Hydrogeologic Investigation of the Floridan Aquifer System
Moore Haven Site
Glades County, Florida

Preliminary Report

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CONTENTS

Figures

Appendices

Executive Summary

The Comprehensive Everglades Restoration Plan (CERP) – jointly being conducted by the U.S. Army Corps of Engineers (USACE) and South Florida Water Management District (SFWMD) – is focused on storing available water currently lost to tide. The Aquifer Storage and Recovery (ASR) technology has been identified as a major storage option, particularly in the vicinity of Lake Okeechobee, where available water has been identified. The Lake Okeechobee ASR Pilot Project was designed to address some of the technical and regulatory uncertainties of storing treated surface water via ASR systems. Hydrogeologic testing of smaller diameter test/monitor wells was identified as one of the first tasks in evaluating ASR potential proximal to Lake Okeechobee.

The purpose of this project is to provide site-specific hydrogeologic on the Floridan Aquifer System (FAS) at three separate sites in support of the Lake Okeechobee ASR Pilot Project. Data collected from the testing and monitoring of these test wells will be instrumental in site selection for future ASR systems, inclusion in the proposed ASR regional study, development of a conceptual hydrogeologic model, and other future regional hydrogeologic and hydro-chemical assessments.

This report primarily describes the drilling, construction, and testing of the 12-inch diameter test/monitor well identified as GLF-6 at the Moore Haven Site. It summarizes and presents data obtained during drilling and testing operations and analyses conducted. GLF-6 is the designation used to obtain a SFWMD well construction permit (Permit Number SF041901A). The test/monitor well (GLF-6) was constructed on SFWMD-owned right-of-way proximal to the SFWMD's S-77 water control structure on the C-43 Canal in the northwest quarter of Section 12 of Township 42 South, Range 32 East.

The scope of the investigation consisted of constructing and testing a test/monitor well drilled to a total depth of 2,030 feet below pad level (bpl). If the Moore Haven site is chosen as a site for an ASR system as part of the Lake Okeechobee ASR Pilot Project, well GLF-6 will be modified to accommodate monitor zone(s) consistent with the future ASR well.

The main findings of the exploratory drilling and testing program at this site are as follows:

- Lithologic information and geophysical logs obtained from GLF-6 indicate that soft non-indurated detritial clays, silts, sands and poorly indurated mudstones of the Hawthorn Group predominate from 160 to 850 feet bpl. These low permeable sediments act as confining units separating the Floridan Aquifer System (FAS) from the Surficial Aquifer System (SAS).

- The top of the FAS, as defined by the Southeastern Geological Society AdHoc Committee on Florida Hydrostratigraphic Unit Definition (1986) was identified at a depth of approximately 845 feet bpl.

- Lithologic and geophysical logs, packer test results, and specific capacity test results indicate low production capacity of the upper Floridan aquifer from 855 to 1,110 feet bpl.

- The lower Ocala Limestone and upper Avon Park Formation form 1,110 to 1,600 feet bpl form and inter-aquifer confining unit within the FAS at this site.

- A productive horizon in the Middle Floridan aquifer from 1,600 to 1,740 feet bpl yielded a specific capacity of 175 gpm/ft of drawdown.

- The drilling data, open-hole and production-type logs (e.g. flow, temperature logs) indicates good production from 1,600 and 1,740 feet bpl. Below 1,740 feet bpl, the productive capacity is limited (as indicated by the fluid-type logs) suggesting lower permeability, semi-confining units near the base of this productive horizon.

- Composite water quality sampling during straddle test and geophysical log data was used in tandem to identify the base of the USDW at approximately 1,860 feet bpl. Total dissolved solids concentrations below 1,950 feet bpl are similar in concentration to seawater.

Acknowledgements

The authors gratefully acknowledge the many people that aided in the successful completion of this project. We would like to thank the technical and professional staff of the South Florida Water Management District who reviewed the manuscript or lent technical expertise to the writing of the report. They include Mr. Peter Kwiatkowski, and Mr. John Lukasiewicz. We would also like to thank Electronic Support and Data Acquisition and Water Quality staff for the field support provided during construction and testing operations.

Introduction

Background

The Comprehensive Everglades Restoration Plan (CERP) – jointly being conducted by the U.S. Army Corps of Engineers (USACE) and South Florida Water Management District (SFWMD) – is focused on storing available water currently lost to tide. The Aquifer Storage and Recovery (ASR) technology has been identified as a major storage option, particularly in the vicinity of Lake Okeechobee, where available water has been identified. The Lake Okeechobee ASR Pilot Project was designed to address some of the technical and regulatory uncertainties of storing treated surface water via ASR systems. Hydrogeologic testing of smaller diameter test/monitor wells was identified as one of the first tasks in evaluating ASR potential proximal to Lake Okeechobee.

The purpose of this project is to provide site-specific hydrogeologic information regarding the Floridan Aquifer System (FAS) at three separate sites in support of the Lake Okeechobee ASR Pilot Project. Data collected from the testing and monitoring of these wells will be instrumental in site selection for future ASR systems, inclusion in the ASR Regional Study, development of a conceptual hydrogeologic model, and other future regional hydrogeologic and hydro-chemical assessments.

Scope

This report primarily describes the drilling, construction, and testing of a 12-inch diameter test/monitor well identified as GLF-6 at the Moore Haven site. It summaries and presents data obtained during drilling and testing operations and analyses conducted.

Project Description

The Moore Haven test site is located approximate 65 miles west of the Atlantic Ocean and approximately 500 feet west of the western boundary of Lake Okeechobee in unincorporated Glades County, Florida. The test/monitor well (GLF-6) was constructed on a SFWMD-owned right-of-way proximal to the SFWMD S-77 water control structure on the C-43 Canal (Caloosahatchee River) in the northwest quarter of Section 12 of Township 42 South, Range 32 East (**Figure 1**).

The SFWMD issued a notice to proceed to Diversified Drilling Corp (DDC) on April 16, 2001 to drill and construct three 12-inch diameter test/monitor wells at separate locations proximal to Lake Okeechobee. On July 18 2001, construction began on the third test/monitor well identified as GLF-6. Drilling, testing and construction of this well were completed on January 15, 2002.

Figure 1. Project Location – GLF-6

Exploratory Drilling and Well Construction

Test/Monitor Well (GLF-6)

Diversified Drilling Corporation (DDC) began site preparation during mid-June, 2001. After minor clearing and rough grading of the site, the ground surface beneath the drill rig and settling tanks was lined with an impermeable high density polyethylene (HDPE) liner, which was covered with 10-inches of granular fill to protect the liner. A two-foot thick temporary drilling pad was then constructed using crushed limestone. An earthen berm two-feet in height above pad level surrounded the perimeter of the rig and settling tanks. This earthen berm was constructed to contain drilling fluids and/or formation waters produced during well drilling, testing, and well construction activities **(Figure 2)**.

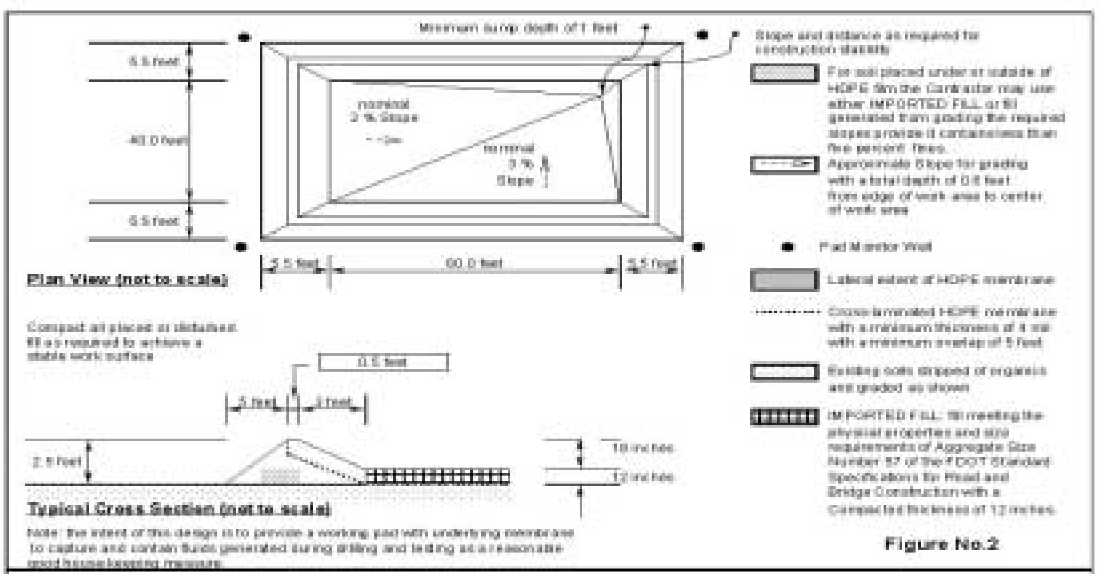

Figure 2. Well Pad Schematic

DDC installed four pad monitor wells at the corners of the temporary drilling pad prior to the start of drilling operations. SFWMD monitored the water quality of these wells on a weekly basis to ensure no releases of brackish water occurred during construction.

Lithologic (well cuttings), packer test, and borehole geophysical log data were used to determine the actual casing setting depths. The pilot hole was reamed to specified diameters and casing installed. Three concentric steel casings (24-, 18-, and 12-inch-diameter) were used in the construction of the Floridan aquifer test/monitor well (GLF-6).

DDC initiated drilling activities for GLF-6 on July 18, 2001. Drilling operations began by advancing a 12.75-inch diameter pilot hole to a depth of 83 feet below pad level (bpl) via the mud-rotary method. The 12.75-inch diameter pilot hole was reamed to a depth of 83 feet bpl using a nominal 29-inch diameter staged reaming bit. In accordance with the well construction specifications, the reamed borehole was geophysically logged (caliper) to verify depths and to calculate cement volumes for subsequent cement grouting operations (**Appendix A-1**). On July 18, 2001, DDC installed the nominal 24-inch diameter, steel pit casing, (ASTM A53, Grade B, and 0.375-inch wall thickness) in the nominal 29-inch diameter borehole to a depth of 81 feet bpl. The annulus was pressure grouted to land surface using 231 cubic feet (ft^3) of ASTM Type II, Portland cement (15.6 lbs./gal). A factory mill certificate for the 24-inch diameter steel pit casing is provided in **Appendix B.**

After installing the 24-inch diameter pit casing, DDC continued drilling the pilot hole with a nominal 8-inch diameter bit using the mud-rotary method. On July 24, 2001, DDC advanced the pilot hole through the Pleistocene-Pliocene aged sediments and into the Hawthorn Group to a depth of 216 feet bpl. That same day, MV Geophysical Surveys, Inc. of Ft. Myers, Florida, geophysically logged the pilot hole from 80 feet to 216 feet bpl without incident. The logging suite consisted of the following logs: 4-arm caliper, natural gamma ray, spontaneous potential (SP), borehole compensated sonic (BHC) and dual induction/laterolog combination. The individual log traces from geophysical log run No. 2 are presented in **Appendix A-2.**

Using well cuttings and geophysical log data, the base of the Surficial Aquifer System (SAS) was identified at approximately 160 feet bpl where a greenish-gray phosphatic, sandy-silt-clay unit was first encountered. In addition, the natural gamma log indicated an increase in natural gamma ray emissions, which corresponded to the lower permeable silty, phosphatic clays, found at similar depth. On July 25, 2001, DCC reamed the nominal 8-inch diameter pilot hole to 207 feet bpl using a nominal 23-inch diameter staged bit reamer. The nominal 23-inch borehole was geophysically logged (caliper-natural gamma ray) to verify depths and to calculate cement volumes for subsequent grouting operations. The caliper log showed no unusual borehole conditions that would prohibit proper installation of the 18-inch diameter casing (**see Appendix A-3)**. DDC then installed the 18-inch diameter, steel casing (ASTM A53, Grade B, and 0.375-inch wall thickness) in the nominal 23-inch diameter borehole to a depth of 205 feet bpl. Once installed, the 18-inch diameter steel pipe was pressure grouted using 246 ft^3 of

ASTM Type II neat cement. An additional 64 ft^3 of ASTM Type II neat cement was used to bring cement levels in the annulus to surface, completing surface casing installation on July 26, 2001.

The purpose of the surface casing is to prevent unconsolidated surface sediments from collapsing into the drilled hole, to isolate the SAS from brackish water contamination, and to provide drill rig stability during continued drilling operations. A factory mill certificate for the 18-inch diameter surface casing is provided in **Appendix B**.

With the surface casing installed, DDC continued to advance the nominal 8-inch diameter pilot hole via the closed circulation mud-rotary drilling method. On August 3, 2001, DDC completed pilot hole drilling operations through the Miocene-aged Hawthorn Group unconsolidated to semi-consolidated sediments. Drilling operations continued through the Oligocene and upper Eocene-aged carbonates of the upper Floridan aquifer to a depth of 1,299 feet bpl. Several 4-inch diameter conventional cores were collected from the following depth intervals: 784 to 798 feet bpl, 874 to 886 feet, and 988 to 1,006 feet bpl. During coring operations, various lengths of core were retrieved to surface. A core recovery efficiency of 73 percent was achieved from 784 to 1,006 feet bpl.

While preparing the pilot hole for logging operations, water flow at approximately 1,140 bpl developed, which diluted the drilling fluids reducing the hydrostatic pressure of the mud column. As a result of this pressure reduction, unconsolidated quartz sand intervals within the lower Arcadia Formation (Hawthorn Group) became unstable and sloughed into the borehole, back-filling it from 750 feet to 1,299 feet bpl. Consequently, DDC removed the quartz sand from within the borehole to a depth of 1,075 feet bpl, allowing the remaining volume of sand to stay in place to help seal off a potentially permeable zone at 1,120 feet bpl.

On August 15, 2001, Schlumberger Wireline Services began geophysical logging operations within the nominal 8-inch diameter pilot hole from 205 feet to 1,075 feet bpl. However, during logging operations, the pilot hole required re-circulation due to the presence of a thick mud cake below 900 feet bpl. DDC re-entered the borehole and conditioned it for approximately one hour. Logging operations continued without further incident to a depth of 1,075 feet bpl and completed on August 16, 2001. The geophysical logging suite included both conventional and specialty logs as follows: caliper, spontaneous potential (SP), natural gamma ray spectrometry (NGS), high resolution array induction (AIT), dipole sonic imager (DSI), compensated density with photoelectric factor (PEF), compensated neutron, ultrasonic borehole imager (UBI), and fullbore formation micro-imager (FMI). A composite of the geophysical log traces that were exempt from post-processing from geophysical run no. 4 is provided in **Appendix A-4**.

Review of lithologic data (located in **Appendix C**) and geophysical logs (**Appendix A-4**) from the subject borehole indicates that the top of the FAS occurs at a depth of approximately 850 feet bpl. However, the final 12-inch steel production casing was set at a depth of 855 feet bpl for reasons listed below:

1. Seal off overlying silty clays of the Hawthorn Group and carbonate mud stringers and fine quartz and phosphatic sands within the lower portion of the Arcadia Formation to avoid future drilling problems
2. Facilitate reverse-air-drilling operations through the underlying permeable horizons of the FAS to the anticipated depth of 2,000 feet bpl.
3. Locate the casing in a competent, well-indurated rock unit to reduce undermining (erosion) at its base as a result of natural and induced high velocity upward flow.
4. Evaluate flow characteristics of the FAS within the anticipated open-hole interval of 7855 to 2,000 feet bpl.
5. Avoid non-productive, phosphate-bearing silt/sand from approximately 550 to 850 feet bpl – as evidenced by the drill cuttings and peaks on the natural gamma ray log trace, which will help to avoid potential impacts to FAS water quality.

Therefore, on August 16, 2001, the nominal 8-inch diameter pilot hole was temporarily back-filled with 3/8-inch diameter crushed limestone gravel to approximately 710 feet bpl. DDC reamed the nominal 8-inch diameter pilot hole using a nominal 17-inch diameter staged bit reamer. On August 23, 2001, DDC circulated and geophysically logged (caliper and natural gamma) the nominal 17-inch diameter borehole to its total depth without incident. The caliper log trace showed no unusual borehole conditions that would prohibit proper installation of the 12-inch diameter casing to 855 feet bpl **(caliper log trace provided in Appendix A-5**). Once the 12-inch diameter casing was installed (ASTM A53, Grade B, and 0.375-inch wall thickness) to a depth of 855 feet bpl, it was rotated and reciprocated to confirm that it was free within the borehole for subsequent cement grouting. The factory mill certificate and the casing installation log for the 12-inch diameter casing are provided in **Appendix B.** DDC then circulated approximately 15,000 gallons of fluid through the annular space to displace the heavy drilling mud that was previously required for borehole stabilization. This post-conditioning water flush reduces the potential mixing of grout and drilling mud (of similar densities) during grouting operations, reducing the risk of mud channels (annular voids).

After the post-conditioning water flush, pressure-grouting operations began by installing tremie pipe (2.375-inch diameter) to 752 feet bpl. A volume of 410 ft^3 (350 sacks @ 94lbs/sack) of ASTM C-150 Type II neat cement was then pumped during pressure grouting operations. A temperature/gamma survey was conducted 12 hours after cementing operations ceased. This survey was used to identify the top of the cement within the annulus as a result of pressure grouting. A significant shift in the temperature gradient log and corresponding deflection in the temperature differential log occurred at 330 feet bpl (see **Appendix A-6** for temperature-gamma log), which suggests that the top of the first stage was located at that depth. Steel tubing was then used to physically locate (hard tag) the cement level within the annulus. The physical tag indicated the cement level at 336 feet bpl, which was in close agreement to that suggested by the temperature log. An additional 285 ft^3 of ASTM Type II neat cement was pumped on August 24, 2001 via the tremie method causing cement returns at surface. Actual cement volumes pumped during casing installation were in close agreement to theoretical volumes (approximately 114 % of theoretical). The 14% cement overage is due to washouts that are present near the base of the 18-inch diameter casing (205 to 245 feet bpl) and in the lower Arcadia Formation (760 to 820 feet bpl).

