Seminole Tribe of Florida
Hollywood Reservation
Deep Injection Well Completion Report
EPA Permit SEA 0001

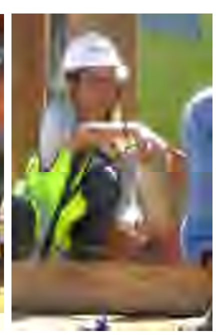
January 2019

Volume 1 – Report

Hazen

Hazen Project 41086-013



Hazen

Hazen and Sawyer
4000 Hollywood Boulevard, Suite 750N
Hollywood, FL 33021 • 954.987.0066

January 11, 2019

Jason Meadows, P.G.
Environmental Protection Agency
WPD / GWUIC
61 Forsyth Street SW, 9T25
Atlanta, Georgia, 30303

Re: Completion Report
EPA Permit No. SEA 0001
Seminole Tribe of Florida – Hollywood Reservation

Dear Mr. Meadows:

Enclosed is the Deep Injection Well Completion Report and Deep Injection Well Operation and Maintenance Manual submitted for the Seminole Tribe of Florida Hollywood Reservation in accordance with above-referenced permit and the Code of Federal Regulations. The Completion Report presents the results of the construction and testing of IW-1, IW-2 and the associated dual-zone monitoring well MW-1. These wells are located at the Hollywood Reservation Wastewater Treatment Plant / Water Treatment Plant. Surface facilities are being constructed for these wells, and a request to place the wells in operation will be submitted in the near future. Also attached is EPA Form 7520-9 "Completion Form For Injection Wells". If there are any questions, please contact our office at (954) 987-0066.

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Very truly yours,
Hazen and Sawyer

1/11/19

Michael W. Wengrenovich, PE
Senior Associate
Registration No. 34939

Albert Muniz, PE
Vice President
Registration No. 35587

1/11/19

STATE OF FLORIDA
PROFESSIONAL ENGINEER
LICENSE
No 35587
ALBERT MUNIZ

Attachments

c: Brian Smith, EPA
Armando Ramirez, SFWMD
Bob Verrastro, SFWMD
Luis Rioseco, STOF-PWD
Juan Mata, STOF-PWD
Mario Isidron, STOF-PWD
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Stacy Myers, STOF-ERMD
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Patricia Carney, Hazen

Hazen File: 41086-013 - CR

41086-013 HW DIW CR 004 ltr

OMB No. 2040-0042 Approval Expires 12/31/2011

EPA

United States Environmental Protection Agency
Washington, DC 20460

Completion Form For Injection Wells

Administrative Information

1. Permittee Seminole Tribe of Florida - Hollywood Reservation

Address *(Permanent Mailing Address) (Street, City, and ZIP Code)*
Public Works Adminstration
6600 Taft Street, Suite 100, Hollywood, Florida 33024

2. Operator Seminole Tribe of Florida - Hollywood Reservation

Address *(Street, City, State and ZIP Code)*
6600 Taft Street, Suite 100
Hollywood, Florida 33024

3. Facility Name Seminole Tribe of Florida - Hollywood Reservation WWTP / WTP

Telephone Number 954-894-1060

Address *(Street, City, State and ZIP Code)*
6400 North 64th Avenue
Hollywood, Florida 33024

4. Surface Location Description of Injection Well(s)

State Florida **County** Broward

Surface Location Description

NE 1/4 of NE 1/4 of SW 1/4 of SE 1/4 of Section 02 Township 51S Range 41E

Locate well in two directions from nearest lines of quarter section and drilling unit

Surface
Location 52 ft. frm (N/S) 2n Line of quarter section
and 16 ft. from (E/W) 3rd Line of quarter section.

Well Activity

- x Class I
- Class II
  - Brine Disposal
  - Enhanced Recovery
  - Hydrocarbon Storage
- Class III
- Other

Well Status

- x Operating
- Modification/Conversion
- Proposed

Type of Permit

- Individual
- x Area : Number of Wells 2

Lease Number n/a **Well Number** SES01100001 and 2

Submit with this Completion Form the attachments listed in Attachments for Completion Form.

Certification

I certify under the penalty of law that I have personally examined and am familiar with the information submitted in this document and all attachments and that, based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment. (Ref. 40 CFR 144.32)

Name and Official Title *(Please type or print)* Michael W. Wengrenovich, P.E.

Signature Mul WW

Date Signed 1/11/19

EPA Form 7520-9 (Rev. 12-08)

PAPERWORK REDUCTION ACT

The public reporting and record keeping burden for this collection of information is estimated to average 49 hours per response for a Class I hazardous facility, and 47 hours per response for a Class I non-hazardous facility. Burden means the total time, effort, or financial resource expended by persons to generate, maintain, retain, or disclose or provide information to or for a Federal Agency. This includes the time needed to review instructions; develop, acquire, install, and utilize technology and systems for the purposes of collecting, validating, and verifying information, processing and maintaining information, and disclosing and providing information; adjust the existing ways to comply with any previously applicable instructions and requirements; train personnel to be able to respond to the collection of information; search data sources; complete and review the collection of information; and, transmit or otherwise disclose the information. An agency may not conduct or sponsor, and a person is not required to respond to, a collection of information unless it displays a currently valid OMB control number. Send comments on the Agency's need for this information, the accuracy of the provided burden estimates, and any suggested methods for minimizing respondent burden, including the use of automated collection techniques to Director, Collection Strategies Division, U.S. Environmental Protection Agency (2822), 1200 Pennsylvania Ave., NW, Washington, D.C. 20460. Include the OMB control number in any correspondence. Do not send the completed forms to this address.

Attachments to be submitted with the Completion report:

I. Geologic Information

1. Lithology and Stratigraphy

A. Provide a geologic description of the rock units penetrated by name, age, depth, thickness, and lithology of each rock unit penetrated.

B. Provide a description of the injection unit.

(1) Name
(2) Depth (drilled)
(3) Thickness
(4) Formation fluid pressure
(5) Age of unit
(6) Porosity (avg.)
(7) Permeability
(8) Bottom hole temperature
(9) Lithology
(10) Bottom hold pressure
(11) Fracture pressure

C. Provide chemical characteristics of formation fluid (attach chemical analysis).

D. Provide a description of freshwater aquifers.

(1) Depth to base of fresh water (less than 10,000 mg/l TDS).
(2) Provide a geologic description of aquifer units with name, age, depth, thickness, lithology, and average total dissolved solids.

II. Well Design and Construction

1. Provide data on surface, intermediate, and long string casing and tubing. Data must include material, size, weight, grade, and depth set.

2. Provide data on the well cement, such as type/class, additives, amount, and method of emplacement.

3. Provide packer data on the packer (if used) such as type, name and model, setting depth, and type of annular fluid used.

4. Provide data on centralizers to include number, type and depth.

5. Provide data on bottom hole completions.

6. Provide data on well stimulation used.

III. Description of Surface Equipment

1. Provide data and a sketch of holding tanks, flow lines, filters, and injection pump.

IV. Monitoring Systems

1. Provide data on recording and nonrecording injection pressure gauges, casing-tubing annulus pressure gauges, injection rate meters, temperature meters, and other meters or gauges.

2. Provide data on constructed monitor wells such as location, depth, casing diameter, method of cementing, etc.

V. Logging and Testing Results

Provide a descriptive report interpreting the results of geophysical logs and other tests. Include a description and data on deviation checks run during drilling.

VI. Provide an as-built diagrammatic sketch of the injection well(s) showing casing, cement, tubing, packer, etc., with proper setting depths. The sketch should include well head and gauges.

VII. Provide data demonstrating mechanical integrity pursuant to 40 CFR 146.08.

VIII. Report on the compatibility of injected wastes with fluids and minerals in both the injection zone and the confining zone.

IX. Report the status of corrective action on defective wells in the area of review.

X. Include the anticipated maximum pressure and flow rate at which injection will operate.

Volume 1 – Report

Transmittal Letter

EPA Form 7520-9

Table of Contents

41086-013 HW DIW CR 005 report

List of Tables

Figures

Graphics

Volume 2 – Appendices

Appendices (Continued)

Abbreviations and Terms

als – above land surface

BHC – borehole compensated [sonic log]

BHTV – borehole televiewer

bls – below land surface

CBL – cement bond log

CCL – casing collar locator

CF – cubic feet

CFR – Code of Federal Regulations

Contractor – Youngquist Brothers, Inc.

DIL – dual induction log

DIW – deep injection well

Engineer – Hazen and Sawyer and subconsultants

EPA – Environment Protection Agency [United States]

F – Fahrenheit

FPS – feet per second

FRP – fiberglass reinforced plastic

ft – feet

gal – gallons

gpd – gallons per day

gpm – gallons per minute

GRL – gamma ray log

Hazen – Hazen and Sawyer

HDPE – high density polyethylene

HW – Hollywood [Reservation]

IW – injection well

IWPS – Injection Well Pump Station

Lab – Pace Analytical Services, LLC

LAF – log after flushing

LMZ – lower monitor zone

LOP – log out of position

mCi – millicurie

Abbreviations and Terms (Continued)

MG – million gallons

mg/L – milligrams per liter

MGD –million gallons per day

MIT – mechanical integrity test

MW – monitor well

NAD – North American Datum (NAD83)

NAVD – North American Vertical Datum (NAVD88)

O&M – operation and maintenance

psi – pound per square inch

psig – pounds per square inch gauge

ROP – rate of penetration

RTS – radioactive tracer survey

SAMW – shallow aquifer monitor well

SAS – surficial aquifer system

SP – spontaneous potential [log]

STOF – Seminole Tribe of Florida

TDS – total dissolved solids

TKN – total Kjeldahl nitrogen

TSS – total suspended solids

UMZ – upper monitor zone

USDW – Underground Source of Drinking Water

µS/cm –microsiemens per centimeter

VDL – variable density log

WOB – weight on bit

WTP – water treatment plant

WWTP – wastewater treatment plant

1. Injection Well Program

1.1 Introduction

On November 1, 2016, in conformance with the Code of Federal Regulations (CFR), the United States Environmental Protection Agency (EPA) issued Permit No. SEA 0001 (the Well Permit) to the Seminole Tribe of Florida (STOF) for the construction of two 16-inch diameter Class I injection wells (IW-1 and IW-2) and associated deep dual-zone monitor well (MW-1) located at the STOF Hollywood Reservation Wastewater Treatment Plant / Water Treatment Plant (WWTP / WTP). An abridged copy (without attachments) of the Well Permit is included in **Appendix A**.

The Hollywood Reservation is located within Broward County Florida in Section 2, Township 51S and Range 41E. The latitude and longitude for the midway point of the wells is 26^{o} 2’ 7.01” North and 80^{o} 13’ 13.48” West. The street address of the facility is 6400 North 64th Avenue, Hollywood Florida 33024. A location map of the project site is presented in **Figure 1**. A well location site plan is presented in **Figure 2**. Well latitude and longitude locations are identified in **Table 1-1**.

Table 1-1: Well Locations

Well	EPA ID No.	Latitude	Longitude
IW-1	SES0112 0001	N-26-02-05.52	W-80-13-13.44
IW-2	SES0112 0002	N-26-02-08.49	W-80-13-13.51
MW-1	N/A	N-26-02-07.01	W-80-13-13.48

IW-1 and IW-2 were constructed in accordance with Contract Documents prepared by Hazen and Sawyer (Hazen) entitled “Seminole Tribe of Florida Wastewater Treatment Plant, Deep Injection Wells", dated October 2016. These executed plans and specifications for drilling two injection wells and one dual-zone monitor well formed the basis of an agreement between the STOF and Youngquist Brothers, Inc. (referred to hereinafter as "Contractor") to construct the wells. The STOF issued a Notice-to-Proceed to the Contractor for the construction of the wells on February 27, 2017. Substantial completion for the injection well project was achieved on May 21, 2018. Installation of the stainless steel wellheads on the injection wells was completed on October 31, 2018. Connections of the wells to the treatment facilities are being constructed under a separate contract.

Hazen, hereinafter referred to as "the Engineer", was retained by the STOF to provide construction management services for the project. The Engineer provided on-site supervision during all testing, geophysical logging, casing installation and cementing operations. Construction phase responsibilities of the Engineer included obtaining approval from the EPA on key elements of the project and reporting project progress weekly to the EPA.

1.2 Purpose

The purpose of this report is to:

- Summarize the information obtained during the construction and testing of IW-1, IW-2 and MW-1,
- Describe the methods used to analyze the data,
- Document the approved well casing setting depths and monitoring zones,
- Document the demonstration of mechanical integrity of the injection wells,
- Identify confinement above the injection zone, and
- Verify that the wells are suitable for receiving flow at the intended pumping rates to allow for long-term operational testing of the injection wells.

1.3 Elements of the Injection Well Contract

The project Contract Documents contained provisions for the construction and testing of the two injection wells and the associated monitor well. The two 16-inch diameter injection wells were planned to be constructed to a depth of 3,500 feet below land surface (bls), and the deep dual-zone monitor well was planned to be drilled to 1,740 feet bls. Provisions of the contract included:

- Conducting geologic logs to confirm lithologic boundaries and gross lithologic properties
- Conducting the following geophysical logs: X-Y caliper, gamma ray, spontaneous potential, fluid conductivity, dual induction, borehole compensated sonic / variable density log, fluid resistivity, temperature, flowmeter, borehole televiewer, cement bond and log derived water quality
- Conducting borehole and completed well video surveys
- Collecting and analyzing conventional cores
- Conducting straddle packer and single packer tests in discrete zones of the pilot holes of each injection well and dual-zone monitor well to determine the hydrologic properties of lithologic units
- Collecting and analyzing water samples obtained after the drilling of the pilot holes in various zones with packer tests to determine water quality at various depths
- Collecting and analyzing background water samples from the monitoring zones and the injection zone
- Conducting mechanical integrity testing on the injection wells including casing pressure tests, video surveys, radioactive tracer surveys and temperature logs

- Conducting casing hydrostatic pressure tests on final monitor well casing strings, and
- Conducting short term injection tests in each completed injection well to demonstrate the ability of the injection well system to accept secondary treated WWTP effluent and WTP concentrate at the intended flow rate.

2. Well Drilling, Testing and Construction

2.1 Well Construction

Well construction began with IW-2, followed by IW-1, and then MW-1. IW-1 was constructed approximately 300 feet south of IW-2. MW-1 was constructed midway between IW-1 and IW-2, or 150 feet from each injection well. The location of these wells is illustrated in **Figure 1** and **Figure 2**. Drilling above 1,000 feet bls was performed by the mud rotary method and drilling below 1,000 feet bls was performed by the reverse air method. During the drilling of the wells, testing and geophysical logging were performed. Well downhole measurements were recorded by the Contractor in depth bls. The land surface elevations (at the time of drilling) for IW-1, IW-2, and MW-1 are identified in **Table 2-1**. The top elevation of the flange of the casings are identified in **Table 2-1**.

Table 2-1: Land Surface and Casing Elevations

Well	Land Surface Elevation[1] (feet NAVD88)	Well Casing Flange Elevation[1] (feet NAVD88)	Additional Information
IW-1	10.7	10.7	Top of 16-inch casing flange
IW-2	10.8	10.8	Top of 16-inch casing flange
MW-1	10.7	15.45	Top of 6-5/8-inch casing flange
MW-1	10.7	13.48	Top of 16-inch landing flange

1. At the time of drilling the wells, in feet NAVD88.

The injection wells were constructed concurrently. Drilling began with the first rig on site at IW-2. A few weeks later, the second drill rig began drilling at IW-1. After the completion of IW-2, the rig was moved to the MW-1 site. The well spud and completion dates are presented in **Table 2-2**.

Table 2-2: Well Spud and Completion Dates

Well	Spud Date	Well Completion Date[1]	Wellhead Completion Date
IW-1	June 30, 2017	February 11, 2018	October 31, 2018
IW-2	May 15, 2017	December 7, 2017	October 31, 2018
MW-1	December 19, 2017	March 7, 2018	April 27, 2018

1. For the purpose of this table, the well completion date is defined by the completion of cementing of the final casing

2.2 Drilling of IW-1 and IW-2

The drilling of IW-1 and IW-2 proceeded generally as identified in the Contract Documents. However, due to borehole conditions, some adjustments to the casing seat depths and cementing plans were submitted to and approved by EPA. In addition, for the two larger sized injection well casings (42 and 50-

inch), the Contractor elected to upsize the casing from 42 to 44-inch diameter and from 50 to 54-inch diameter due to availability. No reduction to the annular space resulted when using the larger casing sizes and the EPA approved the casing up-sizing. No changes were made to the final injection casing diameters. Actual depths and diameters of casings are identified herein in the profiles of the completed wells IW-1 and IW-2 presented in **Figure 3** and **Figure 4**, respectively.

Drilling activities are summarized in the following outline which identifies bit diameters, borehole depth, casing diameters and casing depths. Boreholes were drilled a few feet deeper than the casing depths to facilitate installation of the casing. The following is a summary of the drilling activities for IW-1 and IW-2 including depths of boreholes drilled and casing seat depths. Where depths differ between wells, specific depths for each well were noted.

1. Set 66-inch diameter pit pipe to a depth of 8 feet bls.
2. Drill a borehole with a 64-1/2-inch diameter bit to 253 feet bls using mud rotary method.
3. Set and cement 54-inch diameter casing to 249 feet bls (IW-1) and 250 feet bls (IW-2).
4. Drill a borehole with a 52-1/2-inch diameter bit to 1,006 feet bls (IW-1) and 1,005 feet bls (IW-2) using mud rotary method.
5. Set and cement 44-inch diameter casing at 1,003 and 1,005 feet bls at IW-1 and IW-2, respectively.
6. Drill a pilot hole with a 12-1/4-inch diameter bit to approximately 2,004 feet bls (IW-1) and 2,000 feet bls (IW-2) using reverse air method.
7. Backplug pilot hole with cement.
8. Drill a borehole with a 42-1/2-inch diameter bit to 2,005 feet bls (IW-1) and 2,004 feet bls (IW-2) using reverse air method.
9. Set and cement 34-inch diameter casing at 2,000 feet bls.
10. Drill a pilot hole with a 12-1/4-inch diameter bit to 3,005 feet bls (IW-1) and 3,000 feet bls (IW-2) using reverse air method.
11. Backplug pilot hole with cement.
12. Drill a borehole with a 32-1/2-inch diameter bit to 2,925 feet bls (IW-1) and 3,003 feet bls (IW-2) using reverse air method.
13. Set and cement 24-inch diameter casing at 2,920 feet bls (IW-1) and 3,000 feet bls (IW-2).
14. Drill a borehole with a 22-1/2-inch diameter bit to 3,501 feet bls (IW-1) and 3,503 feet bls (IW-2) using reverse air method.

Due to underground conditions, modifications were required between 2,000 and 3,000 feet bls that resulted in changes to the depth of the boreholes and casing depths. Upon review of the geophysical logs conducted in the IW-1 pilot hole from 2,000 to 3,000 feet bls, a cavernous zone was identified from 2,950 to 3,000 feet bls. The X-Y caliper log showed the pilot hole diameter in this interval to be erratic, ranging from 16 inches to 43 inches. The Contractor installed a bridge plug at 2,940 feet bls to facilitate installing the 24-inch casing above the cavernous zone. The changes made at IW-1 were coordinated with EPA.

2.2.1 Drilling of MW-1

The drilling of MW-1 proceeded generally as identified in the project Contract Documents. The depths of the monitor zones were based on the data collected during the drilling and testing of IW-1 and IW-2 and modified based on the data from the drilling and testing of MW-1 and from the field conditions at MW-1. A profile of the completed MW-1 is presented in **Figure 5**. The selection of the monitor zone depths is discussed later in the report. The following is a summary of the drilling of MW-1.

1. Set 54-inch diameter pit pipe to a depth of 8 feet bls.
2. Drill a borehole with a 46-1/2-inch diameter bit to 254 feet bls using mud rotary method.
3. Set and cement 36-inch diameter casing at 250 feet bls.
4. Drill a borehole with a 34-1/2-inch diameter bit to 1,004 feet bls using mud rotary and reverse mud methods.
5. Set and cement 24-inch diameter casing at 1,000 feet bls
6. Drill a pilot hole with a 12-1/4-inch diameter bit to 1,810 feet bls using reverse air method.
7. Backplug the pilot hole with cement to 1,000 feet bls, placing gravel with a sand cap in the intended monitor zones.
8. Drill a borehole with a 22-1/4-inch diameter bit to 1,503 feet bls using reverse air method.
9. Set and cement 16-inch diameter casing at 1,500 feet bls, the top of the upper monitor zone (UMZ).
10. Drill a borehole with a 14-3/4-inch diameter bit to 1,760 feet bls using reverse air method.
11. Drill a borehole with a 12-1/4-inch diameter bit to 1,810 feet bls using reverse air method.
12. Set and cement 6-5/8-inch diameter fiberglass reinforced plastic (FRP) casing at 1,770 feet bls, the top of the lower monitor zone (LMZ).

Monitor zone depths are identified in **Table 2-3**.

Table 2-3: Monitor Zone Depths

Description	Depth of Monitor Zone (feet bls)
Upper Monitor Zone	1,500 – 1,529
Lower Monitor Zone	1,770 – 1,810

2.3 Data Collection and Reporting

Data was collected during the construction of the wells using various methods and procedures as described in this Section. Independent testing and laboratory analyses performed by subcontractors of Youngquist Brothers, Inc. included the water quality analyses (by Pace Analytical Services, LLC) and testing of rock cores (by Ardaman & Associates, Inc.). Pace Analytical Services is hereby identified as the Lab.

Daily progress and activities were monitored and recorded. The Contractor and Engineer independently prepared daily progress reports during well construction. In addition to recording daily drilling progress, the reports included other pertinent drilling information such as drilling speed, weight on the drill bit and penetration rates. Any problems encountered during drilling were observed and noted by the Contractor. Activities related to the installation of well casings, cementing or other materials, as well as their quantities, were included in the Contractor reports. Detailed descriptions of test procedures and data collection, including results of inclination surveys to verify hole straightness, were recorded. The length and configuration of tools introduced into the borehole were noted. Copies of the daily reports were included in summary reports that were transmitted to the EPA on a weekly basis.

2.4 Drilling Progress

During the drilling of the wells, the weight on bit (WOB) and rate of penetration (ROP) were monitored by the Contractor. The results were supplied by the Contractor on a continuing basis. The results from the WOB / ROP were transmitted to EPA weekly and are presented in **Appendix B**.

An inclination survey was conducted every 90 feet in the pilot holes and other boreholes to confirm straight hole requirements for the wells. Borehole straightness was in compliance with the project specifications. The results from the inclination surveys were transmitted to EPA weekly and are presented in **Appendix C**.

2.5 Drilling Fluid Samples

Drilling fluid samples were collected from pilot holes every 45 feet below 1,000 feet bls during reverse air drilling to determine water quality. Samples were analyzed for chlorides, total dissolved solids (TDS), conductivity, ammonia, total Kjeldahl nitrogen (TKN) and pH. The samples were sent to state certified laboratory Pace Analytical Services for analysis. A summary of the results of these tests are presented in **Graphic 1, Graphic 2** and **Graphic 3** for IW-1, IW-2 and MW-1, respectively. This summarized data, along with a copy of the reports from the laboratory, are presented in **Appendix D**.

2.6 Lithologic Samples

Samples of drill cuttings were collected and described during drilling of wells IW-1, IW-2 and MW-1. Two sets of grab samples of the cuttings were collected at 10-foot intervals, and observed formation changes, from the initial boreholes from land surface to the total depth of each well. Circulation time (the time required for drilled cuttings to reach the surface) was calculated regularly to assure that accurate sample depths were identified. After initial examination, the samples were described by the Engineer's on-site personnel. A geologic description of each sample was entered into a log. The lithology of the limestone cuttings was characterized using the Dunham classification system for carbonate sedimentary rocks (1962). Samples were characterized for rock type, color, consolidation, texture, cementation, hardness/induration, fossil type, and visible porosity and permeability. These logs are presented in **Appendix E**. After construction of the wells was complete, the Contractor sent one set of these samples to the Florida Bureau of Geology in Tallahassee, Florida.

2.7 Geophysical Logs

At the completion of each stage of borehole drilling, geophysical logs were conducted. The purpose of these logs was to assist in casing seat selection, identify confining sequences and to help identify the location of monitoring zones. The geophysical logs performed, including a brief description of the information provided by the logs, are as follows:

- X-Y Caliper – Identification of hole diameter and hole geometry.
- Gamma-Ray Log (GRL) – Measurement of the natural gamma ray radiation of the formation, used as a tie-in between logs.
- Dual Induction Log (DIL) – A resistivity log that identifies differentiation between limestone and dolomite beds, and, along with the gamma ray log, is useful in the correlation of lithologic units.
- Borehole Compensated (BHC) Sonic / Variable Density Log (VDL) – Identification of the confining sequences, as well as identification of zones which could cause problems during cementing.
- Log Derived Water Quality – A log used to determine the water quality of the formation by depth. It is derived from a combination of the results from four other geophysical logs, borehole compensated sonic, DIL, X-Y caliper and gamma ray logs.
- Flowmeter Log – Determination of where fluid may be entering or exiting the borehole.
- Fluid Resistivity – An electric geophysical log used to measure conductivity of the formation fluid. Results are typically presented as resistivity, the inverse of conductivity.
- Temperature – Provides a profile of static and dynamic temperature of the borehole, may be useful in determining changes in fluid movement.
- Borehole Televiewer (BHTV) – Determination of where structural features (bedding planes, fractures, vugs and voids) are located.
- Spontaneous Potential (SP) Log – An electric geophysical log used to identify the presence of clays and shales in the formation.
- Cement Top Temperature – Verification of the annular space fill-up after each cementing stage.

