Docket 40-8743
PDR

OTT

OTT WATER ENGINEERS, INC.

P.O. Box 17787, Denver, Colorado 80217
(303) 458-0821

Return to
D. Cramer
396-55

June 19, 1981

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U.S. Nuclear Regulatory Commission
[illegible]
Mail Section

Mr. Tom Fleming
U.S.N.R.C.
7915 Eastern Avenue
Silver Spring, Maryland 20910

Dear Mr. Fleming:

Enclosed are ten copies of the Conoco Sand Rock Uranium Mill project DES sections prepared by Ott Water Engineers. One copy has also been sent to Dr. Roy Williams as you requested.

Calculations of seepage from tailings Pit 35N have been reviewed only briefly for this draft. I am still waiting for the stage-volume-area relationships for the Pit, and expect to receive this information sometime next week from Mr. Terry Quigley. This data will allow a more thorough check of the assumptions and resulting seepage estimates.

If during your review of these sections you have any questions or comments feel free to contact me or Dr. Catherine Kraeger-Rovey, also in our office.

Sincerely,

Mary T. Cervera

Mary T. Cervera
Staff Engineer

MTC/ms

cc: Dr. Roy Williams w/enc.

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Section 4.3 Direct Effects and Their Significance

Section 4.6 Unavoidable Adverse Impacts

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3.6 WATER

This section contains a review of existing hydrologic conditions at Conoco's Sand Rock project area as presented in Conoco's Environmental Report. It includes a discussion of field tests and their analyses as well as a description of the area's hydrologic setting.

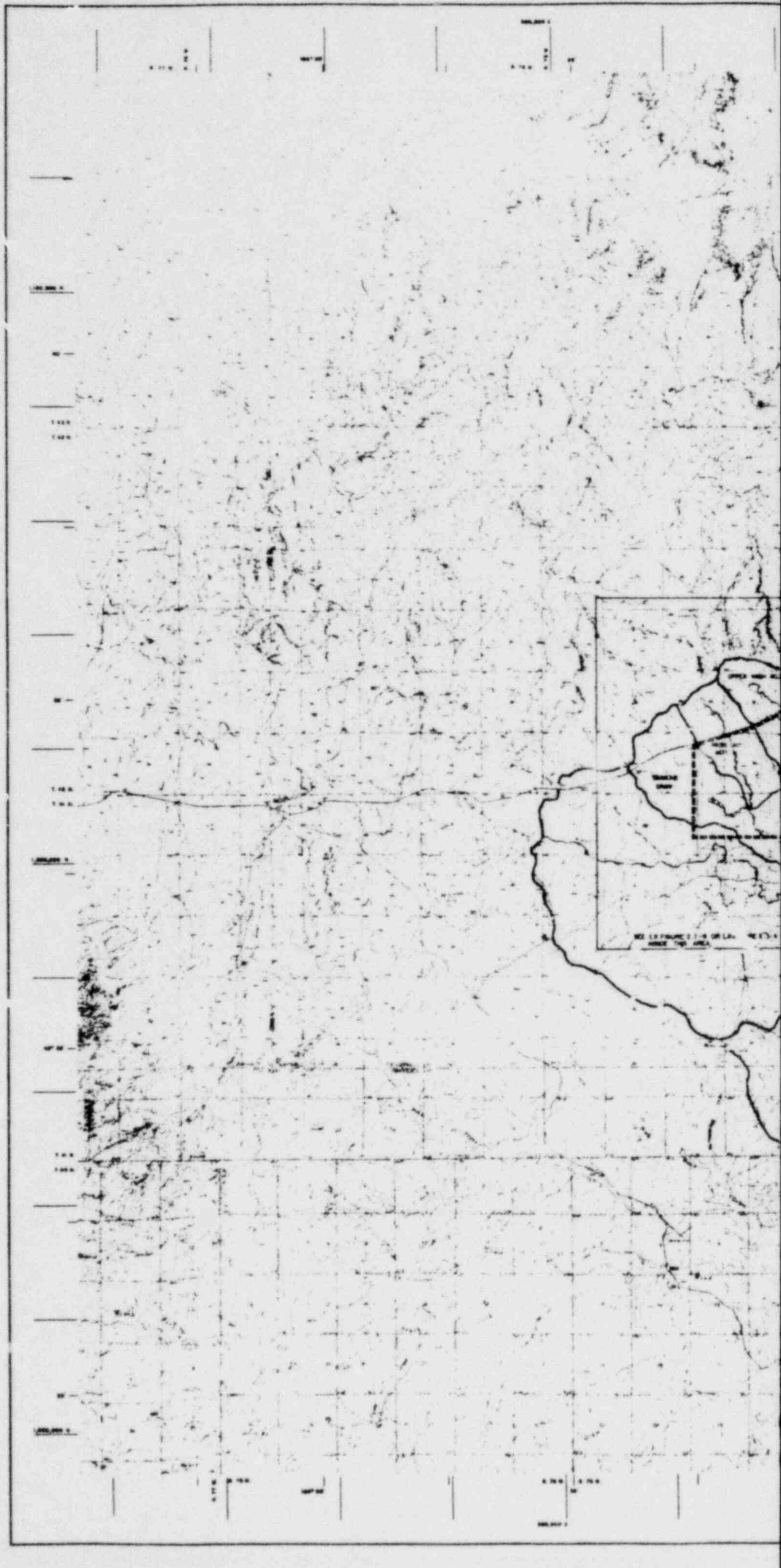
Surface water conditions are presented in Section 3.6.1. Section 3.6.2 describes area groundwater conditions including the geologic setting and aquifer properties. Both sections also contain chemical and radiological water quality assessments.

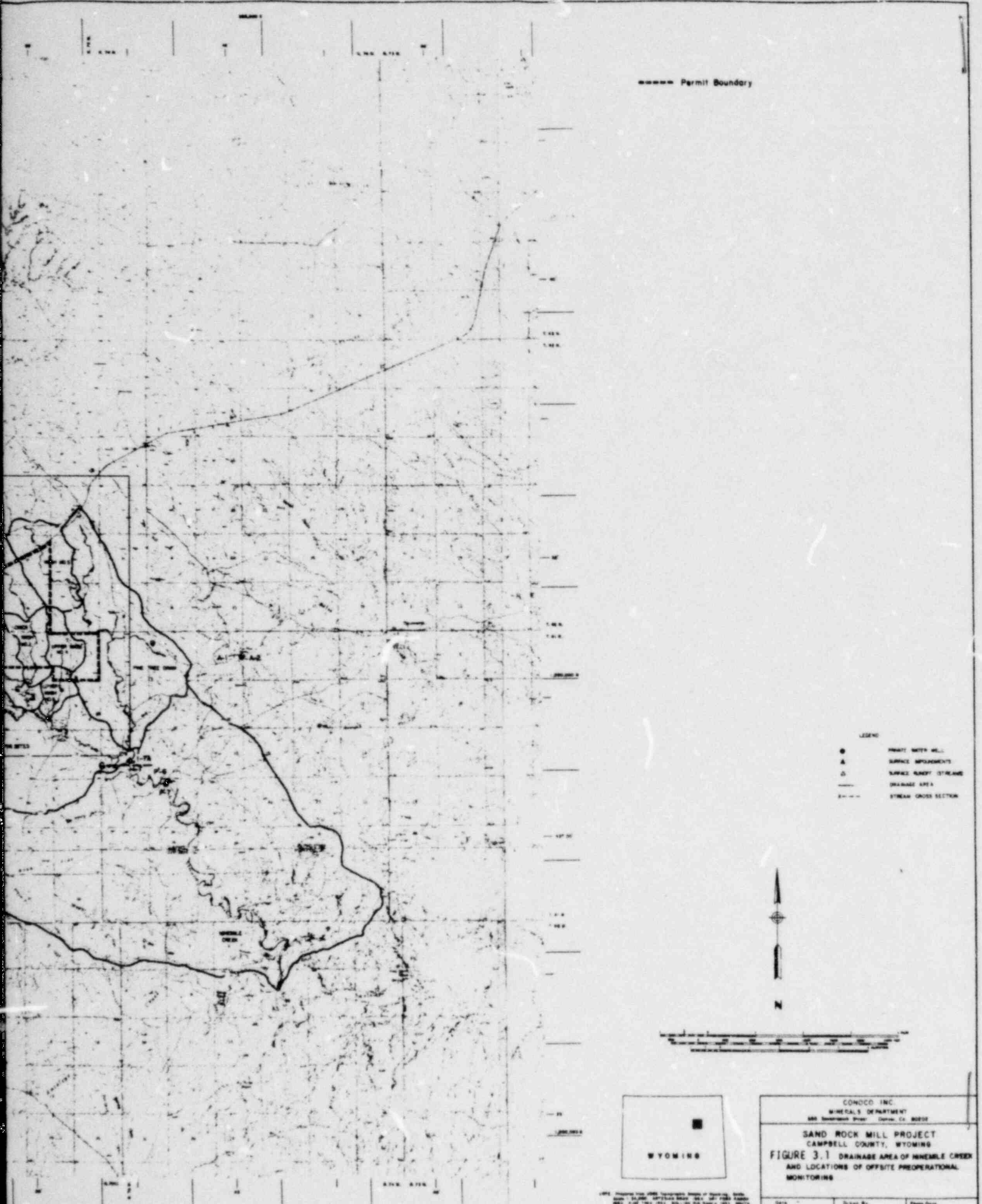
3.6.1 SURFACE WATER

3.6.1.1 DRAINAGE BASINS

The Sand Rock project area lies entirely within the drainage basin of Ninemile Creek, [illegible] tributary to Antelope Creek. Antelope Creek flows into the South Cheyenne River (Wyoming nomenclature) which joins the Belle Fourche River in South Dakota to form the Cheyenne River. The Cheyenne River subsequently flows into the Missouri River. Ninemile Creek's drainage is shown on Figure 3.1 and the Ninemile Creek tributaries which are relevant to the Sand Rock project are shown on Figures 3.1 and 3.2. The entire Antelope Creek drainage basin is shown on Figure 3.3.

Antelope Creek has a drainage area of 2,500 square kilometers (980 square miles) with an approximate channel length of 100 kilometers (62 miles), and an average gradient of 0.006 (ft/ft). The elevation at Antelope Creek's headwaters is approximately 1,900 meters (6,225 feet) above mean sea level (msl), and 1,340 meters (4,400 feet) at its confluence with the South Cheyenne River. The U.S. Geological Survey has a stream gaging station on Antelope Creek approximately ten miles upstream from its mouth. The drainage area is 2,480 square kilometers (959 square miles) at the gage.





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[illegible] Denver, Co. 80202

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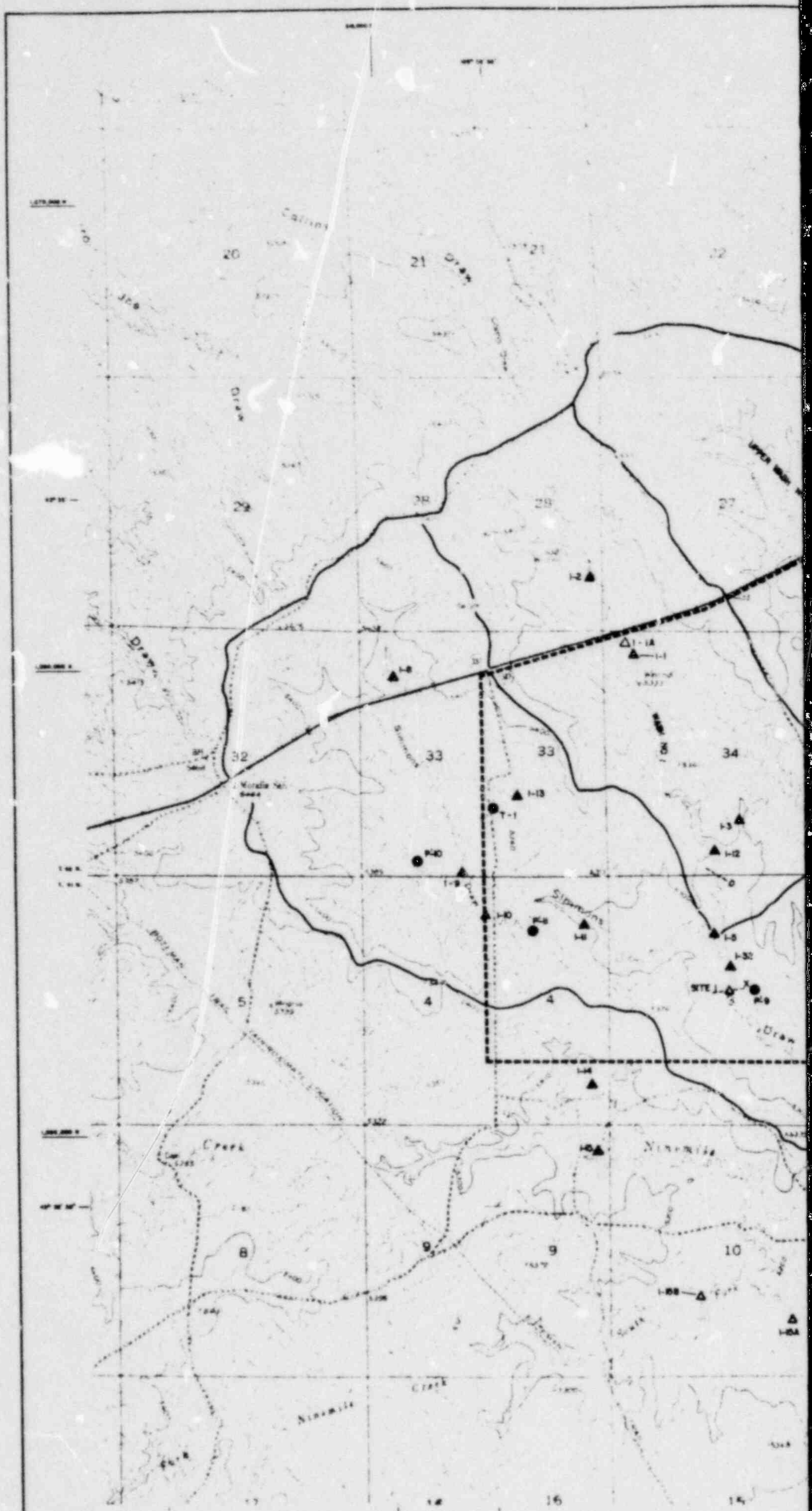
FIGURE 3.1 DRAINAGE AREA OF NINEMILE CREEK AND LOCATIONS OF OFFSITE PREOPERATIONAL MONITORING

Date Revision	Drawn By Checked By	Photo Date Approved
Contour Interval 20' & 40'	Drawing Number	


Collins
Draw
Joe
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UPPER
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34
I-2
I-1A
I-1
I-8
I-13
T-1
I-3
I-12
I-9
I-10
I-5
I-32
SITE
5
Simmons
Draw
5
4
4
I-14
I-15
Creek
Ninemile
8
9
9
10
I-16B
I-16A
Ninemile
Creek
Fork
16
15

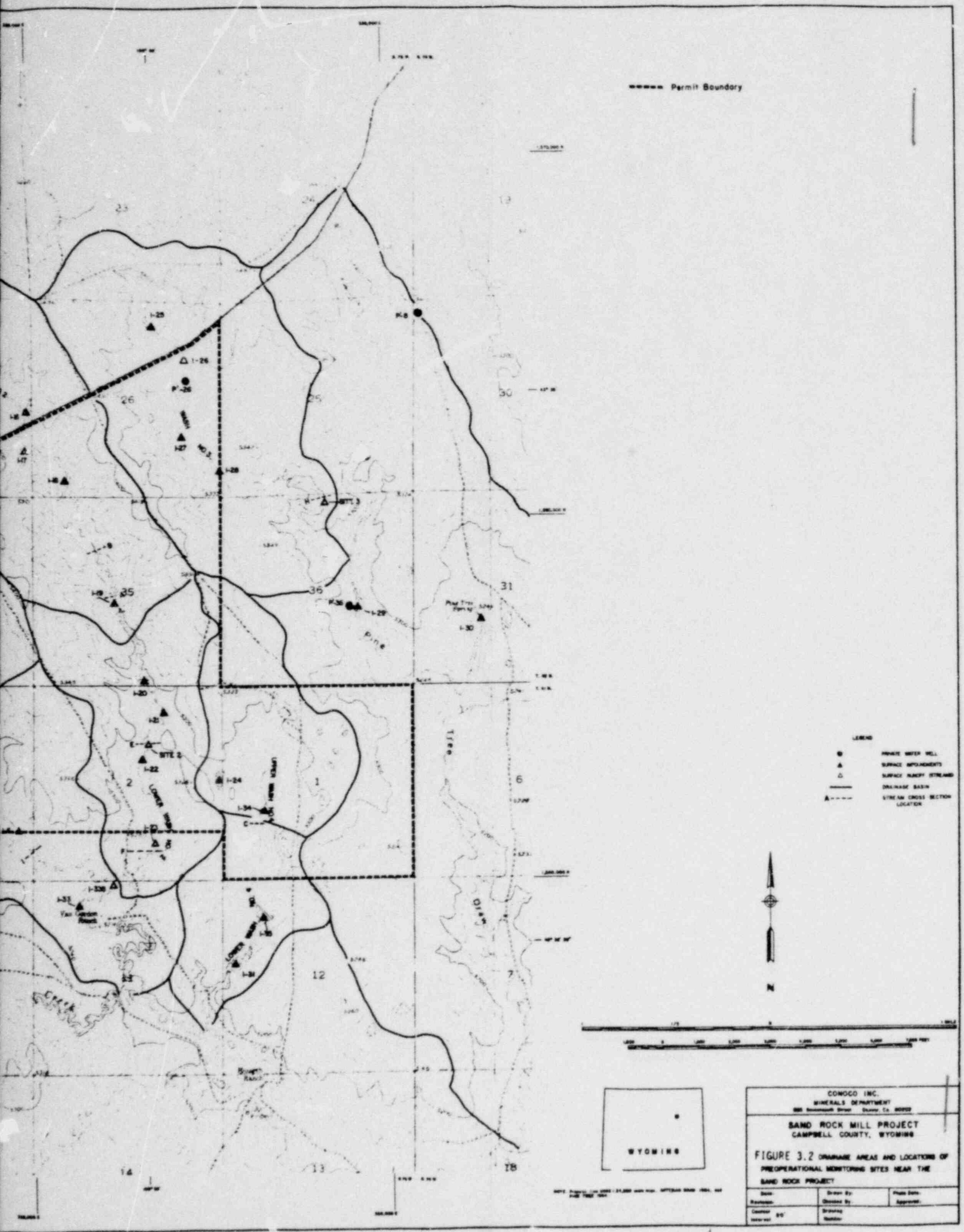

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FIGURE 3.2 DRAINAGE AREAS AND LOCATIONS OF PREOPERATIONAL MONITORING SITES NEAR THE SAND ROCK PROJECT

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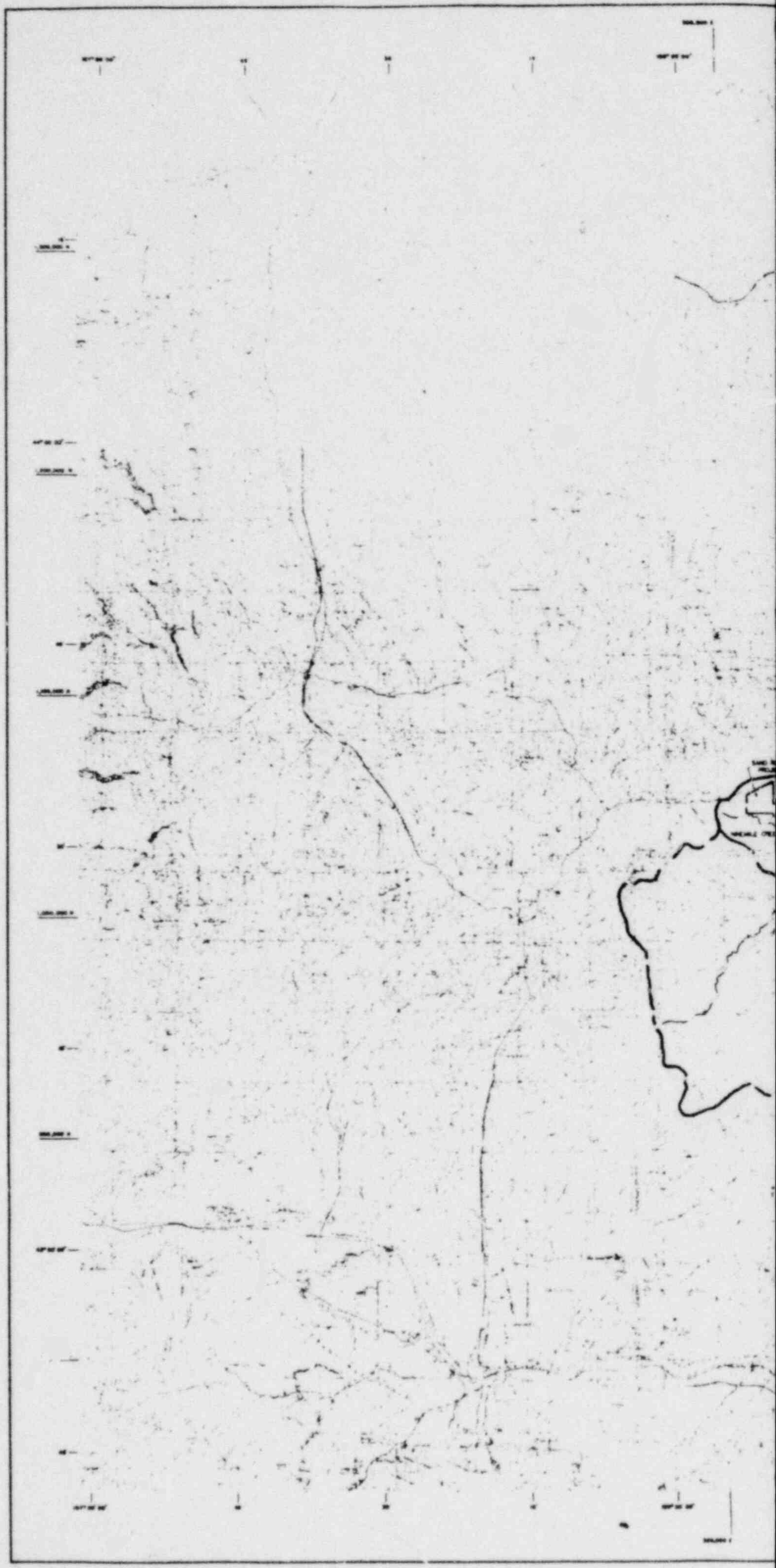
Contour Interval 20'	Drawing Number	



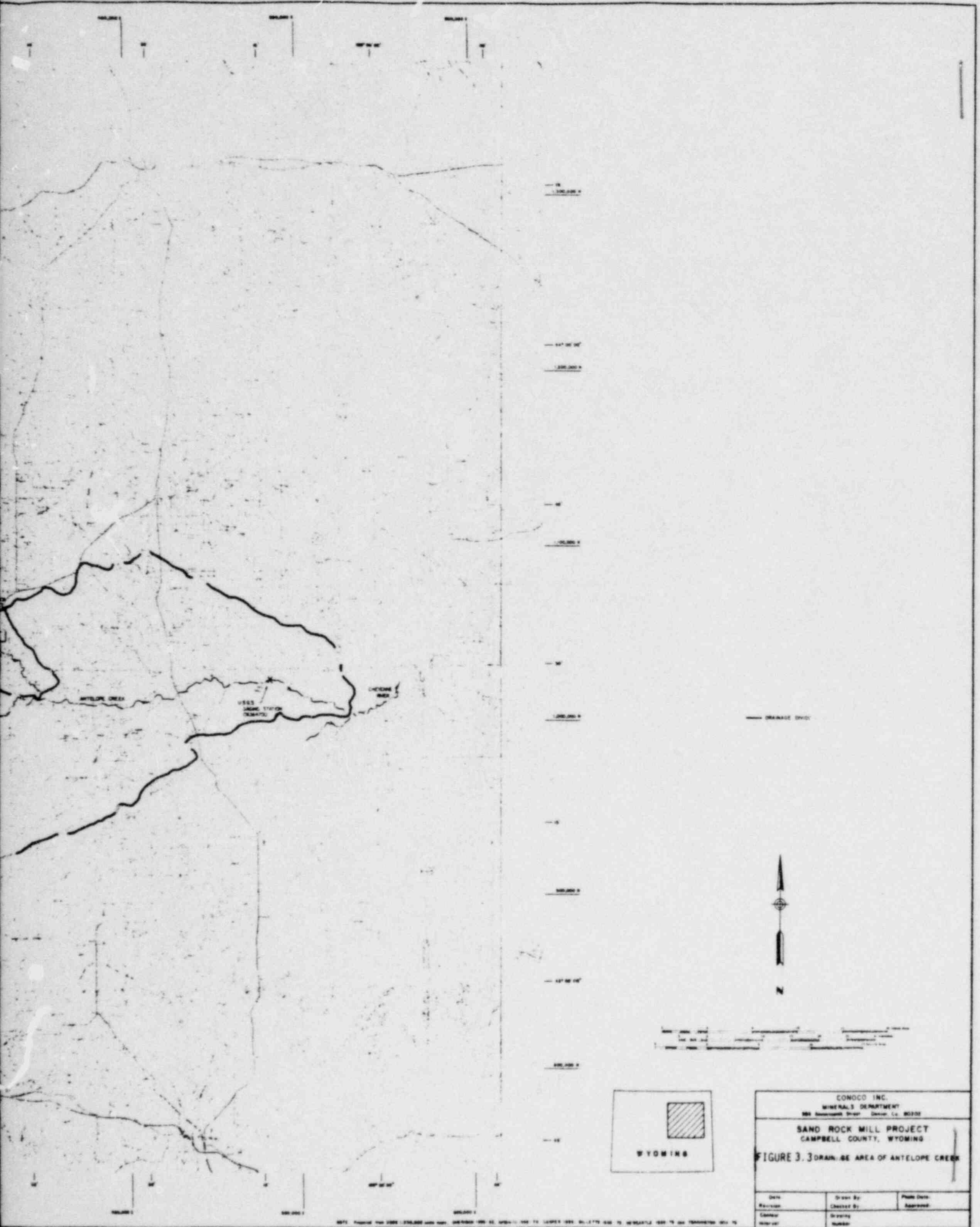


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FIGURE 3.3 DRAINAGE AREA OF ANTELOPE CREEK

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Contour Interval	Drawing Number	

Ninemile Creek has a total drainage area of 160 square kilometers (63 square miles), a channel length of approximately 32 kilometers (20 miles), and an average channel gradient of 0.006 (ft/ft). The elevation difference from headwaters to mouth is 186 meters (610 feet) with a maximum basin elevation of approximately 1,680 meters (5,500 feet) above msl. Upstream of monitoring site 1-7 (Figure 3.2) 88 square kilometers (34 square miles) of the Ninemile Creek basin drain the Sand Rock project area. The channel length within this area is approximately 17 kilometers (10.5 miles) with an average gradient of 0.007 (ft/ft).

Simmons Draw is a Ninemile Creek tributary flowing southeasterly through the Sand Rock project (Figures 3.1 and 3.2). Its total drainage area is 21 square kilometers (8.1 square miles). The channel length is 11 kilometers (6.8 miles) with an average gradient of 0.007 (ft/ft). Total basin elevation difference is 79 meters (260 feet) with a maximum elevation of approximately 1,670 meters (5,475 feet), above msl.

Pine Tree Draw, with a drainage area of 21 square Km (8.2 square miles), flows from the north into Ninemile Creek on the eastern edge of the project area (Figures 3.1 and 3.2). The channel length is approximately 12 kilometers (7.6 miles), and the average gradient is 0.009 (ft/ft). The maximum basin elevation approaches 1,670 meters (5,470 feet) above msl, and the minimum is approximately 1,560 meters (5,110 feet).

Simmons Draw has tributaries which flow in a predominantly southerly direction in the Sand Rock project area. These tributaries are labeled Washes 1 and 2 on Figures 3.1 and 3.2. Wash 2 is further subdivided into Upper Wash 2 and Lower Wash 2 based on the channel reach being upstream and downstream of the proposed mining Pit 35N. Wash [illegible] which is a tributary to Ninemile Creek, is also further divided into Upper Wash 4 and Lower Wash 4 at the location of the proposed mill tailings evaporation pond dam.

Wash 1 has a drainage area of 4.4 square kilometers (1.7 square miles), a channel length of 4.5 kilometers (2.8 miles), and an average channel gradient of 0.014 (ft/ft). The basin elevation difference is approximately 62 meters (205 feet) with a maximum elevation of 1,670 meters (5,475 feet) above msl.

Upper Wash 2 and Lower Wash 2 have drainage areas of 4.9 (1.9) and 2.5 square kilometers (0.95 square miles), respectively. Their respective channel lengths are 5.0 (3.1) and 3.5 kilometers (2.2 miles) with average gradients of 0.012 and 0.007 (ft/ft).

The drainage areas of Upper Wash 4 and Lower Wash 4 are 1.8 (0.70) and 1.4 square kilometers (0.53 square miles), respectively. Channel lengths are 0.74 (0.46) and 2.1 kilometers (1.3 miles) with respective gradients of 0.017 and 0.013 (ft/ft).

Wash 3 (see Figures 3.1 and 3.2) drains into Pine Tree Draw from the northwest in Section 36 of T42N-R75W. Its drainage area is 4.7 square kilometers (1.8 square miles), the channel length and average gradient are 5.1 kilometers (3.2 miles) and 0.014 (ft/ft), respectively, and the basin elevation difference is approximately 70 meters (230 feet). The maximum basin elevation is approximatey 1,670 meters (5,480 feet) above msl.

Drainage basin characteristics for Antelope Creek, Ninemile Creek, and all of the tributaries relevant to the Moore Ranch project area are summarized in Table 3.6.1.1.

3.6.1.2 CHANNEL GEOMETRY

Representative channel cross sections for Upper Wash 2 in the area of Pit 35N and upstream from this pit are shown on Figures 3.4 and 3.5,

TABLE 3.6.1.1

DRAINAGE BASIN CHARACTERISTICS FOR THE SAND ROCK PROJECT AREA

Drainage Basin	Drainage Area (mi^2)	Channel Length (mi)	Elevation Differences (ft)	Channel Gradient (ft/mi)	Channel Gradient (ft/ft)
Antelope Creek (total)	980	62	1,825	29.4	0.006
Antelope Creek (at USGS gage)	959	52	1,775	34.1	0.006
Ninemile Creek (total)	63	20	610	30.5	0.006
Ninemile Creek (@ I-7)	34	10.5	390	37.1	0.007
Pine Tree Draw	8.2	7.6	370	48.9	0.009
Simmons Draw	8.1	6.8	260	38.2	0.007
Wash No. 1	1.7	2.8	205	73.2	0.014
Upper Wash No. 2	1.9	3.1	190	61.3	0.012
Lower Wash No. 2	0.95	2.2	80	36.4	0.007
Wash No. 3	1.8	3.2	230	71.9	0.014
Upper Wash No. 4	0.70	0.46	130	90.2	0.017
Lower Wash No. 4	0.53	1.3	90	69.2	0.013

respectively. Figure 3.6 shows a typical channel cross-section of Upper Wash 4 downstream of the proposed mill evaporation pond, and Figure 3.7 shows a channel cross-section for Wash 1 west of the backfill storage area. Channel conveyance characteristics including discharge, cross-sectional area, velocity, channel gradient, hydraulic radius, Manning's roughness coefficient the the volumes for the 5-year and 100-year floods are also shown for each channel cross-section on their respective figures. Locations of each channel cross-section site are shown on Figure 3.2. Additional channel cross-sections for Lower Wash 2, Simmons Draw, Ninemile Creek, and Wash 3 at crest stage gage locations are shown on Figures 3.8, 3.9, 3.10 and 3.11, respectively. Figure 3.12 shows a channel cross-section with channel conveyance characteristics computed of Simmons Draw downstream from the Moore Ranch project area. These channel cross-section sites are also shown on Figure 3.12.

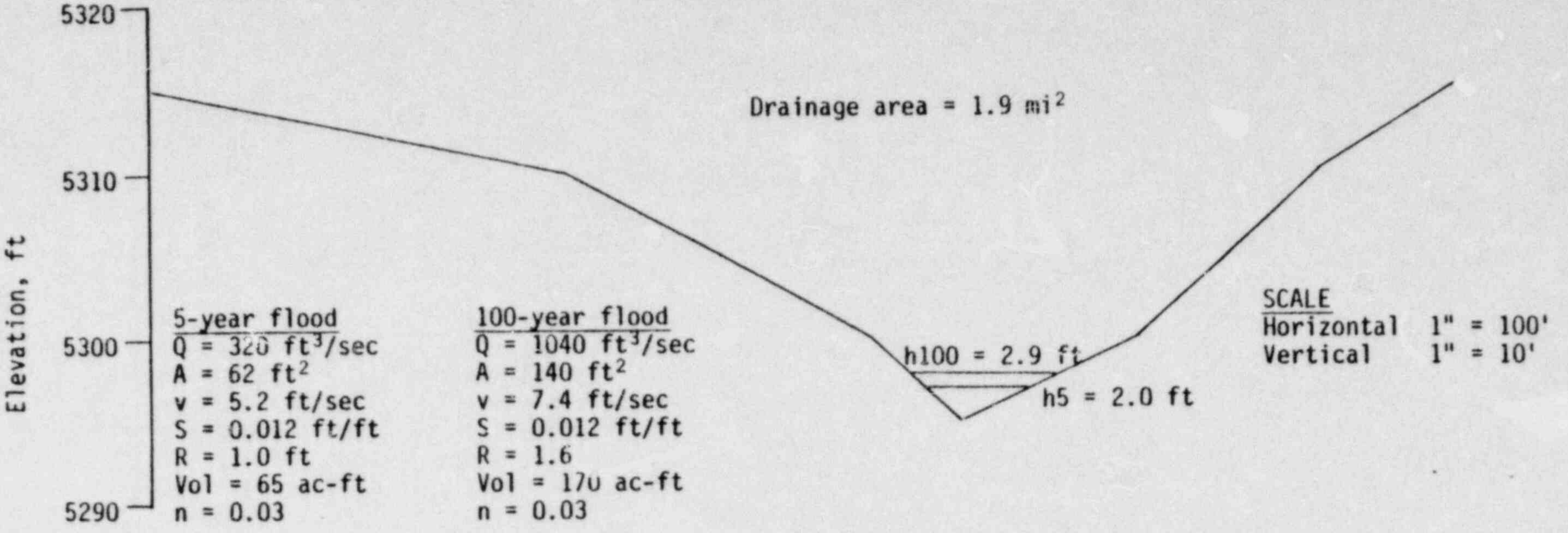
Samples of channel bed material from Simmons Draw, Wash 2, and Wash 3 were collected and subjected to mechanical and radiation analysis. Typically, only 10 to 15 percent of the samples passed through the 0.1 millimeter sieve. Curves of grain size distribution are given in Figure 3.13, 3.14 and 3.15.

Channel bed radionuclides are discussed in Section 3.6.1.6 and test results are given in Table 3.6.1.7.

3.6.1.3 SURFACE WATER RUNOFF

FLOOD ANALYSIS

In Wyoming at least three techniques are available for estimating flood flows and volumes in ungaged basins for different recurrence intervals. Lowham (1976) presented a basin characteristics technique whereby peak flow was related to drainage area with consideration of different regions in the state.



5-year flood
$Q = 320\ ft^3/sec$
$A = 62\ ft^2$
v = 5.2 ft/sec
S = 0.012 ft/ft
R = 1.0 ft
Vol = 65 ac-ft
n = 0.03

100-year flood
$Q = 1040\ ft^3/sec$
$A = 140\ ft^2$
v = 7.4 ft/sec
S = 0.012 ft/ft
R = 1.6
Vol = 170 ac-ft
n = 0.03

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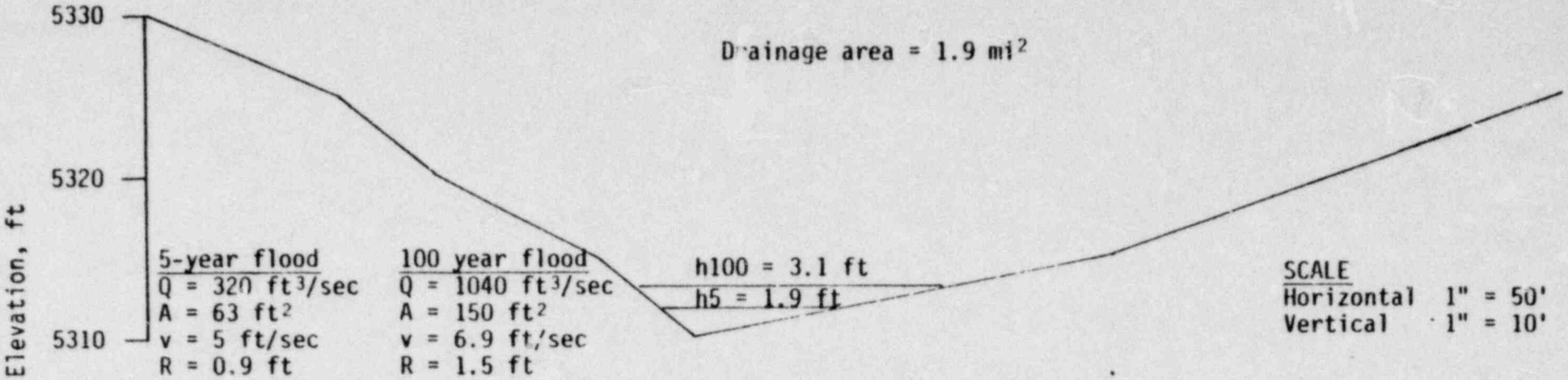
FIGURE 3.4

CHANNEL-CROSS SECTION OF UPPER WASH NO. 2 IN VICINITY OF PIT 35N (LOCATION A SHOWN ON FIGURE 3.2).



Drainage area = 1.9 mi^2

5-year flood
Q = 320 ft^3/sec
A = 63 ft^2
v = 5 ft/sec
R = 0.9 ft
S = 0.012 ft/ft
Vol = 65 ac-ft
n = 0.03

100 year flood
Q = 1040 ft^3/sec
A = 150 ft^2
v = 6.9 ft/sec
R = 1.5 ft
S = 0.012 ft/ft
Vol = 170 ac-ft
n = 0.03

SCALE
Horizontal 1" = 50'
Vertical 1" = 10'

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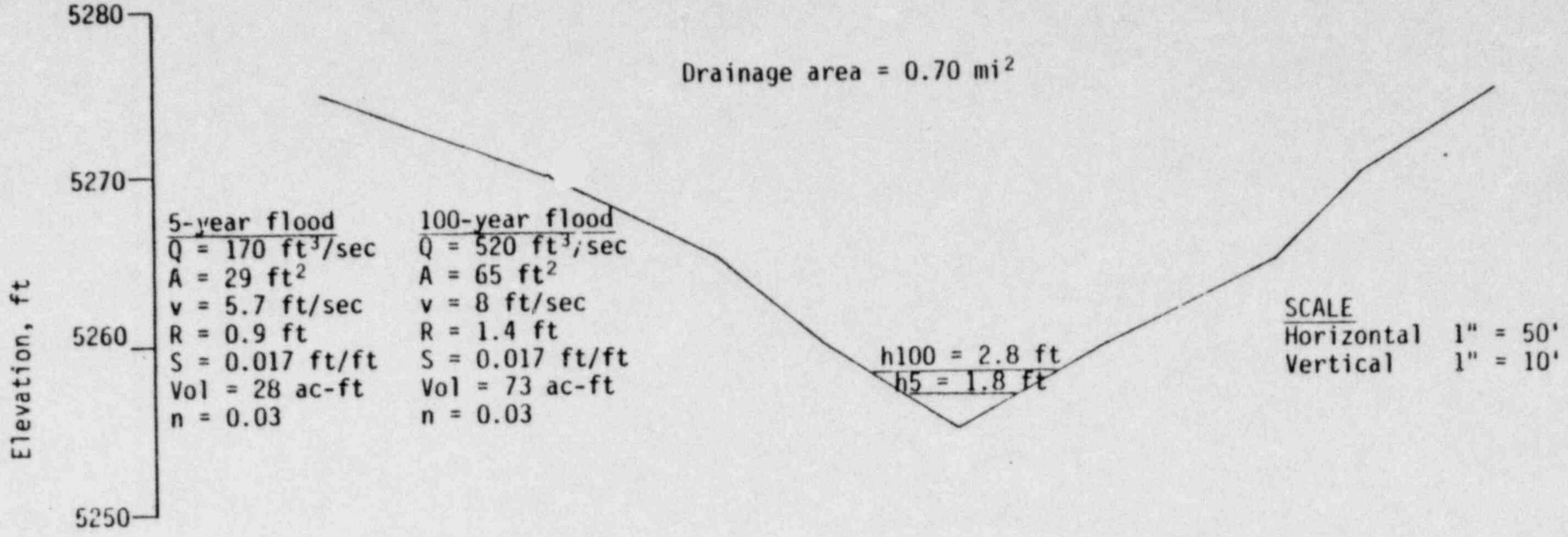
FIGURE 3.5

CHANNEL-CROSS SECTION OF UPPER WASH NO. 2 UPSTREAM OF PIT 35N (LOCATION B SHOWN ON FIGURE 3.2).



5-year flood
Q = 170 ft³/sec
A = 29 ft²
v = 5.7 ft/sec
R = 0.9 ft
S = 0.017 ft/ft
Vol = 28 ac-ft
n = 0.03

100-year flood
Q = 520 ft³/sec
A = 65 ft²
v = 8 ft/sec
R = 1.4 ft
S = 0.017 ft/ft
Vol = 73 ac-ft
n = 0.03

SCALE
Horizontal 1" = 50'
Vertical 1" = 10'

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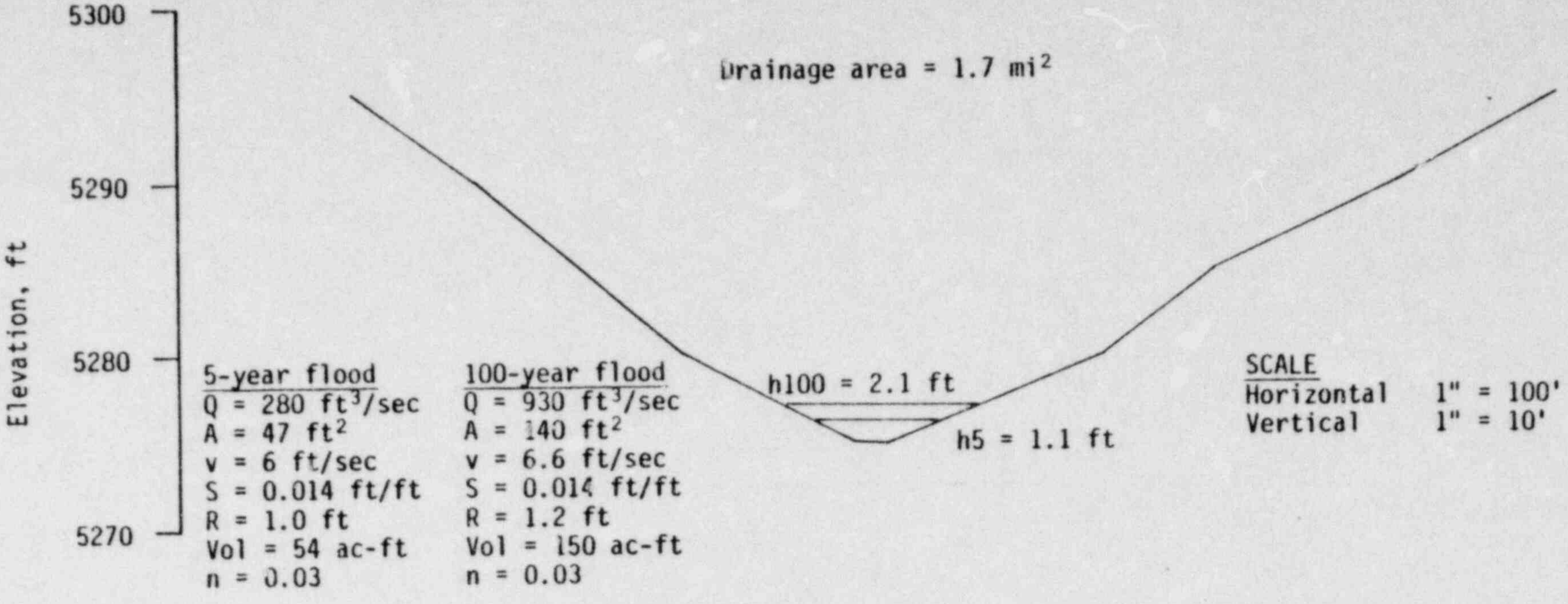
FIGURE 3.6

CHANNEL-CROSS SECTION OF UPPER WASH NO. 4 DOWNSTREAM FROM MILL TAILINGS EVAPORATION POND (LOCATION C SHOWN IN FIGURE 3.2).



5-year flood
$Q = 280\ ft^3/sec$
$A = 47\ ft^2$
v = 6 ft/sec
S = 0.014 ft/ft
R = 1.0 ft
Vol = 54 ac-ft
n = 0.03

100-year flood
$Q = 930\ ft^3/sec$
$A = 140\ ft^2$
v = 6.6 ft/sec
S = 0.014 ft/ft
R = 1.2 ft
Vol = 150 ac-ft
n = 0.03

SCALE
Horizontal 1" = 100'
Vertical 1" = 10'

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FIGURE 3.7

CHANNEL-CROSS SECTION OF WASH NO. 1 WEST OF SOUTHERN OVERBURDEN DUMP (LOCATION D SHOWN ON FIGURE 3.2).

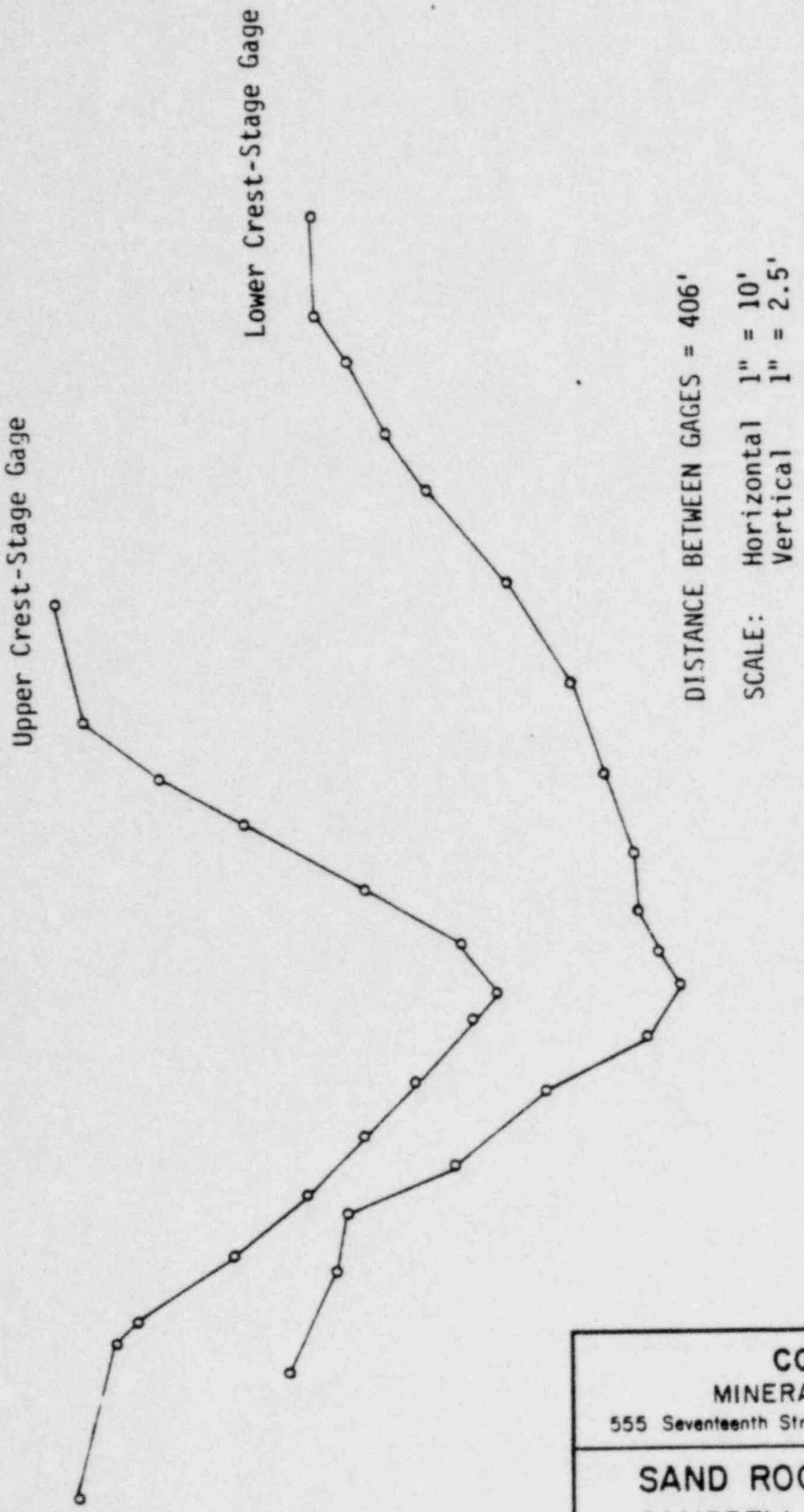

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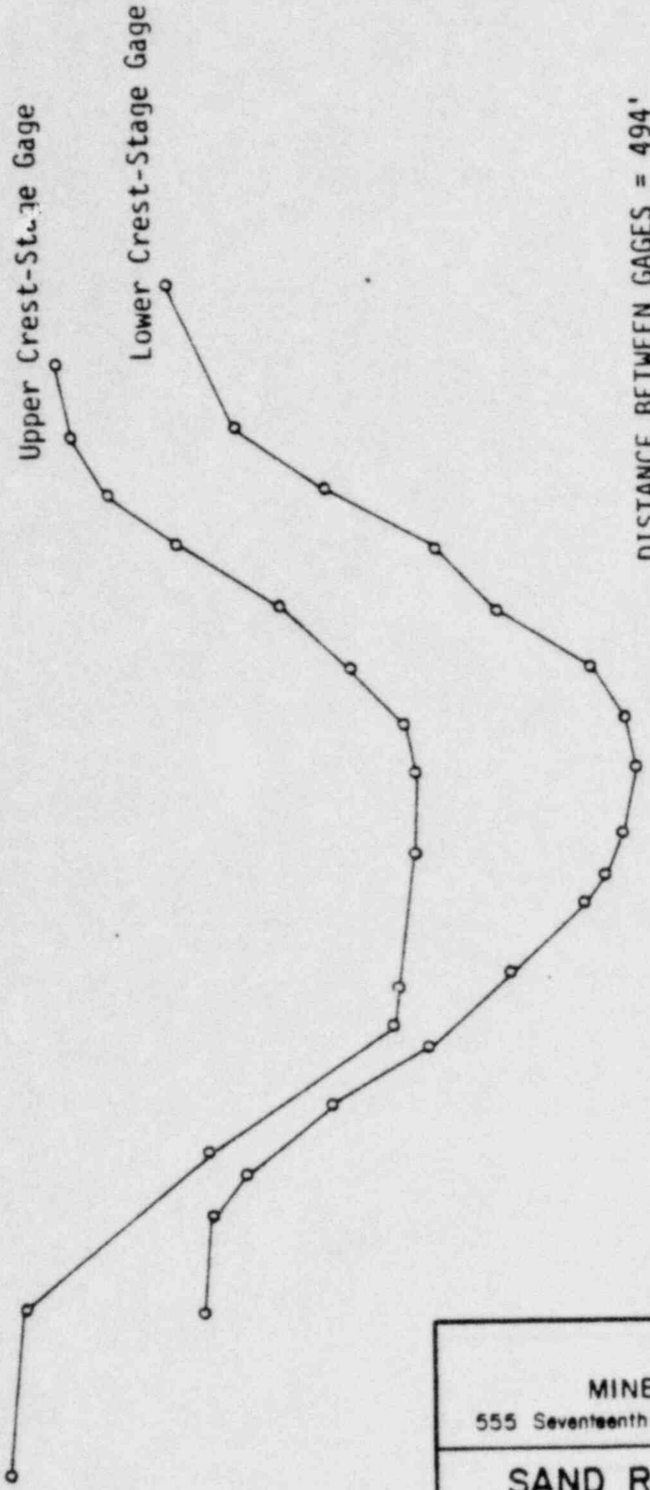
FIGURE 3.8

CHANNEL-CROSS SECTIONS OF LOWER WASH NO. 2 AT UPPER AND LOWER CREST-STAGE GAGES (LOCATION E SHOWN ON FIGURE 3.2).



DISTANCE BETWEEN GAGES = 494'

SCALE: Horizontal 1" = 10'
Vertical 1" = 2.5'

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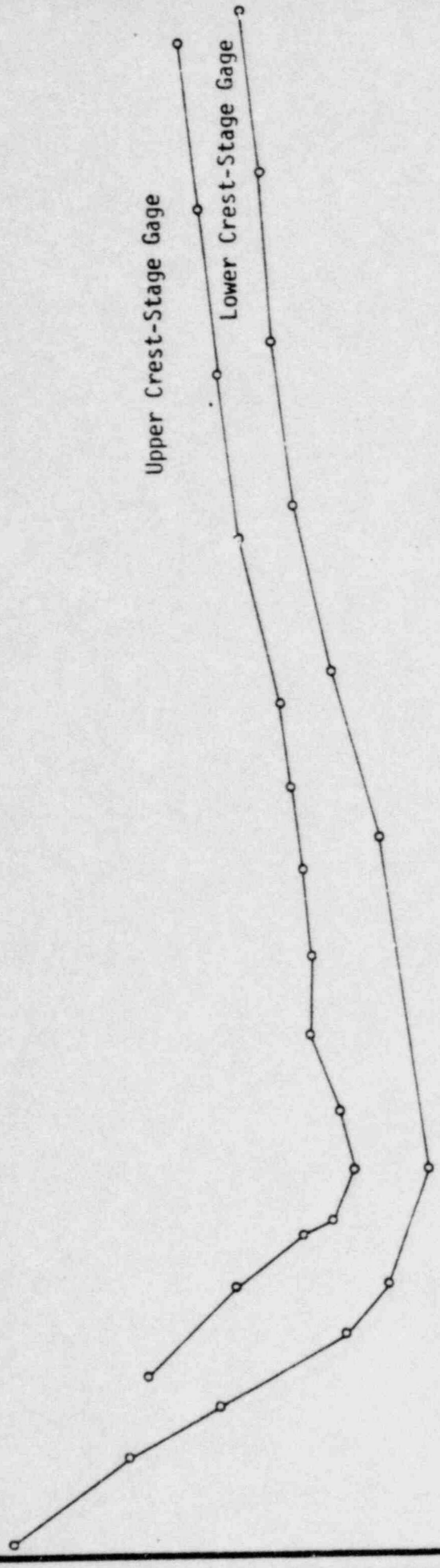
FIGURE 3.9

CHANNEL-CROSS SECTIONS OF SIMMONS DRAW AT UPPER AND LOWER CREST-STAGE GAGES (LOCATION F SHOWN ON FIGURE 3.2).



DISTANCE BETWEEN GAGES = 365'

SCALE: Horizontal 1" = 10'
Vertical 1" = 2.5'

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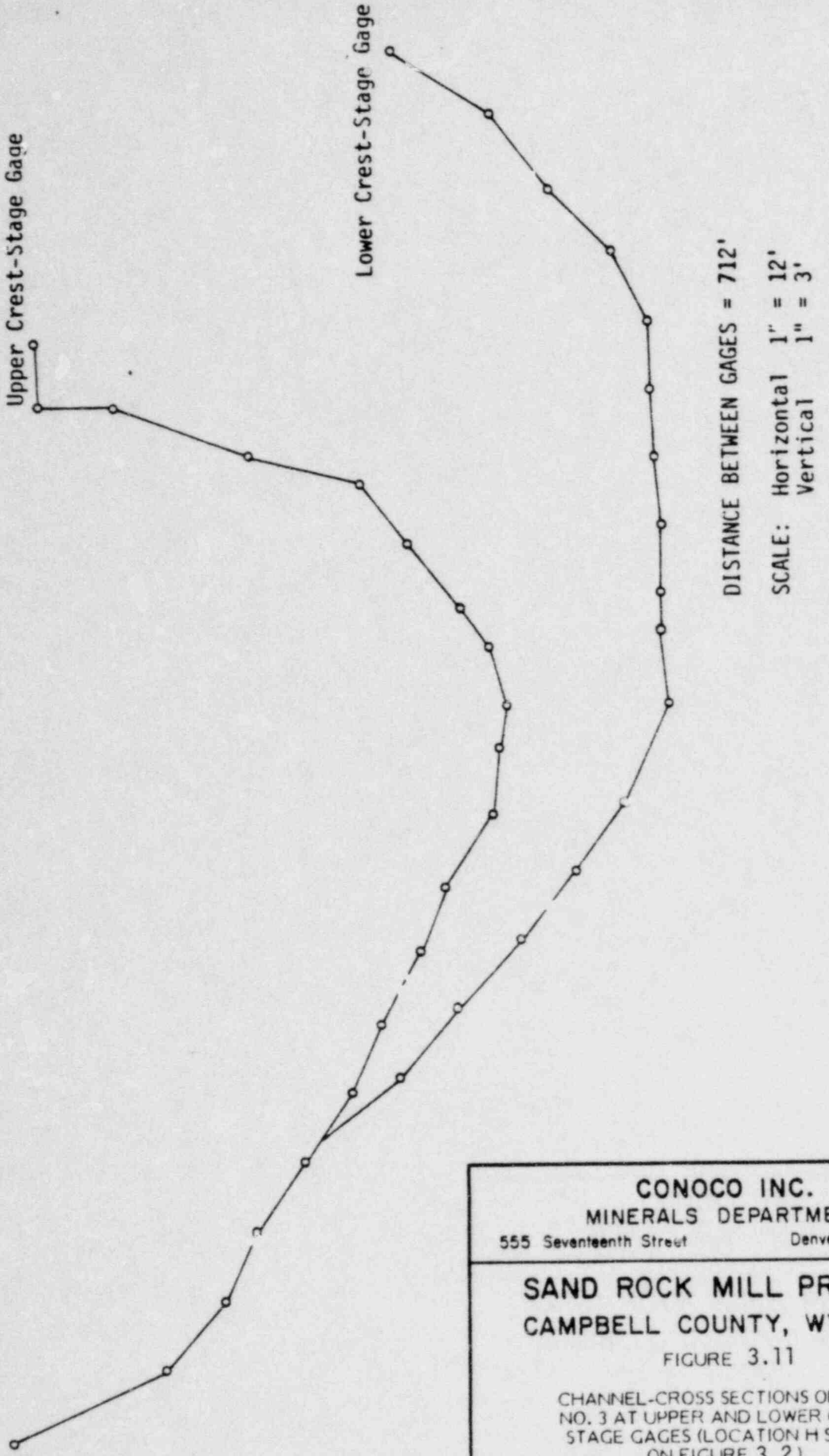
FIGURE 3.10

CHANNEL-CROSS SECTIONS OF NINEMILE CREEK AT CREST-STAGE GAGES (LOCATION G SHOWN ON FIGURE 3.1).



DISTANCE BETWEEN GAGES = 712'

SCALE: Horizontal 1" = 12'
Vertical 1" = 3'

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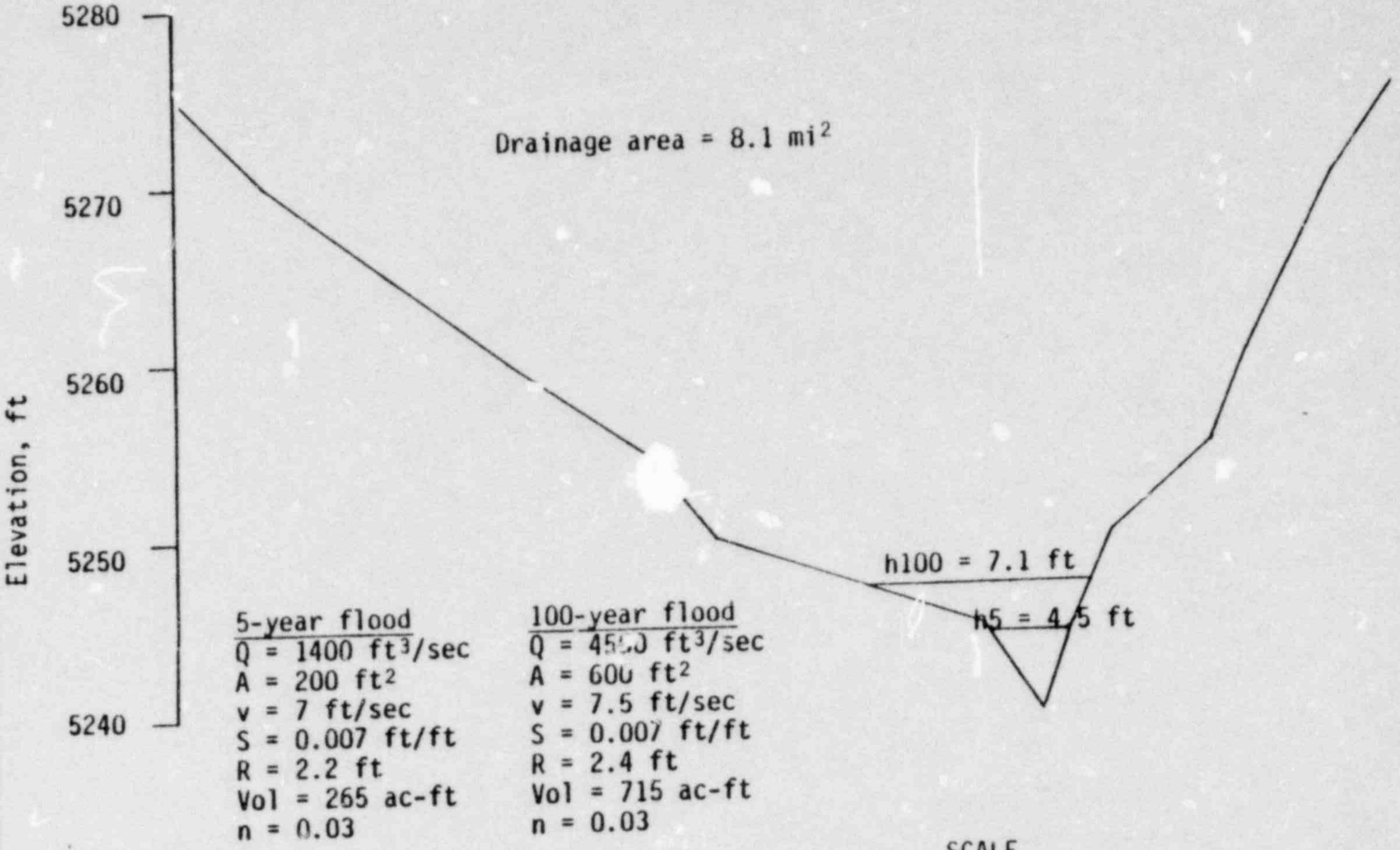
FIGURE 3.11

CHANNEL-CROSS SECTIONS OF WASH NO. 3 AT UPPER AND LOWER CREST-STAGE GAGES (LOCATION H SHOWN ON FIGURE 3.2).



Drainage area = 8.1 mi^2

5-year flood
Q = 1400 ft^3/sec
A = 200 ft^2
v = 7 ft/sec
S = 0.007 ft/ft
R = 2.2 ft
Vol = 265 ac-ft
n = 0.03

100-year flood
Q = 4500 ft^3/sec
A = 600 ft^2
v = 7.5 ft/sec
S = 0.007 ft/ft
R = 2.4 ft
Vol = 715 ac-ft
n = 0.03

SCALE
Horizontal 1" = 200'
Vertical 1" = 10'

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FIGURE 3.12

CHANNEL-CROSS SECTION FOR SIMMONS DRAW DOWNSTREAM FROM MOORE RANCH PROJECT AREA (LOCATION I SHOWN ON FIGURE 3.2).