Once grouting operations were completed, DDC installed a well header on the 12-inch diameter steel casing as part of pressure testing operations. The wellhead was sealed at the surface via the temporary header to facilitate the test. Next, the well was filled with water and pressurized to approximately 50 pound per square inch (psi) using a high-pressure water pump. A preliminary 1-hour pressure test was conducted on August 27, 2001. During this test, internal casing pressures fell 10 psi - a 20 % reduction, which exceeded the test tolerance limit of +/- 5%. DDC then made appropriate adjustments to the well head configuration, isolating surface leaks observed during the preliminary pressure test.

Once properly sealed, SFWMD notified FDEP of the scheduled pressure test date for the 12-inch diameter casing. The formal pressure test was conducted and successfully completed on August 29, 2001; however, a FDEP representative was unable to attend the test. During the course of the 60 minute pressure test, the total pressure within the 12-inch diameter casing decreased 0.75-psi, representing a 1.5 % decline – well within the test tolerance limit of +/- 5% **(Table 1.)**

Table 1.

Official Pressure Test on 12-inch Casing String
GLF-6

Date	Time Hour	Elasped Time (min)	Pressure Reading psi	Delta Pressure psi	Remarks	Recorded By
08/29/01	10:06	0	50.00	0.00	Start of Pressure Test	JH
08/29/01	10:11	5	50.00	0.00		JH
08/29/01	10:16	10	50.00	0.00		JH
08/29/01	10:21	15	50.00	0.00		JH
08/29/01	10:26	20	50.00	0.00		JH
08/29/01	10:31	25	50.00	0.00		JH
08/29/01	10:36	30	50.00	0.00		JH
08/29/01	10:41	35	49.75	0.25		JH
08/29/01	10:46	40	49.75	0.25		JH
08/29/01	10:51	45	49.50	0.50		JH
08/29/01	10:56	50	49.50	0.50		JH
08/29/01	11:01	55	49.25	0.75		JH
08/29/01	11:06	60	49.25	0.75	End of Pressure Test Total Pressure Change 0.75 psi	JH

Witnessed By: Paul F. Linton, SFWMD (Engineer of Record)
Recorded By: Jeff Herr, SFWMD

On August 29, 2001, DDC drilled through the cement-plug (a result of pressure grouting) at the base of the final casing string and began to remove the temporary backfill material (3/8-inch diameter crushed limestone and quart sand) from the original pilot hole via the mud-rotary technique. DDC re-drilled the pilot hole to its original total depth of 1,299 feet bpl on August 30, 2001.

On September 12, 2001, the fourth conventional core was collected from 1,299 to 1,317 feet bpl. The recovered length of core material was 18 feet (100% recovery efficiency). DDC then drilled a nominal 8-inch diameter pilot hole from 1,317 to 1,571 feet bpl via the mud-rotary method. On September 15, 2001, DDC cut the fifth conventional core from 1,571 to 1,591 feet bpl, with 100% of the core recovered at surface. Mud-rotary drilling continued through the Eocene-aged carbonates to a depth of 1,602 feet bpl.

A cavernous dolomitic limestone-dolostone unit was encountered at 1,602 feet bpl, which caused a loss of mud circulation and a 2-foot drop of the drill rod. DDC re-mixed and circulated approximately 12,000 gallons of drilling fluid in an effort to regain circulation; these efforts were unsuccessful. A decision was made to switch to the reverse-air drilling method to continue pilot-hole drilling to the anticipated depth of 2,000 feet bpl. Consequently, DDC reconfigured the drilling equipment to accommodate reverse-air-drilling operations. SFWMD personnel installed water quality probes into the C-43 Canal equipped with sondes used to collect temperature, pH, specific conductance, dissolved oxygen, and turbidity data. These probes were deployed 100 meters upstream from the point of discharge (POD), 100 meters downstream from the POD, and 800 meters downstream from the POD. During reverse-air drilling operations, formation water was diverted through a series of 7,500-gallon settling tanks then discharged into the C-43 Canal via a 12-inch diameter PVC pipe equipped with a silt screen to minimize particulate matter being discharged. SFWMD personnel collected water quality data (3 times daily) from the C-43 Canal during discharges produced from the test/monitor well to comply with FDEP-issued National Pollutant Discharge Elimination System (NPDES) permit monitoring requirements (Permit No. FL0186279).

On September 18, 2001, DDC began to drill a nominal 8-inch diameter pilot hole from 1,602 to 1,788 feet bpl via the reverse-air method. On September 21, 2001, the sixth conventional core was cut from 1,788 to 1,795 feet bpl. However, only seven of the anticipated 20-foot section was cored because the core barrel (20 feet in length) plugged off at 1,795 feet bpl, which halted coring operations. The recovered length of core material was 2 feet (29% recovery efficiency). On September 25, 2001, DDC completed drilling operation on the pilot-hole to a total depth of 2,030 feet bpl. Once the pilot hole was completed, it was air developed and prepared for geophysical logging operations.

On September 26, 2001, Schlumberger Wireline Services began specialty geophysical logging operations within the nominal 8-inch diameter pilot hole from 855 to 2,030 feet bpl. The first tool (natural gamma-induction-neutron-density combination; referred to as the “Platform Express”) recorded information from 855 to 1,970 feet bpl. It was evident during logging that 50 feet of the borehole was lost due to sloughing of poorly consolidated material while tripping out the drill pipe. The next geophysical sonde run was the formation micro-resistivity imager (FMI). Schlumberger personnel limited the micro-resistivity logging depth to 1,600 feet bpl because of borehole rugosity (discerned from the caliper log obtained during the first log run) below this depth could easily damage the pad-oriented tool. In addition, the data collect by the micro-resistivity tool would be of little value due to the configuration of the borehole. After completing the micro-resistivity log, the dipole sonic imager (DSI) was conducted to a depth 1,690 feet bpl. During the two previous logging runs, the poorly consolidated material continued to backfill the borehole to 1,690 feet bpl. A decision was made to re-enter and clear the back-fill material from the pilot hole to 2,020 feet bpl and continue logging operations thereafter. However, while tripping the DSI tool out of the borehole, it became stuck near the base of the steel casing at 860 feet bpl. Schlumberger personnel attempted to free the sonde without success. Consequently, DDC subcontracted Baker-Hughes to perform recovery "fishing" operations. Baker-Hughes successfully retrieved the DSI tool to surface on September 29, 2001. Once Baker-Hughes retrieved the DSI tool to surface, Schlumberger inspected and re-calibrated the sonde to conduct a cement bond log within the nominal 12-inch diameter casing. Open-hole logging operations were discontinued until the borehole could be cleared to its total depth and its stability evaluated. The successful specialty geophysical log runs to various depths included the following: density caliper, spontaneous potential (SP), natural gamma ray, high resolution array induction (ATI), dipole shear sonic imager (DSI), compensated density with photo electric factor (PEF), and compensated neutron. A composite of the geophysical log traces that were exempt from post-processing during geophysical log run no. 7 is provided in **Appendix A-7**.

On October 3, 2001, DDC tripped into the pilot hole with a nominal 8-inch diameter bit and removed the naturally occurring backfill material from 1,690 to 2,030 feet bpl via the reverse-air method. They continued to swab and re-drill the pilot hole below 1,900 feet bpl in an effort to stabilize the borehole. After three days, these efforts succeeded whereby DDC pulled the drill bit up to 1,600 feet bpl and tripped to the bottom of the pilot hole noting only 1 foot of backfill material. A borehole video survey was then conducted to evaluate borehole stability within the open section (855 to 2,030 feet bpl). On October 8, 2001, MV Geophysical Surveys, Inc. completed an unobstructed video log to the full depth of the nominal 8-inch diameter pilot hole. The video survey indicated that the borehole was relatively stable but highly fractured and cavernous below 1,600 feet bpl. Based on the information provided by the video survey, production logs (e.g., flowmeter, temperature etc.) were conducted with minimal risk of losing tools downhole. In an effort to further stabilize and clear the borehole, DDC tripped into the pilot hole with a nominal 8-inch diameter bit on October 10, 2001 to prepare for production logging activities. On October 12, 2001, MV Geophysical Surveys, Inc. successfully ran a suite of production logs which included; a flowmeter run under dynamic and static conditions; a fluid resistivity – high resolution temperature log; and a 4-arm caliper – natural gamma log to 1,970 feet bpl. In addition, water samples were to be collected from the wellbore every 100 feet from 1,500 to 2,000 feet bpl via a wireline fluid sampler (i.e., thief sampler). However, the thief sampler was damaged while tripping in to retrieve the first down hole sample, and this activity was temporarily discontinued. A composite of the production log traces completed by MV Geophysical Surveys, Inc is included **Appendix A-8.**

Straddle-packer test intervals were selected using the information provided by analysis of the geophysical logs and lithologic data, and the first of six tests began on October 22, 2001. The purpose of these tests was to characterize the water quality and production capacities of specific intervals within the larger open-hole interval (855 to 2,030 feet bpl). Hydraulic characterization of intervals having total dissolved solids (TDS) concentration greater than 10,000 milligrams per liter (mg/L) was not considered due to their limited potential for ASR application. This TDS concentration also corresponds to the lower limit of an "Underground Source of Drinking Water" (USDW), defined as an aquifer containing water with a TDS concentration of less than 10,000 mg/L.

During the course of packer testing operations, MV Geophysical obtained water samples from the wellbore every 100 feet from 1,500 to 1,970 feet bpl via a wireline fluid sampler (i.e., thief sampler). Field parameters including temperature, pH specific conductance, oxidation/reduction potential (ORP) and chloride content were measured once retrieved to surface. The water quality results from the individual fluid samples are summarized in the geophysical logging section of this report.

During hydraulic testing of the lower section of the pilot hole, DDC began permanent but incremental back plug operations of the bottom 285 feet of the nominal 8-inch diameter pilot hole. Back-plugging operations began on October 25, 2001 and completed on November 8, 2001. During back-plugging operations, DDC pumped 21 cubic yards of pea size gravel and 40 sacks (52 ft^3) of Type II neat cement. This volume brought cement levels from the base of the pilot hole at 2,030 feet bpl to 1,745 feet bpl.

DDC completed packer-testing operations on November 21, 2001 (see the Packer Test Section of this report for a description of the methods and a summary of the results). The water quality data obtained from the straddle-packer tests were used in tandem with the geophysical logs to identify the base of the USDW at approximately 1,860 feet bpl. The production and water quality results for the various packer tests are presented in the next section

On January 11, 2002, the final stage of well construction began by DDC installing a semi-permanent inflatable packer at 1,560 feet bpl. The purpose of this packer is to isolate the brackish to saline waters below this depth, prohibiting inter-aquifer transfer of water and allow flexibility in the future final design of this test/monitor well (e.g., single or dual-zone monitor well). The current well completion for GLF-6 is summarized below and illustrated in **Figure 3**:

- Permanent steel casing (12-inch diameter) set to 855 feet bpl,
- Open hole interval from 855 feet to 1,560 feet bpl,
- Long-term 7.0-inch diameter (Tam) inflatable packer set at 1,560 feet bpl,
- Open hole interval from 1,560 feet to 1,745 feet bpl,
- Nominal 8-inch diameter pilot hole, back plugged using pea-size gravel and neat cement from 1,745 feet to 2,030 feet bpl.

The technical specifications for the semi-permanent inflatable packer are provided in **Appendix B.**

During the week of January 7-11, 2002, DDC installed a 12-inch diameter wellhead and 6-foot by 6-foot concrete pad with 4-foot high steel coroner posts completing well construction activities at this site. DDC completed demobilization and site restoration on January 15, 2002. **Table 2** summarizes well construction and testing activities related to test/monitor well - GLF-6.

Construction - Testing Summary GLF-6, Moore Haven Site	
Date	**Description of Activities**
04/16/01	Project Initiation (Notice to Proceed)
06/28/01	Site preparation and mobilzation
07/18/01	Drilled a 12.750-inch pilot hole to 83 feet bpl.
07/19/01	Reamed pilot hole using a nominal 30 inch diameter bit to 83 feet bpl.
07/19/01	Conducted caliper/natural gamma surver on reamed borehole (Run No. 1)
07/19/01	Installed pit casing (80 ft; 24-inch diameter steel)
07/24/01	Drilled a 7.875-inch diameter pilot hole to 216 feet bpl.
07/24/01	Conducted geophysical logging on pilot hole to 216 feet bpl (Run No. 2)
07/25/01	Reamed pilot hole with a nominal 23 inch diameter bit to 206 feet bpl.
07/25/01	Conducted caliper/natural gamma survey on reamed bolehole (Run No. 3).
07/25/01	Installed surface casing (205 ft; 18-inch diameter steel)
08/01/01	Drilled a 7.875-inch diameter pilot hole to 784 feet bpl.
08/02/01	Cored from 784 to 798 feet bpl. (2 feet of recovery)
08/03/01	Drilled a 7.875-inch diameter pilot hole to 875 feet bpl.
08/06/01	Cored from 874 to 886 feet bpl. (12 feet of recovery)
08/07/01	Drilled a 7.875-inch diameter pilot hole to 988 feet bpl.
08/08/01	Cored from 988 to 1,006 feet bpl. (18 feet of recovery)
08/09/01	Drilled a 7.875-inch diameter pilot hole to 1,299 feet bpl.
08/15/01	Conducted geophysical logging on pilot hole to 1,075 feet bpl (Schlumberger Wireline Service - Run No.4).
08/16/01	Back filled pilot hole to 710 feet bpl with crushed limestone.
08/21/01	Reamed pilot hole with nominal 17-inch diameter bit to 859 feet bpl.
08/23/01	Conducted caliper/natural gamma survey on reamed borehole to 859 feet bpl (Run No. 5).
08/23/01	Installed 12-inch diameter steel production casing to 855 feet bpl.
08/23/01	Pressure grouted using 350 sacks of neat cement.
08/24/01	Run temperature survey to verify top of cement at 336 feet bpl (Run No. 6).
08/24/01	Second stage of grouting (225 sacks of neat cement) completed to land surface.
08/29/01	Conducted 50-psi pressure test of 12-inch diameter casing.
08/30/01	Drilled a 7.875-inch diameter pilot hole to 1,299 feet bpl.
09/11/01	Cored from 1,299 to 1,317 feet bpl (18 feet of Recovery)
09/13/01	Drilled a 7.875-inch diameter pilot hole to 1,571 feet bpl.
09/15/01	Cored from 1,571 to 1,591 feet bpl (20 feet of Recovery)
09/17/01	Drilled a 7.875-inch diameter pilot hole to 1,603 feet bpl (lost circulation at ~ 1603 feet bpl.).
09/18/01	Drillers switched to reverse air method.
09/20/01	Drilled a 7.875-inch diameter pilot hole to 1788 feet bpl.
09/21/01	Cored from 1,785 to 1,795 feet bpl (2 feet of Recovery)
09/22/01	Drilled a 7.875-inch diameter pilot hole to 1,910 feet bpl.
09/24/01	Drilled a 7.875-inch diameter pilot hole to 1,975 feet bpl.
09/25/01	Drilled a 7.875-inch diameter pilot hole to 2,020 feet bpl.
09/26/01	Conducted geophysical logging on pilot hole to 2,020 feet bpl (Schlumberger Wireline Services-Run No. 7)
	Note:DSI tool stuck in hole at 855 feet bpl.
10/03/01	Cleaned pilot hole with 7.875-inch diameter bit from 1,650 to 1,970 feet bpl.
10/04/01	Cleaned pilot hole with 7.875-inch diameter bit from 1,970 to 2,030 feet bpl.
10/08/01	Ran video survey on pilot hole to 2,026 feet bpl (part of Run No.8).
10/10/01	Cleaned pilot hole with 7.875-inch diameter bit to 2,030 feet bpl.
10/12/01	Conducted geophysical logging on pilot hole to 1,970 feet bpl. (Production Type Logs - Run No. 8).
10/22/01	Packer test conducted on interval from 1,587 to 2,030 feet bpl.
10/24/01	Collected water samples using thief sampler every 100 feet from 1,500 to 1,970 feet bpl.
10/26/01	Pumped 7 cubic yard of pea gravel in wellbore.
10/29/01	Pumped 6 cubic yard of pea gravel and 10 sacks of neat cement in wellbore.
11/02/01	Packer test conducted on interval from 1,587 to 1,884 feet bpl.
11/05/01	Pumped 3 cubic yard of pea gravel in wellbore.
11/06/01	Pumped 3 cubic yard of pea gravel and 10 sacks of neat cement in wellbore.
11/07/01	Pumped 2 cubic yard of pea gravel and 20 sacks of neat cement in wellbore.
11/09/01	Packer test conducted on interval from 1,587 to 1,745 feet bpl.
11/15/01	Packer test conducted on interval from 1,440 to 1,490 feet bpl.
11/19/01	Packer test conducted on interval from 1,135 to 1,185 feet bpl.
01/11/02	Set temporary Packer at 1,560 feet bpl.
01/15/02	Completed site restoration and demobilization

Table 2. Summary of Well Construction and Testing Activities - GLF-6

After construction was completed, GLF-6 was surveyed relative to permanent reference points by a Florida registered land surveyor, and located on a site plan map by latitude and longitude, and recorded in the public record (**Appendix E**).

