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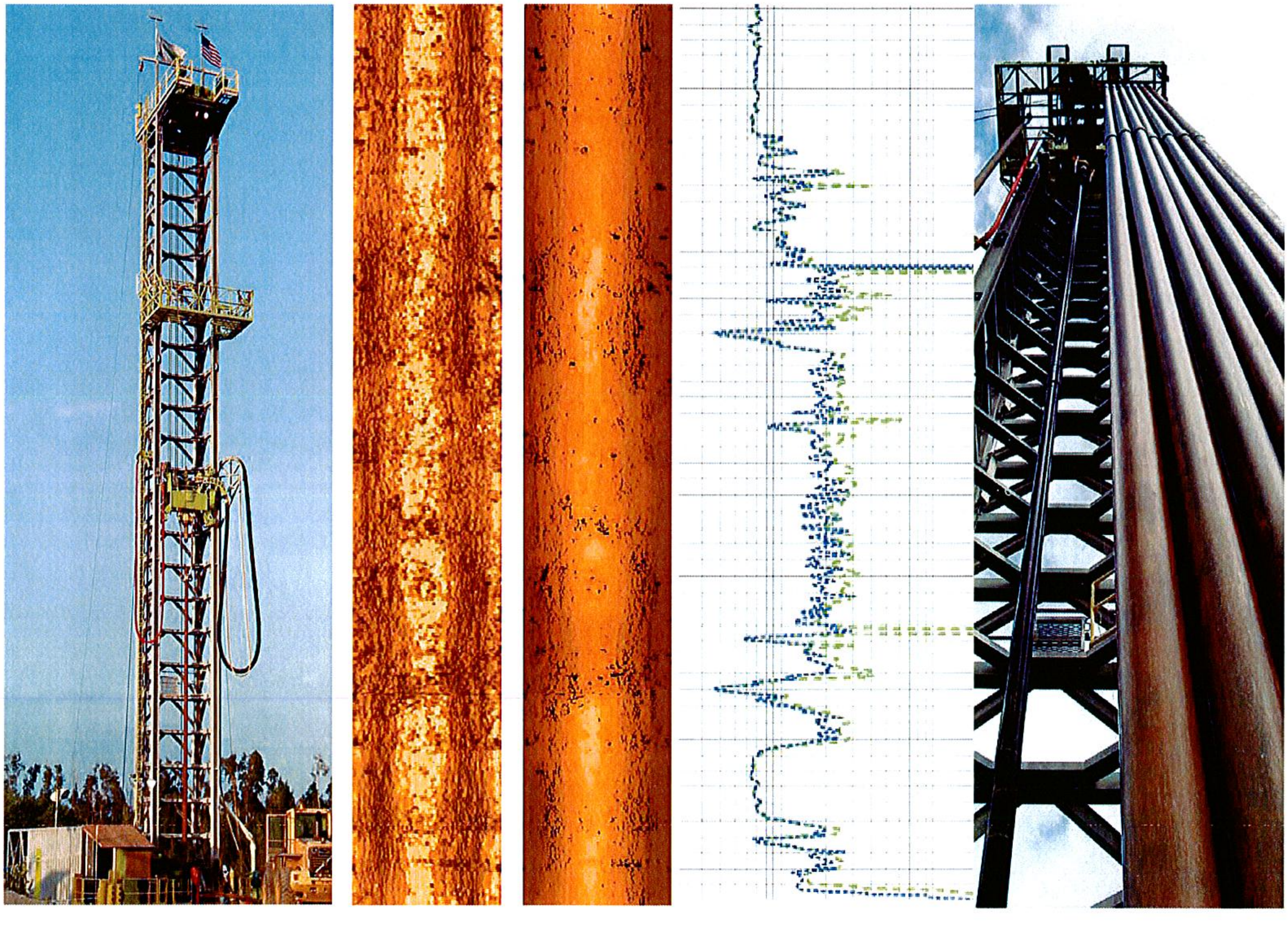
City of Hialeah
Reverse Osmosis Water Treatment Plant Injection Wells IW-1 & IW-2 and Dual-Zone Monitor Well DZMW-1 Completion Report

Abridged Version

November 12, 2010



City of Hialeah
Reverse Osmosis Water Treatment Plant Injection Wells IW-1 & IW-2 and Dual-Zone Monitor Well DZMW-1 Completion Report

Prepared by:

Schlumberger
WATER SERVICES
1567 Hayley Lane
Suite 202
Fort Myers, FL 33907
Tel: +1 239 481-6494
Fax: +1 239 481-6393

Prepared for:

Parsons Water & Infrastructure, Inc.
7600 Corporate Center Drive
Suite 500
Miami, FL 33126

November 12, 2010

SWS Project Number 0044-0122
Abridged Version

Certifications

City of Hialeah Reverse Osmosis Water Treatment Plant
Injection Wells IW-1 & IW-2 and Dual-Zone Monitor Well DZMW-1
Completion Report
Permit 0289249-001-UC

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.

PROFESSIONAL ENGINEER CERTIFICATION

William S. Manahan, P.E. (FL #51423)
Water Resource Engineer

No. 51423
11/12/10

PROFESSIONAL GEOLOGIST CERTIFICATION

David L. Hoffman, P.G. (FL# 2164)
Hydrogeologist

No. 2164
11-12-10

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Executive Summary

An injection well system consisting of two Class I injection wells (IW-1 & IW-2) and one dual-zone monitor well (DZMW-1) was constructed between November 2009 and May 2010 for the City of Hialeah to dispose of concentrate and other liquid wastes from a proposed 17.5 million gallon per day (MGD) reverse osmosis (RO) water treatment plant (WTP) that is planned for construction. Wells IW-1, IW-2, and DZMW-1 were constructed within the 200-foot wide Northwest 166th Street right-of-way, in Hialeah, Miami-Dade County, Florida.

Schlumberger Water Services USA Inc. provided design, permitting, and construction supervision services for the injection well system. Parsons was the design engineer for the new ROWTP. Wells IW-1, IW-2, and DZMW-1 were constructed by Youngquist Brothers, Inc. The Florida Department of Environmental Protection (FDEP) issued the Class I Test Injection Well Construction and Testing Permit (No. 0289249-001-UC) on July 22, 2009.

Wells IW-1 and IW-2 have five casing strings, including the injection tubing with outside diameters of 52, 42, 34, 24, and 16 inches. The 52, 42, and 34 inch diameter casings are composed of new, 0.375-inch thick, steel that conforms to required grades and standards. The 24-inch diameter injection casing is 0.50-inch wall, seamless steel and extends to a depth of 2,975 ft below pad level (bpl) in wells IW-1 and IW-2. The installed injection tubing consists of 15.8-inch outside diameter fiberglass reinforced plastic (FRP) epoxy resin pipe. The casing seat depth for the injection casing is located above the highest significant fracturing in the Boulder Zone. Wells IW-1 and IW-2 are constructed with open hole sections that extend below the casings to a depth of 3,500 ft bpl.

Well DZMW-1 has four casing strings with outside diameters of 30, 20, 12.75, and 6.625 inches. The 30, 20, and 12.75 inch diameter casings are composed of new, 0.375-inch thick, steel that conforms to required grades and standards. The 6.625-inch diameter inner casing consists of FRP pipe. DZMW-1 was constructed with upper and lower monitor zones of 1,900 to 1,950 ft bpl and 2,190 to 2,260 ft bpl, respectively.

Wells IW-1, IW-2, and DZMW-1 were constructed in accordance with the requirements of the FDEP Class I Test Injection Well Construction and Testing Permit and Florida Administrative Code 62-528. FDEP required testing demonstrates that finished wells IW-1 and IW-2 have mechanical integrity. The geologic interval between the injection zone and underground source of drinking water (USDW) was tested and demonstrates characteristics indicative of effective confinement that would be expected to prevent the vertical migration of injected fluids into the USDW.

Injection tests were performed to demonstrate that wells IW-1 and IW-2 are capable of efficiently accepting flow. The maximum flow rate of the injection test was limited to the withdrawal capacity of one test production well constructed in the Upper Floridan Aquifer (The ROWTP and other production wells were not yet constructed at the time of injection well testing). The injection tests demonstrate that wells IW-1 and IW-2 are capable of efficiently accepting flow at the rates tested. A rerate will be necessary when additional water and pump capacity become available.

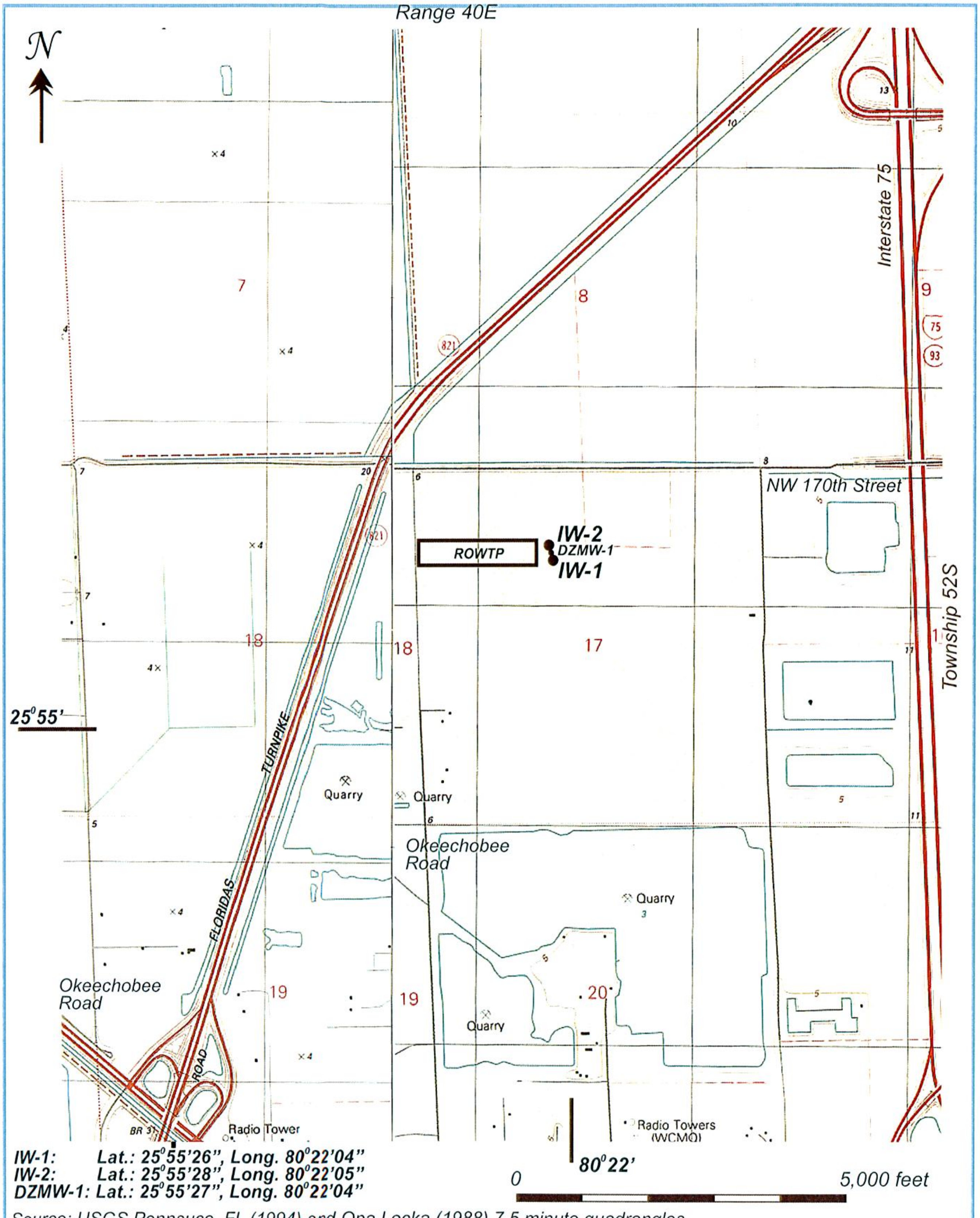
1 Introduction

An injection well system consisting of two Class I injection wells (IW-1 & IW-2) and one dual-zone monitor well (DZMW-1) were constructed for the City of Hialeah to dispose of concentrate and other liquid wastes from a proposed 17.5 million gallon per day (MGD) reverse osmosis (RO) water treatment plant (WTP). The location of the injection well system and proposed ROWTP is shown on **Figure 1-1**. Wells IW-1 and IW-2 were constructed to inject liquid wastes into the so-called "Boulder Zone" of the Lower Floridan Aquifer, which is located between approximately 2,975 and 3,500 ft below pad level (bpl). The Boulder Zone is extensively used for liquid waste disposal in South Florida and contains groundwater that is compositionally very similar to seawater. Class I injection wells by definition inject fluids beneath the lowermost formation containing, within one quarter mile of the well bore, an underground source of drinking water (USDW; Rule 62-528.300(1)(a)(2)), Florida Administrative Code (FAC). An USDW is a non-exempted aquifer that contains water with a total dissolved solids (TDS) concentration of less than 10,000 milligrams per liter (mg/L: Rule 62-528.200(66), FAC).

The FDEP issued the injection well construction permit (0289249-001-UC) on July 22, 2009, a copy of which is provided in **Appendix A**. The ROWTP will treat brackish groundwater from production wells tapping the Upper Floridan Aquifer. Assuming a 75% RO treatment efficiency, the demand for brackish groundwater will be approximately 23.33 MGD for a 17.5 MGD ROWTP. The concentrate waste stream flow from the ROWTP will be approximately 5.83 MGD when operating at full capacity. The design capacity of wells IW-1 and IW-2 is 7.39 MGD based on the injection tubing inside diameter of 14.48-inches. The brackish feedwater will have an estimated maximum TDS concentration of approximately 5,000 mg/L and the concentrate will have an estimated maximum TDS concentration of 20,000 mg/L. The injection well system was designed, permitted, and constructed to provide for 100% back-up capacity.

The monitoring requirements for IW-1 and IW-2 will be met by well DZMW-1, which is located within 150 ft of each injection well as required by Rule 62-528.425(1)(g)(3), FAC. Wells IW-1 and IW-1 are located approximately 85 and 80 feet, respectively, from DZMW-1. Well DZMW-1 was constructed with upper and lower monitor zones of 1,900 to 1,950 ft bpl and 2,190 to 2,260 ft bpl, respectively. An aerial photograph showing the layout of the wells IW-1, IW-2, and DZMW-1 is provided as **Figure 1-2**.

Schlumberger Water Services USA Inc. (SWS) provided design, permitting and construction supervision services. Parsons was the design engineer for the ROWTP. The entire drilling and testing program was overseen by the Underground Injection Control (UIC) Technical Advisory Committee (TAC), which was comprised of representatives from the FDEP, South Florida Water Management District (SFWMD), U.S. Environmental Protection Agency (USEPA), U.S. Geological Survey (USGS) and Miami-Dade Department of Environmental Resources Management (DERM). Daily



IW-1: Lat.: 25°55'26", Long. 80°22'04"
IW-2: Lat.: 25°55'28", Long. 80°22'05"
DZMW-1: Lat.: 25°55'27", Long. 80°22'04"

Source: USGS Pennsuco, FL (1994) and Opa Locka (1988) 7.5 minute quadrangles.

Figure 1-1
City of Hialeah Injection Well System
USGS Topographic Map Showing Injection Well Locations

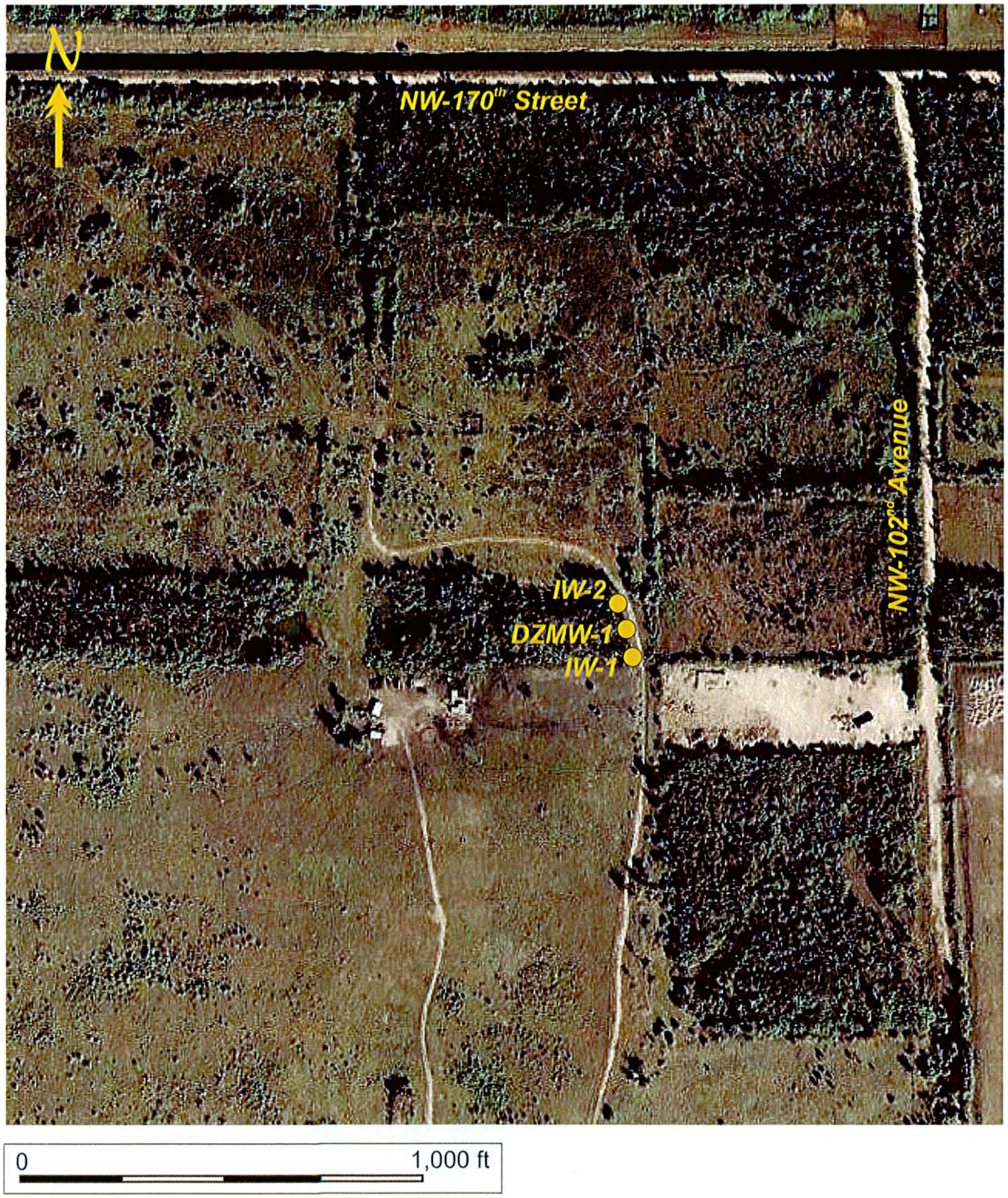


Figure 1-2
City of Hialeah Injection Well System
Aerial Photograph Showing Well Locations

activity logs, weekly progress reports, and other pertinent information were submitted to the TAC weekly. Copies of the weekly TAC letters are provided in **Appendix B** and copies of the weekly construction summaries are included in **Appendix C**.

Construction and testing of the injection well system were performed in accordance with Chapter 62-528, (Underground Injection Control) FAC, the conditions of the FDEP construction permit, and the technical specifications prepared by SWS and approved by the TAC. Any variance to these documents was reviewed by the UIC TAC and approved by the FDEP.

2 Geology and Hydrogeology

2.1 Geology

The geology and hydrogeology of the City of Hialeah ROWTP site are summarized in **Figure 2-1**. The limestone classification system of Dunham (1962) was used to describe the cuttings and cores recovered from wells IW-1, IW-2 and DZMW-1. Colors were described verbally and numerically using a Munsell soil color chart. A geologic column and composite geophysical log for wells IW-1, IW-2 and DZMW-1 are provided in **Appendix D**. A geologist log for the wells is provided in **Appendix E**. The geology encountered in wells IW-1 and IW-2 was very similar. Lithology contacts (e.g., contacts between limestone and dolostone beds) and gamma ray marker beds occur at roughly similar depths.

Plio-Pleistocene Strata

The shallow geology and hydrogeology of Miami-Dade County was described by Fish and Stewart (1991). Fish and Stewart (1991) in their regional cross-sections assigned the uppermost 100 ft of strata in the project site area to the Miami Limestone (Oolite), Fort Thompson Formation, and locally to the Key Largo Limestone. However, it must be emphasized that the Pleistocene and late Pliocene-aged strata in the subsurface of southeastern Florida consist of interfingering and often discontinuous bodies of shallow-water deposits. The subsurface strata therefore often cannot be meaningfully assigned to formations as they are currently defined because they do not constitute continuous mapable bodies (Maliva et al., 2000).

