RESULTS OF AQUIFER STORAGE RECOVERY (ASR) WELL DRILLING AND TESTING

Prepared for the

CITY OF COCOA, FLORIDA

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Section 1
INTRODUCTION

Aquifer storage recovery (ASR) is a water management technique in which large volumes of water are stored in geologic formations on a seasonal basis. The first phase of ASR development for the City of Cocoa consisted of one ASR well with a recovery capacity of approximately 1.5 mgd. Construction and testing were completed, and the facility was permitted by the Florida Department of Environmental Regulation (FDER) for operational use by January 1988.

After the first ASR facility was proven successful, CH2M HILL recommended that the ASR facility be expanded to include five additional wells. This report documents the results of well construction and testing of the five additional wells.

LOCATION AND SITE DESCRIPTION

The Claude H. Dyal Water Treatment Plant (WTP) is located on State Road 520 in Orange County, Florida (see Figure 1-1). The five new ASR wells are located on the Dyal Plant property, as shown in Figure 1-2. The spatial location of the five wells was chosen because of the Dyal property configuration and for compatibility with the ASR concept. A balance between well interference and the stored water envelope was selected to optimize the recovery efficiency of the expanded facilities.

The site is on the coastal lowlands of Florida and within the St. Johns River Valley. Topography around the site is that of marsh and sandy prairie. Vegetation is mainly grasses, saw-palmetto, palm, and cypress.

LOCAL GEOLOGY

The local geology of the Cocoa ASR site consists of carbonate rocks overlain by unconsolidated material. The following three stratigraphic units were encountered during the well construction:

- Undifferentiated surficial deposits
- The Hawthorn Formation
- The Ocala Group

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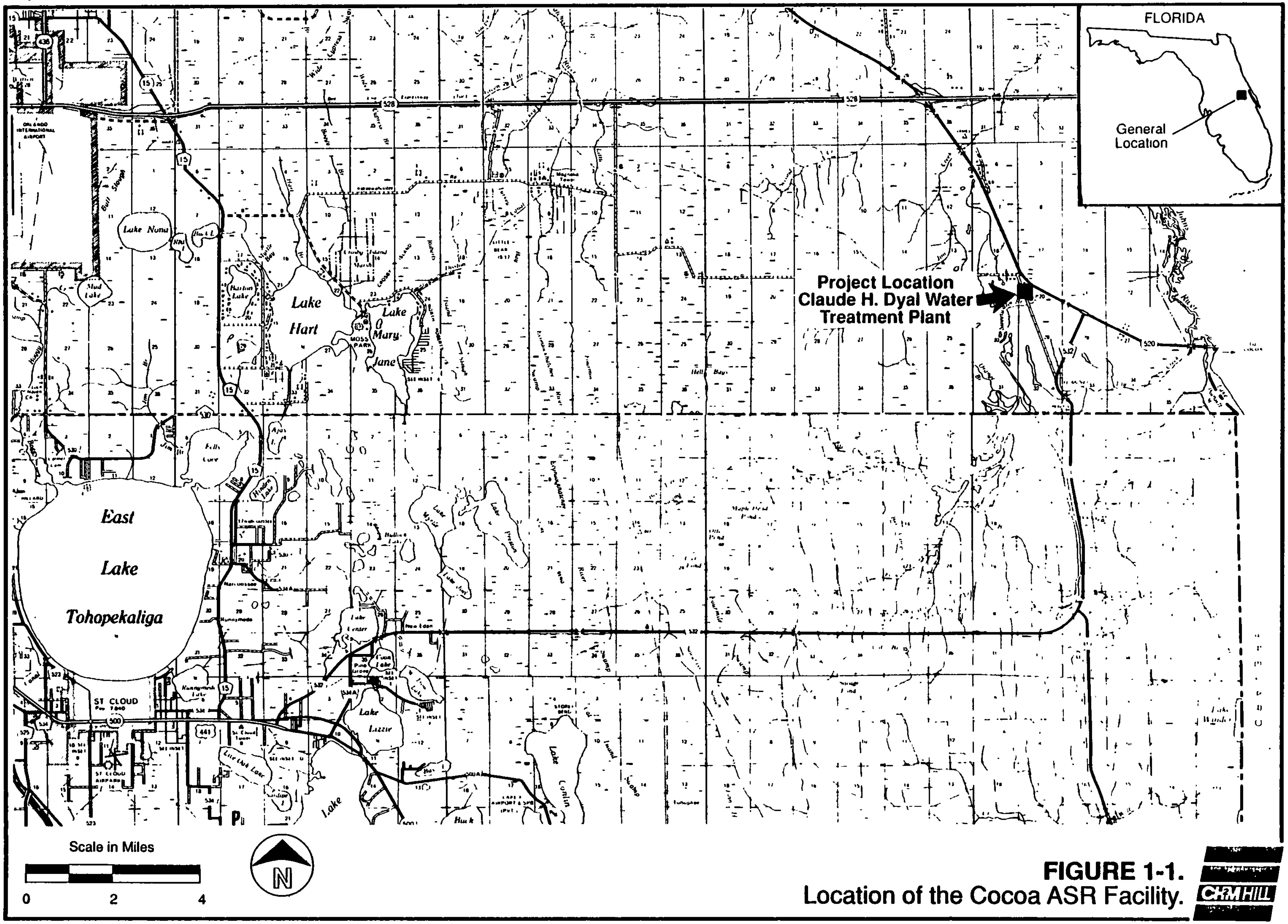

FIGURE 1-1.
Location of the Cocoa ASR Facility.

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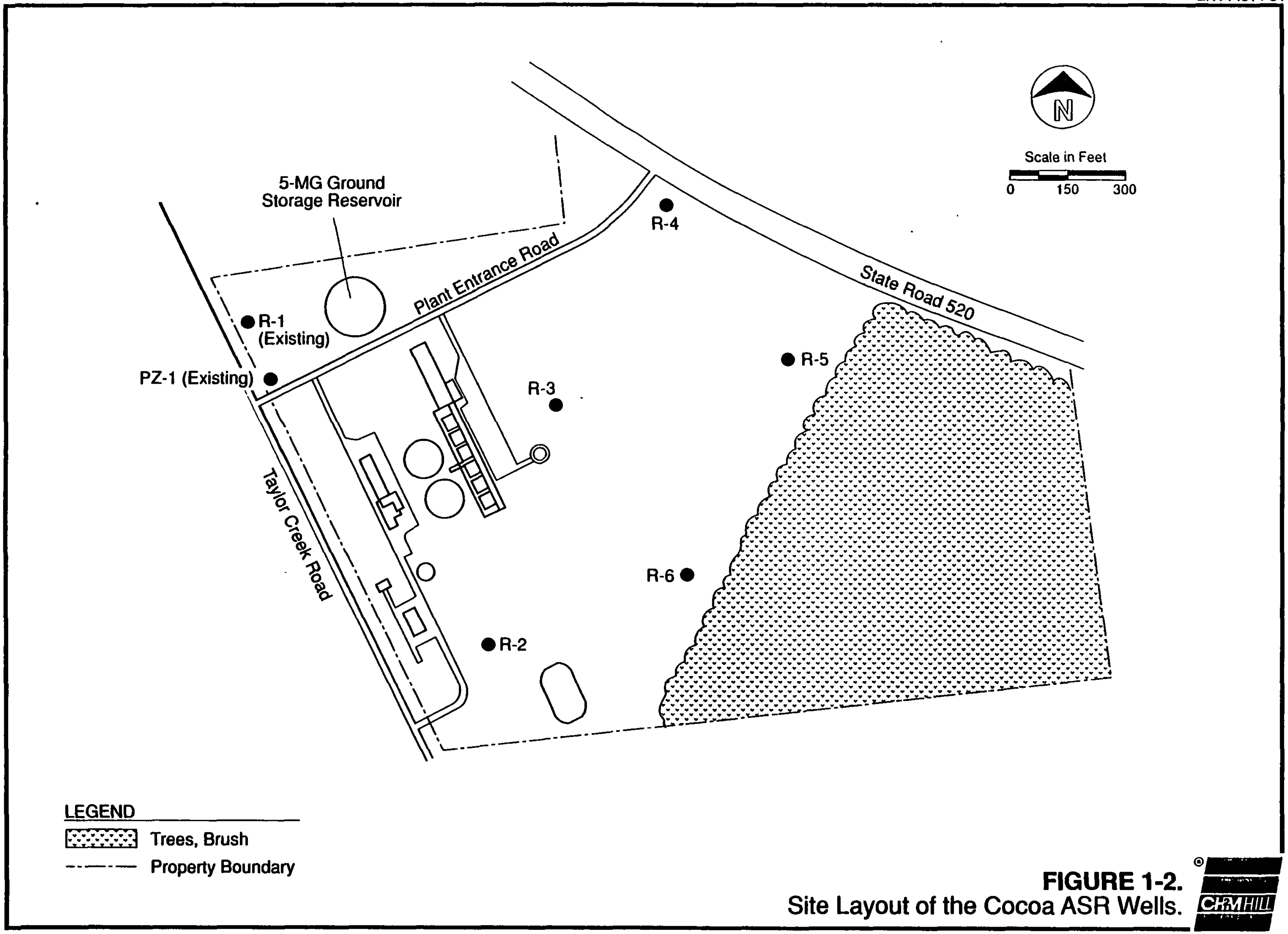

FIGURE 1-2.
Site Layout of the Cocoa ASR Wells.

UNDIFFERENTIATED SURFICIAL DEPOSITS

This unit consists primarily of interbedded sand, shell, and clay deposits. It extends from land surface to approximately 120 feet below land surface (bls). The age of this deposit ranges from late Miocene to Recent.

THE HAWTHORN FORMATION 120-240 feet

The Hawthorn Formation consists chiefly of interbedded sand, clay, dolostone, and limestone. It is often characterized by abundant phosphate content in both consolidated and unconsolidated deposits. The formation is of Miocene Age, and, in this area, grades from a dense green/gray clay to interbedded carbonates, sand, and clays. The Hawthorn Formation is the upper confining bed of the ASR zone.

THE OCALA GROUP

In general, the Ocala group can be characterized as chalky, fossiliferous limestones of upper Eocene Age. The upper part of this group comprises the storage zone for the ASR facility. The lower section, which is less pervious, was not penetrated during drilling and is the lower confining unit. The Ocala/Hawthorn interface exists as an unconformity, whose altitude varies across the site. The top of the Ocala ranges from approximately 240 to 275 feet bls.

Section 2
ASR FACILITY CONSTRUCTION

DESCRIPTION OF THE CONSTRUCTION PROGRAM

The five additional ASR wells were constructed as the first part of the expansion of the existing ASR facility. After drilling and testing specifications were prepared and bids were received, the City of Cocoa awarded the construction contract to Alsay Incorporated of Fort Pierce, Florida, on October 13, 1988. The notice to proceed was issued on November 28, 1988, and Alsay Inc. began construction activities shortly thereafter. The contract was completed on April 10, 1989.

At first, one rotary drilling rig and one crew, working daylight hours only, was assigned to the project. Before completing the first well, Alsay Inc. decided to complete the job with two crews working 12-hour shifts. This schedule was continued throughout the completion of all drilling and performance testing.

The mud rotary method was used to drill through the unconsolidated formations and into the upper portion of the Ocala Formation. Surface casing was installed in approximately the first 120 feet of each well to stabilize the surficial formations. The surface casing was 26-inch-diameter steel casing with a 0.50-inch wall thickness. The surficial casing conformed to ASTM A139, Grade B, and was spiral-welded pipe manufactured by L.B. Foster Company.

After drilling had advanced into the top of the storage zone, the final casing string was placed. The final casing was 16-inch (outside diameter) PVC pipe with a 0.843-inch wall thickness, manufactured by Scepter Mfg. Co. The pipe was solvent-type bell construction and was joined by stainless steel screws and PVC cement. The PVC cement used was heavy-duty gray cement manufactured by Oately, Inc.

Following the setting and cementing of the PVC casing, the drilling resumed with the mud rotary method. The rotary mud drilling method was continued only until enough water was produced from the borehole to sustain reverse-air drilling. The reverse-air circulation drilling method was typically begun within 15 feet below the PVC casing. Formation samples were obtained during drilling at 5-foot intervals for lithologic descriptions during all drilling. Water quality samples were obtained during reverse-air drilling and analyzed in the field and in the Cocoa WTP laboratory.

Following borehole completion, each well was acidized and then developed by a combination of air-lifting and surging. The wells were then temporarily capped until the performance testing. The performance of each well was tested with a variable-rate pumping test followed by a constant-rate test. This testing is discussed further in Section 3.

Following the pumping tests, the wellheads were assembled. After completion, all underground surfaces were coated with coal tar epoxy, and the wellhead excavation was backfilled and compacted. The wells were checked for plumbness and alignment in accordance with AWWA A100. Each well was swabbed and disinfected with a chlorine solution in excess of 50 ppm chlorine. The solution was allowed to remain in the well for a minimum of 4 hours before being removed by pumping. The portions of the wellheads exposed to the atmosphere were then painted with heavy-duty coating manufactured by Pittsburg Paints.

WELL R-2

Construction of Well R-2 began with the drilling of a nominal 8-inch-diameter pilot hole to 130 feet below land surface (bls). The pilot hole was then reamed out to a nominal 32-inch diameter. The reaming resulted in substantial collapse of the borehole.

Upon completion of the reaming, 119 feet of steel surface casing was set and grouted into position with 684 sacks of ASTM C150 neat cement. A nominal 12-inch-diameter pilot hole was then drilled through the 26-inch casing to 290 feet. At approximately 230 feet bls, circulation of drilling fluid was temporarily lost into an apparent highly permeable zone near the base of the Hawthorn Formation. The top of consistent limestone was encountered at 244 feet bls. After completion of the pilot hole, the borehole was reamed to a nominal 22-inch diameter. The final casing consisting of 280 feet of PVC casing was set and grouted into position. The grouting was completed in three stages of 140, 140, and 110 sacks of pozzolan cement.

After the cement had cured, pilot hole drilling was resumed at 285 feet bls. The limestone encountered was white, soft, and friable. At 325 feet bls, a broken zone was encountered, and the cuttings indicated a softer limestone material. The consistency of the limestone varied between soft and very soft to 345 feet bls. At this depth, the cuttings contained limestone fragments and lime mud (marl). This layer was approximately 3 to 5 feet thick. Below this, the drilling continued in soft, white limestone. Within the interval of 365-370 feet bls, the cuttings consisted of tan limestone, slightly harder than previously drilled. The pilot hole was stopped at 370 feet bls.