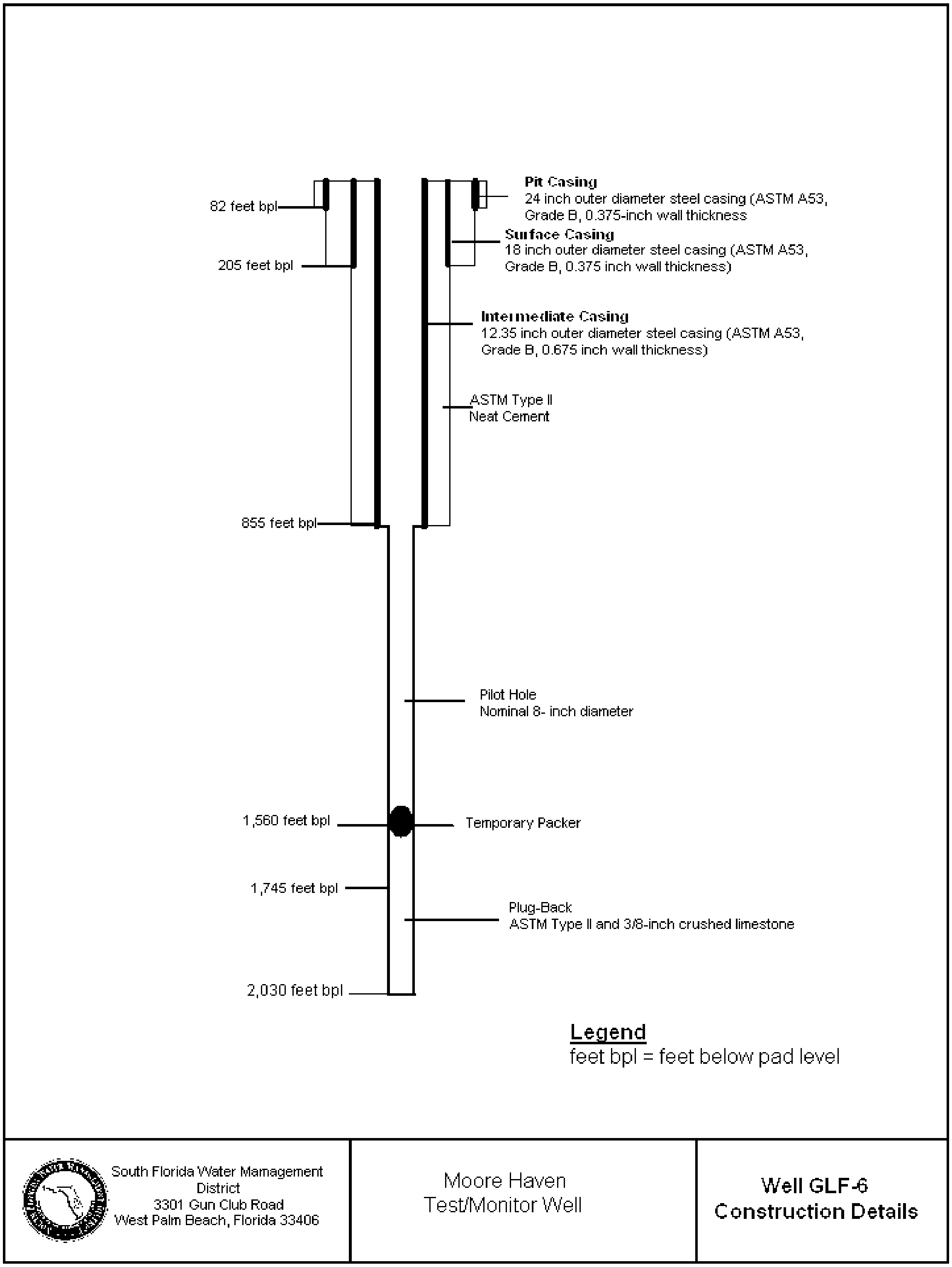

Figure 3. Well Completion Diagram, Test Well No. GLF-6

Hydrogeologic Testing

Specific information was collected during the drilling program to determine the lithologic, hydraulic and water quality characteristics of the FAS at the Moore Haven site. These data were used in the preliminary design of test/monitor well GLF-6.

Formation Sampling
Geologic formation samples (well cuttings) were collected, washed and described (using the Dunham, 1962 classification scheme) on-site during the drilling of the pilot hole. Formation samples were collected and separated based on their dominant lithologic or textural characteristics, and to a lesser extent, color. If a massively bedded unit was encountered, composite samples were taken at a minimum of 5-foot intervals. The representative formation samples were sent to the Florida Geological Survey (FGS) for detailed analysis and long term storage. The field lithologic descriptions for GLF-6 are provided in **Appendix C**. During drilling of the test/monitor well, DDC obtained conventional cores using a 4-inch diameter, 20-foot long, diamond-tipped core barrel. Six rock cores of various lengths were recovered from the FAS between 784 and 1,795 feet bpl with core recoveries of 14 to 100 percent. The six (6) cores will be sent to Core Laboratories located in Midland, Texas to determine the following parameters: horizontal and vertical permeability, porosity, grain density, elastic, electrical and acoustic properties, and lithologic character.

Formation Fluid Sampling
During reverse-air drilling of the pilot hole, samples were taken from circulated return fluids (composite formation water) at 30-foot intervals (average length of drill rod) from 1,650 feet bpl to 2,030 feet bpl. A Hydrolab® multi-parameter probe measured field parameters on each sample, which included temperature, specific conductance, and pH. A field titration method (Hach® Kit) determined chloride concentrations. **Figure 4** shows field-determined specific conductance values and chloride concentrations and calculated TDS concentrations (Hem, 1992) with respect to depth. Between 1,650 to 1,850 feet bpl, specific conductance values gradually increase from 6,000 to 13,400 micromhos per centimeter (umhos/cm) with a corresponding increase in TDS concentrations from 3,500 to 8,000 mg/L. Specific conductance readings increase rapidly from 13,400 to about 25,000 umhos/cm between 1,850 and 1,880 feet bpl. Within this 30-foot interval, specific conductance almost double with calculated TDS concentrations of 14,900 mg/L, which transects the base of the USDW. Specific conductance values gradually increase from 24,888 umhos/cm at 1,880 feet bpl to 52,620 umhos/cm at 1,972 feet bpl. Over the next 60-foot interval, specific conductance values remain constant with an average value of 53,150 umhos/cm.

Geophysical Logging
Geophysical logs were conducted in the pilot hole after each stage of drilling and before casing installation. These logs were conducted to provide a continuous record of the physical properties of the subsurface formations and their contained fluids. These logs were later used to assist in the interpretation of lithology, to provide estimates of permeability, porosity, bulk density, and resistivity of the aquifer, and to determine the

salinity of the ground water (using Archie's equation, [Archie, 1942]). In addition, the extent and degree of confinement of specific intervals can be discerned from the

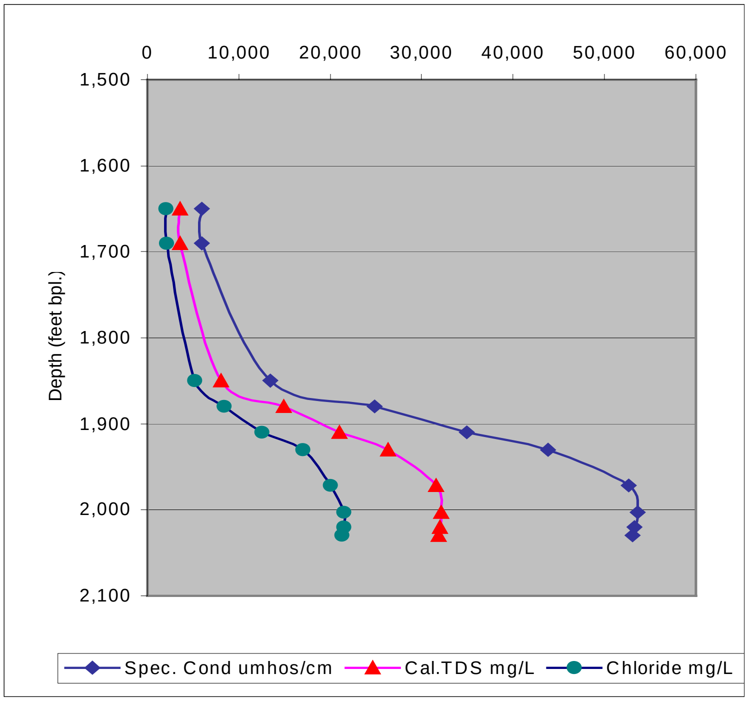

Figure 4. Water Quality with Depth -- Reverse-Air Formation Fluid Returns

individual logs. The geophysical logs also provided data to determine the desired casing setting depths on the test/monitor well. A CBL was conducted on the 12-diameter casing for GLF-6 to assess the quality of grouting operations.

MV Geophysical obtained water samples from the wellbore every 100 feet from 1,500 to 1,968 feet bpl via a wireline fluid sampler (i.e., thief sampler). Field parameters including temperature, pH specific conductance, and ORP, plus chloride content were measured once retrieved to surface. **Table 3** summarizes the water quality results from the individual fluid samples.

Table 3. Water Quality Results of Thief Samples

Depth (ft. bpl.)	Temperature (^{0}C)	pH (S.U.)	Specific Conductance (umhos/cm)	ORP mV	Field Chlorides (mg/L)	Lab Chlorides (mg/L)	Lab TDS (mg/L)
1,500	32.63	7.3	10,808	136	3,560	3,100	6,300
1,600	33.33	7.3	10,811	267	3,600	3,000	6,400
1,700	32.76	7.29	12,992	360	5,100	3,400	7,600
1,800	32.16	7.33	13,685	367	5,400	4,000	8,000
1,900	32.09	7.14	39,505	406	15,340	14,000	24,000
1,968	32.14	6.95	51,597	432	20,100	18,000	33,000

ft .bpl = feet below pad level — umhos/cm = micro-mhos per centimeter
0C = degrees Celsius — mg/L = milligram per Liter
pH = standard unit — ORP = oxidation-reduction potential - mV millivolts

The geophysical logging contractor downloaded all geophysical log data directly from their onsite logging processor in log ASCII standard (LAS) version 1.2 or 2.0 format. The neutron and density porosity values determined calculated from geophysical log data during run No.'s 4 and 8 were derived using a limestone matrix with a density of 2.71 grams per cubic centimeter (gm/cm^3).

The geophysical log traces from log runs No.'s 1 through 8 for well GLF-6 are presented in Appendix A-1 through A-8. The original geophysical logs and video surveys are archived and available for review at SFWMD headquarters located in West Palm Beach, Florida. **Table 4** provides a summary of the geophysical logging operations conducted at this site.

Table 4. Summary of Conventional Geophysical Logging Program -- GLF-6

Run #	Date	Logging Company	Logged Interval (ft.) bpl	Caliper	Natural Gamma	SP	DIL	Sonic	Flow-Meter	Temp	Fluid Res.	Cement Bond Log	Video
1	07/19/01	MV-Geophysical	0-83	x	x								
2	07/24/01	MV-Geophysical	0-216	x	x	x	x	x					
3	07/25/01	MV-Geophysical	83-206	x	x								
5	08/23/01	MV-Geophysical	205-859	x	x								
6	08/24/01	MV-Geophysical	205-855		x					x			
8	10/12/01	MV-Geophysical	855-2020	x	x	x	x		x	x	x		x
9	02/01/02	MV-Geophysical	855-1560	x	x	x	x		x	x	x	x	x

Specialty logging operations conducted by Schlumberger Wireline Services are summarizes in **Table 5**.

Table 5. Summary of Specialty Geophysical Logging Program -- GLF-6

Run #	Date	Logging Company	Logged Interval (ft.) bpl	Natural Gamma Ray Spectrometry (NGS)	Array Induction Imager (AIT)	Compensated Density - Neutron - PEF	Dipole Sonic Imager (DSI)	Formation Micro-Imager (FMI)	Ultrasonic Borehole Imager (UBI)
4	08/15/01	Schlumberger	205-1075	x	x	x	x	x	x
7	09/26/01	Schlumberger	855-2020	x	x	x	x	x	

Packer Tests

Six straddle-packer tests were conducted in the Floridan Aquifer System from 855 to 2,030 feet bpl at this site. The purpose of these tests was to gain water quality and production capacity data on discrete intervals (approximately 50 feet in length) and to establish the depth of the 10,000-mg/L TDS interface.

The procedures listed below were used to conduct individual packer tests in well GLF-6 at the Moore Haven site:

1) Lower packer assembly to the interval selected for testing based on geophysical logs and lithologic data.
2) Set and inflate packers and open the ports between the packers to the test interval.
3) Install a 15-horsepower submersible pump to depth of 60 to 120 feet below the drill floor with a pumping capacity of 30 to 300 gpm.

4) Install two 100-psig-pressure transducers inside the drill pipe and one 30-psig transducer in the annulus connected to a Hermit® 3000 Data Logger to measure and record water-level changes during testing operations.
5) Purge a minimum of three drill-stem volumes.
6) Monitor pressure transducer readings and field parameters (e.g., temperature, specific conductance, and pH) from the purged formation water until stable. These parameters were used to determine the quality of isolation of the packed-off interval.
7) Perform constant rate drawdown and recovery, once the interval was effectively isolated.
8) Collect formation water samples for laboratory water quality analyses following SFWMD's QA/QC sampling protocol.
9) Record recovery data until water levels return to static conditions.

Before ground water sampling, the packer intervals were purged until three borehole volumes were evacuated, or until field parameters of samples collected from the discharge port had stabilized. A limit of +/-5% variation in consecutive field parameter readings was used to determine chemical stability. Field parameters including temperature, specific conductance, and pH were determined on each sample using a Hydrolab® multi-parameter probe. Chloride concentrations were also determined using a field titration method (i.e., Hach® Kit). The flow of water from the discharge point was then adjusted to minimize the aeration and disturbance of the samples. Unfiltered and filtered samples were collected directly from the discharge point by SFWMD staff into a clean plastic bucket. Equipment blanks were obtained prior to sampling to qualify sampling procedures. Replicate samples were also collected from consecutive bailers in accordance with SFWMD Comprehensive Quality Assurance Plan (SFWMD, Comprehensive Quality Assurance Plan, 1999).

Once SFWMD staff collected the samples; they were preserved and immediately placed on ice in a closed container. The composite samples were submitted to the SFWMD Water Quality Laboratory and analyzed for major cation and anions using EPA and/or Standard Method procedures (SFWMD, Comprehensive Quality Assurance Plan, 1999). The analytical results for the samples obtaining during the six packer tests are reported in **Table 6.**

Table 6. Packer Test Water Quality Data from the GLF-6 Test/Monitor Well, Glades County, Florida

			Cations				Anions				Field Parameters		
Identifer	Depth Interval (ft. bpl)	Sample Date	Na^+ (mg/L)	K^+ (mg/L)	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Cl^- (mg/L)	Alka as $CaCO_3$ (mg/L)	SO_4^{2-} (mg/L)	TDS (mg/L)	Specific Conduct. (umhos/cm)	Temp ^{o}C	pH (s.u.)
GLF6_PT6	930-980	11/20/01	1,040	34	176	144	1,938	77	554	4,141	7,139	27.99	7.49
GLF6_PT4	1440-1490	11/15/01	525	14	147	120	1,151	79	406	2,625	4,439	29.64	7.91
GLF6_PT3	1587-1745	11/09/01	2,428	67	359	313	4,711	81	824	9,505	15,160	30.85	7.33
GLF6_PT2	1587-1884	11/02/01	1,897	50	302	240	3,647	81	665	7,412	12,060	30.81	7.35
GLF6_PT1	1587-2030	10/22/01	1,405	39	253	199	2,908	82	595	5,850	9,533	30.77	7.51

Friction loss coefficients were obtained from Appendix 17.A. *Ground Water and Wells*, Driscoll, 1989) according to pipe diameter used during testing operations. This coefficient was then multiplied by the length of pipe to calculate the friction (head) losses as a result of induced flow up the drill pipe. These head losses were then used to correct the drawdown data for specific capacity determinations. The specific capacity (SC) was calculated using the following method:

SC	=	Q / s
Q	=	pumping rate in gpm as measured by an in-line flowmeter,
s	=	aquifer head loss in feet: Measured drawdown minus the pipe friction loss component.

Curve-matching techniques were not used to determine transmissivity values from the drawdown or recovery data collected from straddle packer tests because they generally involve partial penetration, friction loss in small pipe, and short pumping period which violate the analytical method's basic assumptions. In additional, the productive nature of several of the tested intervals enabled them to respond almost instantaneously to the limited applied pumping stress, which induced a pressure wave into the formation. The response to this pressure wave masks their true drawdown and recovery responses. The drawdown and recovery semi-log plots from the individual packer tests are provided in **Appendix D**. The production and static water level data from the individual packer tests are summarized in **Table 7.**

Table 7. Packer Test Specific Capacity Data

Test Name	Interval Tested (ft.)	Pump Rate (gpm)	Total Volume Pumped (gals.)	Initial Head (ft/H2O)	Final Head (ft/H2O)	Total Drawdown (ft)	Total Friction Loss (ft.)	Corrected Drawdown (ft.)	Specific Capacity (gpm/ft)
GLF6_PT6	930-980	100	25,200	105.30	105.31	98.70	19.70	79.00	1.3
GLF6_PT5	1135-1185	1.0	720	107.56	NR	102.69	0.25	102.44	0.01
GLF6_PT4	1440-1490	25	11,500	106.34	106.71	77.40	2.60	74.80	0.33
GLF6_PT3	1587-1745	290	58,900	100.10	100.24	75.50	73.85	1.65	175.76
GLF6_PT2	1587-1884	288	71,200	119.53	119.66	71.92			NR
GLF6_PT1	1587-2030	320	37,200	37.31	36.92	25.43			NR

Hydrogeologic Framework

Two major aquifer systems underlie this site - the Surficial Aquifer System (SAS), the Intermediate Confining Unit, and the Floridan Aquifer System (FAS), with the FAS being the focus of this test well program. These aquifer systems are composed of multiple, discrete aquifers separated by low permeable "confining" units that occur throughout this Tertiary/Quaternary aged sequence. **Figure 5** shows a hydrogeologic section underlying the Moore Haven site.