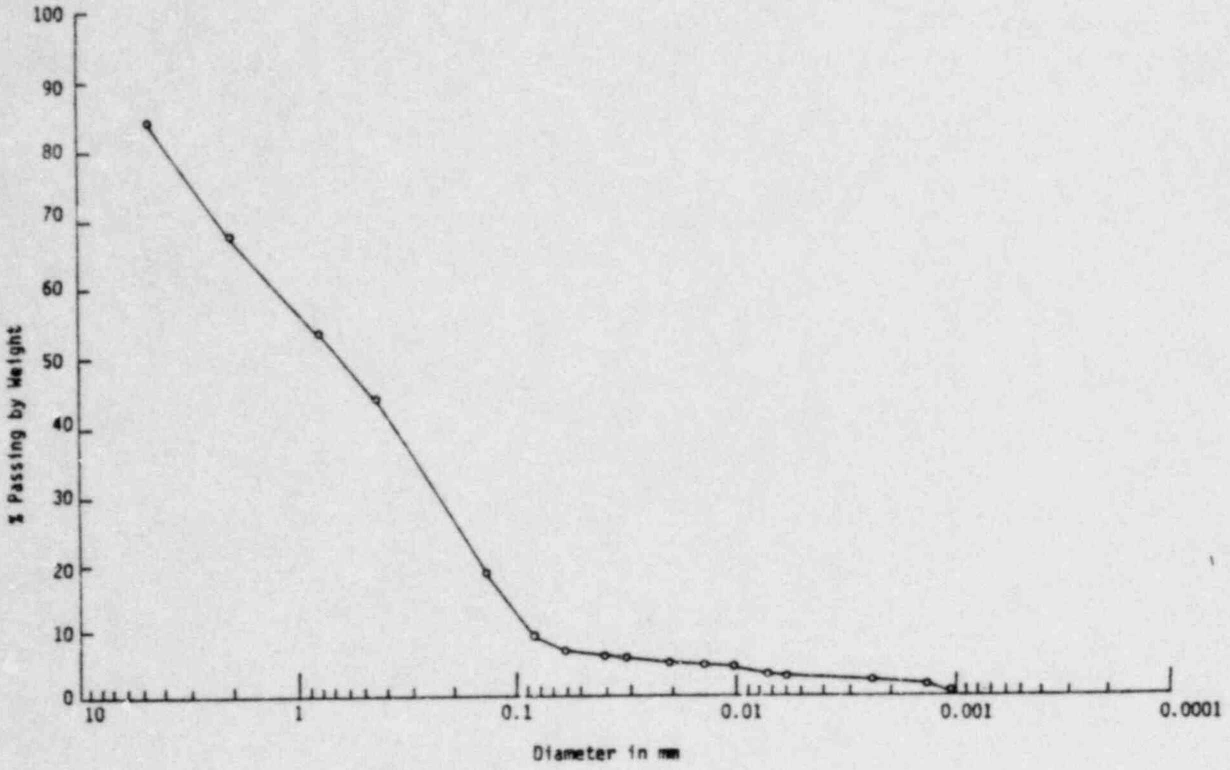

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FIGURE 3.13

GRAIN SIZE DISTRIBUTION
FOR SIMMONS DRAW

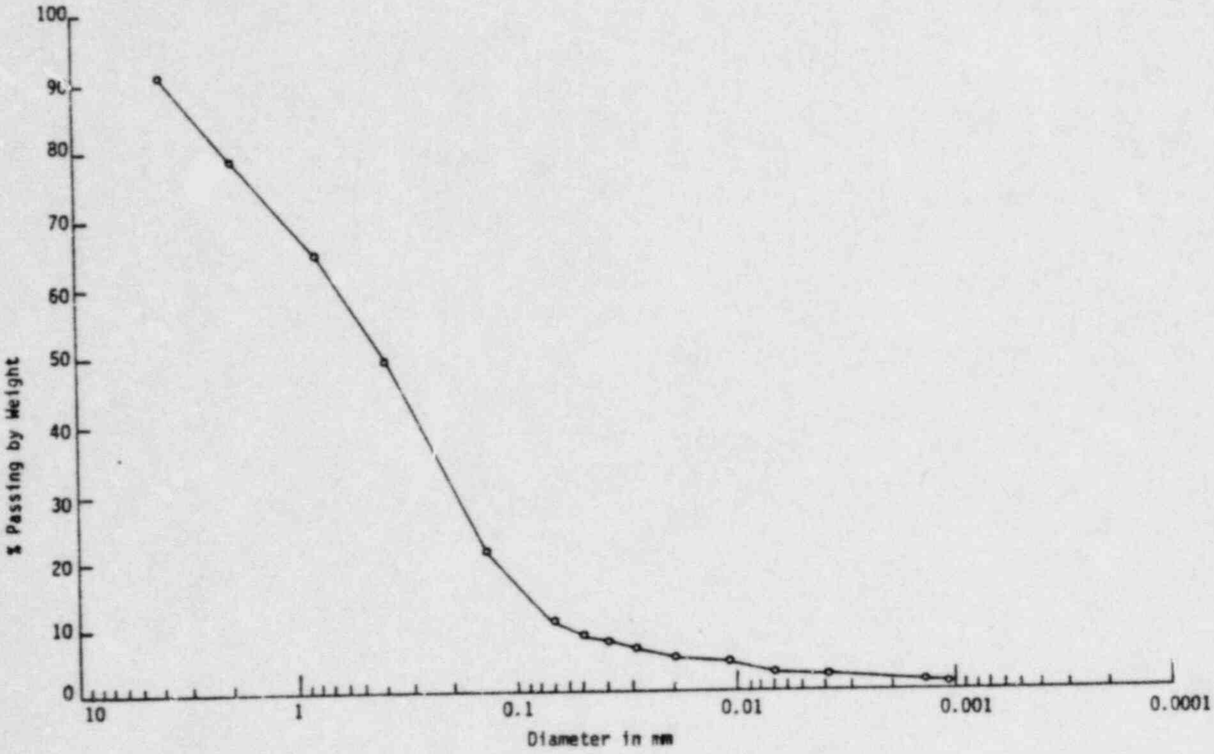

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FIGURE 3.14

GRAIN SIZE DISTRIBUTION
CURVE FOR WASH NO. 2

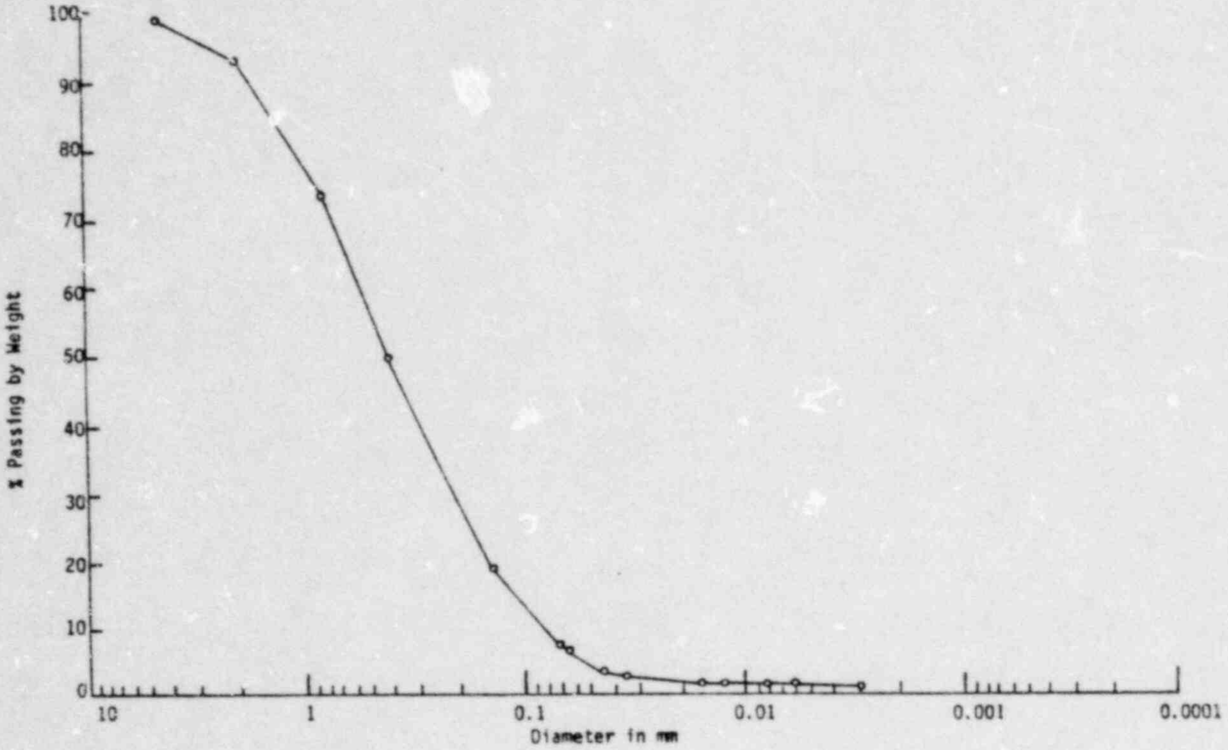

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FIGURE 3.15

GRAIN SIZE DISTRIBUTION
FOR WASH NO. 3

Lowham's regression equations can be used for basins with drainage areas between 13 and 13,727 square kilometers (5 and 5,300 square miles). However, using a graphical approach, this technique can be used for basins slightly less than one square mile in area. The results of this analysis should be used with caution, because it involves extrapolation beyond the range of validity of the regression equation, and the results are typically non-conservative.

For small basins (approximately 26 square kilometers (10 square miles) and less) Craig and Rankl (1977) developed basin characteristic regression equations which use other basin parameters in addition to drainage area to compute peak flows and flood volumes. Also, for small basins, the U.S. Soil Conservation Service (SCS) has developed a technique to estimate peak flows and flood volumes. These techniques are published in their Engineering Field Manual (1969). The SCS technique uses peak rainfall values published by the U.S. Weather Bureau and then takes into consideration soil and vegetation characteristics and basin slope and drainage area to make the flood flow and volume estimates.

Table 3.6.1.2 presents flood flow and volume estimates for the 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year events. For comparison, values obtained by using the three available techniques are tabulated. Mean annual flows using Lowham's technique are also shown. However, mean annual flow values are questionable for ephemeral or intermittent streams because many zero values must be averaged with the relatively infrequent runoff events.

Values listed in Table 3.6.1.2 under the SCS method were obtained using curve number 75 and 24-hour duration precipitation values from Miller and others (1973). Table 3.6.1.3 shows precipitation for selected recurrence intervals for different duration periods.

TABLE 3.6.1.2

PEAK FLOOD DISCHARGES AND FLOOD VOLUMES FOR SELECTED RECURRENCE INTERVALS FOR STREAMS IN THE SAND ROCK PROJECT AREA

Stream	Drainage Area (mi^2)	Lowham's Method						Craig and Rank's Method											
		Flood Discharge, ft^3/sec						Flood Discharge, ft^3/sec						Flood Volume, ac-ft					
		Qa*	5-yr	10-yr	25-yr	50-yr	100-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
Antelope Creek (total)	980	20	3,000	5,400	9,500	14,000	19,000	-	-	-	-	-	-	-	-	-	-	-	-
Antelope Creek (at USGS gage)	959	20	3,000	5,400	9,400	14,000	19,000	-	-	-	-	-	-	-	-	-	-	-	-
Ninemile Creek (total)	63	4.7	1,100	2,000	3,400	5,000	6,900	2,400	4,700	6,900	9,800	14,000	18,000	630	1,100	1,500	2,000	2,400	2,800
Ninemile Creek (permit area)	34	3.4	900	1,600	2,700	3,900	5,500	2,100	3,800	5,300	7,300	10,000	13,000	580	980	1,200	1,600	1,900	2,200
Pine Tree Draw	8.2	1.6	540	930	1,600	2,300	3,200	560	1,100	1,600	2,200	3,100	3,900	98	170	230	310	380	450
Simmons Draw	8.1	1.6	540	920	1,600	2,300	3,200	790	1,400	2,000	2,600	3,600	4,500	170	280	360	470	550	640
Wash No. 1	1.7	0.69	310	520	900	1,300	1,800	220	410	580	770	1,100	1,310	32	55	73	96	110	130
Upper Wash No. 2	1.9	0.73	320	540	940	1,400	1,900	270	480	670	890	1,200	1,500	43	71	92	120	140	160
Lower Wash No. 2	0.95	0.50	250	420	730	1,000	1,500	320	500	640	770	990	1,200	70	100	120	150	170	180
Wash No. 3	1.8	0.71	310	530	920	1,300	1,800	210	400	560	760	1,000	1,300	29	51	67	90	110	130
Upper Wash No. 4	0.70	0.43	220	370	650	940	1,300	150	260	360	460	610	740	21	35	44	57	67	78
Lower Wash No. 4	0.53	0.37	200	340	590	850	1,200	160	270	350	440	570	670	27	41	51	64	73	83

*Qa = mean annual flow (ft^3/sec)

TABLE 3.6.1.2

(CONT.)

		Soil Conservation Service Method												
			Flood Discharge, ft^3/sec						Flood Volume, ac-ft					
Stream	Drainage Area (mi^2)	Qa*	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
Antelope Creek (total)	980	20	-	-	-	-	-	-	-	-	-	-	-	-
Antelope Creek (at USGS gage)	959	20	-	-	-	-	-	-	-	-	-	-	-	-
Ninemile Creek (total)	63	4.7	-	-	-	-	-	-	940	2,000	2,800	4,100	5,100	6,100
Ninemile Creek (permit area)	34	3.4	-	-	-	-	-	-	510	1,100	1,500	2,200	2,800	3,300
Pine Tree Draw	8.2	1.6	-	-	-	-	-	-	120	260	360	540	660	800
Simmons Draw	8.1	1.6	-	-	-	-	-	-	120	250	360	530	660	790
Wash No. 1	1.7	0.69	63	150	250	350	450	550	25	53	75	110	140	170
Upper Wash No. 2	1.9	0.73	68	160	260	370	480	580	28	60	84	120	150	180
Lower Wash No. 2	0.95	0.50	43	100	150	240	310	360	14	30	42	62	77	92
Wash No. 3	1.8	0.71	65	160	260	360	470	570	27	57	80	120	150	170
Upper Wash No. 4	0.70	0.43	34	85	140	190	250	300	10	22	31	46	57	68
Lower Wash No. 4	0.53	0.37	28	70	110	150	210	250	7.9	17	23	35	43	51

*Qa = mean annual flow (ft^3/sec)

TABLE 3.6.1.3

PRECIPITATION VALUES FOR SELECTED RECURRENCE INTERVALS AND DURATIONS IN THE SAND ROCK PROJECT AREA

	Precipitation, in.							
Duration	2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr	500-Yr	Duration
5-Min	.25	.35	.42	.52	.59	.66	.83	5-Min
10-Min	.38	.54	.65	.80	.92	1.03	1.29	10-Min
15-Min	.48	.69	.83	1.01	1.16	1.30	1.64	15-Min
30-Min	.67	.95	1.14	1.40	1.61	1.81	2.27	30-Min
1-Hour	.85	1.21	1.45	1.78	2.03	2.29	2.87	1-Hour
2-Hour	.95	1.33	1.59	1.94	2.22	2.49	3.12	2-Hour
3-Hour	1.03	1.44	1.71	2.09	2.38	2.67	3.33	3-Hour
6-Hour	1.25	1.71	2.01	2.44	2.77	3.10	3.86	6-Hour
12-Hour	1.47	2.00	2.35	2.84	3.22	3.60	4.47	12-Hour
24-Hour	1.70	2.29	2.69	3.24	3.67	4.10	5.09	24-Hour

FLOW REGIME

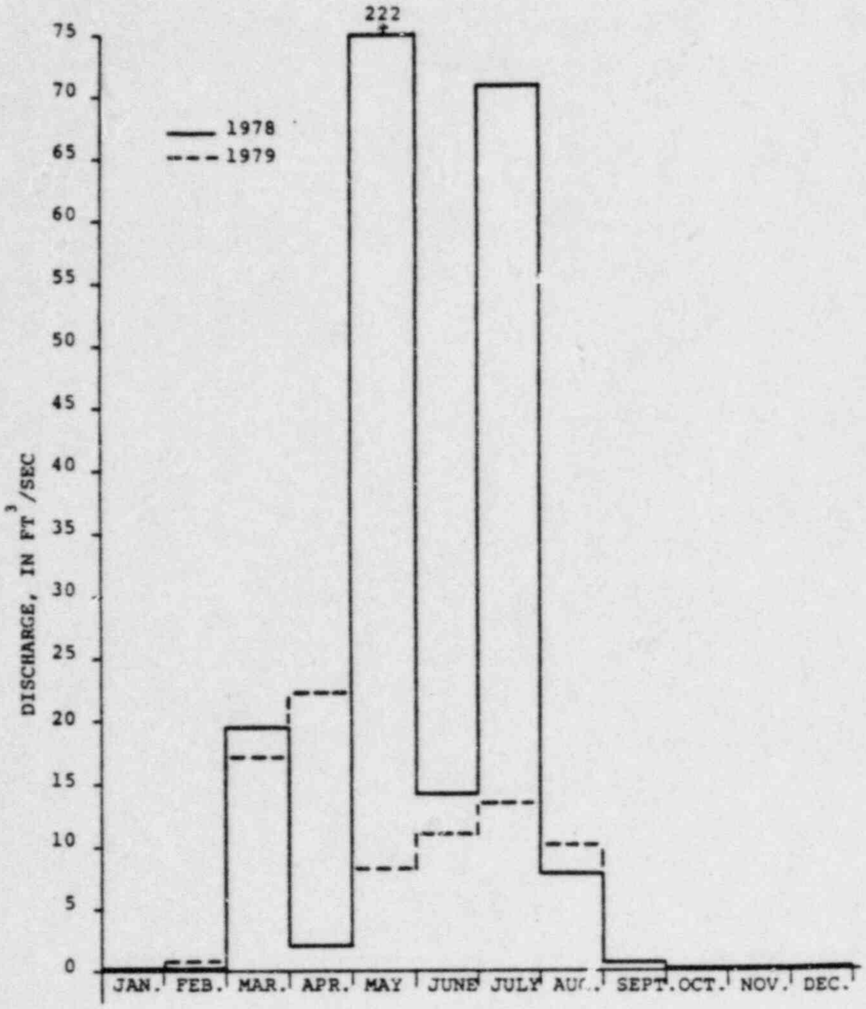
At the U.S. Geological Survey stream gaging site on Antelope Creek, discharge data are available for October 1977 through September 1979. Data are available from the Survey's annual report entitled Water Resources Data for Wyoming. Maximum flow observed during this period was 6,600 cubic feet/second, and minimum daily flow was 0.10 cubic feet/second. Mean discharge for water year 1978 was 0.81 cubic meters/second (28.7 cubic feet/second) and 0.20 cubic meters/second (7.09 cubic feet/second) for water year 1979. Mean monthly discharges for water years 1978 and 1979 are shown on Figure 3.16. Most of the annual runoff occurs during the snowmelt and rainstorm events between March and August

For the smaller tributaries to Ninemile Creek in the Sand Rock project area, long periods of no flow would be expected. As in the case stated above, runoff in Ninemile Creek would be observed mainly during snowmelt and rainstorm events occurring between March and August.

Crest-stage data was not collected at the old surface water gaging stations (Sites 1 through 4) during this program due to very little runoff and unreliability of the existing sites. Crest-stage sampling sites and pond staff gages will be installed in the future to support the operational monitoring program.

3.6.1.4 SURFACE CONTROL STRUCTURES

Several small ponds exist downstream of the Sand Rock project. The first major surface water control structure downstream of the project is the Angostura Reservoir on the Cheyenne River in South Dakota. This reservoir is approximately 320 river kilometers (200 river miles) downstream of the Sand Rock project. Storage capacity of this reservoir for different pool elevations is given in the U.S. Geological Survey Water Supply Papers on surface water data of this area.



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SAND ROCK MILL PROJECT
CAMPBELL COUNTY, WYOMING

FIGURE 3.16

MEAN MONTHLY DISCHARGE FOR
ANTELOPE CREEK NEAR TECKLA, WYOMING,
FOR 1978 AND 1979 WATER YEARS

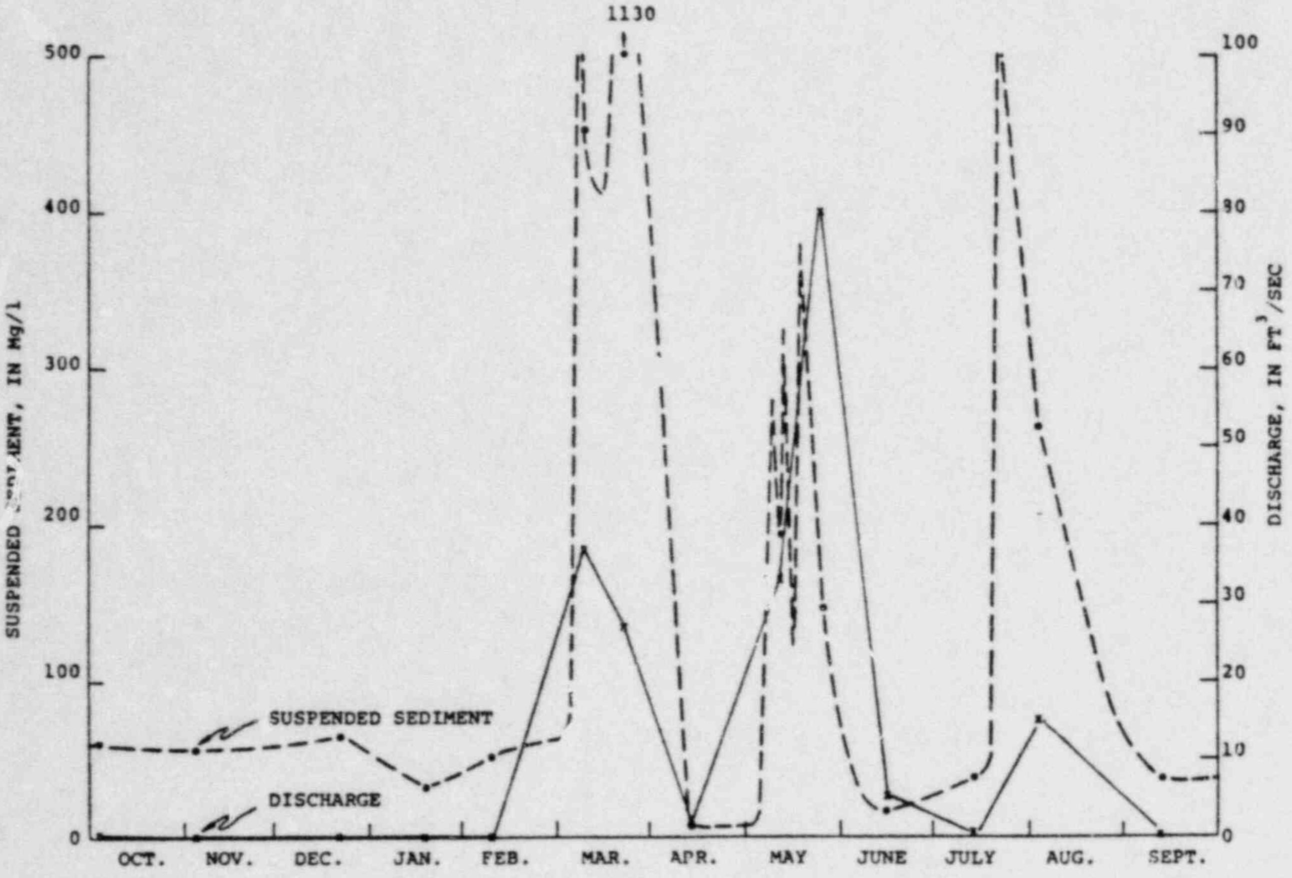
3.6.1.5 SURFACE WATER QUALITY

The U.S. Geological Survey has operated a stream gaging and water quality monitoring site (Antelope Creek near Teckla, Wyoming) since October 1977. Total dissolved solids ranged from less than 300 to greater than 2,000 mg/l in the first 2 years of operation. The water is extremely hard with values often exceeding 1,000 [illegible]. Calcium, magnesium, and sodium are all present in significant concentrations with no single cation being overwhelmingly dominant. Sulfate and bicarbonate are the dominant anions.

Observed suspended sediment concentrations of the Antelope Creek gage ranged from 5 to greater than 1,000 mg/l for the two-year period of record. The sediment content varies directly with water discharge. Therefore, the bulk of the sediment load is transported during spring snowmelt runoff and spring and summer thunderstorms. Figures 3.17 and 3.18 show the seasonal **variations** and the relationship with stream discharge at the Antelope Creek gage for water years 1978 and 1979, respectively.

Baseline surface water sampling began in June, 1979 and is scheduled to continue through the Spring of 1981. Samples are collected in accordance with Wyoming Department of Environmental Quality guidelines. Frequency of sampling (subject to the availability of surface water during dry periods) is guided by recommendations suggested in the NRC's Draft Generic Environmental Impact Statement.

Figure 3.1 displays sampling sites and the drainage patterns in and surrounding the project area. It should be noted that all surface drainage from the proposed project area drains past sample location 1-7 at a point immediately downstream of the confluence of Ninemile Creek and Pine Tree Draw (Section 18, T41N, R74W). Figure 3.2 shows surface runoff and impound ment sites which are located within or near the project area. Table 3.6.1.4 presents analytical data gathered during the program.



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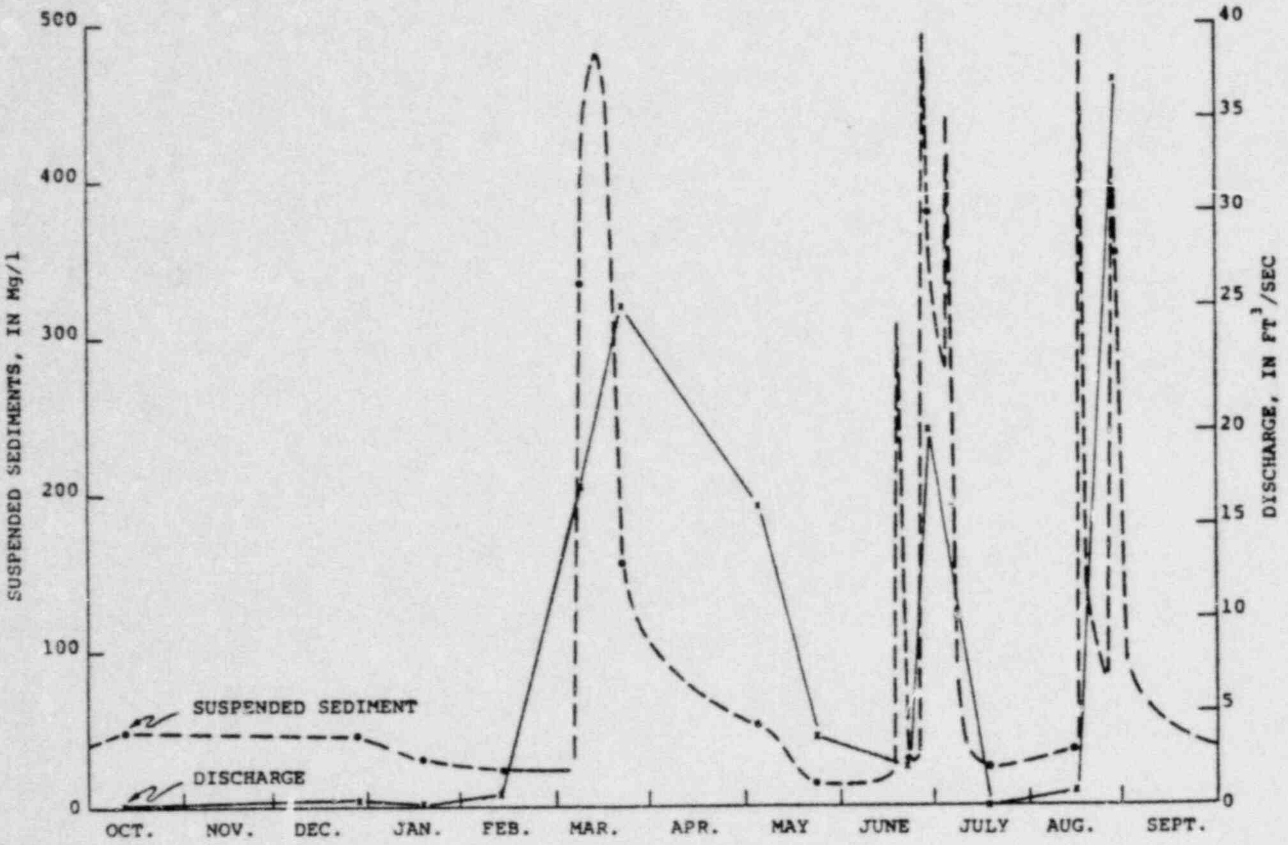
SAND ROCK MILL PROJECT
CAMPBELL COUNTY, WYOMING
FIGURE 3.17

SUSPENDED SEDIMENT AND DISC
FOR ANTELOPE CREEK NEAR TEC
WYOMING FOR WATER YEAR 19



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SAND ROCK MILL PROJECT
CAMPBELL COUNTY, WYOMING
FIGURE 3.18

SUSPENDED SEDIMENT AND DISCHARGE FOR ANTELOPE CREEK NEAR TECKLA, WYOMING FOR WATER YEAR 1979

TABLE 3.6.1.4

SURFACE WATER ANALYSES FOR THE SAND ROCK PROJECT

Surface Site No.	Location	Date	TDS	Conductivity		Temperature	DO	TSS	Turbidity	Na	K	Ca	Mg
	41N-74W												
1-7s (-)	18 SENW	4/21/77[a]	770	935	(-)	(-)	(-)	0.0	–	39	6.3	120	33
(Old Site 4)		3/27/78[b]	322	475	(815)	1.0)	(7.4)	1.4		14	4	68	20
		6/22/79	Dry										
		12/2/78	Dry										
		2/25/80			(-)	(-)	(-)	–	–	–	–	–	–
		3/27/80	612	990	(946)	(10)	(6.5)	–	3.0	41	10	121	36
1-7A (-)	18 SENW	2/25/80	867	1,170	(-)	(-)	(-)	–	9.5	48	17	141	44
	41N-75W												
1-34 (-)	01 SWNW	3/25/80	32	73	(56)	(2)	(13.6)		7.2	6	4	6	1
1-21 (-)	02 NENW	6/22/79	304	500	(441)	(26)	2.9	5	7.2	5	4	60	28
		9/28/79	Dry										
		10/30/79	Dry										
Site 2s	02 NESW	3/22/78[c]	54	62	(-)	–	–	3.1	–	0.3	1	14	0.5
1-22 (-)	02 NESW	6/26/79	60	94	(73)	(26)	8.6	37	34.3	2	5	10	3
		9/28/79	Dry										
1-23s (-)	02 SESW	6/26/79	Dry										
		12/2/79	Dry										
		2/20/80			(-)	(-)	(-)	–	–	–	–	–	–
1-24 (-)	02 SENE	6/26/79	Dry										
		2/20/80			(-)	(-)	(-)	–	–	–	–	–	–
1-5 (-)	03 NWNE	6/26/79	Dry										
		12/21/79	Dry										
	41N-75W												
1-6s (1631)	03 SESE	6/22/79	2,386	2,667			8.2	7	10.4	59	20	528	74
		12/21/79	Dry										
		2/20/80	–	–	(-)	(-)	(-)	–	–	–	–	–	–
Site 1s	03 NWSE	3/27/78[d]	566	810	(460)	(10)	(8.5)	1.25	–	14	4	100	61
1-32 (-)	03 NWSE	6/20/79	1,914	2,130	(1,870)	(21)	3.3	• 4.0	2.3	40	13	417	77
		9/28/79	638	945	(918)	(13)	(9.3)	136	172	15	36	131	37
1-10s (-)	04 NENW	6/20/79	Dry										
		12/21/79	Dry										
1-11 (-)	04 NENE	6/22/79	1,310	1,650	(1,380)	(21)	3.9	20	2.4	56	12	195	83
		9/25/79	842	1,120	(1,060)	(19)	(9.4)	–	–	65	19	106	43
		10/30/79	Dry										
1-14 (-)	04 SESE	6/20/79	Dry										
		9/25/79	1,282	1,700				• 4.0	3.2	39	8	133	127
		2/20/80			(1,070)	(19)	(14.0)	–	–	–	–	–	–
1-15 (-)	09 NENE	6/21/79	430	645	(566)	(23)	3.3	• 4.0	5.0	26	10	96	17
		12/10/79	–	–	(940)	(1)	(8.25)	–	–	–	–	–	–
1-15As (-)	10 SENW	12/21/79	Dry										
		2/25/80			(-)	(-)	(-)						
1-15Bs (-)	10 SWNE	3/25/80	1,164		(1,320)	(2)	(9.9)		2.7	32	10	225	70

TABLE 3.6.1.4

(CONT.)

Surface Site No.	Location	Date	TDS	Conductivity		Temperature	DO	TSS	Turbidity	Na	K	Ca	Mg
	41N-75W												
1-33 (9352)	11 NWNW	6/20/79	259	437	(144)	(18)	2.9	• 4.0	3.6	22	5	54	21
		9/18/79	434	700	(586)	(18)		• 4.0	5.7	19	9	83	24
		9/27/79	—	—	(658)	(17)	(7.18)	—	—	—	—	--	--
		12/10/79			(653)	(2)	(4.20)				-		
		3/25/80	156		(258)	(2)	(5.2)		5.3	6	6	37	9
1-335s (-)	11 NWNE	9/18/79	314	500	—	—	—	• 4.0	6.0	9	16	52	13
		10/10/79	376	580	—	—	—	88	73	9	21	61	24
		10/30/79	—	—	(497)	(3)	(13.0)	—	—	—	—	—	—
1-31 (-)	12 NWSW	6/26/79	308	500	(400)	(25)	6.6	• 4.0	5.0	5	10	58	15
		9/18/79	422	690				• 4.0	3.6	26	8	65	31
		9/28/79	Dry										
		3/25/80	152		(228)	(0)	(11.4)		6.0	3	9	29	6
1-35 (-)	12 NWNW	3/25/80	96		(171)	(0)	(11.6)		9.5	2	7	23	4
	42N-74W												
1-30 (-)	31 SWNE	6/29/79	1,030	1,450	(1,130)	(30)	8.6	• 4.0	6.5	31	9	211	54
(Pine Tree Spring)		3/25/80	844	1,260	(1,130)	(1)	(8.6)	—	6.5	29	9	162	50
	42N-75W												
1-18 (-)	26 SWSW	6/21/79	Dry										
		9/25/79	144	208	(161)	(21)	(16.8)			12	5	32	3
1-25 (-)	26 NENW	6/21/79	88	128	(121)	(24)	3.6	7	7.9	3	7	21	2
1-26s (-)	26NESE	6/21/79	Dry										
		9/28/79	202	322	(265)	(12)	—	• 4.0	14.0	26	22	22	6
		10/30/79	Dry										
		12/21/79	Dry										
		2/20/80	—	—	(-)	(-)	(-)	—	—	—	—	—	—
1-27 (-)	26 SENE	6/29/79	84	110	(79)	(22)	7.3	228	252	4	6	10	1
		9/18/79	202	335	(247)	(21)	—	15	17.8	19	19	27	6
		9/28/79	Dry										
		10/10/79	276	341	(287)	(18)	(12.5)	516	234	32	23	20	7
		12/21/79	Dry										
		4/9/80	85		(99)	(3)	(11.4)		10.9	11	5	13	2
1-28s (-)	26 SESE	6/29/79	Dry										
		9/28/79	Dry										
		10/30/79	Dry										
		12/21/79	Dry										
		2/20/80	—	—	(-)	(-)	(-)	—	—	—	—	—	—
1-16 (-)	27 SENE	6/21/79	106	156	(131)	(22)	3.3	• 4.0	6.0	3	5	26	3
1-17s (-)	27 SESE	6/21/79	Dry										
		9/28/79	Dry										
		10/30/79	Dry										
		12/21/79	Dry										
		2/20/80	—	—	(-)	(-)	(-)	—	—	—	—	—	—
1-2 (-)	28 SESE	6/21/79	49	56	(50)	(24)	3.3	8	4.3	4	6	5	1
1-6 (-)	33 NWNW	6/21/79	83	112	(102)	(21)	2.9	• 4.0	5.0	3	5	17	2
		9/28/79	94	154	(129)	(13)	(5.9)	• 4.0	12.2	1	8	18	3
1-9 (-)	33 SWSE	6/20/79	1,614	2,000	(1,380)	(18)	—	—	—	43	11	354	71
		2/20/80	—	—	(-)	(-)	(-)	—	—	—	—	—	—

TABLE 3.6.1.4

(CONT.)

Surface Site No.	Location	Date	TDS	Conductivity		Temperature	DO	TSS	Turbidity	Na	K	Ca	Mg
1-13 (-)	33 SENW	6/20/79	583	847	(66)	(18)	—	—	—	87	8	53	26
1-1 (-)	34 NESW	6/22/79	438	556	(464)	(24)	3.3	• 4.0	10.0	10	22	78	19
		9/25/79	402	410	—	—	—	354	163	6	34	65	3
		10/30/79	—	—	(538)	(3)	(14.3)	—	—	—	—	—	—
		2/20/80	—	—	(-)	(-)	(-)	—	—	—	—	—	—
1-1As (-)	34 NENE	12/21/79	Dry										
		2/20/80	—	—	(-)	(-)	(-)	—	—	—	—	—	—
1-3 (-)	34 SESW	6/26/79	74	97	(79)	(22)	8.3	10	16.8	1	9	8	2
		9/28/79	Dry										
1-12 (-)	34 SWSE	6/22/79	232	303	(221)	(22)	3.3	124	113	9	14	36	6
		9/28/79	Dry										
		10/30/79	Dry										
		12/21/79	Dry										
1-19 (-)	35 SWNE	6/29/79	76	114	(80)	(18)	2.9	323	440	2	5	12	2
		9/25/79	220	298	(242)	(20)	(18.6)	—	—	5	15	34	6
1-20 (-)	35 SESW	6/20/79	199	156	(144)	(18)	3.3	• 4.0	4.0	3	7	22	5
		9/27/79	—	—	(129)	(19)	(12.2)	—	—	—	—	—	—
		12/10/79	—	—	(298)	(3)	(11.70)	—	—	—	—	—	—
		3/25/80	32	90	(73)	(0)	(11.3)	—	13.0	6	6	7	2
1-19 (-)	36 SENW	6/28/79	81	133	(99)	(24)	8.0	425	510	3	5	14	3
		3/25/80	204	—	(265)	(2)	(15.5)	—	7.9	6	11	35	10
Site 3s	36 NENW	3/22/78[e]	88	96	(-)	(-)	(-)	0.9	—	1	2	16	7

TABLE 3.6.1.4

(CONT.)

Surface Site Nr.	SO_4	Cl	CO_3	HCO_3	pH		Al	NH_3 (as N)	As	Ba	Be	B	Cd	Cr	Cu	F	Fe
I-7s (-)	290	16	0.0	270	8.0	(-)	• .1	—	• .05	• .5	—	.05	• .01	• .1	• .01	0.4	0.25
(Old Site 4)	116	24	0	156	7.53	(6.8)	• .05	0.14	0.02	• .03		0.02	• .002	• .02	• .01	• .1	0.45
	Dry																
	Dry																
	—	—	—	—	—	(-)	—	—	—	—	—	—	—	—	—	—	—
	332	13	0	273	7.71	(7.7)	• .05	• .05	• .002	• .02	• .005	• 1.0	• .005	• .01	.005	.14	• .05
I-7A (-)	446	17	0	271	7.30	(-)	• .05	0.37	• .002	• .02	• .005	• 1.0	0.005	0.02	0.019	0.16	0.23
I-34 (-)	20	2	0	24	6.44	(7.6)	• .05	• .05	• .002	• .02	• .005	• 1.0	• .005	• .01	• .005	• .05	.11
I-21 (-)	33	4	0	300	8.24	(8.15)	• .05	• .05	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	0.33	0.029
	Dry																
	Dry																
Site 2s	5	10	0	44	6.18	(-)	0.15	• .1	0.02	• .03	—	0.03	• .002	• .02	• .01	• .1	0.47
I-2[illegible] (-)	15	4	0	39	7.00	(6.95)	• .005	• .05	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	0.03	0.083
	Dry																
I-23s (-)	Dry																
	Dry																
	—	—	—	—	—	(-)	—	—	—	—	—	—	—	—	—	—	--
I-24 (-)	Dry																
	—	—	—	—	—	(-)	—	—	—	—	—	—	—	—	—	—	—
I-5 (-)	Dry																
	Dry																
I-6s (1631)	1,500	21	0	198	7.79		• .05	0.05	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	0.06	0.031
	Dry																
	—	—	—	—	—	(-)	—	—	—	—	—	—	—	—	—	—	—
Site Is	344	14	0	122	7.52	(6.8)	0.08	• .1	0.03	• .03	—	0.03	• .002	• .02	0.01	• .1	0.97
I-32 (-)	1,315	15	0	249	7.93	(7.85)	• .05	• .05	• .002	• .02	• .005	• 1.0	0.006	• .01	• .002	0.09	0.238
	74	17	0	527	7.91	(7.35)	• .05	0.16	0.007	• .02	• .005	• 1.0	• .002	• .01	0.004	0.14	0.05
I-10s (-)	Dry																
	Dry																
I-11 (-)	1,000	9	0	93	7.78	(7.75)	• .05	• .05	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	0.10	0.014
	410	10	0	234	7.44	(7.15)	• .05	—	• .002	• .02	• .005	• 1.0	• .002	• .01	0.004	0.16	0.06
	Dry																
I-14 (-)	Dry																
	890	17	7	107	8.43		0.08	• .05	• .002	• .02	• .005	• 1.0	• .002	0.01	0.004	0.25	0.08
	—	—	—	—	—	(8.00)	—	—	—	—	—	—	—	—	—	—	—
I-15 (-)	195	6	14	166	8.59	(8.85)	• .05	• .05	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	0.05	0.062
	—	—	—	—	—	(7.25)	—	—	—	—	—	—	—	—	—	—	—
I-15As (-)	Dry																
						(-)											
I-15Bs (-)	666	8	0	351	7.68	(7.4)	• .05	• .05	• .002	• .02	• .005	• 1.0	• .005	.02	.012	.11	• .05

TABLE 3.6.1.4

(CONT.)

Surface Site No.	SO_4	Cl	CO_3	HCO_3	pH		Al	NH_3 (as N)	As	Ba	Be	B	Cd	Cr	Cu	F	Fe
1-33 (9352)	46	5	0	232	8.03	(9.35)	0.10	• .05	• .002	• .02	• .005	• 1.0	0.024	• .01	• .002	0.16	0.095
	99	6	0	295	7.69	(7.05)	• .05	• .05	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	0.20	•0.05
	—	—	—	—	—	(7.00)	—	—	—	—	—	—	—	—	—	—	—
						(7.45)											
	32	3	0	144	7.14	(7.4)	• .05	• .05	• .002	• .02	• .005	• 1.0	• .005	• .01	• .005	• .05	.11
1-33Ss (-)	23	5	0	266	7.86		• .05	• .05		• .02		• 1.0	• .002	• .01	• .002	0.17	0.08
	19	6	0	325	8.14		• .05	.20	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	0.19	0.09
	—	—	—	—	—	(7.95)	—	—	—	—	—	—	—	—	—	—	—
1-31 (-)	143	6	0	98	8.46	(8.85)	• .05	• .05	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	.16	.055
	126	9	0	256	8.09		• .05	• .05		• .02		• 1.0	• .002	• .01	.004	.18	• .05
	Dry					(-)											
	86	2	0	32	6.61	(8.0)	• .05	.06	• .002	• .02	• .005	• 1.0	• .005	• .01	.005	• .05	• .05
1-35 (-)	47	2	0	51	7.38	(9.1)	• .05	• .05	• .002	• .02	• .005	• 1.0	• .005	• .01	• .005	• .05	.07
1-30 (-) (Pine Tree Spring)	467	25	0	376	7.83	(8.05)	• .05	.07	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	.90	0.038
	472	21	0	278	7.61	(8.6)	• .05	.057	• .002	• .02	• .005	• 1.0	• .005	• .01	.009	.80	.10
1-18 (-)	Dry																
	17	2	12	105	8.80	(8.55)	• .05		• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	.09	.05
1-25 (-)	• 1.0	4	0	78	7.69	(8.45)	• .05	• .05	• .002	• .02	• .005	• 1.0	• .002	• .01	.012	.06	.076
1-26s (-)	Dry																
	26	6	0	173	7.88	(7.75)	• .05	.08	• .002	• .02	• .005	• 1.0	• .002	• .01	.002	.12	.25
	Dry																
	Dry																
	—	—	—	—	—	(-)	—	—	—	—	—	—	—	—	—	—	—
1-27 (-)	9	4	0	49	7.03	(6.55)	.10	.11	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	• .05	.126
	22	6	2	168	8.52	(8.50)	• .05	.20	• .002	• .02	• .005	• 1.0	• .002	• .01	.004	.09	.06
	Dry																
	19	8	17	168	8.76	(8.1)	• .05	.12	• .002	• .02	• .005	• 1.0	• .002	• .01	.003	0.15	.49
	Dry																
	17	8	0	68	7.00	(8.4)	• .05	.67	• .002	• .02	• .005	• 1.0	• .005	.02	• .005	• .05	• .05
1-28s(-)	Dry																
	Dry																
	Dry																
	Dry																
	—	—	—	—	—	(-)	—	—	—	—	—	—	—	—	—	—	—
1-16 (-)	9	4	24	88	9.18	(9.70)	• .05	• .05	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	.05	0.137
1-17s (-)	Dry																
	Dry																
	Dry																
	Dry																
	—	—	—	—	—	(-)	—	—	—	—	—	—	—	—	—	—	—
1-2 (-)	8	4	0	20	7.45	(9.20)	• .05	.15	• .002	• .02	• .005	• 1.0	• .002	• .01	.004	.13	.171
1-8 (-)	8	4	24	63	9.30	(9.6)	• .05	.07	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	.08	.320
	17	4	0	71	7.26	(7.55)	• .05	.08	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	.10	.38
1-9 (-)	834	15		481	8.20	(8.25)	• .05	• .05	• .002	• .02	• .005	• 1.0	.013	• .01	• .002	.27	.119
	—	—	—	—	—	(-)	—	—	—	—	—	—	—	—	—	—	—

TABLE 3.6.1.4

(CONT.)

Surface Site No.	SO_4	Cl	CO_3	HCO_3	pH		Al	NH_3 (as N)	As	Ba	Be	B	Cd	Cr	Cu	F	Fe
1-13 (-)	426	5	10	46	9.24	(9.40)	• .05	• .05	• .002	• .02	• .005	• 1.0	.003	• .01	.010	.16	.127
1-1 (-)	114	19	53	171	9.32	(9.40)	• .05	.05	.005	• .02	• .005	• 1.0	• .002	• .01	• .002	.11	.020
	17	18	84	115	9.67	—	.17	.14	.009	• .02	• .005	• 1.0	• .002	• .01	.012	.13	.27
	—	—	—	—	—	(8.35)	—	—	—	—	—	—	—	—	—	—	—
	—	—	—	—	—	(-)	—	—	—	—	—	—	—	—	—	—	—
1-1As (-)	Dry																
	—	—	—	—	—	(-)	—	—	—	—	—	—	—	—	—	—	—
1-3 (-)	• 1.0	2	0	44	6.88	(6.90)	• .05	• .05	• .002	• .02	• .005	• 1.0	• .002	• .01	.003	.04	.080
	Dry																
1-12 (-)	61	15	0	78	7.46	(9.65)	.30	.12	.006	• .02	• .005	• 1.0	.004	• .01	.022	.11	.382
	Dry																
	Dry																
	Dry																
1-19 (-)	• 1.0	4	0	49	7.05	(6.65)	.05	.09	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	• .05	.080
	17	8	0	146	7.52	(7.70)	• .05	—	• .002	• .02	• .005	• 1.0	• .002	• .01	.003	• .05	• .05
1-20 (-)	19	4	10	81	9.06	9.35	• .05	• .05	• .002	• .02	• .005	• 1.0	.002	• .01	.005	.08	.083
	—	—	—	—	—	(9.40)	—	—	—	—	—	—	—	—	—	—	—
	—	—	—	—	—	(7.20)	—	—	—	—	—	—	—	—	—	—	—
	19	2	0	34	6.64	(8.0)	.08	• .05	• .002	• .02	• .005	• 1.0	• .005	• .01	• .005	• .05	.13
1-29 (-)	11	4	0	49	6.86	7.05	.70	• .05	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	.02	.416
	73	3	0	95	7.21	(9.5)	• .05	.07	• .002	• .02	• .005	• 1.0	• .005	• .01	• .005	• .05	.07
Site 3s	25	8	0	44	6.05	(-)	0.31	• .1	0.02	• .03	—	0.03	• .002	• .02	• .01	• .1	0.55

TABLE 3.6.1.4

(CONT.)

Surface Site No.	Pb	Mn	Hg	Mo	Ni	NO_3	Se	V	Zn	U	Pb-210	Po-210	Ra-226	Th-230	Charge Balance
1-7s (-)	• .1	• .05	• .001	• .005	• .1	0.0	• .001	0.007	• .02	32	—	—	—	—	1.7
(Old Site 4)	• .05	0.06	• .001	—	• .02	• .1	• .01	—	0.05	—	—	—	—		0.9
	Dry														
	Dry														
	.06	.01	• .001	• .05	• .01	.72	• .002	• .05		.005					3.1
1-7A (-)	0.06	0.74	• .001	• .05	• .01	0.90	• .002	• .05	0.006						3.7
1-34 (-)	• .05	• .01	• .001	• .05	• .01	.14	• .002		• .05						7.5
1-21 (-)	• .05	0.015	• .001	• .02	• .01	10.0	• .002	• .02	0.006	0±.5	3.0±.3	0.07±.02	0±.05	7.5±.8	0.9
	Dry														
	Dry														
Site 2s	• .01	• .01	• .001	• .02	• .02	• .1	• .01	• .05	0.003	17	—	—	—	—	
1-22 (-)	• .05	0.006	• .001	• .02	• .01	0.31	• .002	• .02	0.007	0±1	0.9±.4	0.13±.04	0±.05	0.2±.1	5.5
	Dry														
1-23s (-)	Dry														
	Dry														
	—	—	—	—	—	—	—	—	—						
1-24 (-)	Dry														
	—	—	—	—	—	—	—	—	—						
1-5 (-)	Dry														
	Dry														
1-6s (1631)	• .05	0.074	• .001	• .02	• .01	0.61	• .002	• .02	0.27						0.7
	Dry														
	—	—	—	—	—	—	—	—	—						—
Site 1s	• .05	0.74	• .001	—	• .02	0.19	• .01	—	0.04	—	—	—	—	—	5.7
1-32 (-)	• .05	0.054	• .001	• .02	• .01	1.35	0.006	• .02	0.021	6±1	1.0±.3	0.17±.03	0±.05	0.2±.1	4.3
	• .05	0.62	• .001	• .02	• .01	4.50	• .002	• .02	0.21						2.3
1-10s (-)	Dry														
	Dry														
1-11 (-)	• .05	0.008	• .001	• .02	• .01	0.32	• .002	• .02	0.014	1.9±.4	5±1	3.2±.4	0.07±.03	13±1	7.8
	• .05	0.64	• .001	• .02	• .01	—	• .002	• .02	0.010						2.1
	Dry														
1-14 (-)	Dry														
	• .05	0.08	• .001	• .02	• .01	0.83	• .002	• .02	0.008						5.0
	—	—	—	—	—	—	—	—	—						—
1-15 (-)	• .05	0.018	• .001	• .02	• .01	0.22	• .002	• .02	0.005	0±1	0±1	0.19±.05	0±.05	0±.1	1.1
	—	—	—	—	—	—	—	—	—						--
1-15As (-)	Dry														
1-15Bs (-)	.08	.26	• .001	• .05	• .01	.17	• .002	• .05	.016						3.1

TABLE 3.6.1.4

(CONT.)

Surface Site No.	Pb	Mn	Hg	Mo	Ni	NO_3	Se	V	Zn	U	Pb-210	Po-210	Ra-226	Th-230	Charge Balance
1-33 (9352)	• .05	0.042	• .001	• .02	• .01	1.20	• .[illegible]02	• .02	0.040	0±1	0.8±.4	0.21±.04	0±.2	0.6±.1	5.7
	• .05	0.08	• .001	• .02	• .01	0.95	• .002	• .02	0.013						1.2
	—	—	—	—	—	—	—	—	—						—
	—	—	—	—	—	—	—	—	—						—
	• .05	.11	• .001	• .05	• .01	.14	• .002	• .05	• .005						1.8
1-335s (-)	• .05	0.28	• .001	• .02	• .01	0.80	• .002	• .02	0.008						5.5
	• .05	0.50	• .001	• .02	• .01	1.58	• .002	• .02	0.012						.4
		—	—	—	—	—	—	—	—						—
1-31 (-)	• .05	0.003	• .001	• .02	• .01	.39	• .002	• .02	0.022	0±1	0±2	0±.03	0±.05	5.8±.4	1.6
	• .05	0.19	• .001	• .02	• .01	.96	• .002	• .02	0.022						1.0
	Dry														
	• .05	.01	• .001	• .05	• .01	.19	• .002	• .05	• .005						1.5
1-35 (-)	• .05	• .01	• .001	• .[illegible]	• .01	.13	• .002	• .05	• .005						3.5
1-30 (-) (Pine Tree Spring)	• .05	0.279	• .001	• .0[illegible]	• .01	1.61	• .002	• .02	.007	2±1	0±.9	0.2±.04	0.35±.05	137±7	0.1
	.09	.24	• .001	• .05	• .01	2.25	• .002	• .05	0.006						4.5
1-18 (	Dry														
	• .05	• .01	• .001	• .02	• .01	—	• .002	• .02	0.006						8.3
1-25 (-)	• .05	.005	• .001	• .02	• .01	.94	• .002	• .02	.008	0±1	1.9±5	0.28±.06	0±.05	1.6±.3	4.5
1-26s (-)	Dry														
	• .05	.17	• .001	• .02	• .01	1.59	• .002	• .02	.010						3.8
	Dry														
	Dry														
	—	—	—	—	—	—	-	—	—						—
1-27 (-)	• .05	.078	• .001	• .02	• .01	1.83	• .002	• .02	.009	0±1	0.5±.3	0.2±.1	0±.05	0±.1	9.6
	• .05	.06	• .001	• .02	• .01	2.54	• .002	• .02	.012						4.5
	Dry														
	• .05	.09	• .001	• .02	• .01	1.94	• .002	• .02	.022						5.2
	Dry														
	• .05	.10	• .001	• .05	• .01	.17	• .002	• .05	• .005						8.8
1-28s (-)	Dry														
	Dry														
	Dry														
	Dry														
	—	—	—	—	—	--	—	—	—						--
1-16 (-)	• .05	.015	• .001	• .02	• .01	.23	• .002	• .02	.003	2±1	0±.7	0.11±.03	0±.05	0±.1	17.0
1-17s (-)	Dry														
	Dry														
	Dry														
	Dry														
	—	—	—	—	—	—	—	—	—						—
1-2 (-)	• .05	.006	• .001	• .02	• .01	1.33	• .002	• .02	.017	0.4±1	1.2±.3	0.39±.07	0±.05	0±.2	4.1
1-8 (-)	• .05	.015	• .001	• .02	• .01	.75	• .002	• .02	.004	0±1	14±2	0.29±.05	0±.05	175±8	24.8
	• .05	.04	• .001	• .02	• .01	.36	• .001	• .02	• .005						7.9
1-9 (-)	• .05	.120	• .001	• .02	• .01	1.00	.008	• .02	.027	3±2	0±.3	0.19±.04	0±.07	38±3	0
	—	—	—	—	—	—	—	—	--						--

TABLE 3.6.1.4

(CONT.)

Surface Site No.	Pb	Mn	Hg	Mo	Ni	NO_3	Se	V	Zn	U	Pb-210	Po-210	Ra-226	Th-230	Charge Balance
1-13 (-)	• .05	.006	• .001	• .02	• .01	.84	.011	• .02	.015	5.4±.2	0±1	0.24±.06	0±.05	0.2±.1	7.0
1-1 (-)	• .05	.020	• .001	• .02	• .01	.42	• .002	• .02	.009	0±2	1.4±.2	0.15±.03	0±.05	0±.1	7.3
	• .05	.04	• .001	• .02	• .01	1.65	• .002	• .02	.027						—
	—	—	—	—	—	—	—	—	—						—
	—	—	—	—	—	—	—	—	—						—
1-1As (-)	Dry														
	—	—	—	—	—	—	—	—	—						—
1-3 (-)	• .05	.00[illegible]	• .001	• .02	• .01	.61	• .002	• .02	.010	0±1	0.7±.3	0.28±.04	1.0±.1	0.5±.1	3.6
	Dry														
1-12 (-)	• .05	.064	• .001	• .02	• .01	1.44	• .002	• .02	.060	2±1	1.2±.3	0.16±.03	0.09±.03	0.0±.1	1.1
	Dry														
	Dry														
	Dry														
1-19 (-)	• .05	.016	• .001	• .02	• .01	.83	• .002	• .02	.012	0±1	0±.7	0.32±.09	0±.05	0.7±.1	2.1
	• .05	• .01	• .001	• .02	• .01	—	• .002	• .02	.011						3.2
1-20 (-)	• .05	• .003	• .001	• .02	• .01	.63	• .002	• .02	.007	0±1	1.1±.4	0.13±.06	0±.05	2.6±.3	8.8
	—	—	—	—	—	—	—	—	—						—
	—	—	—	—	—	—	—	—	—						—
	• .05	.01	• .001	• .05	• .01	.20	• .002	• .05	• .005						4.2
1-29 (-)	• .05	.065	• .001	• .02	• .01	2.24	• .002	• .02	• .023	0±1	0.5±.3	0.13±.03	0.35±.05	0.8±.1	2.5
	• .05	.04	• .001	• .05	• .01	.18	• .002	• .05	• .005						0.8
Site 3s	• .02	0.03	• .001	• .02	• .02	• .1	• .01	• .05	0.003	10					0.1

NOTES: s Denotes flowing stream, the remainder samples are from ponded water.

• Concentration less than this value.

( ) Denotes field measurements.

(2345) Behind site number is State Engineer Permit Number, (-) if no permit.

All concentrations are in mg/l, except Conductivity, in μmhos/cm @ 25°C; Temperature, in °C; DO, in dissolved oxygen units; Turbidity, in NTU; Pb-210, Po-210, Ra-226 and Th-230, in pCi/l; and Charge Balance = Difference in major equivalents divided by sum of major equivalents times 100.

(a) Additional parameters from this sample are: Cyanide - •.02, Phenols - 0.007, M.B.A.S. = •.01, Silver = •.5, Hardness ($CaCO_3$) = 440, Silica (S_iO_2) = 10, C.O.D. = 24, Total Kjeldahl Nitrogen = 1.5, Oil and grease = 0.8, Sulfide (S) = •.001 and Total CO_3 = 130.

(b) Additional parameters from this sample are: Alkalinity (as $CaCO_3$) = 128, Hardness (as $CaCO_3$) = 250, Phosphate = 0.04, Air Temperature = 10°C, @ 1,945 hours water ponded with ice cover, no flow measurement.

(c) Additional parameters from this sample are: Alkalinity (as $CaCO_3$) = 36, Hardness (as $CaCO_3$) = 38, Phosphate = •0.01.

(d) Additional parameters from this sample are: Alkalinity (as $CaCO_3$) = 100, Hardness (as $CaCO_3$) = 500, Phosphate = 0.04, @ 1,810 Flow measurement = 1.37 ft^3/sec and air temperature = 14°C.

(e) Additional parameters from this sample are: Alkalinity (as $CaCO_3$) = 36, Hardness (as $CaCO_3$) = 70, and Phosphate = •0.01.

Total dissolved solids at these sites range from less than 50 to greater than 2,300 mg/l. Some of the lower values represent samples taken during times of snowmelt runoff. Most samples have calcium as the predominant cation with sodium and magnesium as less, but still significant cations. Sodium is not present in quantities large enough to present a hazard for irrigational use. Sulfate and bicarbonate are the dominant anions at the project site and are also dominant downstream at the U.S.G.S. Antelope Creek gage.

Total suspended solids (TSS) in creeks draining the Moore Ranch project area are generally low except during some major runoff events. During these times, TSS values have exceeded 500 mg/l.

Toxic minor elements have not been detected in excessive or potentially dangerous concentrations. Iron has been occasionally observed in levels that would cause inconvenient sink or laundry staining if used as a domestic water supply.

In summary, high sulfate and hardness concentrations would make the surface water draining the project area inconvenient or unpleasant, but not unsuitable for use as a domestic supply. No trace contaminants, including boron, are present in quantities to prevent use as an agricultural water supply. In general, then, the surface water in the Sand Rock project area, when present, is suitable for most prospective uses.

3.6.1.6 RADIONUCLIDES

Due to the ephemeral nature of streams potentially impacted by facility operations, measurement of the radionuclide content of the waters is quite limited both in sample availability (including seasonal flow variations and physical accessibility problems) and suitability (i.e. stagnant or flowing waters). Attempts were made to define a number of locations where sampling could be possible and meet the referenced position paper. The criteria for establishment of permanent sampling locations depend in a large degree to the success of the pre-operational program.

Data obtained to date from the surface water program are given in Tables 3.6.1.5 and 3.6.1.6. Additional regional data for radionclides in surface waters are presented in Table 3.6.1.4

Thorium-230 has been detected at unusual levels (>100 pCi/l in various samples along the headwaters of Simmons Draw in Section 33 near the western side of the permit area. Elevated levels of Thorium also have been detected in the discharge of Pine Tree Spring (1-30).

SEDIMENTS

Sediments at surface water sampling sites were samples for radionuclide analyses. Samples were taken during September and October 1979 for each stream sample; impoundments were sampled only once during the year-long baseline study. Further sampling of stream sediments will be performed in the summer of 1980. Sampling locations are shown in Figure 3.1. Data from the initial sediment sampling is shown in Table 3.6.1.7.

TABLE 3.6.1.5

POND SAMPLE RESULTS
(pCi/l ± 2σ)

	June '79		Sept. '79		Dec. '79	
	Dissolved	Suspended	Dissolved	Suspended	Dissolved	Suspended
I-2						
Pb-210	0.9 ± 0.2	1.2 ± 0.3				
Po-210	0.24 ± 0.03	0.39 ± 0.07				
Ra-226	0.29 ± 0.06	0. ± 0.05	(c)		(c)	
Th-230	0.3 ± 0.1	0. ± 0.2				
Total U_n	0. ± 1.	0.4 ± 0.1				
I-3						
Pb-210	0.7 ± 0.3	0. ± 0.6				
Po-210	0.28 ± 0.04	0.15 ± 0.04				
Ra-226	1.0 ± 0.1	0. ± 0.05	(b)		(b)	
Th-230	0.5 ± 0.1	0. ± 0.1				
Total U_n	0. ± 1.	4.8 ± 0.3				
I-8						
Pb-210	14. ± 2.	0. ± 2.	(a)	(a)		
Po-210	0.29 ± 0.05	0.4 ± 0.1	(a)	(a)		
Ra-226	0. ± 0.05	0. ± 0.05	0.5 ± 0.1	0.4 ± 0.1		
Th-230	175. ± 8.	180. ± 20.	0.6 ± 0.2	0.4 ± 0.1	(d)	
Total U_n	0. ± 1.	1.0 ± 0.1	0.00 ± 2.	1.1 ± 0.1		
I-9						
Pb-210	0 ± 0.3	0. ± 2.				
Po-210	0.19 ± 0.04	0.7 ± 0.4				
Ra-226	0. ± 0.07	0. ± 0.05	(d)		(d)	
Th-230	38. ± 3.	36. ± 3.				
Total U_n	3. ± 2.	1.2 ± 0.2				
I-11						
Pb-210	3.2 ± 0.4	0. ± 7.	(a)	(a)		
Po-210	0.07 ± 0.03	5. ± 2.	(a)	(a)		
Ra-226	0. ± 0.07	0.2 ± 0.1	0.3 ± 0.1	0.3 ± 0.1	(e)	
Th-230	13. ± 1.	32. ± 4.	0.00 ± 0.2	0.7 ± 0.1		
Total U_n	5. ± 1.	1.9 ± 0.4	15. ± 2.	0.4 ± 0.1		
I-15						
Pb-210	0. ± 1.	2. ± 1.			0.00 ± 1.	0.00 ± 2.
Po-210	0.19 ± 0.05	1.9 ± 0.8			0.00 ± 0.1	1.3 ± 0.2
Ra-226	0. ± 0.05	0. ± 0.05	(b)		0.00 ± 0.1	0.8 ± 0.1
Th-230	0. ± 0.1	3.8 ± 0.9			0.4 ± 0.2	0.3 ± 0.1
Total U_n	0. ± 1.	1.0 ± 0.1			109. ± 5.	1.1 ± 0.2
I-19						
Pb-210	0. ± 0.7	2.2 ± 0.7	(a)	(a)		
Po-210	0.32 ± 0.09	1.8 ± 0.2	(a)	(a)		
Ra-226	0. ± 0.05	0.48 ± 0.05	0. ± 0.05	0.3 ± 0.1		
Th-230	0.7 ± 0.1	2.3 ± 0.3	0.3 ± 0.1	0.3 ± 0.1	(f)	
Total U_n	0. ± 1.	1.8 ± 0.1	0. ± 2.	1.0 ± 0.1		
I-20						
Pb-210	1.1 ± 0.4	0. ± 1.	(a)	(a)	0.00 ± 1.	0.00 ± 1.
Po-210	0.13 ± 0.06	0.3 ± 0.1	(a)	(a)	0.00 ± 0.1	0.3 ± 0.1
Ra-226	0. ± 0.05	0. ± 0.05	1.2 ± 0.1	2.2 ± 0.1	0.1 ± 0.1	0.3 ± 0.1
Th-230	2.6 ± 0.3	8.9 ± 0.7	0.2 ± 0.1	0.4 ± 0.1	0.2 ± 0.2	0.00 ± 0.2
Total U_n	0. ± 1.	1.8 ± 0.2	0.00 ± 2.	7.0 ± 0.3	0.00 ± 2.	11.7 ± 0.6

TABLE 3.6.1.5

(CONT.)

