Special Publication SJ98-SP19

Investigation of Groundwater Resources in Central Indian River County, Florida

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ST. JOHNS RIVER WATER MANAGEMENT DISTRICT

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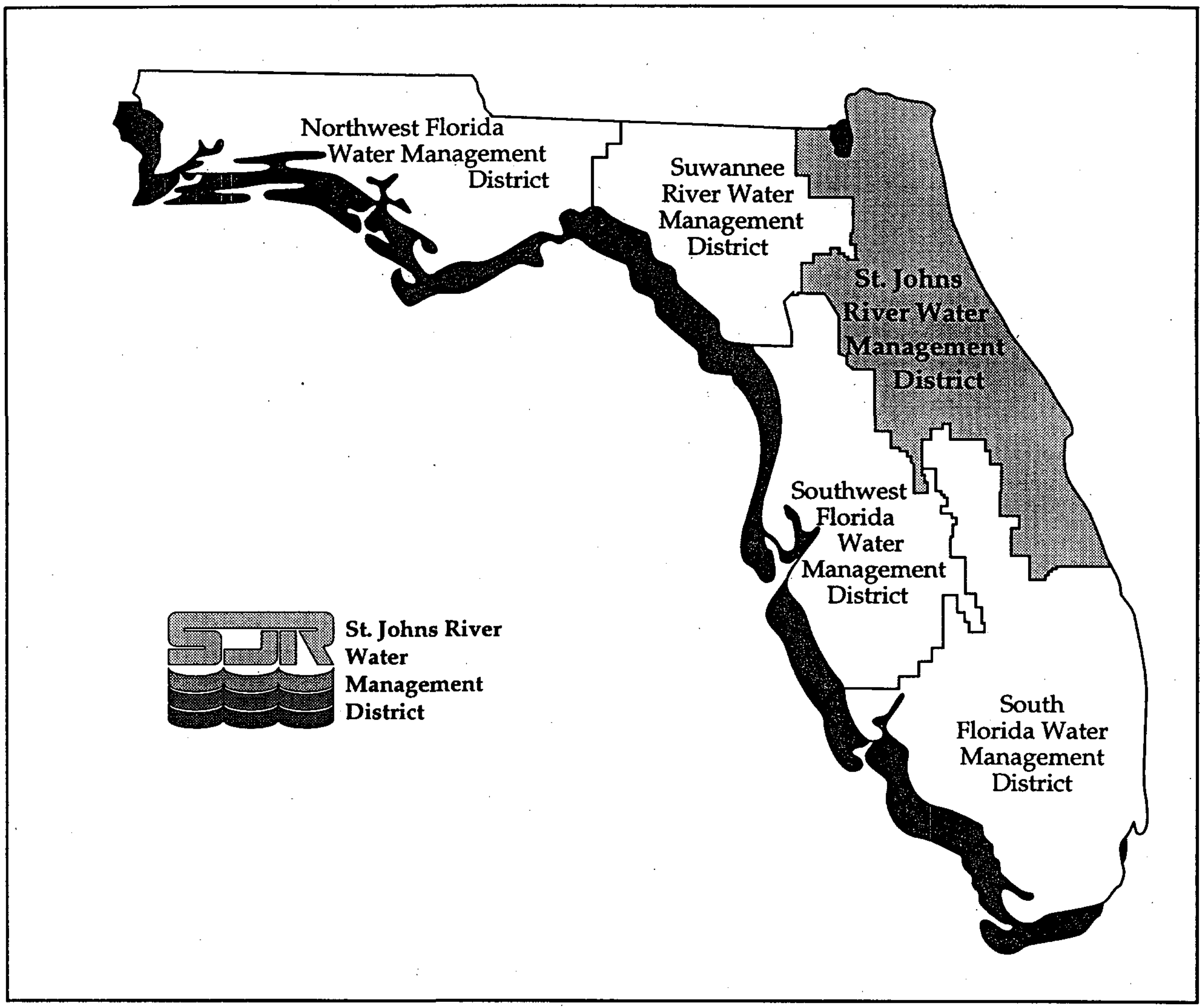

The **St. Johns River Water Management District** (SJRWMD) was created by the Florida Legislature in 1972 to be one of five water management districts in Florida. It includes all or part of 19 counties in northeast Florida. The mission of SJRWMD is to manage water resources to ensure their continued availability while maximizing both environmental and economic benefits. It accomplishes its mission through regulation; applied research; assistance to federal, state, and local governments; operation and maintenance of water control works; and land acquisition and management.

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EXECUTIVE SUMMARY

Increased use of surface water in central Indian River County for citrus irrigation and frost-and-freeze protection is anticipated. However, this surface water supply may prove insufficient. Citrus growers in the area requested that the St. Johns River Water Management District investigate the groundwater system as a potential supplemental water resource. Consequently, the St. Johns River Water Management District undertook this study, including an examination of the geology and hydrogeology of the groundwater system of central Indian River County.

The most productive portion of the surficial aquifer system in the study area occurs in the upper 50 feet (ft) of the system and has a thickness of generally less than 30 ft. Four-inch wells constructed in this portion of the surficial aquifer system can be expected to produce an average of about 74 gallons per minute (gpm). A network of ten production wells in the surficial aquifer system would be required to produce a total of 1 million gallons per day. Such a network is estimated to cost $50,000 to construct.

Horizontal wells constructed 25 ft below the static water level would require from about 83 to 179 ft of screen to produce 100 gpm in the study area. A network of eight horizontal wells in the surficial aquifer system would be required to produce a total of 1 million gallons per day. Such a network is estimated to cost $143,200 to construct.

The surficial aquifer system appears to have limitations as an economically feasible source of water for citrus irrigation and frost-and-freeze protection in the study area.

Only one productive interval was identified in the intermediate aquifer system in the study area. Based on the specific capacity of only 0.08 gallons per minute per foot for a test well in this aquifer system, the intermediate aquifer within this system offers little to no potential for supplying adequate quantities of water for citrus irrigation or frost-and-freeze protection.

Three wells were constructed in the Upper Floridan aquifer in the study area. Two wells are located west of Interstate 95 (I-95) and one well is located east of I-95. Each well only penetrated 50 ft of the Upper Floridan aquifer. Chloride concentrations in the Upper Floridan aquifer are below 260 milligrams per liter west of I-95 (the public drinking water standard for chloride is 250 milligrams per liter). Estimated flow from these wells ranged between 117 and 243 gallons per minute. The upper 50 ft of this aquifer west of I-95 offers the most promise as a source of water for citrus irrigation or frost-and-freeze protection in the study area. The water available from the surficial and intermediate aquifer systems does not appear to be sufficient to supply the daily quantity needed for agricultural irrigation to supplement the use of surface water.

CONTENTS

FIGURES AND TABLES

FIGURES

TABLES

INTRODUCTION

The purpose of this investigation was to assess the availability of water in the surficial, intermediate, and Floridan aquifer systems in central Indian River County as a source of supply for citrus irrigation and frost-and-freeze protection. The objectives of the study were to determine the water-bearing characteristics in the surficial and intermediate aquifer systems and to assess the water quality of the surficial, intermediate, and Floridan aquifer systems in this area, which includes all of Townships 31, 32, and 33 South in Ranges 37 and 38 East (Figure 1).

The St. Johns River Water Management District (SJRWMD) performs water supply needs and sources assessments to meet the requirements of Section 62-40.520, *Florida Administrative Code,* and subparagraph 373.0391(2)(e), *Florida Statutes*. In association with these assessments, SJRWMD performed an evaluation of existing and projected water demands for agricultural irrigation in the Upper St. Johns River Basin (USJRB), concentrating primarily on the Indian River County portion of USJRB (Ritter and Moore 1994). This evaluation indicated that area growers planned to increase surface water use to support proposed increases in agricultural irrigation, primarily for citrus crops. Vergara (1994) reported that surface water in the study area was not available for withdrawal during times of high irrigation demand; when this study began, in 1996, the situation had not changed.

Use of additional surface water for citrus irrigation and frost-and-freeze protection in USJRB depends largely on the development of additional storage capacity for surface water (e.g., retention areas). A 150-acre grove can use approximately 1 million gallons per day (mgd) for irrigation and almost 6.5 mgd for freeze protection (R. Burklew, SJRWMD, pers. com. 1998). Surface water reservoir systems are used widely in the area for storage of water for citrus irrigation. Even though retention areas exist, surface water is not always available for withdrawal for agricultural purposes when it is needed (e.g., during periods of low rainfall). Development of additional reservoir capacity would reduce the acreage available for citrus production and is, therefore, not a desirable alternative for area growers. The USJRB Project, a federal flood-control project for which SJRWMD is the local

