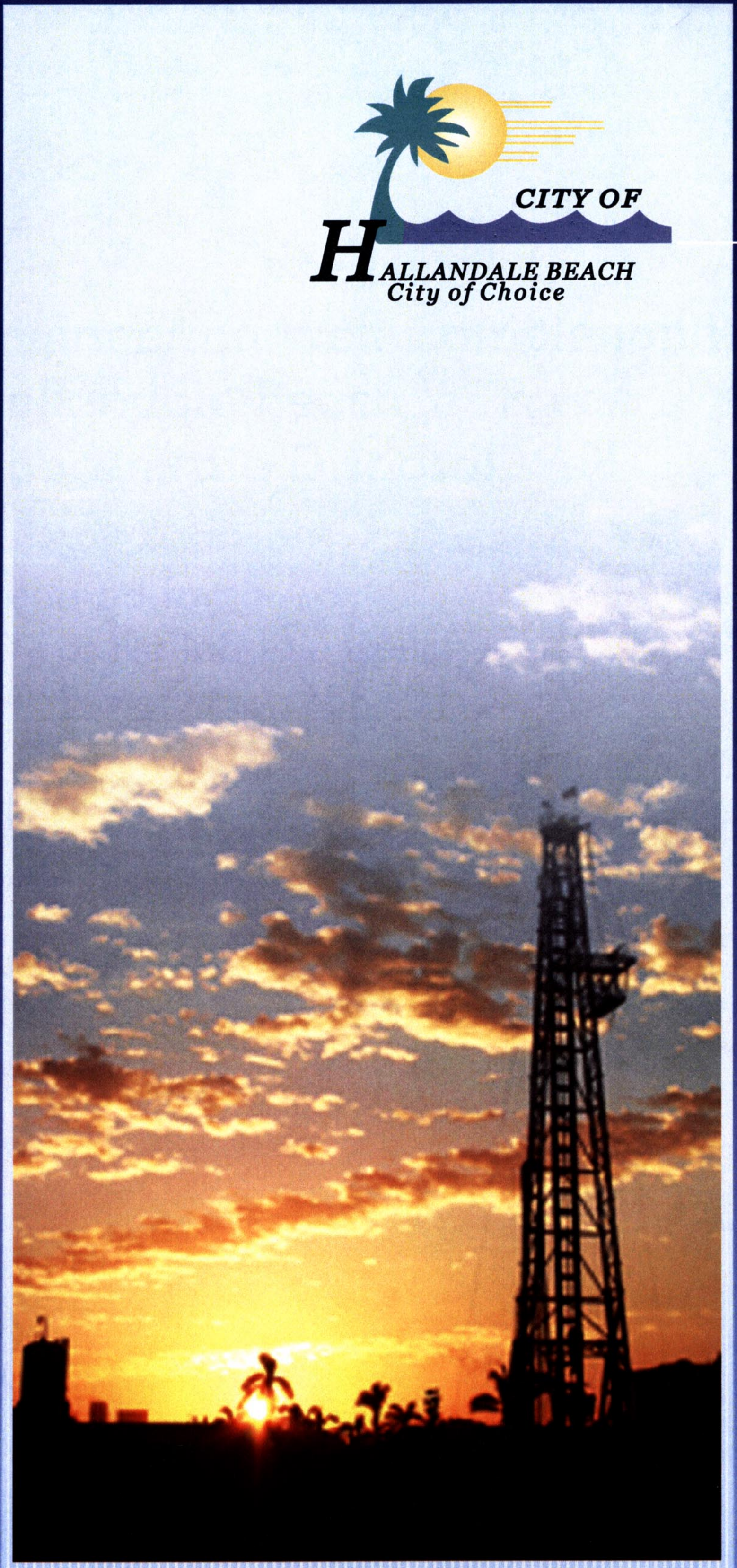

CITY OF
HALLANDALE BEACH
City of Choice

Engineering Well Completion Report
Hallandale Beach WTP
Concentrate Disposal Well

Prepared for
City of Hallandale Beach
City Project No. 258101

February 2007

Prepared by:
Hazen and Sawyer, P.C.
Project No. 40409-000

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February 14, 2007

Joseph R. May, P.G.
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City of Hallandale Beach
UIC Class I Injection Well
Permit Number 227805-001-UC
Engineering Well Completion Report

Dear Mr. May:

In fulfillment of the above-reference permit and Florida Administrative Code 62-528, Hazen and Sawyer is pleased to submit the attached Well Completion Report on behalf of the City of Hallandale Beach. The injection well and dual-zone monitor well are located at the City of Hallandale Beach Water Treatment Plant. This report presents the results of the construction and testing performed during the drilling of the concentrate disposal well and the associated monitor well.

As always, please feel free to call should you have any questions.

> *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.*

Jenny Cheretis, P.E.
Public Works Director

Albert Muniz, P.E.
No. 35587

2/14/07

Very truly yours,

Hazen and Sawyer, P.C.

Albert Muniz, P.E.
Project Manager

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O:40409L034

CITY OF HALLANDALE BEACH - CONCENTRATE DISPOSAL SYSTEM
WELL CONSTRUCTION PEELE-DIXIE WTP
DEP PERMIT NO: 227805-001-UC

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Table of Contents

Chapter 1.0 - Injection Well Program

Chapter 2.0 - Well Drilling and Construction

Chapter 3.0 - Subsurface Conditions

Chapter 4.0 - Final Testing

Chapter 5.0 - Findings and Recommendations

Tables

Figures

Appendices

1.0 Injection Well Program

1.1 Introduction

On October 4, 2005, the City of Hallandale Beach (the City) was issued Permit No. 227805-001-UC by the Florida Department of Environmental Protection (FDEP) for construction of a concentrate disposal system consisting of one 11.75-inch diameter Class-1 injection well (IW-1) and associated dual-zone deep monitor well (MW-1). As noted in the permit, IW-1 was constructed using an FDEP approved alternative design to the standard Class I injection well design for the installation of the injection tubing. The alternative design requires that an interim mechanical integrity test be conducted every 2.5 years. A copy of the test/construction permit is included in Appendix A for reference. The wells are located at the City of Hallandale Beach Water Treatment Plant (WTP) as shown in Figures 1 and 2.

The wells were constructed in accordance with Contract Documents prepared by Hazen and Sawyer (H&S) entitled Contract Documents for the Construction of the Concentrate Disposal Well, dated August 2005. These plans and specifications for drilling one injection well and one dual-zone monitor well formed the basis of a contract between the City of Hallandale beach and Youngquist Brothers, Inc. (referred to hereinafter as "the Contractor").

H&S was retained by the City of Hallandale Beach to provide construction management services for the project. H&S utilized the services of Water Technologies Associates, Inc. (WTA) to provide partial field observation and hydrogeologic services. The H&S and WTA team is hereinafter referred to as "the Engineer". On-site supervision was provided by the Engineer during testing, geophysical logging, casing installation, and cementing operations. Construction phase responsibilities of the Engineer included obtaining FDEP approval on key elements of the project and reporting project progress weekly to the Technical Advisory Committee (TAC), which included members from the FDEP, the Broward County Department of Planning and Environmental Protection (BCDPEP), the South Florida Water Management District (SFWMD) and the United States Geological Society (USGS). The United States Environmental Projection Agency (EPA) is copied on TAC correspondence, but is not a member of the TAC.

- Collecting and analyzing background water samples from the monitoring zones and the injection zones;
- Conducting a hydrostatic pressure test, video survey and radioactive tracer survey on the final casing string to determine mechanical integrity of the injection well; and
- Conducting a short-term injection test to demonstrate the ability of the injection well system to accept effluent at the design flow rate.

2.0 Well Drilling and Construction

2.1 Well Construction

The injection well was constructed prior to the construction of the dual-zone monitor well (i.e., IW–1 constructed prior to MW-1). As shown in Figure 3, the monitor well was constructed approximately 150 feet north of IW-1. During the drilling of the wells, geophysical logging and testing were performed in accordance with the FDEP construction permit. Table 1 presents a summary of the key dates during the construction and testing of IW-1 and MW-1.

The drilling of IW-1 and MW-1 proceeded generally as identified in the project specifications with modifications approved by FDEP. The project specifications identified an outline of a drilling plan with the intention of making modifications to the plan as site specific conditions warranted. The plan included setting casing at selected depths to maintain the formation during drilling and to facilitate the proposed testing. Drilling activities are summarized in the following outlines, which identify nominal depths.

To consistently record downhole depth, all well measurements are recorded in terms of depth below pad level (bpl). Actual depths of casings are identified in the as-built profiles of the completed wells. As-built profiles for IW-1 and MW-1 are presented in Figures 4 and 5, respectively. The injection well was constructed as generally follows:

- Drill a nominal 58-inch diameter borehole to approximately 157 feet bpl using the mud rotary method
- Set and cement 48-inch diameter steel casing to a depth of 152 feet bpl
- Drill a nominal 48-inch diameter borehole to approximately 995 feet bpl using the mud rotary method
- Set and cement 36-inch diameter steel casing to a depth of 990 feet bpl
- Drill a 12 ¼-inch diameter pilot hole to approximately 2,000 feet bpl using the reverse air method and core at depths selected by the Engineer
- Conduct straddle packer tests at depths selected by the Engineer
- Back plug pilot hole with cement
- Drill a nominal 36-inch diameter borehole to approximately 1,900 feet bpl using the reverse air method

2.2 Data Collection

Data was collected during the construction of the wells using various methods and procedures as described in this Section. Geophysical logging was performed by the Youngquist Brothers Geophysical Logging Division. Independent testing and laboratory analyses were performed by subcontractors of Youngquist Brothers, Inc. including the following: water quality analyses were performed by Florida Environmental Laboratories and testing of rock cores was performed by Ardaman & Associates, Inc.

Except as noted, measurements of footage in the wells are referenced to the drilling pad level; the National Geodetic Vertical Datum (NGVD) elevation of the pads at IW-1 and MW-1 are 9.47 and 9.52 feet, respectively.

Daily progress and activities were monitored and recorded during construction and testing. The Engineer prepared daily progress reports during well construction. The Contractor prepared independent daily reports. In addition to recording daily drilling progress, the reports included other pertinent drilling information such as drilling speed, weight on the drill bit, penetration rates, and relative hardness of the formations. Problems encountered during drilling were observed and noted. Activities related to the installation of well casings, cementing or other materials, as well as their quantities, were recorded. Detailed descriptions of test procedures and data collection, including results of inclination surveys to verify straightness of the borehole, were recorded. The length and configuration of tools introduced into the borehole were noted. Copies of the daily and weekly progress reports were transmitted to the TAC members on a weekly basis. Graphs of the drilling weight on bit (WOB) and rate of penetration (ROP) are presented in Appendix B.

An inclination survey was conducted every 90 feet in all pilot and reamed holes to confirm plumbness requirements for the wells. The results from the inclination surveys performed during drilling operations are presented in Appendix C.

2.3 Geologic Samples

Samples of drilled cuttings were collected and analyzed from the drilling of the injection well and monitor well pilot holes. Circulation time (the time required for drilled cuttings to reach the surface) was calculated regularly to ensure that accurate sample depths were recorded. After initial examination, the Engineer's on-site personnel described the samples. A geologic description of each sample was entered into a log. The cuttings from the confining interval were classified in accordance with the scheme of Dunham (1962). These logs are presented in Appendix D. Two sets of drill cuttings were bagged in 10-foot intervals. After the wells were completed, the Contractor sent one set of these samples to the Florida Bureau of Geology in Tallahassee, Florida.

2.4 Cores

During the drilling of the injection well pilot hole, conventional core samples were collected. These samples were reviewed and select samples were sent to an independent laboratory for analysis. The results of the analyses are used to demonstrate confinement. Core depths were selected by the Engineer primarily on the basis of reviewing and interpreting information from other nearby wells and information obtained during the drilling of the injection well including weight on bit, rate of penetration and lithology. The Contractor used 4-inch inside diameter core barrels for this project. Each core was approximately ten feet long. Cores from IW-1 were taken at the depths identified in Table 3.

