Cocoa Recharge

CH2M HILL
Engineers
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February 1, 1985

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GROUNDWATER SEC.

FEB 4 1985

Mr. John Armstrong
Department of Environmental
Regulation
St. Johns River District
3319 Maquire Boulevard
Suite 232
Orlando, Florida 32803-3767

Dear Mr. Armstrong:

Subject: Results of Drilling and Testing Aquifer Storage Recovery Facility, City of Cocoa, Florida

We are sending you four copies of the above referenced document for your review and comment. Please forward the fourth copy to the EPA region IV TAC member.

The six sections of this report represent a status report on the drilling and testing of the facility prior to the storage recovery cycles. A final report will be distributed after the cycles are complete.

Sincerely,

D. Jeffrey Bair
cs

D. Jeffrey Bair, P.E.

jmm/gnR276/16
Attachments
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AQUIFER STORAGE RECOVERY TESTING FACILITY
RESULTS OF DRILLING AND TESTING

Prepared for

CITY OF COCOA, FLORIDA

Prepared by

CH2M HILL
7201 N.W. 11th Place
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CONTENTS

CONTENTS

Section 1
INTRODUCTION

As part of the water resources investigation for the City of Cocoa, CH2M HILL evaluated several water supply alternatives to meet the increasing water demands on the present system. The results of this investigation, presented in January 1982, showed that aquifer storage/recovery has certain cost and water management advantages over the other alternatives. In October 1982, CH2M HILL was authorized by the City of Cocoa to perform several tasks to confirm the feasibility of the aquifer storage/recovery concept.

The purpose of this document is to report the status of the ongoing project at the Dyal Water Treatment Plant, City of Cocoa, which entails construction and testing of aquifer storage/recovery facilities.

The work plan for the project is as follows.

1. Construct one aquifer storage/recovery test well and three observation wells at the Dyal Plant.

2. Install pump, motor, piping, and appurtenances to conduct storage/recovery test cycles.

3. Conduct approximately six storage/recovery cycles during a one-year period, recovering water for treatment at the Dyal Plant.

4. Confirm concept feasibility and cost-effectiveness.

5. Define operational flowrates and duration for both recharge and recovery and develop an expansion plan to meet increasing demands.

At this point, the aquifer storage/recovery well and all observation wells have been completed. The pump, piping, and appurtenances to enable additional pump testing and storage/recovery cycles are near completion. Cycle 1 is scheduled to begin the week of February 11, 1985.

Section 2
THE TESTING FACILITY

HYDROGEOLOGY

The general hydrogeology of the area consists of alternating water bearing formations and confining beds. The deepest water bearing formation encountered during this program was the Avon Park. At a depth of 520 feet below land surface, this limestone formation is highly porous with some cavities. The water is of poor quality, with chloride concentrations exceeding 1,000 mg/L. The Avon Park will be referred to in this report as the lower aquifer.

Overlaying the lower aquifer is a dolomite layer, approximately 20 feet thick, which serves as the lower confining bed. This dolomite layer is the bottom section of the Ocala limestone.

The Ocala limestone is a layered limestone, alternating in its ability to produce water. The storage aquifer is part of the Ocala limestone and consists of two to three water-bearing zones.

Confining the storage aquifer is the Hawthorn formation. This confining bed consists of sands and clays which retard the vertical movement of water.

Above the Hawthorn formation lie undifferentiated sediments of sand, shell, and some clays, which make up the surficial aquifer. This aquifer is of low permeability and is difficult to distinguish from the Hawthorn in the area of this project.

The aquifer storage recovery testing facility consists of one storage recovery well and three monitoring wells. This design allows for monitoring water levels and chemical properties of the storage zone, the upper aquifer, and the lower aquifer. Figures 2-1 and 2-2 show the locations and details of the wells constructed during the testing phase of the storage/recovery program.

DEEP MONITOR WELL (DMW-1)

Deep Monitor Well-1 was the first well constructed during the aquifer storage recovery program. This being the deepest planned well, the construction program was designed to produce as much hydrogeologic information as possible. Three interval pumping tests were performed during three stages of well construction. Numerous chemical analyses of

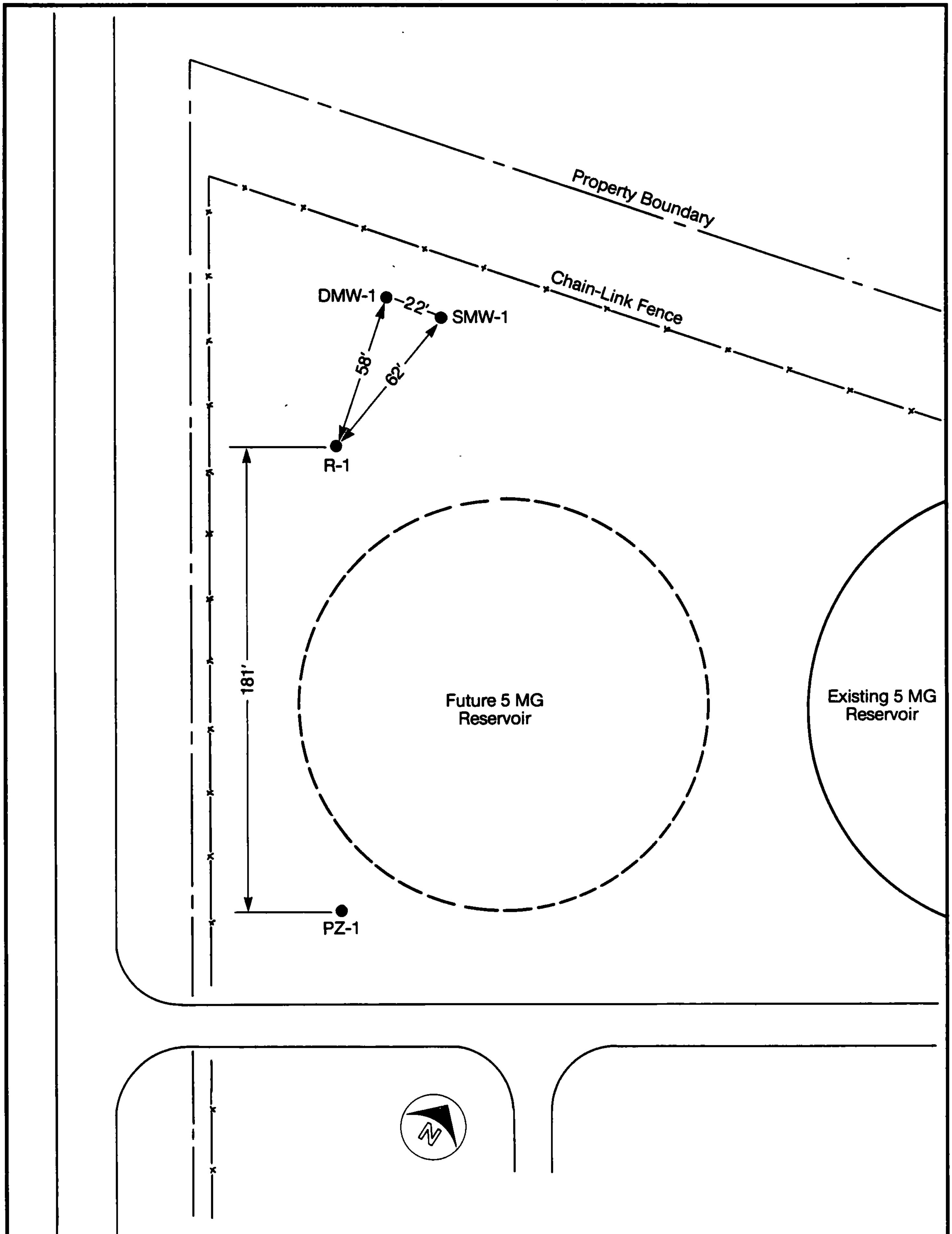

FIGURE 2-1.
Well Locations.