The upper 120 ft of strata encountered at the Hialeah injection well site consists of shelly limestones with varying amounts of quartz sand, which is a typical Fort Thompson Formation lithology. Neither oolitic limestones of the Miami Limestone, nor corraline limestones of the Key Largo Limestone were encountered.

The Fort Thompson Formation is underlain by sandy limestones, shelly sandy clays, and shelly limestones that are part of the Tamiami Formation (Pliocene). The base of the Tamiami Formation is placed at approximately 180 ft bpl, as marked by a downhole lithological change to gray to olive gray sandy clays with common phosphate grains.

Hawthorn Group

The Hawthorn Group (Pliocene to late Oligocene) is a lithologically diverse unit composed of clays, marls, limestones, dolostones, and phosphates. The common presence of phosphate results in the Hawthorn Group having a characteristic high gamma ray activity, particularly compared to the underlying and overlying formations.

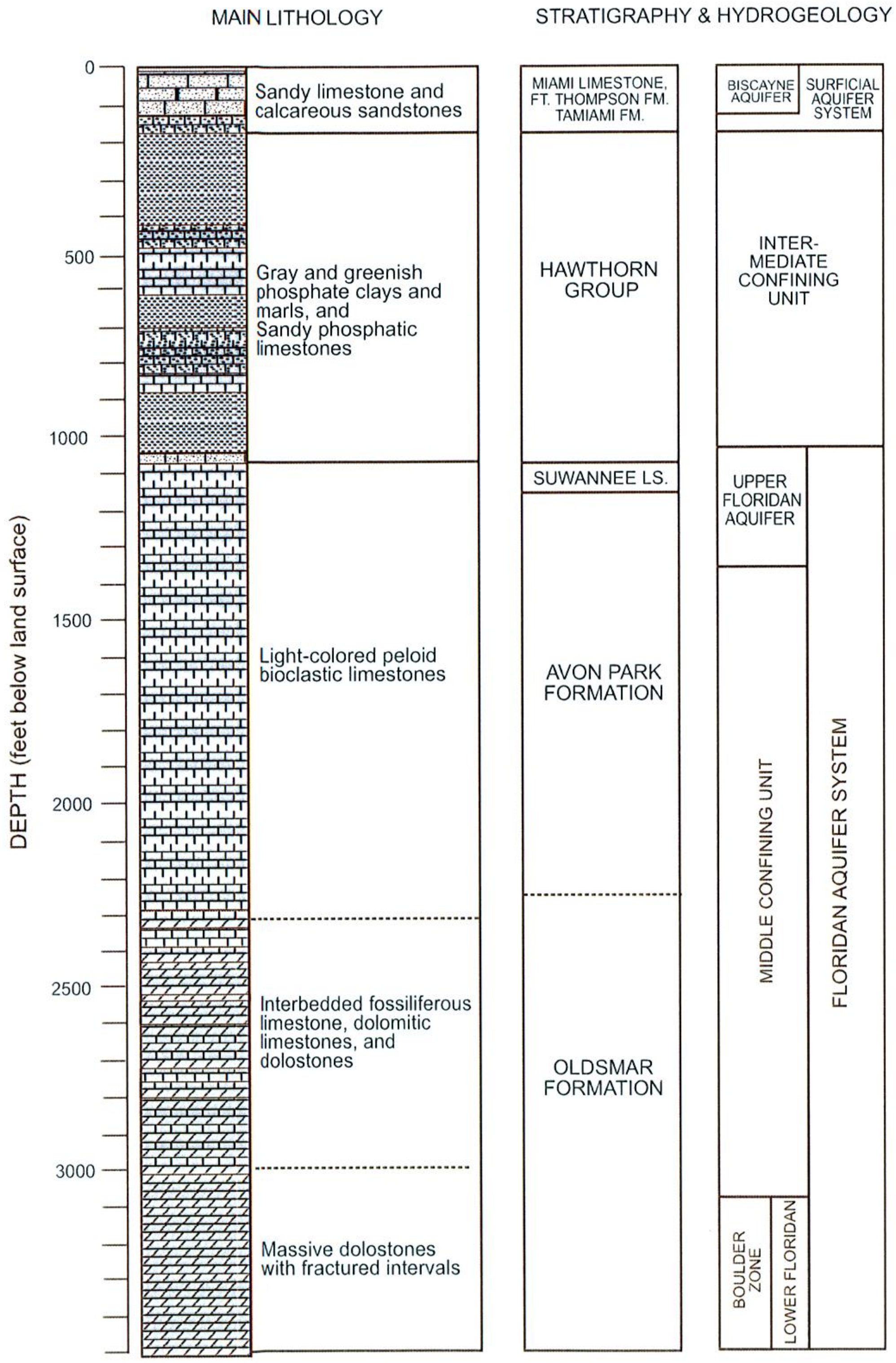


Figure 2-1
City of Hialeah Injection Well System
Hydrogeologic Diagram

The Hawthorn Group in South Florida is divided into two units, the Peace River Formation and underlying Arcadia Formation. As defined by Scott (1988), the Peace River Formation consists of interbedded sands, clays, and carbonate, in which the siliciclastic component predominates. The Arcadia Formation, on the contrary, is a carbonate-rich unit. Scott (1988) described the Arcadia Formation as consisting predominantly of limestone and dolostone containing varying amounts of quartz sand, clay, and phosphate grains.

The boundary between the Peace River Formation and Arcadia Formation at the Hialeah ROWTP injection well site is placed at approximately 430 ft bpl based on the geophysical logs. At that depth there is a pronounced down-hole decrease in gamma ray activity and increase in resistivity, which usually marks the transition from clays to limestones. Limestone was first described in the 440 to 450 ft bpl cuttings sample.

The Arcadia Formation at the Hialeah ROWTP site is lithologically diverse, consisting of alternating intervals of clay or marl and fossiliferous limestone. Clay or marl units are present in the following interval (based on the IW-1 geophysical logs): 650 to 730 ft bpl, 775 to 830 ft bpl, and 950 to 1,040 ft bpl. The basal Hawthorn Group contains abundant phosphate sand, and is readily recognized on gamma ray logs by very high (> 100 GAPI) activity. The base of the Hawthorn Group extends downwards to at least 1,080 ft bpl, as indicated by very high gamma ray activities and the presence of sandy limestones with common (~ 5%) very fine-grained phosphatic sand.

Suwannee Limestone

The strata present between 1,080 and 1,146 ft bpl in well IW-1 are tentatively assigned to the Suwannee (Oligocene), but could alternatively also be part of the lower Arcadia Formation. Present studies of southeastern Florida identify the Suwannee Limestone as being present in northeastern Miami-Dade County (Miller, 1986; Reese, 1994; Reese and Richardson, 2008). The strata from 1,080 to 1,146 ft bpl consist mostly of light gray to pale yellow fossiliferous limestones. Gamma ray activity is intermediate between the very high activity of the lowermost Hawthorn Group and that of the relatively pure limestone of the upper Avon Park Formation.

Avon Park Formation

The top of the Avon Park Formation (Middle Eocene) is placed at 1,146 ft bpl in IW-1 based on an abrupt downhole transition to relatively pure bioclastic grainstones with a low gamma ray activity. The Ocala Limestone (Late Eocene) is not present at the Hialeah ROWTP site

The abundant cone-shaped foraminifera (*Dictyoconus* and similar genera) that are characteristic of the Avon Park Formation are common in the 1,160 to 1,170 ft bpl cuttings sample. The centimeter-sized echinoid Neolaganum dali are common in the 1,190 to 1,200 ft bpl sample. Vernon (1951) noted Neolaganum dali to be very abundant in the upper 50 ft of the Avon Park Formation in Florida peninsula wells. The authors have consistently found it to be common between 10 and 50 ft below the top of the Avon Park Formation in South Florida. The main lithology of the Avon Park Formation in South Florida is light colored (white to pale yellow) bioclast grainstone that is cemented with calcite to varying degrees.

Oldsmar Formation

Picking the boundary between the Avon Park Formation and Oldsmar Formation is complicated because the Eocene formations of Florida are chronostratigraphic rather than lithostratigraphic units (Miller, 1986). Formation boundaries may not therefore correspond to lithological changes. Reese and Memberg (2000) grouped the Eocene Formations in Florida into an 'Eocene Group' because of the similar lithologies and geophysical log responses.

The Avon Park Formation has been described as being 1,100 to 1,200 ft thick in the project site area (Miller, 1986; Reese, 2000), which would place the boundary at roughly 2,250 to 2,350 ft bpl at the Hialeah ROWTP site. The well cuttings indicate a down-hole transition from bioclastic grainstones to more mud-rich lithologies, which are more common in the Oldsmar Formation, at 2,240 ft bpl. The top of the Oldsmar Formation is thus tentatively placed at 2,240 ft bpl, which is consistent with other recent studies of the Floridan Aquifer System (Reese and Richardson, 2008). There is no geophysical change at the 2,240 ft bpl depth.

The Oldsmar Formation contains an upper unit of interbedded limestones and dolostones and a lower unit which consists predominantly of hard, dense dolomite. Dolomitic intervals in the upper Oldsmar Formation grade from dolomitic limestone with scattered rhombohedral dolomite crystals, to calcareous dolomites, to very dense, hard pure dolostones. Limestone and dolostone intervals can be readily differentiated in the borehole logs. Limestone intervals tend to have relatively uniform sonic transit times and resistivities in the 2 to 3 ohm-m range. Dolostones typically have much great resistivities and more variable sonic transit times that are either much lower than those of limestones if the dolostones are unfractured or greater if the dolostones are fractured. Dolostones are readily identifiable in the Avon Park between 2,300 and 2,345 ft and 2,430 and 2,610 ft bpl. Dolomitic limestones are present from approximately 2,610 to 2,845 ft bpl.

The top of the dolomitic lower Oldsmar Formation occurs at approximately 3,045 ft bpl. The dolostones of the lower Oldsmar Formation are typically medium brown to black colored and very dense (i.e., minimal matrix porosity). Secondary porosity (vugs and small cavities) are common and are often lined with euhedral dolomite cement. Fractured intervals may have greatly enlarged boreholes due to collapse during drilling. The base of the Oldsmar Formation is typically placed at the top of the first bedded anhydrite unit of the Cedar Keys Formation. The top of the Cedar Keys Formation was not penetrated during drilling of wells IW-1 or IW-2.

2.2 Hydrogeology

There are two major aquifer systems underlying Miami-Dade County from land surface to a depth of approximately 3,500 ft bpl; the Surficial Aquifer System and the deeper, artesian Floridan Aquifer System. These two aquifer systems are separated by a confining sequence called the Intermediate Confining Unit. The Intermediate Confining Unit contains aquifers suitable for freshwater or brackish-water supply in some areas of Florida (where it is referred to as the Intermediate Aquifer System), but is generally unproductive in the southeastern part of the state. The Floridan Aquifer System is underlain by low transmissivity carbonate and evaporite strata of the Cedar Keys Formation.

Surficial Aquifer System

The Surficial Aquifer System in Florida is defined as the "permeable hydrogeologic unit contiguous with land surface that is comprised principally of unconsolidated clastic deposits" (Southeastern Geological Society Ad Hoc Committee, 1986). The Surficial Aquifer System comprises all materials from the water table to the top of the Intermediate Confining Unit. The base of the Surficial Aquifer System is marked by a significant decrease in the average hydraulic conductivity.

Biscayne Aquifer

The Biscayne Aquifer was defined by Parker (1951) as the hydrologic unit of water-bearing rock that carries unconfined groundwater in southeastern Florida. Parker et al. (1955) later amended the definition of the Biscayne Aquifer to specifically consist of water-bearing rock of Pleistocene to later Miocene age that includes all or parts of the following formations: Tamiami Formation (uppermost part only), Caloosahatchee Marl, Fort Thompson Formation, Anastasia Formation, Key Largo Limestone and Pamlico Sand. The "Biscayne Aquifer", as originally defined is synonymous with "Surficial Aquifer System". Fish and Stewart (1991) restricts the term "Biscayne Aquifer" to only those areas where there is at least 10 ft of section that has a hydraulic conductivity of 1,000 ft/d or more.

The Biscayne Aquifer has been designated as a sole source aquifer and is the principal potable water source in Miami-Dade and Broward Counties. The Biscayne Aquifer is roughly 120 ft thick at the Hialeah ROWTP and consists predominantly of sandy, shelly limestones and shelly sandstones. The base of the Biscayne Aquifer is marked by a downhole lithological transition to sandy, shelly clays.

The Surficial Aquifer System strata below the Biscayne Aquifer consist of interbedded sands, calcareous sandstones, fossiliferous limestones and sandy limestones that are part of the Tamiami Formation (Fish and Stewart, 1991). The base of the Surficial Aquifer System at the Hialeah ROWTP occurs at approximately180 ft bpl, below the deepest Plio-Pleistocene sandstones and limestones.

Intermediate Confining Unit

The Intermediate Confining Unit is defined as including "all rocks that lie between and collectively retard the exchange of water between the overlying Surficial Aquifer System and the underlying Floridan Aquifer System" (Southeastern Geological Society Ad Hoc Committee, 1986). In eastern Miami-Dade County, the boundary between the Surficial Aquifer System and Intermediate Confining Unit essentially coincides with the boundary between the Tamiami Formation and underlying Hawthorn Group, and occurs at approximately 180 ft bpl at the Hialeah ROWTP site.

The boundary between the Intermediate Confining Unit and Floridan Aquifer System was placed at approximately 1,050 ft bpl. The boundary was picked based on a pronounced downhole increase in resistivity, which is indicative of a lithological change from clay-rich strata to cleaner, more porous limestones.

Floridan Aquifer System

The Floridan Aquifer System is one of the most productive aquifers in the United States and underlies all of Florida and parts of Georgia and South Carolina for a total area of about 100,000 square miles (Miller, 1986). The Floridan Aquifer System consists of an extensive sequence of thickly bedded Tertiary-aged limestones and, less abundant dolostones that are connected to varying degrees. The Floridan Aquifer System is quite heterogeneous as far as hydraulic conductivity. Flowmeter log data show that the aquifer consists of a number of zones with very high hydraulic conductivities, which are commonly either solution riddled or fractured, separated by confining or semi-confining intervals of rock with low hydraulic conductivities (Miller, 1986). Confining units within the Floridan Aquifer System in South Florida vary greatly in thickness and vertical continuity.

The Floridan Aquifer System can be subdivided into three main units based on their relative permeabilities; the Upper Floridan Aquifer, the Middle Confining Unit, and the Lower Floridan Aquifer. The Upper Floridan Aquifer consists predominantly of porous limestones that are part of the lower Suwannee Limestone and upper Avon Park Formation. The base of the Upper Floridan Aquifer occurs at approximately 1,365 ft bpl at the Hialeah ROWTP injection well site as indicated on the sonic log by modest (≈ 5%) down-hole decrease in porosity.

The Middle Confining Unit consists of the middle and lower parts of the Avon Park Formation and upper part of the Oldsmar Formation. The porosity and permeability of the individual beds of the Middle Confining Unit are variable, but the overall vertical hydraulic conductivity of the unit is low enough to prevent the migration of fluids between the Upper Floridan Aquifer and Lower Floridan Aquifer. The base of the Middle Confining Unit is placed at the top of the uppermost high-hydraulic-conductivity fractured zone of the Lower Floridan Aquifer, which occur at approximately 3,045 ft bpl at the Hialeah ROWTP site.

Reese and Richardson (2008) documented a flow zone within the Middle Confining Unit, which is referred to as the 'Avon Park permeable zone' (APPZ). Reese and Richardson

(2008) show the APPZ occurs at about 1,700 ft bpl in the project site area. The sonic logs from the Hialeah RWTP indicates the presence of some beds with higher porosites than the overlying and underlying strata between 1,698 and 1,752 ft bpl, which presumably corresponds to the APPZ. The flowmeter logs indicate the presence of a major flow zone between 1,685 and 1,722 ft bpl. The top of the zone varies between wells IW-1 and IW-2. The hydraulic properties of the APPZ were not further evaluated at the Hialeah ROWTP because it is located above the base of the deepest USDW.

The Lower Floridan Aquifer extends from the base of the Middle Confining Unit to the base of the Floridan Aquifer System. The so-called "Boulder Zone" is the principal high transmissivity zone in the Lower Floridan Aquifer and has been used for the underground disposal of various types of liquid wastes since 1943. Transmissivities for some of the dolostones of the Boulder Zone have been reported to be as high as (2.46 x 10^7 ft^2/day (Singh and other, 1983). The Boulder Zone and similar high transmissivity intervals in the Floridan Aquifer system (e.g. Avon Park high transmissivity zone in western peninsular Florida) can be identified by greatly enlarged hole size on caliper logs, exceedingly long sonic transit times, relatively low resistivity, and changes in temperature and flow meter log responses (Haberfeld, 1991; Maliva and Walker, 1998). The Boulder Zone consists mainly of fractured dolostone, in which large cavities develop during drilling as the result of borehole collapse (Safko and Hickey, 1992; Duerr, 1995; Maliva and Walker, 1998). Actual open cavities, as indicated by bit drops during drilling, were not encountered.

Although the geology of wells IW-1 and IW-2 were similar (i.e., lithologies were the same and markers occurred at the approximately the same depths), pronounced differences in the locations of fractured and cavernous flow zones are present between the two wells. The main 'cavernous' injection zones in the Hialeah ROWTP occur at the depths listed in **Table 2-1**.

Table 2-1 Fractured Zones Below USDW (ft bpl from sonic logs)

IW-1	IW-2
NP	2,294 – 2,316
NP	2,432 – 2,440
2,472 – 2,497	2,490 – 2,515
2,576 – 2,612	NP
2,834 – 2,842	2,832 – 2,840
Boulder Zone	
3,145 – 3,160	3,045 – 3,052
3,204 – 3,210	3,068 – 3,090
3,335 – 3,338	3,116 – 3,226
3,360 – 3,380	3,142 – 3,148
3,457 – 3,465	3,170 – 3,202
	3,210 – 3,228
	3,244 – 3,266

The base of the Floridan Aquifer System is generally placed at the top of the uppermost evaporite (anhydrite) bed in the Cedar Keys Formation which ranges from about 3,500 to 3,700 ft bpl in depth in eastern Miami-Dade County (Miller, 1986). The base of the Floridan Aquifer System was not penetrated in wells IW-1 or IW-2.

2.3 Base of Underground Source of Drinking Water

Class I injection wells by definition inject below the base of the lowest USDW, which is defined as water that contain water having a TDS concentration of less than 10,000 mg/L. Class I injection well systems must be constructed and operated so that injected fluids do not migrate upwards and impact USDWs. Identification of the USDW is therefore an important task in injection well programs. Based on regional work performed by Reese (1994), the USDW was anticipated to be encountered between 1,800 to 1,900 ft bpl at the Hialeah injection well site.

The base of the USDW was located, during construction, using water quality data from packer tests and a log-derived TDS plot at an approximate depth of 1,875 ft bpl in well IW-1. A plot showing the log derived TDS with depth is provided as **Figure 2-2**. Two straddle packer tests were performed in IW-1 at depths above (1,838 to 1,855 ft bpl) and below (1,899 to 1,916 ft bpl) to confirm the base of the USDW at an approximate depth of 1,875 ft bpl. TDS was measured at concentrations of 6,360 mg/L and 16,100 mg/L in the packer tests from 1,838 to 1,855 ft bpl and 1,899-1,916 ft bpl, respectively. The straddle packer test data confirmed that the base of the USDW is located at an approximate depth of 1,875 ft bpl. The base of the USDW was also located at the same approximate depth in well IW-2 using a log-derived TDS plot and a straddle packer test performed at a depth of 1,884 to 1,901 ft bpl. The laboratory analytical results indicate a TDS concentration of 13,910 mg/L for the packer test interval of 1,884 to 1,901 ft bpl, which is consistent with the test being performed a short distance below the base of the USDW.

