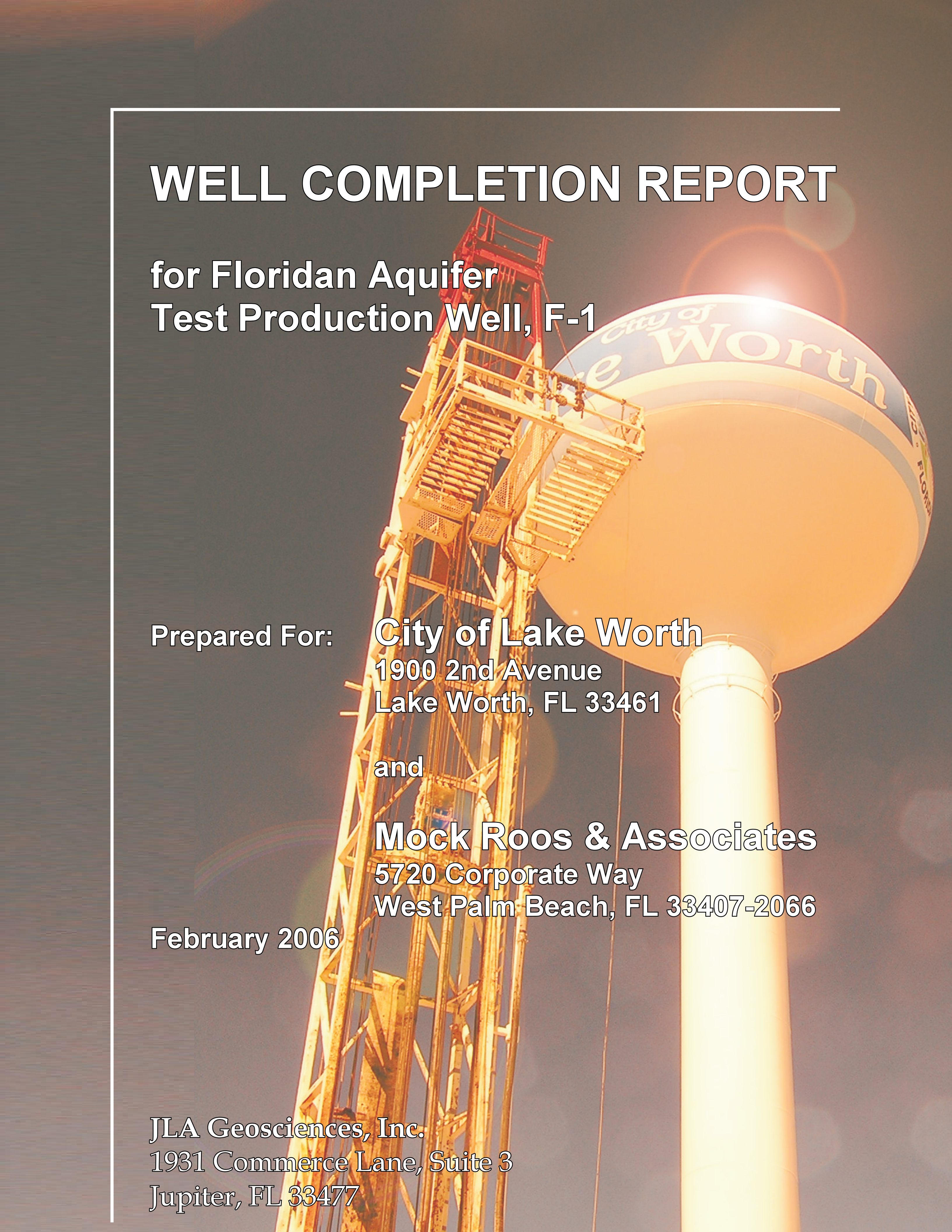

WELL COMPLETION REPORT

for Floridan Aquifer Test Production Well, F-1

Prepared For: **City of Lake Worth**
1900 2nd Avenue
Lake Worth, FL 33461

and

Mock Roos & Associates
5720 Corporate Way
West Palm Beach, FL 33407-2066

February 2006

JLA Geosciences, Inc.
1931 Commerce Lane, Suite 3
Jupiter, FL 33477

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January 2006

prepared by:

JLA Geosciences, Inc.
1931 Commerce Lane, Suite 3
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James L Andersen, P.G., JLA Geosciences, Inc
Licensed Professional Geologist #1103

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1.0 INTRODUCTION

This report documents the procedures, construction details, field test results and recommendations for the construction, development and testing of Floridan Aquifer test well F-1 for the City of Lake Worth, Florida. The project site is located in Lake Worth, Palm Beach County, Florida in Section 28, Township 44 South, Range 43 East, as shown in Figure 1. The well site is physically located east of I-95 and north of Sixth Avenue South, on the south side of the elevated water storage tank at the City of Lake Worth Water Treatment Plant. Well F-1 was constructed as a test production well under SFWMD Construction permit # SF082404A and will be converted to a public water supply well under SFWMD Individual Water Use permit No. 50-00234-W.

This project included construction and testing of a 16-inch by 12-inch diameter PVC test well completed to a total depth of approximately 1,520 feet. By analysis of the geologic formation and water quality samples collected during drilling and geophysical logging of the boreholes, the hydrogeologist was able to determine drilled hole and casing setting depths. Additionally, this information was used in the interpretation of aquifer flow zones and water quality, which were the deciding factors determining total well depth. Drilled pilot holes, boreholes and casing set depths were installed shallower than estimated in the Contract Schedule of Values because targeted zones were stratigraphically higher than expected. The Floridan Aquifer underlying the test well site was found to be productive, having a specific capacity of 99 gallons per minute / foot drawdown (gpm/ft) at the design flow rate of 1,500 gpm. Dissolved chloride concentrations for F-1 were measured in the range of 1,875 mg/l to 1,905 mg/l. Test well F-1 met or exceeded design expectations in terms of water production quantity and water quality.

JLA Geosciences, Inc. prepared technical specifications and performed on-site observation of well construction, development and pump testing. All Webb's

Enterprises, Inc., of Jupiter, Florida was the well contractor for the project. The methods and materials used by the drilling contractor were in accordance with the technical specifications outlined in the contract documents; the standards of the American Water Works Association for Deep Wells (AWWA A100-90); and National Water Well Association standards. Well construction of test well F-1 began in January 2005 and was completed in July 2005.