The borehole was reamed to a nominal 15-inch diameter, and the well was developed by air-lifting through the drill string. The well was later acidized with 3,000 gallons of 31.5 percent hydrochloric acid and developed by air-lifting and surging. During the development, the water produced from Well R-2 was cloudy and white and exhibited high levels of turbidity. Turbidity levels decreased to about 85 NTU after 15 hours of development.

After construction of the wellhead, the straightness and alignment test was conducted and showed no significant deviations. The well was then disinfected and capped.

WELL R-3

Construction of Well R-3 began with the drilling of a nominal 12-inch-diameter pilot hole to 150 feet bls. The pilot hole was then reamed to a 32-inch diameter. Upon completion of reaming, 119 feet of surface casing was installed and grouted into position with 360 sacks of ASTM C150 neat cement. A nominal 12-inch-diameter pilot hole was then drilled to 316 feet bls. The top of competent limestone was encountered at 268 feet bls. The hole was reamed to a nominal 22-inch diameter and 300 feet of PVC casing was set and grouted into position. The grouting was completed in three stages of 140, 150, and 85 sacks of cement, respectively. The first stage was completed with pozzolan cement, and the two remaining stages were completed with neat cement.

After the cement plug was drilled out, the pilot hole drilling resumed at 315 feet bls. From 315 to 325 feet, the cuttings consisted of white and tan, soft fossiliferous limestone. Below 325 feet bls, the limestone was gray to white and very soft until 340 feet bls. Below this depth, the cuttings indicated alternating layers of hard and soft, white to tan limestone. The pilot hole was stopped at 370 feet bls. From 365 to 370 feet bls, the cuttings indicated a very soft zone of tan fossiliferous limestone.

The final pilot hole was then reamed to a nominal 15-inch diameter. The well was first developed by air-lifting through the drill string. Well R-3 was later acidized with 3,000 gallons of 31.5 percent hydrochloric acid and developed by air-lifting and surging.

After construction of the wellhead, the straightness and alignment test was conducted and showed no significant deviations. Well R-3 was then disinfected and capped.

WELL R-4

Construction of Well R-4 began with the drilling of a nominal 12-inch-diameter pilot hole to 150 feet. The borehole was then reamed to a nominal 32-inch diameter, and 118 feet of surface casing was set and grouted into position with 380 sacks of ASTM C150 neat cement. The next pilot hole was then drilled to 315 feet bls. The top of the consistent limestone was encountered at 266 feet. The final casing string was set at 300 feet bls. It was cemented in three stages, the first with 140 sacks of pozzolan cement and the second and third with 150 and 85 sacks of neat cement, respectively. The last pilot hole was then drilled to 370 feet, reamed to a nominal 15-inch diameter, and partially developed.

From 315 to 335 feet bls, the drilling penetrated tan to white, fossiliferous limestone. The rock was fairly soft, but varied somewhat in consistency. A harder limestone layer was briefly encountered at 320 feet. From 335 to 340 feet bls, a gray, harder limestone layer was penetrated. Below this depth, the limestone was white and soft with occasional tan layers at 354, 358, and 360 feet bls. From 360 feet to 370 feet bls, the drilling was in white, fossiliferous limestone. The well was acidized and then developed by air-lifting and surging.

The well was later acidized with 3,000 gallons of 31.5 percent hydrochloric acid and then developed. The wellhead was assembled, straightness and alignment confirmed, and the well disinfected.

WELL R-5

Construction of Well R-5 began with the drilling of a nominal 12-inch-diameter pilot hole to 130 feet. After the pilot hole was reamed to a nominal 32-inch diameter, 117 feet of surface casing was set and grouted into position with 350 sacks of ASTM C150 neat cement. The next pilot hole was then advanced to 315 feet bls. The top of the solid limestone was encountered at 273 feet bls. The pilot hole was reamed out to a nominal 22-inch diameter and the final casing string was set to 300 feet bls. The grouting was completed in the stages of 140 sacks of pozzolan cement, 150 sacks and then 90 sacks of neat cement. After the cement had set, the final pilot hole was drilled into the storage zone to a depth of 370 feet.

The pilot hole drilling from 315 to 330 feet bls was in soft, tan to white, fossiliferous limestone. From 330 to 335 feet bls, the limestone was tan and slightly broken. Below this depth, the drilling was again in white, soft fossiliferous limestone. Occasional hard spots of gray limestone also were penetrated. At 343 feet bls, a soft lime mud (marl) layer was encountered for 1-3 feet. Below this, the cuttings again returned to white and tan, soft limestone. The consistency of the limestone varied between soft and very soft to approximately 368 feet bls. The last 2 feet of drilling consisted of tan limestone, slightly harder than the rock above it. After being reamed to a nominal 15-inch diameter, the well was partially developed by air-lifting through the drill string.

The well was later acidized with 3,000 gallons of 31.5 percent hydrochloric acid and then developed by air-lifting and surging. After wellhead construction, the straightness and alignment test was conducted and the well was found to be plumb. Well R-5 was then disinfected and capped.

WELL R-6

Construction of Well R-6 began with the drilling of a nominal 12-inch-diameter pilot hole to a depth of 150 feet. The borehole was reamed to a nominal 32-inch diameter, and 118 feet of surface casing set and grouted into position with 525 sacks of neat cement. The intermediate pilot hole was then drilled to a depth of 315 feet. The top of the consistent limestone was encountered at 266 feet bls. The borehole was then reamed to a nominal 22-inch diameter. Next, 300 feet of PVC casing was set and grouted into position. The grouting was completed in three stages, the first with 140 sacks of pozzolan cement, the second and third with 150 sacks and 90 sacks of ASTM C150 neat cement, respectively.

After the cement plug was drilled out, the pilot hole drilling was resumed at 315 feet. The limestone encountered from 315 to 328 feet was a soft, white fossiliferous limestone. In the interval of 328 to 334 feet, the cuttings indicated gray, competent limestone. Below this zone, cuttings alternated between the gray limestone and white, soft limestone. At 346 feet bls, the drilling was in white to tan limestone with occasional hard spots. The pilot hole was continued until 370 feet bls and then stopped. A nominal 12-inch-diameter pilot hole was then drilled to

370 feet bls. The hole was reamed to a nominal 15-inch diameter and then partially developed.

The well was later acidized with 3,000 gallons of 31.5 percent hydrochloric acid. The well as developed by air-lifting and surging. The wellhead was assembled, the straightness and alignment confirmed, and the well disinfected.

Section 3
WELL PERFORMANCE TESTING

DESCRIPTION OF TESTING

The performance testing of the five ASR wells lasted approximately two weeks. Each well was first tested with a variable-rate pumping test, followed by a constant-rate pumping test. The variable-rate test, or step test, was conducted primarily to evaluate the hydraulic efficiency of each well. The information obtained from this type of testing is necessary in selecting the proper pump for the well. The constant-rate testing was conducted to evaluate aquifer parameters and the hydraulic interference between the ASR wells. The testing began with Well R-5, and continued in sequence with Wells R-2, R-4, R-6, and R-3. The chronological sequence of the pumping test program is shown in Table 3-1.

All testing was conducted with a contractor-supplied vertical turbine pump powered by a diesel engine. Flow rates were measured with a 6- by 8-inch circular orifice weir and a propeller flowmeter. During each pumping test, water levels were monitored in the pumping well and in each of the other four newly constructed ASR wells. Water levels also were monitored in Well PZ-1, one of the monitor wells constructed for the initial ASR facility.

Water levels were measured in the pumping well with the wetted steel tape method. Water levels in the other wells were continuously recorded with Stevens Type F recorders. Water levels were not monitored in Well R-1, the first ASR well, because the wellhead completion restricted the installation of a water level recorder.

During each of the constant-rate pumping tests, water samples were obtained for water quality analysis. The analysis included field measurements and analysis in the Dyal WTP and CH2M HILL laboratories.

STEP PUMPING TESTS

The step pumping tests consisted of pumping each well in a series of increasing pumping rates, or steps, and measuring the depth to pumping water level in the pumping well. Each step test lasted approximately six hours in four 1.5-hour steps of increasing pumping rates. Water levels in the remaining wells were monitored during this time to obtain a preliminary understanding of the pumping effect on the potentiometric surface. However, these measurements were

Table 3-1
DATES OF PERFORMANCE TESTING, COCOA ASR FACILITY

Well	Step Test	Constant-Rate Test
R-5	March 8	March 9
R-2	March 13	March 14
R-4	March 15	March 16
R-6	March 18	March 19
R-3	March 20	March 21-23

primarily used to set up the water level recorders properly for the constant-rate tests and are not included in this report.

The results of the step tests on the five recently completed ASR wells are presented in Table 3-2. For each pumping step, drawdowns are reported in the pumping well. The results of this testing were used to solve the following equation, which describes the drawdown in the pumping well:

$$s' = BQ + CQ^2$$

where

s'	=	drawdown in pumping well in feet
Q	=	pumping rate in gallons per minute (gpm)
C	=	well-loss coefficient
B	=	formation coefficient

The relationship distinguishes between the component of drawdown because of geologic factors (aquifer parameters) and well bore factors (turbulent flow, quality of the well's completion, etc.). However, since the coefficients were determined from the approximate 90-minute pumping increments, long-term pumping (i.e., 30 days of continuous pumping) will probably result in somewhat larger drawdowns than would be predicted from these results.

CONSTANT-RATE PUMPING TESTS

The constant-rate pumping tests were designed to investigate the hydraulic properties of the storage zone. The testing consisted of pumping each well at a constant pumping rate for a specified period of time. The results of this testing were used to define the injection and recovery capacity of the individual wells and of the complete facility.

The areal arrangement of the expanded ASR facility consists of a center well surrounded by the five others. The pumping tests were designed to include a long-duration test of the center well, Well R-3, to provide the most complete picture of the aquifer response. The perimeter wells were subjected to shorter tests to verify aquifer parameters and determine the individual well pumping times necessary to achieve steady state conditions. The constant-rate tests were approximately 12 hours each for four of the wells, and 45.5 hours for Well R-3.

During each constant-rate pumping test, drawdowns were measured in the pumping well and were recorded in each of the newly constructed ASR wells. These measurements are

Table 3-2
RESULTS OF STEP TEST ANALYSIS, COCOA ASR FACILITY

Well R-2[a,b]

Pumping Rate, Q (gpm)	Elapsed Time (min)	Observed Drawdown Δs (ft)	Q/Δs (gpm/ft)	Adjusted Drawdown Δs' (ft)	Adjusted Q/Δs' (gpm/ft)
385	90	4.35	88.5	3.13	123.0
740	180	10.90	67.9	6.40	115.6
1,000	270	16.65	60.1	8.44	118.5
1,250	360	22.60	55.3	9.80	127.6

[a]Test conducted on March 13, 1989.
[b]$\Delta s' = 8.214 \times 10^{-6} Q^2 + 0.00845Q$.

Well R-3[c,d]

Pumping Rate, Q (gpm)	Elapsed Time (min)	Observed Drawdown Δs (ft)	Q/Δs (gpm/ft)	Adjusted Drawdown Δs' (ft)	Adjusted Q/Δs' (gpm/ft)
390	90	21.75	17.9	20.01	19.5
700	180	40.39	17.1	34.79	20.1
950	270	58.27	16.3	47.95	19.8
1,150	360	73.25	15.7	58.13	19.8

[c]Test conducted on March 20, 1989.
[d]$\Delta s' = 1.143 \times 10^{-5} Q^2 + 0.0506Q$.

Table 3-2
(continued)

Well R-4[e,f]

Pumping Rate, Q (gpm)	Elapsed Time (min)	Observed Drawdown Δs (ft)	Q/Δs (gpm/ft)	Adjusted Drawdown Δs' (ft)	Adjusted Q/Δs' (gpm/ft)
385	90	10.30	37.4	8.56	45.0
730	210	23.21	31.5	16.96	43.0
945	300	32.31	29.2	21.83	43.3
1,215	390	44.08	27.6	27.76	45.4

[e]Test conducted on March 15, 1989.
[f]$S = 1.173 \times 10^{-5} Q^2 + 0.0225Q$.

Well R-5[g,h]

Pumping Rate, Q (gpm)	Elapsed Time (min)	Observed Drawdown Δs (ft)	Q/Δs (gpm/ft)	Adjusted Drawdown Δs' (ft)	Adjusted Q/Δs' (gpm/ft)
380	90	10.98	34.6	9.90	38.4
720	180	25.04	28.8	21.18	34.0
1,100	243	41.05	26.8	32.03	34.3

[g]Test conducted on March 8, 1989.
[h]$S = 7.452 \times 10^{-6} Q^2 + 0.0320Q$.

Table 3-2
(continued)

Well R-6[i,j]

Pumping Rate, Q (gpm)	Elapsed Time (min)	Observed Drawdown Δs (ft)	Q/Δs (gpm/ft)	Adjusted Drawdown Δs' (ft)	Adjusted Q/Δs' (gpm/ft)
380	60	18.24	20.8	15.83	24.0
725	90	39.38	18.4	30.62	23.7
995	180	58.48	17.0	41.98	23.7
1,150	270	69.74	16.5	47.69	24.1

[i]Test conducted on March 18, 1989.
[j]$S = 1.667 \times 10^{-5} Q^2 + 0.420Q$.

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summarized in Tables 3-3 to 3-7. The measurements directly indicate the interference effects between the wells.

The long-duration pumping test on Well R-3 was analyzed with the Walton aquifer analysis method for transient flow with leakance. Drawdown data obtained from each of the wells monitored during this test were analyzed individually. The results indicate a fair amount of hydraulic variability in the aquifer. The results of this analysis are shown in Figure 3-1.

GEOPHYSICAL LOGGING

Geophysical logging was conducted on each of the ASR wells during the pumping tests to provide information on the subsurface hydrogeology and to document borehole conditions before recharge. Logs were run under both static (non-pumping) and pumping conditions, where applicable. A summary of the geophysical logging conducted during this project is shown in Table 3-8; the full-size geophysical logs are included in Appendix C.

WATER QUALITY TESTING

Water quality samples were obtained from the five additional ASR wells during the reverse-air drilling and the during the constant-rate pumping tests. The water samples during drilling were obtained from the drilling discharge at 10-foot depth intervals. These samples were analyzed for standard parameters in the field and in the Cocoa WTP laboratory. The results are presented in Appendix A.

Many water samples were obtained during the constant-rate pumping tests. Samples were obtained every few hours for field analysis including chloride, conductivity, temperature, pH, and turbidity. The chloride concentrations observed during the tests are presented in Figures 3-2 to 3-6, and the complete set of analysis results is presented in Appendix A.