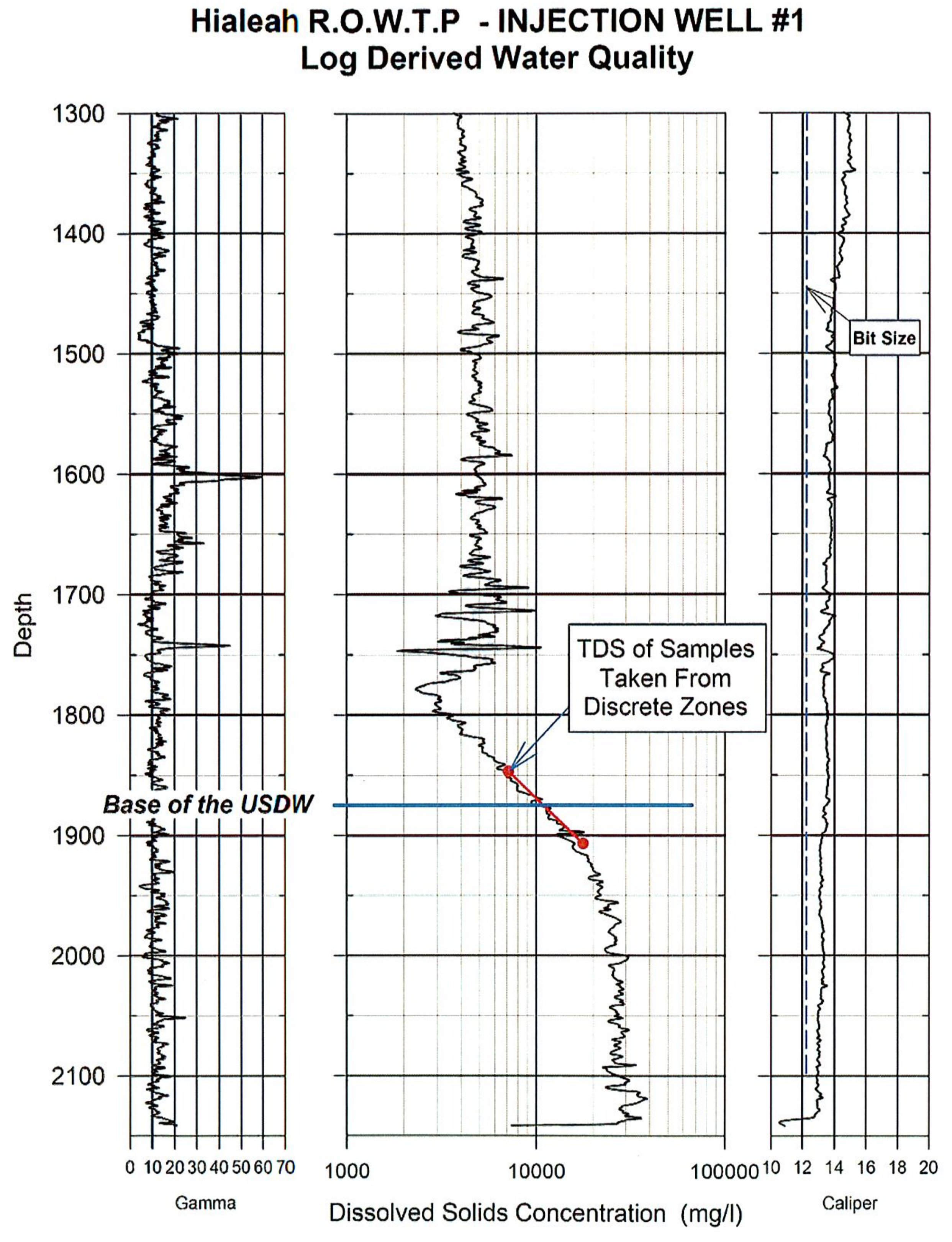


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Figure 2-2
City of Hialeah Injection Well System
Log Derived Total Dissolved Solids in IW-1

3 Injection Well Design and Construction

3.1 Injection Well System Design

Wells IW-1, IW-2 and DZMW-1 were designed, constructed, and tested in accordance with requirements of Chapter 62-528, FAC. An application for an injection well construction permit was submitted to the FDEP on May 27, 2008. The FDEP construction permit (No. 0289249-001-UC) was issued on July 22, 2009, and is valid for three years.

The drill rig pad elevation for wells IW-1 and IW-2 was 3.93 and 4.12 ft, respectively, referenced to the North American Vertical Datum of 1988 (NAVD 88). Wells IW-1 and IW-2 were constructed with a 24-inch diameter injection casing set to 2,975 ft bpl and an open hole extending to approximately 3,500 ft bpl. The design capacity of each injection well is 7.39 MGD, which is based on a tubing diameter of 15.80 inches (14.48-inch inside diameter) and a maximum peak day injection velocity of 10 ft/sec, as per Rule 62-528.415(1)(f)(3), FAC. As as-built construction diagrams for wells IW-1, IW-2, and DZMW-1 are provided as **Figure 3-1, Figure 3-2, and Figure 3-3**, respectively. A detailed construction description is provided below.

A final survey of wells IW-1, IW-2, and DZMW-1 was completed on July 19, 2010 and is provided in **Appendix F**. Based on the surveyed coordinates, IW-1 and IW-2 are spaced 85.6 and 79.7 ft, respectively, from DZMW-1.

3.2 Site Preparation

Wells IW-1, IW-2 and DZMW-1 were constructed in the area of a former construction material landfill. The land surface was stabilized using imported fill prior to set up of the drill rigs. The drilling contractor, Youngquist Brothers, Inc. (YBI) was issued a Notice to Proceed by the City of Hialeah on October 26, 2009. Drilling of IW-1 began on November 7, 2009. Drilling of IW-2 began on November 18, 2009. Wells IW-1 and IW-2 were drilled simultaneously with an approximate two week offset to enable use of the same tools and bits. Drilling of DZMW-1 began on March 26, 2010.

Temporary steel containment pads were installed to contain the drilling rig and mud system. The drilling pad was 23 ft 10 inch by 45 ft 9 inch in dimension with 4 ft high containment walls. The mud system pad was 45 ft by 45 ft with 2 ft high H-beam containment walls. Details of the containment pads are provided in **Appendix F**.

Eight pad monitor wells were constructed near each corner of wells IW-1 and IW-2 by Aqua Terra Solutions, Inc. of Miami, Florida, on November 4, 2009. The 2-inch diameter pad monitor wells were constructed with 10 foot sections of 0.010-inch slot sized screen, which extends from 1.5 to 11.5 ft bpl. The pad monitor wells were installed to enable weekly sample collection and laboratory analyses of groundwater samples to monitor for impacts from surface spillage of saline water. The pad monitor wells were sampled and groundwater was laboratory analyzed weekly by Florida Environmental

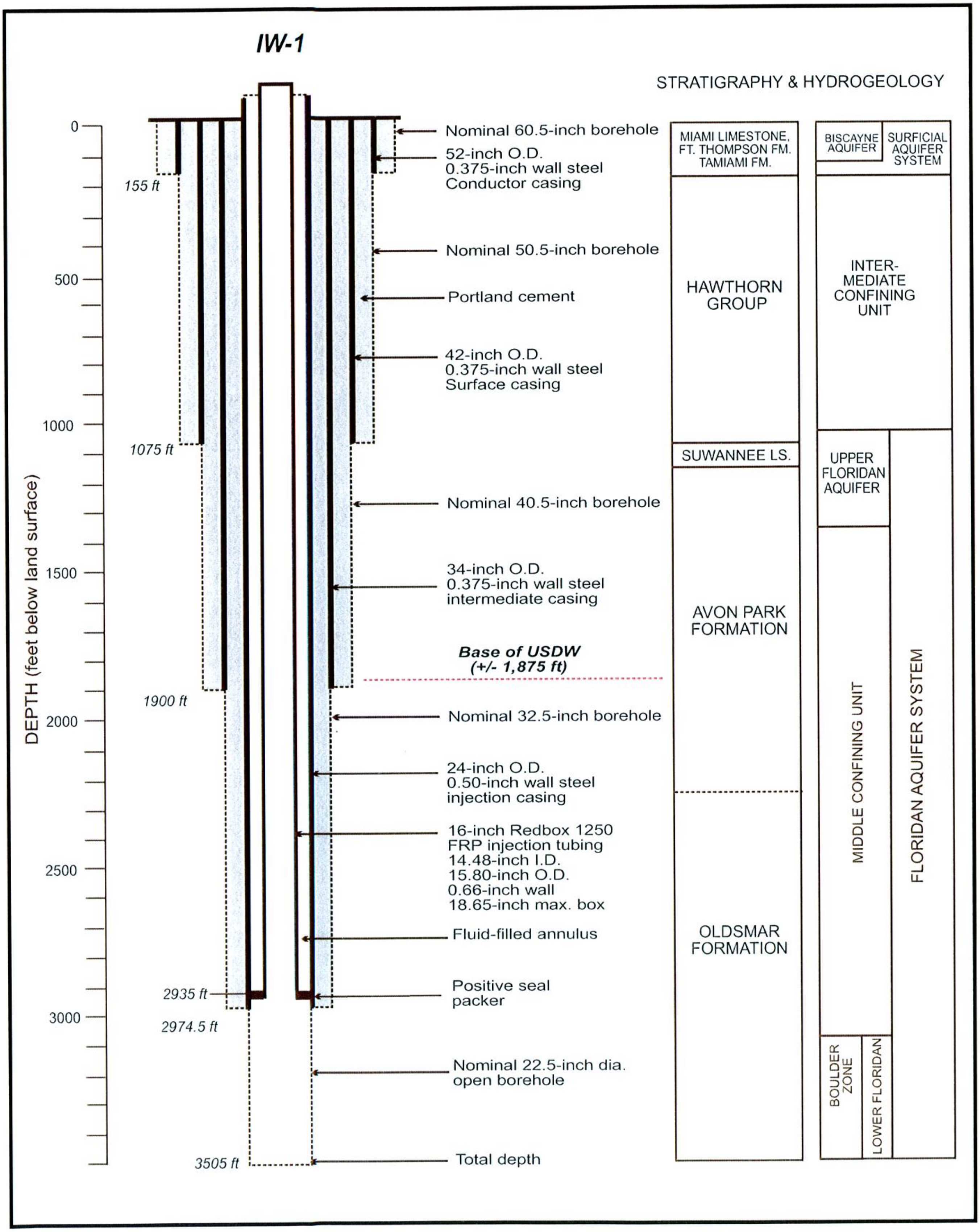


Figure 3-1
City of Hialeah Injection Well System
As-Built Construction Diagram of Injection Well IW-1

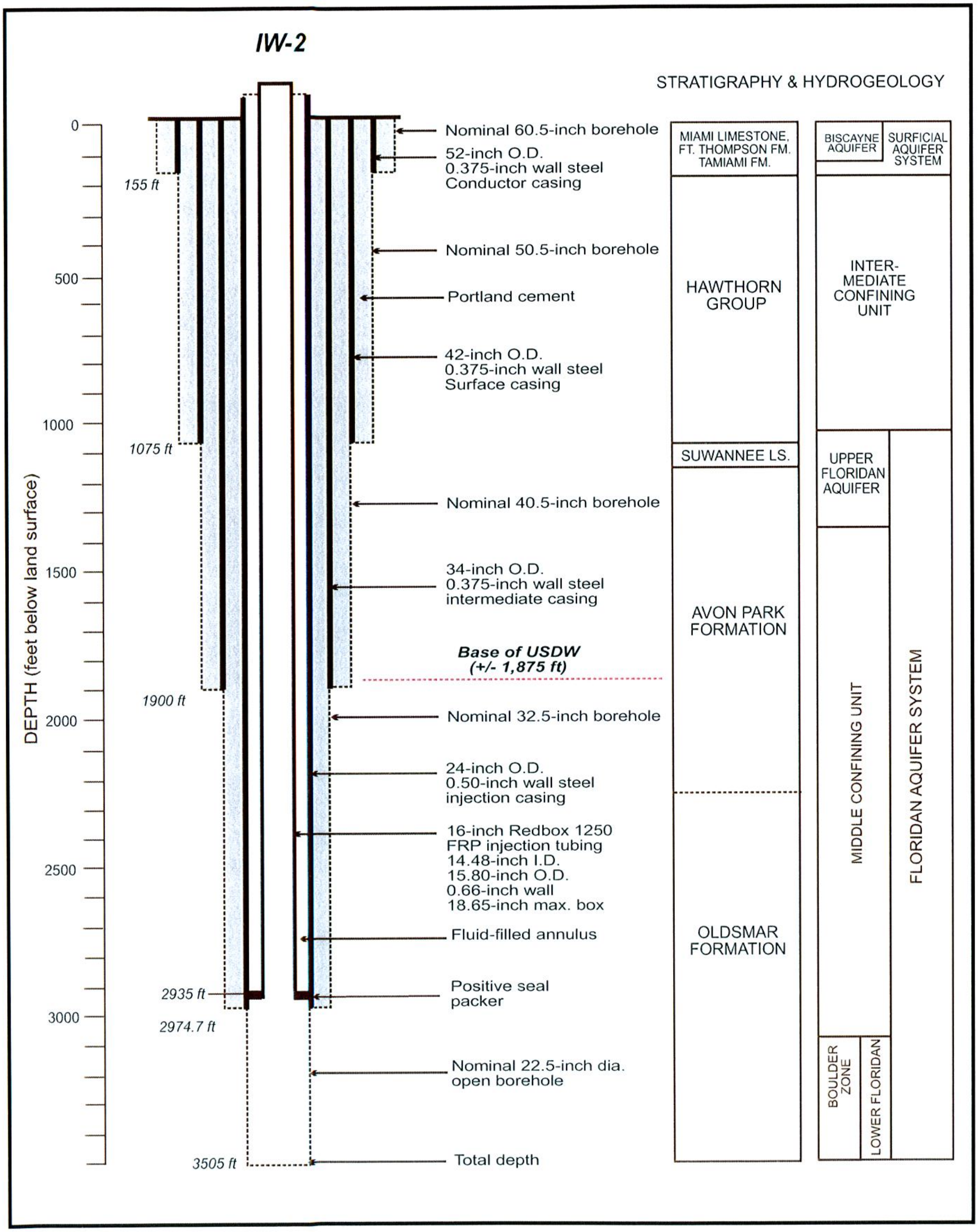


Figure 3-2
City of Hialeah Injection Well System
As-Built Construction Diagram of Injection Well IW-2

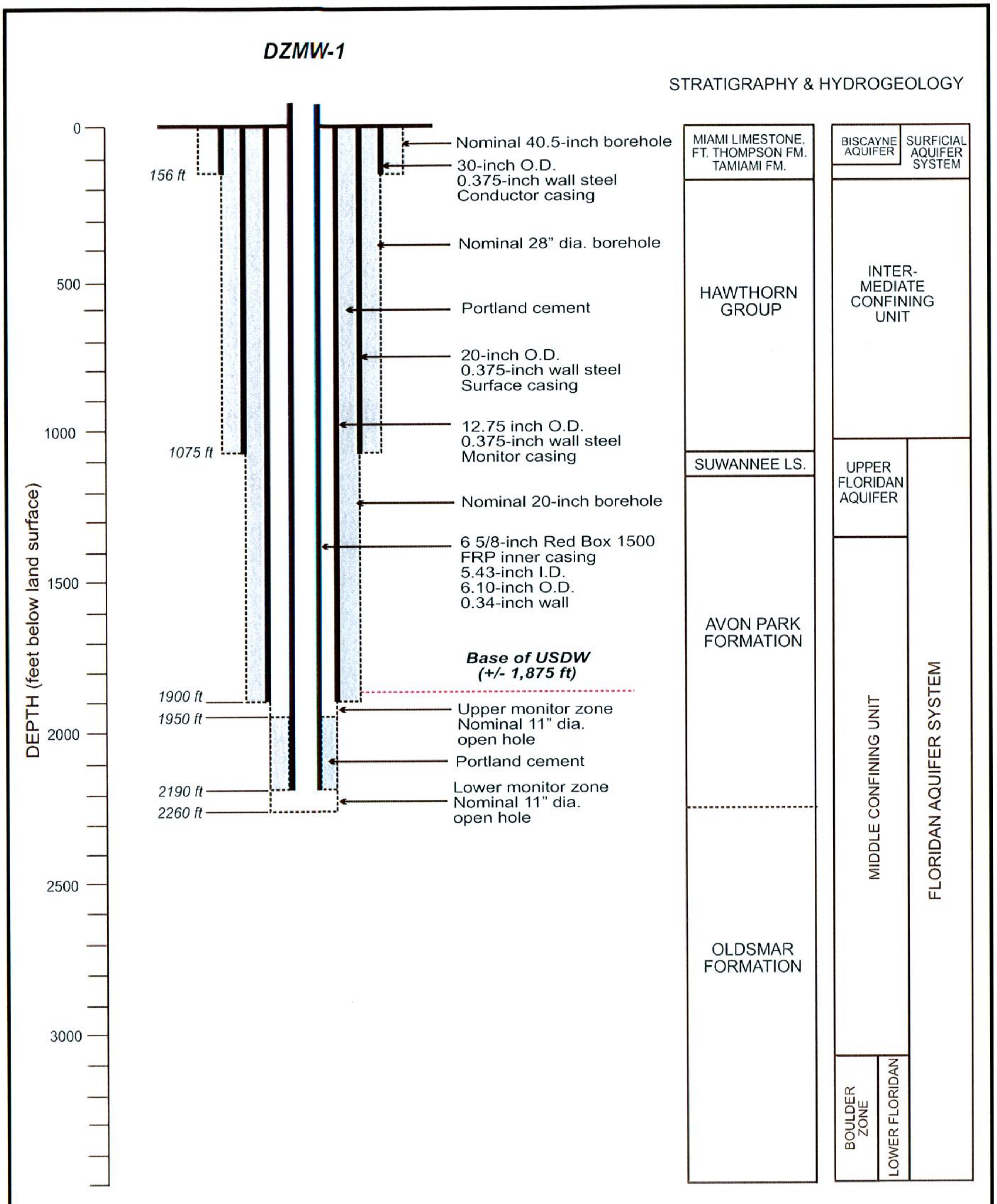


Figure 3-3
City of Hialeah Injection Well System
As-Built Construction Diagram of Dual-Zone Monitor Well DZMW-1

Services, Inc. of Fort Lauderdale, Florida. The pad monitor wells were numbered consecutively with numbers 1 through 8 and surveyed to the nearest 0.01 foot NAVD 88. An exhibit showing the pad monitor well numbering, elevations, and completion reports are provided in **Appendix G**.

3.3 Injection Well IW-1 Construction

Drilling of IW-1 began on November 7, 2009, when a 60.5-inch diameter borehole was completed to a depth of 160 ft bpl. A 52-inch diameter steel conductor casing was then cemented in place to a depth of 155 ft bpl. A 12.25-inch diameter pilot hole was advanced to 1,100 ft bpl, which was subsequently reamed to a 50-inch diameter borehole to 1,079 ft bpl. A 42-inch diameter surface casing was then cemented in place at a depth of 1,075 ft bpl. The 12.25-inch diameter pilot hole was advanced to 2,156 ft bpl, which was subsequently reamed to a 40.5-inch diameter borehole to a depth of 1,905 ft bpl. A 34-inch diameter intermediate casing was then installed to a depth of 1,900 ft bpl. The 12.25-inch diameter pilot hole was advanced to 3,500 ft bpl, which was subsequently reamed to a 32.5-inch diameter borehole to a depth of 2,970 ft bpl and a 22-inch diameter borehole from 2,970 ft bpl to 3,505 ft bpl. A 24-inch diameter steel injection casing was cemented in place to a depth of 2,975 ft bpl at the top of the injection zone. The casing seat depth for the injection casing is located above the highest significant fracturing in the Boulder Zone. A chronology of IW-1 construction and testing is provided in **Table 3-1**.

3.3.1 Casing and Wellhead

The 52-inch, 42-inch, and 34-inch diameter casings are spiral-welded carbon steel with a wall thickness of 0.375-inches that conforms to either API 5L Grade B or Spiral Weld A 139 Grade B standards. The 24-inch diameter injection casing is seamless carbon steel that conforms to ASTM A 53 Grade B standards. Copies of the mill certificates are included in **Appendix F** and casing tally sheets are provided in **Appendix H**. A casing summary for IW-1 is provided in **Table 3-2**. Casing heat numbers were checked against the mill certificates prior to installation.

Casing ends were beveled for butt welding by certified welders. All casings were fitted with centralizers, fabricated by YBI, by welding at 0, 90, 180, and 270 degrees around the casing at each position. Centralizers were installed at 20, 40, and 100 ft above the bottom of the casing, and at 100-foot intervals thereafter up to 100 ft from ground surface, or alternative intervals determined by examination of the caliper logs.

High-strength fiberglass tubing (Red Box 1250), with an outside and inside diameter of 15.8 and 14.48-inches, was installed inside the 24-inch injection casing of wells IW-1 and IW-2. The base of the fiberglass tubing was seated to a depth of 2,935 ft bpl, inside the 24-inch injection casing of IW-1, using an YBI positive seal packer. An exhibit showing construction of the positive seal packer is provided in **Appendix F**. The seat of the fiberglass tubing was located 40 ft inside the base of the 24-inch injection casing.