Samples from each core were selected and sent for analysis to Ardaman and Associates, an independent laboratory. These samples were tested for several parameters including permeability, porosity and specific gravity. Core laboratory analysis results and geologic core descriptions are presented in Appendix E. A summary of the hydraulic conductivity from the laboratory analyses of the cores is presented in Table 4.

2.5 Geophysical Logs

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

- X-Y Caliper – Identification of borehole diameter and geometry
- Gamma Ray – Measurement of the natural gamma ray radiation of the formation, used as a tie-in between logs
- Dual Induction Log (A resistivity log) Identifies differentiation between limestone and dolomite beds, and, along with the gamma ray log, is useful in the correlation of lithologic units
- Borehole Compensated Sonic Variable Density Log (VDL) – Identification of the confining sequences, as well as identification of zones that could cause problems during cementing
- Flow Meter Surveys – Determination of where fluid may be entering or exiting the borehole

- Temperature – Provides a profile of static and dynamic temperature of the borehole, may be useful in determining changes in fluid movement
- Borehole Televiewer (BHTV) – Determination of where structural features (bedding planes, fractures, vugs and voids) are located
- Cement Top Temperature – Verification of the annular space fill-up after each cementing stage
- Cement Bond Log – Used to assess the quality of the bond between the inner casing and the cement grout around the casing. The resulting curve of the log is a function of casing size and thickness, cement strength and thickness, degree of cement bonding and tool centering

Geophysical logs were transmitted to TAC members on a weekly basis during construction. Copies of the logs can be found on a cd-rom at the end of the report. For convenience, many of the same type of logs were merged together. Appendix F presents an index of the logs performed and a tabulation of the logs.

During the geophysical logging and testing of the well, the Engineer was on site to witness the logging and verify quality control procedures. The quality control maintained during the testing program was, to a large extent, provided by Youngquist Brothers Geophysical Logging Division. Industry standard quality control measures were observed and are documented on the logs. Detailed information of the tool calibration program utilized by Youngquist Brothers Geophysical Logging Division is also included in attached Appendix F.

2.6 Video Surveys

Video surveys were conducted and recorded in VHS format in the injection well pilot holes from 1,000 to 3,000 feet bpl, in the injection zone from 3,000 to 3,500 feet bpl and in the injection tubing from land surface to 2,863 feet bpl. Video surveys were also performed on the dual–zone monitoring well from 1,400 to 1,800 feet bpl. Color video surveys were made with the camera lens in two positions; downhole with a radial view and uphole with a horizontal rotating position. Air development was used to displace suspended solids from the well prior to performing the television survey. The open-hole survey allowed the reviewer to visually inspect the formations encountered in the borehole, as well as to observe potential fractures and water-producing zones. Acceptable picture clarity was obtained in the surveys. A log describing the formation and structural features observed in the open hole of the injection well and monitor well is presented in Appendix G. A copy of video survey is also included in Appendix G. Copies of the surveys can be found on DVDs at the end of the report.

2.7 Packer Tests

Straddle packer tests were performed after pilot hole construction of the injection well. Two inflatable packers (plugs) are set in the borehole and water is pumped from between the packers. Packer tests were conducted at intervals to either support demonstration of confinement, to determine water quality so as to define the base of the Underground Source of Drinking Water (USDW), or to identify potential monitoring zones. The packers were used to isolate zones to perform drawdown and recovery tests. The straddle packer intervals were selected based on reviewing and interpreting information from geophysical logs, lithology, cores and other packer tests. Six straddle packer tests were performed in IW-1. Two of the straddle packer tests performed in the injection well identified acceptable monitoring zones for MW-1

The packers were lowered into the pilot hole to the selected interval on the 7 ⅝-inch (outside) diameter drill pipe, inflated and seated against the formation. A 4-inch diameter submersible pump was lowered into the drill pipe approximately 200 feet to introduce stress on the isolated interval. Prior to starting the tests, each zone was developed free of any drilling fluids by means of air lifting and pumping until the specific conductance stabilized. Development time is identified in Table 5. The isolated zone was then allowed to recover from development before beginning the pumping test. During drawdown and recovery, water level measurements were obtained using a data logger attached to a pressure transducer (In-situ Hermit 3000). In addition to the hermit data logger, a battery-operated downhole pressure recorder was used for backup and quality control. The pressure transducer was lowered to a known depth. The method of analysis used on the data collected and recorded during the packer tests was the Modified Non-Equilibrium Formula derived by Cooper and Jacob (1946). The equation of the Cooper-Jacob method is as follows:

$$T = \frac{264Q}{\Delta s}$$

T = coefficient of transmissivity (gpd/ft)

Q = pumping rate (gpm)

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

The calculated hydraulic conductivity from the packer tests are presented in Table 6. The raw packer test data and data plots are presented in Appendix H. Based on the stabilization of the fluid specific conductance prior to starting the packer tests and the drawdown characteristics of the data shown in this Appendix, the hydraulic conductivity values presented from the packer tests are considered valid.

2.8 Packer Test Water Quality

Water samples obtained during the packer tests were analyzed in the field for temperature and conductivity. These water samples were collected during the drawdown phase of the packer test and sent to an independent laboratory for additional analysis. The samples were analyzed and the results are presented in Appendix I. A compilation of the packer test water quality data is presented in Table 7. Log derived water graphs were prepared to compare to the packer test water quality test. This graph shows good correlation, and is presented in Appendix J.

2.9 Casing

Casing heat numbers stamped on the casing were verified with the mill certificates prior to running casing in the hole. Copies of the casing mill certificates are presented in Appendix K. Cementing plans for each casing string were proposed by the Contractor and reviewed by the Engineer prior to cementing. After accepting the proposed plan, casing was set and cemented. A copy of the cement reports for each casing run is presented in Appendix L.

Final casing installations were pressure tested. The 18-inch injection well casing was pressure tested as identified below. The 11.75-inch injection well tubing was pressure tested as part of the demonstration of mechanical integrity described in Section 4, Final Testing. The monitor well 16 and 6 ⅝-inch casings were pressure tested as identified below.

On June 9, 2006, the injection well 18-inch casing was internally pressurized to 164.5 psi. A pressure increase of 4.25 psi was observed over the 60-minute test period. This increase represents a 2.6 percent change in the original pressure, which is within the allowable regulatory limit of 5.0 percent. A copy of the test gauge certification records and certified results of the hydrostatic pressure test are contained in Appendix M.

On July 7, 2006, the injection well 11.75-inch injection well tubing was internally pressurized to 161.25 psi. A pressure increase of 0.75 psi was observed over the 60-minute test period. This increase represents a 0.5 percent change in the original pressure, which is within the allowable regulatory limit of 5.0 percent. A copy of the test gauge certification records and certified results of the hydrostatic pressure test are contained in Appendix M.

On August 7, 2006, the monitor well 16-inch casing was internally pressurized to 75.00 psi. A pressure decrease of 1.75 psi was observed over the 60-minute test period. This decrease represents a 2.3 percent change in the original pressure, which is within 5.0 percent maximum allowable change. A copy of the test gauge certification records and certified results of the hydrostatic pressure test are contained in Appendix M.

On August 24, 2006, the monitor well 6 ⅝-inch casing was internally pressurized to 80.25 psi. A pressure decrease of 3.3 psi was observed over the 60-minute test period. This increase represents a 4.1 percent change in the original pressure, which is within 5.0 percent maximum allowable change. A copy of the test gauge certification records and certified results of the hydrostatic pressure test are contained in Appendix M.

2.10 Cement Bond Logs

Cement bond logs are used to assess the quality of the bond between the casing and the cement grout. The resulting curve of the log is a function of casing size and thickness, cement strength and thickness, degree of cement bonding and tool centering.

The travel time curve (left log track) is run to determine if the tool is properly centered. The critical travel time is the time recorded when the tool is absolutely centralized in high signal areas, areas with no cement (free pipe). Factors affecting the travel time curve are cycle skipping that can be caused by fast formation arrivals and formations that are so dense they actually have a faster transit time than the casing. The basic transit time of steel is slower than some dolomites and limestones. On the amplitude curves (center log track), a time gate is set at the time corresponding to the expected arrival of the casing signal, and the amplitude of the signal in that gate is recorded. A high amplitude indicates a larger casing signal, and therefore a poorer cement bond; a low amplitude indicates a good bond.

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

On June 8, 2006 a cement bond log was performed in the injection well 18-inch casing. From the travel time log it can be seen that good tool centralization was maintained for the entire log. The variable density display shows no strong casing signal on any section of the 18-inch casing. The cement bond log conducted in IW-1 demonstrated that there is a good cement seal around the 18-inch diameter casing and that there are no apparent channels or conduits that would allow fluid movement adjacent to the casing.

On July 7, 2006 a cement bond log was performed in the injection well 11.75-inch FRP tubing. From the travel time log it can be seen that good tool centralization was maintained for the entire log. The variable density display shows no strong casing signal on any section of the 11.75-inch tubing. The cement bond log conducted in IW-1 demonstrated that there is a good cement seal around the 11.75-inch diameter tubing and that there are no apparent channels or conduits that would allow fluid movement adjacent to the tubing.

On August 4, 2006 a cement bond log was performed in the monitor well 16-inch casing. From the travel time log it can be seen that good tool centralization was maintained for the entire log. The variable density display shows no strong casing signal on any section of the 16-inch casing. The cement bond log conducted in MW-1 demonstrated that there is a good cement seal around the 16-inch diameter casing and that there are no apparent channels or conduits that would allow fluid movement adjacent to the casing.

On August 24, 2006 a cement bond log was performed in the monitor well 6 ⅝-inch FRP tubing. From the travel time log it can be seen that good tool centralization was maintained for the entire log. The variable density display shows no strong casing signal on any section of the 6 ⅝-inch tubing. The cement bond log conducted in MW-1 demonstrated that there is a good cement seal around the 6 5/8-inch diameter tubing and that there are no apparent channels or conduits that would allow fluid movement adjacent to the casing.

2.11 Tubing and Packer

A positive seal packer was installed in the 18-inch casing at a depth of 2,863 feet bpl. The 11.75-inch injection tubing is seated on the packer and is centered by centralizers. The 11.75–inch tubing was then cemented in place to surface. A copy of the packer specifications is presented in Appendix N. An as-built profile of IW-1 is presented in Figure 4.

2.12 Monitor Zone Depths

The selection of monitor zones for MW-1 was established based on information available from the drilling and testing of IW-1 and was approved by FDEP. The upper monitor zone was established between 1,400 and 1,448 feet bpl and the lower monitor zone between 1,752 and 1,803 feet bpl. An as-built profile of MW-1 is presented in Figure 5.

3.0 Subsurface Conditions

3.1 Background

This section presents the site-specific geologic and hydrogeologic information obtained during this project and the results of various tests made during construction of IW-1 and MW-1.

3.2 Generalized Geologic Setting

A well-defined, extensive sequence of carbonate sediments is present at the City of Hallandale Beach WTP site. This is consistent with information obtained from other projects in the area. The geologic units found during construction of the monitoring well satisfy the requirements of FAC Rule 62-528. Geophysical logging and testing confirmed the presence of a suitable confining sequence and suitable monitor zones. A brief description of the various geologic units follows.

From land surface to approximately 270 feet bpl, the sediments are comprised of limestone, sandy limestone, limey sandstone, sandy clay and varying amounts of unconsolidated shell and sand. The limestone and sandy limestone are generally very pale orange to light olive gray packstone and grainstone. The limey sandstone is generally light gray to grayish yellow and olive, fine to medium-grained and slightly phosphatic. The sandy clay is grayish olive, soft, plastic and slightly calcareous with very fine to fine-grained quartz sand. Various amounts of shell and quartz sand are also present in these sediments.