In addition, a set of water samples was collected at the beginning, middle, and end of each constant-rate test and were analyzed by the CH2M HILL laboratory in Gainesville, Florida, for major ions and other selected parameters. These samples document native water quality in the area and were analyzed in accordance with the Consumptive Use Permit (CUP) conditions of the St. Johns River Water Management District (SJRWMD). The laboratory results are presented in Appendix A.

Table 3-3
DRAWDOWNS AT WELL R-2 DURING CONSTANT-RATE TESTS, COCOA ASR FACILITY

Time (Minutes)	Pumped Well (R-2)[a] (Feet)	Observation Wells R-3 (Feet)	R-4 (Feet)	R-5 (Feet)	R-6 (Feet)	PZ-1 (Feet)
15	17.7	--	0.6	0.9	2.6	0.8
50	18.8	--	1.7	2.2	4.3	1.6
100	19.2	--	2.5	3.0	5.0	1.9
250	20.1	3.9	3.0	3.5	5.5	2.2
450	19.9	4.0	3.1	3.7	5.6	2.2
650	20.1	4.1	3.2	3.7	5.7	2.2
720 (End of Test)	20.1	4.1	3.2	3.7	5.7	2.3
Distance from Pumped Well (Feet)	0	640	1,228	1,072	548	878

[a]Well R-2 was pumped at a rate of 1,125 gpm.

Table 3-4
DRAWDOWNS AT WELL R-3 DURING CONSTANT-RATE TESTS,
COCOA ASR FACILITY

Time (Minutes)	Pumped Well (R-3)[a] (Feet)	Observation Wells R-2 (Feet)	R-4 (Feet)	R-5 (Feet)	R-6 (Feet)	PZ-1 (Feet)
15	65.3	1.5	2.0	2.1	2.5	0.9
50	67.7	2.7	4.5	4.4	4.3	2.0
100	68.6	3.1	5.6	5.5	5.1	2.3
250	69.4	3.4	6.3	6.2	5.6	2.5
450	70.1	3.5	6.5	6.4	5.7	2.6
650	70.2	3.6	6.7	6.5	5.9	2.9
1,000	69.7	3.6	6.7	6.5	5.9	2.9
1,500	70.1	3.7	6.8	6.6	5.5	2.9
2,000	70.3	3.8	6.7	6.6	5.9	2.9
2,500	70.0	3.7	6.7	6.6	6.0	2.9
2,730 (End of Test)	70.1	3.7	6.8	7.6	6.0	3.0
Distance from Pumped Well (Feet)	0	640	593	612	550	735

[a]Well R-3 was pumped at a rate of 1,100 gpm.

Table 3-5
DRAWDOWNS AT WELL R-4 DURING CONSTANT-RATE TESTS,
COCOA ASR FACILITY

Time (Minutes)	Pumped Well (R-4)[a] (Feet)	Observation Wells R-2 (Feet)	R-3 (Feet)	R-5 (Feet)	R-6 (Feet)	PZ-1 (Feet)
15	31.3	0.4	2.0	6.0	0.8	0.3
50	36.6	1.2	4.4	10.7	2.5	1.2
100	38.9	1.7	5.5	12.7	3.5	1.6
250	40.6	2.1	6.4	14.1	4.4	2.0
450	40.6	2.2	6.5	14.3	4.5	2.1
650	40.6	--	6.6	14.4	--	2.1
730 (End of Test)	40.7	--	6.6	14.5	--	2.1
Distance from Pumped Well (Feet)	0	1,228	593	512	960	1,118

[a]Well R-4 was pumped at a rate of 1,120 gpm.

Table 3-6
DRAWDOWNS AT WELL R-5 DURING CONSTANT-RATE TESTS, COCOA ASR FACILITY

Time (Minutes)	Pumped Well (R-5)[a] (Feet)	Observation Wells R-2 (Feet)	R-3 (Feet)	R-4 (Feet)	R-6 (Feet)	PZ-1 (Feet)
15	33.2	0.5	2.0	5.9	1.7	--
50	37.7	1.7	4.1	10.4	4.0	--
100	39.5	2.2	5.2	12.4	5.0	1.2
250	40.8	2.6	5.9	13.6	5.9	1.6
450	42.2	2.7	6.1	14.1	6.1	1.6
650	42.1	2.7	6.2	14.2	6.2	1.6
870 (End of Test)	42.2	2.7	6.2	14.2	6.2	1.6
Distance from Pumped Well (Feet)	0	1,072	612	512	612	1,336

[a]Well R-5 was pumped at a rate of 1,065 gpm.

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Table 3-7
DRAWDOWNS AT WELL R-6 DURING CONSTANT-RATE TESTS, COCOA ASR FACILITY

Time (Minutes)	Pumped Well (R-6)[a] (Feet)	Observation Wells R-2 (Feet)	R-3 (Feet)	R-4 (Feet)	R-5 (Feet)	PZ-1 (Feet)
15	60.0	2.2	2.4	1.0	1.7	0.4
50	64.7	3.7	4.3	3.0	4.2	1.0
100	65.9	4.4	5.2	3.9	5.4	1.4
250	66.9	4.8	5.8	4.8	6.3	1.6
450	67.2	4.9	5.9	5.1	6.5	1.7
650	67.3	5.1	6.0	5.2	6.6	1.8
724 (End of Test)	67.3	5.2	6.1	5.3	6.7	1.8
Distance from Pumped Well (Feet)	0	548	550	960	612	1,185

[a]Well R-6 was pumped at a rate of 1,100 gpm.

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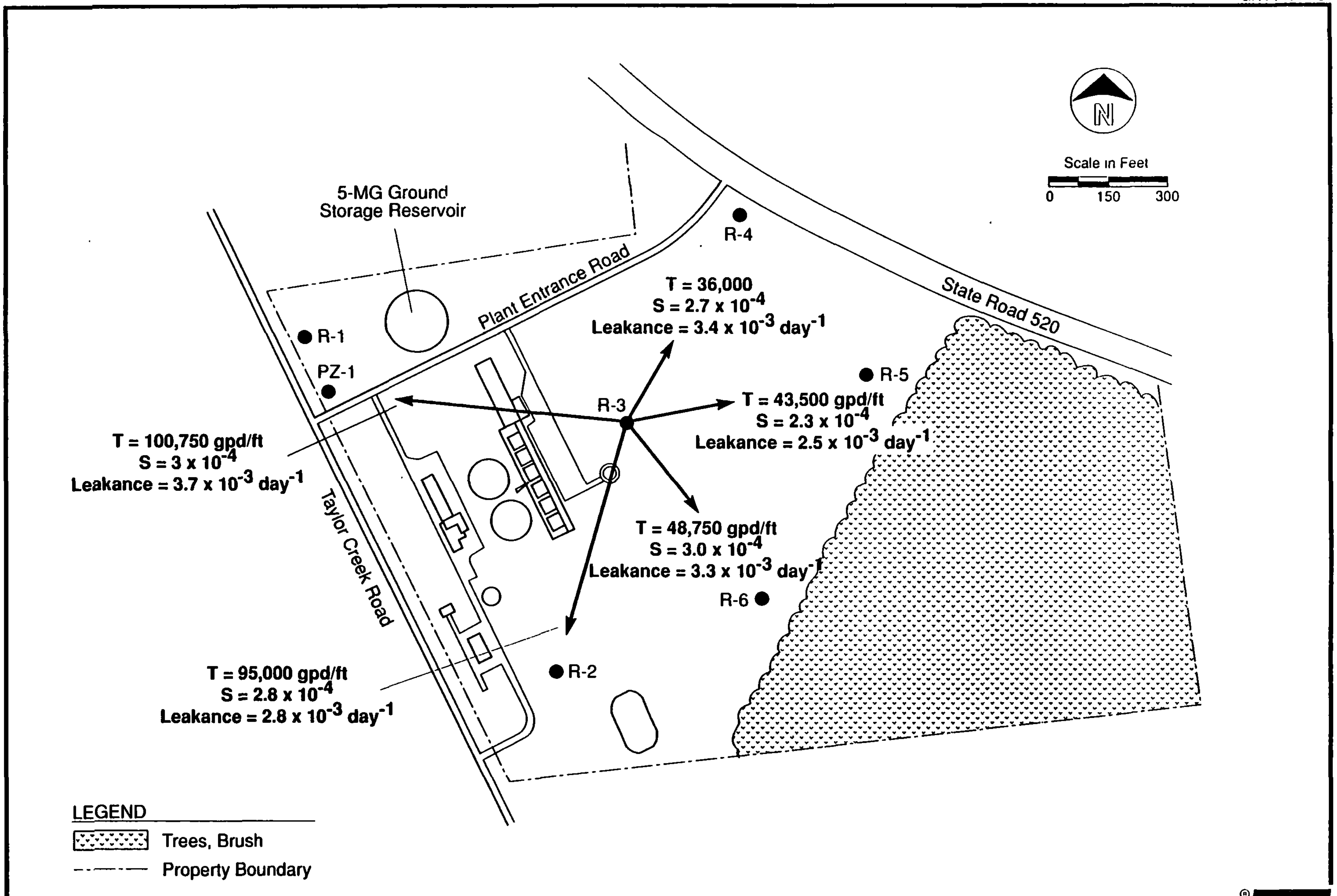

NOTE: The arrows are representative of the magnitude and direction of the measured transmissivities.

FIGURE 3-1.
Results of Long-Duration Pumping Tests at the Cocoa ASR Facility.

Table 3-8
GEOPHYSICAL LOGGING SUMMARY, COCOA ASR FACILITY

Well	Fluid Velocity	Caliper	Temperature	Natural Gamma Ray	Electric	Fluid Resistivity
R-2	P	S	S/P	S	S	S/P
R-3	P	S	S/P	S	S	S/P
R-4	P	S	S/P	S	S	S/P
R-5	P	S	S/P	S	S	S/P
R-6	P	S	S/P	S	S	S/P

Note: Status of well during logging.

S = Static
P = Pumping

GNV14514 S1

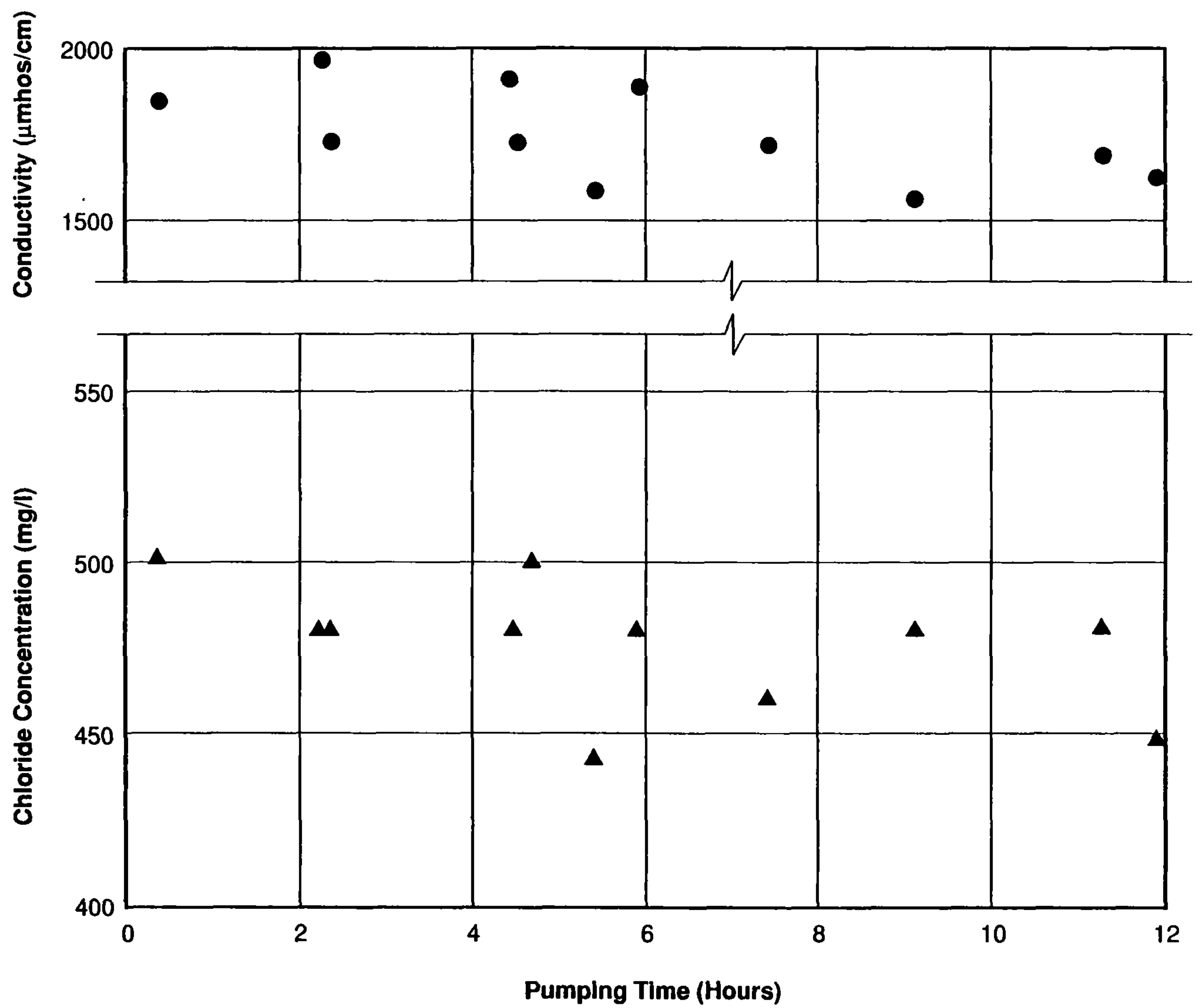

FIGURE 3-2.
Chloride Concentrations Measured in Well R-2, Cocoa ASR Facility.

