EAST GOLDEN GATE WELL FIELD
PUMPING TEST ANALYSIS
FOR THE
CITY OF NAPLES, FLORIDA

In Response to

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

CONSUMPTIVE USE PERMIT NO. 11-00018-W

Prepared by

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Project No. NA30506.90

CITY OF NAPLES EAST GOLDEN GATE WELL FIELD PUMPING TEST ANALYSIS

A 72-hour aquifer pumping test was performed at the Naples East Golden Gate Well Field during April, 1980. This pumping test was performed to comply with a special condition contained in the South Florida Water Management District Consumptive Use Permit No. 11-00018-W requiring that the recharge sources to the production zone of the well field be determined. Figure 1 shows the location of the East Golden Gate Well Field and the pumping test site.

Between November, 1979 and February, 1980, a network of shallow water table (25-ft) and deep production zone (80-ft) monitor wells was installed in an array around Production Well No. 4 in the East Golden Gate Well Field. Figure 2 shows the monitor well layout. The shallow monitor wells were constructed with 4-inch steel casing to a depth of 20 feet below land surface, drilled to 25 feet, and finished with a 5-foot section of 2-inch PVC screen and a 5-foot section of riser pipe. The deep monitor wells were constructed with 4-inch-diameter steel casing to 40 feet with 40 feet of open hole below the casing. Figure 3 shows the well construction details for the shallow and deep monitor wells.

The deep monitor wells were constructed in two configurations, parallel and perpendicular to the Fahka Union canal. The purpose of these two configurations was to evaluate quantitatively the effect of any induced infiltration from the canal upon the producing aquifer and to accurately determine the aquifer parameters through the analysis of the pumping test distance-drawdown relationships. The shallow monitor wells were located in a line from the canal to the production well so that the induced hydraulic gradient in the shallow zone, due to pumping in the deep zone, could be identified.

During the pumping test, water levels were measured in nine wells and at the canal staff gauge. Measurements were also obtained from a barometer and rain gauge. However, during the pumping test no recordable precipitation occurred, and barometric fluctuations were negligible. Prior to the start of the test, two Stevens Type F water level recorders were installed on Monitor Wells S-2 and D-5 to develop pre-test water level trends. The recorder charts were started on March 6, 1980 and were terminated on March 29, 1980, two days prior to the start of the pumping test, due to vandalism. In general, these charts recorded a dry-season decline in water levels at a rate of approximately 0.01 foot per day.

Figure 4 is the distance-drawdown plot for the deep wells after 72 hours of pumping at a constant rate of 855 gpm. A

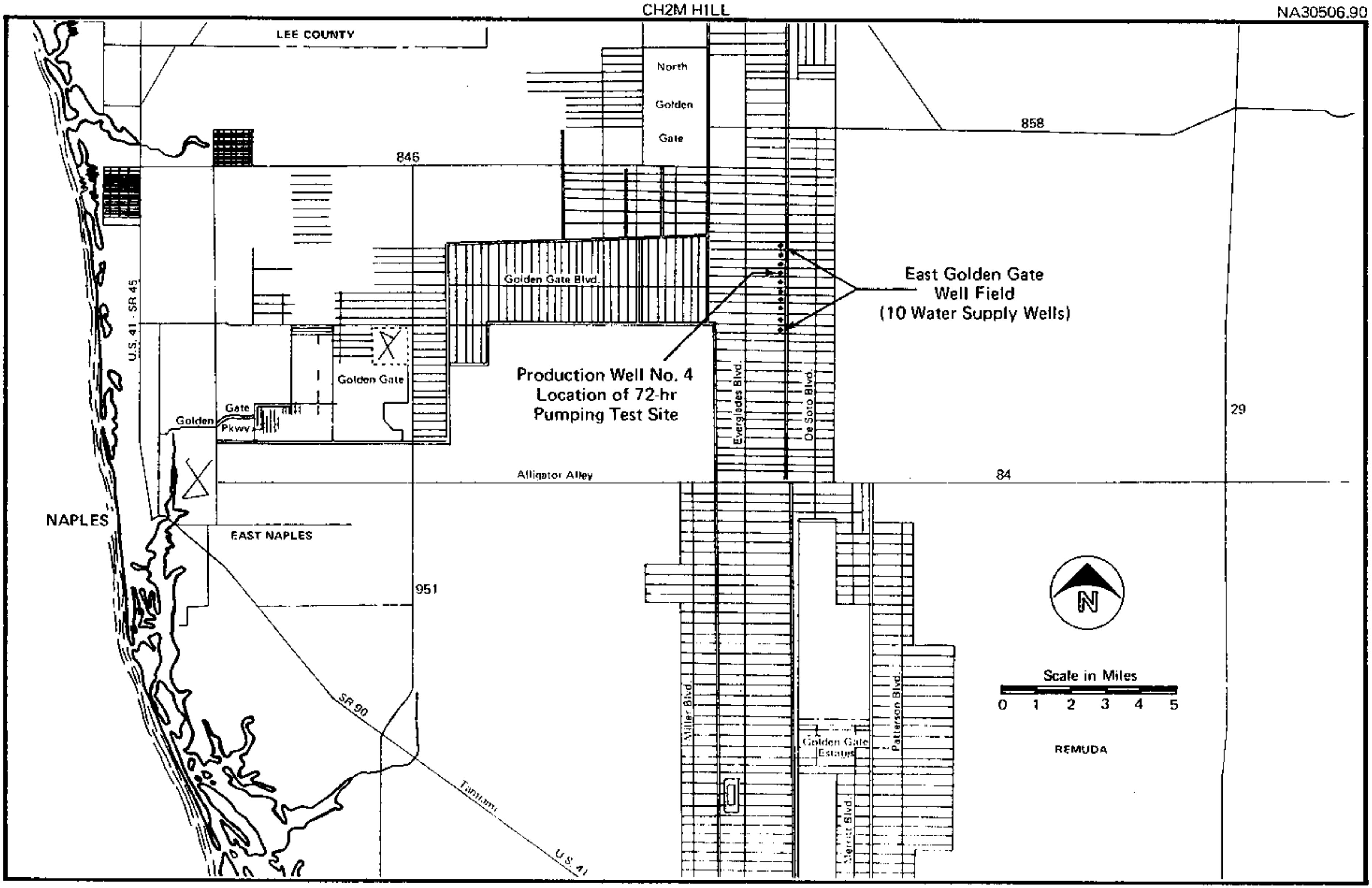


FIGURE 1. Location of East Golden Gate Well Field and pumping test site, Collier County.

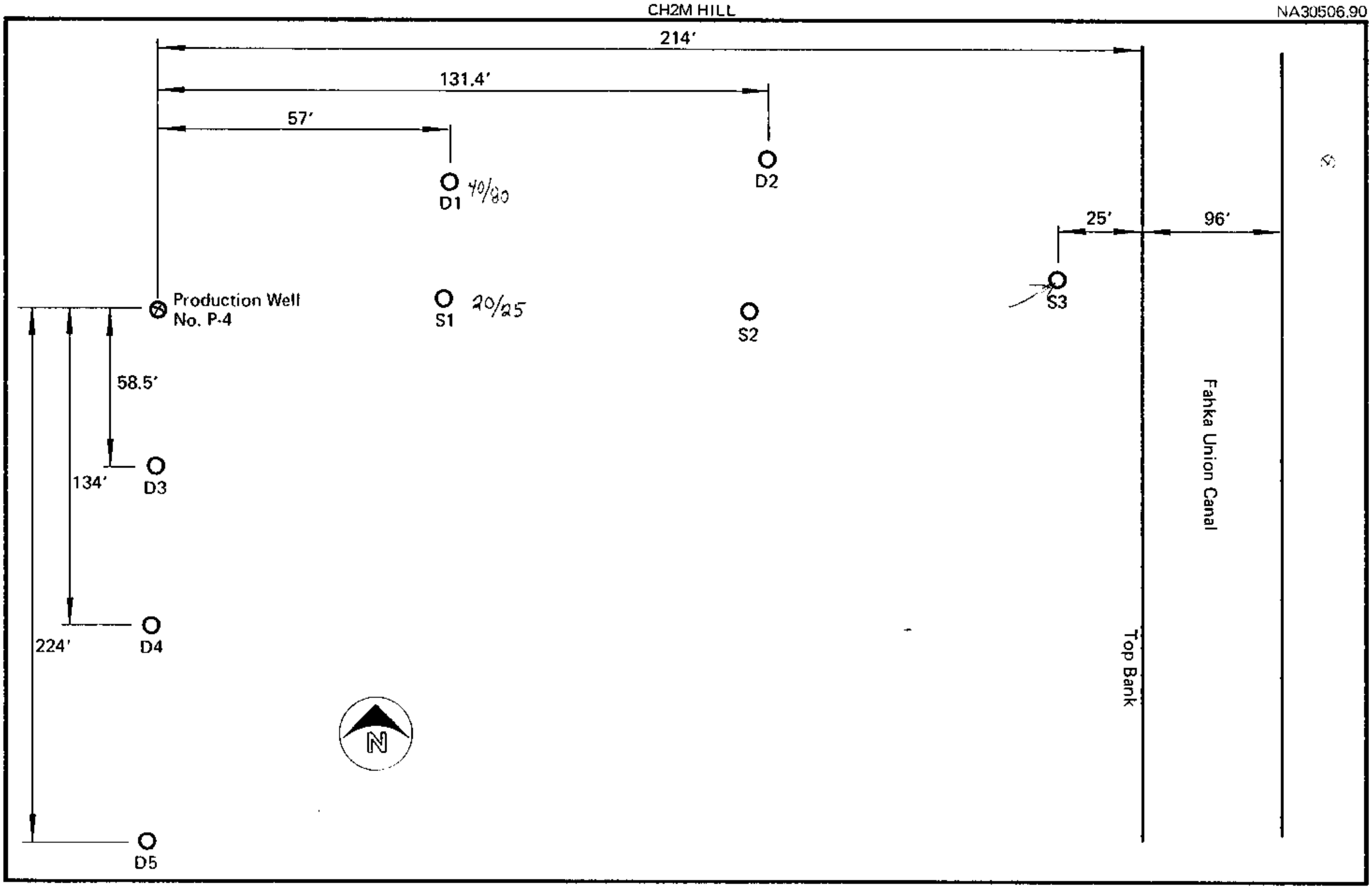


FIGURE 2. Naples East Golden Gate Well Field pumping test monitor well layout.