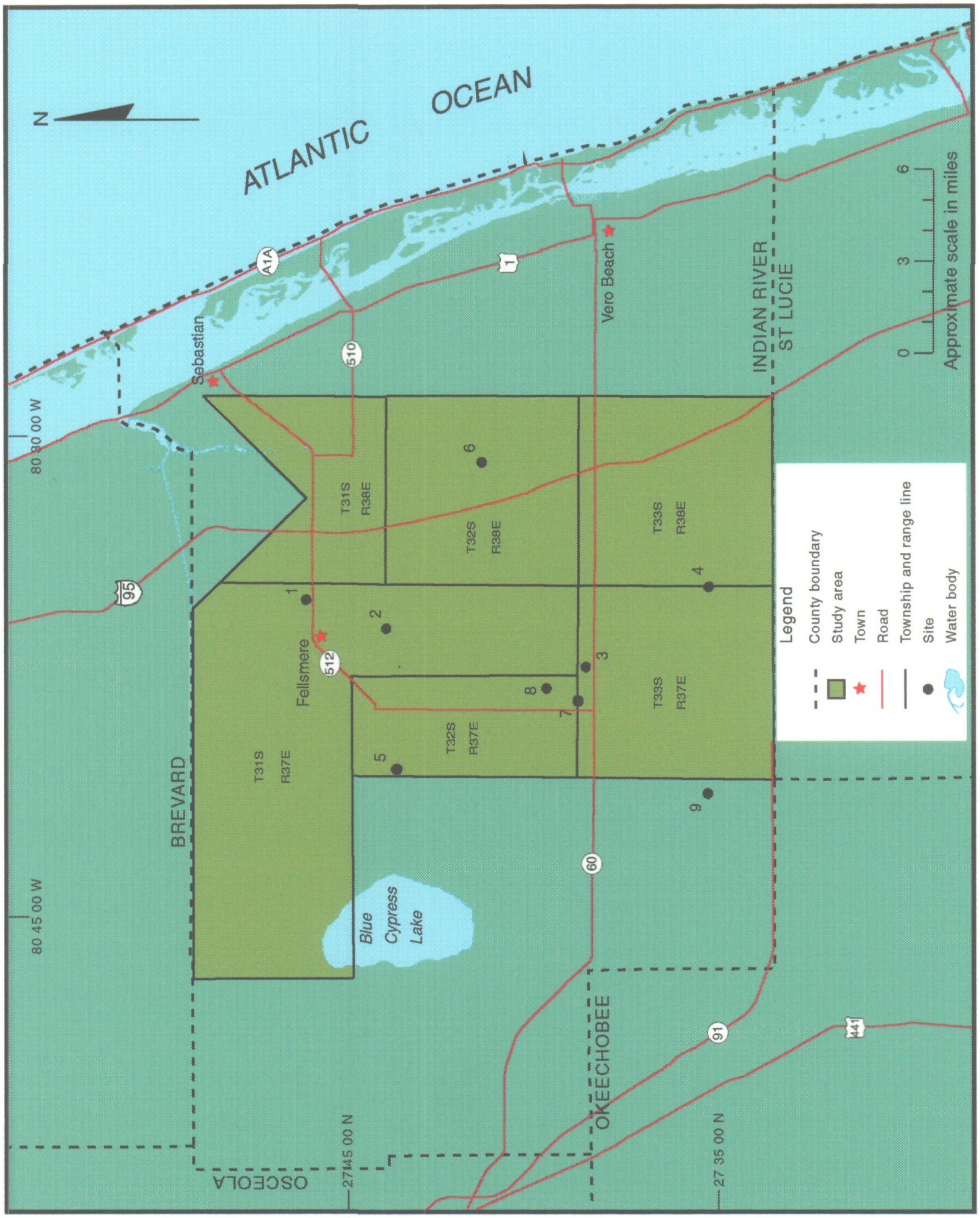

Figure 1. Study area in central Indian River County

sponsor, will create a restored marsh system. Retention areas in this restored marsh system will be the desired source of water supply to support the projected increase in agricultural irrigation and the demand for frost-and-freeze protection. However, growers want an alternative source of irrigation water for periods when surface water would be unavailable.

Groundwater from the Floridan and surficial aquifer systems is available for irrigation purposes. However, wells that penetrate the Upper Floridan aquifer in the area typically produce water with chloride concentrations ranging from 140 to 500 milligrams per liter (mg/L). Wells that penetrate both the Upper and Lower Floridan aquifers typically produce water with chloride concentrations ranging from 290 to 700 mg/L (Schiner et al. 1988). In the past, area growers have reported that these concentrations increase, with pumping from irrigation wells, to levels that are considered too high for citrus irrigation. Inadequate data were available to assess the potential for development of the Floridan aquifer system as a dependable source of supply for citrus irrigation and frost-and-freeze protection. In addition, little was known about the water supply potential of the overlying surficial aquifer system.

The approach to this investigation consisted of the following measures:

- Identifying and reviewing available literature and other pertinent information concerning the hydrogeology of the groundwater system in the Indian River County area
- Developing and implementing a test-well construction plan
- Conducting specific capacity and step drawdown tests on wells in the surficial and intermediate aquifer systems
- Collecting and analyzing water samples from the test wells
- Interpreting the findings.

This report documents the investigation into the availability of water in the surficial, intermediate, and Floridan aquifer systems as a source for irrigating citrus or protecting crops during frosts or freezes in central Indian River County.

HYDROGEOLOGY

The groundwater system in Indian River County consists of the surficial aquifer system, the intermediate confining unit, and the Floridan aquifer system. The surficial aquifer system in Indian River County consists of the Anastasia, Tamiami, Fort Thompson and Caloosahatchee Formations. The Anastasia Formation generally consists of sand, shell, and coquina, and the underlying Tamiami Formation generally consists of interbedded sand and limestone. Both formations are tapped for domestic and public water supplies and generally occur east of Interstate 95 (I-95) in Indian River County. The Fort Thompson and Caloosahatchee Formations consist primarily of sand, silt, and clay. These formations generally occur west of I-95 in the central area of the county. Little information is available in the literature concerning the Fort Thompson or Caloosahatchee Formation in the study area. Reported transmissivities of the surficial aquifer system east of I-95 in Indian River County range from 1,500 to 11,000 square feet per day (ft^2/day) (Schiner et al. 1988).

The confining unit between the surficial aquifer system and the underlying Floridan aquifer system consists of the Hawthorn Group. The top of the Hawthorn Group in the study area occurs at depths ranging from 105 to 130 feet (ft) below land surface. The Hawthorn Group not only acts as the confining unit between the surficial and Floridan aquifer systems but also contains the intermediate aquifer system in the study area. This aquifer system consists of thin lenses of sand, shell, and limestone within the Hawthorn Group. In north-central Indian River County, the intermediate aquifer system generally occurs as a thin zone less than 20 ft thick. According to Bermes (1958), "This aquifer yielded water by natural flow, but after a few years its yield decreased, and the wells were deepened to the Floridan aquifer."

The Floridan aquifer system consists of a thick sequence of interbedded limestone and dolomite. It is the most productive aquifer system in Indian River County, with transmissivities ranging from 4,800 to 1,500,000 ft^2/day (Schiner et al. 1988). Throughout most of the county, the Floridan aquifer system generally contains water with concentrations of chloride and total dissolved solids that exceed public drinking water standards (the standards for chloride and total dissolved solids are 250 and 500 mg/L, respectively). In the central part of the county, the chloride concentration in water generally averages between 140 and 500 mg/L for wells that tap the Upper Floridan aquifer, while the chloride concentration in water generally averages between 290 and 700 mg/L for wells that tap both the Upper and Lower Floridan aquifers (Schiner et al. 1988).

METHODS

The methods of investigation involved drilling test holes and constructing wells in the surficial, intermediate, and Floridan aquifer systems; conducting specific capacity and step drawdown tests on wells in the surficial and intermediate aquifer systems; and collecting and analyzing water samples from the test wells.

A total of ten wells were drilled at eight sites. The well drilling contractor hired by SJRWMD, Huss Drilling, constructed seven test holes and six wells in the surficial aquifer system throughout the study area. Huss Drilling also constructed one test hole through and one well into the intermediate aquifer system. In addition to these wells, SJRWMD constructed three wells in the Upper Floridan aquifer.

Specific capacity and step drawdown tests were conducted on all wells in the surficial and intermediate aquifer systems. Specific capacity and step drawdown tests on wells in the surficial aquifer system were conducted with the drill rig. The wells were pumped at rates of 7.5 to 37.5 gallons per minute (gpm) for periods of 3 to 5 minutes, and the drawdowns were noted. The pumping rate was then increased for a period of 3 to 5 minutes, and drawdowns were measured again. This procedure was repeated until the drawdowns for four pumping rates were obtained. The final pumping rate did not exceed 37.5 gpm.

Specific capacity and step drawdown tests on the intermediate aquifer system were performed with a 2-inch (in.) submersible pump. The well was pumped at rates of 2 to 5.5 gpm for 15-minute periods. Four pumping rates were used.

Water quality samples were collected after three to five well volumes were purged from the wells and the parameters of pH, temperature, and conductivity did not change by more than 10% between two consecutive well volumes. Samples were analyzed for alkalinity, chloride, sulfate, total dissolved solids, metals (calcium, magnesium, sodium, potassium, iron, and strontium), silicon dioxide, silicon, barium, and nutrients (nitrates and nitrites and phosphate). Samples for metals, nutrients, and silicon dioxide were filtered through 0.45-micron filters, acidified, and placed on ice until the samples were returned to SJRWMD. Samples for total dissolved solids also were filtered through 0.45-micron filters. Conductivity was measured on all samples at the laboratory.

An exception to this sampling protocol occurred for samples from the Upper Floridan aquifer at site 6 (well 1, IR0963). The metal samples from this well were not filtered. As a consequence, the total concentrations are reported.

EXAMINATION OF THE SURFICIAL AQUIFER SYSTEM

Between May 20 and June 5, 1996, Huss Drilling drilled six test holes in the surficial aquifer system in central Indian River County for the purpose of obtaining information necessary to characterize the hydrogeology of this aquifer system. The test holes were constructed generally along a north-to-south bearing (sites 1–4) or an east-to-west bearing (sites 5 and 6, with site 2 also on this bearing) (Figure 1).

During drilling, the most productive intervals in these test holes were observed to occur generally in the upper 50 ft of the boreholes, which typically consisted of shell and sand. Below 50 ft, clay and silt predominated (Tables 1 and 2). The thickness of the productive intervals varied between wells but was generally less than 30 ft.

Table 1. Lithology of samples from test holes 1 through 4 on the north-to-south bearing

Depth (feet)	Test Hole 1	Depth (feet)	Test Hole 2	Depth (feet)	Test Hole 3	Depth (feet)	Test Hole 4
0	---------------------	0	---------------------	0	---------------------	0	---------------------
	sand, silt, clay		sand, silt, shell		sand		clayey sand
5		5		5		5	
10		10	---------------------	10	---------------------	10	---------------------
			sand and shell		silty sandy clay		sand and shell
15	---------------------	15		15	---------------------	15	
	sand and clay				sand		
20		20		20		20	
25		26	---------------------	26	---------------------	25	
			sand, silt, clay		sand and shell		
30	---------------------	30		30		30	
	sand and shell						
35		35		35		35	
40		40	---------------------	40	---------------------	40	---------------------
			silty, shelly clay		clay and shell		sand, silt, shell, clay
45	---------------------	45	---------------------	45		45	---------------------
	silt		clay				shelly clay

Table 1—*Continued*

Depth (feet)	Test Hole 1	Depth (feet)	Test Hole 2	Depth (feet)	Test Hole 3	Depth (feet)	Test Hole 4
50		50		50	----------------------	50	----------------------
					sandy clay		sand, silt, shell
55	----------------------	55	----------------------	55	----------------------	55	
	clay		sand, silt, shell		sand and shell		
60		60		60		60	
65		65		65		65	----------------------
							sand and shell
71	----------------------	70		70	----------------------	70	
	sand and shell				sand, silt, shell, clay		
75	----------------------	75	----------------------	75	----------------------	75	----------------------
	silty clay		sand, silt, shell, clay		clay		clay
80		80		80	----------------------	80	----------------------
					clay and shell		sand and silt
86	----------------------	85	----------------------	85	----------------------	85	
	sand, silt, shell		silt and clay		sand and silt		
90	----------------------	90		91	----------------------	90	----------------------
	silty clay				clayey limestone		sand, silt, shell
95		95		95	----------------------	95	----------------------
					shelly, sandy clay		sand and silt
100		100	----------------------	100		100	
			marl				
105	----------------------	105	----------------------	105	----------------------	105	----------------------
	sand, shell, clay		sand, silt, shell, clay		clay		sand, silt, shell, clay
110		110		110		110	
115		115	----------------------	115		115	----------------------
			silty clay				clay
120		120		120		120	
125		125		125		125	
130	----------------------	130		130		130	
	clay						
135		135		135		135	
140	Hawthorn Group	140	Hawthorn Group	140	Hawthorn Group	140	Hawthorn Group