- Cement Bond Log (CBL) – Used to assess the quality of the bond between the inner casing and the cement grout around the casing. The resulting curve of the log is a function of casing size and thickness, cement strength and thickness, degree of cement bonding and tool centering.

Geophysical logs were transmitted to the EPA on a weekly basis during construction and are also presented in **Appendix F** of this report. For convenience for interpretation and for this completion report, many of the same type of logs were merged together (e.g., the dual induction log for IW-1 pilot holes is presented as one continuous log from 1,000 to 3,000 feet bls). Also presented in **Appendix F** is an index of the logs performed. Refer to **Graphics 4** through **Graphic 9** for IW-1, IW-2 and MW-1 X-Y Caliper, Gamma-Ray and Spontaneous Potential, Borehole Compensated Sonic, Dual Induction LL3, Fluid Conductivity, Temperature and Flow logs. Log derived water quality results comparing all three wells are graphically presented in **Graphic 10** and **Appendix G**.

During the geophysical logging and testing of the wells, the Engineer was on site to witness the logging and verify quality control procedures. The Contractor was responsible for quality control maintained during the testing program. Industry standard quality control measures were observed and are documented on the logs. Detailed information of the tool calibration program utilized by the Contractor is attached in **Appendix H**.

2.8 Cores

During the drilling of the injection well pilot holes, conventional core samples were collected, reviewed and analyzed in a laboratory for geologic and hydrogeologic characteristics. Core depths were selected by the Engineer primarily on the basis of reviewing and interpreting information from geophysical logs, lithology, and packer tests. A total of sixteen cores were collected during the drilling of the wells, eight from IW-1 and eight from IW-2. Cores were cut from depths between 1,730 and 2,940 feet bls. The Contractor used a 20-foot long, 4-inch inside diameter core barrel for this project. Cores from IW-1 and IW-2 were taken at the depths identified in **Table 2-4**. Also presented in **Table 2-4** are the percent recovery of each of the cores.

Table 2-4: Injection Well Core Intervals

Injection Well IW-1		
Core Number	Core Interval (feet bls)	Recovery (%)
1	1,856 to 1,871	69
2	1,975 to 1,990	78
3	2,080 to 2,095	85
4	2,235 to 2,250	100
5	2,290 to 2,305	83
6	2,312 to 2,327	100

Injection Well IW-2		
Core Number	Core Interval (feet bls)	Recovery (%)
1	1,730 to 1,745	96
2	1,884.5 to 1,899.5	83
3	2,055 to 2,071	43
4	2,160 to 2,175	97
5	2,290 to 2,305	100
6	2,420 to 2,435	100

41086-013 HW DIW CR 005 report

Injection Well IW-1		
Core Number	Core Interval (feet bls)	Recovery (%)
7	2,485 to 2,498	61
8	2,588 to 2,603	57

Injection Well IW-2		
Core Number	Core Interval (feet bls)	Recovery (%)
7	2,868 to 2,883	80
8	2,925 to 2,940	80

The lithology of the cores was evaluated against the cuttings samples assigned to the same depths to determine if there were any significant biases in the cutting samples. The cores were also examined for the presence of fractures or solution features (vugs) that might be conduits for vertical fluid flow. No biases were observed. Copies of the core lithology descriptions are contained in **Appendix I**.

Samples from each core were selected and sent to an independent laboratory for analysis. These samples were tested for several parameters including vertical and horizontal hydraulic conductivity, permeability, porosity, unconfined compression and specific gravity.

The hydraulic conductivity results for the IW-1 cores range from 6.20 x 10^{-9} to 2.00 x 10^{-3} cm/sec. The average hydraulic conductivity for the IW-1 core sections submitted for analysis was found to be 3.14 x 10^{-4} cm/sec. The hydraulic conductivity results for the IW-2 cores range from 1.10 x 10^{-6} to 2.90 x 10^{-3} cm/sec. The average hydraulic conductivity for the IW-2 core sections submitted for analysis was found to be 4.37 x 10^{-4} cm/sec. Core laboratory analysis results and geologic core descriptions are likewise presented in **Appendix J.** A summary of data from the laboratory analyses of the cores are presented in **Table 2-5**.

Table 2-5: Injection Well Hydraulic Conductivity

Well Number	Core Number	Sample	Tested Interval (feet bls)	Vertical Hydraulic Conductivity (cm/sec)	Horizontal Hydraulic Conductivity (cm/sec)
Injection Well IW-1					
IW-1	1	1	1,857.7 to 1,858.3	1.5 E-03	1.4 E-03
		2	1,861.9 to 1,862.9	5.5 E-04	1.3 E-03
		3	1,864.5 to 1,865.6	6.6 E-04	1.1 E-03
		4	1,868.0 to 1,868.5	3.7 E-04	6.7 E-05
		5	1,868.5 to 1,869.6	4.6 E-04	2.0 E-03
IW-1	2	1	1,979.1 to 1,980.1	7.7 E-07	1.3 E-06
		2	1,980.1 to 1,980.5	3.6 E-07	4.2 E-06
		3	1,981.0 to 1,981.6	3.4 E-06	5.7 E-06
		4	1,982.5 to 1,983.1	9.8 E-08	6.1 E-07
		5	1,983.6 to 1,984.6	1.4 E-07	7.4 E-06
IW-1	3	1	2,083.7 to 2,084.5	3.9 E-06	6.0 E-06

41086-013 HW DIW CR 005 report

Well Number	Core Number	Sample	Tested Interval (feet bls)	Vertical Hydraulic Conductivity (cm/sec)	Horizontal Hydraulic Conductivity (cm/sec)
		2	2,084.5 to 2,085.1	--- (1)	1.6 E-05
		3	2,086.8 to 2,087.6	6.2 E-09	1.1 E-07
		4	2,088.5 to 2,089.0	6.1 E-04	2.0 E-04
		5	2,091.9 to 2,092.7	6.9 E-06	1.4 E-05
IW-1	4	1	2,237.9 to 2,238.5	2.5 E-04	2.5 E-04
		2	2,239.1 to 2,239.6	2.3 E-04	2.1 E-04
		3	2,239.6 to 2,240.3	3.4 E-04	3.3 E-04
		4	2,240.3 to 2,241.0	1.2 E-03	9.7 E-05
		5	2,247.4 to 2,248.3	3.9 E-04	2.6 E-04
IW-1	5	1	2,290.5 to 2,290.9	--- (2)	--- (2)
		2	2,293.6 to 2,294.1	5.1 E-04	4.9 E-04
IW-1	6	1	2,316.0 to 2,316.9	7.6 E-05	6.9 E-05
		2	2,323.0 to 2,323.6	1.0 E-03	5.8 E-05
		3	2,325.4 to 2,326.3	4.7 E-04	4.6 E-04
IW-1	7	1	2,485.8 to 2,486.1	3.0 E-06	4.2 E-06
		2	2,490.1 to 2,490.9	6.8 E-05	1.5 E-04
		3	2,492.1 to 2,492.9	1.6 E-05	1.7 E-05
IW-1	8	1	2,591.2 to 2,591.6	1.7 E-05	1.6 E-05
		2	2,592.5 to 2,593.1	--- (2)	--- (2)
Injection Well IW-2					
IW-2	1	1	1,731.5 to 1,732.4	7.7 E-04	2.2 E-04
		2	1,734.5 to 1,735.3	9.7 E-04	1.2 E-03
		3	1,738.5 to 1,738.8	3.6 E-04	2.1 E-03
		4	1,739.0 to 1,740.0	2.2 E-03	2.9 E-03
		5	1,742.2 to 1,743.1	1.3 E-03	9.5 E-04
IW-2	2	1	1,885.3 to 1,886.2	2.2 E-03	1.8 E-03
		2	1,886.2 to 1,887.1	2.2 E-03	1.1 E-03
		3	1,889.8 to 1,890.5	1.1 E-06	1.5 E-06
		4	1,891.8 to 1,892.6	1.1 E-03	7.6 E-04
		5	1,897.2 to 1,898.0	1.5 E-04	1.1 E-03

41086-013 HW DIW CR 005 report

Well Number	Core Number	Sample	Tested Interval (feet bls)	Vertical Hydraulic Conductivity (cm/sec)	Horizontal Hydraulic Conductivity (cm/sec)
IW-2	3	1	2,058.3 to 2,059.0	8.4 E-05	2.0 E-04
		2	2,059.5 to 2,060.2	1.4 E-04	1.5 E-04
		3	2,060.2 to 2,061.3	1.0 E-04	1.2 E-04
		4	2,061.3 to 2,062.0	1.3 E-03	1.3 E-04
		5	2,066.1 to 2,066.9	1.6 E-04	7.04 E-05
IW-2	4	1	2,162.8 to 2,163.2	8.1 E-05	1.0 E-04
		2	2,163.2 to 2,163.9	1.1 E-04	1.4 E-04
		3	2,164.3 to 2,164.9	4.4 E-06	8.4 E-05
		4	2,165.6 to 2,166.1	1.0 E-04	3.5 E-04
		5	2,167.0 to 2,168.1	8.9 E-04	--- (3)
IW-2	5	1	2,292.5 to 2,293.2	9.1 E-05	7.2 E-05
		2	2,295.3 to 2,296.0	2.0 E-04	4.0 E-04
		3	2,299.7 to 2,301.0	4.1 E-04	2.1 E-04
		4	2,301.4 to 2,301.9	4.6 E-04	3.2 E-04
		5	2,304.1 to 2,304.6	2.3 E-06	2.3 E-06
IW-2	6	1	2,422.7 to 2,423.7	8.8 E-05	6.9 E-05
		2	2,423.7 to 2,424.5	8.3 E-06	7.4 E-06
		3	2,424.5 to 2,425.5	2.8 E-06	3.0 E-06
		4	2,426.2 to 2,427.0	9.3 E-06	9.8 E-06
		5	2,427.2 to 2,428.3	5.1 E-05	6.8 E-05
IW-2	7	1	2,868.4 to 2,868.8	1.2 E-04	7.7 E-05
		2	2,868.8 to 2,869.3	4.6 E-04	3.9 E-04
		3	2,871.4 to 2,871.9	2.4 E-05	5.1 E-05
		4	2,871.9 to 2,872.3	3.3 E-05	4.1 E-05
		5	2,872.3 to 2,873.0	--- (4)	--- (4)
IW-2	8	1	2,926.1 to 2,926.5	1.3 E-04	9.5 E-05
		2	2,928.2 to 2,928.7	4.8 E-04	7.0 E-04
		3	2,930.6 to 2,931.2	1.1 E-04	1.2 E-04
		4	2,931.8 to 2,932.2	2.6 E-04	4.0 E-04
		5	2,932.8 to 2,933.5	4.0 E-04	3.8 E-04

Notes:

1. *Specimen split vertically during trimming for testing.*

41086-013 HW DIW CR 005 report

Well Number	Core Number	Sample	Tested Interval (feet bls)	Vertical Hydraulic Conductivity (cm/sec)	Horizontal Hydraulic Conductivity (cm/sec)

2. *Unconfined compression test only.*
3. *Specimen fractured during cross-coring.*
4. *Tested only for unconfined compressive strength.*

2.9 Video Surveys

Video surveys were conducted and recorded on DVDs at various stages of construction. Videos were recorded in the pilot holes of the injection and monitor wells. Video surveys were also performed in the completed injection wells and dual-zone monitor well from land surface to the well total depth (TD). Color video surveys were made with the camera lens in two positions, downhole with a radial view and sideview with a horizontal rotating position. Air development and pumping were used to displace suspended solids from the well prior to performing the video surveys. The open hole survey allowed the reviewer to visually inspect the formations encountered in the borehole, as well as to observe potential fractures and water-producing zones. Acceptable fluid clarity was obtained in the surveys. A log describing the formation and structural features observed in the video surveys is presented in **Appendix K**. Copies of the video surveys are also included in **Appendix K**.

2.10 Packer Tests

Straddle packer tests were performed in the completed pilot holes following the drilling and geophysical logging of IW-1, IW-2 and MW-1 and one single packer test was conducted following the drilling and geophysical logging of the MW-1 pilot hole. During packer testing, inflatable packers were used to isolate discrete zones in pilot holes in order to determine hydrogeologic properties of the formations and to collect representative samples for water quality analyses. For the straddle packer tests, two inflatable packers were set at depths identified by the Engineer. Formation fluid was pumped out from between the packers. The single packer test was performed by setting one inflatable packer in the pilot hole and pumping formation fluid from the open hole below the packer.

Packer tests were conducted at intervals to either support demonstration of confinement, to determine water quality so as to define the base of the Underground Source of Drinking Water (USDW), or to identify potential monitoring zones. The packer intervals were selected based on reviewing and interpreting information from the geophysical logs, lithology, cores and other packer tests. Eight intervals for each injection well (IW-1 and IW-2) were selected and three intervals were selected for MW-1. For each of the testing procedures conducted, quality control and quality assurance procedures were implemented and documented. Quality control procedures for the packer testing and development records are contained in **Appendix L**.

2.10.1 Packer Pumping Tests

Packer pumping tests were performed to collect background, drawdown and recovery data over selected horizons. The packers were lowered into the pilot hole to the selected interval on 7-inch outside diameter drill pipe, inflated, and seated against the formation. A submersible pump was lowered into the drill pipe to approximately 200 feet bls. Pumping was conducted to introduce hydrogeologic stress on the isolated interval. Prior to starting the tests, each zone was developed free of any drilling fluids by means of air-lifting and pumping until the specific conductance stabilized and turbidity was low.

The isolated zone was allowed to recover from development before beginning the test. The test consisted of recording water levels and pumping rates during the background, drawdown and recovery phases of the packer test. During background, drawdown and recovery water level measurements were recorded using InSitu Level Troll 700 recording pressure transducers. Flow rates and volumes were measured using a calibrated flowmeter / totalizer.

The method of analysis used for the data collected and recorded during the packer tests was the Modified Nonequilibrium Formula derived by Cooper and Jacob (1946). The equation of the Cooper-Jacob method is as follows:

$$T=264Q / \Delta s$$

Where:

T = coefficient of transmissivity (gpd/ft)

Q = pumping rate (gpm)

Δs = change in drawdown over one log cycle (ft)

The order of the packer tests, the depths, the static water level above land surface (als), the development rate, and the calculated hydraulic conductivities for IW-1, IW-2, and MW-1 are identified in **Table 2-6, Table 2-7** and **Table 2-8**, respectively. The packer test data plots are presented in **Appendix M**. Based on the stabilization of the fluid during air and pump development, background, drawdown, and recovery data (presented in **Appendix M**,) the hydraulic conductivity values derived from the packer tests are considered valid except as noted. An additional straddle packer test was attempted in IW-1 over the interval of 1,908 to 1,926 feet bls, however the packers were unable to be successfully set.

Table 2-6: IW-1 Packer Pumping Tests

Packer Interval (feet bls)	Type	Order of Testing	Interval Depth (feet)	Static Water Level (feet als)	Pump Rate (gpm)	Drawdown (feet)	Specific Capacity Estimate (gpm/ft)
1,610 - 1,628	straddle	3	18	20	80	123	0.65
1,883 - 1,901	straddle	2	18	-6	85	58	1.47
1,898 - 1,916	straddle	1	18	-5	62	103	0.60
2,209 – 2,227	straddle	8	18	-9	52	101	0.51
2,250 – 2,268	straddle	7	18	-9	13	110	0.12
2,510 – 2,528	straddle	6	18	-12	24	124	0.19
2,659 – 2,677	straddle	5	18	-12	17	113	0.15
2,859 - 2,877	straddle	4	18	-11	63	111	0.58

Table 2-7: IW-2 Packer Pumping Tests

Packer Interval (feet bls)	Type	Order of Testing	Interval Depth (feet)	Static Water Level (feet als)	Pump Rate (gpm)	Drawdown (feet)	Specific Capacity Estimate (gpm/ft)
1,559 - 1,577	straddle	1	18	33	87	76	1.14
1,714 - 1,732	straddle	2	18	8	69	127	0.54
1,924 – 1,942	straddle	3	18	-3	60	95	0.63
2,329 – 2,347	straddle	8	18	-10	13	107	0.12
2,538 – 2,556	straddle	7	18	-12	12	106	0.11
2,603 – 2,621	straddle	6	18	-12	27	87	0.31
2,628 – 2,646	straddle	5	18	-13	12	106	0.11
2,708 – 2,726	straddle	4	18	-12	17	111	0.15

Table 2-8: MW-1 Packer Pumping Tests

Packer Interval (feet bls)	Type	Order of Testing	Interval Depth (feet)	Static Water Level (feet als)	Pump Rate (gpm)	Drawdown (feet)	Specific Capacity Estimate (gpm/ft)
1,509 - 1,527	straddle	3	18	23	103	19	5.41
1,609 - 1,627	straddle	2	18	18	72	95	0.76
1,758 – 1,810	single	1	52	-9	103	22	4.68

2.10.2 Packer Test Water Quality Samples

Water samples were collected during the packer tests conducted in the IW-1, IW-2 and MW-1 pilot holes. The samples were analyzed by the Lab for selected parameters to determine water quality and to identify the depth of the 10,000 mg/L TDS interface within the wells. The tests were also conducted over intervals considered suitable as potential confining zones and intervals suitable as potential monitor zones. During the packer testing pumping phases, a sample of the formation fluid from the tested interval was collected just prior to shutting off the pump.

Water samples collected during the packer tests were analyzed for TDS, chloride, sulfate, specific conductance (conductivity), ammonia and TKN. The results from each packer test water quality analysis are summarized in **Table 2-9, Table 2-10** and **Table 2-11** and presented in **Graphics 11** through **Graphic 16**. A copy of the water quality laboratory reports from the laboratory are presented in **Appendix N**.

Table 2-9: IW-1 Packer Test Water Quality

Packer Interval (feet bls)	TDS (mg/L)	Chloride (mg/L)	Conductivity (µS/cm)	Ammonia as N (mg/L)	TKN as N (mg/L)	Total Nitrogen (mg/L)	Nitrate + Nitrite (mg/L)	Sulfate (mg/L)
1,610 - 1,628	9,400	4,770	16,300	0.68	0.72	0.73	0.033 (U)	508
1,883 - 1,901	35,600	20,300	43,000	0.020 (U)	0.16 (I)	0.16 (I)	0.033 (U)	2,610
1,898 - 1,916	30,500	19,900	43,300	0.020 (U)	0.18 (I)	0.18 (I)	0.033 (U)	2,510
2,209 – 2,227	18,100	19,400	48,800	0.027 (I)	0.24 (I)	0.24 (I)	0.033 (U)	2,340
2,250 – 2,268	32,000	18,800	53,900	0.020 (U)	0.27 (I)	0.27 (I)	0.033 (U)	2,320
2,510 – 2,528	36,900	19,700	54,400	0.020 (U)	0.22 (I)	0.25 (I)	0.035 (I)	2,630
2,659 – 2,677	34,500	17,200	49,200	0.020 (U)	0.28 (I)	0.28 (I)	0.033 (U)	2,340
2,859 - 2,877	30,400	15,600	38,500	0.020 (U)	0.18 (I)	0.33 (I)	0.15	1,700

(I) – The report value is between the laboratory method detection limit and the laboratory practical quantitation limit
(U) – Indicates that the compound was analyzed for but not detected

Table 2-10: IW-2 Packer Test Water Quality

Packer Interval (feet bls)	TDS (mg/L)	Chloride (mg/L)	Conductivity (µS/cm)	Ammonia as N (mg/L)	TKN as N (mg/L)	Total Nitrogen (mg/L)	Nitrate + Nitrite (mg/L)	Sulfate (mg/L)
1,559 - 1,577	4,510	1,910	7,080	0.44	0.59	0.59	0.033 (U)	458
1,714 - 1,732	30,500	16,000	42,500	0.32	0.45 (I)	0.47 (I)	0.033 (U)	1,120
1,924 – 1,942	36,200	19,700	52,400	0.020 (U)	0.22 (I)	1.70	1.5	2,640
2,329 – 2,347	33,300	20,100	45,900	0.020 (U)	0.36 (I)	0.36 (I)	0.033 (U)	2,490
2,538 – 2,556	37,700	19,700	47,100	0.020 (U)	0.24 (I)	0.24 (I)	0.033 (U)	2,480
2,603 – 2,621	40,200	18,900	49,400	0.020 (U)	0.26 (I)	0.31 (I)	0.046 (I)	2,450
2,628 – 2,646	35,400	18,900	52,500	0.020 (U)	0.22 (I)	0.22 (I)	0.033 (U)	2,450
2,708 – 2,726	39,000	19,200	51,900	0.050	0.28 (I)	0.33 (I)	0.049 (I)	2,500

(I) – The report value is between the laboratory method detection limit and the laboratory practical quantitation limit
(U) – Indicates that the compound was analyzed for but not detected

Table 2-11: MW-1 Packer Test Water Quality

Packer Interval (feet bls)	TDS (mg/L)	Chloride (mg/L)	Conductivity (µS/cm)	Ammonia as N (mg/L)	TKN as N (mg/L)	Total Nitrogen (mg/L)	Nitrate + Nitrite (mg/L)	Sulfate (mg/L)
1,509 - 1,527	3,420	1,430	5,750	0.41	0.41 (I)	0.41 (I)	0.033 (U)	482
1,609 - 1,627	9,800	4,750	16,500	0.71	0.63	0.63	0.033 (U)	528
1,758 – 1,810	36,400	18,200	49,900	0.035 (U)	0.21 (I)	0.21 (I)	0.25 (U)	2,760

(I) – The report value is between the laboratory method detection limit and the laboratory practical quantitation limit
(U) – Indicates that the compound was analyzed for but not detected

2.11 Casing

Both steel and FRP casing were used in well construction. Casing heat numbers stamped on the steel casing were verified with the mill certificates prior to running casing in the hole. Certified welders assembled nominal 30-foot length casing joints to form the completed well casing string as it was lowered downhole. FRP casing was delivered to the site in 30-foot nominal length joints of casing. The FRP casing and tubing for this project was Red Box as manufactured by Future Pipe Industries, Inc. Each joint of casing was individually numbered and identified. A certification of conformance was submitted by the manufacturer for the FRP used in well construction.

In constructing IW-1 and IW-2 a transition to super duplex stainless steel casing was made to the FRP casing below the landing flange of the 16-inch casing. Copies of the casing mill certificates for the steel casing and certifications of conformance for the FRP injection tubing and casing are presented in **Appendix O**. Casings and tubings were fitted with steel centralizers at 0, 90, 180, and 270 degrees around the casing. Centralizers were placed at 20, 60, 100, and 140 feet above the bottom of the casing, then at approximate intervals of 200 feet thereafter. The top most centralizers were placed at 20 feet bls. A summary of the installed casing is presented in **Table 2-12**. Also included in **Table 2-12** is information pertaining to the pit pipes installed.

Table 2-12: Casing Summary

Well	Casing / Tubing Material	Grade	Outside Diameter (inches)	Depth (feet bls)	Thickness (inches)	Additional Information
Injection Well IW-1						
IW-1	spiral welded steel	B	66	8	0.375	pit pipe
IW-1	spiral welded steel	B	54	249	0.375	casing
IW-1	spiral welded steel	B	44	1,003	0.375	casing
IW-1	spiral welded steel	B	34	2,000	0.375	casing
IW-1	seamless steel	B	24	2,920	0.500	casing
IW-1	Red Box[1] – FRP	1500	16	2,910	0.80	tubing
Injection Well IW-2						
IW-2	spiral welded steel	B	66	8	0.375	pit pipe
IW-2	spiral welded steel	B	54	250	0.375	casing
IW-2	spiral welded steel	B	44	1,005	0.375	casing
IW-2	spiral welded steel	B	34	2,000	0.375	casing
IW-2	seamless steel	B	24	3,000	0.500	casing
IW-2	Red Box[1] – FRP	1500	16	2,990	0.80	tubing
Monitor Well MW-1						
MW-1	spiral welded steel	B	48	8	0.375	pit pipe
MW-1	spiral welded steel	B	36	250	0.375	casing

41086-013 HW DIW CR 005 report

Well	Casing / Tubing Material	Grade	Outside Diameter (inches)	Depth (feet bls)	Thickness (inches)	Additional Information
MW-1	spiral welded steel	B	24	1,000	0.375	casing
MW-1	spiral welded steel	B	16	1,500	0.500	casing
MW-1	Red Box[1] – FRP	2500	6.625	1,770	0.58	casing

1. Red Box as manufactured by Future Pipe Industries.

Following installation each casing string was cemented in place. A cementing approach plan was submitted by the Contractor for each installed string. Cementing plans for each casing string were proposed by the Contractor and reviewed by the Engineer prior to each stage of cementing. After each stage, the Contractor provided cement tickets documenting quantities of cement emplaced. Cement top temperature logs were performed after each stage of cementing. A copy of the a cement report and copies of cement tickets for the project is presented in **Appendix P**.

2.12 Cement Bond Logs

Cement bond logs are used to assess the quality of the bond between the casing and the cement grout. The resulting curve of the log is a function of casing size and thickness, cement strength and thickness, degree of cement bonding and tool centering. Cement bond logs were performed on the final steel casings and FRP tubings of IW-1, IW-2, and MW-1.

