City of Hollywood

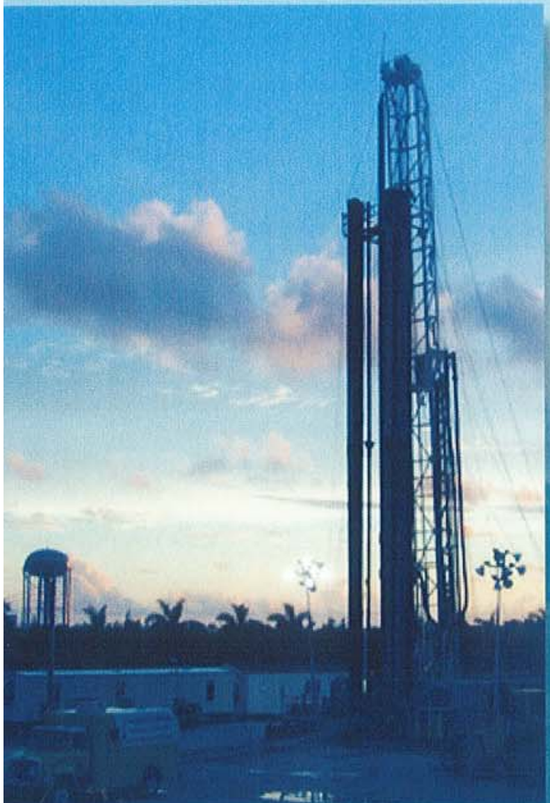
Engineering Well Completion Report
City of Hollywood Southern Regional WWTP
Injection Well Effluent Disposal System

Prepared for
City of Hollywood
City Project No. 95-9713

Prepared by:
HAZEN AND SAWYER
Environmental Engineers & Scientists

In Association with
Water Technologies Associates, Inc.
Project No. 4304

August 2003



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HAZEN AND SAWYER
Environmental Engineers & Scientists

Hazen and Sawyer, P.C.
2101 Corporate Blvd.
Boca Raton, FL 33431
561 997-8070
Fax: 561 997-8159

August 14, 2003

Joseph R. May, P.G.
U. I. C. Program Manager
STATE OF FLORIDA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
Groundwater Section – U. I. C. Permitting
400 North Congress Avenue
Suite 200
West Palm Beach, Florida 33401

City of Hollywood
UIC Class I Injection Well
Permit Number 156419-001-UC
<u>Engineering Well Completion Report</u>

Dear Mr. May:

In fulfillment of the above-referenced 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 Hollywood. The injection wells and dual-zone monitor well are located at the City of Hollywood's Southern Regional Wastewater Treatment Plant. This report presents the results of the construction and testing performed during the drilling of the effluent disposal wells 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.

No. 35587
8/14/03

Albert Muniz

Albert Muniz, P.E.
No. 35587

FOR WVC

Whitfield Van Cott, P.E.
Utilities Director

Very truly yours,,

HAZEN AND SAWYER, P.C.

Albert Muniz

Albert Muniz, P.E.
Project Manager

c:
Heidi Vandor, FDEP/SED
Steve D. Anderson, SFWMD
Witt Van Cott, City
Glenn Cunningham, H&S
James A. Wheatley, H&S
H&S – 4304
George Heuler, FDEP/Tal
Garth D. Hinckle, BCDNRP
Patti Hart, City
Mike Wengrenovich, H&S
Ron Reese, USGS/Mia
Nancy Marsh, USEPA/Atl
Paul Vinci, H&S
John Largey, H&S

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Table 1
Core Depths
City of Hollywood Effluent Disposal System
Southern Regional WWTP Injection Wells

Core #	Depth (feet bpl)	Date
Injection Well No. 1 (IW-1)		
1	1700 - 1714	07/09/02
2	1750 - 1765	07/10/02
3	1800 - 1815	07/11/02
4	1850 - 1864	07/11/02
5	1900 - 1910	07/12/02
6	1950 - 1965	07/13/02
7	2032 - 2042	08/19/02
Injection Well No. 2 (IW-2)		
1	1660 – 1675	12/27/02
2	1680 – 1695	12/28/02
3	1770 – 1785	12/28/02
4	1990 - 2004	12/29/02
5	2050 – 2063.5	02/10/03
6	2065 – 2077	02/11/03
7	2078 – 2091	02/11/03
8	2098 – 2113	02/12/03
9	2175 – 2189	02/13/03
10	2420 – 2435	02/14/03

Table 2
Hydraulic Conductivity Derived From Cores
City of Hollywood Effluent Disposal System
Southern Regional WWTP Injection Wells

Core	Interval	Vertical (cm/sec)	Horizontal (cm/sec)
Injection Well No. 1 (IW-1)			
Core #1	1,712.3 – 1,713.1	3.0 X 10^{-3}	3.7 X 10^{-3}
Core #3	1,804.7 – 1,805.4	1.3 X 10^{-3}	4.3 X 10^{-3}
Core #3	1,806.0 – 1,806.5	1.1 X 10^{-3}	1.3 X 10^{-3}
Core #3	1,802.2 – 1,808.9	5.7 X 10^{-6}	5.1 X 10^{-6}
Core #4	1,862.0 – 1,862.5	6.3 X 10^{-4}	3.2 X 10^{-3}
Core #4	1,862.5 – 1,862.9	2.7 X 10^{-4}	1.8 X 10^{-3}
Core #5	1,901.6 – 1,901.9	3.1 X 10^{-7}	6.7 X 10^{-6}
Core #5	1,902.1 – 1,902.5	3.0 X 10^{-5}	6.3 X 10^{-5}
Core #5	1,902.5 – 1,903.0	1.5 X 10^{-5}	2.8 X 10^{-5}
Core #6	1,962.4 – 1,962.9	5.7 X 10^{-4}	6.3 X 10^{-4}
Core #6	1,962.9 – 1,963.4	1.6 X 10^{-4}	---
Core #7	2,032.4 – 2032.7	1.7 X 10^{-7}	2.6 X 10^{-6}
Core #7	2,033.2 – 2,033.6	1.1 X 10^{-3}	8.0 X 10^{-4}
Core #7	2,034.0 – 2,034.4	1.4 X 10^{-8}	8.2 X 10^{-9}
Core #7	2,034.8 – 2,035.4	1.1 X 10^{-7}	2.0 X 10^{-8}
Core #7	2,041.2 – 2,041.9	2.7 X 10^{-8}	1.2 X 10^{-8}
Injection Well No. 2 (IW-2)			
Core #3	1,770.0 – 1,770.5	3.3 X 10^{-5}	4.3 X 10^{-5}
Core #3	1,772.3 – 1,772.7	1.9 X 10^{-4}	2.3 X 10^{-4}
Core #3	1,773.3 – 1,773.8	1.7 X 10^{-5}	2.2 X 10^{-5}
Core #3	1,776.3 – 1,776.8	1.4 X 10^{-4}	1.9 X 10^{-4}
Core #4	1,990.7 – 1,991.1	4.3 X 10^{-4}	3.9 X 10^{-4}
Core #4	1,991.6 – 1,991.9	1.1 X 10^{-4}	3.4 X 10^{-4}
Core #5	2,052.6 – 2,053.2	1.9 X 10^{-3}	2.1 X 10^{-3}
Core #5	2,054.1 – 2,054.5	1.5 X 10^{-4}	2.9 X 10^{-3}
Core #6	2,065.5 – 2,065.9	5.6 X 10^{-4}	6.9 X 10^{-5}
Core #6	2,067.3 – 2,067.9	5.7 X 10^{-5}	6.5 X 10^{-5}
Core #6	2,067.9 – 2,068.3	3.5 X 10^{-5}	5.0 X 10^{-5}
Core #6	2,068.4 – 2,069.1	3.8 X 10^{-7}	3.2 X 10^{-7}
Core #6	2,069.1 – 2,069.6	2.9 X 10^{-9}	9.3 X 10^{-9}
Core #7	2,081.1 – 2,081.6	1.8 X 10^{-9}	2.5 X 10^{-9}
Core #7	2,081.6 – 2,082.1	1.3 X 10^{-9}	4.7 X 10^{-10}
Core #7	2,084.3 – 2,085.3	1.4 X 10^{-9}	8.7 X 10^{-9}
Core #7	2,085.3 – 2,085.8	2.5 X 10^{-9}	1.3 X 10^{-9}
Core #7	2,087.4 – 2,088.0	9.8 X 10^{-10}	7.0 X 10^{-10}
Core #8	2,100.8 – 2,101.2	1.0 X 10^{-4}	1.5 X 10^{-4}
Core #9	2,175.9 – 2,176.3	1.3 X 10^{-3}	2.8 X 10^{-3}
Core #10	2,422.4 – 2,422.8	2.0 X 10^{-4}	2.3 X 10^{-4}

Table 3
Straddle Packer Test Development
City of Hollywood
Southern Regional WWTP

	Air Development		Pump Development	
Interval (feet bpl)	Time (min)	Rate (gpm)	Time (min)	Rate (gpm)
Injection Well No. 1 (IW-1)				
1,354 – 1,370	113	78	191	74
1,404 – 1,420	82	150	90	73
1,769 – 1,785	292	23.5	150	30
1,894 – 1,910	588	13	120	10
1,959 – 1,975	733	17	158	23
2,046 – 2,062	449	15	138	15
2,193 – 2,209	221	78	100	61
Injection Well No. 2 (IW-2)				
1,390 – 1,408	117	170	159	78
1,510 – 1,528	142	120	157	66
1,760 – 1,778	405	25	485	13
1,810 – 1,828	271	65	126	35
2,093 – 2,111	795	13	255	9
2,265 – 2,283	190	47	225	36
2,300 – 2,318	320	36	238	26
2,410 – 2,428	299	42	186	34

Table 4
Hydraulic Conductivity Derived from Packer Tests
City of Hollywood
Southern Regional WWTP