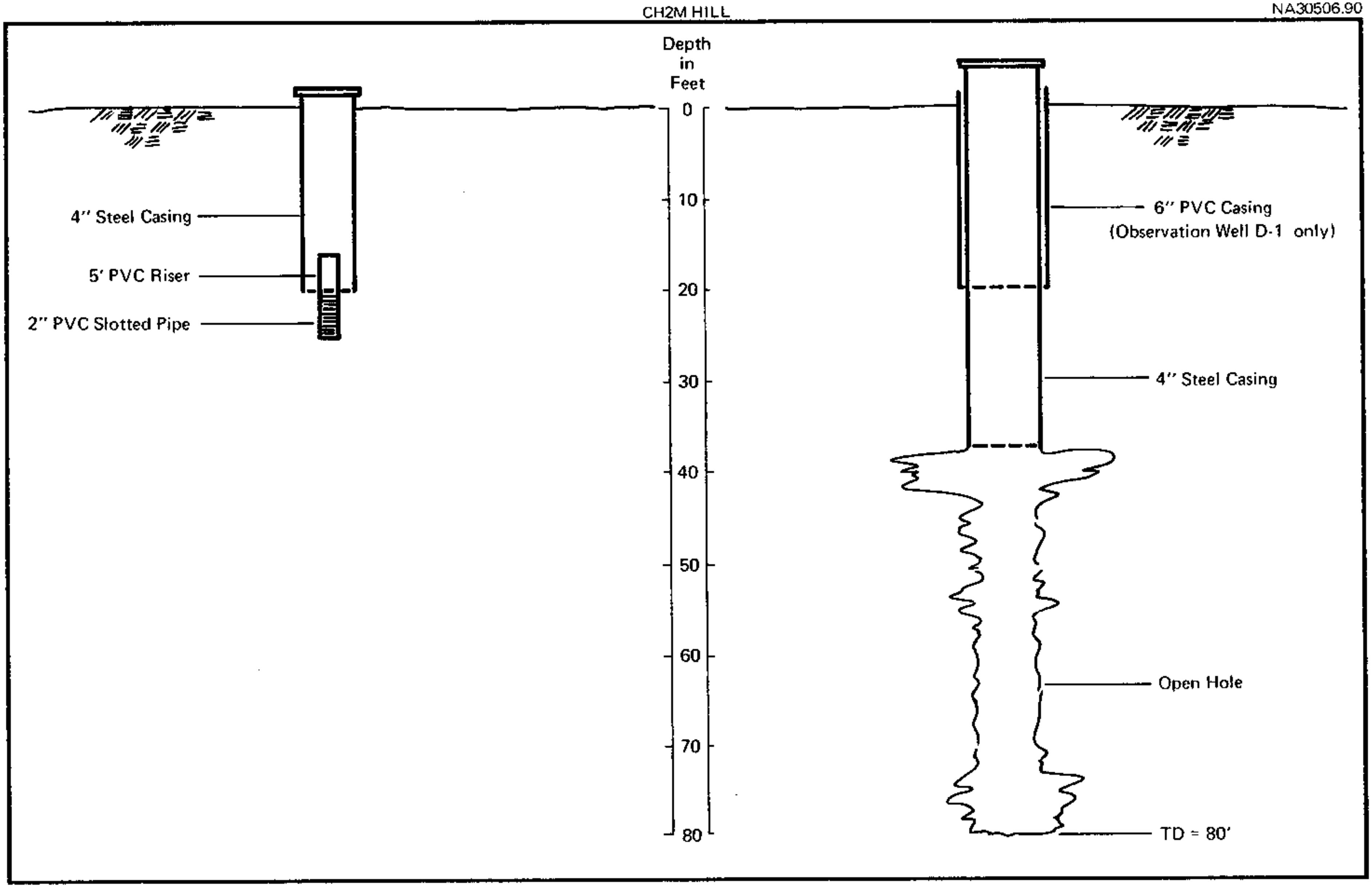


FIGURE 3. Deep and shallow monitor well construction diagram.

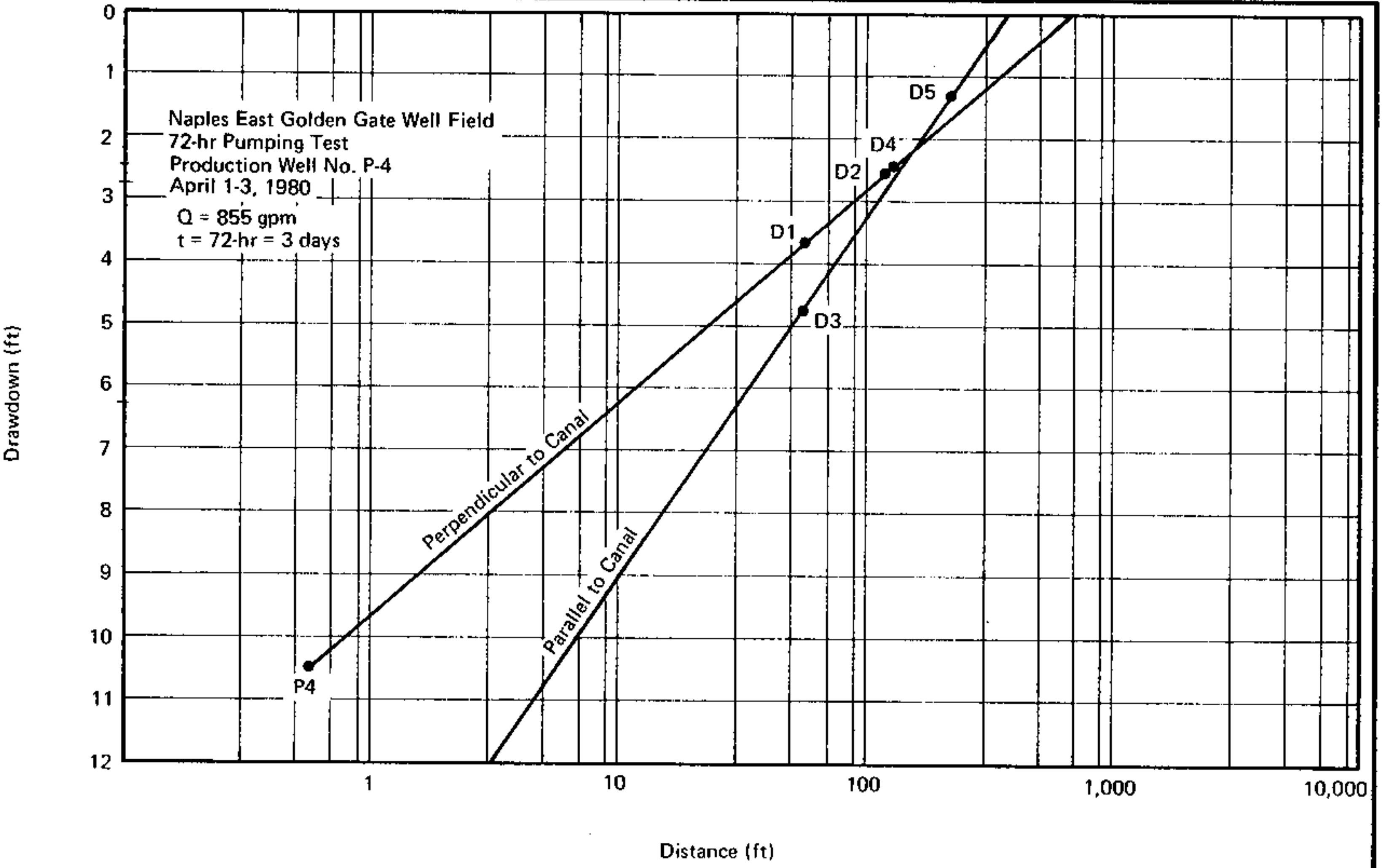


FIGURE 4. Deep monitor well distance vs. drawdown graph.

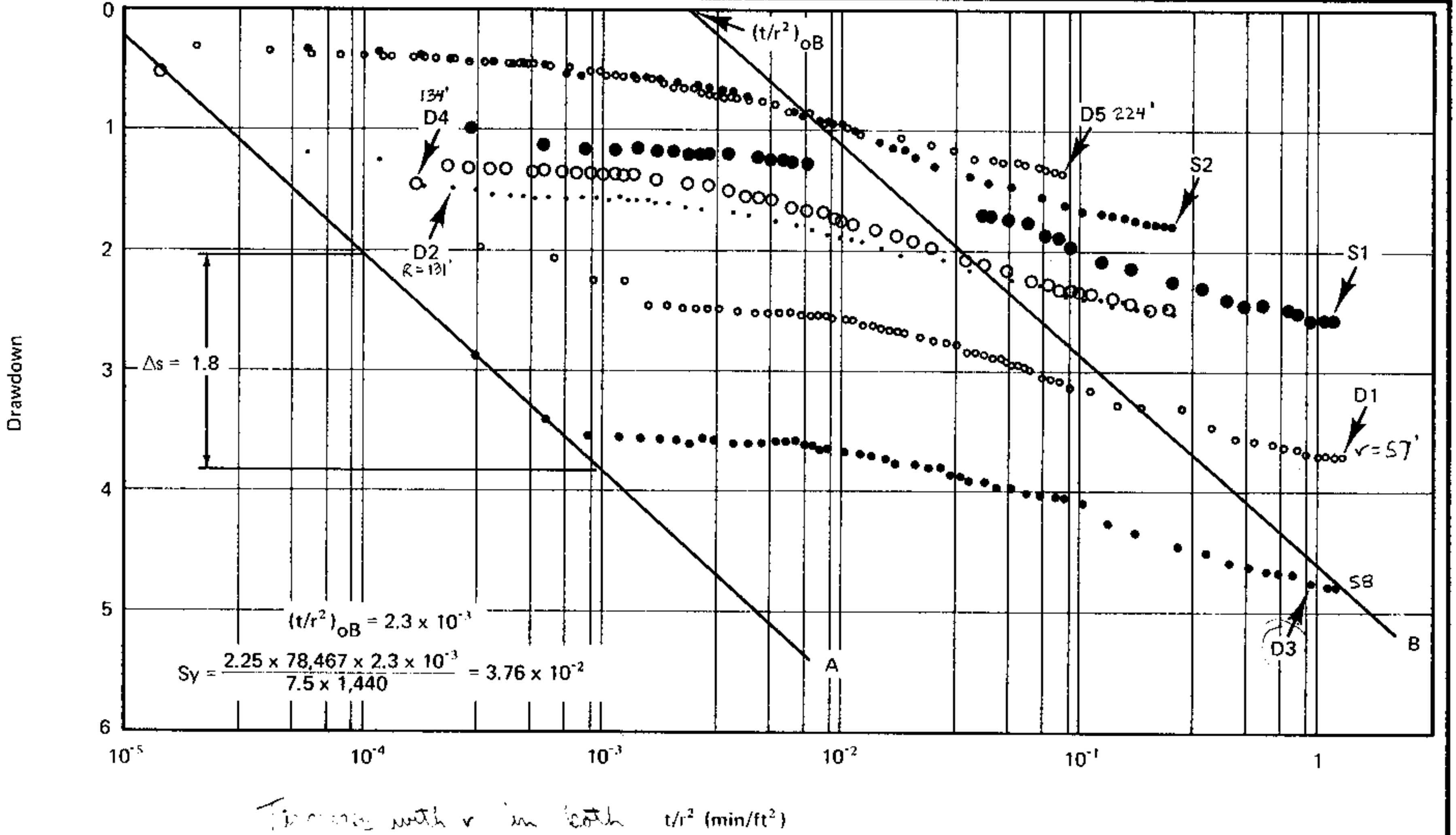
preliminary examination of this plot would indicate a recharge effect from the canal upon the production zone since the array of deep monitor wells perpendicular to the canal experienced less drawdown than the deep monitor wells parallel to the canal. Also, there was an observed hydraulic gradient in the shallow zone from the canal to the pumping well. However, due to the variable nature of the geology in this area (indicated on the well completion reports in the Appendix) Figure 5 was prepared. Figure 5 is a plot of drawdown versus the logarithm of $t/r^2(min/ft^2)$ for all wells (deep and shallow). Figure 5 shows a variation in transmissivity among the deep monitor wells. If the transmissivity were uniform, all the drawdown curves would have started on the same curve and then would deviate on separate horizontal curves at the entrance of any recharge effect. To check whether or not the difference in the distance-drawdown distribution between the two well configurations is due to recharge from the canal or to a difference in transmissivity, a method described by Rorabaugh (1956) was utilized. In this method a straight line is drawn parallel to the initial slope of the drawdown curves, near the end points of the wells nearest the pumped well. The apparent specific yield is then calculated from the intercept of this line with the zero drawdown axis $(t/r^2)_0$. This value is calculated as 3.8×10^{-2}. If a significant recharge effect from the canal had occurred during the 72-hour pumping test, this value of specific yield would be greater than 0.1.? where does 0.1 come from

Based upon the results of the above analysis, log-log plots of the time versus drawdown data were prepared for all the deep monitor wells. Figures 6, 7, and 8 present the resulting plots for three selected deep wells. The log-log plots were analyzed by the match-point method with a set of delayed-yield aquifer type curves.