Note: ------ = top or bottom of an interval

Table 2. Lithology of samples from test holes 6, 2, and 5 on the east-to-west bearing

Depth (feet)	Test Hole 6	Depth (feet)	Test Hole 2	Depth (feet)	Test Hole 5
0	------------------------------	0	------------------------------	0	------------------------
	sand		sand, silt, shell		sand
5	------------------------------	5		5	------------------------
	sand and shell				clay
10		10	------------------------------	10	
			sand and shell		
15		15		15	------------------------
					sand and shell
20		20		20	
25		26	------------------------------	25	
			sand, silt, clay		
30		30		30	
35		35		35	
40		40	------------------------------	40	------------------------
			silty, shelly clay		shelly clay
45		45	------------------------------	45	------------------------
			clay		sand, silt, shell
50		50		50	
55		55	------------------------------	55	
			sand, silt, shell		
60		60		60	------------------------
					clay
65		65		65	
70	------------------------------	70		70	------------------------
	clay				clayey silt
75	------------------------------	75	------------------------------	75	------------------------
	sand and shell		sand, silt, shell, clay		sand, shell, silt
80		80		80	
85		85	------------------------------	85	------------------------
			silt and clay		silt, shell, clay
90	------------------------------	90		90	
	sand, silt, shell				
95	------------------------------	95		95	
	sand, shell, clay				
100	------------------------------	100	------------------------------	100	
	sand and shell		marl		

Table 2—*Continued*

Depth (feet)	Test Hole 6	Depth (feet)	Test Hole 2	Depth (feet)	Test Hole 5
105	------------------------------	105	------------------------------	105	------------------------
	silt, shell, clay		sand, silt, shell, clay		silt and clay
110		110		110	
115	------------------------------	115	------------------------------	115	------------------------
	sand, silt, shell		silty clay		silty clay
120		120		120	
125	------------------------------	125		125	
	clay and sand				
130		130		130	
135		135		135	
140	Hawthorn Group	140	Hawthorn Group	140	Hawthorn Group

Note: ------ = top or bottom of an interval

Several citrus growers had reported the existence of shell beds in central Indian River County. However, the results of the initial test holes drilled in 1996 did not indicate shell beds but sand mixed with shell. Shell beds can be very productive. In June 1997, Huss Drilling drilled two more test holes and constructed one more well in the surficial aquifer system (site 7, IR0957) in central Indian River County. These test holes were drilled in locations where the growers thought there were shell beds in the upper 20 ft of the surficial aquifer system. At drill site 7 (Figure 1), shell beds mixed with sand were encountered, and the test hole was converted into a well in the surficial aquifer system (IR0957, Appendix A). At drill site 8, no shell beds were encountered in the top 20 ft. The aquifer at this site consisted of sandy clay (IR0956, Appendix A).

In 1995, a year before this study began, SJRWMD drilled a well into the surficial aquifer system. The well (IR0863) is located at site 9, west of the study area (Figure 1). At this site, the upper 50 ft had a 10-ft thickness of sand and shell, a finding consistent with the samples collected from the test holes drilled as part of the current project in Indian River County.

Huss Drilling constructed six 4-in. observation wells at sites 2 through 7. The test holes at these locations were plugged, except for the test hole at site 7. Wells at sites 2 through 6 were completed in June 1996. The well at site 7 was completed in June 1997. Each well was constructed with 10 ft of well screen, positioned in deposits observed to be the most productive. The total depth of these wells ranged from 24.0 to 49.5 ft (Table 3).

Table 3. Total depth, drawdown, specific capacity, and chloride concentrations of wells in the surficial aquifer system

Site and Well Number	Station Name	Total Depth (ft)	Drawdown (ft)	Specific Capacity (gpm/ft)	Chloride (mg/L)	
					1996	1997
2	IR0899	27.0	7.22	4.2	49	29*
3	IR0895	40.0	9.04	2.2	213	211*
4	IR0902	25.0	7.29	4.1	106	148*
5	IR0898	36.0	12.06	1.2	65	62*
6	IR0900	49.5	5.70	5.3	601	658*
7	IR0957	24.0	5.80	6.5	NC	95†

Note: ft = foot
gpm/ft = gallons per minute per foot
mg/L = milligrams per liter
NC = not collected

*Collected April 23 and 24, 1997
†Collected August 14, 1997

WATER-BEARING CHARACTERISTICS

Water-bearing characteristics of the surficial aquifer system include specific capacity, transmissivity, and the radius of influence of drawdowns.

Specific Capacity

Specific capacity tests were performed on the six wells. During the tests, each well was pumped at a rate of 7.5 to 38 gpm. Resultant specific capacities ranged from 1.2 to 6.5 gallons per minute per foot (gpm/ft) (Table 3). Total drawdowns ranged from 5.70 to 12.06 ft.

To estimate the production rate of 4-in. wells constructed in the surficial aquifer system, the pumping rate was adjusted such that the water level in these wells did not fall below the top of the well screens. The production rate for each well was estimated by subtracting the depth to the water from the depth to the top of the screen and multiplying the result by the specific capacity (Table 4). A similar evaluation of all test well data indicated that the average reasonable production rate of 4-in. wells producing water from the surficial aquifer system in the study area averages about 74 gpm (0.107 mgd). At this rate, numerous 4-in. wells would be required to produce the quantities of water needed for citrus irrigation.

Table 4. Estimated production rates of 4-inch wells constructed in the surficial aquifer system in central Indian River County

Site and Well Number	Station Name	Depth to Top of Screen (ft)	Depth to Water (ft)	Specific Capacity (gpm/ft)	Production Rate* (gpm)
2	IR0899	17.0	6	4.2	46
3	IR0895	30.0	5	2.2	55
4	IR0902	15.0	1	4.1	57
5	IR0898	26.0	9	1.2	20
6	IR0900	39.5	4	5.3	188
7	IR0957	14.0	2	6.5	78

Note: ft = foot
gpm = gallons per minute
gpm/ft = gallons per minute per foot

*The average production rate for the six wells is 74 gpm.

Transmissivity

The transmissivity of the surficial aquifer system can be estimated using the following equation from Walton (1970):

$$\frac{Q}{s} = \frac{T}{264 \log\left(\frac{Tt}{2{,}693 r_w^2 S}\right) - 65.5} \quad (1)$$

where

$\frac{Q}{s}$ = specific capacity, in gallons per minute per foot
Q = discharge (pumping rate), in gallons per minute
s = drawdown, in feet
T = transmissivity, in gallons per day per foot
t = pumping duration, in minutes
r_w = radius of well, in feet
S = specific yield

The specific capacity used in Equation 1 came from step drawdown tests. Because well 3 is the most centrally located in the study area, transmissivity for well 3 is assumed to be representative of the study area. The results of the step drawdown test for well 3 (IR0895) are shown in Table 5.

Table 5. Step drawdown results for well 3 (IR0895)

Time	Pumping Duration (min)	Drawdown (ft)	Pumping Rate (gpm)	Specific Capacity (gpm/ft)
10:57	0	0	0	0
11:00	3	3.33	7.5	2.25
11:03	3	5.00	12.5	2.50
11:08	5	6.02	13.6	2.26
11:13	5	9.04	20.0	2.21

Note: ft = foot
gpm = gallons per minute
gpm/ft = gallons per minute per foot
min = minute

The average transmissivity of the surficial aquifer system calculated by using Equation 1 for well 3 is 1,406 gallons per day per foot (gpd/ft). A value of 0.167 ft was used for r_w (radius of a 4-in. well), and a value of 0.2 was used for S (a typical value for a well in an unconfined aquifer [Freeze and Cherry 1979]). Based upon this calculation and the fact that the saturated thickness of the surficial aquifer system in this location is 35 ft, the hydraulic conductivity for the surficial aquifer was determined to be 40 gallons per minute per square foot (1,406 gpd/ft divided by 35 ft).

Radius of Influence

The radius of influence for a given well is the radial distance to a point of no drawdown (r_o on Figure 2). Knowledge of the radius of influence is useful to determine the average spacing necessary between wells to avoid well interference. Generally, wells should not be constructed any closer than twice the radius of influence. In a surficial aquifer system, the radius of influence can be calculated from the following equation (Todd 1959):

$$Q = \pi K \frac{h_o^2 - h_w^2}{\ln r_o / r_w} \qquad (2)$$

where

Q = pumping rate, in gallons per day
K = hydraulic conductivity, in gallons per day per square foot
h_o = saturated thickness of the aquifer, in feet
h_w = steady-state water level thickness, in feet
r_o = radius of influence, in feet
r_w = radius of well, in feet

Data collected from well 3 (IR0895) were input into this equation, and the radius of influence was calculated. The thickness of the steady-state water level (h_w) for well 3 was calculated by subtracting the steady-state drawdown from the saturated thickness of the aquifer (35 ft; see p. 15) before pumping of well 3 had commenced. Steady-state drawdown was not achieved during the step drawdown test for well 3; however, after 16 minutes of pumping, the last 5 minutes of which were at 20 gpm, the water level drawdown was 9.04 ft (Table 5). The water level drawdown would have been somewhat greater than 9.04 ft, probably between 15 and 20 ft, had pumping continued until a steady-state condition had been achieved. The radius of influence of the pumping well, based on an assumed steady-state drawdown of 15 to 20 ft, was calculated to range from 6 to 13 ft when the pumping rate was 20 gpm.