2.0 TEST WELL CONSTRUCTION AND TESTING

JLA Geosciences, Inc. (JLA) prepared technical specifications and performed on-site observation during well construction, development and pump testing. The location of the well site is shown on Figure 1. Well construction details including borehole and casing diameters, casing types and depths of completion are provided in Table 1. A schematic diagram of well F-1 is provided as Figure 2. The drilling procedure used for the test well is described below.

2.1 Construction of Well F-1

A pilot hole was advanced from land surface using the mud rotary method with a 12-inch diameter bit. Lithologic samples of the penetrated strata were collected from the circulating mud and a JLA Geosciences geologist prepared a field lithologic log based on the drill cuttings. Pilot-hole drilling continued to a depth of 335 feet below land surface (bls) to determine a suitable depth for surface casing placement. According to the City of Lake Worth Utilities personnel, nearby wells completed in the surficial aquifer had reported losses of drilling fluid circulation at approximately 60 feet bls. A loss of drilling fluid circulation indicating high permeability limestone was noted in the F-1 pilot hole between 57 and 60 feet bls.

Following reaching 335 feet bls with the pilot hole, drilling fluid was circulated to clear the hole of cuttings. Geophysical logging (SP, resistivity logs, gamma ray and caliper log) was then performed by MV Geophysical Services, Inc. of Fort Myers, Florida (MVGS) as described in Section 2.8, Geophysical Logging.

After geophysical logging was completed, a 36-inch diameter borehole was advanced to a depth of approximately 202 feet bls using the mud rotary method. The surface casing was completed to 200 feet bls to prevent the circulation losses, experienced at 60 feet bls, from becoming a problem during subsequent drilling. Additionally, installation of the surface casing prevented the collapse of unconsolidated materials near land surface from undermining the drilling rig foundation. Drilling fluid circulation continued until the mud was clear of cuttings and the borehole was ready to accept casing installation. The surface casing consisted of 30-inch diameter, 0.375-inch thick, steel pipe with factory-beveled joints that were butt welded together. To allow a more uniform grout job, centering guides that position casing in the center of the borehole were welded onto the casing at 40-foot intervals. Upon completion of casing installation, the annular space was grouted using a neat cement mixture from 200 to 100 feet bls and then 6% bentonite mixture of API class B Portland cement from 100 feet bls to land surface. The cement was allowed to harden 24 hours before drilling was resumed.

Following installation of the surface casing, 12-inch diameter pilot hole drilling resumed. Initial drilling of the cement plug was performed using a 26-inch reaming bit assembly with a nominal 12-inch diameter lead bit. The 12-inch diameter pilot hole was drilled to a depth of 1,047 feet bls, and geophysically logged as done previously by MVGS, as described in Section 2.8. From the pilot hole and geophysical data, the length of the 18-inch diameter intermediate casing was determined. The borehole was then reamed to 914 feet bls using the mud rotary method. A ten-foot separation between the lead bit and the reamer bit was necessary to keep the reamed hole from deviating from the pilot hole. After circulating to clear the borehole of drill cuttings and conditioning the drilling fluid, the driller removed the drilling tools and MVGS performed caliper logging of the borehole. The intermediate casing string consisted of 18-inch diameter, 0.375 inch thick butt welded steel casing, and was installed into the nominal 26-inch diameter borehole to a depth of 912 feet bls. The top of the 18-inch diameter casing string was set at 180 feet bls and overlapped the 30-inch diameter surface casing by 20 feet. The casing was pressure grouted using API Class B Portland cement. The initial grouting stage was neat cement in order to obtain maximum strength near the base of the casing; subsequent grouting stages performed by the tremmie method, consisted of a 6% bentonite mixture. Grouting continued until the annular space was completely filled with cement. Following cementing, the well was given a 24-hour cement curing rest period before drilling operations resumed. After the cement hardened, drilling resumed using the reverse air rotary method. A nominal 16.25-inch diameter bit was used to advance the borehole to the total depth of 1,520 feet bls. Upon reaching the total depth of well F-1, the driller cleared the borehole of drill cuttings and MVGS performed geophysical logging as described in Section 2.8.

The final casing (16” x 12” PVC) depth for well F-1 is 1,210 feet bls and was determined based on review of drilling lithologic samples, reverse air drilling water quality data, flow test results, geophysical logs, flow logs and water quality logs. The primary objective during well construction was to select an interval within the Floridan Aquifer with the highest permeability and best water quality. Additionally, the selected interval had to be composed of competent formation material to minimize erosion and the subsequent contribution of particulate matter to the raw water. Some sections of the reverse air drilled borehole were heavily eroded because of the soft formation encountered. These undesirable formation sections were sealed off and grouted behind the final casing string. The interval selected as most desirable for open hole completion of the well was a hard dolomitic limestone and dolomite flow zone sequence located within the lower Ocala Limestone and upper Avon Park Limestone.

The final casing string was composed of Certainteed, Certa-Loc, SDR-17 lock coupling PVC casing. The casing string for well F-1 consisted of 160 linear feet of 16-inch diameter upper casing, a 16-inch by 12-inch reducer bushing and then 1,050 feet of 12-inch diameter lower casing (less the reducer bushing segment) reaching a total casing depth of 1,210 feet bls, Table 1.

Cementing the casing into place was conducted in stages to minimize grouting stress on the PVC casing caused by the heat of hydration. The open hole was first filled with gravel to prevent cement grout from migrating into the producing zone of the well. Once the gravel fill was confirmed to be within 2 to 3 feet of the base of the PVC casing, a small batch of neat cement was placed in the bottom of the casing. The casing was raised to allow the cement to flow into the annulus and then the casing was reset to the selected casing depth. The remaining cement lifts were pumped into the annulus using the tremmie method. After each lift of cement had hardened, the cement fill depth was measured. Well F-1 required eight (8) major grouting stages to completely fill the annular space between the casing and borehole.

The second grouting stage (1st annular tremmie stage) included neat Portland cement only, whereas stages 3 through 8 included up to a 6% bentonite grout mixture. The purpose of going to the higher percentage of bentonite in the cement was to minimize the heat of hydration in the cooling process. Once the grouting was completed a video log of the well was performed to assess the status of the grouting and casing. This method of grouting proved successful.

2.2 Drilling Water Quality Testing

During reverse air drilling in the Floridan Aquifer, specific conductance and chloride concentration of the formation water were measured at intervals of approximately 10 feet. After appropriate lag time, water samples were collected from the reverse air discharge after the bit had drilled at the desired sampling depth. The sample lag time was calculated at the onset of drilling after each drill rod change. Chloride analysis was performed using a Hach titrator and Silver nitrate titrant. A summary of the water quality data collected for well F-1 during drilling is provided in Table 2.

