NORTH COUNTY REGIONAL WATER TREATMENT PLANT INJECTION WELL IW-2 COMPLETION REPORT

VOLUME I - TEXT

MISSIMER INTERNATIONAL INC.
Groundwater and Environmental Services

NORTH COUNTY REGIONAL WATER TREATMENT PLANT INJECTION WELL IW-2 COMPLETION REPORT

VOLUME I - TEXT

prepared for

Collier County
Division of Water
Building H, Collier Government Center
Naples, Florida 22942

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by

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Project Number
FE4-068

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1.0 INTRODUCTION

1.1 Background

This report details the drilling, construction, and testing of a Class I injection well, designated IW-2, at the Collier County Utilities Division's North County Regional Water Treatment Plant (NCRWTP). The NCRWTP currently has a capacity to treat 12 million gallons of water per day (MGD) using softening membranes. The plant will soon be expanded to a capacity of 20 MGD with the addition of low pressure reverse osmosis membranes. Treatment of 12 MGD by the softening membranes would produce approximately 1.2 MGD of concentrate. At build-out to 20 MGD capacity, the NCRWTP will generate a maximum concentrate stream of between 4.75 and 8.57 MGD, depending on the type of treatment process being used.

The completed concentrate disposal system consists of two (2) injection wells, (IW-1 and IW-2), and a dual zone monitor well. Underground Injection Control (UIC) rules classify membrane process concentrate as an industrial waste, which thereby requires the disposal well to be of the tubing and packer design. Injection well IW-1 and the dual zone monitor well were constructed from June 1992 to March 1993. The design of injection well IW-2 is similar to the successful design of well IW-1. Injection well IW-1 has a total depth of 3,210 feet below land surface (ft bls), with the base of the 20-inch diameter casing located at 2,498 ft bls. The bottom of the 16-inch diameter injection tubing is positioned at 2,460 ft bls. The injection zone, commonly referred to in south Florida as the "Boulder Zone", consists of hydraulically connected, highly fractured and cavernous dolomites that are part of the lower and middle Oldsmar Formation. The Boulder Zone in the NCRWTP area extends from approximately 2,404 ft bls to 3,330 ft bls. The dual zone monitor well is located approximately midway between injection wells IW-1 and IW-2 (140 feet from each well), and monitors a shallow zone occurring between 900 and 995 ft bls and a deeper zone between 1,815 and 1,930 ft bls.

1.2 Scope

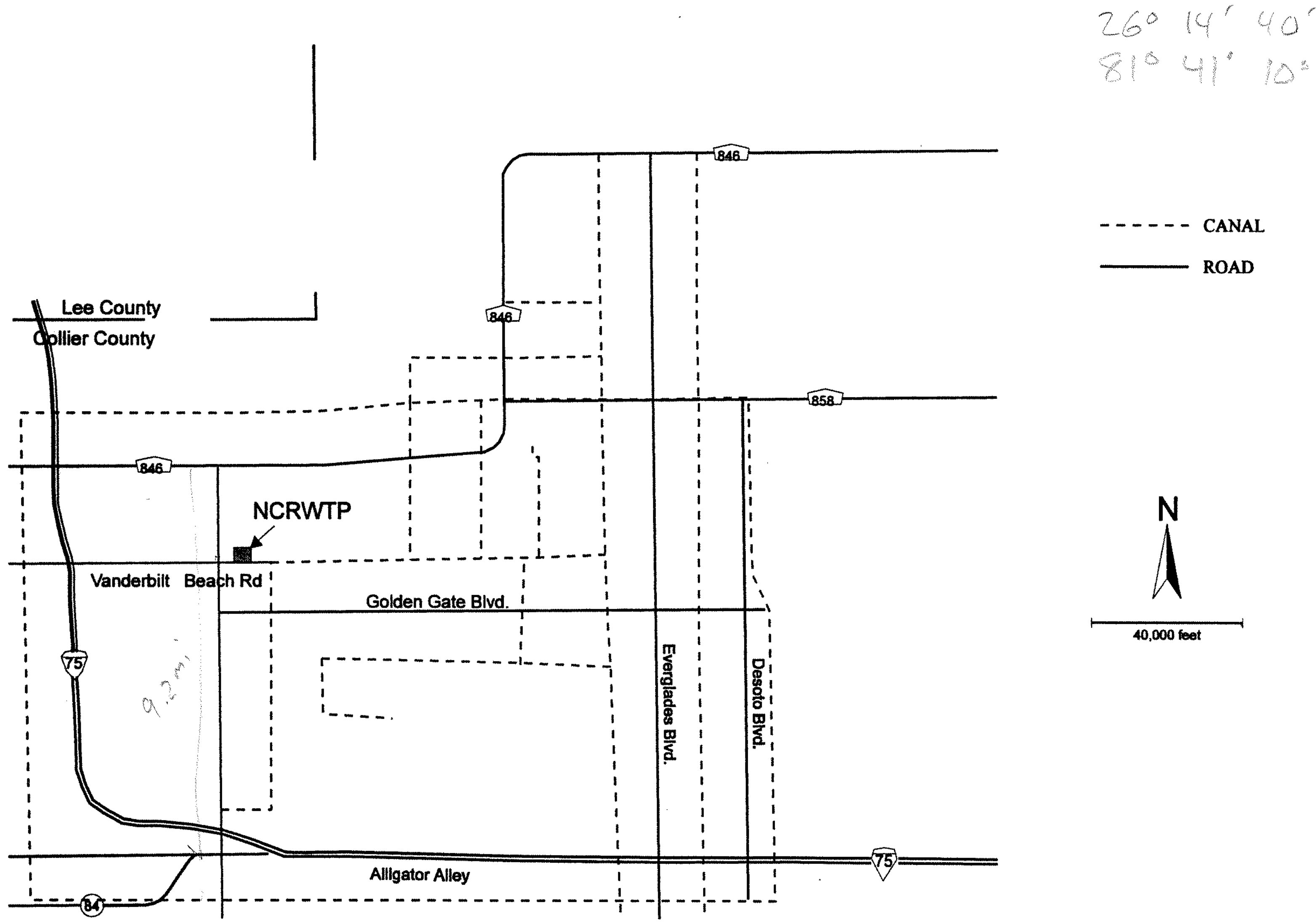
Missimer International was authorized by the Collier County Board of Commissioners on February 28, 1995, to provide consulting services for the design, permitting, construction oversight, and testing of one Class I injection well (IW-2) at the NCRWTP. The NCRWTP is located in the northwest corner of the Golden Gate Estates area of Collier County, as shown in Figure 1.

Injection well IW-2 is designed to dispose of membrane reject concentrate at a maximum rate of 6.3 MGD, which is equivalent to approximately 4,400 gallons per minute (GPM). Injection well IW-2 will provide 100% redundancy capacity for well IW-1.

1.3 Project Description

The application for the Florida Department of Environmental Protection (FDEP) Injection Well Construction permit was submitted in September, 1991. The FDEP issued construction permit # UC11-203675 on July 30, 1992 for the construction and testing of one Class I injection well. The permit will expire on July 30, 1997, thereby requiring the obtainment of an Operational Permit prior to the expiration date. A copy of the well construction permit and related correspondences are included in Appendix A.

Construction of injection well IW-2 began in November, 1995. Youngquist Brothers, Inc., was contracted to perform the drilling and testing of the well. The injection well, wellhead, hydropneumatic system and associated piping, were completed in April, 1996. FDEP approval for operational testing was granted on May 21, 1996, and the well was put into operation on May 30, 1996. The entire drilling and construction program was overseen by the FDEP Technical Advisory Committee (TAC), which was composed of representatives of the FDEP, South Florida Water Management District



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Pr. Name:	COLLIER COUNTY NCRWTP IW2		
Pr. No. FH4-68	DWG No. AO - 1	Date: 7/8/96	

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FIGURE 1. Site Location Map

(SFWMD), U.S. Environmental Protection Agency (USEPA) and U.S. Geological Survey (USGS). Daily activity logs, weekly construction summaries and other pertinent information were submitted to the TAC weekly. Copies of the weekly TAC letters are provided in Appendix B and copies of the weekly construction summaries are included in Appendix C. The TAC also met periodically to review construction progress and to approve specific seat casing depths and testing programs.

Construction and testing of injection well IW-2 was performed in accordance with Florida Administrative Code (FAC) Chapter 62-528 (Underground Injection Control), the conditions of the FDEP construction permit, and the technical specifications prepared by Missimer International, Inc., and approved by the TAC.

2.0 GEOLOGY AND HYDROGEOLOGY

2.1 Geology

The geology and hydrogeology of Collier County has been described in a number of investigations originated by the U.S. Geological Survey, the South Florida Water Management District, academic research, and by various consultants, including Missimer International. The stratigraphic terminology used in this report, which is summarized in Figure 2, conforms to that given in the Florida Geological Survey Special Publication 28 and Bulletin 59 (Scott, 1988). The limestone classification scheme of Dunham (1962) was used to describe the cuttings and cores recovered from injection well IW-2. A partial bibliography is given at the end of this report (Chapter 6). A geologic column with construction data for injection well IW-2 is provided in Plate 1 and a composite geophysical log for IW-2 is provided in Plate 2 (in envelope, back cover).

A brief description of the geologic formations, aquifers, and confining beds encountered during the drilling of injection well IW-2 is provided below. The geologic and hydrogeologic units are described from youngest to oldest. A geologist log for well IW-2 is included in Appendix D.

Pamlico Sand

The uppermost formation encountered in the Golden Gate Estates area is the Pamlico Sand. The Pamlico Sand is Late Pleistocene-aged and is present at the surface of much of South Florida. This unit ranges in thickness up to about 6 feet at the NCRWTP. The Pamlico Sand consists predominantly of fine to medium-grained quartz sand, with lesser amounts of shell, detrital clays and organic constituents. Permeability is generally medium to low (10 to 100 ft/day) depending on the quantity of secondary constituents.

SYSTEM	SERIES		LITHOSTRATIGRAPHIC UNIT	HYDROSTRATIGRAPHIC UNIT	
QUATERNARY	HOLOCENE		UNDIFFERENTIATED PLEISTOCENE-HOLOCENE SEDIMENTS	SURFICIAL AQUIFER SYSTEM	
	PLEISTOCENE				
TERTIARY	PLIOCENE		TAMIAMI FORMATION		
	MIOCENE		HAWTHORN GROUP	INTERMEDIATE CONFINING UNIT OR AQUIFER SYSTEM	
	OLIGOCENE		SUWANNEE LIMESTONE	FLORIDAN AQUIFER SYSTEM	UPPER FLORIDAN AQUIFER SYSTEM
	EOCENE	UPPER	OCALA LIMESTONE		
		MIDDLE	AVON PARK FORMATION		MIDDLE CONFINING UNIT
		LOWER	OLDSMAR FORMATION		LOWER FLORIDAN AQUIFER SYSTEM
	PALEOCENE		CEDAR KEYS FORMATION		
CRETACEOUS AND OLDER			UNDIFFERENTIATED	SUB - FLORIDAN CONFINING UNIT	

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Pr. Name: COLLIER COUNTY NCRWTP

Pr. No. FH4 - 68 DWG No. TBL - 1 DWG Date: 6/19/96

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FIGURE 2. Lithostratigraphic and hydrostratigraphic nomenclature for southern Florida

Ft. Thompson/Tamiami Formation (Undifferentiated)

The Pamlico Sand is underlain by the Pleistocene-aged Fort Thompson Formation in southwestern Florida. The lithology of the Fort Thompson Formation is highly variable and includes fresh-water, marine, and brackish water limestones, marls, sands, and shells. In northwest Collier County, the Fort Thompson Formation consists primarily of hard sandy limestone and calcareous sandstone that contains pockets of quartz sand and thin beds of dense fresh-water limestone.

The Pliocene-aged Tamiami Formation, which unconformably lies below the Fort Thompson Formation, is also lithologically highly variable. At least nine mappable members or facies have been identified in the Tamiami Formation in southwestern Florida, which include such diverse lithologies as marls, sands and sandstones, dolosilt, and limestone (Missimer, 1992). The three member units recognized in the NCRWTP area are, in order of increasing depth, the Pinecrest Limestone, the Bonita Springs Marl, and the Ochopee Limestone. The formal name, Pinecrest Sand Member of the Tamiami Formation, was introduced by Hunter (1968) to name late to middle Pliocene shelly sands in Monroe, eastern Collier, Glades, and southern Highlands counties. According to Meeder (1979), Pliocene reefal limestones of Collier and southern Lee counties are facies equivalent with the Pinecrest Sand Member and in this report are referred to as the Pinecrest Limestone Member of the Tamiami Formation.

The undifferentiated Fort Thompson Formation and Pinecrest Limestone in the NCRWTP site area consists of sandy, highly fossiliferous limestones that contain varying quantities of mollusk shells, corals, bryozoans, and barnacles. The dissolution of aragonitic shells in the limestone locally results in greatly enhanced porosity and permeability. Trenching and dewatering during the construction of the water treatment plant exposed some good subcrops of the undifferentiated Fort Thompson/Pinecrest unit, in which several small karstic features were observed at the top of the limestone.

These karstic features contribute greatly to the flow of water through this unit.

A thin sequence of gray marls lies between the Pinecrest and Ochopee Limestone Members of the Tamiami Formation. This unit is referred to in this report as the Bonita Springs Marl Member of the Tamiami Formation. The Bonita Springs Marl is actually a sandy, sometimes shelly, carbonate clay. The amount of fine-grained quartz silt and sand varies from 10 to 30 percent. The overall thickness of the unit is variable. The overall permeability of this unit is low, with the actual value varying with the proportion of sand and other impurities. The Bonita Springs Marl Member is only 5 feet thick at the NCRWTP site.

The Ochopee Limestone Member of the Tamiami Formation was named by Mansfield (1939) for the light gray to white sandy fossiliferous limestone that crops out near the town of Ochopee in Collier County (Hunter, 1968). The Ochopee Member typically has an extensive development of secondary porosity formed by the dissolution of the aragonitic shells of mollusks. The large interconnected molds gives the unit a very high permeability. Thin beds of sandstone and marl are present near the base of the member. The undifferentiated Fort Thompson Formation and Tamiami Formation is approximately 195 feet thick in IW-2.

Hawthorn Group

The Miocene-aged Hawthorn Group lies unconformably beneath the Tamiami Formation. The Hawthorn Group is regionally extensive and underlies most of Florida and parts of Georgia and South Carolina. It is a lithological diverse unit that contains varying sequences of limestones, dolomites, sands, sandstones, marls, clays, and phosphates. The commonly high phosphate concentration of numerous beds within the Hawthorn Group results in these beds having a high gamma ray log response. In southern Florida, the Hawthorn Group is subdivided into two formations: the Peace

River Formation and the underlying Arcadia Formation.

