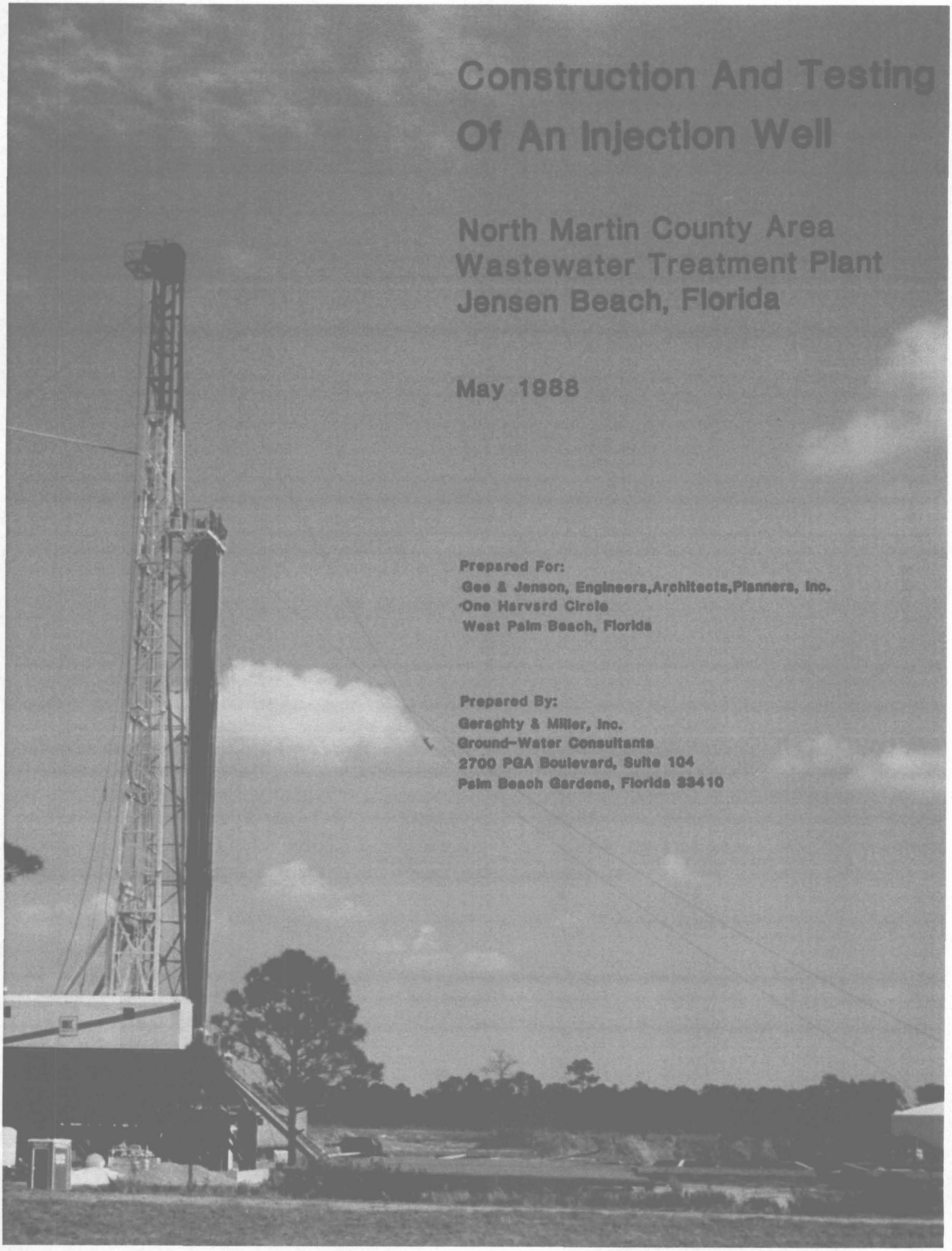

Construction And Testing Of An Injection Well

North Martin County Area Wastewater Treatment Plant Jensen Beach, Florida

May 1988

Prepared For:

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GERAGHTY & MILLER, INC.

CONSTRUCTION AND TESTING
OF AN
INJECTION WELL
NORTH MARTIN COUNTY AREA
WASTEWATER TREATMENT PLANT
JENSEN BEACH, FLORIDA

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TABLE OF CONTENTS

GERAGHTY & MILLER, INC.

FIGURES, TABLES AND APPENDICES

FIGURES

TABLES

APPENDICES

CONSTRUCTION AND TESTING OF AN INJECTION WELL NORTH MARTIN COUNTY AREA WASTEWATER TREATMENT PLANT JENSEN BEACH, FLORIDA

INTRODUCTION

On December 24, 1986, the Edward J. DeBartolo Corporation obtained Permit No. UC43-122610 from the FDER (Florida Department of Environmental Regulation) to construct one 9.75-inch-inside-diameter, Class I Test-Injection Well at the site of the North Martin County Area Wastewater Treatment Plant. Figure 1 shows the project site location. The plant is located adjacent to the North Martin County Utilities Water Treatment Plant and well field, just east of U.S. Highway One and south of Jensen Beach Boulevard (State Road 707A).

Contract documents and specifications prepared by Geraghty & Miller, Inc., were made available to qualified contractors for bidding on the well construction. The specifications contained provision for the drilling and testing of one 9.75-inch-inside-diameter injection well to a total depth of 3500 feet. Also presented was a program for the plugging and abandonment of the well in the event that suitable conditions were not found. Bids were received by the Edward J. DeBartolo Corporation in December 1986, and the contract was awarded to Drillers Incorporated of Houston, Texas, on December 23, 1986. The Notice to Proceed was issued on January 18, 1987.

Drillers Incorporated mobilized manpower and equipment to the proposed plant site on January 19, 1987. The contract length was 150 days; however, the hole was not completed to a total depth of 3381 feet until September 2, 1987. In April 1987 the intermediate casing collapsed below 1690 feet during the chlorination of the two annular monitoring tubes. This prevented the successful completion of the two monitor tubes in the injection well. A separate deep monitor well system had to be installed which enabled sampling of both the upper and lower monitor zones. The monitor well is located a short distance to the southeast of the injection well.

Construction of the separate monitor well began on September 8 and was completed on October 20, 1987. Final testing of the injection well, including the extra testing required by the regulatory agencies as a result of the collapse of the intermediate casing, was completed by November 7, 1987.

As a condition of the permit, the FDER requested that, upon completion of drilling and testing, a final report summarizing the information obtained during the program be submitted along with an application to operate the well.

This report documents the results of the investigation. It contains information collected during the well construction and testing programs; conclusions regarding the capability of the injection zone to accept effluent and the integrity of the confining sequence; and a monitoring program that will provide the information necessary to evaluate well performance during operation of the disposal system. Copies of the various geophysical logs, geologic logs, and reports of chemical analysis of water samples and core tests are included in the Appendices. Details relating to the integrity of the well after the casing collapse are discussed in this report along with subsequent related construction problems. A detailed description of the problems, solutions and methods of testing for integrity after repairs to the well were effected are presented.

FINDINGS

1. The data demonstrate the existence of an extremely transmissive injection zone saturated with saline water containing more than 10,000 mg/L TDS.