The travel time curve (left log track) is run to determine if the tool is properly centered. The critical travel time is the time recorded when the tool is absolutely centralized in high signal areas, particularly areas with no cement (free pipe). Factors affecting the travel time curve are cycle skipping that can be caused by fast formation arrivals and formations that are so dense they actually have a faster transit time than the casing. The basic transit time of steel is slower than some dolomites and limestones.

On the amplitude curves (center log track), a time gate is set at the time corresponding to the expected arrival of the casing signal, and the amplitude of the signal in that gate is recorded. A high amplitude indicates a longer distance casing signal, which therefore indicates a poorer cement bond; a low amplitude indicates a good bond.

The variable density display (right log track) displays the entire wave signal. If there is no bond, an arrival is seen at the time corresponding to the casing velocity. As the cement becomes thicker and stronger (compressive strength), the casing signal becomes weaker.

2.12.1 IW-1 Final Steel Casing Cement Bond Log

On December 30, 2017 a cement bond log was performed in the 24-inch final steel casing of IW-1. From the travel time log it can be seen that good tool centralization was maintained for the entire log. The amplitude curve from 2,896 to 2,492 feet bls shows readings generally below 15 millivolts indicating a very good to excellent bond. The variable density display over this interval shows a few small sections with a moderate casing signal. From a depth of 2,492 feet to 2,020 feet bls, the log displays several sections with a higher amplitude and stronger casing signal on the variable density display. This type of reading can indicate the potential of a microannulus or possibly cement channeling along these intervals.

The low amplitude and low casing signal at the tie-in to the previously installed and cemented 34-inch diameter casing set at 2,000 feet bls demonstrate an excellent tie-in between the two casings. From a depth of 2,000 feet to 1,340 feet bls, the log displays sections with a higher amplitude and stronger casing signal on the variable density display. It is important to note that 34-inch steel casing had been previously installed and cemented from a depth of 2,000 feet bls to land surface. Above 1,340 feet to a depth of 330 feet bls, the amplitude curve over the entire casing shows few readings above 10 millivolts and weak casing signals indicating a very good bond. The interval from approximately 330 feet bls to land surface had no cement in place at the time the log was conducted to provide casing signal base line data. A strong casing signal can be seen on the variable density display. The cement bond log conducted in IW-1 demonstrated that there is an adequate cement seal tie-in between the 24-inch diameter casing and the 34-inch diameter casing and that and that there is a very low potential for fluid movement adjacent to the casing.

2.12.2 IW-1 FRP Tubing Cement Bond Log

Following the installation of the 16-inch diameter FRP tubing a background CBL was conducted on February 3, 2018. This background or "before cementing" CBL was conducted because FRP casing does not respond to the signals used for a CBL in the same manner as steel casing. Therefore, it is necessary to run the log before and after cementing to determine the section of casing where cement occupies the annular space. On February 11, 2018, a cement bond log was performed in the IW-1 16-inch FRP tubing after cementing. From the travel time log it can be seen that good tool centralization was maintained for the entire log. Comparing the amplitude curves from before and after cementing, the responses after cementing are significantly different than those recorded before placing cement behind the tubing. The variable density display shows no strong tubing signal on any of the cemented section of the 16-inch tubing. The cement bond log conducted on IW-1 16-inch FRP tubing demonstrates that there is a good cement seal around the 16-inch diameter tubing and that there are no channels or conduits that would allow fluid movement adjacent to the cemented section of the casing.

2.12.3 IW-2 Final Steel Casing Cement Bond Log

On November 8, 2017, a cement bond log was performed in the IW-2 24-inch final steel casing. From the travel time log, it can be seen that good tool centralization was maintained for the entire log. From the bottom of the logged interval at 2,993 feet bls to a depth of approximately 2,000 feet bls, the amplitude curve over the casing shows very few readings above 15 millivolts, indicating an excellent bond. The variable density display shows no strong casing signal on any section in this same interval. At 2,000 feet bls, amplitude is approximately 15 mV, and the variable density display shows a moderately weak casing signal, indicating a good tie-in between the 24-inch casing and the 34-inch steel casing that was previously installed to a depth of 2,000 feet bls. Between 2,000 and 1,770 feet bls the amplitude curve shows several sections with readings above 15 millivolts in addition to moderate to strong casing signals. It is important to note that the 34-inch casing was previously installed and cemented from 2,000 feet bls to land surface. From 1,770 to approximately 290 feet bls, the amplitude curve and variable density display demonstrate excellent bond. The interval from 290 feet bls to land surface had no cement in place at the time the log was conducted to provide casing signal base line data. A strong casing signal can be seen on the variable density display. The cement bond log conducted in IW-2 demonstrated that there is a good cement seal around the 24-inch diameter casing and that there are no channels or conduits that would allow fluid movement adjacent to the casing.

2.12.4 IW-2 FRP Tubing Cement Bond Log

Following the installation of the 16-inch diameter FRP tubing, a background CBL was conducted on December 1, 2017. On December 7, 2017, a cement bond log was performed in the IW-2 16-inch FRP tubing after cementing. From the travel time log it can be seen that good tool centralization was maintained for the entire log. Comparing the amplitude curves from before and after cementing, the responses after cementing are significantly different than those recorded before placing cement behind the tubing. From the bottom of the logged interval to approximately 2,740 feet bls, the amplitude curve shows several sections with relatively low readings. The variable density display shows some sections with very weak casing signals, but generally demonstrates good bond. The variable density display shows no strong tubing signal on any of the cemented section of the 16-inch tubing above 2,740 feet bls. Amplitude readings are also low within this same interval. The interval from approximately 330 feet bls to land surface had no cement in place at the time the log was conducted to provide signal base line data. The cement bond log conducted on IW-2 16-inch FRP tubing demonstrates that there is a good cement seal around the 16-inch diameter tubing and that there are no channels or conduits that would allow fluid movement adjacent to the cemented section of the casing.

2.12.5 MW-1 Steel Casing Cement Bond Log

On February 23, 2018, a cement bond log was performed in the MW-1 16-inch steel casing. From the travel time log, it can be seen that good tool centralization was maintained for the entire log. The amplitude curve from the bottom of the logged interval at 1,482 feet bls to approximately 1,130 feet bls shows most amplitude readings not more than 15 mV, indicating a good bond. The variable density display shows few strong casing signals on this interval of the 16-inch casing. Between 1,130 and 1,000 feet bls, the amplitude is generally less than 30 millivolts, with only a few short sections reaching a maximum peak of about 40 millivolts indicating the potential of a microannulus or possibly cement channeling along these intervals. The variable density display shows casing signals which are generally moderate with few sections showing low casing signals over this interval of the 16-inch casing.

The low amplitude and low casing signal at the tie-in of the 16-inch casing into the previously installed and cemented 24-inch diameter casing set at 1,000 feet bls demonstrate a tie-in between the two casings. From a depth of 1,000 to approximately 350 feet bls the log displays sections with low amplitude and weak casing signals on the variable density display indicating good bond. It is important to note that 24-inch steel casing had been previously installed and cemented from a depth of 1,000 feet bls to land surface. The interval from 350 feet bls to land surface had no cement in place at the time the log was conducted to provide casing signal base line data. A strong casing signal can be seen on the variable density display. The cement bond log conducted in MW-1 demonstrated that there is a good cement seal tie-in between the 16-inch diameter casing and the 24-inch diameter casing and that and that there is a very low potential for fluid movement adjacent to the casing.

2.12.6 MW-1 FRP Casing Cement Bond Log

Following the installation of the 6-5/8-inch diameter FRP casing a background CBL was conducted March 3, 2018. On March 8, 2018, a cement bond log was performed in the MW-1 6-5/8-inch casing after cementing was completed. From the travel time log it can be seen that good tool centralization was maintained for the entire log. The amplitude curve from 1,770 to approximately 1,530 feet bls shows responses significantly different than those recorded before cementing material behind the casing. The variable density display shows no strong casing signal on any of the cemented section of the 6-5/8-inch casing. The amplitudes and travel times within the upper monitoring zone from 1,500 to 1,529 feet bls indicate that no material exists between the 6-5/8-inch FRP casing and the formation. The cement bond log conducted on MW-1 6-5/8-inch casing demonstrates that there is a good cement seal around the 6-5/8-inch diameter casing and that there are no channels or conduits that would allow fluid movement adjacent to the cemented section of the casing.

3. Subsurface Conditions

3.1 Background

In this section, the subsurface conditions are described including geology, hydrogeology and water quality. The base of the USDW, the injection zone and confinement intervals are identified.

3.2 Generalized Geologic Setting

A well-defined, extensive sequence of carbonate sediments is present at the site. Various lithostratigraphic units were identified based on the data obtained during the drilling of the wells as described in Section 2. This is consistent with information obtained from other projects in the vicinity. A summary of the encountered is in **Table 3-1**.

Table 3-1: Depths of Lithologic Units

Depth (feet bls)	Thickness (feet)	Formation Name
0 to 230	230	Undifferentiated, Miami Limestone, Anastasia and Tamiami Formations
230 to 1,030	800	Hawthorn Group
1,030 to 2,760	1,730	Avon Park Formation
2,760 to 3,500	740	Oldsmar Formation
2,940 to 3,500	560	"Boulder Zone"

Geologic formation samples (well cuttings) from the initial boreholes were collected during drilling operations and described based on their dominant lithologic and textural characteristics, and, to a lesser extent, color using Dunham classification system (1962) for carbonate rocks. Detailed lithologic logs are provided in **Appendix E**. The various formations that were penetrated by IW-1, IW-2, and MW-1 correlate closely with each other, demonstrating the continuity and uniformity of the beds. A description of the lithostratigraphy and its relationship to the hydrostratigraphy of the wells is provided below.

3.2.1 Undifferentiated Surficial Sediments and the Pliocene-Pleistocene Series

The upper 40 to 60 feet of the stratigraphic column consists of the undifferentiated Quaternary sediments which are generally unconsolidated very fine-grained quartz sand. The Pliocene-Pleistocene Series is composed of the Miami Limestone, the Anastasia Formation and the Tamiami Formation. These formations are present from the base of the Quaternary sediments to approximately 230 feet bls. The lithology is highly variable and comprised of interbedded limestone and calcareous sandstone, with varying amounts of unconsolidated shell and sand. The limestones contain varying amounts of sand and clay and are primarily light olive gray (5Y 6/1), pale yellowish brown (10YR 6/2) and very pale orange (10YR 8/2). This lithology is moderately to well indurated with the cement type primarily sparry calcite.

The interbeds are slightly sandy and clayey and are generally weakly phosphatic. Various amounts of unconsolidated shell and quartz sand are also present in these sediments. The boundaries between the individual formations were unable to be determined. The surficial aquifer system is located within these formations.

3.2.2 Hawthorn Group

The Hawthorn Group is situated within the Upper Miocene to Upper Oligocene Series. Within the site, the Hawthorn Group is located from approximately 230 feet to 1,030 feet bls. It is comprised of the Peace River Formation and the Arcadia Formation. The Peace River Formation extends to approximately 510 feet bls and is predominantly composed of olive gray (5Y 3/1 to 5Y 4/1) slightly phosphatic sandy limey clay and marl with varying amounts of fine-grained quartz sand and detrital carbonate. Rare interbeds of very hard cryptocrystalline chert are occasionally present within the Peace River Formation. The Arcadia Formation extends from 510 feet to about 1,030 feet bls. This unit consists of weakly phosphatic limestone and clay with varying amounts of quartz sand and detrital carbonate. This upper portion of the Hawthorn Group primarily forms the intermediate aquifer system / intermediate confining unit. Within the lower 80 feet of the Arcadia Formation, from 950 to 1,030 feet, the lithology is much more permeable and comprises the uppermost portion of the Upper Floridan aquifer system.

3.2.3 Avon Park Formation

The Avon Park Formation is comprised wholly within the Middle Eocene Series from approximately 1,030 feet to 2,770 feet bls. The upper portion of the Avon Park Formation from approximately 1,030 to 1,900 feet bls is composed almost entirely of limestone (grainstone to packstone). This limestone is typically very pale orange (10YR 8/2), grayish orange (10YR 7/4) to pale yellowish brown (10YR 7/2), fine to medium grained, moderately to well indurated, and fossiliferous. The lower portion of the Avon Park Formation, from about 1,900 to 2,760 feet bls, consists of limestone (mudstone to packstone), very pale orange (10YR 8/2) to yellowish gray (5Y 8/1), very fine to coarse grained with poor to moderate induration. The limestone is interbedded with limey dolostone, moderate yellowish brown (10YR 5/4), microcrystalline to fine grained, and well indurated. These dolostone units comprise less than 10% of the sequence. The Avon Park Formation is situated in both the Upper and Lower Floridan aquifer.

3.2.4 Oldsmar Formation

The Oldsmar Formation is comprised wholly within the Lower Eocene Series from approximately 2,760 feet bls to the base of the injection wells at 3,500 feet bls. The upper limit of the Oldsmar Formation was unable to be definitively determined based on the lithostratigraphy encountered within the well bores. However, a noticeable decrease in gamma ray activity below 2,760 feet bls may indicate that the top of the Oldsmar Formation occurs at this depth. The upper portion from 2,760 to 3,000 feet bls consists of interbedded limestone (mudstone to grainstone) and dolostone, very pale orange (10YR 8/2), very fine to fine grained with moderate induration. The limestone is interbedded with dolostone, moderate yellowish brown (10YR 5/4) to dark yellowish brown (10YR 4/2) and cryptocrystalline to fine grained euhedral crystals. Below 3,000 feet bls the sequence is composed of dolostone with interbedded limestone. The dolostone in the lower interval is predominantly very pale orange (10YR 8/2) or dark yellowish brown (10YR 4/2), massive, fine grained and dense with some dissolution features. The Oldsmar Formation is situated in the Lower Floridan aquifer.

The “Boulder Zone” extends from approximately 2,940 to at least 3,500 feet bls in the lower portion of the Oldsmar Formation. The lower limit of the “Boulder Zone” was not determined since drilling was terminated at approximately 3,500 feet bls. The video surveys show that the dolostone in this zone exhibits extensive dissolution cavities as well as fracturing.

3.3 Hydrogeologic Setting

The depth and thickness of hydrogeologic units are identified in this section.

3.3.1 Surficial Aquifer System

The surficial aquifer system (SAS) comprises the upper 230 feet of rock and sediments and are Pleistocene and Upper Miocene sandstone, limestone, clay and unconsolidated sand and shell. Within the SAS is the Biscayne aquifer which is used as a source of drinking water throughout South Florida.

3.3.2 Intermediate Confining Unit

Underlying the Biscayne aquifer are approximately 800 feet of Miocene clay and marl of the Hawthorn Group which form a confining bed between the Biscayne Aquifer and the Oligocene to Eocene limestones and dolomites of the Floridan aquifer. This is the intermediate confining unit and extends from approximately 230 feet to 950 feet bls.

3.3.3 Floridan Aquifer

The Floridan aquifer includes the upper Floridan aquifer, the middle semiconfining unit 1, the Avon Park permeable zone, the middle semiconfining unit 2, the uppermost permeable zone of the Lower Floridan aquifer, the Lower Floridan confining unit and the “Boulder Zone”. Water from the Floridan aquifer in South Florida contains concentrations of dissolved solids which exceed drinking water standards. The aquifer is not currently used as a main source of drinking water in Broward County; however, some water utilities have begun to use the Floridan aquifer for water supply purposes.

3.3.4 “Boulder Zone”

The “Boulder Zone” extends from approximately 2,940 to at least 3,500 feet bls in the lower portion of the Floridan aquifer. As previously stated, the lower limit of the “Boulder Zone” was not determined since drilling was terminated at approximately 3,500 feet bls. This unit is used as an injection zone for the disposal of secondary treated effluent and membrane WTP concentrate throughout the State of Florida due to its hydrogeologic properties. The upper limit of the injection zone is considered to be the same as the upper limit of the “Boulder Zone”.

Highly fractured and cavernous dolostones are characteristic of the “Boulder Zone” which make the unit highly permeable. Average porosity in the “Boulder Zone” as recorded in the BHC sonic log is approximately 24%. Bottom hole temperature within the “Boulder Zone” is approximately 55 degrees Fahrenheit (^{o} F) at IW-1, and approximately 52^{o} F at IW-2. Bottom hole pressure within the “Boulder Zone” is 1,331 psi at IW-1, and 1,294 psi at IW-2. The hydrostatic pressure of the “Boulder Zone” is approximately 11 psi at IW-1 and IW-2.

3.3.5 Hydrogeologic Units Summary

A summary of the various hydrogeologic units encountered is in **Table 3-2**.

Table 3-2: Depths of Hydrogeologic Units

Depth (feet bls)	Thickness (feet)	Hydrogeologic Units
0 – 230	230	Surficial aquifer system
230 – 950	720	Intermediate confining unit
950 – 1,230	280	Upper Floridan aquifer system
1,230 – 1,570	340	Middle semiconfining unit 1
1,630	-	Base of brackish water (base of USDW)
1,570 – 1,640	70	Avon Park Permeable Zone
1,640 – 2,010	340	Middle semiconfining unit 2
2,010 – 3,500	1,490	Lower Floridan aquifer system
2,010 – 2,190	180	Uppermost major permeable zone
2,190 – 2,940	750	Lower Floridan confining unit
2,940 – 3,500	560	“Boulder Zone”

3.4 Water Quality

Water quality was reviewed at various stages of construction. Drilling fluid samples were collected during the drilling of pilot holes using the reverse air drilling method. Formation fluids were analyzed from isolated sections of the borehole during the single packer and straddle packer tests conducted in the IW-1, IW-2 and MW-1 pilot holes.

3.4.1 Drilling Fluid Water Quality

Samples of the drilling fluid were collected during the drilling of the pilot holes at 45-foot intervals below 1,000 feet bls. Samples were collected during the addition of drill pipe to the drill string. Samples were sent to the Lab and analyzed for chlorides, TDS, conductivity, ammonia, TKN, nitrate, nitrite and pH. Water quality testing results of these test are presented in graphical format in **Graphic 1, Graphic 2** and **Graphic 3**. For convenience, the following interpretations use the terms nitrogen to refer to both ammonia and TKN. Because the patterns for TDS, conductivity, and chlorides are similar, TDS will be used to collectively describe the water quality patterns with depth for these three parameters.

The water quality analytical results from samples collected during the drilling of IW-1 show that throughout the entire depth of the pilot hole nitrogen appeared to be relatively stable below 1.5 mg/L. Between 2,651 feet bls and 2,741 feet bls nitrogen concentration was below method detection limits in the water quality samples. From approximately 1,000 feet bls to a depth of 1,662 feet bls results show that TDS appear to be relatively stable below 5,000 mg/L. At 1,662 feet bls there was a sharp consistent increase in the TDS concentration to a depth of 2,381 feet bls where TDS peaked at 41,200 mg/L. Below 2,381 feet bls TDS levels decreased.

The water quality analytical results from samples collected during the drilling of IW-2 show that throughout the entire depth of the pilot hole nitrogen appeared to be relatively stable below 1.5 mg/L. At 1,169 feet bls and 2,474 feet bls there was a sharp increase in nitrogen levels. Nitrogen levels were generally higher in the pilot hole from 1,000 to 2,000 feet bls than in the pilot hole from 2,000 to 3,000 feet bls. At a depth of 1,754 feet bls and above TDS appeared to be relatively stable, typically below 5,000 mg/L. At 1,799 feet bls there was a sharp increase in the TDS levels until 2,429 feet bls. Below 2,429 feet bls TDS freshened and remained generally stable at approximately 32,000 mg/L.

The water quality test results from drilling MW-1 show that throughout the entire depth of the pilot hole to the total depth at 1,810 feet bls the nitrogen appeared to be relatively stable below 1.5 mg/L. From the beginning of the pilot hole to a depth of 1,302 feet bls the TDS concentrations appeared to be relatively stable below 5,000 mg/L. From 1,302 to 1,482 feet bls results indicate that TDS concentrations increased sharply. Between 1,482 and 1,617 feet bls, TDS concentrations decreased slightly, then increased again below 1,617 feet to the total depth of the well.

3.4.2 Packer Test Water Quality

Water samples collected during straddle and single packer testing conducted in the IW-1, IW-2 and MW-1 pilot holes were analyzed by the Lab for selected water quality parameters. The water samples from the packer tests were analyzed for selected parameters to assess water quality and to identify the 10,000 mg/L TDS interface within the wells. The tests were conducted in intervals considered suitable as potential confining zones and intervals potentially suitable as monitor zones.

During the packer tests, a sample of the formation water from the tested interval was collected just prior to shutting off the pump at the end of the pumping phase. Water samples from the packer tests were analyzed for TDS, chloride, specific conductance, ammonia, TKN, nitrate, nitrite, and sulfate. Results of the laboratory analyses are presented in **Appendix N** and in **Table 2-9, Table 2-10** and **Table 2-11**. For convenience, the following interpretations use the term nitrogen to refer to ammonia, TKN, nitrate, and nitrite. Because the patterns for TDS, conductivity, and chlorides are similar, TDS will be used to collectively describe the water quality patterns with depth for these three parameters. Depths indicated in this section refer to the centerline of the packer rounded to the nearest foot. Graphical presentations of the packer water quality test results are presented in **Graphics 11** through **Graphic 16**.

Water quality results were obtained from three packer tests performed in the IW-1 pilot hole drilled from 1,000 to 2,000 feet bls. The water quality test results from these packer tests show varying water quality. At a depth of 1,620 feet bls, the TDS was 9,400 mg/L, slightly below the 10,000 mg/L TDS threshold. At 1,890 and 1,910 feet bls, TDS increased sharply above 30,000 mg/L. Water quality results indicate that nitrogen levels are low and decrease with depth. Over this same interval, sulfate showed a general increase from 500 mg/L to greater than 2,500 mg/L.

Five packer tests were performed in the IW-1 pilot hole from 2,000 to 3,000 feet bls. The results from these tests show a decrease in TDS concentrations at 2,220 feet bls and a subsequent increase to greater than 30,000 mg/L below 2,220 feet bls. Sulfate and nitrogen concentrations remained relatively stable throughout all five packer tests when compared to the results from the packer tests in the previous pilot hole.

Water quality results were obtained from three packer tests performed in the IW-2 pilot hole from 1,000 to 2,000 feet bls. The water quality results from these tests show varying water quality. At a depth of 1,570 feet bls, the TDS was 4,510 mg/L. Additional tests show vastly greater concentrations with depth, reaching a maximum of 36,200 mg/L TDS at 1,930 feet bls. Nitrogen concentrations were relatively low and decreased slightly with depth. The results indicate that sulfate concentrations generally increase with depth from 458 mg/L to 2,640 mg/L.

Five packer tests were performed in the IW-2 pilot hole from 2,000 to 3,000 feet bls. The water quality results showed a generally stable trend in TDS concentrations ranging between 30,000 and 40,000 mg/L. Nitrogen concentrations generally continued to decrease slightly with depth. Sulfate concentrations tracked very closely to each other between 2,450 and 2,500 mg/L.

Water quality results were obtained from two packer tests performed in the MW-1 pilot hole from 1,000 to 1,810 feet bls. The results demonstrate an increase in TDS concentrations with depth, ranging from 3,420 mg/L at 1,520 feet bls to 36,400 mg/L at 1,790 feet bls. Nitrogen concentrations, while remaining relatively low, varied slightly with depth. Analyses indicate that nitrogen increased from 1,520 to 1,620 feet bls, then subsequently decreased at 1,790 feet bls. Following a similar trend as in the two injection wells, sulfate concentrations in the monitor well increased with depth from 482 to 2,760 mg/L.

3.4.3 Log Derived Water Quality

Log derived water quality is calculated from a combination of the data from four other geophysical logs that provide an indication of formation water quality by depth. This log uses sonic porosity from the borehole compensated sonic log, deep induction from the DIL, hole size from the caliper and gamma ray logs. This log is useful to estimate where the TDS concentration was equal to or greater than 10,000 mg/L. Log derived water graphs and are presented in **Appendix G**.

3.4.4 Base of the USDW

The base of the USDW is defined as water having a concentration less than 10,000 mg/L TDS. The base of the USDW was identified by interpretation of the log derived water quality geophysical log and by performing water quality analysis on samples obtained from packer tests. Based on the log derived water quality data for IW-1, IW-2 and MW-1, the depth where TDS is 10,000 mg/L occurs at 1,630 feet bls in all three wells, as presented in **Graphic 10** and in **Appendix G**. Based on the water quality testing performed during packer testing for IW-1, IW-2 and MW-1, the depth where TDS is 10,000 mg/L occurs at approximately 1,630 feet bls in all three wells. The water quality test results from the packer testing show good correlation to the log derived water quality testing results. Based on the information from the log derived water quality logs and the packer test results, the base of the USDW for the site has been identified at 1,630 feet bls. Land surface in the area of the wells at the time of drilling was approximately 9 feet NAVD88.

3.5 Confinement Analysis

Injection wells are required to have confinement as identified in the Permit and in 40 CFR 146. Confinement is generally described in 40 CFR 146 as a geological formation, group of formations, or part of a formation that is capable of limiting fluid movement above an injection zone. The Permit identifies confinement must be present between the deepest USDW and the top of the injection zone. This subsection identifies the geophysical logging and testing performed to support the identification of confinement.

3.5.1 Identification of Confining Units

The approach to the evaluation of vertical confinement in IW-1 and IW-2 was as follows. Available borehole geophysical and geological data, and open hole testing data were used to identify intervals of rock between the base of the USDW (1,630 feet bls) to approximately 3,000 feet bls that exhibit confining properties. The vertical confinement provided by each interval was then evaluated. Particular attention was given to locating beds of limestone, dolostone, or clay that have low matrix vertical hydraulic conductivities and are not penetrated by fractures and / or solution cavities. Such beds provide the primary vertical confinement of the injected fluid. Intervals identified in having good confining characteristics are described in Subsection 3.6.