The contact between the Tamiami Formation and the Peace River Formation occurs at approximately 200 feet bls at the NCRWTP and is marked by a lithological transition downward from fossiliferous limestone to fossiliferous fine-grained quartz sandstone. The upper Peace River Formation sandstone interval is approximately 50 feet thick. The middle and lower parts of the Peace River Formation consist predominantly of olive gray and greenish-gray dolomitic and phosphatic marls and clays with subsidiary limestone beds. The marls and clays are soft (plastically deformable) and have very low permeabilities. The Peace River Formation is approximately 200 feet thick in the NCRWTP area.

The boundary between the Peace River Formation and the underlying Arcadia Formation occurs at approximately 400 ft bls. The formation boundary is marked in the Golden Gate Estates area by a sharp downward lithological change from dark greenish-gray phosphatic clay to very light gray to yellowish-gray fossiliferous limestone. The Arcadia Formation contains a complex assemblage of carbonate and siliciclastic units including light-colored fossiliferous limestones, clay and marl beds, and olive gray and yellowish brown dolomite beds. The limestones consist mostly of fossiliferous mudstones to packstones, in which mollusks are the most abundant fossil types. Coral fragments were abundant between 650 ft bls and 668 ft bls. Cemented carbonate sands (grainstones) are absent or rare.

The dolomite in the Arcadia Formation is mostly finely crystalline and very hard. The dolomite beds may have very high permeabilities due to the presence of fractures and/or cavernous horizons. The dolomites between 710 ft bls to 830 ft bls in particular appear to be highly fractured and/or contain cavernous intervals, as indicated by the caliper and sonic logs. The Arcadia Formation is approximately 490 feet thick at the NCRWTP.

Suwannee Limestone

The upper boundary of the Oligocene-aged Suwannee Limestone occurs at approximately 890 ft bls and is marked by a downward change from phosphatic limestones, dolomites, and marls/clays, to light-colored (yellowish gray to very pale orange), non-phosphatic, fossiliferous peloidal limestones. The limestones of the Suwannee Limestone consist mostly of poorly to moderately well-cemented carbonate sands that are texturally classifiable as packstones and grainstones. Foraminifera are the most abundant fossils in the Suwannee Limestone, whereas foraminifera are relatively uncommon in the Hawthorn Group. Echinoderm and mollusk fragments are also common in the Suwannee Limestone. The contact between the Arcadia Limestone and the Suwannee Limestone can be readily identified on natural gamma ray logs by an attenuation in the log response, which reflects the lower phosphate concentration of the Suwannee Limestone.

Porosity in the Suwannee Limestone is relatively high (30-45%) and is mostly intergranular. The lower half of the formation has a somewhat higher phosphate concentration, which is manifested by a higher gamma ray log response. The Suwannee Limestone is approximately 410 feet thick in the NCRWTP area.

Ocala Limestone

The contact between the Late Eocene-aged Ocala Limestone and the Suwannee Limestones occurs at approximately 1300 feet in wells IW-1 and IW-2. The Ocala Limestone-Suwannee Limestone boundary is subtle in the NCRWTP area and is marked by a transition from mostly yellowish gray to predominantly very pale orange and white limestone. The Ocala Limestone in IW-2 consist mostly of fossil peloid grainstones whereas the immediately overlying lower Suwannee Limestone consist mostly of packstones. The greater purity of the Ocala Limestone compared to the

Suwannee Limestone is manifested by a slight reduction in gamma ray log response.

A general characteristic of the Ocala Limestone is an abundance of large foraminifera tests, such as Operculinoides sp., Nummulites sp., and Lepidocyclina sp. Large foraminifera tests were not particularly abundant in the IW-2 cuttings. The fossils of the upper Ocala Limestone in IW-2 consist mostly of mollusk shells and echinoid spines.

The Ocala Limestone was subdivided into three distinct units by Puri (1957) when it was elevated to group status. These three formations are not readily apparent in the subsurface of the NCRWTP area or all of peninsular Florida and therefore group status has recently been abandoned. The Ocala Limestone is approximately 380 feet thick in IW-2.

Avon Park Formation

The top of the Middle Eocene-aged Avon Park Formation occurs at approximately 1678 feet in well IW-2. The boundary between the Ocala Limestone and Avon Park Formation is also subtle. The uppermost Avon Park Formation consists of light-colored fossil peloid packstones and/or grainstones and is thus lithologically very similar to the limestones of the Ocala Limestone. The upper Avon Park Formation however also contains some pale yellowish brown limestones and yellowish gray marl beds, which are absent or rare in the Ocala Limestone. The Ocala Limestone-Avon Park Formation boundary can best be identified in southwest Florida by a marked downhole increase in activity on the gamma ray log.

The echinoid Neolaganum dali was found by Vernon (1951) to be very abundant in the upper 50 feet of the Avon Park Formation in Florida peninsula wells. Echinoid fragments were observed in the sample from 1680 to 1690 ft bls in well IW-2 and the above noted centimeter-sized echinoid was common in the IW-2 cuttings from 1690 to 1730 ft bls, thus confirming the approximate position of the Ocala Limestone-Avon Park Formation boundary at about 1678 ft bls.

The Avon Park Formation is a lithologically diverse unit. The bulk of the Avon Park Formation in well IW-2 consists of very pale orange to yellowish brown-colored limestones that are classified as fossil peloid or fossil packstones and grainstones. Foraminifera are the most abundant fossils. The distinctive cone-shaped dictyoconid foraminifera are very abundant in parts of the Avon Park Formation. Dolomite beds are present throughout the Avon Park Formation but overall comprise less than 10% of the formation. The dolomite beds are pale to moderate yellowish brown or light olive gray and have lower porosities than the limestone beds. The Avon Park Formation is approximately 534 feet thick in well IW-2.

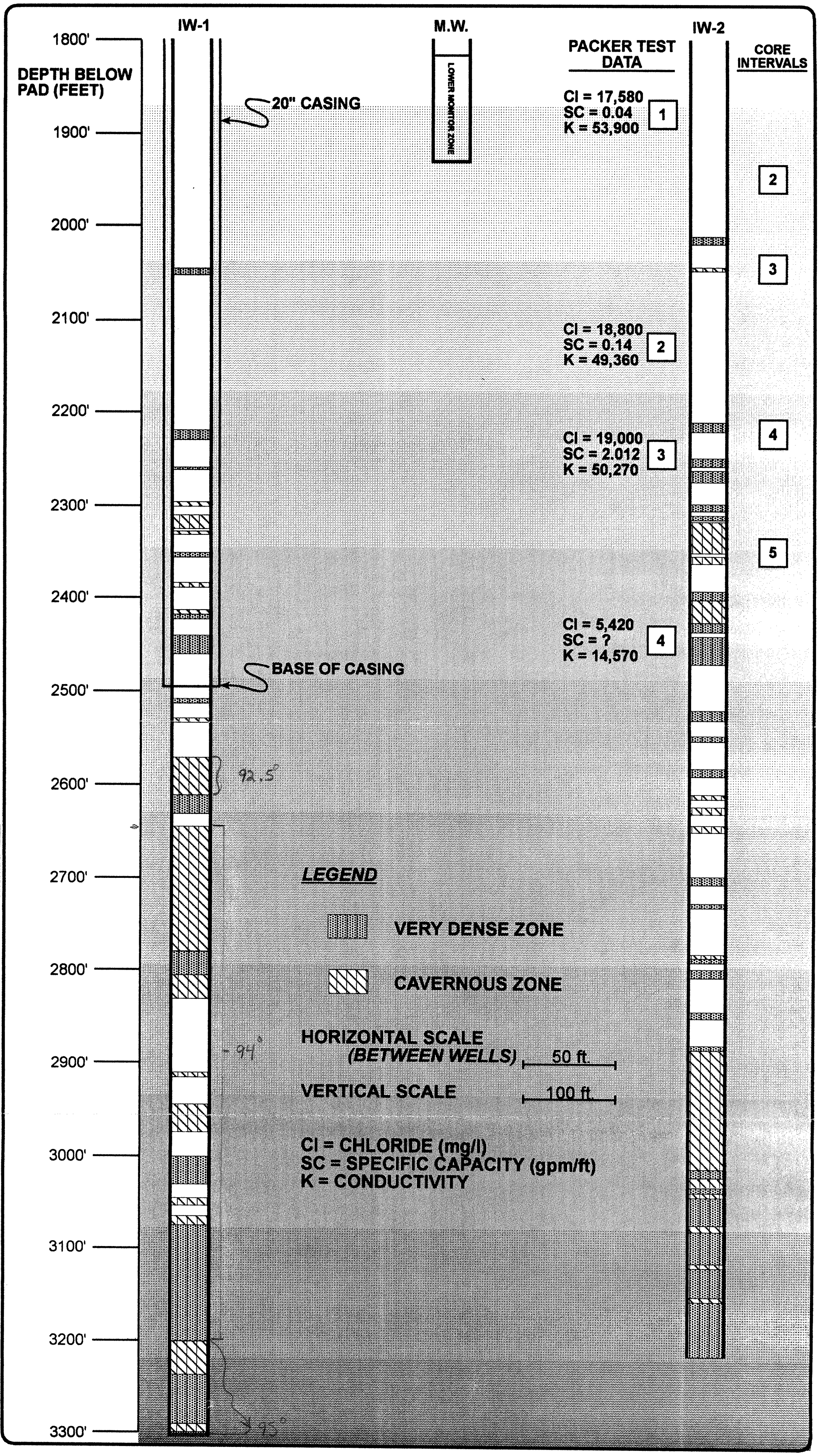
Oldsmar Formation

The Oldsmar Formation consists predominantly of early Eocene-aged limestones and dolomites. Limestone and dolomite are subequally abundant in the upper half of the formation, whereas the lower half of the formation consists primarily of dolomite. The boundary between the Avon Park Formation and the Oldsmar Formation occurs at approximately 2212 ft bls in injection well IW-2. The top of the Oldsmar Formation in IW-2 is marked by the first appearance of a thick (5+ feet) bed of dark-colored dolomite. The Avon Park-Oldsmar Formation contact can be identified in geophysical logs by an abrupt a downhole increase in gamma ray activity, decrease in sonic travel time (and sonic porosity), and increase in resistivity.

The limestones of the upper Oldsmar Formation are compositionally and texturally similar to the Avon Park Formation limestones. The bulk of the limestones consists of very pale orange to pale yellowish brown fossil peloid packstones and grainstones, in which foraminifera are the most abundant identifiable fossils. The Oldsmar Formation dolomites range in color mostly from dark yellowish brown to dark gray. The dolomites from about 2920 ft bls to 3200 ft bls are somewhat lighter colored than then overlying dolomites. The Oldsmar dolomites are microcrystalline to finely crystalline, very hard, and have a low matrix porosity and permeability. Vugs and cavernous zones are present in the dolomite, which are interconnected to varying degrees.

Commonly occurring within the Oldsmar Formation in southern Florida is an extremely permeable zone that is referred to as the "Boulder Zone". The Boulder Zone consists of intervals of cavernous and fractured dolomites that have very high transmissivities and porosities. The term Boulder Zone was first used by drillers exploring for oil to describe a zone that reacts in a manner similar to drilling through alluvial boulders. The name is misleading because the zone does not contain boulders, but instead an intricate network of vugs, fractures, and caverns. Haberfeld (1991) states that the highly permeable Boulder Zone can be recognized on geophysical logs by greatly enlarged hole sizes on the caliper log, exceedingly long sonic transit times, very low resistivity, and changes on temperature and flowmeter logs. Hickey (1990) suggested that the Boulder Zone consists of highly fractured dolomites and that the cavities develop only after drill bit penetration.

The distribution of cavernous zones in the injection zones of injection wells IW-1 and IW-2 is illustrated in Figure 3. The location of cavernous intervals is highly variable in both the vertical and horizontal direction. For example, a 270 foot thick interval containing large cavernous zones is present in the NCRWTP injection well IW-1 from 2560-2830 ft bls, which is absent 280 feet away in well IW-2. The major cavernous interval encountered in well IW-2 are summarized below:



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Pr. Name: Collier County NCRWTP
Pr. No. FH4-68 DWG No. 1 Date: 4/21/96

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FIGURE 3. Collier County North County Regional Water Treatment Plant: IW-1 and IW-2 Injection Zone Comparison

Cavernous Interval	Vertical Extent (feet)		Depth Below Casing
	Unit	Cumulative	
2318-2356	38	38	Above casing
2404-2420	16	54	Above casing
2886-3018	132	186	388

The cavernous interval from 2886 to 3018 ft bls is the main injection zone in IW-2. The degree of hydraulic connection between the different cavernous intervals could be evaluated during the drilling and testing of well IW-2 because the injectate bubble from well IW-1 is less saline and cooler than the displaced Oldsmar groundwater. The injectate from IW-1 was detected in the cavernous zones at 2404-2420 ft bls and 2886-3108 ft bls, but not in the 2318-2356 ft bls cavernous zone. The latter zone is thus not connected to the well IW-1 and IW-2 injection zones.

Injection well IW-2 did not penetrate the contact between the Oldsmar Formation and the underlying Paleocene-aged Cedar Keys Formation. The contact between the two formations was located at 3370 ft bls in well IW-1. The Cedar Keys Formation is composed of essentially unfossiliferous gypsum, anhydrite, and microcrystalline dolomite.

2.2 Hydrogeology

The hydrogeology of the northwest Collier County is characterized by three major aquifer systems: the Surficial Aquifer System, the Intermediate Aquifer System, and the Floridan Aquifer System. These three principal aquifer systems, when combined, extend from the water table, located several feet below land surface, to the near the top of the Cedar Keys Formation, located at approximately 3370 feet bls. The three principal aquifer systems contain numerous individual aquifers that are separated by intervening low permeability confining units.

Surficial Aquifer System

The Surficial Aquifer System in the NCRWTP area extends from the water table down to a depth of approximately 270 feet bls. The base of the Surficial Aquifer System is located at the top of the uppermost thick (> 1 foot) continuous marl bed in the upper Peace River Formation. The Surficial Aquifer System thus includes the Pamlico Sand, undifferentiated Fort Thompson Formation and Tamiami Formation, and part of the Peace River Formation (approximately 70 feet in IW-2). Thin marl units form semi-confining beds at several horizons within the aquifer system. Domestic wells in the Golden Gate Estates area tap the upper part of the Surficial Aquifer System. The domestic wells generally have sufficient yields and water quality. The lower aquifer units of the Surficial Aquifer System contain brackish water that is not potable without treatment.

Intermediate Aquifer System

The Intermediate Aquifer System (sometimes referred to as the Intermediate Confining Unit) lies between the Surficial Aquifer System and the Floridan Aquifer System. The base of Intermediate Aquifer System at the NCRWTP extends from approximately 270 ft bls to 710 ft bls. The base Intermediate Aquifer System is placed at the bottom of the lower Hawthorn confining unit, which in the NCRWTP area would be lowest thick continuous marl or clay bed in the lower Arcadia Formation. The Intermediate Aquifer System contains several limestone aquifers separated by clay or marl confining units. The water in the Intermediate Aquifer System aquifers is brackish and requires desalinization in order to be used as potable water source.