	June '79		Sept. '79		Dec. '79	
	Dissolved	Suspended	Dissolved	Suspended	Dissolved	Suspended
I-22						
Pb-210	0.9 ± 0.4	1.1 ± 0.5				
Po-210	0.13 ± 0.04	0.60 ± 0.06				
Ra-226	0. ± 0.05	0. ± 0.08	(b)		(g)	
Th-230	0.2 ± 0.1	0.5 ± 0.1				
Total U_n	0. ± 1.	1.7 ± 0.2				
I-25						
Pb-210	1.0 ± 0.7	1.9 ± 0.5				
Po-210	0.28 ± 0.08	0.28 ± 0.06				
Ra-226	0 ± 0.1	0 ± 0.05	(h)		(h)	
Th-230	1.8 ± 0.3	1.6 ± 0.3				
Total U_n	4. ± 2.	0. ± 1.				
I-27						
Pb-210	1.8 ± 0.3	0.5 ± 0.3	(a)	(a)		
Po-210	0.5 ± 0.2	0.2 ± 0.1	(a)	(a)		
Ra-226	0 ± 0.06	0 ± 0.05	1.7 ± 0.1	1.8 ± 0.1	(h)	
Th-230	16 ± 1	0 ± 0.1	0.5 ± 0.1	0.3 ± 0.1		
Total U_n	0.9 ± 0.2	0. ± 1.	4.0 ± 0.3	0. ± 2.		
I-29						
Pb-210	5. ± 3.	0.5 ± 0.3				
Po-210	1.5 ± 0.3	0.13 ± 0.03				
Ra-226	0.41 ± 0.07	0.35 ± 0.05	(b)		(b)	
Th-230	3.3 ± 0.4	0.8 ± 0.1				
Total U_n	0. ± 0.2	0. ± 1.				
I-31						
Pb-210	0.4 ± 0.2	0. ± 2.				
Po-210	0. ± 0.07	0. ± 0.03				
Ra-226	0. ± 0.05	0. ± 0.05	(b)		(e)	
Th-230	0.7 ± 0.1	5.8 ± 0.4				
Total U_n	0. ± 0.2	0. ± 1.				
I-33						
Pb-210	1.1 ± 0.6	0.8 ± 0.4	(a)	(a)	0. ± 1.	0.2 ± 0.1
Po-210	0.14 ± 0.06	0.21 ± 0.04	(a)	(a)	0.5 ± 0.1	
Ra-226	10. ± 1.	0. ± 0.2	0.6 ± 0.1	4.1 ± 0.2	0. ± 0.1	0.2 ± 0.1
Th-230	2.3 ± 0.4	0.6 ± 0.1	0.3 ± 0.1	0.3 ± 0.1	0. ± 0.2	0.2 ± 0.1
Total U_n	0. ± 0.2	0. ± 1.	0.9 ± 0.1	0. ± 2.	1.5 ± 0.2	13.6 ± 0.2
I-18						
Pb-210			(a)	(a)		
Po-210			(a)	(a)		
Ra-226	(b)		0.1 ± 0.1	0.12 ± 0.05	(b)	
Th-230			0.4 ± 0.1	0.5 ± 0.1		
Total U_n			11.1 ± 0.6	0. ± 2.		
I-32						
Pb-210			(a)	(a)		
Po-210			(a)	(a)		
Ra-226	(b)		3.1 ± 0.2	1.2 ± 0.1	(b)	
Th-230			0.7 ± 0.3	0.0 ± 0.1		
Total U_n			1.6 ± 0.2	75. ± 4.		

(a) Analysis not required
(b) Site dry
(c) Analysis in progress
(d) Replaced by sampling site I-1A
(e) Site frozen
(f) Removed from program
(g) Replaced by sampling site I-32
(h) Replaced by sampling site I-28

TABLE 3.6.1.6

STREAM SAMPLING RESULTS
(pCi/l ± 2σ)

	June '79	July '79	Aug. '79	Sept. '79	Oct. '79	Nov. '79	Dec. '79
I-1A							
Total Ra-226	(a)	(a)	(a)	(a)	0.9 ± 0.1	(a)	(a)
Total Th-230					3.9 ± 0.4		
Total U_n					150. ± 8.		
TSS					0. ± 2.		
I-6							
Total Ra-226	(a)	2.0 ± 0.1	(a)	(a)	(a)	(a)	(a)
Total Th-230		18. ± 1.					
Total U_n		4. ± 1.					
Suspended Pb-210		0.9 ± 0.4					
Suspended Po-210		0.45 ± 0.06					
Suspended Total U_n		0. ± 1.					
Dissolved Pb-210		0.6 ± 0.4					
Dissolved Po-210		0.25 ± 0.03					
Dissolved Total U_n		4. ± 1.					
I-7	(a)	(a)	(a)	(a)	(a)	(a)	(a)
I-10	(a)	(a)	(a)	(a)	(a)	(a)	(a)
I-17	(a)	(a)	(a)	(a)	(a)	(a)	(a)
I-23	(a)	(a)	(a)	(a)	(a)	(a)	(a)
I-26							
Total Ra-226	(b)	(b)	(b)	1.2 ± 0.1	(a)	(a)	(a)
Total Th-230				0.6 ± 0.1			
Total U_n				0. ± 2.			
Suspended Ra-226				0.2 ± 0.1			
Suspended Th-230				0.5 ± 0.1			
Suspended U_n				0.3 ± 0.1			
TSS							
Dissolved Ra-226				0.8 ± 0.1			
Dissolved Th-230				0.3 ± 0.1			
Dissolved U_n				0. ± 1.			
I-33s							
Total Ra-226	(a)	(a)	(a)	0.2 ± 0.1	0.9 ± 0.1	(d)	(d)
Total Th-230				0.4 ± 0.1	0. ± 0.6		
Total U_n				4. ± 2.	0. ± 3.		
Suspended Ra-226				0.2 ± 0.1	(c)		
Suspended Th-230				0.4 ± 0.1	(c)		
Suspended U_n				0.2 ± 0.1	(c)		
TSS							
Dissolved Ra-226				0.2 ± 0.1	(c)		
Dissolved Th-230				0.3 ± 0.1	(c)		
Dissolved U_n				3. ± 2.	(c)		

(a) Dry site
(b) Site added to program due to expansion of permit area
(c) Analysis in progress
(d) Frozen site

TABLE 3.6.1.7

SEDIMENT RESULTS

Sample Number	Collection Date	Analysis	Results pCi/gm dry weight $\pm 2\sigma$
Streams			
I-1	10/30/79	Ra-226	(a)
		Th-230	1.4 ± 0.1
		Pb-210	(a)
		U_n	3.3 ± 0.2
I-17	10/30/79	Ra-226	1.03 ± 0.05
		Th-230	1.20 ± 0.07
		Pb-210	(a)
		U_n	2.07 ± 0.10
I-26	9/28/79	Ra-226	1.39 ± 0.05
		Th-230	2.0 ± 0.2
		Pb-210	(a)
		U_n	1.08 ± 0.05
I-28	10/30/79	Ra-226	1.83 ± 0.09
		Th-230	1.4 ± 0.1
		Pb-210	(a)
		U_n	0.63 ± 0.05
I-33S	10/10/79	Ra-226	0.76 ± 0.04
		Th-230	0.9 ± 0.1
		Pb-210	(a)
		U_n	2.40 ± 0.12
Ponds			
I-1 Sec. 34	10/30/79	Ra-226	0.59 ± 0.03
		Th-230	0.75 ± 0.10
		Pb-210	(a)
		U_n	1.04 ± 0.05
I-3	10/30/79	Ra-226	0.82 ± 0.04
		Th-230	1.2 ± 0.1
		Pb-210	(a)
		U_n	1.56 ± 0.08

(a) Analysis not complete at report preparation

TABLE 3.6.1.7

(CONT.)

Sample Number	Collection Date	Analysis	Results pCi/gm dry weight ± 2σ
I-8	9/27/79	Ra-226	0.52 ± 0.03
		Th-230	1.2 ± 0.1
		Pb-210	
		U_n	1.95 ± 0.10
I-11	10/30/79	Ra-226	(a)
		Th-230	1.6 ± 0.1
		Pb-210	(a)
		U_n	2.3 ± 0.1
I-12	10/30/79	Ra-226	1.67 ± 0.06
		Th-230	1.1 ± 0.1
		Pb-210	(a)
		U_n	1.12 ± 0.06
I-18	9/25/79	Ra-226	1.83 ± 0.07
		Th-230	1.47 ± 0.08
		Pb-210	(a)
		U_n	1.68 ± 0.08
I-19	9/25/79	Ra-226	1.62 ± 0.07
		Th-230	1.4 ± 0.1
		Pb-210	(a)
		U_n	2.8 ± 0.1
I-20	9/27/79	Ra-226	0.84 ± 0.04
		Th-230	1.13 ± 0.06
		Pb-210	(a)
		U_n	1.17 ± 0.06
I-21	10/30/79	Ra-226	0.74 ± 0.04
		Th-230	0.81 ± 0.06
		Pb-210	(a)
		U_n	0.50 ± 0.04
I-22	10/30/79	Ra-226	0.43 ± 0.03
		Th-230	
		Pb-210	
		U_n	1.52 ± 0.08

(a) Analysis not complete at report preparation

TABLE 3.6.7.7

(CONT.)

Sample Number	Collection Date	Analysis	Results pCi/gm dry weight ± 2σ
I-27	10/10/79	Ra-226	2.47 ± 0.10
		Th-230	1.5 ± 0.1
		Pb-210	(a)
		U_n	2.74 ± 0.14
I-31	9/28/79	Ra-226	3.51 ± 0.16
		Th-230	1.6 ± 0.1
		Pb-210	(a)
		U_n	4.2 ± 0.2
I-33	9/27/79	Ra-226	1.01 ± 0.04
		Th-230	1.4 ± 0.1
		Pb-210	(a)
		U_n	4.47 ± 0.22

(a) Analysis not complete at report preparation

3.6.2 GROUNDWATER

The groundwater systems in the project area, including the vicinity of the evaporation pond (Section 1, T41N-R75W) and the tailings disposal site in Pit 35N (Section 35, T42N-R75W), were investigated in detail. The major topics presented in this discussion are the geologic setting, recharge areas, aquifer properties, water movement, springs, and groundwater quality.

3.6.2.1 GEOLOGIC SETTING

The site is situated in the southwestern part of the Powder River Basin approximately 19 kilometers (12 miles) east-northeast of the Tertiary Wasatch-Fort Union formation contact. The Wasatch formation is the surface geologic unit in this area, and is part of the thick Powder River sedimentary series consisting of interbedded sandstones, siltstones, claystones and coals. Seeland (1976) found that the Wasatch sandstones were deposited in a fluvial paleodrainage system which flowed generally northward. These channel deposits are the host rocks for many uranium ore deposits.

The Fort Union formation under lies the Wasatch formation and consists of fine grained fluvial silts and clays. These silts and clays are layered between wedges of arkosic sandstones which were deposited as alluvial fans and braided stream channels. The relative amount of coarse, permeable clastics increases near the top of the Fort Union. The contact between the two formations is gradational and, except in isolated areas of the Powder River basin, is arbitrarily set at the top of the thicker coals or of some thick sequence of clays and silts. The top of the Roland coal is assumed to be the boundary in the Sand Rock Mill area.

Several sandstone lenses, which could be significant aquifers, are present below the Roland coal. The hydrologic properties of these sandstones are diverse and little is known about them.

The Teapot and Parkman sandstones are approximately 2,590 to 2,740 meters (8,500 to 9.000 feet) below land surface in this area. These sandstones are the next hydrologically significant geologic units below the Fort Union sands. The water quality of three well samples from the Parkman sandstone in Johnson County (Whitcomb, Cummings and McCullough, 1966) near the outcrop of this formation contained total dissolved solids from 1360 to 3060 mg/l. Water quality is poorer at greater distances from the outcrop area, making the use of these aquifers questionable.

The Madison limestone and Tensleep sandstone are approximately 4,570 meters (15,000 feet) below the land surface and are expected to produce the largest discharge rates from wells in this area. The Madison is known to flow at several thousand gallons per minute to the Midwest area (Crist and Lowry, 1972), and the flows from the Tensleep sandstone in this area are in the hundreds of gpm. However, the water quality of the Madison and Tensleep in the Midwest area is poor and is anticipated to be worse near the project area. Therefore, even though the Madison and Tensleep aquifers produce large quantities of water, the quality makes these aquifers unusable. Only the Roland coal and the upper Wasatch formation units will be discussed further, because the lower units are not expected to be influenced by this project.

The local surface geology consists of the Wasatch formation for several miles from the proposed mine and mill site. The top of the Roland Coal is approximately 335 meters (1,100 feet) deep in this area. The dip of the top of the Roland coal is to the west-northwest at an average rate of one degree.

Conoco exploration nomenclature has designated most sands above the Roland coal using decreasing numbers with depth. Cross-sections from exploration logs were developed for this area to evaluate the areal distribution of these sands. The 40 and 50 sands are normally separated only by a few feet of shale or mudstone and extend areally. These two sands contain some coarse material in most areas and are considered very significant aquifers.

The 60 sand is fairly massive and continuous over most of the area. The 68 sand, which is above the 60 sand, is normally a significant sand in this area and is probably connected to the 60 sand at some locations. The 68 sand is the first sand below the 70 sand, which contains the ore deposits in the area. The thickness of the 70 sand is normally in the range of 18 to 24 meters (60 to 80 feet) in this area and is areally extensive. The dip of the 70 sand is generally less than one degree toward the northwest.

A thin coal seam exists a few feet above the top of the 70 sand and in most areas has been labeled by Conoco as the E coal. The average dip of the E coal is one-half of one degree.

The remainder of the lithologic section above the 70 sand consists mainly of mudstones (claystones), sandstones and thin coal lenses. The thickness of each of these units varies considerably over this area. Figure 3.19 shows a schematic of the lithologic units in the evaporation pond area. A claystone, referred to as the Lower mudstone, exists below the E coal in the evaporation pond area and has been labeled the Upper mudstone. A very thin seam of coal exists between this claystone (Upper mudstone) and the sandstone above it. These two units have been termed Upper coal and Upper sandstone in the evaporation pond area. A mudstone exists above the Upper coal in some areas, and the Upper coal was not detected in numerous holes.

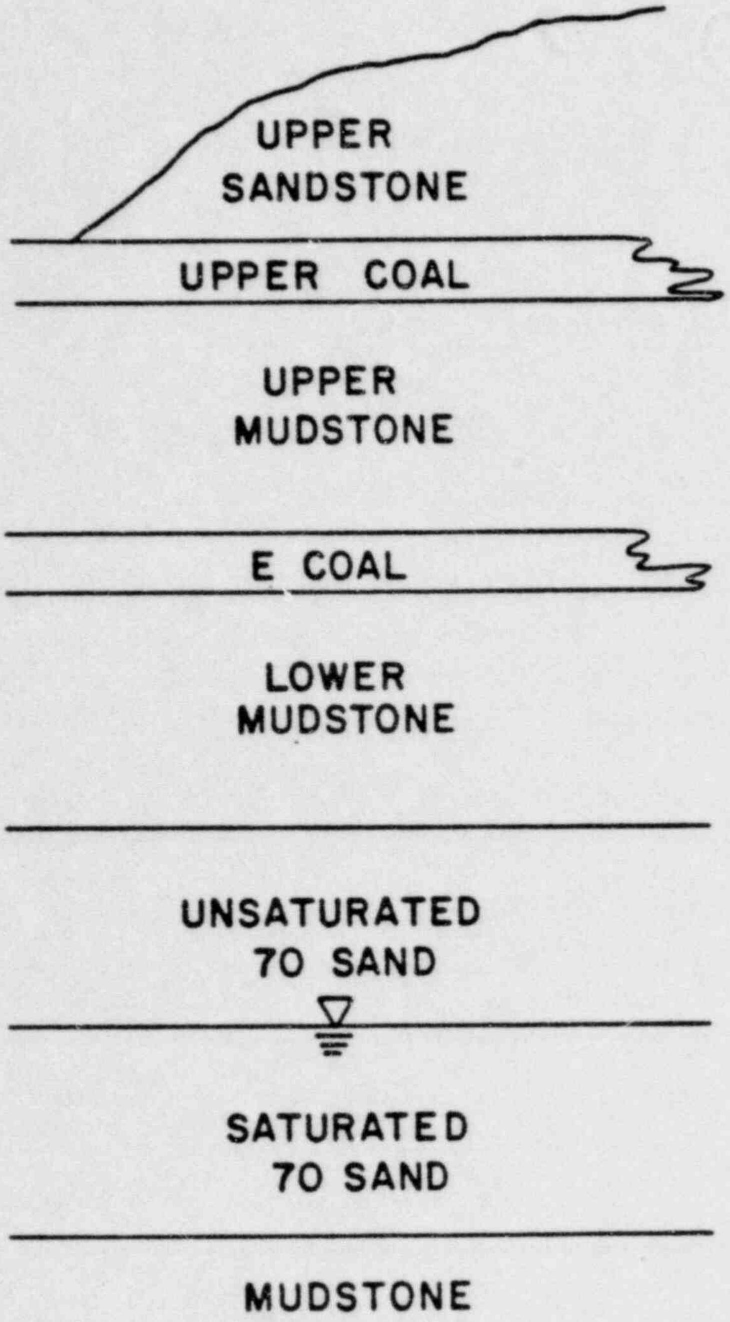

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FIGURE 3-19

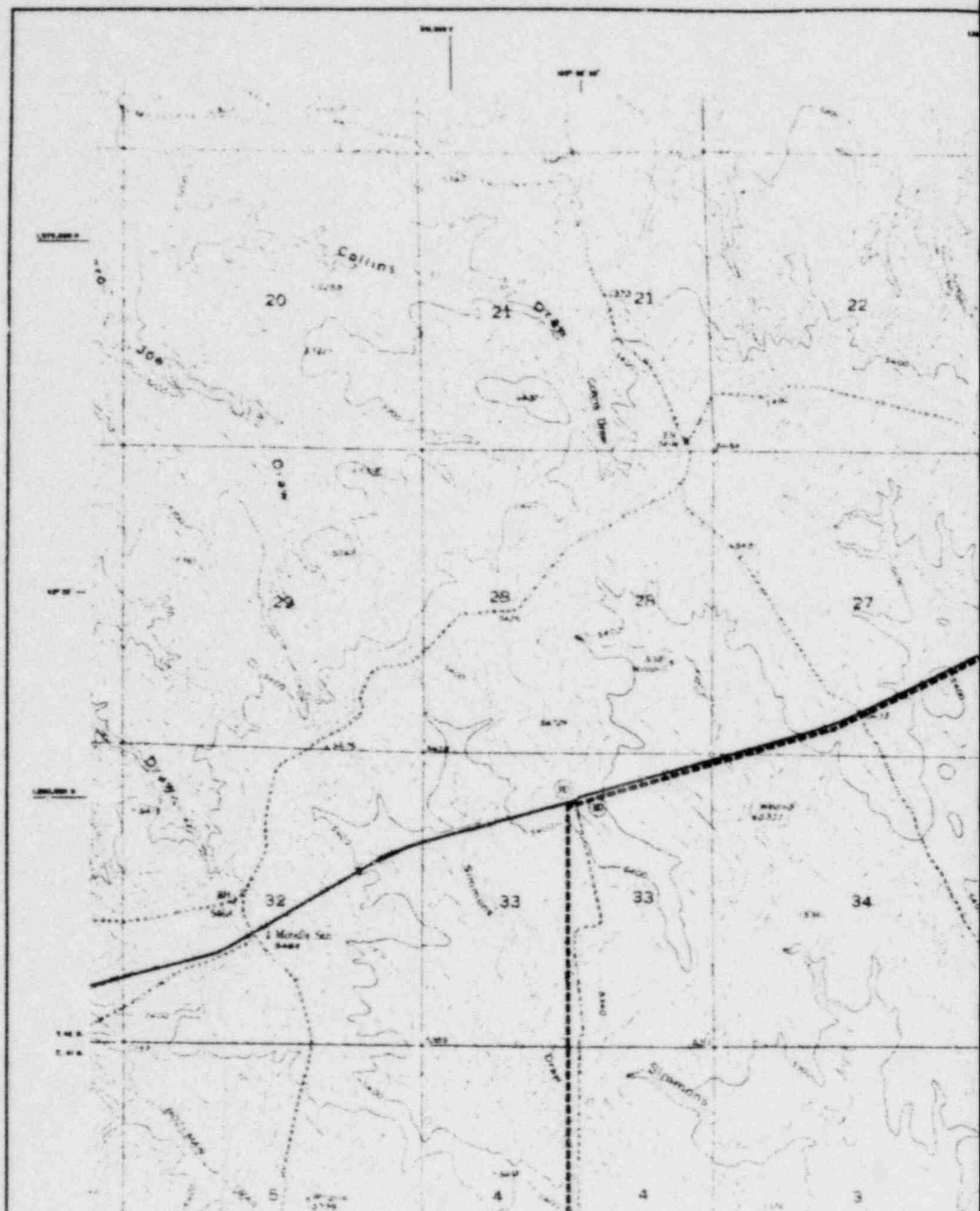
SCHEMATIC OF LITHOLOGIC UNITS IN EVAPORATION POND AREA

The lithologic units above the E coal in the tailings disposal area of Pit 35N do not correlate well. The structure of the top of the E coal and 70 sand is similar to the structure in the evaporation pond area (Hydro, 1980). The mudstone between the E coal and the 70 sand is not as thick in the area of Pit 35N as in the evaporation pond area. Thin, noncontinuous sandstone units are interbedded in the mudstones (claystones) above the E coal.

3.6.2.2 RECHARGE AREAS

The outcrop area of the 70 sand is important to the flow in this groundwater system. The low permeability materials above the 70 sand should essentially restrict recharge to the 70 sand except in its outcrop area. The quality of water from the claystone and coal above the 70 sand is normally poorer than the 70 sand water quality. This also indicates that very little of the 70 sand water is derived fromthese upper units. The upper (unsaturated) portion of the 70 sand contains very low permeabilities, which indicates very little water has flowed in this portion of the aquifer to dissolve the cementation.

Figure 3.20 presents the outcrop of the 70 sand near the Sand Rock project. This outcrop includes areas of the 70 sand which are covered by alluvium and topsoil. The outcrop map is derived mainly from the 70 sand structure map and some known exposures. These areas would be susceptible to recharge to the 70 sand aquifer, also. The 70 sand crops out in a large percentage of Sections 11 and 12 of T41N-R75W and Sections 6 and 7 of T41N-R74W. Water which enters the outcrop area flows down-dip in the 70 sand.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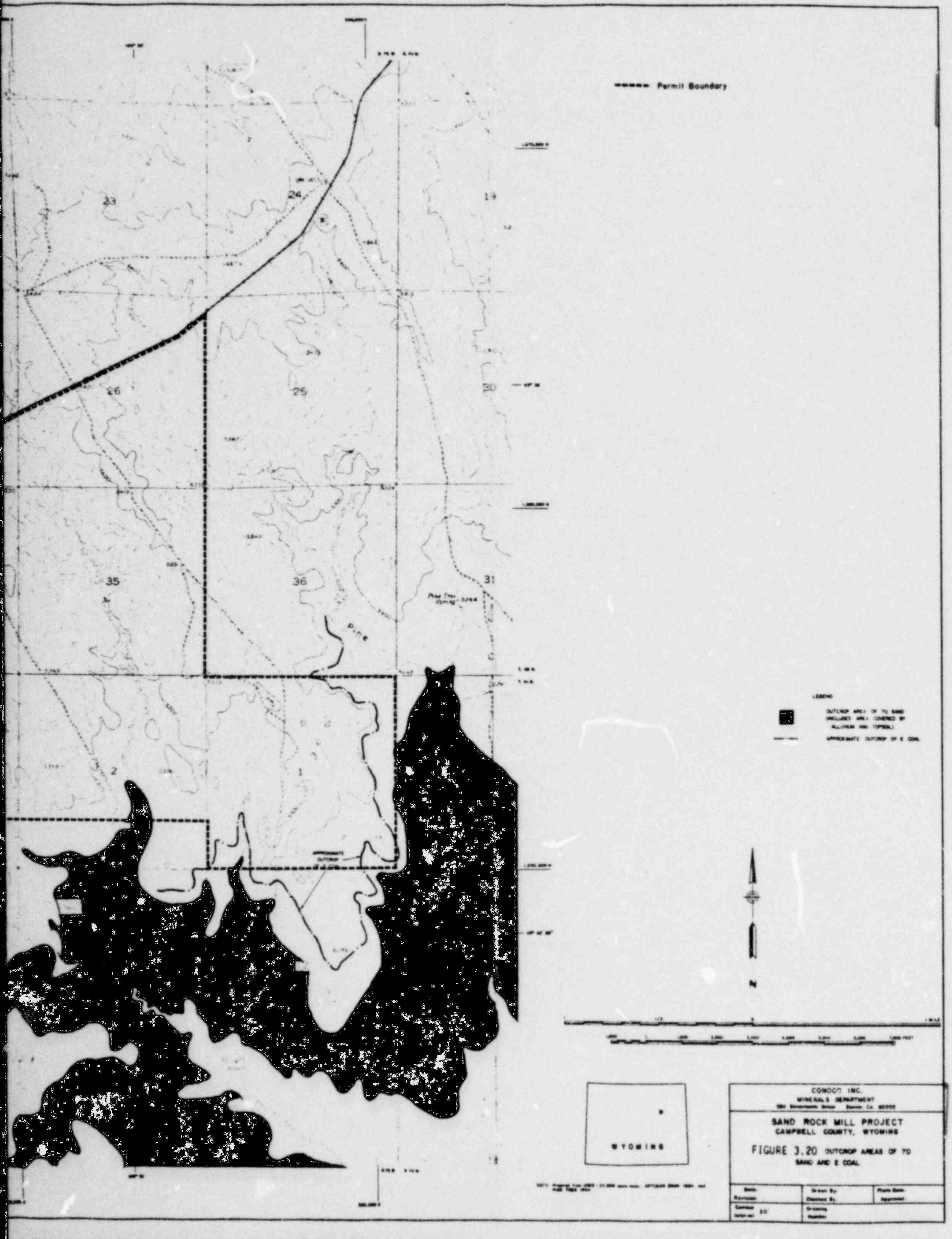

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FIGURE 3.20 OUTCROP AREAS OF 70 SAND AND E COAL

Scale: Revision:	Drawn By: Checked By:	Photo Date: Approved:
Contour Interval: 20'	Drawing Number:	

An outcrop line is shown on Figure 3.20 for the E coal. This outcrop line is inferred from the structure map of the E coal in Figure 3.19. Recharge to the E coal and the Lower mudstone should occur mainly in the area of the outcrop line in the eastern half of Section 1, T41N-R75W. Recharge to all units above the 70 sand probably occurs principally in their outcrop areas, because of alternating low permeability materials.

3.6.2.3 PIEZOMETER AND WELL CONSTRUCTION

A total of 47 piezometers and/or wells were constructed in the evaporation pond and tailings disposal site (35N) areas, 17 in and around Pit 35N, and 30 in the area of the evaporation pond. These piezometers and wells have been used to define the static-water levels, permeabilities and water quality of the shallow geologic units. Table 3.6.2.1 and Figure 3.21 present basic data for the evaporation pond area, including date drilled, depth drilled, perforated interval, lithologic unit and water level for each piezometer. Table 3.6.2.2 gives the same data for the Pit 35N mine area. Twenty-three additional wells have been used to define the groundwater hydrology for the 70 sand and deeper units in other than the evaporation pond and tailings disposal sites. The completion details for these wells is given in Table 3.6.2.3.

3.6.2.4 SUBSOIL AND AQUIFER PROPERTIES

The transmission (transmissivity and hydraulic conductivity) and storage (storage coefficient and specific yield) ability of the aquifers and partially saturated material are discussed in this section. Additional material properties, moisture content, bulk density and grain sizes will also be discussed.

TABLE 3.6.2.1

BASIC COMPLETION AND WATER LEVEL DATA FOR THE EVAPORATION POND AREA (AREA 10)

Hole No.	Date Drilled	Depth Drilled (ft-LSD)	Perforated Interval (ft-LSD)	Lithologic Unit	Water Level Date	Water Level Depth (ft-MP)	Water Level Elev. (ft-MSL)	Elevation of M.P. (ft-MSL)	M.P. Above LSD (ft)
P-1	9/79	51	38-48	LMS - E Coal	4/3/80	dry	5,236.6	5,287.9	1.6
P-2	3/9/80	50.5	35-50	LMS - E Coal*	4/2/80	43.79	5,250.5	5,294.3	1.8
P-3	3/11/80		39-49	LMS	3/27/80	50.5	5,233.4	5,283.9	2.4
P-4				LMS - E Coal*	3/24/80	23.18	5,266.7	5,289.9	1.1
P-4B	3/3/80	33.2	28-33	UMS - E Coal	3/27/80	21.80			1.8
P-4B-1	3/3/80	33	28-33	UMS - E Coal	3/27/80	20.26			3.1
P-4C	3/3/80	25	12-25	UMS - U Coal	3/27/80	19.22			2.6
P-4CA	3/25/80	30	25-30	UMS	3/27/80	22.65			3.7
P-5	3/9/80	47	43-45.5	E Coal	3/24/80	28.37	5,271.9	5,300.3	2.3
P-6	3/4/80	40	28.5-38.5	USS	3/24/80	35.75	5,278.4	5,314.1	1.7
P-7	3/4/80	160	130-160	70SS	3/4/80	133	5,175.6	5,308.6	0.5
P-7A	3/4/80	160	75-90	U70SS	4/10/80	88.49	5,220.4	5,308.9	0.8
P-8	3/9/80	59.5	32-58	LMS - E Coal	4/2/80	26.09	5,296.9	5,269.0	2.1
P-9	3/10/80	35	25-35	LMS - E Coal*	4/2/80	14.60	5,266.1	5,280.7	2.1
P-9A	3/25/80	18	12-18	UMS	4/9/80	16.04	5,264.3	5,280.3	1.7
P-10	3/10/80	59.5	33-59.5	LMS - E Coal*	3/24/80	28.30	5,268.0	5,296.3	0.5
P-11	3/7/80	20	16.5-19	E Coal	3/27/80	18.60	5,254.0	5,272.6	0.3
P-12	3/9/80	32.5	29-32	E Coal	4/9/80	30.90	5,276.5	5,307.4	1.0
P-13	3/13/80	19.5	9-19	UMS	4/11/80	17.60	5,263.6	5,281.2	0.4
P-13A	3/25/80	28	22-28	E Coal	3/27/80	19.96	5,263.9		3.1
P-15	3/11/80	35	27-35	LMS - E Coal*	3/27/80	23.03	5,263.5	5,286.5	2.0
P-15A	3/25/80	21	17-21	UMS	3/27/80	22.9	5,263.5		1.9
P-16	3/11/80	73	58-73	U 70 SS	3/24/80	75.5	5,218.9	5,294.4	2.4
P-17	3/13/80	89.5	79.5-89.5	U 70 SS	3/24/80	92.7	5,211.9	5,304.6	2.6
P-18		25	14-18	All	3/27/80	22.25	5,250.8	5,273	0.3
P-19	3/14/80	59	30-57	LMS	4/10/80	31.34	5,254.2	5,285.5	3.5
P-20	2/28/80	119.3	107-119	S 70 SS	3/27/80	97.54	5,184.5	5,282.0	0.7
P-20A		107.2	99-107	S 70 SS	3/26/80	98.18			1.1
P-20B		117.5	107-117	S 70 SS	3/26/80	98.79			1.6
P-21	3/18/80	120.4	88-118	S 70 SS	3/24/80	75.32	5,177.5	5,252.8	2.8

NOTE:

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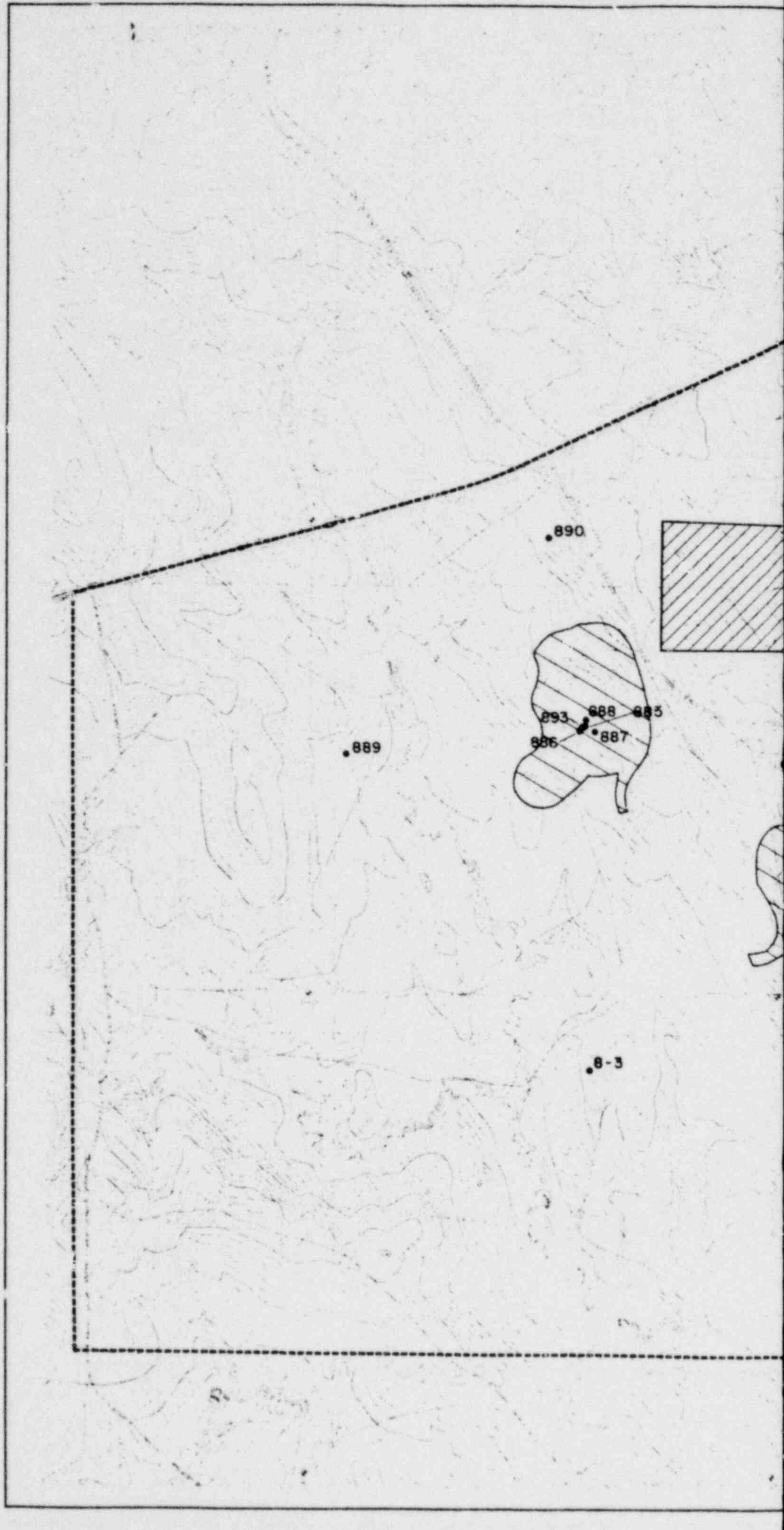
E Coal = E Coal

U Coal = Upper Coal
USS = Upper Sandstone
U 70 SS = Upper (Unsaturated) 70 Sand
70 SS = 70 Sandstone
S 70 SS = Saturated 70 Sandstone

* Completion of well questionable.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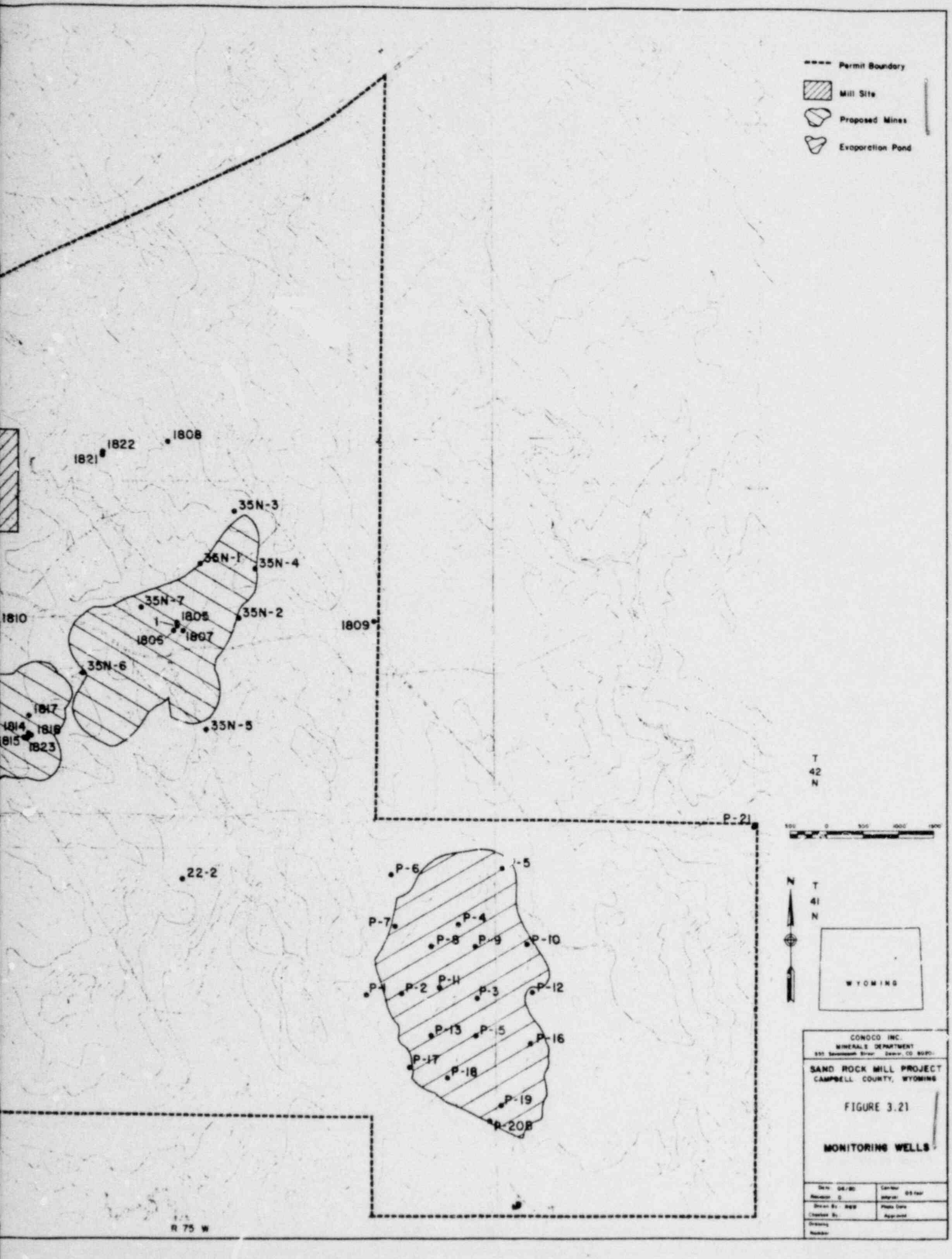

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CAMPBELL COUNTY, WYOMING

FIGURE 3.21

MONITORING WELLS

Date 06/80
Revision 0
Contour interval 05 feet
Drawn By
Checked By
Photo Date
Approved
Drawing Number

TABLE 3.6.2.2

BASIC COMPLETION AND WATER LEVEL DATA FOR THE 35N PIT TAILINGS DISPOSAL AREA

Hole No.	Date Drilled	Depth Drilled (Ft-LSD)	Perforated Interval (Ft-LSD)	Lithologic Unit	Water Level Date	Water Level Depth (Ft-MP)	Water Level Elev. (Ft-MSL)	Elevation of M.P. (Ft-MSL)	M.P. Above LSD (Ft)
35N-1C		179.7	154-179	U70SS	5/15/80	dry	-	5354.8	1.2
35N-1D		43.2	36-44	SS	5/16/80	39.54	5314.9	5354.4	0.8
35N-1E		29.0	21-29	MS	5/15/80	28.86	5326.1	5355.0	1.4
35N-2A		159.5	145-160	U70SS	5/21/80	147.25	5191.0	5338.3	0.8
35N-2B		131.0	126-131	SS	5/19/80	124.28	5214.1	5338.4	0.9
35N-2C		73.3	64-74	MS	5/19/80	69.52	5269.4	5338.9	1.4
35N-3		29.5	20-30	SS	4/09/80	dry	-	5401.9	3.2
35N-4		131.6	112-132	SS-MS	4/09/80	dry	-	5389.3	1.0
35N-5		79.0	69-79	SS	5/19/80	78.4*	5219?	5294.7	1.3
35N-6		90.3	80-90	SS	5/15/80	86.87	5236.5	5323.4	1.2
35N-7A		182.9	143-183	70SS	5/18/80	132.30	5172.9	5305.2	1.1
35N-7B		115.4	101-116	U70SS	5/15/80	dry	-	5305.6	1.5
35N-7C		83.4	74-84	SS	5/15/80	82.09	5229.3	5311.4	4.3
35N-7D		99.0	92-99	E Coal	5/18/80	97.39	5207.9	5305.3	1.2
35N-7E		27.4	22-28	SS	5/15/80	18.90	5289.7	5308.6	1.5
35N-7F		17.7	12-18	MS	5/15/80	14.97	5294.5	5309.5	2.4
35N-7G		59.2	51-59	U Coal	5/18/80	33.14	5272.2	5305.3	1.2

NOTE:

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E Coal = E Coal

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USS = Upper Sandstone
U 70 SS = Upper (Unsaturated) 70 Sand
70 SS = 70 Sandstone
S 70 SS = Saturated 70 Sandstone

* Completion of well questionable.

TABLE 3.6.2.3

BASIC WELL COMPLETION DATA FOR WELLS IN THE MINE AREA

Well No.	Aquifer	Collar Elevation (Ft.Abv.msl)	Depths (Ft.) Total	Casing	Perforated Interval	Gravel Pack	Diameters (In.) Drill Bit	Casing (I.D.)	Type Casing	State Permit	Date Drilled
1810	70SS	5378	265	265	200-260	X	8-3/4	3"	PVC	39650	07/29/77
1808	70-68SS	5377	275	275	195-275	X	9-7/8	5"	PVC	39651	07/28/77
1809	70SS	5356	230	230	135-225	X	8-3/4	3"	PVC	39652	07/28/77
889	70SS	5334	240	260	200-260	X	8-3/4	3"	PVC	39653	07/29/77
890	70-68SS	5410	330	330	240-330	X	8-3/4	3"	PVC	39654	07/29/77
22-2	70SS	5287	165	165	85-165	X	8-3/4	3"	PVC	39655	08/01/77
8-3	70-68SS	5308	175	175	105-175	X	9-7/8	5"	PVC	39656	08/01/77
885	70SS	5350	240	240	180-240	X	9-7/8	5"	PVC	39648	07/22/77
886	70SS	5349	240	240	180-240	X	8-3/4	3"	PVC	-----	07/21/77
887	68SS	5347	320	320	290-320	X	8-3/4	3"	PVC	-----	07/20/77
888	70SS	5352	250	250	180-240	X	8-3/4	3"	PVC	-----	07/21/77
1	70SS	5331	240	240	200-240		6-1/4	5"	PVC	39649	09/17/77
1805	70SS	5331	240	240	120-240	X	8-3/4	3"	PVC	-----	07/22/77
1806	70SS	5324	220	220	120-200	X	8-3/4	3"	PVC	-----	07/21/77
1807	68SS	5328	290	290	250-290	X	8-3/4	3"	PVC	-----	07/22/77
1814	70SS	5345	207	207	143-207		9-7/8	5"	Steel	-----	11/02/78
1815	70SS	5348	208	208	142-208	X	5-1/8	3"	PVC	-----	11/08/78
1816	70SS	5343	207	207	138-207	X	5-1/8	3"	PVC	-----	11/08/78
1817	70SS	5350	233	233	143-233	X	5-1/8	3"	PVC	-----	11/08/78
893	70SS	5348	240	240	153-240	X	9-0	5"	Steel	-----	11/21/78
1821	Roland Coal	5355	1200	1200	1120-1200		8-3/4	6"	Steel	-----	10/22/79
1822	50-40SS	5355	740	740	560-600						
					640-680						
					700-720		8-3/4	6"	Steel	-----	10/26/79
1823	68SS	5345	240	240	210-240		8-3/4	6"	Steel	-----	03/30/80

NOTE:

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U Coal = Upper Coal
USS = Upper Sandstone
U 70 SS = Upper (Unsaturated) 70 Sand
70 SS = 70 Sandstone
S 70 SS = Saturated 70 Sandstone

* Completion of well questionable.

TRANSMITTING PROPERTIES

The results of the constant head injection tests from the low yielding wells and dry piezometers in the evaporation pond and tailings disposal areas will be presented first. The permeability and transmissivity results from the 70 sand wells will follow.

A brief discussion of the aquifer test analysis is given in Appendix A.

Twenty-four constant-head injection tests were conducted to determine the saturated hydraulic conductivity (permeability) of the subsoil materials in the evaporation pond area. The injection rates necessary to maintain the water level at the top of the casing were measured. Most of the injection tests were conducted approximately three to four hours. The constant head used in the permeability computation was the static water level for unsaturated rock units. These two depths were measured from the top of the well casing. Dry piezometers were filled with water for oneor two days prior to the tests to saturate the unit being tested.

Table 3.6.2.4 summarizes permeabilities obtained from constant-head and pump tests in the Sand Rock project area. The permeabilities from packer tests in the evaporation pond area are summarized in Table 3.6.2.5. Packer tests were performed in the areas of the proposed evaporation pond embankments. Their locations are shown on Figure 3.22. The method of testing, well completion and permeabilities are discussed in detail in the final Hydrological Report (Hydro, June 1980).

STORAGE PROPERTIES

Storage coefficients (the storage ability of a confined aquifer) were determined at five locations in the 70 sand aquifer. Two 70 sand tests were conducted to measure the specific yield (the storage ability of an unconfined aquifer) for the 70 sand. Table 3.6.2.4 presents these storage values.

TABLE 3.6.2.4

SUMMARY OF AQUIFER CHARACTERISTICS FROM CORRECT ANALYSES

Well #	Formation	T ft^2/day	S	Comments
P-1	L. Mudstone + E. Coal	0.41	.021	
P-3	L. Mudstone	0.21	-	
P-4	L. Mudstone + E. Coal	0.019	.000013	
P-9A	U. Mudstone	0.041	.001	
P-12	E. Coal	0.055	.0088	
P-15A	U. Mudstone	0.60	.0011	
P-18	Alluvium	3.34	.000042	Very low S for alluvium
P-20B	70SS	0.23	-	recovery test
P-21	70SS	0.31	-	recovery test
35N-2A	U.70SS	0.35	-	recovery test
35N-4	Mudstone	0.15	0.53	
35N-7A	70SS	156.	-	recovery test
35N-7E	SS	0.16	.032	
885 (pump) 886 (observe)	70SS	107.	.015/.001	Streltsova type curve
885 (pump) 888 (observe)	70SS	23.	.0029	Streltsova type curve
886	70SS	241.	-	recovery test
887	68SS	0.25	-	recovery test
1(pump) 1805(observe)	70SS	112.	.00052	Streltsova type curve
1(pump) 1806(observe)	70SS	112.	.00028	Streltsova type curve
1814(pump) 1816(observe)	70SS	508.	.0007	Streltsova type curve
1823	68SS	25	-	recovery test

TABLE 3.6.2.5

SUMMARY OF SUBSOIL PERMEABILITIES FROM PACKER TESTS EVAPORATION POND AREA

Hole Number	Test Interval (ft-LS)	Lithologic Unit*	Hydraulic Conductivity (Permeability)	
			ft/yr	cm/sec
PD-3	30-40	LMS	<1.0	$<9.7 \times 10^{-7}$
PD-5	11.5-16.5	UMS	<1.4	$<1.4 \times 10^{-6}$
	17-22	UMS	63	6.1×10^{-5}
	31-36	LMS	<0.8	$<7.7 \times 10^{-7}$
PD-6	18-23	UMS	<1.5	$<1.4 \times 10^{-6}$
	25-30	E Coal	2.3	2.2×10^{-6}
	29.5-34.5	LMS	1.6	1.5×10^{-6}
PD-7	10-15	USS	330	3.2×10^{-4}
	16-21	UMS	320	3.1×10^{-4}
	25-30	E Coal	1.5	1.4×10^{-6}
PD-8	7-12	USS	5,070	4.9×10^{-3}
	24-29	UMS	<1.0	$<9.7 \times 10^{-7}$
PD-9	18-23	USS	1.5	1.4×10^{-6}
	28-33	UMS	<0.9	$<8.7 \times 10^{-7}$
	32-37	E Coal	<0.7	$<6.8 \times 10^{-7}$
PD-10	12-17	UMS	1.4	1.4×10^{-6}
	17-22	UMS	1.1	1.1×10^{-6}
	24-29	UMS	<1.0	$<9.7 \times 10^{-7}$
	29-34	UMS	<0.8	$<7.7 \times 10^{-7}$

TABLE 3.6.2.5

(CONT.)

Hole Number	Test Interval (ft-LS)	Lithologic Unit*	Hydraulic Conductivity (Permeability) ft/yr	Hydraulic Conductivity (Permeability) cm/sec
PD-11	7-12	USS	250	2.4×10^{-4}
	12-17	USS	1.4	1.4×10^{-6}
	17-22	UMS	<1.3	$<1.3 \times 10^{-6}$
PD-11	24-29	U Coal	<0.9	$<8.7 \times 10^{-7}$
	29-34	UMS	<0.8	$<7.7 \times 10^{-7}$
PD-12	17-22	LMS	1.3	1.3×10^{-6}
	26-31	LMS	<1.1	$<1.1 \times 10^{-6}$
	34-39	U70SS	490	4.7×10^{-4}
PD-14	6-11	USS	360	3.5×10^{-4}
	27-32	LMS	1.2	1.2×10^{-6}
PD-15	7-12	USS	<2.1	$<2.0 \times 10^{-6}$
	14.5-19.5	USS	<1.4	$<1.4 \times 10^{-6}$
	27-32	LMS	<1.1	$<1.1 \times 10^{-6}$
PD-16	8-13	UMS	<2.3	$<2.2 \times 10^{-6}$
	17-22	USS	430	4.2×10^{-4}
	20-25	USS-U Coal	410	4.0×10^{-4}
	30-35	UMS	<0.8	$<7.7 \times 10^{-7}$

TABLE 3.6.2.5

(CONT.)

Hole Number	Test Interval (ft-LS)	Lithologic Unit*	Hydraulic Conductivity (Permeability)	
			ft/yr	cm/sec
PD-17	6-11	USS	6.4	6.2×10^{-6}
	8-13	USS	620	6.0×10^{-4}
	17-22	USS	240	2.3×10^{-4}
	20-25	USS-U Coal	630	6.1×10^{-4}
	25-30	UMS	<0.9	$<8.7 \times 10^{-7}$
	35-40	E Coal	0.7	6.8×10^{-7}
PD-18	11-16	USS	34	3.3×10^{-5}
	19-24	USS	1.2	1.2×10^{-6}
PD-19	12-17	USS	1,060	1.0×10^{-3}
	18-23	U Coal	800	7.7×10^{-4}
PD-20	5-10	USS	12	1.2×10^{-5}
	15-20	USS	140	1.4×10^{-4}
	22-27	UMS	1.0	9.7×10^{-7}
PD-21	8-13	USS	2,800	2.7×10^{-3}
	22-27	USS	17	1.6×10^{-5}
PD-22	14-19	USS	1.4	1.4×10^{-4}
PD-24	6-11	USS	210	2.0×10^{-4}
	17-22	UMS	59	5.7×10^{-5}
	22-27	USS	72	7.0×10^{-5}

TABLE 3.6.2.5

(CONT.)

Hole Number	Test Interval (ft-LS)	Lithologic Unit*	Hydraulic Conductivity (Permeability)	
			ft/yr	cm/sec
PD-26	11-16	USS	5.1	4.9×10^{-6}
	20-25	USS	13	1.3×10^{-5}
	27-32	USS	730	7.1×10^{-4}

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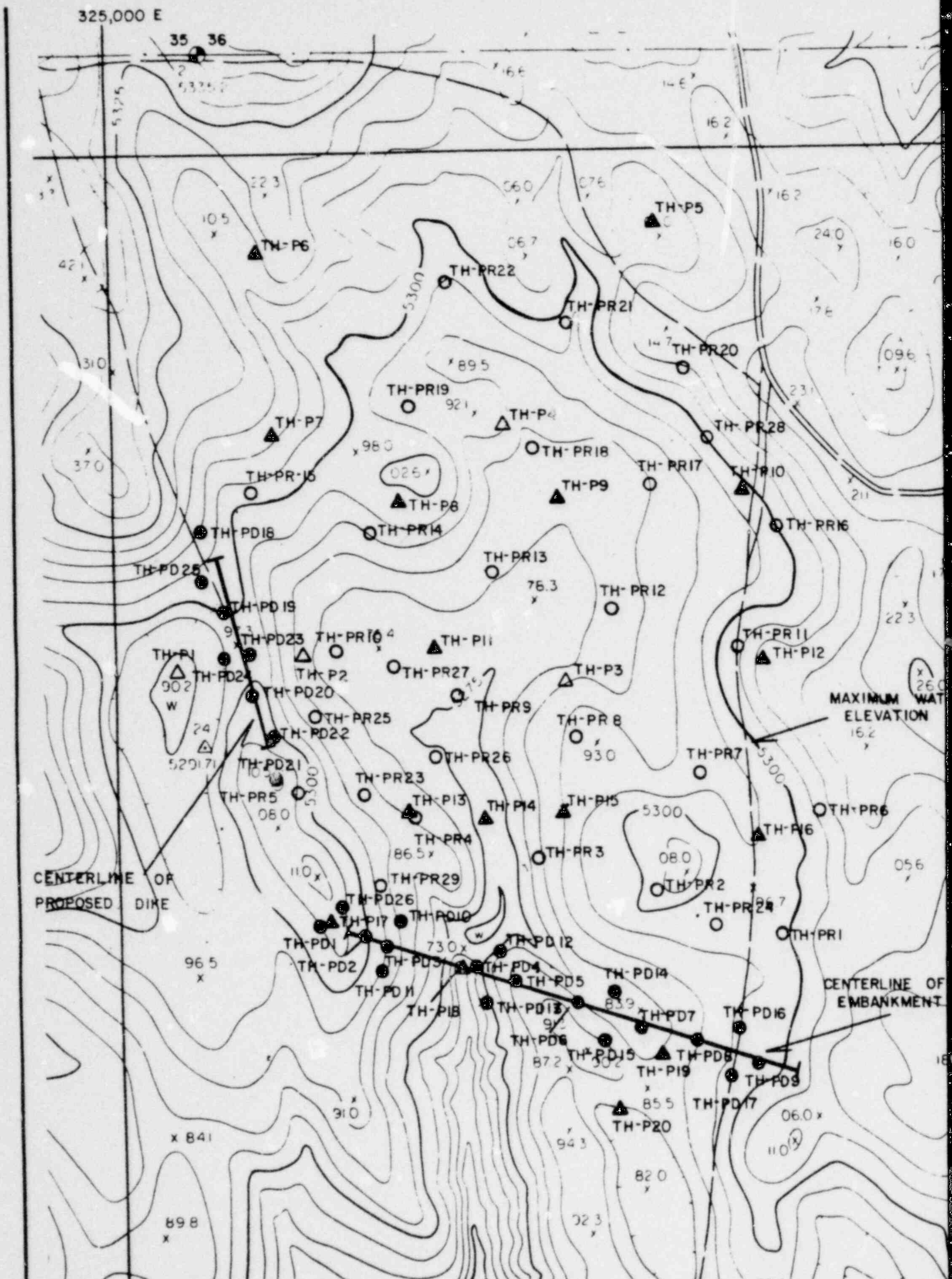
325,000 E
35
36
5325
5300
TH-P5
TH-P6
TH-PR22
TH-PR21
TH-PR20
TH-PR19
TH-P4
TH-P7
TH-PR18
TH-PR28
TH-PR17
TH-P10
TH-PR-15
TH-P8
TH-P9
TH-PD18
TH-PR14
TH-PR16
TH-PR13
TH-PD25
TH-PR12
TH-PD19
TH-PD23
TH-PR10
TH-P11
TH-PR11
TH-P1
TH-P2
TH-P12
TH-PD24
TH-PR27
TH-P3
TH-PD20
TH-PR9
TH-PR25
TH-PR 8
MAXIMUM WAT
ELEVATION
TH-PD22
TH-PR26
TH-PR7
TH-PD21
TH-PR23
TH-PR5
TH-P13
TH-P14
TH-P15
TH-PR6
TH-PR4
TH-P16
TH-PR3
CENTERLINE OF
PROPOSED DIKE
TH-PR29
TH-PR2
TH-PD26
TH-PR24
TH-P17
TH-PD10
TH-PR1
TH-PD1
TH-PD12
TH-PD3
TH-PD4
TH-PD2
TH-PD5
TH-PD14
TH-PD11
CENTERLINE OF
EMBANKMENT
TH-P18
TH-PD13
TH-PD7
TH-PD16
TH-PD6
TH-PD15
TH-PD8
TH-P19
TH-PD9
TH-PD17
TH-P20
W
250
16.6
14.6
16.2
22.3
10.5
06.0
07.6
16.2
24.0
16.0
42.1
06.7
17.6
31.0
89.5
09.6
92.1
23.1
37.0
98.0
02.6
21.1
76.3
22.3
90.2
26.0
16.2
93.0
08.0
08.0
05.6
186.5
11.0
96.7
73.0
96.5
83.9
87.2
90.2
85.5
06.0
91.0
84.1
94.3
11.0
82.0
89.8
92.3
96.2
84.3

△ Exploratory holes drilled during preliminary investigation, September 9 - 20, 1979.

▲ Exploratory holes drilled for installation of piezometers during final investigation, February 28 - March 24, 1980.

○ Reservoir exploratory holes drilled during final investigation, February 25 - March 24, 1980.

● Embankment foundation exploratory holes drilled during final investigation, March 4 - 24, 1980.

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CAMPBELL COUNTY, WYOMING

FIGURE 3.22
LOCATION OF PACKER TEST HOLES

EXPLORATION POND AND
TEMPORARY TAILINGS DISPOSAL AREA

Date June 1980
Revision
Drawn By
Checked By
Drawing Number Fig. 1B

ADDITIONAL MATERIAL PROPERTIES

Additional material properties (Chen 1980) were also used in the hydrological analysis. The porosity of the materials at the site is in the range of 40 per cent while most non-saturated rock had moisture contents in the range of 15 per cent. The average bulk density of the materials is roughly 2.65 g/cm^3.

3.6.2.5 WATER LEVEL

Tables 3.6.2.1 and 3.6.2.2 give a static-water level for each piezometer. Several 70-sand wells have been monitored since their installation in 1977, and this data is given in Table 3.6.2.6. Figure 3.21 gives the location of the preoperational groundwater monitoring sites. A discussion of the water level elevations and changes for each geologic unit is presented.

The water level elevation map for the 70 sand aquifer is presented in Figure 3.23 for the Sand Rock project area. The outcrop area of the 70 sand, which is the recharge area for this aquifer, is given in Figure 3.20. This recharge area and the data points in Table 3.6.2.6 were used to construct the piezometric surface for the 70 sand aquifer. The water level elevation contours are closely spaced next to the recharge areas where the saturated thickness is less. Therefore, steeper gradients are required to transmit the water in this area than further down gradient. The water level elevation is lower in the center of Section 1 (T41N-R75W) than in the center of Section 2 because Section 1 is farther from the outcrop area. The water level elevation varies from a high which is greater than 1,585 meters (5,200 feet) near the outcrop area to less than 1,573 meters (5,160 feet) north of the permit area.

Table 3.6.2.6 summarizes water level variations. Water levels in wells 22-2 and 1809 have varied approximately one foot over this period. Water level fluctuations for wells 1810, 885 and 1 have been in the range of 0.6, 0.9 and 1.2 meters (2,3 and 4 feet), respectively.