2. The top of the injection zone occurs at about 3000 feet below pad level. The base of the injection zone is at 3350 feet, for a total thickness of approximately 300 feet. The majority of fluid will be accepted into cavities between 3000 feet and 3100 feet.

3. The transmissivity of the injection zone is estimated to be greater than 2,100,000 gpd/ft (gallons per day per foot). This zone is capable of accepting the design volume of effluent from the North Martin County Area Wastewater Treatment Plant at an acceptable injection pressure.

4. The contact between waters with less than 10,000 mg/L of TDS and non-potable water occurs at a depth of approximately 1850 feet.

5. The hydraulic conductivity of the confining sequence, as determined from the straddle-packer pumping tests, occurred in the range of 0.0020 cm/s (centimeters per second). Vertical hydraulic conductivities determined from core tests ranged from 0.0000006 cm/s to 0.00049 cm/s; and horizontal hydraulic conductivities from the cores ranged from 0.00000052 cm/s to 0.00031 cm/s.

6. A monitor well was drilled and two monitor zones were selected. The lower zone is from 2186 feet to 2206 feet and the upper zone is from 1720 feet to 1740 feet below pad level.

7. The presence of a highly transmissive injection zone filled with water having greater than 10,000 mg/L TDS, a suitable confining sequence, suitable monitor zones, and proof of mechanical integrity will permit the use of the injection well for disposal of treated effluent at the North Martin County Area Wastewater Treatment Facility, in accordance with existing State and Federal UIC (Underground Injection Control) Regulations.

RECOMMENDATIONS

The following recommendations are requirements of Chapter 17-28 FAC for the safe operation of an injection well. These procedures should be carried out rigorously to ensure compliance with the conditions of an operating permit and ensure successful operation of the well.

1. Well-head injection pressures should be monitored and recorded continuously. Monthly averages as well as maximum and minimum values should be reported to the FDER on a monthly basis.

2. The flow rate into the well should be monitored and recorded continuously. Average daily flow rates as well as the total daily volume of effluent pumped into the well should be reported to the FDER on a monthly basis.

3. Samples from the monitor tubes should be collected monthly and analyzed for fecal coliform, BOD (5-day), specific conductivity, pH, temperature, and chloride. The results of these analyses should be sent to the FDER on a monthly basis.

4. A specific injectivity test should be performed quarterly. Well-head pressures should be recorded simultaneously with injection rate during the test, and test results should be reported to the FDER upon completion.

5. The well should be tested for mechanical integrity every five years in accordance with Chapter 17-28 FAC.

DATA COLLECTION

Data were collected by various methods during the construction of the injection well. Each of these methods is discussed in this section. Except as noted, measurements of footages in the well were referenced to the top of the cement pad floor.

As required under Specific Condition 3 of the construction permit issued by FDER, progress reports of the day-to-day activities during well construction were compiled by the field personnel, who were present at all times. Daily footage; drilling speed; penetration rates; the relative hardness of the formations; and problems encountered during drilling, such as lost circulation, were observed and noted. All activities connected with the installation of casing or monitor tubing, cementing, and material quantities were included in these reports. Detailed descriptions of test procedures and data collection were recorded, including the performance of surveys to monitor hole straightness. A separate construction log was used to record material quantities by bid item; lengths and configurations of tools introduced into the borehole were noted. Copies of the daily progress reports and a weekly summary of activities were forwarded to the TAC (Technical Advisory Committee) for this project on a weekly basis.

Samples of drilled cuttings were collected every ten feet and at each change in formation during pilot-hole drilling. After microscopic examination of the samples, the Geraghty & Miller on-site geologist described the samples and prepared a geologic log. A copy of this log is found in Appendix A, along with a copy of the log compiled during the drilling of the monitor well. A continuous summary log also was prepared which correlated lithology, weight on bit, penetration rate, and a summarized geologic description (all on a vertical scale of 20 feet to an inch), enabling correlation with all geophysical logs. This log helps to ensure that information from all sources is assimilated in order to properly evaluate the geophysical logs, borehole tests, and hole conditions during construction. A copy of this log also was forwarded in the TAC on a weekly basis, at their request.

Circulation time (the time required for drilled cuttings to reach the surface after being cut from the face of the bit) was calculated regularly to ensure that accurate sample depths were recorded. The circulation times during the drilling of this well were usually long due to the use of the mud-rotary drilling method to a depth of 2947 feet. One set of samples from the well was sent by the Contractor to the Florida Bureau of Geology in Tallahassee, Florida.

During the drilling of the pilot hole, five cores were collected at intervals of approximately 150 feet between depths of 2100 and 2700 feet. The core barrel used was 10 feet in length by 4 inches in diameter. Each core was described in detail by a Geraghty & Miller geologist, then a portion of each core was selected and sent to a testing laboratory where it was tested to determine vertical and horizontal hydraulic conductivity, specific gravity, modulus of elasticity, porosity and compressive strength. A copy of the laboratory report and the core descriptions with photographs are included in Appendix B. Figure 2 shows details of the coring program.

Gyroscopic surveys of the pilot hole were conducted by Sperry Sun Company from pad level to a final depth of 2900 feet below pad level. A gyroscopic survey was conducted on the 12-1/4-inch-diameter pilot hole from 850 feet to 2000 feet below pad level, and from 2000 feet to 2940 feet below pad level. Surveys also were run inside the collapsed intermediate casing after milling operations were completed. The gyroscopic surveys showed that the pilot hole was within the specifications; the final closure was a distance of 11.22 feet in the direction N 36.92 W, based on measurements calculated every thirty feet using the Radius of Curvature Method. A copy of the gyroscopic survey of the entire pilot hole is found in Appendix C together with gyroscopic surveys run in the collapsed casing after milling operations were completed.

The gyroscopic surveys provided evidence that the holes reamed for the intermediate and injection casing strings tracked the pilot hole. The survey run in the milled-out section of casing provided evidence that milling operations were confined to the collapsed casing and had not "kicked off" into the formation.

A total of five straddle-packer tests were conducted in the two stages of pilot-hole drilling: two tests were run in the section of pilot hole drilled between 850 and 2010 feet below pad level, and three tests were run in the section of pilot hole between 2010 and 2940 feet below pad level. Each straddled interval was 20 feet in length. After the packers were lowered into the hole on a string of 5-1/2-inch-diameter drill pipe, the were inflated and seated against the formation. Figure 3 shows a typical straddle-packer assembly. Each of the zones between the straddle packers was air-developed to remove any drilling mud present in the formation prior to testing. Development was complete when the fluid discharged from the well was clear and the water-quality parameters (chloride and conductivity) were stable. Chloride concentration and conductivity were measured every fifteen minutes throughout the development time. For testing purposes, a 4-inch-diameter submersible pump was lowered into the well to a depth of about 250 feet below pad level. The pump then was switched on and water-level measurements were obtained in the drill pipe with an M-scope; the discharge was sampled periodically and the samples were analyzed in the field for chloride concentration, temperature, and conductivity. Each interval was pumped for two hours and, just prior to shut-down, a water sample was collected for analysis by a state-certified laboratory. Each sample was analyzed for TDS, chlorides, and conductivity. After the pump was turned off, water-level measurements were recorded for three hours. Table 1 summarizes the intervals tested and times of pumping. The water-quality results from the straddle-packer intervals are discussed in another section and the laboratory analyses can be found in Appendix D.