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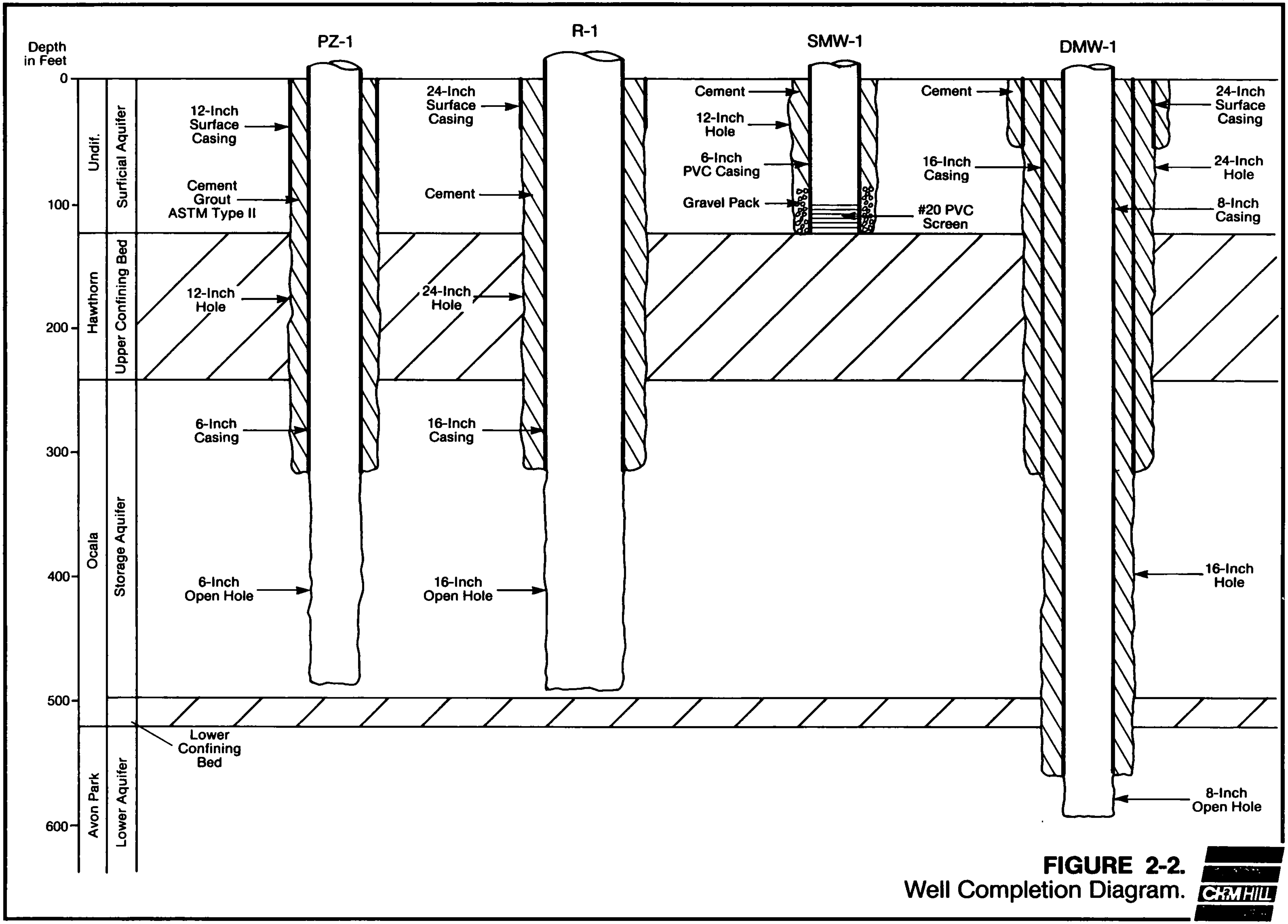

FIGURE 2-2.
Well Completion Diagram.

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the formation water were performed. This data was used to adjust the remaining drilling program to optimize the storage/recovery concept.

DMW-1 now serves as a monitor in the lower aquifer. The well has a total depth of 595 feet, with an 8-inch steel casing set and cemented to 560 feet. An 8-inch nominal open hole extends from 560 to 595 feet. A well completion diagram is shown in Figure 2-3.

PRODUCTION ZONE MONITORING WELL (PZ-1)

Production Zone Monitoring Well-1 was the second well constructed during this program. This well was designed to monitor water level changes in the storage zone. The well is 485 feet deep, with 6-inch casing set and cemented to 315 feet. An open hole extends from 315 feet to 485 feet.

SHALLOW MONITORING WELL (SMW-1)

Shallow Monitoring Well-1 serves as the surficial aquifer monitor. The well was constructed with 100 feet of 6-inch PVC casing and a 20-foot section of No. 20 slotted PVC well screen. The annular space around the screen is gravel-packed with 6-20 U.S. STD sieve size gravel, and the casing is sealed with cement.

RECHARGE WELL (R-1)

The recharge well will be used to inject water into the storage zone. All the information obtained while drilling the previous wells was incorporated into the design of this well. The well is 489 feet deep, with 315 feet of 16-inch casing cemented to the surface. A 16-inch nominal open hole extends from 315 feet to 489 feet.

EXISTING WELLS

A U.S. Geological Survey monitoring well was located 2,300 feet from the recharge well, northwest of the Dyal Plant. The well is 381 feet deep, with 245 feet of 3-inch steel casing. This well was not located until December 4, 1984, and was not yet monitored. It is intended to monitor this well in the further testing of the aquifer storage recovery facility.

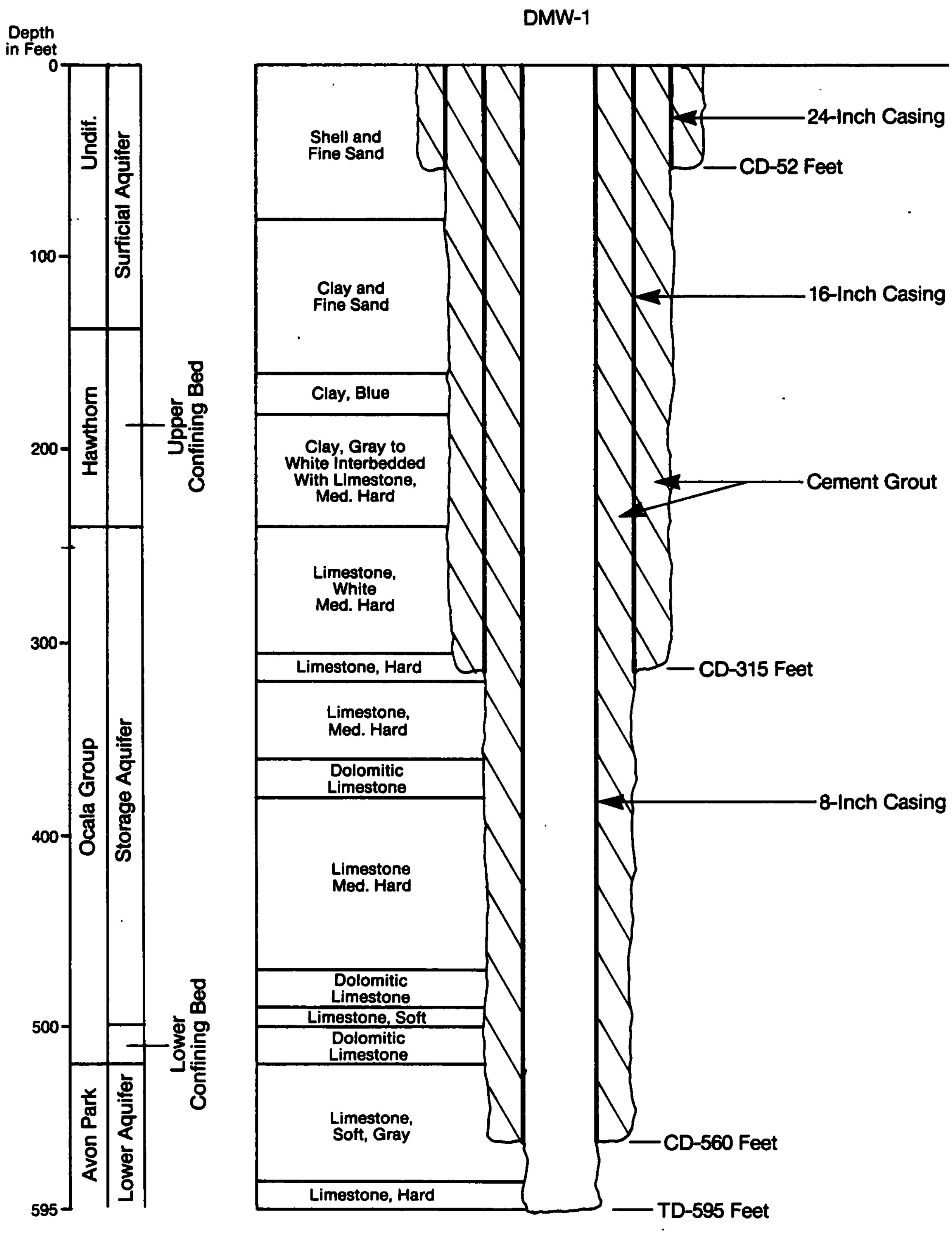

FIGURE 2-3.
DMW-1.

