CHAPTER 6

GROUNDWATER HYDROLOGY

6.1 AQUIFER DELINEATION

The Navajo Mine is located on the western flank of the San Juan Structural Basin in northwestern San Juan County approximately 15 miles west of Farmington, New Mexico. The geologic formation dips gently to the east toward the center of the basin at an angle of one to two degrees and steepens toward the outcrop areas where a fairly abrupt monocline (Hogback) can be observed. A more thorough description of the regional and localized geology of Navajo Mine is provided in CHAPTER 5.

The mine and adjacent areas are underlain by the Pictured Cliffs Sandstone Formation, Fruitland-Kirtland Formation, and unconsolidated alluvial deposits in the valleys of the San Juan River, Chaco River, and the Chinde and Cottonwood Arroyos. A number of ground water monitoring wells have been completed (EXHIBIT 6-1) in the geologic formations on and near the permit area. These monitoring wells are described in the Billings & Associates (1989) report found in APPENDIX 6E. To obtain hydrologic information, a piezometer installation program was conducted throughout the mine area to estimate the water-bearing potential of the above geologic formations. Information on the water-bearing zones within these formations was obtained during drilling by monitoring fluid return, air injection pressure, and lithology.

Aquifers were delineated using two different methods. The first approach treated the individual coal seams in the Fruitland Formation as separate aquifers. This resulted in the potentiometric surface maps for the major coal seams (EXHIBITS 6-2 through 6-5). Since the coal seams are discontinuous through the formation, an alternate approach for delineation was considered which utilized United States Geological Survey (USGS) data and treated the coal seams and interbedded lithologic units of the Fruitland Formation as a single aquifer. The single aquifer approach was previously evaluated (Billings, 1987) A copy of the Billings (1987) report is located in APPENDIX 6D . Information from the ground water studies was used to prepare the potentiometric maps found in Appendix 6D, that were obtained from APPENDIX 6F (Special Condition 4A). Even though there is very little water present and transmissivities are low, the individual seams will be treated as separate aquifers in the quantity, and quality descriptions in this chapter.

The Pictured Cliffs Sandstone was found to be water bearing throughout most of the permit area. Selected lenticular coal-bearing strata of the Fruitland Formation were also found to be marginally wet within the permit area; these strata include: 1) the No. 8 seam, 2) the No. 7 seam, 3) the No. 4-6 seam, and 4) the No. 2-3 seam. Groundwater was only observed in the quaternary alluvial deposits within the stream channels of Chinde and Cottonwood Arroyos.

As shown on Exhibit 6-1, springs and seeps occur along upper Chinde Wash, above the lease boundary. The springs and seeps are due to NAPI irrigation return flows. Because there are several springs along this reach of Chinde Wash, individual springs have not been identified. Instead, a broad reach of stream where the springs occur has been delineated on EXHIBIT 6-1.

The source of water for the transient springs and seeps appear to be extensive irrigation activities upgradient of Chinde Wash. It is unknown to what extent these springs will continue to flow in the future, as Navajo Mine has no effect on or control of the water source of the springs. The saturation of the regolith (eolian sand) and spring occurrence represents a distinct change from baseline conditions. No springs in the regolith would have been present prior to NAPI activities, and Chinde Wash would not have been a perennial stream.

The springs are the result of excess, unused irrigation water migrating downward through a spatially extensive and permeable eolian sand that underlies much of the irrigated fields. When this water encounters the less permeable siltstones and shales of the underlying Fruitland Formations, it migrates laterally along a stratigraphic contact of unconsolidated eolian sand and bedrock. As Chinde Wash progressively downcuts through the eolian sand and into the underlying bedrock, the water migrating along this stratigraphic contact discharges into the wash.

The springs are limited to the area of this contact along the banks of the wash. Areas further away from the contact and downstream within the badland areas of the Chinde Wash no longer receives spring discharges.

