This Report was included as an Appendix of

City of Sunrise –
Sawgrass Wastewater Treatment Plant
Injection Well System
Request for Operational Permit Renewal

October 2003

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APPENDIX A

ENGINEERING REPORT ON THE DRILLING AND TESTING OF THE CITY OF SUNRISE INJECTION AND MONITORING WELLS

APRIL 1985

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Section 1
INTRODUCTION

SCOPE

The scope of work for the City of Sunrise's West Broward Regional Wastewater Disposal Facility included the construction of two 24-inch injection wells and one-dual zone monitor well, construction of three effluent pump stations and the installation of a distribution system to pipe effluent to the Sunrise Wastewater Treatment Plant No. 3. Craig A. Smith and Associates served as the prime consulting engineer for the entire project and the engineer of record for the transmission facilities and pump stations, while CH2M HILL served as the engineer of record for the deep injection well portion of the project.

The existing system of discharging treated effluent to percolation ponds and canals will be phased out with the completion of the injection facilities. The effluent will then be used for injection into the saltwater "boulder zone" through the two injection wells and possible future irrigation of green areas.

Southeast Underground, Inc. of Cape Coral, Florida, was selected as the prime contractor for the project and was responsible for constructing the pump stations and installing the distribution system. Layne Atlantic, Inc., Orlando, Florida, worked under subcontract to Southeast Underground to construct the two injection wells and the dual zone monitor well. This report describes the construction of the two injection wells and the dual-zone monitor well.

In February 1984, Layne Atlantic commenced with the drilling of the wells. The two injection wells and the dual-zone monitor well were drilled simultaneously in stages. The well construction was completed in January 1985. The expected completion date of November 1984 was extended due to the collapsing of one of the intermediate casings of the first injection well (IW-1). Prior to construction, the City of Sunrise submitted a construction permit application to the Department of Environmental Regulation (DER). DER construction permit No. UD06-66797 was granted on August 4, 1983 with an original expiration date of January 1, 1985. The permit expiration date was later extended to April 1, 1985, upon discussion with the DER. The permit as found in Appendix A, contains specific conditions relating to the location of the site, design parameters and specific construction criteria including equipment, testing and monitoring requirements. Specific construction details of the wells can be found in the contract specifications.

REGULATORY AGENCY INVOLVEMENT

Throughout the construction process a number of local, state and federal regulatory agencies were involved. The Technical Advisory Committee (TAC) coordinated these agencies which included the DER (state and local), South Florida Water Management District (SFWMD), Broward County Environmental Quality Control Board (BCEQCB) and the United States Geological Survey (USGS). Periodically, TAC meetings were held to fully inform its members of the project progress and to review current data collected. Special TAC meetings were held to discuss the recommended 24-inch casing settings of the injection wells; to analyze the cause of the collapse of the intermedial casing of IW-1, the extent of the damages and the remedial action to be taken which would assure the mechanical integrity of the completed well; and the proposed monitoring programs during construction and operation of the injection wells. Summaries of these TAC meetings are included in Appendix B.

ACKNOWLEDGEMENTS

This project is the result of the vision and dedication of the leaders of the City of Sunrise which with determination and perserverence have made it possible. Among them are: Mayor John Lomelo, Jr.; and council members John Montgomery, Bernard Weiselberg, Bill Colon, Lawrence Hoffman, and Nancy Rankine.

Completion of this project was an outstanding accomplishment, considering the serious difficulties caused by the collapse of one of the inner casings of IW-1. Its successful completion was the result of continuous communication between the executors of the construction of the project and the Technical Advisory Committee (TAC) of the Florida Department of Environmental Regulation (DER).

Those individuals who played a key role in this achievement were:

BCEQCB (Broward County Environmental Quality Control Board): Mr. Bruce Kester, TAC member

DER (Department of Environmental Regulation): Mr. Roy M. Duke, Jr., Manager South Florida District, Mr. John Guidry, Chairman, TAC, Mr. Richard Deuerling, TAC Member

SFWMD (South Florida Water Management District): Dr. Leslie Wedderburn, TAC Member

USGS (U.S. Geological Survey): Mr. Fred Meyer, TAC Member

LAYNE ATLANTIC CO.: Messrs. Ralph Palmer, Project Superintendent, Russ Carlin, Bill Neeley

CRAIG A. SMITH & ASSOCIATES: Messrs. Craig A. Smith, Bill Landis, Gene Schriner, and Richard DeVivero

CH2M HILL: Messrs. J. I. Garcia-Bengochea, Phil Waller, Sean Skehan, and Dave Snyder.

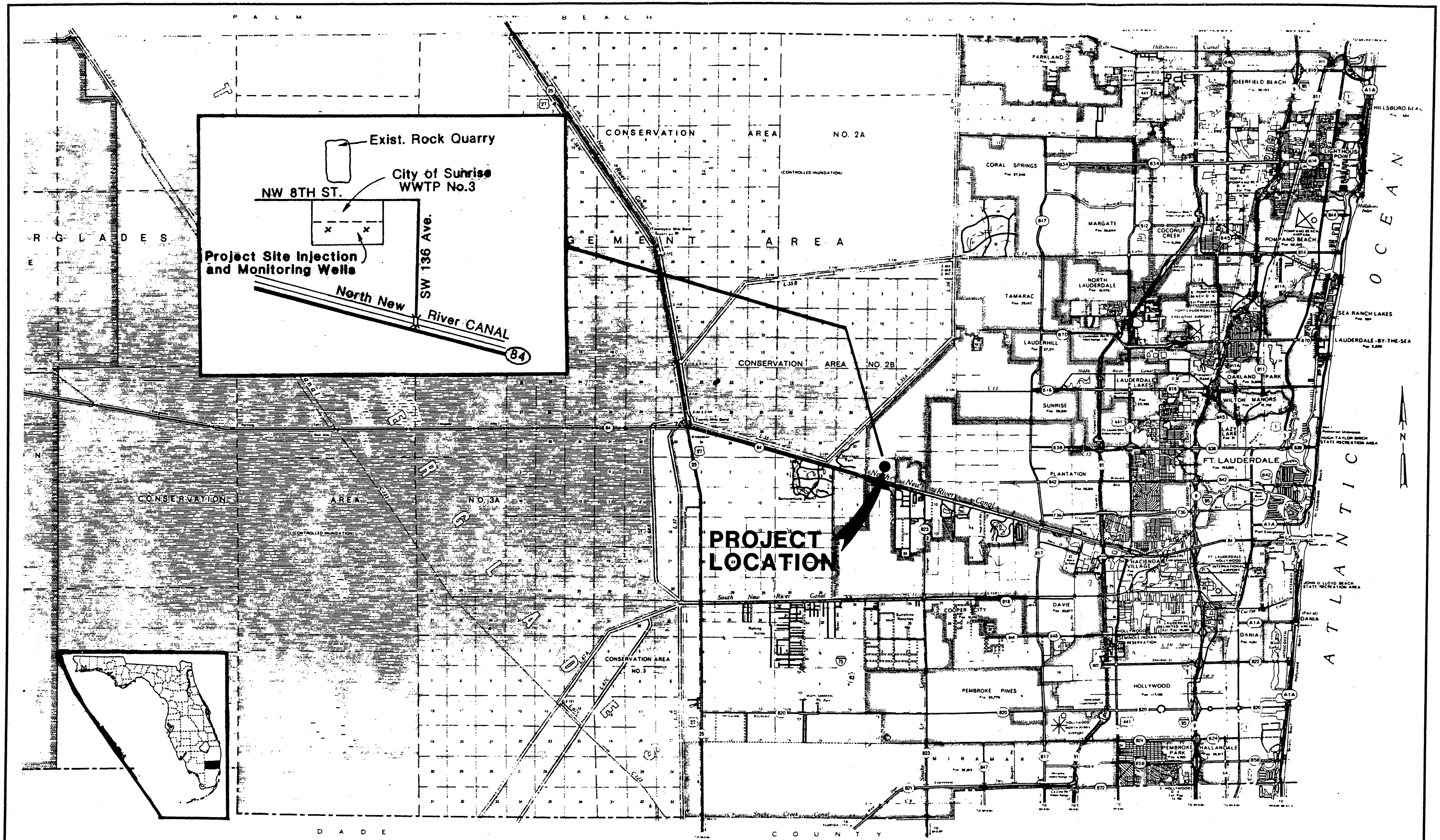
Section 2
WELL CONSTRUCTION

INJECTION WELL CONSTRUCTION

The site location of the injection wells is at the City of Sunrise Wastewater Treatment Plant (WWTP) No. 3. The treatment plant is located at 14150 Northwest 8th Street, in the NW 1/4 of the NE 1/4 of Section 3, Township 50 south, Range 40 east. Figure 2-1 shows the location of WWTP No. 3 in Sunrise, Florida.