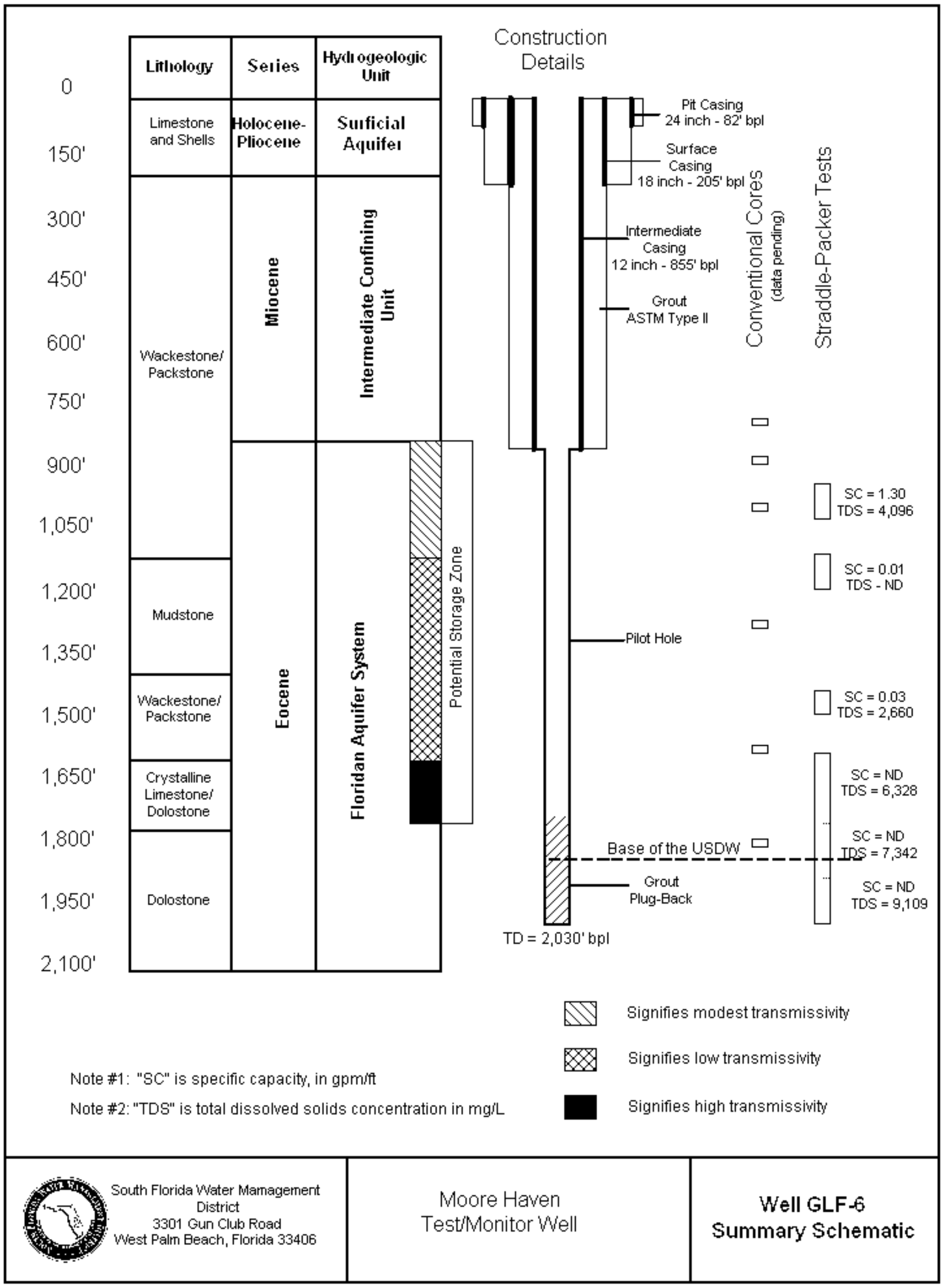

Figure 5. **Hydrogeologic Section for the Moore Haven Site – GLF-6.**

Surficial Aquifer System

The SAS extends from land surface (top of the water table) to a depth of 160 feet bpl. It consists of Holocene and Pliocene-Pleistocene aged sediments. The undifferentiated Holocene sediments occur from land surface to a depth of 10 feet bpl, and consist of unconsolidated light gray, very fine to coarse-grained quartz sands and silt. The sediments from 10 to 82 feet in depth are composed primarily of medium to dark gray, poorly to moderately indurated shell hash mixed with up to 50% fine-grained quartz sand. Unconsolidated, poorly sorted (fine to coarse-grained) quartz sands are present from 82 feet to 160 feet bpl. Low permeability, poorly sorted silty-sands at 160 feet bpl form the base of the SAS at this site. An increase in the natural gamma ray activity below a depth 160 feet bpl suggests an increase in clay content and phosphate percentages, with emissions above 30 American Petroleum Institute (API) units.

Intermediate Confining Unit

Below the SAS lies the Intermediate Confining Unit, which extends from 160 to 850 feet bpl at this location. The Peace River and Arcadia Formations of the Miocene-Pliocene aged Hawthorn Group (Scott, 1989) act as confining units, separating the FAS from the SAS. Lithologic information obtained from drill cuttings from GLF-6 indicates that the Hawthorn Group sediments consist predominately of soft non-indurated detritial clays, silts and poorly to moderately indurated mudstones/wackestone with minor amounts of quartz sand and shell (see lithologic description in **Appendix C**).

The signature of the photoelectric (PEFZ) log with average values of 2 barnes per electron (b/e) from 160 to 460 feet bpl indicates a clayey silt to fine-sand unit with a minor carbonate component. The bulk density (RHOZ) and the derived porosity logs (DPHZ and NPHI curves) suggest that this unit is composed of low density, high porosity siliciclastic sediments within a calcilutite matrix (average of 42 porosity units (p.u.)). The geophysical log data corresponds well with the lithologic data. Qualitatively, the induction log also suggests a porous horizon, whereby the resistivity profile shows separation between the resistivity curves as a result of drilling mud invading the porous sediments **(see Appendix A-4).** The base of this interval is marked by two washouts at 430 and 445 feet bpl as seen on the caliper log trace (HCAL). These washouts correspond to friable quartz sand/silt lens and used to identify the base of this predominately siliciclastic unit (interpreted to be the Peace River Formation).

A transition in lithology occurs from 460 to 520 feet bpl, whereby the carbonate fraction increases with corresponding decrease in the siliciclastics. This transition is evident on the geophysical logs by a slight increase in the PEFZ values (2.5 to 3.0 b/e) and by the signature of the derived porosity curves. The top of this interval is identified by an increase in natural gamma activity, positive shift in the SP log trace and slight increase in borehole diameter.

A change in lithology occurs below 520 feet bpl - identified by an increase in bulk density readings and natural gamma radiation with a corresponding decrease in derived porosity and sonic transit times (Arcadia Formation?). The Photoelectric (PEFZ) log values within this interval range between 3 to 4 b/e indicating a carbonate lithology including a minor silt/sand component (Hallenburg, 1998). Thin, intermittent, moderately indurated carbonate units are apparent on the sonic log from 520 to 730 feet bpl that produce an irregular, spiked sonic trace with average sonic travel times of ~90 usec/ft. The natural gamma log below 520 feet bpl indicates thin, intermittent, gamma radiation peaks, associated primarily with intervals of significant phosphate sand/silt content (**Appendix A-4**).

The lithology from 730 to 850 feet bpl shifts slightly in lithologic character to a mixed carbonate/siliciclastic unit. It is composed of poorly to moderate indurated mudstones with 30 to 40% greenish-gray clays and silts with intervals of unconsolidated quartz sand. This interval is noted by a positive shift in resistivity, photoelectric (average value of 3 b/e) and bulk density values. The unconsolidated, quartz sands identified during drilling caused infilling of the borehole and would be problematic, if not isolated, to further drilling and testing operations. These low permeability units form the lower boundary of the Intermediate Confining Unit.

Floridan Aquifer System

The FAS consists of a series of Tertiary-age limestones and dolostones. The system includes permeable sediments of the lower Arcadia Formation, Suwannee Limestone, Ocala Limestone, Avon Park Formation, and the Oldsmar Formation. The Paleocene-age Cedar Keys Formation with evaporitic gypsum and anhydrite forms the lower boundary of the FAS (Miller, 1986).

Upper Floridan Aquifer

The top of the FAS, as defined by the Southeastern Geological Society AdHoc Committee on Florida Hydrostratigraphic Unit Definition (1986), coincides with the top of a vertically continuous permeable carbonate sequence. The upper Floridan aquifer (UFA) consists of thin, high permeable water bearing horizons interspersed within thick, low permeable units of early Miocene to middle-Eocene aged sediments, including the Arcadia Formation, Suwannee Limestone, Ocala Limestone, and the Avon Park Formation. At this site, the top of the FAS occurs at a depth of 850 feet bpl, which coincides with the top of the Ocala Limestone.

The sharp formation contact between the Miocene/Oligocene-aged Arcadia Formation (Hawthorn Group) and the underlying Eocene-aged Ocala Limestone at a depth of 850 feet bpl is identified by a change in lithology from a dark gray to green, moderately indurated, arenaceous limestone to a light-gray to white, moderately indurated mudstone. This discontinuity at 850 feet bpl coincides with a significant attenuation of the natural gamma activity, increase in the formation resistivity and bulk density, with a corresponding decrease in porosity (based on the derived neutron-density porosity data). Reese (personal communication) suggests that the interval for 850 to 950 feet bpl is part of the basal Hawthorn unit and that the top of the Ocala Limestone occurs at 950 feet bpl, based on correlation of natural gamma ray logs in the area.

Generally, two predominant permeable zones exist within the UFA with the uppermost typically occurring between 700 and 1,300 feet bpl. The most transmissive part usually occurs near the top, coincident with an unconformity at the top of the Oligocene- or Eocene-aged formations (Miller, 1986). Well cuttings and production-type geophysical logs suggest that neither of these productive horizons at formation contact exist within the upper Floridan aquifer at this site resulting in limited productive capacities. A slight deflection in the temperature gradient/differential and dynamic flowmeter log traces at 950 feet bpl suggests the presence of a minor flow zone (**Appendix A-8**). However, a specific capacity test on an interval from 930 to 980 feet bpl, which straddled these flow indicators present within the Ocala Formation, yielded only 1.3 gallons per minute per foot (gpm/ft) of drawdown when pumped at a rate of 100 gpm. Bennett (2001) noted similar production in the UFA at a site in northeastern Hendry County with a reported specific capacity of three gpm/ft of drawdown.

The lower portion of the Ocala Limestone from 980 to 1,110 feet bpl consists of white to light-gray friable mudstones and wackestones. There was very little evidence of significant water production discerned during drilling operations or from the lithologic and geophysical log data over this interval. However, a minor flow zone may be present based on a minor deflection in the temperature and fluid resistivity log traces **(see Appendix A-8)** at the base of this interval.

Middle Floridan Confining Unit

The lithologic character of the upper portion of the Avon Park is generally very similar in lithologic character to the lower Ocala Limestone. The top of the Avon Park Formation is tentatively identified at depth of 1,215 feet bpl at the site, based on a lithologic change from a white mudstone/wackestone to a tan moderately indurated packstone. In addition, this lithologic change is confirmed in the geophysical log data by a slight increase in natural gamma activity, and a general decrease in borehole diameter, bulk density and derived porosity values **(Appendix A-7)**. The lower Ocala Limestone and upper Avon Park Formation from 1,110 to 1,600 feet bpl form an inter-aquifer confining unit within the FAS at this site. This interval consists of low permeability mudstones and wackestones. A packer test in the lower Ocala Limestone (1,135 to 1,185 feet) and Avon Park Formation (1,440 to 1,490 feet bpl) yielded specific capacities of 0.01 gpm/ft and 0.3 gpm/ft, respectively. Formation samples from this interval do not show evidence of large-scale secondary porosity development (e.g., good pinhole, or moldic porosity). In addition, the production-type geophysical logs traces (e.g., temperature and flowmeter logs) indicate no significant productive horizons, as seen by smooth log traces in both the temperature and flowmeter logs, which supports the confining nature of this interval.

Middle Floridan Aquifer

Permeable intervals have been documented within the Avon Park Formation, ranging in depth from 1,400 to 1,600 feet bpl (Miller, 1986). At this site, moderate to well indurated mudstones to packstones inter-bedded with well-indurated crystalline limestones and dolostones occur from 1,600 to 1,740 feet bpl. The dolostone units are cryptocrystalline to surcosic in nature, with the limestone units showing evidence of varying degrees of pinhole and moldic porosity development. A cavernous dolostone unit was encountered at 1,600 feet bpl, which caused a loss of mud circulation and a 2-foot drop of the drill rod. DDC re-mixed and circulated approximately 10,000 gallons of drilling fluid in an effort to regain circulation; these efforts were unsuccessful. During reverse-air drilling, the majority of the natural artesian flow from the wellbore is produced below this depth, supported by the flowmeter data. A specific capacity test on an interval from 1,587 to 1,745 feet bpl, which straddled the cavernous dolostone unit, yielded a specific capacity value of approximately 175 gpm/ft of drawdown. Water quality analysis of samples taken during this test yielded chloride and TDS concentrations of 4,711 mg/L and 9,505 mg/L, respectively. Once the pilot hole was back-plugged to 1,745 feet bpl, the open hole section (855 feet to 1,745 feet bpl) produced approximately 4,200 gpm under natural artesian flow. After the semi-permanent packer was installed at 1,560 feet bpl, the open hole section (855 feet to 1,560 feet bpl) produced 300 to 400 gpm also under natural artesian flow, representing a 90% reduction in artesian flow.

Miller (1986) observed that portions of the lower Avon Park Formation are fine-grained and have low permeability, thereby acting as inter-aquifer confining units within the FAS. At this site, an inter-aquifer confining unit composed of well-indurated, crystalline brown to black dolostones with intermittent mudstone to packstone units occurs in the subsurface from 1,740 to 1,850 feet bpl.

Lower Floridan Aquifer
A textural change from well-indurated, cryptocrystalline dolostones to predominately well indurated sucrosic to microcrystalline dolostones occurs below 1,850 feet bpl. These dolostones are moderately to highly permeable, fractured, and cavernous that occur interspersed within less permeable dolostone and limestone units. This change is noted by a highly variable caliper log, a decrease in formation resistivity and a positive deflection in the temperature gradient log (**see Appendix A-8).**

A well-defined flow zone from 1,850 to 1,880 feet bpl was noted during reverse-air drilling by a substantial increase in water production and significant change in water quality of the reverse-air returns. Specific conductance readings increased rapidly from 13,400 to about 25,000 umhos/cm between 1,850 and 1,880 feet bpl, with calculated TDS concentrations of 14,900 mg/L, transecting the base of the USDW. Specific conductance values gradually increase from 24,888 umhos/cm at 1,880 feet bpl to 52,620 umhos/cm at 1,972 feet bpl. Over the next 60-foot interval, specific conductance values remain constant with an average value of 53,150 umhos/cm.

Based on information provided by Meyers (1989) and Reese (2000), the interval from 1,850 to 2,030 feet bpl was identified as the upper dolostone unit of the lower Floridan aquifer, part of the lower Avon Park Formation.

The top of the Oldsmar Formation is often difficult to identify because of a lack of diagnostic microfossils, generally obliterated by diagenetic effects or a lithologic character similar to the overlying Avon Park Formation. The top of the Oldsmar in south Florida is often identified based on the presence of a dolostone unit discerned on geophysical logs by increased gamma ray counts and resistivity values. If these criteria are used, the Oldsmar Formation could be identified at 1,880 feet bpl, which corresponds to the occurrence of a well indurated, crystalline (euhedral to subhedral) dolostone. Based on lithologic criteria defined by Miller (1986), the lack of a glauconite marker bed used by Duncan et al., (1994), and the absence of Early Eocene index fossils such as Helicostegina gyralis (Chen, 1965), the Oldsmar Formation was not encountered at this site.

Summary

A 12.75-inch outer diameter test/monitor well (GLF-6) was successfully constructed and tested in accordance with the SFWMD technical specifications at the Moore Haven site.

Lithologic information and geophysical logs obtained from GLF-6 indicate that soft non-indurated detritial clays, silts and poorly indurated mudstones of the Hawthorn Group predominate from 160 to 850 feet bpl. These low permeable sediments act as a confining unit, separating the Floridan Aquifer System (FAS) from the overlying Surficial Aquifer System (SAS).

The top of the FAS, as defined by the Southeastern Geological Society AdHoc Committee on Florida Hydrostratigraphic Unit Definition (1986) was identified at a depth of approximately 850 feet bpl.

Lithologic and geophysical logs, packer test results, and specific capacity test results indicate low production capacity of the upper Floridan aquifer from 855 to 1,110 feet bpl.

The lower Ocala Limestone and upper Avon Park Formation form 1,110 to 1,600 feet bpl form and inter-aquifer confining unit within the FAS at this site.

A productive horizon in the Middle Floridan aquifer from 1,600 to 1,740 feet bpl yielded a specific capacity of 175 gpm/ft of drawdown.

The drilling data, open-hole and production-type logs (e.g. flow, temperature logs) indicates good production from 1,600 and 1,740 feet bpl. Below 1,740 feet bpl, the productive capacity is limited (as indicated by the fluid-type logs) suggesting lower permeability, semi-confining units near the base of this productive horizon.

Composite water quality sampling during straddle test and geophyscial log data was used in tandem to identify the base of the USDW at approximately 1,860 feet bpl. Total dissolved solids concentrations below 1,950 feet bpl are similar in concentration to sea water.

Conclusions

1. Potential ASR zones generally exists from the top of the Floridan Aquifer System (855 feet bpl) to the base of the USDW (1,860 feet bpl) at the GLF-6 site.