Depth Interval (feet bpl)	Pumping Rate (gpm)	Maximum Drawdown (feet)	Drawdown Hydraulic Conductivity (cm/sec)	Drawdown Transmissivity (gpd/ft)	Recovery Hydraulic Conductivity (cm/sec)	Recovery Transmissivity (gpd/ft)
Injection Well No. 1 (IW-1)						
1,354 – 1,370(1)	70	96.5	9.4×10^{-4}	319	6.2×10^{-4}	212
1,404 – 1,420(1)	73	43.2	2.1×10^{-3}	741	1.5×10^{-3}	507
1,769 – 1,785	30	76.7	3.8×10^{-4}	132	3.5×10^{-4}	121
1,894 – 1,910	6.4	144.5	3.8×10^{-5}	13	4.3×10^{-5}	15
1,959 – 1,975	27	132.2	2.0×10^{-4}	68	1.8×10^{-4}	65
2,046 – 2,062	12	135.0	8.9×10^{-5}	30	8.5×10^{-5}	29
2,193 – 2,209	61	119.0	4.9×10^{-4}	167	5.6×10^{-4}	191
Injection Well No. 2 (IW-2)						
1,390 – 1,408(1)	77	31	2.2×10^{-3}	2,032	1.3×10^{-2}	5,028
1,510 – 1,528	66	56	1.8×10^{-3}	44	1.2×10^{-3}	470
1,760 – 1,778	16	129	1.1×10^{-4}	4	1.0×10^{-4}	39
1,810 – 1,828	34	87	3.6×10^{-4}	10	3.4×10^{-4}	32
2,093 – 2,111	9	125	6.1×10^{-5}	24	6.1×10^{-5}	24
2,265 – 2,283	33	103	3.0×10^{-4}	114	3.3×10^{-4}	128
2,300 – 2,318	23	100	2.2×10^{-4}	87	2.2×10^{-4}	84
2,410 – 2,428	24	86	2.7×10^{-4}	105	3.2×10^{-4}	121

(1) - Packer test used to obtain water quality data

Table 5
Water Quality Analysis from Packer Tests
City of Hollywood
Southern Regional WWTP

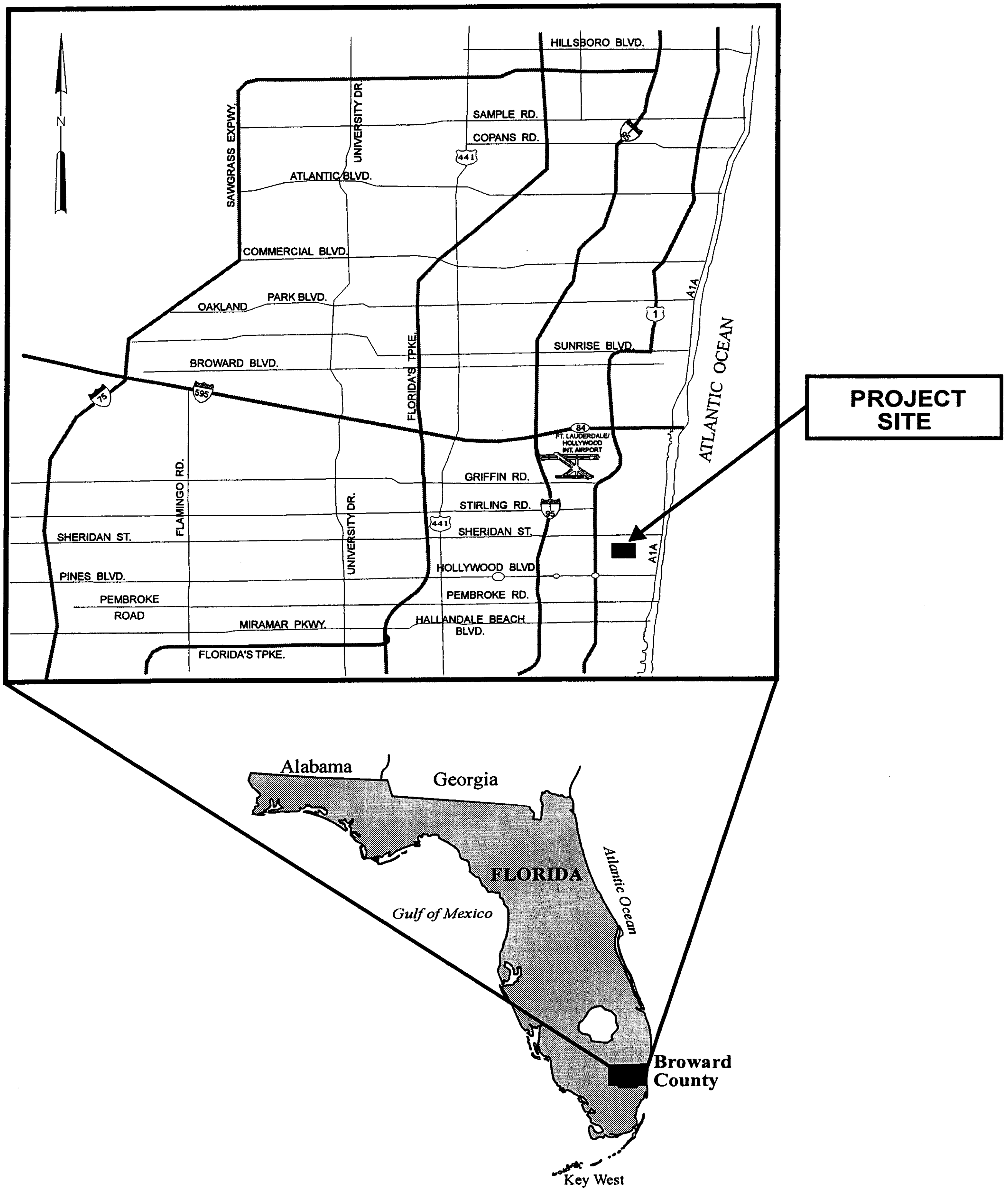
Interval (feet bpl)	TDS (mg/L)	Chloride (mg/L)	Conductivity (umhos/cm)	Nitrogen (Total) (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Nitrogen (Organic) (mg/L)	Ammonia (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Sulfate (mg/L)
Injection Well No. 1 (IW-1)										
1,354 – 1,370	6,992	3,650	11,040	1.14	<0.05	<0.05	.571	0.569	1.14	510
1,404 – 1,420	13,640	7,170	18,600	5.97	3.74	<0.05	1.65	0.576	2.23	560
1,769 – 1,785	35,708	20,830	43,600	.391	<0.05	<0.05	.391	<0.04	0.391	2,630
1,894 – 1,910	35,100	23,783	48,500	6.34	6.34	<0.05	<0.1	<0.04	<0.1	2,589
1,959 – 1,975	38,980	21,670	49,200	14.3	14.0	<0.05	.307	0.042	0.349	2,948
2,046 – 2,062	36,700	20,200	53,100	<0.1	<0.05	<0.05	<0.1	<0.04	<0.1	2,672
2,193 – 2,209	34,800	21,700	51,300	0.80	0.80	<0.05	<0.1	<0.04	<0.1	2,960
Injection Well No. 2 (IW-2)										
1,390 – 1,408	9,924	7,095	16,630	0.837	<0.05	<0.05	0.299	0.538	0.837	537
1,510 – 1,528	29,948	22,340	43,700	0.900	<0.05	<0.05	0.794	0.106	0.900	1,871
1,760 – 1,778	37,460	21,170	49,500	0.223	<0.05	<0.05	0.223	<0.04	0.223	2,460
1,810 – 1,828	38,640	23,700	51,000	0.46	<0.05	<0.05	0.462	<0.04	0.462	2,800
2,093 – 2,111	42,120	21,280	50,900	1.86	1.70	<0.05	0.159	<0.04	0.159	2,680
2,265 – 2,283	43,320	20,300	48,800	1.82	1.60	<0.05	0.217	<0.04	0.217	2,680
2,300 – 2,318	41,520	20,180	50,800	0.174	<0.5	<0.5	0.174	<0.04	0.174	2,600
2,410 – 2,428	40,170	21,200	50,400	0.202	<0.50	<0.50	0.202	<0.04	0.202	2,580

Table 6
Plugging and Abandonment Cost Estimate
City of Hollywood
Southern Regional WWTP

Task	Unit Cost	Plan Estimate
Injection Wells		
Mobilization	$20,000	$20,000
Mechanical Integrity Test (MIT)	$40,000	$40,000
Crushed Limestone 8,000 cu ft	$10/cu ft	$80,000
Neat Cement 20,000 cu ft	$10/cu ft	$200,000
20% Contingency		$68,000
TOTAL for Two Injection Wells		*$408,000*
Dual-Zone Monitor Well		
Mobilization	$10,000	$10,000
Neat Cement 3,000 cu ft	$10/cu ft	$30,000
20% Contingency		$8,000
TOTAL for Monitor Well		*$48,000*
TOTAL Costs		**$456,000**

Figures

4304 FIGURE-1.CDR



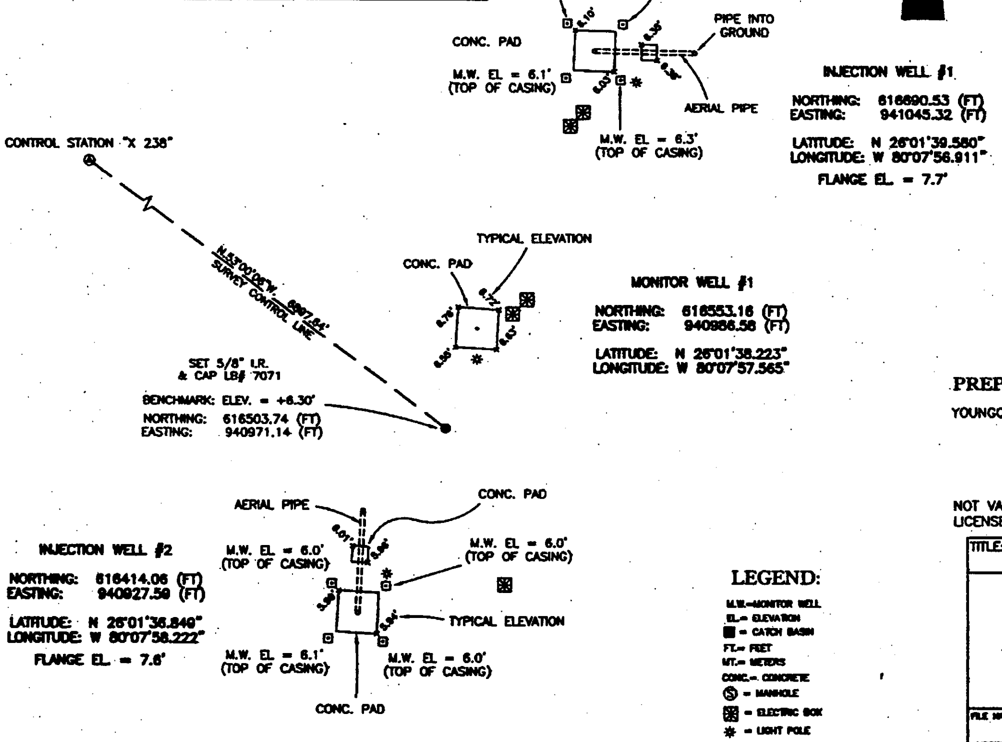
HAZEN AND SAWYER Environmental Engineers & Scientists	CITY OF HOLLYWOOD FLORIDA INCORPORATED 1925	CITY OF HOLLYWOOD EFFLUENT DISPOSAL SYSTEM SOUTHERN REGIONAL WWTP INJECTION WELLS	FIGURE
		PROJECT LOCATION MAP	**1**