Table 3-1 IW-1 Construction and Testing Chronology	
Date	**Event**
November 7 to 10, 2009	Drill nominal 60.5-inch borehole 0 to 160 ft bpl.
November 11, 2009	Run geophysical logs on 60.5-inch borehole from 0 to 160 ft bpl.
November 11, 2009	Weld, lower, and cement 52-inch casing 0 to 155 ft bpl.
November 12 to 14, 2009	Drill nominal 12.25-inch pilot hole 160 to 1,100 ft bpl.
November 15, 2009	Run geophysical logs on 12.25-inch pilot hole from 160 to 1,100 ft bpl.
November 16 to 23, 2009	Ream nominal 50.5-inch borehole 155 to 1,079 ft bpl.
November 23 to 25, 2009	Run short trips to condition borehole.
November 26, 2009	Run caliper and gamma ray geophysical logs on reamed borehole from 155 to 1,079 ft bpl.
November 27, 2009	Weld and lower 42-inch casing from surface to 1,075 ft.
November 27 to 29, 2009	Cement 42-inch casing to surface.
Nov 29 to Dec 1, 2009	Covert rig from mud-rotary to reverse-air.
December 1 to 5, 2009	Drill nominal 12.25-inch pilot hole 1,079 to 2,156 ft bpl.
December 5 to 7, 2009	Run geophysical logs on pilot hole from 1,075 to 2,156 ft bpl.
December 7 to 10, 2009	Run Packer Test No. 1, 2 and 3.
December 11 to 12, 2009	Cement pilot hole.
December 13 to 20, 2009	Ream nominal 40.5-inch borehole 1,079 to 1,905 ft bpl.
December 21 to 26, 2009	Rig inactive over Holiday.
December 27, 2009	Run caliper and gamma ray log on 40.5-inch borehole 1,075 to 1,905 ft bpl.
December 27 to 28, 2009	Weld and lower 34-inch casing to 1,900 ft bpl.
December 28 to 31, 2009	Cement 34-inch casing to surface.
January 1 to 23, 2010	Drill nominal 12.25-inch pilot hole to 3,500 feet bpl and drill core no. 1-5.
January 24 to 25, 2010	Run geophysical logs on pilot hole from 1,900 to 3,500 ft bpl
January 26 to 28, 2010	Run Packer Test No. 4, 5, and 6.
January 29, 2010	Set bridge plug at 3,022 to 3,030 ft bpl.
Jan 30 to February 1, 2010	Cement pilot hole from 3,030 to 1,943 ft bpl.
February 1 to 16, 2010	Ream nominal 32.5-inch borehole 1,900 to 2,970 ft bpl.
February 17, 2010	Step borehole from 32.5-inch to 22.5-inch diameter (2,970 to 2,974 ft bpl).
Feb 18 to March 4, 2010	Ream nominal 22.5-inch borehole 2,974 to 3,500 ft bpl.
March 4, 2010	Run caliper and gamma ray logs on 32.5 and 22.5-inch intervals.
March 5, 2010	Break down drill pipe.
March 6 to 7, 2010	Weld and lower 24-inch casing to 2,975 ft bpl.
March 8 to 15, 2010	Cement 24-inch casing.
March 16, 2010	Pressure test 24-inch casing.
March 17 to 18, 2010	Install Fiber-Reinforced Pipe (FRP) injection casing.
March 19, 2010	Pump Barracore and seat FRP injection casing.
March 20 to 24, 2010	Develop and sample injection zone.
March 25, 2010	Drilling rig activities completed.
May 13, 2010	Conduct annular pressure test.
May 15 to May 18, 2010	Conduct injection test.
May 18, 2010	Run video log.
May 19, 2010	Run radioactive tracer survey.

Table 3-2 IW-1 Casing Summary

Diameter (inches)	Wall (inches)	Depth (ft bpl)	Type	Source
52	0.375	155	ASTM A139 Grade B	Yieh Corporation Ltd.
42	0.375	1075	ASTM A139 Grade B API 5L/API 2B	Yieh Corporation Ltd. Canadian Phoenix Steel Prod. Arcelor Mittal (Romania)
34	0.375	1900	ASTM A139 Grade B API 5L/API 2B	Cangzhou Steel Pipe Co., Ltd Canadian Phoenix Steel Prod. Arcelor Mittal (Romania)
24	0.50	2975	ASTM A53/A106/API 5L Grade B	Tenaris Cangzhou Qiancheng Steel Pipe Co., Ltd Waxi Dexin Steel Tube Co., Ltd. Waxi Zhenda Special Steel Tube Manufacturing Co., Ltd.
16	0.66	2933	ASTM D2996 ASTM D2310	Future Pipe Industries (Wenzhou Baofeng Special Steel Co, Ltd; stainless steel)

The annulus between the 24-inch injection casing and 16-inch fiberglass tubing is fluid filled with a 1.019 % solution of corrosion inhibitor, Baracor® 100.

A wellhead detail for well IW-1 is provided in **Appendix F**. The top section of the 16-inch diameter injection tubing is finished with 316L schedule 40 stainless steel pipe. The finished wellhead elevations are provided in the survey, which is provided in **Appendix F**.

3.3.2 Cementing Program

Casings were cemented in place with ASTM Type II (high sulfate resistance) Portland cement. The first cement stage for the 52-inch conductor, 42-inch surficial and 34-inch intermediate casings were pressure grouted, with all subsequent cement stages emplaced using the tremie pipe method. A triple seal packer was set at the base of the 24-inch injection casing, which was cemented in place using the tremie pipe method. Cement emplaced at the bottom 100 ft (approximately) of the 42-inch surface and 34-inch intermediate casing and bottom 200 ft of the 24-inch injection casing were neat. The remainder of the annulus for 52-inch conductor, 42-inch surface, and 34-inch intermediate casings were cemented with 12% bentonite (gel) cement. The remainder of the annulus around the 24-inch injection casing was cemented with 6% bentonite (gel) cement. A 3% calcium chloride ($CaCl_2$) mixture was added during cementing through a lost circulation zone between 2,030 and 2,412 ft bpl. The use of $CaCl_2$ was approved by the FDEP on February 3, 2010 for the lost circulation zone. A temperature log was run after the cement stages to verify the presence of cement throughout the interval and to locate the top of the cemented annulus. The FDEP gave approval on February 3, 2010 to forgo temperature logging during cementing of the 24-inch injection casing through the lost circulation zone due to the increased number of stages. The top of the cement was also measured by tagging with cement tubing, including the lost circulation zone. A summary of the IW-1 casing cement program is provided in **Table 3-3**. Copies of the cement stage logs are provided in **Appendix I**.

Table 3-3 IW-1 Casing Cement Summary

Stage No.	Date	Cement Mixture	Barrels pumped	Cubic ft pumped	Sacks pumped	Tag Depth (ft bpl)	Ft of fill
52-inch diameter conductor casing							
1	11/11/2009	12% gel	106	594	270	0	160
		Neat	88	492	418		
42-inch diameter surface casing							
1	11/28/2009	12% gel	262	1,467	667	439	636
		Neat	118	661	560		
2	11/29/2009	12% gel	461	2,582	1,173	0	439
34-inch diameter intermediate casing							
1	12/28/2009	12% gel	175	980	446	1,580	320
		Neat	121	678	574		
2	12/29/2009	12% gel	187	1,047	476	1,402	178
3	12/29/2009	12% gel	160	896	407	1,206	196
4	12/30/2009	12% gel	206	1,154	524	1,018	188
5	12/30/2009	12% gel	274	1,534	697	525	493
6	12/31/2009	12% gel	296	1,658	753	0	525
24-inch diameter injection casing							
1	3/10/2010	Neat	100	560	475	2,878	80
2	3/10/2010	Neat	105	588	498	2,787	91
3	3/11/2010	Neat	25	140	119	2,650	137
		6% gel	116	650	375		
4	3/11/2010	6% gel	100	560	324	2,517	133
5	3/12/2010	6% gel	120	672	388	2,461	56
6	3/12/2010	3% $CaCl_2$	30	168	142	2,412	49
7	3/12/2010	3% $CaCl_2$	30	168	142	2,364	48
8	3/12/2010	3% $CaCl_2$	30	168	142	2,319	45
9	3/12/2010	3% $CaCl_2$	30	168	142	2,266	53
10	3/13/2010	6% gel	222	1,243	719	2,030	236
11	3/13/2010	6% gel	157	879	508	1,835	195
12	3/14/2010	6% gel	260	1,456	842	1,370	465
13	3/14/2010	6% gel	285	1,599	924	877	493
14	3/15/2010	6% gel	301	1,689	976	326	551
15	3/17/2010	6% gel	175	982	567	0	326

3.3.3 Inclination Surveys

Inclination refers to the degree of deviation of the borehole from a true vertical alignment. The drilling of a straight, vertical borehole is critical for the proper setting and cementing of casings at their required depth. Inclination surveys were performed at 90 foot intervals during the drilling of pilot holes and reamed holes for casings. The 90 foot survey interval met the FDEP deviation survey requirement (Rule 62-528.410 (3) (a), FAC.

The FDEP requirement specifies that the maximum allowable inclination from the vertical at any portion of a hole or survey point is one degree. The Technical Specifications for the well construction also requires that the maximum allowable difference between any two successive survey points is 0.5 degree (30 minutes). The maximum inclination recorded during the drilling of IW-1 was 0.75 degrees in a pilot hole at a depth of 1,165 ft bpl. The difference between this survey point and successive survey point was 0.5 degrees. Well IW-1 thus met the inclination survey requirements and has an acceptable vertical alignment. The inclination survey data are compiled in **Appendix J.**

3.3.4 Pad Monitor Well Data

Monitoring of water quality and elevation measurements was completed using four pad monitor wells referred to as PMW-5, PMW-6, PMW-7, and PMW-8, which surround well IW-1. Monitoring was performed prior to the start of injection well construction on November 5, 2009, each week during injection well construction (29 weeks total), and one week after complete demobilization on June 5, 2010. At the request of the FDEP, monitoring of the pad monitor wells continues monthly. The water quality and elevation monitoring data for the four pad monitor wells are compiled in **Appendix G**. The salinity in the monitor wells has fluctuated over the monitoring periods, but there is no evidence that well construction activities have had a significant adverse impact on the water table aquifer.

3.4 Injection Well IW-2 Construction

Drilling of IW-2 began on November 18, 2009, when a 60.5-inch diameter borehole was completed to a depth of 158 ft bpl. A 52-inch diameter steel conductor casing was then cemented in place to a depth of 155 ft bpl. A 50.5-inch diameter borehole was advanced to 1,082 ft bpl. A 42-inch diameter surface casing was then cemented in place at a depth of 1,075 ft bpl. A 12.25-inch diameter pilot hole was advanced to 1,940 ft bpl, which was subsequently reamed to a 40.5-inch diameter borehole to a depth of 1,905 ft bpl. A 34-inch diameter casing was then installed to a depth of 1,900 ft bpl. The 12.25-inch diameter pilot hole was advanced to 3,500 ft bpl, which was subsequently reamed to a 32.5-inch diameter borehole to a depth of 2,970 ft bpl and a 22-inch diameter borehole from 2,970 ft bpl to 3,505 ft bpl. A 24-inch diameter steel injection casing was cemented in place to a depth of 2,975 ft bpl at the top of the injection zone. The casing seat depth for the injection casing is located above the highest significant fracturing in the Boulder Zone. A chronology of IW-2 construction and testing is provided in **Table 3-4**.

Table 3-4 IW-2 Construction Chronology

Date	**Event**
November 4, 2009	Install pad monitoring wells.
November 18 to 19, 2009	Drill nominal 60.5-inch borehole 0 to 158 ft bpl.
November 19, 2009	Run geophysical logs on 60.5-inch borehole from 0 to 158 ft bpl.
November 20, 2009	Weld, lower, and cement 52-inch casing 0 to 155 ft bpl.
November 21 to 28, 2009	No rig activity because 50.5-inch bit in use on IW-1
Nov 29 to December 10, 2009	Drill nominal 50.5-inch borehole 155 to 1,082 ft bpl.
December 11, 2009	Run geophysical logs on 50.5-inch borehole from 155 to 1,082 ft bpl.
December 13, 2009	Weld, lower, and cement 42-inch casing from 1,075 ft bpl to surface.
December 14 to 15, 2009	Convert rig from mud-rotary to reverse-air.
December 16 to 18, 2009	Drill nominal 12.25-inch pilot hole from 1,082 to 1,940 ft bpl.
December 19, 2009	Run geophysical logs on 12.25-inch pilot hole from 1,082 to 1,940 ft.
December 20, 2009	Run Packer Test No. 1 (1,884 to 1,901 ft bpl).
December 21 to 22, 2009	Cement 12.25-inch pilot hole from 1,159 to 1,940 ft bpl.
December 23 to 26, 2009	Rig inactive over Holiday.
December 26 to 29, 2009	No rig activity while waiting on 40.5-inch bit and rig repairs.
Dec 30, 2009 to Jan 7, 2010	Ream nominal 40.5-inch borehole 1,082 to 1,905 ft bpl.
January 8 to 11, 2010	No rig activity while waiting on 34-inch casing to arrive.
January 11, 2010	Run caliper and gamma ray logs on 40.5-inch borehole 1,080 to 1,905 ft bpl.
January 12, 2010	Weld and lower 34-inch casing from 1,905 ft bpl to surface.
January 13 to 16, 2010	Cement 34-inch casing to surface.
Jan 17 to Feb 6, 2010	Drill nominal 12.25-inch pilot hole 1,905 to 3,500 ft bpl and drill core no. 1 – 5.
February 7, 2010	Run geophysical logs on pilot hole from 1,905 to 3,500 ft bpl
February 8 to 11, 2010	Run Packer Test No. 2, 3, and 4.
February 12 , 2010	Set bridge plug at 3,010 to 3,028 ft bpl.
February 12 to 14, 2010	Cement pilot hole from 3,028 to 1,970 ft bpl.
February 15 to March 1, 2010	Ream nominal 32.5-inch borehole 1,900 to 2,970 ft bpl.
March 1 to 2, 2010	Step borehole from 32.5-inch to 22.5-inch diameter from 2,970 to 2,974 ft bpl.
March 2 to 17, 2010	Ream nominal 22.5-inch borehole 2,974 to 3,505 ft bpl.
March 18, 2010	Break down drill pipe.
March 19, 2010	Run caliper and gamma ray log on 32.5 and 22.5-inch borehole intervals.
March 20 to 24, 2010	Weld and lower 24-inch casing to 2,975 ft bpl, run preliminary pressure test.
March 25 to April 1, 2010	Cement 24-inch casing.
April 2 to 4, 2010	Rig inactive.
April 5, 2010	Pressure test 24-inch casing.
April 6, 2010	Rig inactive.
April 7 to 8, 2010	Thread and lower Fiber Reinforced Pipe (FRP) injection casing.
April 19, 2010	Seat FRP injection casing and pump corrosion inhibitor.
April 10, 2010	Develop injection zone.
April 11, 2010	Drill rig activities completed.
April 13, 2010	Run video log.
April 27, 2010	Built up wellhead to final grade.
May 5, 2010	Pressure test annulus.
May 10 to May 13, 2010	Conduct injection test.
May 13, 2010	Run radioactive tracer survey.

3.4.1 Casing and Wellhead

The 52-inch, 42-inch, and 34-inch diameter casings are spiral-welded carbon steel with a wall thickness of 0.375-inches that conform to API 5L Grade B or Spiral Weld A 139 Grade B standards. The 24-inch diameter injection casing is composed of seamless carbon steel that conforms to ASTM A 53 Grade B standards. Copies of the mill certificates are included in **Appendix F** and casing tally sheets are provided in **Appendix H**. A casing summary is provided in **Table 3-5**. Casing heat numbers were checked against the mill certificates prior to installation.

Table 3-5 IW-2 Casing Summary

Diameter (inches)	Wall (inches)	Depth (ft bpl)	Type	Source
52	0.375	155	ASTM A139 Grade B	Yieh Corporation Ltd.
42	0.375	1,075	ASTM A139 Grade B	Yieh Corporation Ltd. Canadian Phoenix Steel Prod. Arcelor Mittal (Romania)
34	0.375	1,900	ASTM A139 Grade B API 5L/API 2B	Cangzhou Steel Pipe Co., Ltd Canadian Phoenix Steel Prod. Arcelor Mittal (Romania)
24	0.50	2,975	ASTM A53/A106/API 5L Grade B	Tenaris Cangzhou Qiancheng Steel Pipe Co., Ltd Waxi Dexin Steel Tube Co., Ltd. Waxi Zhenda Special Steel Tube Manufacturing Co., Ltd.
16	0.66	2,935	ASTM D2996 ASTM D2310	Future Pipe Industries (Wenzhou Baofeng Special Steel Co, Ltd; stainless steel)

Casing ends were beveled for butt welding by certified welders. All casings were fitted with centralizers, fabricated by YBI, by welding at 0, 90, 180, and 270 degrees around the casing at each position. Centralizers were installed at 20, 40, and 100 ft above the bottom of the casing, and at 100-foot intervals thereafter up to 100 ft from ground surface, or alternative intervals determined by examination of the caliper logs.

The base of the fiberglass tubing was seated to a depth of 2,935 ft bpl, inside the 24-inch injection casing, using an YBI positive seal packer. An exhibit showing construction of the positive seal packer is provided in **Appendix F**. The seat of the fiberglass tubing was located 40 ft inside the base of the 24-inch injection casing. The annulus between the 24-inch injection casing and 16-inch fiberglass tubing is fluid filled with a 1.019 % solution of corrosion inhibitor, Baracor® 100.

A wellhead detail for well IW-2 is provided in **Appendix F**. The top section of the 16-inch tubing is finished with 316L schedule 40 stainless steel pipe. The finished wellhead elevations are provided in the survey, which is located in **Appendix F**.

3.4.2 Cementing Program

Casings were cemented in place with ASTM Type II (high sulfate resistance) Portland cement. A copy of the cement mill certificate is provided in **Appendix I**. The first cement stage for the 52-inch conductor, 42-inch surficial and 34-inch intermediate casings were pressure grouted, with all subsequent cement stages emplaced using the tremie pipe method. A triple seal packer was set at the base of the 24-inch injection casing, which was cemented in place using the tremie pipe method. Cement emplaced at the bottom 100 ft (approximately) of the 42-inch surface and 34-inch intermediate casings and bottom 200 ft of the 24-inch injection casing were neat. The remainder of the annulus for the 52-inch conductor, 42-inch surface, and 34-inch intermediate casings were cemented with 12% bentonite (gel) cement. The remainder of the annulus around the 24-inch injection casing was cemented with 6% bentonite (gel) cement. A 3% calcium chloride ($CaCl_2$) mixture was added during cementing through a lost circulation zone between 2,291 and 2,439 ft bpl. The top of the cement was tagged with cement tubing, including the lost circulation zone between 2,291 and 2,439 ft bpl. A summary of the casing cement program is provided in **Table 3-6**. Copies of the cement stage logs are provided in **Appendix I**.

3.4.3 Inclination Surveys

Inclination surveys were performed at 90 foot intervals during the drilling of pilot holes and reamed holes for casings. The 90 foot survey interval met the FDEP deviation survey requirement (Rule 62-528.410 (3) (a), FAC. The maximum inclination recorded during the drilling of IW-2 was 0.375 degrees in a pilot hole at a depth of 90 ft bpl. The inclination of the successive survey point was <0.25 degree. IW-2 thus met the inclination survey requirements and has an acceptable vertical alignment. The inclination survey data are compiled in **Appendix J**.

3.4.4 Pad Monitor Well Data

Monitoring of water quality and elevation measurements was completed using four pad monitor wells referred to as PMW-1, PMW-2, PMW-3, and PMW-4, which surround well IW-2. Monitoring was performed prior to the start of injection well construction on November 5, 2009, each week during injection well construction (29 weeks total), and one week after complete demobilization on June 5, 2010. At the request of the FDEP, monitoring of the pad monitor wells continues monthly. The water quality and elevation monitoring data for the four pad monitor wells are compiled in **Appendix G**. The salinity in the monitor wells has fluctuated over the monitoring periods, but there is no evidence that well construction activities have had a significant adverse impact on the water table aquifer.