When the installation and cementing of the injection casing was complete, a pressure test was conducted on the casing prior to drilling the open-hole section through the injection zone. The casing was filled with water and placed under a pressure of 300 psi (pounds per square inch) for a one-hour period. This pressure is much greater than the expected maximum well-head operating pressure. The injection casing held this pressure for the entire one-hour period, and therefore passes the test for integrity testing specified in Chapter 17-28.24(6)(c) FAC. A copy of the pressure test data is found in Appendix E.

Once the pressure test had been successfully completed, the cement plug at the bottom of the 9.75-inch-diameter casing was drilled out and the final open hole was drilled to total depth. A copy of the second pressure test, conducted after the separated length of injection casing was discovered, is also presented in Appendix E.

The quality of construction materials used during the construction of both the injection and monitor wells was required to meet a minimum standard. For this reason, the Contractor was required to submit the Mill Certificates for each string of well casing and tubing. Copies of these Mill Certificates are presented in Appendix F. Details of the cementing program were submitted to the regulatory agencies before emplacement; actual quantities of cement blended and pumped were recorded, and the cement records from both the injection and monitoring wells are presented in Appendix G.

A number of geophysical logs were conducted during the construction of the injection well. Most logs were run at the completion of the various stages of pilot-hole drilling and in the open borehole beneath the final casing. The purpose of these logs was to collect data on the presence and nature of the injection zone and the confining sequence above it and to locate potential monitor zones. Dual Induction (shallow, medium, and deep investigation tools), temperature, caliper, natural gamma ray, and borehole-compensated sonic logs were made. Additionally, caliper logs were run in the 44-inch-diameter open hole, the nominal 38-inch-diameter open hole, the nominal 30-inch-diameter open hole, and the nominal 20-inch-diameter open hole to provide information on the volume of the respective boreholes prior to setting casing and cementing.

The Dual Induction log was used to differentiate between limestone and dolomite beds and, along with the gamma-ray log, aided in the correlation of lithologic units in the hole. The borehole-compensated sonic log was useful in identifying the injection zone and the confining sequence, as well as in helping to identify possible zones which could cause problems during cementing.

In order to determine the nature of the construction problems experienced during the drilling of this well, the TAC required the running of a number of extra geophysical logs. After it became necessary to mill out the collapsed portion of the 20-inch-diameter intermediate casing, caliper logs were run to show the results of milling operations. Later, after the final injection casing was set and cemented in place, a cement bond log was conducted. This cement bond log (CBL), which was required by the regulatory agencies and listed in the specifications, indicated that there was a problem with the cement seal between the formation and casing. Subsequent similar logs were run; they confirmed that a problem existed.

While running the caliper log scheduled as part of the geophysical logging conducted in the open borehole, it was determined that a 24-foot length of the injection casing had become separated from the string and dropped into the open borehole. It had become lodged above the injection zone and about 42 feet below its original location. As a result of this, additional investigations were proposed by Geraghty & Miller, Inc., to the TAC. These investigations consisted of running a second pressure test and a radioactive tracer survey in the injection well. Geraghty & Miller's report entitled "DeBartolo Injection Well Tracer Survey Evaluation" discusses the results of the cement bond logs and the tests conducted in the well which resulted in confirmation that the well did not have adequate vertical hydraulic isolation behind the 9.75-inch-diameter injection casing. This report can be found in Appendix H.

A cement evaluation tool (CET) log also was conducted on the final 9.75-inch-diameter injection casing, at the request of the TAC, in order to test the validity of the cement bond logs. The results were inconclusive. Remedial construction measures included a cement squeeze operation up behind the final injection casing. A report detailing the methods and testing associated with this operation can be found in Appendix I. That report, entitled "DeBartolo Injection Well Evaluation of Cement Squeeze Operation," was presented to the TAC as confirmation that remedial measures in the well had been successful, and that the well now had mechanical integrity.

As a result of the construction problems experienced during drilling of the injection well, the water-level data obtained from the deep monitor zone during the injection test was particularly important. If fluids from the Boulder Zone were migrating into the lower monitor zone, a corresponding increase in water level would be recorded. Although the responses during the actual injection test did not indicate any migration, the TAC required an extended period of water-level monitoring during operational testing. In conjunction with the water levels, tidal data, barometric data and injection rates were compiled. The graphs assimilated from these data are contained in Appendix J.

The only geophysical log conducted on the separate, dual-completion monitor well was a caliper log run prior to the installation of the 2-3/8-inch-diameter tubing.

Copies of the geophysical logs conducted during the construction and testing of the injection and monitor wells, including all the extra logs, are presented in Appendix K. Logs referred to in each of the two reports contained in Appendices H and I also are presented in Appendix K.

After completion of the monitor and injection wells, the wells were pumped to obtain water samples from the two monitor zones and from the injection zone. The samples were analyzed for a variety of constituents.

This was done to establish the "natural" or background quality of the water in the various zones prior to any disposal of treated effluent. Copies of the laboratory reports of the analyses are contained in Appendix D, along with the water-quality data from the straddle-packer tests.

Upon completion of water-quality sampling in both wells, a final injection test was conducted. During the test, a Geophysical Research Corporation Amerada Gauge (EPG-520) was used to measure temperature and pressure in the injection zone. Prior to the test, about 29 hours of background temperature and pressure data were collected. In addition, 12 hours of recovery data were recorded following the test. Data were collected every ten seconds at the start of the test, up to a maximum of every 15 minutes as the test progressed. Water-level measurements were recorded in the deep monitor zone, up to a maximum of ten-minute intervals. Data also were collected from pressure gauges installed on the shallow monitor tube and the injection well head.

Following the injection test, clear potable water was pumped into the well prior to surveying with the video camera. The survey provided visual data on the condition of the injection casing and the nature of the injection zone. It also indicated that the total depth of the well is 3325 feet below pad level. The tapes have been supplied to members of the Technical Advisory Committee requesting the information.

When injection testing was complete, the mechanical integrity temperature log was run on the injection well, followed by a radioactive tracer survey (for details refer to the report in Appendix I). Slugs of radioactive Iodine 131 were released during a period of no pumping; while injecting water at a rate of 1950 gpm (gallons per minute); and while injecting at a rate of 600 gpm. During the entire radioactive tracer test, water was removed from the deep monitor well by air-lift pumping at a rate of approximately 20 gpm. Analyses of the tracer survey indicated that no upward migration of injected fluids was occurring, demonstrating that the well has mechanical integrity.