Floridan Aquifer System

The top of the Florida Aquifer System occurs at approximately 710 ft bls at the NCRWTP site. It is one of the most productive aquifers in the United States and underlies all of Florida and parts of Georgia and South Carolina for a total area of about 100,000 square miles. The Floridan Aquifer System consists of an extensive sequence of thickly bedded Tertiary-aged limestones and, less abundantly dolomites, that are connected to varying degrees. The system includes the lower part of the Hawthorn Group (lower Arcadia Formation), the Ocala Limestone, the Avon Park Formation, and the Oldsmar Formation. The base of the Floridan Aquifer System is generally placed at the top of the uppermost evaporite bed in the Cedar Keys Formation. All of the water in the Floridan Aquifer System in southern Florida is of brackish to marine quality.

Confining units within the Floridan Aquifer System in southwestern Florida vary greatly in thickness and vertical continuity. Thin clay beds may provide a much higher degree of confinement than much thicker marly and/or dense limestones. Dolomite beds with common vugs or small cavities may be very effective confining units or may have high permeabilities depending upon the degree to which the vugs or cavities are interconnected. The microcrystalline dolomite matrix in general has very low porosities and permeabilities. Vertical fractures and solution features are locally present within apparent confining units, which may result in high degrees of connections between aquifers.

The Floridan Aquifer System can be subdivided into three main units based on their relative permeabilities, the Upper Floridan Aquifer, the Middle Confining Unit, and the Lower Floridan Aquifer. The Upper Floridan Aquifer consists of porous limestones and, to a lesser degree, dolomites that are part of the lower Arcadia Formation, Suwannee Limestone, and upper part of the Ocala Limestone. The uppermost unit of the Upper Floridan Aquifer is the lower 180 feet of the Arcadia Formation of the Hawthorn Group, which consists of approximately 120 feet of dolomite underlain by fossiliferous limestones (mudstones to packstones). The dolomites appear to be fractured in places, with corresponding high transmissivities. The remainder of the aquifer consists of primarily of fossiliferous peloidal packstones and grainstones with relative high porosities (35-45%, from sonic logs). The base of the Upper Floridan Aquifer in injection well IW-2 is located at approximately 1440 ft bls, at which depth there is a general decrease in porosity. The Upper Floridan Aquifer is approximately 730 feet thick in well IW-2.

The base of the "Underground Source of Drinking Water" (USDW) is located in the lower Suwannee Limestone at approximately 1190 ft bls. A USDW is defined as an aquifer containing water with less than 10,000 milligrams per liter (mg/l) of total dissolved solids (TDS).

The Middle Confining Unit extends from approximately 1440 ft bls to the top of the first cavernous dolomite unit in the upper Oldsmar Formation, which in well IW-2 is located at approximately 2310 ft bls. The composite thickness of the Middle Confining Unit in IW-2 is approximately 870 feet. The Middle Confining Unit consists mostly of fossiliferous limestones with less abundant dolomite beds. The porosity and permeability of the individual beds of the Middle Confining Unit is variable, but the overall vertical hydraulic conductivity of the unit is low enough to prevent the migration of fluids between the Upper and Lower Florida Aquifers. Results of the tests and surveys performed to demonstrate confinement are presented in Section 4.8.

The Lower Floridan Aquifer includes the lower two thirds of the Oldsmar Formation. In well IW-2 it extends from approximately 2310-3370 ft bls. The Boulder Zone is the principal high transmissivity zone in the Lower Floridan Aquifer and has been used for the underground disposal of various types of waste water since 1943. Transmissivities for some of the dolomites of the Boulder Zone have been reported to be as high as (2.46 x 10^7 ft^2/day (Singh and other, 1983). Water quality and temperature data indicates that the upper 94 feet (2310-2404 ft bls) of the Lower Floridan Aquifer in well IW-2 is not hydraulic connected to the underlying Boulder Zone injection intervals (see Section 4.8). Groundwater within the Lower Floridan Aquifer is chemically very similar to seawater. Temperature of the water measured at a depth of approximately 2500 ft bls is about 92°C.

3.0 WELL DESIGN AND CONSTRUCTION

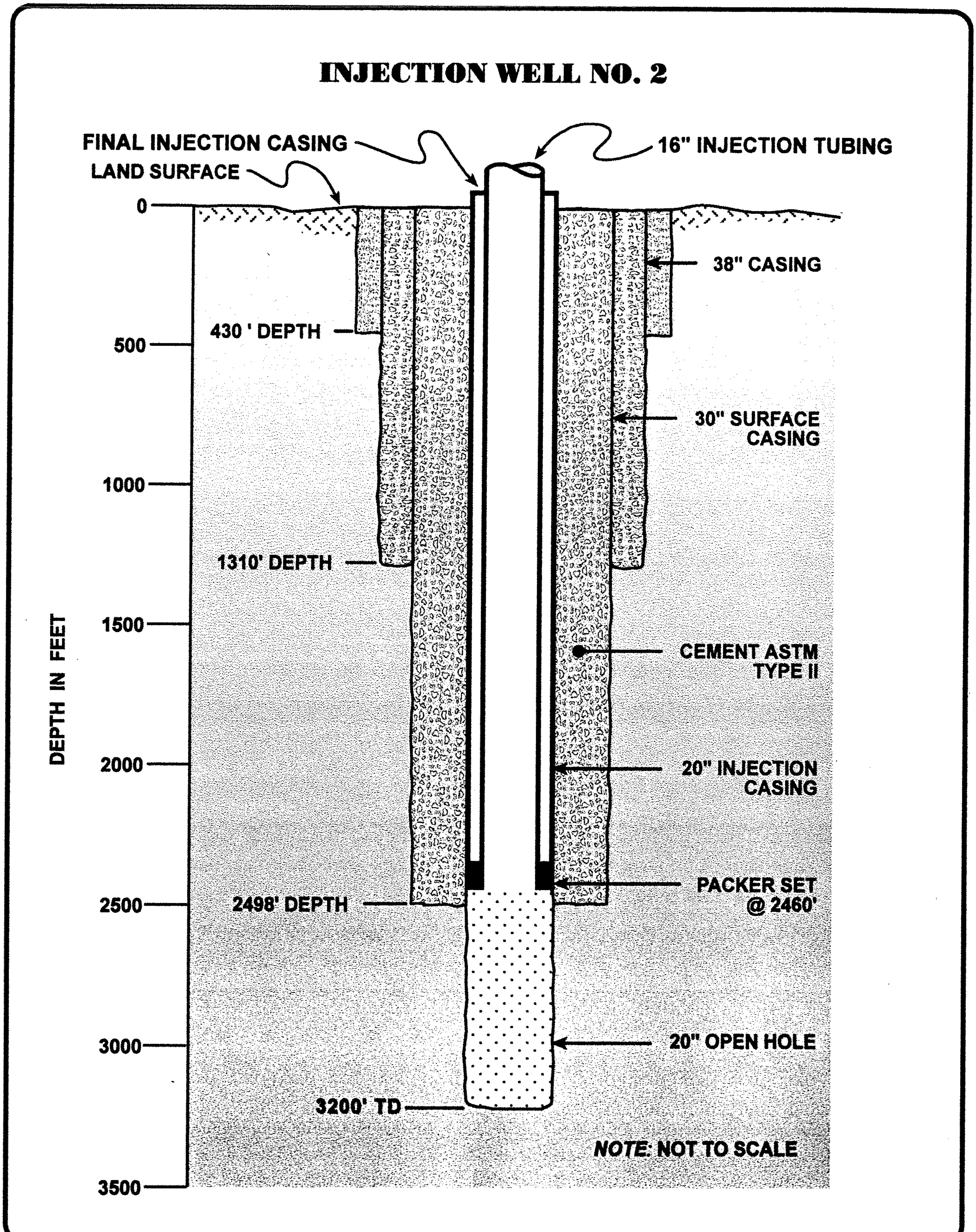
3.1 Well Design

Injection well IW-2 was designed, constructed, and tested in accordance with the requirements of Chapter 62-528 of the Florida Administrative Code. The preliminary design of injection well IW-2 was based upon the successful design of well IW-1. An application for a construction permit was submitted to the FDEP in September 1991. Final technical specifications for well IW-2, which incorporated additions and deletions requested by the TAC, were submitted to the FDEP in December 1991. The FDEP construction permit was issued on July 30, 1992 and is valid for a five (5) year period.

Injection well IW-2 is of the tubing and packer design. The injection casing is 20-inches in diameter and extends down to a depth of 2498 ft bls. The injection tubing with the attached packer is 16 inches in diameter and extends down to 2460 ft bls. The injection zone is of open hole design and extends from the base of the injection casing down to a depth of 3210 ft bls. Maximum permittable capacity of the well is approximately 6.3 million gallons per day (MGD) of WTP concentrate based on the tubing diameter and design standard flow velocity of 8 feet per second. A well construction diagram is provided in Figure 4 and a detailed construction description is provided below. Diagrams and photographs of the wellhead and hydropneumatic system are provided in Figures 5 and 6

3.2 Site Preparation.

The drilling contractor, Youngquist Brothers, Inc., was given notice to proceed with construction on October 30, 1995, and began mobilizing and preparing the site on November 2, 1995. Before construction of the drilling pad could begin, a storm water retention area located immediately southeast of the injection well IW-2 location had to



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Pr. Name: NCRWTP IW-2
Pr. No. FH4-68 DWG No. 1 Date: 4/20/96

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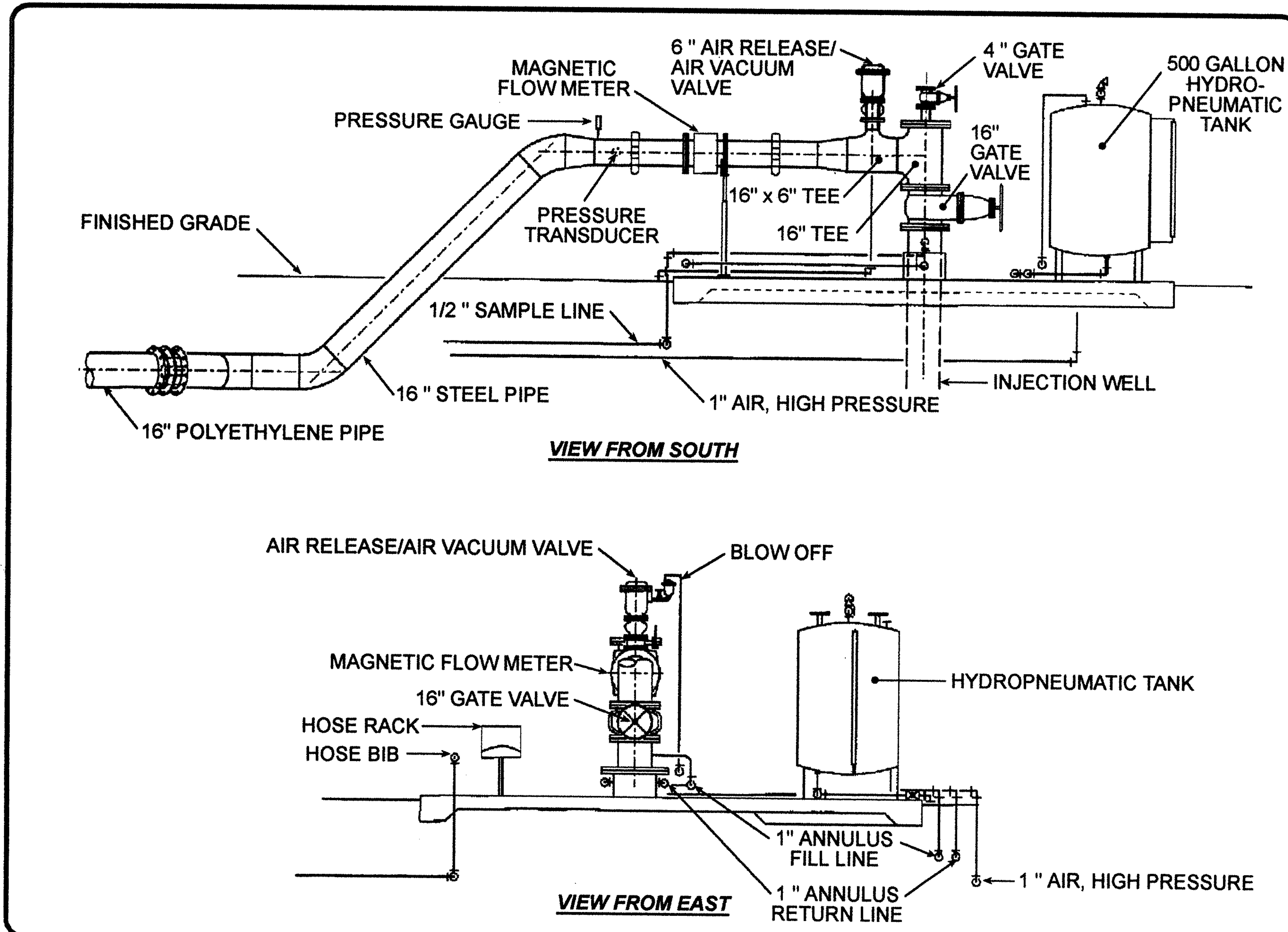
FIGURE 4. Injection Well IW-2 Construction Diagram



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Pr. Name: COLLIER COUNTY NCRWTP				
Pr. No. FH4-68	**DWG No.** FF-5	**DWG Date:** 7/12/96	**Rev.No.**	