2. Additional production-type geophysical logging (i.e., flowmeter, temperature, fluid resistivity) should be conducted from the base of casing (855 feet bpl) down to the temporary packer (1,560 feet bpl) to more fully evaluate the upper and middle portions of the FAS for ASR potential. This approach will ensure that the highly productive zones below 1,600 feet bpl will not overwhelm the less overlying permeable zones during testing so that a better evaluation of this interval for ASR potential can be obtained.

3. Following the recommended flow logging, an evaluation should be conducted if acidization or additional specific capacity testing of GLF-6 is warranted to further evaluate ASR potential.

4. If the Moore Haven site is chosen as a site for an ASR system as part of the Lake Okeechobee ASR Pilot Project, GLF-6 will need to be modified to accommodate monitor zone(s) consistent with the future ASR well.

References

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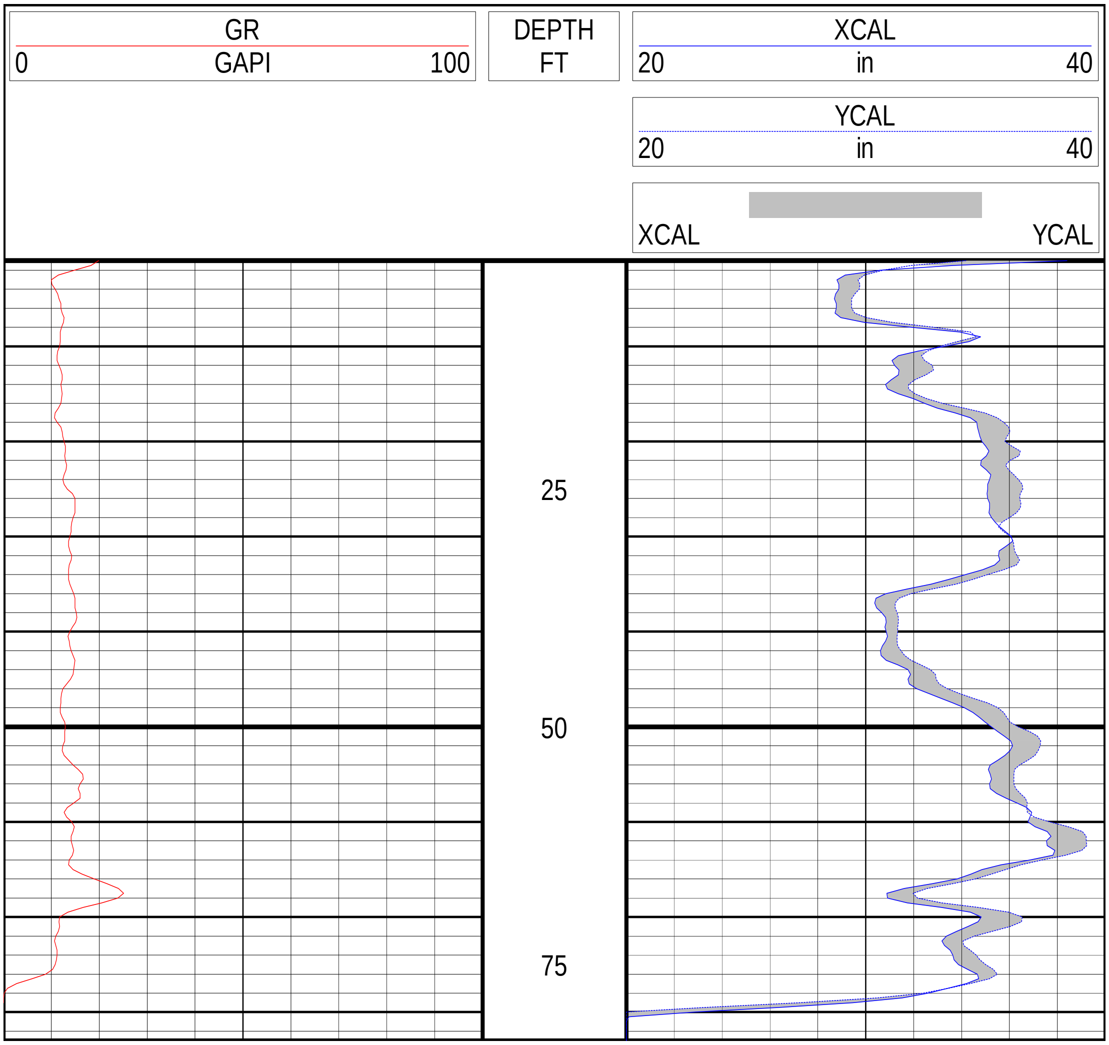