Based on the value for the radius of influence and the steady-state water level drawdown for well 3, wells producing water from the surficial aquifer system in the study area will have relatively steep

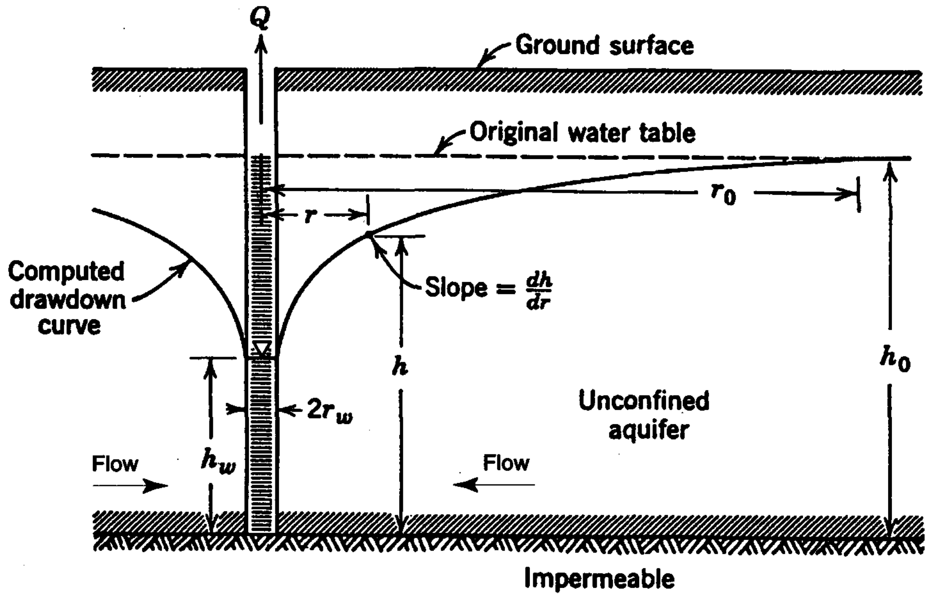

Figure 2. Illustration of terms used in equation 2 (p. 16) to determine the radius of influence of a pumping well (Todd 1959)

cones of depression. This characteristic probably will limit the amount of water that can be withdrawn from a screened well in the surficial aquifer system. The steeper the cone of depression, the deeper the drawdown. In a screened well, drawdown should not be any deeper than the top of the screen.

WATER QUALITY

Water samples were collected from test wells 2–6 in 1996 for laboratory analysis to determine chloride concentrations; concentrations ranged from 49 to 601 mg/L, respectively (Table 3). The anomalously high chloride concentration for well 6 may be the result of infiltration of water being discharged from a nearby, free-flowing well in the Floridan aquifer system. The samples collected from the six wells were observed to display a slight yellowish tint, suggesting that the wells are high in iron. All of these wells are in close proximity to surface water canals, which may be a source of water to the wells. Infiltration of such surface water to wells often results in some discoloration of the groundwater. The results of the 1996 water quality analyses are included in Appendix B.

Wells 2–6 were resampled for water quality in April 1997 (Appendix B). The chloride concentrations did not differ from the 1996 results by more than 57 mg/L (Table 3). Well 7 was sampled in August 1997; the chloride concentration was 95 mg/L.

Wells 6 (IR0900) and 3 (IR0895) had chloride concentrations above 200 mg/L for 1996 and 1997 (Table 3). As noted above, the high chloride concentration in well 6 is due to the influence of a nearby, free-flowing well in the Floridan aquifer system. The high chloride concentration in well 3 probably is due to the influence of water from the Floridan aquifer system (e.g., through a corroded well casing).

HORIZONTAL WELLS

In addition to evaluating the availability of water from vertical production wells pumping in the surficial aquifer system, SJRWMD investigated the possibility of developing adequate supplies of water from horizontal wells. Typically, horizontal wells are constructed several feet below the elevation of the water table in the surficial aquifer system and extend for several tens to hundreds of feet in a horizontal direction. Such wells should be constructed no more than 25 ft below the static water level (Driscoll 1986). Horizontal wells may be constructed in the vicinity of surface water bodies so that these water bodies act as a source of water to the wells. Such construction may serve to decrease turbidity and concentrations of bacteria and other undesirable particulates from surface water bodies (Driscoll 1986). Horizontal wells that are constructed in areas away from the influence of surface water bodies depend solely on the surficial aquifer system as a source of water. The availability of water from these wells is influenced strongly by local precipitation.

The use of horizontal wells as a dependable source of supply may require a storage facility for use in times when the infiltration rate is too low to supply the desired quantities of water, that is, during periods of extended pumping or drought. The storage facility may consist of a large tank connected to the well. Horizontal wells typically require more maintenance than conventional, vertical wells because they generally contain a greater screen length. Fine-grained sediments can enter the filter pack, thus reducing its permeability. This condition can be expected to occur commonly during peak production periods (Driscoll 1986). Other maintenance problems may include iron bacteria encrustation and inorganic deposits of calcium and magnesium, both of which can be expected to contribute to reductions in discharge from the wells. These problems are not uncommon in conventional, vertical screened wells; however, the cost of maintenance can be expected to be considerably higher in horizontal wells because of the greater screen lengths than in vertical wells.

The productivity of a horizontal well can be calculated using the following equation (Driscoll 1986). Some of the parameters used in Equation 3 are depicted in Figure 3.

$$Q = \frac{KL\left(D^2 - d^2\right)}{2880\, r_o} \qquad (3)$$

where

Q = yield from the well (pumping rate), in gallons per minute
K = hydraulic conductivity of filter pack sediment, in gallons per day per square foot
L = length of infiltration screen, in feet
D = distance between the static water level and the bottom of the well, in feet
d = thickness of water above the bottom of the well while the well is in operation, in feet
r_o = distance to the point of no drawdown, in feet (radius of influence)

Typical values of r_o for well 3 ranged from 6 to 13 ft for a pumping rate of 20 gpm and a K value of 40 gallons per day per square foot. In Equation 3, the hydraulic conductivity of the filter pack is assumed to be the same as that of the material from the surficial aquifer system.

Based on this equation, in central Indian River County, a horizontal well constructed 25 ft below the static water level in the surficial aquifer system and adjacent to a surface water body could be expected to require about 17 to 36 ft of infiltration screen to produce 20 gpm (Table 6). Increasing the screen length would result in a directly

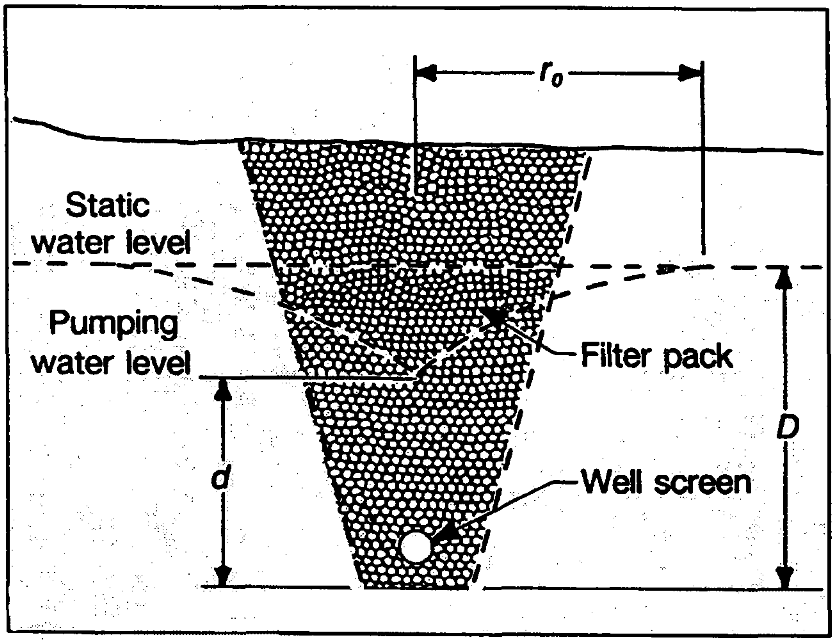

Figure 3. Illustration of terms used in Equation 3 (p. 19) to determine the productivity of a horizontal well (Driscoll 1986)

proportional increase in yield from the well. Therefore, based on the information in Table 6, a well designed to produce 100 gpm could be expected to require from about 83 to 179 ft of infiltration screen.

Costs

A vertical 4-in. well constructed in the surficial aquifer system in the study area could be expected to cost about $5,000 (G. Smith, O.E. Smith's Sons, pers. com. 1996). Screened wells constructed in the surficial aquifer system are subject to mineral and biological encrustation, which can contribute to reductions in rates of discharge. Frequent maintenance of well screens probably would be required in order to maintain reasonable rates of discharge. Construction of a network of wells in the surficial aquifer system adequate to produce a total of 1 mgd would require about ten wells at a total cost of about

Table 6. Values for parameters used in Equation 3 to calculate the length of an infiltration screen required for a horizontal well in central Indian River County

Parameter	Radius of Influence (r_o)	
	6 ft	13 ft
Q	20 gpm	20 gpm
K	40 gpd/ft^2	40 gpd/ft^2
D	25 ft	25 ft
d	10 ft	10 ft
L	16.5 ft	35.7 ft

Note:
d = thickness of water above the bottom of the well while the well is in operation
D = distance between the static water level and the bottom of the well
ft = foot
gpd/ft^2 = gallons per day per square foot
gpm = gallons per minute
K = hydraulic conductivity of filter pack sediment
L = length of infiltration screen
Q = pumping rate

$50,000. Operation and maintenance of such a well network could be very time-consuming and expensive.

A horizontal well constructed in the surficial aquifer system in the study area could be expected to cost $17,900 (J.A. Sawyer, W.C. Roese Contracting, pers. com. 1996). Screened wells are subject to clogging of the filter pack, iron bacteria encrustation, and inorganic deposits. Frequent maintenance of well screens probably would be required in order to maintain reasonable rates of discharge. Construction of a network of horizontal wells in the surficial aquifer system adequate to produce a total of 1 mgd would require about eight wells at a total cost of about $143,200. Operation and maintenance of such a well network could be very time-consuming and expensive.

EXAMINATION OF OTHER AQUIFER SYSTEMS

The surficial aquifer system is not as productive as originally believed for use in supplying water for citrus irrigation or frost-and-freeze protection. Therefore, the capacity of other aquifer systems was explored.

INTERMEDIATE AQUIFER SYSTEM

In June 1997, Huss Drilling drilled a 4-in. test hole (site 8; Figure 1) through the intermediate aquifer system in central Indian River County. The Hawthorn Group is 271 ft thick at this site and occurs between 109 and 380 ft in depth. It generally consists of sandy, silty clay. Fossiliferous limestone occurs between 265 and 298 ft in depth and was the only aquifer encountered within the Hawthorn Group. Thus, the intermediate aquifer system is 33 ft thick at this site. A geophysical log of the test hole can be found in Appendix C.