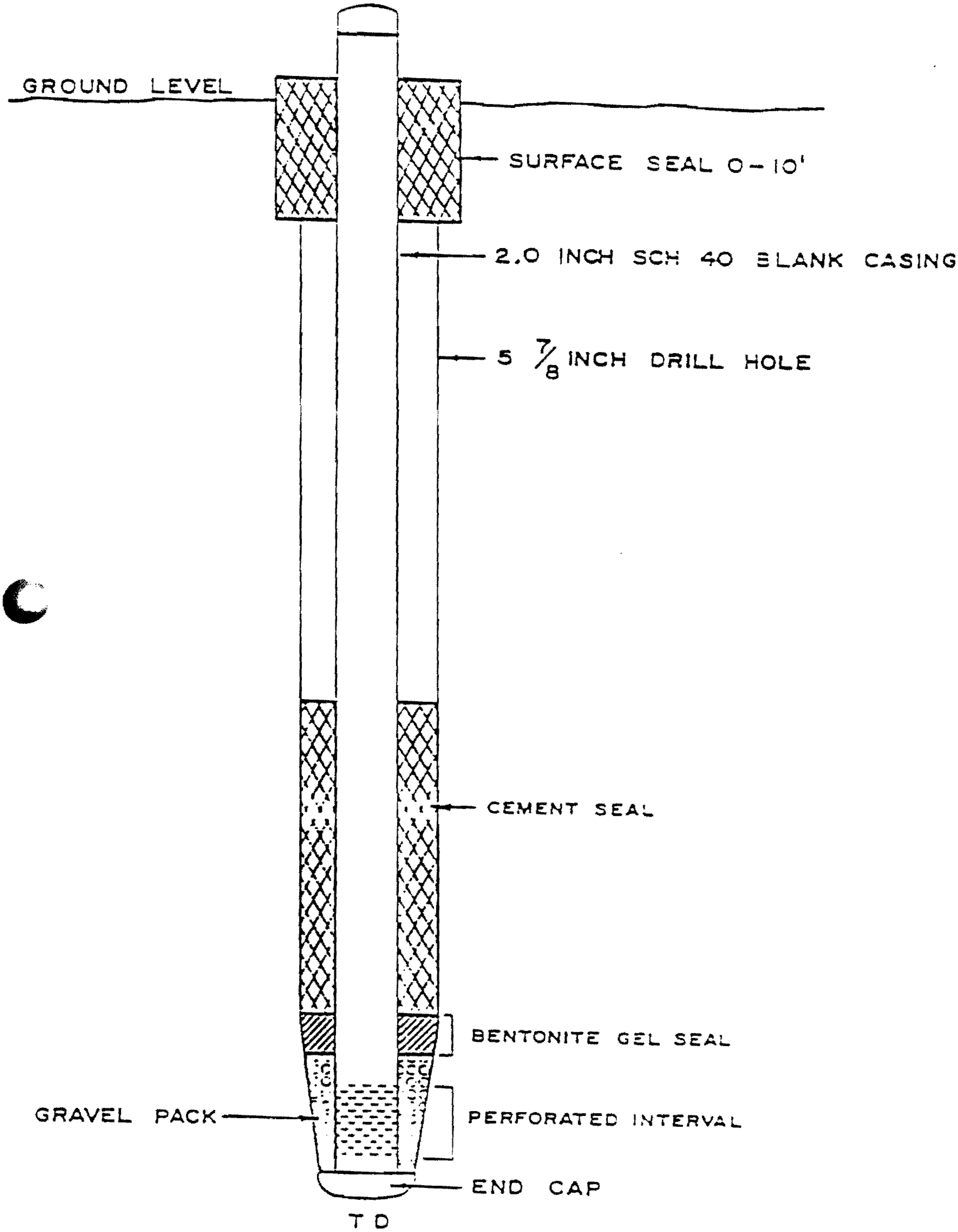
The quantity and quality of the spring discharges into Chinde Wash has not been characterized. However, Navajo Mine does collect a monthly grab sample from Chinde Wash surface water in the area of the springs (station CD-1A). The surface water at station CD-1A is a sodium sulfate water type. TDS ranges from 170 to 2240 mg/l. No seasonal correlation in the data is discernable. More detailed information on station CD-1A is available in the quarterly and annual reports.