2.3 Drilling Flow Testing

During reverse air drilling through the Floridan Aquifer, flow tests were performed to evaluate the specific capacity of the penetrated open interval. The tests were performed after every drill rod change (approximately every 30 feet). To perform the test, a construction header was fitted to the flanged 30-inch diameter surface casing and sealed to the drilling tools with a rubber stripping header. The construction well head effectively sealed the well so that drilling could be done under artesian conditions. The construction header was equipped with a valved, 12-inch diameter flow port, a 2-inch port for adding brine "kill" water to stop the well from flowing if needed, and a 3/4-inch manometer fitting. A manometer tube was fitted to the construction header to measure the potentiometric water level, which under static conditions reached as high as 24 feet above land surface.

The flow rate was measured using an orifice weir and an in line flow meter that was installed in the 12-inch diameter HDPE pipe line that discharged to the lined pond. An in-line centrifugal pump was used to boost pressure to deliver maximum potential flow rate to the pond. Water levels in the well were measured during the pump test and compared to static, no-flow conditions measured at the beginning of each day and after each test. Measurement of flow rate (Q) and draw down in the well (dh), allowed calculations of specific capacity (C_s) of the well to be approximated using the formula $C_s = Q/dh$ (Freeze and Cherry, 1979).

Table 2 includes a summary of the calculated values for specific capacity from the flow tests conducted during advancement of the drill pipe, and immediately following completion of well drilling.

2.4 Borehole Jetting Development

During the drilling process, fine grained sediment is generated that is only partially removed from the well by traditional pump development methods. These settled solids can be slowly released from a well into the raw water over time and are problematic to micron filters and reverse osmosis membranes. Traditional development methods that employ pumping methods at land surface do not effectively impart enough velocity at the locations deep in the borehole needed to dislodge the settled solids in a timely and cost effective manner. Very high pumped flows of turbid brackish water from wells are also often times difficult to manage and sometimes not feasible.

A plan was developed to deliver high velocities directly in the borehole with the use of the drill rig and a rotating jetting tool. Following completion of the well but before acid treatment, a jetting tool consisting of four opposing jets spaced 90 degrees apart and one additional jet facing directly downward, was installed into the wells open hole interval. Using the mud system pumps and drilling tools, approximately 500 to 600 gpm of water was delivered through the five jet development tool, imparting an exit velocity of approximately 20 feet per second. During jetting, the well was pumped to the formation water disposal system to remove jet-dislodged sediment from the well bore. This process was continued as the jetting tool was rotated and passed up and down the borehole. The development process took 40 hours of jetting followed by 60 hours of development pumping. Development proved very effective given the outcome of the pumping test results and low silt density index (SDI) of the raw water.

2.5 Well Acidization

Based on preliminary testing results following well construction, the initial specific capacity for F-1 was 58 gpm/ft of drawdown at a flow rate of 1,000-1,100 gpm. This was slightly less than the targeted specific capacity of 80 gpm/ft at design flow. Not knowing what the actual drawdown impacts would be from the wellfield, this conservative estimate was based on previous experience and was a preliminary estimate of the capacity needed to keep pumping water levels above land surface. It was for this reason that the well design included acid treatment. Additionally, higher capacity wells may reduce the need for future rehabilitation and/or the number of future wells that will ultimately be needed.

F-1 was acidized on June 6, 2005. The acidization procedure consisted of installing 1,410 feet of drop tubing into the well, and pumping 7,000 gallons of 32%, (20^{o} Baume) hydrochloric acid into the open interval, followed by enough water to displace the tubing. During pumping, the wellhead was sealed and fitted with a pressure gauge to monitor internal casing pressure. A relief valve and gas discharge hose was installed on the wellhead to vent off excess pressure in the well if needed. Venting was not necessary. After completing the acidization procedure, the well remained undisturbed for approximately 12 hours until development of the well was resumed.

Following acid treatment and development, the specific capacity of well F-1 was determined to have increased to 112.6 gpm/ft at 1,000 gpm. This represented an improvement of 94 percent due to the acid treatment.

2.6 Well Development Pumping

Well F-1 was developed using a diesel-powered, vertical turbine test pump equipped with a 12-inch diameter pump and 10-inch diameter column pipe capable of pumping at a steady rate 500 gallons per minute (gpm) to 4,000 gpm. Based on prior experience with wells of this size, a steady flow of 4,000 gpm was considered necessary to effectively remove particulate matter from within the borehole.

Formation water from the Floridan Aquifer test well was discharged to the high density polyethylene (HDPE) lined formation water disposal pond via 12-inch and 16-inch diameter, above ground HDPE pipe to settle particulate matter and reduce turbidity.

The pump development protocol called for steady pumping at the maximum rate until the discharge water was visibly free of solids and turbidity. Following the steady flow period, the well was pumped intermittently with surge and rest periods. Development progress was measured by performing silt density index (SDI) testing on the raw water. Additionally, the specific capacity of the well was measured periodically during development to evaluate progress by improvement in well performance. Development was considered complete when the SDI test results were consistently near or below a value of 1.0 at design flow and the well no longer produced suspended sediment. In a few cases the SDI values exceeded 1.0 but were at flow rates higher than design.

2.7 Drawdown Testing

Following acidization and well development, a step drawdown test was performed on the well using the development pump and discharge setup. The completed well was pump tested to assess well yield and anticipated drawdown, and to aid in final well pump selection. The flow rates for the test were measured with an in-line flow meter, certified in calibration just prior to the start of this project. Before starting the test, the static water level was measured with an elevated manometer tube. The five-step drawdown test discharge rates ranged from 1,000 to 3,000 gpm. These rates bracketed the original design pumping rate of 1,500 gpm for well F-1 upon completion. Water levels were measured in the well at intervals of 5 to 15 minutes at each pumping rate until a near equilibrium drawdown within the well occurred. Water quality was measured during or at the conclusion of each step. Parameters measured in the field included: specific conductance, temperature, chloride, hydrogen sulfide, turbidity, suspended sand and silt density index (SDI).

The drawdown data was used in conjunction with the pumping rates to obtain estimated specific capacity values for each pumping rate. Results of the Step Drawdown Pump Test are provided in Table 3.