TABLE 3.6.2.6

WATER LEVEL DATA FOR THE 70 SAND WELLS

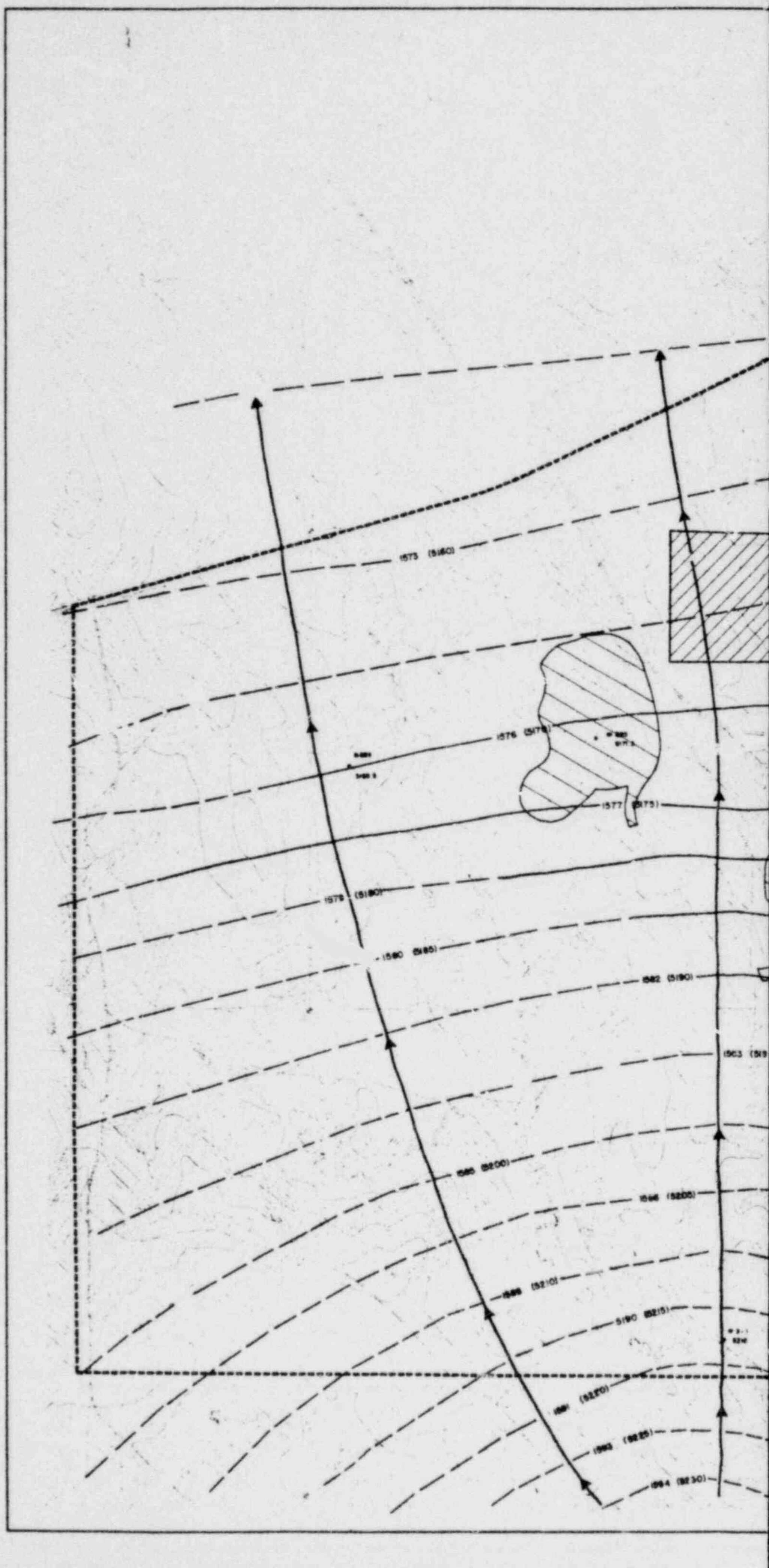
	Well											
	22-2		885		889*		1		1809		1810	
Date	Depth	Elev.	Depth	Elev.	Depth	Elev.	Depth	Elev.	Depth	Elev.	Depth	Elev.
8/17/77			181.3	5,168.7			159.8	5,171.2				
8/24/77							159.2	5,171.8				
9/15/77	97.9	5,189.1	180.3	5,169.7	163.3	5,170.7			187.6	5,168.4	207.2	5,170.8
10/26/77	98.1	5,188.9	180.3	5,169.7	164.1	5,169.9	158.2	5,172.8	187.5	5,168.5	207.5	5,170.5
1/24/78			180.2	5,169.8			157	5,174				
2/13/78			180.3	5,169.7			157	5,174				
3/21/78			179.8	5,170.2			156.7	5,174.3				
9/13/78	97.67	5,189.3			17.5	5,316.5			187.83	5,168.2	205.17	5,172.8
2/15/79	98.50	5,188.5	179.58	5,170.4	30.83	5,303.2					205.83	5,172.2
3/1/79	98.33	5,188.7	179.08	5,170.9	38.33	5,295.7	157.67	5,173.3	188.17	5,167.8	205.58	5,172.4
5/30/79	98.17	5,188.8	178.33	5,171.7	42.83	5,291.2	158.17	5,172.8	187.76	5,168.2	205.50	5,172.5
7/19/79	97.87	5,189.2	178.75	5,171.3	49.50	5,284.5	156.17	5,174.8	187.33	5,168.7	205.08	5,172.9
9/4/79	97.58	5,189.4	178.33	5,171.7	50.17	5,283.8	156.42	5,174.6	187.31	5,168.7	205.50	5,172.5
9/29/79							156.00	5,175.0				
11/30/79	97.67	5,189.3	179.67	5,170.3	53.62	5,280.4	156.00	5,175.0	187.71	5,168.3	205.17	5,172.8
12/21/79							156.00	5,175.0				

	Well											
	22-2		885		889		1		1809		1610	
Date	Depth	Elev.	Depth	Elev.	Depth	Elev.	Depth	Elev.	Depth	Elev.	Depth	Elev.
1/2/80	97.58	5,189.4	178.5	5,171.2	62.00	5,272.0	156.08	5,174.9	187.67	5,168.3	205.08	5,172.9
4/15/80					56.17	5,277.8	—	—	187.33	5,168.7	204.83	5,173.2
4/16/80							155.67	5,175.3				

	Well									
	893		1814		1815		1816		1817	
Date	Depth	Elev.	Depth	Elev.	Depth	Elev.	Depth	Elev.	Depth	Elev.
11/16/78			161.3	5,183.7	162.6	5,185.4	158.3	5,184.7	166.5	5,183.5
12/1/78			161.1	5,183.9	162.4	5,185.6	158.2	5,184.8	166.5	5,183.5
6/19/79	179.0	5,169.0	159.92	5,185.1						
9/26/79	179.0	5,169.0	159.0	5,186.0						
9/27/79	178.5	5,169.5								
12/2/79	178.0	5,170.0	159.67	5,185.3						
4/1/80			159.67	5,185.3						
4/9/80	178.08	5,169.9								

Note: Depth, in ft below LS
Elev., in ft above MSL

* Fluctuations in water level hint at improper completion of well (see Section 2.7.1.5)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1576 (5170)
1577 (5175)
1579 (5180)
1580 (5185)
1582 (5190)
1583 (519
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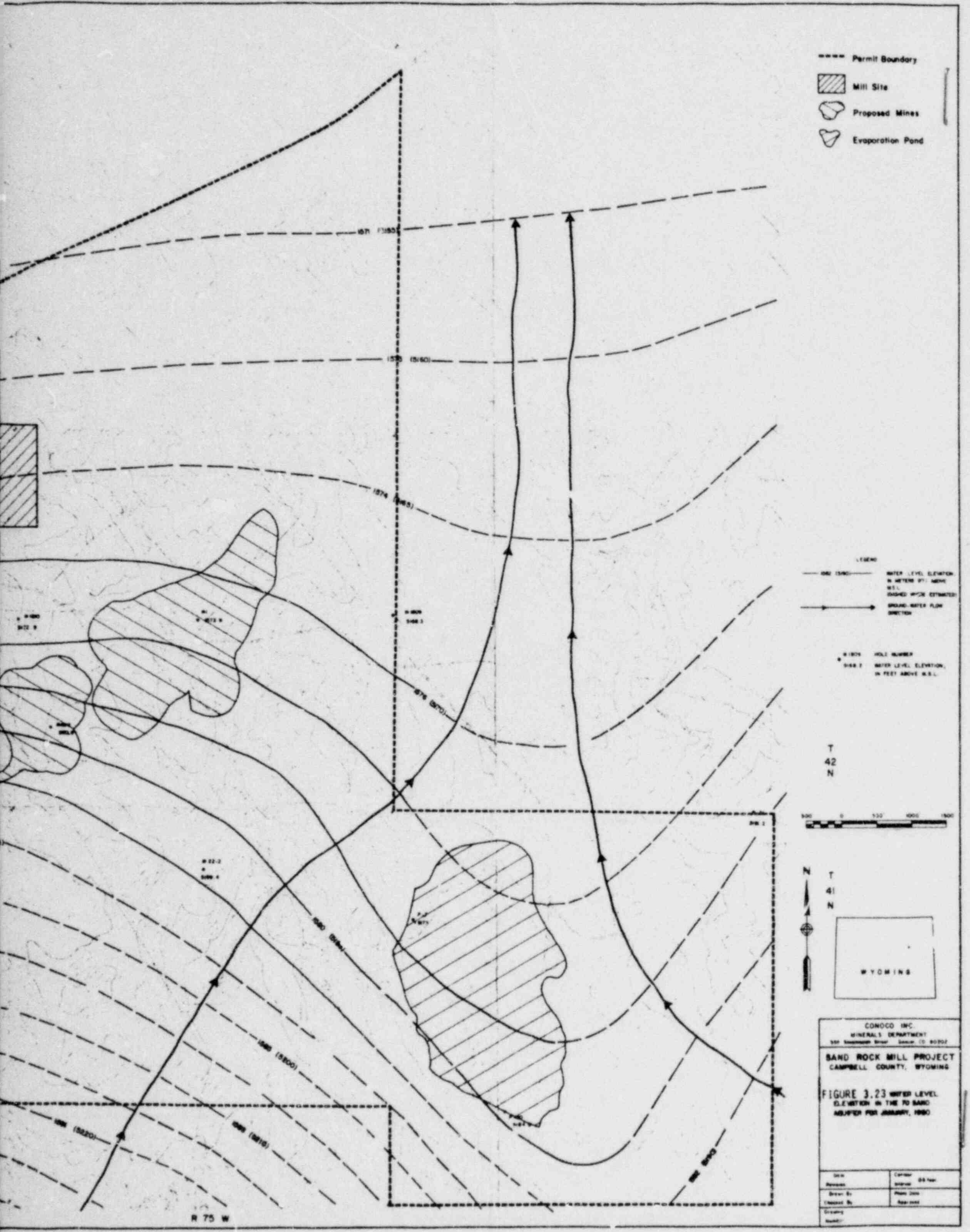
1586 (5205)
1588 (5210)
5190 (5215)
1591 (5220)
1593 (5225)
1594 (5230)



CONOCO INC.
MINERALS DEPARTMENT

SAND ROCK MILL PROJECT
CAMPBELL COUNTY, WYOMING

FIGURE 3.23 WATER LEVEL ELEVATION IN THE 70 SAND AQUIFER FOR JANUARY, 1980

Tables 3.6.2.1 and 3.6.2.2 present the water level elevation for the Upper mudstone, Upper coal and Upper sandstone in the evaporation pond area and mudstone and sandstones in the tailings disposal area piezometers. The water level elevations of the Upper coal and Upper mudstone are fairly close to the elevations in the Lower mudstone and E coal.

Response of well 887 (68SS) to pumping in Well 885 (70SS) and response of well 1807 (68SS) to pumping in well 1 (70SS) suggest that connections exist between the 70 and 68 sandstones in the vicinity of pits 35N and 34.

3.6.2.6 WATER MOVEMENT

The hydraulic gradient of the 70 sand aquifer can be obtained from Figure 2.5. The gradient of the water table in the 70 sand varies from 0.012 to 0.0018 m/m with an average value of 0.006 m/m. An average horizontal rate of movement of the groundwater in the 70 sand was estimated to be 1.2×10^{-3} cm/sec (1200 ft/yr) from an average horizontal permeability of 1.9×10^{-3} cm/sec (2,000 ft/yr), an effective porosity of 0.01 and the above average gradient. In general, movement of water in the 70 sand should gradually decrease with distance from the recharge area. Flow directions in the 70 sand are shown in Figure 3.23.

Hydraulic gradients in the E coal and lower mudstone vary from 0.004 to 0.05 m/m with an average gradient in the range of 0.015 m/m. The steeper and flatter gradients should be an indication of lower and higher permeabilities, respectively. An average gradient of 0.015 m/m and a permeability of 4.8×10^{-6} cm/sec (5 ft/yr) should yield a velocity fairly representative of both the low and high permeability areas. A groundwater velocity of 1.4×10^{-6} cm/sec (1.5 ft/yr) was calculated from the above hydraulic gradient and permeability values and an effective porosity of 0.05. This shows that the groundwater in the E coal and Lower mudstone moves very slowly. The flow directions for the Lower mudstone and E coal are north and west which follow the slope of these units.

Water levels in the Upper mudstone and Upper coal piezometers are very close to the water levels in nearby Lower mudstone and E coal wells (Hydro, 1980). Therefore, gradients in the Upper mudstone and Upper coal are thought to be very similar to those in the Lower mudstone and E coal. Flow direction in the Upper mudstone and Upper coal are probably similar to those of the Lower mudstone.

Rates of water movement in the tailings disposal area for the mudstones and sandstones above the 70 sand are estimated to be in the range of the velocities for E coal and Lower mudstone in the evaporation pond area.

3.6.2.7 GROUNDWATER QUALITY

Although groundwater quality data were available in Conoco's June, 1979 Mine Permit Application to the State of Wyoming, a specific baseline program was initiated in mid-1979 to satisfy NRC requirements.

Sampling procedures have been consistent with State of Wyoming guidelines and frequency of sampling was determined by recommendations in the NRC's Draft Generic Environmental Impact Statement.

The groundwater quality data in the Sand Rock project area has been collected from three sources: 1) private wells, 2) the Conoco Inc. mine monitoring wells and 3) the evaporation pond and tailings disposal site wells. The water quality for the three sources are tabulated in Tables 3.6.2.7, 3.6.2.8 and 3.6.2.9 respectively. Figure 3.21 gives the location of the Conoco Inc. wells, while the private wells are shown on Figures 3.1 and 3.2. The groundwater quality is very hard with total dissolved solids normally greater than 500 mg/1.

TABLE 3.6.2.7

GROUNDWATER QUALITY FOR PRIVATE WELLS NEAR CONOCO'S SAND ROCK PROJECT

Well No.	Well Location	Date	TDS	Conductivity		Temperature	Na	K	Ca	Mg	SO_4	Cl	CO_3	HCO_3	pH	
	41N-74W															
A-1 17304	04 NESE	6/26/79[(a)]	492	820	(705)	(17)	39	9	101	15	187	6	0	234	7.53	(7.15)
		12/7/79[(b)]	606	870	(839)	(7)	46	9	107	17	215	8	0	278	7.73	(7.70)
A-2 17302	04 SENE	6/26/79[(c)]	655	1,100	(676)	(17)	13	9	156	10	179	25	0	312	7.91	(7.00)
		8/14/79	—	—	(647)	(15)	—	—	—	—	—	—	—	—	—	(7.45)
		12/7/79	670	1,130	(1,069)	(9)	9	9	169	27	160	61	0	307	7.61	(7.70)
P'-6 9309	17 SWSE	6/28/79	831	1,270	(1,083)	(16)	107	10	128	19	460	12	0	151	7.66	(7.30)
P'-7 12240	17 SWSE	6/28/79	509	940	(795)	(14)	48	8	100	20	212	16	0	239	7.58	(7.05)
	41N-75W															
P'-9 —	03 NESW	6/20/79	1,024	1,389	(1,163)	(13)	45	13	201	48	550	7	0	312	7.32	(6.85)
		9/27/79	1,012	1,365	(1,258)	(12)	42	11	186	46	450	6	0	315	7.57	(6.95)
		3/26/80	964	1,300	(1,249)	(11)	42	13	197	47	516	6	0	327	7.61	(7.30)
P'-11 —	04 NENW	8/16/79	1,048	1,500	(1,308)	(12.5)	65	12	165	53	548	8	0	283	7.74	(7.45)
	42N-74W															
P'-8 14683	30 NWNW	6/28/79	2,339	2,710	(2,466)	(16)	16	11	512	116	1,270	4	0	366	6.95	(6.60)
I-30 — (Pine Tree Spring)	31 SWNE	6/29/79	1,030	1,450	(1,176)	(30)	31	9	211	54	467	25	0	376	7.83	(8.85)
		3/25/80	844	1,260	(1,131)	(1)	29	9	162	50	472	21	0	276	7.61	(8.6)
	42N-75W															
P'-10 —	33 SWSE	6/20/79	1,566	1,923	(1,608)	(18)	37	5	375	58	910	12	0	359	7.71	(7.45)
T-1 12299	33 SENW	6/26/79	661	1,100	(924)	(15)	87	9	106	17	270	10	0	254	7.49	(7.35)
		9/18/79	690	1,060	(896)	(14)	85	9	106	20	284	7	0	249	7.69	(6.90)
		9/25/79	—	—	(920)	(19)	—	—	—	—	—	—	—	—	—	(7.05)
P'-36 —	36 SENW	10/10/79	604	921	(801)	(15)	15	6	109	43	154	8	0	390	7.72	(7.30)
		12/10/79	693	1,070	(1,042)	(9.5)	13	5	143	51	251	7	0	398	7.80	(7.70)

Notes: Number below well number is the State Engineer's G.W. Permit Number.

All concentrations are in mg/l except Conductivity, in µmhos/cm @ 25°C; Temperature, in °C; pH in pH units, U; Pb-210, Po-210, Ra-226 and Th-230 in pCi/l; and Charge Balance = difference in major equivalents divided by sum of major equivalents times 100.

( ) Denotes field measurements.

* Denotes less than the value.

(a) Additional parameter for the sample is silver = *0.01.

(b) Additional parameters for this sample are silver = *.01 and alkalinity (as $CaCO_3$) = 228.

(c) Additional parameter for this sample is silver = *0.01.

TABLE 3.6.2.7

(CONT.)

Well No.	Al	NH_3 (as N)	As	Ba	Be	B	Cd	Cr	Cu	F	Fe	Pb	Mn	Hg
A-1	• .05	• .05	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	0.13	0.011	• .05	0.007	• .001
17304	• .05	• .05	• .002	• .02	• .005	• 1.0	• .002	• .01	0.007	0.19	• .05	• .05	0.02	• .001
A-2	• .05	• .05	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	0.16	0.024	• .05	• .003	• .001
17302	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	• .05	0.10	• .002	• .02	• .005	• 1.0	.056	• .01	.022	.22	.17	.17	.02	• .001
P'-6	• .05	• .05	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	.08	.592	• .05	.072	• .001
9309														
P'-7	• .05	• .05	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	.14	.424	• .05	.078	• .001
12240														
P'-9	• .05	• .05	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	.13	.069	• .05	.088	• .001
--	• .05	--	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	• .05	• .05	• .05	.07	• .001
	• .05	0.10	• .002	• .02	• .005	• 1.0	• .005	• .01	0.010	0.12	0.10	0.07	0.08	• .001
P'-11	• .05	0.06	• .002	• .02	• .005	• 1.0	.008	• .01	.009	.14	.02	• .05	.02	• .001
--														
P'-8	• .05	0.09	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	.31	5.842	• .05	.856	• .001
14683														
I-30	• .05	0.07	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	0.90	0.038	• .05	0.279	• .001
--	• .05	0.57	• .002	• .02	• .005	• 1.0	• .005	• .01	0.009	0.80	0.10	0.09	0.24	• .001
(Pine Tree Spring)														
P'-10	• .05	• .05	• .002	• .02	• .005	• 1.0	.013	• .01	• .002	.36	.139	• .05	.03	• .001
--														
T-1	• .05	• .05	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	.17	.012	• .05	.016	• .001
12299	• .05	• .05	• .002	• .02	• .005	• 1.0	• .002	• .01	.005	.23	.12	• .05	.06	• .001
	--	--	--	--	--	--	--	--	--	--	--	--	--	--
P'-36	• .05	2.81	• .002	• .02	• .005	• 1.0	• .002	• .01	.002	.27	5.6	• .05	.08	• .001
--	--	0.14	--	--	--	--	--	--	--	--	--	--	--	--

TABLE 3.6.2.7

(CONT.)

Well No.	Mo	Ni	NO_3	Se	V	Zn	U	Pb-210	Po-210	Ra-226	Th-230	Charge Balance
A-1	• .02	• .01	1.70	• .002	• .02	1.80	37 ± 2	0 ± .3	0.03 ± 0.1	0.15 ± .05	0 ± .1	1.9
17304	• .05	• .01	1.86	• .002	• .02	1.83						1.6
A-2	• .02	• .01	24.0	• .002	• .02	0.054	20 ± 1	0.3 ± .1	0 ± .04	0.15 ± .04	0.4 ± .1	0.8
17302	—	—	—	—	—	—	—	—	—	—	—	--
	• .05	• .01	36.0	• .002	• .05	.135						8.4
P'-6 9309	• .02	• .01	.30	• .002	• .02	.054	0 ± 2	0 ± 1	0 ± .02	0.35 ± .05	0.2 ± .1	1.9
P'-7 12240	• .02	• .01	.22	• .002	• .02	.041	6 ± 1	0 ± .05	0 ± .06	0.74 ± .07	0.3 ± .1	0.8
P'-9	• .02	• .01	1.16	.007	• .02	.024	32 ± 2	1.6 ± .2	0.4 ± .05	2.0 ± .1	0.2 ± .1	1.5
—	• .02	• .01	—	• .002	• .02	.006						1.6
	• .05	• .01	0.44	• .002	• .05	0.007						1.3
P'-11 --	• .02	• .01	.88	• .002	• .02	.050						1.7
P'-8 14683	• .02	• .01	.34	• .002	• .02	0.945	7 ± 1	0 ± .5	0.08 ± .02	0.75 ± .07	0 ± .1	5.1
I-30	• .02	• .01	1.61	• .002	• .02	0.007	2 ± 1	0 ± .9	0.2 ± .04	0.35 ± .05	137 ± 7	0.1
--	• .05	• .01	2.25	• .002	• .05	0.006						4.5
(Pine Tree Spring)												
P'-10 --	• .02	• .01	.39	• .002	• .02	.078	17 ± 1	1.9 ± .7	0.10 ± .02	0 ± .08	0 ± .1	0.1
T-1	• .02	• .01	1.43	• .002	• .02	.113	44 ± 2	0 ± .4	0.02 ± .01	0.41 ± .06	0.3 ± .1	3.0
12299	• .02	• .01	3.05	• .002	• .02	.070						3.2
	—	—	--	--	--	--	--	--	--	--	--	--
P'-36	• .02	• .01	1.07	• .002	• .02	.720						0.2
--	—	—	.39	—	—	—						0.3

TABLE 3.6.2.8

GROUNDWATER QUALITY FOR CONOCO'S SAND ROCK MONITORING WELLS

Well No.	Well Location	Date	TDS	Conductivity		Temperature	Na	K	Ca	Mg	SO_4	Cl	CO_3	HCO_3	pH	
	41N-75W															
22-2	02 NWNE	1/3/80	508	725			13	8	96	23	106	5	0	305	6.95	
8-3 (W-4A)	03 NENW	6/28/79	1,460	1,950	(1,610)	(8)	8	12	354	58	980	6	0	361	7.10	(6.85)
		9/27/79	1,426	1,910	(1,660)	(12)	9	12	278	96	750	6	0	371	7.30	(6.50)
		12/6/79	1,566	1,800	(1,680)	(10)	8	13	245	120	936	6	0	361	7.23	(7.75)
		4/9/80	1,398	2,000	(1,750)	(10)	10	14	251	115	860	12	0	256	6.75	(7.1)
	42N-75W															
893 (W-1)	34 NESW	11/30/78	975	1,100		(11.1)	42	10	180	36	470	2	0	235	7.1	
		6/27/79	820	1,250	(1,080)	(15)	47	12	158	35	427	6	0	264	7.54	(7.25)
		9/27/79	870	1,250	(1,150)	(13)	43	11	158	37	408	6	0	278	7.27	(6.95)
		10/10/79	914	1,240	(985)	(15)	45	12	160	34	418	6	0	266	7.45	(7.70)
		12/21/79	874	1,150	(1,120)	(11)	44	12	155	40	410	5	0	266	7.23	(7.65)
		4/9/80	842	1,350	(1,150)	(11)	47	12	159	40	460	10	0	281	7.31	(7.5)
885	34 NESW	4/12/78(a)	836	1,113		--	31.5	8.1	208	33.5	426	3.3	0	281	7.53	
886	34 NESW	4/12/78(b)	827	1,299		--	46	9.5	228	43	75	4.9	0	851	7.44	
887	34 NESW	4/12/78(c)	1,170	1,490		--	54	9.1	265	56	459	11	0	375	7.66	
888	34 NESW	4/12/78(d)	855	1,155		--	54	8.1	180	30	424	6.4	0	311	7.97	
889	34 NWSW	1/3/80	462	640		--	12	8	79	23	198	5	0	134	6.60	
		4/15/80	395	630	(570)	(11)	8	8	78	21	192	6	0	146	7.24	(7.0)
	42N-75W															
1 (W-2)	35 NWSE	4/12/78(a)	286	504		--	8.4	7.0	80	14.0	72.5	<2	0	228	7.87	
		11/30/78(b)	364	510		(11.4)	14	7.7	81	15	73	1	0	172	6.7	
		6/27/79	218	440	(363)	(15)	13	8	47	14	85	6	0	195	7.90	(7.75)
		9/29/79	254	464	(442)	(14)	15	8	54	14	64	3	0	217	7.68	(7.20)
		12/21/79	352	515	(473)	(10)	14	8	67	16	71	4	0	242	7.15	(7.40)
		4/16/80	182	295		--	7	7	35	9	46	4	0	127	7.45	(7.6)
1805	35 NWSE	4/12/78(h)	765	996		--	60	7.7	143	29	433	6.4	0	178	8.06	
1806	35 SWNE	4/12/78(i)	886	1,290		--	41	9.1	234	46	28	4.9	0	975	7.25	
1807	35 SWNE	4/12/78(j)	680	1,100		--	35	8.4	187	35	98	<2.0	0	663	7.44	
1808 (W-4B)	34 NWNE	6/28/79	573	950	(800)	(15)	69	9	93	19	303	10	0	161	7.45	(7.20)
		9/27/79	570	930	(789)	(14)	69	9	86	17	300	8	0	171	7.48	(6.45)
		12/15/79	608	900	(813)	(9)	63	8	84	17	280	6	0	159	7.34	(7.65)
		4/2/80	684	1,010	(988)	(10)	77	10	115	24	405	8	0	173	8.04	(8.2)
1809	34 NESE	4/15/80	877	1,220	(1,160)	(14)	59	12	104	34	432	8	0	317	7.61	(7.5)
1810	34 NWSW	4/15/80	824	1,350	(943)	(13)	47	12	159	40	460	10	0	281	7.31	(7.6)
1814 (W-3)	34 SWSW	11/30/78(c)	1,006	1,130		(13.5)	22	8.3	190	38	497	3	0	248	6.5	
		6/27/79	987	1,440	(1,230)	(13)	42	12	201	45	461	8	0	307	7.29	(7.05)
		9/26/79	1,068	1,480	(1,290)	(13)	45	14	201	46	490	10	0	305	7.19	(6.80)
		12/2/79	1,104	1,380	(1,390)	(10)	41	12	197	51	508	5	0	285	7.09	(7.85)
		4/1/80	1,016	1,370	(1,380)	(10)	44	13	203	52	562	6	0	305	7.47	(7.3)
1821	34 NWNW	10/25/79	680	1,020	(620)	(15)	131	9	78	6	136	12	0	427	7.93	(7.55)
1822	34 NWNW	10/28/79	468	760	(566)	(13)	90	7	53	8	166	10	0	183	7.77	(7.60)

TABLE 3.6.2.8

(CONT.)

Well No.	Al	NH_3 (as N)	As	Ba	Be	B	Cd	Cr	Cu	F	Fe	Pb	Mn	Hg
22-2	• .05	0.13	• .002	• .02	• .005	• 1.0	• .002	• .01	0.003	0.27	1.51	• .05	0.68	• .001
8-3	• .05	0.11	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	0.03	1.98	• .05	0.33	• .001
(W-4A)	• .05	0.81	• .002	• .02	• .005	• 1.0	• .002	0.01	0.004	0.07	2.4	• .05	0.33	• .001
	• .05	0.47	• .002	• .02	• .005	• 1.0	• .002	• .01	0.002	0.13	2.65	0.07	0.33	• .001
	• .05	0.11	• .002	• .02	• .005	• 1.0	0.006	0.03	0.010	0.09	3.75	0.08	0.32	• .001
893	0.04	0.15	• .002	0.07	—	0.1	• .005	0.01	• .02	0.1	0.3	0.03	0.03	• .0005
(W-1)	• .05	• .05	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	0.12	4.43	• .05	0.13	• .001
	• .05	0.13	—	• .02	—	• 1.0	• .02	• .01	0.002	0.15	8.7	• .05	0. 7	• .001
	• .05	0.36	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	0.14	7.3	• .05	0.15	• .00[illegible]
	• .05	0.13	• .002	• .02	• .005	• 1.0	• .002	• .01	0.007	0.13	7.55	• .05	0.16	• .001
	• .05	• .05	• .002	• .02	• .005	• 1.0	• .005	0.03	• .005	0.10	7.25	0.05	0.16	• .001
885	• .1	• .1	0.004	0.19	• .005	0.2	• .005	• .01	• .01	0.1	0.66	—	0.23	0.00003
886	• .1	0.18	0.008	1.5	• .005	0.2	• .005	• .01	• .01	0.4	5.2	—	2.3	• .00002
887	• .1	• .1	• .002	0.22	• .005	0.2	• .005	• .01	• .01	0.2	0.18	—	0.34	• .00002
888	• .1	0.65	0.019	0.22	• .005	0.2	• .005	• .01	• .05	0.2	0.18	—	1.5	• .00002
889	• .05	0.05	• .002	• .02	• .005	• 1.0	• .005	• .01	0.003	0.36	• .05	• .05	0.21	• .001
	• .05	0.09	• .005	• .05	• .005	• 1.0	• .005	0.02	• .005	0.34	• .05	• .05	0.23	• .001
1	• .1	• .1	• .002	0.13	• .005	0.1	• .005	• .01	• .01	0.1	• .005	—	0.02	• .00002
(W-2)	0.05	0.01	• .002	0.06	—	0.1	• .005	0.01	• .03	0.1	0.02	0.01	0.01	• .0005
	• .05	• .05	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	0.15	• .05	• .05	0.004	• .001
	• .05	0.21	• .002	• .02	• .005	• 1.0	• .002	• .01	• .002	0.17	• .05	• .05	0.02	• .001
	• .05	0.15	• .002	• .02	• .005	• 1.0	• .002	• .01	0.003	0.15	• .05	• .05	0.02	• .001
	• .05	0.05	• .002	• .02	• .005	• 1.0	• .005	0.02	• .005	0.15	• .05	• .05	• .01	• .001
1805	• .1	• .1	0.006	0.15	• .005	0.2	• .005	• .01	• .01	0.2	0.11	—	0.06	• .00002
1806	• .1	0.15	0.029	1.4	• .005	0.2	• .005	• .01	• .01	0.2	12	—	2.2	• .00002
1807	• .1	0.1	0.013	0.67	• .005	0.2	• .005	• .01	• .01	0.2	1.9	—	1.8	• .00002
1080	• .05	0.38	• .002	• .02	• .005	• 1.0	• .002	0.01	• .002	0.21	0.13	• .05	0.09	• .001
(W-4B)	• .05	1.02	• .002	• .02	• .005	• 1.0	• .002	• .01	0.003	0.27	0.21	• .05	0.13	• .001
	• .05	0.10	• .002	• .02	• .005	• 1.0	• .002	• .01	0.005	0.23	0.11	• .05	0.06	• .001
	• .05	• .05	• .002	• .02	• .005	• 1.0	• .005	0.02	• .005	0.20	• .05	0.07	0.05	• .001
1809	• .05	0.33	0.009	• .02	• .005	• 1.0	0.005	0.02	0.019	0.20	2.37	0.07	1.22	• .001
1810	• .05	0.09	• .002	• .02	• .005	• 1.0	• .005	0.02	0.010	0.34	• .05	• .05	1.22	• .001
1814	0.05	0.11	• .002	0.06	—	1.0	• .005	0.01	• .03	0.1	0.4	0.03	0.05	• .0005
(W-3)	• .05	• .05	.002	• .02	• .005	• 1.0	• .002	• .01	• .002	0.13	5.7	• .05	0.168	• .001
	• .05	• .05	• .002	• .02	• .005	• 1.0	• .02	• .01	0.003	0.14	11.0	• .05	0.21	• .001
	• .05	0.14	• .002	• .02	• .005	• 1.0	• .002	• .01	0.008	0.12	12.1	• .05	0.20	• .001
	• .05	• .05	• .002	• .02	• .005	• 1.0	• .005	0.02	0.009	0.09	10.0	0.08	0.21	• .001
1821	• .05	0.80	• .002	0.06	• .005	• 1.0	0.004	• .01	• .002	0.40	• .05	• .05	0.05	• .001
1822	• .05	0.07	• .002	• .02	• .005	• 1.0	• .005	• .01	• .002	• .05	• .05	• .05	0.02	• .001

TABLE 3.6.2.8

(CONT.)

Well No.	Mo	Ni	NO_3	Ag	Se	V	Zn	U	Pb-210	Po-210	Ra-226	Th-230	Charge Balance
22-2	• .05	• .01	0.89	• .01	• .002	• .05	0.035						0.7
8-3	• .02	• .01	0.58		• .002	• .02	0.047	71 ± 4	0 ± 0.6	0.12 ± .03	0.60 ± .07	0 ± .4	6.8
(W-4A)	• .02	• .01	0.51	• .01	• .002	• .02	0.021						1.4
	• .05	• .01	0.24	• .01	• .002	• .05	0.006						5.8
	• .05	• .01	0.15	• .01	• .002	• .05	0.015						2.8
893	• .01	0.02	0.64		0.0023	• .01	0.3	81	—	—	302 ± 20	—	1.0
(W-1)	• .02	• .01	0.18		• .002	• .02	0.014	58 ± 3	10 ± .5	1.5 ± .1	126 ± 6	0.3 ± .1	1.0
	• .02	• .01	4.20	• .01	—	• .02	0.038						0.5
	• .02	• .01	2.19	• .01	• .002	• .02	0.025						0.7
	• .05	• .01	0.32	• .01	• .002	• .05	0.047						0.8
	• .05	• .01	0.12	• .01	• .002	• .05	0.010						3.2
885	0.002	0.02	0.64	0.006	• .005	• .005	0.03	38			163 ± 20	—	4.5
886	0.004	0.02	0.11	0.006	• .005	• .005	0.03	6.6	--	—	170 ± 15	—	4.6
887	0.004	0.03	• .05	0.009	• .005	• .005	0.02	8.8	—	—	1.2 ± 1.2	—	12.1
888	0.003	0.02	0.21	0.006	• .005	• .005	0.03	4.1	—	—	8.2 ± 3.0	—	0.3
889	• .05	• .05	0.81	• .01	• .002	• .05	0.077						0.8
	• .05	• .01	0.26	• .01	• .002	• .05	0.023						3.0
1	• .002	• .01	0.07	• .005	0.115	• .005	0.02	338	—	—	69 ± 10	—	3.5
(W-2)	• .01	0.01	0.64		0.36	• .01	0.1	399	—	—	27.6 ± 1.7	—	16
	• .02	• .01	0.23	—	0.041	• .02	0.038	294 ± 15	0 ± .2	0.2 ± .03	8.0 ± .4	0.0 ± .1	9.2
	• .02	• .01	0.82	• .01	0.093	• .02	0.051						2.8
	• .05	• .01	0.44	• .01	0.103	• .05	0.037						0.8
	• .05	• .01	0.19	• .01	0.065	• .05	0.008						3.0
1085	0.002	0.02	• .05	• .005	• .005	• .005	0.01	10	--	--	6.6 ± 2.3	--	1.0
1806	• .005	0.03	0.07	0.009	• .005	• .005	0.03	12	--	--	125 ± 17	--	2.2
1807	• .002	0.02	• .05	0.006	• .005	• .005	0.07	3.4	--	--	6.6 ± 2.3	--	3.6
1808	• .02	• .01	0.27	—	• .002	• .02	0.016	71 ± 4	0 ± .6	0.12 ± .03	0.60 ± .07	0 ± .4	1.0
(W-4B)	• .02	• .01	0.38	• .01	• .002	• .02	0.015						1.9
	• .05	• .01	0.35	• .01	• .002	• .05	0.084						0.4
	• .05	• .01	0.16		• .002	• .05	• .005						0.7
1809	• .05	• .01	0.25	• .01	• .002	• .05	0.020						2.0
1810	• .05	• .01	0.26	• .01	• .002	• .05	0.012						3.2
1814	• .01	0.02	0.64	—	0.012	• .01	0.04	352	—	—	753 ± 45	--	-3
(W-3)	• .02	• .01	0.33	—	• .002	• .02	0.035	106 ± 5	0 ± .1	0.26 ± .05	5.1 ± .3	0 ± .1	3.3
	• .02	• .01	0.86	• .01	• .002	• .02	0.087						2.1
	• .05	• .01	0.40	• .01	• .002	• .05	0.099						2.3
	• .05	• .01	0.18		• .002	• .05	0.017						0.6
1821	• .02	• .01	0.35	• .01	• .002	• .02	0.018						1.0
1822	• .02	• .01	0.27	• .01	• .002	• .02	• .005						4.7

TABLE 3.6.2.8

(CONT.)

Notes: Concentration in mg/l except Conductivity, in mhos/cm @ 25°C; Temperature, in °C; pH, in pH units; U, Pb-210, Po-210, Ra-226 and Th-230. in pCi/l and Charge Balance = difference in major equivalents divided by sum of major equivalents time 100.

( ) Field Measurements; (W-3) Conoco monitoring well number.

* Concentration less than value.

(a) Additional parameters for this sample are Silica (as SiO_2) = 10; Alkalinity (as $CaCO_3$) = 188; Total Hardness (as $CaCO_3$) = 219; Redox Potential = 196; Nitrite (as N) = *.05; Phosphorus (as P) = *.02; and Total Iron = *1.0.

(b) Additional parameters for this sample are Phosphate = 0.04 and Nitrite = *.01.

(c) Additional parameters for this sample are Phosphate = 0.025 and Nitrite = *.01.

(d) Additional parameters for this sample are Silica (as SiO_2) = 9.9; Alkalinity (as $CaCO_3$) = 232.5; Total Hardness (as $CaCO_3$) = 560; Redox Potential = 206; Nitrite (as N) = 0.13; Phosphorus (as P) = *.03 and Total Iron = 1.3.

(e) Additional parameters for this sample are Silica (as SiO_2) = 19.2; Alkalinity (as $CaCO_3$) = 703; Total Hardness (as $CaCO_3$) = 640; Redox Potential = 208; Nitrite (as N) = *.05; Phosphorus (as P) = 0.02; and Total Iron = 49.

(f) Additional parameters for this sample are Silica (as SiO_2) = 8.6; Alkalinity (as $CaCO_3$) = 310; Total Hardness (as $CaCO_3$) = 749; Redox Potential = 207; Nitrite (as N) = *.05; Phosphorus (as P) = *.02; and Total Iron = 1.0.

(g) Additional parameters for this sample are Silica (as SiO_2) = 17.1; Alkalinity (as $CaCO_3$) = 257; Total Hardness (as $CaCO_3$) = 494; Redox Potential = 197; Nitrite (as N) = *.05; Phosphorus (as P) = 0.04; and Total Iron = 23.

(h) Additional parameters for this sample are Silica (as SiO_2) = 4; Alkalinity (as $CaCO_3$) = 147; Total Hardness (as $CaCO_3$) = 418; Redox Potential = 196; Nitrite (as N) = *.05; Phosphorus (as P) = *.02; and Total Iron = 4.6.

(i) Additional parameters for this sample are Silica (as SiO_2) = 19.9; Alkalinity (as $CaCO_3$) = 806; Total Hardness (as $CaCO_3$) = 720; Redox Potential = 227; Nitrite (as N) = *.05; Phosphorus (as P) = 0.02; and Total Iron = 54.

(j) Additional parameters for this sample are Silica (as SiO_2) = 12.3; Alkalinity (as $CaCO_3$) = 546; Total Hardness (as $CaCO_3$) = 538; Redox Potential = 210; Nitrite (as N) = *.05; Phosphorus (as P) = 0.02; and Total Iron = 8.8.

TABLE 3.6.2.9

GROUNDWATER QUALITY FOR THE EVAPORATION POND AND TAILINGS SITE FOR CONOCO'S SAND ROCK PROJECT

Well No.	Date	TDS	Conductivity		Temperature	Na	K	Ca	Mg	SO_4	Cl	CO_3	HCO_3	pH	Al	NH_3 (as N)	As	Ba	Be
P-9A & P-4C	4/02/80	4,028	3,700	(2,855)	(7.2 & 8.9)	90	18	532	336	2,860	38	0	281	7.41	0.06	.05*	0.003	.02*	
P-12 & P-4B1	4/02/80	2,624	2,590	(2,170)	(9.0 & 8.0)	37	17	517	131	1,635	29	0	415	7.60	.05*	0.09	0.004	.02*	
P-5	4/02/80	260	550	(420)	(8.5)	19	7	61	19	96	4	0	207	7.60	.05*	.05*	0.005	.02*	
P-13A & P-15	4/02/80	4,516	4,000	(3,160)	(8.5 & 8.0)	86	30	655	342	3,070	58	0	122	6.85	0.21	2.10	0.003	.02*	
P-2 & P-9	4/02/80	3,052	2,980	(2,385)	(8.2 & 8.1)	56	22	493	218	1,940	29	0	293	7.67	.05*	1.04	.002*	.02*	
P-10 & P-19	-	-	-	-	(9.8 & 8.1)	-	-	-	-	-	-	-	-	-	-	-	-	-	
P-7	5/23/80	1,743	1,150	(1,462)	(11.1)	38	12	329	75	1,165	27	0	176	7.55	0.05*	.08	.002*	.02*	
P-20B	5/23/80	1,606	2,220	(1,467)	(11.1)	35	22	349	76	970	27	0	220	7.75	.05*	.15	.002*	.02*	
35N-2A	5/23/80	1,002	1,390	(972)	(11.2)	88	15	152	36	614	9	0	176	7.82	.05*	.11	.002*	.02*	
35N-6	5/23/80	724	1,050	(904)	(10.0)	28	10	149	37	374	7	0	220	8.43	.05*	.16	.002*	.02*	
35N-7A	5/23/80	327	599	(463)	(12.0)	20	10	61	13	102	2	0	215	7.85	.05*	.09	.002*	.02*	
35N-7C	5/23/80	443	680	(534)	(8.5)	24	9	80	24	197	4	0	185	7.78	.05*	.21	.002*	.02*	
35N-7E	5/23/80	288	480	(366)	(9.5)	6	5	57	22	73	4	0	215	7.59	.05*	.08	.002*	.02*	
35N-7F	5/23/80	250	410	(399)	(8.0)	8	5	59	19	40	7	0	195	7.77	.05*	.13	.002*	.02*	
35N-7G	5/23/80	256	488	(334)	(10.0)	18	7	61	16	28	4	0	239	7.72	.05*	.09	.002*	.02*	

Notes: Concentrations in mg/l, except Conductivity which is in umhos/cm @ 25°C, Temperature in °C, pH in pH units, Pb 210, Po 210, Ra 226 and Th 230 in pCi/l, and Charge Balance = Difference in major equivalents.

( ) Denotes field measurements.

* Denotes less than value.

TABLE 3.6.2.9 (cont'd)

B	Cd	Cr	Cu	F	Fe	Pb	Mn	Hg	Mo	Ni	NO_3	Se	V	Zn	U	Pb210	Po210	Ra226	Th230	Charge Balance
1.0*	0.016	0.05	0.039	0.21	.05*	0.13	0.98	.001*	.05*	0.02	0.62	.002*	.05*	0.028	-	-	-	-	-	5.3
1.0*	0.013	0.05	0.029	0.13	.05*	0.14	1.34	.001*	.05*	.01*	1.37	.002*	.05*	0.016	-	-	-	-	-	3.8
1.0*	.005*	.01*	.05*	0.29	.05*	.05*	0.16	.001*	.05*	.01*	0.21	.002*	.05*	0.006	-	-	-	-	-	1.0
1.0*	1.129	0.05	0.036	0.51	22.9	0.17	2.57	.001*	.05*	0.51	0.46	.002*	.05*	0.666	0.12	0 ± 1	0 ± .1	0.39 ± .04	2.0 ± .4	1.6
1.0*	0.014	0.04	0.031	0.20	3.50	0.17	1.50	.001*	.05*	.01*	0.23	.002*	.05*	0.012	0.025	0 ± 1	0 ± .1	0.66 ± .06	1.5 ± .2	0.6
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.0*	.008	0.01*	.02	0.18	0.05*	0.10	0.12	.001*	.05*	.01*	.89	.002*	.05*	.329	-	-	-	-	-	6.4
1.0	.008	.01*	.03	.08	.05*	.10	.61	.001*	.05*	.01*	.35	.002*	.05*	.092	-	-	-	-	-	2.4
1.0*	.005*	.01*	.02	.16	.05*	.05*	.18	.001*	.05*	.01*	.23	.002*	.05*	.005*	-	-	-	-	-	3.8
1.0*	.005*	.01*	.01*	.13	.05*	.05*	.14	.001*	.05*	.01*	.44	.002*	.05*	.008	-	-	-	-	-	1.6
1.0*	.005*	.01*	.02	.15	.05*	.05*	.11	.001*	.05*	.01*	.06	.002*	.05*	.008	-	-	-	-	-	6.5
1.0*	.005*	.01*	.02	.17	.05*	.05*	.10	.001*	.05*	.01*	.22	.002*	.05*	.006	-	-	-	-	-	0
1.0*	.005*	.01*	.01*	.19	.05*	.05*	.07	.001*	.05*	.01*	.11	.002*	.05*	.101	-	-	-	-	-	1.1
1.0*	.005*	.01*	.02*	.22	.05*	.05*	.01*	.001*	.05*	.01*	.56	.002*	.05*	.005*	-	-	-	-	-	8.2
1.0*	.005*	.01*	.01*	.15	.05*	.05*	.05	.001*	.05*	.01*	.22	.002*	.05*	.005*	-	-	-	-	-	7.1

The major cation is calcium, while sulfate is the major anion. The sulfate, hardness and iron in some of the groundwater would make its use undesirable. The nitrate concentrations in well A-2 (see Table 3.6.2.7 and Figure 3.1) are significantly above the recommended drinking water standard.

Selenium at levels in excess of water standards has also been detected in Well 1 (W-2) in the ore zone.

3.6.2.8 RADIONUCLIDES

Groundwater monitoring for radionuclide analyses at the Sand Rock mill site began in June 1979. Groundwater monitoring for water quality parameters had been underway since 1977 at a number of onsite and offsite locations. Sampling specifically for radionuclides to meet with NRC requirements was performed for wells used by local residents for the watering of livestock, irrigation or direct consumption. The well locations are shown in Figure 3.1 and 3.2.

Data from the wells sampled are presented in Table 3.6.2.10. Wells centered in the three pit areas consistently produce Ra-226 concentrations in excess of the 5pCi/l standard.

TABLE 3.6.2.10

GROUNDWATER SAMPLING RESULTS[b]

	June '79	Sept. '79	Dec. '79	Mar. '80
T-1				
Pb-210	0.00 ± 0.4	(c)	(e)	(e)
Po-210	0.02 ± 0.01	(c)		
Ra-226	0.41 ± 0.06	0.2 ± 0.2		
Th-230	0.3 ± 0.1	0.6 ± 0.1		
Total U_n	44. ± 2.	21. ± 2.		
P′-10				
Pb-210	1.9 ± 0.7	(f)	(f)	(f)
Po-210	0.10 ± 0.02			
Ra-226	0.00 ± 0.08			
Th-230	0.00 ± 0.1			
Total U_n	17. ± 1.			
P′-11				
Pb-210	(e)	(e)	(e)	(e)
Po-210				
Ra-226				
Th-230				
Total U_n				
P′-36				
Pb-210	(g)	(c)	1.0 ± 0.3	(e)
Po-210		(c)	0.00 ± 0.1	
Ra-226		1.4 ± 0.1	0.07 ± 0.02	
Th-230		0.3 ± 0.1	0.2 ± 0.1	
Total U_n		0.00 ± 3.	10. ± 2.	
P′-8				
Pb-210	0.0 ± 0.5	(g)	(g)	(g)
Po-210	0.08 ± 0.02			
Ra-226	0.75 ± 0.07			
Th-230	0.00 ± 0.1			
Total U_n	7. ± 1.			

TABLE 3.6.2.10

(CONT.)

	June '79	Sept. '79	Dec. '79	Mar. '80
P′-6				
Pb-210	0.00 ± 1.			
Po-210	0.00 ± 0.02			
Ra-226	0.35 ± 0.05	(c)	(c)	(c)
Th-230	0.2 ± 0.1			
Total U_n	0.00 ± 2.			
A-1				
Pb-210	0.00 ± 0.3			
Po-210	0.03 ± 0.01			
Ra-226	0.15 ± 0.05	(c)	(c)	(c)
Th-230	0.00 ± 0.1			
Total U_n	37. ± 2.			
A-2				
Pb-210	0.3 ± 0.1			
Po-210	0.00 ± 0.04			
Ra-226	0.15 ± 0.04	(c)	(c)	(c)
Th-230	0.4 ± 0.1			
Total U_n	20. ± 1.			
P′-9				
Pb-210	1.6 ± 0.2	(d)		
Po-210	0.40 ± 0.05	(d)		
Ra-226	2.0 ± 0.1	2.1 ± 0.1	(e) (c)	
Th-230	0.2 ± 0.1	1.1 ± 0.1		
Total U_n	32. ± 2.	22. ± 2.		

(a) Analyses in progress
(b) pCi/l ± 2σ
(c) Removed from program due to distance from permit area
(d) Analysis not required
(e) Pump inoperative
(f) Well of insufficient quality for sampling
(g) Added to program upon expansion of permit area

APPENDIX 3 A

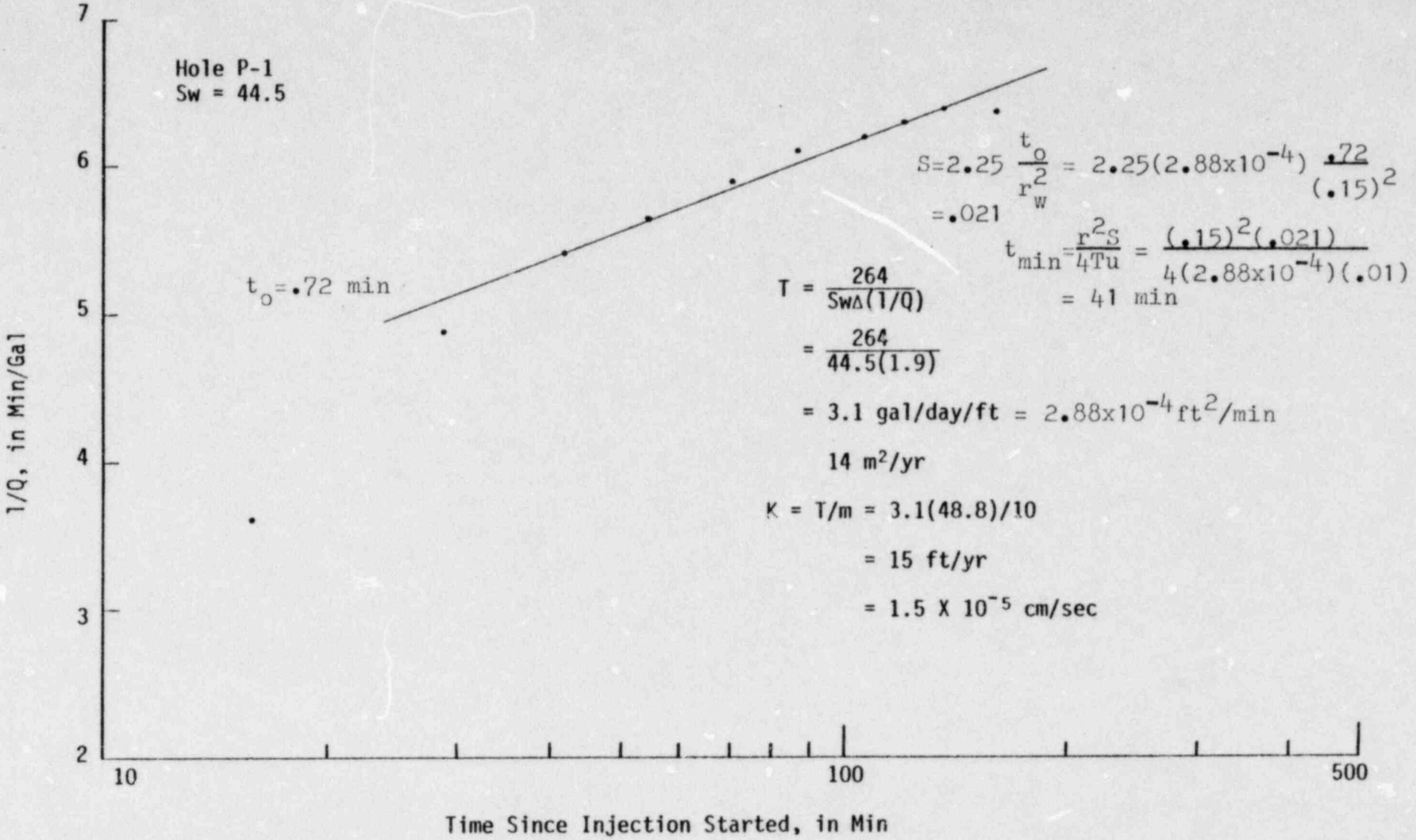
DISCUSSION OF PERMEABILITY TESTS

DISCUSSION OF AQUIFER TEST ANALYSES

Our evaluation of the aquifer test data analysis indicates that some of the tests were run for insufficient periods of time to be analyzed by the straight-line method used in the report. Applying the straight-line method to data collected at insufficient time periods will introduce significant error in the determination of aquifer properties. To avoid these errors, the test data should be re-analyzed using the curve matching procedure outlined in Lohman (1972, Page 23). The curve matching procedure should be used on aquifer test data for well Nos. P-2, P-6, P-8, P-11, P-13, P-13A, P-17, 35N-1C, 35N-2C, 35N-3, 35N-5, 35N-6, 35N-7C, 35N-7D, 35N-7F, and 35N-7G.

The remaining aquifer tests were apparently conducted and analyzed correctly. A summary of the computed aquifer characteristics is given in Table 2.4. Figures A.1 through A.22 are plots of well test data with calculations of transmissivity (T), permeability (K), storage coefficient (S) and minimum test length (tmin).

A detailed description of the aquifer test methods is given in Appendix A of the report by Hydro-Engineering, Hydrology of the Evaporation Pond and Tailings Disposal Areas for the Sand Rock Project, 1980.



$S = 2.25 \frac{t_o}{r_w^2} = 2.25(2.88\times10^{-4}) \frac{.72}{(.15)^2}$

$= .021$

$t_{min} = \frac{r^2 S}{4Tu} = \frac{(.15)^2(.021)}{4(2.88\times10^{-4})(.01)}$

$= 41$ min

$T = \frac{264}{S_w \Delta(1/Q)}$

$= \frac{264}{44.5(1.9)}$

= 3.1 gal/day/ft = 2.88×10^{-4} ft^2/min

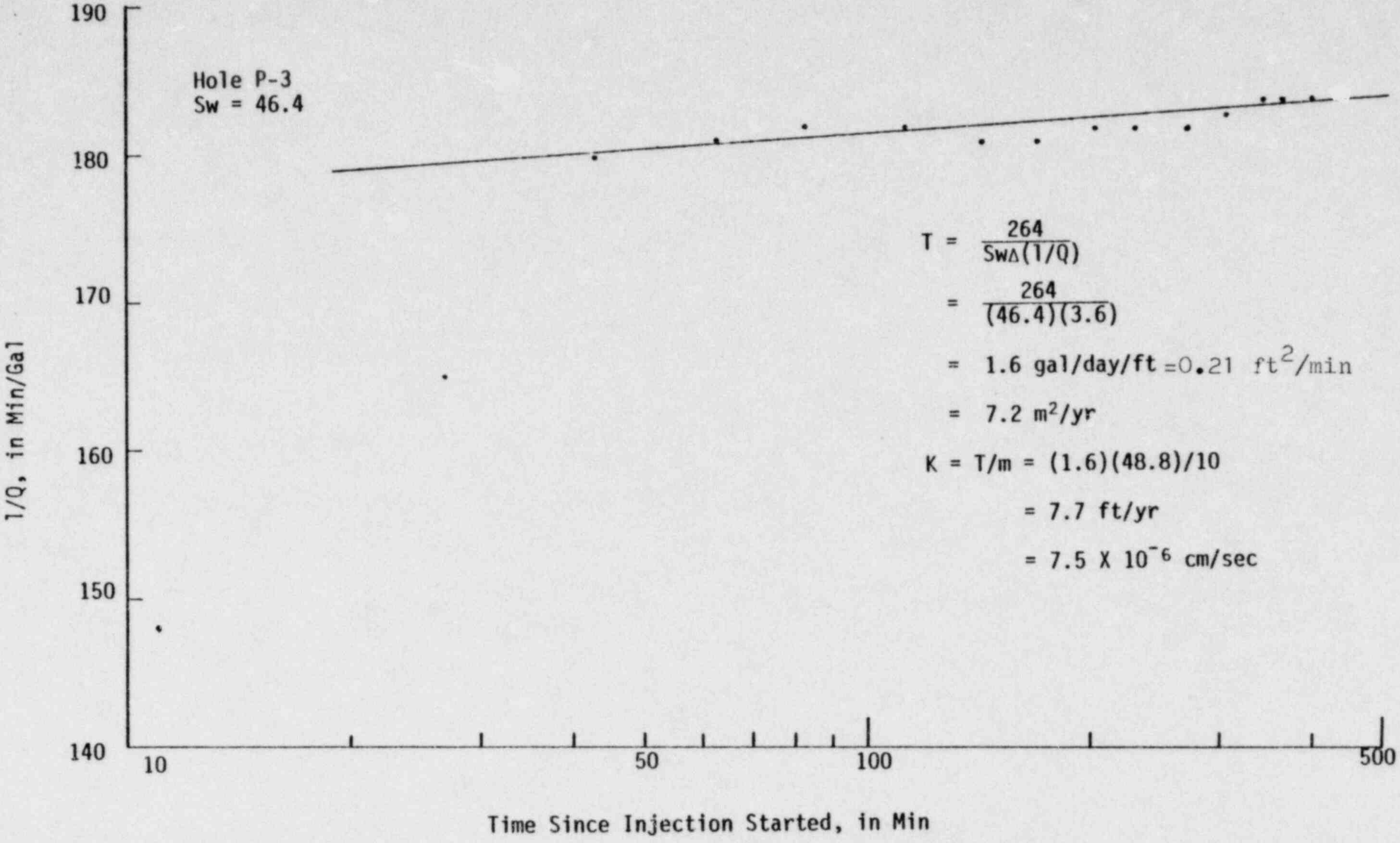
14 m^2/yr

K = T/m = 3.1(48.8)/10

= 15 ft/yr

= 1.5 X 10^{-5} cm/sec

FIGURE A.1 CONSTANT HEAD TEST FOR HOLE P-1 (LOWER MUDSTONE AND E COAL)



$$T = \frac{264}{Sw\Delta(1/Q)}$$

$$= \frac{264}{(46.4)(3.6)}$$

= 1.6 gal/day/ft = 0.21 ft^2/min

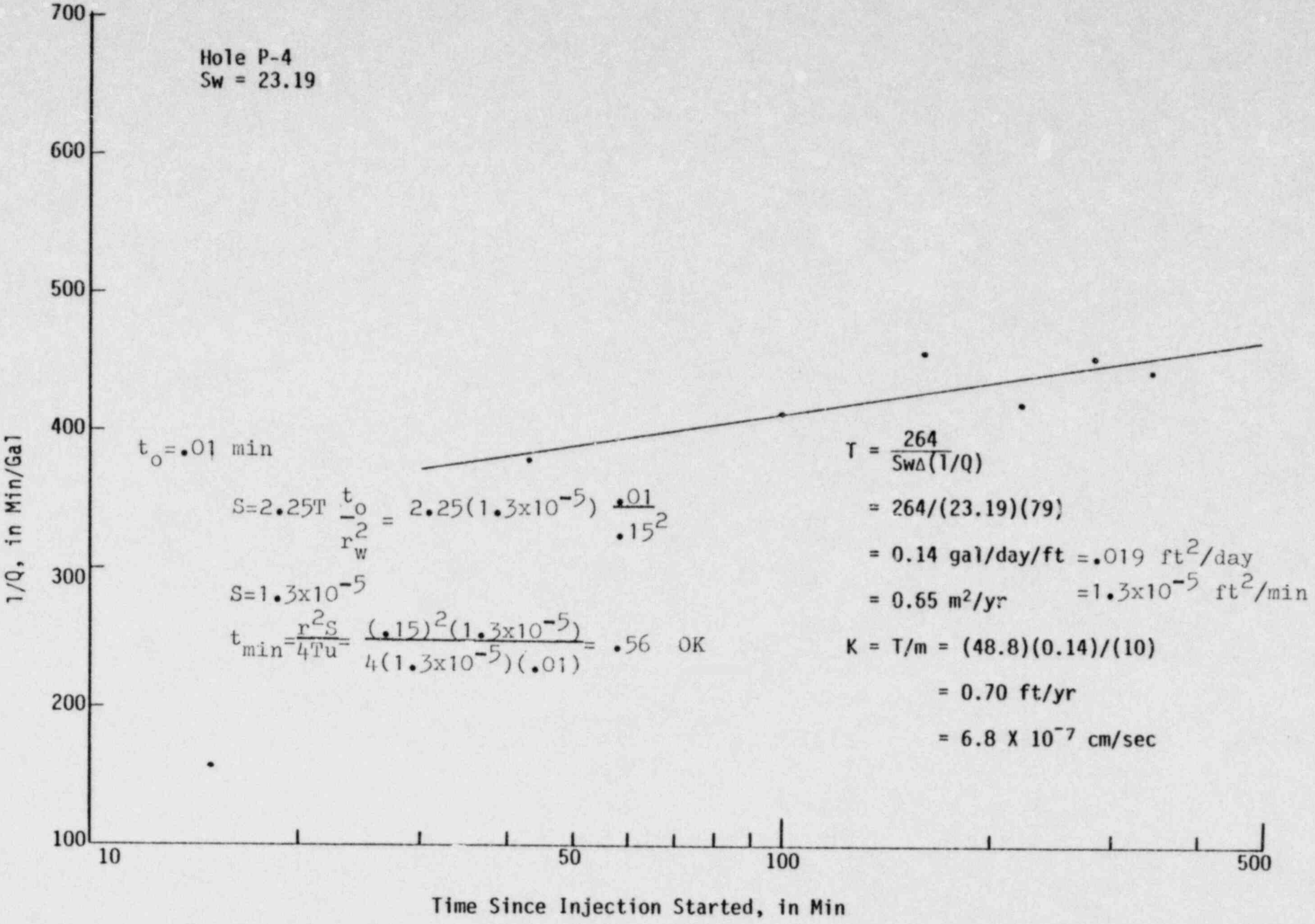
= 7.2 m^2/yr

K = T/m = (1.6)(48.8)/10

= 7.7 ft/yr

= 7.5 X 10^{-6} cm/sec

FIGURE A.2 CONSTANT HEAD TEST FOR HOLE P-3 (LOWER MUDSTONE)



Hole P-4
Sw = 23.19

$t_o = .01$ min

$S = 2.25T \frac{t_o}{r_w^2} = 2.25(1.3\times10^{-5}) \frac{.01}{.15^2}$

$S = 1.3\times10^{-5}$

$t_{min} = \frac{r^2 S}{4Tu} = \frac{(.15)^2(1.3\times10^{-5})}{4(1.3\times10^{-5})(.01)} = .56$ OK

$T = \frac{264}{Sw\Delta(1/Q)}$

$= 264/(23.19)(79)$

$= 0.14$ gal/day/ft $= .019$ ft^2/day

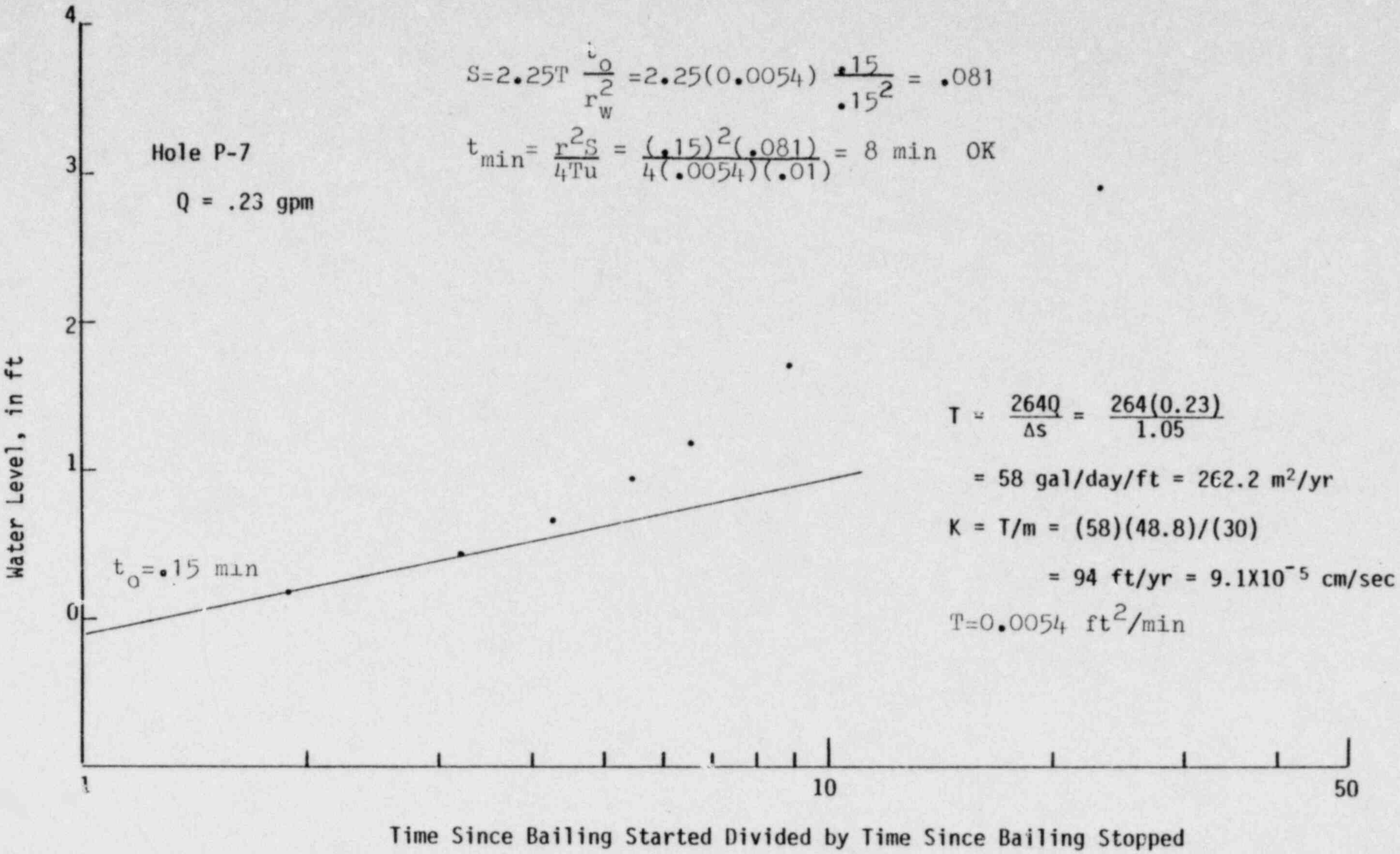
$= 0.65$ m^2/yr $= 1.3\times10^{-5}$ ft^2/min

$K = T/m = (48.8)(0.14)/(10)$

$= 0.70$ ft/yr

$= 6.8 \times 10^{-7}$ cm/sec

FIGURE A.3 CONSTANT HEAD TEST FOR HOLE P-4 (LOWER MUDSTONE AND E COAL)