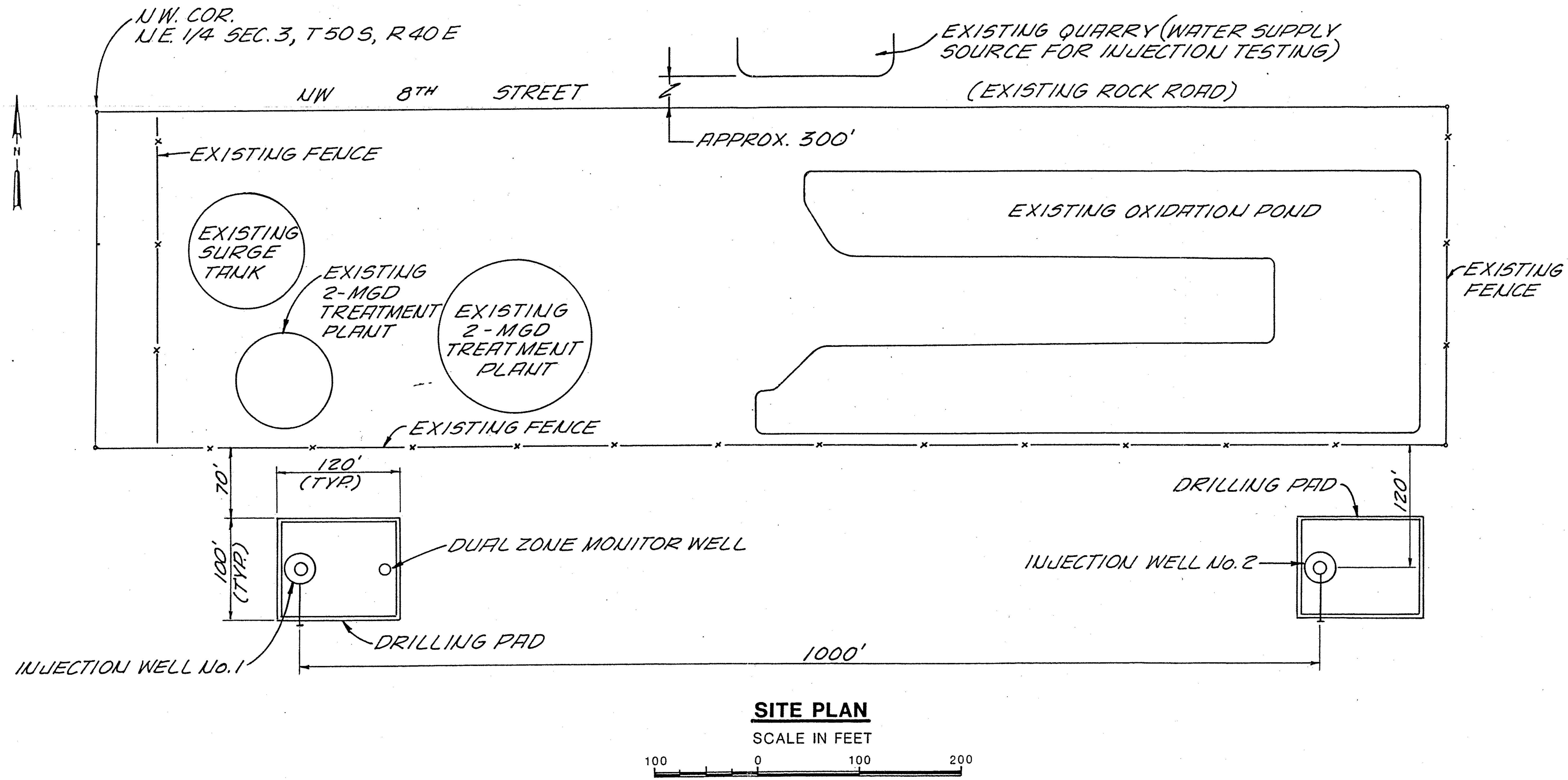
Construction at WWTP No. 3 first began in December 1983 with clearing and grubbing of the site. Figure 2-2 shows a site plan with the location of the wells. After the location was cleared, the drilling pad locations were filled and compacted with crushed limestone. The pads were then constructed utilizing a post tension reinforcing design and a single monolithic concrete pour. The drilling pads, 100 by 120 feet with a 6-inch curb were designed to support the combined loads of the drilling rigs with the various suspended casing loads and to contain drilling fluid and saltwater that may be produced during well construction.

Drilling on the two injection wells began in February 1984; IW-2 was completed in August 1984 and IW-1 was completed in January 1985. Drilling of the dual zone monitor well commenced in October 1984 and was completed in November 1984. Two rotary drilling rigs were used for the construction of the three wells. A Wilson 7500, with a rated hook load of 450,000 lbs, was used to drill IW-2 and to complete IW-1. A Gardiner-Denver 3000, with a rated hook load of 200,000 lbs, was used to drill the upper part of IW-1 to 1800 feet and the pilot hole to 3200 feet. The Gardiner-Denver 3000 was also utilized to drill the dual zone monitor well. Two methods of rotary drilling, standard mud circulation and reverse air circulation, were utilized to drill the wells.



LOCATION OF SUNRISE WWTP No.3
IN BROWARD COUNTY, FLORIDA

FIGURE 2-1



SITE PLAN

SUNRISE WWTP No.3-INJECTION and MONITOR WELLS

FIGURE 2-2

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Formation cuttings were removed from the bore hole by the mud circulation method down to approximately 1000 feet. Below 1000 feet, the reverse air circulation method was used to remove formation cuttings and to take formation water samples. The water samples were taken at 30-foot intervals from 1000 to 3200 feet during pilot hole drilling. These water samples were collected to obtain qualitative water quality data.

The drilling schedule and casing setting depths were designed around the particular characteristics of the geologic structures that are present in southeast Florida. Pilot holes were drilled in stages to anticipated casing setting depths. Formation samples were collected in 10-foot intervals while drilling the pilot hole. Geophysical logs were then run to aid in the interpretive analysis of the formation samples. Tables 2-1 and 2-2 summarize the drilling and the geophysical logging at the injection wells. Casing setting depths were then selected and the pilot hole reamed to the depth selected. At Sunrise, four strings of steel casings were used in the construction of the injection wells; 54", 44", 34", and 24".

The 54-inch casings (0.500 wall thickness) for both IW-1 and IW-2 were set and cemented to a depth of approximately 200 feet from land surface. This casing was set through the surficial Biscayne aquifer and into the upper Hawthorn formation to prevent possible contamination to the Biscayne Aquifer. This protects southeast Florida's primary source of potable fresh water during subsequent drilling operations.

The 44-inch casings (0.500 wall thickness) were installed and cemented to approximately 1000 feet below land surface, through the Hawthorn formation and into the upper Floridan aquifer.

Table 2-1
Summary of Drilling and Geophysical Logging at IW-1

Drilled Depth (feet)	Diameter (inches)	Date Completed	Logs Run	Drilled Section and/or Remarks
235	17½	2/11/84	caliper, electric resistivity, spontaneous potential, gamma ray	Pilot hole prior to setting 54" casing
217	60	2/15/84	None	Reamed hole for 54" casing
1062	17½	2/21/84	caliper, long and short normal electric, gamma ray, spontaneous potential	Pilot hole prior to setting 44" casing
1038	52	3/4/84	None	Reamed hole for 44" casing
1850	17½	3/26/84	caliper, long and short normal electric, gamma ray, spontaneous potential, temperature, fluid resistivity	Pilot hole prior to setting 44" casing
1791	42	4/3/84	None	Reamed hole for 34" casing
--	(34" casing)	4/12/84	caliper, temperature	Run on collapsed casing
3200	17½	10/31/84	caliper, temperature, flow meter, fluid resistivity, gamma ray, long and short normal electric, gyroscopic directional survey, T.V. survey	Ran pump test, T.V. survey, picked depth at which to set 24" casing, logs run static and during pump-out test
2700	32½	12/31/84	caliper, gyroscopic directional survey (run on reamed hole prior to installing 24" casing), cement bond log (run on cemented 24" casing)	Reamed hole for 24" casing
3200	22½	--	caliper, T.V. survey	Ran final pump test, T.V. survey, injection test

Table 2-2
Summary of Drilling and Geophysical Logging at IW-2

Drilled Depth (feet)	Diameter (inches)	Date Completed	Logs Run	Drilled Section and/or Remarks
240	17½	2/28/84	caliper, electric resistivity, spontaneous potential, gamma ray	Pilot hole prior to setting 54" casing
214	60	3/8/84	None	Reamed hole for 54" casing
1045	17½	3/14/84	caliper, long and short normal electric, spontaneous potential, gamma ray	Pilot hole prior to setting 44" casing
1015	52	3/18/84	None	Reamed hole for 44" casing
1810	17½	4/9/84	caliper, long and short normal electric, gamma ray, fluid resistivity	Pilot hole prior to setting 34" casing
1800	42½	4/22/84	None	Reamed hole for 34" casing
3302	17½	5/20/84	caliper, long and short normal electric, gamma ray, temperature, fluid resistivity, flow meter, temperature, fluid resistivity, gyroscopic directional survey, T.V. survey	Ran T.V. survey, picked depth at which to set 24" casing, logs run static and during injection test
2725	32½	6/11/84	caliper, gyroscopic directional survey (run on reamed hole prior to installing 24" casing), cement bond log (run on cemented 24" casing)	Reamed hole for 24" casing
3200	22½	7/17/84	caliper, T.V. survey	Ran injection test, T.V. survey

This casing serves as a construction casing sealing off the swelling clays and soft limestones of the Hawthorn formation that may interfere with reverse air drilling below 1000 feet to the total depth of the well.

The 34-inch casings (0.375 inch wall thickness) were installed and cemented to a depth of approximately 1800 feet below land surface. These casings are used to provide protection to the upper Floridan aquifer system which contain a brackish water with less than 10,000 mg/l total dissolved solids concentration. Two artesian aquifer zones in this interval are used as monitoring zones in the dual zone monitor well constructed as part of this project.

The 24-inch casings (0.500 wall thickness) are the conductor casings for the effluent at the injection wells. These casings were installed and cemented to an approximate depth of 2700 feet where a competent formation was found right above the injection interval, also known as the "boulder zone" because of its cavernous, highly fractured dolomite. Below 2700 feet in depth, the caliper logs showed the potential for cavities which could jeopardize the integrity of the cementing. Tables 2-3 and 2-4 summarize the casing depths and the type and quantity of cement used for cementing the injection wells. Figures 2-3 and 2-4 show well completion diagrams for the two injection wells.

MILLING OF COLLAPSED CASING AT IW-1

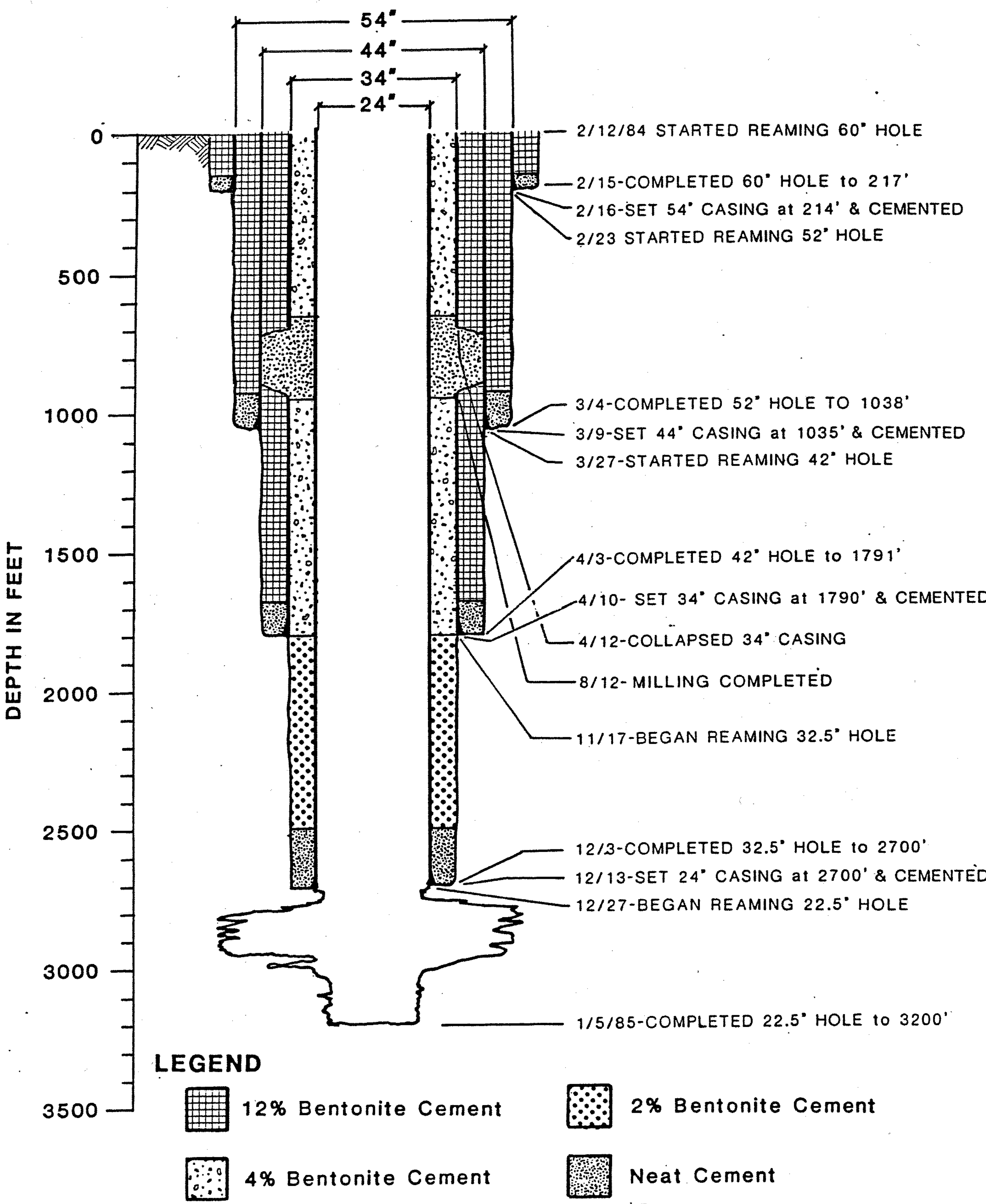
On April 12, during the third stage of cementing on the 34-inch casing at IW-1, the casing collapsed. Cementing had proceeded from 947 feet to approximately 357 feet when the differential pressure of the heavier cement on the outside of the casing (in the annulus) exceeded the collapse strength of the 34-inch casing. A caliper log was run and indicated