2.8 Geophysical Logging

Geophysical logs were performed in the pilot hole and/or reamed hole at each stage of well construction. The logs were used to aid in the decision-making and data gathering process to determine hole dimensions, casing setting depths, geologic formation characteristics, water quality, flow zone and aquifer characteristics. After completion of pilot hole drilling into the top of the Floridan Aquifer, a suite of geophysical logs was performed. This suite of logs including dual induction and fluid resistivity logs; self potential (SP) and natural gamma ray and were run by MVGS. The final suite of geophysical logs was conducted after completion of drilling the open interval, and included dual induction and fluid resistivity logs; self potential, natural gamma, temperature, caliper and flow. The final suite of geophysical logs were also performed by MVGS. JLA Geosciences observed the logging runs. Copies of the geophysical logs for each well are included in Appendix D.

The fluid flow logs revealed the presence of an enhanced production zone in the test well extending downward from approximately 1,210 to 1,450 feet bls. The flow zones where formation water enters the borehole consist of numerous small solution features that are not uniformly distributed across the completion interval. The individual solution features are more evident in the video log. The fluid geophysical logs were performed under flowing conditions.

2.9 Video Log

Following the completion of the well, Morton Pump and Drilling Company, Inc. performed a down-hole video on August 31, 2005. The video was performed under flowing conditions. Evidence of cement grout was generally limited to the area at and just below the base of the 12-inch casing which was at a depth of 1,210 feet bls. The casing in the well appeared to be in good condition as evidenced by the final video log for the well. Several areas of solution cavities and vertical fractures were visible in the flow zone intervals of the test well.

3.0 HYDROGEOLOGY

East Central Palm Beach County has two aquifer systems, the Surficial Aquifer and the upper Floridan Aquifer System. The drilling phase of the project penetrated these two aquifers to a depth of 1,520 feet. A JLA Geosciences geologist was present during key phases of the drilling to collect lithologic samples and log the geologic formation materials encountered. A lithologic log of well F-1 is provided in Appendix A. A hydrostratigraphic section showing the typical lithologies, aquifers and formation names encountered during drilling is provided as Figure 3.

3.1 Surficial Aquifer System

The surficial aquifer is the only fresh groundwater resource in southeast Florida and has a maximum thickness of approximately 500 feet in the area of well F-1. Descending from land surface, the surficial aquifer system formations include the Pamlico Sand, Anastasia, Fort Thompson, Caloosahatchee Marl, and Tamiami (Miller, 1987).

The veneer of sand covering most of south Florida, known as the Pamlico Sand, is also present beneath the site. The sand consists of fine to medium grained loose quartz sand grains, loose detrital clay and shell, and may be cemented as cap rock near the water table surface. Sand extends to a depth of 30 to 40 feet beneath the site where it becomes interbedded with sandstone and shell. Because the Pamlico does not have a distinct lower contact, the exact depth is not known.

The Anastasia Formation underlies the Pamlico and is commonly composed of coquina and mixtures of sand, shell, sandy limestone and sandstone. Lithologies of the Anastasia Formation vary greatly within Palm Beach County (Miller, 1987); however, vertical changes in lithology tend to follow a downward progression from unconsolidated sand and shell to calcareous sandstone and limestone. Sandstone and limestone units in the Anastasia and possibly of the similar aged Fort Thompson formation make up the producing zone of the surficial aquifer.

Regionally the units that underlie the Anastasia and the Fort Thompson are the Caloosahatchee Marl (Pleistocene and Pliocene), Tamiami Formation (Pliocene age) and/or the Formations of the Hawthorn Group (Miocene to late Oligocene age). Specific depths and even presence of these units are unclear in the available literature. Underlying the site, the associated lithologies consist of sand, shell, sandy limestone, and sandstone. With depth, these units undergo a downward fining trend and ultimately become the underlying confinement of the surficial aquifer system. The basal confining unit of the surficial aquifer occurs at approximately 530 feet bls beneath the site. From this depth, interbedded clay, sandstone marl and limestone predominate.

3.2 Intermediate Confining Unit

The intermediate confining unit consists of the relatively impermeable calcareous clays and silts of the Hawthorn Group. The Miocene to late Oligocene aged Hawthorn sediments consist of dense, olive gray clayey unlithified limemud, fine to very fine quartz and phosphate sand and silt. Also present are beds of shell and sandy limestone within the upper and lower reaches of the unit. Beneath the site, the thickness of the intermediate confining unit is approximately 310 feet. The predominantly clayey upper section of the unit is known as the Peace River Formation. The phosphatic limemuds and sandy-phosphatic limestones that underlie the Peace River are of the Arcadia Formation (Reese, 2000).

3.3 Floridan Aquifer System

The Floridan Aquifer System, a confined aquifer, underlies the intermediate confining unit. The brackish upper portion, having total dissolved solids concentrations less than 5,240 mg/l, is called the upper Floridan Aquifer. The entire thickness of the upper Floridan was not penetrated during drilling, but is expected to be approximately 1,000 feet thick. The upper Floridan is predominantly composed of interbedded limestone and dolomite of early Oligocene to middle Eocene age. Four primary rock units comprise the upper Floridan Aquifer System. From approximately 840 feet beneath the site, in descending order, these units are the Basal Hawthorne Unit (late Oligocene age), Suwannee Limestone (early Oligoocene age); Ocala Group (late Eocene age), and Avon Park Limestone (middle Eocene age) (Reese, 2000).

The maximum depth penetrated drilling test well F-1 was 1,520 feet bls. The lithology approaching the terminus of each well consisted of interbedded, fine grained, and fossiliferous, to microcrystalline limestone and dolomite.

The producing zones within the Floridan aquifer can generally be referred to as "flow zones". A flow zone is typically a thin sequence of highly solutioned rock where water, flowing within the aquifer, is concentrated. Numerous thin flow zones may contribute water to the open interval of a well and often times a high percentage of the water produced by the well comes from one or two thin flow zones.

Based on the lithologic logs, geophysical logs and wellhead flow data, the most productive flow zone occurred between approximately 1,210 feet bls and 1,450 bls in test well F-1. For this report, this interval will be referred to as the mid-Floridan production zone.

Because the flow zones are typically separated from each other by continuous sequences of low permeability strata, water quality may vary significantly with depth. Water quality improves with depth as was found in similar wells drilled for the Town of Jupiter, Martin County, and South Martin County Regional Utility. Historically, geologists believed that water quality in the Floridan Aquifer was best in its uppermost reaches and it is a relatively new revelation that water quality actually improves with depth. Within the last few years, the United States Geological Survey (USGS) has studied the issue however a definitive reason has yet to be determined.

3.4 Floridan Aquifer Head Pressures

Prior to performing step drawdown testing, static water levels were measured in Floridan Aquifer Well F-1. Water levels were physically measured using a manometer tube that was connected to the construction wellhead assembly and elevated vertically by fastening the tube to the rig derrick. At the beginning of each working day the static (non-pumping) water level was measured relative to land surface and recorded as feet above land surface (als).