WELL DRILLING AND CONSTRUCTION

Injection Well

The construction of the DeBartolo Injection Well began with the installation of 48-inch-diameter pit casing which was vibrated into place to a depth of 62 feet below ground level. This casing was installed before the cement drilling pad was constructed. After the pad was constructed, a 44-inch-diameter borehole was drilled and completed to a total depth of 178 feet below pad level. Clay was encountered at a depth of 165 feet. Thirty-eight-inch-diameter, 0.375-inch-wall thickness, conductor casing was set to a final depth of 173 feet below pad level and cemented in place in two stages. A nominal 38-inch-diameter borehole was drilled from the bottom of the 38-inch-diameter casing and continued to a depth of 850 feet below pad level through the Hawthorn Formation. A caliper log was run, then 850 feet of 30-inch diameter surface casing was installed in this borehole.

Below the surface casing, a 12-1/4-inch-diameter hole was drilled to a total depth of 2013 feet below pad level using the mud-rotary drilling method. Upon completion of the pilot hole to 2013 feet below pad level, the following geophysical surveys were conducted:

gyroscopic
gamma ray
single-point resistivity
temperature
Dual Induction
borehole-compensated sonic
caliper

Two straddle-packer tests then were conducted in the open pilot hole. The first interval pumped was between 1720 feet and 1740 feet; the second was between 1895 feet and 1915 feet below pad level. Each zone was air-developed for approximately 5 hours to remove the drilling mud before shutting down to allow the water level to recover and installing a submersible pump in preparation for a pumping test.

Upon completion of the testing, the 12-1/4-inch-diameter pilot hole was stage-reamed to a nominal 30 inches in diameter in order to accommodate the 20-inch-diameter intermediate casing. A caliper log was run in the open borehole and the intermediate casing was set to a depth of 2005 feet below pad level. Two lengths of the casing were externally coated with an epoxy phenolic paint (the paint application was certified by a qualified specialist in corrosion control before installation in the well). These casing lengths were located adjacent to the upper and lower monitor zones. The lower monitor tube (with the lower 20 feet slotted) then was placed in the annulus outside the intermediate casing at a depth of 1915 feet below pad level, after pumping one stage of cement. The slotted portion of the monitor tube was gravel-packed to a depth of 1860 feet and a sand cap was emplaced above the gravel to a depth of 1845 feet below pad level. Cement was emplaced between the sand cap above the lower monitor tube and the base of the upper monitor zone at a depth of 1740 feet below pad level. The upper monitor tube then was installed, and gravel- and sand-packed before cementing operations were completed on the 20-inch-diameter intermediate casing to pad level. Both monitor tubes were developed with air to remove the mud and loose material in the formation.

Drilling of the pilot hole continued from 2005 feet to a total depth of 2947 feet below level--the first significant zone of lost fluid circulation. During the drilling of this interval, five cores were

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collected to demonstrate confinement of the formation. Data on cored intervals and percent recovered are shown in Table 2. Other information about the cores is presented in Appendix B.

Geophysical logs were run in the open pilot hole between 2005 feet and 2947 feet below pad level. These logs were similar to those conducted in the previous stage of the pilot hole, between the depth of 850 and 2005 feet. Three straddle-packer testing intervals were selected and testing was conducted in the borehole. The selected intervals were 2720 feet to 2740 feet, 2575 feet to 2595 feet, and 2180 feet to 2200 feet below pad level. A summary of the straddle-packer test data from all five tests is shown in Table 3.

Following the completion of the packer tests, a cement plug was set at approximately 2943 feet, above a sand and gravel plug located at the bottom of the pilot hole. Once the plug was in place, preparations were made to ream out the pilot hole with a 19-1/2-inch-diameter bit prior to setting the 9.75-inch-diameter injection casing. However, the bit would not pass through a tight section of casing at 1715 feet below pad level. Successively smaller-diameter bits were run into the well, but each failed to pass through the same section of the casing. It then was discovered that the 20-inch-diameter casing had collapsed below a depth of about 1690 feet below pad level.

4/25 – Drillers Inc. says csg. may be separated.
TAC – 4/29
5/12 – DER receives written notification from G&M about csg. collapse.

The collapse occurred less than 24 hours before discovery, when the Contractor attempted to disinfect the two annular monitor tubes. The tubes were connected to high-pressure pumps and a disinfectant solution pumped into the monitor tubes. Pressures in excess of 400 psi (pounds per square inch) were applied to the tubes, which were located between the unsupported intermediate casing and the formation. The pressures externally applied to the casing through the monitor tubes exceeded the plastic collapse pressure of the 20-inch-diameter, 0.375-inch-wall

The only zones which were unsupported were the 2 monitor zones:
1860-1915' & 1704-1740

thickness steel casing. This activity resulted in the collapse of the casing adjacent to the two monitor tubes.

Following the discovery of the collapse, the Contractor milled out the intermediate casing using several successively larger-diameter tapered mills. A caliper log then was run to determine the profile of the milled-out casing, and a gyroscopic survey was conducted to provide assurances that milling operations had not created a new borehole outside the casing. These surveys were performed at the request of the TAC.

After satisfying the regulatory agency's concerns about the success of the milling operations, permission was granted to proceed with the installation of the injection casing with the proviso that the casing would be cemented to surface in one stage. One-stage cementing is a practice commonly used in the construction of oil wells, but almost never used when cementing long strings of casing in injection wells. The stated reason for cementing this well in one stage was to ensure that the cement would intrude into the annulus behind the collapsed intermediate casing, filling up any voids or channels which might be present. The TAC believed that this could only be achieved with a one-stage cementing process.

Approximately 13 hours after the completion of cementing, a temperature log was run from 2873 feet below pad level to surface. This was followed by an attempt to run a pressure test, but the temperature changes observed during cement curing were affecting pressures inside the casing, so the test was abandoned. A cement bond log then was run by Southern Resource Exploration. After the completion of the cement bond log on June 2, 1987, a pack-off gland was installed on the top of the 9.75-inch-inside-diameter casing. By this time, the temperature changes resulting from cement curing were negligible and another pressure test was conducted, with successful results. A pressure of 300 psi (pounds per square inch) was maintained without change on the injection casing for one hour, as required, to demonstrate internal mechanical integrity. The results of this test are presented in Appendix E.

Because of problems highlighted on the previously-run cement bond log, a second cement bond log was run in the well, this time by Schlumberger. Both bond logs indicated the possible presence of a microannulus or numerous voids and channels behind the injection casing, so additional cement bond logs were run while the casing was pressurized at increments between 1200 psi and 2200 psi, in order to eliminate any microannulus.

During the period that the cementing problems were being identified, drilling operations on the well proceeded. A 9-1/4-inch-diameter hole was drilled, using the reverse-air drilling method, from 2897 feet to the total depth of the well at 3505 feet below pad level.

After a sample of water from the injection zone was collected for analysis by a state-certified laboratory, geophysical logging was conducted in the open hole. The first log attempted was a caliper log; the tool hung up in the hole at 2903 feet below pad level (just below the supposed bottom of the casing). After freeing the tool, Schlumberger ran the tool to a total depth of 3470 feet, then logged the hole upward until reaching 2864 feet, where the caliper log indicated that the bottom of the casing occurred (not at 2905 feet, where it was originally set). The log further indicated that there was an interval above 2934 feet which extended for 24 feet and consisted of a gauge-sized hole which appeared to be casing. It was assumed from this log that a length of casing had separated from the string and dropped down into the open borehole. Attempts were made to move the length of casing. These actions did not appear to affect its position or orientation in the borehole.