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Section 3
CONSTRUCTION OF THE TESTING FACILITY

GEOPHYSICAL LOGGING

Geophysical logging was used extensively in the aquifer storage testing facility construction. Deep Monitor Well-1 was logged after each interval to yield valuable design information about the formations and the water in them. During the interval tests on this well, flowmeter, caliper, and temperature logs were run to identify producing intervals. Gamma ray and electric logs were used to confirm stratigraphic contacts. Fluid conductance logs provided information about formation water quality.

As the construction of the testing facility continued, a log sequence was run on each well. The summary of geophysical logging is presented in Table 3-1. Full-size copies of the geophysical logs run during this program are included in Appendix B.

INTERVAL TESTS

At three separate stages of construction of DMW-1, drilling was interrupted and an interval pumping test performed. Two types of tests were conducted--variable rate and constant rate. The type of test and location of the interval tested were based on field indicators during drilling. The results of the tests are presented in Table 3-2. A chemical analysis of the water produced from each interval is included in Appendix A.

During the interval tests, logs were run and samples were taken of formation water at specific depths. These depth samples are considered to be as close as possible to the actual in-situ formation water below the point of sampling. The depth samples were analyzed for specific conductance and chloride concentration. The results of the depth samples are presented in Table 3-3.

GENERAL DRILLING METHODS

The wells for the aquifer storage recovery testing facility were constructed in a sequence and method that provided data used in the final design of the prototype storage well. Construction began August 20, 1984, and was completed October 9, 1984. All the wells were drilled using conventional rotary methods with drilling mud until competent limestone was encountered. The casing was set and cemented. The drilling method was then changed to reverse air. This change occurred no deeper than 20 feet below the casing setting.

Table 3-1
SUMMARY OF GEOPHYSICAL LOGGING

	Electric (16,64,SP)	Natural Gamma Ray	Temperature	Fluid Conductance	Fluid Velocity	Caliper
Deep Monitor Well						
1. Pilot Hole to 350 ft (mud-filled hole)	X	X				
2. Exploratory hole to 425 ft (air reverse-drilled) during first capacity test			X[a]	X[a]	X	X
3. Exploratory hole to 525 ft (air reverse-drilled) during second capacity test			X	X		X
4. Exploratory hole to 595 ft (air reverse-drilled) during third capacity test	X	X	X[a]	X[a]	X	X
Recharge Well						
1. After completion						
Static	X	X	X	X		X
During pumping test			X	X	X	
Production Zone Monitor Well						
1. After completion						
Static	X	X	X	X		X
Pumped			X	X	X	

[a]Static and pumped.

Table 3-2
INTERVAL TESTS ON DMW-1

Interval Test #1
(Open Hole, 315 to 425 ft)

Q (gpm)	ΔS (ft)	Q/ΔS (gpm/ft)	Adjusted ΔS (ft)	Adjusted Q/ΔS (gpm/ft)
110	27.5	4.0	27.5	4.0
180	44.5	4.0	44.5	4.0
245	59.3	4.1	59.3	4.1

C = O, B = 1.84 min/ft², T = 1,180 ft²/day

Interval Test #2
(Open Hole, 315 to 525 ft)

Q (gpm)	ΔS (ft)	Q/ΔS (gpm/ft)	Adjusted ΔS (ft)	Adjusted Q/ΔS (gpm/ft)
475	43.5	10.9	40.2	11.8
680	64.4	10.6	57.5	11.8
760	74.5	10.2	65.9	11.5

C = 0.00083 min^2/ft^5, B = 0.639 min/ft², T = 3,340 ft²/day

Interval Test #3
(Open Hole, 315 to 595 ft)

Q (gpm)	ΔS (ft)	Q/ΔS (gpm/ft)	T (ft²/day
1,150	65.0	23.8	6,820

Table 3-3
DEPTH SAMPLE ANALYSIS

Date	Well	Depth (ft)	Sample Depth	Chlorides (mg/L)	Specific Conductance (µmhos/cm)
09/04/84	DMW-1	425	318	258	1,220
			350	144	835
09/06/84		525	320	412	1,640
			450	457	1,850
			500	1,010	3,620
09/11/84		595	440	958	3,410
			540	1,100	3,850
			580	1,450	4,960
10/18/84	R-1	489	340	310	1,270
			415	340	1,350
			475	370	1,380

While drilling with reverse air, drilling was stopped approximately every 20 feet; the air-lifted water was allowed to clear up, and a water sample was taken. The sample was analyzed by the City laboratory at the Dyal plant for chloride concentration and specific conductance. The water quality during drilling is presented in Table 3-4.

CONSTRUCTION OF DEEP MONITOR WELL (DMW-1)

The construction of DMW-1 began by drilling a 10-inch pilot hole to a depth of 101 feet with conventional rotary mud methods. Forty feet of 24-inch surface casing was driven into place to hold back the upper unconsolidated sands and shells. The pilot hole was advanced to 344 feet. Electric and gamma ray logs were run in the mud-filled hole to aid in the selection of a casing setting. The top of the Ocala limestone was identified from the logs at 240 feet. The depth to set casing was picked as 315 feet, due to soft, clay-like lenses above 315 feet. The hole was reamed to 23-inch diameter, 320 feet deep. During the reaming operation it became necessary to add 12 more feet of surface casing and grout it into place. Three hundred and fifteen feet of 16-inch steel casing was cemented into the hole using pressure grouting methods and 350 sacks of Portland cement.

After the 24-hour curing time, the 10-inch pilot hole was continued through the cement plug using reverse-air methods. During drilling, an additional water sample was taken of the air-lifted fluid between the scheduled sampling points. The water level during drilling was also closely monitored. Based on the above parameters, 425 feet was chosen as the depth for the first interval test. A variable rate test was performed, with pumped logs run during the highest pumping rate. The pumping rates were 110, 180, and 245 gpm. Depth samples were taken at 318 and 350 feet.

The 10-inch pilot hole was continued with the same sampling schedule. At 470 feet, a hard, dark-brown dolomitic limestone was encountered. This formation continued to 520 feet. At 525 feet drilling was interrupted and the second interval test was scheduled.

A variable rate interval test was performed using rates of 475, 680, and 760 gpm. Geophysical logs were run both during static conditions and while pumping at the highest rate. Depth samples were taken at 320, 450, and 500 feet.

Drilling continued with the 10-inch pilot hole. The Avon Park formation was identified at a depth of 520 feet. The rock was a soft, porous, gray limestone of poor water quality. A 2-foot-deep cavity was encountered at 585 feet, and a significant increase in water level occurred in

Table 3-4
WATER QUALITY DURING DRILLING

Date	Well	Depth (ft)	Chlorides (mg/L)	Specific Conductance (µmhos/cm)
08/30/84	DMW-1	345	350	1,472
		355	340	1,340
		365	320	1,482
		375	310	1,310
		385	310	1,160
		400	280	1,190
		408	280	1,110
		415	260	1,190
		425	190	955
09/05/84	DMW-1	440	290	1,350
		450	290	1,240
		460	290	1,320
		470	300	1,370
		480	340	1,312
		490	330	1,430
		500	330	1,460
		510	340	1,370
		520	410	1,680
		525	410	1,840
09/07/84	DMW-1	530	460	1,780
		540	505	1,840
		550	530	--
		560	590	2,060
		570	585	2,400
		580	730	2,760
		585	710	2,500
		595	850	3,320
09/24/84	PZ-1	340	330	1,310
		360	330	1,290
		380	330	1,330
		400	310	1,310
		420	320	1,300
		440	320	1,300
		460	330	1,300
		480	350	1,330
09/25/84		485	340	1,380
10/09/84	R-1	330	320	1,440
		340	340	1,420
		365	340	1,380
		385	340	1,390
		407	330	1,360
		425	340	1,370
		440	340	1,390
		460	330	1,380
		470	340	1,370
		489	340	1,390

association with it. Immediately following the cavity, a formation change was encountered. Layered hard dolomite and softer limestone followed to 595 feet. The third interval test was scheduled.

The interval was pumped at a constant rate of 1,550 gpm for approximately 4 hours. The water quality was checked during this test to determine the quality of the water in the Avon Park zone. Depth samples were taken at 440, 540, and 580 feet. The water was found high in chlorides (over 1,000 mg/L), with specific conductance 3,000 to 5,000 μmhos/cm.

The values from the chemical analysis indicated a formation probably undesirable for a storage zone. It was decided to use the upper water-bearing zones for storage and to monitor the Avon Park as the lower zone.

To ensure a complete seal between the lower zone and the storage zone, 8-inch steel casing was set and cemented to 560 feet. The 10-inch pilot hole was reamed out to a 12-inch diameter to a depth of 565 feet. The 8-inch nominal casing was cemented from 560 feet to the surface. The 10-inch pilot hole was cleaned out to 595 feet and the completed monitoring well developed with air until clear water was produced.