SURVEY PLAT

OF EXISTING WELLS
AT THE HOLLYWOOD SOUTHERN REGIONAL WWTP
LOCATED IN
BROWARD COUNTY, FLORIDA

THE COORDINATES SHOWN HEREON WERE BASED ON GPS REAL-TIME TIES TO "X 238" CONTROL STATION.

DESIGNATION - X 238
PID - AD2465
STATE/COUNTY - FL/BROWARD
USGS QUAD - FORT LAUDERDALE SOUTH (1994)
NAD 83/99 GEOGRAPHIC COORDINATE - N 26°02'19.20346" W 080°08'57.82828"
NAD 83/99 STATE PLANE COORDINATE - FLORIDA EAST ZONE
NORTHING: 189,175.923 (MT)
EASTING: 285,129.483 (MT)



NOTES:

THIS PLAT PREPARED AS A SPECIFIC PURPOSE SURVEY FOR THE PURPOSE OF LOCATING THE EXISTING WELLS AT THE HOLLYWOOD SOUTHERN REGIONAL WWTP.

BEARINGS AND COORDINATES SHOWN HEREON ARE STATE PLANE FOR THE FLORIDA EAST ZONE NAD 83/1999 ADJUSTMENT AND BASED ON GPS REAL-TIME TIES TO CONTROL STATION "X 238".

ELEVATIONS SHOWN HEREON ARE BASED ON THE NATIONAL GEODETIC VERTICAL DATUM OF 1929 (NGVD 29), FROM TIES TO CONTROL STATION "X 238" ELEVATION = +13.05' AND BENCHMARKS ON SITE PROVIDED BY THE CLIENT.

UNDERGROUND IMPROVEMENTS, UTILITIES AND/OR FOUNDATIONS WERE NOT LOCATED UNLESS OTHERWISE NOTED.

DATE OF LAST FIELD WORK: 8-5-2003

PREPARED FOR:

YOUNGQUIST BROTHERS, INC.

Scott M. Shore
SCOTT M. SHORE
PROFESSIONAL SURVEYOR AND MAPPER
FLORIDA CERTIFICATE NO. LS# 5743

DATE SIGNED: 8-6-2003

NOT VALID WITHOUT THE SIGNATURE AND THE ORIGINAL RAISED SEAL OF A FLORIDA LICENSED SURVEYOR AND MAPPER.

TITLE: SPECIFIC PURPOSE SURVEY

METRON
SURVEYING & MAPPING, LLC
LAND SURVEYORS · PLANNERS
LB# 7071

5245 RAMSEY WAY, SUITE #2
FORT MYERS, FLORIDA 33907
PHONE: (239) 275-8575
FAX: (239) 275-8457
www.metronfl.com

FILE NAME:	FIELD BOOK/PAGE:	PROJECT NO.:	SHEET:
2858SR.DWG	134/15	2858	1 OF 1

SURVEY DATE:	DRAWN BY:	SCALE:	CHECKED BY:	(S-T-R)
8-5-2003	SMS	1"= 60'	TLM/SMS	

HAZEN AND SAWYER
Environmental Engineers & Scientists

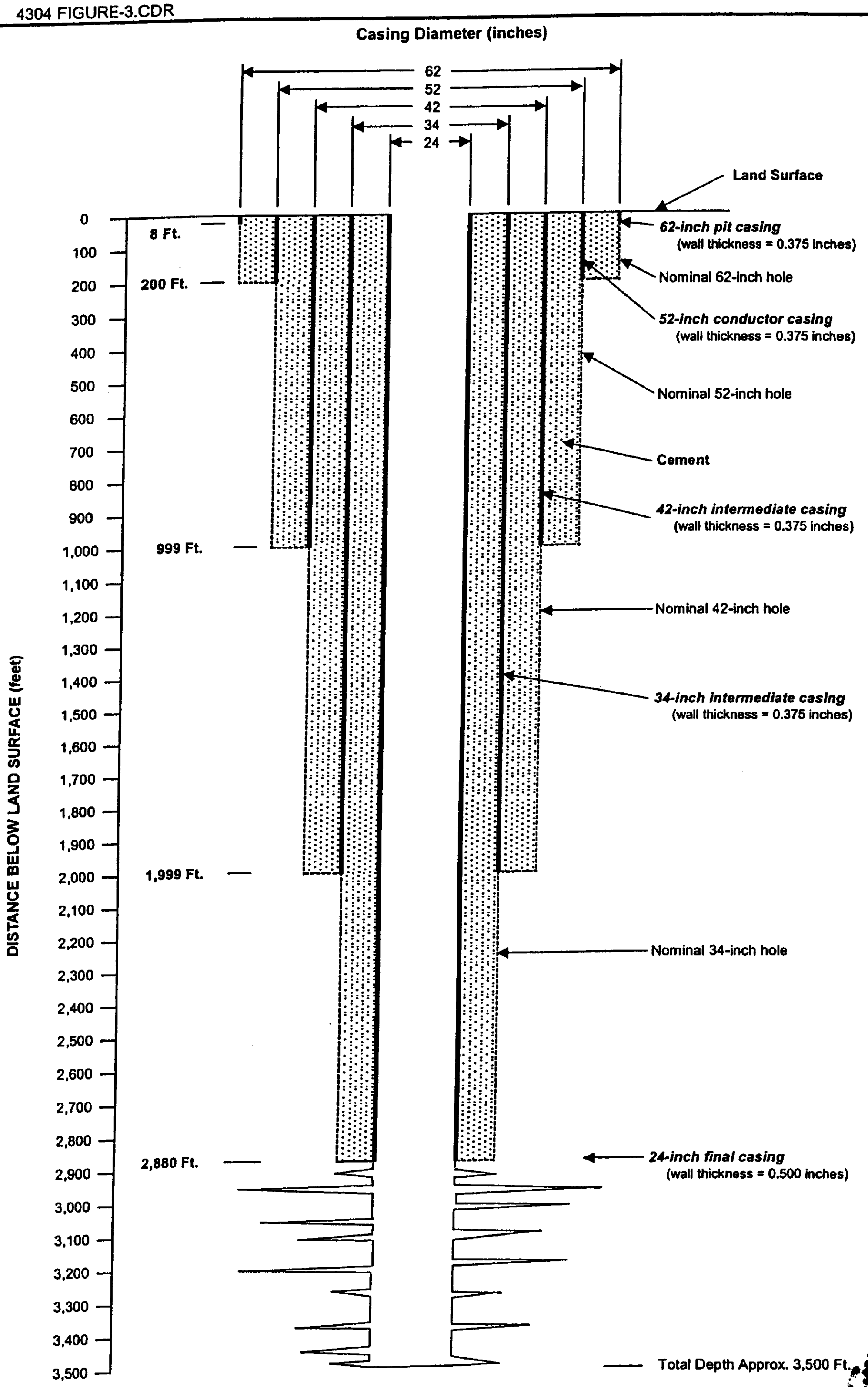
CITY OF HOLLYWOOD EFFLUENT DISPOSAL SYSTEM
SOUTHERN REGIONAL WWTP INJECTION WELLS

SITE PLAN

FIGURE
2

4304 FIGURE-2.CDR

4304 FIGURE-3.CDR



INJECTION WELL No. 1 (IW-1)