Table 2-3
Casing Depths, Types and Quantities of Cement Used at IW-1

Diameter of Casing (inches)	Casing Wall Thickness (inches)	Casing Depth Below Pad (feet)	Type of Cement	Amount of Cement (Sacks)	Remarks
54	0.500	214	Neat 12% Gel	158 372	Casing cemented in one stage
44	0.500	1035	Neat 12% Gel	147 1597	Casing cemented in one stage
34	0.375	1790	Neat 12% Gel	331 3515	Casing cemented in 5 stages (1 primary pressure grout and and 4 tremie stages) Casing collapsed in third stage from 690' to 920'
24	0.500	2700	Neat 2% Gel 4% Gel	961 3187 2660	Casing cemented in 9 stages (1 primary pressure grout and 8 tremie stages)

Table 2-4
Casing Depths, Types and Quantities of Cement Used at IW-2

Diameter of Casing (inches)	Casing Wall Thickness (inches)	Casing Depth Below Pad (feet)	Type of Cement	Amount of Cement (Sacks)	Remarks
54	0.500	215	Neat 12% Gel	354 372	Casing cemented in one stage
44	0.500	865	Neat 12% Gel	433 1335	Casing cemented in one stage
34	0.375	1797	Neat 12% Gel	431 3390	Casing cemented in 7 stages (1 primary pressure grout and 6 tremie stages)
24	0.500	2720	Neat 2% Gel 4% Gel	568 4684 2602	Casing cemented in 10 stages (1 primary pressure grout and 9 tremie stages)



WELL COMPLETION DIAGRAM FOR IW-1

FIGURE 2-3

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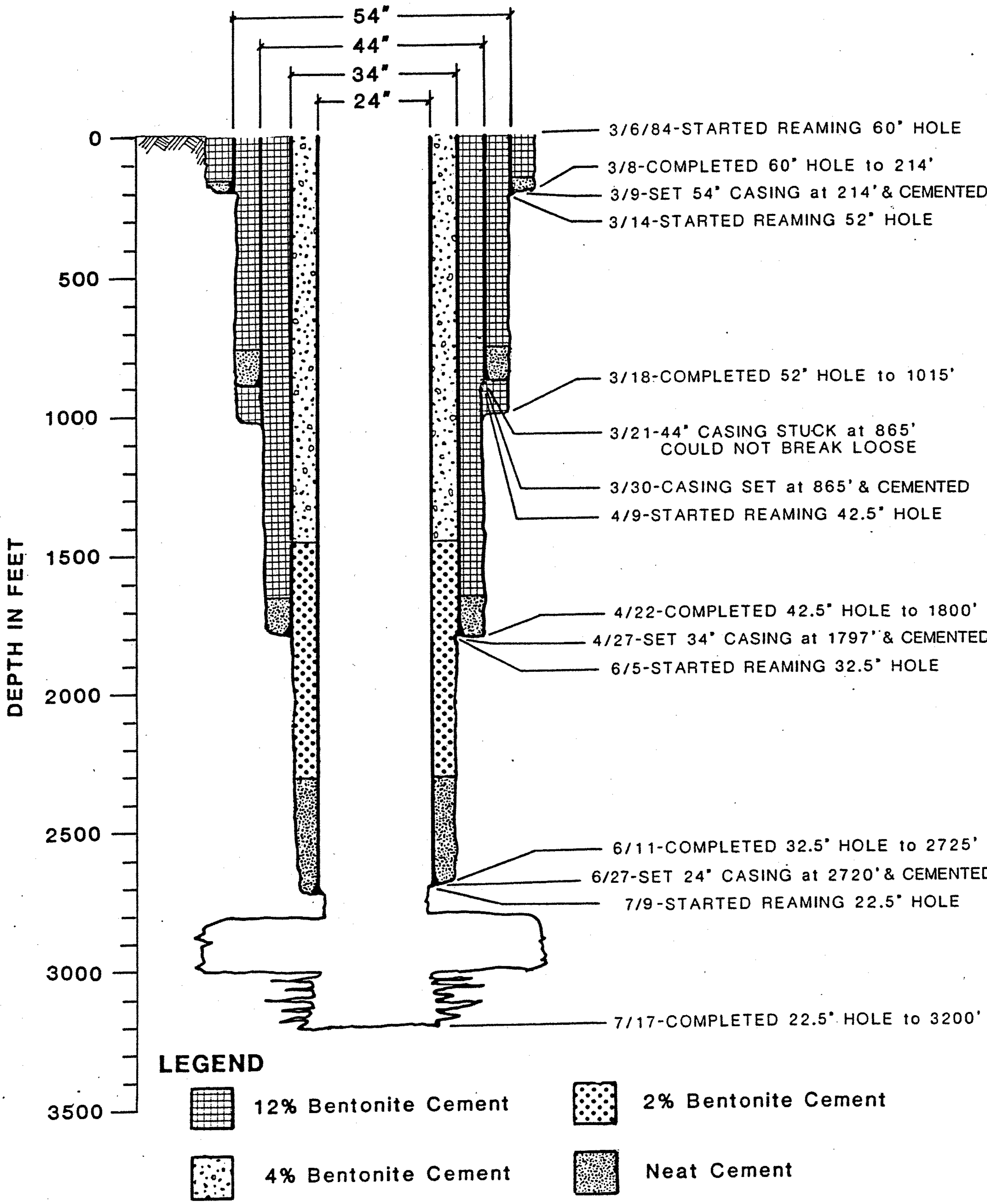

WELL COMPLETION DIAGRAM FOR IW-2

FIGURE 2-4

CH2M HILL

the 34-inch casing was collapsed from approximately 690 to 920 feet, which placed the collapsed section within the 44-inch casing set at 1035 feet. A meeting was held with the TAC to discuss the remedial methodology proposed by Layne Atlantic, the drilling contractors. Milling of the collapsed pipe was revised and approved conditioned to: 1) the remaining uncemented 34-inch annulus was cemented to the surface; 2) the milling would not damage the 44-inch casing; and 3) the interim structure formed by the previously cemented 44-inch casing and the un-milled section of the 34-inch test would pass a mechanical integrity test in addition to the final test of the completed well. Table 2-5 outlines the remedial proceure and mechanical integrity testing required by the TAC upon completion of the milling.

The milling began on April 19 with a rigid down hole assembly of stabilizers, drill collars, drill pipe and special downhole milling tools (watermelon, taper and junk mills). As milling continued, the design of the milling assembly and the milling tools was varied to meet the hole conditions. The progress was slow but ultimately the alternate use of mill barrel and junk mill assemblies proved to be the most successful. By November 15, the final clean out was completed and the mechanical tests were satisfactorily passed. At that time, Layne Atlantic was able to resume drilling of the pilot hole. Figure 2-5 summarizes the milling operations at IW-1.

MONITOR WELL CONSTRUCTION

A dual-zone monitor well was constructed to monitor two zones in the Floridan aquifer system located above the confining bed overlying the injection zone. The construction methods were the same as used for the injection wells. The monitor well will be used to monitor for any

Table 2-5
Remedial Procedure and Mechanical Integrity Tests
Approved by TAC
for the Milling of the 34" Casing
at IW-1

1. Finish cementing the annulus of the 34-inch casing to surface (completed 4/18/84).

2. Mill the collapsed casing carefully, using stabilizers and centralizers, in order to guard the 44-inch casing against damage (completed milling 8/12/84, cement and milling debris cleaned from bottom of casing 9/26/84).

3. Run a caliper log after completion of milling (completed 11/3/84).

4. Run a television survey of the milled casing; use a rotary sidewall mirror on the collapsed section (completed 11/15/84).

5. Run a hydraulic pressure test of the milled 34-inch casing and exposed 44-inch casing at 50 psi for one hour (completed 8/16/84).