The dissolution features and generally poor cementation apparent in the upper 270 feet of sediments give this unit the high permeability characteristic of the Biscayne Aquifer. These sediments are Pleistocene to Miocene in age and correspond to descriptions of the Pamlico Sand and Anastasia Formations.

From approximately 270 feet to 830 feet bpl, the sediment is predominantly composed of pale olive to olive gray, plastic clay. From 830 feet to 930 feet bpl, the sediment is predominantly highly calcareous clay with various amounts of marl, limestone and sand.

The calcareous clay is mostly pale or light grayish olive, soft and composed of silty clay with interbedded limestone present throughout the interval. The limestone varies from light olive gray to dark gray sparry mudstone to packstone. The sediments in the interval between approximately 270 and 930 feet bpl are Miocene to Late Eocene in age and correspond to the Hawthorn Formation.

From about 930 feet to 2,010 feet bpl, the sequence is composed almost entirely of limestone rarely interbedded with dolomite, typically a pale orange to grayish orange, fine to medium grained packstone. The limestone in this sequence is Middle to Late Eocene age and is delineated as part of the Suwannee Limestone.

Between 2,010 and 2,920 feet bpl, limestone is interbedded with light to moderate yellowish-brown and fine to medium grained to cryptocrystalline dolomite and dolomitic limestone. The limestone in this interval is generally very pale orange to grayish orange, pelloidal or micritic, fine to medium grained and soft. This section is comprised of sediments of Early to Middle Eocene Age of the Avon Park Limestone.

The "boulder zone" extends from approximately 2,920 to at least 3,500 feet bpl in the Lower Oldsmar Formation. The lower limit of the injection zone was not determined since drilling was terminated at approximately 3,500 feet bpl. The television surveys indicate that the dolomite in this zone exhibits extensive dissolution cavities as well as fracturing.

The various formations penetrated by IW-1 and MW-1 correlate closely with those encountered in the other wells in the area, demonstrating the continuity and uniformity of the beds. A hydrogeologic cross section of the wells on site is presented in Figure 5.

The various formations penetrated by IW-1 and MW-1 correlate closely with those encountered in the other wells in the area, demonstrating the continuity and uniformity of the beds. A hydrogeologic cross section of the wells on site is presented in Appendix D.

3.3 Hydrogeologic Setting

The upper 270 feet of rock and sediments are Pleistocene and Upper Miocene sandstone, limestone, clay and unconsolidated sand and shell. These sediments comprise the Biscayne Aquifer which is used as a source of drinking water throughout South Florida.

Underlying the Biscayne Aquifer are approximately 560 feet of Miocene clay and marl of the Hawthorn Formation which form a confining bed between the Biscayne Aquifer and the Oligocene to Eocene limestones and dolomites of the Floridan Aquifer. The clay and marl confining sequence is called the Hawthorn Formation. Water from the Floridan Aquifer in South Florida contains concentrations of dissolved solids which exceed drinking water standards. The aquifer is not currently used as a main source of drinking water in Broward County; however, some water utilities have begun to use it.

Within the Eocene limestones, confining sequences have been identified between 1,500 and 2,000 feet bpl and from 2,100 feet to 2,500 feet bpl. As discussed in Section 3.5 they consist of thick sequences of dense limestone with some interbedded layers of dolomite and are discussed in greater detail later in this report.

3.4 Water Quality

Water samples were collected from isolated sections of the borehole during the straddle packer tests. The water samples from the packer tests were analyzed for selected parameters to establish background water quality and to identify the depth at where there is 10,000 mg/L of total dissolved solids (TDS).

The tests were conducted in intervals considered suitable as confining zones and intervals suitable as monitor zones. During the packer tests, a sample of the formation water from the tested interval was collected just prior to shutting off the pump, after significant development time. Water samples from the packer tests were analyzed for TDS, chloride, specific conductivity, ammonia, and total kjeldahl nitrogen. Results of the laboratory analyses are presented in Appendix I. Table 5 summarizes the results of the laboratory analyses from the packer tests.

The base of the USDW is defined as water having a total dissolved solids (TDS) concentration of 10,000 mg/L. The base of the USDW was identified by performing water quality analysis on samples obtained from packer tests and geophysical log interpretation. Based on the water quality testing, the base of the USDW currently occurs at approximately 1,440 feet bpl. Data compiled from geophysical logs, including the dual induction log, is useful in determining the base of the USDW. From these logs water quality can be derived. The log derived water quality data places the base of the USDW at approximately 1,440 feet. This data is confirmed by the water quality results of the packer test conducted in IW-1 between 1,431 and 1,444 feet that yielded a TDS concentration of 10,592 mg/L. A copy of the log derived water quality graph from IW-1 is attached and is presented in Appendix J.

3.5 Confinement Analysis

The approach to the evaluation of vertical confinement at the City of Hallandale Beach WTP is as follows. Available borehole geophysical, geological data and open hole testing data were used to identify intervals from 1,440 feet bpl (base of the USDW) to 3,000 feet bpl that exhibit confining properties. The vertical confinement provided by each interval was then evaluated. Particular attention was paid to locating beds of limestone, dolomite, clay or marl that have low matrix vertical hydraulic conductivities and are not penetrated by fractures and/or solution cavities. Such tight beds provide the primary vertical confinement of the injected concentrate.

3.5.1 Identification of Confining Units

The presence of satisfactory confining sequences between 1,440 and 3,000 feet bpl was established during the drilling of IW-1. A letter previously submitted to the TAC documented the presence of this confinement on site. This letter from the Engineer is dated May 16, 2005 and is referred to as the "18-inch Casing Seat Request".

3.5.2 Geophysical Logs

The wire line geophysical logs for IW-1 were examined in detail for the presence of units of rock that could provide vertical confinement for injected fluids. A combination of sonic, caliper and resistivity logs were used to identify well-cemented limestone and/or dolomite beds that would be expected to have low matrix porosities and hydraulic conductivities. Borehole televiewer logs were used to locate fractures and/or cavernous zones that could be conduits for vertical fluid flow. Information on the orientation and thickness of beds was also obtained from the borehole televiewer logs.

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

Flowmeter, temperature, and fluid resistivity/conductivity logs provide information on the location of flow zones into wells and on changes in the salinity of formation waters. These logs did not provide useful information concerning vertical confinement. Flowmeter logs are of limited value for identifying individual beds with low vertical hydraulic conductivities because a single zone of high hydraulic conductivity very often dominates the flow for the entire tested interval

3.5.3 Characterization of Well Cuttings

Cuttings collected during the pilot hole drilling of IW-1 (land surface to 3,000 feet bpl) were examined in detail for lithology, macroporosity (visible porosity) and apparent matrix hydraulic conductivity using a stereomicroscope. The cuttings were grab samples collected at 10-foot intervals during the construction of the well. The lithology of the limestones cuttings was characterized using the limestone classification scheme of Dunham (1962). The most common grain types were silt to fine-sand sized rounded carbonate grains that are described as either peloids (fecal pellet-shaped grains of indeterminate origin) or as bioclasts (transported fossil fragments). The mineralogy of the samples (calcite versus dolomite) was confirmed by reaction with dilute hydrochloric acid. Dolomite was classified according to crystal size as being either microcrystalline (crystals are not visible with the low-powered microscope), finely crystalline (1/64 to 1/16 mm) or medium crystalline (1/16 to 1/4 mm).

The macroporosity (visible porosity) of the samples was characterized as being very low (< 2%), low (2-5%), moderate (5-15%), high (15-25%), or very high (>25%). The apparent matrix hydraulic conductivity was qualitatively evaluated as being very low to high based on the porosity, size of the pores, and likely degree of interconnection of the pores.

3.5.4 Core Examination and Data Analysis

Twelve cores were recovered from 1,665 to 2,300 feet bpl in IW-1. The lithology of the cores was evaluated to determine if there were any significant biases in the cutting samples. The well cuttings appeared to have somewhat less intergranular carbonate mud than the cores. In some limestone cuttings, the carbonate mud appeared to have been washed out of the samples during drilling. Some limestone cuttings, particularly grainstone and packstone lithologies, thus appear to be more porous than they actually are. The cores were also examined for the presence of fractures or solution features (vugs) that might be conduits for vertical fluid flow. A copy of the core descriptions is contained in Appendix E. Sections of each core were selected and submitted for laboratory analysis for hydraulic conductivity. Results from the laboratory core analysis are summarized in Table 2. The complete laboratory analysis is presented in Appendix E.

3.5.5 Packer Test Data

Straddle packer test data collected during the drilling of IW-1 were analyzed for information on the hydraulic conductivity of potential confining units. A total of eleven straddle packer tests were conducted. The straddle packer data were analyzed using the Cooper and Jacob (1946) modification of the Theis (1935) non-equilibrium equation (i.e., the straight-line method). The transmissivity values calculated from both the pumping and recovery phase data for each test were similar.

It should be noted that the transmissivity and average hydraulic conductivities values calculated from the packer test data are largely a function of horizontal hydraulic conductivities. Packer test data thus tend to over estimate vertical hydraulic conductivities. For example, a packer test performed on an interval containing one or more high hydraulic conductivity beds interbedded between very low hydraulic conductivity beds would give a high transmissivity and average hydraulic conductivity value whereas the interval would have a very low vertical hydraulic conductivity. The results from each packer test are contained in Appendix H. A summarization of the results of the packer tests is shown in Table 4.

3.5.6 Stratigraphic Correlation

The geologic logs of IW-1 and MW-1 indicate excellent correlation as would be expected from wells in such close proximity. In addition to very similar overall lithology, yellowish gray packstone to grainstone with similar percentages and type of yellowish gray wackestone was observed in samples from both wells from 1,430 to 1,450 feet and a sequence of very pale orange packstone with similar accessory components was observed in samples from both wells from 1,560 to 1,600. Additionally, medium gray, hard, vuggy mudstone was observed in both wells at 1,670 and very similar quantities of medium light gray very fine grained mudstone were observed from 1,710 to 1,730. Samples collected from the proposed monitor zone in both wells also indicate excellent correlation. Similar percentages of light olive gray mudstone occurred at 1,770 and very similar dolomitic packstone was observed in samples from both wells at 1,780. Minor lithologic variations such as the presence or absence of soft very fine grained sediments and other minor to trace constituents can be attributed to variations in drilling parameters such as rate of penetration and drilling fluid weight and viscosity. In addition, the reverse air drilling method does not generally yield high quality lithologic samples. Very high circulation rates and fluid turbulence tend to have a detrimental effect on sample quality.

The geophysical logs also indicate excellent correlation between the two wells. An example of this correlation can be seen when the dual induction, sonic and variable density logs from IW-1 and MW-1 are placed side by side. With the logs in this position, it can be seen that the logs are very similar. Examples of this can be seen on the dual induction logs with very similar responses in both wells. Over the intervals of 1,450 to 1,520 and from 1,680 to 1,710 feet bpl good correlation can be seen as responses are at approximately the same depths and of approximately the same magnitude. Excellent correlation can also be seen on the sonic porosity logs from 1,450 to 1,480, from 1,550 to 1,600, from 1,690 to 1,700 and within the proposed lower monitor zone from 1,740 to 1,770 feet bpl. The VDL logs also indicate excellent correlation between IW-1 and MW-1 through the entire interval from 1,450 to 1,600; 1,690 to 1,700 and within the proposed lower monitoring zone from 1,760 to 1,790 feet bpl. Although not as pronounced, the gamma ray logs show similar responses from 1,590 to 1,610 and from 1,740 to 1,760. Even though IW-1 and MW-1 were drilled using different diameter bits, the caliper logs over the interval of 1,400 to 1,800 feet bpl show good correlation appear indicating that the formations encountered are very similar.