City of Hollywood
Southern Regional WWTP Injection Wells

8/12/03

ALBERT MUNIZ, P.E.
Registration No. 35987

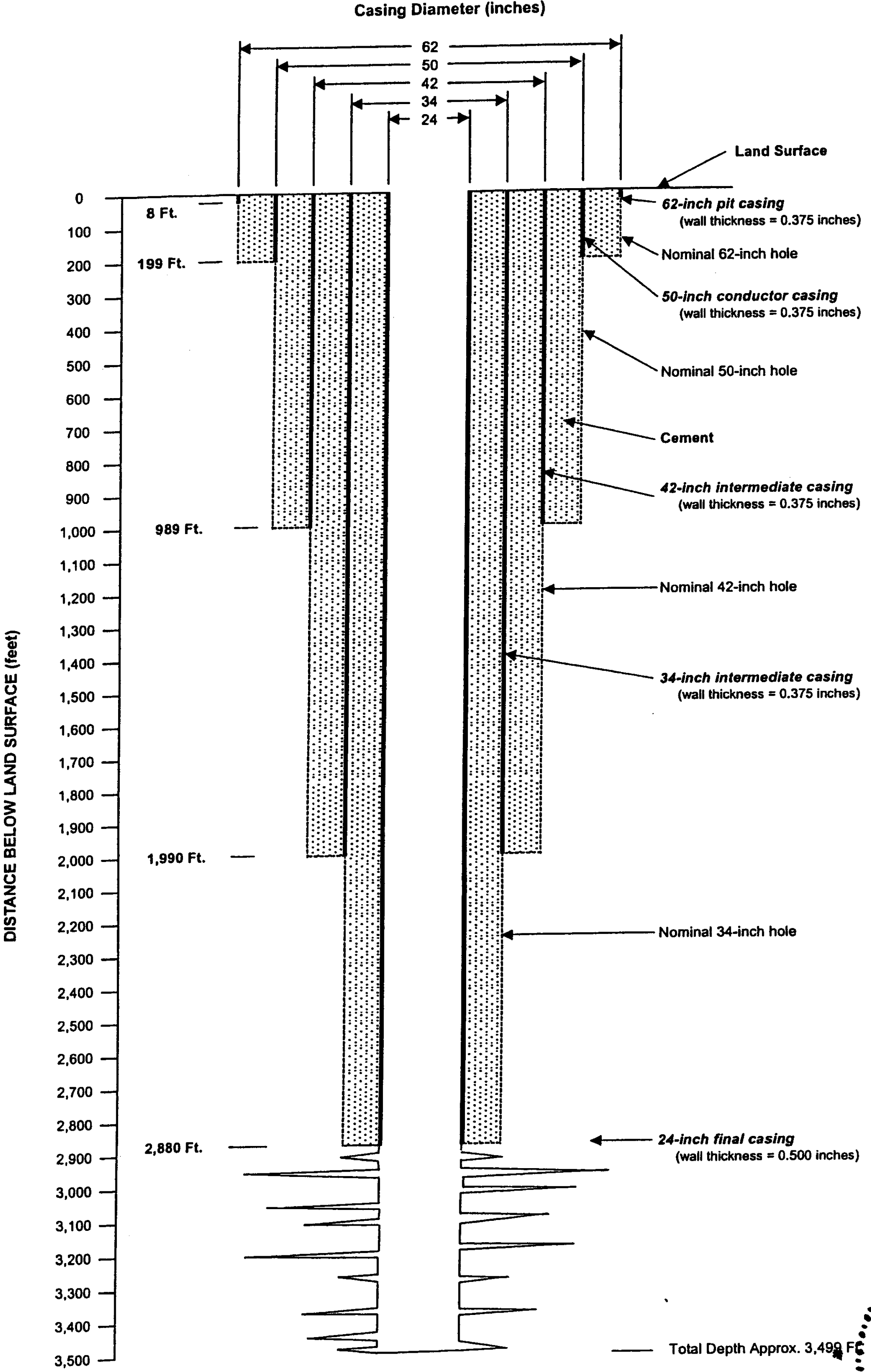
HAZEN AND SAWYER
Environmental Engineers & Scientists

CITY OF HOLLYWOOD EFFLUENT DISPOSAL SYSTEM
SOUTHERN REGIONAL WWTP INJECTION WELLS

Injection Well No. 1 As-Built Well Profile

FIGURE
3

4304 FIGURE-4.CDR



INJECTION WELL No. 2 (IW-2)

City of Hollywood
Southern Regional WWTP Injection Wells

8/12/03

ALBERT MUNIZ,
Registration No. 35587

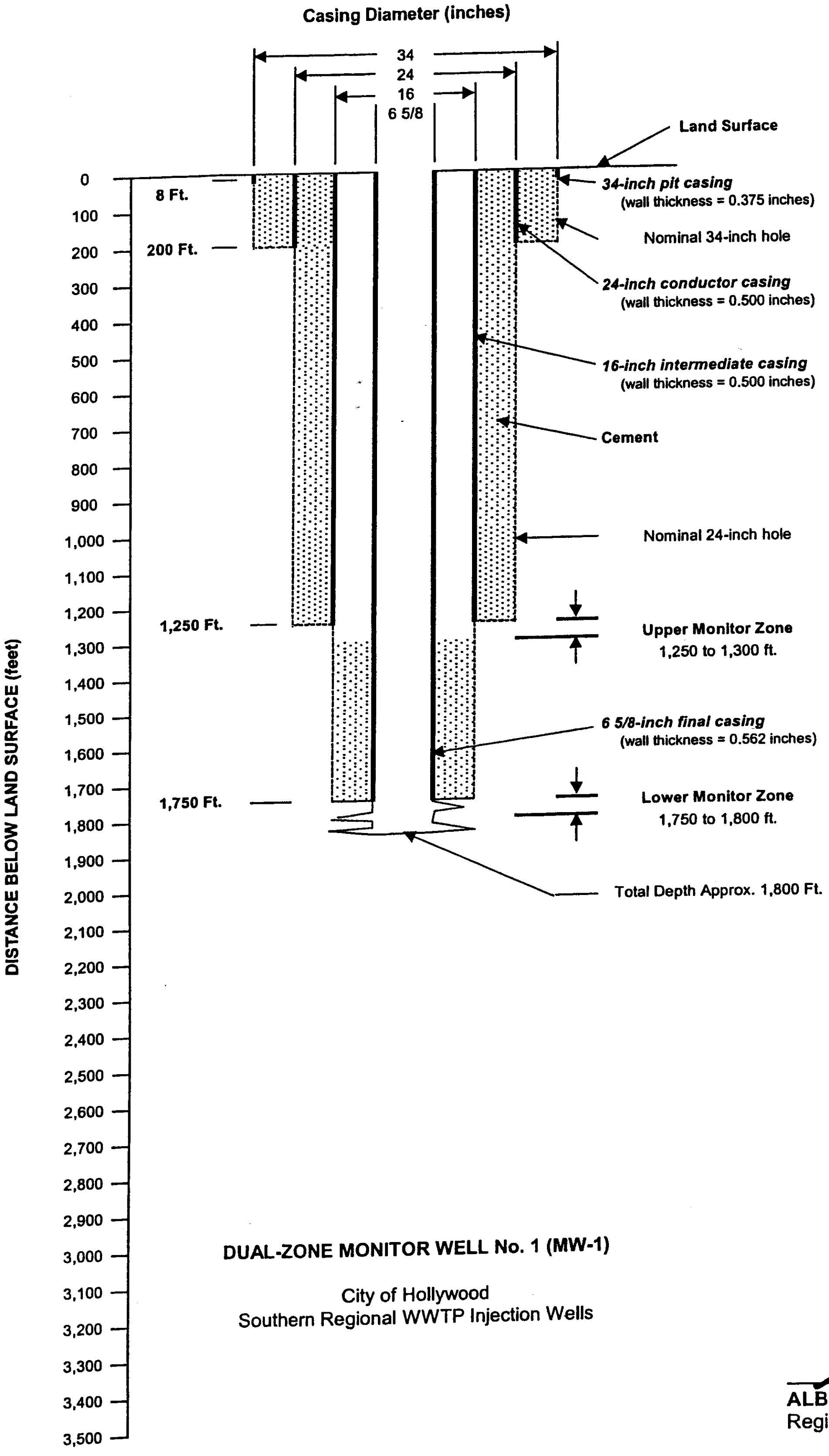
HAZEN AND SAWYER
Environmental Engineers & Scientists

CITY OF HOLLYWOOD EFFLUENT DISPOSAL SYSTEM
SOUTHERN REGIONAL WWTP INJECTION WELLS

Injection Well No. 2 As-Built Well Profile

FIGURE
4

4304 FIGURE-5.CDR



DUAL-ZONE MONITOR WELL No. 1 (MW-1)

City of Hollywood
Southern Regional WWTP Injection Wells

8/12/03

ALBERT MUNIZ, P.E.
Registration No. 35587

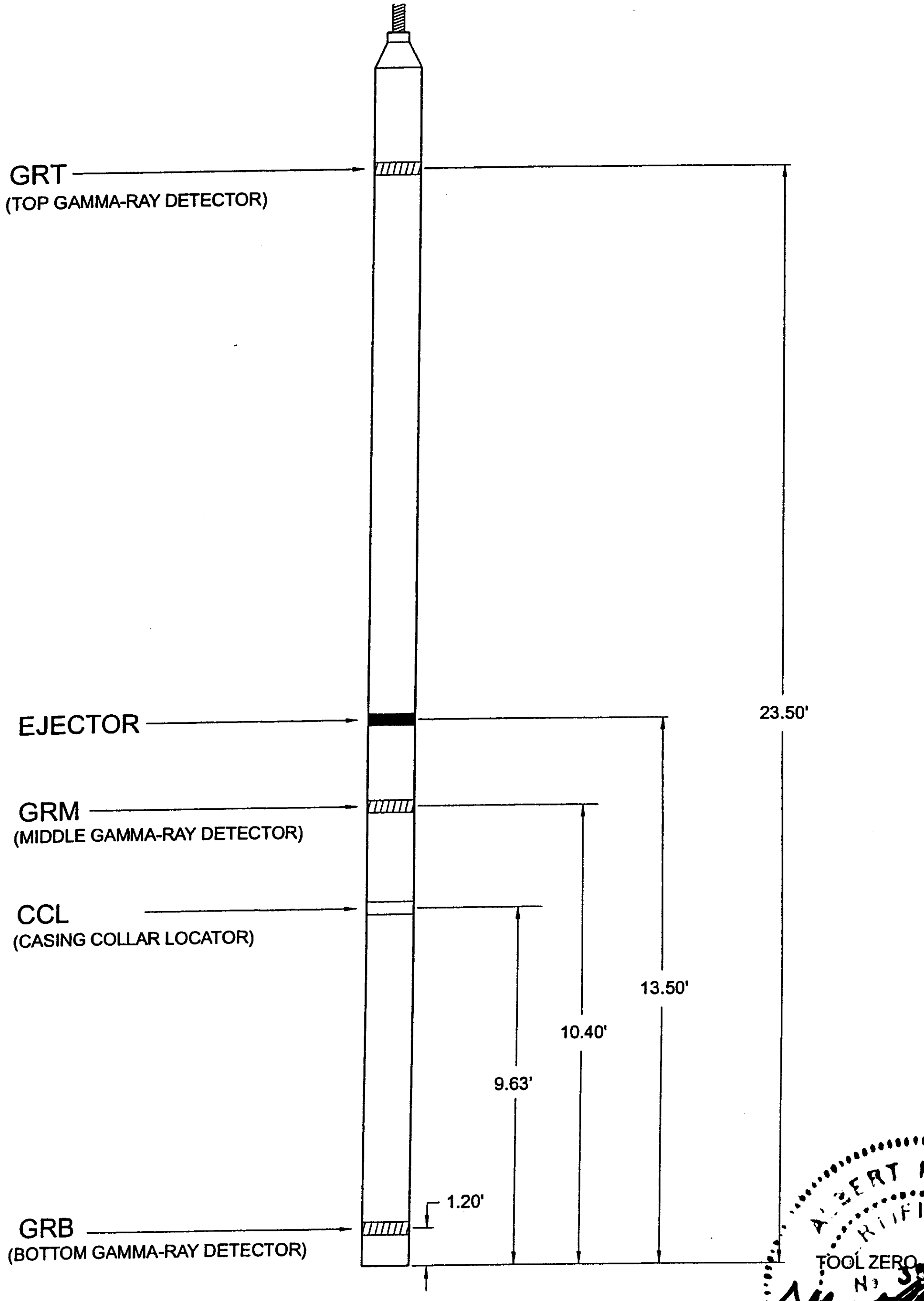
HAZEN AND SAWYER
Environmental Engineers & Scientists