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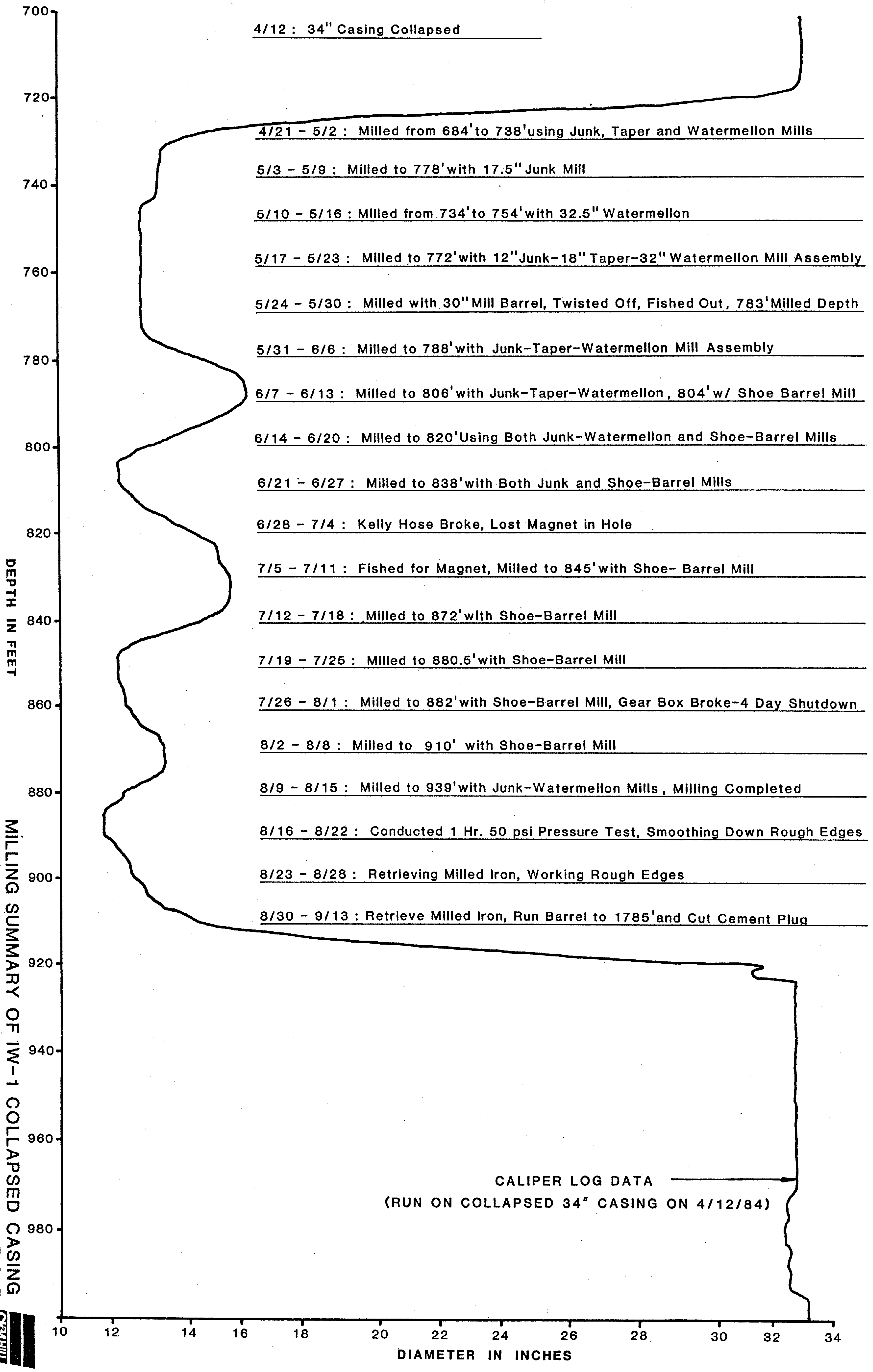

MILLING SUMMARY OF IW-1 COLLAPSED CASING
FIGURE 2-5

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Table 2-6
Summary of Drilling and Geophysical Logging at the Dual Zone Monitor Well

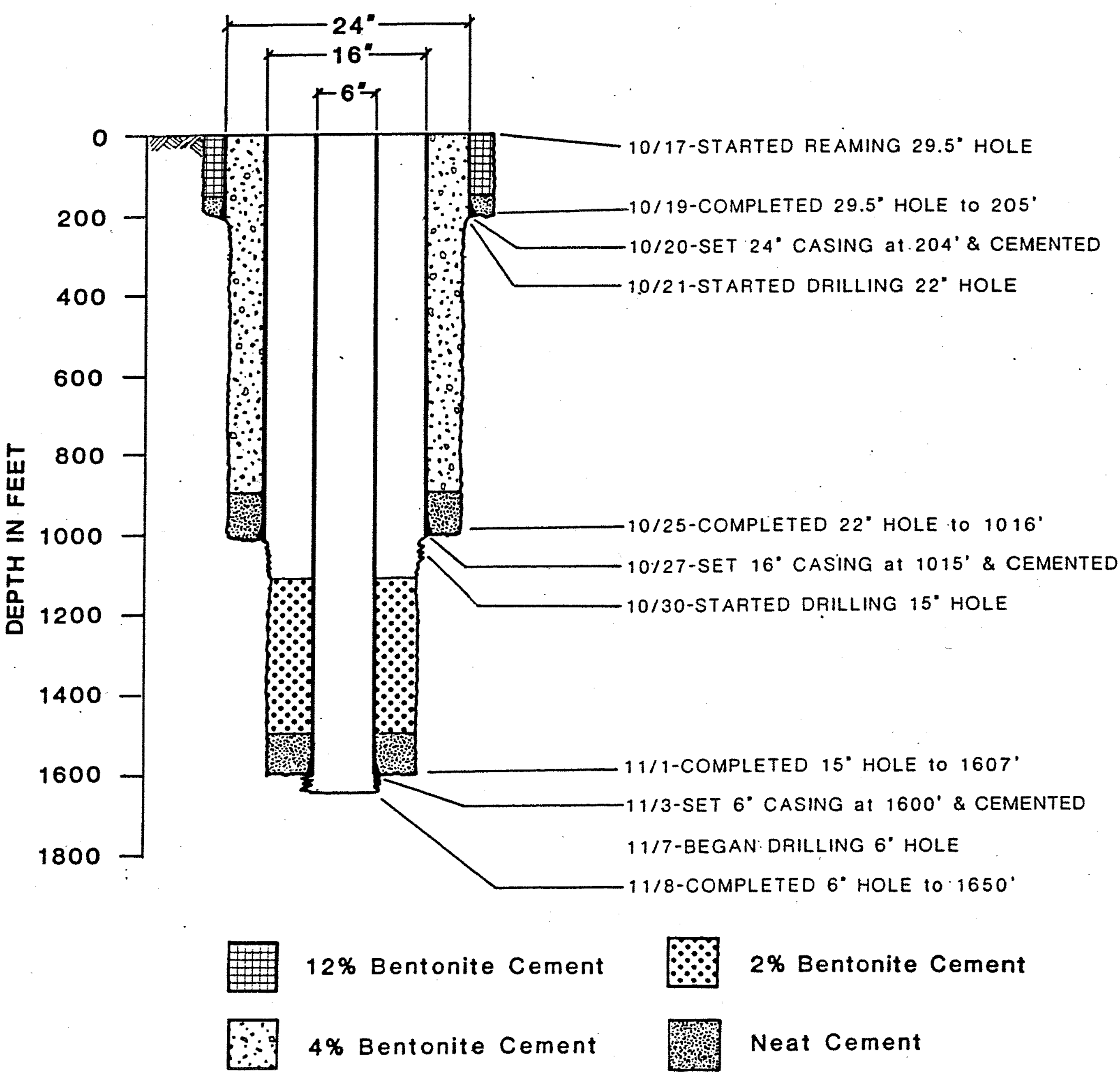
Drilled Depth (feet)	Hole Diameter (inches)	Date Completed	Logs Run	Remarks
243	17½	10/16/84	caliper, electric resistivity, spontaneous potential, gamma ray	Pilot hole prior to setting 24" casing
205	29½	10/13/84	None	Reamed hole for 24" casing
1016	22	10/25/84	caliper, long and short normal electric gamma ray, spontaneous potential	Hole for 16" casing
1607	15	11/1/84	caliper, gamma ray, spontaneous potential, electric resistivity	Hole for 6" casing
--	6" casing	11/3/84	temperature	Run to determine cement fillup
--	6" casing	11/7/84	cement bond log	Run to check cement bond to 6" casing
1650	6	11/8/84	caliper, electric resistivity, gamma ray,	Completed hole for lower monitor zone (1600'-1650'); Ran T.V. survey

upward migration of the injected effluent. Figure 2-6 shows the monitor well completion diagram and Table 2-6 summarizes the drilling and the geophysical logs performed at the monitor well.

The casing setting depths at the monitor well were basically the same as that used for upper three casings at the injection wells. A 24-inch casing was used through the Biscayne aquifer, a 16-inch casing was installed through the Hawthorn and into the upper Floridan aquifer, and a 6-inch casing was installed to 1600 feet into a monitoring zone selected in the lower Floridan aquifer. Table 2-7 summarizes the monitor well casing settings and the type and quantities of cement used.

Table 2-7
Casing Depths, Types and Quantities of Cement Used at Dual Zone Monitor Well

Diameter of Casing (inches)	Casing Wall Thickness (inches)	Casing Depth Below Pad (feet)	Type of Cement	Amount of Cement (Sacks)	Remarks
24	0.500	204	Neat 12% Gel	85 124	Casing cemented in one stage
16	0.375	1015	Neat 4% Gel	111 700	Casing cemented in one stage
6	0.432	1600	Neat 2% Gel	93 300	Casing cemented in 3 stages (1 primary pressure grout and and 2 tremie stages)



WELL COMPLETION DIAGRAM OF
DUAL-ZONE MONITOR WELL

FIGURE 2-6

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Section 3
GEOLOGIC, GEOPHYSICAL, HYDROLOGIC AND WATER QUALITY DATA

GEOLOGIC DATA

The stratigraphic profile of the Sunrise injection site was created by correlating data from the formation samples, taken every 10 feet during the pilot hole drilling, with geophysical logs run on the pilot holes. In general, a contiguous profile was observed across the site which included a diverse stratum of limestones, phosphatic and calcareous clays, and dolomites. A detailed lithologic log of each well is included in Appendix C.

The strata penetrated in the upper 210 feet represents recent deposits through and inclusive of the Pliocene series. Lithologically, this stratum is composed primarily of a white abundantly fossiliferous limestone with some calcareously cemented sands interbedded down to approximately 160 feet. This represents the Anastasia formation of the Biscayne aquifer and exhibits a high permeability. At approximately 160-feet, higher gamma ray counts are seen to occur and represent a transition into the Tamiami formation. Lithologically, some limestone with sandy clays and siltstone are observed down to approximately 210 feet.

At 210 feet down to 280 feet, a gray-green dense clay occurs. Extending below this to 480 feet, a sandy (areneceous) limestone occurs. This represents the Hawthorn formation of the Miocene series. Also of the Miocene series is the Tampa limestone that occurs from approximately 480 feet down to 1000 feet. Lithologically, this is a soft sandy limestone with phosphatic sands and interbedded clays at the base of the formation. The Hawthorn formation and the Tampa limestone represent a confining bed of low permeability separating the Biscayne and Floridan aquifers.

The gamma ray logs from the site make a sharp shift to higher measured counts in the 1000 to 1020-foot interval down to 1120 feet. This shift represents the transition from the Tampa limestone into the Suwannee limestone of the Oligocene series. The Suwannee limestone also represents the upper interval of the Floridan aquifer system. Lithologically, this formation is characterized by a hard white fossiliferous limestone and a calcareously cemented grainstone. This stratum exhibits high permeability with artesian flow present. This flow zone was selected for monitoring of the upper Floridan aquifer at the dual zone monitor well.

Below 1120 feet and extending down to 2800 feet, the gamma ray logs maintain a low, stable count rate through the Avon Park and Lake City limestones of the upper Eocene series. Lithologically, this interval is primarily composed of a micro fossilian calcilutite with some sparsely interbedded dolomites. This formation is very soft with low permeability. In the lower section of this formation (approx. 2700 to 2800 feet in depth) the caliper logging showed significant hole enlargement due to dredging of this soft formation while drilling. This strata is generally viewed as a confining unit separating the upper Floridan aquifer from the boulder zone.