CONSTRUCTION OF PRODUCTION ZONE MONITORING WELL (PZ-1)

Production Zone Monitoring Well-1 was constructed by drilling a 12-inch nominal hole to 320 feet. During drilling, fine sands continually washed into the borehole, making it necessary to drive 98 feet of 12-inch steel surface casing to keep the hole open. The 6-inch casing was set and cemented to 315 feet.

After the 24-hour curing time, a 6-inch nominal hole was advanced with rotary methods, using water in place of driller's mud. At a depth of 340 feet the drilling method was changed over to reverse-air methods.

As the hole was advanced, water samples were taken every 20 feet. The drilling was completed at 485 feet. The well was then developed with air until clear water was produced.

CONSTRUCTION OF SHALLOW MONITOR WELL-1 (SMW-1)

Shallow Monitor Well-1 was constructed by drilling a 12-inch nominal hole to 120 feet. Surface casing was found to be unnecessary. One hundred feet of 6-inch PVC casing, and 20 feet of No. 20 slotted screen, were assembled with glue and couplings and lowered into the borehole. Commercially-graded gravel (6-20 grade) was tremied around the screen. The gravel pack was placed from the bottom of the borehole to 15 feet above the top of the screen.

A portland cement/bentonite slurry was prepared onsite by mixing 11 sacks portland cement, one sack bentonite, and approximately 65 gallons of water. The slurry was tremied down the annulus to seal the space from the top of the gravel to the ground surface.

After the 24-hour curing time, the finished well was developed with air until the water was clear and sand-free.

CONSTRUCTION OF RECHARGE WELL (R-1)

The recharge well was constructed by drilling a 23-inch nominal hole to 320 feet using conventional rotary mud methods. Forty feet of 24-inch surface casing were driven during the initial drilling. Sixteen-inch casing was set and cemented to a depth of 315 feet.

Reverse air drilling was used to drill a 16-inch nominal hole to a total depth of 489 feet. The well was developed with air until the water was clear. Geophysical logging later determined the hole had filled in to 480 feet total depth.

Section 4
TESTING THE FACILITY

INTRODUCTION

After completion of the four wells in the testing program, the recharge well (R-1) was pump tested. A variable-rate test was performed first, and after recovery, a constant-rate test. These tests provided specific data necessary to calculate aquifer characteristics and water quality data needed to evaluate the aquifer storage recovery potential.

The pumped well (R-1) was equipped with a temporary vertical turbine pump driven by a diesel engine connected to a right-angle drive. A flowmeter, as well as a circular orifice weir, were installed in the discharge line to measure flowrates.

Each monitoring well was equipped with a Stevens recorder to record water levels before, during, and after the pumping tests. The recorders were operating for approximately 10 days before the tests to obtain information on the normal variation of the water levels. The background data is presented as Figure 4-1.

The pumped well (R-1) was equipped with a pressure transducer coupled to a hydrologic monitor for each pumping test. This arrangement for data collection allowed the tests to be conducted by one engineer and a pump operator.

STEP TEST

A variable rate or step-drawdown test was conducted as the first aquifer pumping test after completion of the recharge well. The purpose of testing the well with a step test was to obtain information on how the well would behave under a range of pumping rates. The well was pumped at "steps" of 430, 660, and 930 gpm for one hour each step.

PUMPING TEST

After allowing full recovery of Well R-1 from the step test, a constant rate pumping test was performed. This test was designed to provide data for calculating the aquifer parameters needed to completely describe the aquifer system. The discharge stream was monitored for specific conductance and chloride content throughout the test to check for possible intrusion of the poor quality lower aquifer water into the pumped zone.

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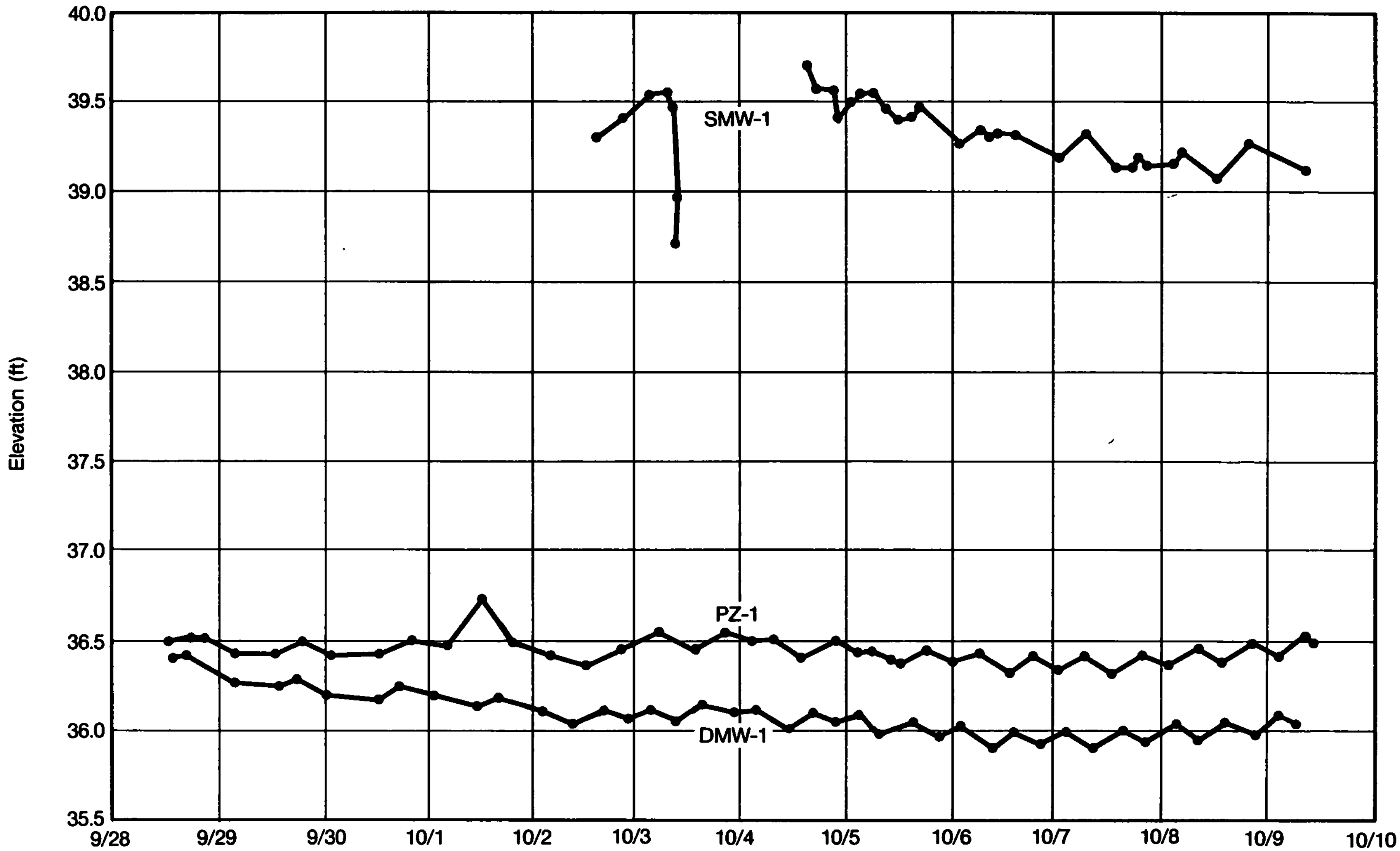

FIGURE 4-1.
Background Water Levels.

Well R-1 was pumped for 10 hours at a rate of 1040 gpm and then allowed to recover. The water level data is presented as time-drawdown curves in Figure 4-2 and Figure 4-3. The water quality data is presented in Table 4-1, and the complete chemical analyses in Appendix A.