3.5.2 Geophysical Logs

The geophysical logs performed in IW-1, IW-2 and MW-1 were examined in detail for the presence of intervals that have a high potential of providing vertical confinement for injected fluids. A combination of gamma ray, borehole compensated sonic with variable density, spontaneous potential, X-Y caliper and resistivity logs were used to identify limestone and / or dolostone beds that would be expected to have low matrix porosities and low hydraulic conductivities. Borehole televiewer logs and video surveys were used to locate fractures and / or cavernous zones that could be conduits for vertical fluid flow. Information on the orientation and thickness of beds was also obtained from the BHTV logs.

The development and conditioning of the wells prior to logging is not an issue for the sonic, caliper, gamma ray, temperature, resistivity and BHTV logs as these logs were designed for and are often run in mudded boreholes. Small scale features, such as bed contacts, are readily distinguishable on the BHTV log which indicates that borehole conditions did not have a significant adverse effect on log quality.

Flowmeter, temperature and fluid resistivity/conductivity logs provide information on the location of flow zones into wells and on changes in the quality of formation waters. These logs were run under both static and dynamic conditions. These logs did not provide useful information concerning vertical confinement. Fluid resistivity/conductivity and temperature were relatively constant in all wells below the base of the USDW. Flowmeter logs under the best of circumstances can provide information on the location of beds or series of beds with high horizontal hydraulic conductivities. Flowmeter logs are of very limited value for identifying beds with low vertical hydraulic conductivities because a single zone of high hydraulic conductivity very often dominates the flow for the entire tested interval making it difficult to evaluate other portions of the logged interval.

3.5.3 Characterization of Well Cuttings

Formation cuttings were collected during the drilling of initial boreholes in IW-1, IW-2 and MW-1. The cuttings were grab samples collected at 10-foot intervals to the total depth of each well. The lithology of the limestone cuttings was characterized using the limestone classification scheme of Dunham (1962) as identified in Section 2.5. Samples were characterized for rock type, color, consolidation, texture, cementation, hardness, induration, and fossil type. The lithologic samples aided in identifying the contacts between formations, selection of coring intervals, packer test intervals, and understanding the overall physical characteristics of formations penetrated by the borehole. Descriptions of the lithology encountered during drilling of the wells are presented in **Appendix E**.

3.5.4 Core Examination and Data Analysis

Sixteen cores were collected from IW-1 and IW-2 from 1,730 to 2,940 feet bls as identified in Section 2. There were no cores collected from MW-1. The lithology of the cores was evaluated to determine if there were any significant biases in the cutting samples. The well cuttings appeared to have somewhat less intergranular carbonate mud than the cores. In some limestone cuttings, the carbonate mud appeared to have been washed out of the samples during the drilling process. Some limestone cuttings, particularly grainstones and packstones, thus appear to be more porous than they actually are. The cores were also examined for the presence of fractures or solution features (vugs) that might be conduits for vertical fluid flow. Copies of the core descriptions are contained in **Appendix I**. Sections of each core were selected and submitted for laboratory analysis for hydraulic conductivity. A summary of laboratory results as well as the laboratory reports are presented in **Appendix J**.

3.5.5 Packer Test Data

Single and straddle packer test data collected during the drilling of IW-1, IW-2 and MW-1 were analyzed for information regarding the hydraulic conductivity of potential confining units. The packer test data were analyzed using the Cooper and Jacob (1946) modification of the Theis (1935) nonequilibrium equation (i.e., the straight-line method). The transmissivity values calculated from both the pumping and recovery phase data for each test were very similar.

Transmissivity and average hydraulic conductivities values calculated from the packer test data are largely a function of horizontal hydraulic conductivities. Packer test data thus tend to overestimate vertical hydraulic conductivities. For example, a packer test performed on an interval containing one or more high hydraulic conductivity beds interbedded between very low hydraulic conductivity beds would give a high transmissivity and average hydraulic conductivity value whereas the interval would have a very low vertical hydraulic conductivity. The results from each packer pumping test are contained in **Appendix M**.

3.5.6 Stratigraphic Correlation

The geologic and geophysical logs of IW-1, IW-2 and MW-1 indicate excellent correlation as would be expected from wells in such close proximity. An example of this excellent correlation is visible higher in the boreholes on the gamma ray log with a pronounced deflection at 1,030 feet bls in both injection wells IW-1 and IW-2 and the dual-zone monitoring well MW-1. Another example of this excellent correlation can be seen when the BHCS w/VDL logs from IW-1 and IW-2 are placed side by side. With the logs in this position, it is evident that the logs are generally similar. Examples of this can be seen with a sharp increase in sonic delta times and a distortion in the VDL patterns at 2,750 feet bls, at the same depth and of the same general magnitude. This correlation can also be seen on the VDL, gamma ray, dual induction and BHTV logs.

3.5.7 Criteria for Identification of Confinement Intervals

Beds or intervals of rock that are likely to offer good vertical confinement were identified using the following criteria:

- Low sonic transit times and derived sonic porosities.
- VDL pattern consisting of either straight parallel vertical bands, where lithology is relatively uniform, or a "chevron" pattern of continuous parallel bands, where the formation consists of interbedded rock with differing densities and/or degrees of consolidation. Fractured rock typically has an irregular VDL log pattern.
- Low vertical hydraulic conductivities measured on core samples.
- Low hydraulic conductivities calculated using packer test data.
- Low macroporosity (i.e., visible pore spaces) and a high degree of cementation (induration) as observed in microscopic examination of cuttings and core samples.
- Borehole diameters on caliper logs close to the bit size. Fractured dolomite and limestone are commonly manifested by an enlarged borehole.
- Relatively high resistivity, which in the middle and lower portions of the Floridan aquifer system (FAS) are often indicative of dolostone beds with low hydraulic conductivities.
- Absence of evidence of fractures from the video survey and BHTV log.

3.6 Confinement Intervals

The confinement properties of the strata between the base of the USDW (1,630 feet bls) and 3,000 feet bls were evaluated using the previously discussed criteria and data. Three confining intervals were identified based on their vertical confinement properties and are discussed below.

3.6.1 Interval from 1,980 to 2,030 Feet bls

This interval consists predominantly of light-colored limestones. These limestones are commonly cryptocrystalline to very fine-grained hard mudstones with moderate to high degrees of induration. These sediments often display minimal macroporosity. The mudstones are interbedded with moderately soft to moderately hard pelloidal packstones with moderate degrees of induration. These packstone beds can potentially provide better vertical confinement than the mudstone beds. One core was collected over this interval and five sections were submitted for laboratory analyses. Reported vertical hydraulic conductivities range from 9.8×10^{-8} to 3.9×10^{-6} cm/sec.

Sonic porosities throughout the interval generally range between 40 and 50%. Porosities derived from the analysis of core sections over this interval range from 33 to 35%. The relatively high sonic porosities and low macroporosities indicate that the formation over this interval has a high microporosity. Microporous limestones tend to have much lower hydraulic conductivities than more coarsely porous limestones.

Neither the BHTV logs nor the video surveys conducted over this interval revealed evidence of caverns or fractures which would facilitate vertical migration of fluid into the USDW. The borehole diameter remained close to the bit size throughout the drilling of the pilot hole; indicating a low potential that fractures are not present throughout this interval. The VDL pattern consists of generally parallel bands, indicating a relatively uniform stratigraphy and the absence of fractures or caverns over this interval. The lithologic and geophysical data collected within this interval are characteristic of an interval with good vertical confinement.

3.6.2 Interval from 2,290 to 2,490 Feet bls

The primary lithologies encountered over this interval are light-colored limestones (mudstones and packstones). These are generally cryptocrystalline to fine grained and moderately hard with moderate to high degree of induration. Some hard, microcrystalline, dark-colored dolostones exist within this interval as well. These sediments typically display some degree of macroporosity that does not appear to be hydraulically interconnected. A total of five cores were collected over this interval and 18 sections were selected for laboratory analysis. Reported vertical hydraulic conductivities range from 2.8 x 10^{-6} to 5.1 x 10^{-4} cm/sec. One packer test was conducted over the interval of 2,329 to 2,347 feet bls and yielded a hydraulic conductivity of 1.2 x 10^{-4} cm/sec.

Derived sonic porosities measured in this interval range between 20 to 40%, but typically are lower than 30%. At a depth of approximately 2,490 feet bls, the sonic porosity decreased to about 10%. Porosities from the analyzed core sections range from 20 to 37%. No evidence of fractures or caverns was observed on the BHTV or video survey conducted over this interval. Fractured formations are typically manifested by a borehole larger than the diameter of the bit. The VDL pattern consists of parallel bands, indicating relatively uniform stratigraphy with no apparent fractures present. The geological and geophysical data demonstrate that this interval will provide a high potential for vertical confinement between the injection zone and the USDW.

3.6.3 Interval from 2,590 to 2,720 Feet bls

Pelloidal packstone limestones make up much of the lithology of this interval. There are generally fine grained, and moderately hard to hard with a high degree of induration. Macroporosity was generally not observed in the lithologic samples from this interval. One core was collected over this interval and one section was submitted for laboratory analysis. The vertical conductivity of the tested section was 1.7 x 10^{-5} cm/sec. Four packer tests were conducted over this interval and yielded hydraulic conductivities ranging from 1.2 x 10^{-4} to 3.7 x 10^{-4} cm/sec.

From the BHC sonic log, porosities for this interval are generally low, ranging from 20 to 30%. At approximately 2,690 feet bls, porosity reaches a minimum of about 15%. Analysis of the core section from this interval shows a porosity of 25%. No evidence of fractures or dissolution cavities was observed on the BHTV or video survey conducted over this interval. The parallel bands from the VDL over this interval demonstrate an interval of sediments with very little variation and a low potential for fractures. This interval exhibits geologic and geophysical characteristics of good vertical confinement.

3.6.4 Confinement Summary

During the drilling and testing of these wells at the STOF Hollywood Reservation, an extensive program was implemented to identify confining sequences between the base of the USDW and the injection zone. Considered in making the determination of confinement were lithology, geophysical logging results, core analysis, and pump testing analyses. The primary lithologies encountered over the confining intervals are light-colored limestones (mudstones and packstones) and dolostones. A number of cores and packer tests were performed. Three intervals located between the base of the USDW and the top of the injection zone were identified as having good confining characteristics.

- Interval from approximately 1,980 to 2,030 feet bls
- Interval from approximately 2,290 to 2,490 feet bls
- Interval from approximately 2,590 to 2,720 feet bls

The limestones and dolostones have geologic and geophysical characteristics indicative of good confinement. Sonic porosities range mostly between 20 and 50%. Core sample total porosities generally range between 20 and 35%. The hydraulic conductivities identified from packer testing range from 1.2 x 10^{-4} to 3.7 x 10^{-3} cm/sec. The vertical hydraulic conductivity of core samples ranges from 9.8 x 10^{-8} to 5.1 x 10^{-4} cm/sec.

Neither the BHTV logs nor the video surveys conducted over these intervals yielded evidence of caverns or fractures which would facilitate vertical migration of fluid into the USDW. The VDL patterns consist of generally parallel bands, indicating a relatively uniform lithology and the absence of fractures or caverns over this interval. The geologic and geophysical data collected over these intervals exhibit characteristics of a suitable interval of vertical confinement.

Limestones and dolostones identified in IW-1 and IW-2 have geologic and geophysical characteristics of beds or intervals of rock that are likely to offer good vertical confinement meeting the criteria described in Section 3.5.7. The geologic units encountered during construction of the wells satisfy the requirements of 40 CFR 146. The presence of suitable confining sequences above the injection zone and suitable monitor zones above the confining sequences were determined by geophysical logging and testing as identified in this report.

A generalized Hydrogeologic Column is presented in **Graphic 17**. This graphic identifies and illustrates generalized limits of formations encountered, lithologic descriptions, and hydrology. It includes the limits of aquifers, the base of the USDW, confining intervals below the USDW and above the “boulder zone” (the injection zone).

4. Completed Well Testing

4.1 General

After the construction was completed on IW-1, IW-2 and MW-1, final testing was performed. This testing included performing a mechanical integrity test (MIT) of both injection wells, pressure testing of the dual-zone monitor well casings, performing a final video survey of dual-zone monitor well and a short-term injection test on each of the injection wells. Background water quality samples from the IW-1 and IW-2 injection zones and the upper and lower monitor zones of MW-1 were collected and analyzed. After receiving approval from EPA, a short-term injection test was performed on IW-1 and IW-2.

Well construction was completed by installing wellheads at each of the wells. Under a future contract, another contractor will install wastestream disposal piping between the injection wells and the injection well pump station. The other contract also includes the construction of concrete pads at the wellheads, instrumentation and monitor well sample disposal piping to the on-site sanitary sewer system.

4.2 Mechanical Integrity Testing

In accordance with 40 CFR 146.8, the injection wells were tested for mechanical integrity. Testing consisted of a hydrostatic pressure test of the injection casing, a high-resolution temperature log, a video survey and a radioactive tracer survey (RTS). The hydrostatic pressure test, which was conducted at a pressure at least 50% greater than the anticipated maximum allowable operating pressure, identifies internal casing integrity. The temperature log identifies temperature variations in the well. The video survey provides visual verification of internal casing integrity. The radioactive tracer survey provides data on the external mechanical seal of the casing. The following describes the testing methods, results of the testing and presents the interpretation of the data collected during the mechanical integrity tests to verify that the mechanical integrity of the constructed wells is intact at the time of testing.

4.2.1 IW-1 Tubing Pressure Test

On March 13, 2018, the 16-inch FRP injection well tubing was internally pressurized to 154 psi. A pressure decline of 2-1/2 psi was observed over the 60-minute test period. This decline represents a 1.6 percent change in the original pressure, which is within the 5.0 percent limit identified for this project. A copy of the test gauge certification record and certified results of the hydrostatic pressure test are contained in **Appendix Q**.

4.2.2 IW-1 Temperature Log

On April 20, 2018 the Contractor conducted a high-resolution temperature log on IW-1 from land surface to the base of the open borehole. The temperature within the 16-inch diameter FRP tubing decreased steadily from 71° F to 60° F from the land surface to approximately 2,820 feet bls. Temperature increased to about 67° F from 2,820 feet bls to approximately 2,912 feet bls, just below the base of the 16-inch diameter FRP tubing. The temperature decreased sharply between 2,912 and 3,000 feet bls to about 43° F and remained relatively stable to approximately 3,340 feet bls. This decrease may indicate that most of the injected fluid will be received by the formation above 3,000 feet bls. Temperature increased slightly from 43º F to approximately 45º F from 3,340 feet bls to the base of the open borehole. The temperature log showed no indication that the well lacks mechanical integrity. A copy of the temperature log is presented in **Appendix F**.

4.2.3 IW-1 Video Survey

A video survey of the completed IW-1 was performed on April 6, 2018 from land surface to a depth of 3,500 feet bls. Water clarity was good, enabling the camera to capture clear images of the casing interior, casing seat and open-hole section. The survey revealed that the casing was in excellent condition. The open hole appeared to be mostly dolostone with several highly fractured and cavernous zones. The video survey showed no indication that the well lacks mechanical integrity. A copy of the video survey in DVD format is included in **Appendix K**.

4.2.4 IW-1 Radioactive Tracer Survey

On April 20, 2018, a RTS was conducted on IW-1. The test began by conducting a background gamma ray log followed by a casing collar locator (CCL) tie-in pass. The background gamma ray log was reprinted on each out-of-position logging run to serve as a means of comparison. Each logging run is identified by its name presented at the top of the log. After the completion of the background gamma ray log, the logging tool ejector was calibrated to a 0.4 millicurie (mCi) per second discharge, and the reservoir was loaded with 6 mCi of radioactive Iodine 131 (I-131).

Both RTS tests were conducted under dynamic conditions. For the first test an injection rate of 38 gpm was established using potable water. The tracer ejector was positioned five feet above the bottom of the casing. The recorder was placed in the time drive mode, and a 1 mCi slug of tracer material was ejected. The readings from the middle gamma ray detector began to increase from background about 20 seconds after ejection. The readings from the bottom detector increased from background approximately one minute and 38 seconds after ejection. No detection of the tracer material was observed at the upper gamma ray detector any time during 60 minutes of time drive monitoring. The tools were then logged out-of-position (LOP #1) to a depth of 2,700 feet bls. The results of the log out-of-position showed no indication of tracer material movement up hole. The injection casing was then flushed with approximately 4,000 gallons of potable water. Following the flushing, an out-of-position log was conducted (LAF #1) from below the casing to 2,700 feet bls. This log showed that all tracer material had been flushed out of the casing as the gamma ray levels on the top, middle and bottom detectors returned to background levels. These results demonstrate casing integrity and that there are no channels behind the casing.

The second tracer test was also a dynamic test. The injection rate into the well was adjusted to 37 gpm using potable water. The logging tools were positioned so that the ejector was five feet above the bottom of the casing. The recorder was placed in time drive mode, and a 2 mCi slug of tracer material was ejected. The readings from the middle gamma ray detector began to increase from background about 21 seconds after ejection. The readings from the bottom detector increased from background approximately 2 minutes and 5 seconds after ejection. No detection of the tracer material was observed at the upper gamma ray detector any time during 60 minutes of time drive monitoring. The tools were then logged out-of-position (LOP #2) to a depth of 2,700 feet bls. The results of the log out-of-position showed no indication of tracer material movement up hole. The injection casing was then flushed with potable water at a rate of 147 gpm. The ejector port was positioned at a depth of 3,069 feet bls and the remaining 3 mCi of I-131 was dumped. Following the flushing, a final gamma ray log was conducted on the total depth of the well. The logs were recorded over traces of the initial background log and showed excellent repeatability on all detectors. These results demonstrate casing integrity and that there are no channels behind the casing. A schematic of the logging tool is shown in presented with the logs. A copy of the radioactive tracer survey of the injection well, the I-131 assay and the flowmeter calibration certification are contained in **Appendix F**.

4.2.5 IW-2 16-inch FRP Tubing Pressure Test

On March 12, 2018, the 16-inch injection well FRP tubing was internally pressurized to 154 psi. A pressure decrease of 1/2 psi was observed over the 60-minute test period. This increase represents a 0.3 percent change in the original pressure, which is within the 5.0 percent limit identified for this project. A copy of the test gauge certification records and certified results of the hydrostatic pressure test are contained in **Appendix Q**.

4.2.6 IW-2 Temperature Log

On April 18, 2018 the Contractor conducted a high-resolution temperature log on IW-2 from land surface to the base of the open borehole. The temperature within the 16-inch diameter FRP tubing decreased steadily from 71^{o} F to 54^{o} F from the land surface to approximately 2,950 feet bls. Temperature increased by about 1^{o} F from 2,950 feet bls to approximately 3,003 feet bls, just below the base of the 24-inch diameter steel casing. The temperature decreased sharply between 3,003 and 3,030 feet bls to about 43^{o} F and remained relatively stable to approximately 3,200 feet bls. This decrease may indicate that most of the injected fluid will be received by the formation above 3,030 feet bls. Temperature increased slightly from 43^{o} F to approximately 46^{o} F from 3,200 feet bls to the base of the open borehole. The temperature log showed no indication that the well lacks mechanical integrity. A copy of the temperature log is contained in **Appendix F**.

4.2.7 IW-2 Video Survey

A video survey of the completed IW-1 was performed on April 13, 2018 from land surface to a depth of 3,499 feet bls. Water clarity was good, enabling the camera to capture clear images of the casing interior, casing seat and open-hole section. The survey revealed that the casing was in excellent condition. The open hole appeared to be dolostone and limestone with several fractured and cavernous zones. The video survey showed no indication that the well lacks mechanical integrity. The video survey descriptions and a copy of the video surveys in DVD format are included in **Appendix K**.

4.2.8 IW-2 Radioactive Tracer Survey

On April 18, 2018, a RTS was conducted on IW-2. The test began by conducting a background gamma ray log followed by a CCL tie-in pass. The background gamma ray was log reprinted on each out-of-position logging run to serve as a means of comparison. Each logging run is identified by its name presented at the top of the log. After the completion of the background gamma ray log, the logging tool ejector was calibrated to a 0.4 mCi per second discharge, and the reservoir was loaded with 6 mCi of I-131.

Both RTS tests were conducted under dynamic conditions. For the first test an injection rate of 35 gpm was established using potable water. The tracer ejector was positioned five feet above the bottom of the casing. The recorder was placed in the time drive mode, and a 1 mCi slug of tracer material was ejected. The readings from the middle gamma ray detector began to increase from background about 23 seconds after ejection. The readings from the bottom detector increased from background approximately three minutes after ejection. No detection of the tracer material was observed at the upper gamma ray detector any time during 60 minutes of time drive monitoring. The tools were then logged out-of-position (LOP #1) to a depth of 2,790 feet bls. The results of the log out-of-position showed no indication of tracer material movement up hole. The injection casing was then flushed with approximately 10,600 gallons of potable water. Following the flushing, an out-of-position log was conducted (LAF #1) from below the casing to 2,780 feet bls. This log showed that all tracer material had been flushed out of the casing as the gamma ray levels on the top, middle and bottom detectors returned to background levels. These results demonstrate casing integrity and that there are no channels behind the casing.

The second tracer test was also a dynamic test. The injection rate into the well was adjusted to 37 gpm using potable water. The logging tools were positioned so that the ejector was five feet above the bottom of the casing. The recorder was placed in time drive mode, and a 2 mCi slug of tracer material was ejected. The readings from the middle gamma ray detector began to increase from background about 15 seconds after ejection. The readings from the bottom detector increased from background approximately 2 minutes and 38 seconds after ejection. No detection of the tracer material was observed at the upper gamma ray detector any time during 60 minutes of time drive monitoring. The tools were then logged out-of-position (LOP #2) to a depth of 2,780 feet bls. The results of the log out-of-position showed no indication of tracer material movement up hole. The injection casing was then flushed with potable water at a rate of 137 gpm. The ejector port was positioned at a depth of 3,100 feet bls and the remaining 3 mCi of I-131 was dumped. Following the flushing, a final gamma ray log was conducted on the total depth of the well. The logs were recorded over traces of the initial background log and showed excellent repeatability on all detectors. These results demonstrate casing integrity and that there are no channels behind the casing. A schematic of the logging tool is shown in presented with the logs. A copy of the radioactive tracer survey of the injection well, the I-131 assay and the flowmeter calibration certification are contained in **Appendix F**.

4.2.9 MIT Conclusions

Based on the results of the temperature logs, hydrostatic pressure tests, video surveys and radioactive tracer surveys, IW-1 and IW-2 have been demonstrated to have mechanical integrity in accordance with 40 CFR §146.8.

4.3 Monitor Well Casing Pressure Tests

On February 24, 2018, the 16-inch monitor casing was internally pressurized to 74-3/4 psi. A pressure increase of 1-3/4 psi was observed over the 60-minute test period. This increase represents a 2.3 percent change in the original pressure, which is within the 5 percent limit. A copy of the test gauge certification records and results of the hydrostatic pressure test are presented in **Appendix Q**.

On March 9, 2018, the 6-5/8-inch monitor casing was internally pressurized to 74-1/2 psi. A pressure increase of 3/4 psi was observed over the 60-minute test period. This increase represents a 1 percent change in the original pressure, which is within the 5 percent limit. A copy of the test gauge certification records and results of the hydrostatic pressure test are presented in **Appendix Q**.

4.4 Monitor Well Final Video Survey

A video survey of the completed monitor well was performed on March 20, 2016 from land surface, through the completed 6-5/8-inch diameter FRP casing to a depth of 1,797 feet bls. Water clarity was good, enabling the camera to capture clear images of the casing interior, casing seat and open-hole section. Particulate matter in the fluid column below 1,797 feet bls obstructed the view of the remaining section of the borehole. The survey revealed that the casing was in excellent condition. In the observable portion of the open hole section, there appeared to be no material that would hinder well performance. A copy of the video survey in DVD format is included in **Appendix K**.

4.5 Background Water Quality

Water samples were obtained from both the upper and lower monitor zones of MW-1 and the injection zone of IW-1 and IW-2. Prior to sampling, the wells were developed by using the reverse air procedure then allowing the well to flow naturally for a minimum of three well volumes. The samples were analyzed for a variety of constituents to establish the "natural" or background quality of the water. Background water quality laboratory analysis results from the injection zones of IW-1 and IW-2 and the upper and lower monitor zones of MW-1 are presented in **Appendix R**. Background Water Quality of Select Constituents is presented in **Table 4-1**.