The chosen early and late match-point values are indicated on the selected curves. The aquifer parameters calculated from the match-point method were then used to calculate theoretical monitor well drawdowns at the end of 72 hours. These calculated theoretical drawdowns were in close agreement with the observed drawdowns. This indicates that the differences in drawdowns between the different deep monitor well configurations is due primarily to the differences in transmissivity among the wells rather than the effect of induced infiltration from the canal. Table 1 is a summary of the aquifer parameters obtained from the match-point method and the calculated theoretical drawdowns based on these parameters.

Table 1 shows that the transmissivity varies from 16,400 ft^2/day to 62,400 ft^2/day, the early storage coefficient from 5.3×10^{-5} to 3.6×10^{-4}, and the late storage coefficient from 1.5×10^{-3} to 7.2×10^{-2}. The magnitude of the late storage coefficient indicates that the aquifer in this area resembles a delayed-yield aquifer situation. This conclusion is confirmed by the

3,4,5 Trend N-S / 1,2 Trend E-W



Trends with r in both
[illegible] ?

Naples East Golden Gate Well Field
72-hr Pumping Test
April 1-3, 1980

FIGURE 5. Drawdown vs. t/r^2 for selected monitor wells.

Q = 855

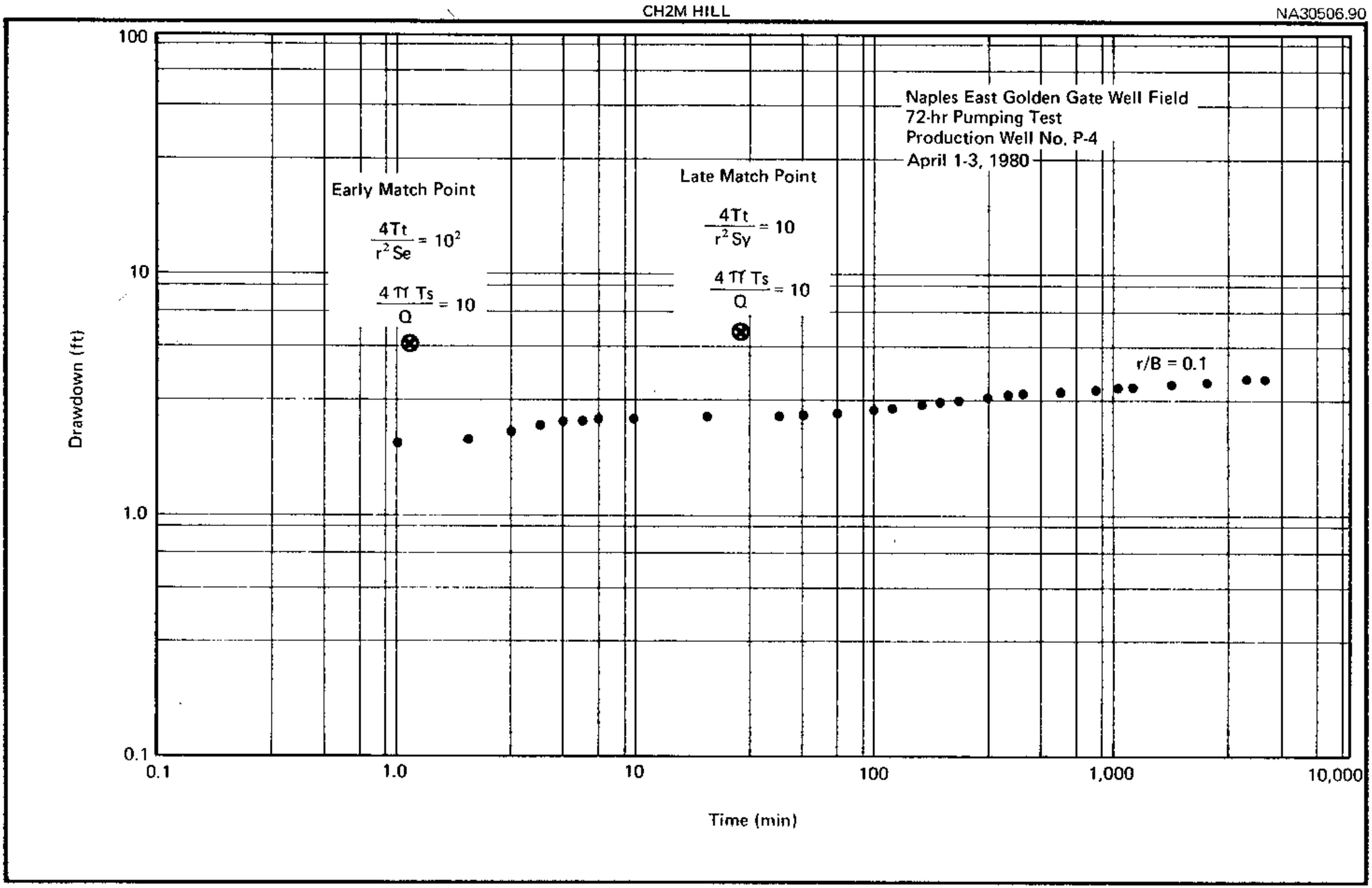


FIGURE 6. Drawdown vs. time for observation well D1.

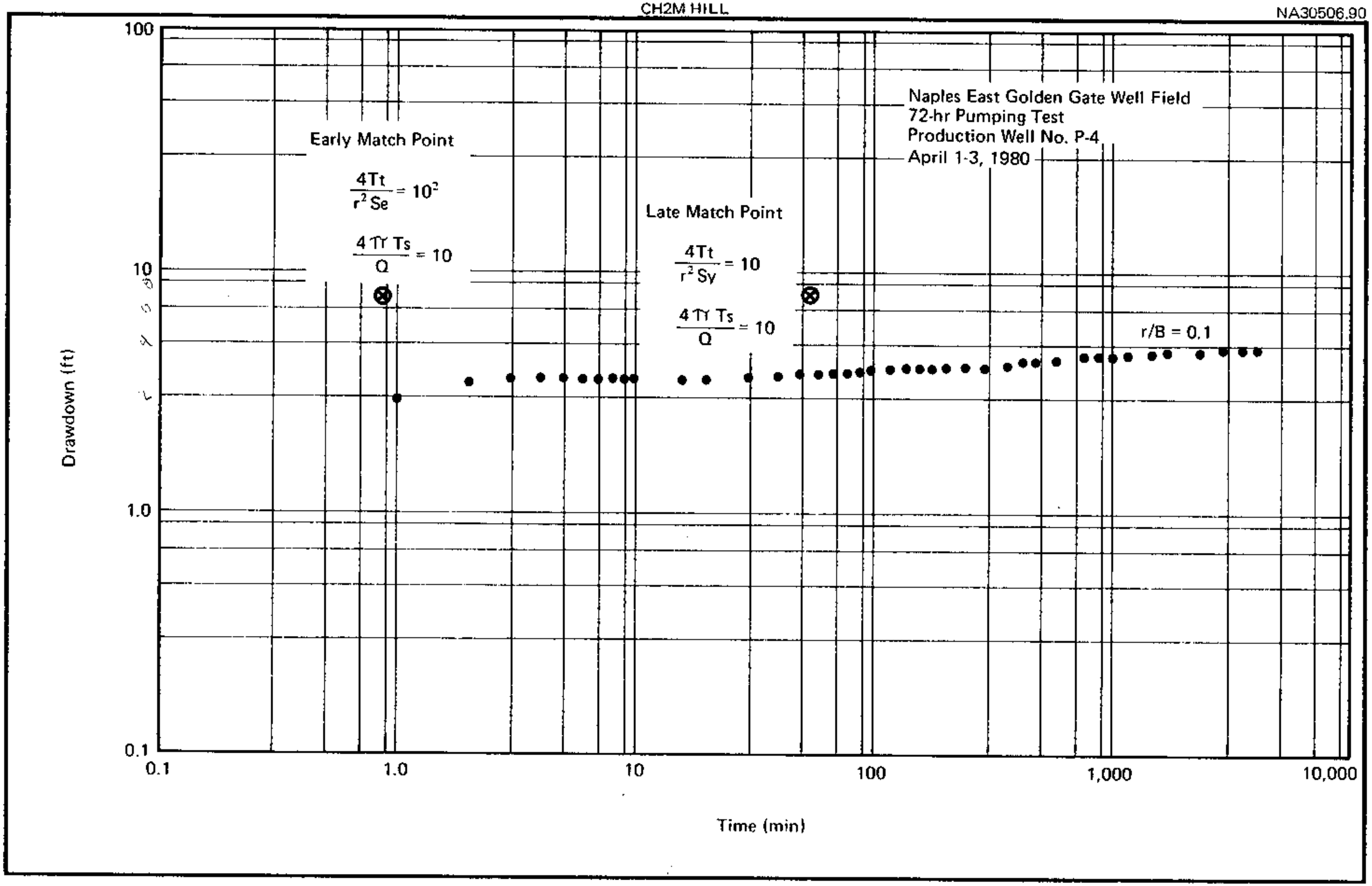


FIGURE 7. Drawdown vs. time for observation well D3.