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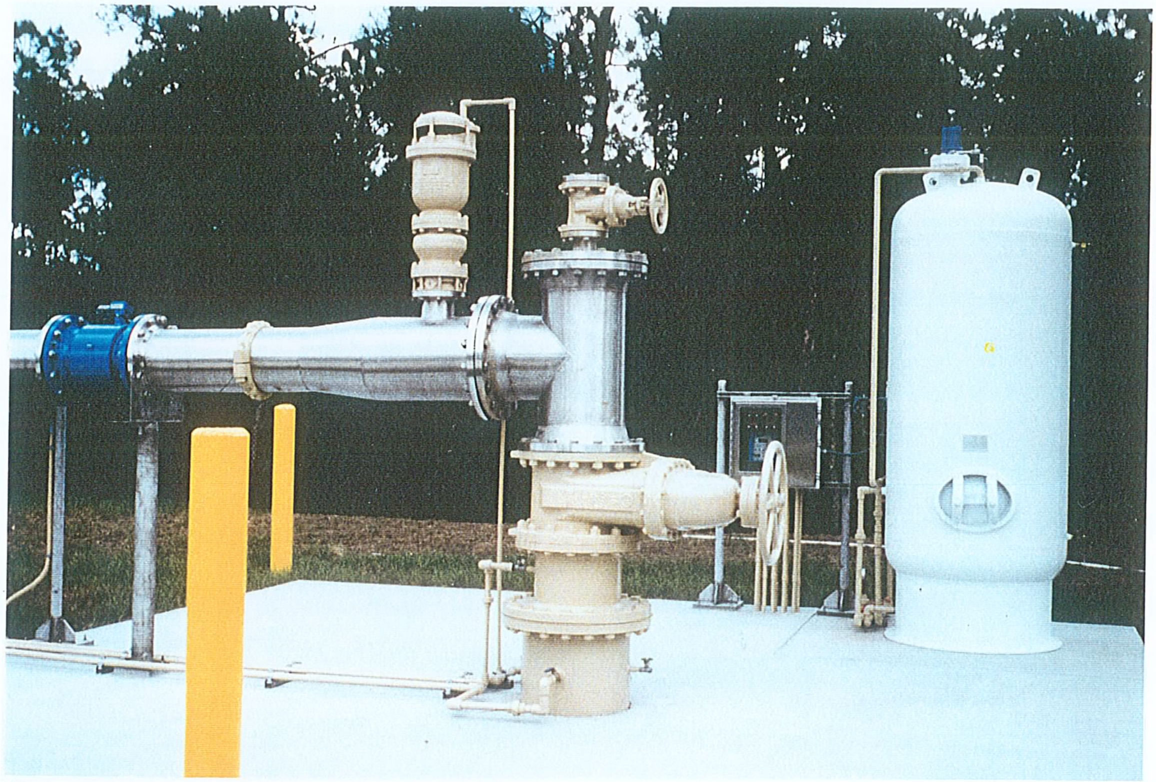
FIGURE 5. Wellhead and Hydropneumatic System Diagram



WELLHEAD AND HYDROPNEUMATIC TANK

MAGNETIC FLOW METER

MISSIMER INTERNATIONAL, INC.	Pr. Name: COLLIER COUNTY NCRWTP	Groundwater and Environmental Services
	Pr. No. FH4-68 DWG No. FF-6 Date: 7/8/96	

FIGURE 6. Wellhead and Hydropneumatic System

be filled to grade and a new temporary retention pond constructed near the southeast corner of the water treatment plant site (Figure 7). The retention pond was filled with clean sand and soil hauled in from an off-site source.

Four shallow monitor well were constructed near the corners of the staked off drilling pad site between November 7 and 16, 1995. These wells were installed so that the water table aquifer could be tested during drilling for increases in salinity resulting from spilled saline water. The shallow monitor wells were installed by West Coast Drilling, Inc., using the mud rotary method. The shallow monitor wells were 15 to 18 feet deep and were constructed of 4-inch diameter schedule 40 polyvinyl chloride (PVC) with 10 feet of 0.032-inch machine-slotted screen and 5 to 8 feet of solid riser. A 6/20 grade quartz sand filter pack was installed around the screen, which was sealed with a sand/clay layer and neat Portland cement. Youngquist Brothers installed a steel protective casing around each well. All 4 wells were sampled weekly for temperature, conductivity, and chloride concentration and water levels were measured by an on-site Missimer International hydrogeologist. Three (3) well volumes of water were purged from each well prior to sampling to ensure collection of representative groundwater samples.

Construction of the drilling pad began on November 9, 1995. The drilling pad was approximately 70 ft by 80 ft in lateral dimensions and constructed of steel reinforced concrete. The pad thickness varied from approximately 6-inches to 12-inches depending on how much support was required. After mobilizing the drilling equipment (Figure 8), a two foot high concrete block retaining wall was installed around the boundary of the drilling pad to contain potential spills of water and/or drilling fluids.

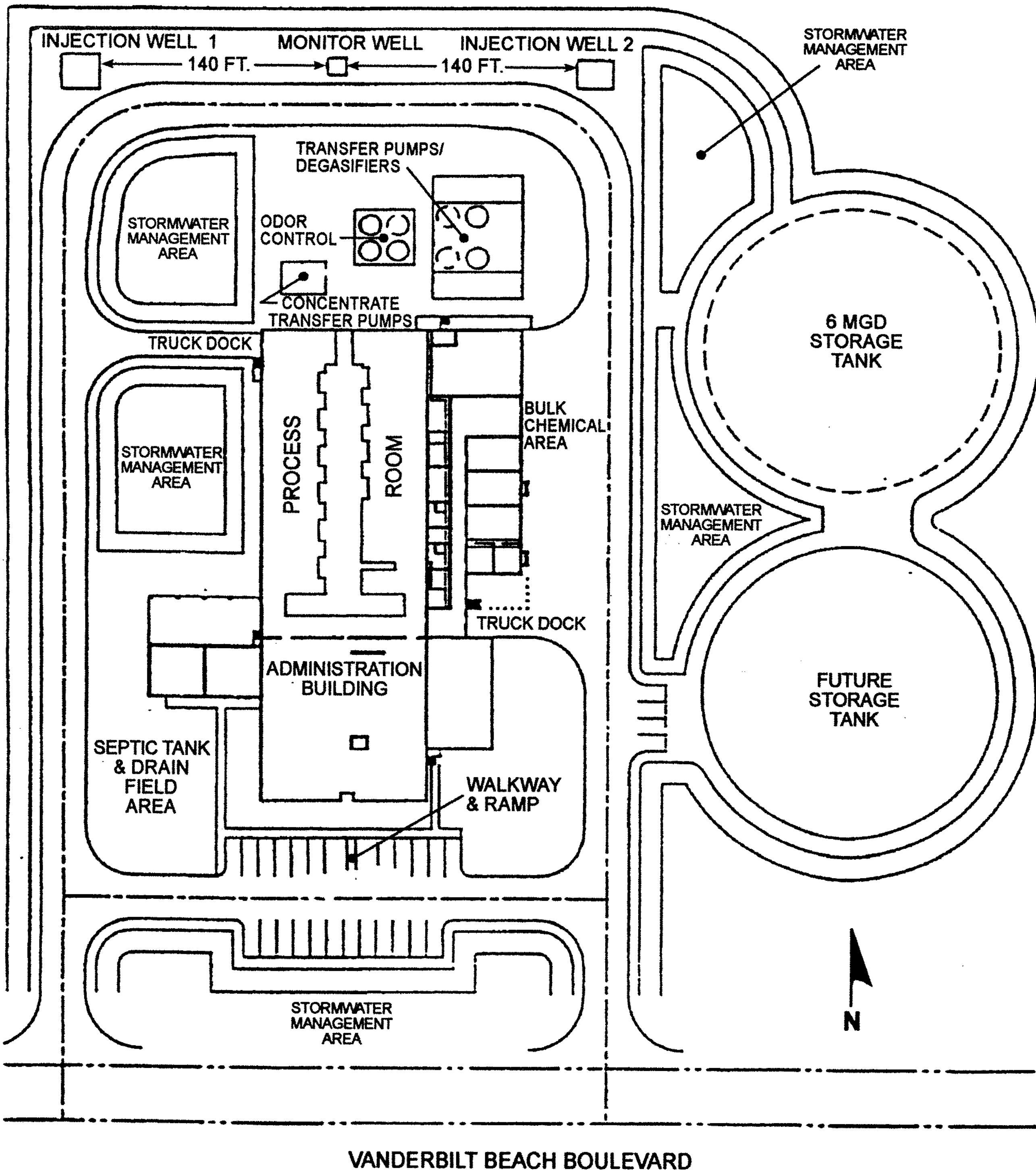


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FIGURE 7. Site Plan

MISSIMER INTERNATIONAL, INC.

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FIGURE 8. Youngquist Brothers Drilling Rig

3.3 Injection Well Construction

Youngquist Brothers began construction of injection well IW-2 on November 20, 1995. when a 51-inch diameter pit casing was installed to a depth of 17 ft Bls. The next day, the drilling began, using the mud rotary method, of a 48-inch borehole through the Surficial Aquifer System and the Peace River Formation of the Hawthorn Group to a total depth of 430 ft Bls. The reverse air drilling method was used for the remainder of the well construction. A chronology of the well construction and testing is provided in Table 1.

3.3.1 Casing, Tubing, and Packer

The 38-inch diameter conductor casing and 30-inch diameter surface casings are spiral welded carbon steel conforming to ASTM A139 Grade B standards with a wall thickness of 0.375 inches. The 20-inch diameter injection casing and 16-inch diameter injection tubing are seamless carbon steel conforming to ASTM A53 Grade B standards with a wall thickness of 0.500 inches. Casing ends were beveled for butt welding by certified welders using the wire-feed method. All casings were fitted with Halliburton-type centralizers by welding at 0, 90, 180, and 270 degrees around the casing at each position. The centralizers were either located at the specific intervals stated in Section 04020 of the Technical Specifications or at alternative intervals determined by examination of the caliper logs.

The 38-inch diameter conductor casing was set at 430 ft bls, just below the top of the Arcadia Formation of the Hawthorn Group. The 30-inch diameter surface casing was installed to isolate the USDW aquifers from the more saline water in the underlying aquifers. The bottom of the 30-inch diameter surface casing was set at 1310 ft bls, approximately 120 feet below the base of the USDW, which is located at approximately 1190 ft bls at well IW-2.

TABLE 1

WELL CONSTRUCTION CHRONOLOGY
COLLIER CO. NCRWTP INJECTION WELL IW-2

DATE*	EVENT
November 3 to 17, 1995	Construction of drilling pad
November 7 and 16, 1995	Installed perimeter shallow monitor wells around drilling pad
November 11 to 17, 1995	Set up drilling rig on concrete drilling pad.
November 20, 1995	Drilled 52.5-inch diameter hole to 17 ft BP (below pad) and set 17 ft of 51-inch diameter pit pipe in hole.
November 21, 1995	Conducted initial sampling of perimeter monitoring wells.
November 21, 1995	Drilled 48-inch diameter hole to 43 ft BP. Shut down for Thanksgiving.
November 27 to December 3, 1995	Drilled 48-inch diameter hole to 435 ft BP.
December 3 and 4, 1995	Set 38-inch diameter casing to 430 ft BP. Cemented annulus with 892.3 cubic feet of neat cement and 2245.8 cubic feet of 12% gel cement.
December 5 and 6, 1995	Drilled 12 1/4-inch diameter pilot hole to 1310 ft BP.
December 7, 1995	Ran caliper, gamma ray, sonic, dual induction, flowmeter and temperature logs.
December 7 and 8, 1995	Cemented pilot hole with 915 cubic feet of 25% gel and 1796 cubic feet of 12% gel cement.
December 11 to 17, 1995	Reamed 38-inch diameter hole to 1315 ft BP.
December 18, 1995	Ran caliper and gamma ray logs.
December 18, 1995	Set 30-inch diameter casing to 1310 ft BP.
December 18 to 21, 1995	Cemented annulus with approximately 8652 cubic feet of cement.
December 26 to 27, 1995	Drilled 12 1/4-inch diameter pilot hole to 1778 feet.
December 27, 1995	Core no. 1 was taken from 1778 ft BP to 1794 ft BP.
December 28, 1995	Drilled 12 1/4-inch diameter pilot hole to 1880 feet.

TABLE 1

WELL CONSTRUCTION SUMMARY (Continued)

DATE*	EVENT
December 28 and 29, 1995	Caliper and gamma ray logs were run and single packer test no. 1 was conducted from 1862 to 1880 ft BP.
December 30, 1995	Drilled 12 1/4-inch diameter pilot hole to 1910 feet.
December 30 and 31, 1995	Core no. 2 was attempted from 1910 to 1924 ft BP and from 1925 ft BP to 1940 ft BP, with very poor recovery both attempts. An adequate amount of core was recovered during the third attempt from 1952 ft BP to 1970 ft BP.
January 1, 1996	Drilled 12 1/4-inch diameter pilot hole to 2040 feet.
January 1, 1996	Core no. 3 was taken from 2040 ft BP to 2056 ft BP.
January 2, 1996	Drilled 12 1/4-inch diameter pilot hole to 2138 ft BP.
January 3, 1996	Caliper and gamma ray logs were run and single packer test no. 2 was conducted from 2116 ft BP to 2138 ft BP.
January 4, 1996	Drilled 12 1/4-inch diameter pilot hole to 2213 ft BP.
January 4, 1996	Core no. 4 was taken from 2213 ft BP to 2229 ft BP.
January 5, 1996	Drilled 12 1/4-inch diameter pilot hole to 2259 ft BP.
January 5 to 8, 1996	Caliper and gamma ray logs were run and single packer test no. 3 was conducted from 2236 ft BP to 2259 ft BP.
January 9, 1996	Drilled 12 1/4-inch diameter pilot hole to 2340 ft BP.
January 9 and 10, 1996	Core no. 5 was taken from 2340 ft BP to 2356.5 ft BP.
January 10 and 11, 1996	Drilled 12 1/4-inch diameter pilot hole to 2455 ft BP.
January 11, 1996	Caliper and gamma ray logs were run and single packer test no. 4 was conducted from 2434 ft BP to 2455 ft BP.
January 12 and 13, 1996	Drilled 12 1/4-inch diameter pilot hole to 2550 ft BP.

TABLE 1

WELL CONSTRUCTION SUMMARY (Continued)

DATE*	EVENT
January 13, 1996	Ran caliper, gamma ray, sonic, dual induction, flowmeter and temperature logs.
January 14 to 16, 1996	Ran television survey of pilot hole.
January 18 and 19, 1996	Cemented pilot hole with 2581 cubic feet of 12% gel cement.
January 19 to 31, 1996	Reamed 28.5-inch diameter hole to 2500 ft BP.
January 31 to February 8, 1996	Drilled 13.5-inch pilot hole to 3210 ft BP and performed wiper trips.
February 8 to 12, 1996	Performed additional wiper trips and ran caliper, gamma ray, sonic, dual induction, flowmeter and temperature logs. Logs had to be run in segments because of ledges in the hole.
February 12 and 13, 1996	Ran television survey of pilot hole.
February 13 to 18, 1996	Reamed 18.5-inch diameter open hole interval to 3210 ft BP.
February 18 to 21, 1996	Wiper trips were run on the open hole interval from (1300 ft BP to 3210 ft BP).
February 21, 1996	Caliper and gamma ray logs were run from 1300 ft BP to 3210 ft BP.
February 23, 1996	Set 20-inch diameter casing to 2498 ft BP.
February 24 and 25, 1996	Set bridge plug below 20-inch diameter casing.
February 25 to 27, 1996	Conducted unofficial pressure tests of 20-inch diameter casing.
February 27 to March 1, 1996	Cemented annulus of 20-inch diameter casing with 6220 cubic feet of 12% gel cement and 561 cubic feet of neat cement.
March 2, 1996	Ran television survey of 20-inch diameter casing.
March 3, 1996	Ran cement bond log of 20-inch diameter casing.
March 4, 1996	Conducted official pressure test of 20-inch diameter casing. Casing passed test.