Geophysical logging on the open borehole was conducted on July 6, 1987. Another caliper log, a sonic log, a Dual Induction log, a temperature log, and another cement bond log run in conjunction with a Cement Evaluation Tool (CET) log all were conducted. The latter two logs (cement bond and CET), previously not released by the Contractor to Geraghty & Miller, Inc., have now been released and are contained in Appendix K. At this stage in the construction of the well, a second pressure test and the first radioactive tracer survey were conducted. The casing maintained a pressure of 151 psi for one hour without change. The results of the radioactive tracer survey showed the presence of channels or voids up to a depth of at least 2400 feet below pad level.

A squeeze cementing operation was conducted as a means to restore external mechanical integrity to the injection well. This operation included the setting of a drillable packer in the separated length of 9.75-inch-diameter casing in the open borehole. This packer was set at 2919 feet below pad level in order to form a bridge plug above the injection zone. Sand was added above the packer to a depth of 2910 feet below pad level and four barrels of cement with a compressive strength of 1500 psi (pounds per square inch) were emplaced above the sand cap. The top of this cement was tagged at 2897 feet below pad level. Six barrels of cement with a compressive strength of 500 psi were emplaced above the 1500-psi cement. The top of the cement then was tagged at 2874 feet below pad level (six feet below the bottom of the injection casing).

A drillable packer was set inside the 9.75-inch-diameter injection casing at a depth of 2828 feet below pad level. This packer was fitted with a valve so that fluids might be pumped through the packer using 2-3/8-inch-diameter tubing. Following the installation of the packers, a temperature survey was run and an injectivity test was conducted in order to determine the approximate pumping rate and pressures to be used during the squeeze-cementing operation. These data were evaluated prior to finalizing the details of the cementing procedure.

As a result of the temperature log analysis, the cement-squeeze procedure was modified to incorporate a radioactive tracer (Iodine 131). The tracer was added to the Injectrol (a product which is a sealant similar to caulk with a low compressive strength) which was pumped ahead of the ASTM Type II cement used in the squeeze operation.

Additional details and the analysis of the success of the cementing procedure can be found in Appendix I, a previously submitted report which evaluates the cement-squeeze operation.

After completion of the testing associated with the squeeze operation, the two packers were drilled out and the well re-opened to the injection zone.

Figure 4 shows the scenario of the construction problems experienced during the drilling of this well. An as-built diagram of the completed well is shown in Figure 5. A detailed cement record for this well can be found in Appendix G.

Monitor Well

Construction of the monitor well, which is located a few feet to the southeast of the injection well pad, began on September 16, 1987, when 24-inch-diameter pit casing was vibrated into the ground to a depth of 59 feet below pad level using a vibratory hammer. A nominal 24-inch-diameter borehole then was drilled from land surface to a total depth of 200 feet below. Eighteen-inch-diameter casing was installed and cemented in place with neat ASTM Type II cement to a depth of 175 feet below pad level.

Drilling of a nominal 18-inch-diameter ream proceeded from the top of the cement plug inside the 18-inch-diameter casing, at a depth of 166 feet below pad level, to a total depth of 857 feet below pad level. Twelve-inch-diameter, 0.375-inch wall thickness casing then was run into the hole and cemented in place to 850 feet below pad level.

A nominal 12-inch-diameter borehole was drilled below the casing to a total depth of 2214 feet below pad level and 2-3/8-inch-diameter J55-grade tubing (with the lower 20 feet perforated) was run into the borehole. The tubing was coated with a protective epoxy paint prior to installation to prevent corrosion of the tubing in intervals where there was no cement. The lower screened interval was gravel- and sand-packed up to a depth of 2135 feet below pad level. A cement cap then was emplaced and two additional cementing stages were pumped in order to fill up the interval between the two monitor zones.

After the waiting time for the cement to cure had elapsed, the upper monitor tube was installed in the borehole. Gravel-packing of the interval began as soon as the monitor tubing was set. The top of the gravel was tagged at 1715 feet; a sand cap emplaced above the gravel was tagged at 1703 feet below pad level. Three stages of cement then were necessary to seal the annulus between the top of the sand cap at 1703 feet and land surface.

The detailed cement record for this well can be found in Appendix G; a monitor-well completion diagram is shown in Figure 6. The geologic log can be found in Appendix A with the geologic log from the injection well.

The two monitor zones were developed and water samples collected from each to establish background water quality. The results of these analyses are found in Appendix D.

SUBSURFACE CONDITIONS

Background

The final design of the injection well was based on information collected during the drilling and testing of the pilot hole. Although much of the design criteria were based on other wells in the area, the drilling and testing program was designed to provide flexibility and to allow for changes in well completion that might be dictated by site-specific geologic conditions. The drilling specifications and program were based on available data on regional and local geologic conditions and from existing injection wells in the area. This section on subsurface conditions presents the site-specific geologic conditions encountered during this project.

Geologic Setting

A well-defined, areally-extensive sequence of carbonate sediments is present at the Jensen Beach site and throughout the region. As shown on Figure 7, the confining sequence and injection zone are present at similar depths in four wells in Indian River, St. Lucie, Martin, and Palm Beach Counties. These wells are the Hercules well in Vero Beach, the GDU South Port well in Port St. Lucie, the ENCON well in Jupiter, and the DeBartolo well in Jensen Beach. The locations of these wells are shown in Figure 8.

The geologic units found during the construction of the DeBartolo well satisfy the requirements of Chapter 17-28 FAC. The injection zone is capable of receiving the design volume of effluent (2.80 million gallons per day at peak flow) and disposal of the effluent into this zone should not result in the contamination of any underground source of drinking water. A brief description of the various geologic units follows.

From land surface to a depth of approximately 165 feet, the sediments are comprised of limestone, sandstone, and clay with varying amounts of unconsolidated shell and sand. The limestone is a yellowish-grey to pinkish-gray biomicrite. The sandstone is generally light gray to dark gray and is comprised of quartz and phosphatic minerals. This material is fine- to medium-grained and poorly- to well-cemented with small shell fragments. Various amounts of sand and shell also are present within the sediments. These sediments are Pleistocene in age and correspond to descriptions of the Pamlico Sand and Anastasia Formation in Martin County.

From 165 feet to a depth of about 185 feet, the formation consists of a grayish-olive clay with varying amounts of sand and shell. Between 185 feet and about 355 feet, the clay is a light olive gray in color and is interbedded with limestone, sand, and shell. These descriptions correspond to those of the Caloosahatchee Marl and Tamiami Formation of Post-Miocene Age.

In the interval between 355 feet and 650 feet, the sediment is predominantly composed of an olive-gray, plastic clay with various (usually small) amounts of sand and shell. Marl, which is a carbonate mud, predominates from 650 feet to about 720 feet. At this location the marl occurs as a light olive-grey, soft, plastic sediment with some quartz and phosphate sands. Below 720 feet, the marl is interbedded with layers of moderately well-cemented limestone and shell. Very few traces of marl were identified in the formation samples but other drilling data confirmed its presence in this interval. These formations correspond to descriptions for the Hawthorn Formation and possibly the Tampa Formation or the Suwannee Limestone. The presence of the Tampa Formation in Martin

County is uncertain and only tentative correlations have been attempted. No limestone typical of that characterizing the Tampa was identified in the DeBartolo well.