Upon completion of drilling, the static water level of test well F-1 was 20.3 feet als (+/- 44.3 feet NGVD).

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

The following conclusions are made based on results of the drilling and testing conducted during wellfield construction.

1. Floridan Aquifer Test Well, F-1 was constructed for the City of Lake Worth between January 2005 and July 2005 in accordance with the Contract specifications. The well was constructed using a drilling approach that enabled testing of the upper Floridan Aquifer for productivity and water quality prior to installation of the final casing string. Well F-1 was drilled to a total depth of 1,520 feet bls. The open-hole production interval for test well F-1 was 1,210 to 1,520 feet bls.

2. At the design pumping rate of 1,500 gpm, the specific capacity of well F-1 is expected to be 99 gpm/ft.

3. At the design pumping rate of 1,500 gpm the expected pumping water level in test well F-1 is approximately 15 feet als. This pumping water level will decrease (drawdown in each well will increase) with the number of Floridan Aquifer wells brought on-line.

4. The chloride concentration in the groundwater samples collected from the test well after pump testing were approximately 1,900 mg/l.

5. SDI results for the test well can be expected to be at or below a value of 1.0 when pumped at the design flow rate of 1,500 gpm. The design criterion for SDI of raw water for reverse osmosis plants is typically less than 3.0.

6. During testing, the static head measured in test well F-1 was 20.3 feet als (+/- 44.3 feet NGVD).

7. Most of the flow entering the well is produced from a 240 foot thick sequence of dolomite and limestone beds in the lower Ocala Limestone and Avon Park Limestone.

8. During drilling formation water having a chloride concentration of Approximately 2,400 mg/L was encountered overlying the production zone.

4.2 Recommendations

1. The design flow rate for the wells is 1,500 gpm. Based on the tested specific capacity and an allowance for ten percent degradation in productivity, the pumping water level at 1,500 gpm in each of the wells should stay above land surface in the near term. With time the specific capacity may degrade. If the specific capacity degrades more than ten percent, acidizing and or additional development of the well should be considered in order to restore well performance.

2. Water levels should be collected weekly on pumping wells and at least monthly on non-pumping wells. Not only will this confirm pumping equipment is operating within design criteria, but it will allow tracking of well performance and forecasting well problems.

3. Water quality samples should be collected monthly from pumping wells and at a minimum, analyzed for chloride and specific conductance. Well pumpage should be rotated so that all wells are used and monitored. Any time a water sample is collected, a minimum of three (3) casing volumes of water should be purged from the well prior to sample collection. Three casing volumes for test

well F-1 is 34,507 gallons. The Floridan Aquifer is a leaky aquifer with varying water quality both vertically and horizontally. Given this, water quality for test well F-1 is expected to vary over time. Rotation of well usage minimizes the stress on the aquifer in any one area and will help to limit water quality degradation.

4. Prior to bringing new wells on line, each well should be pumped to waste and SDI checked to confirm that conditions in the wells have not changed.

5. The well construction and development procedures specified for this project should be used for future wells constructed for the City of Lake Worth. The specific capacities, chemical and physical qualities of raw water from the wells met or exceeded expectations.

6. The City of Lake Worth's existing Floridan Aquifer drawdown model to evaluate anticipated wellfield drawdown for the South Florida Water Management District water use permit application was estimated based on regional aquifer hydraulic values. With the completion of subsequent Floridan aquifer wells for the City, an aquifer performance test (APT) should be performed so that the model can be updated and re-address the proposed individual well pumping rates if appropriate. Additionally, the APT may provide data as to the leakiness of the aquifer and potentially address long term long term water quality stability in the aquifer.

5.0 REFERENCES

Freeze, R.A., and J.A. Cherry. 1979. Groundwater. Prentice-Hall, Inc., Englewood, N.J. 604 pp.

JLA Geosciences, Inc., 2003. Martin County Utilities Well Completion Report for Floridan Aquifer Wells TFRO-1 through TFRO-5 at Tropical Farms Water Treatment Plant.

Miller, W.L. 1980. Geologic Aspects of the Surficial Aquifer in the Upper East Coast Planning Area, Southeast Florida. U.S. Geological Survey Open File Report 80-586, 2 Sheets.

Miller, W.L. 1987. Lithology and base of the Surficial Aquifer System, Palm Beach County, Florida. U.S. Geological Survey Open File Report 85-637.

Parker, G.G., G.E. Ferguson, S.K. Love and others. 1955. Water resources of Southeastern Florida. U.S. Geological Survey Supply Paper 1255.