TABLE 1

WELL CONSTRUCTION SUMMARY (Continued)

DATE*	EVENT
March 4 to 6, 1996	Set 16-inch diameter casing to 2460 ft BP. Displaced water in annulus with Baracor, a corrosion inhibitor.
March 6 to 7, 1996	Conducted preliminary (unofficial) pressure tests of 16-inch and 20-inch diameter casings and annulus.
March 8, 1996	Conducted official pressure tests of 16-inch diameter casing and annulus. Casing and annulus passed test.
March 8 and 9, 1996	Drilled out cement plug and conducted wiper trip of open hole to 3210 ft BP.
March 9 to 11, 1996	Started to break down rig and prepare for the injection test.
March 11 to 14, 1996	Conducted injection test, which consisted of a 24 hour background monitoring phase, and 18 hour injection phase, and a 12 hour recovery phase.
March 15 and 16, 1996	Performed television survey of 16-inch diameter casing and open hole.
March 17, 1996	Ran flowmeter and temperature logs.
March 18, 1996	Performed radioactive tracer survey. Well passed test.
March 19 to April 17	Demobilized drilling rig and equipment, installed wellhead and piping, and restored site.

* Dates indicate the time period from 0800 hours to 0800 hours the following day, which corresponds to the shift hours of the well-site geologists.

The 20-inch diameter injection casing was set at a depth of 2498 ft bls. The Technical Specifications called for the setting of the 20-inch diameter casing at about 2500 ft bls because the top of the highly fractured and cavernous interval of the Boulder Zone is located at approximately 2560 ft bls in NCRWTP injection well IW-1. The bottom of the 20-inch diameter casing is located approximately 94 below the top of the hydraulically connected part of the Boulder Zone, which is located at 2404 ft bls, and approximately 363 feet above the top of the main cavernous injection zone in well IW-2, which is located at 2861 ft bls.

The 16-inch diameter injection tubing was set at a depth of 2460 ft Bls. Section 04060 of the Technical Specifications called for the injection tubing packer to be a fully retrievable polished bore receptacle (PBR) packer like a Texas Iron Works Type LH Packer with JGS holddowns, polished barrel, and a 4-unit seal assembly or approved equivalent. This standardly used oilfield type packer can leak fluid and has been found to be non-retrievable in practice. Youngquist Brothers proposed instead using an alternative packer design, which they call a "YBI Positive Seal Packer". This device is composed of mild steel rings with machined, opposing angle-tapered mating surfaces. The outer ring is welded to the 20-inch diameter casing and the inner ring is welded to the 16-inch diameter injection tubing. The two taper surfaces are in contact over a length of 6-inches. The opposing angle seal is a proven technology and has the advantage of being fully retrievable and relatively inexpensive. The use of the YBI Positive Seal Packer was approved by the TAC and Collier County Utilities. Youngquist Brothers has provided a three year warranty on the seal, because this packer application is experimental, even though the technology is not. A diagram and photographs of the YBI Positive Seal Packer are provided in Figures 9 and 10. A casing mill certification summary is provided in Table 2. Copies of the mill certificates and casing tally are included in Appendix E.

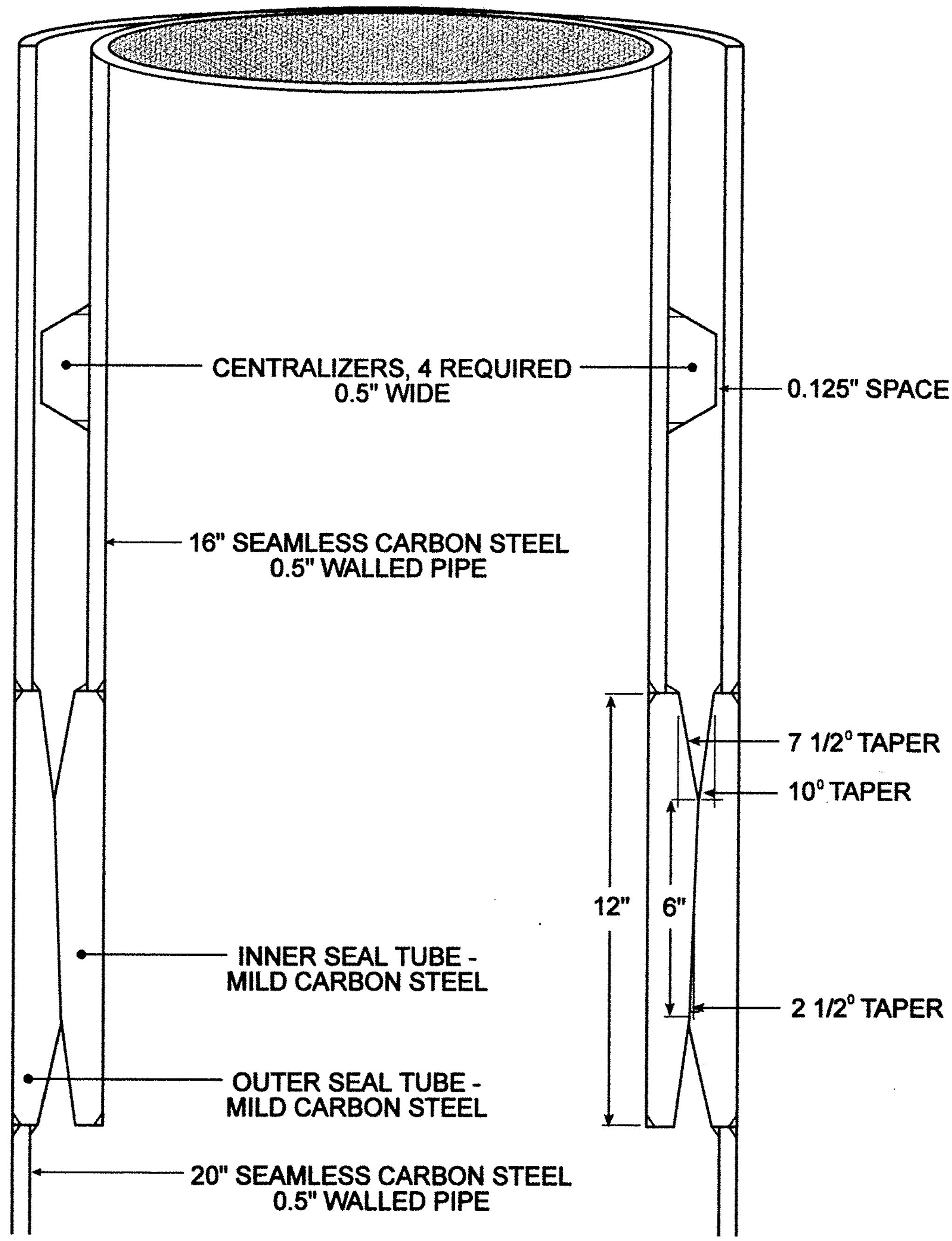

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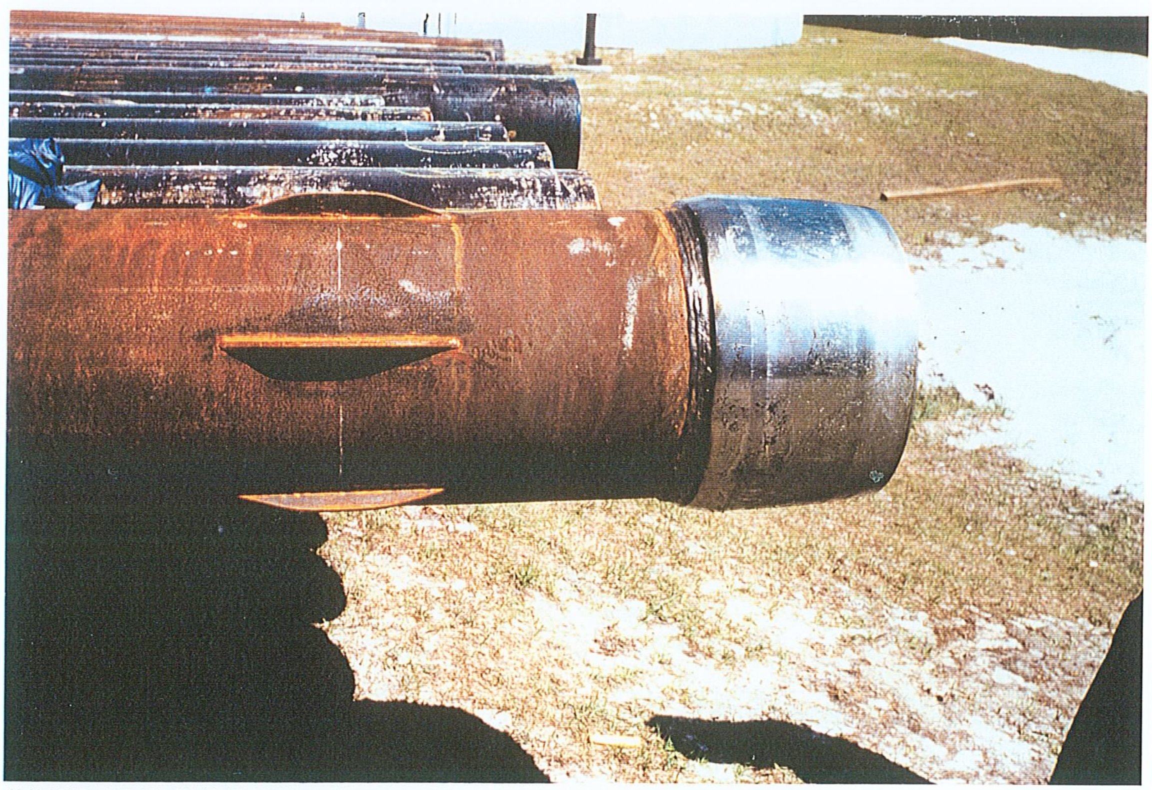
FIGURE 9. YBI Positive Seal Packer Diagram

OUTER SEAL TUBE WELDED ONTO 20 - INCH DIAMETER CASING



INNER SEAL TUBE WELDED ONTO 16 - INCH DIAMETER CASING

MISSIMER INTERNATIONAL, INC.	**Pr. Name:** COLLIER COUNTY NCRWTP **Pr. No.** FH4-68 **DWG No.** FF-10 **Date:** 7/8/96	Groundwater and Environmental Services

FIGURE 10. YBI Positive Seal Packer

TABLE 2

CASING MILL CERTIFICATION SUMMARY
COLLIER CO. NCRWTP INJECTION WELL IW-2

SEATING DATE	CASING DIAMETER (inches)	WALL THICKNESS (inches)	CASING TYPE	DEPTH (FEET BPL)	CERTIFICATE NUMBERS	INSPECTOR	DATE INSPECTED
12/3/95	38	0.375	ASTM A139 Grade B	430	189955	R.J. Kenny	11/10/95
12/18/95	30	0.375	ASTM A139 Grade B	1310	56087	R.E. Blankensop	11/27/95
2/23/96	20	0.500	ASTM A53 Grade B	2498	DS26366 01	D.S. Dabkowski	1/16/95
3/6/96	16	0.500	ASTM A53 Grade B	2460	DR60170 01	D.S. Dabkowski	9/15/95

3.3.2 Cementing Program

Casings were cemented into place with ASTM Type II (high sulfate resistance) Portland cement. The casings were grouted in stages, with a temperature log run after each stage to verify the presence of cement throughout the interval and to locate the top of the cemented annulus. The top of the cement was also measured by tagging with cement tubing. The first cement stage for each casing was pressure grouted, with all subsequent stages installed using the tremie method. The bottom 100 feet of the 38-inch casing and the bottom 200 feet of both the 30-inch and 20-inch casings were cement with neat Portland cement. The remainder of each casing were cemented with a maximum of 12% bentonite gel. Table 3 summarizes the cementing program of injection well IW-2.

TABLE 3

CASING CEMENT SUMMARY
COLLIER CO. NCRWTP INJECTION WELL IW-2

CASING DIAMETER: 38 INCH			CASING DEPTH: 430 FEET BP			
CEMENT STAGE NO.	DATE	CEMENT MIXTURE	BARRELS PUMPED	CUBIC FEET PUMPED	SACKS PUMPED	TAG DEPTH (FT BP)
1	12/4/95	12% GEL NEAT	400 128	2245.8 718.7	1020.8 653.3	30
2	12/4/95	NEAT	31	173.6	147.1	PL

CASING DIAMETER: 30 INCH			CASING DEPTH: 1310 FT BP			
CEMENT STAGE NO.	DATE	CEMENT MIXTURE	BARRELS PUMPED	CUBIC FEET PUMPED	SACKS PUMPED	TAG DEPTH (FT BP)
1	12/19/95	12% GEL NEAT	300 350	1683.3 1963.9	765.1 1664.3	810
2	12/19/95	12% GEL	100	561.1	255.1	780
3	12/20/95	12% GEL	100	561.1	255.1	740
4	12/20/95	8% GEL NEAT	84 22	471.7 123.5	253.6 104.7	735
5	12/20/95	12% GEL	150	841.7	382.6	711
6	12/21/95	12% GEL	200	1122.0	510.1	454
7	12/21/95	12% GEL	236	1324.0	601.8	PL

CASING DIAMETER: 20 INCH			CASING DEPTH: 2498 FT BP			
CEMENT STAGE NO.	DATE	CEMENT MIXTURE	BARRELS PUMPED	CUBIC FEET PUMPED	SACKS PUMPED	TAG DEPTH (FT BP)
1	2/27/96	12% GEL NEAT	50 100	280.5 561.0	127.5 475.4	2295
2	2/28/96	12% GEL	335	1879.3	854.2	1838
3	2/29/96	12% GEL	418	2345.0	1065.9	1348
4	2/29/96	12% GEL	410	2300.1	1045.5	539
5	3/1/96	12% GEL	145	813.5	370.0	230
6	3/3/96	12% GEL	45	242.5	114.7	_
7	3/3/96	12% GEL	42.5	238.4	108.4	PL

4.0 HYDROGEOLOGICAL TESTING/DATA COLLECTION

Data was collected during the drilling of well IW-2 on the hydrology and geology of the penetrated strata. The data was utilized to evaluate the alignment of the borehole, confirm the presence of adequate injection and confinement zones, and to locate casing seating depths.

4.1 Inclination Surveys

Inclination refers to the degree of deviation of the borehole from a true vertical alignment. The drilling of a straight, vertical borehole is critical for the properly setting and cementing of the casings at their required depths. Inclination surveys were performed at 60 foot (2 joint) intervals during the drilling of both the pilot holes and the reaming of the borehole, as required in the Technical Specifications. The 60 foot survey interval exceeded the FDEP requirement of a survey every 90 feet (3 joints) in the pilot hole, as promulgated in Section 62-528.410 (3) FAC. Each survey was performed by sending a TOTCO™ deviation survey tool on a wire line inside the drill pipe to a specified depth above the drill bit. The surveys were recorded on a paper disk which indicates the degree of deviation from the vertical. The paper charts had a range from 0 to 1.75 degrees from vertical. The performance of the inclination surveys were witnessed by the Missimer International field geologists.