Between 750 feet and about 1100 feet, the limestone consists of a moderately soft, fossiliferous, white to very pale orange limestone (in the lower part) which contains numerous, sometimes large, foraminifera. The formation corresponds to descriptions of the late Eocene-age Ocala Limestone.

The interval between 1100 feet and 2050 feet deep consists of layers of limestone, predominantly biomicrite to biosparite, with some layers of hard dolomite. No dolomite appears in the upper part of this interval, but it does occur in the lower part, where it is a dark yellowish brown and cryptocrystalline. The limestone in this interval consists of a white to cream-colored, highly fossiliferous, chalky micrite in the upper part and a light brown sparite with some layers of chert, peat, and dolomite in the lower part. The section is of middle Eocene age and corresponds to the Avon Park Formation. The term "Formation" when applied to the unit is used in this report to describe the previously-named Avon Park and Lake City Limestones, in accordance with recent USGS nomenclature (Miller, 1986). This change in identification for the unit makes it consistent with the current North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature, 1983). This unit (named by Applin and Applin in 1944) was identified on the basis of microfossil evidence, so it is in reality a biostratigraphic unit which has been mapped as if it was a rock-stratigraphic unit.

There is very little stratigraphic evidence at the DeBartolo well site upon which to separate the Avon Park and Lake City Limestones into two units. Thus, for the purposes of this report, Miller's suggestion to adopt the Avon Park Formation for the entire unit is accepted.

From 2050 feet to 2890 feet, limestone is present. This limestone shows signs of dolomitization at intervals, mostly near the base. The rock becomes moderately soft and dense with increasing depth, and exhibits lower porosity. Porosities measured from cores collected in the depth interval between 2100 feet and 2700 feet range from 15.3 percent to 38.2 percent.

The first significant zone of lost circulation was encountered during drilling below 2890 feet. From this depth, to a depth of about 3150 feet, the interval consists of interbedded dolomite and limestone. The dolomite is pale to dark yellowish brown, crystalline to cryptocrystalline, massive and dense, showing evidence of dissolution. The limestone found at these depths is similar to that which was described in the interval above. The formation between 2050 feet and 3350 feet is the early Eocene-age Oldsmar Formation, which is a determination consistent with the Miller (1986) report. The lower part of this formation, between 3000 feet and 3350 feet is known as the Boulder Zone. Below 3150 feet to the total depth of the borehole at 3500 feet, the rock is composed completely of dolomite.

Below 3350 feet, the character of the dolomite changes; it becomes very pale orange to bluish grey, is no longer cavernous, and becomes harder and more dense. This depth may represent the boundary between rocks of early Eocene age and the older Paleocene rocks. The rocks below 3350 feet would correspond to those of the Cedar Keys Formation, as described by Miller (1986).

The injection zone extends from approximately 3000 feet to 3350 feet, in the lower part of the Oldsmar Formation. Results from the television survey indicate that the dolomite in this zone exhibits extensive dissolution cavities and fracturing. Open-spaced crystal growth is apparent in the vugs within the dolomite retrieved from well cuttings. The majority of the injected fluid will be accepted into cavities between 3000 feet and 3100 feet.

Hydrogeologic Setting

The upper 185 feet of sediments beneath the site are Pleistocene and Pliocene-age sand, silt, limestone, and shell. These sediments contain the surficial aquifer which is used as a source of drinking water throughout the county.

Underlying the surficial aquifer are approximately 365 feet of Miocene-age clays and marls which form a confining bed between the surficial aquifer and the Eocene-age limestones and dolomites of the Floridan aquifer. This confining bed is called the Hawthorn Formation. Water quality in the Floridan aquifer is poor in comparison to the surficial aquifer. Water from the Floridan aquifer in this area contains concentrations of dissolved solids which exceed drinking water standards. The aquifer generally is not used as a source of drinking water in the county because of the additional treatment required to meet the potable standards and the availability of better-quality water at shallower depths in the overlying surficial aquifer. The Floridan aquifer exists under artesian conditions with a potentiometric level above land surface. The dense Miocene clays of the overlying Hawthorn Formation provide good confinement for this aquifer.

A confining sequence above the injection zone is present between 2200 feet and 2940 feet below pad level in the DeBartolo well. It consists of a thick sequence of dense limestone with some interbedded layers of dolomite. This confining sequence overlies a section of highly permeable dolomite of the lower Oldsmar Formation referred to as the "Boulder

Zone". This zone contains highly mineralized water and is used throughout south Florida for the disposal of treated domestic effluent.

Confining Sequence

Information on the nature of the confining sequence was obtained during various phases of the drilling and testing program. During pilot-hole drilling, drill cuttings were collected and examined by the on-site geologist and five cores were taken in the interval between 2169 and 2702 feet. A portion of each core was selected and sent to a laboratory to be analyzed for a number of parameters, including porosity, and vertical and horizontal hydraulic conductivity. The vertical permeabilities ranged from 0.000000626 cm/sec to 0.000173 cm/sec, indicating good confinement. A table summarizing the core data and listing the intervals which were tested is included in Appendix B. The data from the cores, lithologic descriptions, laboratory test data, and copies of the geophysical logs are presented in the Appendices.

Injection Zone

The anticipated presence of a suitable injection zone in the Jensen Beach area was based on data from the other wells in the area. Other injection wells and exploratory wells have been drilled in Martin County and surrounding counties. It also was believed that the thick cavernous dolomites of the lower Oldsmar Formation existed throughout the area and, in particular, at the Jensen Beach site. The first indications of the presence of an injection zone (Boulder Zone) in the DeBartolo well were found at approximately 2945 feet below pad level, about 900 feet below the top of the Oldsmar. During the direct mud-circulation drilling of the pilot hole, the first significant zone of lost circulation was encountered at this depth. Plugging problems and erratic weights on bit and penetration rates were noted during reverse-air drilling below this depth. These problems were attributed to an excessively-hard, fractured, and permeable formation. The drill cuttings were composed mainly of hard, cryptocrystalline to finely-crystalline dolomite with evidence of dissolution features and fine, mineral-filled fractures. The primary injection zone lies between approximately 3000 feet and 3350 feet.

The injection zone and the occurrence of dolomite are shown clearly on the Dual Induction and borehole-compensated sonic logs presented in Appendix K. The resistivity profile shown on the Dual Induction log varies considerably within the injection zone. This variation is due to the presence of massive, dense dolomite (higher resistivity) along with fractures and cavities confining highly-mineralized water (lower resistivity). On the borehole-compensated sonic log, the faster transit velocities and cycle skipping between 3000 feet and 3100 feet confirm the presence of fractured dolomite containing large cavities. The presence of large cavities and fractures also can been seen on the television survey.