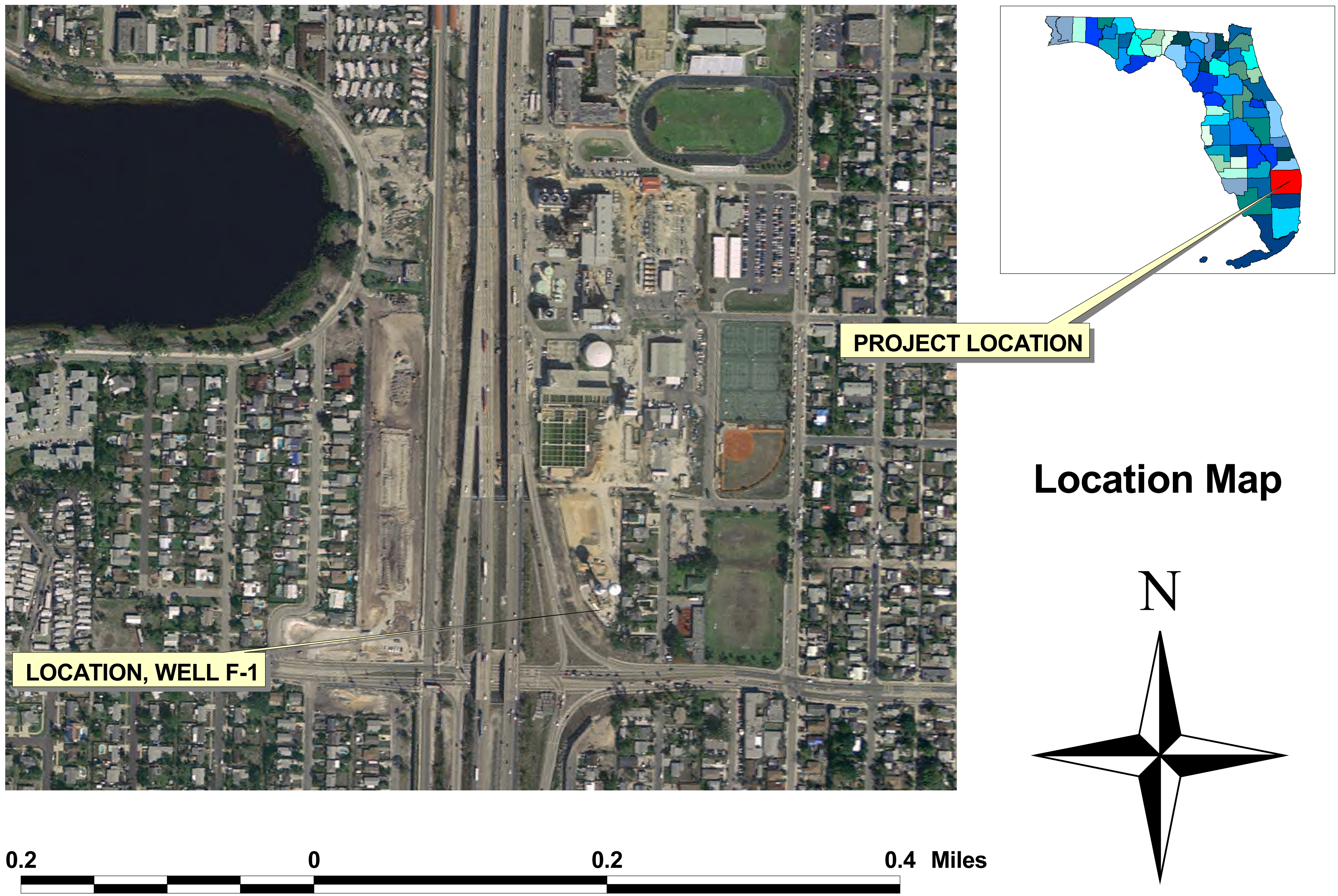
Reese, R.S., S.J. Memberg. 2000. Hydrogeology and the Distribution of Salinity in the Floridan Aquifer System, Palm Beach County, Florida. U.S. Geological Survey Water Resources Investigations Repot 99-4061.

Shine, M.J., D.G.J. Padgett, W.M. Barfknecht. 1989. Groundwater resource assessment of Eastern Palm Beach County, Florida. South Florida Water Management District Technical Publication 89-4.

Stemle, Andersen & Associates, Inc., 1998. Town of Jupiter Water System Floridan Aquifer Well Completion Report for Production Wells RO-8, RO-9 and RO-10.

FIGURES

Figure 1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LOCATION, WELL F-1
Location Map
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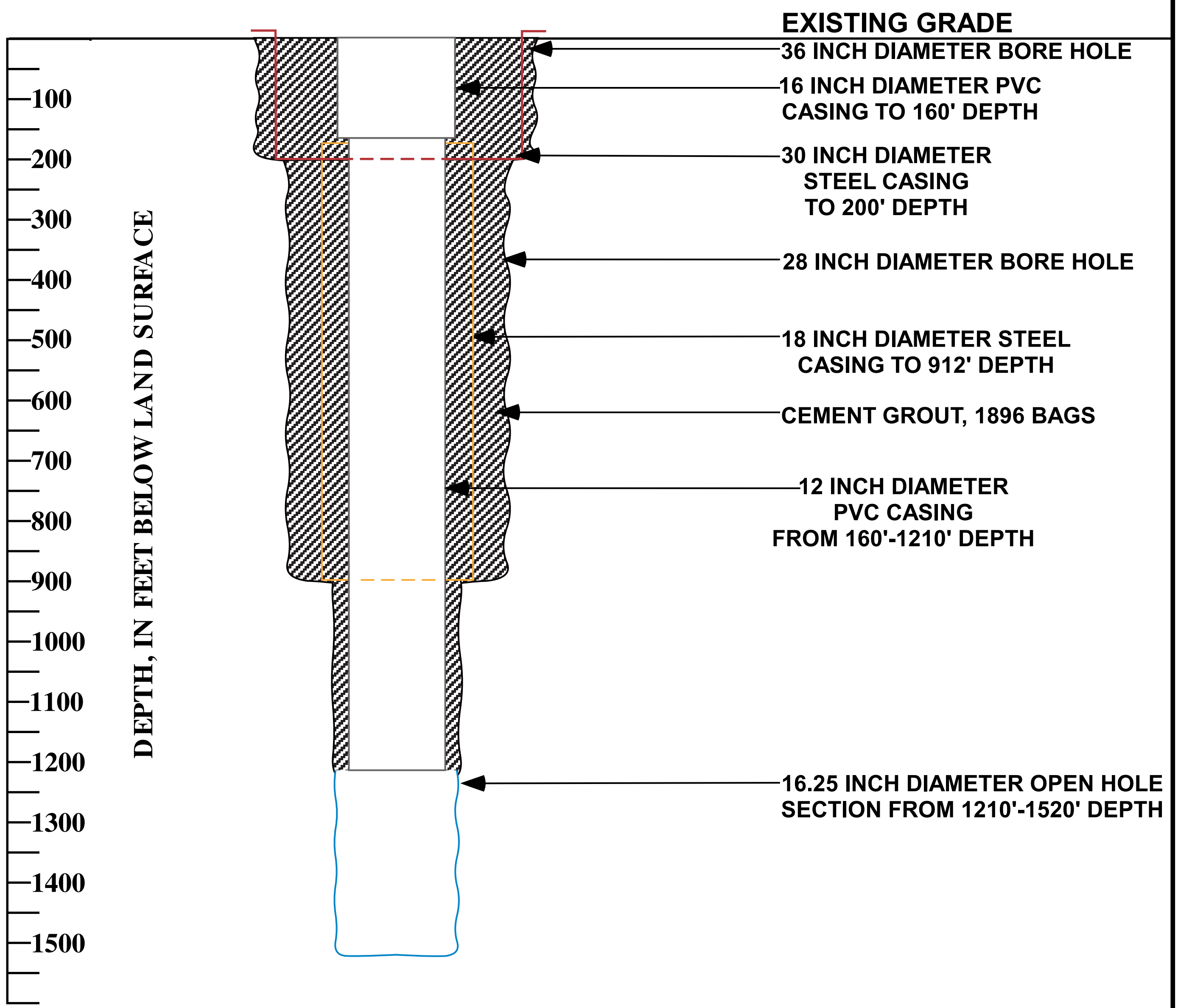


LEGEND:

- PVC WELL CASING
- CEMENT GROUT
- SURFACE CASING
- OPEN BORE HOLE
- INTERMEDIATE CASING

JLA Geosciences, Inc.