$S = 2.25T \frac{t_o}{r_w^2} = 2.25(0.0054)\frac{.15}{.15^2} = .081$

$t_{min} = \frac{r^2 S}{4Tu} = \frac{(.15)^2(.081)}{4(.0054)(.01)} = 8$ min OK

Hole P-7

Q = .23 gpm

$t_o = .15$ min

$T = \frac{264Q}{\Delta s} = \frac{264(0.23)}{1.05}$

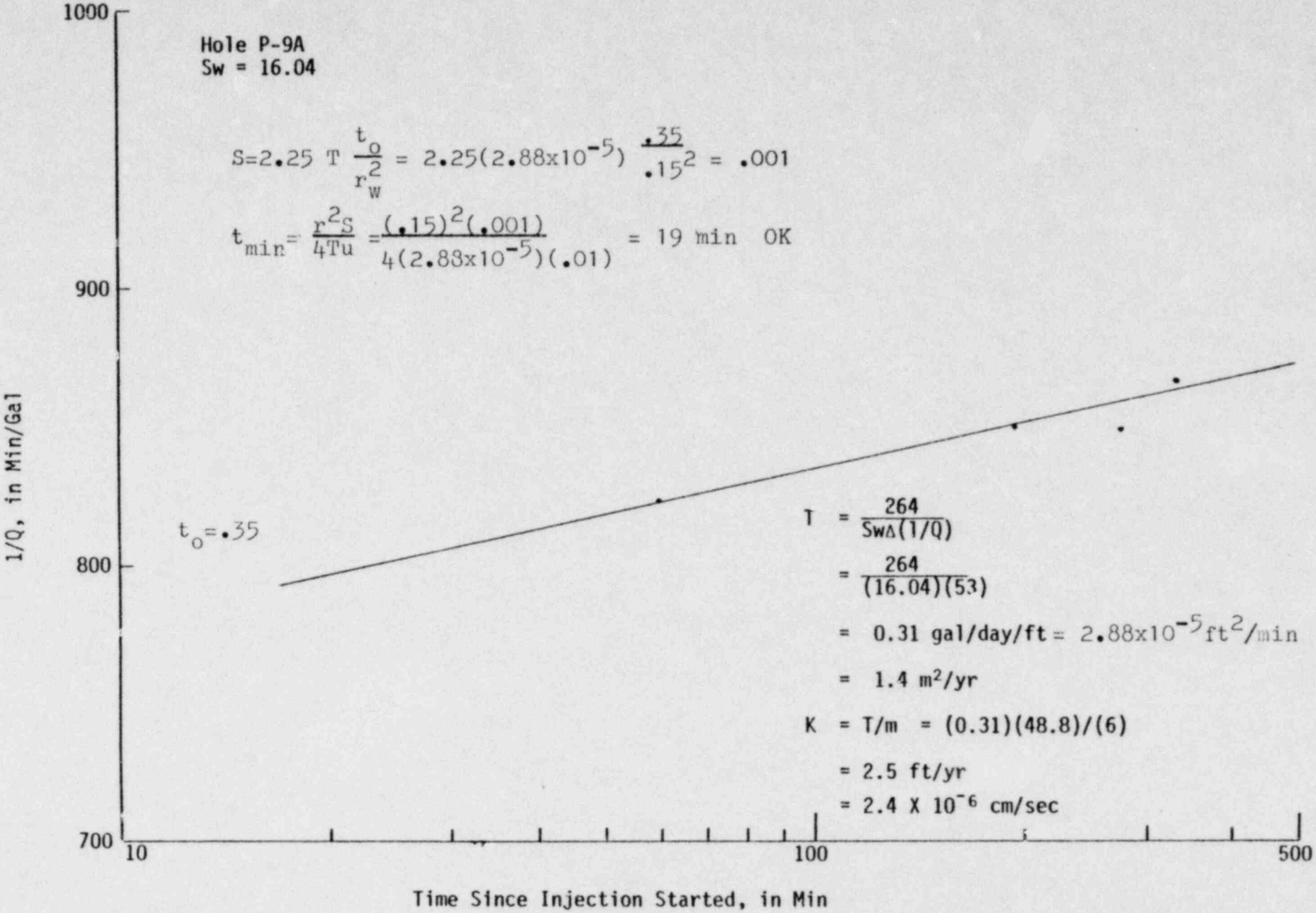
= 58 gal/day/ft = 262.2 m^2/yr

K = T/m = (58)(48.8)/(30)

= 94 ft/yr = 9.1X10^{-5} cm/sec

T=0.0054 ft^2/min

FIGURE A.4 . RECOVERY TEST FOR HOLE P-7 (70 SAND)



Hole P-9A
Sw = 16.04

$$S=2.25\,T\,\frac{t_o}{r_w^2} = 2.25(2.88\times10^{-5})\,\frac{.35}{.15^2} = .001$$

$$t_{min} = \frac{r^2S}{4Tu} = \frac{(.15)^2(.001)}{4(2.83\times10^{-5})(.01)} = 19 \text{ min} \quad \text{OK}$$

$t_o = .35$

$$T = \frac{264}{Sw\Delta(1/Q)}$$

$$= \frac{264}{(16.04)(53)}$$

$= 0.31$ gal/day/ft $= 2.88\times10^{-5}$ ft^2/min

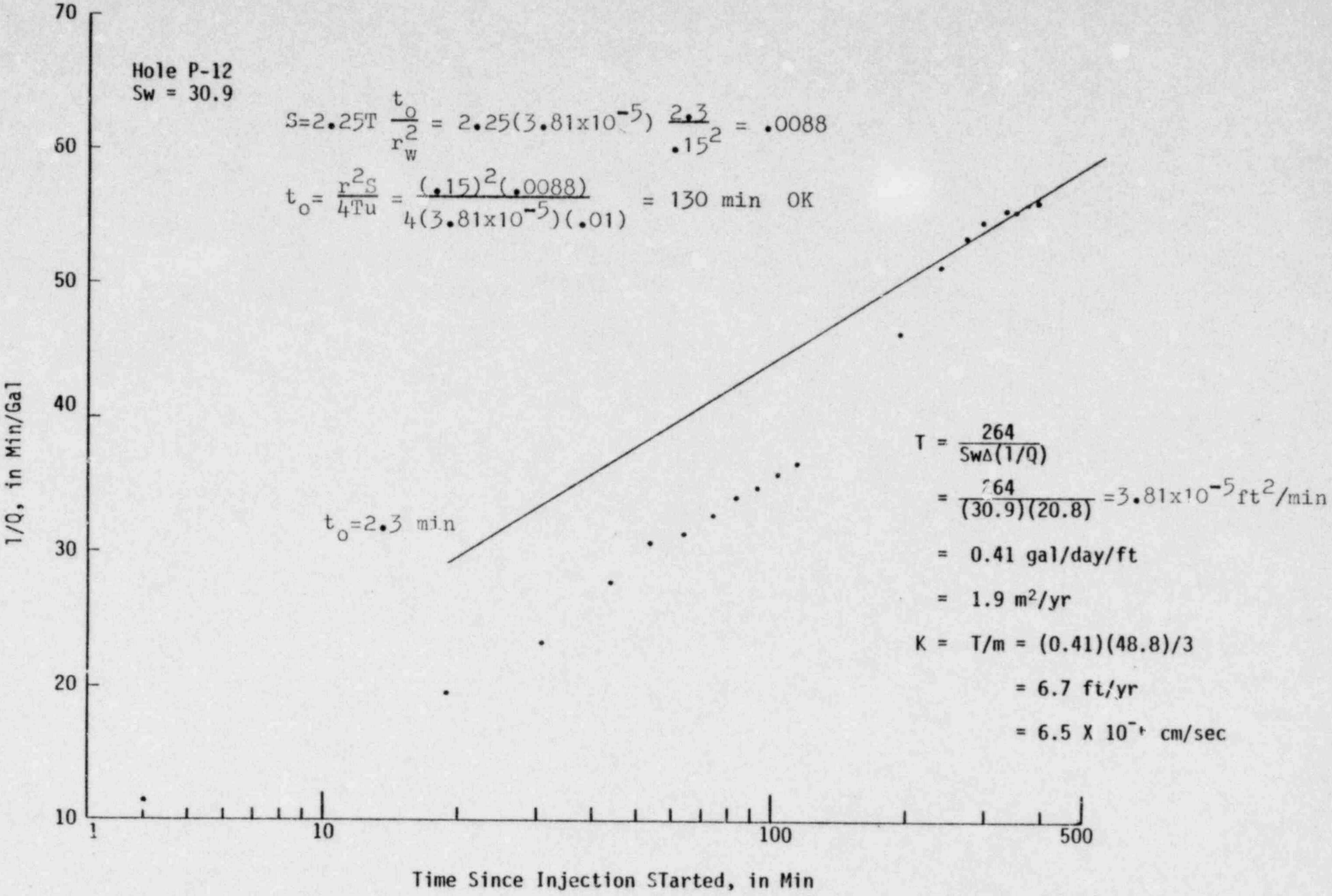
$= 1.4$ m^2/yr

$K = T/m = (0.31)(48.8)/(6)$

$= 2.5$ ft/yr

$= 2.4 \times 10^{-6}$ cm/sec

FIGURE A.5 CONSTANT HEAD TEST FOR HOLE P-9A (UPPER MUDSTONE)



Hole P-12
Sw = 30.9

$S=2.25T\frac{t_o}{r_w^2} = 2.25(3.81x10^{-5})\frac{2.3}{.15^2} = .0088$

$t_o=\frac{r^2S}{4Tu} = \frac{(.15)^2(.0088)}{4(3.81x10^{-5})(.01)} = 130$ min OK

$t_o=2.3$ min

$T = \frac{264}{Sw\Delta(1/Q)}$

$= \frac{264}{(30.9)(20.8)} = 3.81x10^{-5}ft^2/min$

= 0.41 gal/day/ft

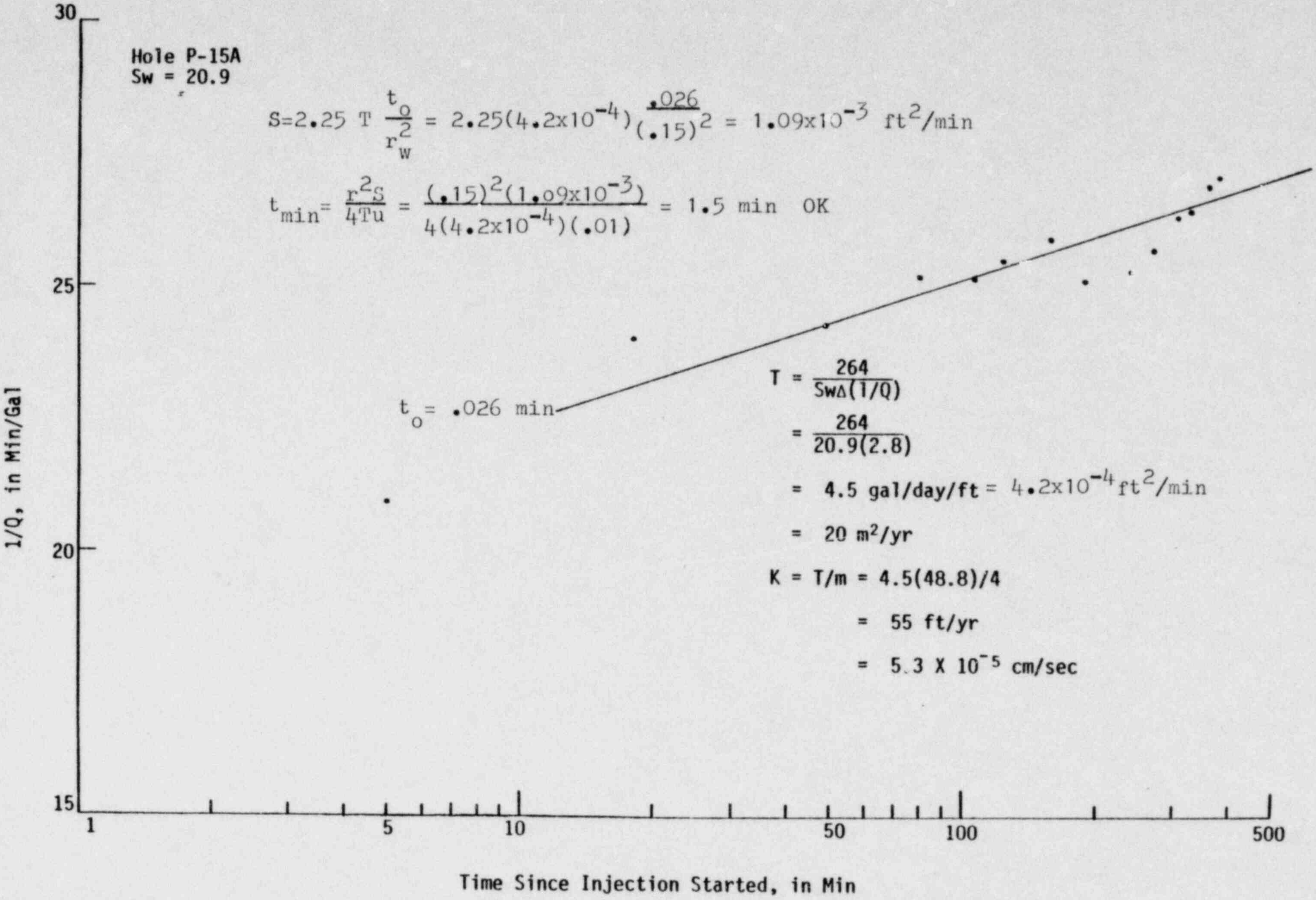
= 1.9 m^2/yr

K = T/m = (0.41)(48.8)/3

= 6.7 ft/yr

= 6.5 X 10^{-6} cm/sec

FIGURE A.6 CONSTANT HEAD TEST FOR HOLE P-12 (E COAL)



Hole P-15A
Sw = 20.9

$$S = 2.25\,T\,\frac{t_o}{r_w^2} = 2.25(4.2\times10^{-4})\frac{.026}{(.15)^2} = 1.09\times10^{-3}\ \text{ft}^2/\text{min}$$

$$t_{min} = \frac{r^2 S}{4Tu} = \frac{(.15)^2(1.09\times10^{-3})}{4(4.2\times10^{-4})(.01)} = 1.5\ \text{min}\quad \text{OK}$$

$$T = \frac{264}{Sw\Delta(1/Q)}$$

$$= \frac{264}{20.9(2.8)}$$

$= 4.5$ gal/day/ft $= 4.2\times10^{-4}$ ft^2/min

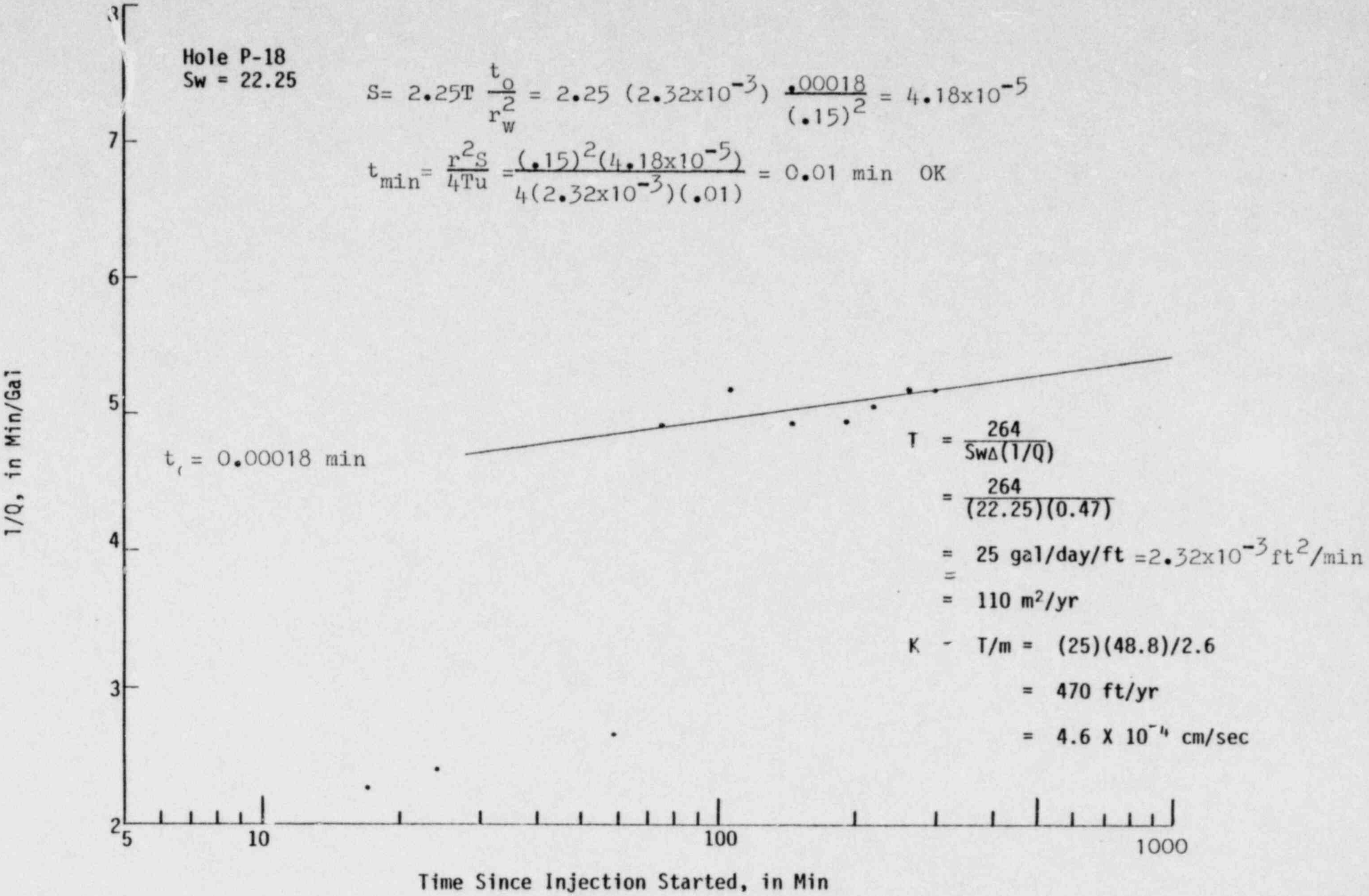
$= 20$ m^2/yr

$K = T/m = 4.5(48.8)/4$

$= 55$ ft/yr

$= 5.3 \times 10^{-5}$ cm/sec

FIGURE A.7 CONSTANT HEAD TEST FOR HOLE P-15A (UPPER MUDSTONE)



$$S = 2.25T \frac{t_o}{r_w^2} = 2.25\ (2.32\text{x}10^{-3})\ \frac{.00018}{(.15)^2} = 4.18\text{x}10^{-5}$$

$$t_{min} = \frac{r^2 S}{4Tu} = \frac{(.15)^2(4.18\text{x}10^{-5})}{4(2.32\text{x}10^{-3})(.01)} = 0.01 \text{ min} \quad \text{OK}$$

t_o = 0.00018 min

$$T = \frac{264}{Sw\Delta(1/Q)}$$

$$= \frac{264}{(22.25)(0.47)}$$

= 25 gal/day/ft = $2.32\text{x}10^{-3}$ ft^2/min

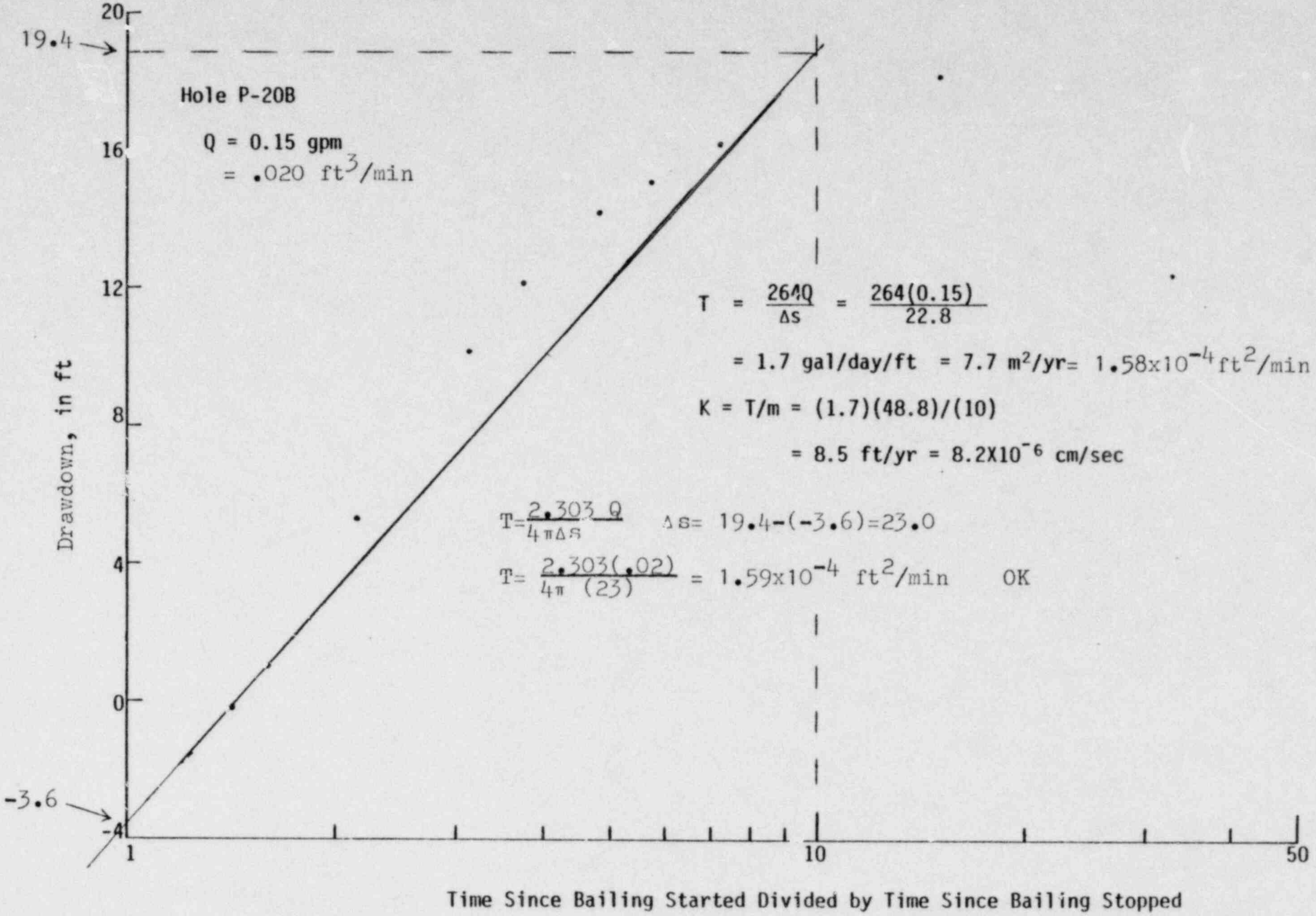
= 110 m^2/yr

K = T/m = (25)(48.8)/2.6

= 470 ft/yr

= 4.6 X 10^{-4} cm/sec

FIGURE A.8 CONSTANT HEAD TEST FOR HOLE P-18 (ALLUVIUM)



Hole P-20B

$Q = 0.15$ gpm

$= .020\ ft^3/min$

$T = \frac{264Q}{\Delta s} = \frac{264(0.15)}{22.8}$

$= 1.7$ gal/day/ft $= 7.7\ m^2/yr = 1.58 \times 10^{-4} ft^2/min$

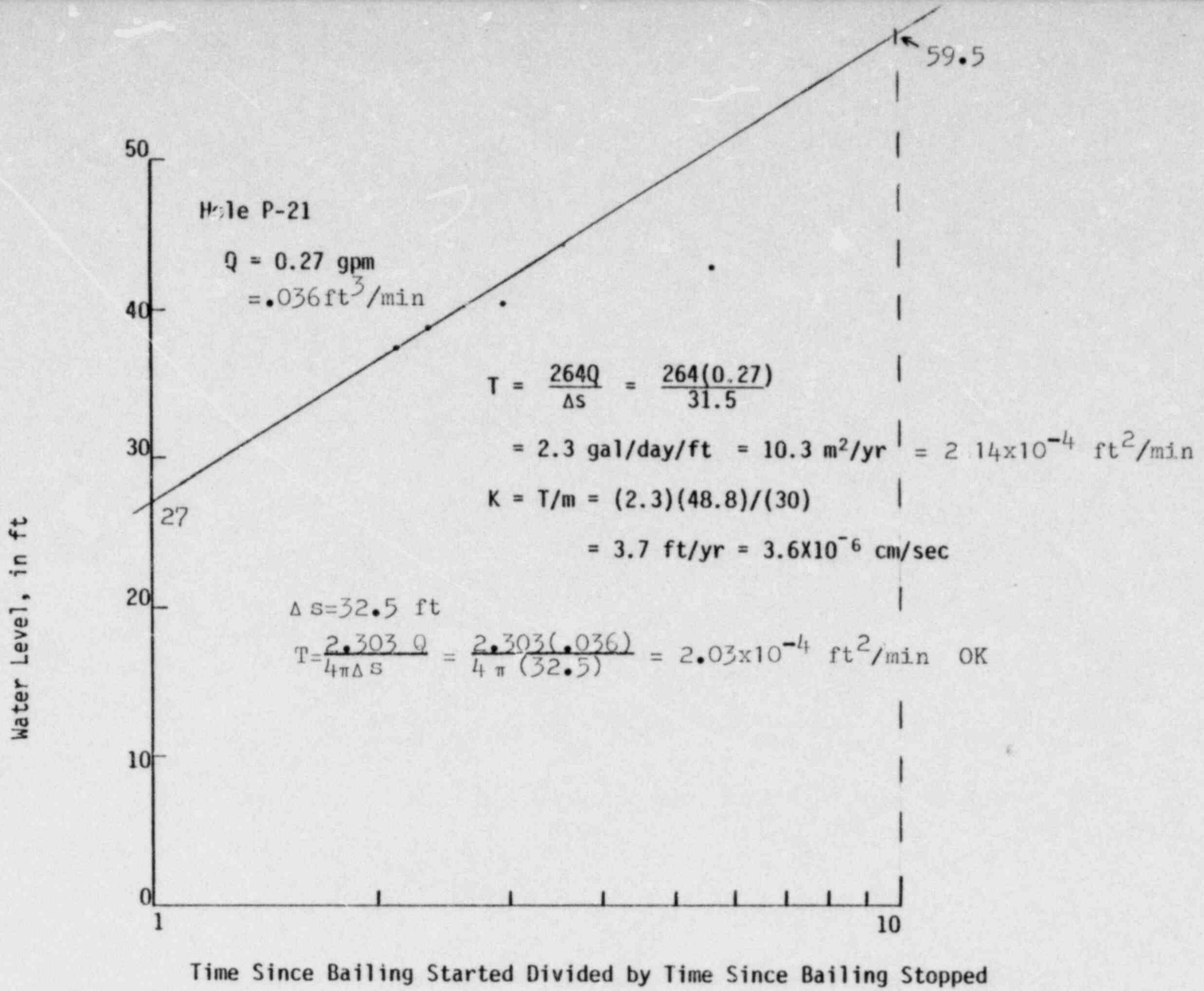
$K = T/m = (1.7)(48.8)/(10)$

$= 8.5$ ft/yr $= 8.2 \times 10^{-6}$ cm/sec

$T = \frac{2.303\ Q}{4\pi\Delta s}$ $\Delta s = 19.4-(-3.6) = 23.0$

$T = \frac{2.303(.02)}{4\pi\ (23)} = 1.59 \times 10^{-4}\ ft^2/min$ OK

FIGURE A.9 . RECOVERY TEST FOR HOLE P-20B (70 SAND)



Hole P-21

Q = 0.27 gpm

$= .036 \text{ ft}^3/\text{min}$

$$T = \frac{264Q}{\Delta s} = \frac{264(0.27)}{31.5}$$

$= 2.3$ gal/day/ft $= 10.3$ m^2/yr $= 2.14 \times 10^{-4}$ ft^2/min

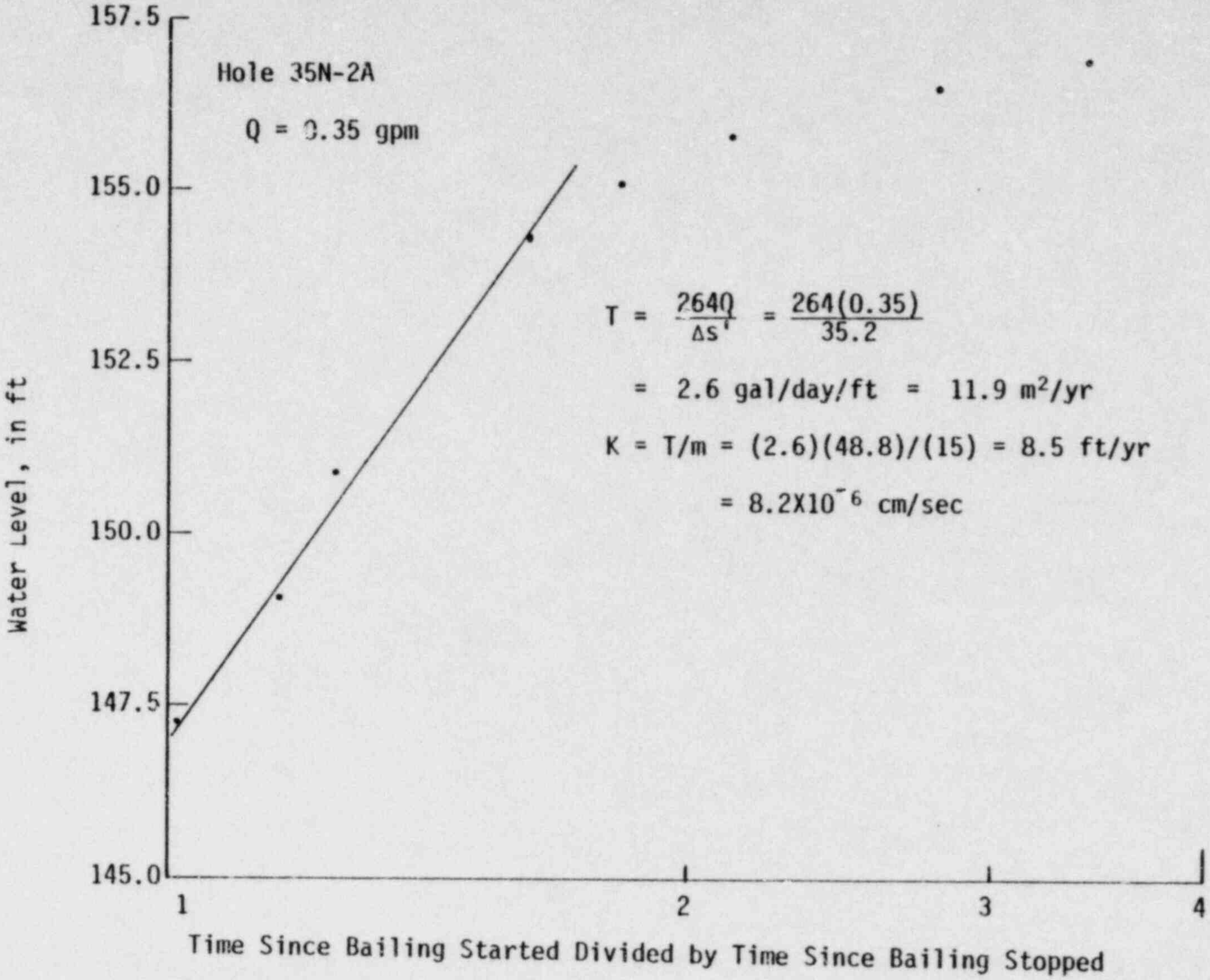
$K = T/m = (2.3)(48.8)/(30)$

$= 3.7$ ft/yr $= 3.6 \times 10^{-6}$ cm/sec

$\Delta s = 32.5$ ft

$$T = \frac{2.303\,Q}{4\pi\Delta s} = \frac{2.303(.036)}{4\pi(32.5)} = 2.03 \times 10^{-4} \text{ ft}^2/\text{min} \quad \text{OK}$$

FIGURE A.10 . RECOVERY TEST FOR HOLE P-21 (70 SAND)



Hole 35N-2A

$Q = 0.35$ gpm

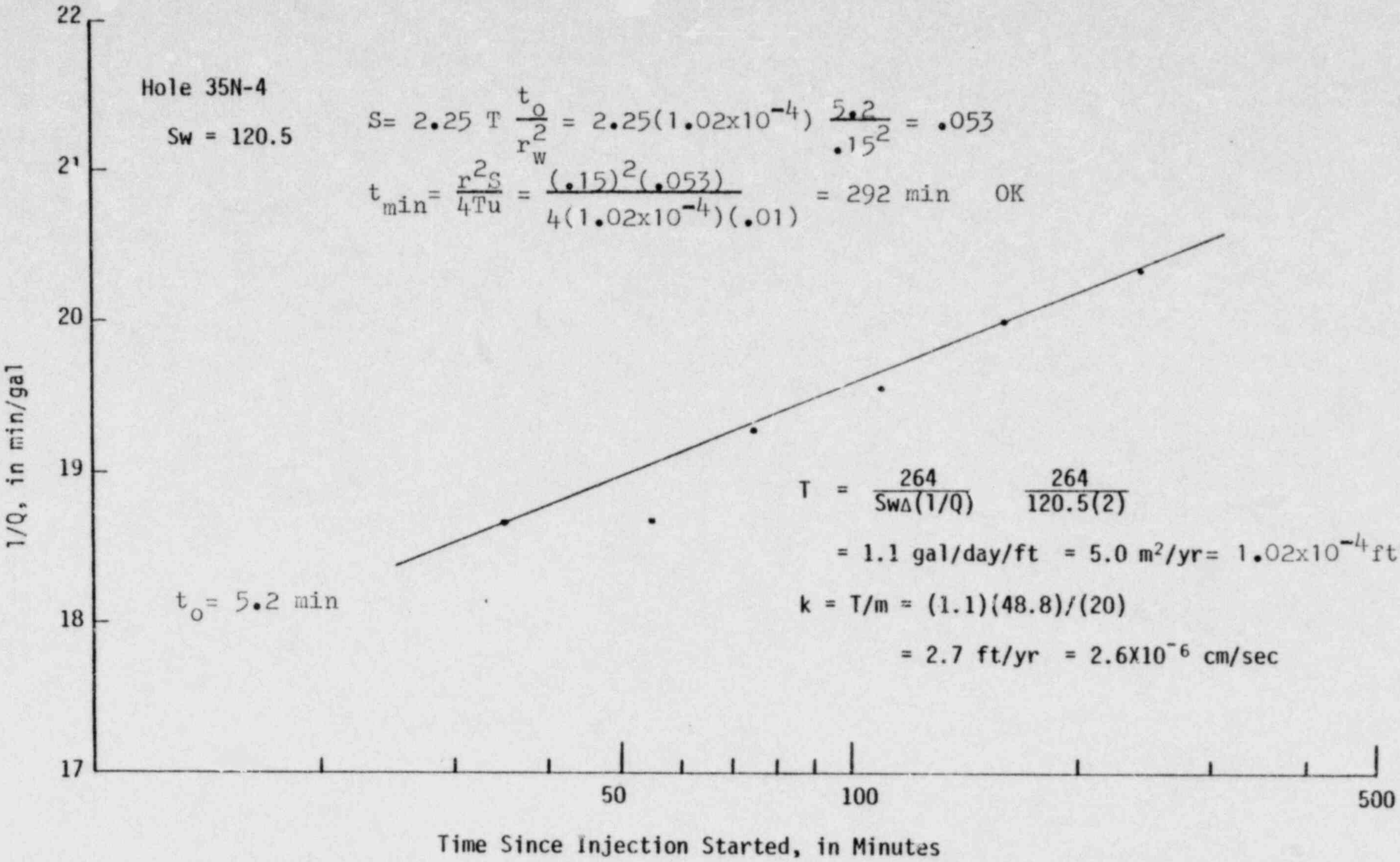
$$T = \frac{264Q}{\Delta s'} = \frac{264(0.35)}{35.2}$$

$= 2.6$ gal/day/ft $= 11.9\ \text{m}^2/\text{yr}$

$K = T/m = (2.6)(48.8)/(15) = 8.5$ ft/yr

$= 8.2\text{X}10^{-6}$ cm/sec

FIGURE A.11 RECOVERY TEST FOR HOLE 35N-2A (UPPER 70 SANDSTONE)



Hole 35N-4

Sw = 120.5

$$S = 2.25\,T\,\frac{t_o}{r_w^2} = 2.25(1.02\text{x}10^{-4})\,\frac{5.2}{.15^2} = .053$$

$$t_{min} = \frac{r^2S}{4Tu} = \frac{(.15)^2(.053)}{4(1.02\text{x}10^{-4})(.01)} = 292 \text{ min} \quad \text{OK}$$

$$T = \frac{264}{Sw\Delta(1/Q)} \quad \frac{264}{120.5(2)}$$

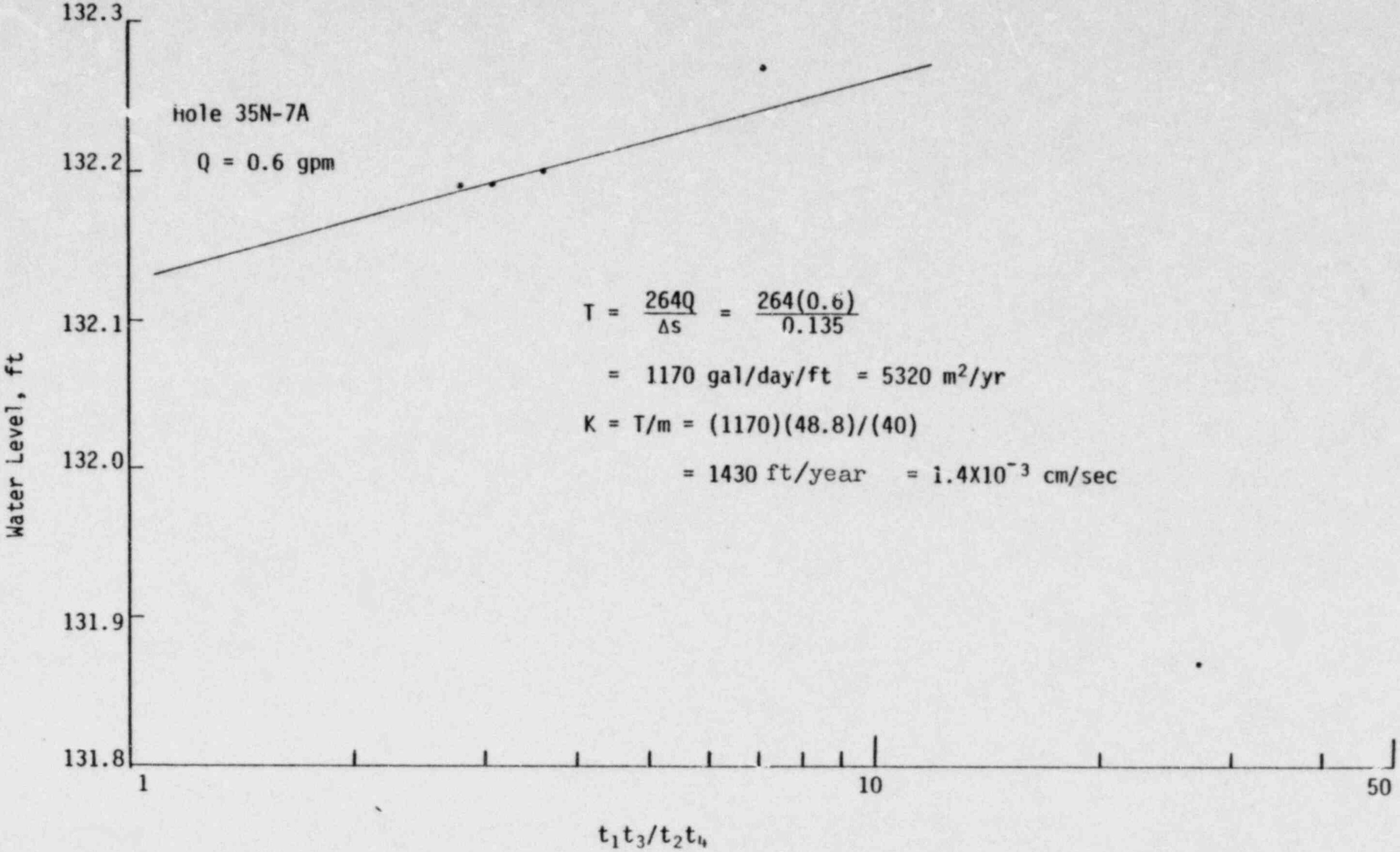
$$= 1.1 \text{ gal/day/ft} = 5.0\ \text{m}^2/\text{yr} = 1.02\text{x}10^{-4}\ \text{ft}^2/\text{min}$$

$$k = T/m = (1.1)(48.8)/(20)$$

$$= 2.7 \text{ ft/yr} = 2.6\text{X}10^{-6} \text{ cm/sec}$$

$t_o = 5.2$ min

FIGURE A.12 CONSTANT HEAD TEST FOR HOLE 35N-4 (MUDSTONE)



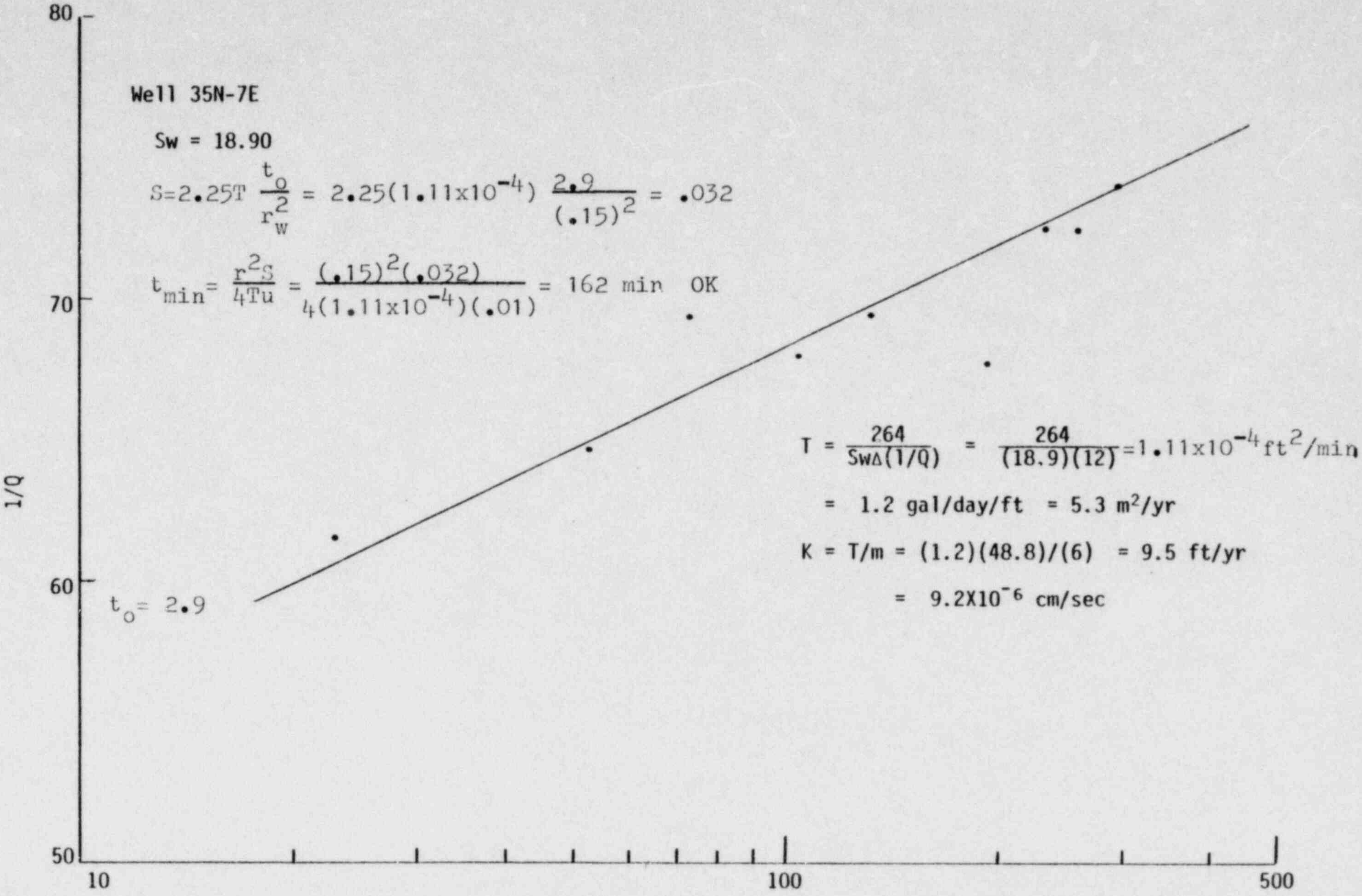
$$T = \frac{264Q}{\Delta s} = \frac{264(0.6)}{0.135}$$

$$= 1170 \text{ gal/day/ft} = 5320 \text{ m}^2\text{/yr}$$

$$K = T/m = (1170)(48.8)/(40)$$

$$= 1430 \text{ ft/year} = 1.4\text{X}10^{-3} \text{ cm/sec}$$

FIGURE A.13 RECOVERY TEST FOR HOLE 35N-7A (70 SANDSTONE)



Well 35N-7E

$Sw = 18.90$

$$S = 2.25T\frac{t_o}{r_w^2} = 2.25(1.11\text{x}10^{-4})\,\frac{2.9}{(.15)^2} = .032$$

$$t_{min} = \frac{r^2S}{4Tu} = \frac{(.15)^2(.032)}{4(1.11\text{x}10^{-4})(.01)} = 162 \text{ min} \quad \text{OK}$$

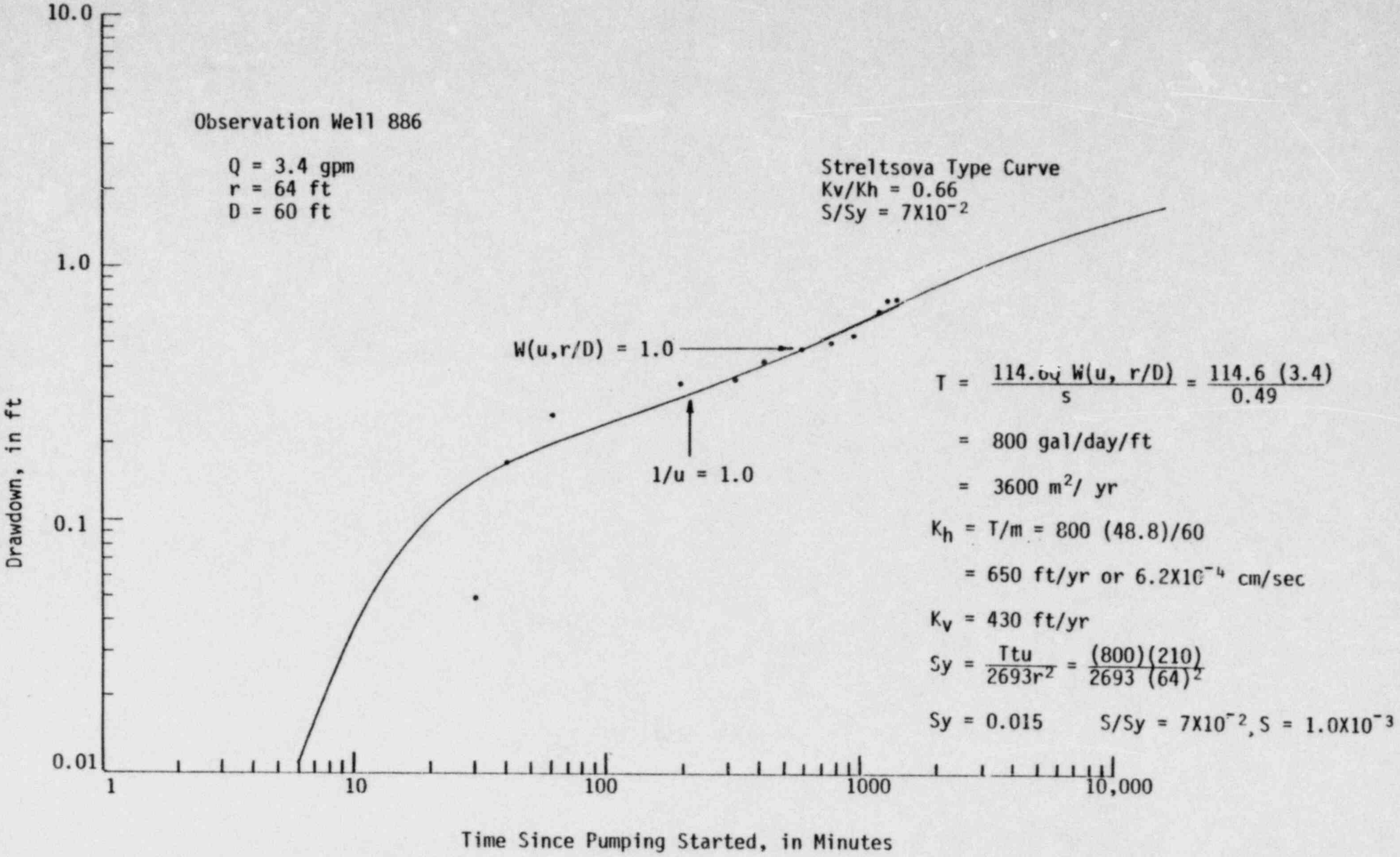
$$T = \frac{264}{Sw\Delta(1/Q)} = \frac{264}{(18.9)(12)} = 1.11\text{x}10^{-4}\,\text{ft}^2/\text{min}$$

$= 1.2$ gal/day/ft $= 5.3$ m^2/yr

$K = T/m = (1.2)(48.8)/(6) = 9.5$ ft/yr

$= 9.2\text{X}10^{-6}$ cm/sec

FIGURE A.14 CONSTANT HEAD TEST FOR HOLE 35N-7E (SANDSTONE)



$$T = \frac{114.6Q\ W(u,\ r/D)}{s} = \frac{114.6\ (3.4)}{0.49}$$

$= 800$ gal/day/ft

$= 3600\ m^2/\ yr$

$K_h = T/m = 800\ (48.8)/60$

$= 650$ ft/yr or $6.2X10^{-4}$ cm/sec

$K_v = 430$ ft/yr

$$Sy = \frac{Ttu}{2693r^2} = \frac{(800)(210)}{2693\ (64)^2}$$

$Sy = 0.015$ $S/Sy = 7X10^{-2}, S = 1.0X10^{-3}$

FIGURE A.15 DRAWDOWN IN OBSERVATION WELL 886 FROM PUMPING WELL 885 (70 SAND)

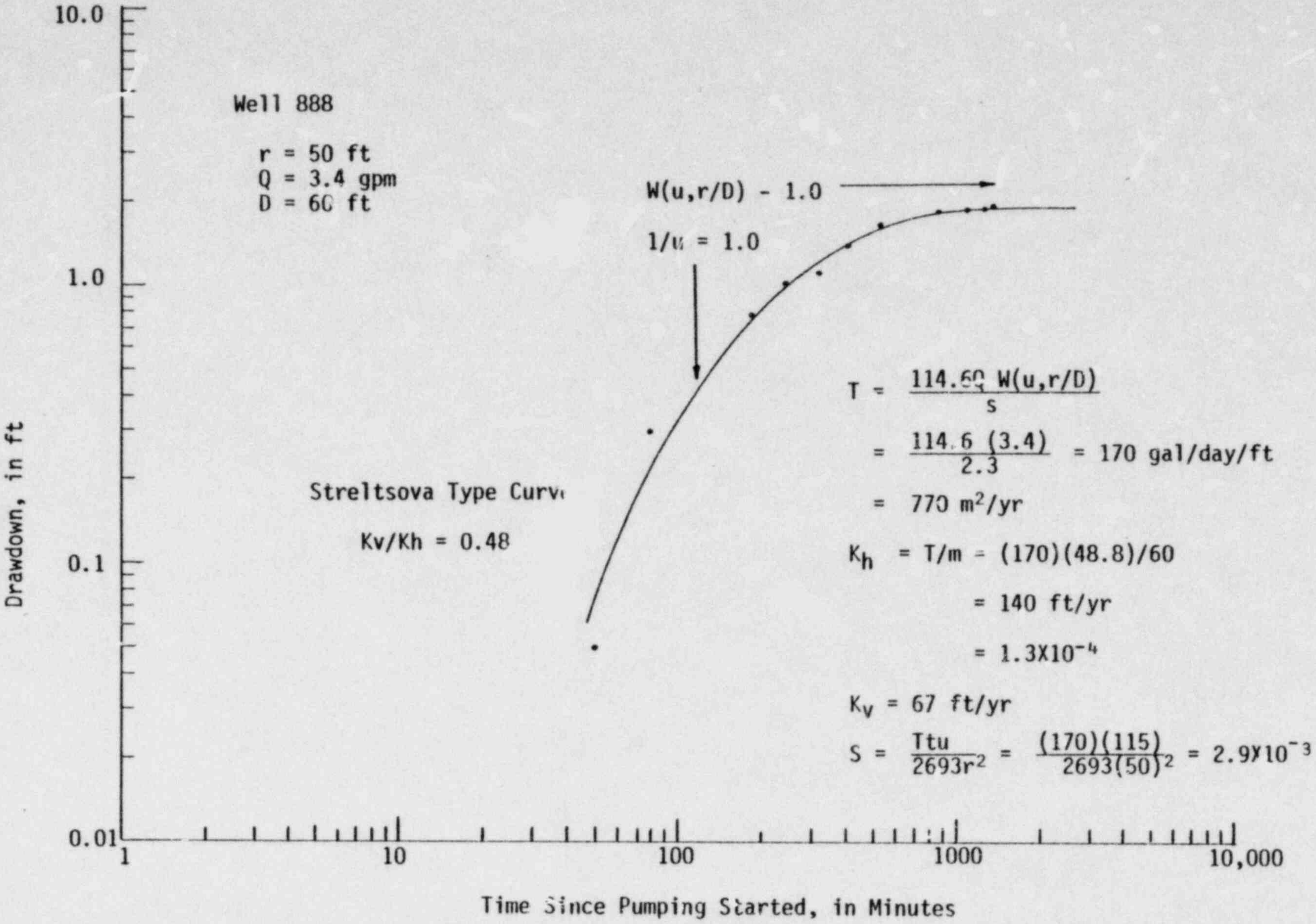
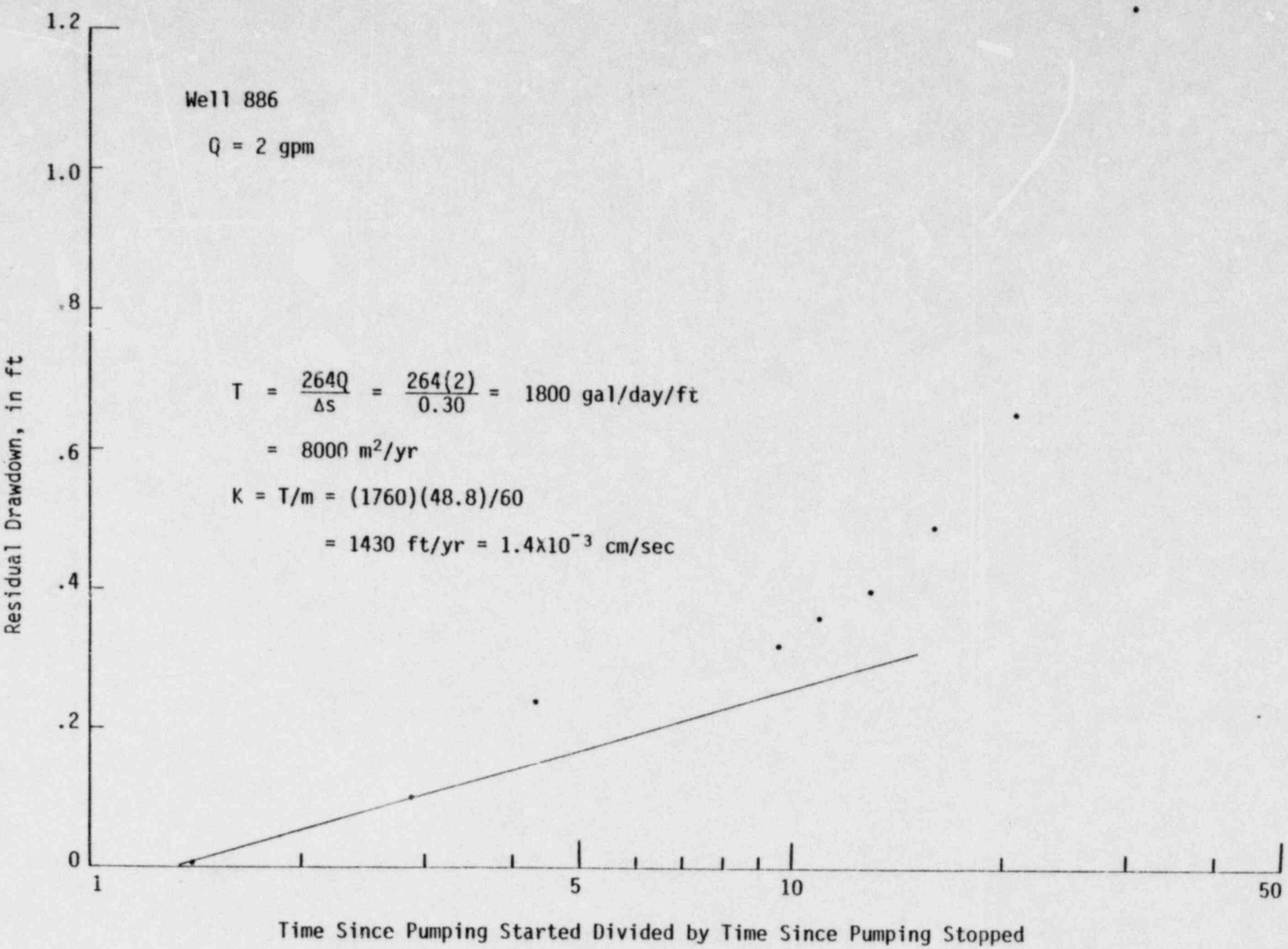


FIGURE A.16 DRAWDOWN IN OBSERVATION WELL 888 FROM PUMPING WELL 885 (70 SAND)



Well 886

Q = 2 gpm

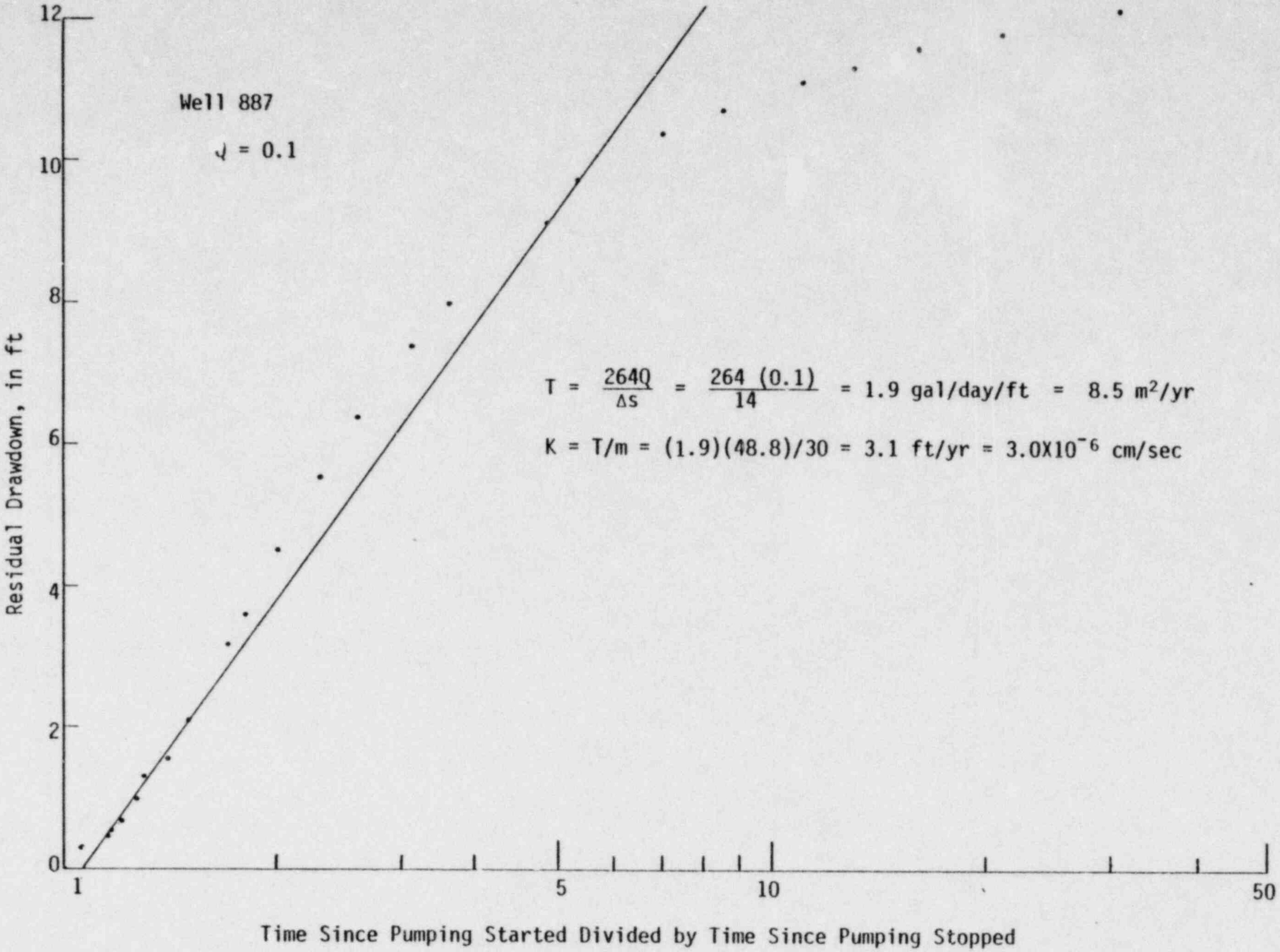
$$T = \frac{264Q}{\Delta s} = \frac{264(2)}{0.30} = 1800 \text{ gal/day/ft}$$

$$= 8000 \text{ m}^2\text{/yr}$$

$$K = T/m = (1760)(48.8)/60$$

$$= 1430 \text{ ft/yr} = 1.4\text{X}10^{-3} \text{ cm/sec}$$

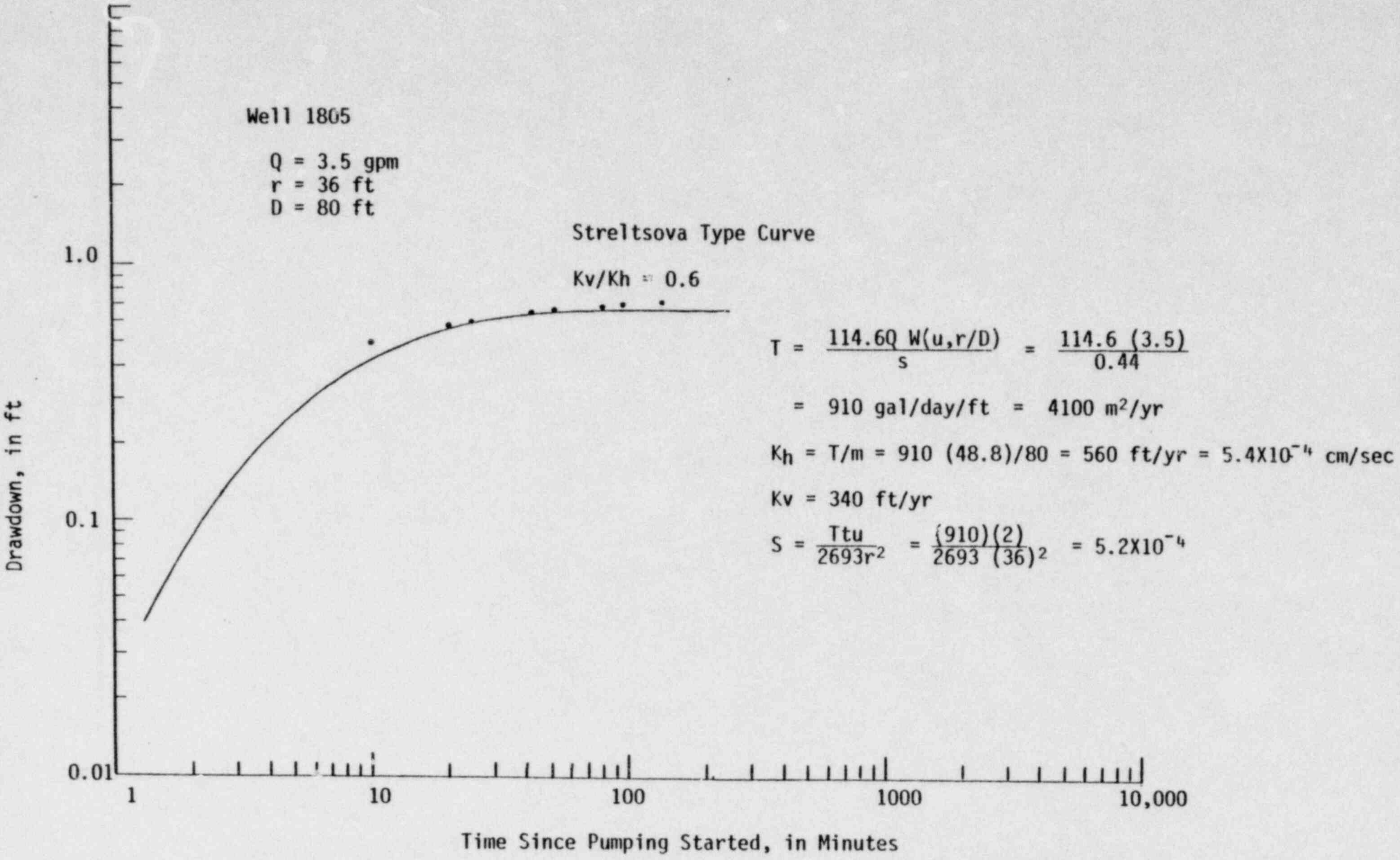
FIGURE A.17 . RECOVERY OF PUMPING WELL 886 (70 SAND)



$$T = \frac{264Q}{\Delta s} = \frac{264\ (0.1)}{14} = 1.9\ \text{gal/day/ft} = 8.5\ \text{m}^2\text{/yr}$$

$$K = T/m = (1.9)(48.8)/30 = 3.1\ \text{ft/yr} = 3.0\text{X}10^{-6}\ \text{cm/sec}$$