Water Quality

Water samples were collected from two zones in the monitor well, after development, and from the injection zone to determine background water quality. The samples from the monitor zones show that they straddle the 10,000-mg/L TDS (Total Dissolved Solids) interface. The injection zone sample from the DeBartolo well compares favorably with water-quality data obtained from other injection wells in the area. The contact between potable and non-potable water in the ENCON well was found to occur at approximately 1850 feet and the interface was identified as occurring "between 1750 feet and 1850 feet (below the lower monitoring zone)" in the South Port well in Port St. Lucie. Results of water-quality analyses of samples from the monitor well and from the injection zone are presented in Appendix D.

The interface between waters less than and greater than 10,000 mg/L TDS is known to be between 1740 feet and 1895 feet below land surface, based on the water-quality data obtained from the straddle-packer tests and the monitor well. This correlates well with data obtained from both the ENCON well to the south and the Port St. Lucie well to the north. The depth at which the interface is believed to exist in each of four wells is shown in Figure 7.

INJECTION TEST

On November 3, 1987, an electronic pressure/temperature sensor was installed in the well. The sensor, manufactured by Geophysical Research Corporation, is capable of detecting pressure changes of as little as 0.01 psi (pounds per square inch). Background pressure and temperature readings were collected for a period of 29 hours. The sensor was positioned at a depth of 2845 feet below the pad (approximately 20 feet above the bottom of the casing) so that the data collected during the test would be representative of the injection zone and would not be influenced by turbulence from fluid exiting the injection casing. Background water levels also were recorded in the deep monitor well, and well-head pressure was recorded on the shallow monitor well during the same time period. In addition to bottom-hole pressures and temperatures recorded during the test, injection well-head pressures were monitored and the flow rate into the well was recorded in gallons per minute.

The pressure and temperature data collected from the bottom-hole transducer during the test are shown in Figure 9.

The injection test began at 8:13 p.m. on November 4, 1987, and was terminated 24 hours later. After the test, 12 hours of recovery data were collected. The injection test was conducted using fresh water pumped from the newly-constructed retention and holding ponds. Water was accumulated in these ponds before the test; during the test, the ponds were recharged from a nearby Martin County Utilities hydrant. The water was pumped from the ponds using a variety of small contractor-type centrifugal pumps and was directed through a large reservoir tank in which the injection pump was situated. This pump was capable of delivering the required 1950 gpm for the test against a well-head pressure of about 60 psi. The flow was measured with a flowmeter which recorded both the cumulative volume pumped and the actual flow rate simultaneously. The maximum maintained injection rate during the test was approximately 2000 gpm.

During the initial 10 minutes of the test, the pressure and temperature fluctuated as the valves were opened and the test flow rate was established. After the rate stabilized, within the first 15 minutes of the test, the bottom-hole pressure had increased by 4.61 psi. Thereafter it remained fairly constant, not increasing by more than 0.15 psi over the stabilized pressure readings. Tidal and minimal pump fluctuations were responsible for these slight pressure changes. The tidal fluctuations were observed in the deep monitor wells, as can be seen from Figure 8, which shows the injection pressure and temperature data collected from the bottom-hole transducer compared with the water-level measurements recorded in the deep monitor zone of the monitor well.

Immediately after the pump was turned off at the end of the test, the pressure decreased by 2.27 psi, then fluctuated for a few minutes. It gradually decreased by about 0.50 psi during the following 7 hours. For the final 5 hours of recovery readings, the pressure increased slightly, reflecting the upward trend of the tidal cycle as measured in the deep monitor well.

Background bottom-hole temperature readings were a constant 75.4 degrees Fahrenheit. After the pump was turned on and the water from the ponds entered the well, the bottom-hole temperature increased. The pond water had an ambient temperature of about 80 degrees Fahrenheit at the beginning of the test. Within the first 30 minutes of the test, the bottom-hole temperature had reached a maximum of 78.4 degrees Fahrenheit. This temperature was maintained for about two hours, then it gradually declined to a minimum of 76.5 degrees Fahrenheit in the early morning of November 5 (about 8:00 a.m.).

After 10:00 a.m. the temperature in the well began to increase to a maximum of 79.7 degrees Fahrenheit, which was reached by mid-afternoon (3:00 p.m.), after which it began to decrease. It continued to decline for the length of the test. The temperature gradient declined after the pump was turned off; the bottom-hole temperature had stabilized at about 76.8 degrees by the end of the recovery period. Temperature fluctuations in the well were due to the injection of surface water, which was warmed by the sun during the day and cooled off at night.

The background data collected from the deep monitor zone shows a cyclical fluctuation in water level, which is usual for similar wells that are influenced by tidal cycles. At the TAC's request, the injection test was started on the downward trend of one of these tidal cycles.

The water levels in the deep monitor zone continued to decline after injection began. Throughout the injection test and recovery period the water levels were unaffected by fluid injection into the Boulder Zone. Upon presentation of the data to the TAC, however, the asymmetry of the tidal responses caused some concern; this resulted in a static water level monitoring period of 4 months during operational testing, which was required in order to attempt to reproduce the cyclical tidal effects measured during the test, background and recovery readings. The data collected for the TAC is presented graphically in Appendix J, along with the relevant barometric and plant operating data. On May 10, 1988, the water-level monitoring restriction was suspended.

The data from the injection test, geophysical logs, and television survey all show that the injection zone in the DeBartolo well has the high transmissivity characteristic of the "Boulder Zone" in south Florida. A rough estimate of the transmissivity of the injection zone was made based on the injection test data using a method described by Walton (1970). Assuming that the specific capacity of the well is equal to the specific injectivity measured during the injection test, the transmissivity is estimated to be greater than 2,100,000 gpd/ft.

OPERATION AND MAINTENANCE

When the injection well is operating during long-term injection testing and over its operational life, 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 aid in permit compliance during the initial testing period and during the operation of the system.

Injection-Well Data Collection

Records of the well head pressure, injection rate, and cumulative daily volume of injected fluid will be collected from the well on a continuous basis, beginning with the start of injection. Values of maximum and average injection pressure and rate will be recorded on a daily basis for monthly submission to the FDER. Monthly average, maximum, and minimum values of injection pressure, injection rate, and volumes also will be reported to the FDER. Measurements of the injection pressure and rate should be made at the same time and recorded so that correlations between these two values can be made. It is essential that performance data be collected from the start in order to establish baseline information to satisfy regulatory requirements and to serve as a benchmark for future data comparison and analysis of performance. These records will be maintained permanently.

Monitor-Well Data Collection

The purpose of monitor-zone data collection is to detect changes in water quality in the monitor zones that could be attributed to the injection of treated effluent. The parameters established for analysis are chloride, specific conductance, fecal coliform, 5-day BOD and TDS (total dissolved solids). Following initiation of injection, analysis for these constituents will be conducted weekly until the issuance of the operating permit, then monthly for the duration of injection. In order to collect the monitor-zone data, the monitor zones have been equipped with sampling pumps. At least three well volumes will be pumped from the monitor zones before samples are taken. The water from the monitor zones will be discharged into the treated effluent wet well and pumped into the injection well.