Table 4-1: Background Water Quality of Select Constituents

Constituent	Unit	Upper Monitor Zone	Lower Monitor Zone	IW-1 Injection Zone	IW-2 Injection Zone
TDS	mg/L	3,590	35,400	33,000	31,200
Chlorides	mg/l	2,020	18,400	19,900	19,400
Conductivity @ 25 °C	µs/cm	6,638 (F)	53,432 (F)	52,800	47,000
Ammonia	mg/L	0.41	0.035 (U)	0.035 (U)	0.020 (U)
TKN	mg/L	0.40 (I)	0.086 (U)	0.15 (I)	0.20 (I)
Nitrate	mg/L	0.025 (U)	0.025 (U)	0.29	0.31
Nitrite	mg/L	0.025 (U)	0.025 (U)	0.025 (U)	0.025 (U)
Sulfate	mg/L	466	2,400	2,550	2,500
Total Phosphorus (as P)	mg/L	0.050 (U)	0.050 (U)	0.050 (U)	0.050 (U)
pH @ 25 °C	Std. Units	8.19 (F)	7.79 (F)	7.9	7.8
Fecal Coliform	CFU/100 mL	---	---	---	1.0 (U)

Constituent	Unit	Upper Monitor Zone	Lower Monitor Zone	IW-1 Injection Zone	IW-2 Injection Zone
E. coli	---	Absent	Absent	Present	---
Temperature	°C	23.8 (F)	27.2 (F)	19.0 (F)	---
Alkalinity, Total as $CaCO_3$	mg/L	92.2	120	66.8	
Gross Alpha	pCi/L	9.16	25.0	6.20	5.90
Radium-226	pCi/L	3.68	10.2	2.74	2.74
Radium-228	pCi/L	0.782 (U)	0.658 (U)	0.723 (U)	0.694 (U)

Notes:
(F) – Field Measurement
(I) – The report value is between the laboratory method detection limit and the laboratory practical quantitation limit
(U) – Indicates that the compound was analyzed for but not detected

4.6 Short Term Injection Tests

A short-term injection test was performed on each injection well to demonstrate that the injection wells are capable of accepting flow at the requested rate. A fresh water source for performing the tests at high flow rates was not available at the intended test rate of 3,800 gpm. Testing would be from injection well to injection well. The injection tubing diameter limited the size of the pumping unit that could be used in the source injection well. A plan was developed to air lift out of the source injection well into an open containment tank and use a centrifugal pump to pump down the injection well being tested. The plan for a 24-hour short-term injection test on each well was submitted and approved by the EPA. The controlled tests included of a 24-hour background period, a 24-hour pumping period (including testing at an increased flow rate for the final hour) and a 12-hour recovery period

The Contractor installed temporary facilities to perform the short-term injection tests. Initially, 2-3/8-inch diameter airline was lowered into the source well and connected to an air compressor at the surface. Steel pipe was installed from the temporary wellhead on the source well to a 30,000-gallon containment tank. A diesel-driven pump capable of pumping at the intended rate was installed at the containment tank. Piping including an inline flowmeter was installed from the pump to the test well. A gate valve was installed in the pipeline between the pump and the flowmeter to control the pumping rate. This system was designed by the Contractor to air-lift fluid from the source well into the containment tank, then pump water from the injection zone at the desired rate into the test well. After the completion of the first test, the system was reversed to conduct the test on the other well. Prior to performing the background phase of each injection test, the Contractor ran a preliminary test to make sure the systems were working properly.

The Contractor installed temporary pressure transducers to monitor pressure during the tests. Pressure transducers were installed 30 feet bls and at the bottom of the injection tubing and on the test injection well. The Contractor also installed temporary transducers 30 feet bls in both zones of the dual-monitor well. Barometric pressure was monitored, and tidal data was obtained. Prior to performing the background phase of each injection test, the Contractor ran a preliminary test to assure the systems were working properly. Redundant transduces were also installed.

4.6.1 IW-1 Injection Test

On April 10, 2018, the IW-1 short-term injection test was initiated, beginning with the 24-hour background period. After performing the background monitoring, the 24-hour injection test was conducted. For the first 23 hours, the base injection rate was 4,200 gpm (6.05 MGD). This injection rate equates to a velocity of 8.2 FPS. During the last hour of the test, the injection rate was increased to 4,800 gpm (6.91 MGD). This injection rate equates to a velocity of 9.3 FPS.

Pressure was continuously monitored prior to, during and after the injection test. The wellhead shut-in pressure before the testing was approximately 11 psi. The average and maximum wellhead pressure during the base rate test rate of 4,200 gpm, were approximately 23 and 25 psi, respectively. During the last hour of the pumping test at the increased flow rate of 4,800 gpm, the average and maximum wellhead pressure were approximately 24 and 26 psi, respectively. The wellhead shut-in pressure after the testing was approximately 9 psi and was generally increasing during the 13-hour recovery period. The bottom hole pressure during the whole test period was identified as being approximately 1,295 psi. Data from the downhole pressure transducers did not show an increase in bottom hole pressure during pumping. A slight variation of downhole pressure generally aligns with tidal stages. Monitor well pressures were observed at approximately 11 and 8 psi for the UMZ and LMZ, respectively. During the test, no measurable pressure changes attributable to injection were detected in any of the monitor zones. Results of the testing of IW-1 are presented in **Graphic 18**.

4.6.2 IW-2 Injection Test

On April 3, 2018, the IW-2 short-term injection test was initiated, beginning with the 24-hour background period. After performing the background monitoring, the 24-hour injection test was conducted. For the first 23 hours, the base injection rate was 4,200 gpm (6.05 MGD). This injection rate equates to a velocity of 8.2 FPS. During the last hour of the test, the injection rate was increased to 4,800 gpm (6.91 MGD). This injection rate equates to a velocity of 9.3 FPS.

Pressure was continuously monitored prior to, during and after the injection test. The wellhead shut-in pressure before the testing was approximately 11 psi. The average and maximum wellhead pressure during the base rate test rate of 4,200 gpm, were approximately 23 and 25 psi, respectively. During the last hour of the pumping test at the increased flow rate of 4,800 gpm, the average and maximum wellhead pressure were approximately 26 and 27 psi, respectively. The wellhead shut-in pressure after the testing was approximately 8 psi and was generally increasing during the 18-hour recovery period. The bottom hole pressure during the whole test period was identified as being approximately 1,331 psi. Data from the downhole pressure transducers did not show an increase in bottom hole pressure during pumping. A slight variation of downhole pressure generally aligns with tidal stages. Monitor well pressures were observed at approximately 11 and 8 psi for the UMZ and LMZ, respectively. During the test, no measurable pressure changes attributable to injection were detected in any of the monitor zones. Results of the testing of IW-1 are presented in **Graphic 19**.

4.6.3 Injection Test Summary

The results of the tests indicated that the wells can be pumped at a rate of 4,800 gpm for IW-1 and IW-2. There was no attributable increase in bottom hole pressure associated with the pumping test. Monitor well pressures were observed as being approximately 11 and 8 psi for the UMZ and LMZ, respectively. The bottom hole pressure for IW-1 and IW-2 was identified as being approximately 1,295 and 1,331 psi for IW-1 and IW-2 respectively. Data from the downhole pressure transducers did not show an increase in bottom hole pressure during pumping. The shut-in pressure for IW-1 and IW-2 was identified as being approximately 9 and 11 psi for IW-1 and IW-2 respectively. The results of the tests indicate that the injection wells can be pumped at 4,800 gpm and maintain integrity of the formation. A summary of the results of the 24-hour short-term injection tests are presented in **Table 4-2**.

Table 4-2: Injection Test Summary

Well	Shut-In Pressure (psig)	Injection Rate (gpm)	Injection Rate (MGD)	Average Wellhead Pressure (psig)	Average Downhole Pressure (psi)	Specific Injectivity (gpm/psi)
IW-1	9	4,200	6.05	23	1,295	183
IW-1	9	4,800	6.91	25	1,295	192
IW-2	10	4,200	6.05	24	1,331	175
IW-2	10	4,800	6.91	26	1,331	185

5. Additional Information

5.1 General

After the construction and testing of the two injection wells and dual-zone monitor wells, additional information about well completion is being provided. Included in this Section is a copy of the final site survey, a report on the plugging and abandonment (P&A) of the shallow aquifer monitor wells and the P&A plan for IW-1, IW-2 and MW-1.

5.2 Site Survey and Wellhead Elevations

A copy of the survey of the site and a drawing with surveyed wellhead elevations performed and signed by a Land Surveyor registered in the State of Florida is presented in **Appendix S**.

5.3 SAMWs P&A Documentation

Following the completion of the construction and testing of the injection wells and dual-zone monitor well, the 16 shallow aquifer monitor wells were plugged and abandoned with the approval of the EPA. The wells were plugged with neat cement grout and cut off one foot below grade. A copy of the plugging and abandoning completion report is included in **Appendix T**.

5.4 Injection Well and Monitor Well P&A Plans

If either of the injection wells or the dual-zone monitor well have to be abandoned, the wells must be effectively sealed (or plugged) to prevent upward migration of fluid through the casing. During the permitting of these wells, a P&A plan was developed for both the injection well and the dual-zone monitor well and these plans were included in the Well Permit. At the time of P&A, these procedures should be reviewed again since conditions may have changed.

The plugging program will require the services of a qualified drilling contractor with equipment capable of installing drill pipe to a depth of 3,500 feet and pumping neat cement. Cement used for the P&A should be either ASTM C150 Type II or API Class B.

In accordance with the Well Permit, the EPA must be notified of the intent to P&A the well and an updated copy of EPA Form 7520-14 must be submitted. See **Appendix U** for a copy of the form submitted with the Well Permit. The plugging of well is to be in accordance with the Well Permit and 40 CFR 146. After approval is obtained from the EPA, plans to P&A the well may continue.

5.4.1 Injection Well P&A Plan

Both injection wells are of similar size and therefore only one P&A plan has been prepared for the injection wells. This injection well P&A that was submitted with the Permit plan has been updated as presented in **Appendix U**. The opinion of probable cost for the P&A Plan has been identified as approximately $300,000 for each injection well.

5.4.2 Dual-Zone Monitor Well P&A Plan

The P&A plan for the dual-zone monitor well (MW-1) has been updated and has been updated is presented in **Appendix U**. The opinion of probable cost for the P&A Plan has been identified as $160,000. At the time of P&A, this procedure should be reviewed again since conditions may have changed.

6. Findings and Recommendations

6.1 Findings

The following list summarizes the findings during the construction of the injection and monitor wells:

- The base of the USDW, the point where the water has a concentration of 10,000 mg/L TDS, occurs approximately at 1,630 feet bls.
- Confining sequences were identified between 1,979 feet and 2,720 feet bls.
- Vertical hydraulic conductivity determined from core testing within the confining sequences ranged from 6.2×10^{-9} to 2.2×10^{-3} cm/sec.
- Hydraulic conductivity determined from packer testing within the confining sequences ranged from 1.2×10^{-4} to 3.7×10^{-4} cm/sec.
- Data demonstrate the existence of a transmissive injection zone (the “boulder zone”) below 3,000 feet bls.
- The injection zone is capable of accepting injectate at a rate of 4,800 gpm (6.91 MGD) at a reasonable injection pressure that will not promote fractures in the injection zone or confining sequences.
- FRP tubing in IW-1 and IW-2 were each successfully hydrostatically pressure tested at 154 psi.
- The testing requirements performed in accordance with 40 CFR 146.8 demonstrated that IW-1 and IW-2 have mechanical integrity.
- Dual-zone monitor well 16 and 6-5/8-inch diameter casings were successfully hydrostatically pressure tested at 74-3/4 and 74-1/2 psi, respectively.
- Dual-zone monitor well MW-1 was drilled and constructed with the upper monitor zones from 1,500 to 1,529 feet bls and the lower zone is from 1,770 to 1,810 feet bls.
- The injection horizons were identified for IW-1 and IW-2, as follows:
  - IW-1: 2,920 – 3,501 feet bls
  - IW-2: 3,000 – 3,503 feet bls

6.2 Conclusions

The presence of favorable geologic conditions, a highly transmissive active injection zone located below the base of the USDW, suitable confining sequence, and suitable monitor zones will permit the use of these injection wells for disposal of secondary treated WWTP effluent and membrane WTP concentrate at the STOF reservation in accordance with existing federal underground injection control regulations.

Based on the results of the geophysical logging and testing performed at the STOF WWTP / WTP, injection wells IW-1 and IW-2 have mechanical integrity and are ready to begin operational testing. Once piping to the injection wells, and ancillary equipment is installed, a request to perform operational testing will be made to the EPA.

6.3 Recommendations

The above ground facilities will need to be completed prior to placing the wells in service. The well drilling construction stopped at the wellheads. Under a separate ongoing construction contract, the following items will be constructed: concrete pads around the wells, pipelines to the injection wells, booster pumps, monitor well pumps, pipelines from the dual-zone monitor well to the sanitary sewer system, instrumentation and controls and electrical work. Operation of MW-1 is expected to begin within one month after the construction of the surface facilities. Injection well operation will begin after approval from EPA.

The following procedures are in accordance with requirements of the Well Permit and in compliance with 40 CFR §143.13 for the safe operation of an injection well system. These procedures should be carried out conscientiously to assure compliance with the injection well construction permits (refer to **Appendix A**) and all regulatory requirements and to assure successful operation of the well system. Reporting shall be quarterly as identified in the Well Permit. Additional information on monitoring and reporting data is discussed in Section 6.4.

- Dual-zone monitor well pressure shall be continuously monitored.
- Injection wellhead pressure shall be continuously monitored.
- Flow to injection wells shall be continuously monitored.
- Dual-zone monitor well water quality shall be monitored weekly for the first eight weeks and then monthly in concert with the permit requirement for the existing monitor wells on site.
- Wastestream (WTP concentrate and WWTP effluent) water quality shall be monitored monthly.
- Injection well injectivity tests shall be performed quarterly.
- A complete analysis of the wastestream shall be performed yearly.
- Injection well mechanical integrity tests shall be performed at least once every five years.
- The capacity of the injection wells can be increased in the future by performing an additional injection test.

6.4 Well Operation, Maintenance and Future Testing

When each injection well is operational, a variety of data will be collected to satisfy statutory/permit requirements and to assist in managing the system. This Subsection discusses the basic requirements for data collection to maintain permit compliance during both the initial testing and long-term operation of the injection well system. The construction permits for IW-1 and IW-2 expire December 1, 2021. It is essential that the performance data collection begin upon operational startup to establish baseline information which both satisfies regulatory requirements and serves for future data comparison and performance analyses. These records should be permanently maintained.

6.4.1 Monitor Well Data Collection

The purpose of monitor zone data collection is to detect changes in water quality attributable to the injection of treated effluent into the nearby injection wells. To collect the water quality samples, the deep monitor well zones have been equipped with two sampling pumps, one for each zone. Interconnection of piping from the different zones and wells is not permitted by EPA. Prior to collecting water samples for analysis, at least three to five well volumes must be purged from the monitor zones. Well water will be pumped to the proposed effluent pump station. Once the appropriate amount of water has been purged from the well, water quality samples will be taken at the wellhead. Water quality testing of the monitor well shall be performed weekly for the first three months of operation of the injection wells, and then monthly after that period.

Dual-zone monitor well water quality is to be monitored through samples taken from the dual-zone monitor well zones which are to be collected and analyzed for several parameters. A list of the constituents to be tested for as required by EPA is presented in **Table 6-1**. The frequency of testing is monthly unless otherwise noted. TDS, conductivity, chlorides, ammonia, TKN, nitrate, nitrite, sulfate, total phosphorous, sodium, pH and temperature. The results of these analyses are to be sent to the EPA monthly. Monitor well samples shall be tested for Primary and Secondary Drinking Water Standards on a yearly basis.

The pressure in both zones of the dual-zone monitor well is to be continuously monitored and recorded. Average, maximum and minimum pressure are to be reported to EPA quarterly.

Table 6-1: Sampling During Well Operation

Constituent	Monitor Well	WTP Concentrate	WWTP Effluent
TDS	M	M	M
Chlorides	M	M	M
Conductivity	M	M	M
Total Suspended Solids (TSS)	M	M	M
Ammonia	M	M	M
TKN	M	M	M
Nitrate	M	-	M
Nitrite	M	-	M
Sulfate	M	-	M
Total Phosphorus	M	-	M
pH	M	M	M
Fecal Coliform	M	M	M

Constituent	Monitor Well	WTP Concentrate	WWTP Effluent
Temperature	M	M	M
Total Hardness	M	M	M
Calcium Hardness	M	M	M
Magnesium Hardness	M	M	M
Gross Alpha	Q	Q	-
Radium-226	Q	Q	-
Radium-228	Q	Q	-
Specific Gravity	-	M	M
Complete Primary and Secondary Drinking Water Standards	-	A	A

M: Monthly
Q: Quarterly
A: Annually

6.4.2 Injection Well Data Collection

Beginning with the start of the use of injection wells, injection records should be maintained to evaluate injection well performance. Cumulative injection volume shall be monitored daily. The pressure at the injection wellheads is to be continuously monitored and recorded. Monthly average, maximum and minimum pressure are to be recorded. The flow rate into the injection wells is to be continuously monitored and recorded. Average, maximum, and minimum flow rates, as well as the total volume of effluent pumped into the well are to be recorded on a monthly basis. All information shall be reported quarterly to EPA. An annual summary of the results of monitoring shall be submitted with the quarterly report due in January of the following year.

6.4.3 Injectivity Testing

Periodic determination of the injectivity of a well is used as a measure of the efficiency of a well and is a permit requirement as a management tool for the injection well system. The injectivity test involves injecting effluent into a well at a predetermined rate and recording the injection pressure. The shut-in pressure of the injection well is to be measured before beginning the injectivity test. The injectivity is calculated by dividing the injection rate by the required injection pressure (wellhead injection pressure minus shut-in wellhead pressure). The result is expressed as gallons per minute per pounds per square inch (gpm/psi).

Factors affecting the injection wellhead pressure are a function of:

- The density differential between treated effluent and the formation water in the injection zone;
- The friction loss in the casing; and
- The formation loss (injection zone transmissivity).

The formation loss is fairly constant as long as the temperature and density of the injection and formation fluids remain constant. Friction loss in the casing and bottom hole pressure can vary as a result of changes in the flowrate, physical condition of the injection zone and physical condition of the pipe. In general, pressure builds slowly with time (for a given pumping rate) as the casing "ages". Similarly, plugging of an injection zone can cause a gradual pressure build-up over time. The testing rates for injectivity testing should be established as soon as the well is placed in operation. The test procedure should be easily repeatable.

A specific injectivity test is required to be performed quarterly. The pumping rates should be established after the well is in operation. Flow to the wells and wellhead pressures are to be recorded during this period. Test results are to be reported to the EPA upon completion of the testing.

6.4.4 Future Mechanical Integrity Testing

An injection well has mechanical integrity when there is no leak in the casing and no fluid movement into the underground source of drinking water through channels adjacent to the well bore. Mechanical integrity testing includes a pressure test, a radioactive tracer survey, a high-resolution temperature log and a video survey. This testing will be used, along with the monitoring data of the upper and lower monitor zones, to demonstrate the absence of fluid movement above the injection zone.

Each injection well is to be tested for mechanical integrity at least once every five years in accordance with 40 CFR 146.13. Based on the dates of testing during construction, the next MIT to be performed on IW-1 and IW-2 is March 13, 2023 and March 12, 2023, respectively. In accordance with the Well Permit, the proposed MIT plan must be submitted to the EPA for approval at least sixty days prior to the required completion date. **Table 6-2** identifies the dates of the pressure tests performed on IW-1 and IW-2, and the next required MIT dates.

Table 6-2: Mechanical Integrity Test Dates

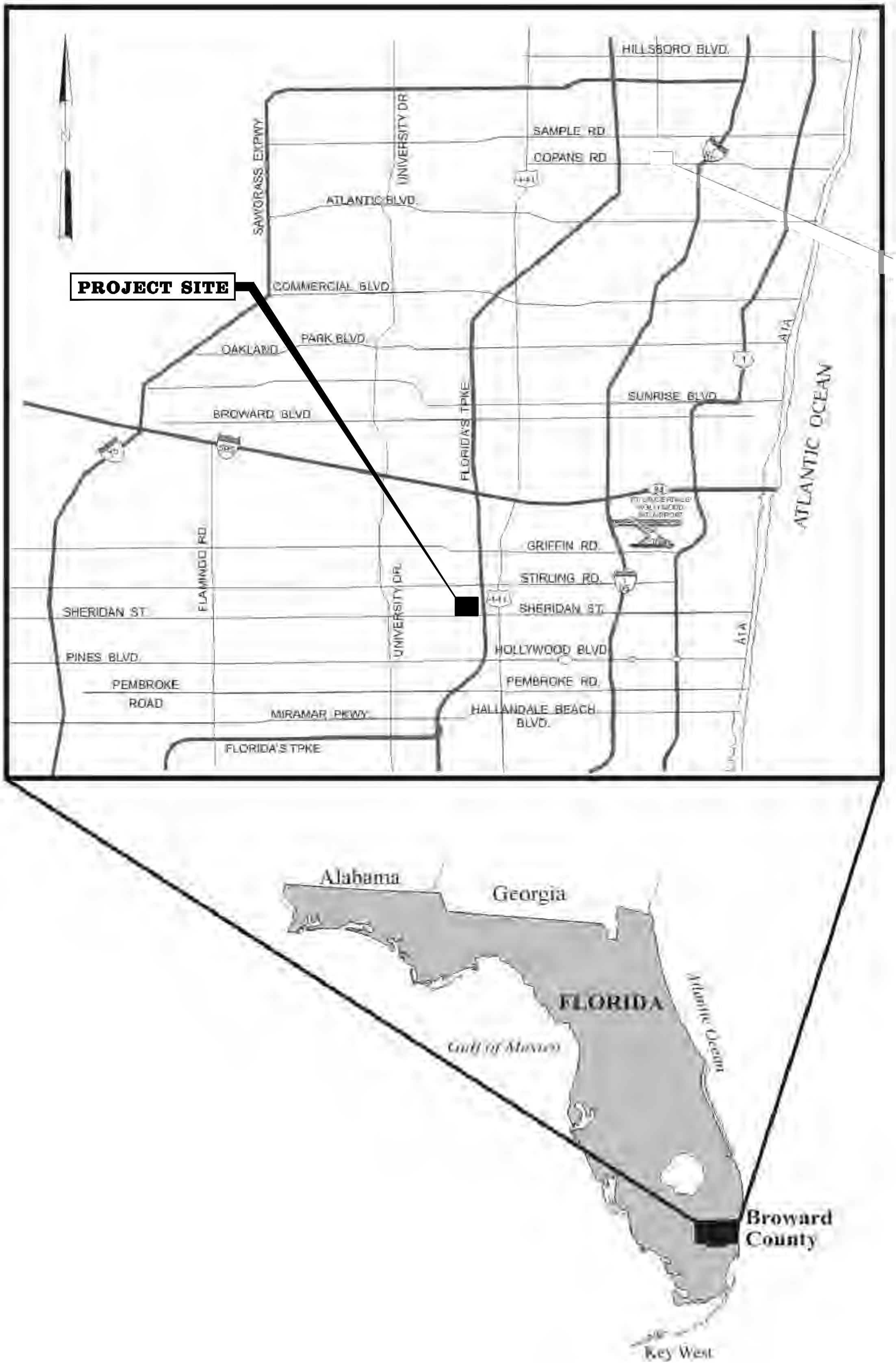
Well	Date of Pressure Test	Required Date of Pressure Test	Required Date of Submittal to EPA
IW-1	March 13, 2018	March 12, 2023	January 10, 2023
IW-2	March 12, 2018	March 11, 2023	January 10, 2023

Testing must be witnessed by professional engineer or a professional geologist. At the completion of the MIT, a report must be submitted to the EPA. The report is required to include EPA Form 7520-3. A copy of this form is included in **Appendix V**.

6.4.5 Wastestream Analysis

Water quality testing of the wastestream (WTP concentrate and WWTP effluent) shall be performed on a monthly basis once the injection wells become operational. The results shall be reported to EPA quarterly. A list of the constituents to be tested for as required by EPA is presented in **Table 6-1**. In addition to the monthly testing, concentrate samples shall be tested for Primary and Secondary Drinking Water Standards annually.