CITY OF HOLLYWOOD EFFLUENT DISPOSAL SYSTEM
SOUTHERN REGIONAL WWTP INJECTION WELLS

Monitor Well No. 1 As-Built Well Profile

FIGURE
5

4304 FIGURE-6.CDR



ALBERT MUNIZ, P.E. No. 35587

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Registration No. 35587

8/12/03

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Environmental Engineers & Scientists

CITY OF HOLLYWOOD EFFLUENT DISPOSAL SYSTEM
SOUTHERN REGIONAL WWTP INJECTION WELLS

RTS TOOL

FIGURE
6

1.0 Injection Well Program

1.1 Introduction

On April 15, 2002, the City of Hollywood was issued Permit No. 156419-001-UC by the Florida Department of Environmental Protection (FDEP) for the construction of two 24-inch diameter Class-1 injection wells (IW-1 and IW-2) and one dual-zone monitor well (MW-1). A copy of FDEP's permit is included in Appendix A. The wells are located at the City of Hollywood Southern Regional Wastewater Treatment Plant (WWTP). A location map of the project site is presented in Figure 1.

The wells were constructed in accordance with Contract Documents prepared by Hazen and Sawyer (H&S) entitled Contract Documents Southern Regional Wastewater Treatment Plant Injection Wells, dated March 2002. These plans and specifications for drilling two injection wells and one dual-zone monitor well formed the basis of a contract between the City of Hollywood and Youngquist Brothers, Inc. (referred to hereinafter as "the Contractor").

H&S was retained by the City of Hollywood (the City) 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 Survey (USGS). The United States Environmental Projection Agency (EPA) is copied on TAC correspondence, but is not a member of the TAC.

1.2 Purpose

The purpose of this report is to summarize the information obtained during the construction and testing of IW-1, IW-2, and MW-1. The following information is included in this report:

- Description of methods used to analyze the data
- Documentation of the approved casing setting depths and monitoring zones for MW-1
- Demonstration of mechanical integrity of the injection wells
- Identification of confinement above the injection zone

- Verification that the wells are suitable for the designed pumping rates to allow long-term operational testing of the injection wells.

1.3 Elements of the Injection Well Contract

The project specifications contained provisions for the construction and testing of the two injection wells and the associated monitor well. The well design was based on the data obtained from other wells in the area. The 24-inch diameter injection wells were constructed approximately 3,500 feet below land surface. The deep dual-zone monitor well (also called the monitor well) was constructed to a total depth of 1,800 feet.

Provisions of the contract included:

- Monitoring depth, weight on bit, rate of penetration, inclination and drilling fluid properties during the drilling of the wells;
- Collecting and logging formation cuttings (samples), to confirm lithologic boundaries and gross lithologic properties;
- Collecting and analyzing conventional cores to complement the geologic logging and to identify hydrologic properties of the lithologic formations;
- Conducting the following geophysical logs at various points during the well construction: X-Y caliper, gamma ray, fluid conductivity, dual induction, borehole compensated sonic/VDL, fluid resistivity, temperature, flowmeter and borehole televiewer;
- Conducting open hole video (television) surveys;
- Conducting straddle packer and single packer tests in discrete zones of the injection well pilot hole to determine the hydrologic properties of lithologic units;
- Collecting and analyzing water samples taken during the packer tests to determine water quality variations with depth;
- Conducting casing cement top temperature logs and cement bond logs on various casing strings during the cementing operations;
- 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 wells; and
- Conducting a short-term injection test in the completed injection wells 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 first injection well was constructed prior to the construction of the dual-zone monitor well (i.e., IW–1 constructed prior to MW-1). The second injection well was constructed after the construction of the first injection well and the dual-zone monitor well (i.e., IW–2 constructed after IW–1 and MW-1). The monitor well was constructed approximately 150 feet southwest of IW-1 and 150 feet northeast of IW–2. Well locations are presented in Figure 2. During the drilling of the wells, geophysical logging and testing were performed. Well construction was in accordance with the FDEP construction permit. Refer to Appendix A for a copy of the permit.

The drilling of IW-1, MW-1, and IW–2 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 steel casing at selected depths in order 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, which are identified in the as-built profiles of IW-1, MW-1, and IW–2, are presented in Figures 3, 4 and 5, respectively. Injection well IW–1 was constructed as generally follows:

- Drill a nominal 58-inch diameter borehole to approximately 204 feet bpl using the mud rotary method.
- Set and cement a 52-inch diameter steel casing to a depth of 200 feet bpl.
- Drill a nominal 52-inch diameter borehole to approximately 1,003 feet bpl using the mud rotary method.
- Set and cement a 42-inch diameter steel casing to a depth of 999 feet bpl.
- Drill a nominal 12¼-inch diameter pilot hole to approximately 2,010 feet bpl using the reverse air method and core at depths selected by the Engineer.
- Backplug pilot hole with cement.
- Drill a nominal 42-inch diameter borehole to approximately 1,995 feet bpl using the reverse air method.
- Set and cement a 34-inch diameter steel casing to a depth of 1,990 feet bpl.

- Drill a nominal 12¼-inch diameter pilot hole to approximately 3,000 feet bpl using the reverse air method and core at depths selected by the Engineer.
- Set cement plug at 2,880 feet bpl and back plug pilot hole with cement.
- Drill a nominal 34-inch diameter pilot hole to approximately 2,884 feet bpl using the reverse air method.
- Set and cement a 24-inch diameter steel casing to a depth of 2,880 feet bpl.
- Drill a nominal 24-inch diameter borehole to approximately 3,500 feet bpl using the reverse air method.

The drilling of MW-1 proceeded generally as identified in the project specifications. Drilling activities are summarized in the following outline. The depth of the monitor zones was based on the data collected during the drilling and testing of IW-1. The selection of the monitor zone depths is discussed later in the report. The dual–zone monitor well was constructed as generally follows:

- Drill a nominal 32-inch diameter borehole to approximately 205 feet bpl using the mud rotary method.
- Set and cement in place 24-inch diameter steel casing at 200 feet bpl.
- Drill a nominal 24-inch diameter borehole to approximately 1,251 feet bpl using the mud rotary method.
- Set and cement in place 16-inch diameter steel casing at 1,250 feet bpl.
- Drill a nominal 16-inch diameter borehole to approximately 1,748 feet bpl using the reverse air method.
- Drill a nominal 10-inch diameter borehole from 1,478 feet bpl to approximately 1,800 feet bpl using the reverse air method.
- Set and cement in place 6⅝-inch diameter fiberglass reinforced pipe (FRP)at 1,750 feet bpl using cement baskets, filling the annular space of the final casing with cement from 1,750 to 1,300 feet bpl.

The upper monitor zone (UMZ) was established between 1,250 and 1,300 feet bpl and the lower monitor zone (LMZ) between 1,750 and 1,800 feet bpl. The upper outside 1,600 feet of the 6⅝-inch diameter casing was coated with a corrosion resistant epoxy-phenolic compound.

The second injection well (IW–2) was constructed as generally follows:

- Drill a nominal 58-inch diameter borehole to approximately 205 feet bpl using the mud rotary method.
- Set and cement a 50-inch diameter steel casing to a depth of 199 feet bpl.
- Drill a nominal 50-inch diameter borehole to approximately 996 feet bpl using the mud rotary method.
- Set and cement a 42-inch diameter steel casing to a depth of 989 feet bpl.
- Drill a nominal 12¼-inch diameter pilot hole to approximately 2,000 feet bpl using the reverse air method and core at depths selected by the Engineer.
- Backplug the pilot hole with cement.
- Drill a nominal 42-inch diameter borehole to approximately 1,995 feet bpl using the reverse air method.
- Set and cement a 34-inch diameter steel casing to a depth of 1,990 feet bpl.
- Drill a nominal 12¼-inch diameter pilot hole to approximately 3,000 feet bpl using the reverse air method and core at depths selected by the Engineer.
- Set cement plug at 2,902 feet bpl and back plug pilot hole with cement.
- Drill a nominal 34-inch diameter pilot hole to approximately 2,885 feet bpl using the reverse air method.
- Set and cement a 24-inch diameter steel casing to a depth of 2,880 feet bpl.
- Drill a nominal 24-inch diameter borehole to approximately 3,500 feet bpl using the reverse air method.