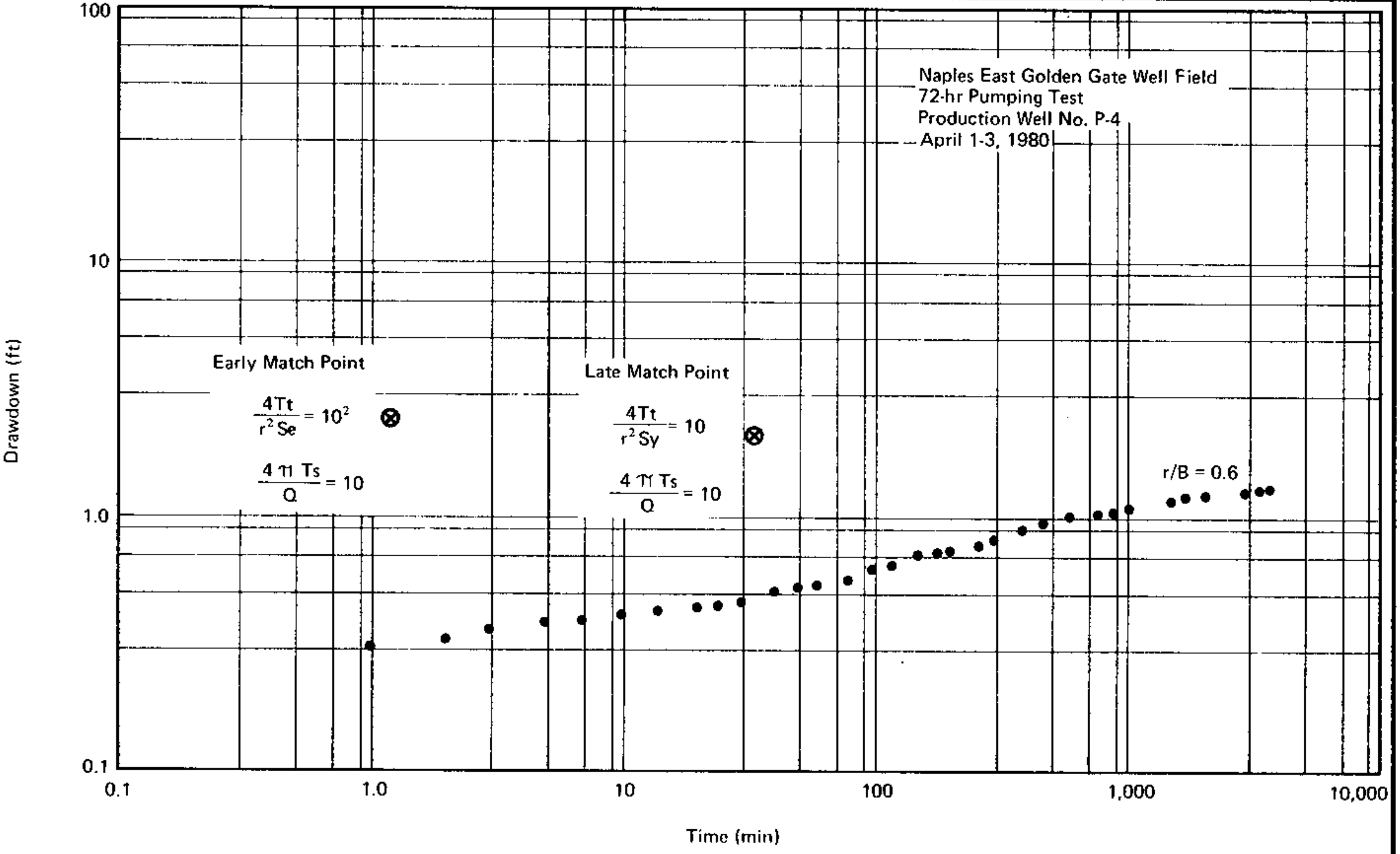


FIGURE 8. Drawdown vs. time for observation well D5.

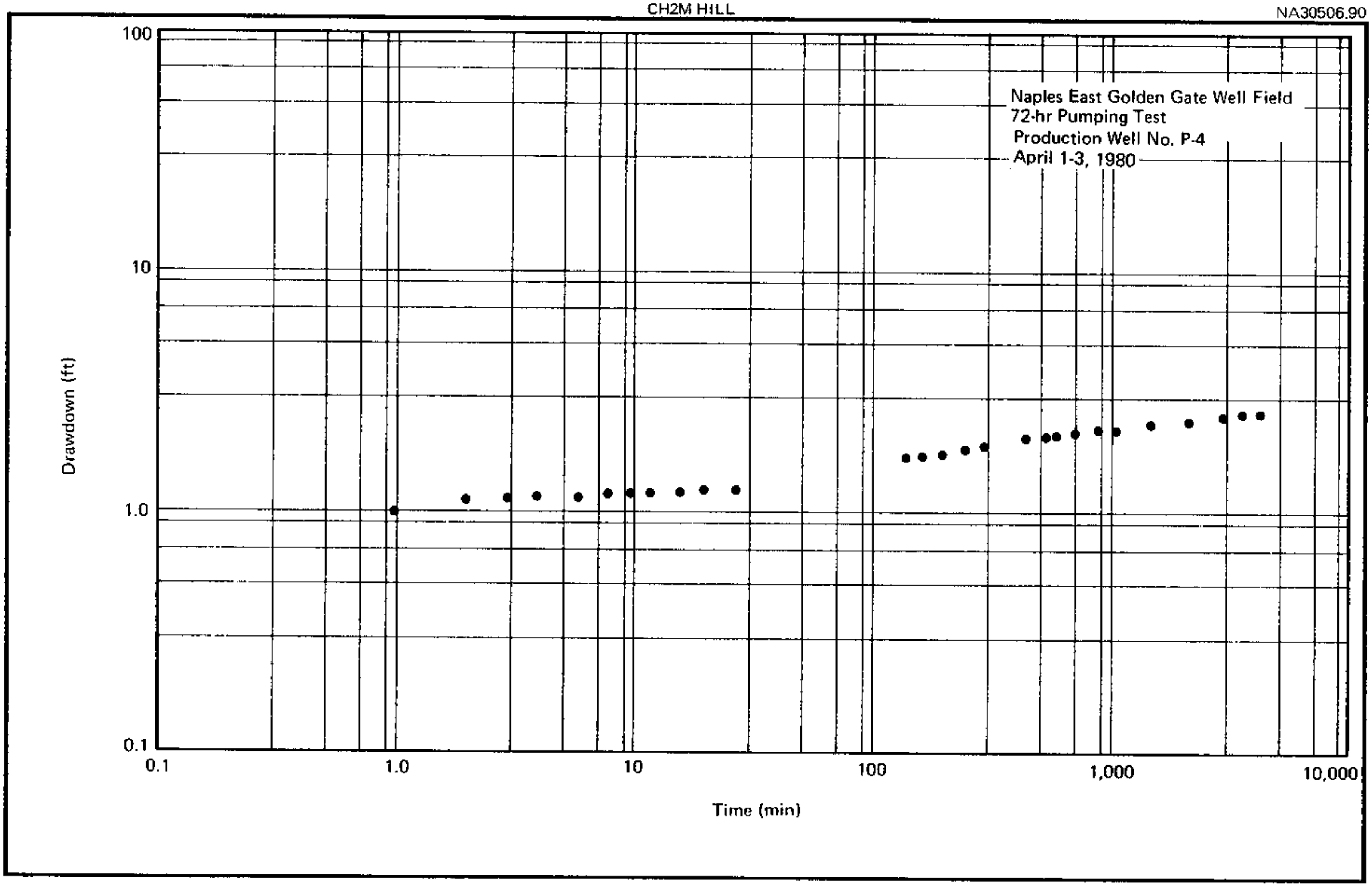


FIGURE 9. Drawdown vs. time for observation well S1.

Table 1
SUMMARY OF MATCH-POINT METHOD
(Delayed-Yield Analysis)

Well	r (ft)	S_{Early}	S_{Late}	T (ft^2/day)	$s_{Calc.}$ (ft)	s_{Actual} (ft)
D1	57	2.50×10^{-4}	5.4×10^{-2}	22,600 170,000	3.65	3.70
D2	131.4	8.9×10^{-5}	7.4×10^{-3}	37,400 280,000	2.60	2.51
D3	58.5	1.20×10^{-4}	7.2×10^{-2}	16,400 123,000	4.70	4.76
D4	134	5.3×10^{-5}	1.5×10^{-3}	48,500 363,000	2.38	2.48
D5	224	3.6×10^{-4}	1.1×10^{-2}	62,400 467,000	1.30	1.34

production zone distance-drawdown plot (Figure 4), which shows a relatively tight cone of depression, approximately 600 feet to the zero drawdown line, which is typical of a high leakance delayed-yield situation.

Figure 9 is the time-drawdown plot for shallow well S-1, which shows that 1/3 of the drawdown of this well in the shallow zone due to pumping in the deep zone occurred in less than 1 minute. This indicates a good hydraulic connection of the shallow zone with the deep zone through the semi-confining bed. High leakage rates, such as those evident in this area, tend to make the aquifer respond as in a delayed yield aquifer situation.

Static water level elevations in all wells, shallow and deep, were approximately equal prior to the start of the test, but at the end of 72 hours there was a head differential of approximately 0.6 to 0.8 foot in adjacent shallow and deep wells (D-1 versus S-1 and D-2 versus S-2) indicating some vertical impediment to flow. Table 2 is a summary of the static water level elevations and the water level elevations after 72 hours of pumping.

A shallow well step drawdown test was performed on Wells S-1 and S-2 to evaluate the transmissivity and permeability of the upper zone. The wells were pumped at rates from 5 gpm to 60 gpm. The drawdown values obtained were then corrected for well losses and were analyzed by two methods. Transmissivity values in the shallow zone were calculated to range from 25,200 ft^2/day to 33,900 ft^2/day, with an average permeability value of 1,400 ft/day based upon an assumed saturated thickness of 20 ft. These transmissivity values from the shallow zone are of the same order of magnitude as those from the deep zone. This is in agreement with data obtained during the drilling of the monitor wells in which lost circulation zones were encountered at 3', 12', and 22' in some of the wells.

Although some recharge from the canal probably occurred during this test, we believe that the amount was minimal. Two factors contributing to the lack of a major recharge impact from the canal during the 72-hour pumping test are the large transmissivity of the shallow zone and the good hydraulic connection between the deep and shallow zones. The large quantity of available recharge in the shallow zone would mask the effect of any recharge from the canal. Also, at the time the pumping test was conducted, the canal was at a low flow condition. During the wet season, observable canal water levels are 5 to 7 feet higher than the dry-season canal water levels. It is felt that the canal does have a seasonal impact upon the recharge to the aquifer in the East Golden Gate Well Field area.

Table 2
NAPLES EAST GOLDEN GATE WELL FIELD
PUMPING TEST WATER LEVEL ELEVATIONS

Well	r (ft)	Static Water Level Elevation (ft-msl)	Water Level Elevation After 72 Hours Pumping (ft-msl)	Drawdown (ft)
P-4	0.58	8.78	-1.63	10.41
D1	57	9.15	5.45	3.70
D2	131.4	9.08	6.57	2.51
D3	58.5	8.98	4.22	4.76
D4	134	8.90	6.42	2.48
D5	224	8.90	7.56	1.34
S1	60'	8.87	6.29	2.58
S2	132	8.95	7.17	1.78
S3	189	8.94	7.19	1.75
Canal	214	8.88	8.84	

The Golden Gate Canal system drains a sizable area. Significant quantities of freshwater are allowed to flow into Naples Bay at certain times of the year. Since much of the recharge to the production wells in the East Golden Gate area is local, the amount of freshwater available for local recharge would be increased by raising some of the weir elevations in the Fahka Union canal, thereby reducing the quantity of freshwater allowed to flow into Naples Bay during the dry season. Raising canal water levels would increase shallow ground-water levels and therefore would increase the quantity of water stored in the water table and also allow for a greater percentage of evapotranspiration salvage to be obtained under well field pumping conditions.