Figure A-1. Geophysical Log Run No. 1 – GLF-6

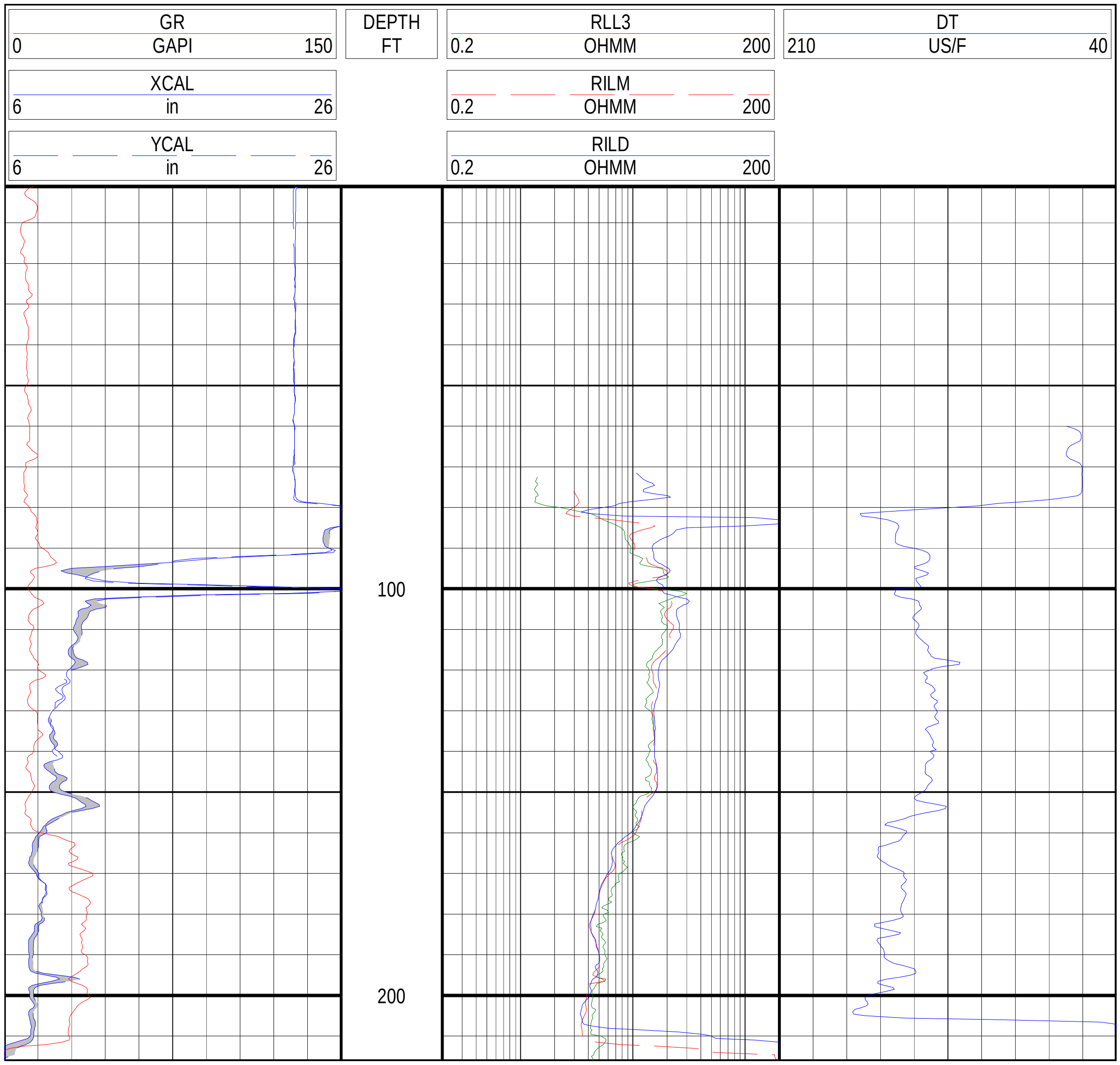

Figure A-2. Geophysical Log Run No. 2 – GLF-6

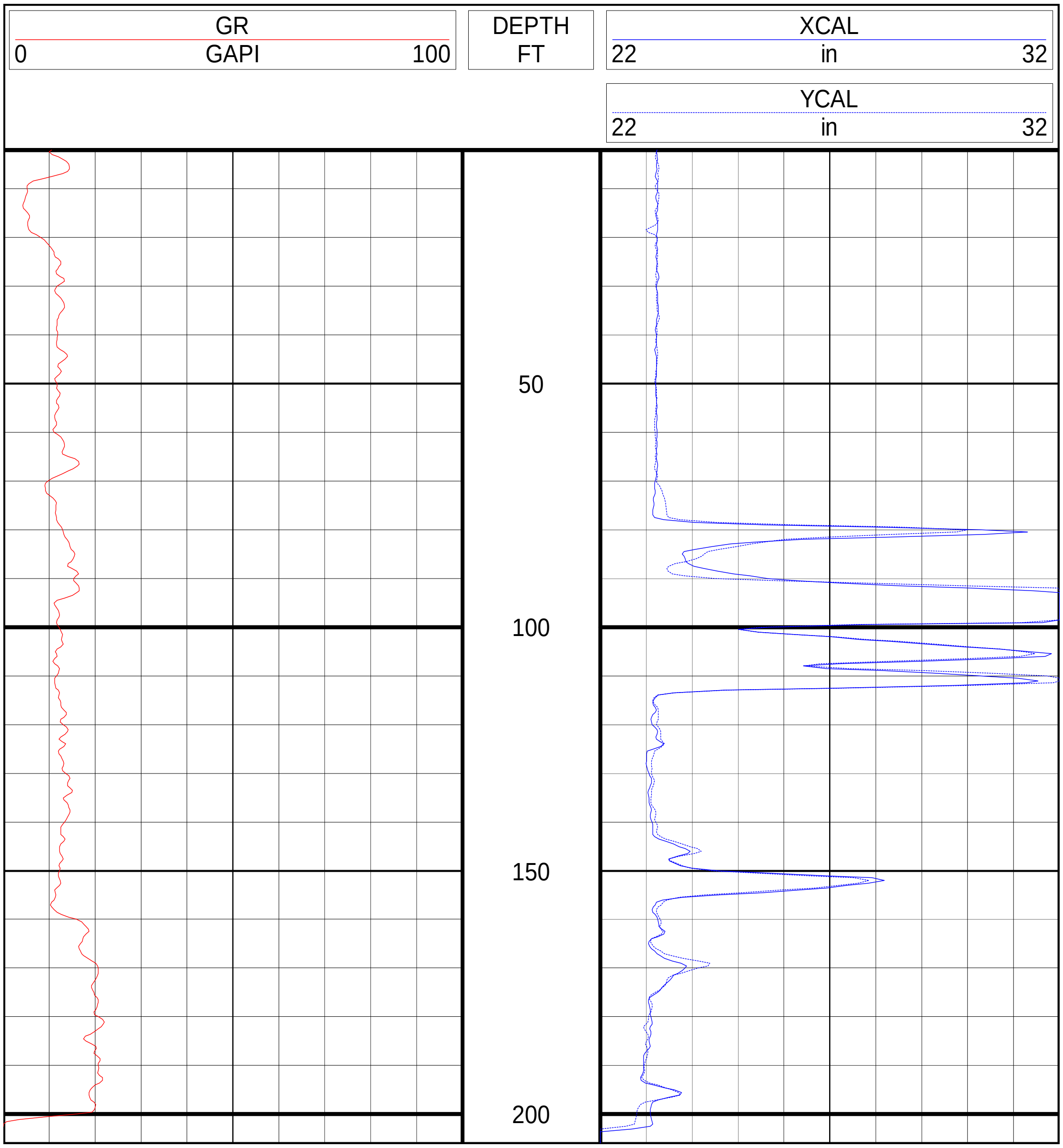

Figure A-3. Geophysical Log Run No. 3 – GLF-6

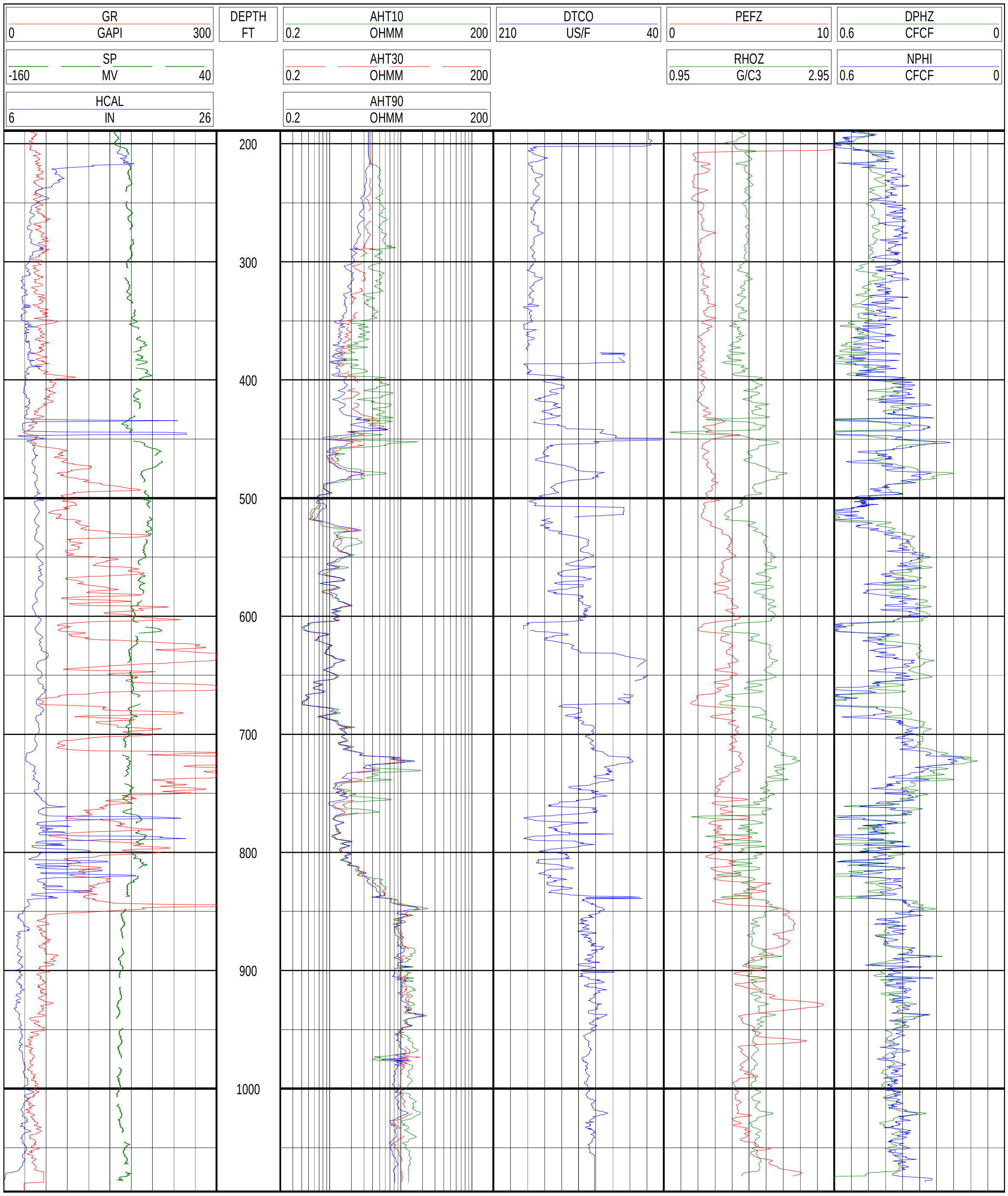

Figure A-4. Geophysical Log Run No. 4 – GLF-6

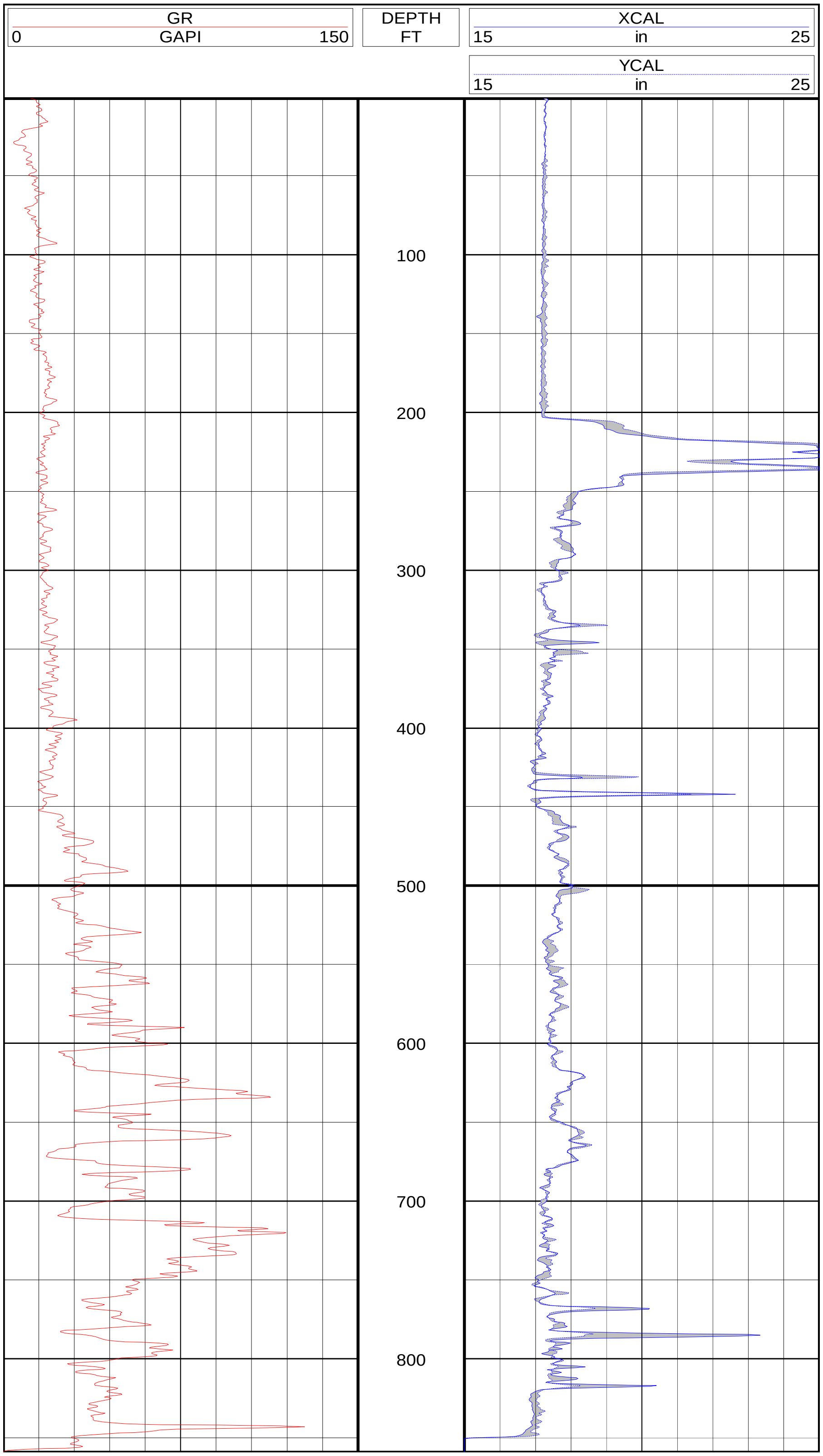

Figure A-5. Geophysical Log Run No. 5 – GLF-6

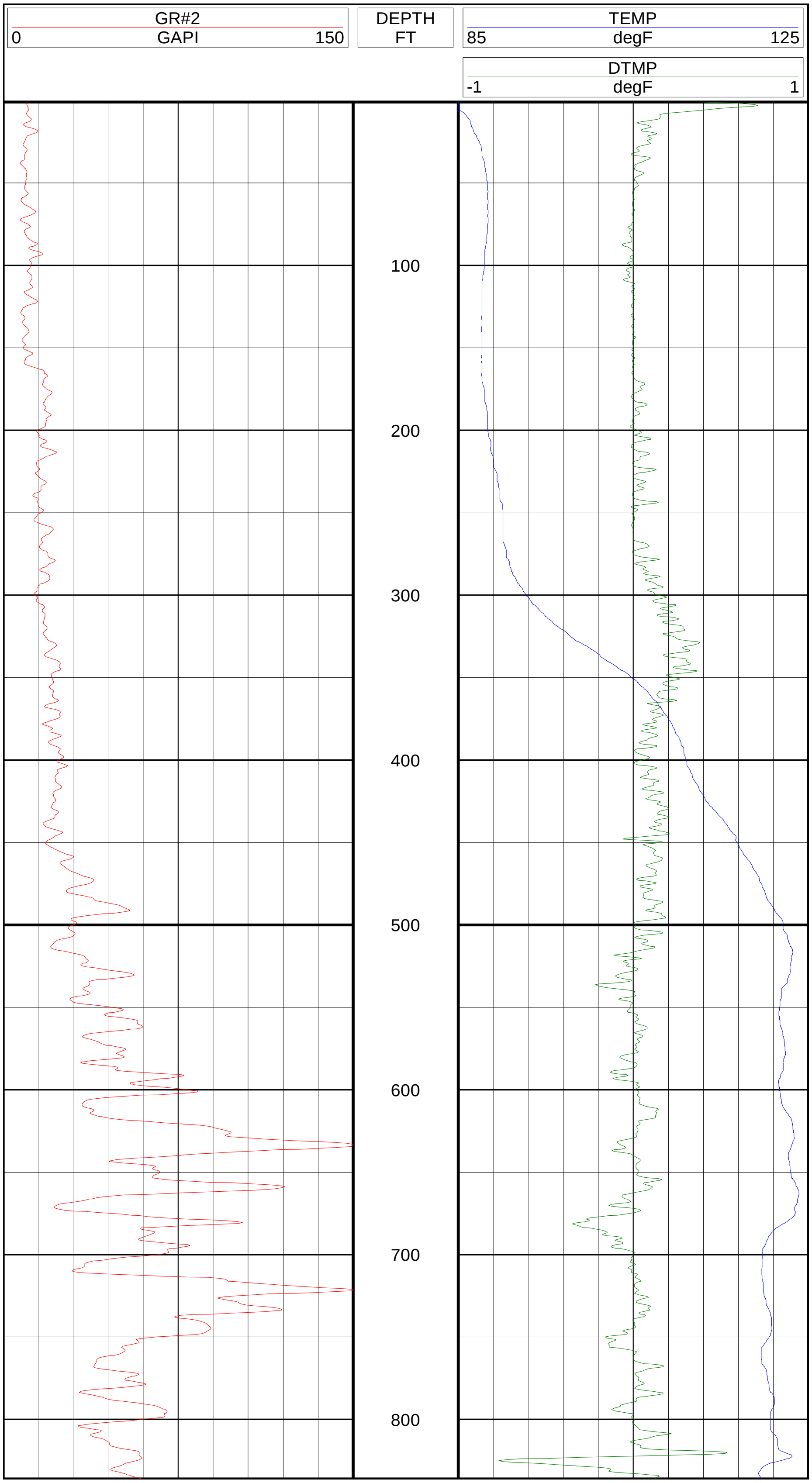

Figure A-6. Geophysical Log Run No. 6 – GLF-6

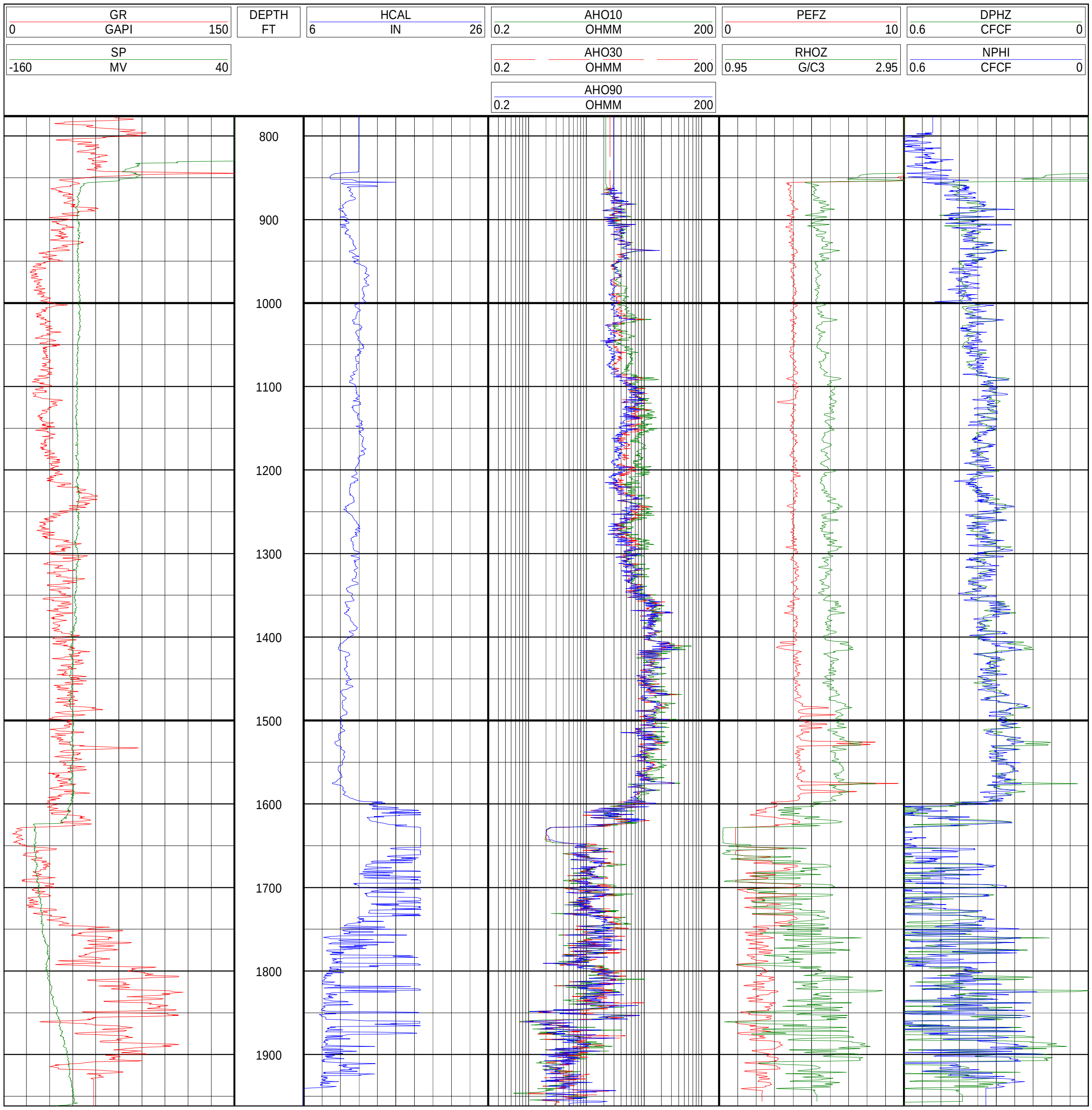

Figure A-7. Geophysical Log Run No. 7 – GLF-6

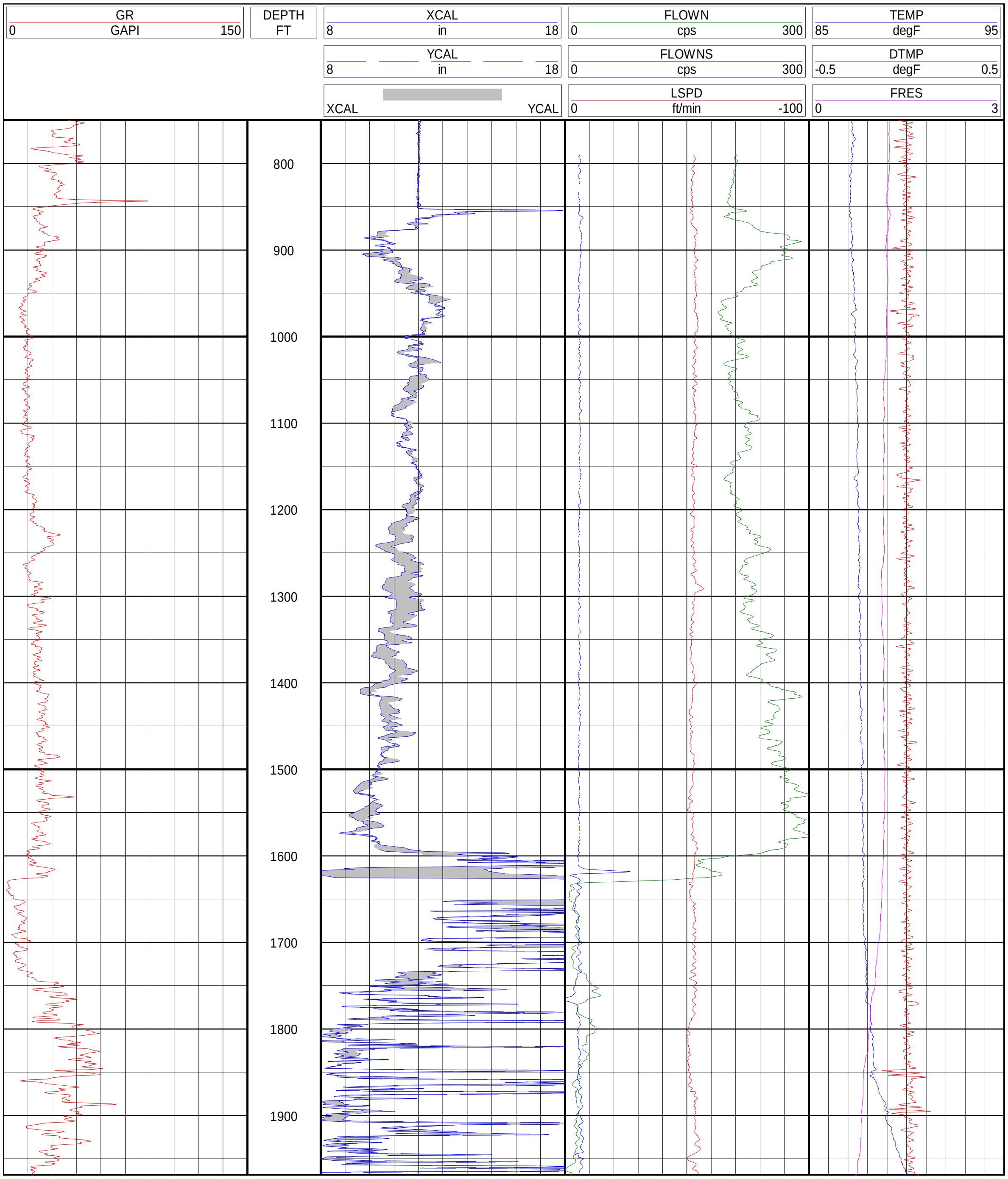

Figure A-8. Geophyscial Log Run No.8 – GLF-6

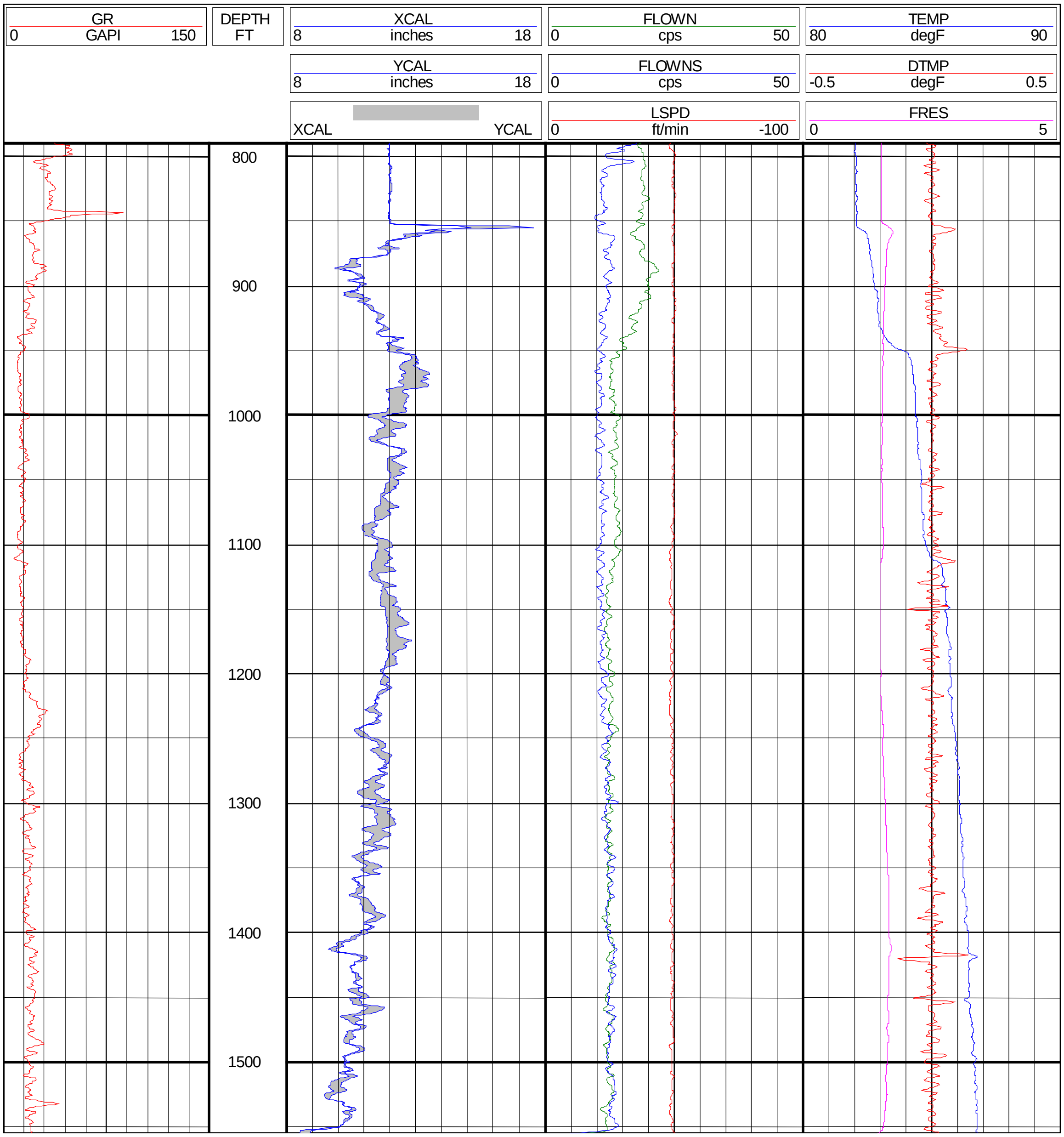

Figure A-9. Geophysical Log Run No. 9 – GLF-6

검 사 증 명 서 (A)

