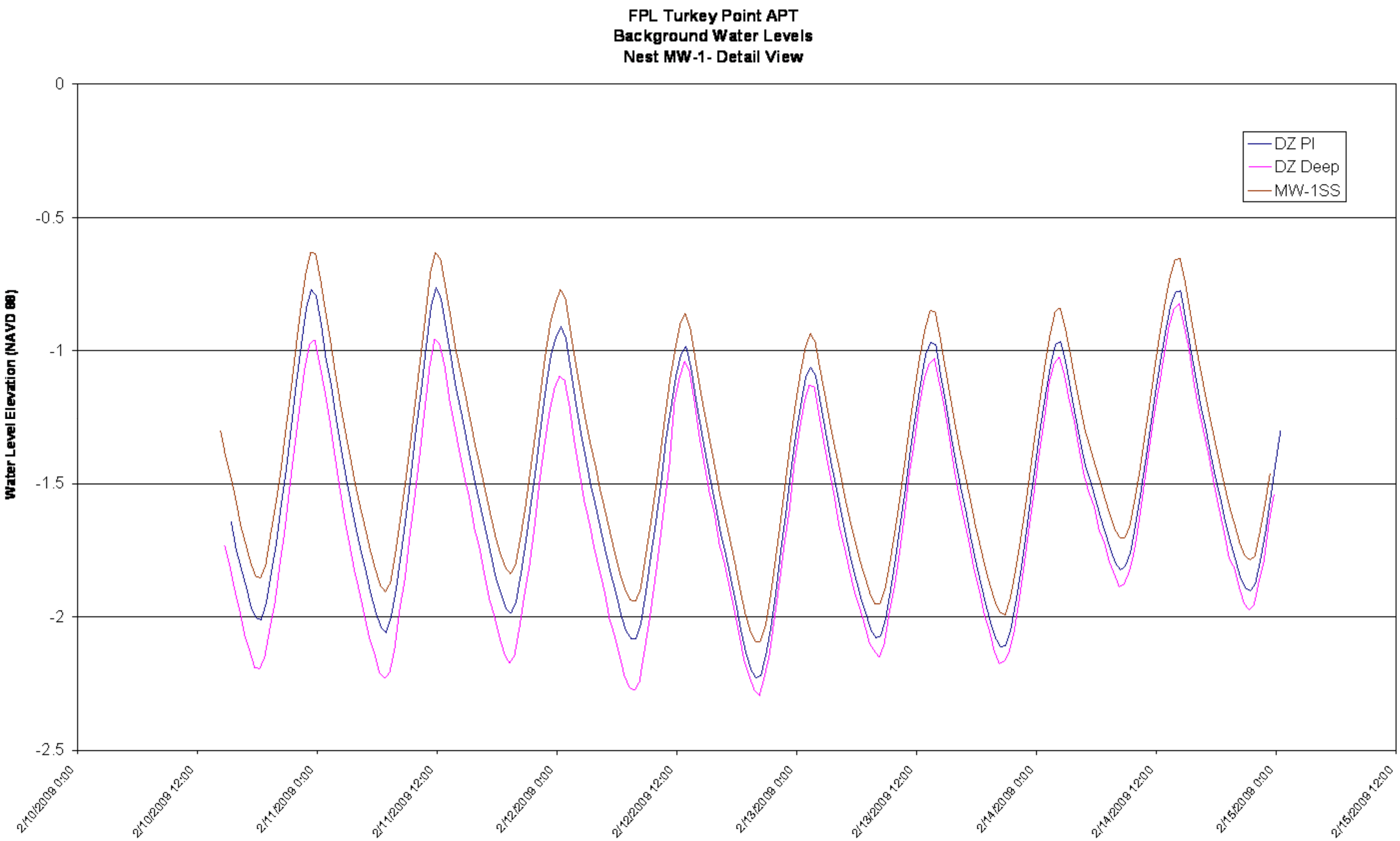
DATE 8/19/09

FIGURE 5.3



Source: water levels obtained during APT program;
Note: MW-1SS corrected to equivalent saltwater heads

FPL — Florida Power and Light	HDR Engineering, Inc. 5426 Bay Center Drive Suite 400 Tampa, Florida 33609	**Background (Pre Test) Water Levels at Nest MW-1 Showing Biscayne Bay** Turkey Point Exploratory Drilling and Aquifer Testing Program	DATE 8/19/09 FIGURE 5.4