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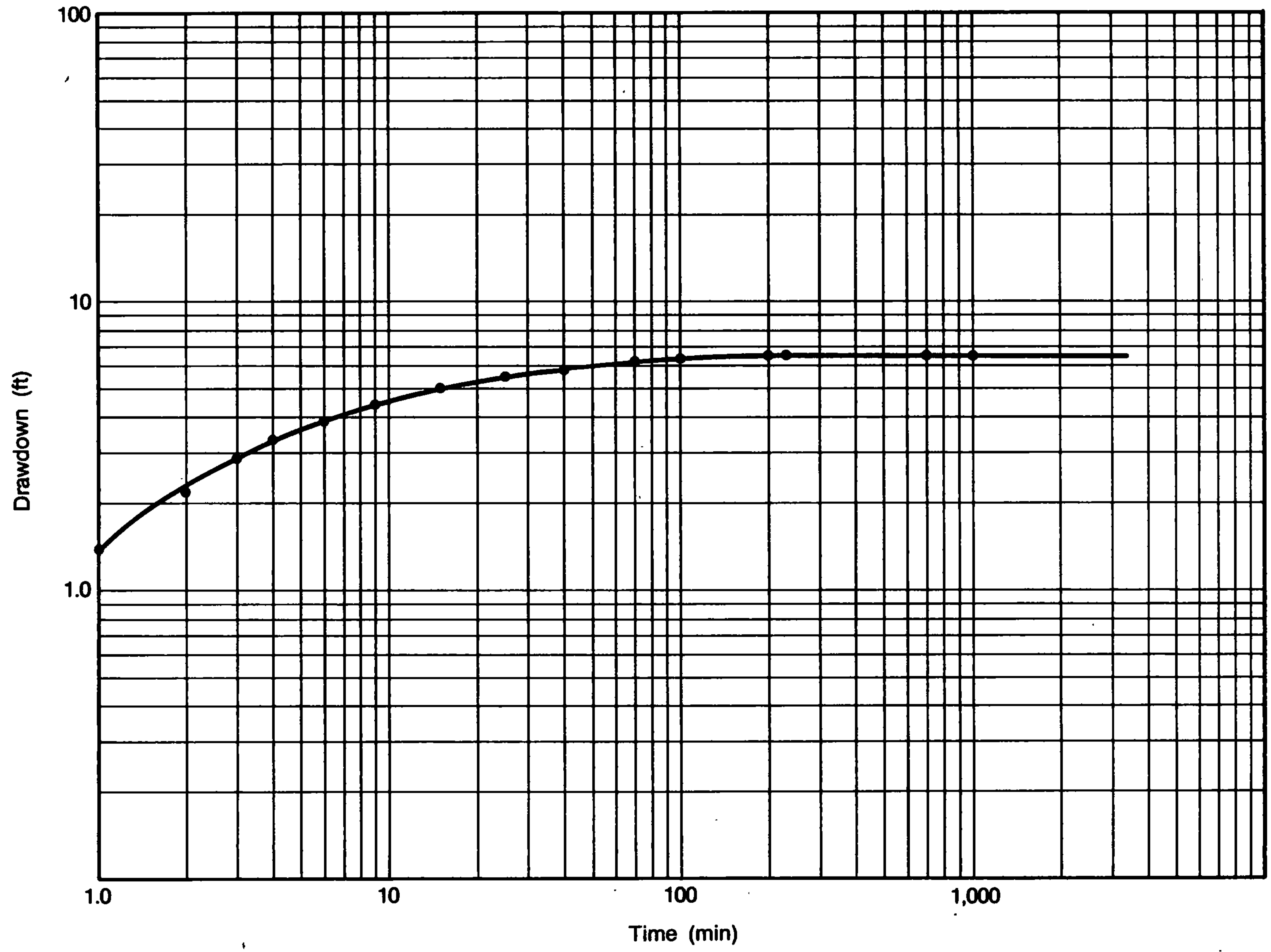

FIGURE 4-2.
PZ-1 Drawdown During Pumping Test.

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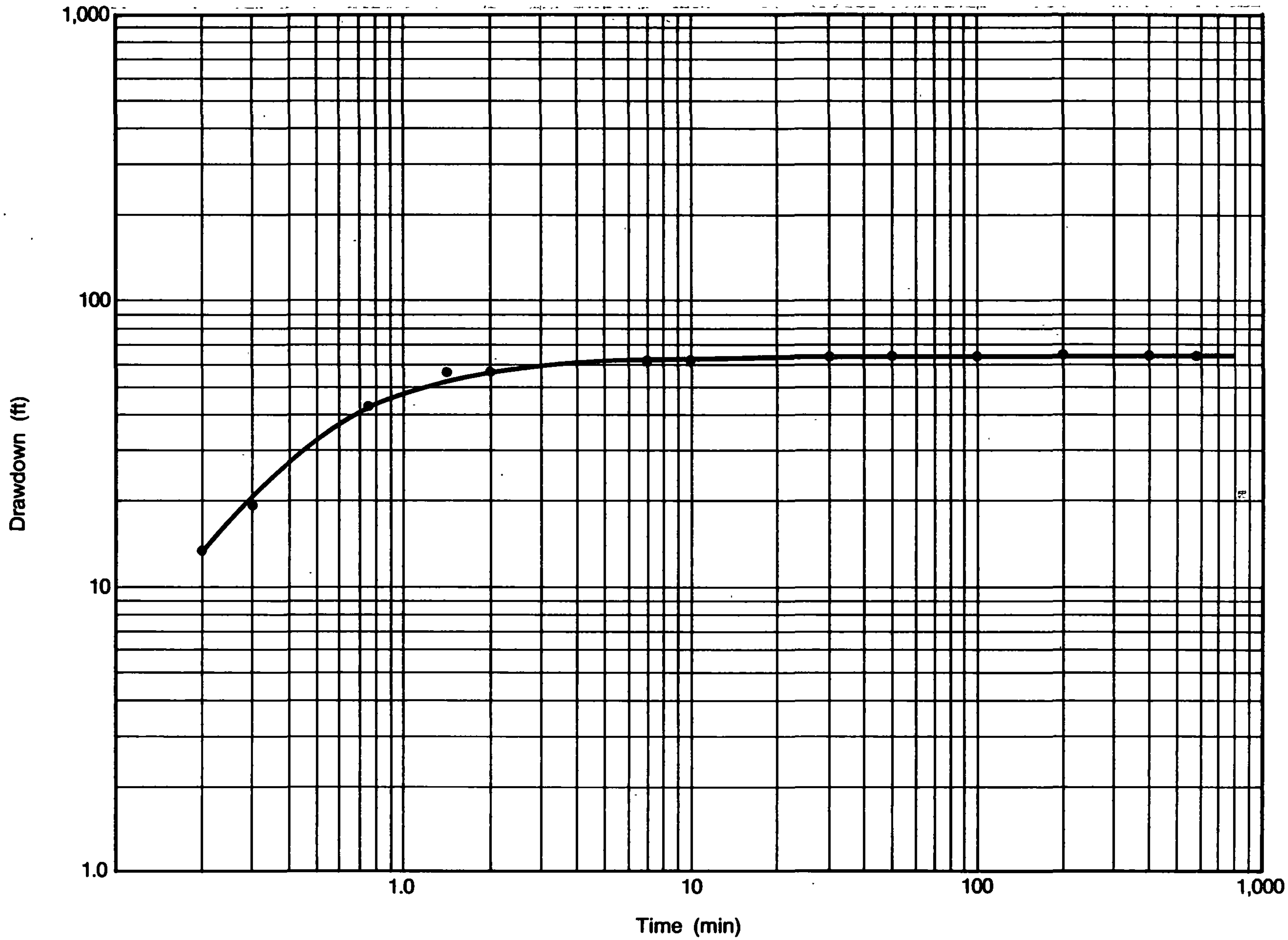

FIGURE 4-3.
R-1 Drawdown During Pumping Test.

Table 4-1
WATER QUALITY DURING (R-1) PUMP TEST

Sample Type	Time	Specific Conductance (µΩ/cm)	Chloride (mg/L)
GRAB	08:02	1370	340
GRAB	08:55	1380	350
GRAB	10:13	1360	350
GRAB	11:01	1370	350
GRAB	12:22	1580	350
GRAB	13:06	1610	340
GRAB	14:01	1630	340
GRAB	15:16	1560	340
GRAB	15:47	1360	330
GRAB	17:02	1350	330
DEPTH (340 ft)	11:10	1260	320
DEPTH (415 ft)	10:56	1360	350
DEPTH (475 ft)	10:40	1330	370
DEPTH (340 ft)	17:40	1270	310
DEPTH (415 ft)	17:33	1350	370
DEPTH (475 ft)	17:18	1380	370

Section 5
ANALYSIS OF TESTING

AQUIFER PARAMETER ANALYSIS

The first test performed, the step test, was run specifically to determine the well losses. The head loss caused by water entering the well can be included in a general drawdown equation as:

$$\Delta S = BQ + CQ^2$$

ΔS = Drawdown in pumping well

Q = Pumping rate

BQ = Formation loss

CQ^2 = Well loss

The head loss in the well is assumed to be proportional to the flowrate squared (Q^2). The coefficients (B) and (C) are determined from the test data.

The measured specific capacity values were adjusted for the well losses and an estimate of the aquifer transmissivity was made. The estimate was based on the well known Thiem equation. The step test results are presented in Table 5-1.