SCALE: AS SHOWN

DRAWN BY: JWF

DATE: 08/22/05

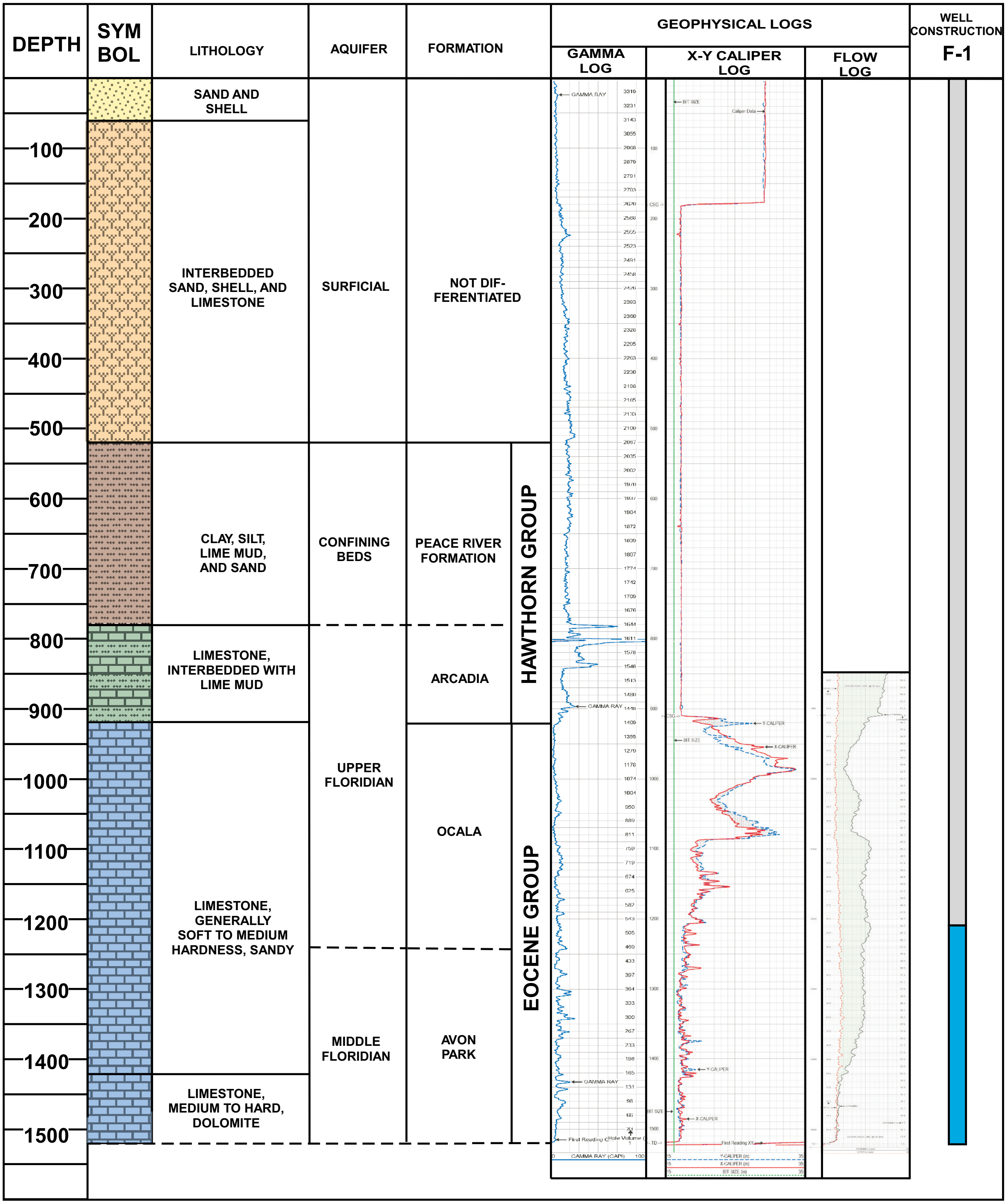
DWG #: 01

PROJECT SITE: LAKE WORTH UTILITIES, TEST WELL F-1

PROJECT NO: 03-31

PROJECT TITLE: WELL CONSTRUCTION DIAGRAM

FIGURE NO: 2



LEGEND: WELL CASING

OPEN INTERVAL

JLA Geosciences, Inc.

DRAWN BY: JWF DATE: 08-23-05 SCALE: AS SHOWN

PROJECT SITE: LAKE WORTH UTILITIES

PROJECT NO: 03-31

FIGURE TITLE: HYDROSTRATIGRAPHIC SECTION FLORIDAN AQUIFER TEST WELL F-1

FIGURE NO: 4

TABLES

TABLE 1

WELL CONSTRUCTION DETAILS

CITY OF LAKE WORTH UTILITIES
FLORIDAN AQUIFER TEST PRODUCTION WELL F-1

WELL NUMBER	TOTAL DEPTH (ft.)	CASING DETAILS									OPEN HOLE COMPLETION	
		OUTER CASING (Surface Casing)			INTERMEDIATE CASING (Floridan Aquifer Casing)			INNER CASING (Final Casing)				
		TYPE	DIA. (in.)	DEPTH (ft.)	TYPE	DIA. (in.)	DEPTH INT. (ft.)	TYPE	DIA. (in.)	DEPTH (ft.)	DIA. (in.)	DEPTH INT. (ft.)
F-1	1520	Steel	30	200	Steel	18	180-912	CERTA-LOC SDR 17 PVC	16, 12	0-160, 160-1210	16.25	1210-1520

Abbreviations:

ft. - Feet below land surface
in. - Inches
PVC - Poly vinyl chloride
INT. - Interval

TABLE 2

WATER QUALITY AND WELL FLOW CAPACITY SUMMARY

CITY OF LAKE WORTH UTILITIES
FLORIDAN AQUIFER TEST PRODUCTION WELL F-1
DRILLING DATA (FROM 924 TO 1550 FEET BLS)