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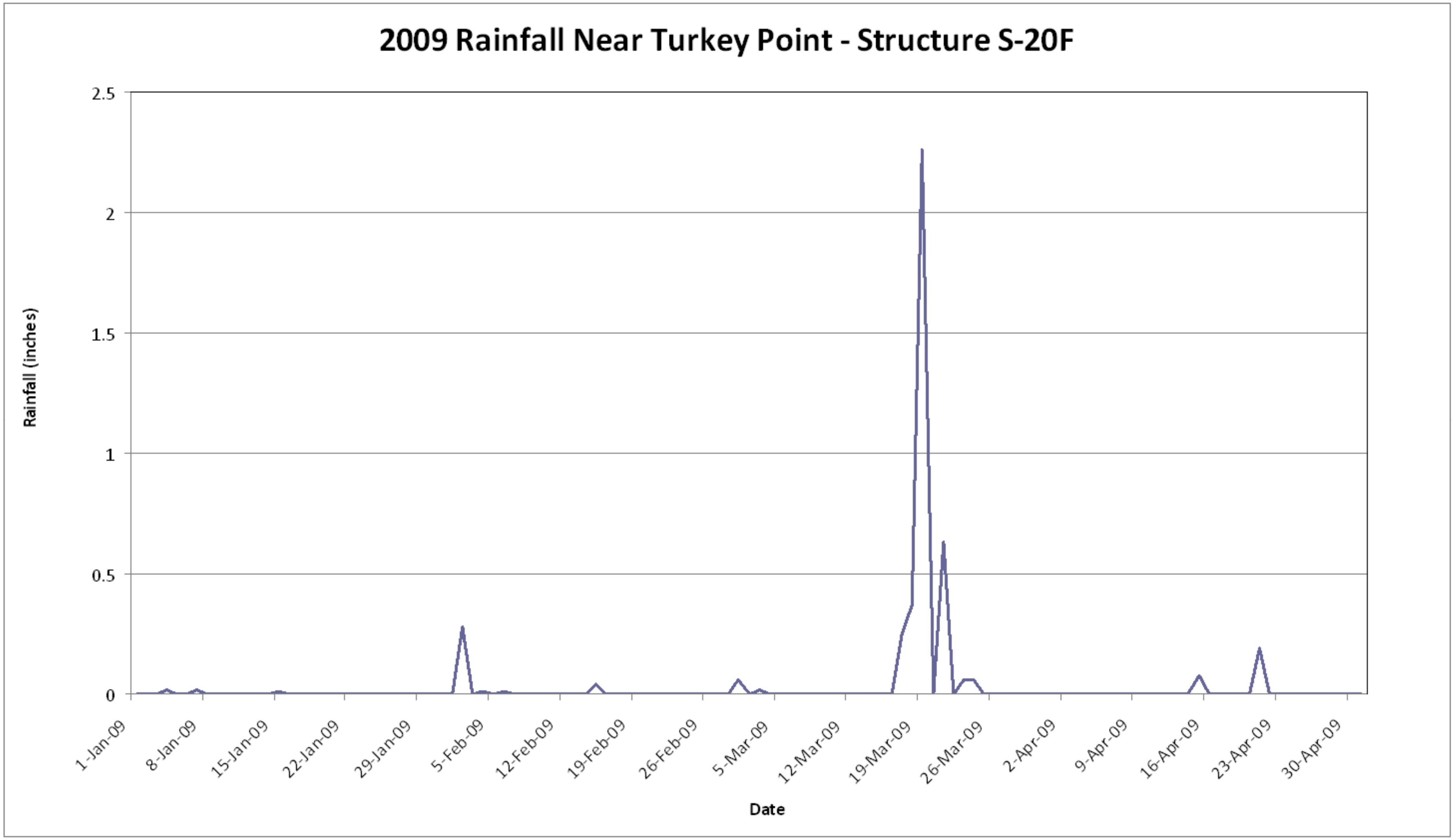
Nest MW-1 Background Groundwater Elevations, Detail View