The maximum allowable inclination from vertical, as required in FAC 62-528.410 (3) and in the Technical Specifications is one degree (60 minutes) and the maximum allowable difference between any two successive surveys is one-half of a degree (30 minutes). The greatest deviation from vertical measured in either a pilot hole or a reamed hole survey was 0.38°. The inclination survey data is compiled in Appendix C.

4.2 Formation sampling

Two sets of samples were collected of the cuttings during the drilling of the pilot holes. The cuttings samples were collected at a minimum of 10-foot intervals and at formation changes One set of samples was shipped to the Florida Geological Survey and the other was archived by Missimer International. Splits of the samples were washed and described on site by the Missimer International field geologists using a stereomicroscope. Selected samples were tested for mineralogy using dilute hydrochloric acid and Alizarin Red stain. A geologists log for well IW-2 is included in Appendix D.

4.3 Formation Fluid sampling

Water samples were collected from the discharge line every 30 feet during the reverse air drilling of the pilot hole. Water samples were also collected during the reaming of the 28.5-inch borehole in order to confirm the location of the top of the injectate bubble from well IW-2. The collected water samples were analyzed in the field for conductivity, using a YSI, Inc., Model 3000 T-L-C Meter. Chloride concentrations were measured in each sample by titration with silver nitrate using a potassium chromate indicator. The results of the water analyses are compiled in Appendix F.

4.4 Coring Program

Five (5) cores were collected of selected intervals above the injection zone during the drilling of the 12 1/4-inch pilot hole. The purpose of the coring program was to evaluate the confinement of the injection zone. The cores were taken using a 4-inch inner diameter, 10-foot long, carbide-tipped coring barrel. A summary of the coring program is presented in Table 4.

TABLE 4

CORING PROGRAM SUMMARY
COLLIER CO. NCRWTP INJECTION WELL IW-2

CORE NUMBER	DATE CORED	INTERVAL CORED (feet below pad level)	PRECENT RECOVERY
1	12/27/95	1778.0-1794.0	100%
2	1/1/96	1952.0-1969.0	100%
3	1/1/96	2040.0-2056.0	90%
4	1/4/96	2214.0-2228.0	100%
5	1/10/96	2340.0-2356.5	60%

Three (3) samples of each core were selected by Missimer International for analysis. The core samples were shipped by Youngquist Brothers to Ardaman & Associates, Inc., for analysis of porosity, vertical and horizontal permeability, unconfined compressive strengths and Young's Modulus. The reported vertical permeabilities range from 3.1 X 10^{-4} cm/sec (8.8 X 10^{-1} ft/day) at approximately 1779.5 ft bls to 1.5 X 10^{-7} cm/sec (4.3 X 10^{-4} ft/day) at approximately 2347.0 ft bls. The results of the core analyses is summarized in Table 5 and the laboratory reports and core geologic descriptions are compiled in Appendix G.

4.5 Geophysical Logging Program

Borehole geophysical surveys are performed by lowering sensing devices into the borehole to measure and record various physical properties of the borehole. The geophysical logging program performed during the construction and testing of NCRWTP injection well IW-2 was designed to collect information on the hydrogeology on penetrated strata, data on borehole geometry that would assist in setting and cementing casing strings and determining packer test intervals, and evaluating the integrity of the casing cements. A full suite of logs (gamma ray, caliper, sonic, flowmeter, temperature, dual induction resistivity) were run after completion of each segment of the pilot hole. Gamma ray and caliper logs were run on the reamed hole before the setting of the 38, 30, and 20-inch diameter casings. A cement bond log was run after the cementing of the 20-inch casing. All geophysical logs were run by Florida Geophysical Logging, Inc., and were witnessed by Missimer International personnel. A summary of all borehole geophysical logs run on IW-2 is provided in Table 6.

TABLE 5

CORE ANALYSES SUMMARY
COLLIER CO. NCRWTP INJECTION WELL IW-2

DEPTH	ORIENTATION	SPECIFIC GRAVITY	POROSITY	PERMEABILITY (cm/sec)	PERMEABILITY (ft/day)
1779.5	Vertical Horizontal	2.68	0.32 0.34	3.1×10^{-4} 4.0×10^{-5}	8.8×10^{-1} 1.1×10^{-1}
1783.5	Vertical Horizontal	2.68	0.32 0.31	2.1×10^{-4} 1.6×10^{-5}	6.0×10^{-1} 4.5×10^{-2}
1785.0	Vertical Horizontal	2.71	0.29 0.29	3.0×10^{-4} 8.8×10^{-6}	8.5×10^{-1} 2.5×10^{-2}
1954.0	Vertical Horizontal	2.71	0.20 0.22	2.9×10^{-5} 4.5×10^{-6}	8.2×10^{-2} 1.3×10^{-2}
1956.0	Vertical Horizontal	2.71	0.22 0.23	1.1×10^{-5} 2.6×10^{-5}	3.1×10^{-2} 7.4×10^{-2}
1958.0	Vertical Horizontal	2.70	0.23 0.21	5.9×10^{-6} 1.1×10^{-6}	1.7×10^{-2} 3.1×10^{-3}
2047.0	Vertical Horizontal	2.71	0.27 0.28	5.2×10^{-7} 3.0×10^{-7}	1.5×10^{-3} 8.5×10^{-4}
2050.0	Vertical Horizontal	2.68	0.29 0.27	1.8×10^{-6} 1.1×10^{-6}	5.1×10^{-3} 3.1×10^{-3}
2052.0	Vertical Horizontal	2.69	0.32 0.32	9.6×10^{-7} 1.8×10^{-6}	2.7×10^{-3} 5.1×10^{-3}
2216.0	Vertical Horizontal	2.74	0.27 0.24	1.1×10^{-6} 1.6×10^{-5}	3.1×10^{-3} 4.5×10^{-2}
2221.0	Vertical Horizontal	2.66	0.24 0.23	3.9×10^{-7} 3.5×10^{-7}	1.1×10^{-3} 9.9×10^{-4}
2226.0	Vertical Horizontal	2.72	0.25 0.25	7.4×10^{-6} 1.7×10^{-6}	2.1×10^{-2} 4.8×10^{-3}
2245.5	Vertical Horizontal	2.74	0.24 0.23	1.8×10^{-6} 1.3×10^{-6}	5.1×10^{-3} 3.7×10^{-3}
2347.0	Vertical Horizontal	2.92	0.06 0.05	1.5×10^{-7} $<1.0 \times 10^{-9}$	4.3×10^{-4} $<2.8 \times 10^{-6}$
2356.0	Vertical Horizontal	2.83	0.07 0.06	3.2×10^{-6} $<1.0 \times 10^{-9}$	9.1×10^{-3} $<2.8 \times 10^{-6}$

TABLE 6

SUMMARY OF GEOPHYSICAL LOGS
COLLIER CO. NCRWTP INJECTION WELL IW-2

LOG DATE	LOG TYPE	LOGGED INTERVAL (feet)	COMMENTS
12/3/95	Caliper, Gamma Ray	0-435	48-inch open hole
12/4/95	Cement Temperature	0-430	38-inch casing
12/7/95	Caliper, Gamma Ray, Dual Induction, Sonic, VDL, Temperature, Flowmeter	420-1308	Pilot hole
12/18/95	Caliper, Gamma Ray	430-1315	36.5-inch reamed open hole
12/19/95 to 12/21/95	Cement Temperature	0-1315	30-inch casing
12/28/96	Caliper, Gamma Ray	1270-1880	Prior to packer test no. 1
1/2/96	Caliper, Gamma Ray	1280-2138	Prior to packer test no. 2
1/5/96	Caliper, Gamma Ray	1882-2260	Prior to packer test no. 3
1/11/96	Caliper, Gamma Ray	1250-2455	Prior to packer test no. 4
1/13/96	Caliper, Gamma Ray, Dual Induction, Flowmeter, Sonic, VDL, Temperature	1300-2546	Pilot hole
2/10/96	Temperature	2480-2897	Pilot hole
2/12/96	Caliper, Gamma Ray, Dual Induction	1490-3210	Pilot hole
2/12/96	Flowmeter, Temperature	2480-2897	Pilot hole
2/12/96	Sonic, VDL	2475-3210	Pilot hole
2/21/96	Caliper, Gamma Ray	1294-3210	18.5 and 28.5-inc reamed open holes
2/28/96 to 3/1/96	Cement Temperature	0-2490	20-inch casing
3/3/96	Cement Bond	35-2466	20-inch casing
3/4/96	Cement Bond	2380-2497	20-inch casing
3/4/96	Cement Temperature	0-260	20-inch casing
3/16/96	Temperature, fluid resistivity	0-3210	Open hole
3/16/96	Flowmeter	2454-3210	Open hole
3/18/96	Gamma Ray	0-2970	Radioactive tracer study

4.6 Television Surveys

Television surveys were performed on the pilot hole below the base of the 30-inch casing (1310 ft bls), the 20-inch and 16-inch diameter casings, and the reamed open hole interval. The purpose of these surveys were to obtain information on the nature of the rocks penetrated and to evaluate the integrity of the casings. The television surveys were performed Florida Geophysical Logging, Inc., using a color TV camera and video recorder. The camera tool had the capability of viewing both downward and laterally. Because of the presence of ledges and obstructed intervals that blocked the lowering of the camera tool, the surveys of the pilot hole and open hole had to be conducted in segments. The final videotape of each survey consists of segments sequentially "spliced" together. The television surveys were witnessed in their entirety by Missimer International field geologists. The videotapes of the open hole intervals were later reviewed and described. A summary of the television surveys is provided in Table 7 and a description of the videotaped pilot hole and reamed hole is provided in Appendix H.

4.7 Single Packer Tests

Four (4) single packer tests were performed on the pilot hole of IW-2 from between 1862 ft bls and 2455 ft bls. The packer tests were run to primarily to obtain information about the location and degree of confinement of the Middle Confining Unit between the Upper Floridan Aquifer and the Boulder Zone. The following procedures were used to perform the single packer tests:

1) The preliminary choice of intervals to be tested was made based on the geological and geophysical logs from IW-1.

2) A caliper log was run on the pilot hole after drilling to the predetermined depth.

TABLE 7

SUMMARY OF TELEVISION SURVEYS
COLLIER CO. NCRWTP INJECTION WELL IW-2

VIDEO NUMBER	VIDEO DATE	DEPTHS (ft BP)	COMMENTS
1	1/14/96 to 1/16/96	1340-2539	12 1/4-inch pilot hole
2	2/13/96	2450-3159	13 1/2-inch pilot hole
3	3/2/96 to 3/3/96	0-1498	20-inch diameter casing
4	3/14/96 to 3/16/96	0-3216	16-inch diameter casing Reamed open hole (injection zone)

3) An inflatable packer was connected to the end of the drill pipe and set at a depth determined by examination of the caliper log. The desired test interval was 20 ft ± 10 ft. A submersible pump and pressure transducer connected to a Hermit™ Model 2000C data logger were installed in the drill pipe, 200-250 feet below pad level.

4) The packer zone was developed using either air lift or a submersible pump. At a minimum, the zone was developed until a drill string casing volume of water was purged and the temperature and conductivity of the development water stabilized.

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

6) The first pumping step was started. The packer zone was pumped at a constant rate until the water level stabilized. At the end of each step, a water sample was collected for field analysis for temperature, conductivity, and chloride concentration. The pumping rate was then increased for additional steps.

7) At the end of the last step, water samples were collected by Youngquist Brothers for laboratory analyses of conductivity, chloride, sulfate, and total dissolved solids concentrations.

8) The pump was shut off and recovery data were collected.

Only one step was possible in Test No. 3 because of the very low transmissivity of the Packer Test interval. The test interval for Packer Test No. 4 was located within the injectate bubble from well IW-1, which resulted in an high artesian flow rate of approximately 108 gpm. The results of the single packer test are summarized in Table 8 and compiled in Appendix I.

TABLE 8

SUMMARY OF PACKER TEST RESULTS
COLLIER CO. NCRWTP INJECTION WELL IW-2

DATE	DEPTH INTERVAL (feet)	TEST NO.	STEP NO.	PUMPING RATE (gpm)	SPECIFIC CAPACITY (gpm/ft)	ESTIMATED HYDRAULIC CONDUCTIVITY* (ft/day)	CONDUCT-IVITY (µmhos/cm)	CHLORIDE CONC. (mg/l)	TOTAL DISSOLVED SOLIDS (mg/l)
12/29/95	1862-1880	1	1	2.0	0.04	0.42	53,900	17,580	
			2	3.3	0.04	0.41	53,800	18,240	
			3	5.4	0.04	0.42	54,100 (39,700)	17,680 (18,985)	(22,540)
1/3/96	2116-2138	2	1	1.0	0.16	1.32	57,940	18,540	
			2	3.2	0.16	1.44	52,480	19,140	
			3	7.0	0.14	1.29	49,360	18,800	
			4	11.0	0.13	1.18	51,490 (40,200)	18,900 (19,495)	(23,040)
1/7/96 to 1/8/96	2236-2259	3	1	2.0	0.012	0.09	50,270 (41,400)	19,000 (20,495)	(23,640)
1/11/96	2434-2455	4		108	7.9	88.56	14,570 (15,410)	5,420 (5,865)	(7,350)

Notes: * Estimated hydraulic conductivities were calculated using Walton's estimate of transmissivity from specific capacity.
Laboratory results provided by Youngquist Bros., Inc., are given in parentheses.

4.8 Evaluation of Confining Units

The overlying confinement of the injection zone from the USDW is provided by low transmissivity limestones and dolomites that belong to the Ocala, Avon Park, and Oldsmar Formations. The location and degree of confinement was evaluated using core, drill cutting, packer test, geophysical log, and television survey data.

Confinement is provided by formations in which the sediments or rocks have low vertical hydraulic conductivities (permeabilities). Of the testing conducted during the construction of well IW-2, only the core analyses provided a direct measurement of vertical hydraulic conductivity. Information on hydraulic conductivity may be inferred from the other data sources. All other factors being equal, particularly pore size and geometry, hydraulic conductivity is positively correlated with porosity.

The strata penetrated below the base of the 30-inch diameter casing in well IW-2 can be subdivided into four main units (I to IV) based on their lithological and petrophysical properties. The porosity and permeability data for units I through IV are summarized in Table 9.

Unit I, which extends from the base of the 30-inch diameter casing down to approximately 1920 ft bls, consists of fossiliferous limestones that offer a low to moderate degree of confinement. Unit I encompasses all but approximately 10 feet of the Ocala Limestone and the upper part of the Avon Park Formation. Open fractures are sparse in Unit I and, where present, are of little vertical extent. Porosities range mostly from approximately 28% to 38%. The mean vertical permeability of 3 analyses of core samples from 1779.5 to 1785.0 ft bls was 4.7×10^{-1} feet/day (213.2 millidarcies).