Sample Depth (feet)	Chloride Conc. (mg/l)	Specific Conductance (uhmos/cm)	Wellhead Flow (gpm)	Specific Capacity (gpm/ft)	Temp. (C)
924	2315	7880	na	na	na
924	na	4255	na	na	na
956	2285	3020	na	na	25.7
Wellhead 956	na	7800	200	na	25.1
960	2395	7630	na	na	25.3
970	2270	7590	na	na	25.3
980	1780	5980	na	na	25.4
Wellhead 988	1680	5920	75	19.2	24.9
988	2160	7350	na	na	24.9
1000	2175	7350	na	na	25.0
1010	1550	5980	na	na	25.0
1012	2305	7850	na	na	24.3
Wellhead 1019	na	na	50	11.2	na
1019	2370	7870	na	na	24.3
1040	2240	7470	na	na	24.7
1049	2285	7840	na	na	25.1
Wellhead 1049	2135	7340	45	16.1	27.1
1060	2325	7500	na	na	25.3
1070	2010	7200	na	na	25.7
1081	2275	7840	na	na	24.5
*1112	2160	7580	na	na	24.4
1120	2220	7190	na	na	24.5
1130	2240	7440	na	na	24.4
1140	2010	7020	na	na	24.4
1170	1665	5650	na	na	23.8
Wellhead 1175	2020	na	105	19.9	na
1175	na	5740	na	na	23.8

TABLE 2 (continued)

WATER QUALITY AND WELL FLOW CAPACITY SUMMARY

CITY OF LAKE WORTH UTILITIES
FLORIDAN AQUIFER TEST PRODUCTION WELL F-1
DRILLING DATA (FROM 924 TO 1550 FEET BLS)

Sample Depth (feet)	Chloride Conc. (mg/l)	Specific Conductance (uhmos/cm)	Wellhead Flow (gpm)	Specific Capacity (gpm/ft)	Temp. (C)
1180	1655	5800	na	na	na
1190	1700	5690	na	na	24.0
1200	na	5700	na	na	24.0
1206	1645	5730	na	na	23.8
1210	1680	5700	na	na	23.5
1220	1680	5700	na	na	23.5
1230	1670	5760	na	na	23.5
Wellhead 1237	1850	6330	175	55.0	23.5
1237	1725	5850	na	na	23.5
1250	1775	5830	na	na	23.7
1260	1720	na	na	na	Na
Wellhead 1270	1725	na	300	65.6	Na
1270	1685	na	na	na	Na
1280	1700	5800	na	na	23.8
1290	1705	5840	na	na	23.7
Wellhead 1300	1765	6130	400	75.6	23.8
1300	1690	5870	na	na	23.7
1310	1550	na	na	na	Na
1320	1695	na	na	na	na
1330	1760	6060	na	na	23.9
Wellhead 1331	1775	6150	467.5	74.9	24.1
1350	1685	5820	na	na	1380
1362	1780	6370	na	na	23.7
Wellhead 1362	1770	na	532.5	86.4	na

TABLE 2 (continued)

WATER QUALITY AND WELL FLOW CAPACITY SUMMARY

CITY OF LAKE WORTH UTILITIES
FLORIDAN AQUIFER TEST PRODUCTION WELL F-1
DRILLING DATA (FROM 924 TO 1550 FEET BLS)

Sample Depth (feet)	Chloride Conc. (mg/l)	Specific Conductance (uhmos/cm)	Wellhead Flow (gpm)	Specific Capacity (gpm/ft)	Temp. (C)
1370	1765	6050	na	na	23.6
1380	1765	6050	na	na	23.5
1387	1825	6240	na	na	23.4
1390	1830	na	na	na	na
Wellhead 1394	1750	na	560	113.4	na
1400	1800	6330	na	na	23.4
1410	1820	6200	na	na	23.4
1420	1745	6060	na	na	23.3
1426	1750	6030	na	na	23.2
Wellhead 1426	1815	na	700	117.4	na
1430	1750	5950	na	na	23.0
1440	1725	5930	na	na	23.0
1450	1705	5840	na	na	23.0
1457	1750	5930	na	na	1487
Wellhead 1457	1780	6110	767.5	152.0	23.2
1470	1800	6130	na	na	23.3
1480	1820	6050	na	na	23.4
1489	1700	5780	na	na	23.1
Wellhead 1489	1805	6110	807.5	159.0	23.4
1500	1755	5830	na	na	23.2
1510	1765	6020	na	na	23.2
1520	1800	6090	na	na	23.1
Wellhead 1520	1810	6140	812.5	148.5	23.2

Notes:

TABLE 2 (continued)

WATER QUALITY AND WELL FLOW CAPACITY SUMMARY

CITY OF LAKE WORTH UTILITIES
FLORIDAN AQUIFER TEST PRODUCTION WELL F-1
DRILLING DATA (FROM 924 TO 1550 FEET BLS)

*1142	-	Make-up water shut off at drilling depth 1142 feet,
mg/l	-	milligrams per liter, chloride concentration determined by the mercuric nitrate titration method
Conc.	-	Concentration
umhos/cm	-	micromhos per cubic meter related to 25.0 °C
Temp.	-	Temperature
°C	-	degrees Celsius
gpm	-	gallons per minute
gpm/ft	-	gallons per minute per foot of drawdown, measured using a measuring tape and manometer tube
na	-	parameter not analyzed
nm	-	not measured

TABLE 3

STEP DRAWDOWN TEST RESULTS

CITY OF LAKE WORTH UTILITIES
FLORIDAN AQUIFER TEST PRODUCTION WELL F-1

WELL: F-1 TEST DATE: 7/06/2005
STATIC WATER LEVEL: Referenced starting head, + 20.3 feet above existing land surface.

DRAWDOWN DATA

Pumping Rate (gpm)	Pumping Duration (min)	Water Level (ft. of head relative to LS)	Drawdown (feet)	Specific Cap. (gpm/ft)
1000	120	+ 11.4	8.9	112.4
1500	120	+ 5.2	15.2	99.0
2000	160	- 1.5	21.8	91.7
2430	90	- 12.9	33.2	73.1
3000	90	- 24.3	44.6	67.3

WATER QUALITY DATA

Pumping Rate (gpm)	Total Pumping Duration (min)	SDI Result	Turbidity (ntu)	Hydrogen Sulfide (ppm)	Dissolved Chloride (mg/l)	Specific Conductance (uS/cm)
1000	120	0.9	0.45	3	1900	6070
1500	120	0.4	0.40	3	1890	6140
2000	160	0.6	0.30	3	1905	6170
2500	90	0.5	0.30	3	1875	6090
3000	90	0.6	0.15	3	1890	6110

Notes:
gpm - gallons per minute
mg/l - milligrams per liter
uS/cm - microsiemens (micromhos) per cm
ppm – parts per million
LS - land surface
SDI - Silt Density Index
ntu – nephelometric turbidity units
NA - not available