The interval from 2800 to 3200 feet represents the Oldsmar limestone of the lower Eocene series. At this site, the lithology is characterized by some soft fossilian calcilutite and a hard, fine to coarsely crystalline, highly fractured and cavernous dolomite with high permeability to 3150 feet. This highly fractured zone is known as the "boulder zone," which is the injection interval at the Sunrise site and other injection wells in southeast Florida. Below 3150 feet, the formation becomes more massive and displays less permeability and fracturing. Figure 3-1 shows a generalized lithologic detail at the Sunrise site and copies of geophysical logs from IW-2.

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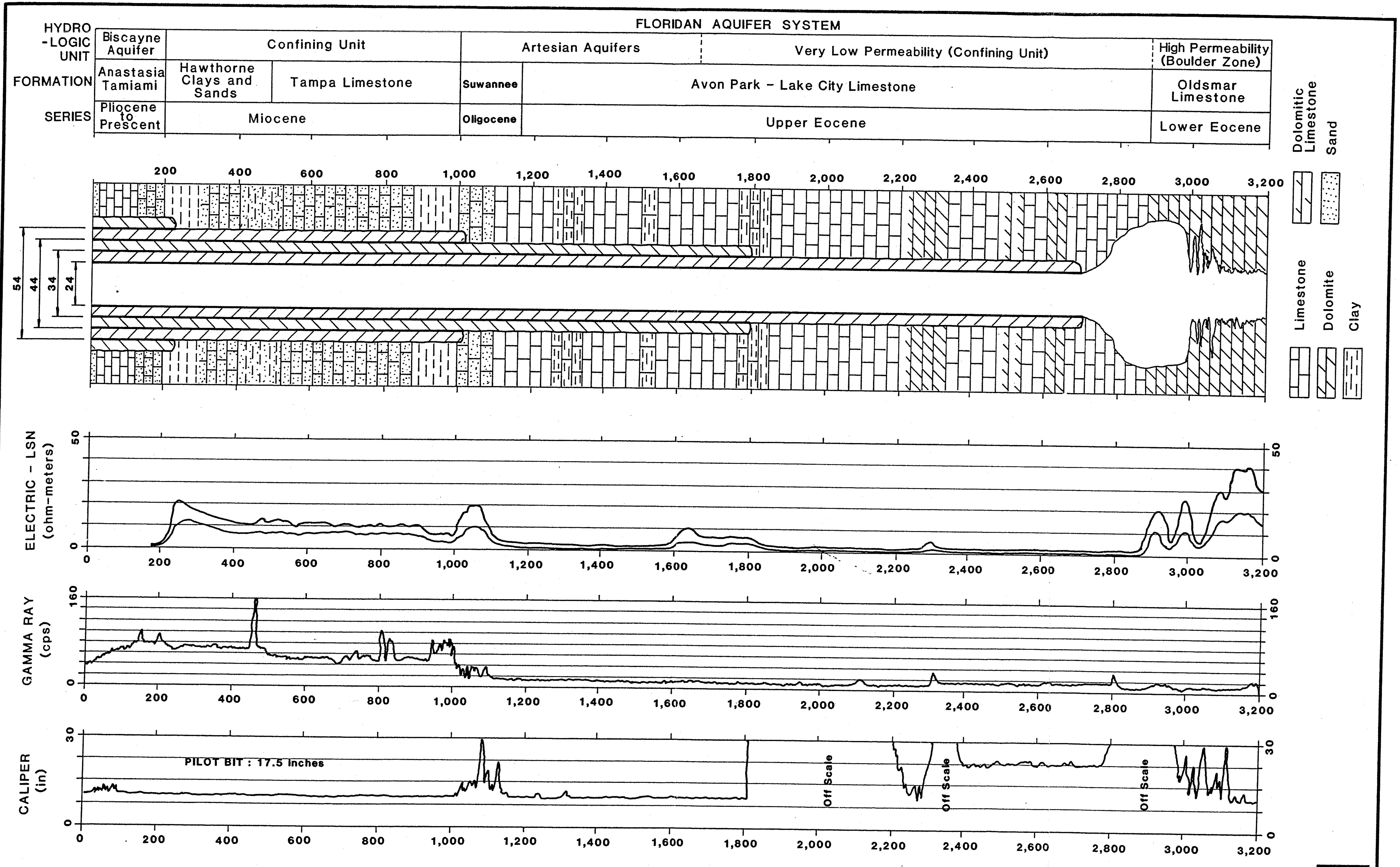

FIGURE 3-1
Generalized Lithologic Detail For Sunrise Site

GEOPHYSICAL LOGGING

Geophysical logs are used to identify and collect specific data from underground geologic structures. Geophysical logs were performed on all the pilot hole intervals and are then used to correlate with the formation samples, taken while drilling, to determine formation boundaries and obtain other necessary in-situ borehole data. This data is used to determine optimum casing setting depths and given to the TAC to satisfy certain regulatory requirements. Geophysical logs were also run during pump out and injection tests on the lower pilot holes (from 1800 to 3200 feet). These logs identified water production intervals, the quantity of water being produced from these intervals, and the location of the major confining zones.

Figures 3-2 and 3-3 summarize the geophysical logs performed during pumping of the lower pilot holes at each injection well. A close analysis of the logs and formation samples indicates similar lithology at both injection wells from 1800 to 2700 feet. Hydrologically this zone is characterized by relatively low permeability with a few minor water production intervals that comprise 15 to 25 percent of the approximate 4,000-gpm tested pump rates (lower rates run for geophysical logging). Generally, this zone is considered as the major confining bed between the injection zone and the upper Floridan artesian aquifers.

Below 2700 feet, some differences occur lithologically between the two injection wells. The caliper and flowmeter logs for IW-2, shown on Figure 3-3, indicate that the major permeability of the boulder zone is from 3050 to 3150 feet where approximately 75 to 80 percent of the injected fluids exited. In contrast, the same logs for IW-1, shown on Figure 3-2, indicate the major permeability of the boulder zone from 2800 to 3100 feet and 80 to 85 percent of

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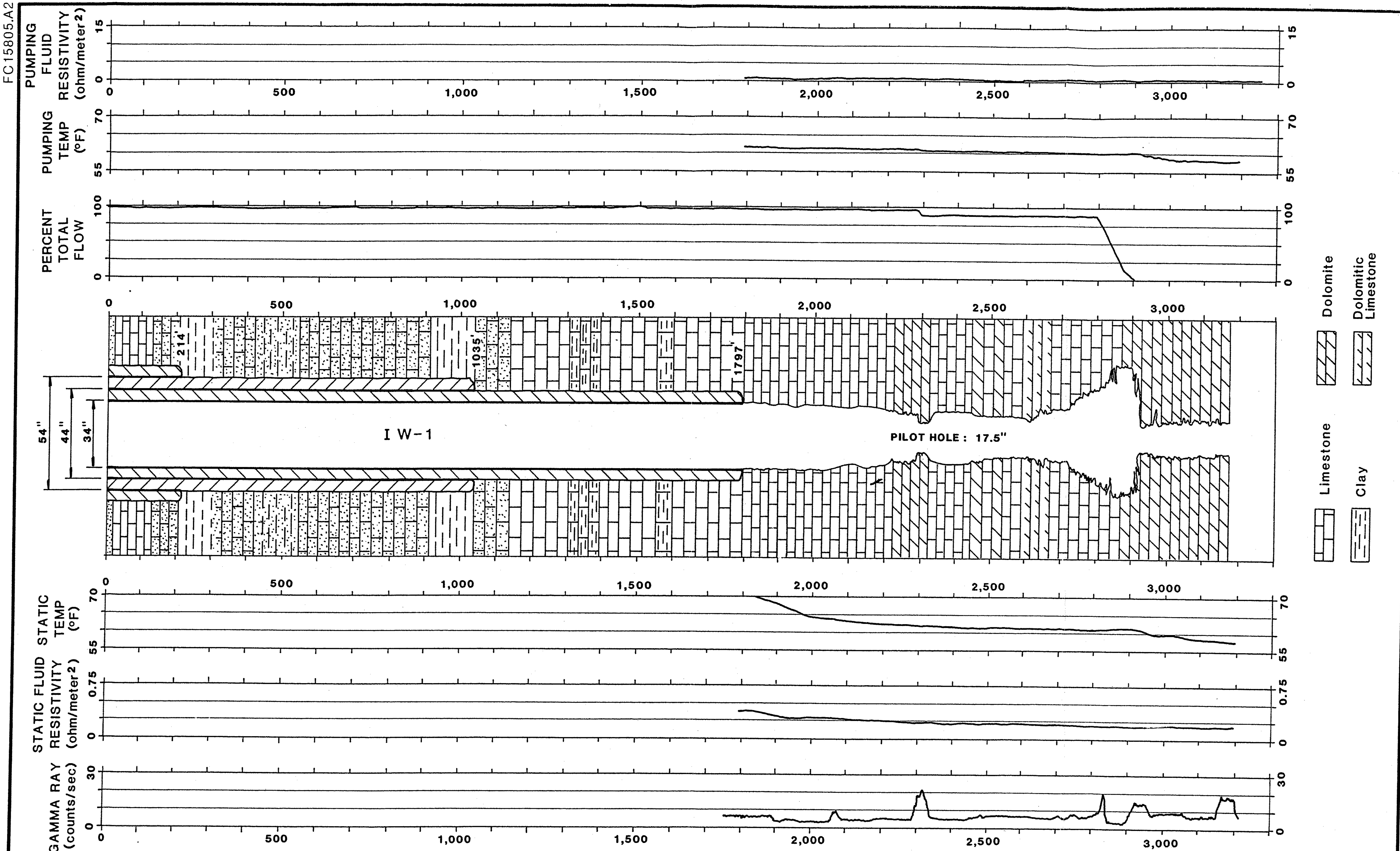

FIGURE 3-2
Summary of Geophysical Logs from Lower Pilot Hole Pump Out Test at I W-1