FIGURE A.18 RECOVERY OF PUMPING WELL 887 (68 SAND)



$$T = \frac{114.6Q\ W(u,r/D)}{s} = \frac{114.6\ (3.5)}{0.44}$$

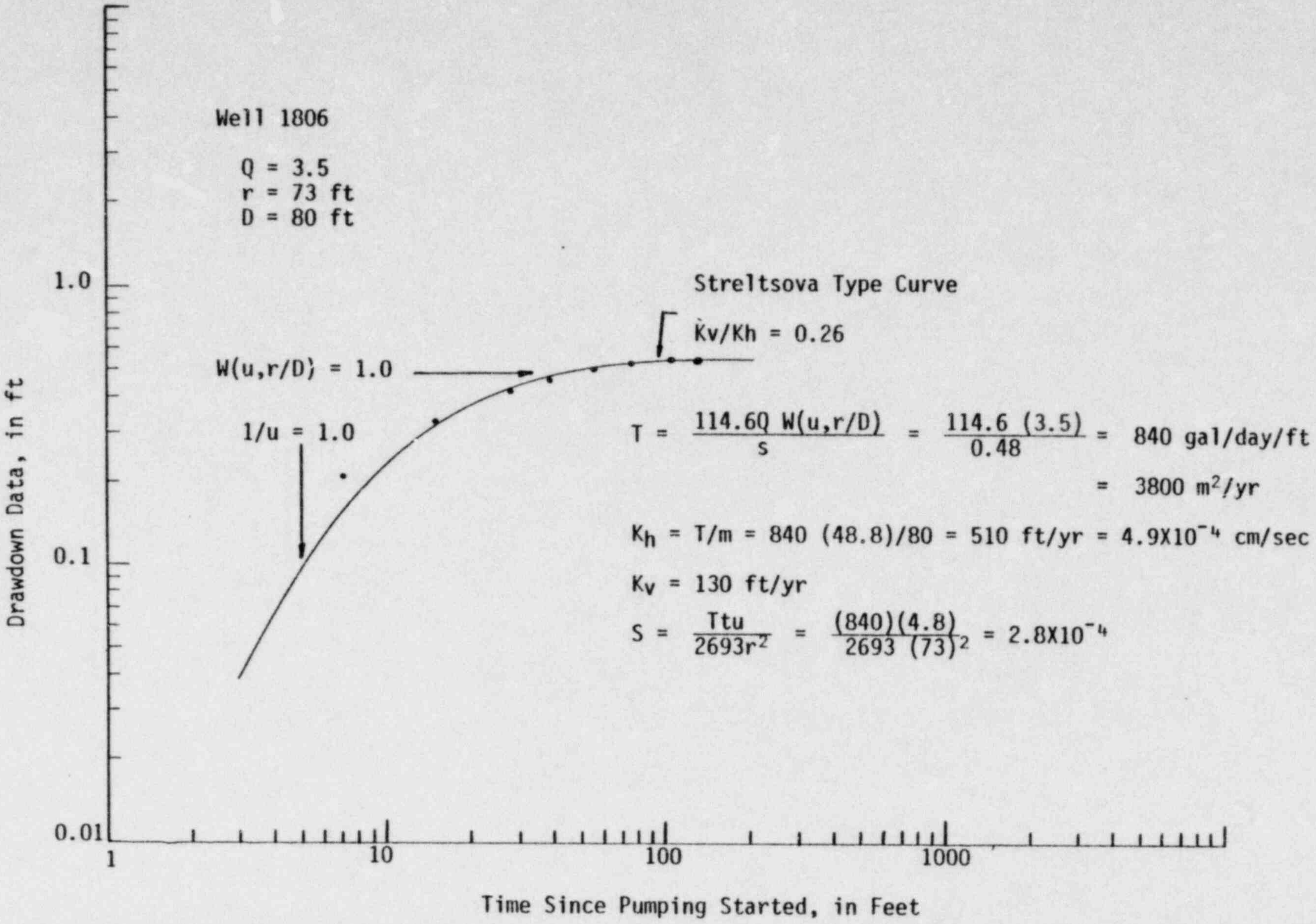
$$= 910 \text{ gal/day/ft} = 4100 \text{ m}^2\text{/yr}$$

$$K_h = T/m = 910\ (48.8)/80 = 560 \text{ ft/yr} = 5.4\text{X}10^{-4} \text{ cm/sec}$$

$$K_v = 340 \text{ ft/yr}$$

$$S = \frac{Ttu}{2693r^2} = \frac{(910)(2)}{2693\ (36)^2} = 5.2\text{X}10^{-4}$$

FIGURE A.19 . DRAWDOWN IN OBSERVATION WELL 1805 FROM PUMPING WELL 1 (70 SAND)



$T = \frac{114.6Q\ W(u,r/D)}{s} = \frac{114.6\ (3.5)}{0.48} = 840$ gal/day/ft

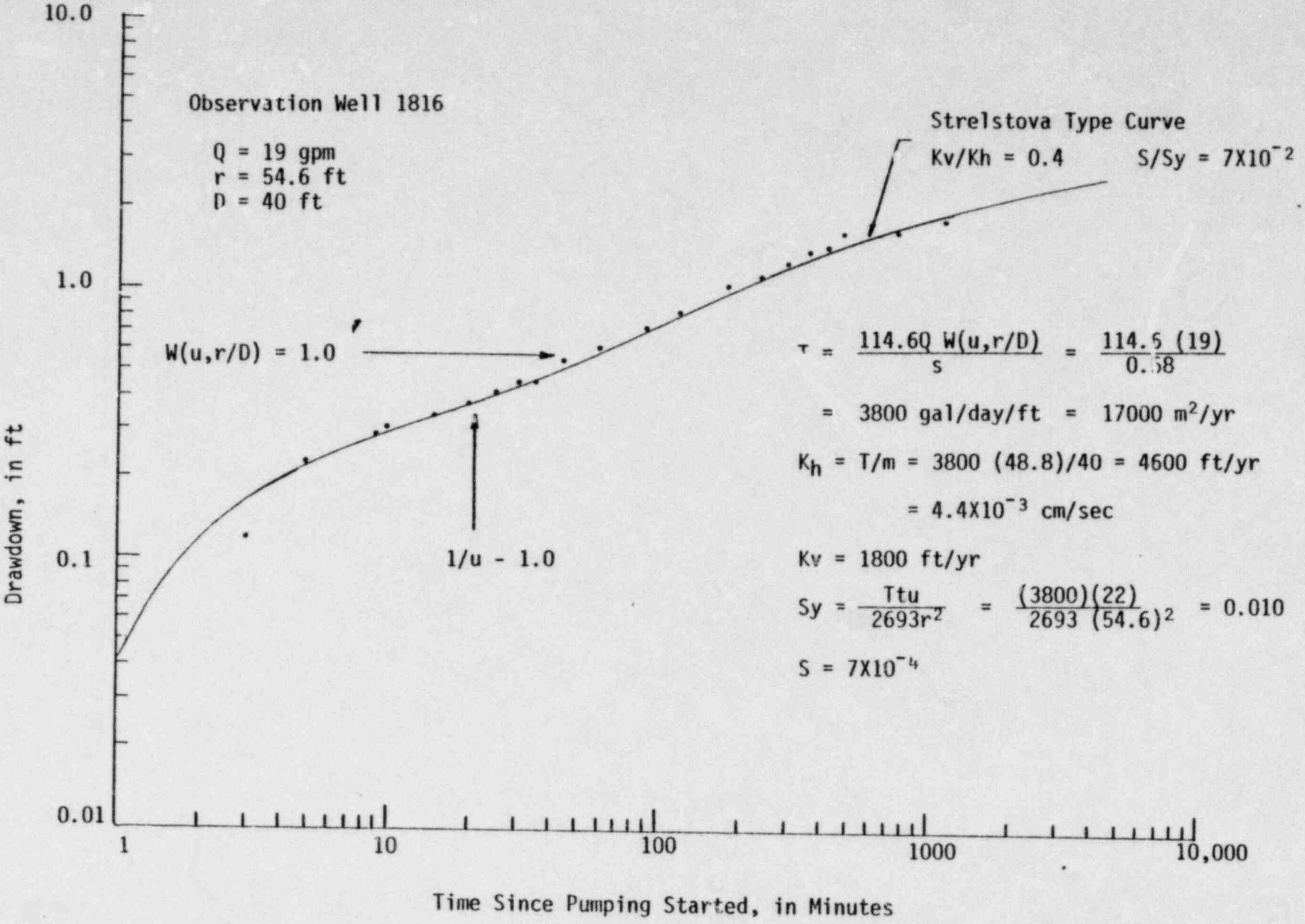
$= 3800\ m^2/yr$

$K_h = T/m = 840\ (48.8)/80 = 510$ ft/yr $= 4.9X10^{-4}$ cm/sec

$K_v = 130$ ft/yr

$S = \frac{Ttu}{2693r^2} = \frac{(840)(4.8)}{2693\ (73)^2} = 2.8X10^{-4}$

FIGURE A.20 DRAWDOWN IN OBSERVATION WELL 1806 FROM PUMPING WELL 1 (70 SAND)



$$T = \frac{114.6Q\ W(u,r/D)}{s} = \frac{114.6\ (19)}{0.58}$$

$$= 3800\ \text{gal/day/ft} = 17000\ \text{m}^2/\text{yr}$$

$$K_h = T/m = 3800\ (48.8)/40 = 4600\ \text{ft/yr}$$

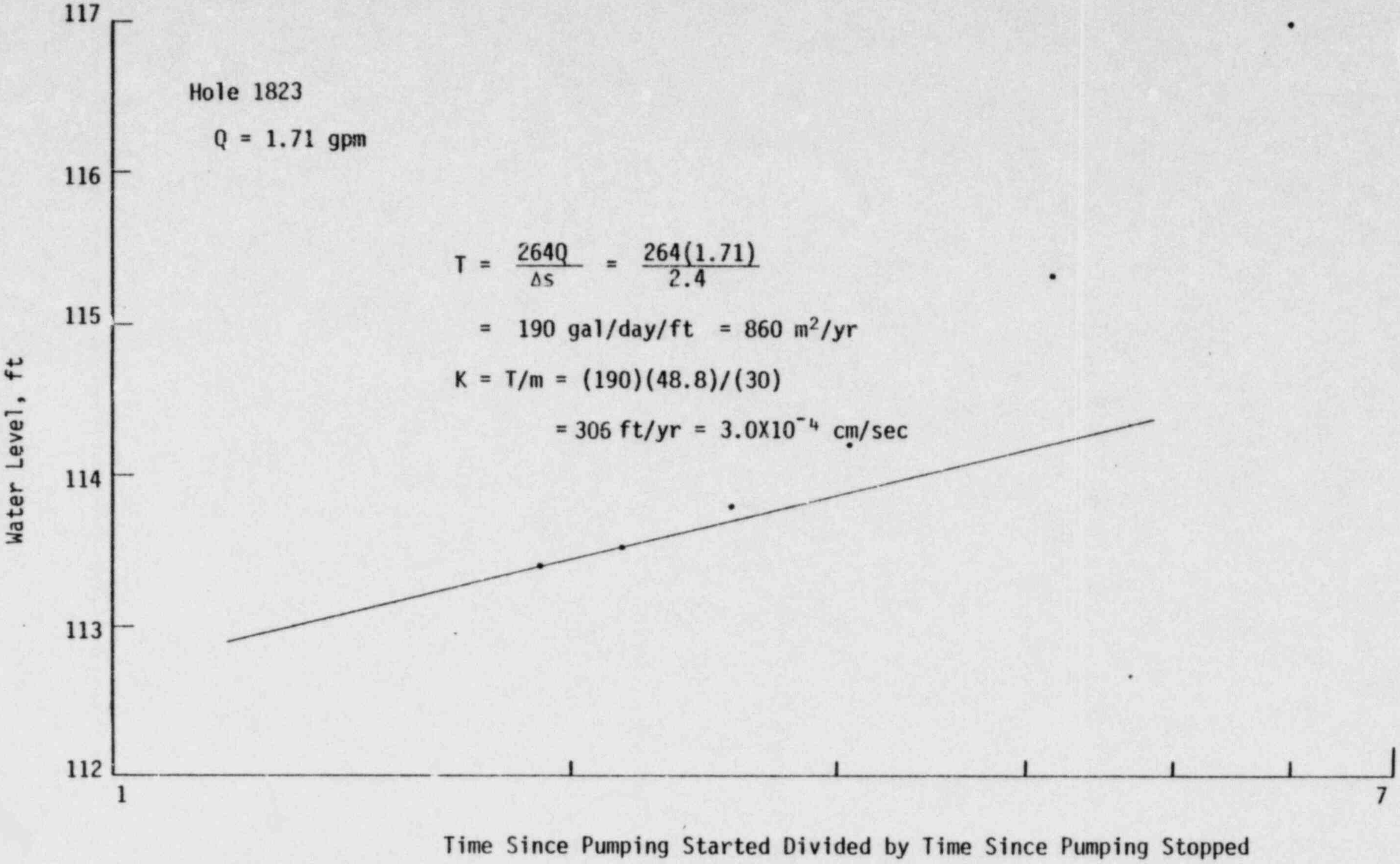
$$= 4.4\text{X}10^{-3}\ \text{cm/sec}$$

$$Kv = 1800\ \text{ft/yr}$$

$$Sy = \frac{Ttu}{2693r^2} = \frac{(3800)(22)}{2693\ (54.6)^2} = 0.010$$

$$S = 7\text{X}10^{-4}$$

FIGURE A.21 DRAWDOWN IN OBSERVATION WELL 1816 FROM PUMPING WELL 1814 (70 SAND)



Hole 1823

$Q = 1.71$ gpm

$$T = \frac{264Q}{\Delta s} = \frac{264(1.71)}{2.4}$$

$$= 190 \text{ gal/day/ft} = 860 \text{ m}^2\text{/yr}$$

$$K = T/m = (190)(48.8)/(30)$$

$$= 306 \text{ ft/yr} = 3.0\text{X}10^{-4} \text{ cm/sec}$$

FIGURE A.22 RECOVERY OF PUMPING WELL 1823

APPENDIX 3B

IDENTIFICATION OF CONOCO ENVIRONMENTAL REPORT FIGURES AND TABLES USED IN SECTION 3.6

REPORT FIGURE NUMBER	CONOCO FIGURE NUMBER	REPORT TABLE NUMBER	CONOCO TABLE NUMBER
3.1	2.7-5	3.6.1.1	2.7-10
3.2	2.7-6	3.6.1.2	2.7-11
3.3	2.7.7	3.6.1.3	2.7-12
3.4	2.7-8	3.6.1.4	2.7-13
3.5	2.7-9	3.6.1.5	2.10-4
3.6	2.7-10	3.6.1.6	2.10-5
3.7	2.7-11	3.6.1.7	2.10-6
3.8	2.7-12	3.6.2.1	2.7-1
3.9	2.7-13	3.6.2.2	2.7-2
3.10	2.7-14	3.6.2.3	2.7-3
3.11	2.7-15	3.6.2.4	* *
3.12	2.7-16	3.6.2.5	2.7-5
3.13	2.7-17	3.6.2.6	2.7-6
3.14	2.7-18	3.6.2.7	2.7-7
3.15	2.7-19	3.6.2.8	2.7-8
3.16	2.7-20	3.6.2.9	2.7-9
3.17	2.7-21	3.6.2.10	2.10-3
3.18	2.7-22		
3.19	2.7-1		
3.20	2.7-2		
3.21	2.7-3		
3.22	*		
3.23	2.7-4		

*Figure 3.22 is from Chen and Associates, Geotechnical Investigation for the Proposed Evapoation Pond and Temporary Tailings Disposal Area. Figure 2B.

**Table 3.6.2.4 is a list of aquifer test results selected from Conoco Table 2.7-4.

4.2.2 WATER QUALITY

This section contains a description of work Conoco has done to monitor surface and groundwater quality in the Sand Rock area. It includes pre-operational water quality assessment, operational monitoring programs, and post-mining restoration plans.

Section 4.2.2.2 also includes a presentation of the groundwater flow and ion migration models that are used to estimate the impacts of mine operations on area groundwater.

4.2.2.1 SURFACE WATER MONITORING

PRE-OPERATIONAL MONITORING

Baseline surface water sampling began in June, 1979 and is scheduled to continue through the Spring of 1981. Samples are collected in accordance with Wyoming Department of Environmental Quality guidelines. Frequency of sampling (subject to the availability of surface water during dry periods) is guided by recommendations suggested in the NRC's Draft Generic Environmental Impact Statement.

Figure 3.1 displays sampling sites and the drainage patterns in and surrounding the project area. It should be noted that all surface drainage from the proposed project area drains past sample location 1-7 at a point immediately downstream of the confluence of Ninemile Creek and Pine Tree Draw (Section 18, T41N, R74W). Figure 3.2 shows surface runoff and impoundment sites which are located within or near the project area. Table 3.6.1.4 presents analytical data gathered during this program and results are discussed in Section 3.6.1.5.

Crest-stage data was not collected at the old surface water gaging stations (Sites 1 through 4) during this program due to very little runoff and unreliability of the existing sites. Crest-stage sampling sites and pond staff gages will be installed in the future to support the operational monitoring program.

PROPOSED OPERATIONAL MONITORING PROGRAMS

Five sites are proposed for the monitoring of surface runoff: 1-7, 1-10, 1-28, 1-33S and 1-1A. In addition, surface flow from site 1-30 (Pine Tree Spring) will be monitored by a continuous recorder which will be installed during 1980. These locations are shown in Figures 3.1 and 3.2.

Crest stage and sample stage for the event the sample is collected from will be recorded. Self-samplers are proposed for each of these five runoff sites to enable the collection of samples from very short duration flows. Ponds 1-7A, 1-20, 1-31, 1-32, 1-33 and 1-35, which are downstream of the program area will be monitored (See Figures 3.1 and 3.2). Site 1-16, which is up-gradient of the project area, will be monitored for background water quality.

Table 4.2.2.1 lists the surface water sites. The complete list of parameters (List A of Table 4.2.2.3) will be analyzed each spring with only the modified list (List B of Table 4.2.2.3) for the other three quarters (if water is available). Dissolved oxygen, total suspended solids and stage are added to the groundwater list of parameters for the surface samples sites.

A NOTE OF CAUTION: pond samples can be misleading because the amount of evaporation that has occurred before collecting the sample.

If the surface water monitoring indicates contamination of the runoff, steps will be taken immediately to correct the program. The overall program will be developed according to state and federal requirements and recommendations.

SURFACE DRAINAGE RESTORATION

The final surface drainage system plan is shown in Figure 3.7-13. Ephemeral channels and drainage systems will be reconstructed to approximately the same dimensions as the premining drainages. The evaporation pond impoundment will be backfilled and the sedimentation dams and flood control structures will

TABLE 4.2.2.1

OPERATIONAL SURFACE WATER MONITORING SCHEDULE

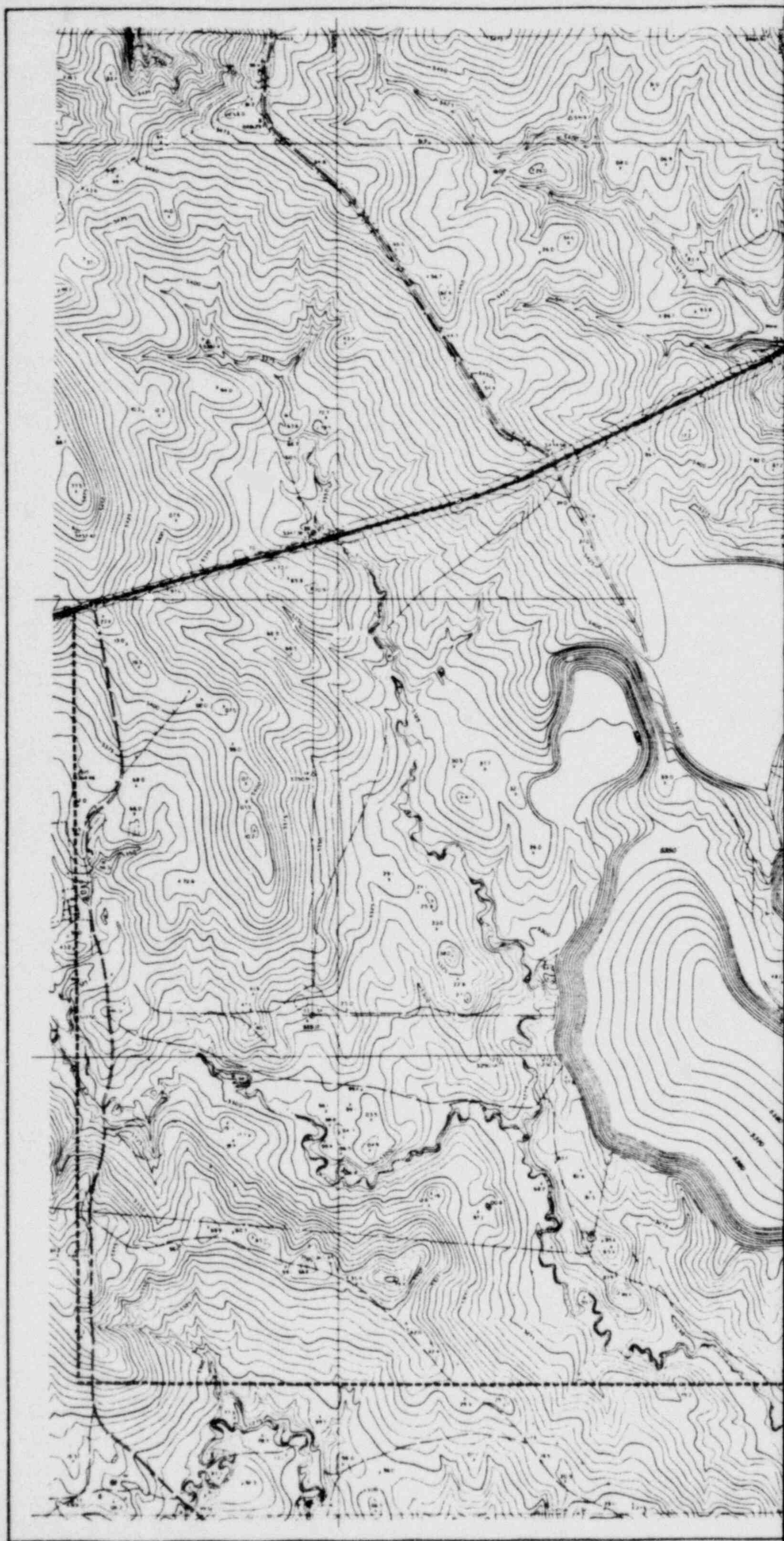
SITE NAME	STREAM	SAMPLING FREQUENCY	PARAMETERS TO BE SAMPLED*
	Private Ponds		
I-7A	Ninemile Creek	Annual(Spring)	List A, plus stage
		Quarterly	List B, plus stage
I-35	Lower Wash No. 4	Annual (Spring)	List A, plus stage
		Quarterly	List B, plus stage
I-31	Lower Wash No. 4	Annual (Spring)	List A, plus stage
		Quarterly	List B, plus stage
I-33	Simmons Draw	Annual (Spring)	List A, plus stage
		Quarterly	List B, plus stage
I-20	Lower Wash No. 2	Annual (Spring)	List A, plus stage
		Quarterly	List B, plus stage
I-16	Upper Wash No. 2	Annual (Spring)	List A, plus stage
		Quarterly	List B, plus stage
I-32	Simmons Draw	Annual (Spring)	List A, plus stage
		Quarterly	List B, plus stage
	Streams		
I-7	Ninemile Creek	Annual(Spring)	List A, plus crest stage
		Quarterly	List B, plus crest stage
I-33S	Simmons Draw	Annual (Spring)	List A, plus crest stage
		Quarterly	List B, plus crest stage

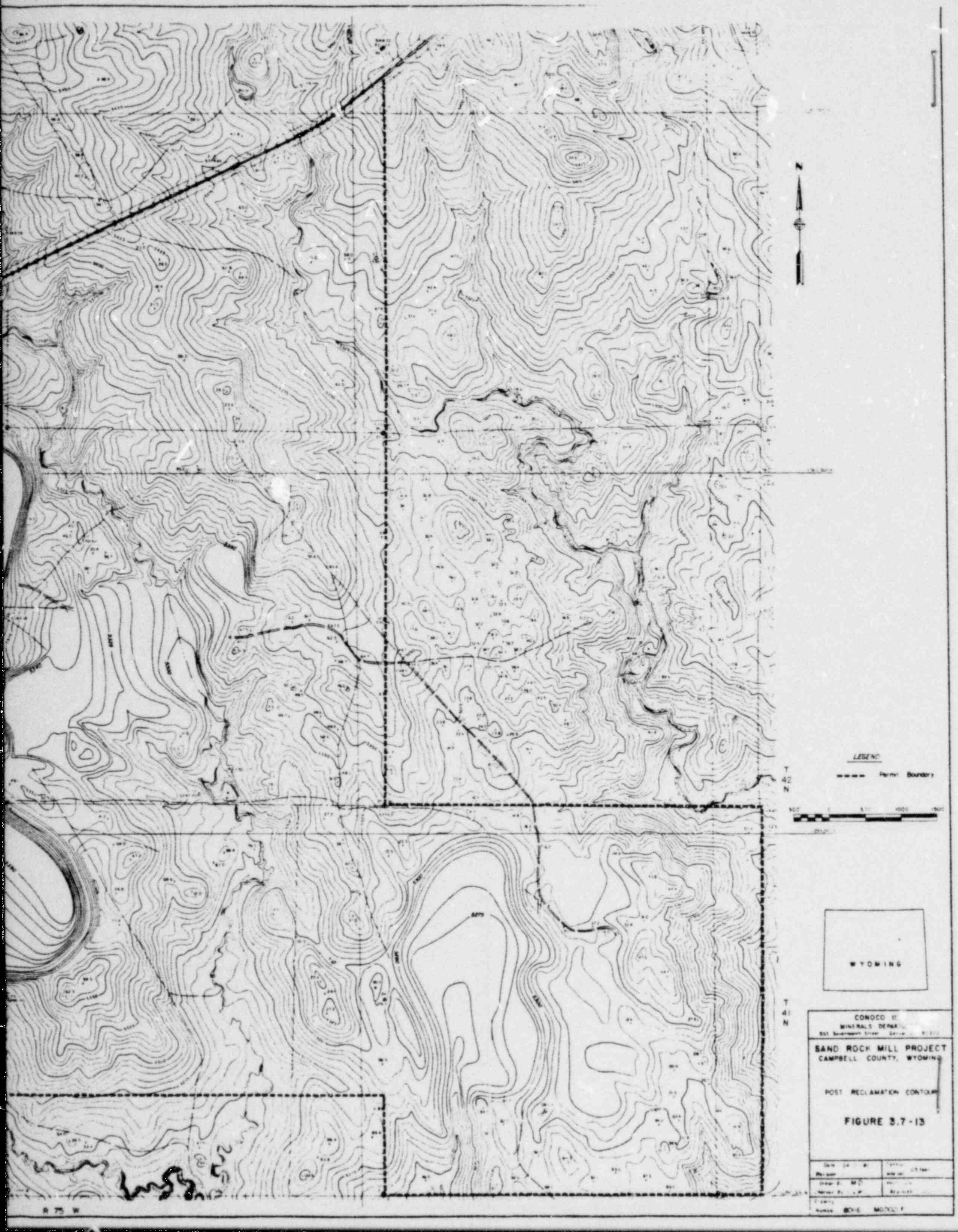
TABLE 4.2.2.1

(CONT.)

SITE NAME	STREAM	SAMPLING FREQUENCY	PARAMETERS TO BE SAMPLED
I-10	Simmons Draw	Annual(Spring)	List A, plus crest stage
		Quarterly	List B, plus crest stage
I-30 (Pine Tree Spring)	Pine Tree Draw	Annual (Fall)	List A
		Quarterly	List B
		Continuous	Discharge
I-28 (or Site 3)	Pine Tree Draw	Annual (Spring)	List A, plus crest stage
		Quarterly	List B, plus crest stage
I-1A	Wash No. I	Annual (Spring)	List A, plus crest stage
		Quarterly	List B, plus crest stage

*List A and List B are given in TABLE 4.2.2.3





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POST RECLAMATION CONTOURS

FIGURE 3.7-13

be flattened and graded. Recontouring will be done in a way to promote deposition rather than erosion and care will be taken to re-establish meander frequency in the drainages. Diversion ditches will be filled, covered with topsoil, and revegetated with an approved mixture of grasses, forbs and shrubs. All of the reconstructed stream channels and drainage areas will be covered with topsoil and revegetated. In the reclaimed areas, the surface drainage will be reconstructed such that it approximates the premining drainage in area, slope, and direction of flow.

4.2.2.2 GROUNDWATER

PRE-OPERATIONAL MONITORING

PHYSICAL AND CHEMICAL PARAMETERS

Although groundwater quality data were available in Conoco's June, 1979 Mine Permit Application to the State of Wyoming, a specific baseline program was initiated in mid-1979 to satisfy NRC requirements.

Sampling procedures have been consistent with State of Wyoming guidelines and frequency of sampling was determined by recommendations in NRC's Draft Generic Environmental Impact Statement.

Monitoring results are given in Tables 3.6.2.7, 3.6.2.8, and 3.6.2.9 for the private wells, Conoco's monitoring wells, and the tailings management areas, respectively. Figure 3.21 shows the location of Conoco's monitoring wells, while the private wells are shown in Figures 3.1 and 3.2. Results of the groundwater monitoring are discussed in Section 3.6.2.

GROUNDWATER MODEL

The flow model developed by McWhorter and Nelson (1978, 1979) was used to determine the seepage rate from the evaporation pond and Pit 35N. The theory of this model will be presented first with a discussion of the ion migration model theory following.

FLOW MODEL THEORY

Seepage from a new tailings disposal site will consist of flow into a partially saturated zone and eventually to a saturated zone. Figure 4.2.1 shows a schematic of two systems which are relevant to the Sand Rock lithologic systems. The first step in using McWhorter and Nelson's model is to determine if saturation or partial saturation will govern flow above the wetting front. The following equation (Equation 14 of McWhorter and Nelson 1979) enables the determination of whether the flow behind the wetting front will be saturated.

For Case A

$$y + Dt + Dl - Kmv\ (Dt/Kt + Dl/Kl)$$

if above is: $< hd$, partially saturated flow

$> hd$, saturated flow

where: y = Depth of tailings pond (fluid) in cm (ft)

Dt = Thickness of tailings material, in cm (ft)

Dl = Thickness of liner, in cm (ft)

Kmv = Vertical permeability of mudstone, in cm/sec (ft/yr)

Kt = Vertical permeability of tailings, in cm/sec (ft/yr)

Kl = Vertical permeability of liner, in cm/sec (ft/yr)

hd = Displacement pressure, in cm (ft)

For Case B

$$y + Dt + Dl + Dm - Ksv\ (Dt/Kt + Dl/Kl) + Dm/Kmv$$

if above is: $< hd$, partially saturated flow

$> hd$, saturated flow

where: Ksv = Vertical permeability of unsaturated 70 sand, in cm/sec (ft/yr)

Dm = Thickness of mudstone, in cm (ft)

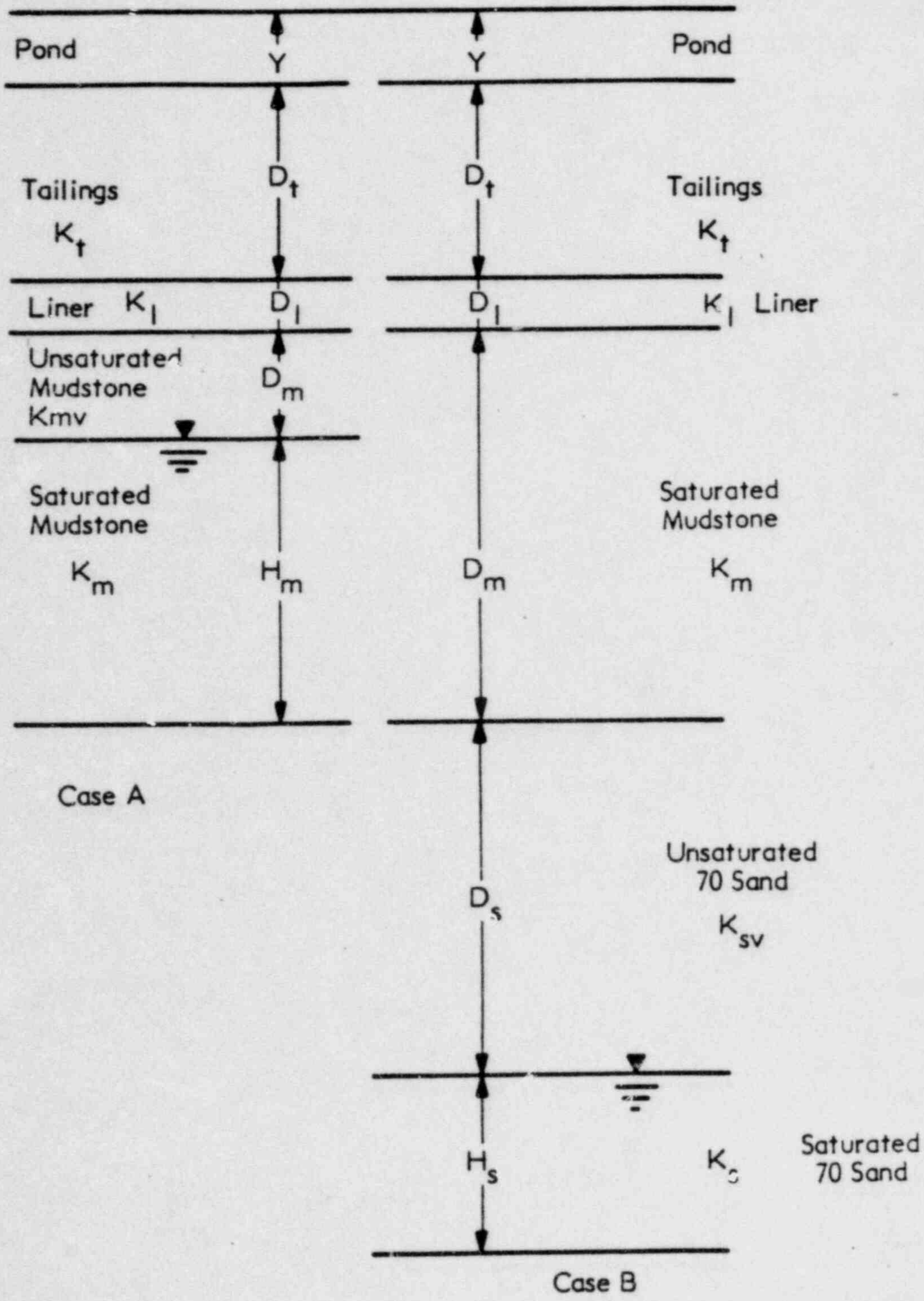

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FIGURE 4.2-1

SCHEMATIC OF SEEPAGE
MODEL PARAMETERS

The displacement can be calculated from the following equation:

$$hd = -9.66 \left(\frac{Kmv}{n - \Theta r} \right)^{-0.401}$$

For Case A

where:
n = porosity
Θr = specific retention (residual water content)
hd = displacement pressure, in cm
Kmv = vertical permeability of mudstone, in cm/sec

For Case B, replace Kmv with Ksv

This relationship was established by a least squares fit of measured data by McWhorter and Nelson (1978). The smallest value used in this correlation was -240 cm (-7.87 ft). The displacement pressure equation will produce very small (large negative) values for low permeability material, values which are outside the range of data used in this correlation. It is doubtful that displacement pressures are as small as this equation produces for low permeability material. Therefore, we will use a minimum value of -300 cm (-10 ft) for displacement pressure in this analysis.

We will present the theory for saturated and partially saturated flow conditions because the Sand Rock mill area subsoil and rock material properties indicate that seepage behind the wetting front should be saturated without liners and partially saturated with liners. McWhorter and Nelson presented flow equations for different conditions and labeled them Stages I, II and III. The first of the following two equations is used to compute the seepage rate, while the second yields the time of seepage.

For Case A (Stage 1)

$$q = Kmv\left(\frac{L + A - hc}{L + Kmv\,B}\right) \quad \text{(saturated)}$$

$$q = \frac{A - hd(q/Kmv)}{B}^{\frac{1}{2+3\lambda}} \quad \text{(unsaturated)}$$

$$t = \frac{n-\theta i}{Kmv}(L + (kmvB - A + hc)\ \text{In}\left[\frac{L + A - hc}{A - hc}\right]$$

where: q = Seepage rate (Darcy velocity), in cm/sec (ft/yr)

L = Distance from the top of the foundation material to the wetting front, in cm (ft)

$A = Y + Dt = Dl$

$B = Dt/Kt + Dl/Kl$

hc = effective capillary drive, in cm (ft)

θi = initial moisture content

λ = pore size distribution parameter. normally 2

For Case B (Stage 1)

Replace Kmv with Ksv

$A = Y + Dt + Dl + Dm$

$B = Dt/Kt + Dl/Kl + Dm/Kmv$

t = Time since Stage 1 started, in sec (yr)

Stage II flow does not exist if Stage 1 flow is saturated. Therefore, Stage III saturated flow should govern Sand Rock mill area flow conditions next. The following equation (Stage III) starts governing the flow as soon as saturated seepage reaches the water table (groundwater mound reaches the bottom of tailings).

For Case A

$$\frac{4\ Km\ Hm\ t}{Sy\ R^2} = \exp(w) - \exp(wo) - \frac{(w-wo)}{1.1!} - \frac{w^2 - wo^2}{2.2!} - \frac{w^3 - wo^3}{3.3!} - \ldots$$

w = $(4\ Km\ Hm\ Dm)/R^2qm$

wo = $(4\ Km\ Hm\ Dm)/R^2qmo$

where:
Hm = Aquifer thickness of mudstone, in cm (ft)

t = Time since Stage III started, in sec (yrs)

Km = Horizontal permeability, in cm/sec (ft/yr)

Sy = Specific yield of aquifer

R = Equivalent radius of pond, in cm (ft)

qmo = Seepage rate at end of Stage II (Stage I for this case), in cm/sec (ft/yr)

For Case B

Replace Km with Ks,
Hm with Hs,
Dm with Dm + Ds

where:
Ks = Horizontal permeability of saturated 70 sand aquifer, in cm/sec (ft/yr)

Hs = Aquifer thickness of saturated 70 sand aquifer, in cm(ft)

Two unknowns exist in the above equation. The equation is solved by entering a seepage rate and computing the corresponding time value. McWhorter and Nelson also stated that Stage III analyses were improved by replacing Hm (Hs) by Hm + (Dm + hd)/2(Hs + (Ds + hd)/2).

THEORY OF PIT WALL SEEPAGE MODEL

McWhorter and Ortiz developed a flow model forpredicting seepage into pit walls from the static and the capillarity driving forces. The theoretical development of this model is presented in Union Carbide's Source Material License SUA-648 in 1979. The following equation accounts for a linear changing head of the static head in the pit and the capillary drive.

$$q = (n - \Theta)\ \frac{RK(t - ti)^2}{n - \Theta} + \frac{2K\left(\frac{D}{2} - hc\right)(t - ti)}{n - \Theta}^{1/2}$$

where: q = Seepage rate, in cm/sec (ft/yr)

n = porosity of seepage layer

Θ = Natural water content of layer

r = Linear rate of rise in static head, in cm (ft)

K = Permeability, in cm/sec (ft/yr)

D = Thickness of seepage layer, in cm (ft)

hc = Capillary driving force, in cm (ft)

t = Project time, in sec (yrs)

ti = Time at which saturated level reaches top of layer in sec (yrs)

Times greater than the time it took for the saturated level to reach the top of the layer are inputs to this equation with the seepage rate as the product.

THEORY OF INTERCEPT DRAIN SPACING

The Ellipse equation which was used to space the intercept drains in the bottom of the pit is as follows:

$$S = \left(\frac{4K(m^2 + 2\ am)}{q}\right)^{\frac{1}{2}}$$

where: S = Spacing of drains, in feet

K = Permeability of drain material in inches/hr

m = Vertical distance, after drawdown, of phreatic surface above drain at midpoint between lines, in feet

a = Depth of barrier below drain, in feet

q = Drainage coefficient, in inches/hr

Figure 4.2.2 gives a schematic which shows the parameters of the Ellipse equation. Pages 163-180 of the USDA, S.C.S. book "Drainage of Agricultural Land" give a good discussion of the Ellipse equation. The drainage coefficient is the inches per hour of infiltration. It is obtained in our case by subtracting out the surface runoff, tailings water retained and evaporated water from total rate of water input to the tailings. The area to which the water is being applied must be divided into the infiltration rate to obtain the infiltration in inches/hr.

ION MIGRATION MODEL

GENERAL THEORY

Water seeping through subsoil can transport dissolved ions with it. In addition to transportation of ions through the momentum of the seeping water, other mechanisms, such as molecular diffusion, hydrodynamic dispersion, and adsorption can affect ion movement relative to the host water movement.

Diffusion is the mixing process, at a molecular level, which accounts for the movement of dissolved ions from areas of higher to lower relative concentrations in a given solution. Hydrodynamic dispersion is caused by the complexities of the porous medium and is more mechanical in nature. For more detailed information on diffiusion and dispersion, the reader should refer to Fried (1975), Schaidegger (1954), and Scheidegger (1961).

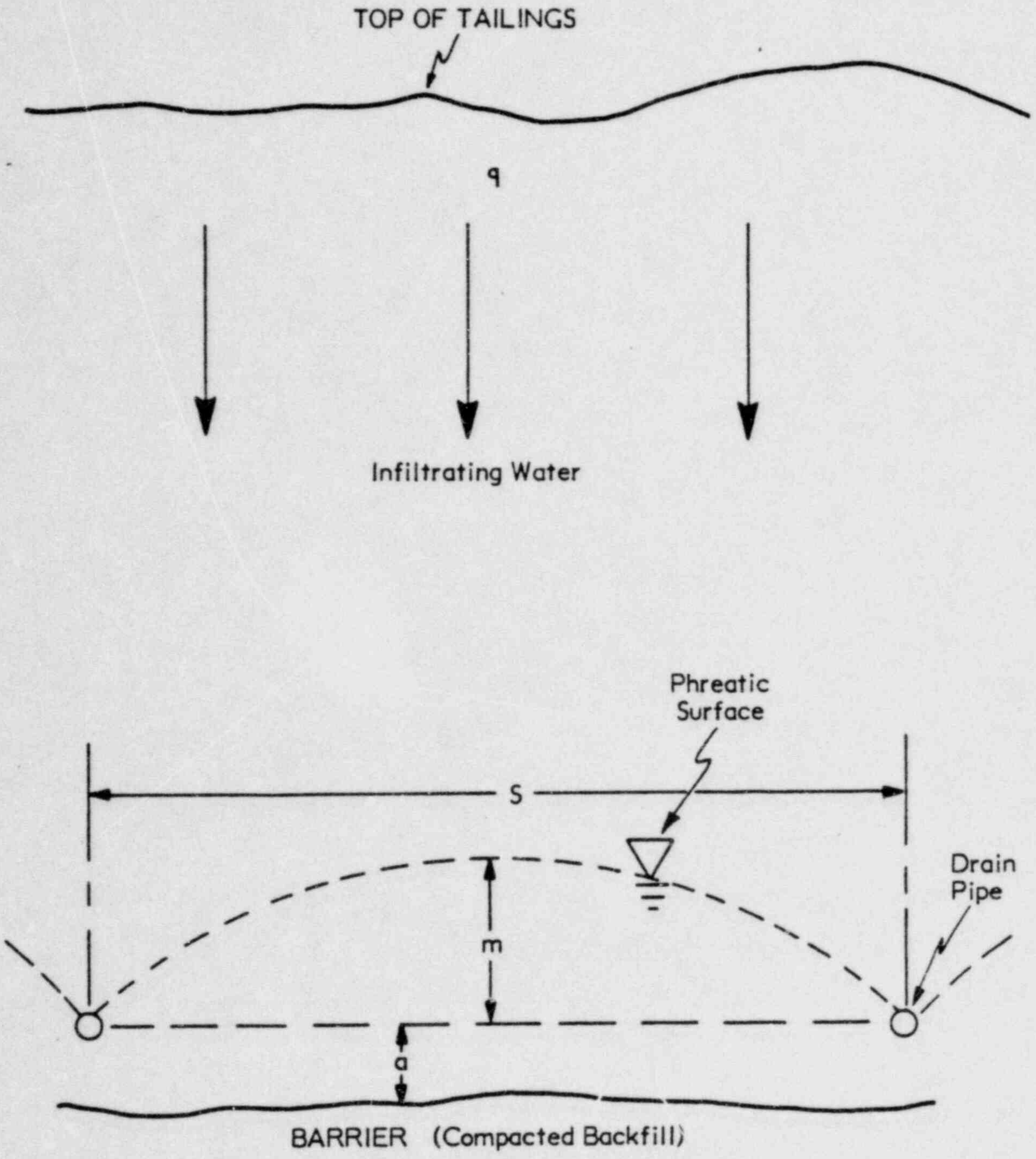

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FIGURE 4.2-2

SCHEMATIC OF INTERCEPTOR DRAINS

When a slug of tracer is injected into a porous medium it is not detected as a slug at distance down gradient from the injection site. Rather, it is detected as a gradually increasing concentration to a maximum value and then as a gradually decreasing concentration. This phenomenon is due to the combined effects of molecular diffusion and hydrodynamic dispersion. Quantitatively, hydrodynamic dispersion has the greater effect on solute transport, but both are accounted for and lumped together in some computational forms as a single dispersion coefficient. Hoopes and Harleman (1967), Lenau (1972), and Gelhar and Collins (1971) discuss techniques for determining dispersion and dispersion coefficient using tracer injection techniques.

Baetsle (1967) relates that much laboratory work has shown that the dispersion coefficient (D) can be related to interstitial water velocity (v) by the relationship:

$$\log D - \log v - 1$$

Banks and Jeresate (1962) related dispersion coefficient to seepage velocity and particle diameter (d) by the formula:

$$D = a\ d\ v$$

where a is a dimensionless constant shown by Ebach and White (1958) to be 1.92.

Low permeabilities that exist for most strata in the area of the project make extension injection tests impractical. Therefore, dispersion coefficients were estimated by velocity and particle diameter relationships.

Adsorption is a chemical process where ions in solution attach themselves to unoccupied activation sites or replace other ions already sorbed to solid particles. In general, clay minerals have high exchange and adsorption capacities and high valence, high atomic weight cations have greater replacing power. Robinson (1962) has presented a literature review and summary of the principal of ion exchange processes with respect to the disposal of high level radioactive wastes. A more theoretical treatment of adsorption by clays is presented by Bolt (1954).

One quantitative parameter for defining ion adsorption on soils is the distribution coefficient (Kd), also called the adsorption coefficient. It is usually considered that within trace concentration ranges, this coefficient is constant (Hajek and Ames, 1966). Kd may be calculated using the following formula:

$$Kd = \left(\frac{Ci - C_{eq}}{C_{eq}}\right)\left(\frac{ml}{g}\right)$$

where: C_i = initial concentration,

C_{eq} = equilibrium concentration,

ml = milliliters of solution,

and g = grams of soil or rock

This computational form is a simplification of the classical Freundlich isotherm, derived originally from the adsorption of a gas by a solid (Kelley, 1948). The Freundlich equation is as follows:

$$M = Kc^{1/n}$$

where: M = weight of cations adsorbed from a solution at equilibrium with a known weight of exchange material,

K and n = constants, and

c = cations remaining in solution.

The simplification made in the computational form presented previously is to assume the constant, n, and thus the exponent, 1/n, equals unity.

MODEL PRESENTATION

By assuming no effects due to dispersion, diffusion, and convention, Hajek (1969) developed the following formula to predict ion migration velocity:

$$V_i = \frac{V}{1 + \frac{Bd \cdot Kd}{n}}$$

where: V_i = ion velocity,

V = seepage velocity,

Kd = distribution coefficient,

Bd = bulk density,

and n = volumetric moisture content.

Routson (1969) describes a special solution to a partial differential solute transport equation developed by Hougen and Marshall (1947). This solution takes the following form:

$$C/C_o = \tfrac{1}{2}\left(1 - \mathrm{erf}\left(\frac{X - Vx \cdot t/a}{2/Dm \cdot t/a}\right)\right)$$

where $a = 1 + \frac{Bd \cdot Kd}{n}$

C = effluent concentration of solute,

C_o = influent concentration of solute,

n = pore fraction of exchanger,

Kd = equilibrium distribution coefficient,

Dm = dispersion coefficient,

Vx = average solution velocity,

x = distance from influent site,

t = elapsed time measured from initial disposal,

and $\mathrm{erf}(x)$ = error function of $x = \frac{2}{\pi} \int_o^x e^{-t^2}\, dt.$

This model assumes that diffusion and hydrodynamic dispersion can be accounted for in a single dispersion coefficient. It also has limitations imposed by the assumptions of constant porosity, distribution coefficient, permeability and flow rate. By making rather detailed field and laboratory tests, good estimates of Kd, porosity, permeability, and seepage velocity can be obtained, and good approximations of ion migration can be made.

PROPOSED OPERATIONAL MONITORING PROGRAMS

Conoco has monitored both water levels and quality in the permit area wells since the fall of 1977. A partial record of verifiable data was present to the DEQ in Conoco's June, 1979 Mine Permit Application. Additional informationis also presented in Section 3.6.2.

PRIVATE WELLS

Pine Tree Spring (1-30) and six private wells will be monitored: P'-9, P'11, P'-8, P'26, T-1 and P'-36 (Figure 3.2). Pine Tree Spring was included with these wells because it receives water from groundwater. Continuous discharge of Pine Tree Spring will be measured with a recorder.

PROJECT MONITORING WELLS

The project monitoring wells (Figure 3.21) consist of wells near the evaporation pond and tailings disposal area (Pit 35N) along with wells throughout the permit area. Wells 22-2, 889, 893, 1808, 1809, 1810 and 1823 will be monitored at the same frequency as the private wells with two exceptions: water levels in Wells 1809 and 1810 will be measured continuously with the water level recorders. Annual samples are proposed for the two wells because the recorder will have to be removed for sampling. The mill water supply wells will be sampled at the pipeline as it enters the mill. If a significant change in water quality occurs each water supply well will be sampled.

GROUNDWATER MONITORING - TAILINGS AREA

Prior to drilling additional monitor wells adjacent to proposed tailings disposal areas i.e., Pit 35N and the evaporation pond, Conoco will determine the best array for monitoring of any potential seepage from the final project tailings management plan in accordance with NRC and DEQ guidelines.

Some of the existing wells may serve as satisfactory monitors for the detection of any possible seepage.

METHODOLOGY

All water sampling will be done in accordance with appropriate EPA, Wyoming DEQ and NRC Guidelines. Whenever possible, water levels will be measured prior to collection of samples.

Tables 4.2.2.1 and 4.2.2.2 present the schedule for monitoring all surface and groundwater sites respectively. Lists A and B of Table 4.2.2.3 present the procedures and parameters to be analyzed.

POST-MINING GROUNDWATER CONDITIONS

Material removed as overburden and interburden will be replaced as described in Section 3.7. No other special measures will be required to reconstruct or restore the aquifer in the mining zone.

After reclamation has been completed, the groundwater will recover and stabilize from the dewatering effects of mining (see Section 4.3). After the recovery and stabilization the groundwater quality and quantity and potentiometric surface will be equivalent to the premining conditions. Although the aquifer that will be disturbed is a confined aquifer, the premining potentiometric head is only a few feet higher than the upper limit of the aquifer.

TABLE 4.2.2.2

OPERATIONAL GROUNDWATER MONITORING SCHEDULE

SITE NAME	SAMPLING FREQUENCY	PARAMETERS TO BE SAMPLED*
	Private Wells	
P'-9	Annual (Fall)	List A, plus W.L. if accessible
	Quarterly	List B, plus W.L. if accessible
P'-11	Annual (Fall)	List A, plus W.L.
	Quarterly	List B, plus W.L. if accessible
P'-8	Annual (Fall)	List A, plus W.L. if accessible
	Quarterly	List B, plus W.L. if accessible
I-30	Annual (Fall)	List A
	Quarterly	List B
	Continuous	Discharge
T-1	Annual (Fall)	List A, plus W.L. if accessible
	Quarterly	List B, plus W.L. if accessible
P'-26	Annual (Fall)	List A, plus W.L. if accessible
	Quarterly	List B, plus W.L.
P'-36	Annual (Fall)	List A, plus W.L. if accessible
	Quarterly	List B, plus W.L. if accessible

TABLE 4.2.2.2

(CONT.)

SITE NAME	LITHOLOGIC UNIT	SAMPLING FREQUENCY	PARAMETERS TO BE SAMPLED*
		Project Monitoring Well	
22-2	70SS	Annual (Fall)	List A, plus W.L.
		Quarterly	List B, plus W.L.
889	70-68SS	Annual (Fall)	List A, plus W.L.
		Quarterly	List B, plus W.L.
893 will be replaced by 890, @ Project yr 5	70SS	Annual (Fall)	List A, plus W.L.
	Quarterly	List B, plus W.L.	
1808	70-68SS	Annual (Fall)	List A, plus W.L.
		Quarterly	List B, plus W.L.
1809	70SS	Annual (Fall)	List A, plus W.L.
		Continuous	W.L.
1810	70SS	Annual (Fall)	List A
		Continuous	W.L.
1823 will be replaced Project yr. 7 by a well near 1810)	68SS	Annual (Fall)	List A, plus W.L.
		Quarterly	List B, plus W.L.
Mill Water Supply	50-40 Roland Coal	Annual (Fall)	List A, plus pumping W.L. for each mill supply well
		Quarterly	List B, plus pumping W.L. for each mill supply well

*List A and List B are given in Table 6-3.
SS = Sandstone

TABLE 4.2.2.3

LIST A
COMPLETE LIST

Bottle A Sample* No preservative	Bottle B Sample* HNO_3 Preservative	Bottle C Sample* H_2SO_4 Preservative	Bottle D Sample No Preservative	Field Measurements
Total Dissolved Solids, TDS	Aluminum, Al	Ammonia, NH_3 (as N)	Total Suspended Solids, TSS (only for surface water)	pH
Boron, B	Arsenic, As	Nitrate, NO_3 (as N)		Temperature
Fluoride, F	Barium, Ba			Conductivity
Potassium, K	Cadmium, Cd			Dissolved Oxygen, DO (only for surface water)
Calcium, Ca	Chromium, Cr			Stage (only for surface water)
Chloride, Cl	Copper, Cu			
Sodium, Na	Iron, Fe			
Magnesium, Mg	Lead, Pb			
Sulfate, SO_4	Manganese, Mn			
Carbonate, CO_3	Mercury, Hg			
Bicarbonate, HCO_3	Nickel, Ni			
pH	Selenium, Se			
	Silver, Ag			
	Zinc, Zn			
	Vanadium, V			
	Molybdenum, Mo			

NOTES: *Samples filtered in field, before adding preservative.

Groundwater samples will be pumped samples, taken after at least two volumes of casing have been pumped. For very low producing wells bail dry, then sample recovery water.

TABLE 4.2.2.3

(CONT.)

LIST B
MODIFIED LIST

Bottle A Sample* No Preservative	Bottle B Sample* HNO_3 Preservative	Bottle D Sample* No Preservative	Field Measurements
Cl	Cadmium, Cd	Total Suspended Solids, TSS (only for surface water)	pH
SO_4	Lead, Pb		Temperature
			Bicarbonate, HCO_3
			Carbonate, CO_3
			Conductivity
			Dissolved Oxygen, DO (only for surface water)
			Stage (only for surface water)

NOTES: *Samples filtered in field, before adding preservative.

Groundwater samples can be bailed, if conductivity of the water is similar to pump sample.

4.3.3 WATER

This section contains an assessment of the direct effects of mine operations on area surface and groundwaters.

Several retention dams on the project site will reduce the area draining to Ninemile Creek. Section 4.3.3.1 discusses the area reduction for each of the project structures.

Groundwater impacts are discussed in Section 4.3.3.2. These include effects of mine dewatering, mill water supply, and seepage from the evaporation pond and Pit 35N tailings disposal sites.

4.3.3.1 SURFACE WATER

MINE AREA

The main change in the surface water system from the Sand Rock project will be the small reduction in the contributing drainage area to Ninemile Creek. The drainage of Upper Wash No. 2 (see Figures 2.7-5 and 2.7-6 for drainage and Figure 2.1-2 for dam locations) will be cut off by Dam 2 during the life of the project. This area is only 4.9 square kilometers (1.9 square miles), which is only 1.5 per cent of the drainage area of Ninemile Creek. Dam 2 will be removed during final reclamation with very little change in the drainage of Upper Wash No. 2.

Dam No. 2 has been designed to contain two 100-year storms and prevent surface runoff from entering Pit 35N. Surface runoff entering Dam No. 2 can be used in project operations but it is anticipated that the reservoir will be dry for intermittent periods of time.

A small dam will be constructed in Wash No. 2 just above Pit 35N to contain any runoff from the area between Dam No. 2 and Pit 35N.

The mining of pit 35S will reduce the drainage area to the Lower Wash No. 2. The total drainage area to the Lower Wash No. 2 is 2.5 square kilometers (0.95 square miles) while the crest area of Pit 35S is 154,000 square meters (0.06 square miles.)

The mining of Pit 34 will reduce the drainage area of Wash No. 1. The surface area at the crest of pit 34 is 205,000 square meters (50.7 acres) which is only 4.7 percent of the drainage area to Wash No.1. The disturbance of the surface, which is mainly caused by the overburden dumps, will increase the sediment load in surface runoff. Dam 2 will retain runoff from the mill and most of the northern overburden damp while runoff from the southern overburden damp area will flow to Dam 1A or 1B for settling. Dams 1A and 1B will be designed to retain a 10-year flood. The main impact expected to surface water is from the small reduction in drainage area to Ninemile Creek. There are currently four dams constructed in Wash No. 2 and two dams in Wash No. 1 which prohibit most of the runoff from entering Ninemile Creek. These existing dams have the capacity to hold all but major runoff events. The water within these impoundments is used for local stock and wildlife watering. The maximum reduction of drainage area to Ninemile Creek will be when all three pits are in operation. A total drainage of 9.3 square kilometers (3.6 square miles) will be blocked from flowing to Ninemile Creek. This is only 5.7 percent of the total drainage area of Ninemile Creek and approximately 14 percent of the drainage above the only two surface water rights (State Engineer Water Permit Nos. 3308 and 14212) downstream of the mine on Ninemile Creek (see Figure 2.2-1.)

EVAPORATION POND AREA

The evaporation pond dam has been designed to have a 1.2 meter (4 feet) freeboard following the runoff from the probable maximum flood series. Therefore, the evaporation pond should not discharge any water from any surface runoff event. The probable maximum thunderstorm for a one-hour duration is 30 centimeters (12 inches), while the six-hour storm is estimated to be 1.36 times this value. The 100-year, six-hour precipitation event was determined to be 8.1

centimeters (3.2 inches) from the NOAA Atlas 2. The probable maximum precipitation (PMP) series is 140 percent of the probable maximum precipitation plus the 100-year rainfall. This value is 66 centimeters (26 inches) for the Sand Rock mill area. The probable maximum flood series was computed from the precipitation quantities in the order of 40 percent of PMP, the PMP event, and the 100-year precipitation event. The following equation was used to calculate the runoff for the PMP series:

$$R = (P-02S)^2/(P+0.8S)$$

where:

R = runoff, in inches

P = precipitation, in inches

S = 4.28 for the normal antecedent moisture conditions, in inches (CN = 70)

= 1.76 for wet antecedent moisture conditions, in inches (CN-85)

The calculated runoff into the evaporation pond from the probably maximum flood series is listed in the following table:

Precipitation	SCS Curve Number		Runoff
16.5 cm (6.5 in.)	70		8.1 cm (3.2 in.)
41 cm (16.1 in.)	85		36.6 cm (14.4 in.)
8 cm (3.2 in.)	85		4.6 cm (1.8 in.)
		Total =	49.3 cm (19.4 in.)

The amount of runoff for the probable maximum flood series is 49.3 centimeters (19.4 inches) or 0.94 million cubic meters (770 AC-FT) for the evaporation pond drainage area.

Drainage from the Upper Wash No. 4 will be retained within the evaporation pond. Therefore, surface water downstream of the evaporation pond should not be impacted except for the small reduction in drainage area. The drainage area of Upper Wash No. 4, which will be blocked by the evaporation pond, is 1.8 square kilometers (0.69 square miles). This drainage is only 1 percent of the Ninemile drainage area and currently has one dam which retains all but the major runoff events. Reclamation of the evaporation pond will restore the entire drainage of Upper Wash No. 4 to the Ninemile Creek drainage.

The disposal of tailings in Pit 35N will not increase the amount of drainage area lost beyond that blocked during mining.

4.3.3.2 GROUNDWATER

MINE DEWATERING IMPACTS

Mine dewatering is estimated to last seven, four and three years respectively for Pits 35N, 34 and 35S. Dewatering of Pit 35N will begin during year 1 when overburden stripping reaches the top of the ore zone in Cut 35N-1 (see Section 3.7). Water in the 70 sand aquifer is espected to be encountered in Pit 34 six years after dewatering starts in Pit 35N. Pumpage from both Pits 35N and 34 should overlap for one year. Groundwater is expected to be encountered in Pit 35S nine years after dewatering starts in Pit 35N. Dewatering in Pits 34 and 35S should also overlap for one year.

The aquifer properties in the area of each pit presented in Section 3.6 were used to predict the mine inflow. Table 4.3.3.1 shows the parameters used for the mine dewatering calculations for each pit.

Streltsova type curves best define the drawdown curves from the pump tests of the 70 sand aquifer and should govern the flow of water into the pits. All of the Streltsova type curves converge on the Theis curve with time,and for large inflow radii as the pit they converge within a few days. Therefore, Theis' flow equation will yield the same values as Streltsova's after a few days when the specific yield is used as the storage value in Theis' equation. The constant head form of Theis' equation was used to estimate the inflow rate to the open pits. The constant head was varied in steps of 1.5 meters/month (5 feet/month) to approximate the lowering of the pit bottom with time. Maximum constant heads of 24 meters (80 feet), 9.1 meters (30 feet) and 3.0 meters (10 feet) were used for Pits 35N, 34 and 35S, respectively. The original saturated thickness of the 70 sand aquifer in the areas of Pits 35N, 34 and 34S are 24 (80), 18 (60) and 12 meters (40 feet) respectively. The maximum constant head in Pits 34 and 35S are considerably less than the original saturated thickness because the pit dewatering of Pit 35N reduces the saturation thickness significantly before mining these two pits.

TABLE 4.3.3.1

PARAMETERS USED TO PREDICT MINE DRAINAGE RATES

	Pit					
Parameter	**35N**		**34**		**35S**	
Project Year Dewatering Starts	-1		6		9	
Length of Dewatering, Years	7		4		3	
Transmissivity, square meters/year (gal/day/ft)	4,100	(900)	2,300	(500)	17,000	(3,800)
Specific Yield	0.010		0.015		0.010	
Maximum Constant Head meters (feet)	24	(80)	9.1	(30)	3.0	(10)
Rate of Penetration of Mining meters/month (ft/month)	1.5	(5)	1.5	(5)	1.5	(5)
Pit Radius, meters (feet)	150	(500)	150	(500)	150	(500)

The aquifer properties presented above were used to obtain the estimated inflow rates with time since pumpage starts in Pit 35N. Figure 4.3-1 presents the cumulative mine drainage from all three pits with time.