Unit II, which extends from approximately 1920 ft bls to 2310 ft bls, consists of fossiliferous limestones with subsidiary dolomite beds that encompass the lower part

TABLE 9

DESCRIPTION OF CONFINEMENT
COLLIER CO. NCRWTP INJECTION WELL IW-2

UNIT	DEPTHS (ft BP)	LITHOLOGY	SONIC LOG POROSITY* (%)	CORE DATA						PACKER TEST ESTIMATED HYDRAULIC CONDUCTIVITY** (ft/day)
				POROSITY (%)	VERTICAL PERMEABILITY (ft/day)					
					HIGH	LOW	MEAN	NO. ANALYSES		
I	1310-1920	Fossiliferous Limestones	28-38	29-34	8.8×10^{-1}	6.0×10^{-1}	4.7×10^{-1}	3		4.2×10^{-1} (#1)
II	1920-2310	Fossiliferous limestones and subsidiary dolomite	23-30	20-32	8.2×10^{-2}	1.1×10^{-3}	8.9×10^{-3}	10		1.5×10^{-1} (#2) 1.2×10^{-2} (#3)
III	2310-2404	Cavernous and vuggy dolomite and subsidiary limestone	15-25	5-7	9.1×10^{-3}	4.3×10^{-4}	3.2×10^{-3}	2		ND
IV	2404-3210	"Boulder Zone" Cavernous and vuggy dolomite and subsidiary limestone	0-25	ND	ND	ND	ND	ND		7.9 (#4)

NOTES:
- * Range of matrix ("background") values; excludes cavernous intervals and isolated log peaks.
- ** Average value for test. Packer test number is given in parentheses.
- ND No data.

of the Avon Park Formation and the upper 98 feet of the Oldsmar Formation. Unit II offers generally good confinement. Open fractures are sparse and, where present, are of little vertical extent. There is a distinct, approximately 7% decrease in the sonic log porosity at about 1920 ft bls. The mean vertical permeability of 10 analyses of core samples from Unit II was 8.9 X 10^{-3} feet/day (4.04 millidarcies), which is approximately one fiftieth the mean of the Unit I samples. The lowest measured permeability was 1.1 X 10^{-3} feet/day (0.50 millidarcies). The mean hydraulic conductivity of the 2236 to 2259 ft bls interval was estimated from the packer test data to be 1.2 X 10^{-2} feet/day.

Unit III, which extends from approximately 2310 ft bls to the top of the cavernous zone at 2404 ft bls, consists of vuggy dolomites (cavernous in places) and subsidiary limestones that belong to the upper Oldsmar Formation. Despite the common occurrence of vugs and cavernous intervals, Unit III is the primary effective confining unit for the underlying Boulder Zone. The dolomite matrix is very finely to finely crystalline and has a very low porosity and permeability. The vertical permeabilities of 2 core samples from Unit III were 9.1 X 10^{-3} feet/day (4.1 millidarcies) and 4.3 X 10^{-4} feet/day (0.19 millidarcies). The vugs and cavernous intervals in Unit III are largely unconnected with each other and with the Boulder Zone.

The excellent confinement offered by Unit III is indicated by the reverse air discharge water quality data, and the temperature, flowmeter, and dual induction resistivity logs. The concentrate that has been injected in well IW-1 has a lower salinity ($\approx$ 3,000 - 5,000 mg/l total dissolved solids), and thus lower density, than the marine waters in the Lower Florida Aquifer ($\approx$ 35,000 mg/l total dissolved solids). The top of the buoyant injectate bubble from well IW-1 was clearly detected in well IW-2 by an abrupt downhole decrease in salinity and increase in temperature and water flow into the well. The downhole increase in temperature, as recorded on the fluid temperature log run on the flowing well, reflects the mixing of the relatively cool injectate water with an increasing proportion of the warmer formation waters. All of the above noted data sources indicate that the top of the injectate bubble is located at approximately 2404 ft bls (at the top of a cavernous dolomite interval) and that the injectate from IW-1 has not migrated upward through the dolomites of Unit III.

Unit IV consists of the cavernous and vuggy dolomites of the Boulder Zone. The cavernous intervals are interconnected as evidenced by the lateral and vertical migration of injected water from well IW-1. The base of the 20-inch casing in IW-1 is at 2500 ft bls, whereas the top of the injectate bubble in IW-2 is located at 2404 ft bls. The injectate has thus migrated upward approximately 96 feet from the uppermost injection point.

5.0 MECHANICAL INTEGRITY TESTS

The mechanical integrity tests (MIT's) of injection well IW-2 were designed to analyze the integrity of the casing materials and the quality of the bond between the annular grout (cement) and the well casings. The MIT program consisted of the following tests:

a) Cement temperature logs of the 38-inch, 30-inch, and 20-inch diameter casings.
b) Cement bond log of the 20-inch casing.
c) Pressure tests of the 16-inch and 20-inch diameter casings and the annular space betweem the 16-inch and 20-inch diameter casings.
d) Television survey of the 16-inch and 20-inch diameter casings.
e) Injection test.
f) Radioactive tracer survey (RTS).

All of the MIT procedures were witnessed by Missimer International personnel and were judged to have been completed in a satisfactory manner in accordance with the well construction and testing specifications and FDEP requirements. The MIT procedures and results are described below:

5.1 Temperature log

The first test performed on the 38-inch, 30-inch, and 20-inch casings was a series of cement temperature logs (CTLs). The CTLs were performed after each successive cementing stage. The curing of cement is an exothermic reaction. The generated heat of hydration of cement emplaced in the annulus between the casing and formation can be readily detected and measured using a temperature probe run through the casing. If curing proceeds too rapidly the temperature will "flash", resulting in a spike in the temperature log. Conversely, a significant drop in temperature across a section of casing can indicate the absence of cement in part of the annulus. All of the CTLs confirmed the presence of significant cement and that appropriate curing temperatures were maintained in the annular cement. Copies of the CTL log were provided to the FDEP with the weekly construction reports.

5.2 Cement bond log of the 20-inch casing

The cement bond log (CBL) is an acoustic geophysical log that is used to evaluate the quality of the bond between the casing and the cement grout, and between the cement and the formation. The CBL is performed by lowering the logging tool down the hole while transmitting an acoustic signal outward from the tool toward the casing wall. The signal penetrates the casing, cement grout, and formation, and is reflected back to a receiver in the logging tool. The signal is recorded by the logging instrument and various qualities of the signal (described below) are displayed on the printout of the log.

Travel time

Travel time is the time that it takes for the signal to travel from the transmitter, through the casing fluid, casing, cement, and formation, and back to the receiver. Travel time is useful for evaluating whether the logging tool was properly centered within the casing during the running of the CBL. Constant tool centralization is critical to the obtainment of an interpretable CBL because an uncentered tool will produce erratic responses, rendering the log useless for evaluating cement fill and bond. A properly centered tool will result in a relatively straight travel time log with only minor deviations at casing joint locations.

Amplitude

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

Total Energy Display

The third portion of the CBL is the total energy display, which is displayed as a variable density waveform log (VDL). The VDL is produced from the arrivals of the acoustic waves at a receiver spaced approximately five (5) feet below the primary receiver on the logging tool. The VDL is used to qualitatively assess the bond between the cement and the formation and to detect the presence of channels in the cement grout, which would allow injected fluids to migrate behind the casing wall. In order to be able to interpret the VDL log, the signature of casing joints must be examined. Casing joints, which normally appear as W-shaped "chevron" patterns, are clearly visible in uncemented well casings, whereas the pattern is barely discernable in cemented casings. The CBL is therefore run before cementing the upper 200 feet of the annuluses of the 20-inch and 30-inch casings.

Summary and Evaluation of the CBL of the 20-inch casing

A CBL was run on the 20-inch diameter casing from 2466 feet BP to 35 ft BP on March 3, 1996. The CBL was performed by Florida Geophysical Logging, Inc., and was witnessed by Pam Tate (Missimer International). The tool could not pass below the packer shoe of the 16-inch diameter casing. On March 4, 1996, a smaller centralizer was placed on the tool and CBL was run on the interval from 2380 feet BP to 2497 feet BP. The logging of the later interval was witnessed by Elizabeth Shawkey (Missimer International).

The travel time log, which validates the rest of the log, is found on the left side of the CBL chart. The transit times display a background level of 560 to 600 microseconds (μsec), which is relatively constant throughout the log. The deviations from the background are predominantly sharp positive (increased travel time) peaks and appear to correlate with casing joints and changes in the density of the formation (e.g.,, contacts between relatively porous and non-porous beds). Overall, the transit time log indicates adequate tool centralization, allowing for a valid evaluation of the amplitude curve.

The casing signal amplitude curve is presented in the middle track of the CBL and the the VDL is presented on the right track. The amplitude and VDL indicate a sufficient continuity of cement for the majority of the casing length. The amplitude of the greater part of the cemented casing ranged from 0 to 10 millivolts. Variation in cement bonding was detected in the following intervals by a higher than background (greater than 20 mV) signal amplitudes:

630 - 675 ft BP,
698 - 722 ft BP,
870 - 910 ft BP,
1110 - 1145 ft BP,
1370 - 1390 ft BP, and
1635 - 1645 ft BP

The lower part of the cased interval (1750 to 2498 ft BP) gave a consistently low signal amplitude indicating proper cement bonding conditions. There is an apparent correlation between good cement bonding and the use of neat cement in the lower zone. The 12% gel mix used to grout the upper part of the casing has the greatest variation in bonding quality.

The bond between the cement grout and the formation, as represented by the VDL, was also interpreted to be satisfactory, due to the minimal perturbations in the VDL. At least some of the perturbations that are present in the VDL, such as between 1690 ft BP and 1710 ft BP, appear to be correlated with lithological variations (e.g., contacts between well-lithified and poorly lithified limestone and marl beds). The cementing program carried out on injection well IW-2 was evidently adequate to allow the cement to bond well to the entire borehole wall and to cure with minimal separation.

In summary, the cement bond log run on the 20-inch diameter injection casing provides strong evidence that the casing was properly cemented and meets the standards set forth in Section 62-528.410 FAC (8/95).

5.3 Pressure tests

Pressure tests were performed on the 16-inch and 20-inch diameter casings and the annular space between the 20-inch diameter casing and the 16-inch diameter casing in order to evaluate the integrity of the casings and joint welds. The tests were conducted after the cement had cured but before the cement plug at the base of the casing had been drilled out. For each test a flange was first welded to the top of the casing. A wellhead was then bolted to the top flange of the casing, and a pressure gauge and relief valves were fitted to the wellhead. Any air present in the casing was bled off to eliminate the effect of air compression and expansion. The casing was then pressurized with water and the pressure loss over the course of one hour was recorded. The results of the pressure test are summarized in Table 10 and the test data is compiled in Appendix I.

TABLE 10

SUMMARY OF PRESSURE TEST RESULTS
COLLIER CO. NCRWTP INJECTION WELL IW-2

TEST NO.	DATE	SUBJECT	INITIAL PRESSURE (psi)	FINAL PRESSURE (psi)	PRESSURE CHANGE (psi)	PERCENT CHANGE	PASS/FAIL*
1	3/4/96	20-inch casing	149	146	-3.0	-2.00%	Pass
2	3/8/96	16-inch casing	160	159.25	-0.75	-0.46%	Pass
3	3/8/96	Annulus between 16 and 20-inch casings	158	156.5	-1.5	-0.95%	Pass

* The criteria for passing the pressure test is a change in pressure of no more than five (5) percent from the initial test pressure after one hour, per Section 62-528.410 (7)(c) (8/95).

An inflatable packer was set just above the base of the 20-inch diameter casing (2496 ft bls) on March 3, 1996. Preliminary pressure tests were then performed to confirm that the casing and all fittings were tight. The official pressure test of the 20-inch casing was conducted on March 4, 1996. The test was witnessed by Elizabeth Shawkey, Bob Wright, and Buzz Walker (Missimer International), Bill Musselwhite (Youngquist Brothers) and Jack Myers (FDEP). The casing was pressured to 149 pounds per square inch (psi) at the start of the test. After one hour the pressure had dropped to 146 psi, which calculates to an approximately two (2) percent decrease. The measured pressure decrease was thus below the test passing criteria of a change in pressure of no more than five (5) percent from the initial test pressure after one hour, as set forth in Section 62-528.410 (7)(c) FAC (8/95).

The pressure test of the 16-inch diameter casing and the annulus between the 16-inch diameter and 20-inch diameter casings were conducted on March 8, 1996. An inflatable packer had previously been installed in the 16-inch casing at a depth of 2440 ft BP, which is approximately 19 feet above of the bottom of the casing. The pressure tests were witnessed by Elizabeth Shawkey (Missimer International) and Rick Orth (FDEP). The 16-inch diameter casing was first pressurized to 160 psi. After one hour the pressure in the casing had dropped to only 159.25 psi, which calculates to a 0.5% decrease. The annulus was then pressurized to 158 psi. After one hour the pressure in annulus had dropped to only 156.5 psi, which represents a decrease of 0.9%. Both the 16-inch diameter casing and the annulus between the 16-inch diameter and 20-inch diameter casings met the pressure test passing criteria of a change in pressure of no more than five (5) percent from the initial test pressure after one hour.

The results of the pressure testing thus indicate that both the 16-inch diameter and 20-inch diameter casings are free of leaks and that the packer between the two casings is providing a tight seal.

5.4. Television surveys of the 20-inch and 16-inch diameter casings

A borehole television survey was performed on the 20-inch diameter injection casing on March 2 and 3, 1996 and on the 16-inch casing on March 14 and 16, 1996. A footage summary of the television surveys is provided in Table 7. A downward looking camera was used to obtain information concerning the integrity of the casings. No apparent breaches of the casings that might indicate a lack of mechanical integrity were observed. The packer shoe of the 20-inch diameter casing was examined with the lateral camera in order to determine whether there was any damage or encrustation on the contact surface that could prevent the obtaining of a tight seal with the 16-inch diameter casing (injection tubing). The packer surface did not appear to be damaged or encrusted.

5.5. Injection test

5.5.1. Procedures

A constant rate injection test was performed on injection well IW-2 in order to evaluate the hydraulic characteristics of the well and injection zone. During a constant rate injection test, the system is tested by pumping fluid at a rate equal to or higher than the expected maximum and permitted operating rate. This pumping rate is maintained as constant as feasibly possible throughout the injection phase of the test.