CH2M HILL

GNV14514.S1

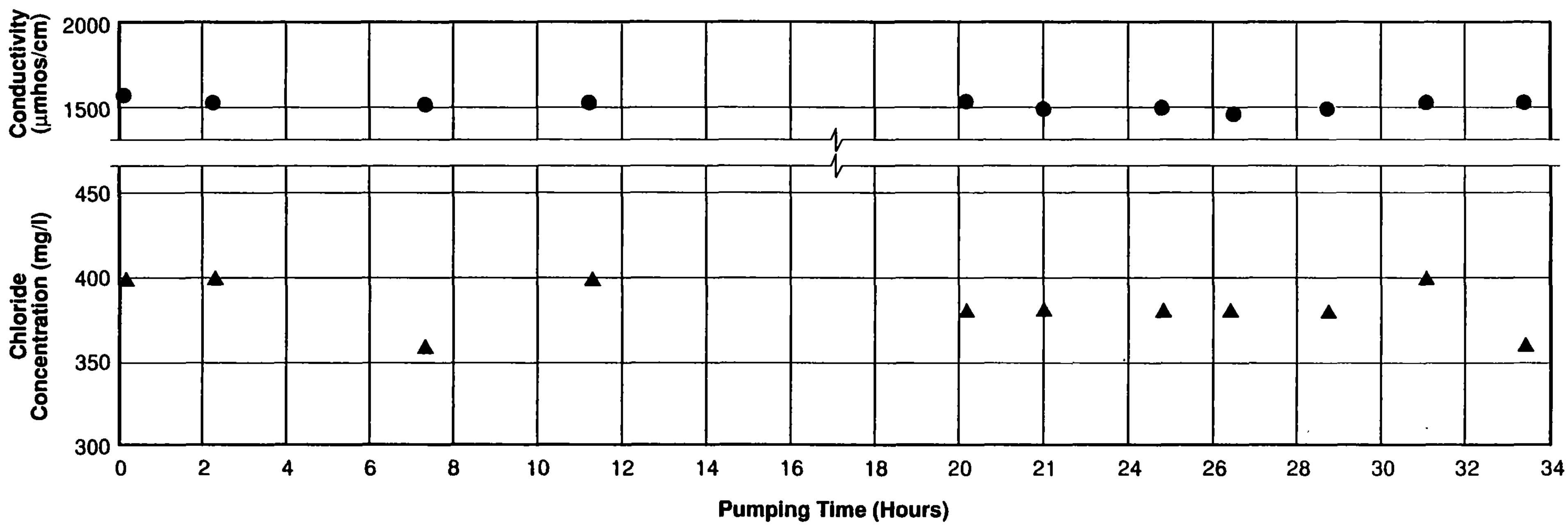

FIGURE 3-3.
Chloride Concentrations Measured in Well R-3, Cocoa ASR Facility.

CH2M HILL

GNV14514 S1

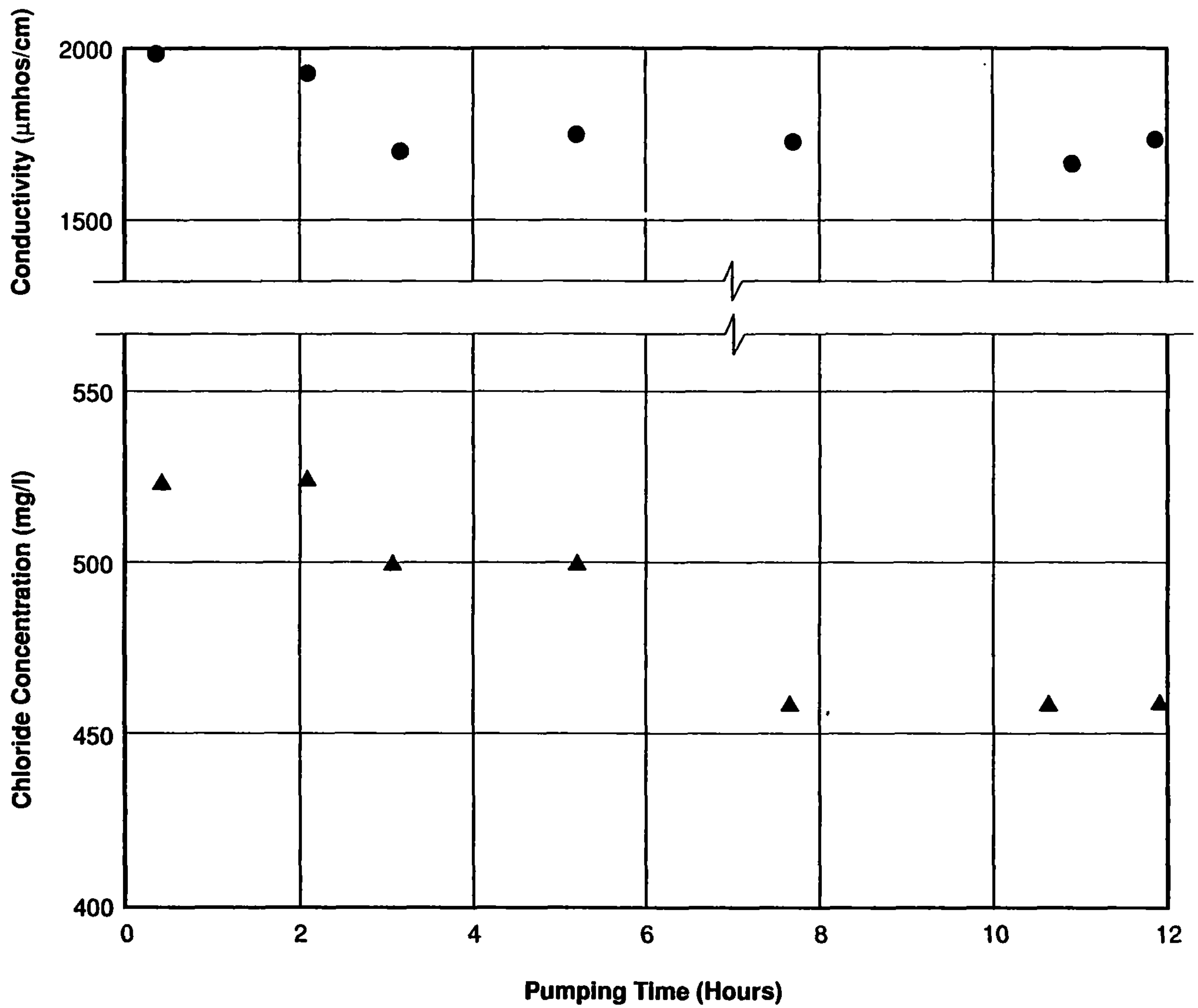

FIGURE 3-4.
Chloride Concentrations Measured in Well R-4, Cocoa ASR Facility.

CH2MHILL

GNV14514.S1

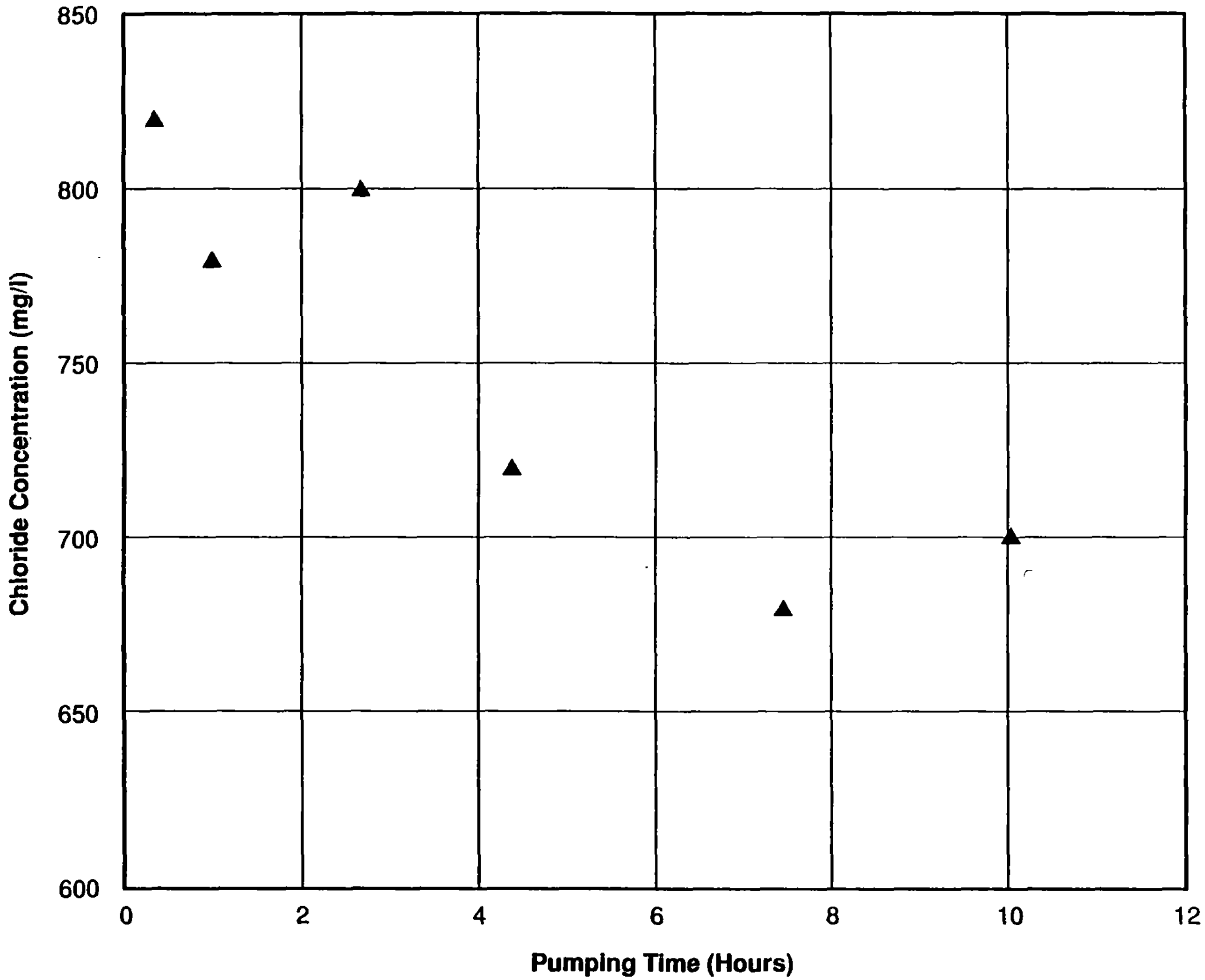

FIGURE 3-5.
Chloride Concentrations Measured in Well R-5, Cocoa ASR Facility.

CH2M HILL

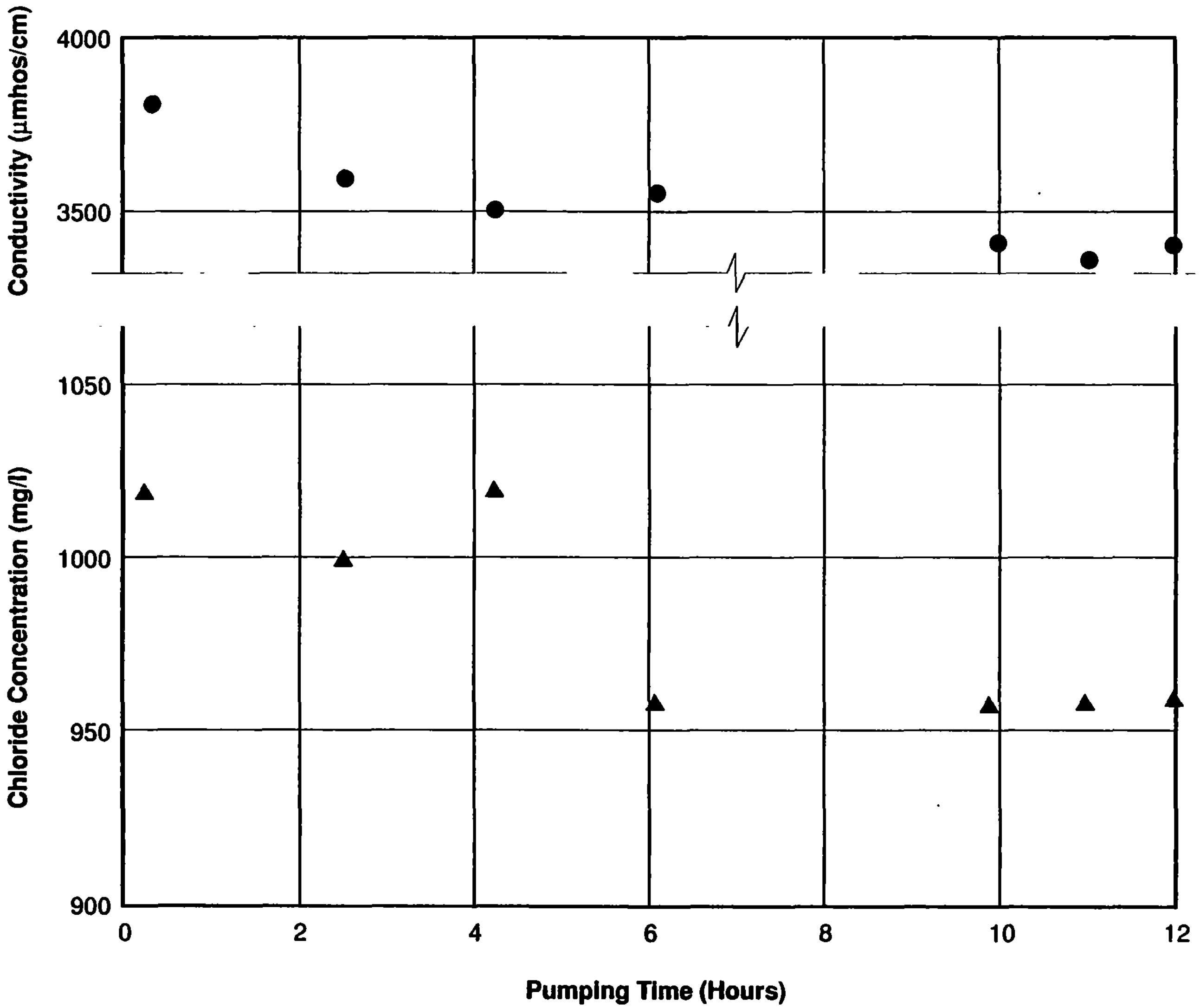

FIGURE 3-6.
Chloride Concentrations Measured in Well R-6, Cocoa ASR Facility.

CH2M HILL

Section 4
SUMMARY AND DISCUSSION OF RESULTS

Five ASR wells were constructed at the City of Cocoa Dyal WTP as an expansion of the existing ASR facility. The wells are all completed with a final casing string of 16-inch PVC set into the top of the Floridan aquifer. Each well is of open-hole construction. The construction included the wells and the uppermost portion of the wellheads only. This construction ended with a 16-inch lateral and blind flange at ground surface.

Pumping tests were conducted on each well, and aquifer parameters calculated. In addition, water samples were obtained and the water quality of the aquifer at each well location was determined. The results of this portion of the project will be used to design and construct the remaining facilities for the expanded ASR facility. This will include the pumps, piping, and associated equipment to transport water for storage and recovery to and from the facility.

HYDRAULIC RESPONSE OF THE AQUIFER

The results of the testing indicate that the selected storage zone is fairly well confined and generally exhibits transmissivities slightly lower than that of the first ASR well, R-1. The exception is in the area of Well R-2, where a higher transmissivity is exhibited. This area has resulted in Well R-2 having a relatively high specific capacity. The values for leakance obtained from the testing indicate a slightly higher leakance occurs near the recently constructed wells relative to the first ASR well. The estimated hydraulic properties near each well are shown in Figure 4-1.