In order to distinguish between the two monitor zones in the monitor well, refer to the diagram in Figure 5. They can be distinguished in the field by remembering that the shallow monitor zone will flow because it is under artesian pressure, and chloride concentrations and TDS values will have significantly lower values than in the deep monitor zone.

Injectivity Testing

A well's injectivity is a function of (1) friction loss in the casing, (2) the bottom-hole driving pressure, and (3) the density differential between treated effluent and the formation water in the injection zone.

The latter is a constant as long as the temperature and density of the injection fluid remain constant. Bottom-hole driving pressure and friction loss in the casing can vary as a result of changes in the flow rate, plugging of the injection zone, and the physical condition of the pipe. In general, pressures build 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 with respect to time; this is not expected at the DeBartolo well because of the cavernous nature of the injection zone.

Periodic determination of a well's injectivity can be used as a measure of a well's efficiency, and it is recommended as a management tool for the injection well system. Performing the test is relatively simple. It involves injecting into a well at two or more injection rates and recording the injection pressure for each rate. The injectivity is calculated by dividing the injection rate by the injection pressure (well-head pressure minus the static or non-pumping pressure). The result is expressed as gallons per minute per psi of pressure. As noted, testing should be conducted at a minimum of two rates so that future comparisons can be made.

A procedure for injectivity testing should be established as soon as the wells are placed in operation in order to collect baseline operating data. The procedure should be easily repeatable so that injectivities can be computed for the same injection rates. Testing should be conducted quarterly for the life of the well.

Mechanical Integrity

An injection well has mechanical integrity if there is no leak in the casing and no fluid movement into the underground source of drinking water through channels adjacent to the injection well bore. In accordance with FAC 17-28.13 (6) and 17-28.25(1), the mechanical integrity of the injection well must be demonstrated every five years. The injection casing will be pressure tested, or tested by other approved method, to demonstrate absence of leaks. A temperature or noise log and monitoring of overlying aquifers will be conducted to demonstrate absence of fluid movement through channels adjacent to the injection well bore. The performance of a radioactive tracer test as part of mechanical integrity testing also may be required.

The initial mechanical integrity of the DeBartolo injection well was determined by numerous tests including pressure-testing the injection casing twice--once at 300 psi for one hour with no change in pressure, and a second time at 151 psi for one hour with no change in pressure. The pressure test data are shown in Appendix E. Radioactive tracer surveys and a temperature log also were conducted.

Plugging and Abandonment Plan

In the event the DeBartolo well has to be abandoned, it must be effectively sealed or plugged in order to prevent upward migration of fluid from the injection zone or interchange of formation waters through the borehole or along the casing. In order to effectively plug the well, it will be necessary to mobilize a drill rig, "kill" the well, and remove the valve from the well head. The well will be "killed" by filling the casing with 9.0 ppg (pounds per gallon) of drilling mud. After the valve is removed, a bridge-plug assembly will be set at the bottom of the 9.75-inch-diameter injection casing. The plug assembly will consist of a short section of threaded pipe with a bottom plug and two cement baskets attached to the outside. Above this section of pipe will be approximately 100 feet of threaded pipe containing cement ports and several sets of left-hand-threaded couplings. These couplings will be placed at the top and bottom of the bottom joint of casing. This assembly will be lowered into the well to a depth of 2800 feet on a string of drill pipe.

The cement baskets will be expanded and set by adding about five cubic feet of crushed limestone to the well and allowing it to settle. A mixture of neat cement will be pumped into the hole through the drill pipe and the cement ports above the cement baskets in the bridge plug assembly. The quantity of cement pumped should be equivalent to the volume of slurry required to fill the casing from the top of the crushed limestone to one foot below the lowermost left-hand-threaded coupling.

The cement will be allowed to set for 24 hours and then will be "tagged" with a wire line to determine if fill-up has been achieved. If not, additional crushed limestone will be added and another stage of cement pumped (a single stage of cement usually is sufficient to build the first portion of the bridge plug). A strain of no more than 1000 pounds above drill string weight will be exerted. If no movement occurs (other than pipe stretching), the plug will be considered set and the contractor can proceed with disconnecting the assembly by rotating and "backing off" the drill pipe (right-hand rotation will unscrew the pipe from the left-hand-threaded coupling). Then two successive small stages of cement (no more than 100 feet of cement fill-up) will be pumped and given time to set. The remainder of the casing then will be filled with neat cement.

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The completion of this well has been the culmination of approximately two years of hard work, patience, dedication and the cooperative effort of a number of persons from the Edward J. DeBartolo Corporation; Gee & Jenson, Engineers, Architects and Planners, Incorporated; Reese, Macon and Associates, Inc.; the Florida Department of Environmental Regulation; the South Florida Water Management District; the U.S. Environmental

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Geraghty & Miller, Inc., would like especially to thank each of the following individuals for their assistance, guidance, and cooperation throughout the entire project. We would also like to express our regret for the passing of Gus Costas, for whom we had great respect. The fact that this well has been successfully completed at all is a testament to the determination and dedication of the persons mentioned below:

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Respectfully Submitted,
GERAGHTY & MILLER, INC.

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May 1988

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FIGURES

Attachment C

Exempted Notification Sheet

Drawings are Exempt from s.119.07 and s. 24(a), Art. 1 of the State Constitution

If a figure has been removed from this document it was filed in the Plans and Specifications Profile in the UIC Restricted Catalog.

TABLES

TABLE 1

STRADDLE-PACKER TEST INTERVALS

Packer Test Number	Depth Interval (Feet)	Interval Straddle (Feet)	Rate Pumped (gpm)	Time Pumped (Hours)	Maximum Drawdown (Feet)	Recovery Time (Hours)
1	1720-1740	20	42	2	19.42	3
2	1895-1915	20	23	2	9.25	3
3	2723-2743	20	18	2	138.15	3
4	2576-2596	20	30	2	114.95	2
5	2186-2206	20	31	2	38.40	3

TABLE 2

SUMMARY OF CORE DATA

Sample #	Depth Interval (feet)	% Recovered	Vertical Permeability (measured from bottom up) (cm/sec)	Horizontal Permeability (cm/sec)	Total Porosity (%)
1	2171.27-2171.95	94.1	0.000215	0.000000527	15.3
2	2296.40-2296.98	97.0	0.000491	0.0000352	38.2
3	2413.38-2413.91	100.0	0.000000626	0.00000204	19.6
4	2549.54-2550.15	94.0	0.000173	0.000314	31.5
5	2695.08-2695.62	94.0	0.00000334	0.0000268	27.3

Notes: (1) Four-inch-diameter cores.
(2) Analyses performed by Professional Service Industries, Inc., Clearwater, Florida.

TABLE 3

SUMMARY OF
STRADDLE-PACKER TEST ANALYSES
DEBARTOLO INJECTION WELL

Test Interval (Feet Below Pad)	Interval Thickness (Feet)	Hydraulic Conductivity [k] (cm/sec)	Transmissivity [T] (gpd/ft)
1720 - 1740	20	0.0304	4325
1895 - 1915	20	0.0344	5169
2186 - 2206	20	0.0117	1615
2576 - 2596	20	0.0038	522
2723 - 2743	20	0.0019	261

From a Method From Cedergren (1977)