Prior to the start of the test, data control points were established to monitor the effects of injection on the injection well and the monitor well zones. These control points included wellhead and annulus pressure, injection zone pressure and temperature, and monitor well pressure head in both zones. Data was also obtained on barometric pressure and local tidal fluctuations, as these parameters can affect aquifer pressure. The control points and monitoring method are summarized in Table 11. The IW-2

TABLE 11

INJECTION TEST CONTROL POINTS
COLLIER CO. NCRWTP INJECTION WELL IW-2

CONTROL POINT/ ZONE MONITORED	PARAMETERS MONITORED	COLLECTION METHOD(S)
Injection well IW-2 wellhead	Pressure	Manually, dial-type gauge
Injection well IW-2 annulus	Pressure	Manually, dial-type gauge
Injection well IW-2 injection zone vicinity (2850 ft BP)	Pressure Temperature	2500 psi transducers and data logger (Memory Gauge system)
Monitor well, upper zone	Pressure	Transducer and data logger (Hermit system)
Monitor well, lower zone	Pressure	Transducer and data logger (Hermit system)
Barometric data	Atmospheric pressure	Weather Surface
Tidal cyles	Gravitational fluctuations of water level	Computer program for tides of southwest Florida
Flowmeter 1 - Wellhead Injection Line	Injection rate and total volume of fluid injected.	Manually - totalizing meter. Flow rate calculated by dividing flow volume by ellapsed time.
Flowmeter 2 - Wellhead Injection Line	Injection rate and total volume of fluid injected.	Manually - totalizing and direct reading meters. Flow rate calculated by dividing flow volume by ellapsed time.

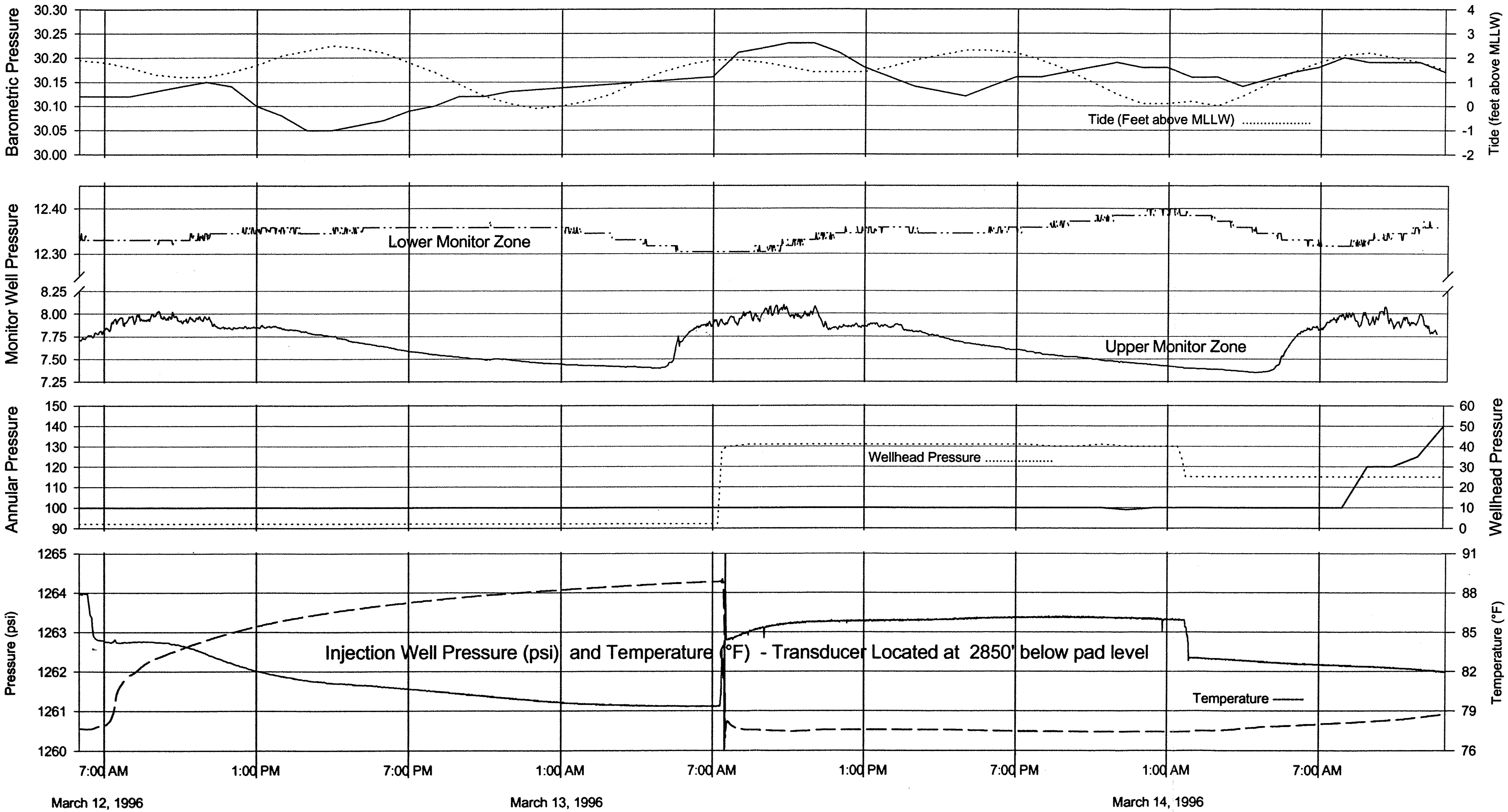
injection test consisted of three phases: a background data collection phase, an injection phase, and a recovery phase. The background data collection phase was started on the morning of March 12, 1996, and lasted for approximately 24 hours. The purpose of the background data collection was to establish baseline pressure conditions at the control points and to acquire information that would permit the effects of tidal and barometric fluctuations to be filtered out of the injection phase pressure data.

The injection phase started on the morning of March 13, 1996, and lasted approximately 18 hours. The test was witnessed in its entirety by Missimer International personnel (Pam Tate, Mike Romero, and Buzz Walker). The average injection rate for the test was approximately 4400 gpm, which calculates to 6,336,000 gallons per day and an injection rate of approximately 8 feet per second. The water was delivered to the well using a temporary 16-inch pipe that was tied into the water plant's raw water main. The raw water main is pressurized from pumps at the production wells and the raw water booster pumping station. Additional pumps were therefore not needed at the NCRWTP in order to achieve the desired flow rates for the test. A check valve and two (2) totalizing flowmeters were installed in the temporary water pipe near the wellhead. The injection rate was continually monitored using the totalizing flowmeters and the rate maintained using a gate valve located at the water main tie in point. Upon completion of the injection phase, the gate valve was closed and the control points were monitored for a 12 hour recovery phase.

5.5.2 Results

The results of the injection test are illustrated in Figure 11 and a copy of the raw data is included in Appendix I. The pressure in the well just above the injection zone (2850 ft BP) increased from a background value just before the start of pumping of 1261.1 pounds per square inch (psi) to a maximum value of 1263.4 psi during the test. The small (2.3 psi) increase in injection zone pressure indicates that the test injection did

FIGURE 11
Results of Injection Test
NCRWTP Deep Injection Well #2 - *Bid # 95-2419*



not significantly stress the injection zone. The injection zone of well IW-2 is thus capable of efficiently accepting the designed capacity of approximately 6.3 million gallons per day.

Wellhead pressure increased from 6.5 psi before the start of the test to 41 psi during the test. The wellhead pressure was relatively constant throughout the injection phase. The wellhead pressure recovered to only 25 psi during the recovery phase. The increase in wellhead pressure from the background value of 6.5 psi to the recovery value of 25 psi reflects the buoyancy of the enlarged freshwater bubble. The annular pressures remained a fairly constant 100 psi throughout the background phase, injection phase, and early part of the recovery phase of the test. Annular pressure increased to 140 psi toward the end of the recovery phase due to thermal expansion of the annular fluid.

The water pressure data from the upper and lower zones of the dual-zone monitor wells exhibits fluctuations throughout the background data collection, injection, and recovery phases of the injection test. The pressure fluctuations appear to be related to barometric pressure and tidal fluctuations. The water pressure in both the upper and lower monitor zones does not appear to have been affected by the injection activities, which suggests that there is both adequate confinement within the aquifer and that the injection well is not a conduit for flow between aquifer zones.

The results of the injection test thus confirm the following:

a) The injection zone is capable of efficiently accepting the designed injection flow.

b) Injection well IW-2 is operable as designed.

c) There is adequate confinement between the injection zone and the base of the lower monitoring zone.

5.6 Radioactive tracer survey (RTS)

A radioactive tracer survey (RTS) was performed on the 20-inch diameter casing by Florida Geophysical Logging, Inc., on March 18, 1996. The test was witnessed in its entirety by Bob Maliva (Missimer International) and Joe Haberfeld (FDEP). Buzz Walker (Missimer International) and Jack Myers (FDEP) were present for parts of the RTS test. The survey was performed under both static and dynamic conditions to evaluate the integrity of the grout seal around the bottom of the 20-inch diameter casing. The integrity of the grout seal is critical to ensure that no upward migration of injection fluids occurs between the casing and the borehole wall.

Four days before the start of the RTS, approximately 6.34 million gallons of raw water had been pumped into injection well IW-2 as part of the injection test. This also served to create a freshwater bubble within which to perform the RTS tests. The temperature and fluid resistivity logs run on March 16, 1996, indicate the base of the freshwater bubble is positioned at approximately 2670 ft bls.

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

Top gamma ray detector (GRT)	23.5 ft
Ejector port	13.5 ft
Middle gamma ray detector (GRM)	11.0 ft
Casing collar locator	9.5 ft
Bottom gamma ray detector (GRB)	1.0 ft

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

1) A background gamma ray log was run from approximately 2980 feet below pad level (BP). The pad level datum was within 1 foot of the adjoining land surface).

2) The bottom of the casing was detected using the casing collar tool at 2496 ft BP.

3) Performed Test 1 - Static Test

3a) Tool was positioned so that the ejector was located 1 foot below the bottom of the 20-inch casing (2497 ft BP).

3b) After recording the gamma ray detectors for 3 minutes in stationary time drive mode, the first slug of tracer (3 millicuries) was released. The detectors were run for an additional 60 minutes in stationary time drive mode. Increased gamma ray activity was detected in the middle detector (GRM) after 55 seconds, in the lower detector (GRL) after 3 min. 45 sec., and in the upper detector (GRT) after 8 min. 50 sec.

3c) Logged out of position up to 2250 ft BP. This depth was approved by Joe Haberfeld. The upper boundary of the tracer stain was detected to be at 2452 ft BP.

3d) Well was flushed with approximately 43,000 gallons of raw water. The casing volume is approximately 23,000 gallons. The flow rate was approximately 3000 gpm.

3e) Logged well from 2500 ft BP to 2250 ft BP. No evidence was found for the upward migration of the tracer outside of the casing.

4) Performed test 2 - Dynamic

4a) A finished water flow rate through the casing of approximately 55 gpm was established. The flow rate ranged during the test from 54 gpm to 55 gpm. A 55 gpm flow rate corresponds to a 0.1 ft/sec water velocity.

4b) Tool was positioned so that the ejector was located 5 feet above the bottom of the 20-inch casing (2491 ft BP).

4c) After recording the gamma ray detectors for 3 minutes in stationary time drive mode, the second slug of tracer (2 millicuries) was released. The detectors were run for an additional 30 minutes in stationary time drive mode. Increased gamma ray activity was detected in GRM after 23 seconds and in GRL after 2 minutes. Increased gamma radiation was not detected in GRT. The flow rate of approximately 0.1 ft/sec was confirmed by the time it took in the tracer to be detected by GRL (12.5 ft / 120 sec = 0.104 ft/sec).

4d) Flushed well with approximately 31,000 gallons of raw water.

4e) Logged out of position up to 2250 ft BP. No evidence was found for the upward migration of the tracer either inside or outside the casing. Possible very minor residual staining of the casing with tracer was detected at about 2491 ft BP, the ejection point for both of the dynamic tests.

5) Performed test 3 - Dynamic (repeat of test 3)

5a) A finished water flow rate through the casing of approximately 55 gpm was established.

5b) Tool was positioned so that the ejector was located 5 feet above the bottom of the 20-inch casing (2491 ft BP).

5c) After recording the gamma ray detectors for 3 minutes in stationary time drive mode, the second slug of tracer (2 millicuries) was released. The detectors were run for an additional 30 minutes in stationary time drive mode. Increased gamma ray activity was detected in GRM after 17 seconds and in GRL after 1 min. 52 sec. Increased gamma radiation was not detected in GRT.

5d) Flushed well with approximately 38,000 gallons of raw water. The ejector was lowered to 2850 ft BP during the flushing of the well and the residual iodine tracer was released into the injection zone.

5e) Logged out of position up to 2250 ft BP. No evidence was found for the upward migration of the tracer either inside or outside the casing.

5f) Logged from 2850 ft BP to the surface. Comparison of the initial and final logs revealed no evidence of increased gamma ray activity in the cased interval of the well.

To summarize, the results of the radioactive tracer survey indicate that no upward migration of the radioactive tracer occurred behind the 20-inch diameter casing. Any upward migration of tracer detected during the tests was due to dispersion and diffusion within the casing. The results of the RTS thus indicate there is a good cement seal at the base of the 20-inch casing and that the well is performing in a satisfactory manner.

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COLLIER COUNTY NCRWTP - INJECTION WELL #2 SUMMARY

PLATE 1.

MISSIMER INTERNATIONAL, INC.

FLORIDA GEOPHYSICAL LOGGING

Company: MISSIMER INTERNATIONAL
Well: NCRWTP IW #2
Field: NORTH COLLIER
County: COLLIER **State:** FLORIDA **Country:** USA

Location:
Section: **Township:** 48S **Range:** 26E **API No.:**
Permanent Datum: Pad Level (P.L.) **Elevation:** **EKB:**
Log Measured From: P.L. **above Perm. Datum** **EDF:**
Drilling Measured From: P.L. **EGL:**

Description	Run 1	Run 2	Run 3	Run 4
Date	12/03/95	12/07/95	1/13/96	2/12/96
Run Number	ONE	THREE	NINE	TEN
Bit Size	48"	12.25	12.25	13.5
Type Fluid	WATER	WATER	WATER	WATER
Top Log Interval	0	420	1310	2490
Bottom Log Interval	435	1308	2475	3210
BHT	N/A	N/A	N/A	89°
Truck	101	102	101	101
Engineer	JONES	WILL/LEE	WILLIAMS	WILL/JONES
Witness	B.MALIVA	TATE/ROME	E.SHAWKEY	SHA/MAL/T

Remarks:
RUN # 10 DEPTH SHIFTED -6 FEET TO MATCH DIL RECORDED ON RUN #9.

Disclaimer:
Interpretations are opinions based upon inferences from electrical or other measurements and algorithms, empirical relationships, and assumptions which are not infallible and with respect to which log analysts may differ. Accordingly, Florida Geophysical Logging, Inc. cannot and does not guarantee the accuracy or correctness of any interpretation and shall not be liable or responsible for any losses, costs, damages, or expenses incurred or sustained by anyone resulting from any interpretation made by any of our officers, agents, or employees.

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PLATE 2