In July 1997, Huss Drilling constructed well 8 (IR0956) in the intermediate aquifer system at this site. The well is 4 in. in diameter and 285 ft deep, with 20 ft of screen. The top of the well casing has a finished elevation of 2.95 ft above land surface. Water barely flows out of the well—the hydrostatic head in the well is 4.57 ft above land surface.

Water-Bearing Characteristics

The specific capacity of well 8 (IR0956) is 0.08 gpm/ft, which indicates that the well is a very poor producer of water. If this well is representative of the intermediate aquifer system in the study area, the intermediate aquifer system has little to no potential for supplying adequate quantities of water for citrus irrigation or frost-and-freeze protection.

Water Quality

The chloride concentration in well 8 (IR0956) was 113 mg/L on August 14, 1997. The results of analyses for other groundwater quality parameters are included in Appendix D.

FLORIDAN AQUIFER SYSTEM

In 1997, SJRWMD drilled wells 9, 10, and 1 in the Upper Floridan aquifer (IR0955, IR0954, and IR0963, respectively) at sites 8, 4, and 6, respectively (Figure 1). These wells are 6 in. in diameter; they penetrate only 50 ft of the Upper Floridan aquifer. The total depths for wells 9, 10, and 1 are 430 ft, 480 ft, and 440 ft, respectively. The Floridan aquifer system is under artesian conditions at each of these wells. The hydrostatic head was 18.11 ft above land surface at well 9 on October 7, 1997. The flow from these wells was estimated on June 22, 1998, as 243 gpm at well 9, 117 gpm at well 10, and 124 gpm at well 1. The geophysical logs for those wells can be found in Appendix C.

Chloride concentrations were 259 mg/L, 95 mg/L, and 518 mg/L in wells 9, 10, and 1, respectively. Chloride concentrations are lowest west of I-95. Well 10 had the lowest chloride concentration in the area, a concentration even lower than that reported in Schiner et al. (1988)—140 to 500 mg/L—for the Upper Floridan aquifer. If wells 9, 10, and 1 were allowed to flow freely , the chloride concentrations probably would stabilize at levels slightly greater than those observed (Schiner et al. 1988). If these three wells are pumped or if pumping occurs in nearby wells, the chloride concentrations can increase.

The results of analyses for other groundwater quality parameters are included in Appendix D.

CONCLUSIONS

The geology and hydrogeology of the groundwater system were examined in this study. Also examined were the costs associated with constructing vertical and horizontal wells in the surficial aquifer system.

The most productive portion of the surficial aquifer system in the study area occurs in the upper 50 ft of the system and has a thickness of generally less than 30 ft. The specific capacity is less than 6.6 gpm/ft for the wells constructed in association with this project and for the wells that penetrate the most productive portion of the surficial aquifer system. The transmissivity of the surficial aquifer system in the study area is about 1,406 gpd/ft. Four-inch wells constructed in the most productive portion of the surficial aquifer system can be expected to produce an average of about 74 gpm (0.107 mgd). A network of ten production wells in the surficial aquifer system would be required to produce a total of 1 mgd. Such a network of vertical wells is estimated to cost $50,000 to construct.

Horizontal wells constructed 25 ft below the static water level would require from about 17 to 36 ft of infiltration screen to produce 20 gpm or from about 83 to 179 ft of screen to produce 100 gpm, in central Indian River County. A network of eight horizontal wells in the surficial aquifer system would be required to produce a total of 1 mgd. Such a network of horizontal wells is estimated to cost $143,200 to construct.

Both vertically and horizontally constructed wells should be expected to require considerable maintenance to avoid reductions in rates of discharge caused by sedimentation and biological and mineral encrustation of the infiltration screens. The surficial aquifer system appears to have limitations as an economically feasible source of water for citrus irrigation or frost-and-freeze protection in the study area.

Only one productive interval was identified by SJRWMD in the intermediate aquifer system in the study area. It is approximately 33 ft thick and occurs between 265 and 298 ft in depth. Based on the specific capacity of only 0.08 gpm/ft for a test well in this aquifer system, the intermediate aquifer within this system offers little to no potential for supplying adequate quantities of water for citrus irrigation or frost-and-freeze protection.

Three wells were constructed in the Upper Floridan aquifer in the study area. Two wells are located west of I-95 and one well is located east of I-95. Each well only penetrated 50 ft of the Upper Floridan aquifer. Chloride concentrations at this depth in the Upper Floridan aquifer are below 260 mg/L west of I-95. The hydrostatic head in this area is about 18 ft above land surface. The estimated flow from these wells ranged between 117 and 243 gpm. The upper 50 ft of the Upper Floridan aquifer, west of I-95, offers the most promise as a source of water for citrus irrigation or frost-and-freeze protection in the study area. The water available from the surficial and intermediate aquifer systems does not appear to be sufficient to supply the daily quantity needed for agricultural irrigation to supplement the use of surface water.

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APPENDIX A—LITHOLOGIC DESCRIPTION OF WELLS 7 AND 8

Well Number: 7 (IR0957)
Total Depth: 30 ft bls
Samples Collected From: 0 to 30 ft bls
Completion Date: June 26, 1997
Owner: SJRWMD

County: Indian River
Location: T. 33 S., R. 37 E., S. 04
Lat.: 27°38'45" Long.: 80°38'28"
Elevation: 28 ft msl
Driller: Huss Drilling

Samples Worked In Field By: J. Sego and D. Toth

Depth (ft bls)	Lithologic Description
0–2	Sand, brown
2–4	SAA, clay in bottom 4 in. of sample
4–6	Sand, brown to 5 ft bls; then sand and clay, gray
6–8	Sand, brown
8–10	Sand, brown to 8.3 ft bls; then clay gray
10–12	Sand and clay, gray
12–14	Sand, fine, gray and shell fragments 2–5 mm, less shell in bottom 6 in.
14–16	SAA to 14.6 ft bls; then clay, gray to 15 ft bls; then SAA
16–18	SAA
18–20	SAA to 18.6 ft bls; then sand, medium-fine, dark gray-clear, clear sand is cemented together; with shell fragments
20–22	SAA, well indurated clear sands
22–24	SAA
24–26	SAA to 25 ft bls; then cemented sands with less shell material
26–28	Sand, fine and clay, gray; with some cemented sand as above, and minor shell, 27.5 ft bls to 28 ft bls is predominantly fine sand
28–30	Sand, fine and clay, gray

Note: ft bls = feet below land surface
ft msl = feet, mean sea level
in. = inch
mm = millimeter
SAA = same as above

Source: Division of Ground Water Programs 1998, in preparation

Well Number: 8 (IR0956)
Total Depth: 380 ft bls
Samples Collected From: 0 to 380 ft bls
Completion Date: June 25, 1997
Owner: SJRWMD

County: Indian River
Location: T. 32 S., R. 37 E.
Lat.: 27°39'41" Long.: 80°37'54"
Elevation: 26 ft msl
Driller: Huss Drilling

Samples Worked In Field By: J. Sego and D. Toth

Depth (ft bls)	Lithologic Description
0–2	Sand, medium, tan-gray; with lenses of clay to 1.5 ft bls; then sand, medium, brown, organic material
2–4	Sand, medium-fine, brown; with organic material
4–6	Clay, brown gray, sandy
6–8	SAA, greater percentage of sand
8–10	SAA with limestone, sandy at 8 ft bls to 8.17 ft bls
10–12	SAA
12–14	SAA, greater percentage of clay to 13 ft bls; with coarser sand from 13 ft bls to 13.25 ft bls
14–16	SAA; with white chert
16–18	SAA; with shell fragments
18–20	SAA, shell bed at 18.5 ft bls to 18.75 ft bls
20–22	SAA; coarse sand 21.75 ft bls–22 ft bls
22–24	SAA to 23 ft bls; then sand, medium, gray with clay and shell, sandy clay, gray from 23.75 ft bls to 24 ft bls
24–26	Sand, gray, with clay to 25 ft bls; then sand, medium, gray; with shell from 25.75 ft bls to 26 ft bls
26–28	Shell; with sand, fine, gray
28–30	SAA; with clay
34–36	Sand, gray and shell
39–41	SAA; with clay
44–46	Clay, sand, and shell
99–101	Clay, gray-green; with sand, fine/silt, and shell, indurated areas with shell casts, trace phosphorite
104–106	SAA; greater percentage phosphorite and sand to 105.5 ft bls; then sand, fine, clayey, gray
109–111	Clay; with sand, fine and phosphorite; seams of fine gray sand , shell, and phosphatic intraclasts from 109 ft bls to 110 ft bls
114–116	Clay, green; with sand, fine/silt, phosphorite, and blebs of sand, gray-green
119–121	SAA; with seams of shell and gray sand

Well 8—*Continued*

Depth (ft bls)	Lithologic Description
124–126	SAA; with silty clay and shell in seams
129–131	SAA
134–136	SAA; with sand, medium-fine and clay seams, trace limestone, white, moldic
139–141	Clay, olive-green; with very fine sand, seams of shell, calcite, and phosphorite throughout
144–146	SAA; with phosphorite up to 0.75 in. diameter
149–151	Clay, green
154–156	Clay, green, and silt/fine sand; trace shell and phosphatic limestone
159–161	Clay, green; with silt
164–166	SAA
169–171	SAA
174–176	Sand, very fine, and clay, green; with phosphorite blebs ($\leq$1 mm)
179–181	Clay, green; with sand, medium-fine and phosphorite, trace shell, sharks tooth (*megaladon*), and calcite
184–186	Clay, green; with sand, medium, some clear well rounded sand pebbles, and phosphorite, minor shell
190–195	Sand, clay, and silt, well indurated, moldic; with shell and phosphorite
200–205	SAA
205–210	SAA; greater percentage of sand and phosphorite
210–215	SAA
215–220	SAA
220–225	SAA; trace limestone at 222.5 ft bls
225–230	Sand, fine, green, indurated; with clay and trace limestone
230–235	SAA to 237 ft bls; then sandstone, light gray, calcareous, breccia; with phosphorite, moldic
235–240	Sand, fine, phosphorite, and clay, dark green-light gray; with shell fragments
240–245	SAA
245–250	Sand, fine, dark gray, phosphatic; with shell
250–255	SAA
255–260	No Return
260–265	SAA
265–270	Clay, white; with phosphorite and cherty limestone
270–275	Sand and shell, light green-white, indurated to 273 ft bls; then sandstone/limestone, phosphatic; with sand and clay, dark green, and coquina, gray
275–280	SAA
280–285	SAA, less phosphatic
285–290	SAA
290–295	SAA