6.2 GROUNDWATER QUANTITY

In order to obtain representative baseline data, piezometers were completed using a rotary drilling rig. Piezometers were completed using air rotary drilling techniques and no drilling mud or additives were used which might have contaminated the well bore. Borings were completed by screening the single appropriate water-bearing zone. A gravel pack, gel seal, and 15-pound cement mixture were used to complete the well to reduce the possibility of cross contamination between water-bearing zones or bore hole leakage. FIGURE 6-1 provides a schematic of a typical piezometer completion.

Copies of the well completion records are found in APPENDIX 6B. Upon completion, each piezometer was purged using an air lift pump to remove drill cuttings and debris from the casing and gravel pack. EXHIBIT 6-6 shows the location of piezometers installed during the 1983/1984 hydrologic study program.

Following piezometer completion and development, water levels were measured in each piezometer. Static water levels were recorded over a period of time will continue to be taken as part of the ground water monitoring program as outlined in Section 6.6 of this chapter.



COMPLETION DIAGRAM

FIGURE 6-1

Aquifer tests were conducted in 1984 on No. 8, No. 7, No. 4-6, and No. 2-3 Coal Seam piezometers and in 1998/1999 on the No. 3 Coals Seam piezometers. For the coal piezometers, two methods of testing were used to provide a representative transmissivity of each unit. The first method used was the Jacob Approximation of Theis (Jacob method) as presented by David and De Wiest (1966) for single bore hole recovery. The Jacob method is a semi-steady state analysis of recovery water levels versus dimension less time. Transmissivity is calculated based upon the relationship between residual drawdown time and the average discharge rate by:

$$T = \frac{2.3Q}{4\pi S}$$

where:		
	T	= transmissivity in ft^2/day
	Q	= Average discharge rate in ft^3/day
	S	= Residual drawdown over one log cycle in feet

The second method was an analysis of well recovery and discharge of the well bore as described by McWhorter (1980). This method is a modification of the standard recovery theory that accounts for the effects of afterflow after pumping has ceased. Transmissivity values calculated using the Jacob method could produce inconsistent and unreliable results due to this effect and result in errors in interpretation of the data plot. The McWhorter method avoids this problem by defining transmissivity as follows:

$$T = \frac{1}{4\pi \; x \; S_n} \; x \; Q_o \; x \; \ln\left\{\frac{t_n}{t_n - t_i}\right\} x \; n - 1 \; x \; Q_1 \; x \; \ln\left\{\frac{t_n - t_i - 1}{t_n - t_i}\right\}$$

$$T = \frac{1}{4}; i = 1$$

where:

T	= Transmissivity in ft^2/day
S_n	= Drawdown at final time
Q_o	= Well discharged at ft^3/day
t_n	= Time in minutes
t_o	= Time at beginning of recovery
Q_i	= Incremental discharge to well given by:

$$Q_i = r_o^2 \frac{(S_{i-1} - S_i)}{(t_i - t_{i-1})}$$

r_o	= Diameter of well casing (feet)
s_i	= Drawdown at (t_i) in feet
t_i	= Time in minutes

6.2.1 Pictured Cliffs Sandstone

The Pictured Cliffs Sandstone was found to be nearly 120 feet thick in the mine and adjacent areas. The formation strikes generally north-south and dips to the east and southeast from one to two degrees. The sandstone is a well cemented marine sand and does not exhibit significant primary permeability, although secondary permeability is prevalent due to small scale fracturing. Aquifer tests performed on piezometers located in the Pictured Cliffs (Wells GM-30; T4-1) by Science Application, Inc. (SAI) (1979) yields an average transmissivity of 0.13 ft^2/day for both slug and recovery tests. FIGURES 6-2 and 6-3 provide data analysis and results for each of these tests. The average permeability and storage coefficients for this formation were determined to be 0.0015 ft/day and 3.4 X 10^{-4}, respectively. These values are consistent with aquifer tests performed on the Pictured Cliffs at other locations near the Navajo Mine area (San Juan Coal Company, 1982; San Juan Coal Company, 1983).