The video surveys of IW-1 and MW-1 also indicate excellent correlation. In addition to very similar overall lithology, moderately light to light colored interbedded limestone was observed from 1,400 to 1,560 feet bpl in both wells as well as light colored weakly bedded limestone from 1,480 to 1,610 feet bpl. Within the proposed lower monitoring zone, generally well to very well indurated dominantly light colored limestone, occasionally interbedded with darker beds and laminations was observed in both wells.

3.5.7 Testing Quality Control Quality Assurance

For each of the testing procedures conducted, quality control and quality assurance procedures were implemented and documented. A copy of the calibration theory and practice for the geophysical logs conducted are contained in Appendix F. Quality control procedures for the packer testing are contained in Appendix H.

3.5.8 Criteria for Identification of Confinement Units

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

- Low sonic transit times and derived sonic porosities
- Variable density log (VDL) pattern consisting of straight parallel vertical bands, where lithology is relatively uniform, or a "chevron" pattern of continuous parallel bands, where the formation consists of interbedded rock with differing densities and/or degrees of consolidation. Fractured rock typically has an irregular VDL log pattern
- Low hydraulic conductivities calculated using packer pump test data
- Low macroporosity (i.e., visible pore spaces) and a high degree of cementation (hardness) as observed in microscopic examination of cuttings and core samples
- Borehole diameters on caliper logs close to the bit size. Fractured dolomite and limestone is commonly manifested by an enlarged borehole

- Relatively high resistivities, which in the middle and lower Floridan Aquifer System are often indicative of tight dolomite and or limestone beds
- Absence of evidence of fractures on the video survey and borehole televiewer log

3.6 Confinement Intervals

The confinement properties of the strata between the base of the USDW (1,440 feet bpl) and 3,000 feet bpl were evaluated using the above criteria and data. The confining intervals are discussed below.

3.6.1 *Interval From 1,500 to 2,000 Feet BPL*

This interval consists predominantly of light-colored limestone with few dolomite interbeds. Wackestones and packstones are the most common lithologies. The wackestones and packstones are interbedded with subsidiary beds of carbonate-mud rich lithologies (fossiliferous mudstones and grainstones). The borehole televiewer log indicates that the beds are horizontal and range in thickness from approximately 0.5 to 10 feet. The bedding appears to consist of stacked sequences of carbonate sand-rich (wackestones and packstones) and carbonate mud-rich (packstones to mudstones) limestones. The mudstone and wackestone beds, which have low macroporosities and are well cemented, can provide better vertical confinement than the thicker grainstone and packstone beds. No evidence of vertical fractures or solution cavities was visible on the borehole televiewer log or the television survey video.

Packer tests were performed in IW-1 over the intervals 1,590 – 1,608. 1,747 – 1,765, 1,765 – 1,783, 1,872 – 1,890, and 1,965 – 1,983 feet bpl within this confinement interval and yielded hydraulic conductivities ranging from 1.2×10^{-4} to 6.6×10^{-4} cm/sec.

Within this confinement interval seven conventional cores were recovered from 1,655 - 1,680, 1,700 – 1,720, 1,770 – 1,795, 1,855 – 1,880, 1,935 – 1,960, 1,965 – 1,974 and 1,975 – 2,000 feet bpl during the drilling of IW-1. The vertical hydraulic conductivity of core samples range from 5.2×10^{-9} to 4.6×10^{-4} cm/sec.

3.6.2 *Interval From 2,100 to 2,500 Feet BPL*

This interval consists of interbedded light-colored limestones and dolomites. Grainstones and packstones are the most common lithologies. The grainstones and packstones are interbedded with subsidiary beds of carbonate-mud rich lithologies (fossiliferous mudstones and wackestones).

The borehole televiewer log indicates that the beds are horizontal and range in thickness from approximately 0.5 to 10 feet. The bedding appears to consist of stacked sequences of carbonate sand-rich (grainstones and packstones) and carbonate mud-rich (packstones to mudstones) limestones. The mudstone and wackestone beds, which have low macroporosities and are well cemented, can provide better vertical confinement than the thicker grainstone and packstone beds. No evidence of solution cavities was visible on the borehole televiewer log or the television survey video and only one local vertical fracture, from 2,100 to 2,102 feet bpl was observed.

Packer tests were performed in IW-1 over the intervals 2,125 – 2,143, 2,285 – 2,303, 2,325 – 2,343, 2,400 – 2,418 and 2,440 – 2,458 feet bpl within this confinement interval and yielded hydraulic conductivities ranging from 2.5 x 10^{-5} to 3.2 x 10^{-4} cm/sec.

Within this confinement interval five conventional cores were recovered from 2,022 – 2,039, 2,040 – 2,065, 2,085 – 2,101, 2,275 – 2,300 and 2,475 – 2,300 feet bpl during the drilling of IW-1. Eighteen sections were submitted for laboratory analysis. The vertical hydraulic conductivity of core samples range from 3.8 x 10^{-11} to 3.4 x 10^{-4} cm/sec.

3.6.3 Confinement Summary

During the drilling and testing of these wells at the City of Hallandale Beach WTP, an extensive program was implemented to identify confinement between the base of the USDW and the depth 3,000 feet bpl. A number of cores and packer tests were performed over a relatively small depth interval.

The limestones and dolomites present from 1,500 to 2,000 feet bpl in IW-1 have geological and geophysical characteristics indicative of good confinement. The available borehole televiewer and television surveys show no evidence of fractures or cavernous zones that could be conduits for the upward migration of injected effluent. The majority of the 1,500 to 2,000 feet bpl interval consists of horizontally bedded, fossiliferous limestone. The limestones have visible porosities (i.e. macroporosities) estimated to range mostly between 0 and 15%. Sonic and core sample total porosities range mostly between 33 and 45%. The majority of the porosity of the limestones is microporosity (microporosity = total porosity minus macroporosity). Microporosity rocks, where unfractured, typically have low hydraulic conductivities. Straddle packer tests conducted within this confinement interval yielded hydraulic conductivities ranging from 1.2 x 10^{-4} to 6.6 x 10^{-4} cm/sec. The vertical hydraulic conductivity of core samples range from 5.2 x 10^{-9} to 4.6 x 10^{-4} cm/sec.

The limestones and dolomites present from 2,100 to 2,500 feet bpl in IW-1 have geological and geophysical characteristics indicative of good confinement. The available borehole televiewer and television surveys show no evidence of fractures or cavernous zones that could be conduits for the upward migration of injected effluent. The majority of the 2,100 to 2,500 feet bpl interval consists of horizontally bedded, fossiliferous limestone interbedded with dolomite. The limestones have visible porosities (i.e. macroporosities) estimated to range mostly between 0 and 15%. Sonic and core sample total porosities range mostly between 33 and 45%. The majority of the porosity of the limestones is microporosity (microporosity = total porosity minus macroporosity). Microporosity rocks, where unfractured, typically have low hydraulic conductivities. Straddle packer tests conducted within this confinement interval yielded hydraulic conductivities ranging from 2.5×10^{-5} to 3.2×10^{-4} cm/sec. The vertical hydraulic conductivity of core samples range from 3.8×10^{-11} to 3.4×10^{-4} cm/sec.

The combined hydrogeological, geological and geophysical data provide reasonable assurance that confinement exists below the USDW.

4.0 Final Testing

4.1 General

After construction of the injection well and dual-zone monitor well was completed, background water samples were collected from IW-1 and MW-1 to be analyzed for primary and secondary drinking water parameters. The injection well was then tested for mechanical integrity and a short-term injection test was conducted of on IW-1. Mechanical integrity testing (MIT) includes a hydrostatic pressure test of the injection casing, a temperature log, a video survey and a radioactive tracer survey (RTS). The short-term injection test consisted of injecting raw groundwater from the City of Hallandale Beach's wellfield into the well for a twelve-hour period.

4.2 Background Water Quality

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

Water samples collected from the City of Hallandale Beach's wellfield were also analyzed, and the results of the analysis are presented in Appendix O.

4.3 Mechanical Integrity Testing

In accordance with FAC Rule 62-528, the injection well was tested for mechanical integrity. Testing consisted of a hydrostatic pressure test of the injection casing, a temperature log, a television survey and a RTS. The hydrostatic pressure test, which was conducted at a pressure at least 50% greater than the maximum allowable operating pressure, identifies internal casing integrity. The temperature log identifies temperature variations in the well. The television survey provides visual verification of internal casing integrity. The radioactive tracer survey provides data on the external mechanical seal of the casing. The following describes the testing methods, results of the testing and presents the interpretation of the data collected during the mechanical integrity tests.

4.3.1 Casing Pressure Test

On June 9, 2006, the injection well 18-inch casing was internally pressurized to 164.5 psi. A pressure increase of 4.25 psi was observed over the 60-minute test period. This increase represents a 2.6 percent change in the original pressure, which is within the allowable regulatory change of 5 percent. A copy of the test gauge certification records and certified results of the hydrostatic pressure test are contained in Appendix M. John Largey (H&S) and Heidi Vandor P.G. (FDEP) witnessed the casing pressure test.

On July 7, 2006, the injection well 11.75-inch injection well tubing was internally pressurized to 161.25 psi. A pressure increase of 0.75 psi was observed over the 60-minute test period. This increase represents a 0.5 percent change in the original pressure, which is within the allowable change of 5 percent. A copy of the test gauge certification records and certified results of the hydrostatic pressure test are contained in Appendix M. John Largey (H&S) witnessed the pressure test.

4.3.2 Injection Well Temperature Log

On September 28, 2006, a temperature log was conducted on IW-1 from the surface to a total depth of 3,500 feet bpl. The temperature log showed a steady decline from about 83° F to about 64° F to a depth of 2,880 feet bpl the approximate base of the 18-inch diameter casing. Below this point, the temperature decreased rapidly to about 51° F to a total depth of 3,500 feet. This decrease seems to indicate that most of the injected fluid will be received by the formation above 3,500 feet. John Largey and Petersen Benjamin witnessed the test. A copy of the temperature log is contained in Appendix F.

4.3.3 Injection Well Television Survey

A survey of IW-1 was performed on November 7, 2006. The survey was performed from pad level to a depth of 3,500 feet bpl. Water clarity was good, enabling the camera to capture clear images of the tubing interior, packer assembly, casing seat and open-hole section. The survey revealed that the tubing was in excellent condition. A video copy of the television survey is included in Appendix G.

4.3.4 Injection Well Radioactive Tracer Survey

On September 28, 2006, a RTS was conducted on IW-1. A schematic of the logging tool is shown in Figure 6. The test began with Youngquist Brothers, Inc., Geophysical Logging Division conducting a background Gamma Ray Log (GRL) and a casing collar locator (CCL). The background GRL, which was "memorized", was reprinted on each "out of position" logging run to serve as a means of comparison. Each logging run is identified at the top of the log. After the completion of the background Gamma Ray Log the logging tool ejector was calibrated to a 0.33 millicuries (MCi) per second discharge rate, and the reservoir was loaded with 8 millicuries of radioactive Iodine 131. The radioactive tracer survey was witnessed by Heidi Vandor from FDEP and by Petersen Benjamin representing Hazen and Sawyer P.C. A copy of the IW-1 RTS log including sketch of the RTS tool is included in Appendix F

The first test conducted (TEST #1) injected at a rate of 59 gallons per minute (gpm) using potable water. The test was conducted by positioning the tracer ejector five feet above the bottom of the casing, setting the recorder in the time drive mode, and ejecting a 1.0 MCi slug of tracer material. After nine minutes all three detectors still showed no evidence of the tracer material having been ejected. It was decided to reset the logs and eject again under the assumption the first eject failed due to clogging of the ejector mechanism. The recorder was set in time drive mode and a 2.0 MCi slug of tracer material was ejected. The readings from the middle gamma ray detector began to increase from background within 10 seconds of ejection. The readings from the bottom detector increased from background approximately two minutes after ejection. No increase in gamma detection by the top gamma ray detector was seen during the 60-minute monitoring period. The tools were then logged out of position (LOP #1) to a depth of 2,690 feet bpl. The results of the log out of position showed no indication of tracer material movement up hole. The injection casing was then flushed with 1,800 gallons of potable water. Following the flushing, an out of position log was conducted (LAF #1) from below the casing to 2,650 feet bpl. This log shows that no tracer material had moved up behind the casing. These results are interpreted as providing evidence that the casing integrity is sound and there are no channels behind the casing.