The inflow rate to Pit 35N will start at a low rate and build to a maximum inflow rate 600 1/m (160 gpm) after approximately 500 days. A gradual drop in the inflow rate should then be observed until pumpage starts in Pit 34. The inflow rate will increase to a maximum of 720 1/m (190 gpm) (bottom of pit) when Pit 34 reaches full penetration. A gradual decrease in the inflow rate will then occur until pumpage stops in Pit 35N. An average inflow rate of 150 1/m (40 gpm) should occur during the two years when Pit 34 is the only pit being dewatered. A maximum of 500 1/m (130 gpm) is expected after the start of mine dewatering in Pit 35S. Inflow should be in the range of 200 1/m (50 gpm) at the end of mining. This analysis produced average inflow rates of 510, 170, and 250 1/m (135, 45, and 65 gpm) for Pits 35N, 34 and 35S respectively. The average inflow rates for each pit were used to estimate the drawdown which will occur from the dewatering. The drawdowns were cumulated for periods when more than one pit is in operation. The recovery form of Theis' equation was used to simulate the recharge after dewatering stopped at the end of mining. A drawdown plot was developed for project year 7, the point in time where Pit 35N has been pumped for seven years and Pit 34 has been pumped for one year (Figure 4.3-2.

The largest impact on the 70 sand aquifer should occur at this time, which is roughly at the end of the ninth year of the project. Figure 4.3-2 gives the estimated drawdown in the 70 sand aquifer after seven and one years of pumping Pits 35N and 34 at 510 1/min (135 gpm) and 170 1/min (45 gpm) respectively. A significant drawdown cone has developed around Pits 35N and 34 for this period of pumping. Most of section 35 and approximately one-half of

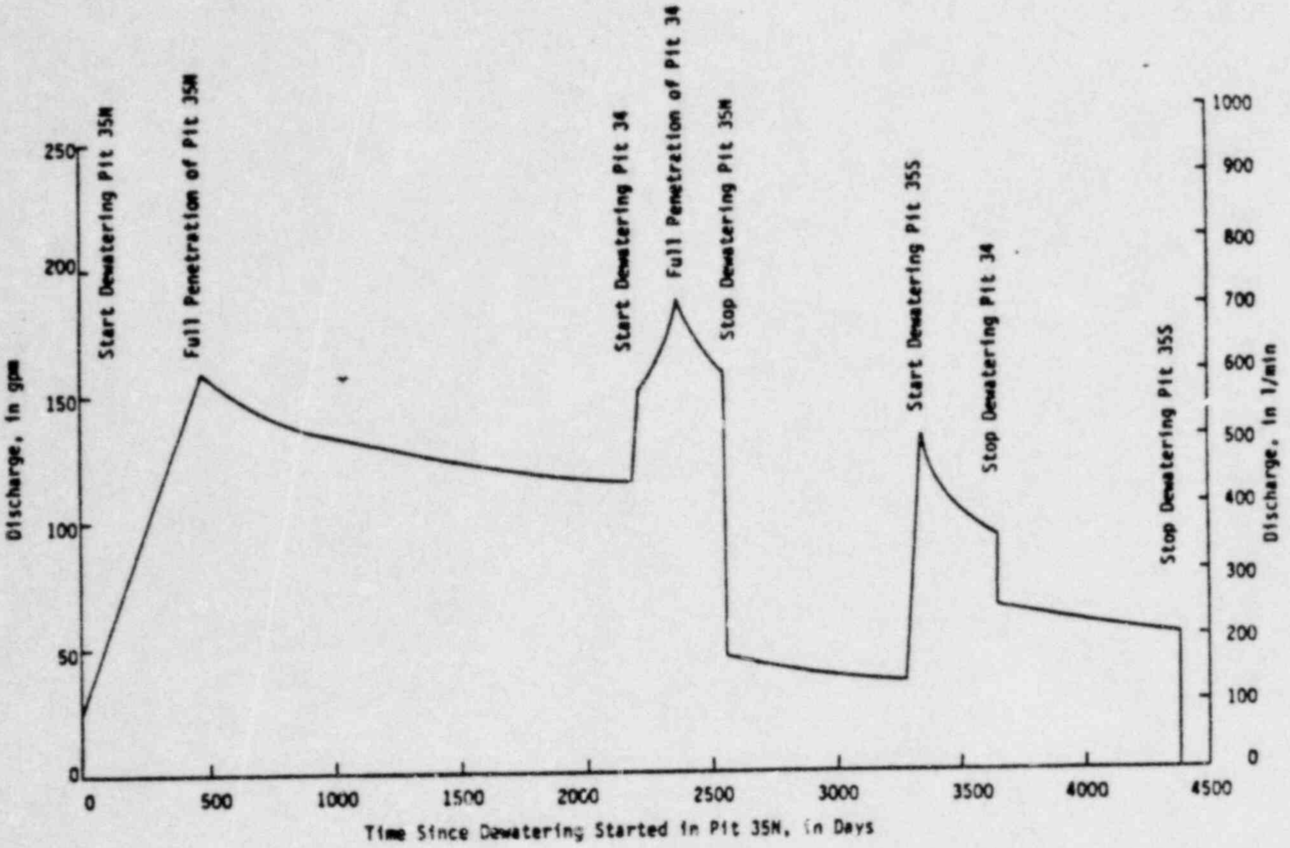

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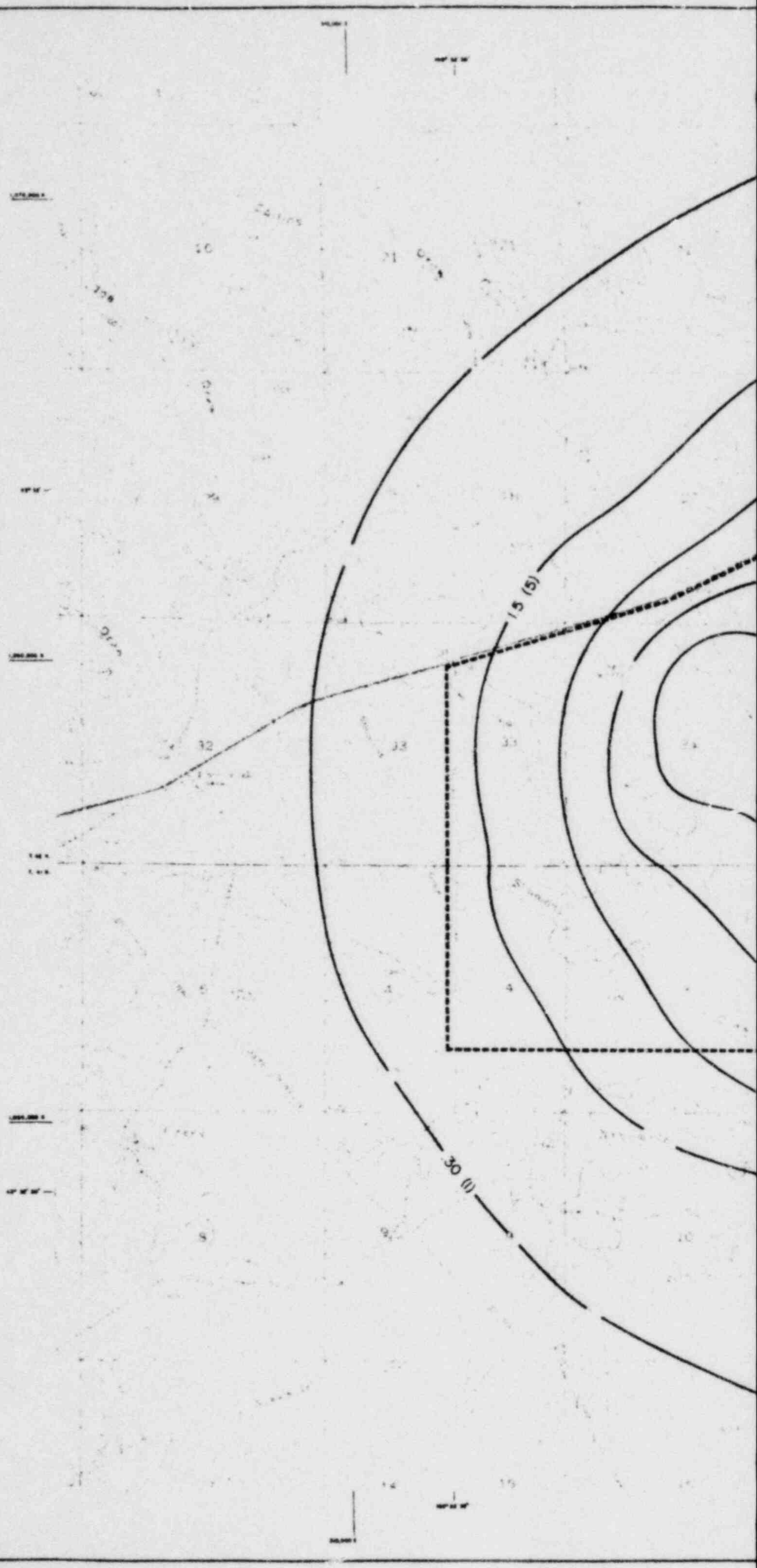
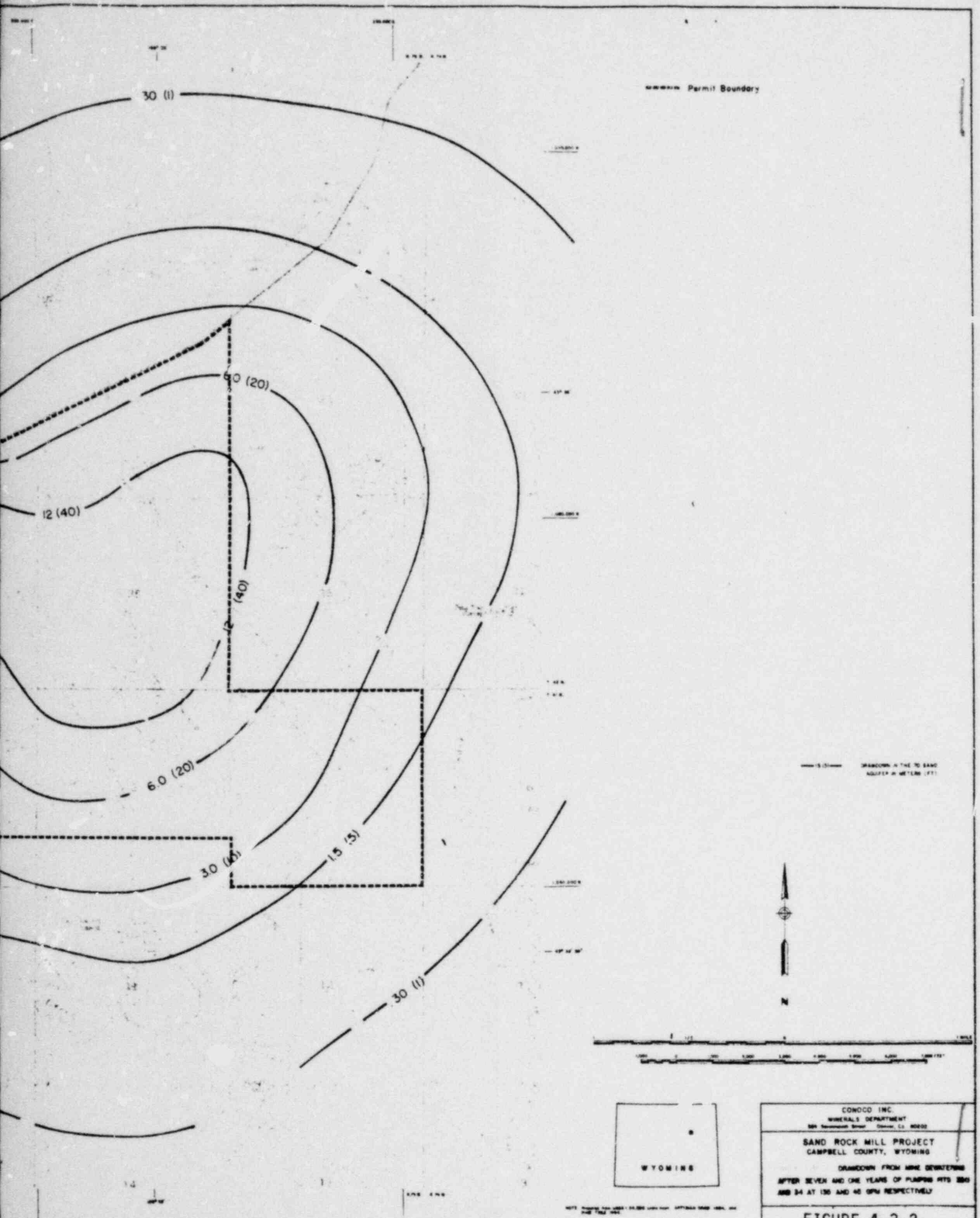
FIGURE 4.3-1

ESTIMATED MINE DRAINAGE
FOR PITS 35N, 34 AND 35S


15 (5)
30 (1)
32
33
4
8
9
10



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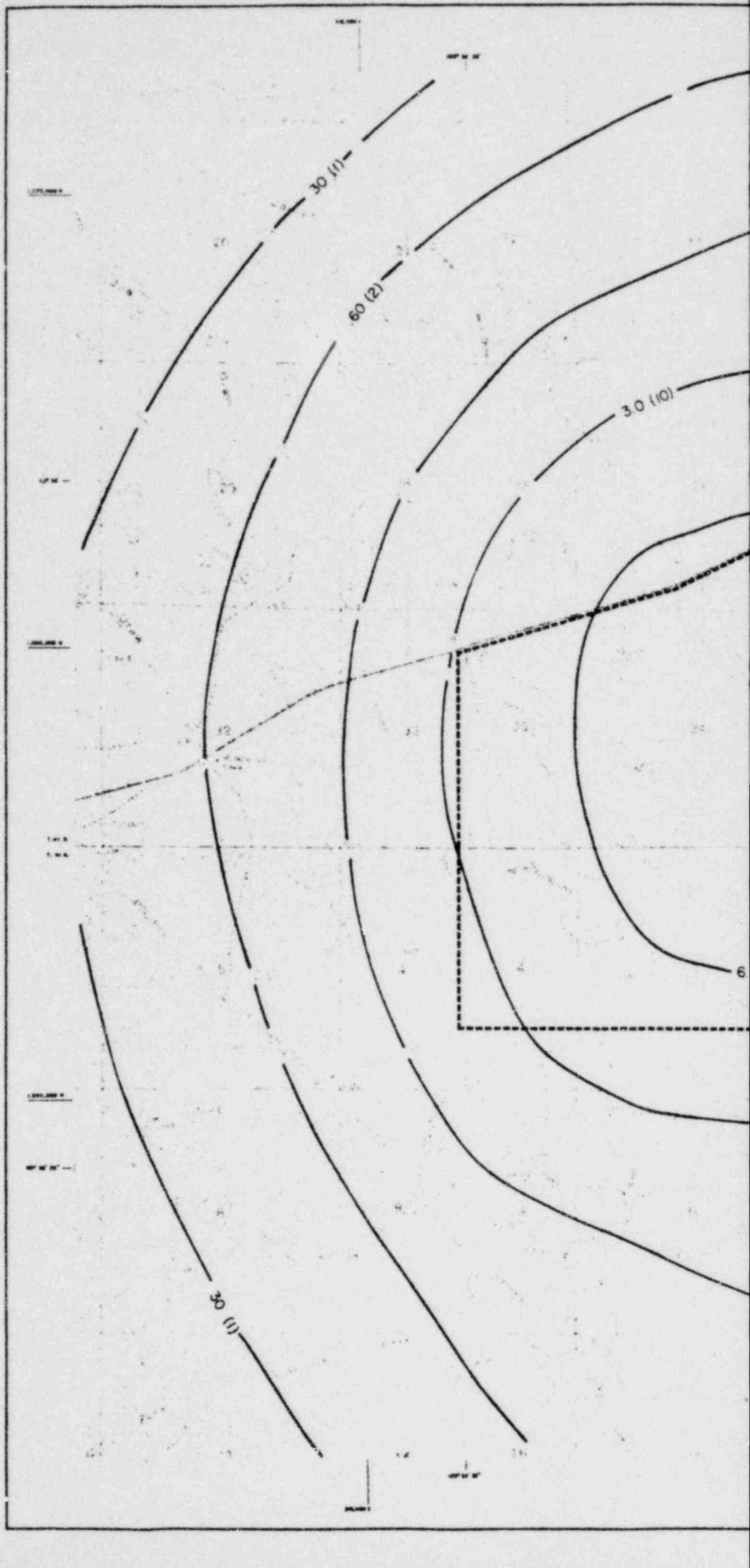
DRAWDOWN FROM MINE DEWATERING
AFTER SEVEN AND ONE YEARS OF PUMPING PITS 33 AND 34 AT 130 AND 45 GPM RESPECTIVELY

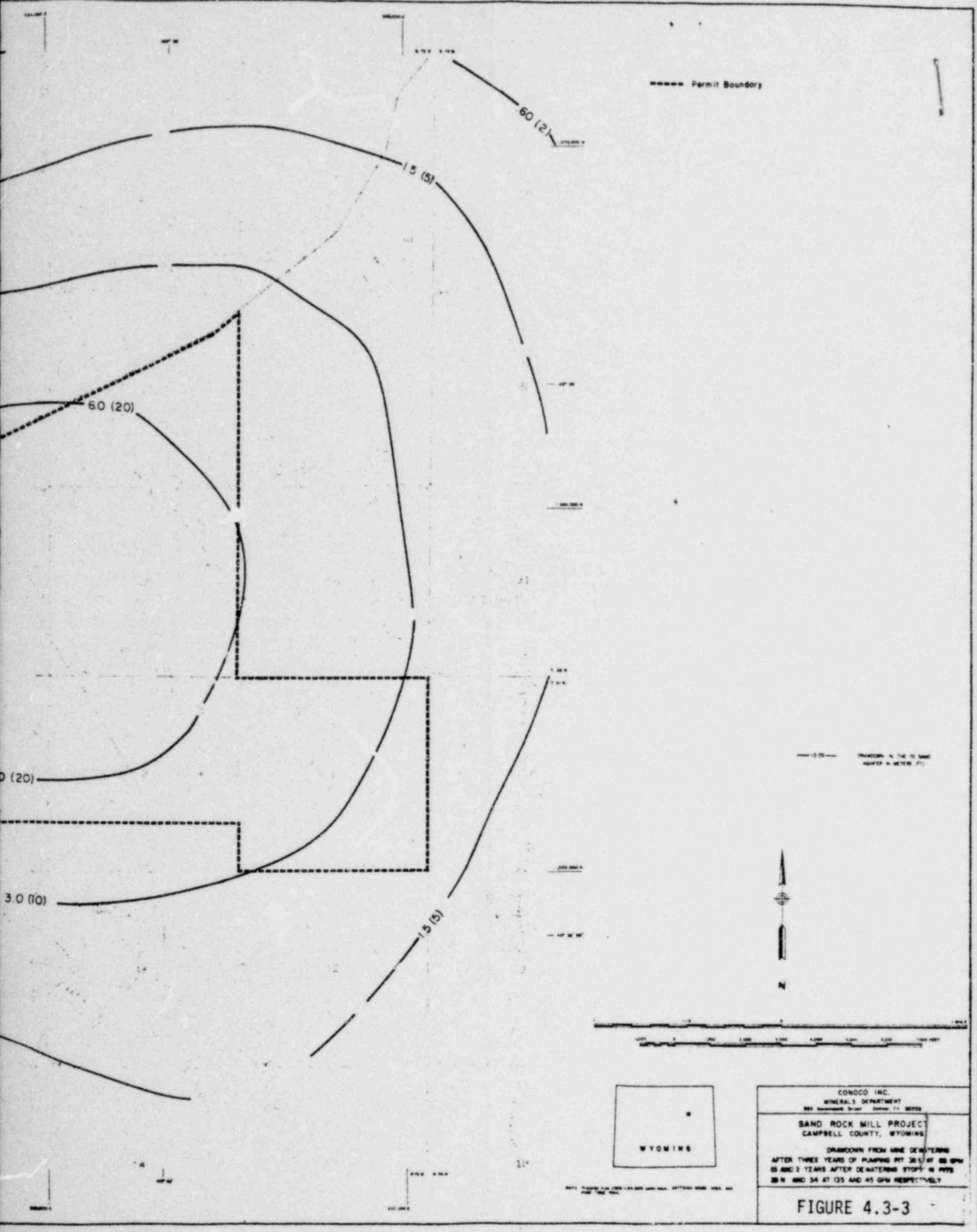
FIGURE 4.3-2

section 34 42N-75W have drawdown greater than 12 meters (40 feet). The 0.30 meter (1.0 foot) contour extends approximately 3,660 meters (12,000 feet) from the edge of the pit. This map presents the largest drawdowns in the 70 sands which will occur during the project life, the time at the end of pumping Pit 35N.

The drawdown cone will extend farther with continued pumping. Figure 4.3-3 presents the estimated drawdowns for the 70 sand aquifer at the end of mine dewatering for the project. Drawdowns inside sections 34 and 35 are predicted to be greater than 6 meters (20 feet) at the end of mining. A significant recovery will have occurred in this area due to the lower discharge rates during the last four years of pumping. The 0.3 meter (1.0 foot) drawdown contour extends to approximately 5,180 meters (17,000 feet) from the edges of the pits. The drawdown in the 70 aquifer is shown in Figure 4.3-4 for nine years after pumpage stops. A significant cone will exist in sections 34 and 35 with an area of several sections inside the 1.5 meters (5 feet) contour. Wells inside the 1.5 meters (5 feet) contour would probably observe some decline in the maximum potential yield while the maximum potential yield of the aquifer should not be influenced outside this contour.

Pine Tree Spring is the only known spring in the cone of drawdown. The spring is located at an elevation of 1598 meters (5244 feet). The top of the 70 sand near the spring is estimated to be at an elevation of 1,591 meters (5,220 feet) (see Figure 4-1 in the report by Hydro-Engineering, 1980), and the piezometric surface of the 70 sand is estimated to be 1,579 meters (5,180 feet) (Figure 4-7, Hydro) above mean sea level. This information indicates that Pine Tree Spring is probably being derived from a stratigraphically higher sand. The head difference in the 70 sand aquifer and the sand which yields the water to the spring indicates that these two systems are not readily connected hydrologically.


30 (1)
60 (2)
3.0 (10)
6
30 (1)



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[illegible]

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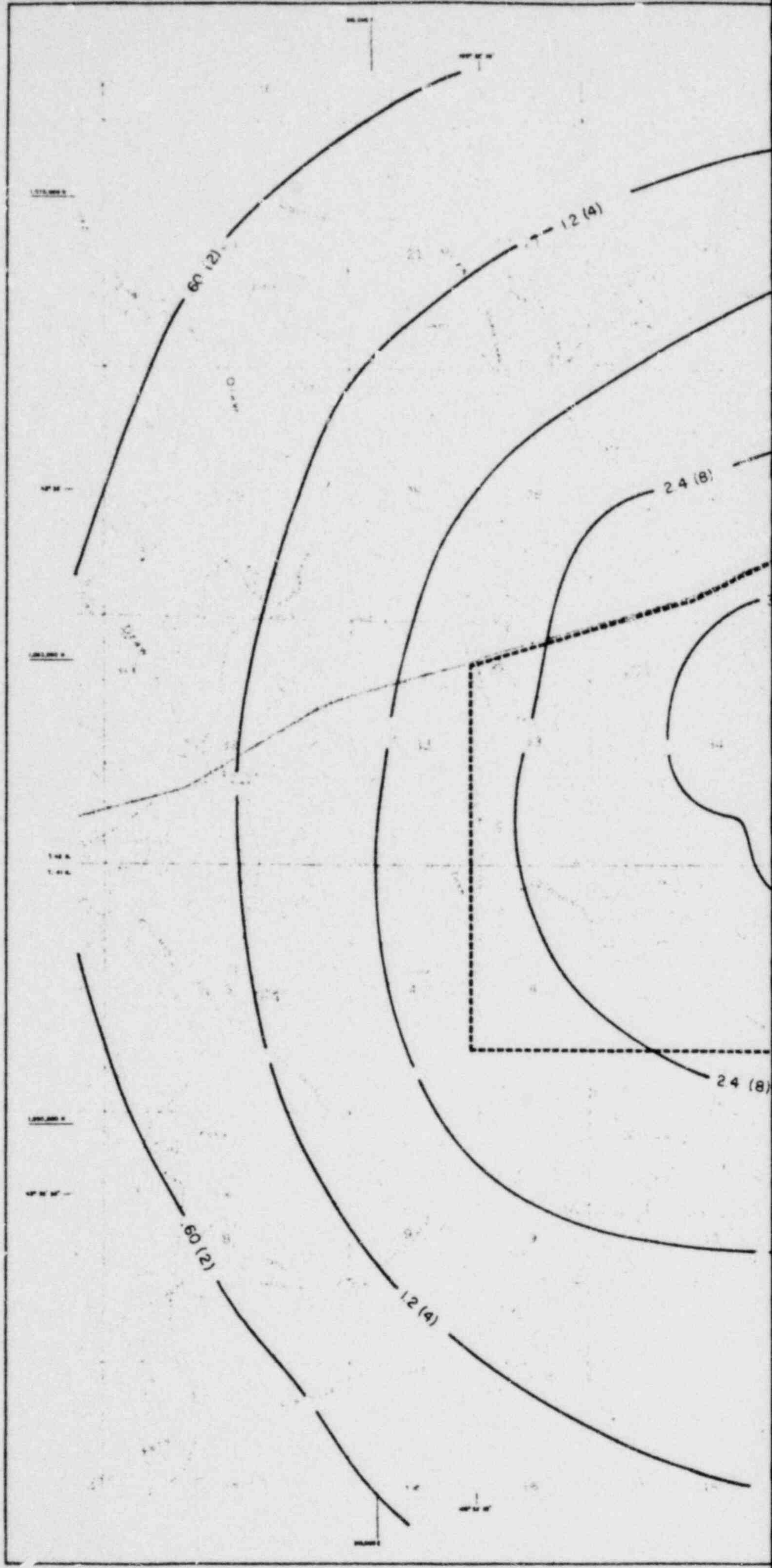
DRAWDOWN FROM MINE DEWATERING AFTER THREE YEARS OF PUMPING PIT 36 S AT [illegible] GPM [illegible] AND 2 YEARS AFTER DEWATERING STOPS IN PITS 35 N AND 34 AT 135 AND 45 GPM RESPECTIVELY

FIGURE 4.3-3


60 (2)
1.2 (4)
2.4 (8)
.60 (2)
1.2 (4)
2.4 (8)

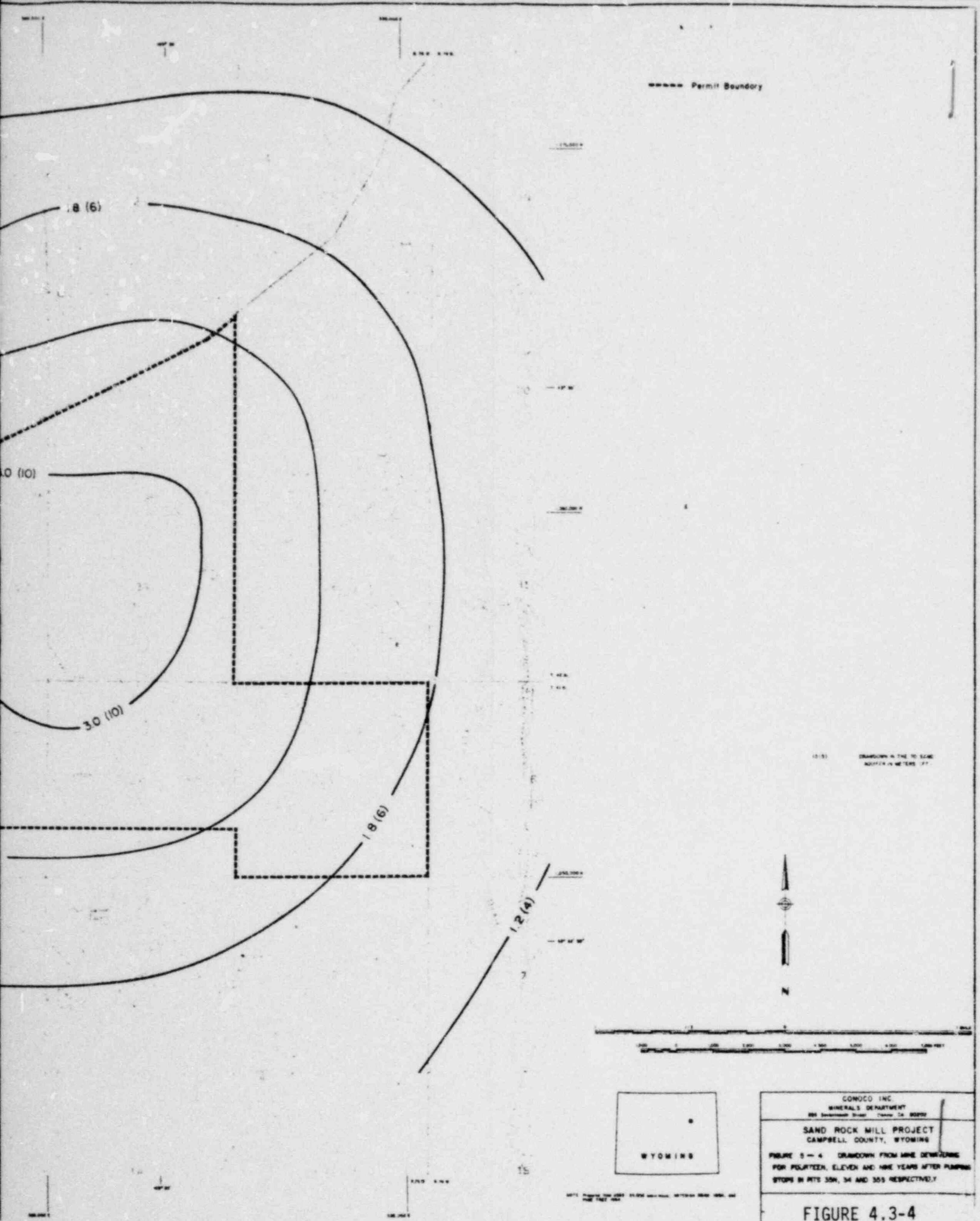


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FIGURE 5 — 4 DRAWDOWN FROM MINE DEWATERING FOR FOURTEEN, ELEVEN AND NINE YEARS AFTER PUMPING STOPS IN PITS 35N, 34 AND 35S RESPECTIVELY

FIGURE 4.3-4

The impact on the 68 sand from mine dewatering is expected to be small. Observation of Well 887 (a 68 sand well) during the 70 sand pump test of Well 1 indicated connection between the two sands. Water-level measurements made in Well 1816 (a 70 sand well) during the pumping of Well 1823 (a 68 sand well) indicated no significant hydrologic connection between these two sands in this area. It is likely that the seal between the two sands in Well 887 is not adequate.

A difference in the water-level elevations of Wells 1823 and 1816 is approximately 14 meters (45 feet), but very little head difference exists between Wells 887 and 1. Even if the 68 and 70 sands are hydrologically connected, pumping the 70 sand aquifer should cause only small drawdowns in the 68 sand aquifer because of low transmissivities found in the 68 sand.

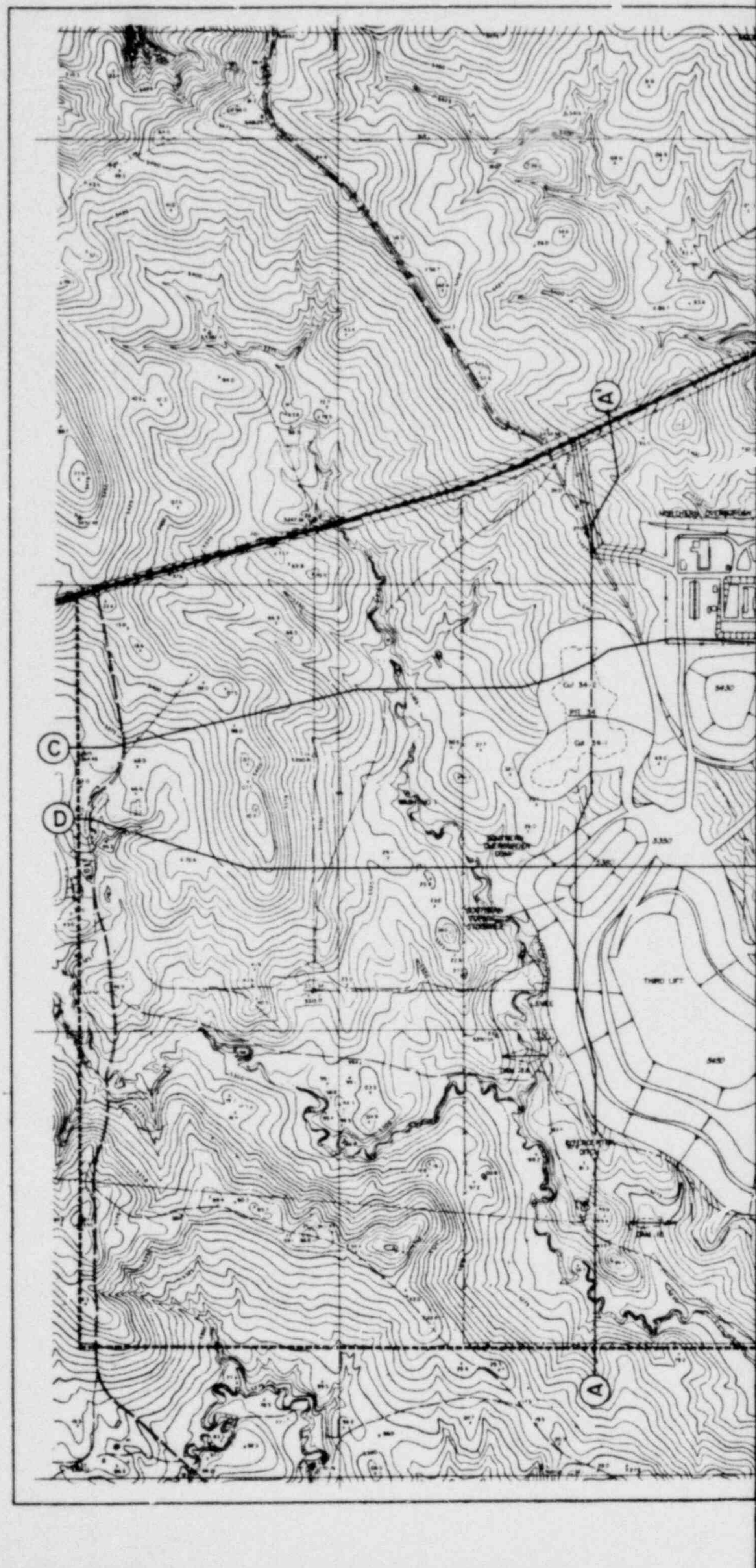
5.1.2 MILL WATER SUPPLY IMPACTS

A groundwater supply of 3,800 l/m (1,000 gpm) for the initial two years and 1,900 l/min (500 gpm) for the remaining 10 years for the mill is needed. The 50-40 sands (see Section 3.6) and the Roland coal are proposed to be the source for this water supply.

Two wells were drilled to test potential groundwater supplies (Figure 3.21). Well 1821 was perforated in the Roland coal, and Well 1822 was completed in the 50-40 sands. A pump test was conducted on each of these wells to determine the quantity and quality of water these aquifers will yield. The water quality from both groundwater sources is generally good. Well 1821 (Roland coal) should be able to be pumped at 275 gpm continuously for 13 years if there is no well interference, while Well 1822 would produce 120 gpm under these conditions.

A combination of the Roland coal aquifer and all sand aquifers above the coal, excluding the 70 sands, is recommended as the source of supply. The water quality from the sands and coal is compatible. Piezometric heads in the sands and coal are nearly equal with greater heads in the upper stratigraphic units. Wells completed in both units should produce approximately 570 l/min (150 gpm) with consideration of well interference. Eight potential well locations are shown in Figure 2.1-2 for the mill work supply wells. At least four of these wells will be needed to supply the desired quantity of water.

Predictions of the impact on the 50-40 sands and Roland coal aquifers were made using the four northern wells at an average rate of 500 l/min (145 gpm). Figure 4.3-5 shows the drawdown at the end of 12 years of continuous pumping these four wells at a total discharge of 2,200 l/min (580 gpm). Transmissivities in the range of 6800 m^2/year (1500 gal/day/ft) and 3,650 m^2/yr (800 gl/day/ft) were determined for the Roland coal and 50-40 sands respectively. A combined transmissivity of 11,000 m^2/yr (2,500gal/day/ft) was used to simulate the impacts from the water supply pumping. Predicted impacts would be less by separating the pumpage rates between the two aquifer systems and determining impacts separately. A storage value of 0.01 was used for the simulation of the drawdown. The storage coefficient of these two aquifers is probably in the range of 10^{-3} to 10^{-4} but drawdown in the 50-40 sands will quickly change this system to unconfined conditions. The storage value will then probably be in the range of 0.05 to 0.1. The predicted drawdown using a 0.01 storage value after 12 years of pumping at an average rate of 580 gpm indicates that the cone extends to 12,000 meters (40,000 feet). Considerable drawdown will have to occur in these two aquifers to impact their transmissivity because each aquifer is under an artesian head of several hundred feet. The 50 sands have approximately 85 meters (280 feet)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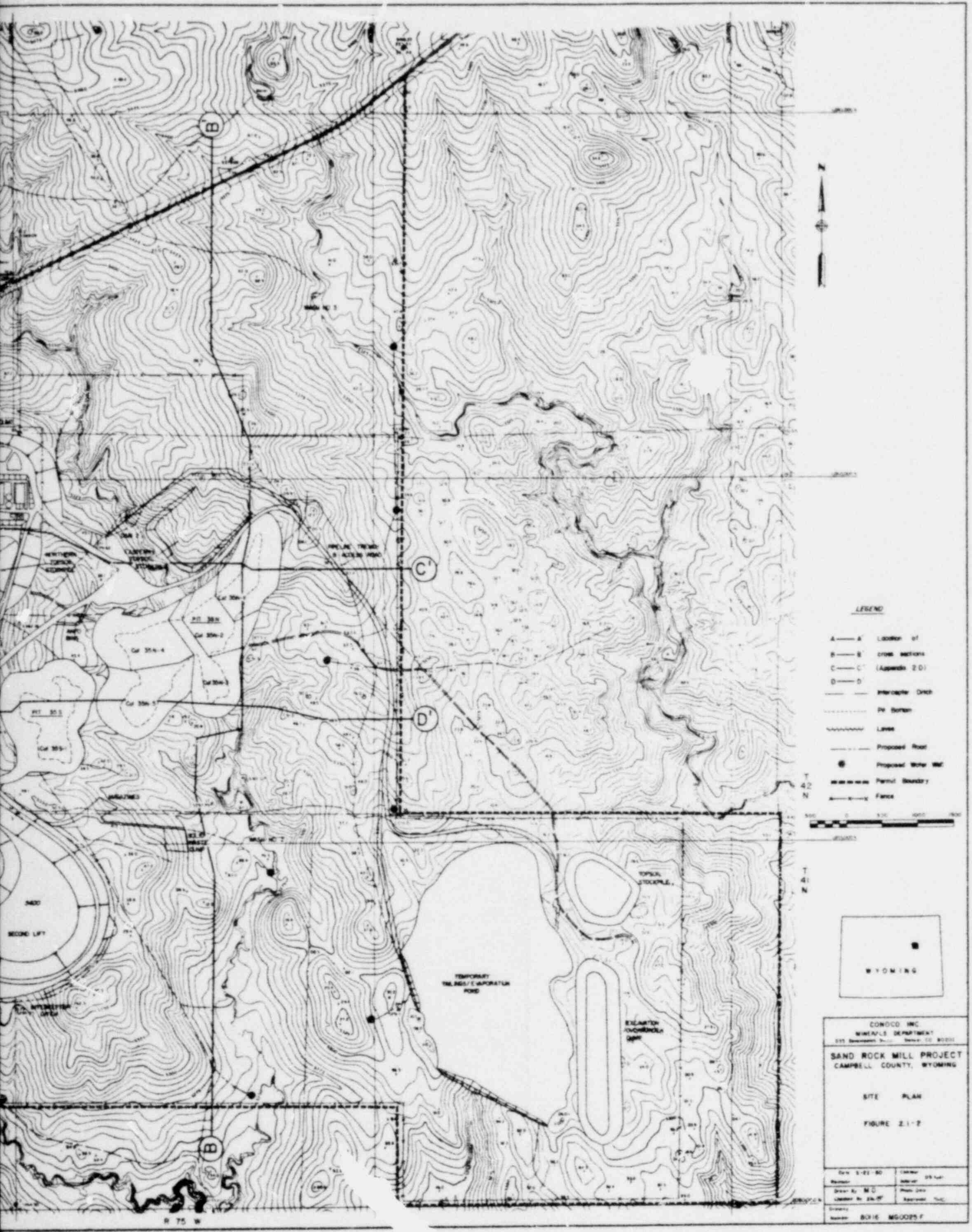

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SITE PLAN

FIGURE 2.1-7

Date 5-21-80
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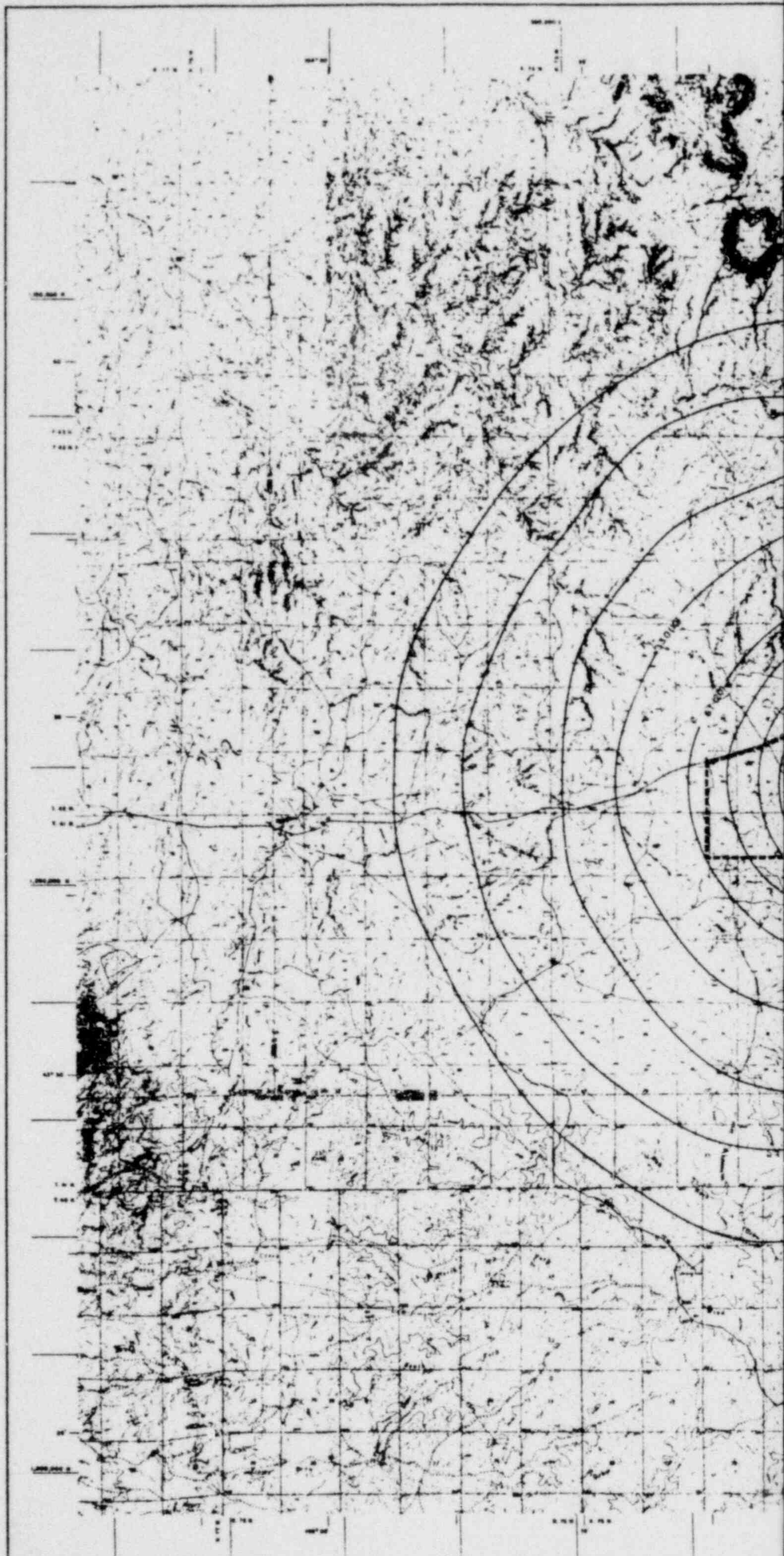
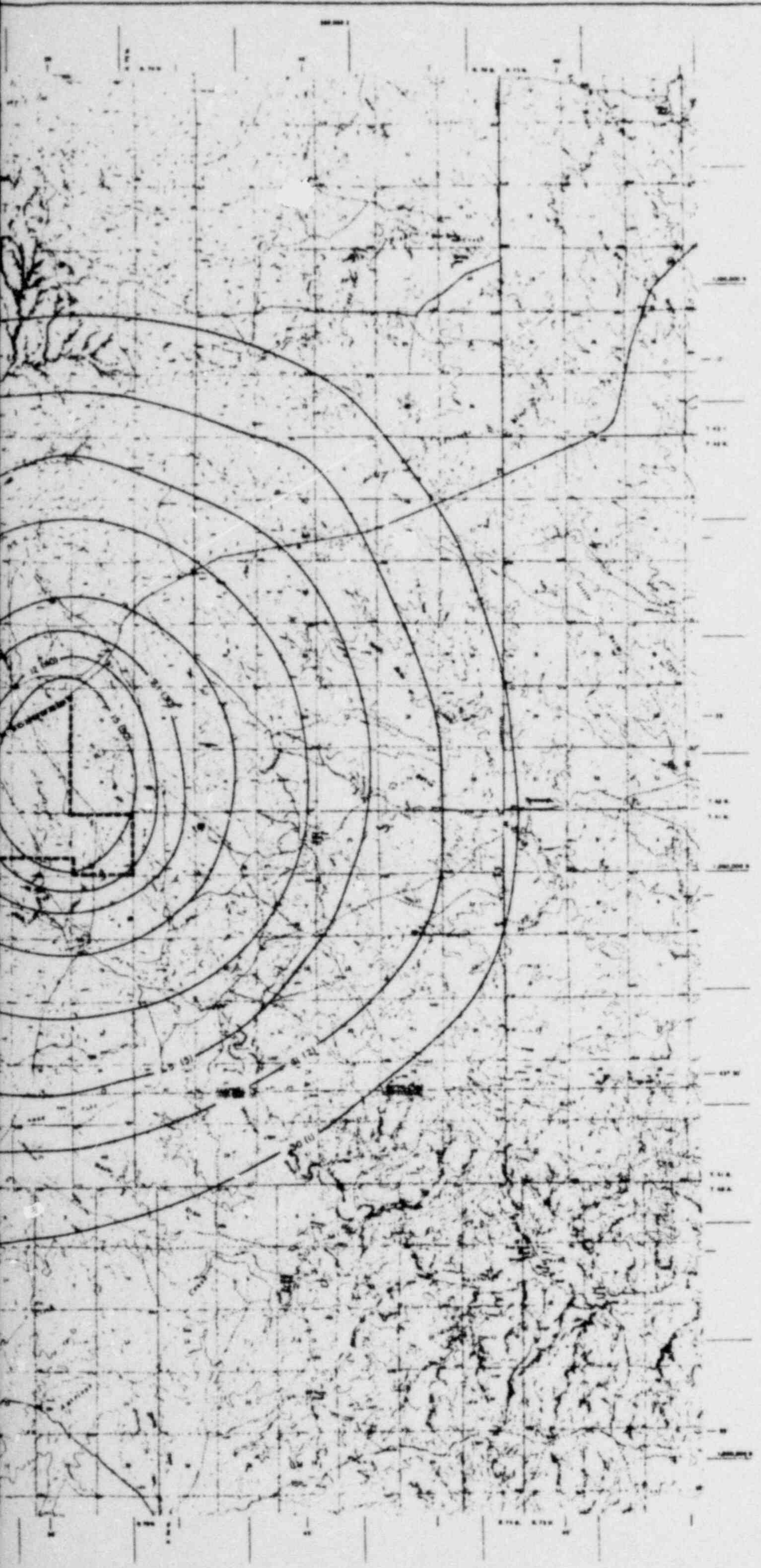
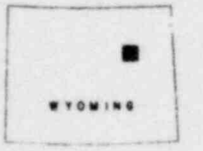
Drawing Number 8016 MG0025 F







NOTE Prepared from USGS Topographic Maps [illegible]

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DRAWDOWN FROM PUMPING THE MILL SUPPLY WELLS FOR TWELVE YEARS AT AN AVERAGE RATE OF 2200 l/MIN. (580 GPM)

FIGURE 4.3-5

of head above the top of these sands. A drawdown in the range of 15 meters (50 feet) will be required to reduce transmissivity of a well in the 50 sand. Greater drawdowns would be required to reduce the production of water from the Roland coal aquifer. Wells two miles beyond the center of the well field should not be greatly impacted. There are currently no wells in these aquifers in the 2-mile radius (see Figure 3.1).

TAILINGS SEEPAGE

The models presented in Section 4.2.2 were used to estimate seepage and ion migration from the evaporation pond and Pit 35N tailings disposal sites. This section discusses the resulting seepage estimates for the unlined pond and for the lined and drained tailings pit.

SEEPAGE ESTIMATES FOR THE EVAPORATION POND

The evaporation pond area surface is 75 per cent exposed mudstone. In the western 25 per cent of the area the mudstone is covered by a layer of sandstone. (See Figure 2.7-1 for a schematic of the lithologic units.) Seepage predictions were conducted for the evaporation pond with a cutoff trench around the edge of the Upper sandstone. This trench would be filled with a bentonite clay or very low permeability material. Seepage estimates were obtained by applying the entire surface area to the mudstone seepage estimates. This was done because the cutoff trench will force seepage which enters the sandstone to enter the mudstone before it can continue.

Average properties for the materials in the tailings pond area were used to predict the seepage rate through the bottom of the pond. The following properties were used in the equations for Case A (see Section 4.2.2.2) for the seepage into Upper mudstone.

$y = 6.1$ m (20 ft)

$Dl = 3\text{x}10^{-8}$m (10^{-8}ft)

$Dt = 3\text{x}10^{-8}$m (10^{-8}ft)

$Dm = 4.6$ m (15ft)

$Kt = 9.6\text{x}10^{-8}$cm/sec (0.1 ft/yr)

$Kl = 9.6\text{x } 10^{-8}$cm/sec(0.1 ft/yr)

$Km = 9.6\text{x}10^{-6}$cm/sec (10 ft/yr)

$Kmv = 9.6 \times 10^{-6}$ cm/sec (10 ft/yr)

$hd = -4.0$m (-13 ft)

$Hm = 6.1$ m (20 ft)

$R^2 = 3.5 \times 10^5 m^2 (3.8 \times 10^6 ft^2)$

Pond $R^2 = 1.5 \times 10^5 m^2 (1.6 \times 10^6 ft^2)$

$n - \theta i = 0.15$

$m - \theta 5 = 0.15$

The following table summarizes results of the Stage I and Stage II seepage calculations:

Stage I: @ L = 15 ft (distance front below tailings)

q = 33 ft/yr (seepage at end of Stage I)

t = 0.038 yr (time at end of Stage I) (goes directly to Stage III)

SEEPAGE RATE (ft/yr)	STAGE III TIME (yrs)	TIME SINCE START OF SEEPAGE (yrs)	SEEPAGE RATE* (gpm)
0.5	0.018	0.056	36
0.3	0.050	0.088	[illegible]
0.2	0.11	0.15	14
0.1	0.46	0.50	7.1
0.08	0.72	0.76	5.7
0.06	1.31	1.34	4.3
0.05	1.90	1.94	3.6
0.04	3.03	3.07	2.8
0.03	5.54	5.58	2.1
0.02	13.2	13.3	1.4

$$\text{* SEEPAGE RATE (gpm)} = \frac{\text{Seepage rate (ft/yr) Pond Area (ft}^2\text{) (7.48 gal/ft}^3\text{)}}{\text{(365 day/yr) (1440 [illegible]/yr)}}$$

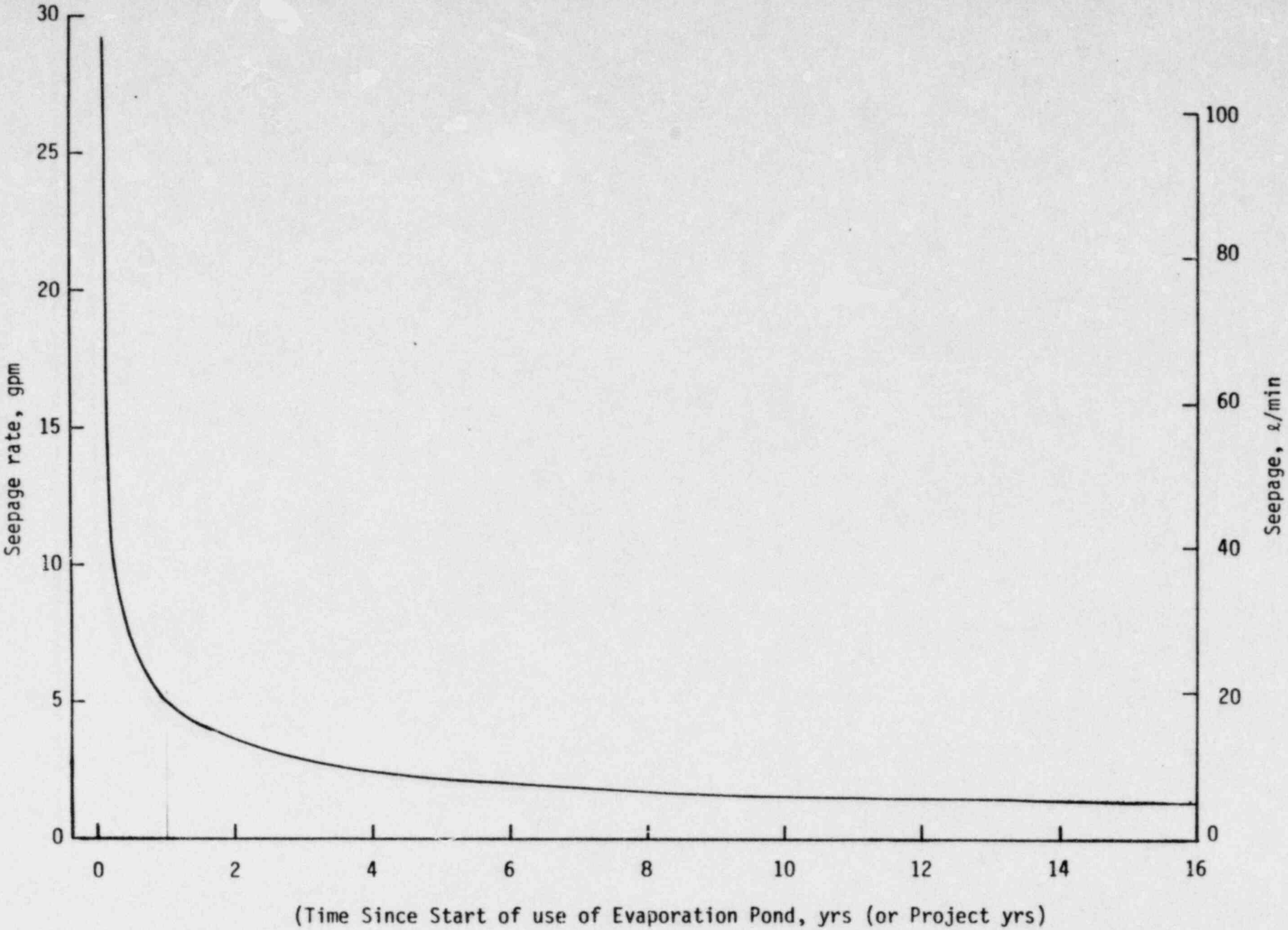
As shown in Figure 4.3-5, the seepage rate from the evaporation pond would be expected to be less than 23 l/min (6 gpm) after one year for the cutoff trench option. Plans call for mine or well water to be stored in the evaporation pond before the start-up of the mill. This practice will enable the early, higher rate of seepage to be mine or well water.

The average seepage rate in the mudstone for the life of the project is predicted to be 0.015 m/yr (0.05 ft/yr). The velocity of the seepage water can be obtained by dividing the effective porosity into the seepage rate. A specific yield of 0.15 has been used for the seepage calculations. This value indicates that the seepage water will move approximately 0.1 m/yr (0.3 ft/yr). A value of 0.05 for the effective porosity will be used for the water velocity and ion migration estimates because it will yield conservative, high movement values. This produces an estimate of 0.3 m/yr (1 ft/yr) for the mudstone in the evaporation pond area. An average of 14 meters (45 feet) of mudstone exists between the evaporation pond and the top of the 70 sand. Approximately 14 meters (45 feet) of unsaturated 70 sand exist in the evaporation pond area also. The permeability of the unsaturated 70 sand is similar to the mudstone, and seepage rates in the unsaturated 70 sand should be close to the rates in the mudstone. A seepage velocity of 0.3 m/yr (1 ft/yr) and 27 meters (90 feet) of material between the pond and saturated 70 sand indicate that it should take 90 years of seepage from the evaporation pond before it reaches this aquifer.

Seepage water from the evaporation pond will carry with it some chemical constituents which may be hazardous to subsequent uses of the 70 sand aquifer. The migration of these contaminants is discussed later in this section.

SEEPAGE ESTIMATES FROM TAILINGS DISPOSAL SITE (PIT 35N)

Seepage can occur through the bottom and pit walls in the tailings disposal site. The model developed by McWhorter and Nelson (1978 and 1979),



(updated 5/81) ESTIMATED SEEPAGE FROM THE EVAPORATION POND WITH CUTOFF TRENCHES IN THE UPPER SANDSTONE

FIGURE 4.3-17

which was used to predict the seepage from the evaporation pond, is also used to estimate the seepage through the bottom of pit 35N. Calculations with and without a compacted liner were conducted to determine the difference in seepage rates. A seepage model developed by McWhorter and Ortiz (see Theory of Pit Wall Seepage Model, Section 4.2.2.2 for a discussion) for seepage into the pit walls was used to predict seepage in the side walls of pit 35N.

The laboratory permeabilities of the recompacted material which will be used to backfill the pit varied from 1.6×10^{-4} for sandstone and 2×10^{-6} cm/sec for the siltstone. An average permeability of 10^{-5} cm/sec was used for the backfill material because the sandstone and siltstone materials will be mixed before backfilling.

Vertical permeabilities of tailings material were determined from laboratory tests which indicated that the average vertical permeability will be in the range of 2×10^{-4} cm/sec (200 ft/yr) (Chen and Associates, 1980). The height of the water surface in the tailings will vary with time as tailings and water are added to the pit. The following equation was used to equate the water balance of the pit and predict the height of the phreatic surface in the tailings.

$$AHSy = Qi\ T - Qs\ T - Qr\ T - AET - Kt\ H\ W\ i\ T$$

where:

H = Average height of water in tailings, in m (ft)

A = Area which tailings is being placed on, in $m^2 (ft^2)$

Sy = Specific yield of the tailings

Qi = Rate of water input to disposal area, in $m^3/yr (ft^3/yr)$

Qs = Rate of water seepage from disposal area, in $m^3/yr (ft^3/yr)$

Qr = Rate of surface water runoff of water from tailings, in m^3/yr (ft^3/yr)

T = Time since start of disposal of tailings in area, in yrs

E = Effective annual evaporation, in m (ft)

K_t = Horizontal permeability of tailings in m/yr (ft/yr)

W = Width of tailings in pit, in m (ft)

i = Gradient of phreatic surface of tailings groundwater, in m/m

The surface area and width of the tailings were varied according to the disposal plan. Values of 0.2, 0.76 m (2.5 ft), 9.7×10^{-4} cm/sec (1000 ft/yr) and 0.04 m/m were used for the specific yield, annual effective evaporation horizontal permeability of the tailings and gradient of the tailings groundwater respectively. A total of 9.9×10^5 m^3/yr (500 gpm) of water will be added with the tailings of which 2.5×10^5 m^3/yr (125 gpm) is expected to be retained in the tailings. The rate of water available to flow in the tailings is 7.5×10^5 m^3/yr (375 gpm). Approximately $9.9 \times 10^4 m^3$/yr (50 gpm) is expected to runoff the tailings surface while less than $2.0 \times 10^4 m^3$/yr (10 gpm) is expected to seep from the pit. The use of the above equation indicates that the phreatic surface in the tailings should stay near the top of the tailings without drains. The head in the tailings was therefore varied as the top of the tailings. Values of -300 cm (-10 ft) and 2 were used for the displacement pressure and the pore-size distribution index, respectively.

These parameters indicated that the material will be saturated behind the wetting front for seepage without a liner. Figure 4.3-6 presents the predicted seepage through the bottom of pit 35N without a liner and without effective drains. These calculations indicate that the seepage rate will be in the range of 300 l/min (80 gpm) shortly after the start of tailings injection. This rate decreases rapidly after the material becomes saturated to less than 40 l/min (10 gpm) after 0.4 years of discharging to pit 35N or at project year 3.4. This rate continues to decrease to below 20 l/min (5 gpm) with only slight increases as the three additional areas of pit 35N are added.

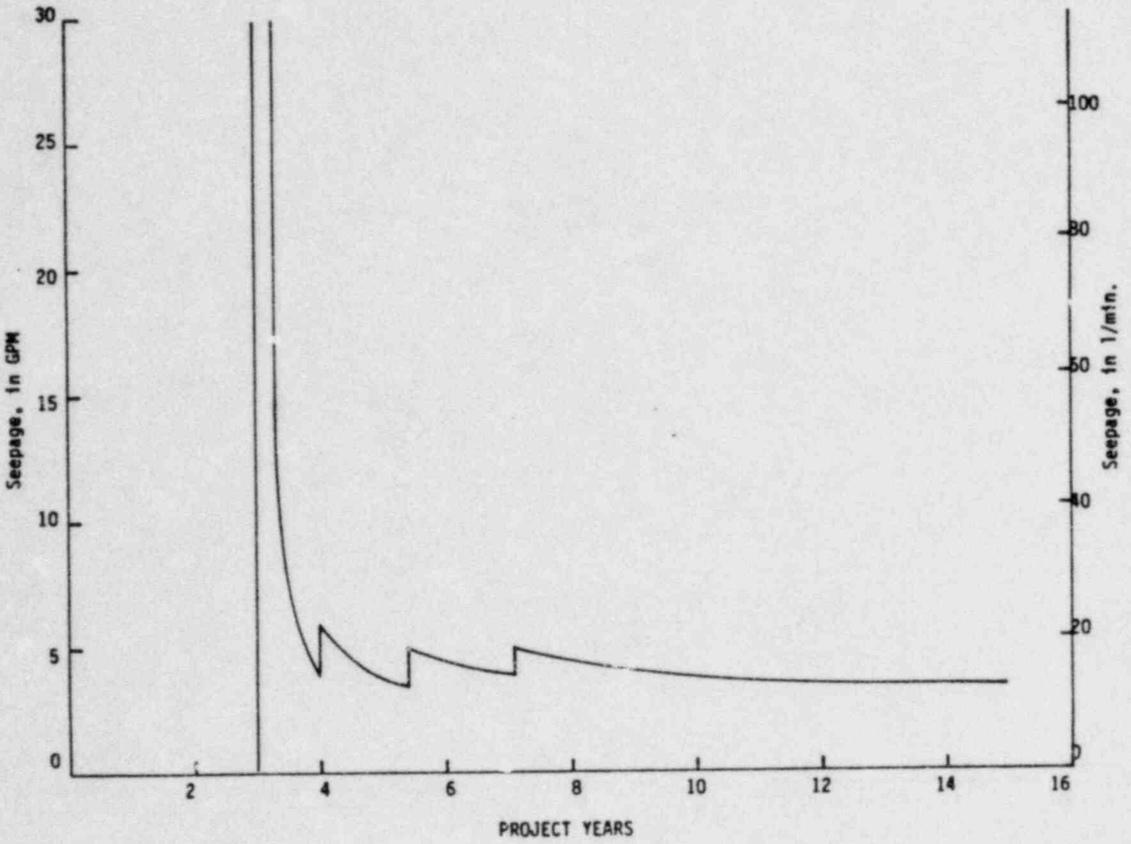


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FIGURE 4.3-6

SEEPAGE THROUGH THE BOTTOM OF THE TAILINGS PIT WITHOUT A COMPACTED LINER AND WITHOUT EFFECTIVE DRAINS

Figure 4.3-7 presents the seepage through the bottom of the tailings with a three foot layer of compacted material which has permeability of 1.4 x 10^{-7}cm/sec (0.14 ft/yr). This permeability was obtained from laboratory tests on recompacted site material to 95 percent maximum density. The head in the tailings was varied with the top of the tailings as in the previous analysis without a compacted liner. A maximum seepage rate of approximately 75 l/min (20 gpm) would be expected as the tailings head builds to a maximum. Seepage estimates decrease fairly rapidly after the groundwater increases the resistance to seepage at year 4.7. A slight increase in the seepage rate is shown as additional area is used for tailings disposal.

Seepage estimates through the pit bottom for a compacted liner with effective drains will be close to seepage without the drains because the seepage estimates are not very sensitive to the head changes.