A two-fold approach was used to estimate potentiometric surface effects resulting from injection and recovery of water. In the wells, direct pumping test water level measurements were used to calculate drawdown and interference effects at varying rates of injection and recovery. These calculations were used to predict the injection and recovery water levels in the ASR wells. Operational injection and recovery rates were chosen to result in equal potentiometric surface elevations in all six wells. The resulting rates are recommended for the facility use. These injection and recovery rates are shown in Table 4-1.

An exception to the above was made for Well R-2. The specific capacity of this well was high relative to the

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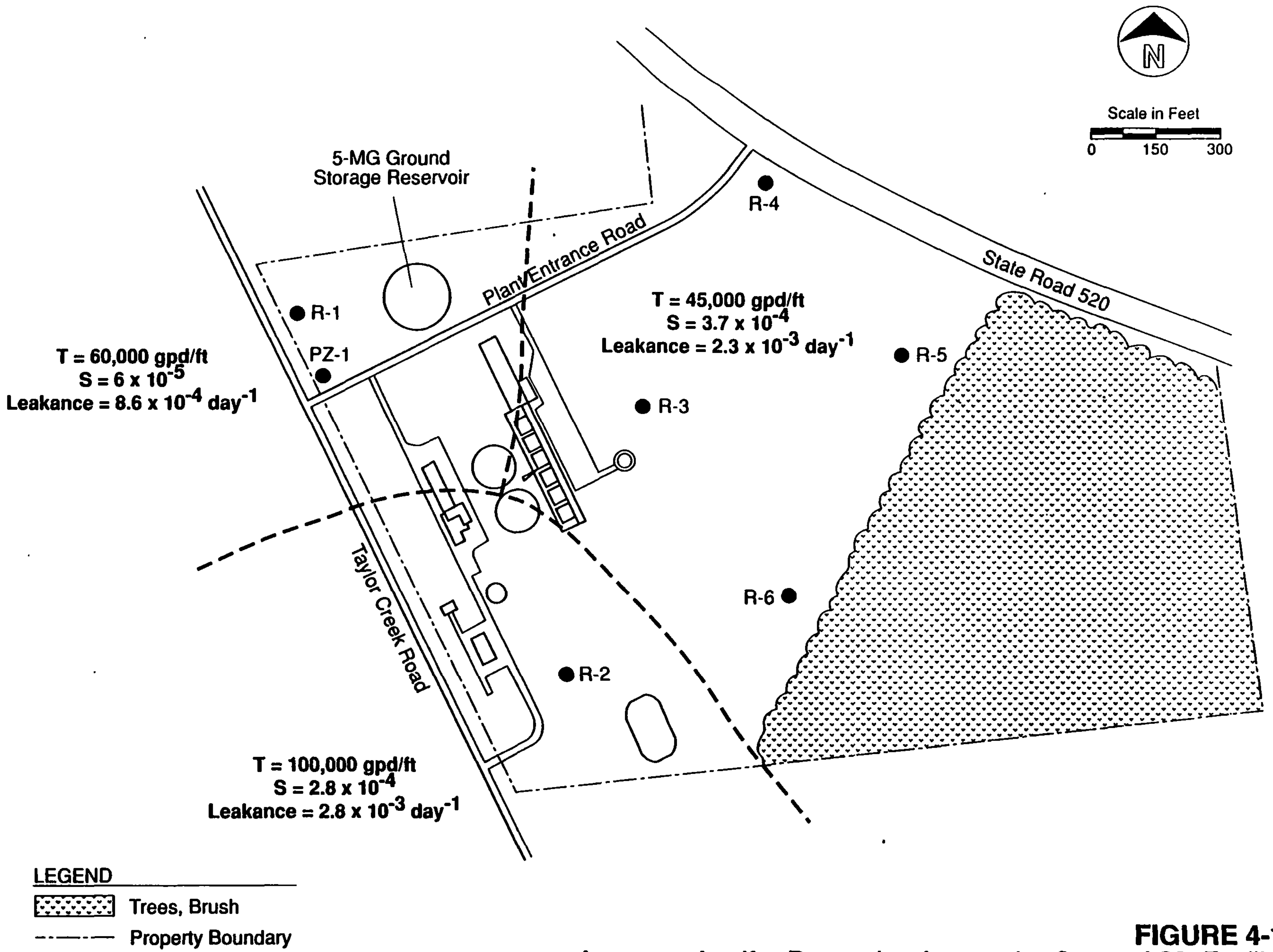

FIGURE 4-1.
Apparent Aquifer Properties Across the Cocoa ASR Facility.

Table 4-1
TARGET RECHARGE/RECOVERY RATES, COCOA ASR FACILITY

Well	Recovery Rates (mgd)	Recovery Rates (gpm)	Estimated Drawdown (ft)	Recharge Rates (mgd)	Recharge Rates (gpm)	Estimated Wellhead Pressure (psi)
R-1	1.45	1,010	65	1.08	750	28
R-2	1.51	1,050	31	1.14	790	14
R-3	0.96	670	65	0.72	500	28
R-4	1.58	1,100	65	1.20	830	28
R-5	1.48	1,030	65	1.08	750	28
R-6	1.04	720	65	.78	540	28
Total	8.02	5,580		6.00	4,160	

Note: Actual recharge/recovery rates will vary as a result of hydraulic variations in the system.

other wells, and the recharge and recovery rates obtained by equating the potentiometric surface became too large. The flow rates for Well R-2 were therefore reduced to be closer to that of the remaining wells.

The recommended rates of injection and recovery were then used to estimate potentiometric surface effects in the area surrounding the ASR facility. These effects were calculated from the transmissivities shown in Figure 4-1, and by superposition. The resulting predicted effects to the potentiometric surface are shown in Figures 4-2 and 4-3.

WATER QUALITY OBSERVATIONS

The background water quality varied across the site. Wells R-5 and R-6 exhibited the highest concentrations of dissolved constituents, with chloride concentrations of 700 and 960 milligrams per liter (mg/l), respectively. The remaining wells exhibited water quality similar to Well R-1, with chloride concentrations ranging from 390 to 450 mg/l. A summary of the water quality observed in each well is presented in Table 4-2, and the complete results are included in Appendix A.

The observed chloride concentrations in each well during the pump testing were plotted to investigate if the observed water quality was representative of background conditions. The plots shown in Figures 3-2 to 3-6 show that water quality generally improved early in the pumping tests and reached an equilibrium before the pumping was complete. This response is considered a result of a small residual of acidization remaining in the well at the start of the pumping tests. By the end of the pumping tests, all acid byproducts were purged from the well, as evidenced by the water quality reaching equilibrium.

The water produced from Well R-2 had high levels of turbidity throughout development and during the pumping tests. Although the testing the turbidity levels were observed to decrease throughout the testing, the turbidity observed at the end of the pumping test was 21 NTU, which exceeds the drinking water standard of 1.0 NTU. The turbidity production is believed to originate from a soft marl located in the borehole at approximately 345 feet bls. The turbidity levels in this well may reduce to drinking water standards with extended pumping, and future ASR cycles may expedite this extended development effort.

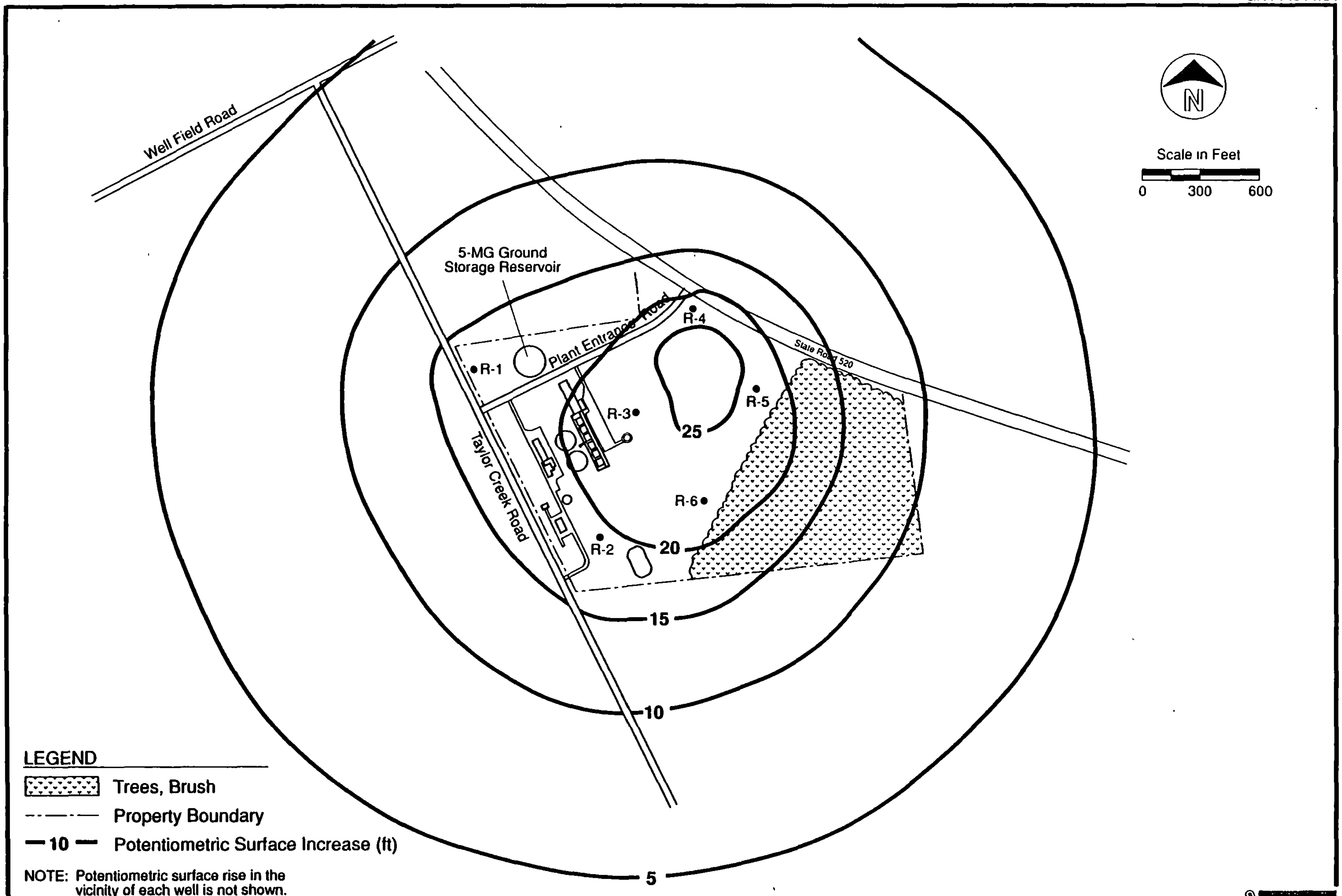

FIGURE 4-2.
Simulated Rise in Potentiometric Surface During 6.0-mgd Injection, Cocoa ASR Facility.

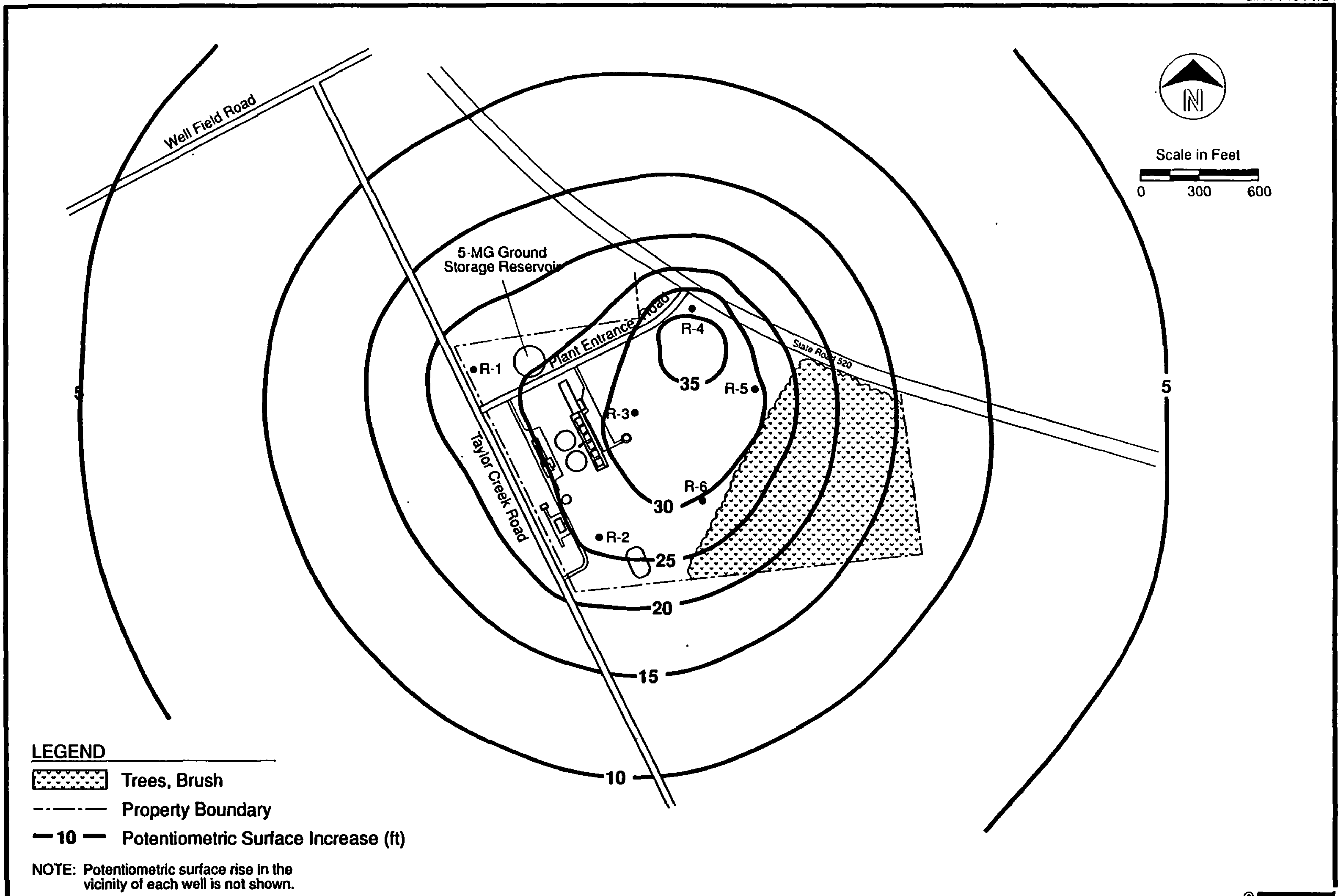

FIGURE 4-3.
Simulated Drawdowns in Potentiometric Surface During 8.0-mgd Recovery, Cocoa ASR Facility.