It is recommended that future production wells be located along the Fahka Union canal. There was an observed flow gradient in the shallow zone from the canal to the pumping well during the 72-hour pumping test. Locating future wells along the canal will help to reduce the quantity of freshwater flowing to Naples Bay, thereby helping to restore the historic hydroperiod in this coastal area, while improving recharge to the shallow aquifer.

Conclusions

1. The deep production zone (40'-80') is very transmissive in the East Golden Gate Area. There is considerable variability in the transmissivity between wells. However, the transmissivity is of the same order of magnitude among wells. The range encountered was from 16,400 ft^2/day to 62,400 ft^2/day, with an average value of 38,000 ft^2/day.

2. The deep production zone responds initially as a leaky artesian aquifer but under long-term conditions resembles a delayed-yield water-table aquifer. This delayed-yield response is due primarily to the high leakance rate of the semi-confining unit between the shallow and deep zone. A good hydraulic connection between the two zones would tend to make the two zones respond as one hydrologic unit under long-term pumping conditions. The range of early storage coefficient values varied from 5.3×10^{-5} to 3.6×10^{-4}. The range of the later storage coefficients was from 1.5×10^{-3} to 7.2×10^{-2}.

3. The shallow water table zone (20'-25') is very transmissive. Transmissivity values obtained from the shallow zone are of the same order of magnitude as those from the deep zone. The average transmissivity value obtained from a step-drawdown test of the shallow zone was 28,000 ft^2/day. The average permeability was determined to be 1,400 ft/day.

4. The shallow water table wells respond very rapidly to pumping in the deep zone. Over 1/3 of the total drawdown in the shallow wells occurs in less than 1 minute.

5. Although the canal is contributing some recharge to the shallow zone, the effect of this recharge upon the deep zone is masked by the large transmissivity of the shallow zone and the good hydraulic connection between the shallow and the deep zone. Therefore, time drawdown aquifer analysis techniques (particularly delayed-yield) are suitable to determine the aquifer characteristics.

6. Most of the recharge to the production zone is from local sources such as the shallow water table and local rainfall.

7. It is recommended that the Fahka Union canal weir elevations be increased to reduce the freshwater outflow from the region. Increasing the canal water levels during the dry season would maintain higher shallow ground-water elevations. In addition to increasing availability of ground-water resources, this would help to improve environmental conditions in a large area that has been severely stressed in recent years due to overdrainage.

8. Future production wells in the East Golden Gate region should be located along the Fahka Union canal to intercept as much as possible of the available freshwater in the canal system before it flows into Naples Bay.

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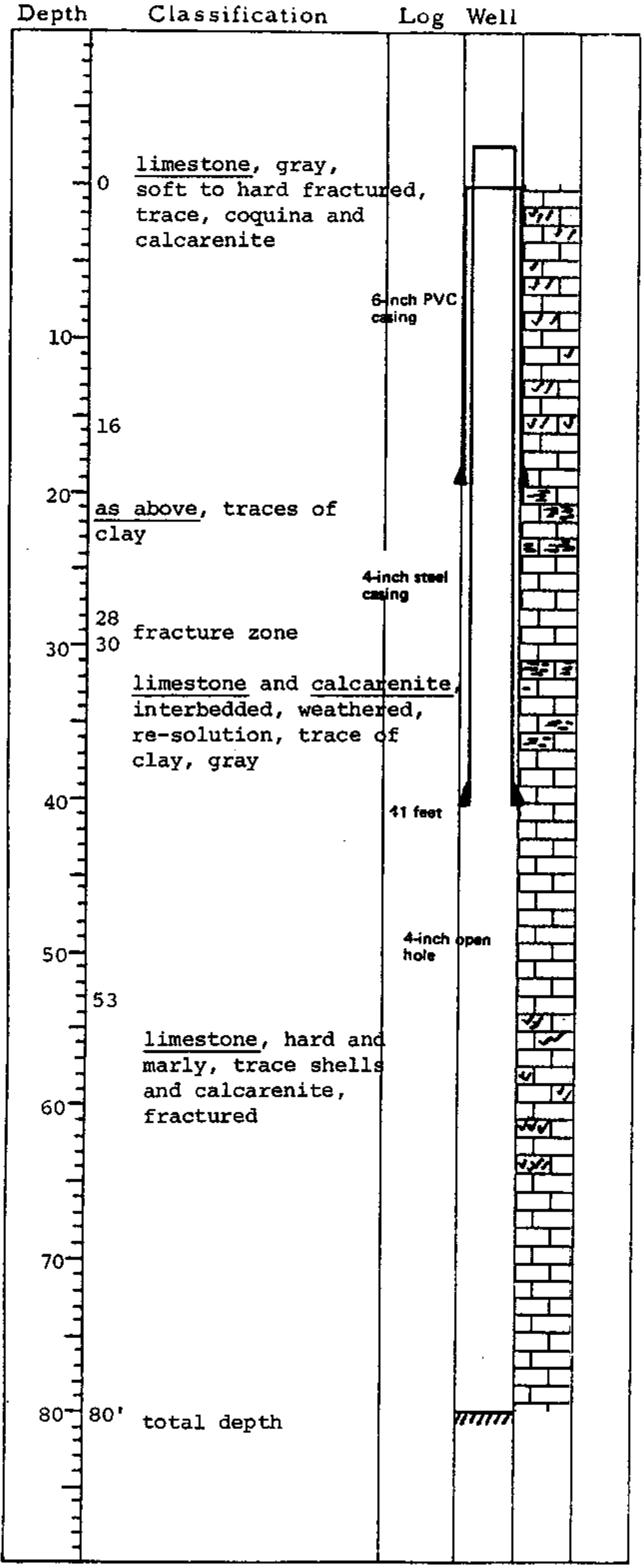
APPENDIX



0 limestone, gray, soft to hard fractured, trace, coquina and calcarenite

16

20 as above, traces of clay

28 fracture zone

30 limestone and calcarenite, interbedded, weathered, re-solution, trace of clay, gray

53 limestone, hard and marly, trace shells and calcarenite, fractured

80' total depth

BC&E CH2M HILL

WELL DRILLING REPORT

Well: D-1

Location: Naples East Golden Gate Well Field

County: Collier State: FL

Ground Elevation: ∿ 13 ft MSL

Diameter: 4 inch

Depth: 80 ft

Static Water Level: 9.15 ft MSL

Date: April 1, 1980

Casing: 6" PVC to 20 ft
4" steel to 41 ft

Screen: none

Construction: rotary

Driller: Green Well Drilling

Date Finished: October 1979

Pumping Test

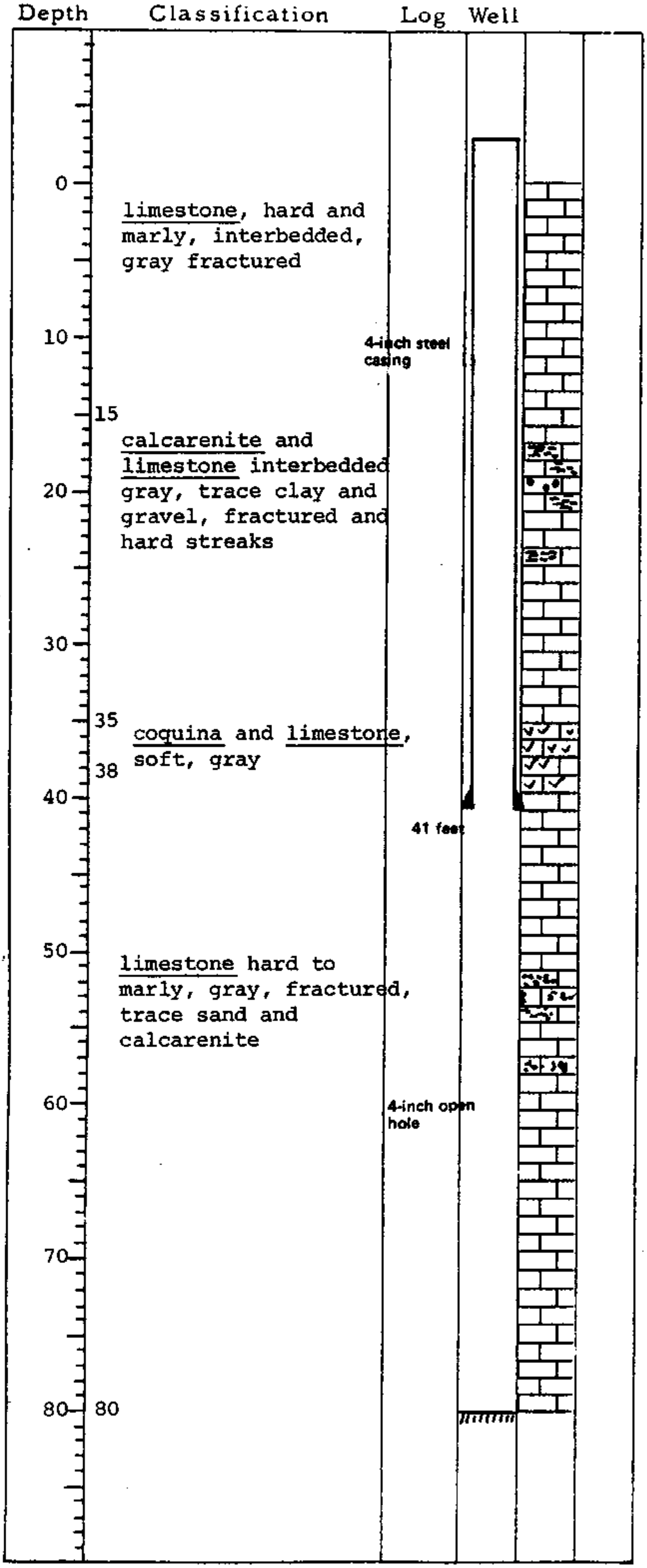
Specific Yield ________ gpm/ft
@ ________ gpm

Water Analysis (ppm)

TDS ________
Total Hard[1] ________
M.O. Alkal.[1] ________
Chloride Cl ________
Iron Fe ________
Sulfate SO_4 ________
Color (APHA) ________
Calcium[1] ________

Compiled by P. Waller, L. Perssons
Date June 1980

[1]as $CaCO_3$



BC&E CH2M HILL

WELL DRILLING REPORT

Well: D-2

Location: Naples East Golden Gate Well Field

County: Collier State: FL

Ground Elevation: ~ 13 ft. MSL

Diameter: 4 inch

Depth: 80 ft

Static Water Level: 9.08 ft MSL

Date: April 1, 1980

Casing: 40'-4"