A summary of casing depths and materials is presented below:

WELL	DIAMETER (inches)		CASING THICKNESS (inches)	CASING MATERIAL	CASING DEPTH (feet)
	Inside	Outside			
Injection Well No. 1					
Pit	61.25	62.00	0.375	Steel	8
Conductor	51.25	52.00	0.375	Steel	200
Surface	41.25	42.00	0.375	Steel	999
Intermediate	33.25	34.00	0.375	Steel	1,999
Final Casing	23.00	24.00	0.500	Steel	2,880
Total Depth	n/a	n/a	n/a	n/a	3,500

WELL	DIAMETER (inches)		CASING THICKNESS (inches)	CASING MATERIAL	CASING DEPTH (feet)
	Inside	Outside			
Injection Well No. 2					
Pit	61.25	62.00	0.375	Steel	8
Conductor	49.25	50.00	0.375	Steel	199
Surface	41.25	42.00	0.375	Steel	989
Intermediate	33.25	34.00	0.375	Steel	1,990
Final Casing	23.00	24.00	0.500	Steel	2,880
Total Depth	n/a	n/a	n/a	n/a	3,499
Monitor Well No. 1					
Pit	33.25	34.00	0.375	Steel	8
Conductor	23.00	24.00	0.500	Steel	200
Intermediate	15.00	16.00	0.500	Steel	1,250
Final Casing	5.501	6.625 (6 ⅝)	0.562	FRP	1,750
Total Depth	n/a	n/a	n/a	n/a	1,800

2.2 Data Collection

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

Except where noted, measurements of footage in the wells are referenced to the pad level. The National Geodesic Vertical Datum (NGVD) elevation at pad level during construction and testing of IW-1, MW-1, and IW-2 are 6.4 ft, 6.4 ft, and 6.6 feet, respectively.

Daily progress and activities were monitored and recorded. 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. All 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 hole straightness, 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 are presented in Appendix C.

2.3 Geologic Samples

Samples of drilled cuttings were collected and analyzed from the drilling of the injection wells and monitor well boreholes. 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 drilled intervals 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 holes, conventional core samples were collected. These samples were reviewed and selected 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 wells 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-1and IW-2 were taken at the depths identified in Table 1.

Samples from each core were selected and sent for analysis to an independent laboratory, Ardaman and Associates. 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 2.

2.5 Geophysical Logs

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

- X-Y Caliper - Identification of hole diameter and hole geometry.
- Gamma Ray - 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. Geophysical logs are presented in Appendix F and are boxed separately. Box 1 contains logs from IW-1, Box 2 contains logs from IW-2 and MW-1, and Box 3 contains logs from MW-1. For convenience, many of the same type of logs were merged together (e.g. the dual induction log for MW-1 presented in Box 2 is continuous from 251 to 1,850 feet bpl). Also in Appendix F is an index of the logs performed and a tabulation of the logs included in each box.

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 Florida Geophysical Logging, Inc. Industry standard quality control measures were observed and are documented on the logs. Detailed information of the tool calibration program utilized by Florida Geophysical Logging is also included in attached Appendix F.

2.6 Video Surveys

Video surveys were conducted and recorded in VHS format. In the injection well 1 (IW-1) pilot holes from 999 to 3,000 feet bpl, and in the injection zone through the nominal 24-inch hole between 3,000 and 3,500 feet bpl. Video surveys were also performed on the dual–zone monitoring well from 1,250 to 1800 feet bpl. In the injection well 2 (IW-2) pilot holes from 989 to 3,000 feet bpl, and in the injection zone through the nominal 24-inch hole between 3,000 and 3,500 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, however, for convenience, the tapes are boxed separately with the geophysical logs. Injection well IW-1 videotapes are included in Box 1, injection well IW-2 videotapes are included in Box 2 and MW-1 videotapes are included in Box 3

2.7 Packer Tests

Straddle packer tests were performed after pilot hole construction of the injection wells. Two inflatable packers (plugs) were set in the borehole and water was 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. Seven straddle packer tests were performed in IW-1, and eight straddle packer tests were performed in IW-2.

Two of the straddle packer tests performed in the injection well 1 (IW-1) identified acceptable monitoring zones for MW-1. These packer tests were the tests conducted over the interval from 1,354-1,370 feet and 1,404-1,420 feet below pad level.

The packers were lowered into the pilot hole to the selected interval on the 7⅞-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 each test, each isolated 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 3. 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 conductivities from the packer tests are presented in Table 4. 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, all of the hydraulic conductivity values presented from the packer tests are considered valid.

2.8 Packer Test Water Quality Samples

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 5. Log derived water graphs were prepared to compare to the packer test water quality test. These graphs show good correlation, and are 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 monitor well 16 and 6⅝-inch casings were pressure tested as identified below. The 24-inch injection well casings were pressure tested as identified below as part of the demonstration of mechanical integrity and are described in Section 4, Final Testing.

On September 24, 2002, the injection well 1 (IW-1) 24-inch casing was internally pressurized to 204.0 psi. A pressure increase of 8.0 psi was observed over the 60-minute test period. This increase represents a 4.0 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 November 07, 2002, the monitor well 16-inch casing was internally pressurized to 71.25 psi. A pressure increase of 2.75 psi was observed over the 60-minute test period. This increase represents a 3.7 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 January 17, 2003, the monitor well 6⅝-inch injection well casing was internally pressurized to 71.25 psi. A pressure increase of 1.5 psi was observed over the 60-minute test period. This increase represents a 2.1 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.

On April 15, 2003, the injection well no. 2 (IW-2) 24-inch casing was internally pressurized to 203.5 psi. A pressure increase of 1.5 psi was observed over the 60-minute test period. This increase represents a 0.8 percent change in the original pressure, which is within the 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 (right log track) displays the entire wave signal. If there is no bond, an arrival is seen at the time corresponding to the casing velocity. As the cement becomes thicker and stronger (compressive strength), the casing signal becomes weaker.

On April 12, 2003, cement bond log was performed in the injection well 1 (IW-1) 24-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 24-inch casing. The cement bond logs conducted in IW-1 demonstrated that there is a good cement seal around the 24-inch diameter casing and that there are no channels or conduits that would allow fluid movement adjacent to the casing.

On November 5, 2002, 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 channels or conduits that would allow fluid movement adjacent to the casing.

On December 12, 2002, a cement bond log was performed in the monitor well 6⅝-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 6⅝-inch casing. The cement bond log conducted in MW-1 demonstrated that there is a good cement seal around the 6⅝-inch diameter casing and that there are no channels or conduits that would allow fluid movement adjacent to the casing.

On April 11, 2003, a cement bond log was performed in the injection well 2 (IW-2) 24-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 24-inch casing. The cement bond log conducted in IW-1 demonstrated that there is a good cement seal around the 24-inch diameter casing and that there are no channels or conduits that would allow fluid movement adjacent to the casing.

2.11 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 1,250 and 1,300 feet bpl and the lower monitor zone between 1,750 and 1,800 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, IW-2 and MW-1.

3.2 Generalized Geologic Setting

A well-defined, extensive sequence of carbonate sediments is present at the City of Hollywood Southern Regional WWTP 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 370 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 a light gray to grayish olive 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 370 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 Anastasia and Plamico Sand formations.

From approximately 370 to 820 feet bpl, the sediment is predominantly composed of light olive gray, limestone and sandstone with abundant plastic clay. From 820 to about 880 feet bpl, the sediment is predominantly yellowish gray to olive plastic clay with very fine grained quartz sand with rare interbedded chert occasionally present throughout the interval. The sediments in the interval between approximately 370 and 880 feet bpl are Miocene to Late Eocene in age and correspond to the Hawthorn Formation.

From about 880 to 2,000 feet bpl, the sequence is composed almost entirely of limestone, 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 approximately 2,000 and 3,000 feet bpl, dolomite is interbedded with limestone, light to moderate yellowish-brown and fine to medium grained to cryptocrystalline. The limestone in this interval is generally very pale orange, pellodial or micritic, fine to medium grained and soft. The television surveys indicate that the dolomite in this zone exhibits extensive dissolution cavities as well as fracturing. The section is comprised of sediments of Early to Middle Eocene Age of the Avon Park Limestone.

Between 3,000 and 3,500 feet bpl, the sediments are dominantly dolomite, pale yellowish-brown to dark yellowish brown and fine to medium grained to cryptocrystalline. The television surveys indicate that the dolomite in this zone exhibits extensive dissolution cavities as well as fracturing. The section is comprised of sediments of Middle Eocene Age of the Avon Park and Oldsmar Formations.

The various formations penetrated by IW-1, IW-2 and MW-1 correlate closely with those encountered in the other wells in the area, demonstrating the continuity and uniformity of the beds. Copies of the geologic logs have been previously submitted.

3.3 Hydrogeologic Setting

The upper 370 feet of rock and sediments are Pleistocene and Upper Miocene sandstone, limestone, clay and unconsolidated sand and shell. These sediments comprise the Biscayne Aquifer that is used as a source of drinking water throughout South Florida.

Underlying the Biscayne Aquifer are approximately 450 feet of Miocene clay and limestone of the Hawthorn Formation that form a confining bed between the Biscayne Aquifer and the Oligocene to Eocene limestones and dolomites of the Floridan Aquifer. The clay and limestone confining sequence is called the Hawthorn Formation. Water from the Floridan Aquifer in South Florida contains concentrations of dissolved solids that 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, a confining sequence has been identified between 1,390 and 3,000 feet bpl as discussed later in Section 3.5. It consists of a thick sequence of dense limestone with some interbedded layers of dolomite and is 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 for monitoring 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, sulfate, specific conductivity, ammonia as nitrogen, nitrate as nitrogen, nitrite as nitrogen, total kjeldahl nitrogen and total organic nitrogen. Results of the laboratory analyses have been previously submitted.

The base of the USDW is defined as water having less than 10,000 mg/L TDS. The base of the USDW was estimated 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 1,390 feet bpl. Also used in determining TDS is the dual induction geophysical log.

From this log water quality can be derived. The log derived water quality data places the base of the USDW at 1,390 feet. This data is confirmed by the water quality results of the packer tests conducted in IW-1 between 1,354 and 1,370 feet bpl, and 1,404 and 1,420 feet bpl which yielded 6,992 mg/L total dissolved solids and 13,640 mg/L respectively. The data is further confirmed by the water quality results of the packer test conducted in IW-2 between 1,390 and 1,408 feet bpl that yielded 9,924 mg/L total dissolved solids. A copy of the log derived water quality graphs from IW-1 and IW-2 are included in Appendix J.

3.5 Confinement Analysis

The approach to the evaluation of vertical confinement at the City of Hollywood Southern Regional WWTP injection well IW-1 and IW-2 locations is as follows. Available borehole geophysical, geological data and open hole testing data were used to identify intervals from 1,390 (base of the USDW) to 3,000 feet bpl, which 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 effluent.