Table 4-2
WATER QUALITY SUMMARY, COCOA ASR FACILITY

	Well				
Parameter[a]	R-2	R-3	R-4	R-5	R-6
pH, units	7.0	7.4	7.1	6.9	7.4
Alkalinity, Total, as $CaCO_3$	170	150	170	160	130
Hardness, Total, as $CaCO_3$	420	380	450	560	600
Hardness, Non-Carbonate, as CaCO3	250	230	280	400	470
Calcium	110	75	130	200	120
Magnesium	35	30	30	45	60
Sodium	185	160	165	300	400
Chloride	425	390	425	690	970
Sulfate	77	64	64	99	162
Bicarbonate	210	185	205	195	160
Total Dissolved Solids	1,000	1,020	1,050	1,900	2,080
Turbidity, NTU	21.0	0.35	0.60	0.40	0.40

[a]All units in mg/l unless otherwise noted.

ASSESSMENT OF ASR POTENTIAL

The results of the testing indicate that the recently constructed wells are generally compatible with the ASR concept. The storage zone exhibits a satisfactory degree of confinement and the overall aquifer response indicates low to medium transmissivities for the intended flows. The background water quality appears to have reached equilibrium at the pumping test rates, which further indicates adequate confinement of the storage zone.

The water quality and aquifer hydraulics near Wells R-3 and R-4 appear to be similar to that of the first ASR well, R-1. For this reason, the storage and recovery of treated water in these two wells is expected to result with the same type of response seen during the testing of Well R-1. The water recovered from these two wells will probably be comparable to the injected water quality up to about 40 to 50 percent of the injected volume. Following this point, an increasing blend of the injected and native waters should be produced, and the trend should continue for the rest of the recovery cycle. The recovery quality observed in Well R-1 was such that drinking water standards were met throughout recovery, even with the blending.

The water in Wells R-5 and R-6 has a higher mineral content than observed in the first ASR well, R-1. However, the aquifer hydraulics in the area of these two wells appear to be similar to Well R-1. These two wells are expected to demonstrate the same type of recovery response as Well R-1; however, the portion of recovery in which a blend of injected and native waters occurs will have a higher concentration of dissolved constituents. During the first ASR cycle, the recovered water from these wells will probably exceed drinking water standards during the latter portion of recovery. The recovery quality is expected to improve with successive cycles and aquifer conditioning, so that 100 percent of the stored volume can be recovered within three or four complete ASR cycles.

The water quality observed in Well R-2 is similar to that in Well R-1, except for the production of excess turbidity. The hydraulics observed in the area of this well are also unique for this system. It is recommended that this well be incorporated into the ASR system with the provision of retreating the recovered water. If the turbidity is not reduced in the recovered flows, the water recovered from this well can then be treated at the Dyal WTP to remove it.

Section 5
RECOMMENDATIONS

The construction and testing reported herein consisted of the five new ASR wells and the first aquifer testing. During this sequence of work, information was obtained to finalize the design parameters for the remainder of the facility which will consist of the pumps, piping, and appurtenances to place the wells in service.

Design, construction, and permitting of the remaining facility components will be necessary to complete the ASR facility. The construction and ultimate operation of these facilities will require various levels of regulatory permits. The three chief permitting activities will be the Public Drinking Water System Construction Permit, the Underground Injection Control (UIC) permit, and the Consumptive Use Permit (CUP).

The design of the above ground piping and controls for the expanded facility was recently completed. In addition, an Application to Construct a Public Drinking Water System Permit Application was also recently submitted to FDER.

As discussed in the preceding sections, well R-2 was found to exhibit higher turbidity levels than the other wells. For this reason, the design of the ASR facility piping will enable Well R-2 to recover to either the raw water intake at the WTP or to the finished water ground storage with the remaining wells. The turbidity levels in the water produced from Well R-2 may diminish with use, and this reduction may require several ASR cycles. If water recovered from this well exhibits turbidity levels incompatable with the rest of the ASR facility, the water may have to be diverted back through the WTP and re-treated.

Following the completion of the piping construction, and following approval from FDER, Well R-2 should be pumped to attempt to reduce turbidity levels. This pumping is expected to take up to about two weeks. The water produced should be diverted to the raw water intake of the WTP. Water quality should be monitored twice per day during this time, including immediate analysis for turbidity. The effects of stopping and restarting pumping also should be investigated during this time.

The construction of the remaining portions of the ASR facility and the additional pumping of well R-2 should be planned for completion by the winter of 1990. At that time, an initial calibration testing program should begin. A total target volume of about 60 million gallons (MG) of treated water should be injected into the six wells. During this portion of the calibration testing, the injection hydraulics should be confirmed and the control values within the piping system adjusted for the resulting conditions.

Recovery should begin immediately following injection and during this portion of the testing, the water quality response of each of the wells should be determined. In addition, the system hydraulics should be confirmed, and the control values within the piping system adjusted for the resulting conditions. The recovery water quality response for each well should be used to finalize the operation plan for the facility. This will consist of the recommended procedure to condition the aquifer to optimize recovery, which may include a sacrificed volume of treated water into some of the wells to hasten the aquifer conditioning.

This initial testing is expected to encompass approximately one month. After this testing, the City should begin the first complete ASR cycle, which would consist of injecting a large volume of treated water for later recovery to the finished water ground storage tank. The detailed schedule of injection and recovery for this cycle will be determined at this time, depending on the results of the initial testing as well as the month in which injection begins.

The UIC permit application was originally submitted in July 1988, and the permit was issued October 11, 1988. The permit is active and expires at the end of September 1990. The existing permit was submitted as a two-part construction/clearance permit for the construction and testing of the five new wells, classified in accordance with FDER 17-28.510 (2) (b) as Group 2 recharge wells.

The City should obtain approval from FDER to maintain this existing permit throughout construction of the remaining system facilities and use it during the initial calibration testing period. Following this initial testing and upon submission of the results to FDER, the clearance portion of the permit should begin, and in accordance with 17-28.620 (4), authorization to use the wells should be requested from FDER. The construction and initial testing schedule will probably not be completed by the permit expiration date of September 1990. Therefore, a time extension for the existing permit will probably be necessary and should be requested from FDER.

The CUP application for the ASR facility was made to the SJRWMD as a part of the well field application dated November 1989. This entire permit application has been petitioned for Administrative Hearing and is scheduled for Hearing on May 16, 1990. The SJRWMD has proposed a condition to the ultimate permit for the ASR facility that requires the submission of certain water quality and aquifer hydraulic testing results. The requested information and testing results are included in this report. The City should submit this report to the SJRWMD and request approval to operate the ASR system after the construction and initial testing have been completed.

A1. WATER QUALITY DURING DRILLING

During reverse-air drilling, samples of the water air-lifted through the drill stem were obtained at approximate 10-foot intervals within the production zone. CH2M HILL personnel analyzed the samples for chloride concentration, conductivity, temperature, and sulfate concentration. The samples also were analyzed in the Dyal WTP laboratory for chloride concentration, conductivity, pH, alkalinity, total hardness, and calcium hardness. The results follow.

City of Cocoa
ASR Well Construction
Water Quality During Drilling
Well R-2

		Field Measurements				Dyal Plant Lab					
										Hardness	
Date	Depth	Chloride (mg/l)	Cond. (umho/cm)	Temp. (F)	Sulfate (mg/l)	Chloride (mg/l)	Cond. (umho/cm)	pH	Alk. (mg/l)	Total (mg/l)	Ca (mg/l)
01/06/89	333	380	2600	75	80	--	--	--	--	--	--
01/06/89	344	420	2240	--	78	--	--	--	--	--	--
01/06/89	354	400	2300	76	95	450	--	7.86	206	320	194
01/06/89	365	440	2200	--	85	460	--	7.90	212	332	172
01/06/89	370	440	2220	--	35	465	--	7.70	196	356	200

City of Cocoa
ASR Well Construction
Water Quality During Construction
Well R-3

		Field Measurements				Dyal Plant Lab					
										Hardness	
Date	Depth	Chloride (mg/l)	Cond. (mhos/cm)	Temp. (F)	Sulfate (mg/l)	Chloride (mg/l)	Cond. (mhos/cm)	pH	Alk. (mg/l)	Total (mg/l)	Ca (mg/l)
03/02/89	335	580	1350	77	55	372	1200	8.06	---	---	---
03/02/89	345	460	1340	77	60	360	1250	8.25	334	294	176
03/02/89	355	440	1350	76	65	370	1250	7.89	---	---	---
03/02/89	365	480	1340	76	65	380	1225	7.94	152	342	204
03/02/89	370	460	1350	76	55	360	1225	7.78	152	320	212

City of Cocoa
ASR Well Construction
Water Quality During Construction
Well R-4

		Field Measurements				Dyal Plant Lab				Hardness	
Date	Depth	Chloride (mg/l)	Cond. (mhos/cm)	Temp. (F)	Sulfate (mg/l)	Chloride (mg/l)	Cond. (mhos/cm)	pH	Alk. (mg/l)	Total (mg/l)	Ca (mg/l)
02/16/89	353	340	1360	76	80	368	1300	7.98	148	320	208
02/16/89	365	380	1460	76	70	400	1350	7.82	140	340	220
02/16/89	370	400	1400	76	66	440	1350	7.90	166	340	238

City of Cocoa
ASR Well Construction
Water Quality During Construction
Well R-5

		Field Measurements				Dyal Plant Lab				Hardness	
Date	Depth	Chloride (mg/l)	Cond. (mhos/cm)	Temp. (F)	Sulfate (mg/l)	Chloride (mg/l)	Cond. (mhos/cm)	pH	Alk. (mg/l)	Total (mg/l)	Ca (mg/l)
02/02/89	347	730	2700	77	100	690	2300	7.88	>500	418	306
02/02/89	357	700	2380	77	105	680	2200	7.85	---	---	---
02/02/89	367	700	2520	76	110	684	2250	8.03	214	250	264
02/02/89	371	720	2480	76	95	688	2300	7.85	160	480	288

City of Cocoa
ASR Well Construction
Water Quality During Drilling
Well R-6

		Field Measurements				Dyal Plant Lab				Hardness	
Date	Depth	Chloride (mg/l)	Cond. (umho/cm)	Temp. (F)	Sulfate (mg/l)	Chloride (mg/l)	Cond. (umho/cm)	pH	Alk. (mg/l)	Total (mg/l)	Ca (mg/l)
01/19/89	325	560	2200	--	--	610	--	8.67	--	--	--
01/19/89	335	1040	3600	75	--	1030	--	8.16	--	--	--
01/19/89	345	1000	3580	76	--	1061	--	8.29	366	564	312
01/19/89	355	1020	3550	76	175	1060	--	8.35	--	--	--
01/19/89	366	1020	3600	76	175	1050	--	7.99	140	586	360
01/19/89	371	1040	3550	76	175	1000	--	8.53	118	554	300

A2. WATER QUALITY RESULTS DURING PUMPING TESTS

During the constant-rate pumping test of each well, water samples were obtained from the pump discharge. Samples were obtained at the beginning, middle, and end of each 12-hour test and at 12-hour intervals during the 45.5-hour test of Well R-3. Laboratory analysis was for the following parameters:

pH	Calcium
Alkalinity (P, Total)	Iron
Conductivity	Magnesium
Hardness, Total	Potassium
Bicarbonate	Sodium
Carbonate	Chloride
Total Dissolved Solids	Sulfate

Each set of laboratory analysis includes a cation/anion balance of each sample, as requested by the SJRWMD.

Engineers
Planners
Economists
Scientists

REPORT OF ANALYSIS

Florida Certification: 82112; E82124

Sample Nos: 64863 - 64868

City of Cocoa	CH2M Hill
Attention: Kevin Bral Address: GNV Copies to: Paul Wallace/GNV	Project No: GNV14514.S1 Received: 03/22/89 Reported: 04/18/89
Collected: 03/14/89 by Paul Wallace Type: water, grab Location: Cocoa EASR	

SAMPLE NUMBER	64863	64864	64865	64866	64867
SAMPLE DESCRIPTIONS	R2PT1L R-2 3-14-89 8:20	R2PT2L R-2 3-14-89 14:05	R2PT3L R-2 3-14-89 20:05	R4PT1L R-4 3-16-89 8:50	R4PT2L R-4 3-16-89 13:45
GENERAL					
pH (Units)	6.95 03/22/89	7.00 03/22/89	7.05 03/22/89	6.80 03/22/89	6.90 03/22/89
Alkalinity, Phenolphthalein	<1.0 03/29/89	<1.0 03/29/89	<1.0 03/29/89	<1.0 03/29/89	<1.0 03/29/89
Alkalinity, Total (as CaCO3)	204 03/29/89	184 03/29/89	174 03/29/89	200 03/29/89	182 03/29/89
Conductivity (umhos/cm)	1980 04/11/89	1930 04/11/89	1870 04/11/89	2000 04/11/89	1940 04/11/89
Bicarbonate (as HCO3)	249 03/29/89	224 03/29/89	212 03/29/89	244 03/29/89	222 03/29/89
Hardness, Total (as CaCO3)	500 04/13/89	441 04/13/89	421 04/13/89	588 04/13/89	529 04/13/89
Carbonate (as CO3=)	<1.0 03/29/89	<1.0 03/29/89	<1.0 03/29/89	<1.0 03/29/89	<1.0 03/29/89
SOLIDS					
Total Dissolved Solids	1130 03/24/89	784 03/24/89	1010 03/24/89	1350 03/24/89	1090 03/24/89
METALS					
Calcium - FL	235	149	108	158	136

NOTE: Values are mg/l as substance unless otherwise stated.
NOTE: TDS and pH samples were out of holding time upon receipt in Laboratory.
REVISED REPORT 4-20-89.

Respectfully submitted,

Thomas C. Emenhiser

Thomas C. Emenhiser, Laboratory Manager

n/r = not requested
NOTE: This report contains test data and no interpretation is intended or implied.