Screen: none

Construction: rotary

Driller: Green Well Drilling

Date Finished: November 1979

Pumping Test

Specific Yield ________ gpm/ft @ ________ gpm

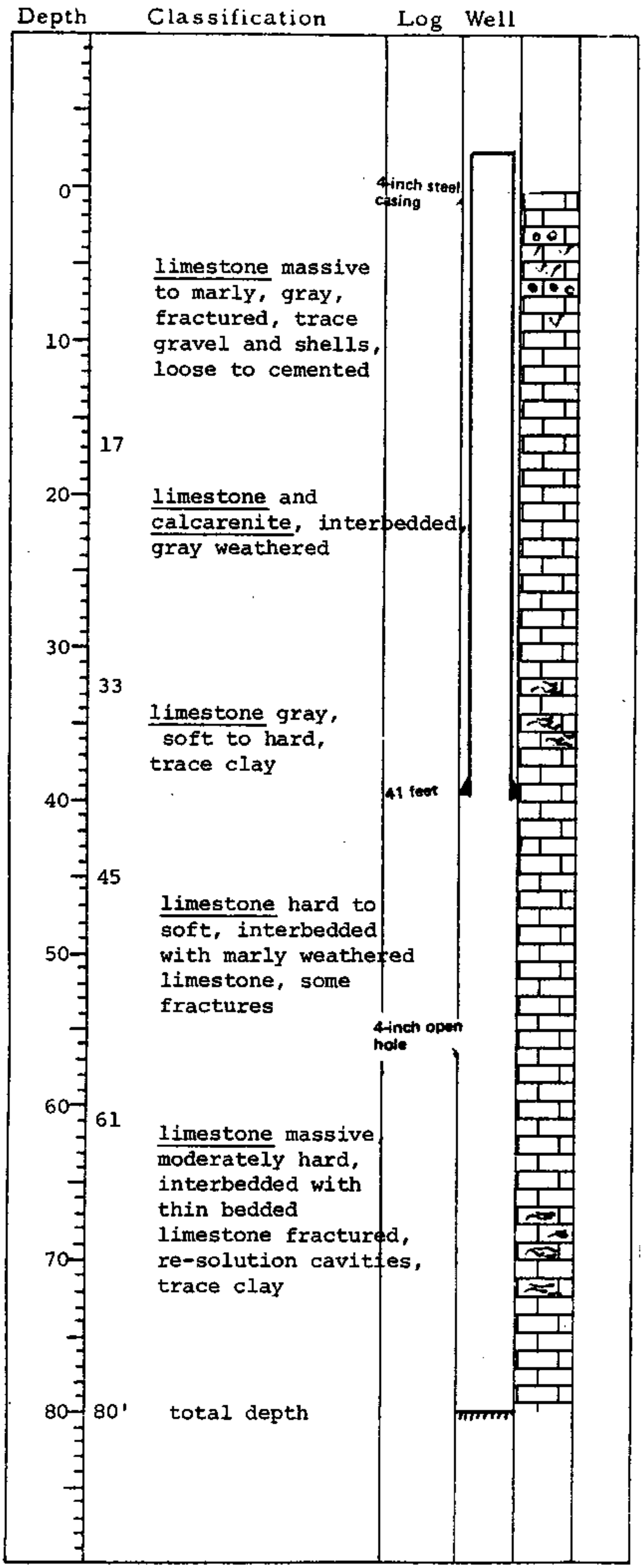
Water Analysis (ppm)

TDS	
Total Hard[1]	
M.O. Alkal.[1]	
Chloride Cl	
Iron Fe	
Sulfate SO_4	
Color (APHA)	
Calcium[1]	

Compiled by P. Waller, L. Perssons

Date June 1980

[1] as $CaCO_3$



Depth	Classification
0	limestone massive to marly, gray, fractured, trace gravel and shells, loose to cemented
17	limestone and calcarenite, interbedded, gray weathered
33	limestone gray, soft to hard, trace clay
45	limestone hard to soft, interbedded with marly weathered limestone, some fractures
61	limestone massive moderately hard, interbedded with thin bedded limestone fractured, re-solution cavities, trace clay
80'	total depth

BC&E CH2M HILL

WELL DRILLING REPORT

Well: D-3

Location: Naples East Golden Gate Well Field

County: Collier State: FL

Ground Elevation: ∿ 13 ft MSL

Diameter: 4 inch

Depth: 80 ft

Static Water Level: 8.98 ft MSL

Date: April 1, 1980

Casing: 4 inch steel to 40 ft

Screen: none

Construction: rotary

Driller: Green Well Drilling

Date Finished: January 1980

Pumping Test

Specific Yield ________ gpm/ft
@ ________ gpm

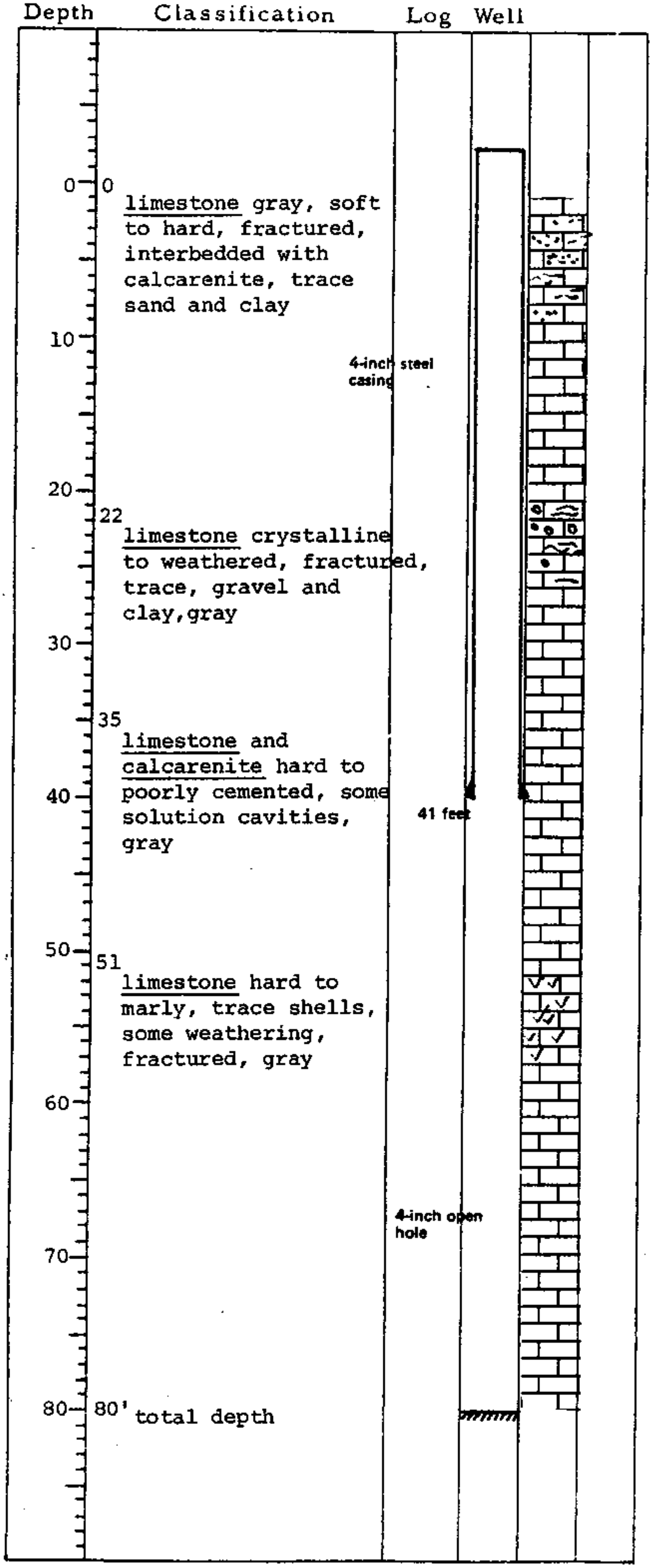
Water Analysis (ppm)

TDS	
Total Hard[1]	
M.O. Alkal.[1]	
Chloride Cl	
Iron Fe	
Sulfate SO_4	
Color (APHA)	
Calcium[1]	

Compiled by P. Waller, L. Perssons
Date June 1980

[1] as $CaCO_3$

BC&E CH2M HILL



0 **limestone** gray, soft to hard, fractured, interbedded with calcarenite, trace sand and clay

22 **limestone** crystalline to weathered, fractured, trace, gravel and clay, gray

35 **limestone** and **calcarenite** hard to poorly cemented, some solution cavities, gray

51 **limestone** hard to marly, trace shells, some weathering, fractured, gray

80' total depth

WELL DRILLING REPORT

Well: D-4

Location: Naples East Golden Gate Well Field

County: Collier State: FL

Ground Elevation: ~ 13 ft MSL

Diameter: 4 inch

Depth: 80 ft

Static Water Level: 8.90 ft MSL

Date: April 1, 1980

Casing: 4 inch steel to 40 ft

Screen: none

Construction: rotary

Driller: Green Well Drilling

Date Finished: January 1980

Pumping Test

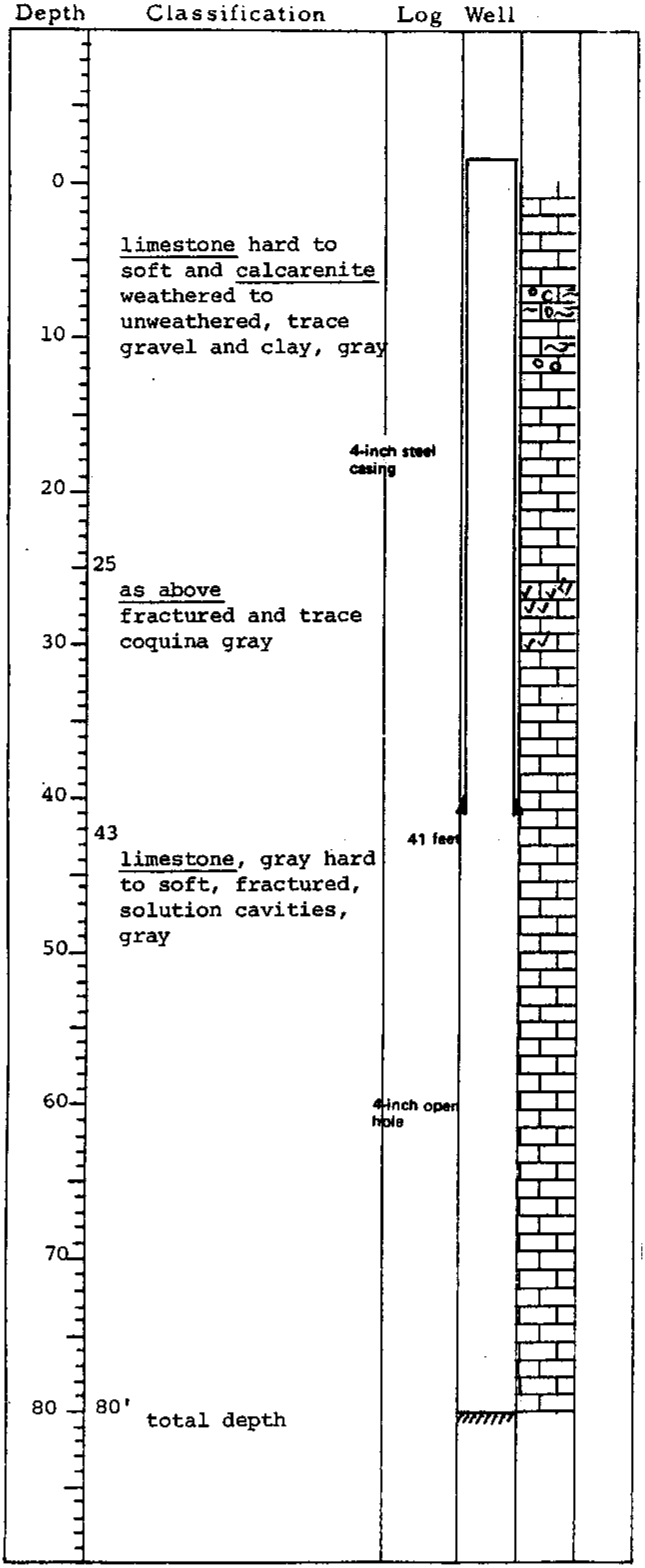
Specific Yield ________ gpm/ft @ ________ gpm