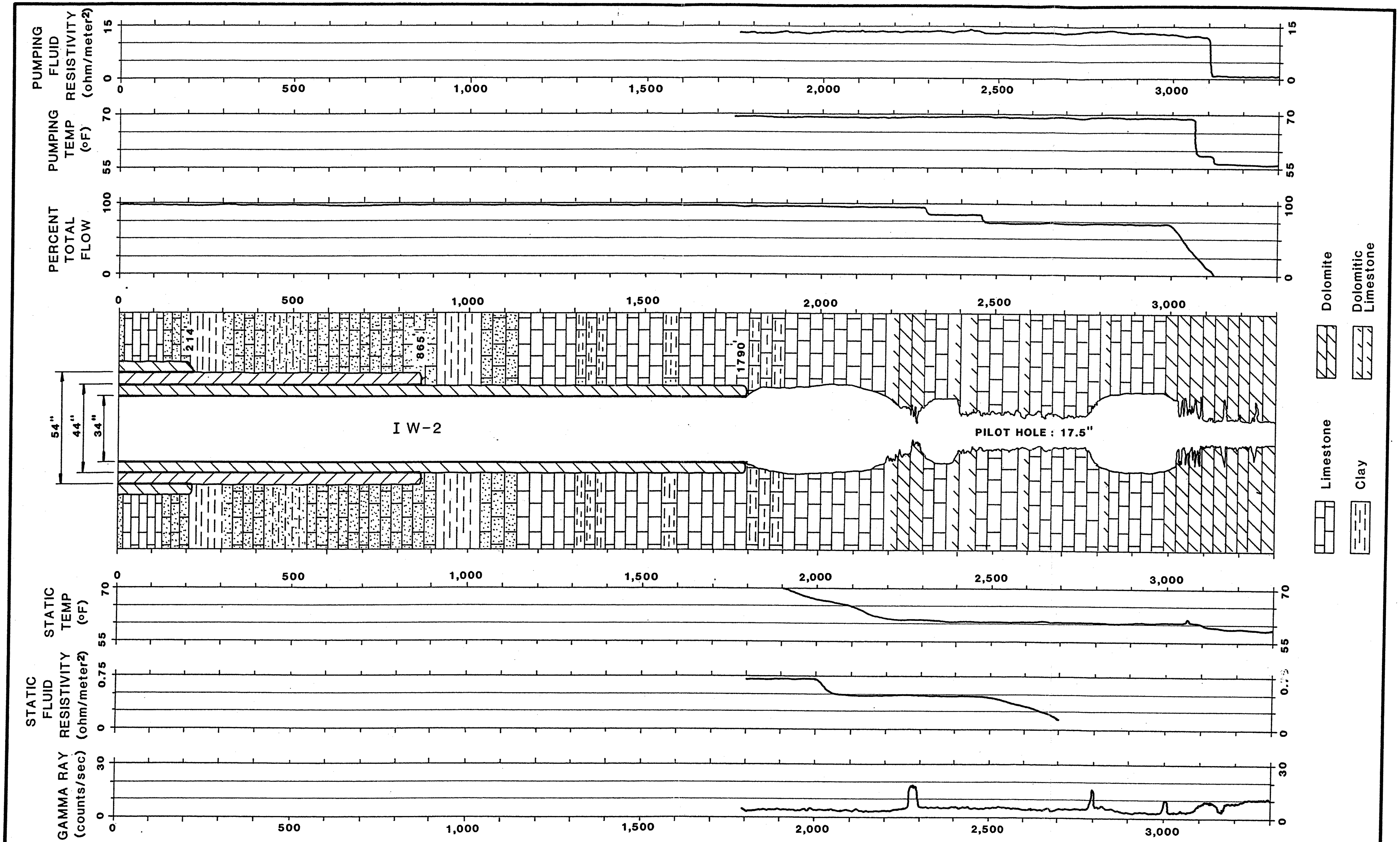

FIGURE 3-3
Summary of Geophysical Logs from Lower Pilot Hole Injection Test at I W-2

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4,000 gpm (pumping rate for logging) originates from approximately 2840 to 2860 feet. This is an approximate 230-foot vertical difference in the top of the major permeability zone between the two wells which are 1000 feet apart.

Figures 3-2 and 3-3 also indicate that the geophysical data correlates very closely with the lithologic profile. One geologic anomaly found at the Sunrise site and also found at other southeast Florida deep injection wells is the inverted temperature gradient seen in the boulder zone. This is characterized by a decrease in temperature with depth from the lower Floridan aquifers to the boulder zone. At the Sunrise site, the bottom hole water temperature was measured at 59°F. Copies of all geophysical logs were submitted during construction and will be compiled together under separate cover.

HYDROLOGIC TESTING AND DATA

Pump-out Tests

During each of the pump out and injection tests, a hydrologic data collection program was established in order to evaluate the capacities of the injection wells. In addition to evaluating the injection capacities, the geophysical logs run during each test identified water producing and confining zones. The geophysical logs were run while pumping at a lower rate of approximately 4,000 gpm to avoid possible damage to the geophysical tools at the higher specified rates of 10,500 gpm. Upon completion of the geophysical logging, the pumping rates were increased to approximately 10,500 gpm.

Each pump-out test was performed with a vertical turbine pump with not less than 100-feet of pump column installed in the well. The salt water pumped from the wells was then piped to a baffled, polypropylene lined settling pond with a maximum capacity of approximately 250,000 gallons. The pond allowed for particle settlement prior to injecting the salt water into the injection well not being tested. Table 3-1 provides a summary of the pump out and injection tests. A flow meter, with totalizing capabilities was installed in the discharge line to measure the flow rates. An air line bubbler system was installed on the pump column with a 100-psi Heise gauge attached to determine water level drawdown. Preliminary steel tape measurements confirmed depth to water measurements taken with the pressure gauge.

Table 3-2 summarizes the specific capacities measured during the pump-out tests of the injection wells. A maximum drawdown of 40.0 feet was seen at IW-2 while pumping approximately 10,000 gpm. Similar specific capacities of 254 and 273 gpm per foot were calculated for IW-1 and IW-2, respectively. The first pump-out test conducted at IW-1 withdrew water through 1790 feet of 34-inch diameter casing. Because frictional head loss increases with increased velocity, the second test with 24-inch casing experienced more frictional head loss than the first because of the additional smaller diameter casing. The measured drawdowns were adjusted for this frictional head loss using the Darcy-Weisbach equation. The friction loss adjustment for the first test was calculated using 1790 feet of casing; the 900 feet of formation was not considered because of the difficulty in estimating a realistic diameter and hole roughness coefficient. If this section was considered, the frictional head loss in the first test would be slightly higher but the adjusted specific capacity would not be changed significantly. A minor water-bearing zone was cased off by the 24-inch casing which accounts for the slight difference in the adjusted specific

Table 3-1
Summary of Pump-out and Injection Testing Program

Type of Test	Well	Date	Remarks
Pump-out	IW-1	11/11/84	17½" pilot hole to 3200'
Pump-out	IW-1	1/9/85	Completed well, 24" casing installed and cemented
Injection	IW-1	1/16/85	Completed well, 24" casing installed and cemented
Injection	IW-2	5/31/84	17½" pilot hole to 3200'
Injection	IW-2	7/23/84	Completed well, 24" casing installed and cemented
Pump-out	IW-2	1/18/85	Completed well, 24" casing installed and cemented

Table 3-2
Pump-out Test Results
Specific Capacities Measured at IW-1 and IW-2

Well	Test Date	Pumping Rate (gpm)	Static Water Level Below Pad (ft)	Measured Drawdown (ft)	Measured Specific Capacity (gpd/ft)	Adjusted[1] Drawdown (ft)	Adjusted Specific Capacity (gpd/ft)	Remarks
IW-1	11/11/84	8750	4.32	18.58	471	17.44	502	Pilot hole test - 34" casing
IW-1	1/9/85	9731	4.38	37.6	254	21.69	449	Completed well test 24" casing
IW-2	1/18/85	9900	4.10	36.21	273	19.66	503	Completed well test 24" casing

[1]Values adjusted using the Darcy-Weisbach equation for frictional head loss.

capacities observed for the two tests at IW-1 (502 gpm/ft vs. 449 gpm/ft adjusted specific capacity). Pump-out and injection test data is included in Appendix D.

Injection Tests

The injection tests utilized the limerock quarry adjacent to WWTP No. 3 as a fresh water supply. Approximately 10,000 gpm was pumped from the quarry and injected into each well being tested. A flow meter with totalizing capabilities was installed in the pipeline to measure the flow rate and a Heise gauge was installed on the wellhead to measure injection pressures. Table 3-3 summarizes the injection test data taken for both IW-1 and IW-2. The respective injection pressures of 35.3 and 41.0 psi indicate a very efficient injection zone. The pressure difference between the two wells is minor and may be related to the 280 foot vertical offset of the injection zones.

WATER QUALITY

As previously mentioned, the reverse air circulation drilling method was utilized below approximately 1000-feet in depth. This allowed for the collection of water samples at the bottom of each drill rod or every 30 feet. At the Sunrise site, the wells were drilled with a closed circulation system which means that all water produced during drilling is returned to the well. This is necessary to avoid the discharge of salt water which would contaminate local surficial water. Because of this closed circulation, a truly representative formation water sample is not always possible due to mixing in the borehole of the return fluid with the brine used as a weighting fluid during drilling through the artesian zones of the Floridan aquifer. However, the water samples are useful in determining general water quality trends and showing major water quality shifts.

Table 3-3
Injection Test Data, IW-1 and IW-2

Well	Date Run	Static Pressure (psi)	Maximum Pressure (psi)	Maximum Flow Rate (gpm)
IW-1	1/16/85	25.2	35.3	10,250
IW-2*	5/31/84	21.2	36.1	10,500
IW-2	7/23/84	26.9	41.0	11,500

*Note: Pilot hole test with 1790' of 34" casing installed.

Tables 3-4 and 3-5 show the results of the water quality analyses for the reverse air samples collected during the drilling of both injection wells. A heavy brine fluid is used to drill through the artesian flow zone of the upper Floridan system resulting in some higher chloride measurements when the brine mixes with the formation samples. As drilling proceeded below the 34-inch casings, set at 1800 feet, more representative formation samples became available since the weighting fluid is not required to control artesian flow below this depth. At IW-1, the well was circulated for approximately 48 hours (for T.V. survey) at 2280 feet and the chlorides ranged from approximately 9,000 to 10,000 mg/l. At IW-1, the chlorides remained relatively stable, down to approximately 2860 feet where the chlorides took a dramatic jump to approximately 19,000 mg/l (essentially seawater) upon drilling into the boulder zone. The same shift occurred at IW-2 but at a deeper interval of approximately 3062 to 3092 feet. These increases in chloride measurements also relate to the location of the top of the major permeability of the injection zone as determined from the geophysical logging data.

Water quality samples were also taken from the discharge during pump-out tests. These samples were taken at the beginning of each test and just prior to shut down. The analyses generally indicate high chloride water typical of the "boulder zone." The complete lab analyses are included in Appendix E. Tables 3-6 and 3-7 show selected results of analyses for water quality parameters measured at IW-1 and IW-2 during the final pump-out test at each well.