Seepage through the pit walls was simulated for heat without effective drains in the bottom of pit. The section of "Theory of Pit Wall Seepage Model" (Section 4.2.2.2 should be reviewed for the model used to predict pit wall seepage. Seepage into the sandstone and coal units which crop out in the pit walls were simulated for heads at the top of the tailings. Permeabilities of 4 x 10^{-5} cm/sec (40 ft/yr) and less were determined for the sandstones and E coal which were tested in pit 35N (see Section 3.6 for a discussion of these tests). This value was used for all the sandstones and E coal which would product a conservatively high seepage estimate. A 5-foot thickness was used for the entire perimeter of the pit for the E coal exposed area while exposed surface areas of 200 m^2 (2,200 ft^2) to 3,900 m^2 (42,000 ft^2) were used for the ten sandstone outcrops. Figure 4.3-8 presents the seepage estimates for the pit walls without effective drains in the pit bottom. Seepage rates increase as the head increases and as additional units are covered by the tailings water. An estimate of over 400 l/min (100 gpm) is indicated toward the end of disposal in pit 35N. This prediction seems high but shows that excessive seepage would occur if the heads are allowed to build in the tailings sand.

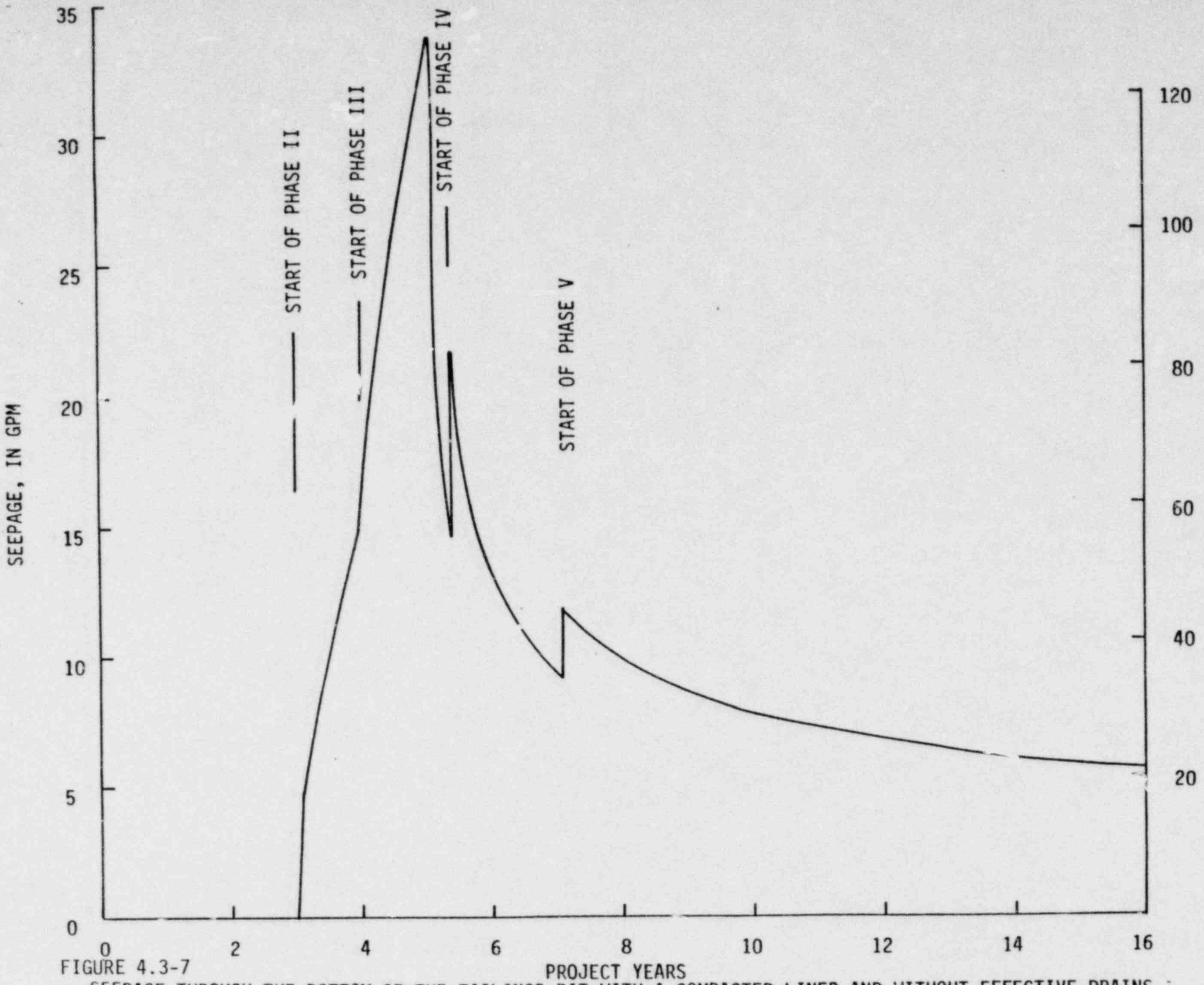

FIGURE 4.3-7
SEEPAGE THROUGH THE BOTTOM OF THE TAILINGS PIT WITH A COMPACTED LINER AND WITHOUT EFFECTIVE DRAINS

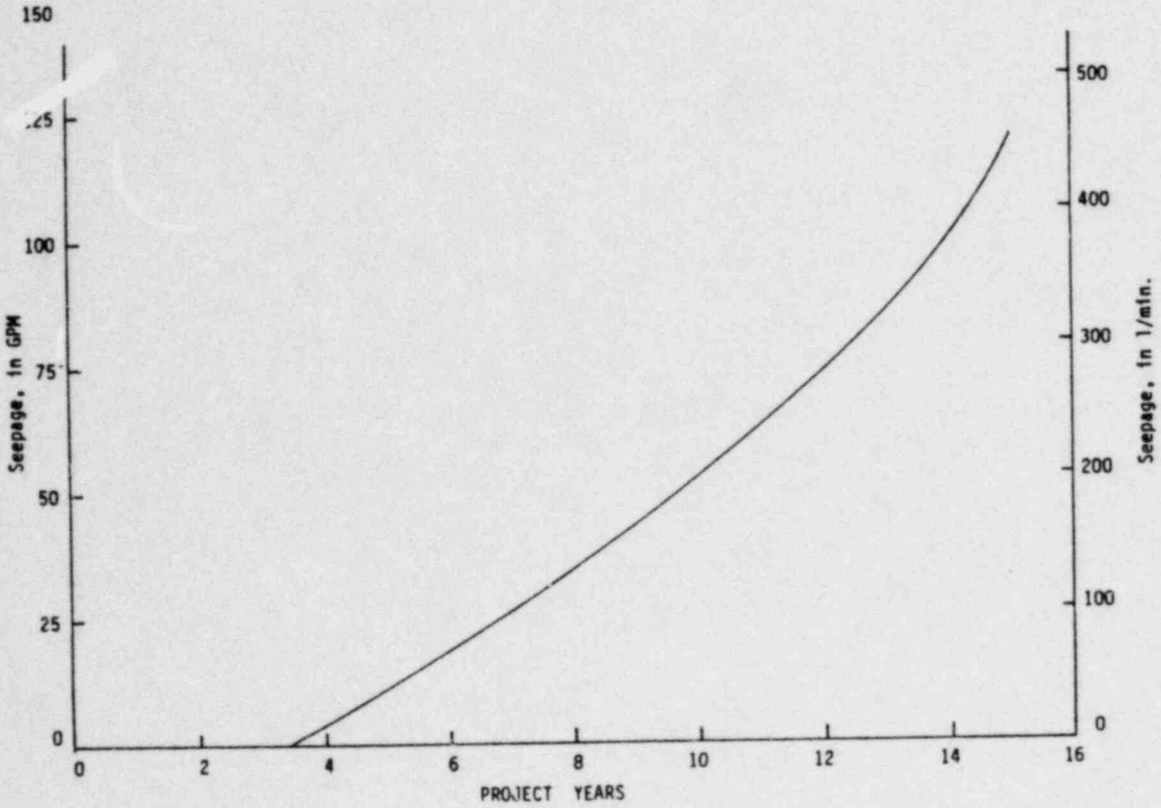

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FIGURE 4.3-8

SEEPAGE ESTIMATE THROUGH THE PIT WALLS WITHOUT A DRAINAGE SYSTEM

Drain pipes have been designed to convey the water from the tailings sand. These drains should maintain the head in the bottom of the pit to less than 1.5 meters (5 feet) for an average. A maximum level of approximately 2 meters (6 feet) should occur half-way between two lateral drains. This head is below any of the sandstones.

The average vertical permeability of the tailings material was determined to be 2 x 10^{-4} cm/sec (200 ft/yr) from laboratory tests (Chen and Associates, 1980). The hydraulic gradient which should govern vertical flow with an effective drain in the bottom of the tailings pit would be near one. The vertical conveyance capacity of the Phase II area (28,000 m^2 or 300,000 ft^2) is 3,200 l/min (850 gpm). This is greater than two and one-half times the quantity of water which should be available to seep into the tailings sand. The capability of the tailings sands to convey more water than available should result in partially saturated flow in the tailings with effective bottom drains. Heads of only one or two meters should occur in the tailings where pockets of saturated flow is occurring. These heads would be present at one point only for a portion of the time.

The capillary drive should be the major driving force for the partially saturated tailings next to the pit walls. The capillary force of the pit wall units will try to pull water into the pit wall while the capillary force of the tailings will try to retain the water in the tailings. These two forces will tend to offset each other. Seepage into the pit wall with effective drains should be insignificant.

DESIGN OF LATERAL DRAIN SPACING

The drain pipes are proposed to be installed in the base of pit 35N to maintain low phreatic heads in the tailings. The drain pipes are sized to to convey the total rate of water which will be available for seeping through the tailings. A total rate of 1,893 l/min (500 gpm) of water will be added to the pit. Specific retention of the tailings sand should trap 473 l/min (125 gpm) of the water while 189 l/min (50 gpm) of the tailings water is expected to runoff the surface. A total rate of 1,230 l/min (325 gpm) was therefore used to select the size of the drain pipes.

The spacing of the intercept drains can be computed from the Ellipse equation which uses the permeability of the drain material, depth of barrier below drain. and vertical distance, after drawdown, of the water table above the drains at the midpoint between the drains. A drainage coefficient, which is based on the application of water, is also used to compute the spacing of drains. The theory of the Ellipse equation is presented in section 4.2.2.2. The following parameters were used in computing the drain spacings.

Permeability drain material = 2.9×10^{-3} cm/sec (3,000 ft/yr)
Water table height between drains = 3.0 m (10 ft)
Depth of barrier below drain = 0.5 m (1.5 ft)
Drainage coefficient = 0.25 cm/hr (0.1 inches/hr)

A spacing of 45 meters (146 feet) was computed from these parameters. Drain spacings of 30 meters (100 feet) are proposed for the Phase II disposal area in pit 35N to insure maximum heads below 3 meters (10 feet) in the bottom of the pit.

The maximum head between the drain for 30 meters (100 feet) spacing would be 1.8 m (6.5 ft). Therefore, the average head on the bottom of the pit should be less than 1.5 meters (5 feet). The drain pipes are proposed to be placed in the middle at 0.9 meters (3 feet) of graded sand which will cover the entire bottom surface of the pit. Drains are proposed along the edge of the pit bottom to maintain the lowest heads in this area of the pit. The effectiveness of the drains in Phase II will be observed to determine if drains will be used in the remainder of the pit. The five drains at the dam of the Phase II area can be extended without additional lines for Phase III because the increased area will decrease the infiltration rate proportionally to the area.

Mannings equation was used with the following parameters to compute the diameter of pipe required to convey the 1,230 l/min (325 gpm).

Discharge = 1,190 l/min (314 gpm)
Slope of pipes = 0.01 m/m
Roughness coefficient = 0.01

A minimum pipe diameter of 8.6 cm (3.4 in) is needed to convey the total discharge using four pipes. Perforated PVC pipe of 10 cm (4 in) diameter will be used for the drains.

CONCLUSION OF SEEPAGE ESTIMATES

The seepage rate from the evaporation pond is expected to be less than 23 l/min (6 gpm) after one year of operation. Higher rates are expected during the first year of operation, but the pond will store mine and well water during this period and any seepage occurring will be with the fresh water. It should require at least 90 years of seeping at the predicted rate before the solutions reach the 70 sand aquifer. The mill solutions will be stored in the evaporation pond for approximately 15 years.

High seepage rates would be expected into the pit 35N walls if the piezometric head in the tailings is allowed to build up. Lateral drain pipes with a continuous drainage blanket have been designed to aid the tailings drainage available to prevent the buildup of a high piezometric head. Seepage from pit 35N should reach a maximum of approximately 80 l/min (20 gpm) during the first two years with a fairly rapid decrease to less than 40 l/min (10 gpm) after the second year of operation.

Seepage from the evaporation pond and pit disposal area should not exceed 100 l/min (25 gpm) at any time of the operations. The average total seepage should be slightly less than 40 l/min (10 gpm).

GROUNDWATER QUALITY IMPACTS

Seepage from the tailings sites has the potential to carry chemical contaminants into the underlying aquifers. This section contains an assessment of the extent of contaminant movement in the project area. Discussions of the determination of distribution coefficients and simulation of ion migration are included.

DISTRIBUTION COEFFICIENTS

The major factors that control the rate of migration of ions in aquifers are the type and concentration of the ion, the velocity of the water, other ionic species and their concentration in the water, the sorptive characteristics of the media, and the porosity of the aquifer. The media will tend to sorb ions from the water. They will be displaced by other ions in the groundwater that are competing for the spaces occupied by the ions. Thus, the higher the ion concentration, the faster a specific ion will move by successive displacements.

The distribution coefficient is a variable that is uniquely determined for only a single set of physical and chemical conditions. Physically, it can be thought of as a measure of the distribution of an ion between the water, or liquid phase, and the solid phase which tends to sorb the ion. A high distribution coefficient indicates a strong tendency for sorption.

Distribution coefficients were determined in a laboratory using a batch technique. Soil and rock samples were collected using a California type sampler from representative strata in several test holes. These samples were oven dried and then broken up. A measured amount of sample was then combined with a 20:1 dilution of tailings water similar in makeup to that expected from the Sand Rock mill. Rock samples and water were combined at a ratio 20:1 (ml water to grams of rock sample) for 24 hours on a rotation type mixer. The mixing apparatus revolved at a rate of 3 rpm. Dissolved chemical parameters of the tailings water solution were measured before and after mixing with the rock samples.

A column technique, whereby tailings water would be allowed to percolate through a column of rock sample, was considered for distribution coefficient tests. However, low permeabilities of the rock material precluded this type of test on relatively undisturbed samples. A simple initial test was conducted whereby California type sampler cores were subjected to approximately three feet of waterhead. It was estimated that a time period of several weeks would be required to obtain the necessary volume of water (2 gallons) through relatively permeable sandstones. The time to collect the volume of water through less permeable mudstones was much longer. Repacked columns have a tendency to form short circuit flow paths through or down the sides of the column. In addition, the process of grinding and repacking the rock sample makes it as far removed from nature as a batch type test, but less reliable. Hajek and Ames (1966) conducted simultaneous batch and column tests for which they reported that the final column Kd fell between those determined at solution to soil ratios of 10:1 and 50:1 by the batch method. The solution to rock ratio of 20: 1 used for these tests falls well within that range.

In a background study on the development of a standard leaching test by Ham and others (1979) for the EPA, column tests were discounted in favor of batch tests for reasons including the following:

1. Problems arising from channeling and nonuniform column packing,
2. Potential unnatural clogging,
3. Edge effects,
4. Long time requirements, and
5. Difficult in obtaining reproducible results even if done by experienced lab personnel.

A leaching test is, of course, different in scope from a test to determine distribution coefficients. However, the principles and problems of the column tests are quite similar.

The mixing device used consisted of a circular sheet of plywood mounted in a vertical position. Containers of rock water mixture were attached to the vertical sheet at an angle of approximately 45° from horizontal. The plywood sheet was then rotated at approximately 3 rpm for 24 hours.

Choice of a length of mixing time is somewhat arbitrary because equilibrium conditions are reached at different times depending on the exchanging or adsorbing ion and exchange or adsorption medium. Robinson (1962) discusses several studies which have indicated that ion exchange or adsorption equilibrium for many ions on different soils and rock types is achieved quite rapidly, generally less than two hours. Hajek and Ames (1966) mixed their soil water samples for 16 hours to allow calculation of equilibrium distribution coefficients. Twenty-four hours was selected as the mixing time for the tests conducted during this study to provide a measure of safety for occurrence of equilibrium conditions.

One reason for diluting the tailings water to 20:1 was to facilitate laboratory analysis. Some of the constituents measured were present in such high concentrations that dilution was necessary to bring the levels within the analytical range. Small errors in analysis would then be magnified into larger errors when multiplying analytical results to take into account the dilution factor. It was thought better to dilute the tailings water prior to mixing with rock samples and measure concentrations directly both before and after mixing.

A laboratory test was conducted to determine the effects on distribution coefficient of diluting the tailings water solution prior to mixing with a soil sample. Five dilutions of tailings water ranging from full strength to 20:1 were mixed with identical soil samples. Arsenic, selenium, and vanadium were determined before and after mixing. The results of this test, shown on Figure 4.3-9 indicate that the distribution coefficient increases with decreaing initial constituent concentration. Also, as a part of this test, pH was measured on each tailings water dilution before and after mixing with the soil sample. A plot of distribution coefficient versus pH after mixing is shown on Figure 4.3-10. As might be expected, distribution coefficient increases with increasing pH.

Upon cursory examination of these results, it might be assumed that diluting the tailings water solution prior to mixing with soil would bias the calculated distribution coefficient in a positive manner. Under natural field conditions, if seeping tailings water were to remain at full strength, this would be true. However, as the water seeps, it will constantly be contacting water retained in the soil or rock formation through which it is seeping. Additionally, adsorption of many ions will be occurring. Therefore, the seeping water will be continually undergoing dilution.

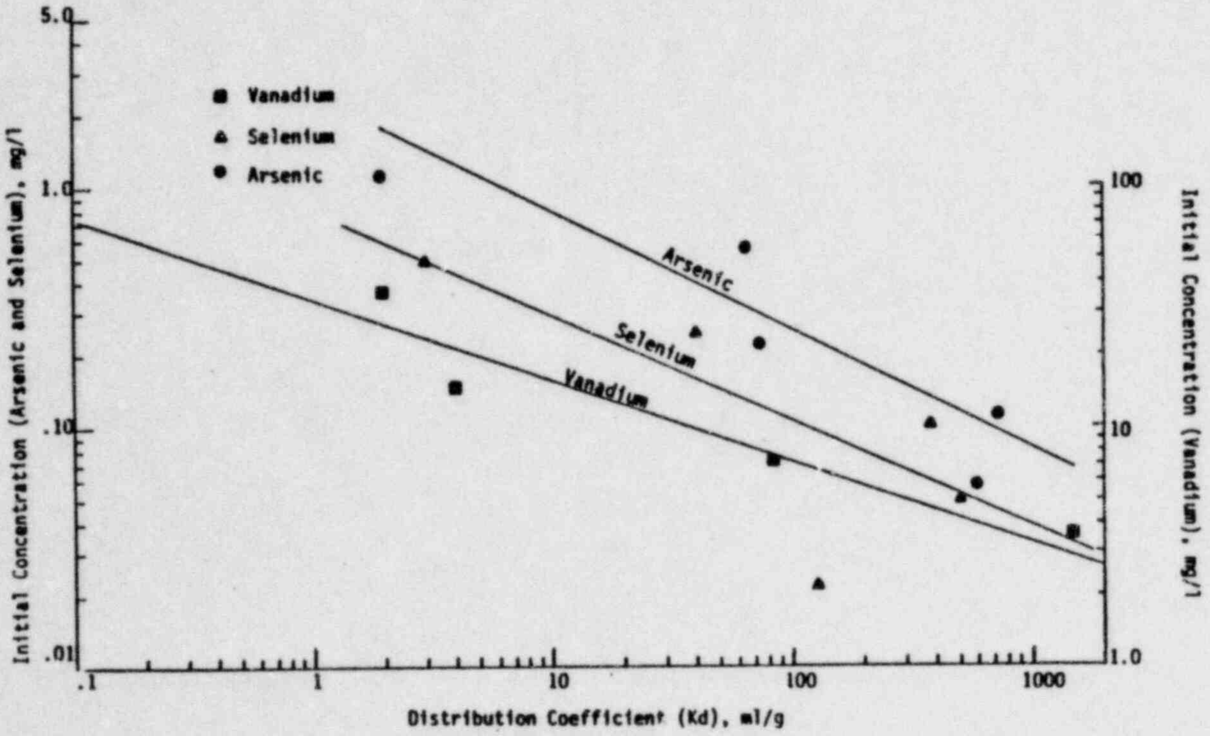

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FIGURE 4.3-9

VARIATION OF DISTRIBUTION COEFFICIENT (Kd)
WITH INITIAL TAILINGS SOLUTION CONCENTRATION
FOR DIFFERENT CHEMICAL CONSTITUENTS WHEN
MIXED WITH LOWER MUDSTONE FROM HOLES P-16 AND P-17

Neutralizing agents such as calcium carbonate ($CaCo_3$) are present in Sand Rock project area rock and soil formations in concentrations generally greater than 1 per cent.

A sample of unsaturated 70 sandstone taken in the pit 35N area and a sample of upper mudstone taken in the tailings evaporation pond area each were measured in the laboratory and contained approximately 4.5 percent $CaCO_3$. Tailings water with a pH of 1.5 contains 0.032 equivalents per liter of hydrogen ions. The soil and rock formations in the Moore Ranch area contain approximately 0.7 equivalents per liter of $CaCO_3$, assuming 2 percent $CaCO_3$. and a soil dry density of 1.75 g/cm^3. The ratio of equivalents per liter of hydrogen ions to $CaCO_3$ is 0.045 or approximately 1:20. Assuming an effective porosity of 0.1, each cubic meter of soil or rock would be invaded by 0.1 cubic meter of seepage water. The soil or rock formations in the Moore Ranch area should, therefore, easily neutralize the tailings water.

Considering the fact that seeping tailings water will be continuously undergoing dilution and neutralization, it would be unrealistic to use distribution coefficients based only on mixture of full strength tailings water with soil or rock samples. However, in the interest of providing margins of safety, conservative estimates of distribution coefficients are used in the simulation of ion migration.

Distribution coefficient tests were conducted on 12 separate rock samples collected from 14 different test holes. Selection of the test holes and strata to be tested was based on obtaining representative samples from major stratigraphic units encountered in the Sand Rock mill evaporation pond and 35-N pit areas. For some tests, samples from more than one depth within the same rock type in the same test hole were composited. Compositing was accomplished by taking equal weights of each rock sample and thoroughly mixing them. Table 4.3.3.2 presents a summary of test holes and strata tested. Figure   shows locations.

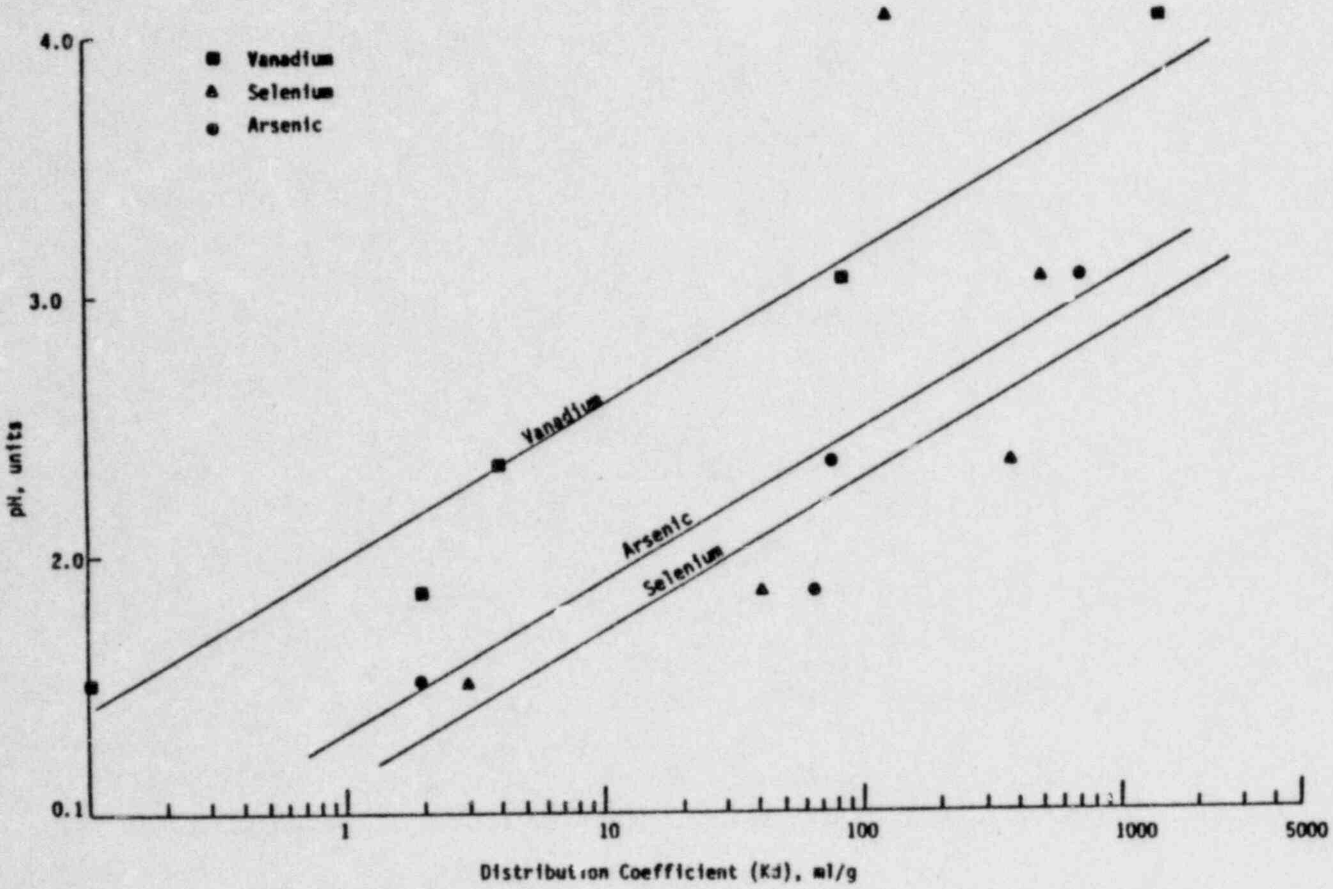

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FIGURE 4.3-10

VARIATION OF DISTRIBUTION COEFFICIENT (Kd) WITH EQUILIBRIUM TAILINGS SOLUTION pH FOR DIFFERENT CHEMICAL CONSTITUENTS WHEN MIXED WITH LOWER MUDSTONE FROM HOLES P-16 AND P-17

TABLE 4.3.3.2

SUMMARY OF ROCK-SAMPLE INFORMATION USED FOR DISTRIBUTION COEFFICIENT TESTS

Test Hole	Sample Depth (Depth-Meters)	Rock Type
P-3	4.6 (15) and 6.1 (20)	Upper mudstone
P-20	30.2 (99) and 31.7 (104)	Saturated 70 sandstone
P-8	5.8 (19), 7.3 (24) and 8.8 (29)	Sandstone
P-9	2.7 (9), 4.3 (14) and 5.8 (19)	Upper mudstone
PD-8 and P-9	10.4 (34) 7.3 (24)	E-coal
P-10	5.8 (19) and 8.8 (29)	Upper mudstone
P-16 and P-17	11.9 (39) and 14.9 (49) 14.9 (49) and 21.0 (69)	Lower mudstone
35N-1	48.8 (160) and 50.3 (165)	Unsaturated 70 sandstone
35N-2	19.5 (64) and 24.1 (79)	Mudstone
35N-6	24.1 (79)	Sandstone
35N-7	31.7 (104), 36.3 (119) and 42.4 (139)	Unsaturated 70 sandstone
35N-7	45.4 (149)	Saturated 70 sandstone

Table 4.3.3.3 presents distribution coefficients for selected chemical parameters for each test conducted. Table 4.3.3.4 gives ranges of distribution coefficients for different rock types for different parameters. The chemical constituents selected for distribution coefficient testing were taken from a list given in a generic impact statement prepared by the U.S. Nuclear Regulatory Commission. Values for these constituents determined from the tailings water solution are given on Table 4.3.3.5. Also, for comparison purposes, maximum permissible concentrations established by the U.S. Public Health Service and modified by the U.S. Environmental Protection Agency in 1975 are shown in this table. Distribution coefficients for mercury, molybdenum, and fluoride were not determined in this study because they were present in undiluted tailings water in concentrations too low to be detected. Some of the laboratory results are not available at the time of this writing, but they will be presented and discussed when received.

Results of the laboratory chemical analyses both before and after exposure to rock samples are presented in Table 4.3.3.6.

ION MIGRATION SIMULATION

Ion mgration will be simulated utilizing the model discussed in Section 4.2.2.2. For review purposes, it takes the form of the following equation:

$$C/Co = \frac{1}{2}\left(1 - \mathrm{erf}\left(\frac{x - Vx \cdot t/a}{2\ Dm \cdot t/a}\right)\right)$$

Where: $a = 1 + \frac{Bd \cdot Kd}{n}$

C = Effluent concentration of solute,

Co = Influent concentration of solute,

n = Pore fraction of exchanger,

Kd = Equilibrium distribution coefficient,

TABLE 4.3.3.3

DISTRIBUTION COEFFICIENTS (Kd) FOR SELECTED CHEMICAL PARAMETERS IN SELECTED TEST-HOLE ROCK SAMPLES

	Distribution Coefficient, in ml/g					
Parameter	Hole P-3 Upper Mudstone	Hole P-20 Saturated 70 Sandstone	Hole P-8 Sandstone	Hole P-9 Upper Mudstone	Holes PD-8 and P-9 E-Coal	Hole P-10 Upper Mudstone
Aluminum	1,200	40	13	1.5	39	>11,000
Ammonia	1.8	<0	<0	1.1	<0	3.6
Arsenic	>550	85	270	>560	11	>560
Cadmium	<0	<0	<0	<0	<0	<0
Calcium	<0	<0	<0	<0	<0	<0
Chloride	<0	<0	<0	<0	<0	<0
Copper	<0	<0	<0	<0	1.8	29
Iron	120	21	32	69	28	9,700
Lead	7.5	<0	10	<0	<0	0
Manganese	3.6	0.45	<0	<0	<0	<0
Selenium	>140	>200	>200	>200	>130	>200
Sodium	<0	<0	<0	<0	<0	<0
Sulfate	<0	0.46	<0	<0	<0	<0
Total dissolved solids	<0	4.9	5.8	<0	<0	3.1
Vanadium	>1,300	2.1	6.2	58	400	>1,400
Zinc	<0	<0	<0	<0	<0	<0

	Distribution Coefficient, in ml/g					
Parameter	Holes P-16 and P-17 Lower Mudstone	Hole 35N-1 Unsaturated 70 Sandstone	Hole 35N-2 Mudstone	Hole 35N-6 Sandstone	Hole 35N-7 Unsaturated 70 Sandstone	Hole 35N-7 Saturated 70 Sandstone
Aluminum	73	5,900	>11,000	>11,000	39	25
Ammonia	0.9	5.2	3.6	<0	0	<0
Arsenic	>560	>550	>560	>560	370	57
Cadmium	<0	<0	<0	<0	<0	<0
Calcium	<0	<0	<0	<0	<0	<0
Chloride	<0	<0	<0	<0	<0	<0
Copper	<0	26	28	13	<0	<0
Iron	63	1,300	33,000	260	34	21
Lead	0	4.4	0	0	<0	<0
Manganese	2.1	<0	0	<0	<0	<0
Selenium	130	>140	130	>200	>200	>200
Sodium	<0	<0	0	<0	<0	<0
Sulfate	<0	<0	0	1.5	0.46	0.95
Total dissolved solids	4.5	<0	1.9	4.2	4.3	4.3
Vanadium	>1,400	>1,300	1,400	>1,400	>1,400	1.6
Zinc	<0	<0	0	<0	<0	<0

NOTES: (1) Distribution coefficients determined by mixing 20:1 dilution of tailings water with dried rock sample at a ratio of 20:1 (ml water to gm rock) for 24 hours.

(2) Values less than zero indicate leaching of the parameter from the rock sample.

(3) Values greater than number are reported, because rock sample stripped out parameter below analytical detection limit. Number value is calculated from lower detection limit.

TABLE 4.3.3.4

RANGE OF DISTRIBUTION COEFFICIENTS OF SELECTED PARAMETERS FOR DIFFERENT ROCK TYPES

	Distribution Coefficient Range, in ml/g		
Parameter	Mudstone	Unsaturated Sandstone	Saturated Sandstone
Aluminum	1.5 - >11,000	13 - 5,900	25 - 40
Ammonia	0.9 - 3.6	<0 - 5.2	<0
Arsenic	>550 - > 560	270 - > 560	57 - 85
Copper	<0 - 29	<0 - 26	<0
Iron	63 - > 33,000	32 - 1,300	21
Lead	<0 - 7.5	<0 - 10	<0
Manganese	<0 - 3.6	<0	<0 - 0.45
Selenium	130 - >200	>140 - > 200	>200
Sulfate	<0	<0 - 1.5	<0 - 0.95
Vanadium	58 - >1,400	6.2 - >1,400	1.6 - 2.1

TABLE 4.3.3.5

CHEMICAL CHARACTERISTICS OF MILL LIQUID EFFLUENT

Constituent	Mill Liquid Effluent Concentration (mg/l except as noted)	USPHS-USEPA Maximum Permissible Concentration (mg/l except as noted)
Aluminum	560	No limit
Arsenic	1.16	0.05
Calcium	420	200
Cadmium	0.16	0.01
Chloride	260	250
Copper	1.96	1
Fluoride	*0.05	1.4 - 2.4
Iron	1,660	0.3
Mercury	*0.001	0.005
Molybdenum	*0.05	No limit
Manganese	49	0.05
Sodium	350	200
Ammonia (as N)	190	0.5
Lead	1.8	0.05
Selenium	0.44	0.01
Sulfate	17,700	250
Vanadium	72	0.1
Zinc	7.2	5
Total dissolved solids	35,440	500
pH (units)	1.48	6 - 9
U-nat (pCi/l)	$1.24 \times 10^4 \pm 0.06 \times 10^4$	550
Radium-226 (pCi/l)	580 ± 30	[illegible]
Thorium-230 (pCi/l)	$1.34 \times 10^5 \pm 0.04 \times 10^5$	2,000
Lead-210 (pCi/l)	$2.6 \times 10^4 \pm 0.2 \times 10^4$	[illegible]

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* Actual value less than reported value

TABLE 4.3.3.6

TAILINGS-WATER CHEMICAL ANALYSES BEFORE AND AFTER MIXING WITH SELECTED TEST-HOLE ROCK SAMPLES

	Concentration, in mg/l (except as noted)					
	Hole P-3		Hole P-20		Hole P-8	
	Upper Mudstone		Saturated 70 Sandstone		Sandstone	
Parameter	Before Mixing	After Mixing	Before Mixing	After Mixing	Before Mixing	After Mixing
Aluminum	29.43	0.10	27.80	9.20	27.80	16.80
Ammonia, as N	9.7	7.7	9.2	10.1	9.2	10.4
Arsenic	0.057	ND (0.002)	0.058	0.011	0.058	0.004
Cadmium	0.009	0.014	0.008	0.011	0.008	0.011
Calcium	28	240	21	95	21	120
Chloride	15	21	13	15	13	15
Conductivity*	3,100	1,800	5,400	2,550	5,400	2,550
Copper	0.095	0.041	0.098	2.125	0.098	0.668
Iron	88.0	1.29	83.0	40.5	83.0	32.0
Lead	0.11	0.09	0.09	0.11	0.09	0.06
Manganese	2.02	1.71	2.28	2.23	2.28	4.90
pH, units	2.36	6.43	2.01	2.48	2.01	2.55
Selenium	0.016	ND (0.002)	0.022	ND (0.002)	0.022	ND (0.002)
Sodium	16	22	13.0	19.0	13.0	32.7
Sulfate	885	925	885	865	885	930
Total dissolved solids	1,048	1,540	1,772	1,424	1,772	1,372
Vanadium	3.23	ND (0.05)	3.58	3.24	3.58	2.73
Zinc	0.361	2.11	0.362	7.380	0.362	2.940

	Concentration, in mg/l (except as noted)					
	Hole P-9		Holes PD-8 and P-9		Hole P-10	
	Upper Mudstone		E-Coal		Upper Mudstone	
Parameter	Before Mixing	After Mixing	Before Mixing	After Mixing	Before Mixing	After Mixing
Aluminum	27.80	25.90	27.80	9.39	27.80	ND (0.05)
Ammonia, as N	9.2	8.7	9.2	9.7	9.2	7.8
Arsenic	0.058	ND (0.002)	0.058	0.038	0.058	ND (0.002)
Cadmium	0.008	0.028	0.008	0.051	0.008	0.012
Calcium	21	510	21	198	21	323
Chloride	13	15	13	29	13	17
Conductivity*	5,400	3,300	5,400	2,350	5,400	1,750
Copper	0.098	0.338	0.098	0.090	0.098	0.040
Iron	83.0	18.6	83.0	34.5	83.0	0.17
Lead	0.09	0.16	0.09	0.11	0.09	0.09
Manganese	2.28	5.60	2.28	2.35	2.28	2.72
pH, units	2.01	2.91	2.01	3.78	2.01	6.82
Selenium	0.022	ND (0.002)	0.022	0.003	0.022	ND (0.002)
Sodium	13.0	25.2	13.0	42.2	13.0	20.0
Sulfate	885	2,120	[illegible]	1,405	885	980
Total dissolved solids	1,772	3,304	1,772	2,200	1,772	1,536
Vanadium	3.58	0.92	3.58	0.17	3.58	ND (0.05)
Zinc	0.362	2.710	0.362	7.000	0.362	1,560

TABLE 4.3.3.6

(CONT.)

	Concentration, in mg/l (except as noted)					
	Holes P-16 and P-17		Hole 35N-1		Hole 35N-2	
	Lower Mudstone		Unsaturated 70 Sandstone		Mudstone	
Parameter	Before Mixing	After Mixing	Before Mixing	After Mixing	Before Mixing	After Mixing
Aluminum	27.80	5.95	29.43	0.49	27.80	ND (0.05)
Ammonia, as N	9.2	8.8	9.7	8.9	9.2	7.8
Arsenic	0.058	ND (0.002)	0.057	ND (0.002)	0.058	ND (0.002)
Cadmium	0.008	0.026	0.009	0.027	0.008	0.012
Calcium	21	232	28	220	21	410
Chloride	13	15	15	17	13	17
Conductivity*	5,400	1,500	3,100	1,600	5,400	1,850
Copper	0.098	0.358	0.095	0.904	0.098	0.041
Iron	83.0	20.0	88	12.70	83.0	ND (0.05)
Lead	0.09	0.09	0.11	0.08	0.09	0.10
Manganese	2.28	2.06	2.02	2.15	2.28	2.64
pH, units	2.01	4.07	2.36	5.95	2.01	7.79
Selenium	0.022	0.003	0.016	ND (0.002)	0.022	0.003
Sodium	13.0	20.4	16	21	13.0	22.6
Sulfate	885	910	885	960	885	950
Total dissolved solids	1,772	1,448	1,048	1,438	1,772	1,616
Vanadium	3.58	ND (0.05)	3.23	ND (0.05)	3.58	ND (0.05)
Zinc	0.362	1.550	0.361	16.40	0.362	0.569

	Concentration, in mg/l (except as noted)					
	Hole 35N-6		Hole 35N-7		Hole 35N-7	
	Sandstone		Saturated 70 Sandstone		Unsaturated 70 Sandstone	
Parameter	Before Mixing	After Mixing	Before Mixing	After Mixing	Before Mixing	After Mixing
Aluminum	27.80	ND (0.05)	27.80	12.40	27.80	9.50
Ammonia, as N	9.2	9.7	9.2	10.8	9.2	9.1
Arsenic	0.058	ND (0.002)	0.058	0.015	0.058	0.003
Cadmium	0.008	0.013	0.008	0.009	0.008	0.022
Calcium	21	288	21	112	21	81
Chloride	13	19	13	15	13	15
Conductivity*	5,400	1,750	5,400	2,350	5,400	1,700
Copper	0.098	0.059	0.098	6.930	0.098	0.660
Iron	83.0	5.85	83.0	40.5	83.0	30.5
Lead	0.09	0.09	0.09	0.13	0.09	0.10
Manganese	2.28	2.45	2.28	2.29	2.28	2.35
pH, units	2.01	6.53	2.01	2.55	2.01	4.07
Selenium	0.022	ND (0.002)	0.022	ND (0.002)	0.022	ND (0.002)
Sodium	13.0	29.8	13.0	18.8	13.0	19.8
Sulfate	885	825	885	845	885	865
Total dissolved solids	1,772	1,464	1,772	1,460	1,772	1,460
Vanadium	3.58	ND (0.05)	3.58	3.32	3.58	ND (0.05)
Zinc	0.362	0.377	0.362	1.840	0.362	1.250

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* Conductivity analyses reported in umhos/cm at 25°C.

All analyses made on 20:1 dilution of tailings water solution.

Dm = Dispersion coefficient,

Vx = Average solution velocity,

Bd = Bulk density of media

x = Distances from influent site,

t = Elapsed time measured from initial disposal,

and

$$\mathrm{erf}(x) = \text{Error function of } x = \frac{2}{\pi} \int_0^x e^{-t^2}\, dt.$$

A seepage velocity of 1 meter/year (3 ft/yr) was used for all ion migration analyses in this study. This value is considered to be conservative as most mudstones and unsaturated sandstones in the Moore Ranch project area exhibit lower seepage rates. The pore fraction of the exchanger was estimated to be 0.05, and a bulk density of 2.65 g/cm^3 was used in all ion migration analyses. A dispersion coefficient of 0.1 square meters/year was estimated using the velocity relationship described earlier. As a measure of conservatism, mill operation was assumed to be approximately 15 years with a present operating life of under 12 years. Migration of major contaminants are described below.

Arsenic - Arsenic is expected to be in the liquid effluent of the Sand Rock mill at a concentration of 1.16 mg/l. This is approximately 20 to 25 times greater than the maximum permissible concentration (mpc) established by the U.S. Public Health Service (PHS) and modified by the U.S. Environmental Protection Agency (EPA). However, arsenic adsorbs relatively strongly, particularly as solution acidity decreases. Figure 4.3-11 shows the migration of arsenic with time at several distances down gradient of the disposal site. Because of adsorption, dilution and dispersion, arsenic should not migrate in quantities in excess of the drinking water standard beyond 0.3 meters.

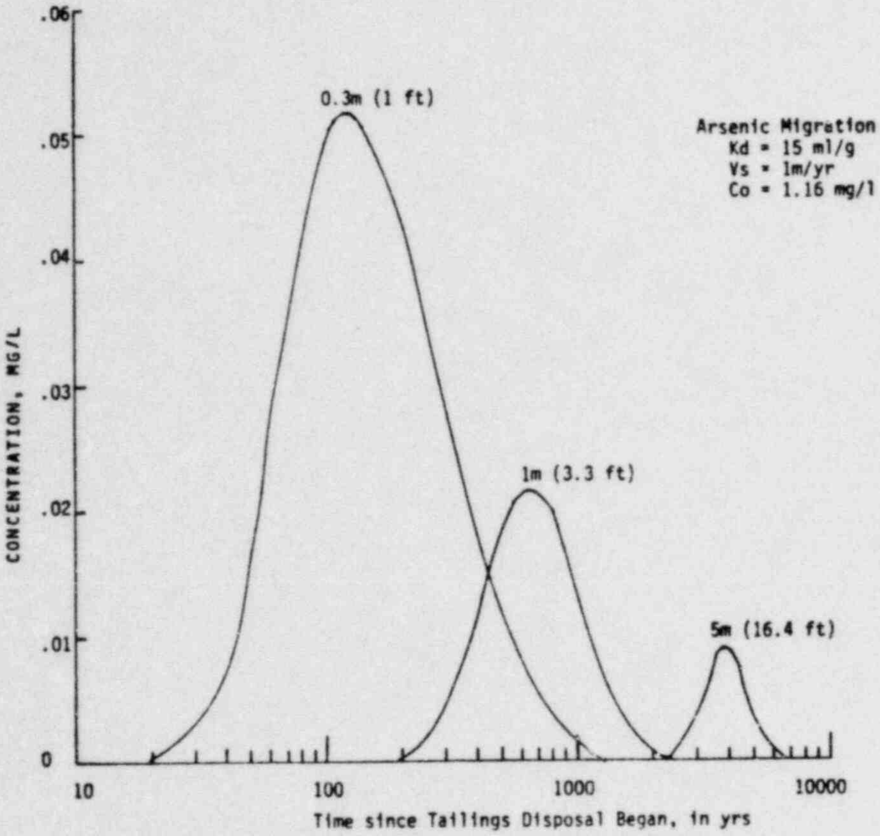

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FIGURE 4.3-11

ARSENIC MIGRATION WITH TIME AT DISTANCES DOWN GRADIENT FROM SAND ROCK MILL TAILINGS DISPOSAL SITE

Selenium and Vanadium - Selenium and vanadium, like arsenic, adsorb relatively strongly, particularly in the mudstones and unsaturated sandstones in the Moore Ranch area. Distribution coefficients (Kd) of 10 and 20 ml/g, respectively, were selected for these constituents and are considered relatively conservative. Figures 4.3-12 and 4.3-13 show ion migration with time for selenium and vanadium, respectively, down gradient from the disposal sites. Like arsenic, concentrations of selenium above drinking water standards are not predicted to move farther down gradient than approximately 1 meter (3 feet) in significant concentrations. The drinking water standard for vanadium is 0.1 mg/l. Concentrations of vanadium above the standard should not migrate beyond 1 meter (3 feet). The high adsorption rates of the soils at the Sand Rock site will quickly remove the excess of the vanadium.

Ammonia - Ammonia will be present in the mill liquid effluent in concentrations near 190 mg/l. Tests during this study indicate that ammonia is moderately adsorptive in mudstones and unsaturated sandstones. Additionally, ammonia will be expected to escape the seepage solution by volatilization or chemical oxidation. Predicted ammonia migration is shown on Figure 4.3-14.

Lead - Lead at a concentration of 1.8 mg/l will be in the tailings effluent in an amount approximately 30 to 40 times the mpc established by the PHS and EPA. Lead appears to be only weakly adsorbed by the mudstones and unsaturated sandstones in the Moore Ranch area. Using a Kd of 3 ml/g, Figure 4.3-15 shows the predicted migration of lead down gradient from the disposal site. This analysis indicates that lead will continue to be in the seepage water in significant concentrations for distances to 5 meters (16 feet).

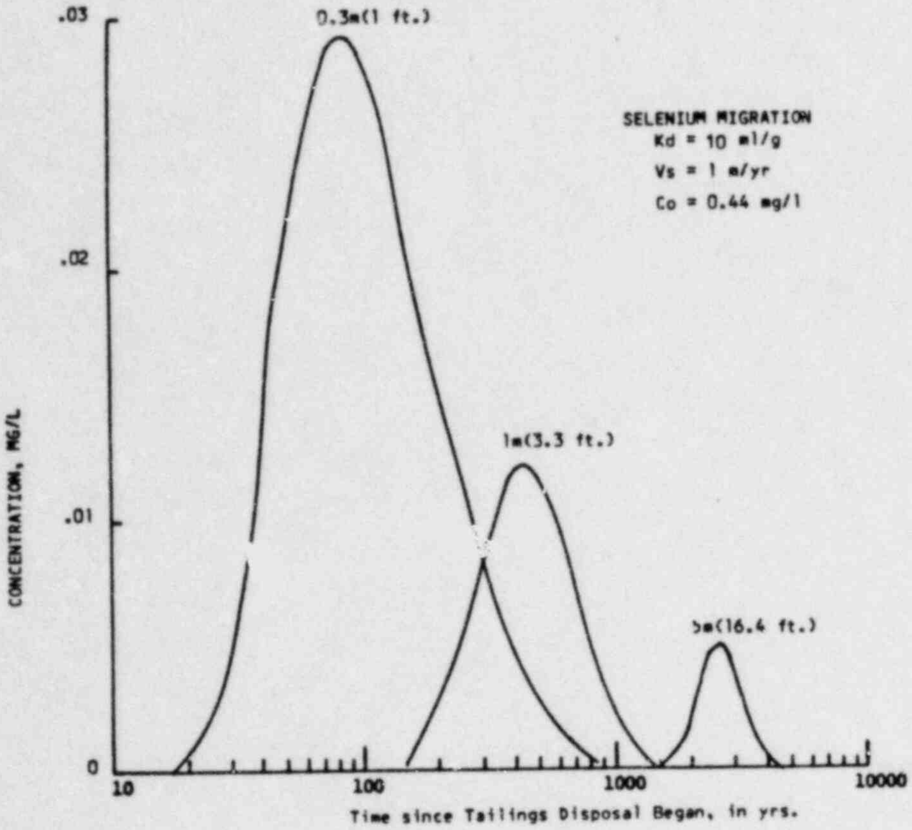

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FIGURE 4.3-12

SELENIUM MIGRATION WITH TIME AT DISTANCES DOWN GRADIENT FROM SAND ROCK MILL TAILINGS DISPOSAL SITE

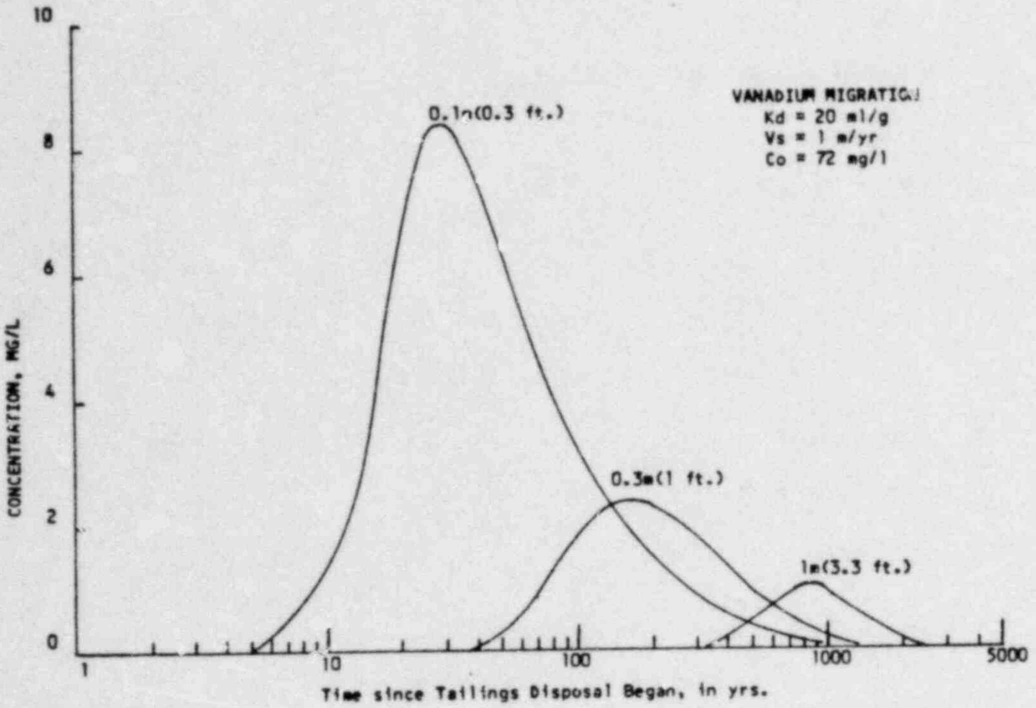

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FIGURE 4.3-13

VANADIUM MIGRATION WITH TIME AT DISTANCE DOWN GRADIENT FROM SAND ROCK MILL TAILINGS DISPOSAL SITE

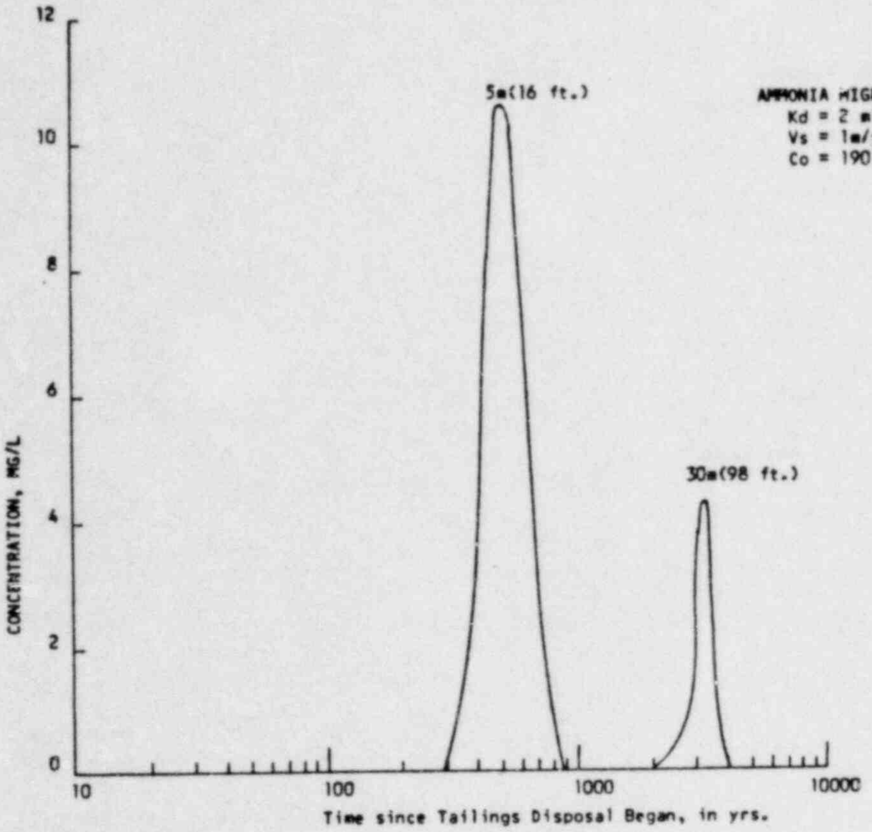

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FIGURE 4.3-14

AMMONIA MIGRATION WITH TIME AT DISTANCES DOWN GRADIENT FROM SAND ROCK MILL TAILINGS DISPOSAL SITE

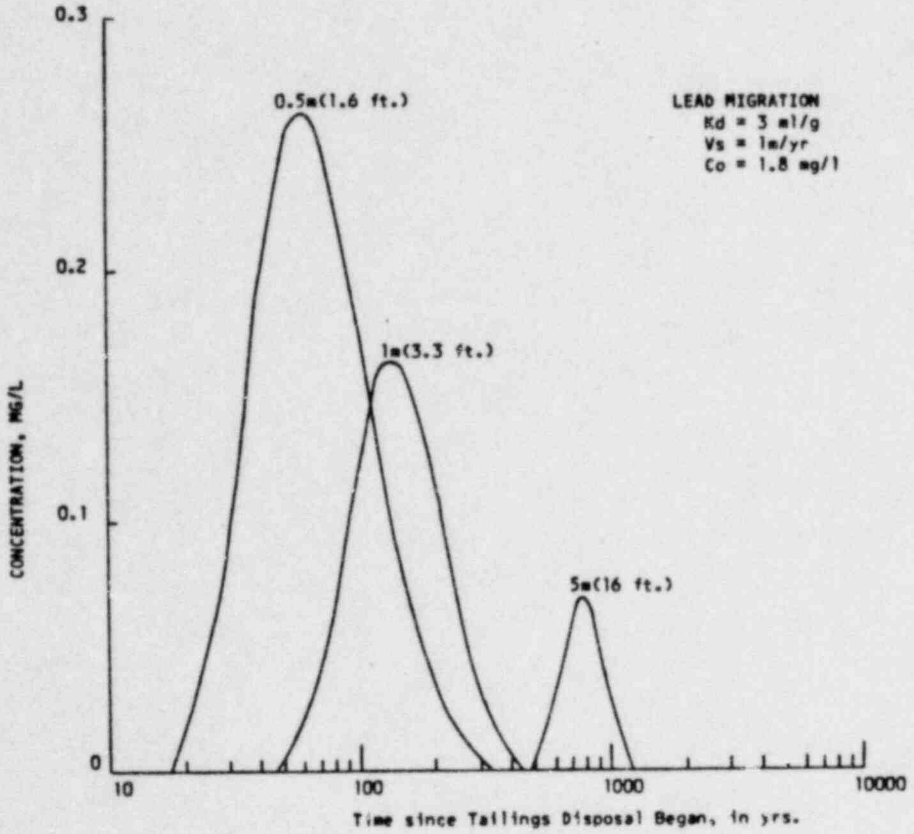

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FIGURE 4.3-15

LEAD MIGRATION WITH TIME AT
DISTANCES DOWN GRADIENT FROM
SAND ROCK MILL TAILINGS DISPOSAL SITE

Sulfate - Although not a potential health hazard, sulfate migration is analyzed because of its potential use as an indicator in monitoring and due to its high initial concentration. Assuming no adsorption or leaching, sulfate is predicted to migrate as shown on Figure 4.3-16. Sulfate, however, cannot be entirely reliably used as a tracer because many of its compounds are insoluble and may precipitate as chemical changes within the seeping solution occur. The seepage rate used in the simulations is approximately three times the value predicted for the evaporation pond. The ion migration model assumes the seepage rate will continue at the same rate after input of contaminants stop. It is therefore unlikely the sulfate concentrations will reach the predicted levels at the 30 meter (98 feet) distance.

Iron and Manganese - The initial concentration of iron (Table 4.3.3.5) is expected to be more than 5,000 times greater than the PHS-EPA mpc. However, as neutralization of the seeping water occurs, most of the iron is expected to precipitate out in the form of oxides. Adsorption and iron exchange could further reduce the iron content of the seeping water.

The geochemistry of manganese is similar to that of iron, with oxide precipitation expected as neutralization of the tailings effluent occurs. Iron and manganese are not considered particularly toxic, but are undesirable in water supplies due to the unpleasant taste they impart and their propensity for staining laundry and procelain fixtures.

Radionuclides - Currently no laboratory data are available from radionuclide distribution coefficient determinations made on Moore Ranch project area soil and rock samples. However, 10 ml/g is considered to be a relatively conservative Kd for radium -226. For this case, radium -226 would move a considerably shorter distance down gradient than previous analyses have indicated

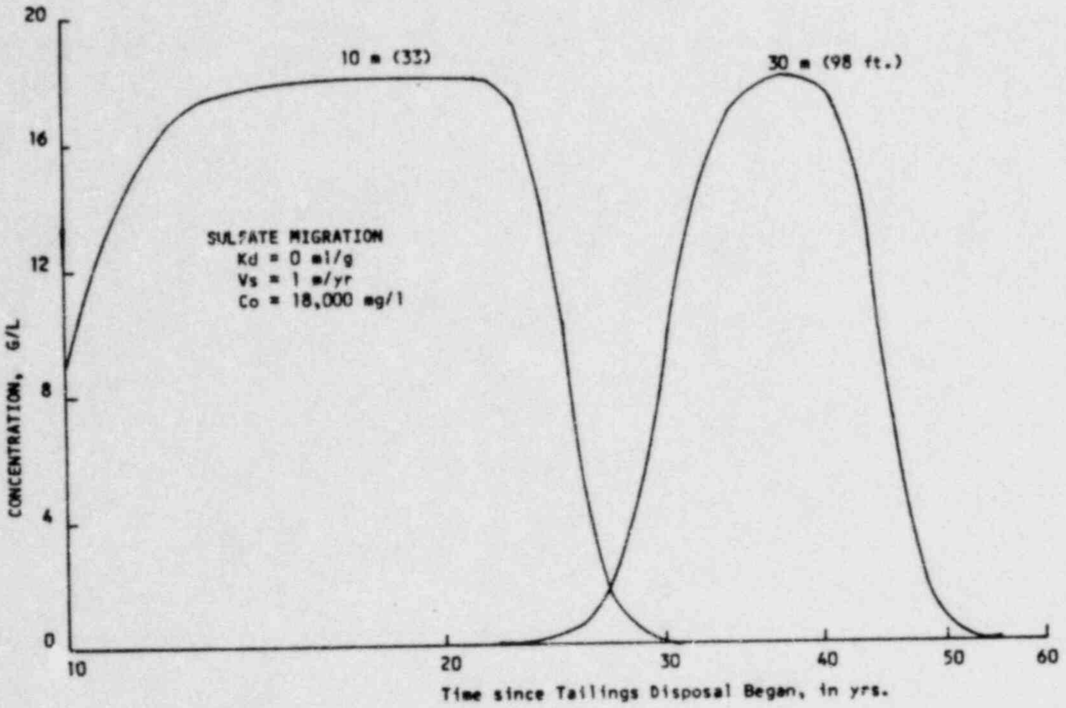

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FIGURE 4.3-16

SULFATE MIGRATION WITH TIME AT DISTANCES DOWN GRADIENT FROM SAND ROCK MILL TAILINGS DISPOSAL SITE for arsenic, selenium, and vanadium. Thorium -230 also is though to have a high Kd value and, thus, would be fixed within the first meter or so down gradient from the evaporation pond and tailings disposal site.

Other potential contaminants - Other constituents of the mill liquid effluent present in excessive quantities include aluminum, cadmium and copper.

Aluminum appears to be strongly adsorbed or precipitated as solution acidity decreases. Therefore, as the seeping solution neutralizes as a result of encountering calcium carbonate, aluminum concentrations should decrease significantly.

Copper is in the liquid effluent from the mill in approximately twice the mpc. This is not highly significant except for the relatively anomalous behavior exhibited. Copper appears to be strongly adsorbed by some rock samples, yet leached by others. Most of the rock samples which strongly adsorbed copper also neutralized the tailings solution to a pH near 6 or above. Therefore, copper compounds are either precipitating out of these lower acidities or are better able to compete for adsorption or exchange sites.

LONG-TERM SEEPAGE

After the life of the mill is complete (approximately 15 years), the solid tailings residue in the tailings evapoation pond will be scraped and redeposited in the in-pit disposal area of pit 35N. At this time a clay sealer will be placed over the tailings in pit 35N to prevent further seepage through and leaching from the deposited material.

In the evaporation pond area recharge to the subsoil and rock formations will be enhanced by the scraping and removal process. Even so, assuming little surface water inflow, recharge volumes will be small because precipitation is in the range of 20 to 30 centimeters (8 to 12 inches) per year, whereas evaporation is in the range of 100 centimeters (40 inches) per year.

The preceding ion migration analyses were made on the assumption that recharge without concentration will continue after cessation of mill tailings disposal. However, since actual recharge will be much less after the removal of the evaporation pond, the seepage rate will be much lower. Therefore, the time for a concentration of a constituent to reach a certain distance will be greater than the actual ion migration curves predicted (Figures 4.3-11 through 4.3-16).

APPENDIX 4A

IDENTIFICATION OF CONOCO ENVIRONMENTAL REPORT FIGURES AND TABLES USED IN SECTIONS 4.2.2 AND 4.3.3

FIGURE NUMBER	CONOCO FIG. NO.	TABLE NUMBER	CONOCO TABLE NO.
4.2-1	6.1-1	4.2.2.1	6.2-3
4.2-2	6.1-2	4.2.2.2	6.2-4
4.3-1	5.7-1	4.2.2.3	6.2-5
4.3-2	5.7-2	4.3.3.1	5.7-1
4.3-3	5.7-3	4.3.3.2	5.7-2
4.3-4	5.7-4	4.3.3.3	5-7-3
4.3-5	5.7-5	4.3.3.4	5.7-4
4.3-6	5.7-8	4.3.3.5	5.7-5
4.3-7	5.7-9	4.3.3.6	5.7-6
4.3-8	5.7-10		
4.3-9	5.7-11		
4.3-10	5.7-12		
4.3-11	5.7-13		
4.3-12	5.7-14		
4.3-13	5.7-15		
4.3-14	5.7-16		
4.3-15	5.7-17		
4.3-16	5.7-18		
4.3-17	***		

*** Figure 4.3-17 is the June, 1981 revision of Hydro-Engineering Figure 5.9.

APPENDIX F: GROUNDWATER IMPACT ANALYSES

Potential groundwater impacts were assessed using the flow and ion migration models described in Section 4.2.2.2. Conservative model parameter values were selected based on the aquifer data presented in Section 3.6.2. The resulting quantified impacts on groundwater flows and quality are discussed in Section 4.3.3.2.

4.6.3 WATER

Major impacts on surface waters will be 1) a temporary reduction in the Antelope Creek drainage area and 2) an increase in stream sediment load caused by surface disturbance. The extent of these impacts and Conoco's plans to minimize them are described in Section 4.2.2.

Groundwater impacts will be 1) 70 sand aquifer drawdown from mine dewatering, 2) 50-40 sand aquifer drawdowns from water supply pumping and 3) physical seepage and contaminant migration into the 70 sand from tailings storage. These effects are described and quantified in Section 4.3.3. The models used to predict seepage and ion migration are described in Section 4.2.2.