A second test (TEST #2) was then conducted at an injection rate of 59 gpm. This test also used potable water as the injection fluid. The tracer ejector was positioned five feet above the bottom of the casing and the recorder was placed in the time drive mode. A 2.0 MCi slug of tracer material was then ejected. The readings from the middle gamma ray detector began to increase from background within 10 seconds of ejection. The readings from the bottom detector increased from background approximately two minutes and twenty seconds after ejection. No detection of the tracer material was seen at the upper gamma ray detector any time during 30 minutes of time drive monitoring. The tool was logged out of position (LOP #2) to a depth of 2,690 feet bpl after the 30-minute test period. While logging out of position a stain of tracer material was observed on the casing at approximately 2,877 feet bpl. The results of the log out of position showed no indication of tracer material movement up hole. The logging tool was then lowered to a depth of 3,500 feet bpl and the remaining 4 mCi of the tracer material was dumped. After dumping the tool, a final gamma ray and log after flush was conducted (FINAL GAMMA RAY) on the total depth of the well.

During the final gamma ray and log after flush the flow rate was increased to 200 gpm. This log shows that all tracer material had been flushed out of the casing because the gamma ray levels on all three detectors returned to background levels. These results are interpreted as providing evidence that the casing integrity is sound. The final gamma log was recorded over traces of the initial background log and showed excellent repeatability on all detectors except for the area around the base of the casing (approximately 2,882 feet bpl) and an injection zone area located at a depth of approximately 3,005 to 3,010 feet bpl. The difference in repeatability around the bottom of the casing is most likely the result of tracer staining around the base of the casing. The difference in repeatability around the injection zone interval of 3,005 to 3,010 feet bpl is most likely a result of tracer material staining on the formation of a highly transmissive formation. Copies of the flowmeter calibration certificate and tracer assay are included in Appendix F.

4.3.5 MIT Conclusions

Based on the results of the temperature log, hydrostatic pressure tests, video survey and radioactive tracer survey, IW-1 has demonstrated to have mechanical integrity.

4.4 Injection Test

On November 17, 2006 a controlled injection test was conducted on IW-1 utilizing raw water from the City's wellfield as the source of water for testing. The test consisted of a 24-hour background period. Transducers were placed such that wellhead pressure changes of IW-1 and both zones of the dual-zone monitoring well (MW-1) could be monitored. After performing background monitoring, the 12-hour test was started. The injection test was conducted at two rates the first rate 2,800 gpm (approximately 10 feet/second) lasted 11 hours, during the last hour of the test the rate was increased to 3,400 gpm (approximately 12 feet/second). The maximum wellhead pressure during the test was approximately 74 psi well within the allowable 2/3 of the pressure test conducted on the tubing. Wellhead shut-in pressure is approximately 29 psi. A copy of the data obtained during the injection test as well as a site survey and wellhead elevations are presented in Appendix P. A summary of the injection rates and wellhead pressure is presented below:

Injection Rate (gpm)	Wellhead Pressure (psi)	Specific Injectivity (gpm/psi)
2,800	61.0	45.9
3,400	73.0	46.6

5.0 Findings and Recommendations

5.1 Findings

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

- The base of the USDW, the point where the water contains 10,000 mg/L TDS, occurs at approximately 1,440 feet bpl
- The confining sequences generally occur between 1,500 feet and 2,000 feet bpl and between 2,100 feet and 2,500 feet bpl
- Vertical hydraulic conductivity determined from core testing within the confining sequences ranged from 3.8x10-11 to 4.6x10-4 cm/sec
- Hydraulic conductivity was determined from packer testing within the confining sequences ranging from 2.5x10-5 to 6.6x10-4 cm/sec
- The data demonstrates the existence of an extremely transmissive injection zone below 3,000 feet bpl saturated with saline water (containing more than 10,000 mg/L TDS)
- The injection zone is capable of accepting the maximum design flowrate equivalent to a velocity of 12 feet per second in the wells at a reasonable injection pressure that will not promote fractures in the injection zone or confining sequences
- IW-1 was successfully pressure tested at 164.5 psi (18-inch casing) and at 161.25 psi (11.75-inch tubing)
- The testing program has demonstrated that IW-1 has mechanical integrity
- One dual-zone monitor well was drilled with the upper lower monitor zone located from 1,400 to 1,448 feet bpl and the lower zone from 1,752 to 1,803 feet bpl

5.2 Conclusions

The presence of favorable geologic conditions, a highly transmissive injection zone filled with water having greater than 10,000 mg/L TDS, suitable confining sequence, and suitable monitor zones will permit the use of injection wells for disposal of concentrate at the City of Hallandale Beach WTP in accordance with existing state and federal underground injection control regulations.

Based on the results of the geophysical logging and testing performed at the City of Hallandale Beach WTP, injection well IW-1 has mechanical integrity and is ready to begin operational testing.

5.3 Recommendations

Operation of the monitor well is to begin within one month after the construction of the surface facilities is complete. Injection well operation may begin operating under the construction permit after operational testing approval is issued by FDEP.

The following recommendations are in accordance with requirements of FAC Rule 62-528 for the safe operation of an injection well system. These procedures should be carried out conscientiously to ensure compliance with the injection well construction permit (refer to Appendix A) and all regulatory requirements and to ensure successful operation of the well. Additional information on monitoring and reporting data is discussed in Section 5.4.

- Dual-zone monitor well pressure is to be continuously monitored
- Injection wellhead pressure is to be continuously monitored
- Flow to injection well is to be continuously monitored
- Dual-zone monitor well water quality is to be monitored weekly
- Concentrate injectate quality is to be monitored monthly
- Injection well injectivity tests are to be performed monthly and annually
- A complete analysis of the concentrate injectate is to be performed yearly
- An interim mechanical integrity test consisting of a casing pressure test will be conducted every 2.5 years
- The eight shallow pad wells are to be maintained for future use

5.4 Well Operation, Maintenance and Future Testing

When the injection well is operational, a variety of data will be collected to satisfy statutory/permit requirements and to assist in managing the system. This section discusses the basic requirements for data collection to maintain permit compliance during both the initial testing and long-term operation of the injection well system. Initially, the injection wells will be operating under the construction permits. A minimum of six months of operation are required before the City can apply for an operating permit. The construction permit for IW-1 expires October 3, 2008. It is essential that the performance data collection begin upon operational startup to establish baseline information that both satisfies regulatory requirements and serves for future data comparison and performance analyses. These records should be permanently maintained.

5.4.1 Monitor Well Data Collection

The purpose of monitor zone data collection is to detect changes in water quality attributable to the injection of treated concentrate into the nearby injection well. To collect the water quality samples, the monitor zones at the dual-zone monitoring well will be equipped with two sampling pumps, one for each zone. Interconnection of piping from the different zones and wells is not permitted by FDEP. Prior to collecting water samples for analysis, at least three well volumes have to be pumped from the monitor zones. Water pumped from each monitor zone will be pumped to a sample sink where samples will be collected for analysis.

Dual-zone monitor well water quality is to be monitored through weekly samples from the two dual-zone monitor well zones which are to be collected and analyzed weekly for TDS, chloride, ammonia, TKN, nitrate, pH, specific conductance, total phosphorous, sulfate, sodium, and temperature. The results of these analyses are to be sent to the FDEP monthly.

Dual-zone monitor well water quality is to be monitored through monthly samples from the two dual-zone monitor well zones which are to be collected and analyzed monthly for gross alpha, radium 226, and radium 228. The results of these analyses are to be sent to the FDEP monthly.

The pressure in both zones of the dual-zone monitor well is to be continuously monitored and recorded. Daily and monthly average, maximum and minimum pressures are to be reported to FDEP monthly.

5.4.2 Injection Well Data Collection

Beginning with the start of the use of the injection well, injection records should be maintained to evaluate injection well performance.

The pressure at the injection wellhead is to be continuously monitored and recorded. Daily and monthly average, maximum and minimum pressures are to be reported to FDEP monthly.

The flow rate into the injection well is to be continuously monitored and recorded. Daily average, maximum, and minimum flow rates, as well as the total volume of concentrate pumped into the well are to be reported to the FDEP on a monthly basis.

5.4.3 Injectivity Testing

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

Factors affecting the injection wellhead pressure are a function of:

- The density differential between concentrate and the formation water in the injection zone;
- The friction loss in the casing; and
- The bottom hole pressure (injection zone transmissivity)

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

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

5.4.4 Mechanical Integrity Testing

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

Pursuant to Rule 62–528, an interim internal mechanical test consisting of a pressure test is to be conducted on the injection well half way between the standard five-year mechanical integrity test. Based on the date of testing during construction, the next interim internal mechanical test is to be performed on or before December 9, 2008.

The injection well is to be tested for mechanical integrity every five years in accordance with FAC Rule 62-528. Based on the date of testing during construction, the next MIT is to be performed on or before June 9, 2011. The proposed MIT plan must be approved by FDEP prior to performing mechanical integrity testing. Request for approval should be made approximately six months prior to the required completion date.

5.4.5 Concentrate Injectate Analysis

Samples from the waste stream are to be collected and analyzed weekly for TDS, TSS, chloride, ammonia, TKN, nitrate, pH, specific conductance, total phosphorous, sulfate, sodium and temperature. The results of these analyses are to be sent to the FDEP monthly.

Samples from the waste stream are to be collected and analyzed monthly for gross alpha, radium 226 and radium 228. The results of these analyses are to be sent to the FDEP monthly.

5.5 Plugging and Abandonment Plan

Each injection well system is required to have a plugging and abandonment plan. Plugging and abandonment plans are required in the event that an injection well system has to be abandoned. Plans must contain provisions to effectively sealed or plug the boreholes and casings to prevent upward migration of the injection zone fluid or the interchange of formation water through the borehole or along the casing. Such plans will require the services of a qualified drilling contractor with equipment capable of installing drill pipe to a depth of 3,500 feet and pumping neat cement. Estimated costs for plugging and abandoning IW-1 and MW-1 are presented in Table 8.