3.5.1 Identification of Confining Units

The presence of satisfactory confining sequences between 1,390 and 3,000 feet bpl was established at the WWTP during the drilling of IW-1 and IW-2. Letters previously submitted to the TAC documented the presence of this confinement on site. These letters from the Engineer are dated September 4, 2002 and March 11, 2003 and are referred to as the "IW-1 24-inch Casing Seat Request" and "IW-2 24-inch Casing Seat Request" respectively.

3.5.2 Geophysical Logs

The wire line geophysical logs for IW-1 and IW-2 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 was used to identify well-cemented limestone and/or dolomite beds that would be expected to have low matrix porosities and hydraulic conductivities. Borehole video surveying 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 video survey 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 video survey 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 video survey 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 water. Temperature and fluid resistivity/conductivity 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 and IW-2 (land surface to 3,000 feet bpl) were examined in detail for lithology, macroporosity (visible porosity) and apparent matrix hydraulic conductivity using a stereomicroscope. A copy of the geologic log is attached. The cuttings were grab samples collected at 10-foot intervals during the construction of the well. The lithology of the limestone 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 cryptocrystalline (crystals are not visible with the low powered microscope) or microcrystalline (crystals are 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 either 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. Geological logs for each well have been previously submitted.

3.5.4 Core Examination and Data Analysis

Seven cores were taken from 1,700 to 2,042 feet bpl in IW-1 and ten cores were recovered from IW-2 between 1,660 and 2,435 feet bpl. 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. The core descriptions have been previously submitted. Sections of each core were selected and submitted for laboratory analysis for hydraulic conductivity. Results from the laboratory core analysis for samples collected from IW-1 have been previously submitted. Results from the laboratory analysis for samples collected from IW-2 are still pending and will be forwarded when received.

3.5.5 Packer Test Data

Straddle packer test data collected during the drilling of IW-1 and IW-2 were analyzed for information on the hydraulic conductivity of potential confining units. 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 have been previously submitted.

3.5.6 Stratigraphic Correlation

The geologic and geophysical logs of IW-1 IW-2, and MW-1 indicates excellent correlation as would be expected from wells in such close proximity.

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.

3.5.8 Criteria for Identification of Confinement Intervals

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

- Low sonic transit times and derived sonic porosities.
- Variable density log (VDL) pattern consisting of either straight parallel vertical bands, where lithology is relatively uniform, or a "chevron" pattern of continuous parallel bands, where the formation consists of interbedded rock with differing densities and/or degrees of consolidation. Fractured rock typically has an irregular VDL log pattern.
- Low 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 (+/- 1,390 feet bpl) and 3,000 feet bpl was evaluated using the above criteria and data. The confining intervals are discussed below.

3.6.1 Interval From 1,500 to 1,900 Feet BPL

This interval consists predominantly of light-colored limestone. 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.

Packer tests was performed over the intervals in IW-1 1,769 to 1,785, and 1,894 to 1,910 feet bpl within this confinement interval and yielded hydraulic conductivities ranging from 3.8×10^{-5} to 3.8×10^{-4} cm/sec. Packer tests were performed over the intervals in IW-2 1,510 to 1,528, 1,760 to 1,778 and 1,810 to 1,828 feet bpl within this confinement interval and yielded hydraulic conductivities ranging from 1.8×10^{-3} to 1.0×10^{-4} cm/sec. No evidence of vertical fractures or solution cavities was visible on the borehole televiewer log or the television survey video. The geological and geophysical data for this interval are characteristic of good vertical confinement.

3.6.2 Interval From 2,040 to 2,550 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.

Packer tests were performed in IW-1 over the intervals 2,046 to 2,062 and 2,193 to 2,209 feet bpl within this confinement interval and yielded hydraulic conductivities ranging from 8.5×10^{-5} to 5.6×10^{-4} cm/sec. Packer tests were performed in IW-2 over the intervals 2,093 to 2,111, 2,265 to 2,283, 2,300 to 2,318 and 2,410 to 2,428 feet bpl within this confinement interval and yielded hydraulic conductivities ranging from 6.1×10^{-5} to 3.3×10^{-4} cm/sec. No evidence of vertical fractures or solution cavities was visible on the borehole televiewer log or the television survey video. The geological and geophysical data for this interval are characteristic of good vertical confinement.

3.6.3 Confinement Summary

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

The limestones and dolomites present from 1,500 to 1,900 feet bpl in the wells 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 1,900 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. The vertical hydraulic conductivity of core samples range from 1.4 x 10-8 to 1.1 x 10-3 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 the injection well construction was completed, the injection wells were tested for mechanical integrity, which also included collection of background water samples from IW-1, IW-2, MW-1, and performance of short-term injection tests on IW-1 and IW-2. The 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 treated effluent from the City's Southern Regional Wastewater Treatment Plant for a twenty four-hour period.

4.2 Background Water Quality

Water samples were obtained from both the upper and lower monitor zones of MW-1 and the IW-1 and IW-2 injection zones. Prior to sampling, the MW-1 upper zone was developed by using the reverse air procedure. The zone was then allowed to flow naturally for a minimum of three well volumes before samples were collected. The MW-1 lower monitor zones as well as the IW-1 and IW-2 injection zones were developed by using the reverse air procedure. After development a submersible pump was used to purge a minimum of three well volumes before samples were collected. 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, injection zones of IW-1 and IW-2, as well as the upper and lower monitor zones of MW-1 are presented in Appendix N.

Water samples of the plant effluent were also collected and analyzed. The results of the analysis are also presented in Appendix N

4.3 Mechanical Integrity Testing

In accordance with FAC Rule 62-528, the injection wells were tested for mechanical integrity. Testing consisted of a hydrostatic pressure test of the injection casing, a temperature log, a television survey and a radioactive tracer survey (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 Tests

On September 24, 2003, the IW-1injection well 24-inch diameter casing was internally pressurized to 204.0 psi. A pressure decrease of 8.0 psi was observed over the 60-minute test period. This increase represents a 4.0 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 presented in Appendix M. Ms. Heidi Vandor, P.G., representing FDEP, and Mr. Albert Muniz, P.E., representing Hazen and Sawyer P.C., witnessed the 24-inch diameter casing pressure test at IW-1.

On April 15, 2003, the IW-2 injection well 24-inch diameter casing was internally pressurized to 203.5 psi. A pressure increase of 1.5 psi was observed over the 60-minute test period. This increase represents a 0.8 percent change in the original pressure, which is within the allowable change of five percent. A copy of the test gauge certification records and certified results of the hydrostatic pressure test are presented in Appendix M. Ms. Heidi Vandor, P.G., representing FDEP, and Mr. Albert Muniz, P.E., representing Hazen and Sawyer P.C., witnessed the 24-inch diameter casing pressure test at IW-2.

4.3.2 Injection Well Temperature Logs

On January 13, 2003, Florida Geophysical Logging, Inc. conducted a temperature log on IW-1 from the surface to a total depth of 3,500 feet bpl. The temperature log showed a decline from about 77 degrees Fahrenheit to about 62 degrees Fahrenheit to a depth of 2,880 feet bpl. Below this point, the temperature decreases to about 48 degrees Fahrenheit to a total depth of 3,500 feet. Herberto Lafayette of Hazen and Sawyer witnessed the test. A copy of the temperature log is presented in Appendix F.

On May 9, 2003, Florida Geophysical Logging, Inc. conducted a temperature log on IW-2 from the surface to a total depth of 3,496 feet bpl. The temperature log showed a decline from about 84 degrees Fahrenheit to about 74 degrees Fahrenheit to a depth of 2,940 feet bpl. Below this point, the temperature decreases to about 50 degrees Fahrenheit to a total depth of 3,496 feet. John Largey of Hazen and Sawyer witnessed the test. A copy of the temperature log is presented in Appendix F.

4.3.3 Injection Well Television Surveys

A video survey of IW-1 was performed on January 8 and January 9, 2003. 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 24-inch diameter casing and open-hole section. The survey revealed that the casing was in excellent condition. A copy of the television survey tape and a description of observations are presented in Appendix G.

A video survey of IW-2 was performed on May 8, 2003. The survey was performed from pad level to a depth of 3,496 feet bpl. Water clarity was good, enabling the camera to capture clear images of the 24-inch diameter casing and open-hole section. A copy of the television survey tape and a description of observations are presented in Appendix G.

4.3.4 Injection Well Radioactive Tracer Surveys

4.3.4.1 Injection Well IW-1

On January 14, 2003, a radioactive tracer survey was conducted on IW-1. A detailed description and interpretation of the radioactive tracer survey is presented in the following text. The test began with Florida Geophysical Logging, Inc., 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. A schematic diagram of the logging tool is represented at the top of the radioactive tracer survey Log. Each logging run is identified at the top of the log run. After the completion of the background Gamma Ray Log the logging tool ejector was calibrated to a 0.25 millicuries (MCI) per second discharge, and the reservoir was loaded with 10 millicuries of radioactive Iodine 131. The radioactive tracer survey was witnessed by Len Fishkin, P.G., from FDEP, and by James A. Wheatley, P.G., representing Hazen and Sawyer P.C. A copy of the IW-1 RTS is presented in Appendix F

The first test conducted (TEST #1) injected at a rate of 100 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 1.5 MCI slug of tracer material. The readings from the middle gamma ray detector began to increase from background within 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 2,650 feet below pad level. The results of the log out of position showed no indication of tracer material movement up hole. The injection casing was then flushed with potable water. Following the flushing an out of position log was conducted (LAF #1) from below the casing to 2,650 feet below pad level. 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 100 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 1.5 MCI slug of tracer material was then ejected. The readings from the middle gamma ray detector began to increase from background within seconds of ejection. The readings from the middle gamma ray detector returned to background approximately 11 minutes after ejection. The readings from the bottom detector increased from background approximately four minutes after ejection. No detection of the tracer material was seen at the upper gamma ray detector any time during 60 minutes of time drive monitoring. The tools were logged out of position (LOP #2) to a depth of 2,650 feet below pad level after the 60-minute test period. The results of the log out of position showed no indication of tracer material movement up hole. The injection casing was then flushed with potable water. Following the flushing, an out of position log was conducted (LAF #2) from below the casing to 2,600 feet below pad level. 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.