Table 3-6 Injection well IW-2 casing cement summary

Stage No.	Date	Cement Mixture	Barrels pumped	Cubic ft pumped	Sacks pumped	Tag Depth (ft bpl)	Ft of fill
52-inch diameter casing							
1	11/20/2009	12% gel	60	336	153	0	158
		Neat	137	770	652		
42-inch diameter casing							
1	12/13/2009	12% gel	450	2,520	1,145	282	788
		Neat	105	588	498		
2	12/13/2009	12% gel	248	1,389	631	0	282
34-inch diameter casing							
1	1/13/2010	12% gel	144	808	367	1,644	256
		Neat	141	792	671		
2	1/14/2010	12% gel	205	1,148	522	1,428	216
3	1/14/2010	12% gel	184	1,030	468	1,269	159
4	1/15/2010	12% gel	207	1,162	528	1,084	185
5	1/15/2010	12% gel	323	1,809	822	493	591
6	1/16/2010	12% gel	284	1,595	725	0	493
24-inch diameter casing							
1	3/26/2010	Neat	120	672	570	2,875	79
2	3/27/2010	Neat	112	627	532	2,812	63
3	3/27/2010	Neat	25	140	119	2,676	136
		6% gel	84	470	272		
4	3/28/2010	6% gel	100	560	324	2,550	126
5	3/28/2010	6% gel	77	431	249	2,486	64
6	3/29/2010	3% $CaCl_2$	30	168	142	2,439	47
7	3/29/2010	3% $CaCl_2$	30	168	142	2,413	26
8	3/29/2010	3% $CaCl_2$	30	168	142	2,359	54
9	3/29/2010	3% $CaCl_2$	30	168	142	2,337	22
10	3/29/2010	3% $CaCl_2$	30	168	142	2,291	46
11	3/29/2010	6% gel	120	672	388	2,148	143
12	3/30/2010	6% gel	175	980	566	1,965	183
13	3/30/2010	6% gel	260	1,456	842	1,543	422
14	3/31/2010	6% gel	320	1,792	1,036	951	592
15	3/31/2010	6% gel	338	1,893	1,094	328	623
16	4/2/2010	6% gel	175	980	566	0	328

3.4.3 Inclination Surveys

Inclination surveys were performed at 90 foot intervals during the drilling of pilot holes and reamed holes for casings. The 90 foot survey interval met the FDEP deviation survey requirement (Rule 62-528.410 (3) (a), FAC. The maximum inclination recorded during the drilling of IW-2 was 0.375 degrees in a pilot hole at a depth of 90 ft bpl. The inclination of the successive survey point was <0.25 degree. IW-2 thus met the inclination survey requirements and has an acceptable vertical alignment. The inclination survey data are compiled in **Appendix J.**

3.4.4 Pad Monitor Well Data

Monitoring of water quality and elevation measurements was completed using four pad monitor wells referred to as PMW-1, PMW-2, PMW-3, and PMW-4, which surround well IW-2. Monitoring was performed prior to the start of injection well construction on November 5, 2009, each week during injection well construction (29 weeks total), and one week after complete demobilization on June 5, 2010. At the request of the FDEP, monitoring of the pad monitor wells continues monthly. The water quality and elevation monitoring data for the four pad monitor wells are compiled in **Appendix G**. The salinity in the monitor wells has fluctuated over the monitoring periods, but there is no evidence that well construction activities have had a significant adverse impact on the water table aquifer.

3.5 Dual-Zone Monitor Well DZMW-1 Construction

Drilling of well DZMW-1 began on March 26, 2010, when a 40.5-inch diameter borehole was completed to a depth of 161 ft bpl. A 30-inch diameter steel conductor casing was then cemented in place to a depth of 156 ft bpl. A 28.5-inch diameter borehole was advanced to 1,079 ft bpl. A 20-inch diameter casing was then cemented in place at a depth of 1,075 ft bpl. A 12.25-inch diameter pilot hole was advanced to 1,940 ft bpl, which was subsequently reamed to an 18.5-inch diameter borehole to a depth of 1,900 ft bpl. A 12.75-inch diameter casing was then installed to a depth of 1,900 ft bpl. An 11-inch borehole was advanced to 2,260 ft bpl and a 6.625-inch fiberglass casing was cemented between 2,190 and 1,950 ft bpl. A chronology of DZMW-1 construction and testing is provided in **Table 3-7**.

3.5.1 Casing and Wellhead

The 30-inch, 20-inch, and 12.75-inch diameter casings are spiral-welded carbon steel with a wall thickness of 0.375-inches that conform to API 5L Grade B, ASTM A 53 Grade B or Spiral Weld A 139 Grade B standards. The 6.625-inch diameter fiberglass casing conforms to ASTM D2996 and D2310 standards. Copies of the mill certificates are included in **Appendix F** and casing tally sheets are provided in **Appendix H**. A casing summary is provided in **Table 3-8**. Casing heat numbers were checked against the mill certificates prior to installation.

Steel casing ends were beveled for butt welding by certified welders. All casings were fitted with centralizers, fabricated by YBI, by welding at 0, 90, 180, and 270 degrees around the casing at each position. Centralizers were installed at 20, 40, and 100 ft above the bottom of the casing, and at 100-foot intervals thereafter up to 100 ft from ground surface, or alternative intervals determined by examination of the caliper logs.

Table 3-7 DZMW-1 Construction Chronology	
Date	**Event**
March 23 to 25, 2010	Mobilize and install temporary drilling pad.
March 26 to 28, 2010	Drill 40.5-inch borehole from 0 to 161 ft bpl using mud-rotary method.
March 28, 2010	Run caliper and gamma ray logs, weld and lower 30-inch casing, cement 30-inch casing.
March 29, 2010	Run temperature log.
Mar 30 to Apr 4, 2010	Drill 28.5-inch borehole from 161 to 1,079 ft bpl using mud rotary method.
April 5, 2010	Circulate to condition borehole, run caliper and gamma ray logs.
April 6, 2010	Weld and lower 20-inch casing.
April 7, 2010	Cement 20-inch casing.
April 7, 2010	Run temperature log.
April 8 to 10, 2010	Drill 12.25-inch pilot hole 1,079 to 1,940 ft bpl using reverse-air method.
April 11, 2010	Run full suite of geophysical logs.
April 12, 2010	Run Packer Test No 1 on interval 1,900 to 1,940 ft bpl.
April 13 to 15, 2010	Ream 18.5-inch borehole 1,079 to 1,900 ft bpl.
April 16, 2010	Run caliper and gamma ray logs.
April 17, 2010	Weld and lower 47 joints of 12.75-inch casing 0 - 1,900 ft bpl.
April 18 to 20, 2010	Cement 12.75-inch casing.
April 20, 2010	Run temperature log after each cement stage.
April 21 to 23, 2010	Drill 11-inch borehole 1,940 to 2,260 ft bpl.
April 24, 2010	Run geophysical logs on interval from 1,900 to 2,260 ft bpl.
April 25, 2010	Run Packer Test No 2 on interval from 2,210 to 2,260 ft bpl.
April 26, 2010	Conduct preliminary pressure test on 12.75-inch casing.
April 27, 2010	Conduct final pressure test on 12.75-inch casing.
April 30, 2010	Install 6.625-inch FRP casing.
May 1 to 3, 2010	Cement 6.625-inch casing from 2,190 to 1,950 ft bpl.
May 4, 2010	Run video log.
May 5, 2010	Pressure test 6.625-inch casing.
May 6, 2010	Built up wellhead to final elevation.
May 10, 2010	Purge and sample water quality of upper and lower monitoring zones.

Table 3-8 DZMW-1 Casing Summary				
Diameter (inches)	**Wall (inches)**	**Depth (ft bpl)**	**Type**	**Source**
30	0.375	155	ASTM A139	Yieh Corporation Ltd.
20	0.375	1,070	APL 5L B/ASTM A53-B	Tianjin Shuangjie
12.75	0.375	1,900	APL 5L B ASTM A53-06	Huludao Steel Pipe Interpipe NMPP
6.625	0.34	2,191	ASTM D2996 ASTM D2310	Future Pipe Industries

3.5.2 Cementing Program

Sulfate-resistant cement (ASTM Type II) was used for all cementing of casings and hole plugging. The first cement stage for the 30-inch conductor, 20-inch surface and 12.75-inch monitor casings were pressure grouted, with all subsequent cement stages emplaced using the tremie pipe method. Cement emplaced at the bottom 100 ft (approximately) of the 30-inch conductor and 20-inch surface casings and bottom 200 ft of the 12.75-inch monitor well casing were neat. The remainder of the annulus for the 30-inch conductor and 20-inch surface casings was cemented with 12% bentonite (gel) cement. The remainder of the annulus around the 12.75-inch monitor casing was cemented with 6% bentonite (gel) cement. A short section of the 6.625-inch inner casing was cemented between 1,950 and 2,190 ft bpl using neat cement. The top of the cement was tagged with cement tubing after each stage. A summary of the casing cement program is provided in **Table 3-9**. Copies of the cement stage logs are provided in **Appendix I**.

Table 3-9 DZMW-1 Casing Cement Summary

Stage No.	Date	Cement Mixture	Barrels pumped	Cubic ft pumped	Sacks pumped	Tag Depth (ft bpl)	Ft of fill
30-inch diameter casing							
1	03/29/10	12% gel	45	252	115	0	157
		Neat	127	711	602		
20-inch diameter casing							
1	04/07/10	12% gel	325	1,820	827	0	1,075
		Neat	116	650	551		
12.75-inch diameter casing							
1	04/18/10	Neat	54	302	256	1,680	201
2	04/19/10	6% gel	100	560	324	1,417	263
3	04/19/10	6% gel	115	644	372	1,214	203
4	04/20/10	6% gel	120	672	388	861	353
5	04/20/10	6% gel	189	1058	612	0	861
6.625-inch diameter casing							
1	05/01/2010	Neat	18	101	85	2040	125
2	05/02/2010	Neat	10	56	47	1972	68
3	05/02/2010	Neat	3	17	14	1950	22

3.5.3 Inclination Surveys

Inclination surveys were performed at 90 foot intervals during the drilling of pilot holes and reamed holes for casings. The 90 foot survey interval met the FDEP deviation survey requirement (Rule 62-528.410 (3) (a), FAC). The maximum inclination recorded during the drilling of DZMW-1 was 0.30 degrees in the 28.5-inch diameter borehole at a depth of 900 ft bpl. The inclination of the successive survey point was <0.25 degree. Well DZMW-1 thus met the inclination survey requirements and has an acceptable vertical alignment. The inclination survey data are compiled in **Appendix J**.

4 Hydrogeological Testing Program

Data were collected during the drilling of wells IW-1, IW-2 and DZMW-1 on the geology and hydrogeology of the penetrated strata. The data were utilized to determine casing depths and to evaluate potential injection and confining zones.

4.1 Formation Zone Sampling

Two sets of samples were collected of the cuttings during the drilling of the pilot holes. The samples were collected at 10 ft intervals. One set of samples was shipped to the Florida Geological Survey and the other was archived by SWS. The cuttings were described on site by SWS hydrogeologists using a hand lens or magnifying glass. Selected samples were tested for mineralogy using dilute hydrochloric acid and Alizarin red stain. The geologist logs for wells IW-1, IW-2, and DZMW-1 are provided in **Appendix E.**

4.2 Formation Fluid Sampling

Water samples were collected from the discharge line every 30 ft during reverse-air drilling of the pilot hole for wells IW-1, IW-2 and DZMW-1. The objectives of reverse-air discharge sampling were to obtain data on changes in salinity with depth and to locate the base of the USDW. The reverse-air discharge samples were collected from a depth of 1,130 to 3,210 ft bpl in IW-1; 1,100 to 2,990 ft bpl in IW-2; and 1,100 to 1,920 ft bpl in DZMW-1. The samples were collected by YBI and analyzed by Florida Environmental Services, Inc. of Fort Lauderdale, Florida, for specific conductance, chloride, ammonia, and total Kjeldahl nitrogen. A summary of reverse air discharge data is provided in **Appendix K** for wells IW-1, IW-2, and DZMW-1.

The reverse-air discharge water quality data for a given depth is not necessarily representative of the formation water quality at that depth because of mixing with water produced higher in the borehole. Changes in the composition of the reverse-air discharge can provide qualitative information on formation water quality. All water produced during the drilling was confined to the closed circulation system.

Water samples were collected from the completed wells IW-1 on March 24, 2010, IW-2 on April 13, 2010, and the upper and lower zones of DZMW-1 on May 10, 2010. The samples were laboratory analyzed for the State primary and secondary drinking water standards as listed in the FDEP UIC permit. Copies of the analytical laboratory reports are provided in **Appendix K.**

4.3 Coring Program

A total of ten cores were collected between the base of the USDW and the injection zone during the drilling of wells IW-1 and IW-2. The purpose of the coring program was to evaluate the confinement above the injection zone. The cores were taken using a 4-inch diameter, 10-foot long, carbide-tipped coring barrel. A summary of the cores obtained from wells IW-1 and IW-2 are provided in **Table 4-1 and Table 4-2**, respectively. Core sample descriptions are provided in **Appendix L.**

Table 4-1 IW-1 Core Summary

Core No.	Date Cored	Interval Cored (ft bpl)	Percent Recovery
1	January 2 to 3, 2010	2,206 – 2,218	42
2	January 4 to 5, 2010	2,303 – 2,313	100
3	January 7 to 9, 2010	2,505 – 2,513	93
4	January 11 to 12, 2010	2,730 – 2,747	100
5	January 13 to 14, 2010	2,816 – 2,831	89

Table 4-2 IW-2 Core Summary

Core No.	Date Cored	Interval Cored (ft bpl)	Percent Recovery
1	January 17, 2010	1,953 – 1,968	90
2	January 19, 2010	2,050 – 2,065	92
3	January 20, 2010	2,100 – 2,108	61
4	January 22 to 24, 2010	2,432 – 2,440	80
5	January 27, 2010	2,775 – 2,786	74

Up to three samples of each core were selected by SWS for laboratory analyses to determine vertical and horizontal hydraulic conductivity, porosity, specific gravity, elastic modulus, and compressive strength. YBI subcontracted Ardaman & Associates, Inc. to perform the analyses. The results of the core analyses collected from IW-1 and IW-2 are summarized in **Table 4-3** and **Table 4-4**, respectively. A copy of the laboratory report is included in **Appendix L.**

4.4 Geophysical Logging Program

Borehole geophysical surveys are performed by lowering sensing devices attached to a wireline into the borehole and recording various physical properties of the rock penetrated by the borehole. The geophysical logging program implemented during the construction and testing of wells IW-1, IW-2 and DZMW-1 was designed to collect information on the hydrogeology of penetrated strata, data on borehole geometry and volume that would assist in the setting and cementing of casing strings and determining packer test intervals, and evaluating the integrity of the casing cements. All geophysical logs were run by the Geophysical Logging Division of YBI. SWS hydrogeologists witnessed all geophysical logging. A summary of the borehole geophysical logging of IW-1, IW-2 and DZMW-1 is provided in **Tables 4-5, 4-6,** and **4-7,** respectively. Interpretations of the geophysical logs are included in **Appendix M.** Copies of the geophysical logs for wells IW-1, IW-2 and DZMW-1 are included on the DVD attached to this completion.

Table 4-3 IW-1 Core Analysis Summary

Depth (ft bpl)	Orientation	Specific Gravity	Porosity	Hydraulic Conductivity (cm/sec)	Hydraulic Conductivity (ft/day)
2,206.5 – 2,207.1	Vertical	2.7	0.329	4.9E-06	1.4E-02
	Horizontal	2.7	0.327	6.1E-06	1.7E-02
2,708.6 – 2,209.2	Vertical	2.72	0.314	5.1E-05	1.4E-01
	Horizontal	2.72	0.305	8.7E-05	2.5E-01
2,304.5 – 2,304.9	Vertical	2.82	0.113	2.6E-09	7.4E-06
	Horizontal	2.82	0.121	4.7E-07	1.3E-03
2,306.8 – 2,307.4	Vertical	2.82	0.211	5.8E-06	1.6E-02
	Horizontal	2.82	0.215	1.0E-05	2.8E-02
2,311.8 – 2,312.4	Vertical	2.82	0.093	3.2E-06	9.1E-03
	Horizontal	2.82	0.086	2.9E-07	8.2E-04
2,507.1 – 2,507.5	Vertical	2.83	0.040	2.1E-07	6.0E-04
	Horizontal	2.83	0.035	2.9E-09	8.2E-06
2,508.6 – 2,509.0	Vertical	2.83	0.070	4.4E-10	1.2E-06
	Horizontal	2.83	0.051	4.6E-09	1.3E-05
2,510.8 – 2,511.5	Vertical	2.85	0.037	1.5E-10	4.3E-07
	Horizontal	2.85	0.036	2.4E-10	6.8E-07
2,733.9 – 2,734.3	Vertical	2.72	0.245	1.6E-04	4.5E-01
	Horizontal	2.72	0.239	1.4E-05	4.0E-02
2,743.3 – 2,743.7	Vertical	2.73	0.300	2.1E-05	6.0E-02
	Horizontal	2.73	0.317	7.9E-05	2.2E-01
2,819.4 – 2,819.9	Vertical	2.74	0.366	1.4E-04	4.0E-01
	Horizontal	2.74	0.354	2.1E-04	6.0E-01
2,827.6 – 2,828.1	Vertical	2.71	0.253	2.8E-08	7.9E-05
	Horizontal	2.71	0.256	5.6E-07	1.6E-03
2,829.8 – 2,830.2	Vertical	2.72	0.216	1.5E-08	4.3E-05
	Horizontal	2.72	0.374	3.9E-05	1.1E-01

Table 4-4 IW-2 Core Analysis Summary

Depth (ft bpl)	Orientation	Specific Gravity	Porosity	Hydraulic Conductivity (cm/sec)	Hydraulic Conductivity (ft/day)
1,955.6 – 1,956.2	Vertical	2.70	0.374	3.9E-05	1.1E-01
	Horizontal	2.70	0.367	8.1E-05	2.3E-01
1,960.4 – 1,961.1	Vertical	2.69	0.360	3.9E-06	1.1E-02
	Horizontal	2.69	0.354	1.7E-05	4.8E-02
2,053.7 – 2,354.5	Vertical	2.72	0.396	2.1E-04	6.0E-01
	Horizontal	2.72	0.393	3.7E-04	1.0E+00
2,058.9 – 2,059.5	Vertical	2.72	0.379	2.5E-04	7.1E-01
	Horizontal	2.72	0.383	6.0E-04	1.7E+00
2,062.6 – 2,063.9	Vertical	2.83	0.327	1.2E-05	3.4E-02
	Horizontal	2.83	0.318	3.1E-05	8.8E-02
2,101.3 – 2,101.7	Vertical	2.71	0.395	6.2E-05	1.8E-01
	Horizontal	2.71	0.369	2.4E-04	6.8E-01
2,102.5 – 2,102.9	Vertical	2.71	0.377	2.0E-04	5.7E-01
	Horizontal	2.71	0.373	2.4E-04	6.8E-01
2,105.9 – 2,106.4	Vertical	2.72	0.392	2.3E-05	6.5E-02
	Horizontal	2.72	0.389	1.7E-04	4.8E-01
2,435.8 – 2,436.2	Vertical	2.83	0.039	2.0E-10	5.7E-07
	Horizontal	2.83	0.031	2.6E-11	7.4E-08
2,438.9 – 2,439.3	Vertical	2.84	0.046	1.3E-11	3.7E-08
	Horizontal				
2,781.5 – 2,781.9	Vertical	2.72	0.327	2.6E-05	7.4E-02
	Horizontal	2.72	0.327	5.7E-05	1.6E-01
2,782.5 – 2,782.9	Vertical	2.71	0.311	1.4E-06	4.0E-03
	Horizontal	2.71	0.289	9.6E-05	2.7E-01

Table 4-5 IW-1 Summary of Geophysical Logging			
Date	**Construction Phase**	**Depth (ft bpl)**	**Geophysical logs**
November 11, 2009	Nominal 60.5-inch borehole	0 - 155	Caliper and gamma ray
November 15, 2009	12.25-inch pilot hole	155 – 1,100	Caliper, gamma ray, dual induction, spontaneous potential
November 26, 2009	Nominal 50.5-inch borehole	155 – 1,075	Caliper and gamma ray
November 28, 2009 November 29, 2009	Cementing 42-inch casing	0 – 1,075	Temperature (after each cement stage)
December 5 to December 7, 2009	12.25-inch pilot hole	1,075 – 2,156	Caliper, gamma ray, borehole compensated sonic with VDL, dual induction, spontaneous potential. Temperature, dynamic and static temperature, fluid resistivity and flowmeter, video log
December 26, 2009	Nominal 40.5-inch borehole	1,075 – 1,905	Caliper and gamma ray
December 27 to December 31, 2009	Cementing 34-inch casing	0 – 1,900	Temperature (after each cement stage)
January 24, 2010 January 25, 2010	12.25-inch pilot hole	1,900 – 3,500	Caliper, gamma ray, borehole compensated sonic with VDL, dual induction, spontaneous potential. Temperature, dynamic and static flowmeter, Borehole televiewer, Borehole video
March 5, 2010	32.5-inch and 22.5-inch reamed borehole	1,900 – 3,505	Caliper and gamma ray
March 10 to March 15, 2010	Cementing 24-inch casing	0 – 2,975	Temperature (after each cement stage)
March 16, 2010	Cementing 24-inch casing	100 – 2,975	Cement bond log
May 18 to May 19, 2010	Completed well	0 – 3,505	Video log, high resolution temperature, gamma ray, radioactive tracer survey

Table 4-6 IW-2 Summary of Geophysical Logging

Date	Construction Phase	Depth (ft bpl)	Geophysical logs
November 20, 2009	Nominal 60.5-inch borehole	0 - 155	Caliper and gamma ray
November 20, 2009	Cementing 52-inch casing	0 - 155	Temperature
December 12, 2009	Nominal 50.5-inch borehole	155 – 1,075	Caliper and gamma ray
December 13, 2009 December 14, 2009	Cementing 42-inch casing	0 – 1,075	Temperature (after each cement stage)
December 19, 2009	12.25-inch pilot hole	1,079 – 1,940	Caliper, gamma ray, borehole compensated sonic with VDL, dual induction, spontaneous potential. Temperature, dynamic and static temperature, fluid resistivity and flowmeter
January 12, 2010	Nominal 40.5-inch borehole	1,075 – 1,905	Caliper and gamma ray
January 13, 2010 to January 16, 2010	Cementing 34-inch casing	0 – 1,900	Temperature (after each cement stage)
February 7, 2010	12.25-inch pilot hole	1,890 – 3,500	Caliper, gamma ray, borehole compensated sonic with VDL, dual induction, spontaneous potential. Temperature, dynamic and static flowmeter, Borehole televiewer
March 19, 2010	32.5-inch and 22.5-inch reamed borehole	1,900 – 3,505	Caliper and gamma ray
March 27, 2010 to April 2, 2010	Cementing 24-inch casing	0 – 2,975	Temperature (after each cement stage)
April 1, 2010	Cementing 24-inch casing	100 – 2,920	Cement bond log
April 13, 2010	Completed well	0 – 3,505	Video log
May 13, 2010	Completed well	0 – 3,505	High resolution temperature, gamma ray, radioactive tracer survey

Table 4-7 DZMW-1 Summary of Geophysical Logging

Date	Construction Phase	Depth (ft bpl)	Geophysical logs
March 28, 2010	40.5-inch borehole	0 - 161	Caliper and gamma ray
March 29, 2010	Cementing 30-inch casing	0 - 155	Temperature
April 5, 2010	28.5-inch borehole	161 – 1,079	Caliper and gamma ray, dual induction, spontaneous potential
April 7, 2010	Cementing 20-inch casing	0 – 1,075	Temperature (after each cement stage)
April 11, 2010	12.25-inch pilot hole	1079 – 1,940	Caliper and gamma ray, borehole compensated sonic with VDL, dual induction, spontaneous potential, temperature (with differential plot) dynamic and static temperature, fluid resistivity and flowmeter, borehole televiewer
April 16, 2010	18.5-inch reamed borehole	1079 – 1,940	Caliper and gamma ray
April 18, 2010	Cementing 12.75-inch casing	0 – 1,940	Temperature after each stage
April 24, 2010	11-inch borehole	1,940 – 2,260	Caliper and gamma ray, borehole compensated sonic with VDL, dual induction, spontaneous potential, temperature (with differential plot) dynamic and static temperature, fluid resistivity and flowmeter, borehole televiewer
May 2, 2010	Cementing 6.625-inch FRP casing	1,700 – 2,191	Temperature (after each cement stage), cement bond log
May 4, 2010	Completed well	0 – 2,260	Video log

4.5 Borehole Video Surveys

The purpose of the video surveys was to obtain information on the nature of the penetrated strata and to evaluate the integrity of the 24-inch diameter casing. Of particular interest is the location of intervals of fractured rock that are potential flow zones. The borehole video surveys were performed by the Geophysical Logging Division of YBI using a color television camera that had both down-hole and side-view capabilities. The surveys were witnessed by SWS hydrogeologists and were subsequently reviewed in detail. A summary of video logs performed on wells IW-1, IW-2 and DZMW-1 is provided as **Table 4-8**. Copies of the video log descriptions are included in **Appendix Q**. Copies of the video logs are provided as DVDs attached to this report.