Table 3-4
Water Quality Data from Pilot-Hole Drilling at IW-1

Depth (ft)	Specific Conductance (µmhos/cm)	Chloride (mg/l)	Remarks
1119	>50,000		High chloride due to brine column used to control artesian flow No analysis done.
1150	As above		Same as above
1180	48,000		Same as above
1301	>50,000		Same as above
1329	As above		Same as above
1360	As above		Same as above
1391	As above		Same as above
1419	As above		Same as above
1430	47,000	20,488	Drilling fluid weight between 9 and 10 lbs/gal, very high chlorides, water level 44" below pad
1460			Same as above
1490			Same as above
1519			Same as above
1549			Same as above
1579			Same as above
1608			Same as above
1638	52,000	23,189	Same as above
1449	>50,000		Same as above
1514	41,000		Same as above
1544	37,000		Same as above

Table 3-4 (Continued)
Water Quality Data from Pilot-hole Drilling at IW-1

Depth (ft)	Specific Conductance (μmhos/cm)	Chloride (mg/l)	Remarks
1575	41,000		Brine column used to kill artesian flow
1605	>50,000		Same as above
1636	39,000		Same as above
1666	40,000		Same as above
1830	10,000	2,649	Using fresh H_2O for makeup from supply well
1860	12,000	3,049	Same as above
1890	11,000	3,349	Same as above
1920	13,000	3,599	Same as above
1950	13,000	3,749	Same as above
1980	12,000	3,499	Same as above
2010	11,000	3,749	Same as above
2040	12,000	3,599	Same as above
2070	12,000	2,749	Added fresh H_2O to tanks, hauled away very thick fluid
2100	1,000	2,849	Same as above
2130	1,000	2,999	Same as above
2160	11,000	3,199	Same as above
2190	13,000	3,399	Same as above
2220	12,000	3,549	Same as above
2250	14,000	4,349	Same as above
2280	16,500	4,749	Circulate bottom for 5 minutes

Table 3-4 (Continued)
Water Quality Data from Pilot-hole Drilling at IW-1

Depth (ft)	Specific Conductance (μmhos/cm)	Chloride (mg/l)	Remarks
2280	27,500	8,747	½ hour open circulation of well
2280	27,000	9,247	1 hour 45 minutes circulation of well to pond
2280	33,000	10,000	Same as above
2280	28,000	9,847	Circulation for 24 hours
2317	35,000	13,782	Reverse air drilling sample
2342	39,000	14,632	Same as above
2405	32,000	12,272	Same as above
2467	34,000	13,334	Same as above
2497	31,250	12,720	Same as above
2536	33,000	12,697	Same as above
2555	28,000	10,124	Same as above
2585	27,000	9,275	Same as above
2616	24,750	8,142	Same as above
2641	34,500	13,452	Same as above
2676	28,500	10,313	Same as above
2705	24,500	8,767	Same as above
2735	22,100	8,803	Same as above
2766	30,000	11,942	Same as above

Table 3-4 (Continued)
Water Quality Data from Pilot-hole Drilling at IW-1

Depth (ft)	Specific Conductance (µmhos/cm)	Chloride (mg/l)	Remarks
2796	24,000	8,732	Reverse air drilling sample
2857	25,000	9,294	Same as above
2886	40,500	16,515	Same as above
2948	45,000	18,313	Same as above
2978	45,000	18,030	Same as above
3007	47,500	18,396	Same as above
3038	48,000	20,175	Same as above
3067	47,900	20,075	Same as above
3098	46,000	19,938	Same as above
3126	47,000	19,800	Same as above
3157	46,000	19,525	Same as above

Table 3-5
Water Quality Data from Pilot-Hole Drilling at IW-2

Depth (ft)	Specific Conductance (μmhos/cm)	Chloride (mg/l)	Remarks
1050	12,000	1,849	Reverse air drilling samples
1080	14,000	2,099	Same as above
1110	13,000	2,149	Same as above
1140	11,000	2,249	Same as above
1230	12,000	2,249	Same as above
1260	12,000	2,349	4 bags of salt added to weight fluid
1290	12,000	2,249	Same as above
1320	10,000	2,249	Same as above
1350	13,000	2,399	Same as above
1379	15,000	2,499	Same as above
1410	15,000	2,649	Same as above
1440	14,000	2,599	Same as above
1470	15,000	2,649	Same as above
1500	14,000	2,399	Same as above
1530	15,000	2,599	Same as above
1560	14,000	2,499	Same as above
1590	13,000	2,499	Same as above
1600	13,200	2,639	Same as above
1610	14,000	2,739	Same as above
1650	13,500	2,699	Same as above
1680	13,900	2,759	Same as above

Table 3-5 (Continued)
Water Quality Data from Pilot-hole Drilling at IW-2

Depth (ft)	Specific Conductance (μmhos/cm)	Chloride (mg/l)	Remarks
1801	13,200	2,649	Reverse air drilling water
1710	11,300	2,779	Same as above
1741	11,600	2,779	Same as above
1771	11,500	2,789	Same as above
1831	24,000	6,035	Drilled out cement plug
1861	24,000	6,044	Same as above
1898	15,000	3,993	Same as above
1920	15,630	3,974	Same as above
1950	15,620	4,011	Same as above
1980	18,000	4,464	Same as above
2012	12,800	3,457	Same as above
2042	14,000	4,337	Same as above
2072	14,900	3,993	Same as above
2102	13,800	4,101	Same as above
2162	15,090	4,083	Same as above
2192	14,000	3,666	Same as above
2222	13,000	4,348	Same as above
2252	13,400	4,198	Same as above
2280	11,000	3,248	Same as above
2310	11,500	3,748	Same as above
2342	11,350	3,498	Same as above
2342	12,000	4,198	Same as above

Table 3-5 (Continued)
Water Quality Data from Pilot-hole Drilling at IW-2

Depth (ft)	Specific Conductance (µmhos/cm)	Chloride (mg/l)	Remarks
2462	12,000	4,848	Reverse air drilling
2580	12,500	4,148	Same as above
2610	12,800	4,248	Same as above
2640	12,000	3,948	Same as above
2670	12,000	4,398	Same as above
2700	12,000	4,148	Same as above
2792	12,300	4,148	Same as above
2832	12,200	4,048	Same as above
2862	12,300	3,898	Same as above
2892	12,000	3,898	Same as above
2942	11,000	3,998	Same as above
2972	11,000	5,048	Same as above
3002	13,000	4,948	Same as above
3062	16,000	6,098	Same as above
3092	44,800	13,547	Same as above
3122	44,900	16,694	Same as above
3152	50,000	15,745	Same as above
3180	49,900	16,394	Same as above
3112	50,000	17,444	Same as above
3242	29,200	15,395	Same as above
3272	49,900	16,944	Same as above

Table 3-6
Selected Water Quality Parameters
Discharge Samples, IW-1
From Final Pump-out Test, 1/9/85

Parameters[a,b]	1 Hour	End of Test
Sodium	10,500	10,250
Sulfate	2,560	2,560
Chlorides	19,300	19,400
Alkalinity as $CaCO_3$	110	115
pH (at 25°C)	6.85	6.84
Temperature (field)	17.0	16.5
Conductance	48,600	46,700
Total Dissolved Solids	33,620	33,230
Iron	0.30	0.20
Carbonate Hardness as $CaCO_3$	110	115
Non-Carbonate Hardness as $CaCO_3$	5,850	5,865
Calcium as $CaCO_3$	1,010	995
Magnesium as $CaCO_3$	4,950	4,985

[a]All parameter concentrations reported as substance unless otherwise indicated.

[b]All concentrations are mg/l unless otherwise indicated.

Table 3-7
Selected Water Quality Parameters
Discharge Samples, IW-2
From Final Pump-out Test, 1/18/85

Parameters[a,b]	1.5 Hours	5 Hours
Sodium	10,500	10,300
Sulfate	2,720	2,720
Chlorides	19,700	20,100
Alkalinity as $CaCO_3$	114	117
pH (at 25°C)	6.87	6.84
Temperature (field, °C)	17.5	17.0
Conductance	49,500	49,100
Total Dissolved Solids	33,430	32,900
Iron	0.15	0.05
Carbonate Hardness as $CaCO_3$	114	117
Non-Carbonate Hardness as $CaCO_3$	6,280	6,290
Calcium as $CaCO_3$	950	975
Magnesium as $CaCO_3$	5,440	5,440

[a]All parameter concentrations reported as substance unless otherwise indicated.

[b]All concentrations are mg/l unless otherwise indicated.

Chapter 4
MONITORING PROGRAM

BACKGROUND DATA

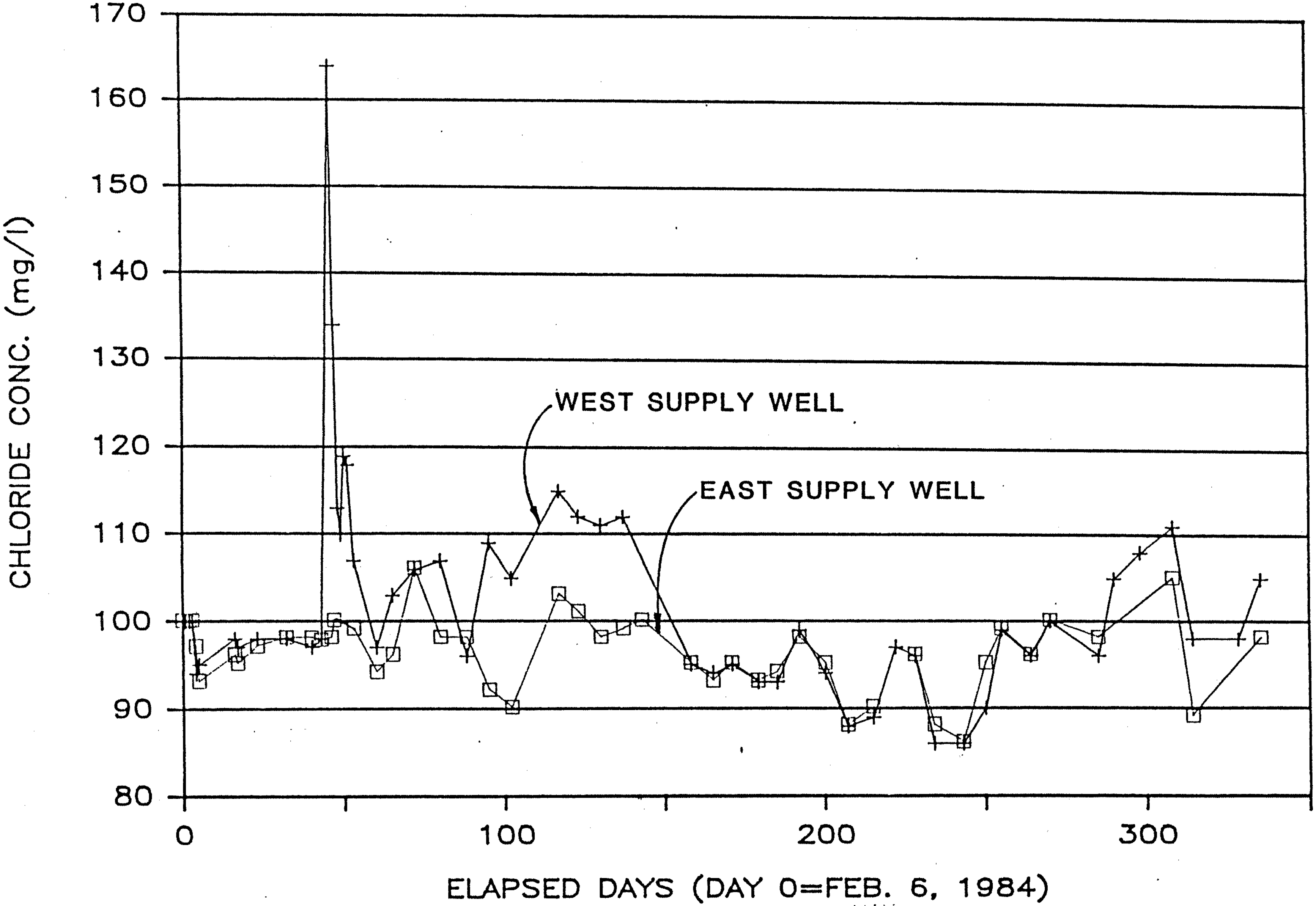
Two types of background data were collected during construction of the wells. They are:

1. Weekly samplings from each of the shallow supply wells in the Biscayne aquifer throughout the construction period.

2. Sampling of the dual-zone monitor well after completion of construction.

Collection of the shallow aquifer chloride data was initiated to monitor against any salt water contamination that might result from the drilling activities. Figure 4-1 displays a constant trend for both supply wells excepting one brief increase where the chlorides quickly returned to background. This could have been caused by the inadvertent introduction of salt into the monitoring well.