Well 8—*Continued*

Depth (ft bls)	Lithologic Description
295–300	SAA to 298 ft bls; then sand, medium-fine, indurated, moldic, phosphatic; with shell
300–310	Sand, fine, green-gray; with clay and shell indurated to poorly indurated
310–320	Clay, green-gray; with sand and phosphorite, indurated, angular clasts of green clay at 303 ft bls to 306 ft bls; then clay, green, indurated
320–330	Clay, dark green, indurated to poorly indurated; with lenses of sand
330–340	SAA
340–350	Clay, green, moldic; with sand, fine
350–360	SAA
360–370	SAA to 367 ft bls; then coquina
370–380	Coquina, white-gray; then limestone, creme fossiliferous (*Lepidocyclina*), phosphatic

Note: ft bls = feet below land surface
ft msl = feet, mean sea level
in. = inch
mm = millimeter
SAA = same as above

Source: Division of Ground Water Programs 1998, in preparation

APPENDIX B—WATER QUALITY IN THE SURFICIAL AQUIFER SYSTEM

Key for use with Tables B1 through B4

*	not determined
-D	denotes dissolved—samples were filtered
Alk-Lab	alkalinity, in the laboratory
Ca	calcium
Cl	chlorides
Cond-Fld	conductivity, in the field
Cond-Lab	laboratory-measured conductivity at 25°C, in micromhos per centimeter
deg C	degrees Celsius
Depth Sam	depth sampled
Fe	iron
ft	foot
J	estimated value—value is not accurate
K	potassium
Mg	magnesium
mg/L	milligrams per liter
Na	sodium
NOx	nitrates and nitrites
P-NS--	precleaned field blank
pH-Field	pH, in the field
PO4	phosphate
Q	sample held beyond the accepted holding time
SiO2	silicon dioxide
SO4	sulfate
Sr	strontium
Std units	standard units
T	value reported is less than the laboratory detection limit
TDS	total dissolved solids
ug/L	micrograms per liter
umhos/cm	micromhos per centimeter
W	water matrix
WL<LSD	water level below land surface
Wtr temp	water temperature

Table B1. Water quality for well 3 (IR0895) and well 5 (IR0898). ***Samples were collected May 29, 1996.***

FILE #: 961422 TOTAL ID: 3 TOTAL STORET: 14

			Alk-Lab (W)	Cl (W)	Cond-Lab (	SO4 (W)
			mg/L	mg/L	umhos/cm	mg/L
			410	940	95	945
1	P-NS--	9605291045	1.000W	1.000T	6.000T	0.000T
2	IR0895	9605291120	357.000	213.000	1400.000	145.000J
3	IR0898	9605291452	279.000	65.000	687.000	10.000

			TDS (W)	NOx-D (W)	Ca-D (W)	Fe-D (W)
			mg/L	mg/L	mg/L	ug/L
			70300	631	915	1046
1	P-NS--	9605291045	1.000T	0.002Q	0.000T	-31.000
2	IR0895	9605291120	949.000	0.020Q	168.000	1720.000
3	IR0898	9605291452	431.000	0.023Q	90.000	680.000

			K-D (W)	Mg-D (W)	Na-D (W)	Cond-Fld
			mg/L	mg/L	mg/L	umhos/cm
			935	925	930	94
1	P-NS--	9605291045	0.100T	0.000T	0.000T	
2	IR0895	9605291120	2.800	23.600	132.000	1615.000
3	IR0898	9605291452	1.700	7.500	62.000	731.000

			Wtr Temp	pH-Field
			deg C	std units
			10	400
1	P-NS--	9605291045		
2	IR0895	9605291120	26.000	6.920
3	IR0898	9605291452	25.000	7.140

Table B2. Water quality for well 2 (IR0899). ***The sample was collected May 23, 1996.***

FILE #: 961351 TOTAL ID: 2 TOTAL STORET: 14

			Alk-Lab (W) mg/L 410	Cl (W) mg/L 940	Cond-Lab (umhos/cm 95	SO4 (W) mg/L 945
1	P-NS--	960523700	2.000	1.000T	4.000T	1.000T
2	IR0899	960523820	244.000	49.000	645.000	34.000

			TDS (W) mg/L 70300	NOx-D (W) mg/L 631	Ca-D (W) mg/L 915	Fe-D (W) ug/L 1046
1	P-NS--	960523700	1.000T	0.003T	0.000T	-56.000T
2	IR0899	960523820	404.000	0.050	79.000	1970.000

			K-D (W) mg/L 935	Mg-D (W) mg/L 925	Na-D (W) mg/L 930	Cond-Fld umhos/cm 94
1	P-NS--	960523700	0.000T	0.000T	0.000T	
2	IR0899	960523820	1.300	7.800	51.000	725.000

			Wtr Temp deg C 10	pH-Field std units 400
1	P-NS--	960523700		
2	IR0899	960523820	24.000	7.220

Table B3. Water quality for well 4 (IR0902) and well 6 (IR0900). ***Samples were collected June 4 and 5, 1996.***

FILE #: 961452 TOTAL ID: 3 TOTAL STORET: 17

			Alk-Lab (W) mg/L 410	Cl (W) mg/L 940	Cond-Lab (umhos/cm 95	SO4 (W) mg/L 945
1	P-NS--	9606031230	1.000W	0.000T	4.000T	0.000T
2	IR0902	960604950	269.000	106.000	1030.000	138.000
3	IR0900	9606051505	243.000	601.000	2420.000	111.000

			TDS (W) mg/L 70300	NOx-D (W) mg/L 631	Ca-D (W) mg/L 915	Fe-D (W) ug/L 1046
1	P-NS--	9606031230	1.000T	0.003Q	0.000T	-55.000T
2	IR0902	960604950	667.000	0.008Q	145.000	654.000
3	IR0900	9606051505	1550.000	0.035Q	234.000	8160.000

			K-D (W) mg/L 935	Mg-D (W) mg/L 925	Na-D (W) mg/L 930	Cond-Fld umhos/cm 94
1	P-NS--	9606031230	0.000T	0.000T	0.000T	
2	IR0902	960604950	5.000	17.500	68.000	1070.000
3	IR0900	9606051505	2.400	18.500	274.000	2678.000

			Weather code no. 41	Wtr Temp deg C 10	pH-Field std units 400	Depth Sam ft 72016
1	P-NS--	9606031230				
2	IR0902	960604950	20.000	24.000	7.100	25.000
3	IR0900	9606051505	20.000	25.000	6.900	49.500

			WL < LSD ft 72019
1	P-NS--	9606031230	
2	IR0902	960604950	
3	IR0900	9606051505	

Table B4. Water quality for well 3 (IR0895), well 5 (IR0898), well 2 (IR0899), well 6 (IR0900), well 4 (IR0902), and well 7 (IR0957). *Samples for wells 2–6 were collected April 23 and 24, 1997; the sample for well 7 was collected August 14, 1997.*

Station Name	IR0895	IR0898	IR0899	IR0900	IR0902	IR0957
Lab Sample Number	971149-1	971149-2	971149-3	971149-4	971149-5	972617-2
Sample Collect Date/Time	9704231115	9704240931	9704240809	9704231414	9704231207	9708141225
Sample Receive Date	970425 0000	970425 0000	970425 0000	970425 0000	970425 0000	970425 0000
Alkalinity (mg/L) (STORET 410)	374.000	290.000	256.000	241.000	264.000	250.959
Cl (mg/L) (STORET 940)	211.000	62.000	29.000	658.000	148.000	95.063
Conductivity (umhos/cm) (STORET 95)	1,530.000	726.000	642.000	2,640.000	1,230.000	870.000
SO4 (mg/L) (STORET 945)	131.000	2.000	40.000	114.000	186.000	57.830
TDS (mg/L) (STORET 70300)	982.000	440.000	409.000	1,630.000	807.000	530.000
SiO2-D (mg/L) (STORET 955)	23.342	20.604	16.996	12.842	11.774	19.072
PO4-D (mg/L) (STORET 671)	0.163	0.020	0.013	0.148	0.009T	0.009T
NOx-D (mg/L) (STORET 631)	-0.001T	0.000T	-0.003T	0.463	0.006T	0.004T
Ca-D (mg/L) (STORET 915)	167.000	91.000	94.000	229.000	171.000	89.300
Fe-D (µg/L) (STORET 1046)	1,940.000	1,200.000	3,590.000	------	1,900.000	1,033.000
K-D (mg/L) (STORET 935)	2.400	1.400	0.700T	1.600	4.800	1.519
Mg-D (mg/L) (STORET 925)	22.200	6.200	7.000	18.000	15.300	11.440
Na-D (mg/L) (STORET 930)	127.000	52.000	34.000	262.000	66.000	55.000
Sr-D (µg/L) (STORET 1080)	------	4,860.000	578.000	8,240.000	7,500.000	1,022.000
Water Temp (deg C) (STORET 10)	24.100	23.760	23.860	23.840	23.610	26.800
pH-Field (std units) (STORET 400)	6.730	6.970	7.040	6.820	6.860	7.230
Conductivity-Field (umhos/cm) (STORET 94)	1,550.000	713.000	640.000	2,680.000	1,250.000	845.000