FIGURES



Hazen

HAZEN AND SAWYER
4000 HOLLYWOOD BOULEVARD, SUITE 750N
HOLLYWOOD, FLORIDA 33021
CERTIFICATE OF AUTHORIZATION NO. : 2771

SEMINOLE TRIBE OF FLORIDA
HOLLYWOOD, FLORIDA

DEEP INJECTION WELLS
HOLLYWOOD RESERVATION

LOCATION MAP

FIGURE **1**

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Hazen

HAZEN AND SAWYER
4000 HOLLYWOOD BOULEVARD, SUITE 750N
HOLLYWOOD, FLORIDA 33021
CERTIFICATE OF AUTHORIZATION NO. : 2771

SEMINOLE TRIBE OF FLORIDA
HOLLYWOOD, FLORIDA

DEEP INJECTION WELLS
HOLLYWOOD RESERVATION

SITE PLAN

FIGURE
2

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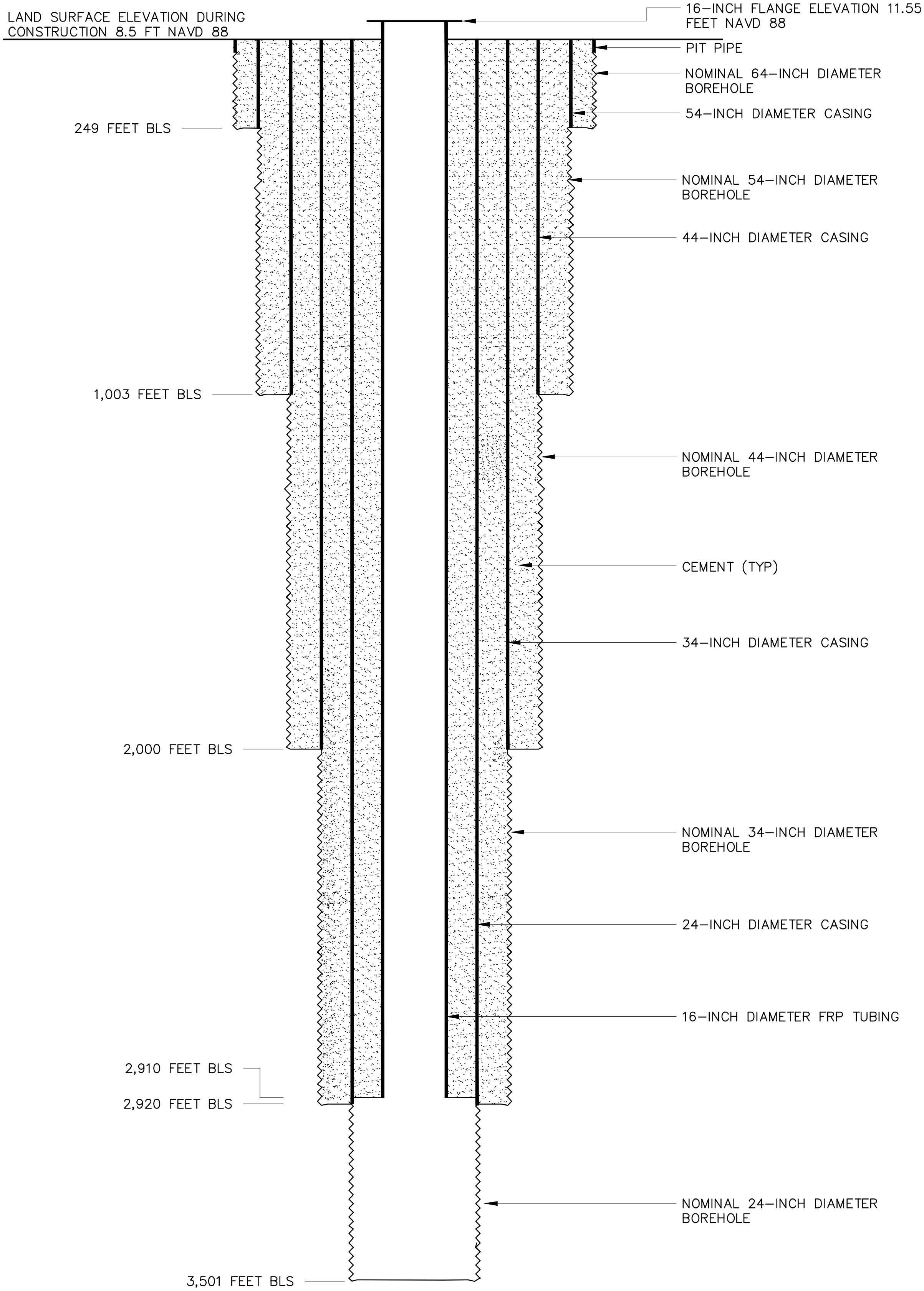

Hazen HAZEN AND SAWYER 4000 HOLLYWOOD BOULEVARD, SUITE 750N HOLLYWOOD, FLORIDA 33021 CERTIFICATE OF AUTHORIZATION NO. : 2771	SEMINOLE TRIBE OF FLORIDA HOLLYWOOD, FLORIDA	DEEP INJECTION WELLS HOLLYWOOD RESERVATION **INJECTION WELL IW-1 PROFILE**	FIGURE **3**

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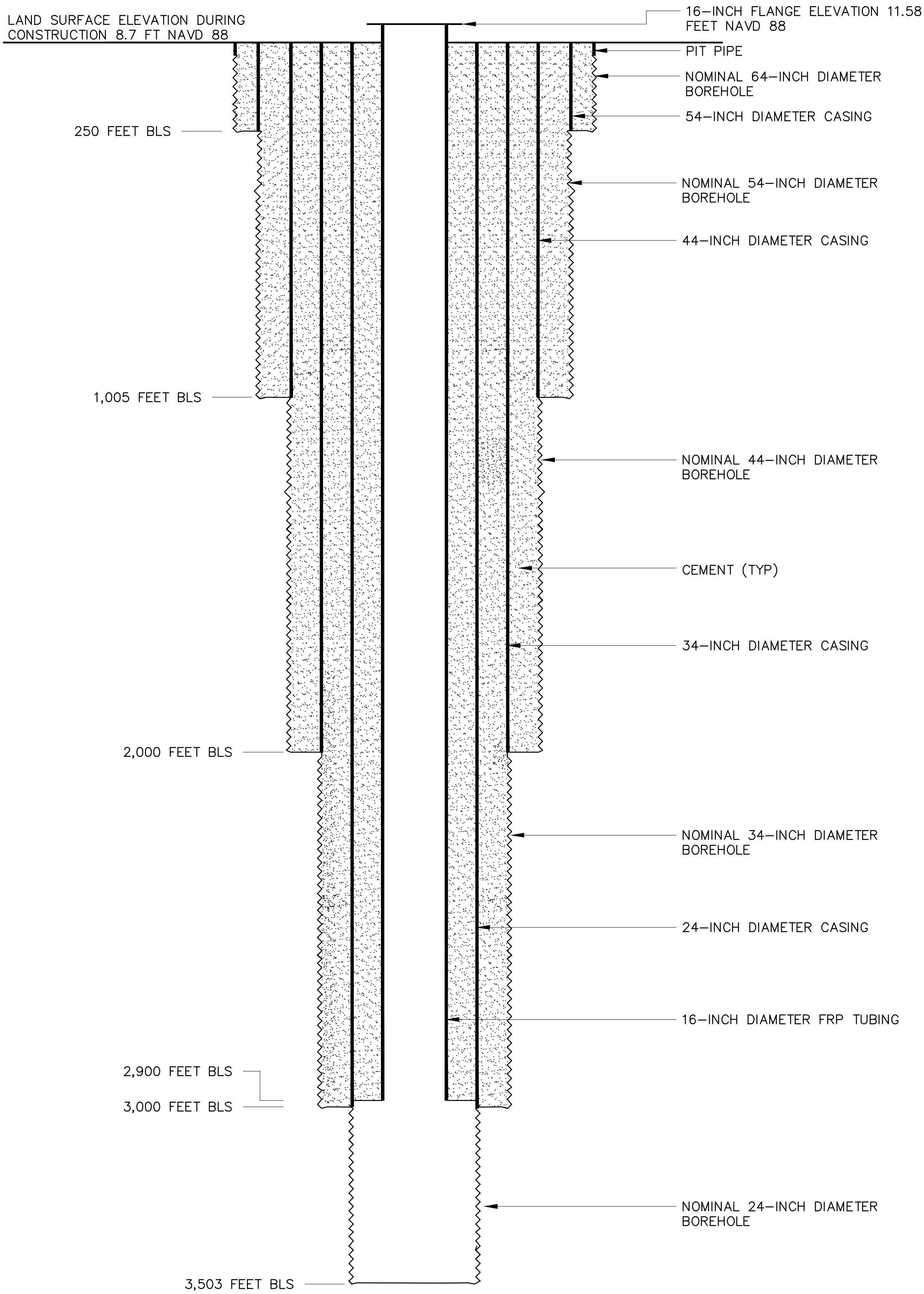
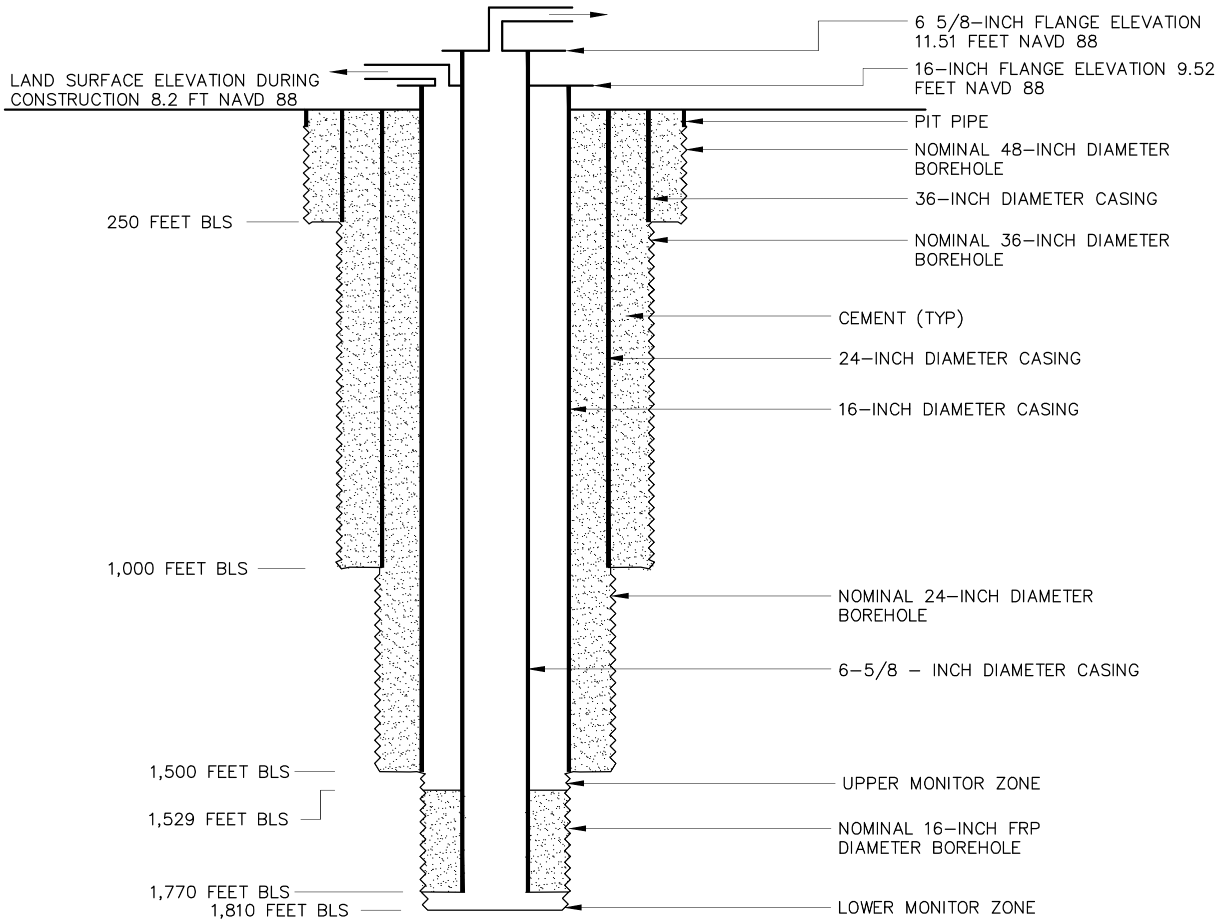


Hazen HAZEN AND SAWYER 4000 HOLLYWOOD BOULEVARD, SUITE 750N HOLLYWOOD, FLORIDA 33021 CERTIFICATE OF AUTHORIZATION NO. : 2771	SEMINOLE TRIBE OF FLORIDA HOLLYWOOD, FLORIDA	DEEP INJECTION WELLS HOLLYWOOD RESERVATION **INJECTION WELL IW-2 PROFILE**	FIGURE **4**



Hazen HAZEN AND SAWYER 4000 HOLLYWOOD BOULEVARD, SUITE 750N HOLLYWOOD, FLORIDA 33021 CERTIFICATE OF AUTHORIZATION NO. : 2771	SEMINOLE TRIBE OF FLORIDA · Tribal Council · IN GOD WE TRUST	SEMINOLE TRIBE OF FLORIDA HOLLYWOOD, FLORIDA	DEEP INJECTION WELLS HOLLYWOOD RESERVATION **DUAL-ZONE MONITOR WELL PROFILE**	FIGURE **5**

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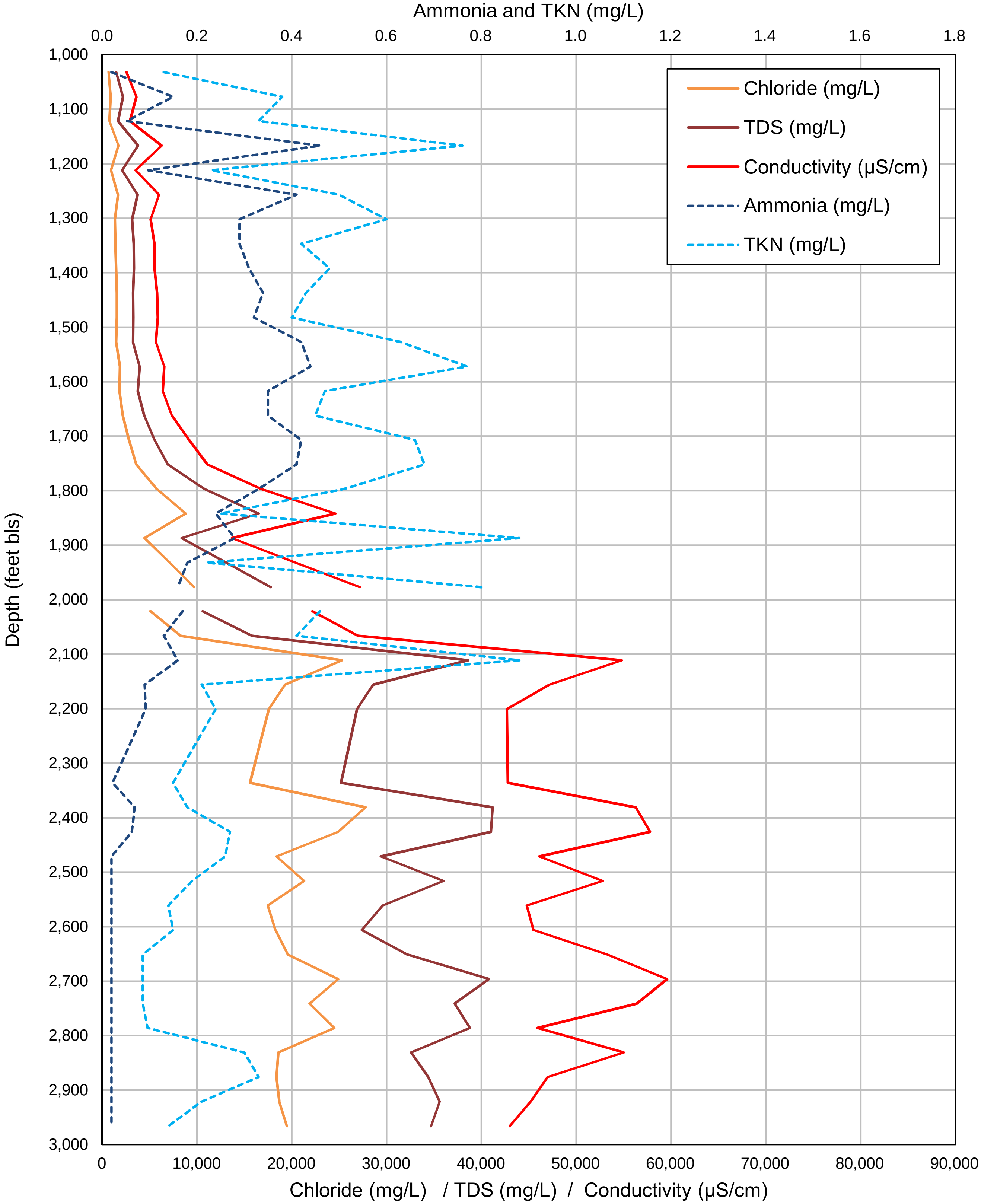
GRAPHICS

Hazen

Graphic 1 - Pilot Hole Drilling Fluid Water Quality
Injection Well IW-1 - 1,000 to 2,000 ft bls and 2,000 to 3,000 feet bls
Seminole Tribe of Florida - Hollywood Reservation



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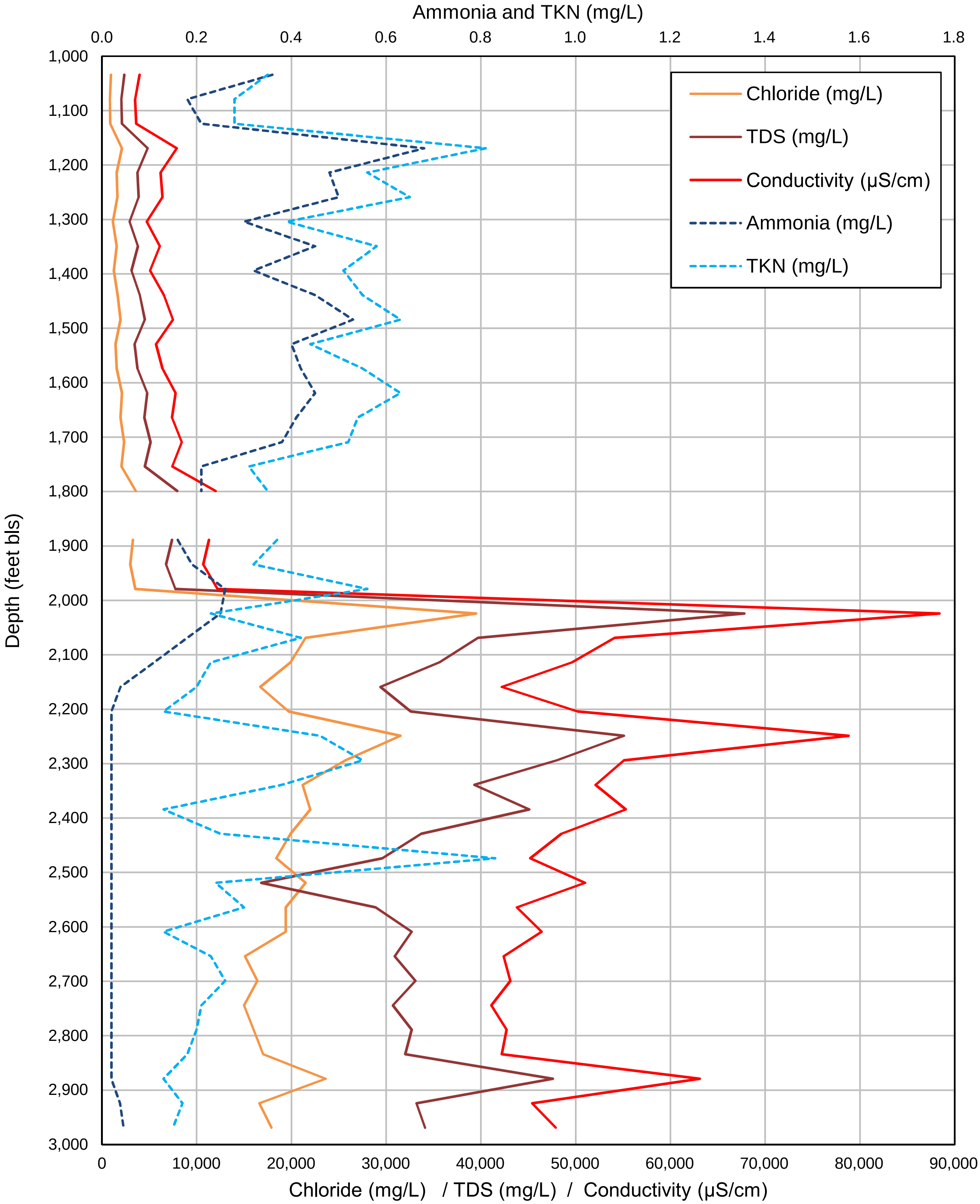
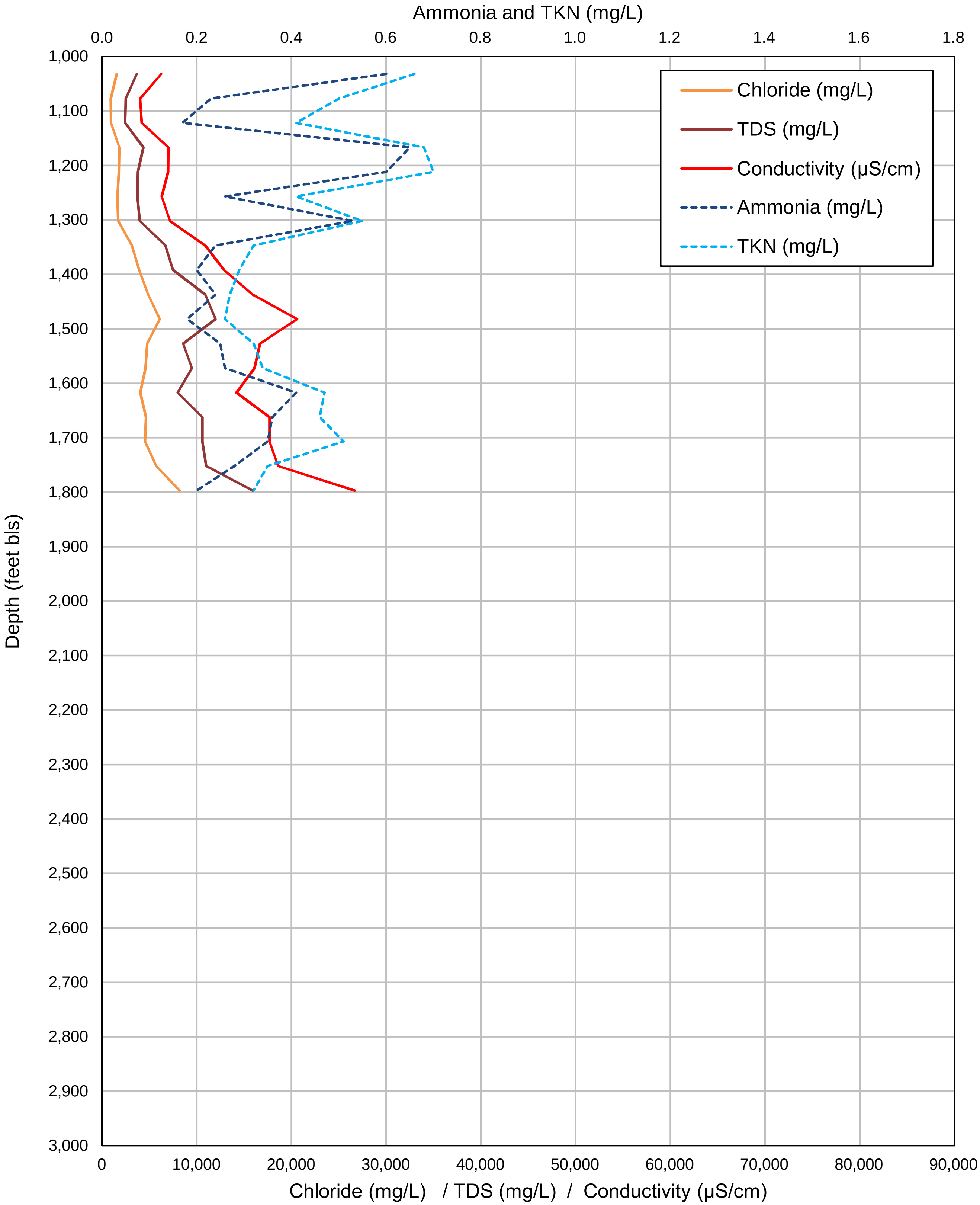
Graphic 2 - Pilot Hole Drilling Fluid Water Quality
Injection Well IW-2 - 1,000 to 2,000 ft bls and 2,000 to 3,000 feet bls
Seminole Tribe of Florida - Hollywood Reservation



Graphic 3 - Pilot Hole Drilling Fluid Water Quality
Dual Zone Monitor Well MW-1 - 1,000 to 1,810 feet bls
Seminole Tribe of Florida - Hollywood Reservation



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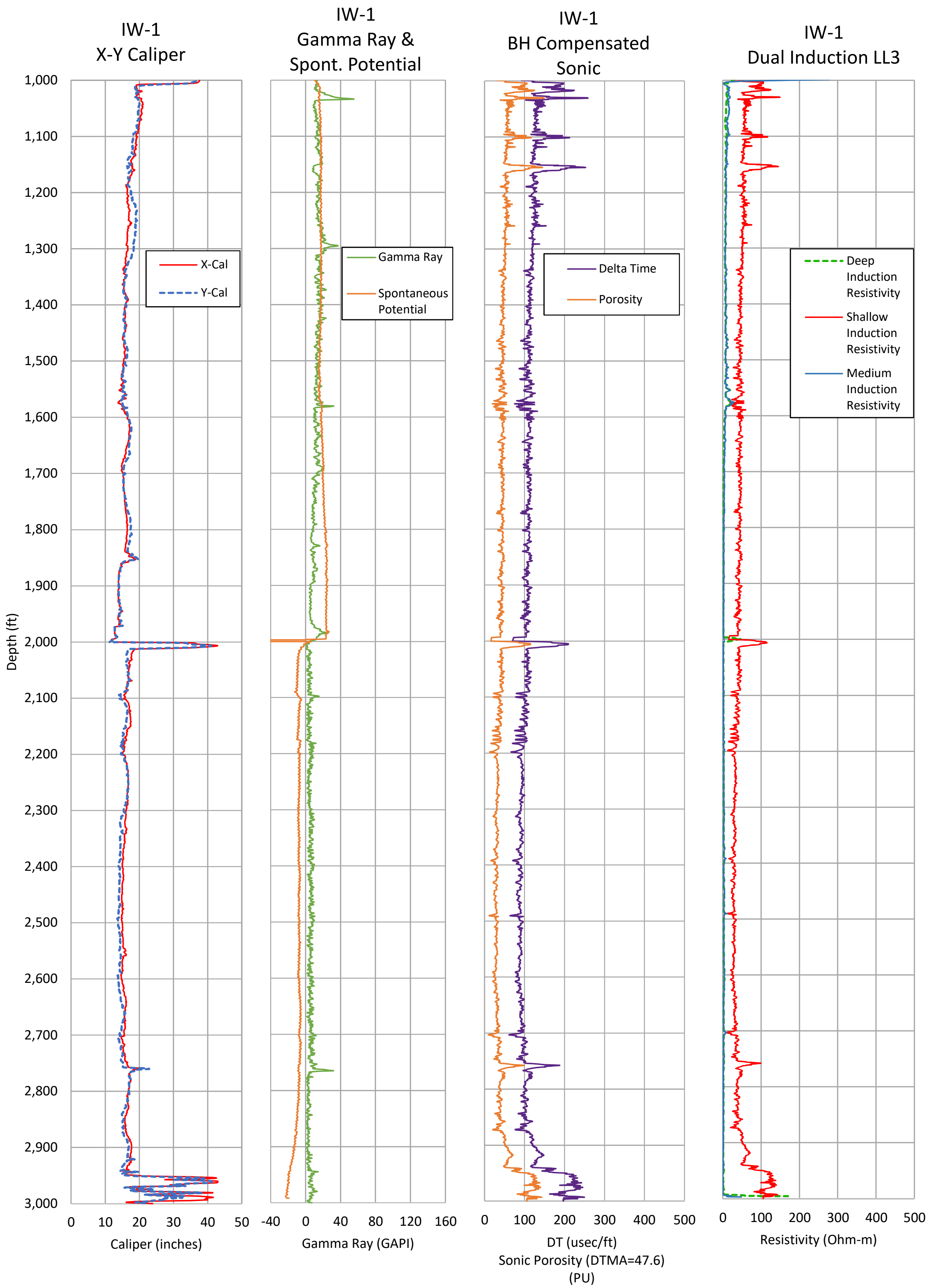
Graphic 4 - Geophysical Logs Group A
IW-1 Pilot Holes 1,000-2,000 ft bls and 2,000-3,000 ft bls
Seminole Tribe of Florida - Hollywood Reservation