At the November 19, 1984 TAC meeting, an intensive background water quality data collection program was discussed for the dual-zone monitor well. This program would provide the data to accurately quantify the existing background conditions of each zone prior to injection well start-up. This program included daily pressure readings and six sampling periods at weekly intervals for: basic physical parameters, fecal coliform bacteria, total organic carbon (TOC), primary and secondary drinking water standards, and a sample for radio isotope analysis for the U.S.G.S. Table 4-1 describes in detail the background sampling program.



CHLORIDE CONCENTRATION AT WATER SUPPLY WELLS DURING CONSTRUCTION

FIGURE 4-1

Table 4-1
Background Sampling Program
Approved by TAC

Monitor Well - (Both zones)

1. Daily pressure readings until recorders are installed.

2. For six weeks, one sample per week, obtain analysis for:

Na	pH
Sulfate	Temperature
Chlorides	Electic Conductance*
Alkalinity	TDS
Fecal Coliform	Total Organic Carbon (TOC)

*Determine relationship to TDS

3. Two samples for analysis of primary and secondary drinking water standards (four total samples).

4. One 5 gal sample for radio-isotope analysis (two samplings).

Table 4-2 shows the daily monitor well pressure readings. These readings show the approximate water pressures of the upper monitor zone (1015' to 1108') and the lower monitor zone (1600' to 1650') at approximately 14.2 and 13.0 psi, respectively. Note that some modulation in these levels are due to changes in the local barometric pressures and possible tidal effects on the upper zone.

Table 4-3 shows selected water quality parameters from the background sampling program at the dual zone monitor well. The data from the 1000 to 1100-foot zone indicates relatively stable results across the sampling period. The chloride and TDS results are slightly higher in the 12/3 and 12/15 samples but stabilize throughout the remainder of the samples. The total organic carbon (TOC) data for both monitoring zones shows a decreasing trend in the first few background samples. The TOC concentration stabilized in the later background samples obtained. The higher TOC concentration in the early samples are probably due to an effect of the drilling and continued sampling of the well removed residual fluids introduced during the drilling. Also, the data from the 1600 to 1650-foot zone reflects a freshening trend from the earliest to the latest samples indicating that the heavy drilling fluids (brine) used to control the artesian flow were still being developed out of the formation. Additional development was initiated and continued (120 hours at 60 gpm) until the chlorides and conductance had stabilized. Two additional sets of samples were then taken and reflect stabilized results for all the measured parameters.

OPERATIONAL MONITORING

The parameters recommended in the operational monitoring program include: injection well flow rates and pressures, water quality of injected effluent and monitor well pressures and water quality. Table 4-4 details the recommended parameters, equipment, and frequency of sampling. This program is similar to other operational monitoring programs used at other southeast Florida injection sites and will be further discussed with the TAC prior to finalizing.

Table 4-2
Background Pressure Readings
At the Dual Zone Monitor Well

Date	Time	Pressure In Annulus (1015'-1108') (psi)	Pressure In 6" Casing (1600'-1650') (psi)
13-Dec	15:00	14.40	12.00
14-Dec	15:00	14.30	11.45
15-Dec	12:50	14.12	11.40
16-Dec	16.30	14.10	12.50
17-Dec	14:30	14.10	12.45
18-Dec	13:10	14.30	12.50
19-Dec	18:00	14.40	12.60
20-Dec	7:30	14.25	12.60
21-Dec	9:00	14.30	12.50
22-Dec	7:00	14.20	12.60
23-Dec	6:00	14.20	12.50
24-Dec	6:00	14.20	12.50
25-Dec	6:00	14.20	12.50
26-Dec	NO SAMPLE		
27-Dec	14:10	14.20	12.45
28-Dec	13.30	14.30	12.30
29-Dec	11:10	13.90	13.10
30-Dec	8:15	14.10	13.00
31-Dec	16.30	14.20	13.00
01-Jan	9:00	13.90	13.00
02-Jan	10:15	14.10	13.10
03-Jan	8:50	14.00	13.10
04-Jan	9:35	14.10	13.40
05-Jan	13:00	14.25	13.50
06-Jan	13:35	14.20	13.60
07-Jan	12:30	14.10	13.50
08-Jan	11:55	14.10	13.50
09-Jan	18:00	14.10	13.65
10-Jan	15:00	14.15	13.50
11-Jan	11:00	14.15	13.50
12-Jan	12:00	14.10	13.45
13-Jan	10:00	14.15	13.40
14-Jan	16:00	14.00	13.45
15-Jan	16:30	14.10	13.65
15-Jan	10:30	14.50	13.70

Table 4-3
Selected Water Quality Parameters[1]
Background Sampling Program

16" Annulus - 1000' to 1100'

Parameters[2]	12/3	12/15	12/28	1/3	1/17	1/21	2/19	2/21
Na	1,860	1,800	1,700	1,630	1,960	1,740	Well	1,660
Sulfate	800	920	820	940	820	840		860
Chlorides	3,080	2,900	2,810	2,760	2,900	2,800	Not	2,790
Alkalinity as $CaCO_3$	74	71	92	91	82	102		115
pH (standard units)	7.33	7.44	7.80	7.70	8.15	7.85	Sampled	7.75
Temperature (°C)	24.0 75.2	23.0 73.4	23.0 73.4	23.5 74.3	24.5 76.1	21.5 70.7		23.0 73.4
Conductance (µmhos/cm)	10,500	10,000	9,780	9,620	10,000	9,800		9,320
TDS	6,550	6,480	5,930	5,830	5,560	5,700		6,210
TOC	15.9	17.0	13.8	14.7	8.77	2.09		2.86
Fecal Coliform (colonies/100 ml)		<1	<1	<1	<1	<1		

6" Zone - 1600' to 1650'

Parameters[2]	12/3	12/15	12/28	1/3	1/17	1/21	2/19	2/21
Na	4,200	3,320	2,820	2,520	2,260	2,180	1,020	990
Sulfate	560	510	590	540	510	540	530	500
Chlorides	6,920	5,450	4,520	4,110	3,850	2,650	1,640	1,710
Alkalinity as $CaCO_3$	104	93	107	98	99	102	105	110
pH (standard units)	7.35	7.49	7.55	7.60	7.80	7.80	7.45	7.85
Temperature (°C)	22.5 72.5	23.0 73.4	23.5 74.3	23.5 74.3	24.5 76.1	21.0 69.8	23.0 73.4	22.5 [illegible]
Conductance (µmhos/cm)	20,600	16,900	14,400	13,300	12,200	11,800	5,820	6,630
TDS	12,000	9,560	8,140	7,660	6,630	6,420	3,740	3,720
TOC	14.8	15.7	10.6	13.8	7.11	2.13	1.91	2.57
Fecal Coliform (colonies/100 ml)	<1	<1	<1	<1	<1	<1		

[1] All analyses expressed as mg/l unless otherwise indicated.
[2] All parameters expressed as substance unless otherwise indicated.

Table 4-4
Recommended Operational Monitoring Program
Sunrise WWTP No. 3 Injection & Monitoring Wells

Parameter	Equipment or Procedure	Frequency
Injection Flow Rate	Large case, circular chart, variable flow recorder (0 to 15 mgd), flow totalizer	Continuous
Injection Pressure	Large case, circular chart, variable recorder (0 to 220 feet of water column)	Continuous
Water Quality of Injected Fluid:		
Specific Conductance	Sample at wellhead	Daily
Chloride Concentration	Sample at wellhead	Daily
Suspended Solids	Sample at wellhead	Daily
Temperature	Sample at wellhead	Daily
Pressure in the Lower Monitoring Zone -- (1600'-1650')	Large case, circular chart, variable pressure recorder	Continuous
Pressure in the Upper Monitoring Zone -- (1015'-1107')	Large case, circular chart, variable pressure recorder	Continuous
Water Quality of Upper and Lower Monitoring Zones:		
Specific Conductance Chloride Concentration Temperature Fecal Coliform BOD_5 Temperature	Sample after flowing zones into the influent lift station via 2-inch hose for 1.5 casing volumes.	Monthly

Chapter 5
SUMMARY AND RECOMMENDATIONS

The construction project for the City of Sunrise involved the upgrading of three wastewater treatment plants to provide for spray irrigation and deep well disposal. An effluent distribution system was installed to WWTP No. 3 where an effluent pumping station, two deep injection wells and a dual zone monitor well were constructed. Construction of the injection wells started in February 1984 and was completed in January 1985. The dual zone monitor well was also constructed within this period from October to November 1984.

The construction program, which has enabled the use of treated effluent for possible future irrigation of green areas and deep well disposal, will end the discharge of treated effluent into adjacent percolation ponds and canals. The excess effluent beyond that used for irrigation will be injected into the "boulder zone" at approximately 2800 to 3200 feet below land surface at the Sunrise WWTP No. 3 site. The boulder zone encountered at both injection wells is a highly fractured cavernous dolomite found at approximately this same depth at other locations in southeastern Florida.

Hydrologic testing data indicates very hugh specific capacities (adjusted for friction losses) of both injection wells of approximately 500 gpm per foot of drawdown. The injection pressures measured during the injection tests at each injection well indicate operating injection pressures not exceeding 40 psi at the designed maximum injection rate of 10,500 gpm. The observed injection pressure of 40 psi indicates a very transmissive injection zone.

CH2M HILL recommends the implementation of the proposed monitoring program. This includes the measurement of injection well flow rates, injection well pressures, effluent water quality, monitor well pressures, and monitor well water quality. Prior to implementation, the final program will be discussed with the TAC.