Table 4-8 Summary of Video Logs

Date	Well	Construction Phase	Depth (ft bpl)
December 7, 2009	IW-1	12.25-inch pilot hole	1,124 - 1,924
January 24, 2010	IW-1	12.25-inch pilot hole	1,900 - 3,500
May 18, 2010	IW-1	Completed well	0 - 3,505
April 12, 2010	IW-2	Completed well	0 - 3,502
May 4, 2010	DZMW-1	Completed well	0 - 2,262

4.6 Packer Tests

4.6.1 Injection Wells IW-1 and IW-2

Packer tests were run in wells IW-1 and IW-2 to: (1) determine the depth of the USDW, (2) characterize water quality of discrete intervals between the base of the USDW and injection zone, and (3) characterize the hydraulics of the confining strata between the base of the USDW and injection zone. Six straddle packer tests were performed in well IW-1. Straddle packer tests 1 and 2 in IW-1 were performed to confirm the vertical location of the USDW as interpreted from geophysical logs. Straddle packer tests in IW-2 were also performed to confirm the vertical location of the USDW. The remaining packer tests in wells IW-1 and IW-2 were performed to characterize the confining strata.

The following procedures were used to perform the straddle packer tests:

1) A caliper log was run on the pilot hole to determine the optimal depth to set the packer. The target test interval was 17 feet thick and had near uniform diameter and a circular cross-section.

2) A submersible pump and pressure transducer were installed inside the drill pipe. A transducer was also set outside of the drill pipe to monitor for changes in pressure (head) that might be indicative of leakage around the packer. The pressure transducers were connected to a Hermit™ Model 3000 data logger.

3) The packer zone was developed using a combination of air lift and the submersible pump. At a minimum, the zone was developed until at least 3 volumes of water were purged from the zone and the specific conductance of the purge water stabilized. The pumping rate for the test was also determined from the specific capacity of the test zone calculated during purging.

4) The water level (head) of the packer zone was allowed to recover.

5) The pumping phase of the test was started, which had a duration of 4 hours. The test was performed at a constant rate. At the end of the pumping phase, a water sample was collected for analysis for chloride, conductivity, sulfate,

total dissolved solids, total Kjeldahl nitrogen, ammonia-N, and total phosphorous. The water sample was collected by YBI and analyzed by Florida Environmental Services, Inc.

6) The pump was turned off and recovery was monitored for either four hours or until the water level recovered to background.

The hydraulic data for the packer test in wells IW-1 and IW-2 are summarized in **Table 4-9** and **Table 4-10**, respectively. The water quality data for packer tests in wells IW-1 and IW-2 are summarized in **Table 4-11** and **Table 4-12**, respectively. Time-drawdown and time-recovery plots for the packer tests are provided in **Appendix R.**

Table 4-9 IW-1 Packer Test Hydraulic Data

Test No.	Depth (ft bpl)	Pump Rate (gpm)	Draw Down (ft)	Pumping Phase		Recovery Phase	
				Transmissivity (gpd/ft)	Average Hydraulic Conductivity (ft/day)	Transmissivity (gpd/ft)	Average Hydraulic Conductivity (ft/day)
1	1,839 – 1,856	15	175	73	0.56	72	0.55
2	1,899 – 1,916	15.5	159	78	0.60	74	0.57
3	1,973 – 1,991	11	136	72	0.55	64	0.49
4	2,234 – 2,251	0.5	21	18	0.14	7	0.05
5	2,399 – 2,417	6	73	49	0.37	63	0.48
6	2,639 – 2,657	8	58	111	0.85	103	0.79

Table 4-10 IW-2 Packer Test Hydraulic Data

Test No.	Depth (ft bpl)	Pump Rate (gpm)	Draw Down (ft)	Pumping Phase		Recovery Phase	
				Transmissivity (gpd/ft)	Average Hydraulic Conductivity (ft/day)	Transmissivity (gpd/ft)	Average Hydraulic Conductivity (ft/day)
1	1,884 – 1,901	5.5	143	52	0.40	48	0.37
2	2,049 – 2,067	22	110	138	1.05	145	1.11
3	2,569 – 2,587	30	86	240	1.83	264	2.02
4	2,259 – 2,277	1	63	11	0.08	11	0.08

Table 4-11 IW-1 Packer Test Water Quality Data

Test No.	Depth (ft bpl)	Total Dissolved Solids (mg/L)	Chloride (mg/L)	Specific Conductance (µmhos/cm)	Sulfate (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Ammonia As Nitrogen (mg/L)
1	1,839 – 1,856	6,360	3,500	9,700	465	0.41	0.39
2	1,899 – 1,916	16,100	9,440	22,000	767	0.34	0.30
3	1,973 – 1,991	26,833	14,100	39,500	1,450	0.15	0.097
4	2,234 – 2,251	35,333	19,400	50,000	2,400	0.25	0.02
5	2,399 – 2,417	26,367	15,800	42,800	1,990	0.23	0.09
6	2,639 – 2,657	37,700	20,800	43,200	2,610	<0.045	<0.01

Table 4-12 IW-2 Packer Test Water Quality Data

Test No.	Depth (ft bpl)	Total Dissolved Solids (mg/L)	Chloride (mg/L)	Specific Conductance (µmhos/cm)	Sulfate (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Ammonia As Nitrogen (mg/L)
1	1,884 – 1,901	13,910	8,200	19,200	706	0.51	0.37
2	2,049 – 2,067	29,000	16,000	34,600	1,670	0.23	0.17
3	2,569 – 2,587	36,467	21,100	42,100	2,850	< 0.045	< 0.01
4	2,259 – 2,277	35,900	20,500	41,700	2,810	< 0.045	< 0.01

4.6.2 Dual-Zone Monitor Well

Packer tests were also run in each of the proposed upper and lower monitor zones of DZMW-1. The tests were performed to confirm that the upper zone had a TDS concentration slightly greater than 10,000 mg/L and was located below the USDW. The tests were also performed to ensure that the proposed upper and lower zones yielded adequate volumes of water needed for future compliance monitoring. The tests in DZMW-1 were performed as off-bottom packer type, with the packer set at the top of the proposed zone and the bottom of the open hole serving as the base of the tested zone. The data analysis and testing procedures performed in the injection well packer tests were also applied to the packer tests performed in DZMW-1.

The hydraulic data and water quality data for the packer tests performed on well DZMW-1 are summarized in **Table 4-13** and **Table 4-14**, respectively. Packer test number 1 and 2 correspond to the upper and lower zones of DZMW-1, respectively. Time-drawdown and time-recovery plots for the packer tests are provided in **Appendix R** along with summaries of the raw test data.

Table 4-13 DZMW-1 Packer Test Hydraulic Data

Test No.	Depth (ft bpl)	Pump Rate (gpm)	Draw Down (ft)	Pumping Phase		Recovery Phase	
				Transmissivity (gpd/ft)	Average Hydraulic Conductivity (ft/day)	Transmissivity (gpd/ft)	Average Hydraulic Conductivity (ft/day)
1	1,900 – 1,940	22	56	831	2.78	633	2.12
2	2,210 – 2,260	12	92	163	0.44	114	0.30

Table 4-14 DZMW-1 Packer Test Water Quality Data

Test No.	Depth (ft bpl)	Total Dissolved Solids (mg/L)	Chloride (mg/L)	Specific Conductance (µS/cm)	Sulfate (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Ammonia As Nitrogen (mg/L)
1	1,900 – 1,940	22,340	11,600	24,400	872	0.53	0.34
2	2,210 – 2,260	31,860	17,100	33,900	1,930	0.11	0.055

5 Injection Zone and Confinement Analysis

5.1 Injection Zone

The injection zone is located within fractured dolostones of the lower Oldsmar Formation. The first fractured zone was encountered at a depth of 3,045 ft bpl in well IW-2 and 3,145 ft bpl in IW-1. The fractured zones continue at various depths within the open hole sections of wells IW-1 and IW-2. The lowermost fractured zones observed in IW-1 and IW-2 were 3,457-3,465 ft bpl and 3,244-3,266 ft bpl, respectively. Caliper logs indicate the presence of fractures and zones of similar diameter of the drill bit suggesting the presence of hard rock. Fractured zones are characterized in the dual-induction logs by deep and medium resistivities of less than 2 ohm-m. The flowmeter logs do not yield much information on the flow characteristics of the injection zone because it is not possible to significantly stress the boulder zone due to its extremely high transmissivity.

5.2 Confinement Analysis

A confinement analysis was performed of the strata between the base of the USDW (1,875 ft bpl) and the top of the injection zone (base of the injection casing at 2,975 ft bpl). The confinement analysis is based on the following data:

- Well cuttings analysis (description)
- Borehole geophysical logs
- Core analyses
- Packer tests

Vertical confinement of injected fluids is provided by strata that have a low vertical hydraulic conductivity. Density-dependent solute-transport modeling of vertical fluid migration in injection well systems in southeastern Florida indicates that the matrix vertical hydraulic conductivity (as measured by core analyses) of the rock typically found in the Middle Confining Unit of the Floridan Aquifer is sufficiently low to prevent significant vertical migration of injected fluid (Maliva et al., 2007). Rapid vertical migration of injected fluid can only occur when there is a high degree of fracturing of (or other conduits through) the confining strata, which cause a large (several orders of magnitude) increase in vertical hydraulic conductivity.

The equivalent vertical hydraulic conductivity (K_z) of a layered formation is expressed as (Freeze and Cherry, 1979):

$$K_z = \frac{d}{\sum_{i=1}^{n} \frac{d_i}{K_i}}$$

Where, d = total thickness, d_i = thickness of bed 'i', and K_i = vertical hydraulic conductivity of bed 'i'. Inasmuch as the equivalent vertical hydraulic conductivity is the sum of the reciprocals of the vertical hydraulic conductivity of the individual beds, its value will depend largely on the hydraulic conductivity of the least permeable beds. Confinement analyses are therefore focused on locating beds with low vertical hydraulic conductivities.

The general characteristics of high transmissivity, fractured zones in the Floridan aquifer system were described by Haberfeld (1991) and include the following:

- Greatly enlarged hole sizes on caliper logs,
- Exceedingly long transit times,
- Very low resistivities, indicating high porosity and saline water,
- Changes on temperature logs,
- Flow in or flow out zones on flowmeter logs, and
- Caverns, cavities, and fractures evident on borehole videos.

High transmissivity intervals in the Floridan aquifer system are often composed of fractured dolostone, which has very low matrix hydraulic conductivity. Dolostones tend to be more brittle than limestones and are thus more likely to be fractured. Fractures in limestones also tend to be healed (closed). Intervals likely to provide good vertical confinement are largely the opposite of those of high transmissivity intervals. The following criteria are characteristic of intervals interpreted as providing good vertical confinement (Maliva and Walker, 1998; 2000):

- Low sonic transit times (preferably < 60 µsec/ft).
- Variable density log (VDL) patterns consisting of a strong (dark) continuous parallel bands that are either vertical, where lithology is relatively uniform, or have a "chevron" pattern where the formation consists of interbedded rock of different hardness.
- Low vertical hydraulic conductivities measured on core samples
- Borehole diameters on caliper logs close to bit size
- Relatively high resistivities, which in the middle and upper parts of the Floridan aquifer system are often indicative of tight dolostone beds.
- Absence of evidence of fractures or other flow conduits on video surveys, borehole televiewer, and fracture identification logs.
- Low macroporosity (i.e., visible pore spaces) and high degree of cementation (hardness), as observed in microscopic examination of cuttings and core samples.

The borehole televiewer log is particularly useful for observing sedimentary bedding and the presence of secondary porosity features that may allow for enhanced flow. Most of the strata between the base of the USDW and top of the injection zone consist of either unfractured interbedded limestone and dolostone (**Figure 5-1A**) or unfractured interbedded limestone and dolostone with porous horizons (**Figure 5-1B**). Porous and vuggy zones (**Figure 5-1C**) may result in greater horizontal hydraulic conductivity, but are separated by intact beds, which result in the interval of bedded rock having a very low equivalent vertical hydraulic conductivity and thus effective confinement.

Fractured intervals are also identifiable on the borehole televiewer log and video log (e.g., **Figure 5-1D**); but the fracturing and cavern development has a limited vertical extent. The fractured horizons result in greatly enhanced horizontal flow, but do not result in a significant increase in the equivalent vertical hydraulic conductivity.

Intervals that were interpreted as having characteristics indicative of good vertical confinement meet the above criteria, particularly the presence of dolostone beds with low sonic transit times and intact horizontal bedding as indicated by the borehole televiewer logs. Intervals lacking both tight intervals and well-developed fracturing are considered to have characteristics indicative of moderate vertical confinement. The unfractured limestones of the Avon Park Formation and upper Oldsmar Formation are considered to have moderate confinement. Intervals interpreted as providing poor vertical confinement contain common fractures and cavernous zones, as evidenced by borehole enlargement and very long sonic transit times.

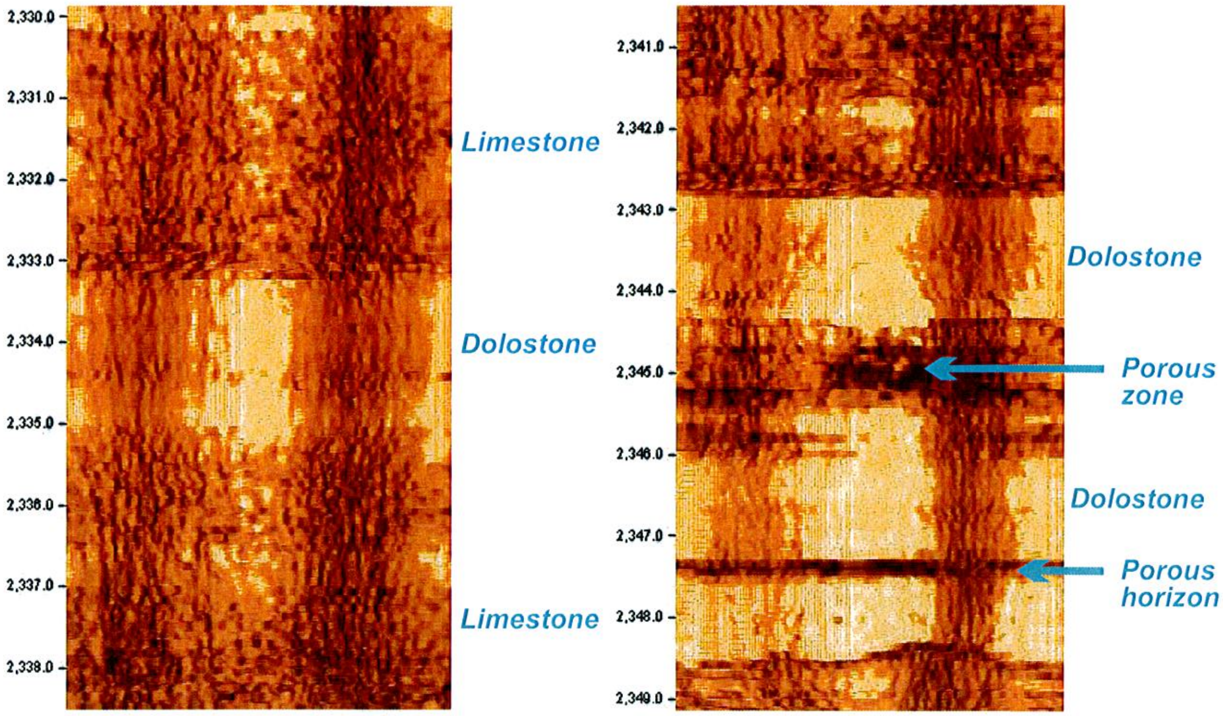
Eight zones with similar confining properties were identified between the base of the USDW (1,875 ft bpl) and top of the injection zone (2,980 ft bpl). A summary of the confining characteristics is provided below. Please note that a range of vertical and horizontal permeability, as measured from cores by the laboratory, are provided when more than one core sample was analyzed.