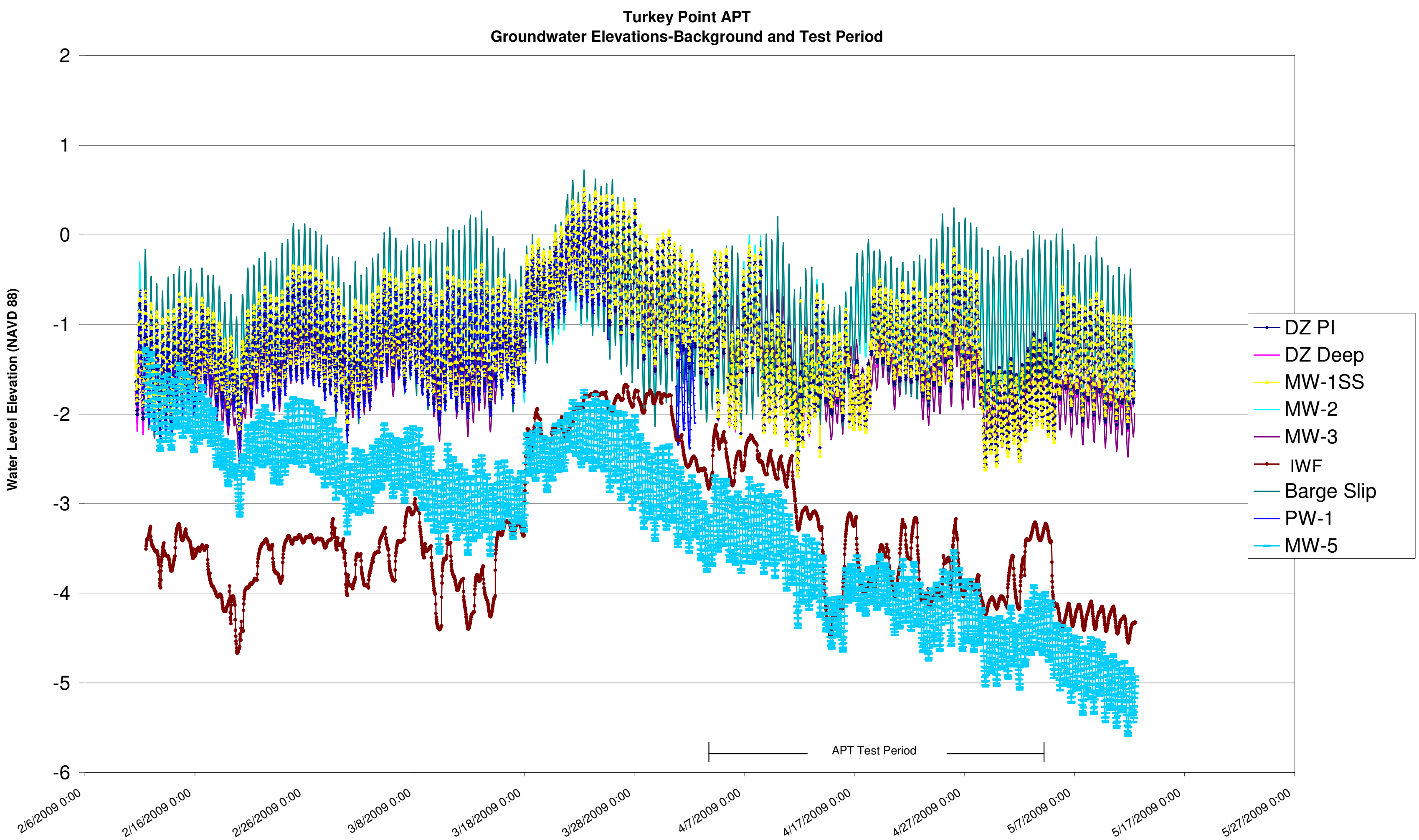
Turkey Point Exploratory Drilling and Aquifer Testing Program