The constant rate pumping test was designed not only to determine the aquifer parameters, but to test the confinement of the poor water quality lower aquifer. The highest pumping rate compatible with the test equipment and well characteristics was chosen. The pumping rate was measured during the test at 1,040 gpm.

The aquifer system at Cocoa is such that water is not only removed from the pumped aquifer, but also from aquifers above and below the pumped zone. To describe this system analytically, three aquifer parameters are needed. These are (1) transmissivity of the pumped zone (T), (2) storage coefficient of the pumped zone (S), and (3) the leakance of the confining beds.

Three methods applicable to the Cocoa site were used to calculate the above parameters. The results of these methods are presented in Table 5-2.

Of the three methods, the Deglee analysis is considered the least accurate for this situation. More observation wells would be necessary to use this method in its full capacity.

Table 5-1
STEP TEST RESULTS (R-1)

Q (gpm)	ΔS (ft)	Q/ΔS (gpm/ft)	Adjusted ΔS (ft)	Adjusted Q/ΔS (gpm/ft)
430	22.3	19.3	18.9	22.3
660	37.6	17.6	29.6	22.3
930	55.8	16.7	39.9	23.3

$C = 0.00103 \ min^2/ft^5$, $B = 0.327 \ min/ft^2$, $T = 6{,}550 \ ft^2/day$

Table 5-2
PUMPING TEST RESULTS (R-1)

	Transmissivity (ft^2/day)	Storage Coefficient	Leakance (day^{-1})
Walton	8,020	2.3×10^{-4}	1.3×10^{-2}
Deglee	4,800	--	3.0×10^{-2}
Hantush - Jacob	9,360	2.4×10^{-4}	9.5×10^{-3}
Step-Test Approximation	6,550	--	--

Based on field observation of the well performance, the Walton analysis is considered the most representative in describing the aquifer parameters.

LEAKANCE

From the aquifer parameter analysis, the value of leakance obtained represents the ability of water to leak into the aquifer through the confining beds. For a complete understanding of the aquifer system behavior, the leakance value was separated into two values, one representing the upper confining bed, the other representing the lower confining bed.

The upper confining unit is the Hawthorn formation. This formation is approximately 120 feet thick in the test area and is made up of sands and clays. Shallow Monitor Well-1 (SMW-1) was used to estimate the leakance of the upper confining unit.

The specific capacity of SMW-1 was estimated after development as 0.07 gpm/ft. This corresponds to a transmissivity in the range of 24 ft^2/day. Leakance of a 120-foot bed with the above (T) is 8.6×10^{-3} day^{-1}. This value of leakance is considered representative of the Hawthorn, based on the drilling of SMW-1. An examination of a flow system with two leaking beds would explain a simple summation of separate leakages, equal to the total leakage. The leakage of the lower bed would be then 4.3×10^{-3} day^{-1}.

PRODUCTION ZONES

During the pumping test on R-1, logs were run to determine the producing zones in the well. It was determined that the main producing zone in R-1 is from a depth of 315 feet to a depth of 340 feet. It is estimated that 60 percent of the water produced from the well comes from this interval.

A secondary producing zone was identified from a depth of 460 feet to a depth of 480 feet. The production from this area is higher than the remaining portions of the well bore and is considered a minor producing zone.

SUMMARY OF AQUIFER SYSTEM

The results of the pumping tests indicate a fairly transmissive aquifer with low storage and moderate leakance. The leakance is of concern due to the poor water quality in the lower aquifer.

The previous analysis, however, indicates the larger percentage of leakance is from the upper confining unit. Leakance from the lower confining unit is believed to be even less than the calculated value would predict, because (1) the major production zone is near the upper confining bed, and (2) the characteristics of the upper confining bed enable it to release water from storage.

Upon the start of pumping, the water levels in both the upper and lower monitored aquifers are affected. This behavior during the step test is shown in Figure 5-1 and during the pumping test in Figure 5-2. The lower aquifer water level, monitored by DMW-1, drops, whereas the upper water level, monitored by SMW-1, increases. This effect begins immediately with the onset of pumping. The observed behavior does not appear to be due to water movement across the confining beds. The behavior is caused by elastic compression and expansion of the aquifer matrix due to pumping stresses.

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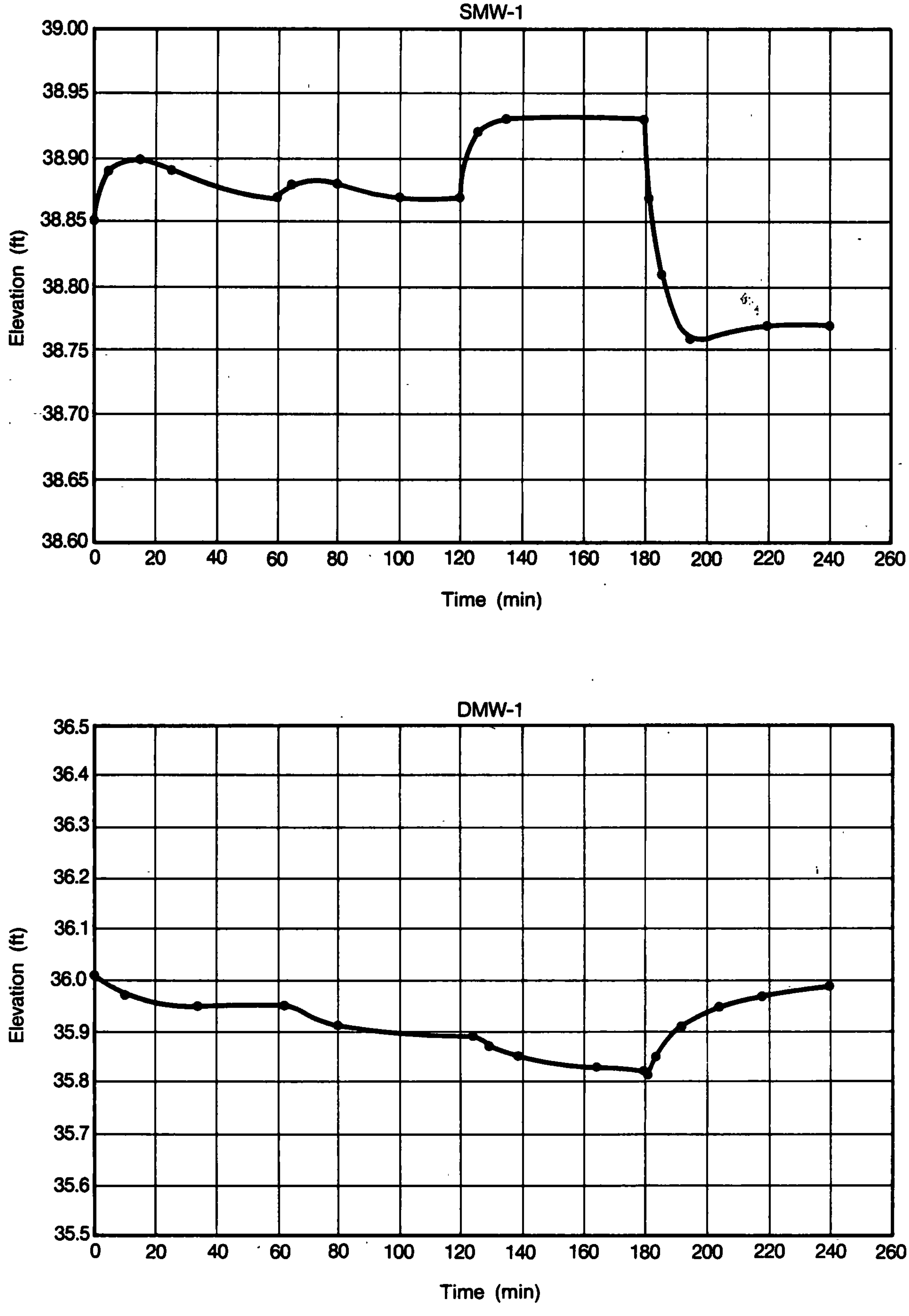

FIGURE 5-1.
Upper and Lower Aquifer Response During the Step Test.