Note: ------ = results not reported

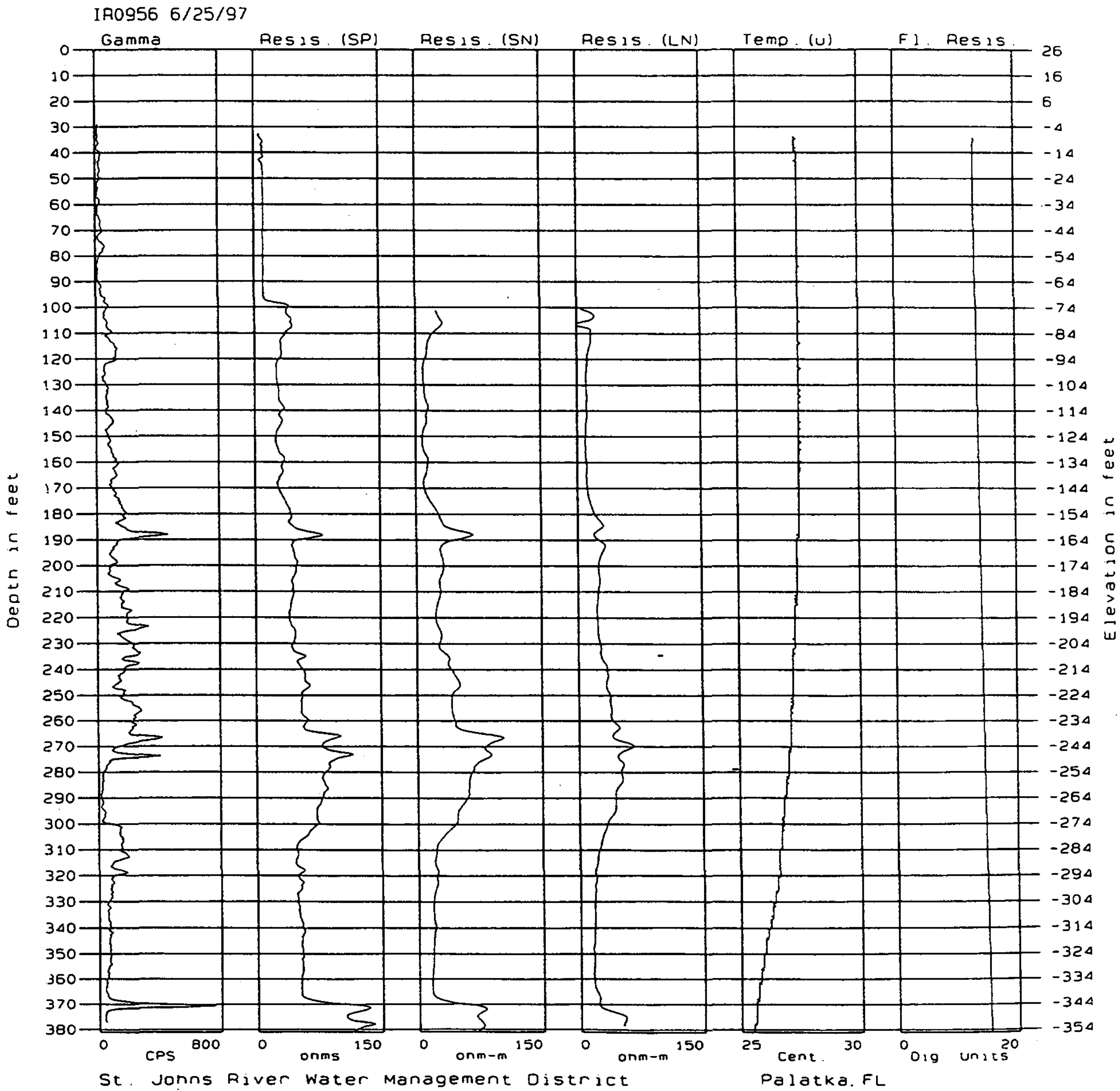
APPENDIX C—GEOPHYSICAL LOGS

GEOPHYSICAL LOGS FOR WELL IR0956

Log Source: St. Johns River Water Management District

Station Name	County INDIANRI	Date Logged
Well ID: IR0956	Latitude: 27D 39M 41S	Depth Logged 381 ft
FGS ID:	Longitude: 80D 37M 54S	Cased Depth
Other ID:	Elevation 26 ft	Water Level ft
Owner	Topo Quad: FELLSMERE 4 NW	Date Measured

Logs Available: GAM. RES. RSN. RLN. TMP. FLR



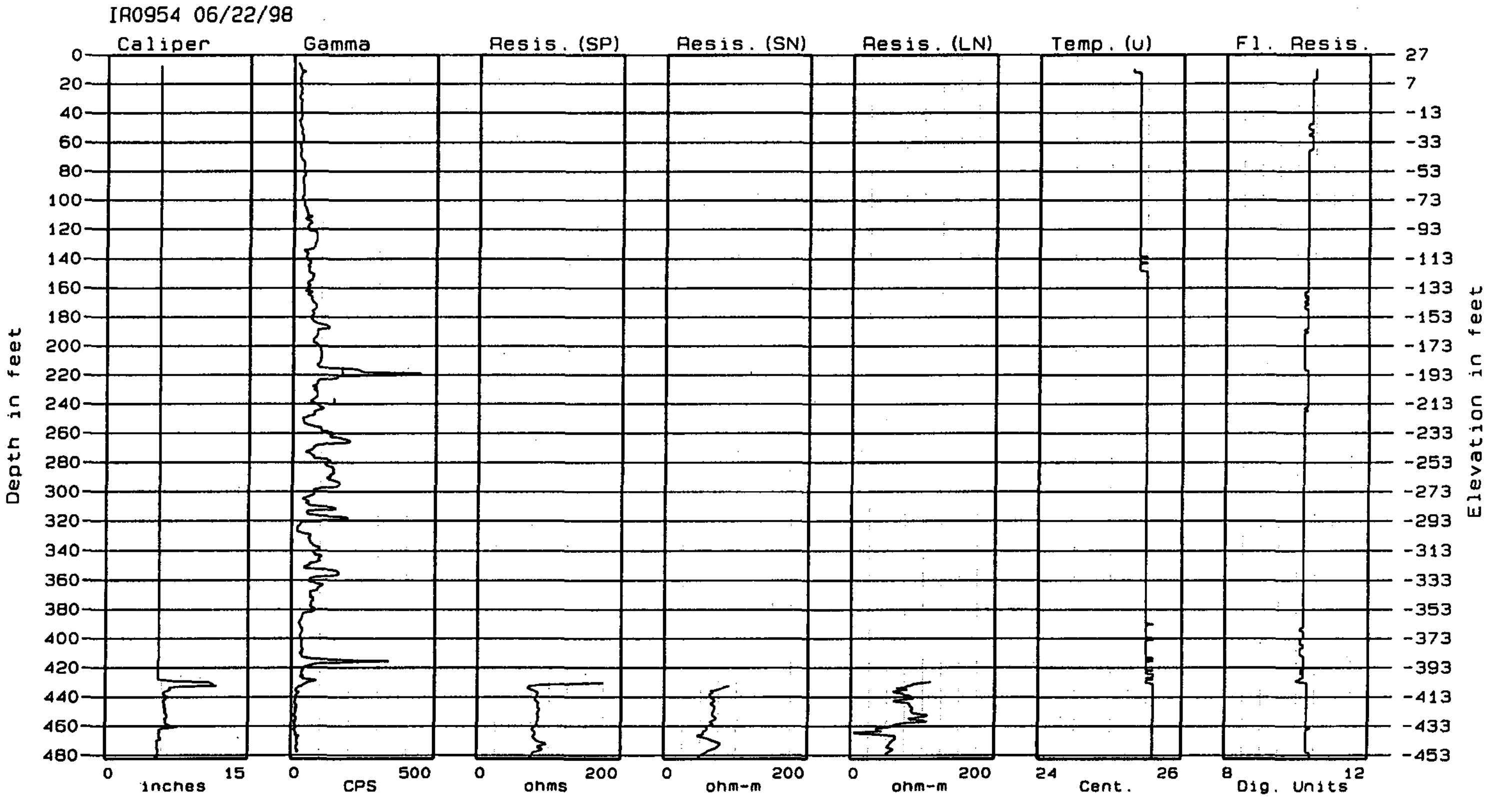
GEOPHYSICAL LOGS FOR WELL IR0954

Log Source: St. Johns River Water Management District

Station Name:
Well ID: IR0954
FGS ID:
Other ID:
Owner:
Logs Available: CAL, GAM, RES, RSN, RLN, TMP, FLR

County: INDIANRI
Latitude: 27D 35M 14S
Longitude: 80D 34M 44S
Elevation: 27 ft.
Topo Quad: FELLSMERE 4 SE

Date Logged:
Depth Logged: 482.5 ft.
Cased Depth:
Water Level: ft.
Date Measured:



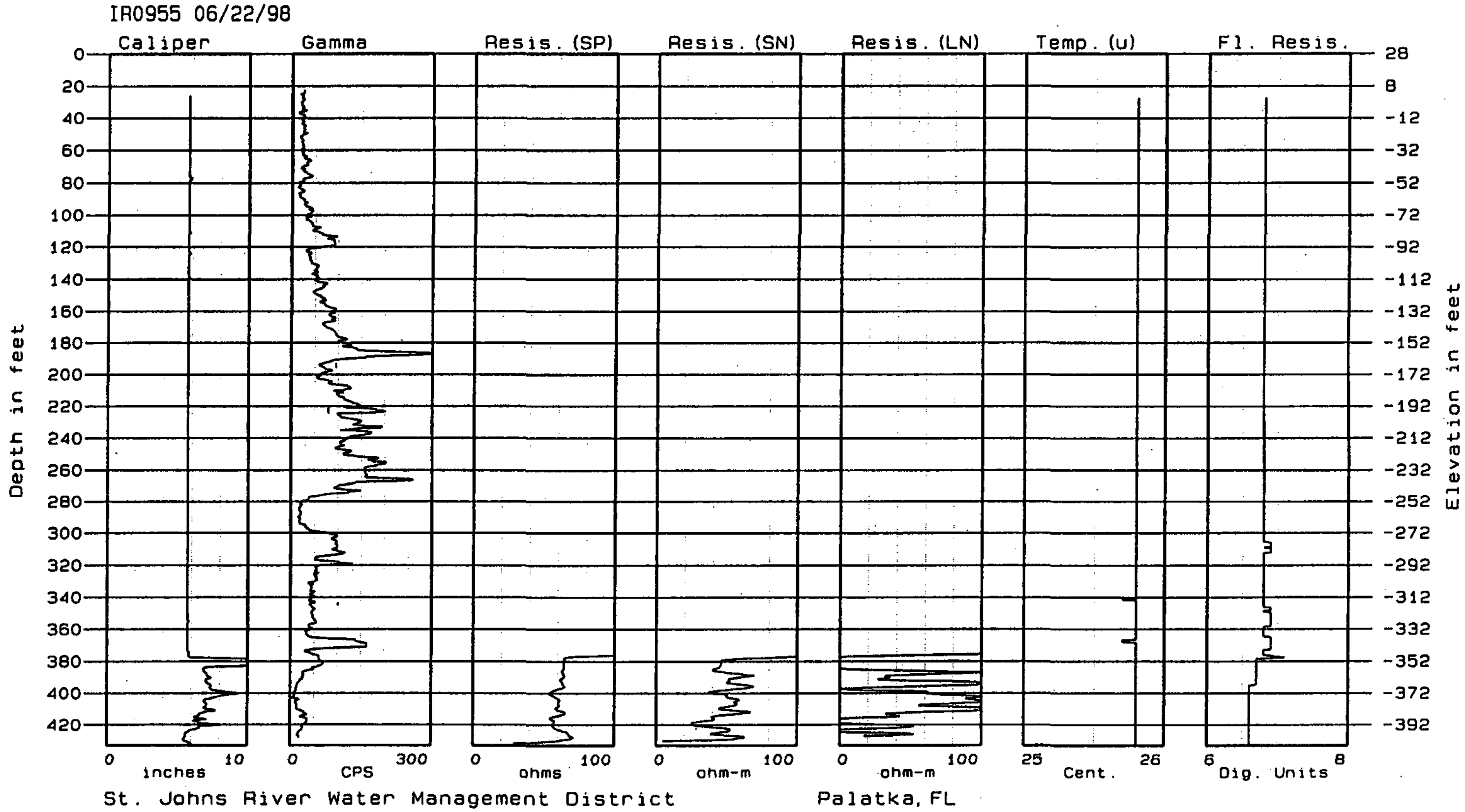
St. Johns River Water Management District Palatka, FL