REPORT OF ANALYSIS

Florida Certification: 82112; E82124

SAMPLE NUMBER	64863	64864	64865	64866	64867
SAMPLE DESCRIPTIONS	R2PT1L R-2 3-14-89 8:20	R2PT2L R-2 3-14-89 14:05	R2PT3L R-2 3-14-89 20:05	R4PT1L R-4 3-16-89 8:50	R4PT2L R-4 3-16-89 13:45
	04/01/89	04/01/89	04/01/89	04/01/89	04/01/89
Iron, Total - FL	0.52	0.22	0.09	0.13	0.06
	04/01/89	04/01/89	04/01/89	04/01/89	04/01/89
Magnesium - FL	35	33	34	34	31
	04/01/89	04/01/89	04/01/89	04/01/89	04/01/89
Potassium	4.58	4.19	4.17	3.51	3.60
	04/05/89	04/05/89	04/05/89	04/05/89	04/05/89
Sodium - FL	178	183	184	165	163
	04/01/89	04/01/89	04/01/89	04/01/89	04/01/89
ANIONS					
Chloride	471	453	424	495	453
	04/12/89	04/12/89	04/12/89	04/12/89	04/12/89
Sulfate	71	74	77	63	63
	04/14/89	04/14/89	04/14/89	04/14/89	04/14/89

NOTE: Values are mg/l as substance unless otherwise stated.
NOTE: TDS and pH samples were out of holding time upon receipt in Laboratory.
REVISED REPORT 4-20-89.

Respectfully submitted,

Thomas C. Emenhiser, Laboratory Manager

n/r = not requested
NOTE: This report contains test data and no interpretation is intended or implied.

City of Cocoa	C H 2 M H i l l
Attention: Kevin Bral Address: GNV Copies to: Paul Wallace/GNV	Project No: GNV14514.S1 Received: 03/22/89 Reported: 04/18/89
Collected: 03/14/89 by Paul Wallace Type: water, grab Location: Cocoa EASR	

SAMPLE NUMBER	64868
SAMPLE DESCRIPTIONS	R4PT3L R-4 3-16-89 20:30
GENERAL	
pH (Units)	7.10 03/22/89
Alkalinity, Phenolphthalein	<1.0 03/29/89
Alkalinity, Total (as CaCO3)	170 03/29/89
Conductivity (umhos/cm)	1860 04/11/89
Bicarbonate (as HCO3)	207 03/29/89
Hardness, Total (as CaCO3)	461 04/13/89
Carbonate (as CO3=)	<1.0 03/29/89
SOLIDS	
Total Dissolved Solids	1050 03/24/89
METALS	
Calcium - FL	122

NOTE: Values are mg/l as substance unless otherwise stated.
NOTE: TDS and pH samples were out of holding time upon receipt in Laboratory.
REVISED REPORT 4-20-89.

Respectfully submitted,

Thomas C. Emenhiser, Laboratory Manager

n/r = not requested
NOTE: This report contains test data and no interpretation is intended or implied.

SAMPLE NUMBER	64868
SAMPLE DESCRIPTIONS	R4PT3L R-4 3-16-89 20:30
	04/01/89
Iron, Total - FL	0.04 04/01/89
Magnesium - FL	32 04/01/89
Potassium	3.49 04/05/89
Sodium - FL	163 04/01/89
ANIONS	
Chloride	424 04/12/89
Sulfate	64 04/14/89

NOTE: Values are mg/l as substance unless otherwise stated.
NOTE: TDS and pH samples were out of holding time upon receipt in Laboratory.
REVISED REPORT 4-20-89.

Respectfully submitted,

Thomas C. Emenhiser, Laboratory Manager

n/r = not requested
NOTE: This report contains test data and no interpretation is intended or implied.

20-Apr-89

CATION/ANION BALANCE

SAMPLE # 64863

(Ca and Mg by AA)

mg/l (as CaCO3)	mg/l (as substance)	meq/l	
	CATIONS		
587.5	235	11.73	Ca
144.2	35	2.88	Mg
*	178	7.74	Na
*	4.58	0.12	K
*	0	0.00	Sr
*	0.52	0.02	Fe
		22.49	TOT
	ANIONS		
204	248.88	4.08	HCO3
0	0	0.00	CO3
0	0	0.00	OH
*	471	13.29	Cl
*	71	1.48	SO4
		18.84	TOT

SUM, cations + anions	41.33
DIF, ¦cations - anions¦	3.64
RPD	8.81%

NOTES:

ACCEPTABLE BALANCE: RPD<=10%

$$RPD = \frac{DIF, |cations - anions|}{SUM, cations + anions} \times 100$$

CATION/ANION BALANCE

SAMPLE # 64864

(Ca and Mg by AA)

mg/l (as CaCO3)	mg/l (as substance)	meq/l	
	CATIONS		
372.5	149	7.44	Ca
135.96	33	2.72	Mg
*	183	7.96	Na
*	4.19	0.11	K
*	0	0.00	Sr
*	0.22	0.01	Fe
		18.23	TOT
	ANIONS		
184	224.48	3.68	HCO3
0	0	0.00	CO3
0	0	0.00	OH
*	453	12.78	Cl
*	74	1.54	SO4
		18.00	TOT

SUM, cations + anions 36.23
DIF, ¦cations - anions¦ 0.23
RPD 0.63%

NOTES:

ACCEPTABLE BALANCE: RPD<=10%

$$RPD = \frac{\text{DIF, } |\text{cations} - \text{anions}|}{\text{SUM, cations + anions}} \times 100$$

20-Apr-89

CATION/ANION BALANCE

SAMPLE # 64865

(Ca and Mg by AA)

mg/l (as CaCO3)	mg/l (as substance)	meq/l	
	CATIONS		
270	108	5.39	Ca
140.08	34	2.80	Mg
*	184	8.00	Na
*	4.17	0.11	K
*	0	0.00	Sr
*	0.09	0.00	Fe
		16.30	TOT
	ANIONS		
174	212.28	3.48	HCO3
0	0	0.00	CO3
0	0	0.00	OH
*	424	11.96	Cl
*	77	1.60	SO4
		17.04	TOT

SUM, cations + anions	33.34
DIF, ¦cations - anions¦	0.74
RPD	2.23%

NOTES:

ACCEPTABLE BALANCE: RPD<=10%

$$RPD = \frac{\text{DIF, } |\text{cations - anions}|}{\text{SUM, cations + anions}} \times 100$$

20-Apr-89

CATION/ANION BALANCE

SAMPLE # 64866

(Ca and Mg by AA)

mg/l (as CaCO3)	mg/l (as substance)	meq/l	
	CATIONS		
395	158	7.88	Ca
140.08	34	2.80	Mg
*	165	7.18	Na
*	3.51	0.09	K
*	0	0.00	Sr
*	0.13	0.00	Fe
		17.95	TOT
	ANIONS		
200	244	4.00	HCO3
0	0	0.00	CO3
0	0	0.00	OH
*	495	13.96	Cl
*	63	1.31	SO4
		19.27	TOT

SUM, cations + anions	37.23
DIF,¦cations - anions¦	1.32
RPD	3.55%

NOTES:

ACCEPTABLE BALANCE: RPD<=10%

$$RPD = \frac{DIF, |cations - anions|}{SUM, cations + anions} \times 100$$

CATION/ANION BALANCE

SAMPLE # 64867

(Ca and Mg by AA)

mg/l (as CaCO3)	mg/l (as substance)	meq/l	
	CATIONS		
340	136	6.79	Ca
127.72	31	2.55	Mg
*	163	7.09	Na
*	3.60	0.09	K
*	0	0.00	Sr
*	0.06	0.00	Fe
		16.52	TOT
	ANIONS		
182	222.04	3.64	HCO3
0	0	0.00	CO3
0	0	0.00	OH
*	453	12.78	Cl
*	63	1.31	SO4
		17.73	TOT

SUM, cations + anions 34.25
DIF, ¦cations - anions¦ 1.21
RPD 3.53%

NOTES:

ACCEPTABLE BALANCE: RPD<=10%

$$RPD = \frac{\text{DIF, |cations - anions|}}{\text{SUM, cations + anions}} \times 100$$

20-Apr-89

CATION/ANION BALANCE

SAMPLE # 64868

(Ca and Mg by AA)

mg/l (as CaCO3)	mg/l (as substance)	meq/l	
	CATIONS		
305	122	6.09	Ca
131.84	32	2.63	Mg
*	163	7.09	Na
*	3.49	0.09	K
*	0	0.00	Sr
*	0.04	0.00	Fe
		15.90	TOT
	ANIONS		
170	207.4	3.40	HCO3
0	0	0.00	CO3
0	0	0.00	OH
*	424	11.96	Cl
*	64	1.33	SO4
		16.69	TOT

SUM, cations + anions	32.60
DIF, ¦cations - anions¦	0.79
RPD	2.43%

NOTES:

ACCEPTABLE BALANCE: RPD<=10%

$$RPD = \frac{\text{DIF, } |\text{cations - anions}|}{\text{SUM, cations + anions}} \times 100$$

City of Cocoa	C H 2 M H i l l
Attention: Kevin Bral Address: GNV Copies to: Paul Wallace/GNV	Project No: GNV14514.S1 Received: 03/27/89 Reported: 04/25/89

Collected: 03/21/89 by Paul Wallace
Type: water, grab
Location: Cocoa EASR

SAMPLE NUMBER	64990	64991	64992	64993
SAMPLE DESCRIPTIONS	Start Test R3 3-21-89 11:10	1/3 Test R3 3-22-89 7:10	2/3 Test R3 3-22-89 21:00	End Test R3 3-23-89 8:25
GENERAL				
pH (Units)	7.25 03/27/89	7.30 03/27/89	7.35 03/27/89	7.40 03/27/89
Alkalinity, Phenolphthalein	<1.0 03/31/89	<1.0 03/31/89	<1.0 03/31/89	<1.0 03/31/89
Alkalinity, Total (as CaCO3)	164 03/31/89	149 03/31/89	148 03/31/89	150 03/31/89
Conductivity (umhos/cm)	1630 04/13/89	1570 04/13/89	1650 04/13/89	1630 04/13/89
Hardness, Carbonate (as CaCO3)	164 03/31/89	149 03/31/89	148 03/31/89	150 03/31/89
Hardness, Total (as CaCO3)	408 04/14/89	377 04/14/89	388 04/14/89	372 04/14/89
Carbonate (as CO3=)	<0.1 04/24/89	<0.1 04/24/89	<0.1 04/24/89	<0.1 04/24/89
SOLIDS				
Total Dissolved Solids	978 03/27/89	950 03/27/89	1020 03/27/89	1040 03/27/89
METALS				
Calcium - FL	88	75	76	76

NOTE: Values are mg/l as substance unless otherwise stated.

Respectfully submitted,

Thomas C. Emenhiser, Laboratory Manager

n/r = not requested
NOTE: This report contains test data and no interpretation is intended or implied.

REPORT OF ANALYSIS

Florida Certification: 82112; E82124

SAMPLE NUMBER	64990	64991	64992	64993
SAMPLE DESCRIPTIONS	Start Test R3 3-21-89 11:10	1/3 Test R3 3-22-89 7:10	2/3 Test R3 3-22-89 21:00	End Test R3 3-23-89 8:25
	04/01/89	04/01/89	04/01/89	04/01/89
Iron, Total - FL	0.14	0.04	0.04	0.03
	04/01/89	04/01/89	04/01/89	04/01/89
Magnesium - FL	29	30	32	32
	04/01/89	04/01/89	04/01/89	04/01/89
Potassium	3.1	3.1	3.2	3.3
	04/05/89	04/05/89	04/05/89	04/05/89
Sodium - FL	148	164	160	163
	04/01/89	04/01/89	04/01/89	04/01/89
ANIONS				
Chloride	434	371	386	386
	04/18/89	04/18/89	04/18/89	04/18/89
Sulfate	58	61	61	64
	04/14/89	04/14/89	04/14/89	04/14/89

NOTE: Values are mg/l as substance unless otherwise stated.

Respectfully submitted,

Thomas C. Emenhiser, Laboratory Manager

n/r = not requested
NOTE: This report contains test data and no interpretation is intended or implied.

CATION/ANION BALANCE

SAMPLE # 64990

(Ca and Mg by AA)

mg/l (as CaCO3)	mg/l (as substance)	meq/l	
	CATIONS		
220	88	4.39	Ca
119.48	29	2.39	Mg
*	148	6.44	Na
*	3.1	0.08	K
*	0	0.00	Sr
*	0.14	0.01	Fe
		13.30	TOT
	ANIONS		
164	200.08	3.28	HCO3
0	0	0.00	CO3
0	0	0.00	OH
*	434	12.24	Cl
*	58	1.21	SO4
		16.73	TOT

SUM, cations + anions	30.03
DIF, ¦cations - anions¦	3.43
RPD	11.42%

NOTES:

ACCEPTABLE BALANCE: RPD<=10%

$$RPD = \frac{\text{DIF, } |\text{cations - anions}|}{\text{SUM, cations + anions}} \times 100$$

CATION/ANION BALANCE

SAMPLE # 64991

(Ca and Mg by AA)

mg/l (as CaCO3)	mg/l (as substance)	meq/l	
CATIONS			
187.5	75	3.74	Ca
123.6	30	2.47	Mg
*	164	7.13	Na
*	3.1	0.08	K
*	0	0.00	Sr
*	0.04	0.00	Fe
		13.43	TOT
ANIONS			
149	181.78	2.98	HCO3
0	0	0.00	CO3
0	0	0.00	OH
*	371	10.47	Cl
*	61	1.27	SO4
		14.72	TOT

SUM, cations + anions	28.14
DIF, ¦cations - anions¦	1.29
RPD	4.58%

NOTES:

ACCEPTABLE BALANCE: RPD<=10%

$$RPD = \frac{\text{DIF, |cations - anions|}}{\text{SUM, cations + anions}} \times 100$$

28-Apr-89

CATION/ANION BALANCE

SAMPLE # 64992

(Ca and Mg by AA)

mg/l (as CaCO3)	mg/l (as substance)	meq/l	
CATIONS			
190	76	3.79	Ca
131.84	32	2.63	Mg
*	160	6.96	Na
*	3.2	0.08	K
*	0	0.00	Sr
*	0.04	0.00	Fe
		13.47	TOT
ANIONS			
148	180.56	2.96	HCO3
0	0	0.00	CO3
0	0	0.00	OH
*	386	10.89	Cl
*	61	1.27	SO4
		15.12	TOT

SUM, cations + anions	28.59
DIF, ¦cations - anions¦	1.65
RPD	5.77%

NOTES:

ACCEPTABLE BALANCE: RPD<=10%

$$RPD = \frac{\text{DIF, |cations - anions|}}{\text{SUM, cations + anions}} \times 100$$

CATION/ANION BALANCE

SAMPLE # 64993

(Ca and Mg by AA)

mg/l (as CaCO3)	mg/l (as substance)	meq/l	
	CATIONS		
190	76	3.79	Ca
131.84	32	2.63	Mg
*	163	7.09	Na
*	3.3	0.08	K
*	0	0.00	Sr
*	0.03	0.00	Fe
		13.60	TOT
	ANIONS		
150	183	3.00	HCO3
0	0	0.00	CO3
0	0	0.00	OH
*	386	10.89	Cl
*	64	1.33	SO4
		15.22	TOT

SUM, cations + anions	28.82
DIF, ¦cations - anions¦	1.62
RPD	5.62%

NOTES:

ACCEPTABLE BALANCE: RPD<=10%

$$RPD = \frac{\text{DIF, } |\text{cations - anions}|}{\text{SUM, cations + anions}} \times 100$$

CH2M HILL Engineers Planners Economists Scientists

REPORT OF ANALYSIS

Florida Certification: 82112; E82124

Cocoa	CH2M Hill
Attention: Kevin Bral Address: GNV	Project No: GNV14514.S1 Received: 03/14/89 Reported: 04/17/89

Collected: 03/09/89 by Kevin Bral
Type: water, grab
Location: Cocoa ASR

SAMPLE NUMBER	64508	64509	64510
SAMPLE DESCRIPTIONS	R5PT1L 10:00 3-9-89	R5PT2L 15:00 3-9-89	R5PT3L 21:50 3-9-89
GENERAL			
pH (Units)	6.70 03/14/89	6.85 03/14/89	6.95 03/14/89
Alkalinity, Phenolphthalein	<1.0 03/29/89	<1.0 03/29/89	<1.0 03/29/89
Alkalinity, Total (as CaCO3)	198 03/29/89	170 03/29/89	156 03/29/89
Conductivity (umhos/cm)	2970 03/30/89	2820 03/30/89	2680 03/30/89
Bicarbonate (as HCO3)	242 04/14/89	207 04/14/89	190 04/14/89
Hardness, Total (as CaCO3)	745 04/13/89	608 04/13/89	559 04/13/89
Carbonate (as CO3=)	<0.1 04/14/89	<0.1 04/14/89	<0.1 04/14/89
SOLIDS			
Total Dissolved Solids	2280 03/16/89	2030 03/16/89	1900 03/16/89
METALS			
Calcium - FL	200	200	100

NOTE: Values are mg/l as substance unless otherwise stated.