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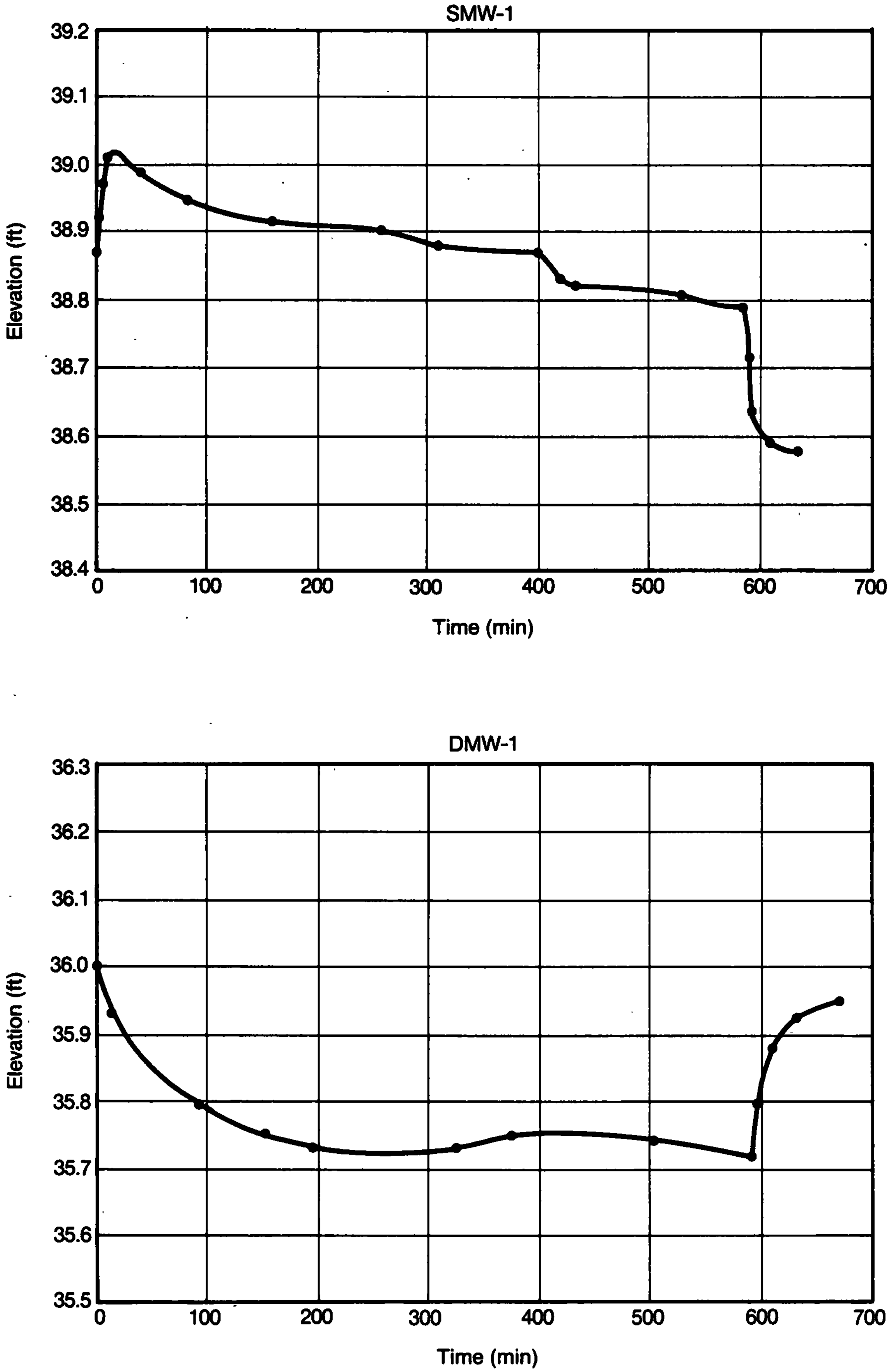

FIGURE 5-2.
Upper and Lower Aquifer Response During the Pumping Test.

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Section 6
STORAGE RECOVERY TEST PLANS

From the general tests performed on the aquifer storage recovery facility, all indications appear positive for its intended use. It is expected to be able to recharge at an approximate rate of 0.5 mgd using only the head available at the 54-inch water main. Recovery rates are anticipated in the range of 1.0 mgd to 1.5 mgd. We anticipate recovery of all stored water.

The installation will soon be ready for conducting aquifer storage recovery cycles. A 2-day pumping test has been conducted to confirm satisfactory operation of the well head facilities, to obtain representative background water quality samples, and to begin obtaining bacteriological clearance data.

The storage recovery cycles will be performed as outlined in Table 6-1. It is anticipated to recover water to the treatment plant beginning with Cycle 2. This will avoid unnecessary loss of water that is available for treatment and consumption.

The testing schedule presented in Table 6-1 differs from the schedule proposed in Table 4 of the December 1983 UIC permit application. The changes reflect recent experience with the concept at other Florida sites, as well as the results of drilling and testing at the Cocoa site.

Table 6-1
AQUIFER STORAGE RECOVERY TESTING SCHEDULE

	Approximate Volume (MG)		Approximate Duration (days)			
Cycle	Recharge	Recovery	Recharge	Storage	Recovery	Cumulative
1	1.5	6.0	3	0	5	8
2	5.0	5.0	10	1	4	23
3	5.0	5.0	10	1	4	38
4	5.0	5.0	10	1	4	53
5	5.0	5.0	10	14	4	81
6	20.0	20.0	40	120	16	257

Notes:

1. Assumed recharge rate = 0.5 mgd; recovery rate = 1.0 to 1.5 mgd.

2. Cycle 1 is intended to recover injected water until background quality is reached.

3. Since this program will be initiated during the dry season, exact volumes and storage periods may be adjusted to meet system peak demands.

Appendix A

CHEMICAL ANALYSIS

CH2M HILL

ENVIRONMENTAL LABORATORIES
7201 N.W. Eleventh Place
P.O. Drawer 1647
Gainesville, Florida 32602
904/377-2442

Sample No. 23231 - 23233

Lab ID No. 82112

REPORT OF ANALYSIS

Client City of Cocoa

Project No. GN14514.B1

Attention Jeff Bair

Received 9/7/84

Address

Reported 9/24/84

Description of Sample:

DMW - 1
Collected 9/6/84

Sample #	Description	Sulfide (mg/L)
23231	Interval 2, Cycle 1	2.0
23232	Pump Test #2, Cycle 2, 660 gpm	2.5
23233	Pump Test #2, Cycle 3, 750 gpm	2.5

Respectfully submitted,

K. D. Starcher Chemist

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FL 1008

CH2M HILL

ENVIRONMENTAL LABORATORIES
7201 N.W. Eleventh Place
P.O. Drawer 1647
Gainesville, Florida 32602
904/377-2442

REPORT OF ANALYSIS

Sample No. 23358 - 23361

Lab ID No. 82112

Client City of Cocoa

Project No. GN14514.B1

Attention Jeff Bair

Received 9/19/84

Address

Reported 10/24/84

Description of Sample:

Deep Monitor Well #1
Interval Test #1
Collected by Bral / Bair

Parameter	#23358 Step 1	#23359 Step 2	#23360 Step 3	#23361 Final
Conductivity (µmhos/cm)	1320	1310	1320	1320
Chloride (mg/L)	285	320	250	260
Iron (mg/L)	---	---	---	0.70
Color (APHA units)	---	---	---	10
Turbidity (NTU)	---	---	---	0.7
Fluoride (mg/L)	---	---	---	1.23
Sulfate (mg/L)	---	---	---	45
Total Sulfide (mg/L)	---	---	---	---
Dissolved Solids, @ 180°C (mg/L)	---	---	---	740
Dissolved Solids, Σ major ions (mg/L)	---	---	---	634
Calcium (mg/L as $CaCO_3$)	---	---	---	182
Magnesium (mg/L)	---	---	---	119
Total Hardness (mg/L as $CaCO_3$)	---	---	---	301
Carbonate Hardness (mg/L as $CaCO_3$)	---	---	---	166
Alkalinity (mg/L as $CaCO_3$)	---	---	---	166
pH	---	---	---	6.95
pH_s @ 25°C.	---	---	---	7.39

Respectfully submitted,

K. D. Starcher
K. D. Starcher Chemist

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FL 1008

CH2M HILL

ENVIRONMENTAL LABORATORIES
7201 N.W. Eleventh Place
P.O. Drawer 1647
Gainesville, Florida 32602
904/377-2442

Sample No. 23362 - 23364

Lab ID No. 82112

REPORT OF ANALYSIS

Client City of Cocoa

Project No. GN14514.B1

Attention Jeff Bair

Received 9/19/84

Address

Reported 10/24/84

Description of Sample:

Deep Monitor Well #1
Interval Test #2
Collected by Bral / Bair

Parameter	#23362 Step 1	#23363 Step 2	#23364 Step 3 Final
Conductivity (μmhos/cm)	1690	1690	1700
Chloride (mg/L)	380	390	400
Iron (mg/L)	---	---	0.10
Color (APHA units)	---	---	5
Turbidity (NTU)	---	---	1.2
Fluoride (mg/L)	---	---	1.17
Sulfate (mg/L)	---	---	62
Total Sulfide (mg/L)	---	---	---
Dissolved Solids, @ 180°C, (mg/L)	---	---	940
Dissolved Solids, Σ major ions (mg/L)	---	---	872
Caldium (mg/L as $CaCO_3$)	---	---	202
Magnesium (mg/L as $CaCO_3$)	---	---	142
Total Hardness (mg/L as $CaCO_3$)	---	---	344
Carbonate Hardness (mg/L as $CaCO_3$)	---	---	155
Alkalinity (mg/L as $CaCO_3$)	---	---	155
pH	---	---	7.10
pH_s @ 25°C.	---	---	7.39

Respectfully submitted,

K D Starcher

K. D. Starcher Chemist

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CH2M HILL

ENVIRONMENTAL LABORATORIES
7201 N.W. Eleventh Place
P.O. Drawer 1647
Gainesville, Florida 32602
904/377-2442

Sample No. 23365 - 23368
Lab ID No. 82112
Revised 1/30/85

REPORT OF ANALYSIS

Client City of Cocoa
Project No. GN14514.B1
Attention Jeff Bair, Kevin Bral
Received 9/19/84
Address
Reported 10/24/84

Description of Sample:
Deep Monitor Well #1
Interval Test #3
Collected by Bral/Bair

Parameter	#23365 Sample 1	#23366 Sample 2	#23367 Sample 3	#23368 Final
Conductivity (µmhos/cm)	3240	3230	3240	3220
Chloride (mg/L)	850	860	860	860
Iron (mg/L)	---	---	---	<0.03
Color (APHA units)	---	---	---	3
Turbidity (NTU)	---	---	---	0.5
Fluoride (mg/L)	---	---	---	0.95
Sulfate (mg/L)	---	---	---	147
Total Sulfide (mg/L)	---	---	---	2.0/2.0
Dissolved Solids (mg/L @ 180°C.)	---	---	---	1900
Dissolved Solids (Σ major ions, mg/L)	---	---	---	1720
Calcium (mg/L as $CaCO_3$)	---	---	---	278
Magnesium (mg/L as $CaCO_3$)	---	---	---	229
Total Hardness (mg/L as $CaCO_3$)	---	---	---	507
Carbonate Hardness (mg/L as $CaCO_3$)	---	---	---	138
Alkalinity (mg/L as $CaCO_3$)	---	---	---	138
pH	---	---	---	7.05
pH_s @ 25°C.	---	---	---	7.32

Respectfully submitted,

K. D. Starcher
K. D. Starcher Chemist

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FL 1008

CH2M HILL

ENVIRONMENTAL LABORATORIES
7201 N.W. Eleventh Place
P.O. Drawer 1647
Gainesville, Florida 32602
904/377-2442

Sample No. 24148

Lab ID #82112

WATER ANALYSIS REPORT

Owner City of Cocoa

Project No. GN14514.B1

Attention Kevin Bral

Received 10/17/84

Address

Reported 11/16/84

SAMPLE LOCATION: R-1
PUMPING TEST (EARLY)

SOURCE OF SUPPLY: ☐ Surface, ☒ Ground

TYPE OF SAMPLE: ☐ Composite, ☒ Grab

SAMPLE COLLECTED BY:

DATE: 10 / 16 / 84 TIME 8:10 ☐ AM ☐ PM

Substance		milligrams per liter MCL	milligrams per liter present	Substance		milligrams per liter as substance	milligrams per liter as $CaCO_3$
Arsenic	As	0.05		Alkalinity, phenolphthalein			0.0
Barium	Ba	1		Alkalinity, total			154
Cadmium	Cd	0.01		Carbon dioxide, free	CO_2	12	28
Chloride	Cl^-	250	335	Bicarbonates	HCO_3^-	187	154
Chromium	Cr	0.05		Carbonates	$CO_3^=$	0.22	0.36
Color, APHA color units		15	8	Hydroxides	OH^-	<0.01	0.01
Copper	Cu	1		Calcium	Ca	84	210
Fluoride	F^-	*	1.17	Magnesium	Mg	26	107
Foaming agents	MBAS	0.5		Total hardness			317
Iron	Fe	0.3	0.10	Carbonate hardness			154
Lead	Pb	0.05		Noncarbonate hardness			163
Manganese	Mn	0.05		Conductivity	1440	µmhos/cm	@ 25° C
Mercury	Hg	0.002		Oxygen, dissolved (field)			mg/L O_2
Nitrate (as N)	NO_3^-	10		Temperature (field)			° C
Odor, threshold odor number		3		pH (field) [6.5-8.5]			
Selenium	Se	0.01		pH (laboratory) 7.40	pH_s @	25 °C	7.39
Silver	Ag	0.05		Stability index (2 pH_s-pH)	7.38		
Sodium	Na	160	169	Saturation index (pH-pH_s)	0.01		
Sulfate	$SO_4^=$	250	55	Aggressive index (pH + log AH)	11.91		
Total dissolved solids @ 180°C		500	974	Sulfide (mg/L)		0.13	
Turbidity, NTU		1	9.80				
Zinc	Zn	5					

THE INFORMATION SHOWN ON THIS SHEET IS TEST DATA ONLY AND NO INTERPRETATION OF THE DATA IS INTENDED OR IMPLIED

Except color, odor, pH and turbidity
MCL Maximum contaminant level
* MCL 1.4-2.4—depends upon avg. daily max. air temp.
< means less than detection limits
N.O.O. means no odor observed

Respectfully submitted,

K D Starcher

K. D. Starcher Chemist

CH2M HILL

ENVIRONMENTAL LABORATORIES
7201 N.W. Eleventh Place
P.O. Drawer 1647
Gainesville, Florida 32602
904/377-2442

Sample No. 24149

Lab ID #82112

WATER ANALYSIS REPORT

Owner City of Cocoa

Project No. GN14514.B1

Attention Kevin Bral

Received 10/17/84

Address

Reported 11/16/84

SAMPLE LOCATION: R-1
PUMPING TEST (LATE)

SOURCE OF SUPPLY: ☐ Surface, ☒ Ground

TYPE OF SAMPLE: ☐ Composite, ☒ Grab

SAMPLE COLLECTED BY:

DATE: 10 / 16 / 84 TIME 17:22 ☐ AM ☐ PM

Substance		MCL (milligrams per liter)	present (milligrams per liter)
Arsenic	As	0.05	
Barium	Ba	1	
Cadmium	Cd	0.01	
Chloride	Cl^-	250	348
Chromium	Cr	0.05	
Color, APHA color units		15	6
Copper	Cu	1	
Fluoride	F^-	*	1.17
Foaming agents	MBAS	0.5	
Iron	Fe	0.3	<0.03
Lead	Pb	0.05	
Manganese	Mn	0.05	
Mercury	Hg	0.002	
Nitrate (as N)	NO_3^-	10	
Odor, threshold odor number		3	
Selenium	Se	0.01	
Silver	Ag	0.05	
Sodium	Na	160	174
Sulfate	$SO_4^=$	250	47
Total dissolved solids @ 180°C		500	997
Turbidity, NTU		1	1.4
Zinc	Zn	5	

Substance		as substance (milligrams per liter)	as $CaCO_3$ (milligrams per liter)
Alkalinity, phenolphthalein			0.0
Alkalinity, total			150
Carbon dioxide, free	CO_2	6.0	14
Bicarbonates	HCO_3^-	182	149
Carbonates	$CO_3^=$	0.42	0.70
Hydroxides	OH^-	0.01	0.03
Calcium	Ca	80.0	200
Magnesium	Mg	27.0	111
Total hardness			311
Carbonate hardness			150
Noncarbonate hardness			161
Conductivity		1440 µmhos/cm @ 25° C	
Oxygen, dissolved (field)			mg/L O_2
Temperature (field)			° C
pH (field) [6.5-8.5]			
pH (laboratory)	7.70	pH_s @ 25 °C	7.42
Stability index ($2\,pH_s$-pH)		7.15	
Saturation index (pH-pH_s)		0.28	
Aggressive index (pH + log AH)		12.18	
Sulfide (mg/L)		0.11	

THE INFORMATION SHOWN ON THIS SHEET IS TEST DATA ONLY AND NO INTERPRETATION OF THE DATA IS INTENDED OR IMPLIED

.. Except color, odor, pH and turbidity
MCL Maximum contaminant level
* MCL 1.4-2.4—depends upon avg. daily max. air temp.
< means less than detection limits
N.O.O. means no odor observed

Respectfully submitted,

K D Starcher

K. D. Starcher, Chemist