The following procedures would be followed to abandon an injection well:

- Obtain a permit from the FDEP
- Suppress the wellhead pressure with drilling mud
- Remove the wellhead assembly
- Fill the open hole up to 20 feet from the of bottom of casing with crushed limestone
- Place a sand cap on the crushed limestone up to 12 feet from the bottom of the 18-inch casing
- Fill open hole, the 18-inch casing and the 11.75-inch tubing with neat cement

The following procedures would be followed to abandon a dual-zone monitor well:

- Obtain a permit from the FDEP
- Suppress the wellhead pressure with drilling mud
- Remove the wellhead assembly
- Fill the deep zone and the 6 ⅝ -inch diameter casing with neat cement grout
- Fill the shallow zone and the 16-inch diameter casing with neat cement grout

TABLES

TABLE 1 - Summary of Testing Dates

FDEP UIC Permit No.: 227805-001-UC

INDENTIFICATION	DESCRIPTION	TESTING DATE
Injection Well No. 1 (IW-1)	18-Inch Casing Pressure Test 11.75-Inch Casing Pressure Test Collection of injection zone water sample	June 9, 2006 July 7, 2006 June 8, 2006
Monitor Well No. 1 (MW-1)	16-Inch Casing Pressure Test 6 ⅝-Inch Casing Pressure Test Collection of upper zone water sample Collection of lower zone water sample	August 7, 2006 August 24, 2006 September 20, 2006 September 20, 2006
Mechanical Integrity Testing	Radioactive Tracer Survey	September 28, 2006
Injection Testing	Injectivity Test	November 17, 2006

TABLE 2 - Casing Schedule

FDEP UIC Permit No.: 227805-001-UC

CASING RUN	DIAMETER (inches) Inside	DIAMETER (inches) Outside	DEPTH (feet)	MATERIAL	WALL THICKNESS (inches)
Injection Well No. 1 (IW-1)					
Pit Casing	59.250	60.000	8	Steel	0.375
Conductor Casing	47.250	48.000	152	Steel	0.375
Surface Casing	35.250	36.000	990	Steel	0.375
Intermediate Casing	27.250	28.000	1,900	Steel	0.375
Final Casing	17.000	18.000	2,883	Steel	0.500
Tubing	10.720	11.750	2,862	FRP	0.490
Tubing Coupling		14.000			
Total Well Depth	---	---	3,500	---	---
Monitor Well No. 1 (MW-1)					
Pit Casing	31.250	32.000	8	Steel	0.375
Conductor Casing	23.000	24.000	162	Steel	0.500
Final Casing	15.000	16.000	1,400	Steel	0.500
Final Casing	5.430	6.100	1,750	FRP	0.340
Total Well Depth	---	---	1,803	---	---

TABLE 3 - Core Depths

FDEP UIC Permit No.: 227805-001-UC

CORE NUMBER	DATE	CORE INTERVAL (feet bpl)
1	March 6, 2006	1,655 - 1,680
2	March 7, 2006	1,700 - 1,720
3	March 8, 2006	1,770 - 1,795
4	March 9, 2006	1,855 - 1,880
5	March 10, 2006	1,935 - 1,960
6	March 10, 2006	1,965 - 1,974
7	March 11, 2006	1,975 - 2,000
8	April 21, 2006	2,022 - ,2039
9	April 23, 2006	2,040 - 2,065
10	April 24, 2006	2,085 - 2,101
11	April 25, 2006	2,275 - 2,300
12	April 26, 2006	2,475 - ,2500

TABLE 4 - Hydraulic Conductivity Derived from Cores
FDEP UIC Permit No.: 227805-001-UC

CORE	INTERVAL (feet bpl)	WELL	HYDRAULIC CONDUCTIVITY	
			Vertical Conductivity (cm/sec)	Horizontal Conductivity (cm/sec)
1	1659.7 - 1660.3	IW-1	1.2×10^{-4}	1.8×10^{-4}
2	1705.4 - 1705.8	IW-1	2.4×10^{-4}	5.9×10^{-4}
3	1772.0 - 1772.5	IW-1	3.0×10^{-5}	4.7×10^{-5}
	1773.2 - 1773.8	IW-1	2.9×10^{-5}	6.3×10^{-4}
	1774.4 - 1775.0	IW-1	2.3×10^{-4}	2.6×10^{-4}
4	1856.1 - 1856.4	IW-1	8.0×10^{-5}	6.2×10^{-4}
	1862.8 - 1863.1	IW-1	4.6×10^{-5}	1.1×10^{-4}
5	1938.9 - 1940.1	IW-1	5.2×10^{-9}	1.4×10^{-9}
	1940.7 - 1941.1	IW-1	5.3×10^{-5}	5.4×10^{-5}
	1944.1 - 1944.5	IW-1	2.9×10^{-4}	5.9×10^{-4}
6	1965.0 - 1965.4	IW-1	3.3×10^{-4}	7.8×10^{-4}
	1967.7 - 1968.2	IW-1	5.8×10^{-5}	5.9×10^{-4}
	1970.0 - 1970.5	IW-1	3.0×10^{-4}	4.7×10^{-4}
	1970.5 - 1971.0	IW-1	1.1×10^{-3}	3.5×10^{-4}
7	1977.2 - 1977.5	IW-1	2.0×10^{-4}	3.8×10^{-4}
	1980.5 - 1980.9	IW-1	6.3×10^{-5}	8.4×10^{-5}
	1982.2 - 1982.6	IW-1	5.5×10^{-5}	1.7×10^{-4}
	1985.3 - 1985.7	IW-1	4.6×10^{-4}	3.9×10^{-4}

TABLE 4 - Hydraulic Conductivity Derived from Cores

FDEP UIC Permit No.: 227805-001-UC

CORE	INTERVAL (feet bpl)	WELL	HYDRAULIC CONDUCTIVITY	
			Vertical Conductivity (cm/sec)	Horizontal Conductivity (cm/sec)
8	2033.6 - 2034.1	IW-1	6.6×10^{-9}	1.0×10^{-8}
	2034.9 - 2035.2	IW-1	2.2×10^{-4}	---
	2035.2 - 2035.6	IW-1	2.4×10^{-4}	2.9×10^{-4}
	2035.6 - 2035.9	IW-1	3.4×10^{-4}	---
	2036.9 - 2037.1	IW-1	2.8×10^{-9}	---
	2037.1 - 2037.3	IW-1	2.0×10^{-7}	1.7×10^{-8}
	2037.3 - 2038.0	IW-1	1.1×10^{-9}	8.1×10^{-9}
	2038.6 - 2039.0	IW-1	3.8×10^{-11}	4.7×10^{-9}
9	2040.0 - 2040.5	IW-1	7.5×10^{-6}	1.1×10^{-5}
	2041.5 - 2042.0	IW-1	1.7×10^{-10}	1.2×10^{-8}
	2042.5 - 2043.2	IW-1	6.2×10^{-9}	7.8×10^{-8}
	2043.5 - 2043.8	IW-1	6.4×10^{-11}	---
10	2086.8 - 2087.2	IW-1	5.3×10^{-10}	9.3×10^{-10}
	2087.5 - 2088.3	IW-1	6.9×10^{-9}	1.6×10^{-8}
	2088.4 - 2089.1	IW-1	2.0×10^{-4}	6.4×10^{-6}
	2091.4 - 2092.8	IW-1	4.3×10^{-11}	1.1×10^{-9}
	2092.9 - 2093.6	IW-1	3.3×10^{-7}	4.3×10^{-7}
	2093.6 - 2094.0	IW-1	3.2×10^{-7}	4.3×10^{-7}
	2094.0 - 2094.5	IW-1	5.5×10^{-7}	---
11	2281.1 - 2281.5	IW-1	4.4×10^{-7}	7.2×10^{-7}
	2281.5 - 2282.0	IW-1	1.6×10^{-5}	2.7×10^{-5}
	2282.0 - 2282.4	IW-1	2.3×10^{-5}	4.3×10^{-5}
	2282.4 - 2282.9	IW-1	3.7×10^{-6}	5.0×10^{-6}
	2283.7 - 2284.1	IW-1	2.0×10^{-6}	1.2×10^{-6}
12	2492.0 - 2492.4	IW-1	3.8×10^{-5}	7.9×10^{-5}
	2496.0 - 2496.5	IW-1	1.6×10^{-5}	2.7×10^{-5}
	2496.5 - 2496.9	IW-1	4.3×10^{-5}	7.5×10^{-5}
	2496.9 - 2497.3	IW-1	2.1×10^{-5}	2.0×10^{-5}
	2499.7 - 2500.0	IW-1	3.7×10^{-10}	---

TABLE 5 - Packer Test Development

FDEP UIC Permit No.: 227805-001-UC

INTERVAL	WELL	AIR DEVELOPMENT		PUMP DEVELOPMENT	
		Time (minutes)	~ Rate (gpm)	Time (minutes)	Rate (gpm)
1,431 - 1,449	IW-1	580	80	88	78
1,590 - 1,608	IW-1	510	60	120	28
1,747 - 1,765	IW-1	779	70	302	50
1,765 - 1,783	IW-1	862	30	269	14
1,872 - 1,890	IW-1	677	35	340	25
1,965 - 1,983	IW-1	705	30	286	23
2,125 - 2,143	IW-1	855	25	240	25
2,285 - 2,303	IW-1	1,395	5	575	3.5
2,325 - 2,343	IW-1	791	10	233	9
2,400 - 2,418	IW-1	480	25	210	15
2,440 - 2,458	IW-1	585	15	401	12

TABLE 6 - Hydraulic Conductivity Derived from Packer Tests

FDEP UIC Permit No.: 227805-001-UC

INTERVAL	WELL	PUMPING RATE (gpm)	MAXIMUM DRAWDOWN (feet)	DRAWDOWN		RECOVERY	
				Hydraulic Conductivity (cm/sec)	Transmissivity (gpd/ft)	Hydraulic Conductivity (cm/sec)	Transmissivity (gpd/ft)
1,431 - 1,449	IW-1	78.3	41.2	2.46×10^{-3}	939.0	9.85×10^{-4}	376.0
1,590 - 1,608	IW-1	29.3	107.5	3.27×10^{-4}	125.0	2.64×10^{-4}	101.0
1,747 - 1,765	IW-1	50.6	92.0	6.48×10^{-4}	247.0	6.60×10^{-4}	252.0
1,765 - 1,783	IW-1	13.6	108.4	1.19×10^{-4}	45.00	1.21×10^{-4}	46.00
1,872 - 1,890	IW-1	28.1	105.1	3.09×10^{-4}	118.0	2.95×10^{-4}	113.0
1,965 - 1,983	IW-1	19.9	87.0	2.50×10^{-4}	95.52	2.65×10^{-4}	101.0
2,125 - 2,143	IW-1	25.9	75.4	3.21×10^{-4}	122.0	3.18×10^{-4}	121.0
2,285 - 2,303	IW-1	2.7	112.7	1.99×10^{-5}	7.58	2.49×10^{-5}	9.50
2,325 - 2,343	IW-1	9.6	102.1	8.74×10^{-5}	33.35	1.01×10^{-4}	38.40
2,400 - 2,418	IW-1	18.3	110.9	1.64×10^{-4}	62.74	1.44×10^{-4}	54.90
2,440 - 2,458	IW-1	13.2	119.3	9.51×10^{-5}	36.30	1.05×10^{-4}	40.06

TABLE 7 - Water Quality from Packer Testing

FDEP UIC Permit No.: 227805-001-UC

INTERVAL	WELL	WATER QUALITY					
		Conductivity (µmhos/cm)	TDS (mg/L)	Chloride (mg/L)	Ammonia (mg/L)	TKN (mg/L)	Sulfate (mg/L)
1,431 - 1,449	IW-1	16,800	10,592	5,400	0.35	1.10	132
1,590 - 1,608	IW-1	53,900	35,328	21,600	0.61	0.74	1,575
1,747 - 1,765	IW-1	51,000	34,960	20,100	0.38	0.84	2,430
1,765 - 1,783	IW-1	56,600	36,488	20,100	0.51	0.65	1,573
1,872 - 1,890	IW-1	51,100	34,924	22,600	0.67	0.79	1,576
1,965 - 1,983	IW-1	51,100	33,276	19,150	0.51	0.60	1,235
2,125 - 2,143	IW-1	55,600	34,748	20,000	0.35	0.51	2,040
2,285 - 2,303	IW-1	53,800	35,640	19,550	U	0.23	1,724
2,325 - 2,343	IW-1	56,100	36,484	19,200	0.36	0.45	1,416
2,400 - 2,418	IW-1	54,300	34,536	19,550	0.33	0.33	1,632
2,440 - 2,458	IW-1	55,100	35,336	19,150	0.50	0.64	2,280

TABLE 8 - Plugging and Abandonment Cost Estimate

FDEP UIC Permit No.: 227805-001-UC

TASK	UNIT COST	NO. OF UNITS	TOTAL COST
Injection Well (IW-1)			
Mobilization	$25,000	1	$25,000
Crushed Limestone (cu-ft)	$15	3,600	$54,000
Neat Cement (sacks)	$15	7,300	$109,500
20% Contingency	---	1	$37,700
Total IW-1	---	---	**$226,200**
Monitor Well (MW-1)			
Mobilization	$15,000	1	$15,000
Neat Cement (sacks)	$15	7,200	$108,000
20% Contingency	---	1	$24,600
Total MW-1	---	---	**$147,600**
TOTAL COST			**$373,800**