GEOPHYSICAL LOGS FOR WELL IR0955

Log Source: St. Johns River Water Management District

Station Name:	County: INDIANRI	Date Logged:
Well ID: IR0955	Latitude: 27D 39M 41S	Depth Logged: 433 ft.
FGS ID:	Longitude: 80D 37M 54S	Cased Depth:
Other ID:	Elevation: 28 ft.	Water Level: ft.
Owner:	Topo Quad: FELLSMERE 4 NW	Date Measured:

Logs Available: CAL, GAM, RES, RSN, RLN, TMP, FLR

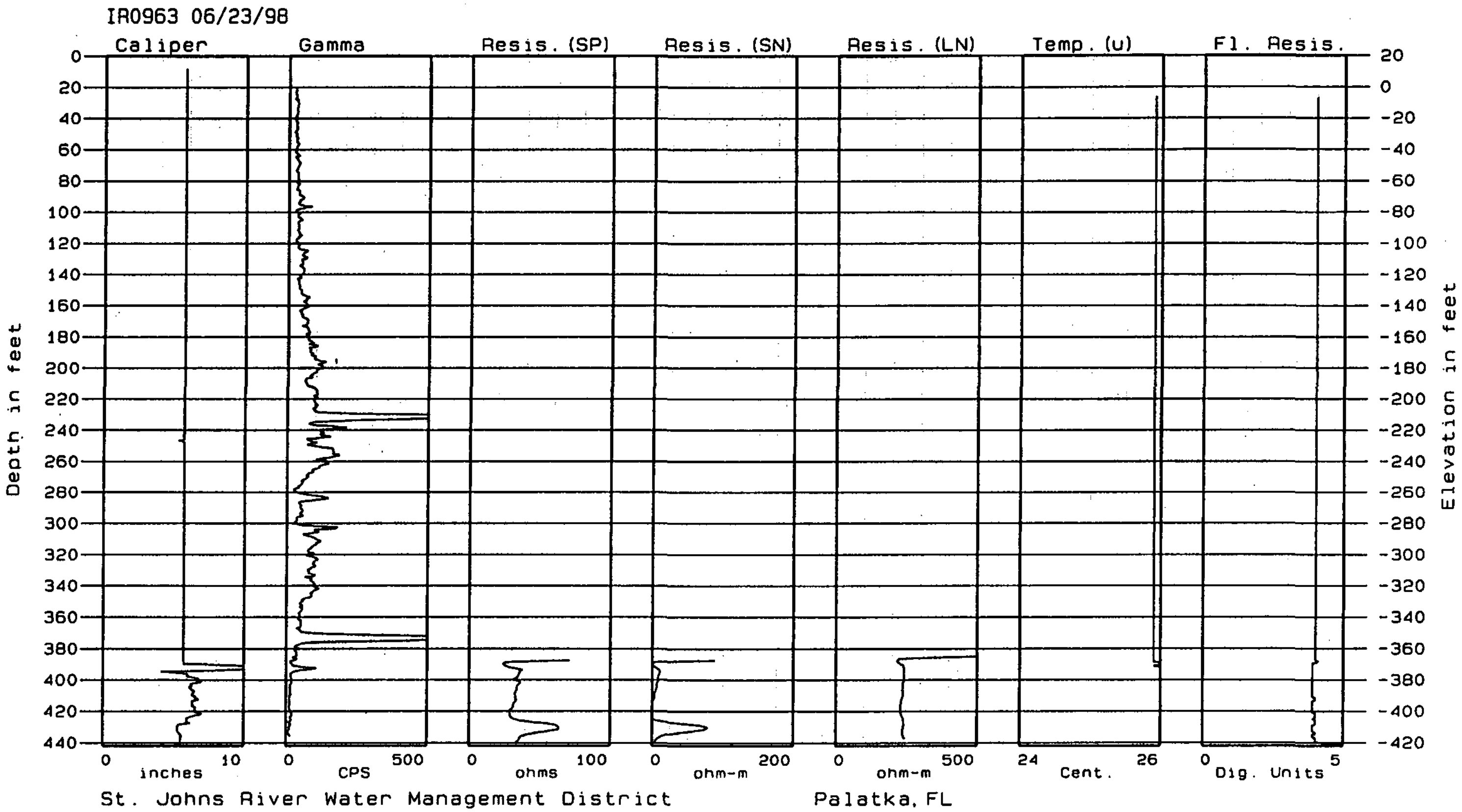


GEOPHYSICAL LOGS FOR WELL IR0963

Log Source: St. Johns River Water Management District

Station Name:	County: INDIANRI	Date Logged:
Well ID: IR0963	Latitude: 27D 41M 25S	Depth Logged: 442 ft.
FGS ID:	Longitude: 80D 30M 48S	Cased Depth:
Other ID:	Elevation: 20 ft.	Water Level: ft.
Owner:	Topo Quad: FELLSMERE 4 NE	Date Measured:

Logs Available: CAL, GAM, RES, RSN, RLN, TMP, FLR



APPENDIX D—WATER QUALITY IN THE INTERMEDIATE AND FLORIDAN AQUIFER SYSTEMS

Key for use with Tables D1 through D3

Ba	barium
-D	denotes dissolved—samples were filtered
Ca	calcium
Cl	chloride
deg C	degrees Celsius
F	fluorine
Fe	iron
J	estimated value—value is not accurate
K	potassium
Mg	magnesium
mg/L	milligrams per liter
Na	sodium
NOx	nitrates and nitrites
pH-Field	pH, in the field
PO4	phosphate
Si	silicon
SiO2	silicon dioxide
SO4	sulfate
Sr	strontium
std units	standard units
T	value reported is less than the laboratory detection limit
TDS	total dissolved solids
ug/L	micrograms per liter
umhos/cm	micromhos per centimeter
Water temp	water temperature

Table D1. Water quality for well 8 (IR0956) in the intermediate aquifer system. *The sample was collected August 14, 1997.*

Station Name	IR0956
Lab Sample Number	L972617-1
Sample Collect Date/Time	970814 1132
Sample Receive Date	970815 0000
Alkalinity (mg/L) (STORET 410)	324.75
Cl (mg/L) (STORET 940)	112.707
Conductivity (umhos/cm) (STORET 95)	1,010.000
SO4 (mg/L) (STORET 945)	40.740
TDS (mg/L) (STORET 70300)	604.000
SiO2-D (mg/L) (STORET 955)	70.798
PO4-D (mg/L) (STORET 671)	0.056
NOx-D (mg/L) (STORET 631)	0.000T
Ca-D (mg/L) (STORET 915)	25.220
Fe-D (µg/L) (STORET 1046)	6.210T
K-D (mg/L) (STORET 935)	14.270
Mg-D (mg/L) (STORET 925)	28.820
Na-D (mg/L) (STORET 930)	123.000
Sr-D (µg/L) (STORET 1080)	5,998.000
Water Temp (deg C) (STORET 10)	27.300
pH-Field (std units) (STORET 400)	7.670
Conductivity-Field (umhos/cm) (STORET 94)	979.000

Table D2. Water quality for well 10 (IR955) and well 11 (IR0954) in the Upper Floridan aquifer. *Samples were collected November 4, 1997.*

Station Name	IR0955	IR0954
Lab Sample Number	980356-2	980356-3
Sample Collect Date/Time	971103 1102	971103 1301
Sample Receive Date	971104 0000	971104 0000
Alkalinity (mg/L) (STORET 410)	163.505	195.952
Cl (mg/L) (STORET 940)	258.586	95.023
Conductivity (umhos/cm) (STORET 95)	1,360.000	957.000
SO4 (mg/L) (STORET 945)	122.969	147.891
TDS (mg/L) (STORET 70300)	752.000	561.000
SiO2-D (mg/L) (STORET 955)	20.697	22.820
PO4-D (mg/L) (STORET 671)	0.008T	0.015
NOx-D (mg/L) (STORET 631)	-0.001T	0.002T
Ca-D (mg/L) (STORET 915)	61.200	36.020
Fe-D (µg/L) (STORET 1046)	7.820T	5.510T
K-D (mg/L) (STORET 935)	6.490	6.970
Mg-D (mg/L) (STORET 925)	37.720	30.170
Na-D (mg/L) (STORET 930)	126.400	100.700
Sr-D (µg/L) (STORET 1080)	8,313.000	6,867.000
pH-Field (std units) (STORET 400)	25.530	25.630
Conductivity-Field (umhos/cm) (STORET 94)	1,462.000	1,032.000

Table D3. Water quality for well 1 (IR0963) in the Upper Floridan aquifer. *The sample was collected August 26, 1997.*

Station Name	IR0963
Lab Sample Number	L972760-1
Sample Collect Date/Time	970826 1308
Sample Receive Date	970829 0000
Alkalinity (mg/L) (STORET 410)	139.640
Cl (mg/L) (STORET 940)	518.177
F (mg/L) (STORET 951)	0.730
SO4 (mg/L) (STORET 945)	125.074
TDS (mg/L) (STORET 70300)	1,130.000
Si-T (mg/L) (STORET 958)	8.650
Ba-T (µg/L) (STORET 1007)	39.000
Ca-T (mg/L) (STORET 916)	84.900
Fe-T (µg/L) (STORET 1045)	297.900
K-T (mg/L) (STORET 937)	8.470
Mg-T (mg/L) (STORET 927)	53.600
Na-T (mg/L) (STORET 929)	218.600
Sr-T (µg/L) (STORET 1082)	10,073.000
Water Temp (deg C)	28.000
Conductivity-Field (umhos/cm) (STORET 94)	2,089.000J