<u>Confining Zone I (1,875 to 2,307 ft bpl)</u>: Moderate confinement

Lithology: Unfractured porous limestones, fractured dolostone at base.
Sonic properties: 95 - 105 µsec/ft, sonic porosity 35 - 34%
Dual induction log: Very uniform response (2 to 3 ohm-m) with minimal separation of tracks. Porous limestone.
Borehole televiewer: No suggestion of any vertical fractures that could result in enhanced vertical flow throughout most of interval. Some fracturing of dolomite between 2,300 and 2,307 ft bpl.
Borehole video survey: Intact rock above 2,297 ft bpl.
IW-1 core vertical permeability: 7.4E-06 to 1.4E-01ft/day
IW-2 core vertical permeability: 1.1E-02 to 1.1E-01 ft/day
IW-1 core horizontal permeability: 1.3E-03 to 2.5E-01ft/day
IW-2 core horizontal permeability: 4.8E-02 to 1.7E00 ft/day

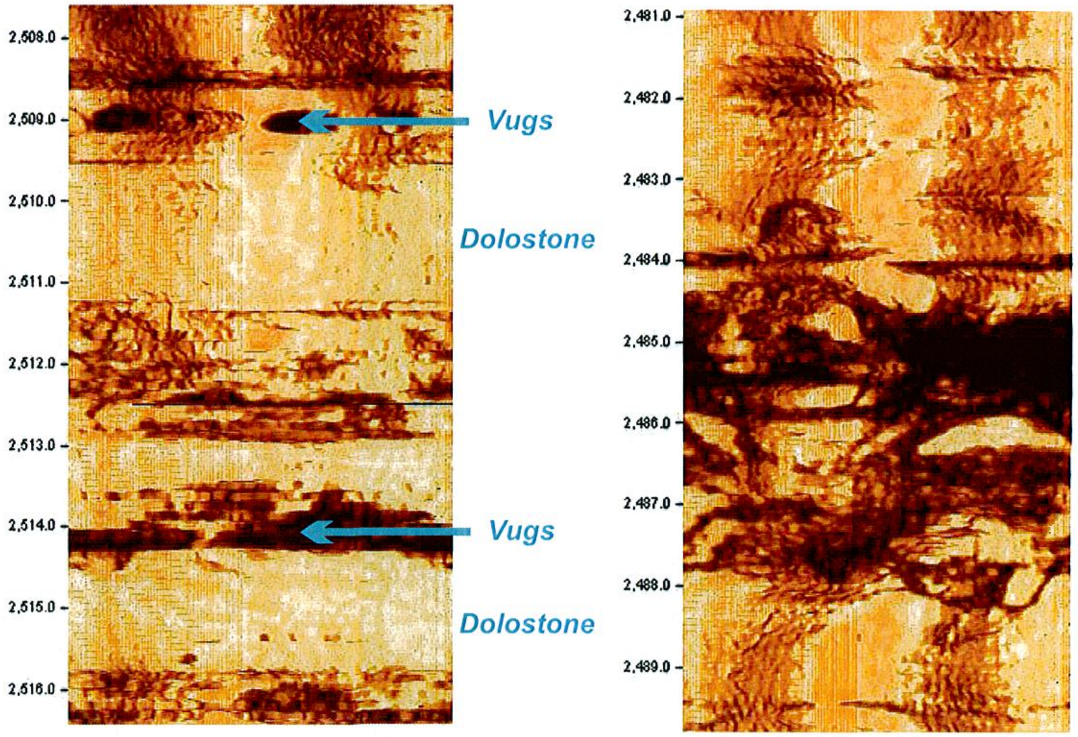
<u>Confining zone II (2,307 to 2,472 ft bpl)</u>: Overall very good confinement

Lithology: Interbedded unfractured dolostone and limestone
Tight dolostones from 2,300-2,320 ft bpl and 2,442-2,472 ft bpl
Sonic properties: Dolostones: 55 – 90 µsec/ft, sonic porosity 5 – 20%
Limestones: mostly between 90 and 95 µsec/ft



A. Unfractured interbedded limestone and dolostone

B. Unfractured interbedded limestone and dolostone with porous horizons



C. Vuggy dolostone with unfractured dolostone beds

D. Fractured cavernous dolostone zone

Figure 5-1 (A-D)
City of Hialeah Injection Well System
Borehole Televiewer Images of Bedding and Porosity

Dual induction log:	High resistivities (10 to 32 ohm-m) reflecting tight dolostone lithology.
Borehole televiewer:	Interbedded (horizontally) limestone and dolostone. No suggestion of significant fracturing. Appears to provide very effective vertical confinement
Borehole video survey:	No significant fracturing.
IW-1 core vertical permeability:	9.1E-03 ft/day
IW-2 core vertical permeability:	3.7E-08 to 5.7E-07 ft/day
IW-1 core horizontal permeability:	8.2E-04 ft/day
IW-2 core horizontal permeability:	7.4E-8 ft/day

<u>Confining zone III (2,472 to 2,497 ft bpl)</u>: Poor confinement

Lithology:	Dolostone with fractures
Sonic properties:	Two zones with high transit times (> 110 µsec/ft); 2,472-2,485 and 2,492-2,497 ft bpl).
Dual induction log:	Highly variable resistivities reflecting porosity variation. Most > 5 ohm-m reflecting dolostone lithology
Flowmeter log:	Major flow zone.
Borehole televiewer:	Vuggy dolostone. Larger vugs and some fractures. Not completely brecciated.
Borehole video survey:	Fracturing well developed from 2478 to 2485 ft.

<u>Confining zone IV (2,497 to 2,536 ft bpl)</u>: Very good confinement

Lithology:	Unfractured dolostone
Sonic properties:	Mostly dolostone, unfractured. Transit times in the 55 to 85 µsec/ft range.
Dual induction log:	High (> 10 ohm-m), which is indicative of low porosity, unfractured dolostones.
Borehole televiewer:	Vuggy dolostone separated by intact beds. May have a high horizontal hydraulic conductivity and very low vertical hydraulic conductivity
IW-1 core vertical permeability:	4.3E-07 to 6.0E-04 ft/day
IW-1 core horizontal permeability:	6.8E-07 to 1.3E-05 ft/day

<u>Confining zone V (2,536 to 2,612 ft bpl)</u>: Generally poor confinement

Lithology:	Dolostone and subsidiary limestone with fractured intervals. Fractured intervals from 2,540 – 2,550 ft bpl and 2,576 to 2,612 ft bpl.
Sonic properties:	Fractured zone from 2,576 to 2,612 ft bpl has transit times mostly in the 140 to 240 µsec/ft range. Unfractured strata have transit times in the 55 to 95 µsec/ft range.
Dual induction log:	Three intervals with deep and medium resistivities of less

than 10 ohm-m, which is indicative of seawater filled fractures.
Borehole televiewer: Cavities and some fracturing. Large cavity from 2,543 to 2,545 ft bpl and fractured dolomite from 2,578 to 2,580 ft bpl.

Confining zone VI (2,612 to 2,834 ft bpl): Good confinement

Lithology: Unfractured limestones and dolostones
Sonic properties: 2,612 to 2,760 ft bpl - mostly unfractured limestone and dolomitic limestone with uniform sonic transit times of 80 to 90 μsec/ft and sonic porosities of about 25%.
2,760 to 2,834 ft bpl - unfractured limestone and dolostone with transit times mostly in 75 to 100 μsec/ft range.
Dual induction log: Generally little variation in resistivity and minimal separation of tracks. Resistivities are mostly in the 3.5 to 5.0 ohm-range, which indicates low porosities.
Borehole televiewer: 2,613 – 2,730 ft bpl horizontally bedded unfractured limestone and dolostones. Some vugs, but no fractures except possibly between 2,755 and 2,779 ft bpl.
IW-1 core vertical permeability: 4.3E-05 to 4.5E-01 ft/day
IW-2 core vertical permeability: 4.0E-03 to 7.4E-02 ft/day
IW-1 core horizontal permeability: 1.6E-03 to 1.1E-01 ft/day
IW-2 core horizontal permeability: 1.6E-01 to 2.7E-01 ft/day

Confining zone VII (2,834 – 2,842 ft bpl): Poor confinement

Lithology: Fractured dolostone.
Sonic properties: Transit time of up to 195 μsec.
Borehole televiewer: Cavity from 2,838 – 2,842 ft bpl

Confining zone VIII (2,842 – 3,028 ft bpl): Moderate confinement

Lithology: Unfractured porous limestone
Sonic properties: Transit times mostly in the 95 to 100 μsec/ft range, sonic porosities mostly between 33 and 45%
Dual induction log: Porous limestone (or dolomitic limestone). Resistivities in the 2 to 3 ohm-m range and only minor separation of the tracks.
Borehole televiewer: Horizontally bedded limestone. Some more porous horizons but no vertical flow features.
Borehole video survey: No significant fracturing.

6 Mechanical Integrity and Injection Tests

Mechanical Integrity Testing (MIT) was performed on wells IW-1, IW-2 and DZMW-1 to analyze the integrity of the casing materials and the quality of the bond between the annular grout (cement) and the well casings. The MIT program for the injection wells consisted of the following elements:

- Cement temperature logs of the 52-inch, 42-inch, 34-inch, and 24-inch diameter casings.
- Pressure tests of the 24-inch diameter injection casing and the annulus between the 24-inch diameter injection casing and 16-inch diameter injection tubing.
- Cement bond log of the 24-inch diameter casing.
- Borehole video survey of the 24-inch diameter casing.
- High-resolution temperature log of the 24-inch diameter casing.
- Radioactive tracer survey (RTS).

The MIT program for the dual zone monitor well consisted of the following elements:

- Cement temperatures log of the 30-inch, 20-inch, and 12.75-inch diameter casings.
- Pressure test of the 12.75-inch and 6.625-inch diameter casings.
- Cement bond logs of the 12.75-inch and 6.625-inch diameter casings.

Injection tests were conducted to evaluate whether or not the completed injection wells can perform as designed. All of the MIT procedures were witnessed by SWS personnel and were judged to have been completed in a satisfactory manner in accordance with the well construction and testing specifications and the FDEP well construction permit. The MIT and injection test procedures and results are described below.

6.1 Cement Top Temperature Logs

Cement top temperature logs were run after each cement stage. The curing of cement is an exothermic reaction. The generated heat of hydration of cement emplaced in the annulus between the casing and formation can be readily detected and measured using a temperature probe run through the casing. If curing proceeds too rapidly, the temperature will "flash" resulting in a spike in the temperature log. Conversely, a significant drop in temperature across a section of casing may indicate the absence of cement in part of the annulus. None of the temperature logs contained anomalies that would suggest either gaps in the cement or inappropriate curing temperatures. Copies of the cement top temperature log interpretations are included in **Appendix M.**

6.2 IW-1 Mechanical Integrity Testing

6.2.1 Injection Casing Pressure Test

The pressure test of the 24-inch diameter injection casing was performed on March 17, 2010. The test was witnessed by David Barnes (SWS) and Gardner Strasser (FDEP). The test was performed after completion of grouting of the casing, except for the upper 326 ft (cement stage 15). A temporary wellhead was installed at the top of the casing and a pressure gauge and relief valve were fitted to the wellhead. Air in the casing was bled off to eliminate the effect of air compression and expansion. The cement at the bottom of the casing served as a bottom seal for the test.

The casing was pressurized with water to 153.0 pounds per square inch (psi) at the start of the test and the pressure over the course of one hour was recorded. The casing pressure after one hour increased to 153.2 psi, a 0.13% increase. The increase in pressure is likely due to the warming of the water within the injection well from the heat of hydration of the cement. The 24-inch diameter casing thus met the FDEP test-passing criteria of no more than 5% change in pressure after one hour (Rule 62-528.410(7)(c), FAC). Documentation of the pressure test and gauge calibration are included in **Appendix S.**

After the test was completed, approximately 41 gallons of bleed-off water was measured. The theoretical bleed-off volume was 32.6 gallons. The variation between the measured and theoretical bleed-off volumes may be related to temperature-related difference in the compressibility of water and expansion of the uncemented upper casing.

6.2.2 Cement Bond Log of IW-1 Injection Casing

The cement bond log (CBL) is a type of acoustic geophysical log that is used to determine the quality of the cement bond between the casing and the cement grout, and between the cement and the formation, and to infer the presence of channels in the cement behind the casing (Nielsen and Aller, 1984). The cement bond log is performed by lowering the logging tool down the hole while transmitting an acoustic signal outwards towards the casing wall. The signal penetrates the casing, cement grout, and formation, and is reflected back to a receiver on the logging tool. The signal is recorded by the logging instrument and various qualities of the signal (described below) are displayed on the printout of the log.

<u>Travel time</u>

Travel time is the time that it takes for the signal to travel from the transmitter, through the casing fluid, casing, and back to the receiver. Travel time is useful for evaluating whether the logging tool was properly centered within the casing during the running of the CBL. Compression-wave velocity in water is much slower than in the steel casing. If the logging tool drifted closer to the casing, then the travel path will be reduced, and thus the transit time will also be reduced. Constant tool centralization is critical to the obtainment of an interpretable CBL because an un-centered tool will produce erratic responses. A properly centered tool will result in a relatively straight travel time log with only minor deviations at casing joint locations.

The travel rates through steel and water are 57.5 and 189 microseconds per foot (µsec/ft), respectively. The travel time for 7 ft (as recorded in the logs) should theoretically be 726 µsec in the 24-inch outer (23-inch inner) diameter injection casing. Longer transit times may occur in well cemented casing as the signal travels a greater distance and sonic velocities of porous limestone are lower than that of steel casing.

Amplitude

The amplitude of the acoustic signal is a measurement of the energy lost by the signal as it passes through the casing into the cement grout. The rate of this attenuation is dependent upon the percent of bonded cement, the casing diameter, and the thickness and material of the casing wall. A casing that is completely un-cemented and in contact with formation fluid or drilling mud will cause the attenuation rate to be very small and the returning amplitude will be relatively high. In a casing section that is well bonded to the cement grout, the wave velocity difference between the casing and cement grout will cause significant attenuation of the acoustic signal and the returning amplitude will be relatively low. When the tool is properly centered, there will be a direct correlation between the amplitude response and the amount of cement bonded to the outer casing wall, as well as the quality of the bond.

Total Energy Display

The total energy display is shown as a variable density log (VDL). The VDL is produced from the arrivals of the acoustic waves at a receiver. The VDL is used to qualitatively assess the bond between the cement and formation and to detect the presence of channels in the cement grout, which might allow fluids to migrate behind the casing wall. Poorly cemented sections of casing generally have strong casing signals, whereas casing signals are absent or weak in well-cemented sections of casing. Casing joints, which normally appear as W-shaped 'chevron' patterns, may be evident in un-cemented well casings, whereas the pattern is usually barely discernable in cemented casing. However, the 'chevron' signal pattern is typical of threaded couplings, rather than the butt-welded casing joints used for the steel injection casings. The CBL was run before cementing the upper 326 ft of the annulus on the 24-inch diameter casing in well IW-1.

Interpretation of Cement Bond Logs

The typical log responses were described by Nielsen and Aller (1984) for the four most common cement situations: (1) uncemented casing, (2) good casing bond and good formation bond, (3) good casing bond but poor formation bond, and (4) microannulus or channeling.

A combination of good casing and formation bonding is characterized by:

- Low amplitude readings;
- Weak casing arrivals on the VDL; and,
- Strong formation arrivals if formation attenuation is not high.

Summary and evaluation of the CBL of the 24-inch diameter casing

100 - 326 ft bpl	Uncemented casing. The uncemented casing provides as baseline against which to evaluate cement bonding in the cemented casing. The travel time is approximately 725 µsec (approximately equal to the theoretical value), amplitude ranges most between 30 and 50 mV, strong casing returns are evident on the VDL.
326 – 1,890 ft bpl	Good cement bonding within the intermediate casing interval. Weak casing and formation returns on the VDL log and low amplitudes (< 10 mV) throughout interval.
1,890 – 2,560 ft bpl	Good and subsidiary moderate bonding. Well-bonded intervals have low amplitudes (< 10 mV) and weak casing returns. Intervals are considered to have moderate bonding have amplitudes between 10 and 25 mV and stronger casing return.
2,560 – 2,722 ft bpl	Moderate to poor cement bonding. Poorly bonded intervals (e.g., 2,634 to 2,679 ft bpl) have transit times of about 730 µsec, amplitudes of 30 to 50 mV, and strong casing returns. Some well bonded intervals are present, which would be expected to obstruct vertical fluid movement.
2,722 – 2,915 ft bpl	Mostly good cement bonding, subsidiary moderate bonding. Well-bonded intervals have low amplitudes (< 10 mV) and weak casing returns. Intervals are considered to have moderate bonding have amplitudes between 10 and 25 mV and stronger casing return.

The results of the cement bond log run on the 24-inch diameter injection casing of IW-1 provide strong evidence that the casing was properly cemented and that there are no continuous gaps in the annulus between the casing and formation that could be conduits for the migration of injected fluids between the injection zone and base of the USDW. Some intervals are present in which the bonding is evaluated to be moderate or poor. However, the zones with possible poor to moderate bonding are interspersed between zones of good cement bonding, which indicates that significant vertical migration of injected water should not occur in the annulus between the injection casing and formation (i.e., any conduits that are present have a limited vertical extent).

6.2.3 Borehole Video of IW-1 Injection Casing

A borehole video survey was performed on the 24-inch diameter casing on May 18, 2010. The video survey procedures are discussed Section 4.5. The casing appeared to be intact with no suggestion of any breaches or other defects that would suggest the absence of mechanical integrity.

6.2.4 High-Resolution Temperature Log

A high resolution temperature log was run on the completed well (3,505 ft bpl to pad level) on May 19, 2010. Sharp changes in temperature within the casing would suggest the presence of flow zones and thus breaches in the casing. The results of the temperature log are summarized below:

0 – 2,800 ft bpl	Gradual decrease in temperature with depth from 73.7°F at 0 ft bpl to 62.8°F at 2,800 ft bpl. No sharp changes in temperature are evident anywhere within the casing.
2,800 – 2,970 ft bpl	Slight downhole increase in temperature to 64.4°F at 2,970 ft bpl.
2,970 – 3,130 ft bpl	Rapid decrease in temperature below injection casing to 52.0°F at 3,130 ft bpl.
3,130 – 3,505 ft bpl	Little variation in temperature with depth. Temperatures are 52.0 ± 0.2°F. Temperature appears to reflect normal geothermal temperatures, whereas temperature data from the overlying strata reflect effects of injection during injection test.

The high-resolution temperature log contains no anomalies that would suggest a lack of mechanical integrity

6.2.5 Radioactive Tracer Survey

A radioactive tracer survey (RTS) was performed on the 24-inch diameter injection casing by the Geophysical Logging Division of YBI, on May 18, 2010. The test was witnessed by David Barnes (SWS) and Mark Silverman (FDEP). The RTS survey is designed to evaluate the integrity of the grout seal around the bottom of the 24-inch diameter casing. The integrity of the grout seal is critical to ensure that no upward migration of injection fluids occurs between the casing and borehole.

A mildly brackish bubble already exists at the injection well site from the previously performed injection tests on wells IW-1 and IW-2, which were performed using raw well water from an existing Upper Floridan Aquifer test production well. The injected water is less saline, and thus less dense, than both native injection zone water and planned injection water (reverse osmosis concentrate).

The ejector/detector tool used for the RTS was equipped with an iodine-131 ejector, a casing collar locator (CCL), and three gamma ray detectors, which were located the following distances from the bottom of the tool:

Top gamma ray detector (GRT)	24.0 ft
Ejector port	13.5 ft
Middle gamma ray detector (GRM)	10.5 ft
Casing collar locator	9.6 ft
Bottom gamma ray detector (GRB)	1.2 ft

The procedures and results of the radioactive tracer survey are summarized below:

1. Background gamma ray log was run from approximately 3,505 ft bpl to pad level.

2. The bottom of the casing was detected using the casing collar locator at its correct depth of 2,974.5 ft bpl.

3. Performed Dynamic Test 1
   - 3a. Tool was positioned so that the ejector was located approximately 5.5 ft above the bottom of the casing (2,969 ft bpl) and an 88 gpm flow was established. The 88 gpm flow rate corresponds to an average velocity of 4.08 ft/min inside the 23-inch inside diameter injection casing.
   - 3b. After recording the gamma ray detector for 3 minutes in stationary time drive mode, the first slug of tracer (2 millicurie of Iodine-131) was released. The detectors were run for an additional 60 minutes in time drive mode. Increased gamma ray activities were first detected in the middle detector (GRM) after 10 seconds and in the bottom detector (GRB) after 135 seconds (2.25 min). The tracer was not detected in top detector (GRT). The tracer flow velocity was 5.47 ft/min (12.3 ft/2.25 min), which agrees reasonably well with the calculated average flow rate. Tracer velocity is typically faster than the average flow velocity because of the greater flow rate within the center of the casing (i.e., water flowing in the center of casing travels faster than water near the casing wall).
   - 3c. Logged up out of position to 2,775 ft bpl. A minor gamma ray peak (≈ 50 GAPI) is evident at 2,914 ft bpl and below 2,962 ft bpl by GRM and GRB. No other suggestion of tracer is evident in casing.
   - 3d. Flushed well with approximately 19,000 gallons of Upper Floridan Aquifer well water and logged up from 2,982 to 2,777 ft bpl. Tracer was not evident at 2,914 ft bpl.

   Interpretation: No firm evidence was observed for the migration of tracer behind the casing. The minor peak detected at the 2,914 ft bpl may be tracer staining on the interior of the casing that was washed away during the flushing of the casing.

4. Performed Dynamic Test 2
   - 4a. Tool was positioned so that the ejector was located approximately 5.5 ft above the bottom of the casing (2,969 ft bpl) and an 88 gpm flow was established. The 88 gpm flow rate corresponds to an average velocity of 4.08 ft/min inside the 23-inch inner diameter injection casing.

4b. After recording the gamma ray detector for 1 minute in stationary time drive mode, the second slug of tracer (2 millicurie of Iodine-131) was released. The detectors were run for an additional 60 minutes in time drive mode. Increased gamma ray activities were first detected in the middle detector (GRM) within 10 seconds and in the bottom detector (GRB) after 108 seconds (1.80 min). The tracer was not detected in top detector (GRT). The tracer flow velocity was 6.8 ft/min, which is substantially greater than the average flow velocity. Tracer velocity is typically faster than the average flow velocity because of the greater flow rate within the center of the casing.

4c. Logged up out of position to 2,790 ft bpl. Tracer stain is evident below 2,968 ft bpl in both the BRM and GRB logs. Small peak at 2,875 ft bpl on GRB.

4d. Flushed well with Upper Floridan Aquifer well water and logged up from 3,050 to 2,800 ft bpl. Tracer was not detected by any of the detectors other than minor staining at the base of the casing, below the ejector port.

Interpretation: The RTS test data have no suggestion of upwards migration of tracer behind the injection casing.

5. Performed final gamma ray log from 3,500 to pad level. Remaining tracer was dumped at 3,080 ft bpl. Tracer was not detected in the cased interval.