DATE 8/19/09

FIGURE 5.5

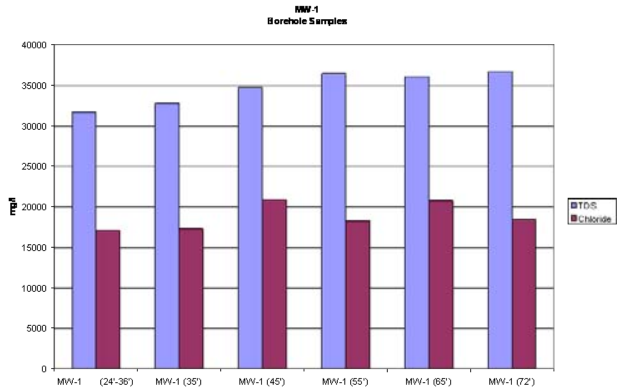


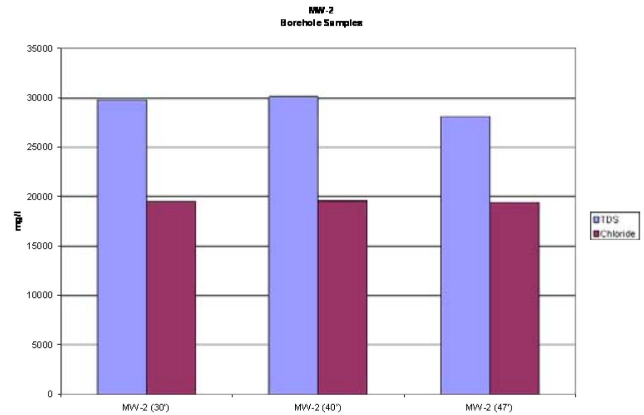
Florida Power and Light	HDR Engineering, Inc. 5426 Bay Center Drive Suite 400 Tampa, Florida 33609	**Rainfall- Station S-20F** Turkey Point Exploratory Drilling and Aquifer Testing Program	DATE 8/19/09 FIGURE 5.6

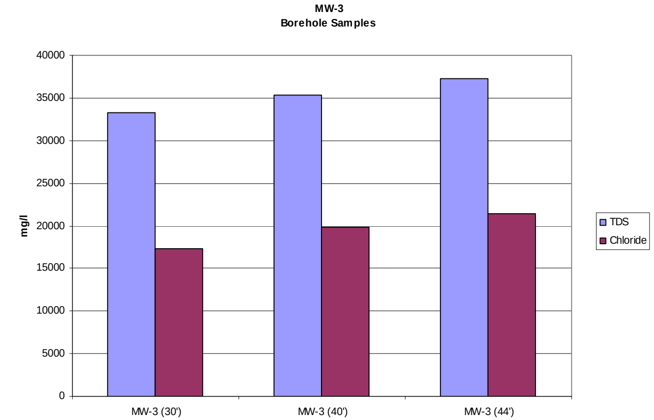


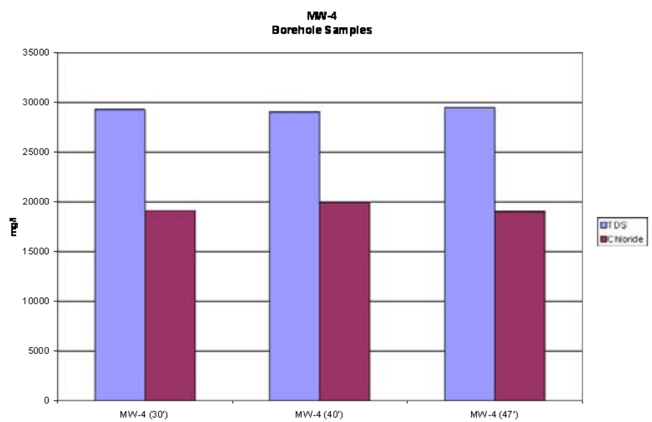
Source: Water level data obtained from site monitoring points

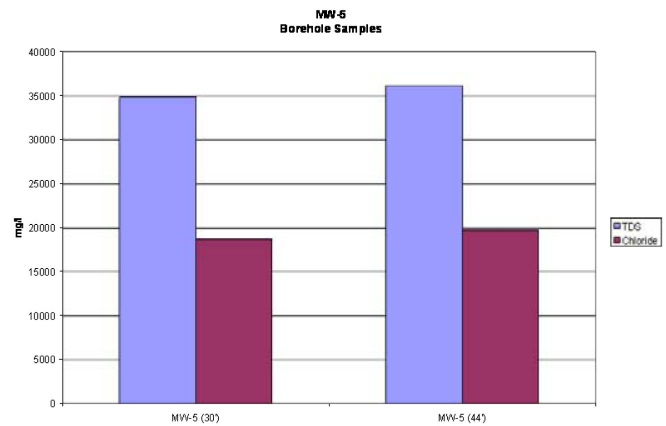
Florida Power and Light	HDR Engineering, Inc. 5426 Bay Center Drive Suite 400 Tampa, Florida 33609	**Background and Test Period Water Levels** Turkey Point Exploratory Drilling and Aquifer Testing Program	**DATE** 8/19/09 **FIGURE** 5.7