FIGURES

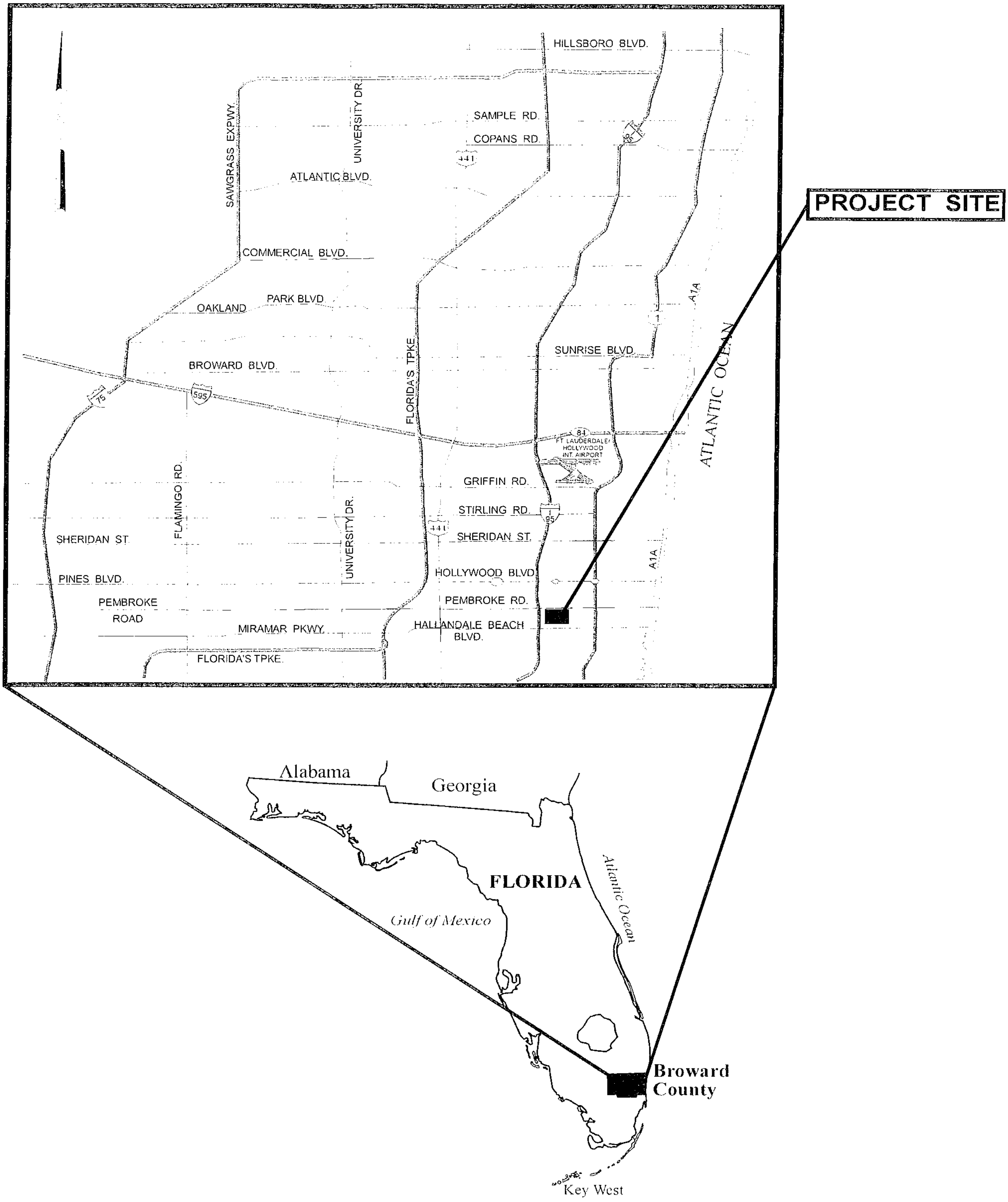

Figure 1
General Location Map

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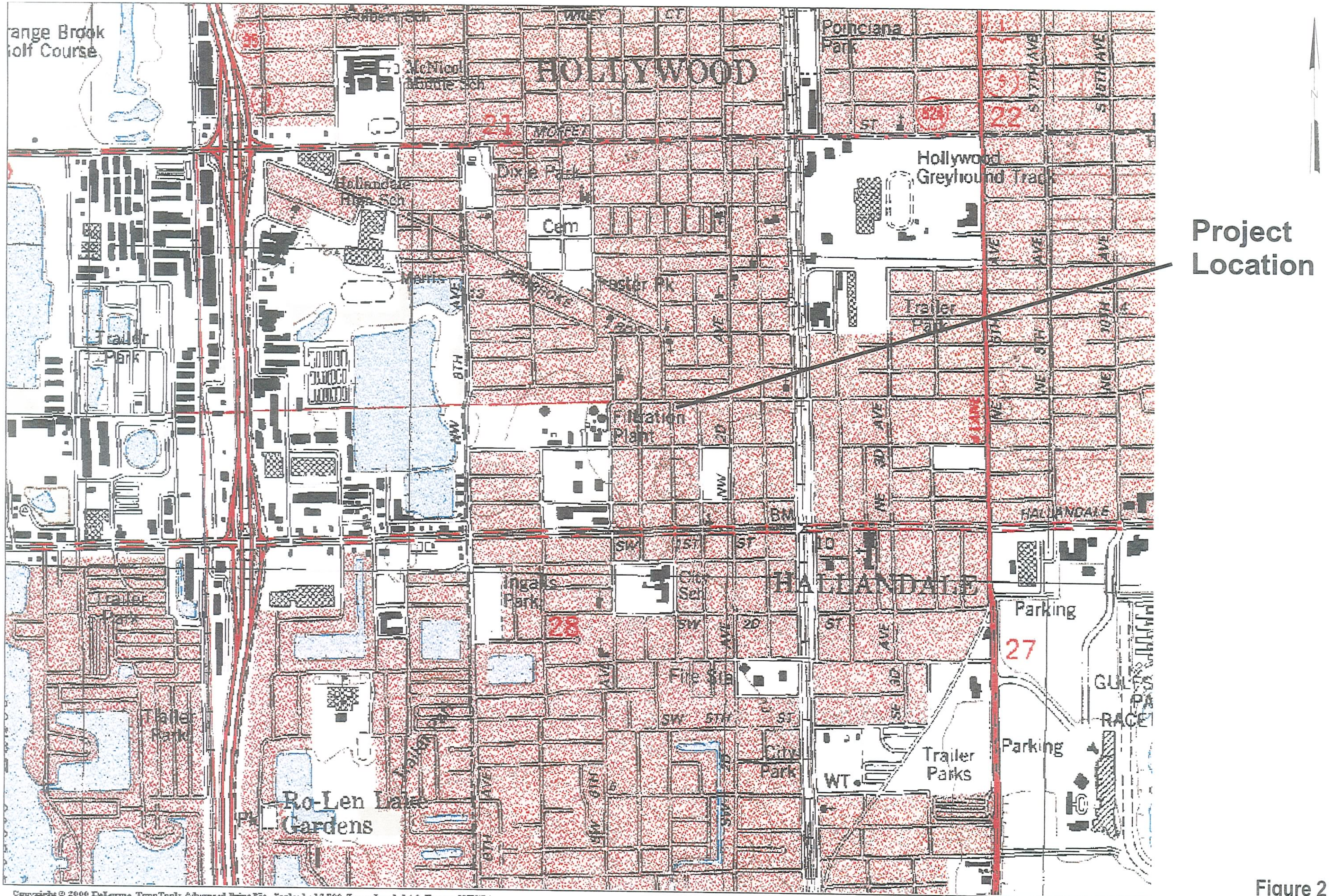

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1000 ft

Figure 2
General Site Location

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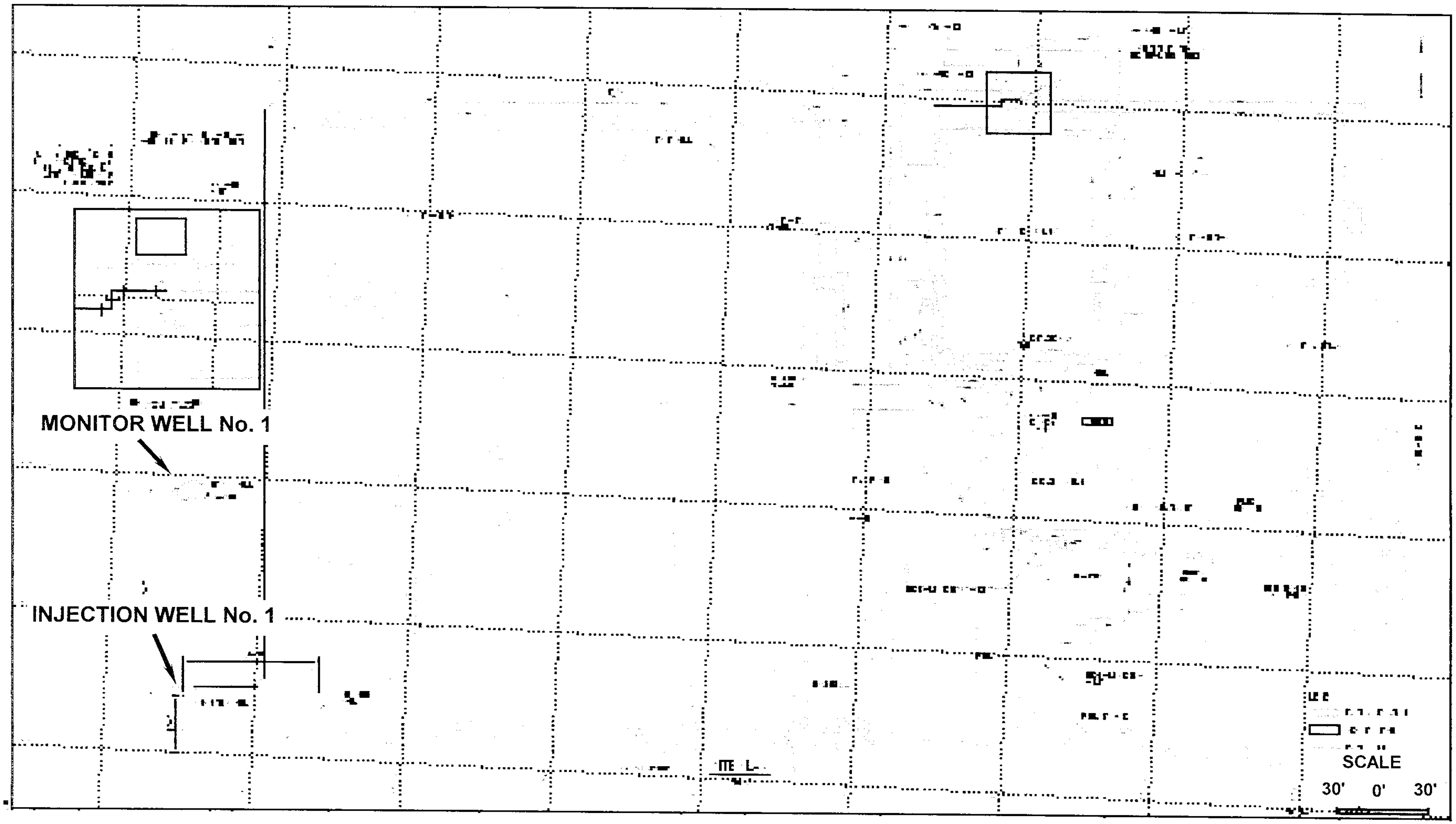