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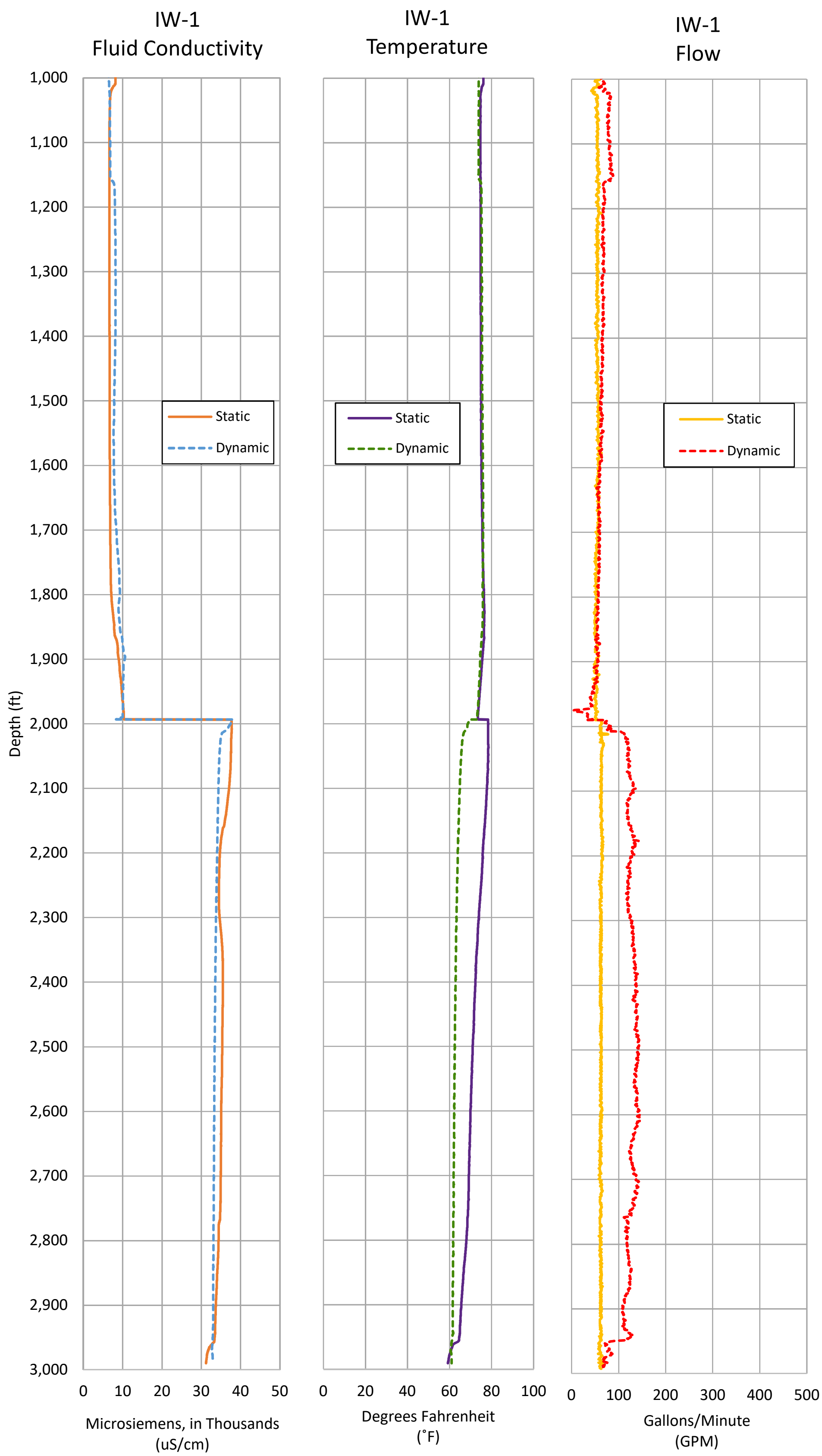
Graphic 5 - Geophysical Logs Group B
IW-1 Pilot Holes 1,000-2,000 ft bls and 2,000-3,000 ft bls
Seminole Tribe of Florida - Hollywood Reservation



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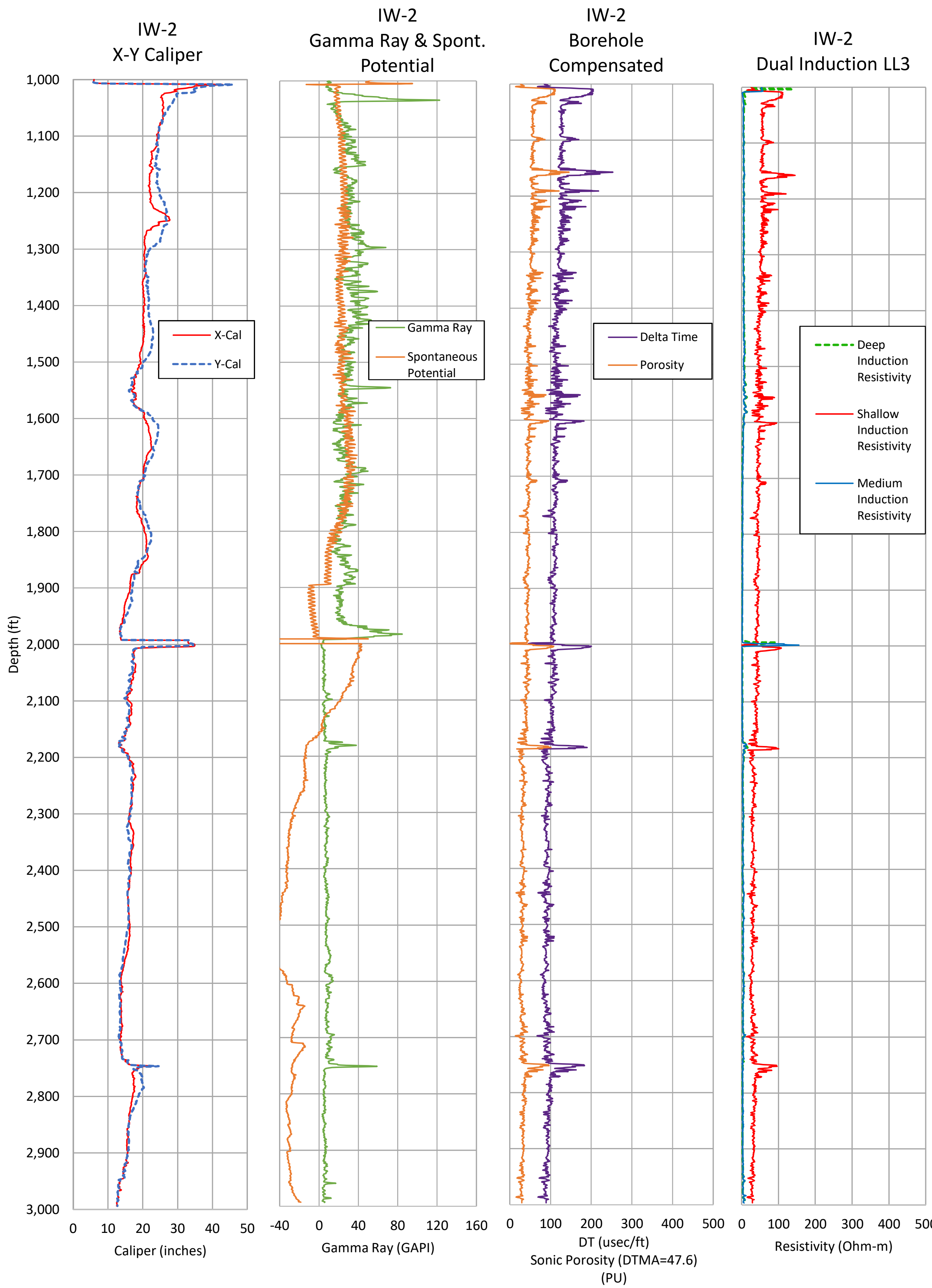
Graphic 6 - Geophysical Logs Group A
IW-2 Pilot Holes 1,000-2,000 ft bls and 2,000-3000 ft bls
Seminole Tribe of Florida - Hollywood Reservation



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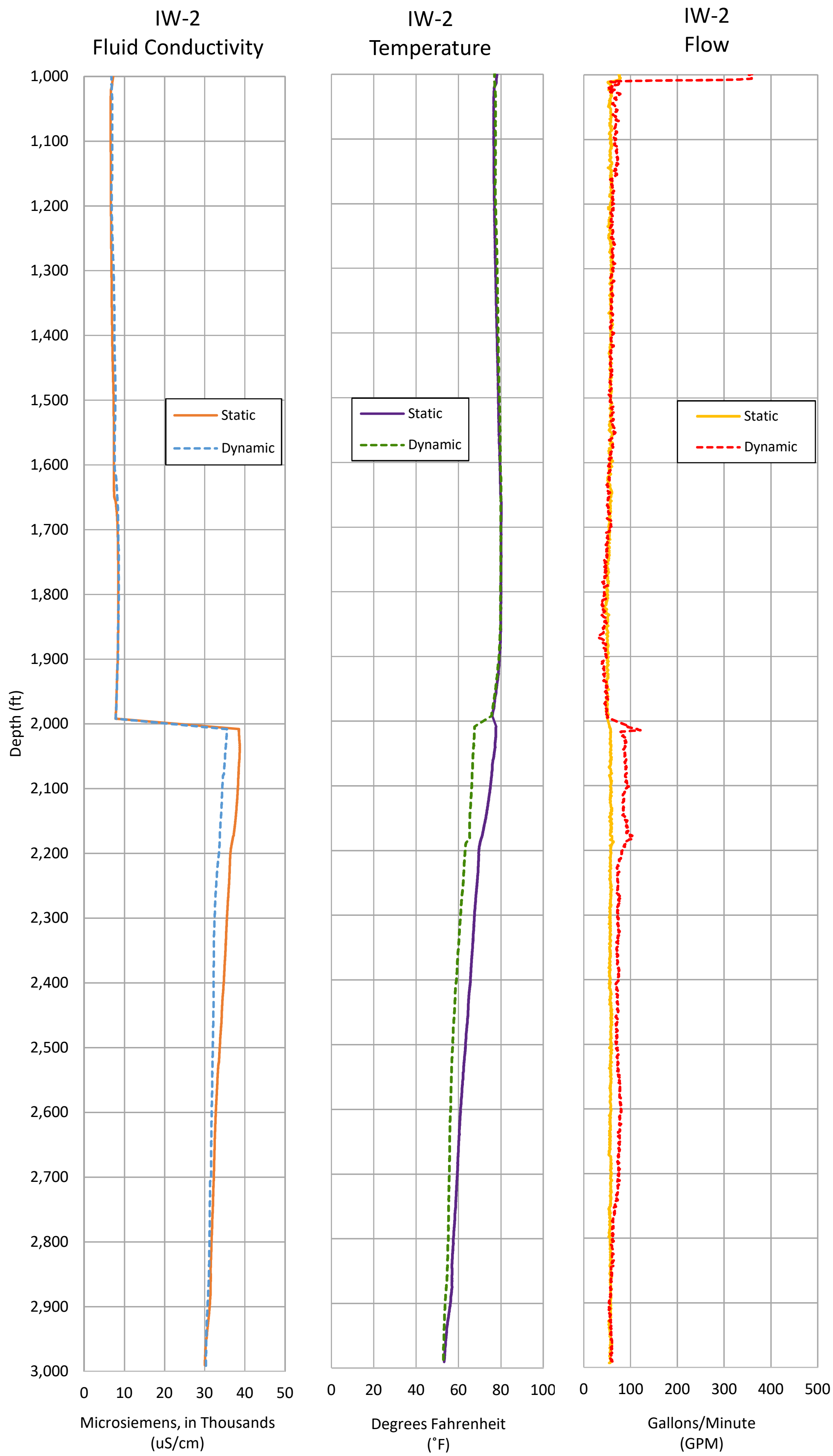
Graphic 7 - Geophysical Logs Group B
IW-2 Pilot Holes 1,000-2,000 ft bls and 2,000-3,000 ft bls
Seminole Tribe of Florida - Hollywood Reservation



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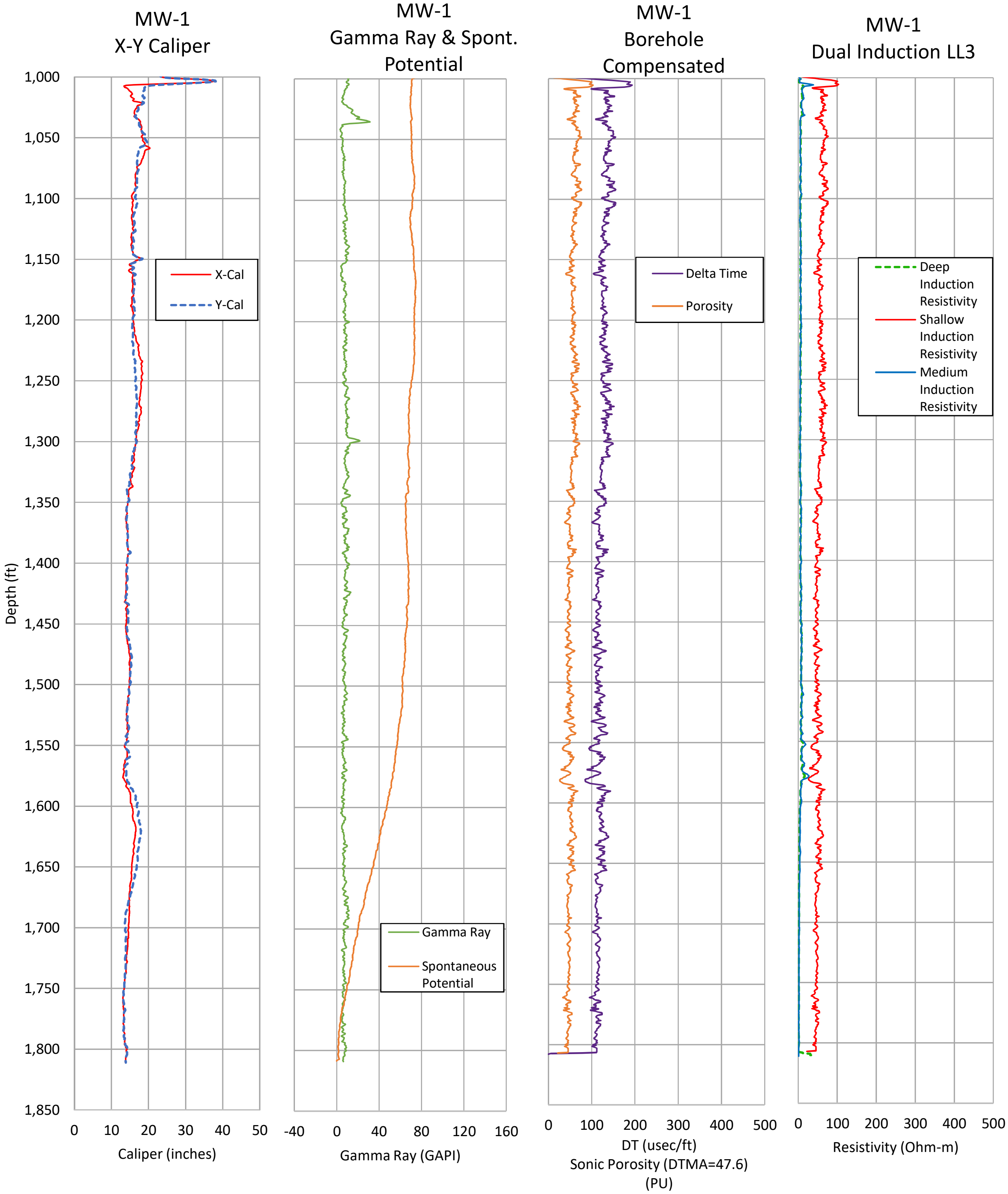
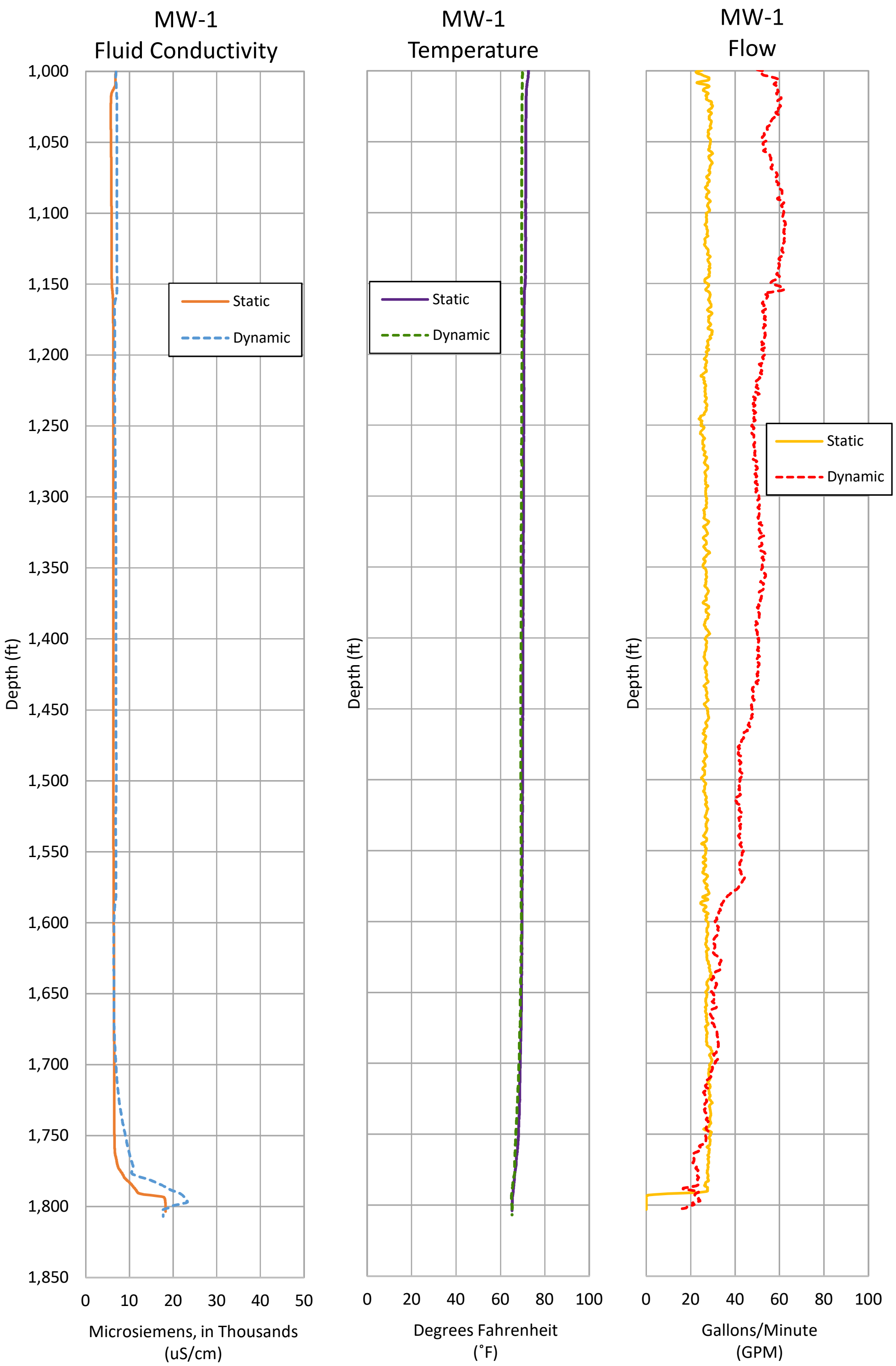
Graphic 8 - Geophysical Logs Group A
MW-1 Pilot Holes 1,000-1,800 ft bls
Seminole Tribe of Florida - Hollywood Reservation

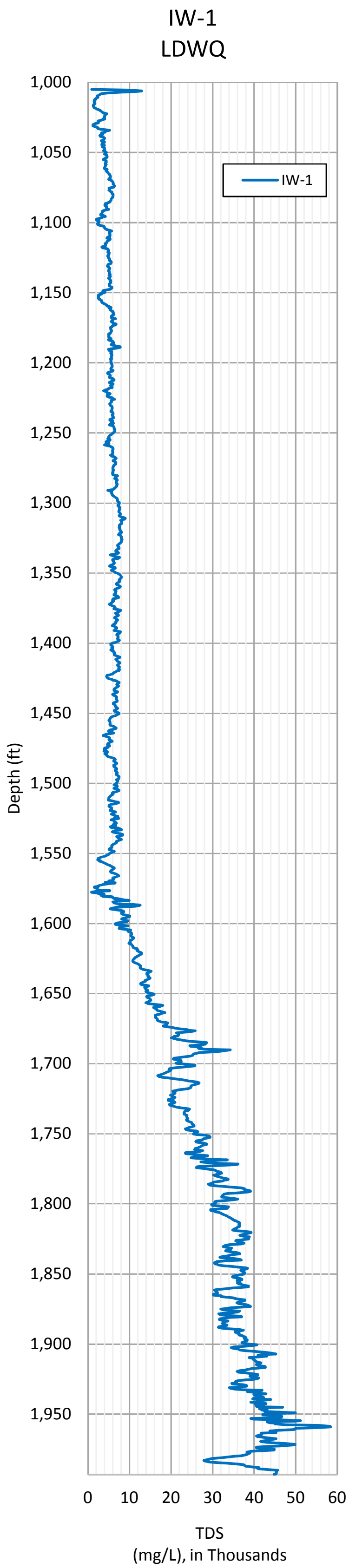


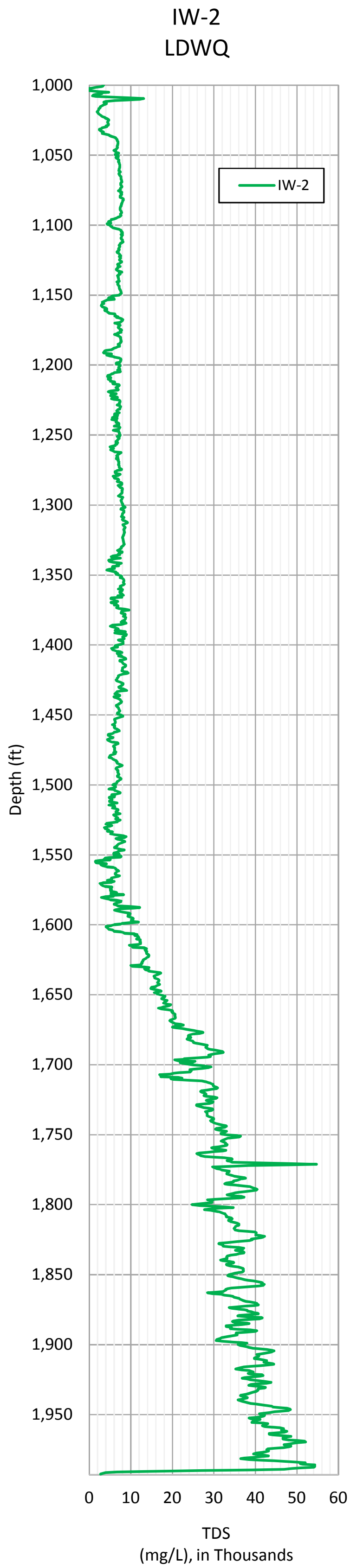
Graphic 9 - Geophysical Logs Group B
MW-1 Pilot Holes 1,000-1,800 ft bls
Seminole Tribe of Florida - Hollywood Reservation