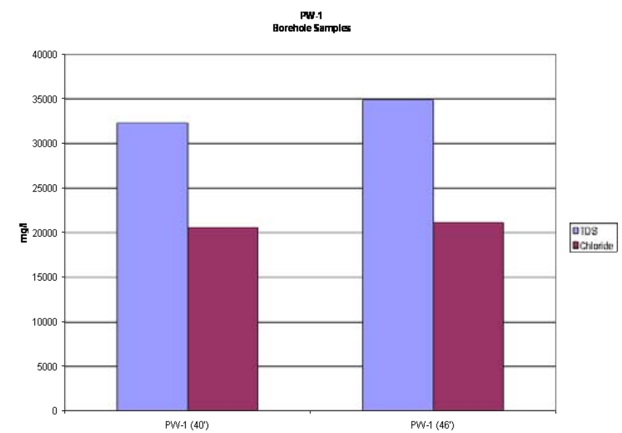












Source: water quality data obtained during APT program

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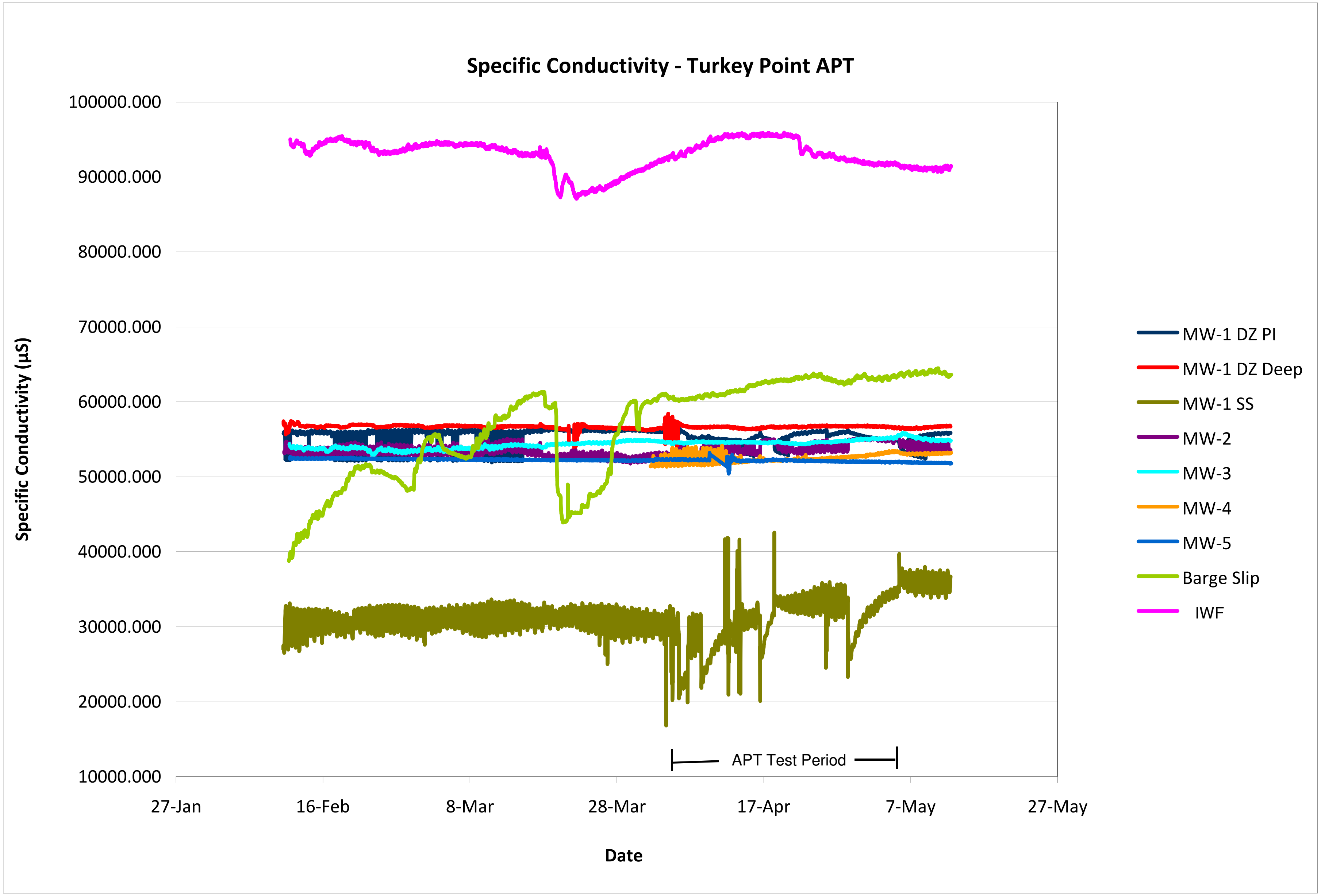
Water Quality Results- Borehole Samples
TDS and Chloride