Figure 3
Site Plan

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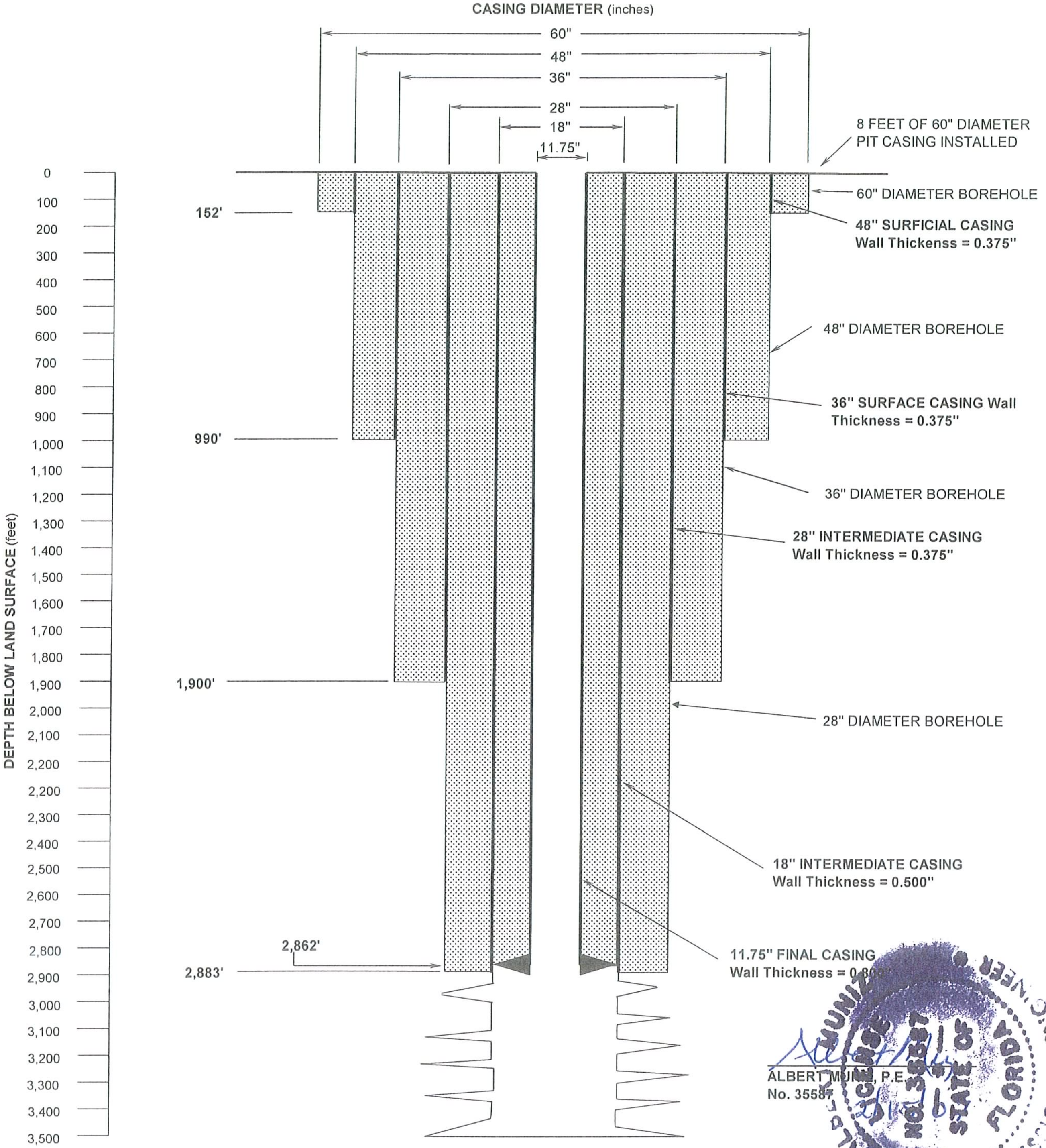

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No. 35587
2/15/06

City of Hallandale Beach
CONCENTRATE DISPOSAL SYSTEM - INJECTION WELL NO. 1 (IW-1)
FDEP UIC Permit No. 227805-001-UC

Figure 4
Injection Well (IW-1) As-Built

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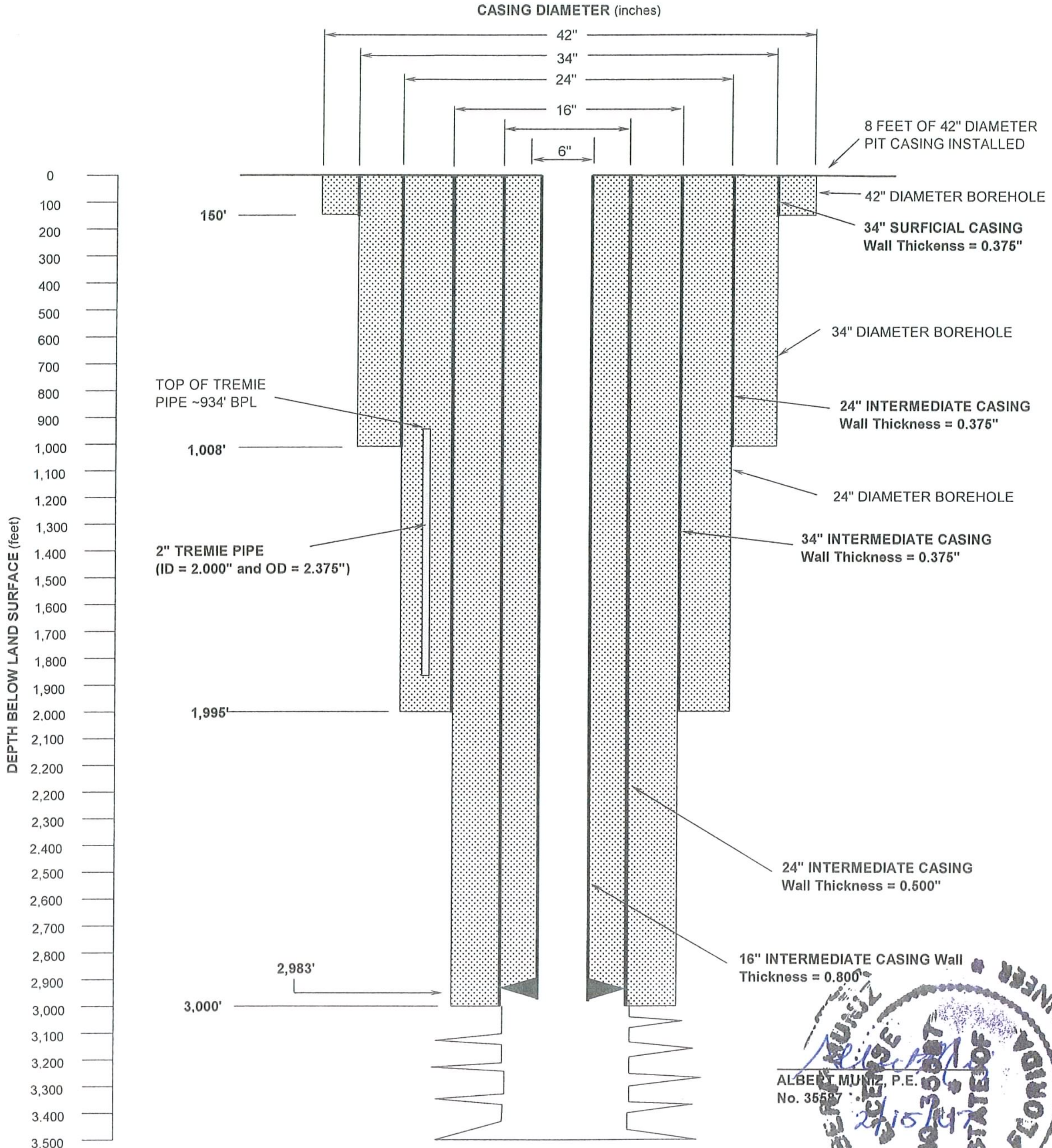

ALBERT MUNIZ, P.E.
No. 35587
2/15/17

City of Hallandale Beach
CONCENTRATE DISPOSAL SYSTEM - MONITOR WELL NO. 1 (MW-1)
FDEP UIC Permit No. 227805-001-UC

Figure 5
Monitor Well (MW-1) As-Built

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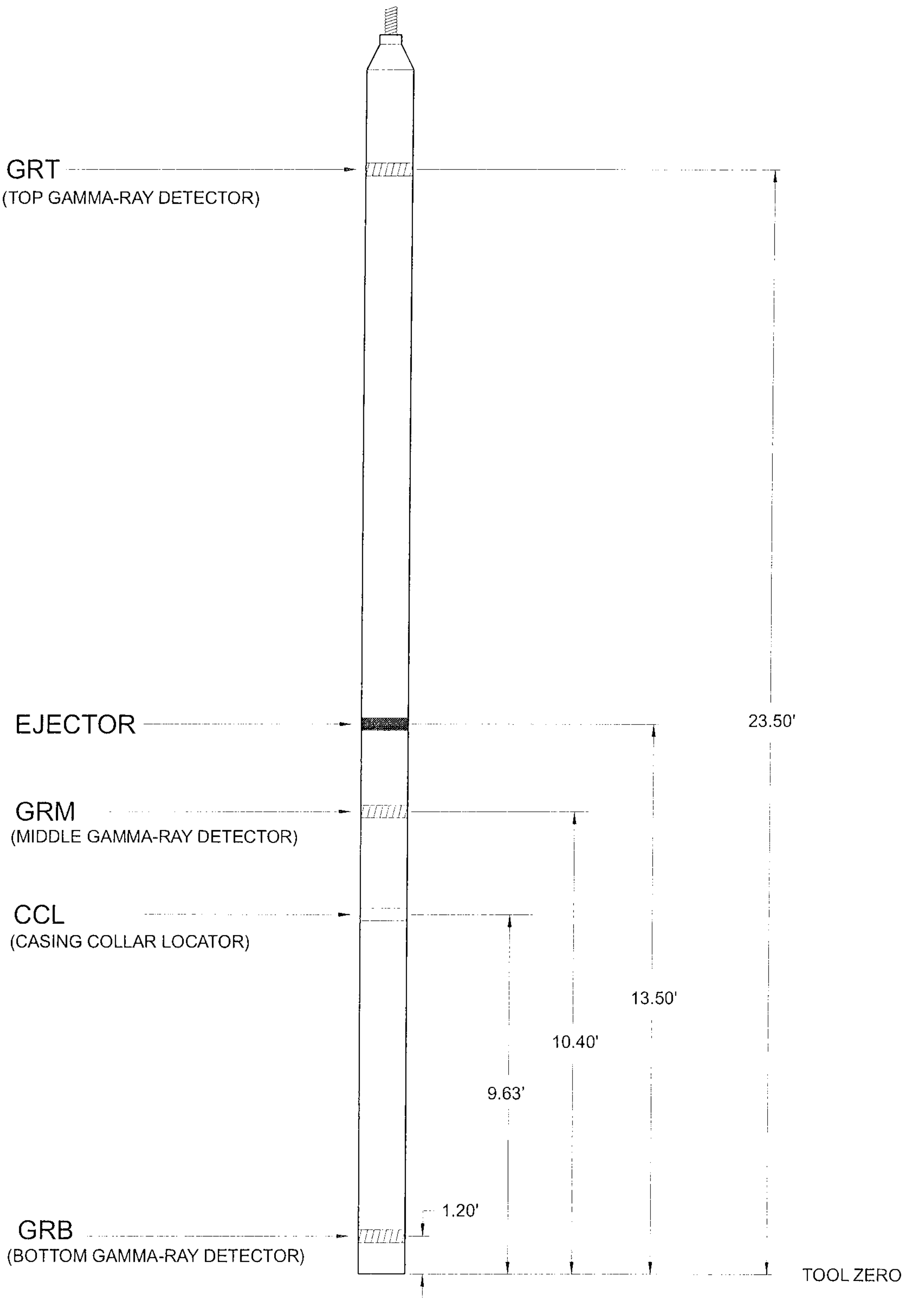

Figure 6
Radioactive Tracer Survey Tool

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