Respectfully submitted,

Thomas C. Emenhiser, Laboratory Manager

n/r = not requested
NOTE: This report contains test data and no interpretation is intended or implied.

SAMPLE NUMBER	64508	64509	64510
SAMPLE DESCRIPTIONS	R5PT1L 10:00 3-9-89	R5PT2L 15:00 3-9-89	R5PT3L 21:50 3-9-89
	03/22/89	03/22/89	03/22/89
Iron, Total - FL	0.24 03/16/89	0.09 03/16/89	0.08 03/16/89
Magnesium - FL	42 03/15/89	45 03/15/89	44 03/15/89
Potassium	6.4 03/17/89	6.8 03/17/89	6.9 03/17/89
Sodium - FL	303 03/17/89	303 03/17/89	303 03/17/89
ANIONS			
Chloride	820 04/11/89	745 04/11/89	693 04/11/89
Sulfate	96 04/06/89	99 04/06/89	99 04/06/89

NOTE: Values are mg/l as substance unless otherwise stated.

Respectfully submitted,

Thomas C. Emenhiser, Laboratory Manager

n/r = not requested
NOTE: This report contains test data and no interpretation is intended or implied.

CATION/ANION BALANCE

SAMPLE # 64508

(Ca and Mg by AA)

mg/l (as CaCO3)	mg/l (as substance)	meq/l	
			CATIONS
500	200	9.98	Ca
173.04	42	3.46	Mg
*	303	13.18	Na
*	6.4	0.16	K
*	0	0.00	Sr
*	0.24	0.01	Fe
		26.79	TOT
			ANIONS
198	241.56	3.96	HCO3
0	0	0.00	CO3
0	0	0.00	OH
*	820	23.13	Cl
*	96	2.00	SO4
		29.09	TOT

SUM, cations + anions 55.88
DIF,|cations - anions| 2.30
RPD 4.12%

NOTES:

ACCEPTABLE BALANCE: RPD<=10%

$$RPD = \frac{\text{DIF, |cations - anions|}}{\text{SUM, cations + anions}} \times 100$$

CATION/ANION BALANCE

SAMPLE # 64509

(Ca and Mg by AA)

mg/l (as CaCO3)	mg/l (as substance)	meq/l	
CATIONS			
500	200	9.98	Ca
185.4	45	3.70	Mg
*	303	13.18	Na
*	6.8	0.17	K
*	0	0.00	Sr
*	0.09	0.00	Fe
		27.04	TOT
ANIONS			
170	207.4	3.40	HCO3
0	0	0.00	CO3
0	0	0.00	OH
*	745	21.02	Cl
*	99	2.06	SO4
		26.48	TOT

SUM, cations + anions 53.52
DIF, |cations - anions| 0.56
RPD 1.05%

NOTES:

ACCEPTABLE BALANCE: RPD<=10%

$$RPD = \frac{\text{DIF, |cations - anions|}}{\text{SUM, cations + anions}} \times 100$$

CATION/ANION BALANCE

SAMPLE # 64510

(Ca and Mg by AA)

mg/l (as CaCO3)	mg/l (as substance)	meq/l	
	CATIONS		
250	100	4.99	Ca
181.28	44	3.62	Mg
*	303	13.18	Na
*	6.9	0.18	K
*	0	0.00	Sr
*	0.08	0.00	Fe
		21.97	TOT
	ANIONS		
156	190.32	3.12	HCO3
0	0	0.00	CO3
0	0	0.00	OH
*	693	19.55	Cl
*	99	2.06	SO4
		24.73	TOT

SUM, cations + anions 46.70
DIF,|cations - anions| 2.76
RPD 5.91%

NOTES:

ACCEPTABLE BALANCE: RPD<=10%

$$RPD = \frac{DIF, |cations - anions|}{SUM, cations + anions} \times 100$$

Engineers
Planners
Economists
Scientists

REPORT OF ANALYSIS

Florida Certification: 82112; E82124

City of Cocoa	CH2M Hill
Attention: Kevin Bral Address: GNV Copies to: Paul Wallace/GNV	Project No: GNV14514.S1 Received: 03/27/89 Reported: 04/25/89

Collected: 03/19/89 by Paul Wallace
Type: water, grab
Location: Cocoa EASR

SAMPLE NUMBER	64987	64988	64989
SAMPLE DESCRIPTIONS	Start Test R6 3-19-89 10:10	Mid Test R6 3-19-89 16:00	End Test R6 3-19-89 22:00
GENERAL			
pH (Units)	7.30 03/27/89	7.40 03/27/89	7.40 03/27/89
Alkalinity, Phenolphthalein	<1.0 03/31/89	<1.0 03/31/89	<1.0 03/31/89
Alkalinity, Total (as CaCO3)	137 03/31/89	128 03/31/89	128 03/31/89
Conductivity (umhos/cm)	3290 04/17/89	3090 04/17/89	3050 04/17/89
Bicarbonate (as HCO3)	167 04/24/89	156 04/24/89	156 04/24/89
Hardness, Total (as CaCO3)	686 04/13/89	617 04/13/89	588 04/13/89
Carbonate (as CO3=)	<0.1 04/24/89	<0.1 04/24/89	<0.1 04/24/89
SOLIDS			
Total Dissolved Solids	2150 03/27/89	2060 03/27/89	2080 03/27/89
METALS			
Calcium - FL	148	130	120

NOTE: Values are mg/l as substance unless otherwise stated.
REVISED REPORT 5-2-89.

Respectfully submitted,

Thomas C. Emenhiser, Laboratory Manager

n/r = not requested
NOTE: This report contains test data and no interpretation is intended or implied.

SAMPLE NUMBER	64987	64988	64989
SAMPLE DESCRIPTIONS	Start Test R6 3-19-89 10:10	Mid Test R6 3-19-89 16:00	End Test R6 3-19-89 22:00
	04/01/89	04/01/89	04/01/89
Iron, Total - FL	0.45 04/01/89	0.07 04/01/89	0.08 04/01/89
Magnesium - FL	59 04/01/89	60 04/01/89	57 04/01/89
Potassium	14.1 04/05/89	14.3 04/05/89	13.4 04/05/89
Sodium - FL	419 04/01/89	413 04/01/89	407 04/01/89
ANIONS			
Chloride	1080 04/18/89	964 04/18/89	964 04/18/89
Sulfate	168 04/14/89	163 04/14/89	162 04/14/89

NOTE: Values are mg/l as substance unless otherwise stated.
REVISED REPORT 5-2-89.

Respectfully submitted,

Thomas C. Emenhiser, Laboratory Manager

n/r = not requested
NOTE: This report contains test data and no interpretation is intended or implied.

28-Apr-99

CATION ANION BALANCE

SAMPLE # 14907

(Ca and Mg by AA)

mg/l (as CaCO3)	mg/l (as substance)	meq/l	
	CATIONS		
370	148	7.39	Ca
243.08	59	4.86	Mg
*	419	18.23	Na
*	14.1	0.36	K
*	0	0.00	Sr
*	0.45	0.02	Fe
		30.84	TOT
	ANIONS		
137	167.14	2.74	HCO3
0	0	0.00	CO3
0	0	0.00	OH
*	1080	30.47	Cl
*	168	3.50	SO4
		36.70	TOT

SUM, cations + anions	67.55
DIF, |cations - anions|	5.86
RPD	8.68%

NOTES:

ACCEPTABLE BALANCE: RPD<=10%

$$RPD = \frac{DIF,\ |cations - anions|}{SUM,\ cations + anions} \times 100$$

25-Apr-89

CATION/ANION BALANCE

SAMPLE # 24708

(Ca and Mg by AA)

mg/l (as CaCO3)	mg/l (as substance)	meq/l	
	CATIONS		
325	130	6.49	Ca
247.2	60	4.94	Mg
*	413	17.97	Na
*	14.3	0.37	K
*	0	0.00	Sr
*	0.07	0.00	Fe
		29.76	TOT
	ANIONS		
128	156.16	2.56	HCO3
0	0	0.00	CO3
0	0	0.00	OH
*	964	27.19	Cl
*	163	3.39	SO4
		33.15	TOT

SUM, cations + anions 62.91
DIF, |cations - anions| 3.39
RPD 5.39%

NOTES:

ACCEPTABLE BALANCE: RPD<=10%

$$RPD = \frac{DIF, |cations - anions|}{SUM, cations + anions} \times 100$$

CATION ANION BALANCE

SAMPLE # 64959

(Ca and Mg by AA)

mg/l (as CaCO3)	mg/l (as substance)	meq/l	
	CATIONS		
300	120	5.99	Ca
234.84	57	4.69	Mg
*	407	17.70	Na
*	13.4	0.34	K
*	0	0.00	Sr
*	0.08	0.00	Fe
		28.73	TOT
	ANIONS		
128	156.16	2.56	HCO3
0	0	0.00	CO3
0	0	0.00	OH
*	964	27.19	Cl
*	162	3.37	SO4
		33.13	TOT

SUM, cations + anions 61.86
DIF, |cations - anions| 4.40
RPD 7.11%

NOTES:

ACCEPTABLE BALANCE: RPD<=10%

$$RPD = \frac{\text{DIF, |cations - anions|}}{\text{SUM, cations + anions}} \times 100$$

Appendix B
WELL R-3 CUTTINGS DESCRIPTION

Depth (ft.)	Description
0- 5	Sand and shell, tan/brown, very fine to fine (sand), phosphorus
5-10	Sand and shell, as above
10-15	Sand and shell, as above
15-20	Sand and shell, as above
20-25	Sand, shell and clay, tan/brown, very fine to fine (sand), phosphorus
25-30	Sand and clay, brown, fine (sand)
30-35	Sand and shell, brown, fine (sand)
35-40	Sand and shell, as above
40-45	Sand and shell, as above
45-50	Sand and shell, as above
50-55	Shells and sand, white, fine (sand)
55-60	Sand shell, tan/brown, very fine to fine (sand)
60-65	Sand and shell, as above
65-70	Sand and shell, gray/brown, fine, sandy limestone fragments
70-75	Sand and shell, as above
75-80	Sand, gray, fine, some shell fragments
80-85	Sand, as above, some clay
85-90	Shell and sand, tan, fine (sand)
90-95	Sand, brown/tan, fine, some shell, weathered lime fragments, slight clay

Depth (ft.)	Description
95-100	Sand, as above
100-105	Sand and clay, brown, fine (sand), shell fragments
105-110	Sand and clay, as above
110-115	Sand, gray, fine, limey, shell fragments
115-120	Sand and shell, gray, fine (sand)
120-125	Sand and shell, as above
125-130	Sand and shell, as above
130-135	Sand and shell, as above
135-140	Sand, gray, fine, some shell
140-145	Sand, as above
145-150	Sand, gray/brown
150-155	Sand and clay, gray/green, fine (sand), some shell fragments, some l.s. fragments
155-160	Sand and clay, gray/green, fine (sand), shell and l.s. fragments, some s.s.
160-165	Clay, green, some sand/shell, phos.
165-170	Clay, green, sand/phosphorus
170-175	Clay, as above
175-180	Clay, as above
180-185	Clay, as above
185-190	Clay and sand, gray/green, fine to very fine, l.s. and s.s. fragments, phos.
190-195	Clay and sand, gray/green, fine to very fine, l.s. fragments, phos.

Depth (ft.)	Description
200-205	Clay, gray/green, very fine, some sand
205-210	Clay, as above
210-215	Clay and sand, gray/green, very fine to fine, l.s. and s.s. fragments, phos.
215-220	Clay and sand, as above
220-225	Clay and sand, as above
225-230	Clay and sand, as above
230-235	Clay and sand, as above
235-240	Sand and clay, gray, fine, l.s. fragments, phos.
240-245	Clay, tan, very fine, weather l.s. fragments
245-250	Clay, as above
250-255	Clay, as above
255-260	Clay, as above
260-265	Limestone, white/tan, soft, limey clay, phos.
265-270	Limestone, as above
270-275	Limestone, white/tan, hard, fossils, abundant phos.
275-280	Limestone, as above
280-285	Limestone, as above
285-290	Limestone, as above
290-295	Limestone, white, soft, fossils, some phos.
295-300	Limestone, as above
300-305	Limestone, as above

Depth (ft.)	Description
310-315	Limestone, white/tan, soft, granular, some phos., fossils
315-320	Limestone, as above
325-330	Limestone, white, soft, granular
330-335	Limestone, as above
335-340	Limestone, white/gray, harder, massive
340-345	Limestone, as above
345-350	Limestone, white/gray, soft
350-355	Limestone, as above
355-360	Limestone, as above
360-365	Limestone, white, soft, granular
365-370	Limestone, white/tan, soft, granular