Turkey Point Exploratory Drilling and Aquifer Testing Program

DATE 8/19/09

FIGURE 6.1



Source: Field water quality data obtained during APT program

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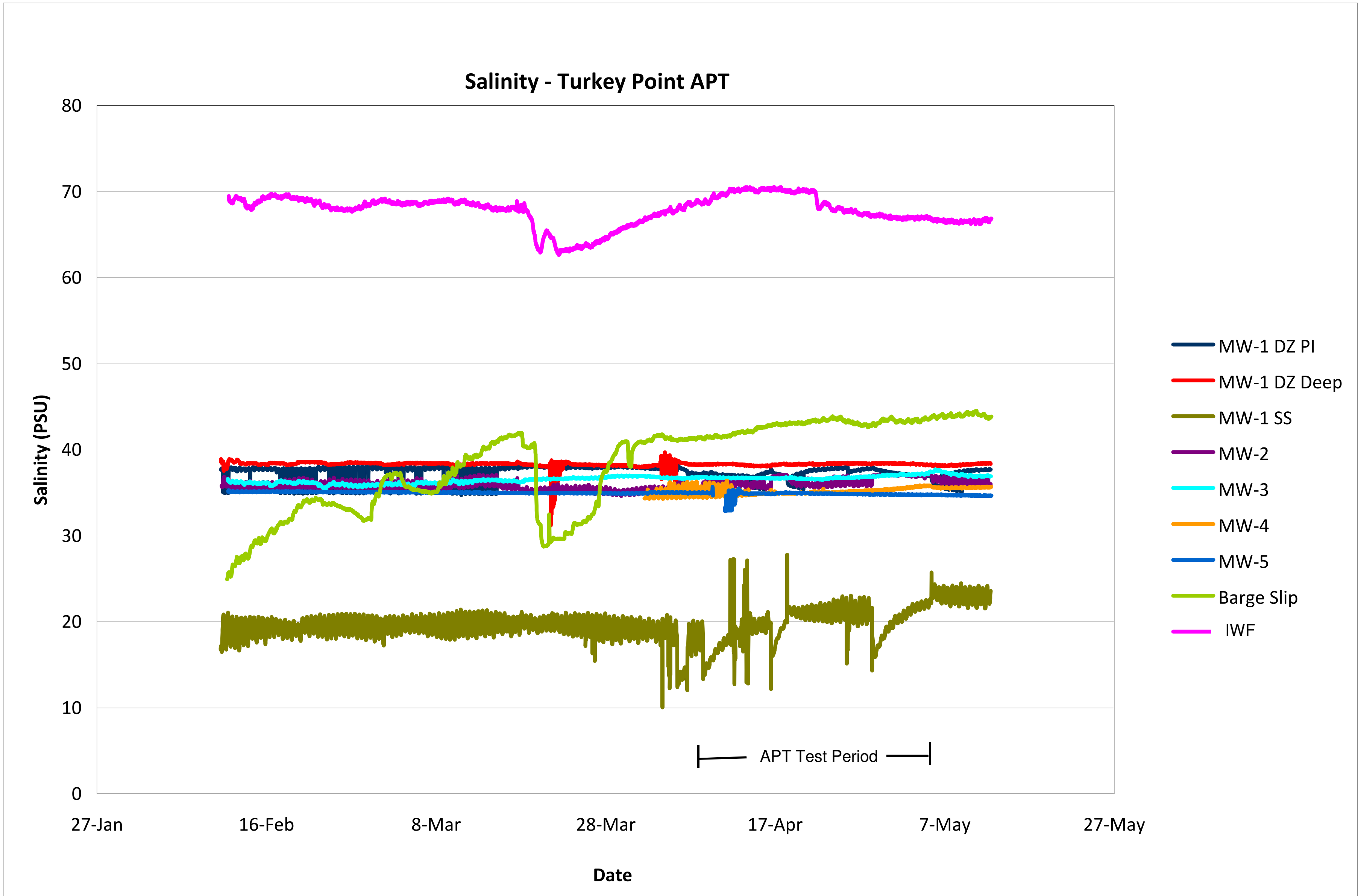
Specific Conductivity- Aqua Troll Data
All Monitoring Points
Turkey Point Exploratory Drilling and
Aquifer Testing Program

DATE 8/19/09

FIGURE 6.2



Source: Field water quality data obtained during APT program

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Salinity- Aqua Troll Data for All Monitoring Points

Turkey Point Exploratory Drilling and Aquifer Testing Program

DATE 8/19/09

FIGURE 6.3