Water Analysis (ppm)

TDS ________
Total Hard[1] ________
M.O. Alkal.[1] ________
Chloride Cl ________
Iron Fe ________
Sulfate SO_4 ________
Color (APHA) ________
Calcium[1] ________

Compiled by P. Waller, L. Perssons
Date June 1980

[1] as $CaCO_3$



0 – 25: limestone hard to soft and calcarenite weathered to unweathered, trace gravel and clay, gray

25 – 43: as above fractured and trace coquina gray

43 – 80: limestone, gray hard to soft, fractured, solution cavities, gray

80' total depth

BC&E CH2M HILL

WELL DRILLING REPORT

Well: D-5

Location: Naples East Golden Gate Well Field

County: Collier State: FL

Ground Elevation: ~ 13 ft MSL

Diameter: 4 inch

Depth: 80 ft

Static Water Level: 8.90 ft MSL

Date: April 1, 1980

Casing: 4 inch steel to 40 ft

Screen: none

Construction: rotary

Driller: Green Well Drilling

Date Finished: February 1980

Pumping Test

Specific Yield ________ gpm/ft
@ ________ gpm

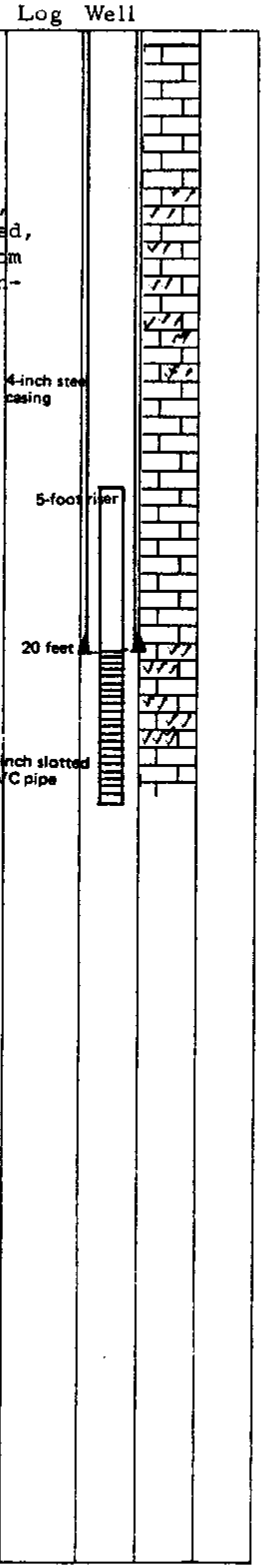
Water Analysis (ppm)

TDS	
Total Hard[1]	
M.O. Alkal.[1]	
Chloride Cl	
Iron Fe	
Sulfate SO_4	
Color (APHA)	
Calcium[1]	

Compiled by P. Waller, L. Perssons
Date June 1980

[1] as $CaCO_3$

Depth	Classification
0	0
5	limestone massive to thin bedded, unweathered to weathered, solution cavities random depths, fractured to unfractured, interbedded with shells, small to large, cemented to uncemented, grayish white.
10	
15	
20	20 limestone as above, some calcarenite seams, trace shells, loose
25	25 total depth
	Note: lost circulation at 3', 12' and 22'



BC&E CH2M HILL

WELL DRILLING REPORT

Well: S-1

Location: Naples East Golden Gate Well Field

County: Collier State: FL

Ground Elevation: ∿ 13 ft MSL

Diameter: 4-inch

Depth: 25 ft

Static Water Level: 8.87 MSL

Date: April 1, 1980

Casing: 4-inch steel to 20 ft

Screen: 2-inch slotted PVC pipe

Construction: rotary

Driller: Green Well Drilling

Date Finished: November 1979

Pumping Test

Specific Yield ________ gpm/ft
@ ________ gpm

Water Analysis (ppm)

TDS	322
Total Hard[1]	312
M.O. Alkal.[1]	300
Chloride Cl	20
Iron Fe	1.80
Sulfate SO_4	16
Color (APHA)	
Calcium[1]	290

Compiled by P. Waller, L. Perssons
Date June 1980

[1] as $CaCO_3$

BC&E CH2M HILL

WELL DRILLING REPORT

Depth Classification Log Well

0

limestone massive crystalline, gray

4

limestone, thinly bedded with shells and solution cavities, gray

8

limestone, firm and marly, trace shells and calcarenite trace sand, loose, gray

15

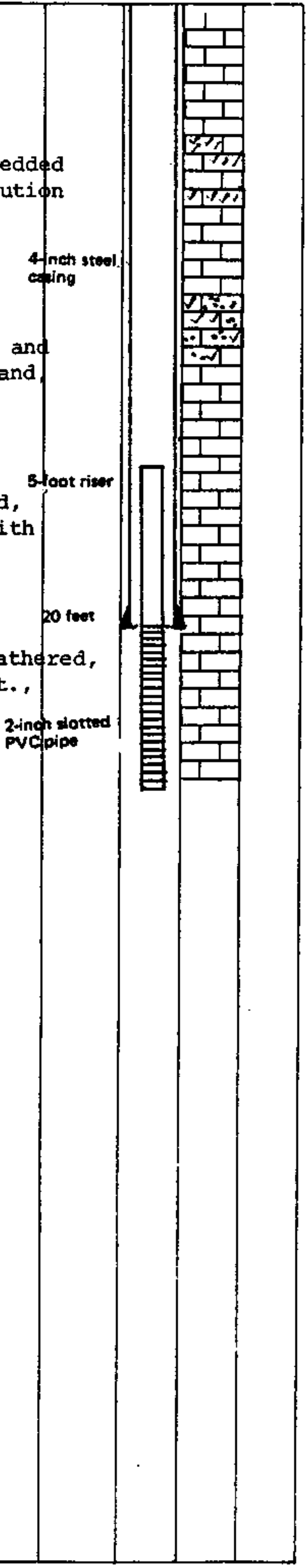
limestone, fractured, gray, interbedded with calcarenite

20

limestone, soft, weathered, hard streak 21-23 ft., trace calcarenite

25

total depth



Well: S-2

Location: Naples East Golden Gate Well Field

County: Collier State: FL

Ground Elevation: ∿ 13 ft MSL

Diameter: 4-inch

Depth: 25 ft

Static Water Level: 8.95 ft MSL

Date: April 1, 1980

Casing: 4-inch steel to 20 ft

Screen: 2-inch slotted PVC pipe

Construction: rotary

Driller: Green Well Drilling

Date Finished: November 1980

Pumping Test

Specific Yield ________ gpm/ft

@ ________ gpm

Water Analysis (ppm)

TDS ________

Total Hard[1] ________

M.O. Alkal.[1] ________

Chloride Cl ________

Iron Fe ________

Sulfate SO_4 ________

Color (APHA) ________

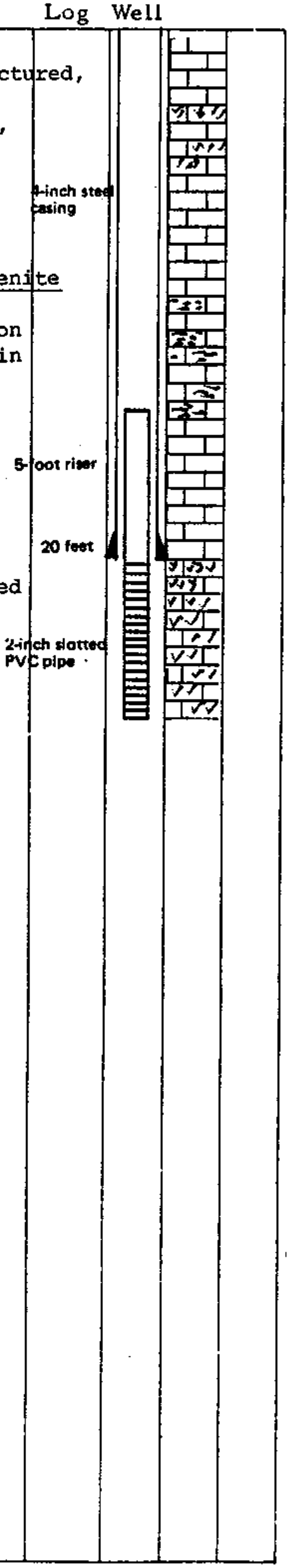
Calcium[1] ________

Compiled by P. Waller, L Perssons

Date June 1980

[1] as $CaCO_3$

Depth	Classification
0	limestone, soft, fractured, thin beds of harder limestone and shells, partially cemented, gray
8	limestone and calcarenite interbedded, gray, fractured and solution cavities, some clay in fillings
20	limestone and cemented shells, gray



BC&E
CH2M HILL

WELL DRILLING REPORT

Well: S-3

Location: Naples East Golden Gate Well Field

County: Collier State: FL

Ground Elevation: ∿ 13 ft MSL

Diameter: 4 inch

Depth: 25 ft

Static Water Level: 8.94 ft MSL

Date: April 1, 1980

Casing: 4-inch steel to 20 ft

Screen: 2-inch slotted PVC pipe

Construction: rotary

Driller: Green Well Drilling

Date Finished: January 1980

Pumping Test

Specific Yield ______ gpm/ft
@ ______ gpm

Water Analysis (ppm)

TDS
Total Hard[1]
M.O. Alkal.[1]
Chloride Cl
Iron Fe
Sulfate SO_4
Color (APHA)
Calcium[1]