The results of the RTS reveal no evidence that would suggest the presence of poor cement conditions that would allow injected water to migrate upwards outside of the injection casing.

6.2.6 IW-1 Mechanical Integrity Testing Conclusions

The results of the mechanical integrity testing program implemented on IW-1 indicates that the well has mechanical integrity. The testing results indicate that the casing is pressure tight and that there is adequate cementation in the annulus between the injection casing and formation to prevent upward fluid migration through the annulus.

6.3 IW-2 Mechanical Integrity Test

6.3.1 Injection Casing Pressure Test

The pressure test of the 24-inch diameter injection casing was performed on April 5, 2010. The test was witnessed by Joseph Abbott (SWS) and Joseph May (FDEP). The test was performed after completion of grouting of the casing, except for last 328 ft (cement stage 15). A temporary wellhead was installed at the top of the casing and a pressure gauge and relief valve were fitted to the wellhead. Air in the casing was bled off to eliminate the effect of air compression and expansion. The cement at the bottom of the casing served as a bottom seal for the test.

The casing was pressurized with water to 160 pounds per square inch (psi) at the start of the test and the pressure over the course of one hour was recorded. The casing pressure after one hour decreased to 155 psi, a 3.1% decrease. The 24-inch diameter casing thus met the FDEP test-passing criteria of no more than 5% change in pressure after one hour (Rule 62-528.410 (7,c) FAC). Documentation of the pressure test and gauge calibration is included in **Appendix T**.

After the test was completed, approximately 43 gallons of bleed-off water were measured. The theoretical bleed-off volume was 29.6 gallons. The variation between the measured and theoretical bleed-off volumes may be related to temperature-related difference in the compressibility of water and expansion of the uncemented upper casing.

6.3.2 Cement Bond Log of IW-2 Injection Casing

The cement bond log (CBL) procedures and interpretation are discussed in Section 6.2.2 with respect to the IW-1 test.

<u>Summary and evaluation of the CBL of the 24-inch diameter casing</u>

100 – 328 ft bpl	Uncemented casing. The uncemented casing provides as baseline against which to evaluate cement bonding in the cemented casing. The travel time is approximately 722 (approximately equal to the theoretical value), amplitude ranges most between 30 and 50 mV, strong casing returns are evident on the VDL.
328 – 1,325 ft bpl	Good cement bonding within the intermediate casing interval. Weak casing and formation returns on the VDL log and low amplitudes (< 10 mV) throughout interval. Transit times are 780 µsec or greater.
1,325 – 1,495 ft bpl	General moderate bonding. Amplitudes between 3 and 20 mV, stronger casing returns than above, transit times between 720 and 760 µsec.
1,495 – 1,680 ft bpl	Good cement bonding within the intermediate casing interval. Weak casing and formation returns on the VDL log and low amplitudes (< 10 mV) throughout interval. Transit times are 780 µsec or greater.
1,680 – 1,900 ft bpl	Moderate to good cement bonding. Amplitudes between 3 and 20 mV, stronger casing returns than above, transit times between 720 and 760 µsec.
1,900 – 2,570 ft bpl	Mostly very good bonding. Most of interval has very low amplitudes (< 2 mV), faint or no casing returns on the VDL,

	and high transit times (> 1,000 µsec).
2,570 – 2,724 ft bpl	Good and subsidiary moderate (2,748 to 2,774 ft bpl), low amplitudes (< 10 mV) and weak casing returns.
2,724 – 2,900 ft bpl	Mostly very good bonding. Low amplitudes (majority of interval < 5 mV), weak (and for some intervals no) casing returns, transit times mostly 770 µsec or greater.

The results of the cement bond log run on the 24-inch diameter injection casing of well IW-2 provide strong evidence that the casing was properly cemented and that there are no continuous gaps in the annulus between the casing and formation that could be conduits for the migration of injected fluids between the injection zone and base of the USDW. Of particular importance, is that the lower part of the injection casing has log responses that are indicative of very good cement bonding.

6.3.3 Borehole Video of IW-2 Injection Casing

A borehole video survey was performed on the 24-inch diameter casing on April 12, 2010. The video survey procedures are discussed Section 4.5. The casing appeared to be intact with no suggestion of any breaches or other defects that would suggest the absence of mechanical integrity.

6.3.4 High-Resolution Temperature Log

A high resolution temperature log was run on the completed well (3,505 ft bpl to pad level) on May 13, 2010. Sharp changes in temperature within the casing would suggest the presence of flow zones and thus breaches in the casing. The results of the temperature log are summarized below:

0 – 2,770 ft bpl	Gradual decrease in temperature with depth from 74.6°F at 20 ft bpl to 66.2°F at 2,770 ft bpl.
2,770 – 3,000 ft bpl	Gradual increase in temperature with depth peaking at 67.6°F at 2,990 ft bpl.
3,000 – 3,150 ft bpl	Rapid downhole decrease in temperature to 53.1 °F at 3,150 ft bpl.
3,150 – 3,485 ft bpl	Relatively constant temperature, 52.7 ± 0.3 °F.

The high-resolution temperature log contains no anomalies that would suggest a lack of mechanical integrity. The temperatures below 3,150 ft bpl are interpreted to be the normal formation temperatures. The open hole temperatures above 3,150 ft bpl are likely effected by the previously performed injection test.

6.3.5 Radioactive Tracer Survey

A radioactive tracer survey (RTS) was performed on the 24-inch diameter injection casing by the Geophysical Logging Division of YBI, on May 13, 2010. The test was witnessed by David Barnes (SWS) and Gardner Strasser (FDEP). The RTS survey is designed to evaluate the integrity of the grout seal around the bottom of the 24-inch diameter casing. The integrity of the grout seal is critical to ensure that no upward migration of injection fluids occurs between the casing and borehole.

A mildly brackish bubble already exists at the injection well site from the previously performed injection tests on wells IW-1 and IW-2, which were performed using raw well water from an Upper Floridan Aquifer test production well. The injected water is less saline, and thus less dense, than both native injection zone water and planned injection water (reverse osmosis concentrate).

The ejector/detector tool used for the RTS was equipped with an iodine-131 ejector, a casing collar locator (CCL), and three gamma ray detectors, which were located the following distances from the bottom of the tool:

Top gamma ray detector (GRT)	24.0 ft
Ejector port	13.5 ft
Middle gamma ray detector (GRM)	10.5 ft
Casing collar locator	9.6 ft
Bottom gamma ray detector (GRB)	1.2 ft

The procedures and results of the radioactive tracer survey are summarized below:

1. Background gamma ray log was run from approximately 3,495 ft bpl to pad level.
2. The bottom of the casing was detected using the casing collar locator at its correct depth of 2,974.7 ft bpl.
3. Performed Dynamic Test 1
   - 3a. Tool was positioned so that the ejector was located approximately 5 ft above the bottom of the casing (2,970 ft bpl) and a 91 gpm flow was established. The 91 gpm flow rate corresponds to an average velocity of 4.22 ft/min inside the 23-inch inner diameter injection casing.
   - 3b. After recording the gamma ray detector for 1 minute in stationary time drive mode, the first slug of tracer (2 millicurie of Iodine-131) was released. The detectors were run for an additional 60 minutes in time drive mode. Increased gamma ray activities were first detected in the middle detector (GRM) after 10 seconds and in the bottom detector (GRB) after 155 seconds (2.58 min). The tracer was not detected in top detector (GRT). The tracer flow velocity was 4.77 ft/min (12.3 ft/2.58 m), which agrees reasonably well with the calculated average flow rate. Tracer velocity is typically faster than the average flow velocity because of the greater flow rate within the center

of the casing.

3c. Logged up out of position to 2,780 ft bpl. The top of the tracer signal occurs at approximately 2,960 to 2,962 bpl in GRM and GRB.

3d. Flushed well with approximately 15,000 gallons of Upper Floridan Aquifer well water and logged up from 2,980 to 2,780 ft bpl. Tracer was still evident, but at lower gamma ray activity, up to 2,962 ft bpl.

Interpretation: The RTS test data suggest that there might have been some minor migration of the tracer behind the bottom 12 ft of the casing. The migration could be due to the use of a packer to cement the 24-inch diameter injection casing and is not considered to be significant as far as the mechanical integrity of the well.

4. Performed Dynamic Test 2

4a. Tool was positioned so that the ejector was located approximately 5 ft above the bottom of the casing (2,970 ft bpl) and a 90 gpm flow was established. Position of the tool was confirmed with the CCL. The 90 gpm flow rate corresponds to an average velocity of 4.17 ft/min inside the 23-inch inner diameter injection casing.

4b. After recording the gamma ray detector for 1 minute in stationary time drive mode, the second slug of tracer (2 millicurie of Iodine-131) was released. The detectors were run for an additional 60 minutes in time drive mode. Increased gamma ray activities were first detected in the middle detector (GRM) after 10 seconds and in the bottom detector (GRB) after 105 seconds (1.75 min). The tracer was not detected in top detector (GRT). The tracer flow velocity was 7.0 ft/min, which is substantially greater than the average flow velocity. Tracer velocity is typically faster than the average flow velocity because of the greater flow rate within the center of the casing.

4c. Logged up out of position to 2,790 ft bpl. Tracer was not positively detected by any of the detectors.

4d. Flushed well with approximately 13,000 gallons of Upper Floridan Aquifer well water and logged up from 2,980 to 2,780 ft bpl. Tracer was not detected by any of the detectors.

Interpretation: The RTS test data do not suggest the upwards migration of tracer behind the injection casing.

5. Performed Dynamic Test No. 3 (higher rate test)

5a. Tool was positioned so that the ejector was located 5 ft above the bottom of the casing (2,970 ft bpl). A 300 gpm flow was established, which is equivalent to an average flow rate of 13.9 ft/min inside the 23-inch inner diameter casing.

5b. After recording the gamma ray detector for 1 minute in stationary time drive mode, a slug of tracer (2 millicurie of Iodine-131) was released. The detectors were run for an additional 60 minutes in time drive mode. Increased gamma ray activities were first detected in GRM within 5 seconds and in GRB after 37 seconds (0.62 min). No increase in gamma ray activity

was recorded in GRT.
The tracer velocity was 19.8 ft/min.

5c. Logged up out of position to 2,780 ft bpl. Tracer was detected above the bottom of the casing up to 2,975 ft bpl by both GRM and GRB, which could be staining inside of the casing.

5d. Logged from 3,050 to 2,780 ft bpl after dumping remaining tracer below the casing. Tracer was not detected above the bottom of the casing.

Interpretation: The RTS test data suggest that might have been some minor migration of the tracer behind the bottom 10 ft of the casing. The migration is likely due to the use of a packer to cement the 24-inch diameter injection casing and is not considered to be significant as far as the mechanical integrity of the well.

6. Performed final gamma ray log from 3,500 to 40 bpl to pad level. Tracer was not detected in the cased interval. Tracer peak is evident at about 3,140 ft bpl, which likely marks a fracture into which the tracer flowed.

The results of the RTS tests reveal no evidence that would suggest the presence of a flow conduit behind the injection casing that could allow for significant vertical migration of fluids. The results were ambiguous as far as the bottom 10 to 12 feet of the casing. In any event, the top of the possibly poorly cemented interval is located approximately 1,100 ft below the base of the USDW and thus is immaterial as far as the mechanical integrity of the injection well.

6.3.6 IW-2 Mechanical Integrity Test Conclusions

The results of the mechanical integrity testing program implemented on IW-2 indicate that the well has mechanical integrity. The testing results indicate that the casing is pressure tight and that there is adequate cementation in the annulus between the injection casing and formation to prevent upward fluid migration through the annulus.

6.4 Injection Test

Constant rate injection tests were performed on wells IW-1 and IW-2 in order to evaluate the hydraulic characteristics of the wells and the injection zone. During these preliminary constant rate injection tests, the system is tested by pumping fluid at the highest flow rate possible given the available water supply (one test production well drilled in the Floridan aquifer). The pumping rate is maintained as constant as feasibly possible throughout the injection phase of the test.

Prior to the start of the each test, data control points were established to monitor the effects of injection on wells IW-1, IW-2 and DZMW-1. These control points included wellhead pressure, and pressure (head) in both monitor zones. The control points and monitoring methods are summarized in **Table 6-1**.

Table 6-1 Injection Test Control Points

Control point/ monitored zone	**Parameters monitored**	**Collection methods**
Injection well wellhead	Pressure	Pressure gauge & Pressure transducer
Other injection well	Pressure	Pressure transducer
Monitor well, upper zone	Pressure	Pressure gauge & Pressure transducer
Monitor well, lower zone	Pressure	Pressure transducer
Barometric data	Atmospheric pressure	Pressure transducer
Tidal cycles	Gravitation fluctuations of water level	Tidal charts
Flowmeter	Injection rate and total flow	Flowmeter (manually read)

6.4.1 IW-1 Injection Test Procedures

The injection tests for each well consisted of three phases: a background data collection phase, an injection phase, and a recovery phase. Water from the Upper Floridan aquifer was injected from a test production well using a temporarily-installed submersible pump, a booster pump and piping to the injection well.

The background data collection phase began on May 15, 2010 and lasted approximately 42 hours. The injection phase was performed on May 17, 2010 and lasted for approximately 12 hours. The test production well supplied a flow rate of between 2.43 and 2.59 MGD for the duration of the injection test. The average flow rate during the 12.05 hour injection period was approximately 1,739 gpm (2.50 MGD). Water supply sufficient for testing at the planned maximum flow rate of 7.39 MGD was not available on-site at the time of testing. Further injection testing at 7.39 MGD will be conducted upon completion of the production well field and pumping station. The recovery phase began immediately after the completion of the injection test.

6.4.2 IW-2 Injection Test Procedures

The background data collection phase began on May 10, 2010 and lasted approximately 24 hours. The injection phase was performed on May 11, 2010 and lasted for approximately 12 hours. The test production well supplied a flow rate of between 2.46 and 2.52 MGD for the duration of the injection test. The average flow rate during the 12.08 hour injection period was approximately 1,724 gpm (2.48 MGD). Water supply sufficient for testing at the planned maximum flow rate of 7.39 MGD was not available on-site at the time of testing. Further injection testing at 7.39 MGD will be conducted upon completion of the production well field and pumping station. The recovery phase began immediately after the completion of the injection test.

6.4.3 Injection Test Results

Plots of the injection test data are included in **Appendix S** along with a CD containing the raw data. The background (static) wellhead pressures in wells IW-1 and IW-2 were approximately 26.0 and 26.5 psi, respectively. The IW-1 and IW-2 injection phase test results are summarized in **Table 6-2** and **Table 6-3**, respectively. Wellhead pressure, as measured on the wellhead pressure gauge, increased to approximately 30 psi during each injection test at rates of 2.50 and 2.48 MGD, an increase of 4.0 psi for IW-1 and 3.5 psi for IW-2. Slight changes in pressures related to injection were detected in the upper or lower zones of DZMW-1. The measured change was instantaneous and is the result of loading and compression of the aquifer.

6.4.4 Injection Test Conclusions

The injection test results indicate that wells IW-1 and IW-2 can efficiently accept a flow rate of 2.5 MGD. Further injection testing will be conducted at the planned rated capacity of 7.39 MGD. The increase in wellhead pressure at an average injection rate of 2.5 MGD was between 4 psi and 3.5 psi for wells IW-1 and IW-2, respectively. This low pressure increase indicates that the injection zone has a very high transmissivity and can accept the design flow rate for the injection well system.

The specific injectivities of IW-1 and IW-2, using the wellhead pressure increase, were approximately 434 and 492 gpm/psi (187 gpm/ft and 212 gpm/ft). The transmissivity of a confined aquifer can be estimated as 2,000 times the specific injectivity (or specific capacity; Driscoll, 1986), which would give a values of 3.7 X 10^5 gpd/ft and 4.2 X 10^5 gpd/ft, respectively. The actual transmissivity of the injection zone aquifer is greater as the wellhead pressure increase includes frictional head losses within the injection casing.

Table 6-2 IW-1 Injection Test Results (manual readings)

Time	Elapsed Time since the start of injection	Elapsed time since the start of monitoring	IW-1 Wellhead pressure (psi)	Upper zone pressure (psi)	Injection Rate (MGD)
08:37	0:00	42:37	26.0	7.2	Start injection
8:49	0:12		31.0	7.2	2.53
9:07	0:30	43:07	30.0	7.2	2.52
9:37	1:00	43:37	30.0	7.0	2.49
10:07	1:30	44:07	30.0	7.0	2.48
10:37	2:00	44:37	30.0	7.1	2.46
11:07	2:30	45:07	30.0	7.1	2.46
11:37	3:00	45:37	30.0	7.1	2.45
12:07	3:30	46:07	30.0	7.1	2.45
12:37	4:00	46:37	30.0	7.1	2.43
13:07	4:30	47:07	30.0	7.1	2.43
13:37	5:00	47:37	30.0	7.2	2.43
13:54	5:17	47:54			Raising flow rate
13:56	5:19	47:56	30.5		2.59
14:07	5:30	48:07	30.5	7.5	2.56
14:37	6:00	48:37	30.5	7.5	2.53
15:07	6:30	49:07	30.0	7.2	2.53
15:37	7:00	49:37	30.0	7.1	2.53
16:07	7:30	50:07	30.0	7.1	2.52
16:37	8:00	50:37	30.0	7.2	2.52
17:07	8:30	51:07	30.0	7.5	2.52
17:37	9:00	51:37	30.0	7.5	2.52
18:07	9:30	52:07	30.0	7.5	2.52
18:37	10:00	52:37	30.0	7.5	2.52
19:07	10:30	53:07	30.0	7.5	2.52
19:37	11:00	53:37	30.0	7.5	2.52
20:07	11:30	54:07	30.0	7.5	2.52
20:34	11:57	54:34	30.0	7.5	2.52
20:40	12:03	54:40			End injection

Table 6-3 IW-2 Injection Test Results (manual readings)					
Time	**Elapsed Time since the start of injection**	**Elapsed time since the start of monitoring**	**IW-2 Wellhead pressure (psi)**	**Upper zone pressure (psi)**	**Injection Rate (MGD)**
12:14	0:00	24:00	26.5	6.5	Begin injection
12:18	0:04	24:04			2.52
12:20	0:06	24:06			2.53
12:23	0:09	24:09	30.0	6.5	2.52
12:54	0:40	24:40	30.0	6.5	2.52
13:18	1:04	25:04	30.0	6.5	2.52
13:48	1:34	25:34	30.0	6.5	2.52
14:18	2:04	26:04	30.0	6.5	2.52
14:48	2:34	26:34	30.0	6.5	2.52
15:18	3:04	27:04	30.0	6.5	2.52
15:48	3:34	27:34	30.0	6.5	2.52
16:18	4:04	28:04	30.0	6.9	2.52
16:48	4:34	28:34	30.0	7.0	2.52
17:18	5:04	29:04	30.0	7.0	2.51
17:48	5:34	29:34	30.0	7.0	2.51
18:18	6:04	30:04	30.0	7.0	2.49
18:48	6:34	30:34	30.0	7.0	2.49
19:18	7:04	31:04	30.0	7.0	2.48
19:48	7:34	31:34	30.0	7.0	2.48
20:18	8:04	32:04	30.0	7.0	2.46
20:48	8:34	32:34	30.0	7.0	2.46
21:18	9:04	33:04	30.0	7.0	2.46
21:48	9:34	33:34	30.0	7.0	2.46
22:18	10:04	34:04	30.0	7.0	2.46
22:48	10:34	34:34	30.0	7.0	2.46
23:18	11:04	35:04	30.0	7.0	2.46
23:48	11:34	35:34	30.0	7.0	2.46
0:15	12:01	36:01	30.0	7.0	2.46
0:18	12:04	36:04			End injection

7 Conclusions

Wells IW-1, IW-2, and DZMW-1 were constructed in accordance with the requirements of the FDEP Class I Test Injection Well Construction and Testing Permit and Florida Administrative Code 62-528. FDEP required testing demonstrates that finished wells IW-1 and IW-2 have mechanical integrity. The geologic interval between the injection zone and underground source of drinking water (USDW) was tested and demonstrates characteristics indicative of effective confinement that would be expected to prevent the vertical migration of injected fluids into the USDW.

Wells IW-1 and IW-2 were constructed with 24-inch diameter injection casings set to 2,975 ft bpl and 22-inch diameter open hole sections to approximately 3,500 ft bpl. Well DZMW-1 was constructed with upper and lower monitor zones of 1,900 to 1,950 ft bpl and 2,190 to 2,260 ft bpl, respectively. DZMW-1 can be used as designed and required by the FDEP.

Injection tests were performed to demonstrate that wells IW-1 and IW-2 are capable of efficiently accepting flow. The flow rate of the injection tests was limited to the available withdrawal capacity of one test production well constructed in the Upper Floridan Aquifer (The ROWTP or other production wells were not yet constructed at the time of testing). The injection tests demonstrate that wells IW-1 and IW-2 are capable of efficiently accepting flow at the rates tested. A rerate will be necessary when additional capacity and pumps become available.

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