For the next test (TEST #3), an injection rate of 200 gallons per minute (gpm) was established using plant effluent. 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 seconds of ejection. The readings from the middle gamma ray detector returned to background approximately ten minutes after ejection. The readings from the bottom detector increased from background approximately one minute 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 tools were then logged out of position (LOP #2) to a depth of 2,650 feet below pad level. The results of the log out of position showed no indication of tracer material movement up hole. These results are interpreted as providing evidence that the casing integrity is sound.

A final background log was conducted (FINAL GAMMA RAY) on the total depth of the well upon the completion of all the abovementioned tests. The background logs were 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 (2,880 feet to 2,900 feet). The difference in repeatability around the bottom of the casing is most likely the result of tracer staining around the base of the casing. It can also be seen where the remaining tracer material was dumped (3,050 - 3,100 feet).

4.3.4.2 Injection Well IW-2

On May 9, 2003, a radioactive tracer survey was conducted on IW-2. A detailed description and interpretation of the radioactive tracer survey is presented in the following text. The test began with Florida Geophysical Logging, Inc., 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. A schematic diagram of the logging tool is represented at the top of the radioactive tracer survey Log. Each logging run is identified at the top of the log run. After the completion of the background Gamma Ray Log the logging tool ejector was calibrated to a 0.25 millicuries (MCI) per second discharge, and the reservoir was loaded with 10 millicuries of radioactive Iodine 131. The radioactive tracer survey was witnessed by Heidi Vandor, P.G., from FDEP, and by James A. Wheatley, P.G., representing Hazen and Sawyer P.C. A copy of the IW-2 RTS is presented in Appendix F.

The first test conducted (TEST #1) injected at a rate of 100 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 1.5 MCI slug of tracer material. The readings from the middle gamma ray detector began to increase from background within seconds of ejection. The readings from the bottom detector increased from background approximately 2 minutes 20 seconds 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 2,650 feet below pad level. The results of the log out of position showed no indication of tracer material movement up hole. The injection casing was then flushed with potable water. Following the flushing an out of position log was conducted (LAF #1) from below the casing to 2,650 feet below pad level. 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 100 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 1.5 MCI slug of tracer material was then ejected. The readings from the middle gamma ray detector began to increase from background within seconds of ejection. The readings from the bottom detector increased from background approximately 2 minutes 20 seconds after ejection. No detection of the tracer material was seen at the upper gamma ray detector any time during 60 minutes of time drive monitoring. The tools were logged out of position (LOP #2) to a depth of 2,775 feet below pad level after the 60-minute test period. The results of the log out of position showed no indication of tracer material movement up hole. The injection casing was then flushed with potable water. Following the flushing, an out of position log was conducted (LAF #2) from below the casing to 2,650 feet below pad level. 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.

For the next test (TEST #3), an injection rate of 140 gallons per minute (gpm) was established using plant effluent. 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 seconds of ejection. The readings from the bottom detector increased from background approximately 1 minute 40 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 tools were then logged out of position (LOP #2) to a depth of 2,650 feet below pad level. The results of the log out of position showed no indication of tracer material movement up hole. These results are interpreted as providing evidence that the casing integrity is sound.

A final background log was conducted (FINAL GAMMA RAY) on the total depth of the well upon the completion of all the abovementioned tests. The background logs were 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 (2,880 feet to 2,900 feet). The difference in repeatability around the bottom of the casing is most likely the result of tracer staining around the base of the casing. It can also be seen where the remaining tracer material was dumped (2,935 - 2,950 feet).

4.3.5 MIT Conclusions

Based on the results of the temperature logs, hydrostatic pressure tests, video surveys and radioactive tracer surveys, IW-1 and IW-2 have demonstrated to have mechanical integrity.

4.4 Injection Tests

4.4.1 Injection Well IW-1

On May 22, 2003 a controlled injection test was conducted on IW-1 utilizing plant effluent as the source of water for testing. The test consisted of a 24-hour background period, during which transducers were placed at a depth of 2,870 feet bpl in IW-1 to monitor bottom hole pressure changes. Transducers were also placed such that wellhead pressure changes of IW-1, IW-2 and both zones of the dual-zone monitoring well (MW-1) could be monitored. After performing background monitoring, the 24-hour test was started. The injection test was conducted at two different injection rates. Injection began at the highest rate based on available flow, which was approximately 16,000 gpm (12.3 ft/sec). The 16,000 gpm injection rate was maintained for approximately one hour (i.e., first hour of 24-hour test). An injection rate of approximately 13,700 gpm (10.5 ft/sec) was maintained for the balance of the test. The maximum wellhead pressure during the test was 52 psi, which is well within the allowable 2/3 of the pressure test (i.e., approximately 137 psi) conducted on the 24-inch diameter casing. Wellhead shut-in pressure was approximately 32 psi before the start of the test. A copy of the data obtained during the injection test, as well as copies of the flowmeter and transducer calibration certificates and wellhead elevations and a copy of the site survey are presented in Appendix O. A summary of the injection rates and wellhead pressure is presented below:

Injection Rate (gpm)	Wellhead Pressure (psi)	Specific Injectivity (gpm/psi)
16,000	52.0	307.69
13,700	48	285.41

4.4.2 Injection Well IW-2

On June 2, 2003 a controlled injection test was conducted on IW-2 utilizing plant effluent as the source of water for testing. The test consisted of a 24-hour background period, during which transducers were placed at a depth of 2,870 feet bpl in IW-2 to monitor bottom hole pressure changes. Transducers were also placed such that wellhead pressure changes of IW-2, IW-1 and both zones of the dual-zone monitoring well (MW-1) could be monitored. After performing background monitoring, the 24-hour test was started. Testing of IW-2 was also conducted at two different injection rates. The initial rate was approximately 14,000 gpm (10.8 ft/sec), and lasted for 23 hours.

Injection was increased during the last hour of the test to 14,400 gpm (11.1 ft/sec). The maximum wellhead pressure during the test was 52 psi well within the allowable 2/3 of the pressure test (i.e., approximately 136 psi) conducted on the annulus. Wellhead shut-in pressure is approximately 33 psi. A copy of the data obtained during the injection test, as well as copies of the flowmeter and transducer calibration certificates are presented in Appendix O. A summary of the injection rates and wellhead pressure is presented below:

Injection Rate (gpm)	Wellhead Pressure (psi)	Specific Injectivity (gpm/psi)
14,000	52.0	269.23
14,400	52.0	276.92

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 1,390 feet bpl at IW-1 and IW-2.
- The confining sequence generally occurs between 1,500 feet and 2,550 feet bpl.
- Vertical hydraulic conductivity determined from core testing within the confining sequences ranged from 9.8×10^{-10} to 1.1×10^{-3} cm/sec.
- Hydraulic conductivity was determined from packer testing within the confining sequences ranging from $3.8.0 \times 10^{-5}$ to 2.2×10^{-3} cm/sec.
- The data demonstrates the existence of an extremely transmissive injection zone below 2,550 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 204.0 psi (24-inch casing). IW-2 was successfully pressure tested at 203.5 psi (24-inch casing).
- The testing program has demonstrated that IW-1 and IW-2 have mechanical integrity.
- One dual-zone monitor well was drilled with the upper lower monitor zone located from 1,250 to 1,300 feet bpl and the lower zone from 1,750 to 1,800 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 treated effluent at the City of Hollywood Southern Regional Wastewater Treatment Plant in accordance with existing state and federal underground injection control regulations.

Based on the results of the geophysical logging and testing performed at the South County Regional Water Treatment Plant, injection wells IW-1 and IW-2 have mechanical integrity and are 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 are 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 pressures are to be continuously monitored.
- Flow to injection wells is to be continuously monitored.
- Dual-zone monitor well water quality is to be monitored weekly.
- Waste stream (plant concentrate) water quality is to be monitored weekly.
- Injection well injectivity tests are to be performed monthly.
- A complete analysis of the waste stream is to be performed yearly.
- Injection well mechanical integrity tests are to be performed every five years.
- The eight shallow pad wells are to have samples collected and analyzed quarterly.

5.4 Well Operation, Maintenance and Future Testing

When the injection wells are 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 permit. Six months of operation are required before the City can apply for an operating permit. The construction permit for IW-1 and IW-2 expires April 15, 2004. 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 effluent into the nearby injection wells. 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. Well water is pumped to the sample sinks in the injection well pump station. Excess well water is discharged into the injection well pump station wetwell, and is pumped down the injection wells.

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, TKN, pH, specific conductance, sulfate, nitrate, sodium, fecal coliform, ammonia and temperature. 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 injection wells, injection records should be maintained to evaluate injection well performance.

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

The flowrate into the injection wells is to be continuously monitored and recorded. Daily average, maximum, and minimum flow rates, as well as the total volume of effluent pumped into each 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 shut-in pressure of the injection well is to be measured before each different injection 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 treated effluent 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 monthly. 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

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.

The injection wells are 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 MITs are to be performed before January 14, 2008 for IW-1 and May 9, 2008 for IW-2. 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 Waste Stream Analysis

Samples from the waste stream are to be collected and analyzed weekly for, TDS, TSS, chloride, sodium, fecal coliform, ammonia, nitrate, TKN, pH, specific conductance, sulfate, temperature, and phosphorus. The results of these analyses are to be sent to the FDEP monthly. During operational testing and quarterly.

5.5 Plugging and Abandonment Plan

In the event that an injection well has to be abandoned, the well must be effectively sealed (or plugged) to prevent upward migration of the injection zone fluid or the interchange of formation water through the borehole or along the casing. The plugging program will require the services of a qualified drilling contractor with equipment capable of installing drill pipe to a depth of 3,500 feet and pumping neat cement.

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 with crushed limestone.
- Place a sand cap on the crushed limestone to the bottom of the 24-inch casing.
- Fill the 24-inch casing 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 6⅝ -inch diameter casing with neat cement grout.
- Fill the shallow zone and the 16-inch diameter casing with neat cement grout

A cost estimate for plugging and abandoning the wells is presented in Table 6.