MILL INSPECTION CERTIFICATE

현대강관주식회사
HYUNDAI PIPE CO.,LTD.
• 본사 · 공장 : 울산광역시 북구 염포동 265번지 (683-040)
HEAD OFFICE : # 265, YUMPO-DONG, BUK-KU, ULSAN, KOREA
(ULSAN PLANT) TEL.280-0114 FAX.(052)287-8916
TLX HDPIPE K 53776
• 서울사무소 : 서울특별시 중구 무교동 77번지 (100-170)
SEOUL OFFICE : # 77, MUGYO-DONG, JOONG-KU SEOUL, KOREA
TEL.3455-0500 FAX 775-7595

성적서번호 CERTIFICATE NO : E09070 페이지 PAGE 1
발행일자 DATE OF ISSUE : AUG. 28. 2000. E4035103
계약번호 CONTRACT (P/O) NO :
품명 COMMODITY : E.R.W. STEEL PIPE
적용규격 SPECIFICATION : API 5L X42/API 5LB/ASTM A53B/ASME SA53B
수요가 CUSTOMER :

G:GOOD

Type of pipe end ÷1	÷2	Dimension (Outdia. x Thick. x Length) ÷3 ÷4	Quantity (PCS)	Weight (KG)	Hydrostatic test kg/cm² / PSI	Tests ÷5–÷14	Heat No.	Yield strength PSI / kgf/mm²	Tensile strength B ÷15	Tensile strength W ÷16	Elongation %	C ×100	Si	Mn	P ×1000	S	Cu ×100	Ni	Cr	Mo	V
BE	OD 24"	x .375" x21.000'	106	95.451	83	G G G G G G	00707	35.8	50.9	53.5	36	20	2	86	18	5	1	2	1	Tr	Tr
		(610.0mm x 9.53mm x 6.401M)			1180			50900	72400	76100											
							01636	34.5	49.2	52.1	34	18	1	80	15	7	1	2	1	Tr	Tr
								49100	70000	74000											
							01638	34.2	49.3	52.0	37	17	2	78	15	5	1	2	1	1	Tr
								48600	70100	74000											
							01700	32.5	47.4	50.0	39	18	1	74	13	8	1	2	1	Tr	Tr
								46200	67400	71100											
BE	OD 24"	x .375" x42.000'	145	261.139	83	G G G G G G	88920	31.7	48.5	51.2	37	18	1	80	15	7	1	1	2	Tr	Tr
		(610.0mm x 9.53mm x 12.802M)			1180			45100	69000	72800											
							01636	34.5	49.2	52.0	34	18	1	80	15	7	1	2	1	Tr	Tr
								49100	70000	74000											
							01638	34.2	49.3	52.0	37	17	2	78	15	5	1	2	1	1	Tr
								48600	70100	74000											
							01641	37.0	51.5	53.9	30	20	2	76	15	7	1	2	1	Tr	Tr

THESE MILL TEST REPORTS APPLY TO
YOUR P.O. # 1087
BARTOW STEEL REF. # 38148

REMARK: Okeechobee Site "C"
Attn: Paul

NOTES:
÷1 Type of pipe End 관종
X: B : Black; G : Galvanized; E : Enameled
X: V : Varnish; R : Removed Varnish; O : Oiling Coating; F : PE Coating; C : Coaltar Coating; A : Asphalt Coating
XX: PE : Plain End; BE : Bevel End; TE : Thread End; TC : Thread Coupling; BL : Bell End; SE : Swaging End; VJ : Victaulic Joint
÷2 NB : Nominal Bore 호칭경, OD : Outside Diameter
÷3 Unit 단위 (M : mm, I : Inch)
÷4 Unit 단위 (M : Meter, F : Feet, I : Inch)
÷5 G : Good
÷6 Visual & Dimension Test 외관 및 치수검사
÷7 Flattening or Bending Test 편평 또는 굽힘시험
÷8 Weld Ductility Test 용접부 연성시험
÷9 Nondestructive Test 비파괴검사
÷10 Drift Test 관통시험
÷11 Flaring Test 확관시험
÷12 Crush Test 압궤시험
÷13 Reverse Flattening Test 역편평시험
÷14 Heat Treatment 열처리
÷15 B : Base Metal 모재부
÷16 W : Weld Part 용접부
÷17 H : Heat(Ladle) Analysis 용강분석, P : Product Analysis 제품분석

본 제품은 관련규격에 합격[illegible]을 보증합니다.
WE CERTIFY THAT THE DESCRIBED [illegible]RIAL HAS HEREIN BEEN

18" OKEECHOBEE SITE "C"

검 사 증 명 서 (A)

MILL INSPECTION CERTIFICATE

현대강관주식회사
HYUNDAI PIPE CO.,LTD.
• 본사·공장: 울산광역시 북구 염포동 265번지
HEAD OFFICE: #265, YUMPO-DONG, BUK-KU, ULSAN, KOREA
(ULSAN PLANT) TEL:280-0114 FAX:(052)287-8916
TLX:HDPIPE K 53776
• 서울사무소: 서울특별시 중구 무교동 77번지
SEOUL OFFICE: #77, MUGYO-DONG, JOONG-KU, SEOUL, KOREA
TEL:3455-0500 FAX:775-7095

성적서번호 CERTIFICATE NO: 614210 페이지 PAGE: 1
발행일자 DATE OF ISSUE: APR. 25. 2001. E4113102
계약번호 CONTRACT (P/O) NO:
품명 COMMODITY: E.R.W. STEEL PIPE
제품규격 SPECIFICATION: API 5L X42/API 5LB/ASTM A53B
수요가 CUSTOMER:

THESE MILL TEST REPORTS APPLY TO
YOUR P.O. # 10871
BARTOW STEEL REF. # 38148

G:GOOD

관종 TYPE OF PIPE END ※1	※2	치수 DIMENSION (OUTDIA. × THICK. × LENGTH) ※3 ※4	수량 QUANTITY (PCS)	중량 WEIGHT (KG)	수압시험 HYDROSTATIC TEST MPa / kgf/cm² PSI	6	7	8	9	10	11	12	13	14	제강번호 HEAT NO.	항복강도 YIELD STRENGTH PSI	인장강도 TENSILE STRENGTH B ※15	W ※16	연신율 ELONGATION %	C ×100	Si	Mn	P ×1000	S	Cu ×100	Ni	Cr	Mo	V	Nb ×1000	Al	Ceq
BVBE	OD	18" x .375" x21.000'	121	81.210	105	G	G	G	G	G				G	A08352	33.5	49.0	52.0	37	18	2	81	12	7	2	1	1	Tr	Tr			
		(457.0mm x 9.53mm x 6.401M)			1490											47600	69700	74000														
															A08747	35.6	51.8	54.5	37	19	1	78	14	7	2	1	1	1	Tr			
																50600	73700	77500														
															137277	32.6	49.2	52.0	46	17	2	73	11	10	1	2	1	1	Tr			
																46400	70000	74000														
BVBE	OD	18" x .375" x42.000'	73	97.989	105	G	G	G	G	G				G	A08352	33.5	49.0	52.0	37	18	2	81	12	7	2	1	1	Tr	Tr			
		(457.0mm x 9.53mm x 12.802M)			1490											47600	69700	74000														
BVBE	OD	20" x .375" x21.000'	101	75.486	100	G	G	G	G	G				G	A05999	35.3	51.9	54.5	35	18	2	80	17	8	1	2	1	Tr	Tr			
		(508.0mm x 9.53mm x 6.401M)			1420											50200	73800	77500														
															Y07773	34.4	50.5	53.5	35	20	1	80	14	8	1	2	1	Tr	Tr			
																49900	71800	76100														
BVBE	OD	20" x .375" x42.000'	58	86.697	100	G	G	G	G	G				G	Y07773	34.4	50.5	53.5	35	20	1	80	14	8	1	2	1	Tr	Tr			
		(508.0mm x 9.53mm x 12.802M)			1420											48900	71800	76100														
		TOTAL ->	353	341.382																												

비고 REMARK

ORIGINAL

주기 NOTES

※1 Type of pipe End 관종
X: B: Black, G: Galvanized, E: Enameled
X: V: Varnish, R: Removal Varnish, O: Oiling Coating, F: PE Coating, C: Coaltar Coating, A: Asphalt Coating
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※2 NB: Nominal Bore 호칭경, OD: Outside Diameter
※3 Unit 단위 (M: mm, I: Inch)
※4 Unit 단위 (M: Meter, F: Feet, I: Inch)
※5 G: Good
※6 Visual & Dimension Test 육안 및 치수검사
※7 Flattening or Bending Test 편평 또는 굽힘시험
※8 Weld Ductility Test 용접부 연성시험
※9 Nondestructive Test 비파괴검사
※10 Drift Test 관통시험
※11 Flaring Test 압확시험
※12 Crush Test 통압시험
※13 Reverse Flattening Test 전개시험
※14 Heat Treatment 열처리
※15 B: Base Metal 모재부
※16 W: Weld Part 용접부
※17 H: Heat(Ladle)Analysis 용해분석, P: Product Analysis 제품분석

본 제품은 관련규격에 합격되었음을 보증합니다.
WE CERTIFY THAT THE DESCRIBED MATERIAL HAS HEREIN BEEN ACCEPTED IN ACCORDANCE WIT[illegible] HE PRESCRIBED SPECIFICATION AND ORDER.

SURVEYOR

H. G. Lee
QUALITY ASSURANCE TEAM GENERAL MANAGER

12" PIPE

검 사 증 명 서(A)

MILL INSPECTION CERTIFICATE

현대강관주식회사
HYUNDAI PIPE CO.,LTD.
• 본사·공장: 울산광역시 북구 염포동 265번지 ⑥⑧③-⓪④⓪
HEAD OFFICE: # 265, YUMPO-DONG, BUK-KU, ULSAN, KOREA
(ULSAN PLANT) TEL:280-0114 FAX:(052)287-8916
TLX:HDPIPE K 53776
• 서울사무소: 서울특별시 중구 무교동 77번지 ①⓪⓪-①⑦⓪
SEOUL OFFICE: # 77, MUGYO-DONG, JOONG-KU, SEOUL, KOREA
TEL:3455-0500 FAX:775-7095

성적서번호 CERTIFICATE NO: E14219 — 페이지 PAGE: 1
발행일자 DATE OF ISSUE: APR. 25. 2001. E4113101
계약번호 CONTRACT (P/O) NO:
품명 COMMODITY: E.R.W. STEEL PIPE
제품규격 SPECIFICATION: ASTM A53 GR.B
수요가 CUSTOMER:

THESE MILL TEST REPORTS APPLY TO
YOUR P.O. # 11359
BARTOW STEEL REF. # 39347

G:GOOD

관종 TYPE OF PIPE END ※1	※2	치수 DIMENSION 외경×두께×길이 (OUTDIA. × THICK. × LENGTH) ※3 ※4	수량 QUANTITY (PCS)	중량 WEIGHT (KG)	수압시험 HYDROSTATIC TEST kg f/cm² / PSI	※5	※6 VISUAL & DIMENSION TEST	※7 FLATTENING (B) TEST	※8 WELD DUCTILITY TEST	※9 N.D.T	※10 DRIFT TEST	※11 FLARING TEST	※12 CRUSH TEST	※13 R-FLATTENING TEST	※14 HEAT TREATMENT	도막시험 COATING TEST 아연부착량 WEIGHT OF ZINC COAT g/m² OZ/Ft²	균일성 DIP TEST TIMES ※5	경도 HARDNESS HRB HV	제강번호 HEAT NO.	항복강도 YIELD STRENGTH PSI	인장강도 TENSILE STRENGTH B ※15 kg f/mm²	W ※16 N/mm²	연신율 ELONGATION %	※17	C ×100	Si	Mn	P ×1000	S	Cu ×100	Ni	Cr	Mo	V	Nb ×1000	Al	Ceq	충격시험 IMPACT Absorbed EGY. JOULE	SHEAR AREA %
BVBE	NB	3" x .216" x21.000'	756	54.613	176	G	G	G		G					G				31341843	30.5	47.2		29		16	Tr	68	14	7	1	2	1	Tr	Tr					
		(88.9mm x 5.49mm x 6.401M)			2500															43400	67100																		
																			31341853	35.4	48.0		36		16	3	33	16	7	1	2	1	Tr	1					
																				50400	68300																		
																			31341873	34.2	46.5		30		15	1	68	12	9	1	2	1	Tr	Tr					
																				48600	66100																		
BVBE	NB	3" x .216" x42.000'	252	36.409	176	G	G	G		G					G				31341843	30.5	47.2		29		16	Tr	68	14	7	1	2	1	Tr	Tr					
		(88.9mm x 5.49mm x 12.802M)			2500															43400	67100																		
BVBE	NB	12" x .375" x21.000'	365	172.386	88	G	G	G		G					G				B33090	33.3	51.1	53.9	31		19	2	76	12	7	1	2	1	Tr	Tr					
		(323.8mm x 9.53mm x 6.401M)			1250															47400	72700	76700																	
																			B33092	32.5	50.0	52.8	34		19	1	78	12	6	1	2	1	Tr	Tr					
																				46200	71100	75100																	
BVBE	NB	12" x .375" x42.000'	201	189.861	88	G	G	G		G					G				B33090	33.3	51.1	53.9	31		19	2	76	12	7	1	2	1	Tr	Tr					
		(323.8mm x 9.53mm x 12.802M)			1250															47400	72700	76700																	
																			B33092	32.5	50.0	52.8	34		19	1	78	12	6	1	2	1	Tr	Tr					

비고 REMARK

ORIGINAL

주기 NOTES

※1 Type of pipe End 관종

X
- B : Black
- G : Galvanized
- E : Enameled

X
- V : Varnish
- R : Removal Varnish
- O : Oiling Coating
- F : PE Coating
- C : Coaltar Coating
- A : Asphalt Coating

XX
- PE : Plain End
- BE : Bevel End
- TE : Thread End
- TC : Thread Coupling
- BL : Bell End
- SE : Swaging End
- VJ : Victaulic Joint

※2 NB : Nominal Bore 호칭경, OD: Outside Diameter
※3 Unit 단위 (M : mm, I : Inch)
※4 Unit 단위 (M : Meter, F : Feet, I : Inch)
※5 G : Good
※6 Visual & Dimension Test 육안 및 치수검사
※7 Flattening or Bending Test 편평 또는 굽힘시험
※8 Weld Ductility Test 용접부 연성시험
※9 Nondestructive Test 비파괴검사 ( )
※10 Drift Test 관용시험
※11 Flaring Test 압확시험
※12 Crush Test 충압시험
※13 Reverse Flattening Test 전개시험
※14 Heat Treatment 열처리
※15 B : Base Metal 모재부
※16 W : Weld Part 용접부
※17 H : Heat(Ladle)Analysis 용연분석, P:Product Analysis 제품분석

SURVEYOR

본 제품은 관련규격에 합격되었음을 보증합니다.
WE CERTIFY THAT THE DESCRIBED MATERIAL HAS HEREIN BEEN ACCEPTED IN ACCORDANCE WITH THE PRESCRIBED SPECIFICATION AND ORDER.

H. G. Lee
QUALITY ASSURANCE TEAM GENERAL MGR.

HPS - B 301 - 631 - 0 - QLT

검 사 증 명 서 (A)

MILL INSPECTION CERTIFICATE

현대강관주식회사
HYUNDAI PIPE CO.,LTD.
• 본사·공장 : 울산광역시 북구 염포동 265번지 ☎283-0040
HEAD OFFICE : # 265, YUMPO-DONG, BUK-KU, ULSAN, KOREA
(ULSAN PLANT) TEL:280-0114 FAX:(052)287-8916
TLX:HDPIPE K 53776
• 서울사무소:서울특별시 중구 무교동 77번지 ☎100-1170
SEOUL OFFICE : # 77, MUGYO-DONG, JOONG-KU, SEOUL, KOREA
TEL:3455-0500 FAX:775-7095

성적서번호 CERTIFICATE NO : E14219 페이지 PAGE : 2
발행일자 DATE OF ISSUE : APR. 25. 2001. E4113101
계약번호 CONTRACT (P/O) NO :
품명 COMMODITY : E.R.W. STEEL PIPE
제품규격 SPECIFICATION : ASTM A53 GR.B
수요가 CUSTOMER :

THESE MILL TEST REPORTS APPLY TO
YOUR P.O. # 11359
BARTOW STEEL REF. # 39347

G:GOOD

관종 TYPE OF PIPE END ※1	※2	치수 DIMENSION 외경×두께×길이 (OUTDIA. × THICK. × LENGTH) ※3 ※4	수량 QUANTITY (PCS)	중량 WEIGHT (KG)	수압시험 HYDROSTATIC TEST MPa kg f/cm² PSI	※5	※6 VISUAL & DIMENSION TEST	※7 FLATTENING (B) TEST	※8 WELD DUCTILITY TEST	※9 N.D.T.	※10 DRIFT TEST	※11 FLARING TEST	※12 CRUSH TEST	※13 R-FLATTENING TEST	※14 HEAT TREATMENT	도막시험 COATING TEST 아연부착량 WEIGHT OF ZINC COAT g/m² OZ/FT²	균일성 DIP TEST TI-MES ※5	경도 HARDNESS HRB HV	제강번호 HEAT NO.	항복강도 YIELD STRENGTH PSI	인장강도 TENSILE STRENGTH B ※15 kg f/mm² N/mm²	W ※16	연신율 ELONGATION %	※17	C ×100	Si	Mn	P ×1000	S	Cu ×100	Ni	Cr	Mo	V	Nb ×1000	Al	Ceq	충격시험 IMPACT 흡수에너지 Absorbed EGY. JOULE	전단면적 SHEAR AREA %
		(323.8mm x 9.53mm x 12.802M)			1250															46200	71100	75100																	
																			B33098	31.6	49.4	52.1	36		18	1	77	13	6	1	2	1	Tr	Tr					
																				44900	70300	74100																	
BVBE	NB	12" x .500" x21.000'	33	20.582	116	G	G	G		G					G				A06394	32.6	50.0	52.8	33		18	1	80	16	8	1	2	1	Tr	Tr					
		(323.8mm x12.70mm x 6.401M)			1650															46400	71100	75100																	
																			B33089	31.1	49.1	52.0	34		17	3	74	11	6	1	2	1	Tr	Tr					
																				44200	69800	74000																	
																			B33098	31.6	49.4	52.1	36		18	1	77	13	6	1	2	1	Tr	Tr					
																				44900	70300	74100																	
																			B33100	31.4	49.1	52.0	38		17	1	77	14	5	2	1	1	Tr	Tr					
																				44700	69800	74000																	
BVBE	NB	12" x .500" x42.000'	16	19.958	116	G	G	G		G					G				B33098	31.6	49.4	52.1	36		18	1	77	13	6	1	2	1	Tr	Tr					
		(323.8mm x12.70mm x 12.802M)			1650															44900	70300	74100																	
		TOTAL ->	1623	493.809																																			

비고 REMARK

ORIGINAL

참고 NOTES

※1 Type of pipe End 관종
X
- B : Black
- G : Galvanized
- E : Enameled

X
- V : Varnish
- R : Removal Varnish
- O : Oiling Coating
- F : PE Coating
- C : Coaltar Coating
- A : Asphalt Coating

XX
- PE : Plain End
- BE : Bevel End
- TE : Thread End
- TC : Thread Coupling
- BL : Bell End
- SE : Swaging End
- VJ : Victaulic Joint

※2 NB : Nominal Bore 호칭경, OD: Outside Diameter
※3 Unit 단위 (M : mm, I : Inch)
※4 Unit 단위 (M : Meter, F : Feet, I : Inch)
※5 G : Good
※6 Visual & Dimension Test 육안 및 치수검사
※7 Flattening or Bending Test 편평 또는 굽힘시험
※8 Weld Ductility Test 용접부 연성시험
※9 Nondestructive Test 비파괴검사 ( )
※10 Drift Test 관통시험
※11 Flaring Test 압확시험
※12 Crush Test 종압시험
※13 Reverse Flattening Test 전개시험
※14 Heat Treatment 열처리
※15 B : Base Metal 모재부
※16 W : Weld Part 용접부
※17 H : Heat(Ladle)Analysis 열연분석, P:Product Analysis 제품분석

SURVEYOR	본 제품은 관련규격에 합격되었음을 보증합니다. WE CERTIFY THAT THE DESCRIBED MATERIAL HAS HEREIN BEEN ACCEPTED IN ACCORDANCE WITH THE PRESCRIBED SPECIFICATION AND ORDER.	H. G. Lee QUALITY ASSURANCE TEAM GENERAL MGR.