Compiled by P. Waller, L. Perssons
Date June 1980

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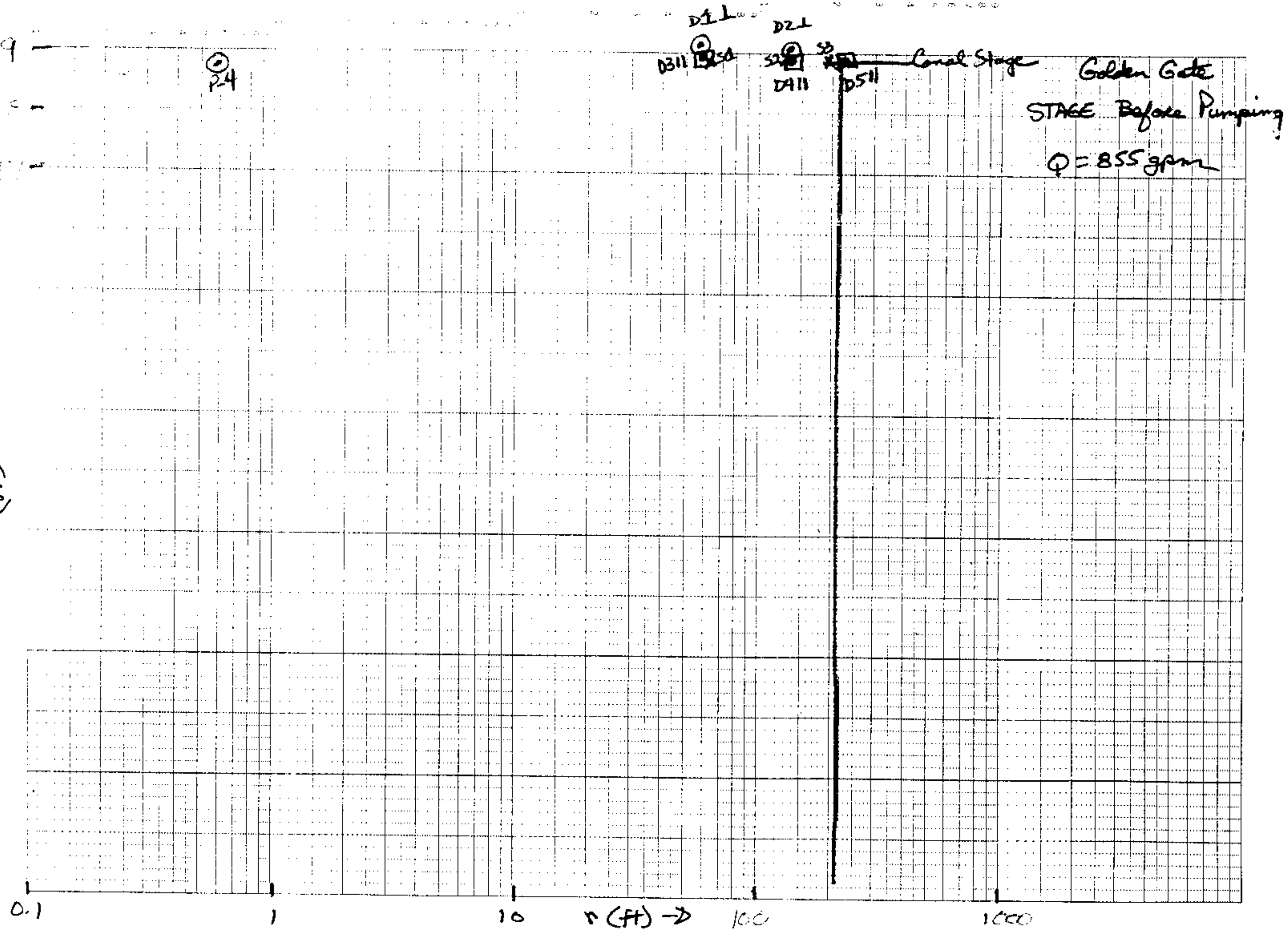
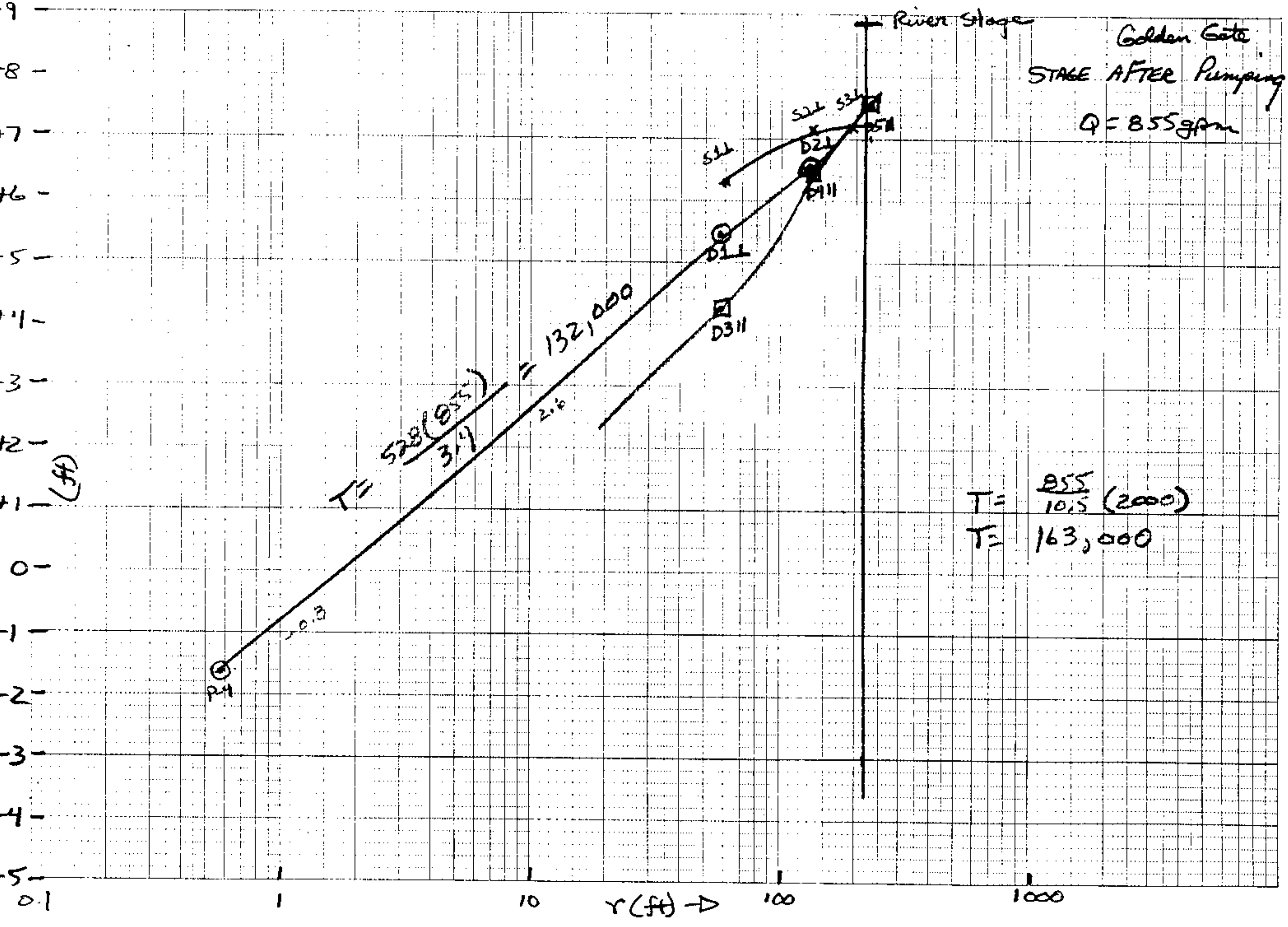
[1] as $CaCO_3$

K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS

46 6210

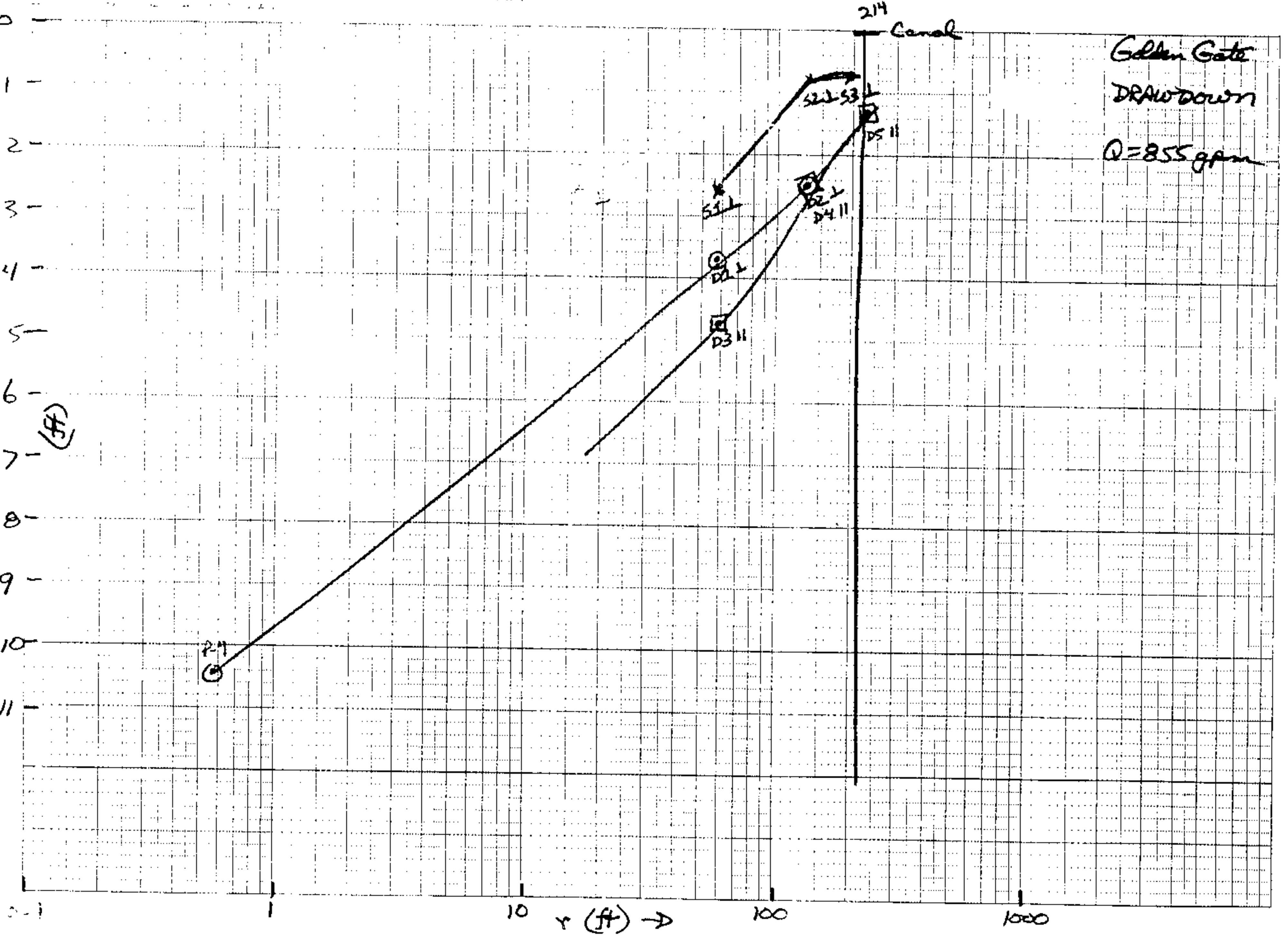


K&E KEUFFEL & ESSER CO. 46 6210



K&E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 6210



Golden Gate
DRAWDOWN
Q=855 gpm