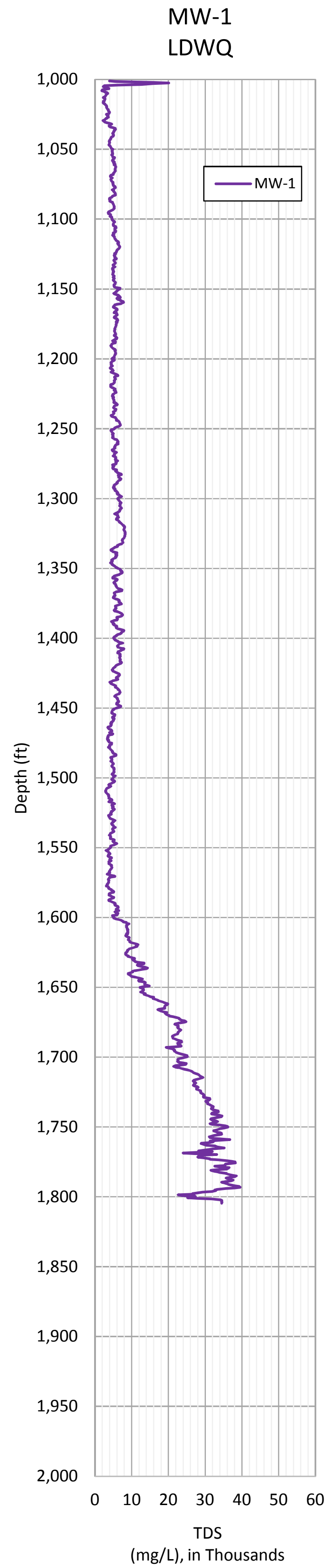


Hazen

Graphic 10 - Geophysical Logs
Log Derived Water Quality
Seminole Tribe of Florida - Hollywood Reservation

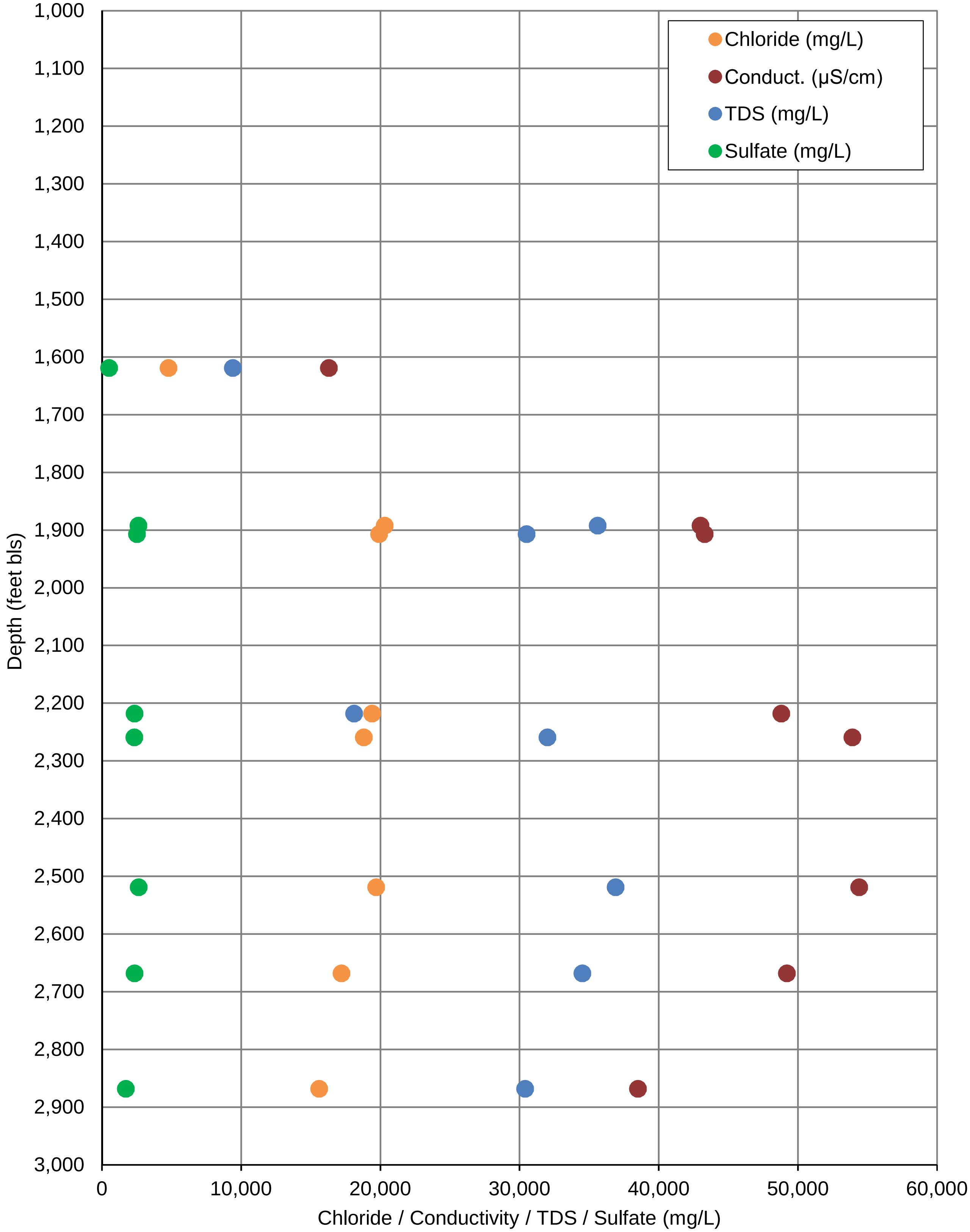






Graphic 11 - Packer Test Water Quality
IW-1 - Nitrogen Series
Seminole Tribe of Florida - Hollywood Reservation

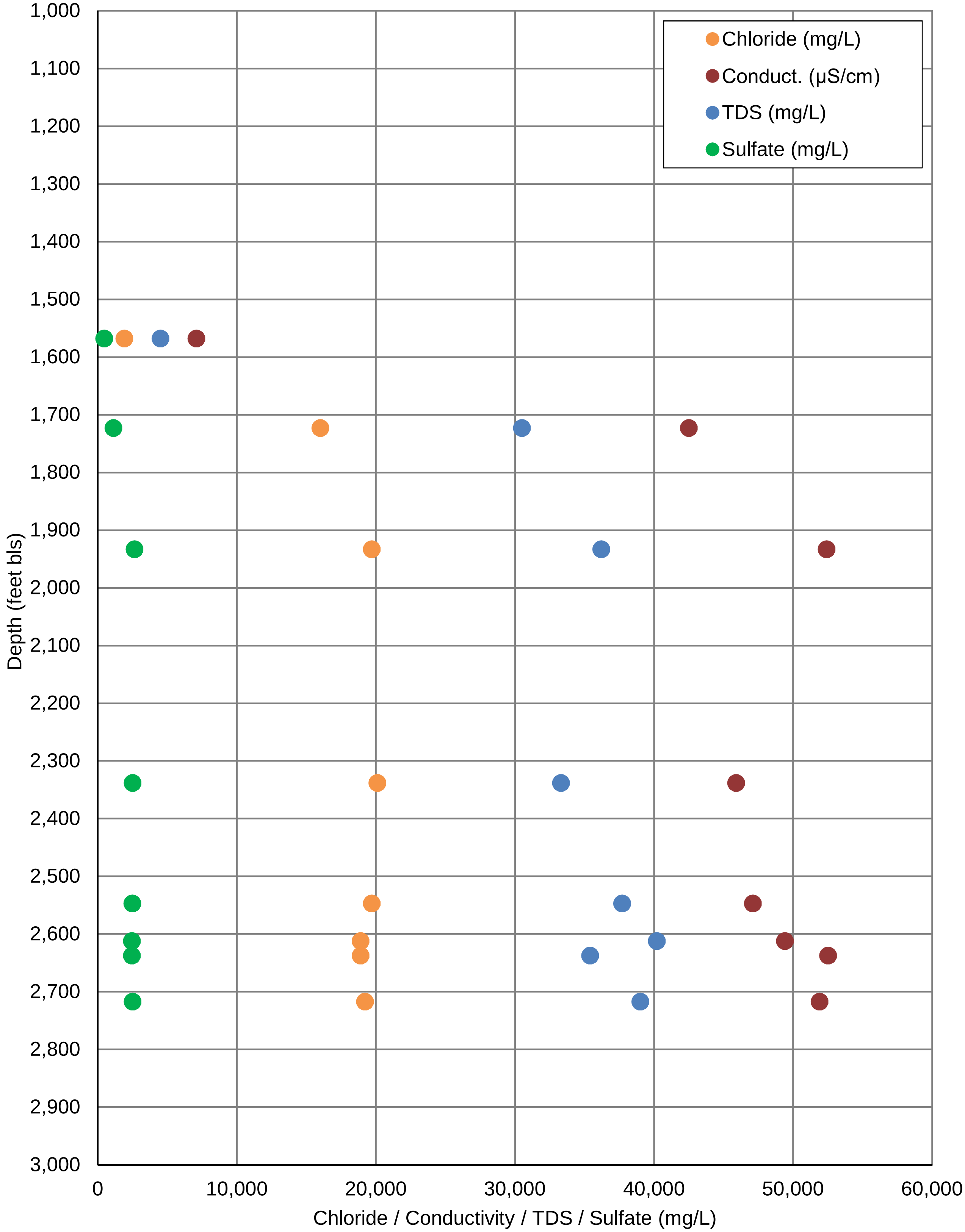
Graphic 12 - Packer Test Water Quality
IW-1 - Salinity and Sulfate
Seminole Tribe of Florida - Hollywood Reservation



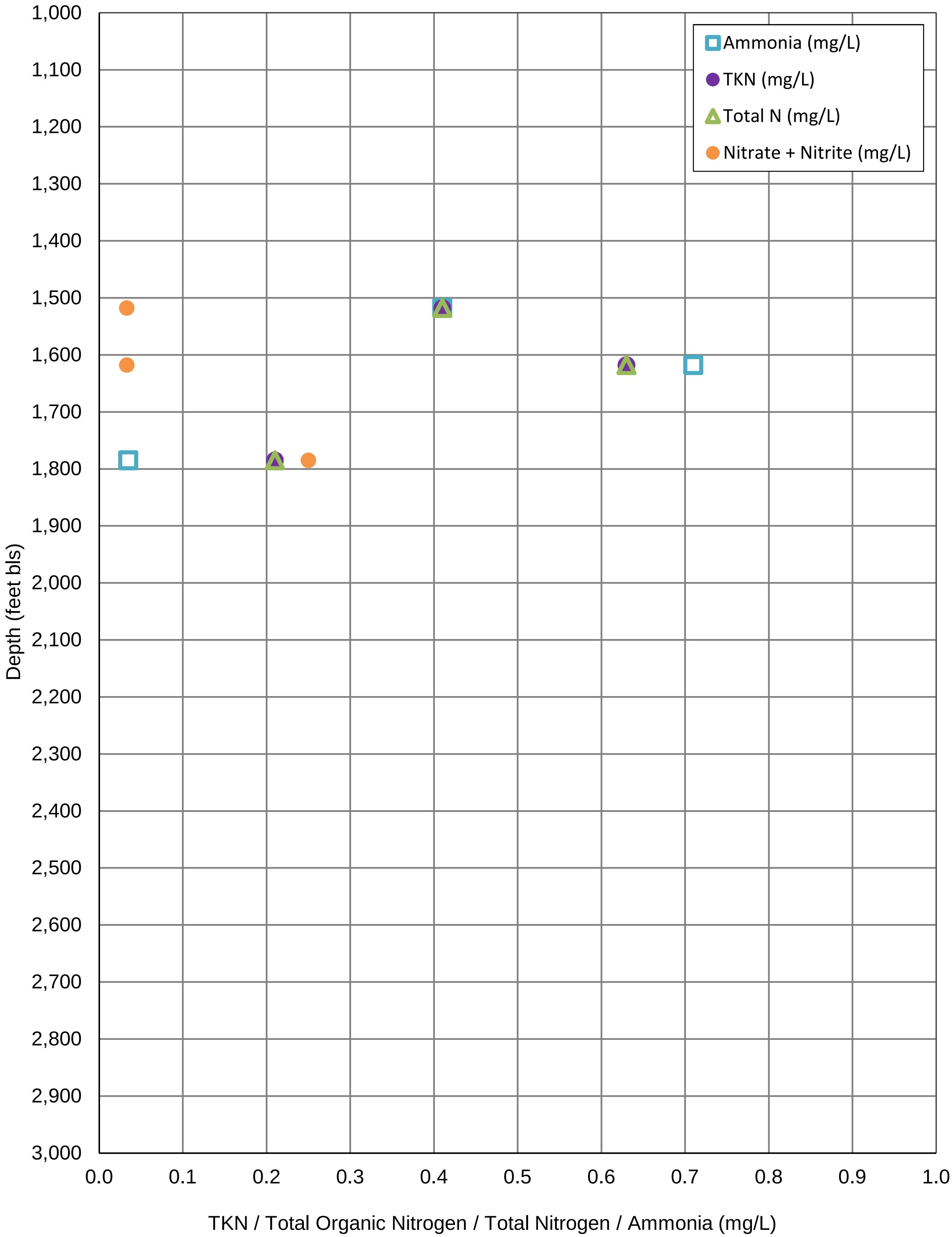
Graphic 13 - Packer Test Water Quality
IW-2 - Nitrogen Series
Seminole Tribe of Florida - Hollywood Reservation

Hazen

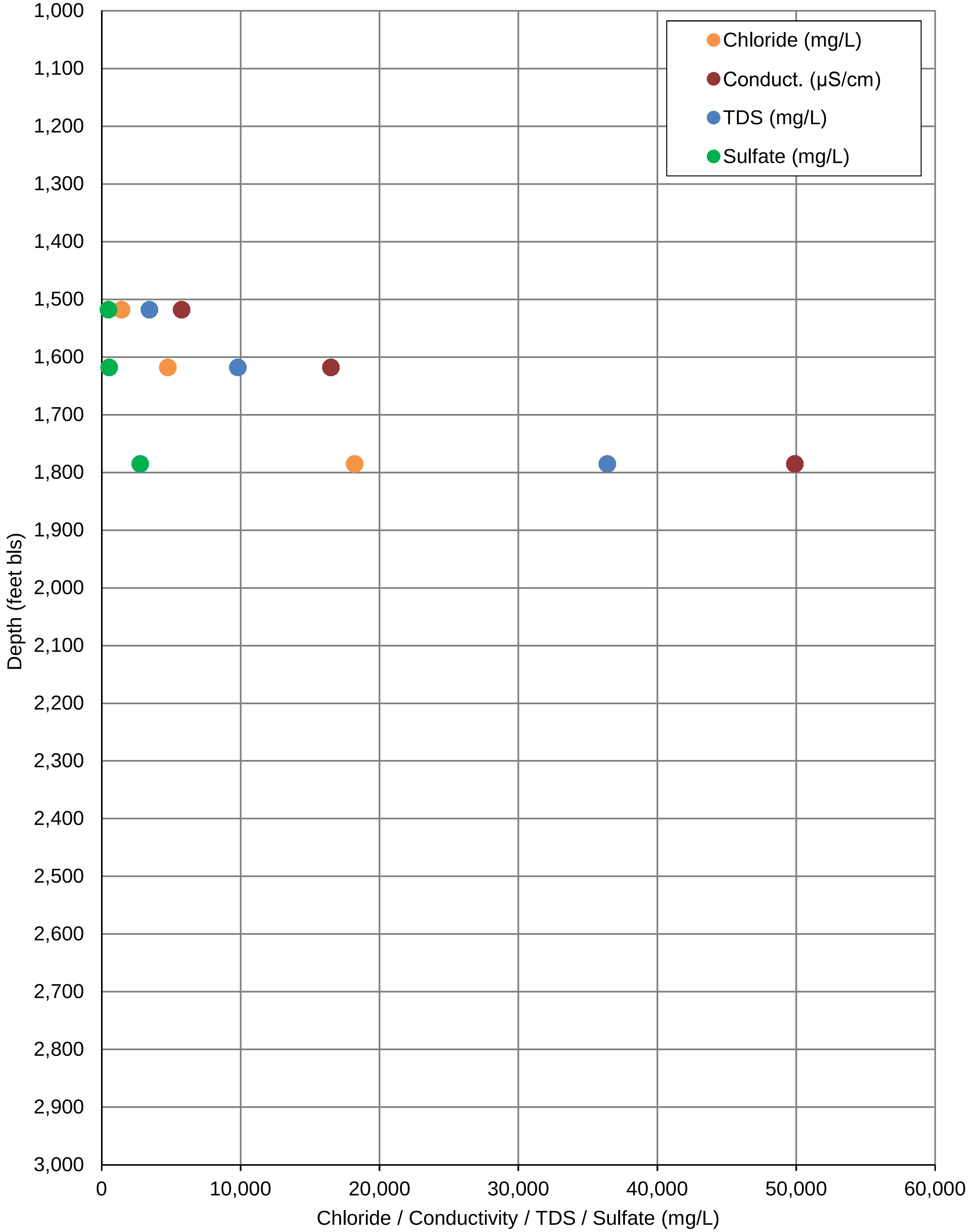
Graphic 14 - Packer Test Water Quality
IW-2 - Salinity and Sulfate
Seminole Tribe of Florida - Hollywood Reservation



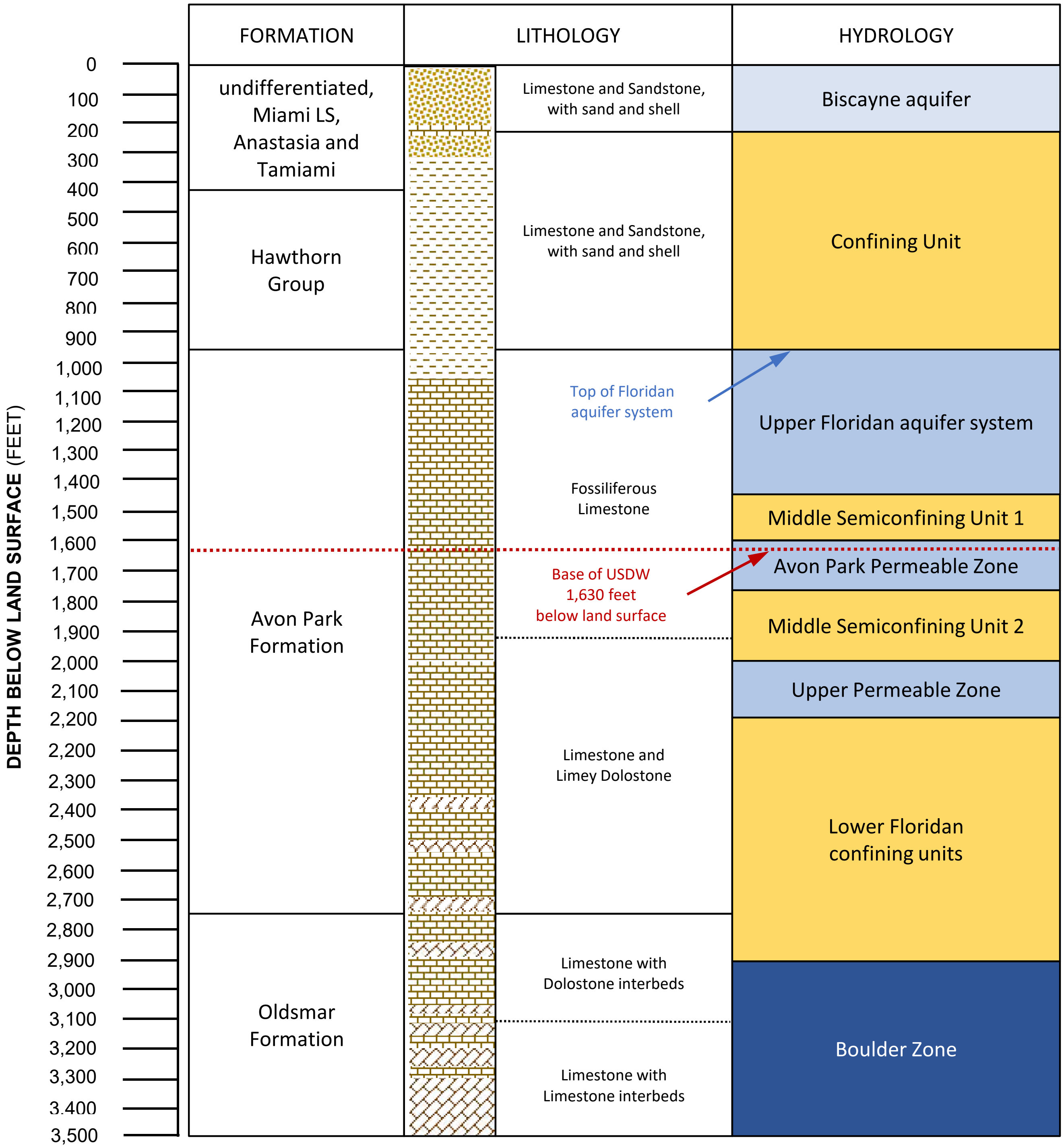
Graphic 15 - Packer Test Water Quality
MW-1 - Nitrogen Series
Seminole Tribe of Florida - Hollywood Reservation



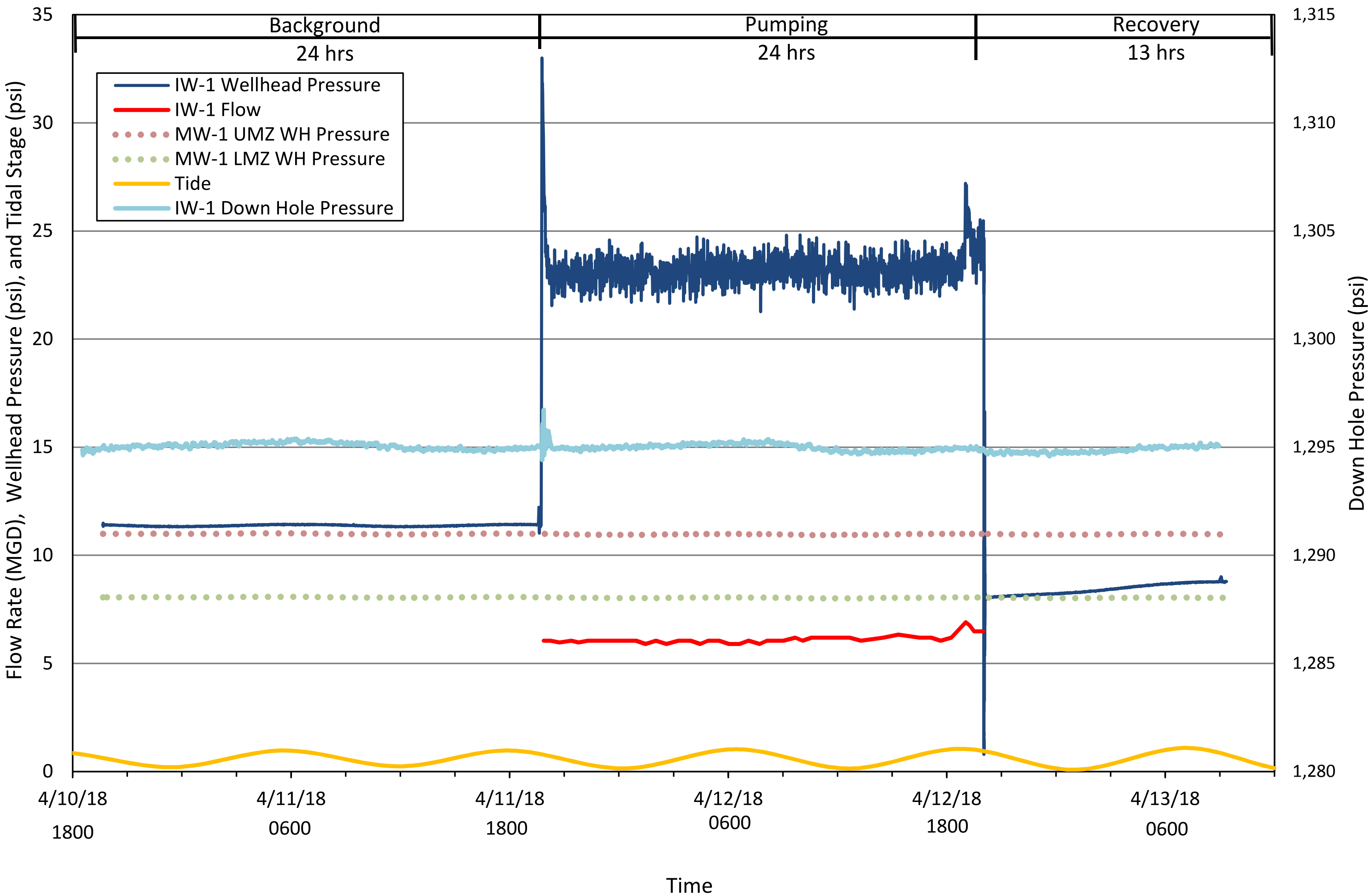
Graphic 16 - Packer Test Water Quality
MW-1 - Salinity and Sulfate
Seminole Tribe of Florida - Hollywood Reservation



Graphic 17 - Generalized Hydrogeologic Column
Seminole Tribe of Florida - Hollywood Reservation



Graphic 18 - Short-Term Injection Test - IW-1
Flow, IW-1 and MW-1 Wellhead Pressures, Down Hole Pressure, and Tide
Seminole Tribe of Florida - Hollywood Reservation



Graphic 19 - Short-Term Injection Test - IW-2
Flow, IW-2 and MW-1 Wellhead Pressures, Down Hole Pressure, and Tide
Seminole Tribe of Florida - Hollywood Reservation