HPS - B 301 - 631 - 0 - OLT

(350 \ 280)

FORM RP-59
July 1979

WELL DRILLER'S LOG

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

PROJECT Lake Okee. ASR Pilot Project WELL NO. GLF-6 DATE 8/23/01

12 inch dia. casing Tally

DEPTH	DESCRIPTION – ROCK TYPE, COLOR, HARDNESS, OTHER					
Casing #	Set #	Heat #	Tag #	Length (ft)	start weld	End weld
12	1	B33098	75583	42.10	11:07	11:17
11	2	B33092	72056	42.10	11:40	11:47
10	3	B33092	75583	42.10	12:07	12:10
9	4	B33092	75583	42.09	12:40	12:47
8	5	B33092	72058	42.13	13:13	13:20
7	6	B33092	72054	42.10	1330	13:40
6	7	B33098	75583	42.10	1350	13:57
5	8	B33092	72049	42.10	14:02	14:12
4	9	B33098	72055	42.12	14:19	14:30
3	10	B33092	72060	42.11	14:44	14:51
2	11	B33098	72057	42.10	15:00	15:10
1	12	B33098	75583	42.11	15:17	15:25
20	13	B33092	75583	42.10	15:36	15:45
19	14	B33092	75583	42.10	15.57	16:05
18	15	B33092	75583	42.10	16:17	16:25
16	16	B33092	75583	42.10	16:35	16:44
17	17	B33098	75583	42.10	16:54	17:05
15	18	B33090	75583	42.10	17:10	17:18
14	19	B33092	75583	42.09	17:47	18:00
13	20	B33098	72053	42.11	18:10	18:20
21	21	B33098	75583	24.65	18:28	18:35
			Total:	866.71		

Lithologic Log
SFWMD Moore Haven Test Well GLF-6
Glades County, Florida

Depth in Feet Below P

From	To	Lithologic Description GLF-6
0	10	Light gray fine quartz sand/silt mix, 40% quartz (dirty sugar sand). Note: shallow sediments may have been reworked, site is near Hoover Dike, the Caloosahatchee and a road. Poor to moderate induration.
10	25	Medium to dark gray shell hash (pelcypods, gastropods, barnacles, bryozoams, and oyster fragments) This shell hash has a fine sand(quartz)/silt matrix . Poor induration.
25	35	Same as above with some large well rounded quartz sand grains (2mm by 4mm and roughly 5% of cuttings)
35	50	Medium to dark gray shell hash (pelcypods, gastropods, barnacles, bryozoams, and oyster fragments) This shell hash has a silt/clay matrix and is better indurated than above. Moderate induration.
50	70	Medium to dark gray shell hash (pelcypods, gastropods, barnacles, bryozoams, and oyster fragments) This shell hash has a fine quartz sand matrix, sand content estimated to approach 50 %. Poor induration
70	82	Medium to dark gray shell hash (pelcypods, gastropods, barnacles, bryozoams, and oyster fragments) This shell hash has a fine sand(quartz)/silt matrix . Poor to moderate induration.
82	160	Light Gray, Poorly sorted quartz sand, predominantly fine but with some larger grains 5mm by 7mm
160	180	Light Gray, Poorly sorted dirty quartz sand, increasing silt matrix compared to above
180	185	Light gray green clay with some sand and silt
185	190	Gray green silty clay
190	217	Green plastic clay with some silt
217	240	Light Green, poorly indurated, sandy silty clay
240	245	Light gray sandy, silty, clay
245	250	Green Gray, soupy, silt, fine sand, clay mix

Lithologic Log
SFWMD Moore Haven Test Well GLF-6
Glades County, Florida

Depth in Feet Below P

250	290	Green Silty Clay, fine sand mix, friable
290	305	Gray green silty, sandy clay, slightly plastic
305	310	light gray green friable silt, fine sand, clay mix, dry
310	355	light gray green friable silt, fine sand, clay mix, hydrated
355	401	light gray green plastic clay with significant silt and fine sand.
401	405	Dark grayish-green plastic clay with coarse quartz sandand phosphatic sand grains (2-4mm)
405	460	Gray green friable Clay with varying amounts of sand and silt.
460	475	Light gray green plastic clay
475	540	Mixed green and white phosphatic clay
540	545	Light gray plastic silty clay
545	560	Light gray to white micritic limestone/clay mix
560	605	Light gray clay marl with shell fragments and fine sand sized phosphorite grains
605	615	Green plastic clay with little to no sand and silt.
615	650	Mixture of green clay with white micritic marl
650	670	White micrite with some phosphorite
675	680	Green Clay
680	710	White micrite with clay and phosphorite
710	743	White shelly micrite with clay

Lithologic Log
SFWMD Moore Haven Test Well GLF-6
Glades County, Florida

Depth in Feet Below P

743	784	Gray green friable silt, fine sand mix with clay
784	804	Hard green clay , interval was cored , but poor capture.
804	845	Light gray green clay with phosphate and shell
845	874	White mudstone
874	886	(Core, 100% recovery) White Mudstone
886	988	White mudstone
988	1,006	(Core, 100% recovery) White Mudstone
1,006	1,125	White mudstone
1,125	1,173	White Wackestone/packstone Large quantities of leps
1,173	1,210	White Wackestone/packstone
1,210	1,215	White Wackestone/packstone, with phosphorite
1,215	1,245	Tan Packstone, interfingered with sandy clay
1,245	1,265	Tan Packstone , better indurated than above
1,265	1,299	White mudstone
1,299	1,317	(Core, 100% recovery) White to tan mudstone
1,317	1,418	White to tan mudstone, friable, micritic, <5% allochems, low intergranular porosity.
1,418	1,463	White to tan mudstone, friable, micritic, <5% allochems, 30% dolomite, low intergranular porosity.

Lithologic Log
SFWMD Moore Haven Test Well GLF-6
Glades County, Florida

Depth in Feet Below P

1,463	1,478	White to tan mudstone, friable, micritic, <5% allochems, 10% dolomite, low intergranular porosity.
1,478	1,508	White to tan mudstone, friable, micritic, <5% allochems, 5% dolomite, low intergranular porosity.
1,508	1,528	White to tan mudstone, friable, micritic, <5% allochems, <1% dolomite, low intergranular porosity.
1,528	1,538	White to tan mudstone, friable, micritic, <5% allochems, <1% dolomite, 1-3 % white clay/lime mud low intergranular porosity.
1,538	1,543	White to tan mudstone, friable, micritic, <5% allochems, 10% dolomite, 1-3 % white and brown clay/ lime mud, low intergranular porosity.
1,543	1,571	White to tan mudstone, friable, micritic, <5% allochems, 10% dolomite, low intergranular porosity.
1,571	1,591	(Core, 100% recovery) Tan mudstone to wackestone
1,591	1,605	White to tan mudstone with small amounts of packstone (sand sized grains)
1,605	1,610	Dark brown to black sucrosic dolostone
1,610	1,615	Tan mudstone
1,615	1,620	Tan mudstone with 30% dolomite
1,620	1,625	Tan mudstone with 30% dolomite, friable
1,625	1,633	Mudstone
1,633	1,664	Cavity
	1,650	**Reverse-air Water Quality Data taken on 9/18/01** **Temp = 30.62C; pH = 7.63 s.u.; SpCond = 5,931 umhos/cm; Cl**
1,664	1,669	Light tan mudstone

Lithologic Log
SFWMD Moore Haven Test Well GLF-6
Glades County, Florida

Depth in Feet Below P

1,669	1,680	Light to dark tan mudstone
1,680	1,735	Moderately indurated, white to light tan mudstone, low intergranular porosity
	1,690	**Reverse-air Water Quality Data taken on 9/19/01** **Temp = 30.94C; pH = 7.05 s.u.; SpCond = 5,960 umhos/cm;**
1,740	1,750	Well indurated, dark brown, crystalline dolostone (sucrosic)
1,750	1,765	Moderately to well indurated, tan colored, crystalline dolostone. 5% white, poorly inudurated mudstone
1,765	1,780	Moderately to well indurated, tan to dark brown cystalline dolostone (sucrousic) moderate intercystalline porosity
1,780	1,788	Moderately to well indurated, tan to dark brown cystalline dolostone (sucrousic) moderate intercystalline porosity; 5 to 10% white moderately indurated mudstone
1,788	1,795	(Core, 28 % recovery) Well indurated tan to dark brown crystalline dolostone (sucrosic) minor vuggy porosity development
1,819	1,855	Well indurated, medium brown to black crystalline (sucrosic) to cyptocrystalline dolostone minor vuggy porosity development; 5 to 10% white to tan poorly to moderately indurated mudstone to wackestone - Dictyoconus present; signficant bit chatter; drilling rate 4 minutes/foot
	1,850	**Reverse-air Water Quality Data taken @ 10:13 hr on 9/22/01** **Temp = 30.75C; pH = 8.11 s.u.; SpCond = 13,444 umhos/cm; ORP = 205 CL = 5,200 mg/l**
1,855	1,860	Moderatley indurated, medium brown to golden brown, cryptocrystalline to crystalline (sucrosic) dolostone, good intercrystalline porosity; recystallized irregular echinoids; some bit plugging
1,860	1,870	Well indurated, medium to dark brown crytalline dolostone, few irregular echinoids present minor intercystalline porosity

Lithologic Log
SFWMD Moore Haven Test Well GLF-6
Glades County, Florida

Depth in Feet Below P

1,870	1,880	Moderately indurated, medium to golden brown crystalline (sucrosic) dolostone , good intercrystalline porosity development - good permeability- increased water flow at land surface and reverse-air returns began to foam
	1,880	**Reverse-air Water Quality Data taken @ 1230 hr on 9/22/01** **Temp = 31.61 C; pH = 7.67; SpCond = 24,882 umhos/cm; ORP = 262; Cl = 8,400 mg/l**
1,880	1,890	Well indurated, medium brown to dark gray microcrystalline to crystalline dolostone minor pin-hole porosity, low intercrystalline porosity - low permeability
1,890	1,900	Moderately indurated, golden brown crystalline (sucrosic) dolostone, good intercrystalline porosity develop. good pin-hole porosity -good permeability
1,900	1,905	Very well indurated, brown to black microcystalline to crystalline dolostone; minor intercrystalline porosity and pin-hole porosity - low permeability - good confinement
1,905	1,910	Moderately to well indurated, medium to golden brown to dark gray microcrystalline to crystalline (sucrosic) dolostone good intercystalline porosity, minor pin-hole porosity; moderately indurated light gray wackstone near base (1,908 to 1,910) with minor pin-hole porosity
	1,910	**Reverse-air Water Quality Data taken @ 1431 hr on 9/22/01** **Temp = 32.59 C; pH = 7.67; SpCond = 34,953 umhos/cm; ORP = 243; Cl = 12,500 mg/l**
1,910	1,920	Moderately to well indurated, medium to golden brown to dark gray microcrystalline to crystalline (sucrosic) dolostone good intercrystalline porosity, minor pin-hole porosity
1,920	1,925	Moderately to well indurated, dark tan to dark gray microcrystalline to crystalline (sucrosic) dolostone good intercrystalline porosity,
1,925	1,940	Moderately to well indurated, dark tan to dark gray striated microcrystalline to crystalline (sucrosic) dolostone good intercrystalline porosity,
1,940	1,945	Dark tan to dark gray dolostone, dark gray is cryptocrystalline and well indurated (70%), dark tan is crystalline sucrosic, and moderately indurated (30%), good intercrystalline porosity,

Lithologic Log
SFWMD Moore Haven Test Well GLF-6
Glades County, Florida

Depth in Feet Below P

	1,940	**Reverse-air Water Quality Data taken @ 11:47 hr on 9/24/01** **Temp = 33.56 C; pH = 7.32; SpCond = 43,840 umhos/cm; ORP = 219; Cl = 17,000 mg/l**
	1,945	**Reverse-air Water Quality Data taken @ 12:30 hr on 9/24/01** **Temp = 31.51 C; pH = 7.50; SpCond = 43,818 umhos/cm**
	1,945	**Reverse-air Water Quality Data taken @ 12:45 hr on 9/24/01** **Temp = 31.28 C; pH = 7.43; SpCond = 45,150 umhos/cm; ORP = 172** (Note: the flow stopped shortly after taking the 12:45 water quality sample. The driller (Bruce Harman) speculated that the density of the water might be suppressing the flow. The site geologist (Jeff Herr) believes that we encountered a producing zone with a lower head, or less dense (better quality) water which would take water. The driller added 40 feet to the airline and the well did produce water, it took approximately 40 minutes to add more airline. The flow rate increased with time.
1,945	1,972	Dark gray cryptocrystalline well indurated dolostone with a tan crystalline (sucrosic) coating, high intercrystalline porosity.
	1,972	**Reverse-air Water Quality Data taken @ 13:50 hr on 9/24/01** **Temp = 31.51 C; pH = 7.16; SpCond = 52,620 umhos/cm; ORP 150; Cl = 20,000 mg/l**
		(Entire open hole discharge) Water Quality Taken @1348 Temp = 31.67 C; pH = 7.40; SpCond = 6,797 umhos/cm; ORP -65
1,972	1,980	Dark gray with Tan and white mottling, crystalline dolostone, well indurated platy fracture. some faces have well developed sucrosic fracture with some graine sizes to 0.5 mm
1,980	1,995	Dark gray with Tan and white mottling, crystalline dolostone, well indurated platy fracture.
1,995	2,000	Light gray with Tan and white mottling, crystalline dolostone, well indurated platy fracture.
2,000	2,005	Dark gray with some tan and brown colored crystalline dolostone, well indurated with some pin-ppoint porosity Sucrosic dolomite crystals coating the interior of vugs.

Lithologic Log
SFWMD Moore Haven Test Well GLF-6
Glades County, Florida

Depth in Feet Below P

	2,003	**Reverse-air Water Quality Data taken @ 1500 on 9/25/01** **Temp = na C; pH = 7.36; SpCond = 53,600 umhos/cm; ORP 150; Cl = 22,500 mg/l**
2,005	2,010	Golden-brown to gray tan cryptocrystalline dolostone, some faces have a crystralline (sucrosic) coating moderate induration, platy fracture
	2,010	**Reverse-air Water Quality Data taken @ 15:45 on 9/25/01** **Temp = 31.89 C; pH = 7.43; SpCond = 52,462 umhos/cm; ORP 229**
	entire OH	(Entire Open Hole Discharge) sample taken @ 15:55 on 9/25/01 Temp = 31.67 C; pH = 7.76; SpCond = 7,009 umhos/cm; ORP -62
2,010	2,015	light tan and light gray crystalline dolostone, moderately indurated with platy fracture. Larger crystaline size on interior surface of vugs.
2,015	2,020	Light-tan gray cryptocrystalline moderately indurated dolostone, rare crystalline coating on some faces.
	2,020	**Reverse-air Water Quality Data taken @ 16:02 on 9/25/01** **Temp = 31.51 C; pH = 7.50; SpCond = 53,299 umhos/cm; ORP 240; Cl = 21,500 mg/l**
2,020	2,026	Mottled gray white and tan, moderately to well indurated dolostone.
2,026	2,027	Grayish tan moderately indurated crystalline dolomite with platy fractures.
2,027	2,030	Grayish tan moderately indurated crystalline dolomite with platy fractures, sucrosic coating on some surfaces.
	2,030	**Drill Stem Reverse-air Water Quality Data taken @ 14:45 on 10/04/01** **Temp = 31.54 C; pH = 7.21; SpCond = 53,100 umhos/cm;**