6.2.2 Fruitland Coal Seams

Water Level elevations, vertical head difference, and the potentiometric surface maps for the four water-bearing coal seams were developed from field data and are presented in FIGURES 6-4 through 6-7 and EXHIBITS 6-2 through 6-5. When the coal seams are combined with the rest of the Fruitland formation and treated as a single aquifer, a potentiometric map can be drawn which more clearly shows the regional potentiometric surface.

TEXT CONTINUED ON PAGE 6-14

SLU[illegible] [illegible]EST
WELL GM30
V = 10 gal.

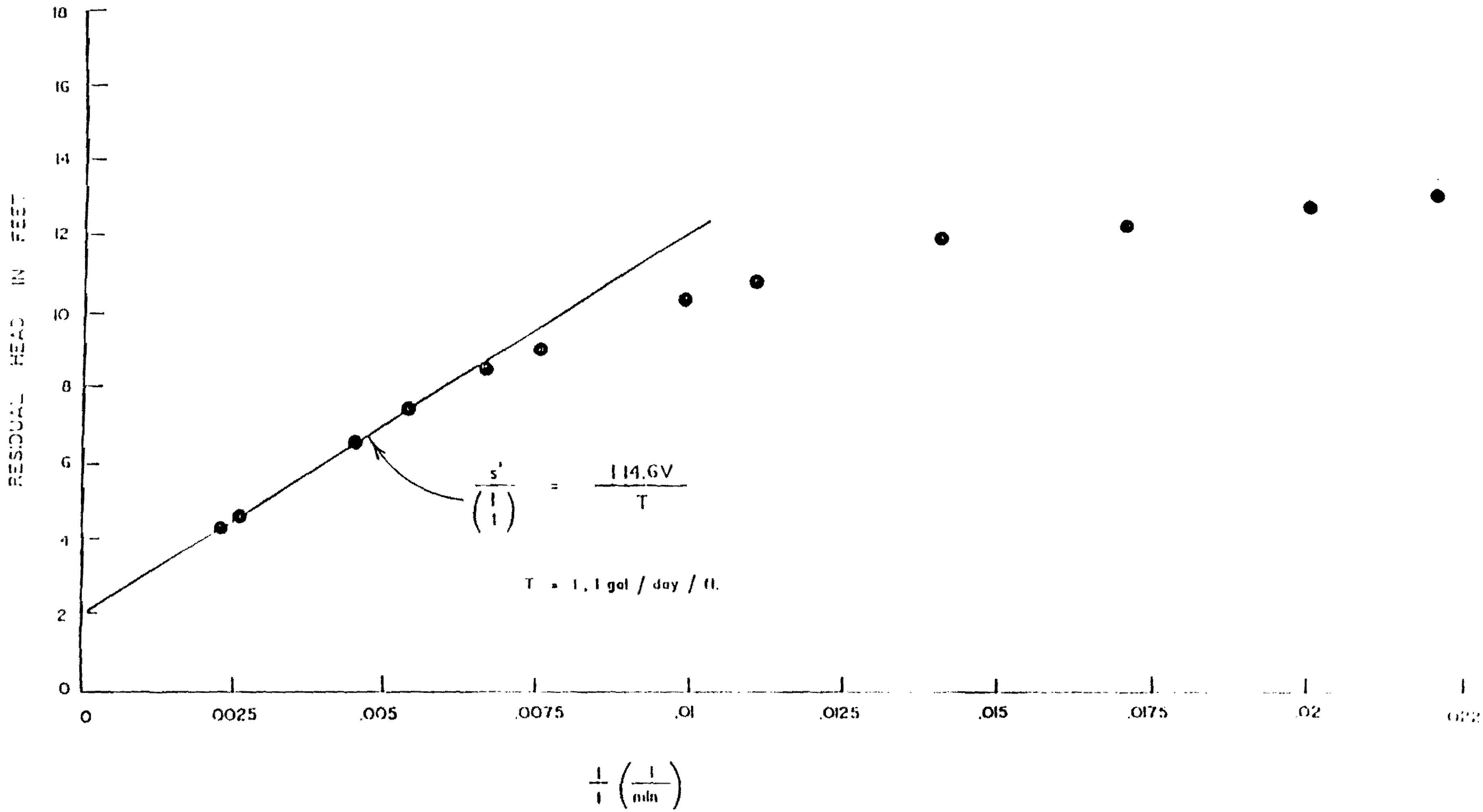
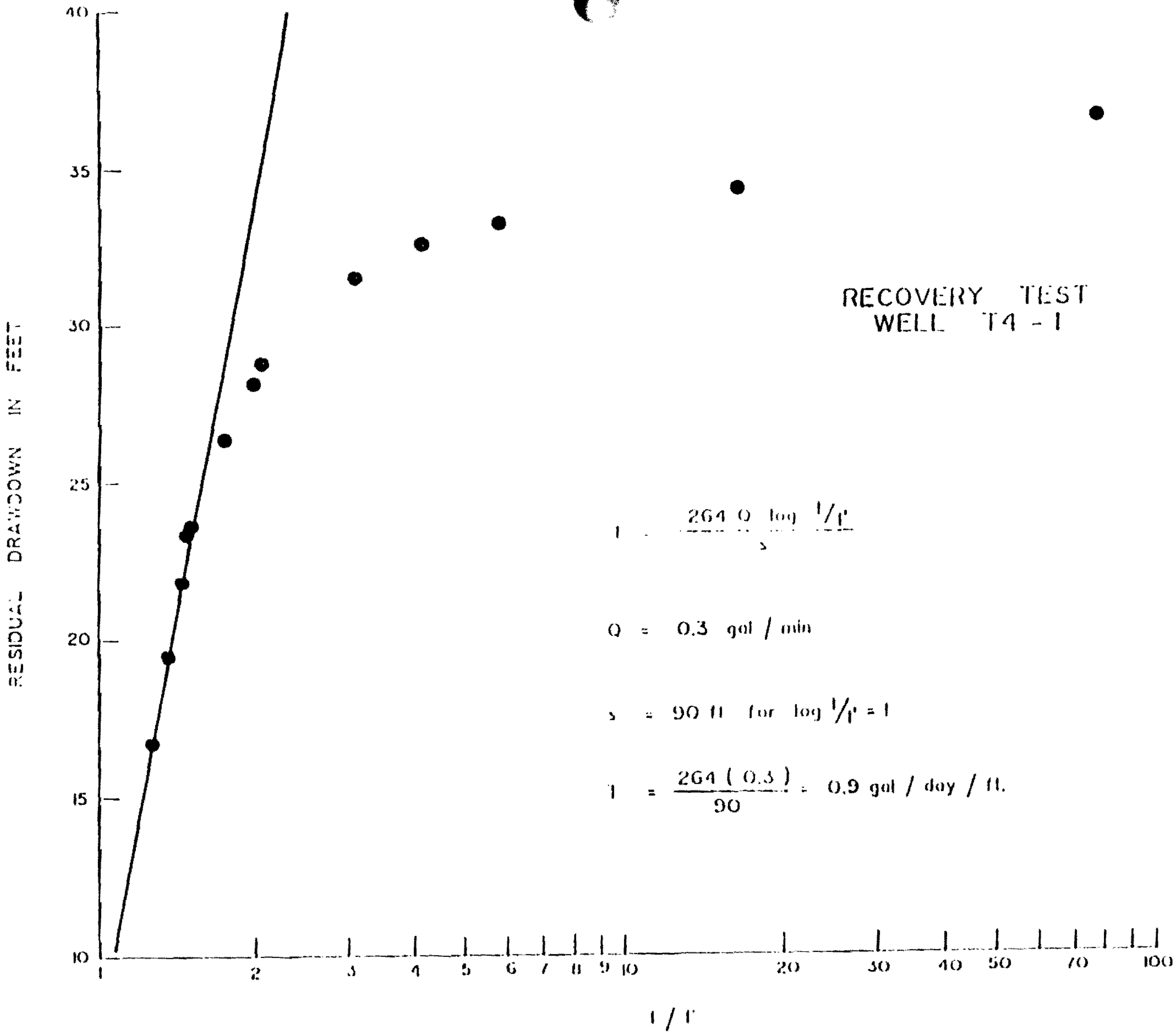
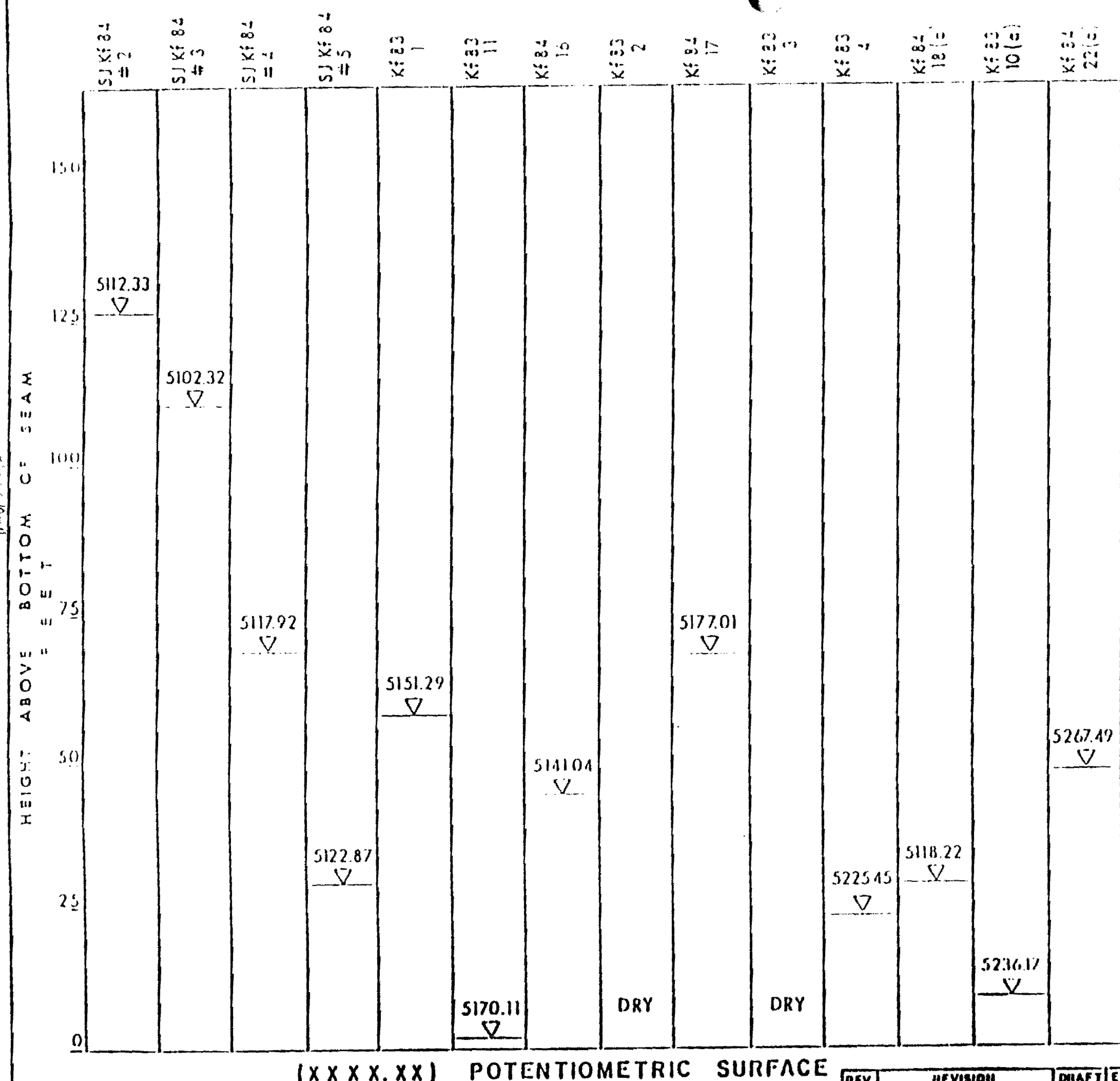


FIGURE 6-2



(PICTURED CLIFFS SANDSTONE)

FIGURE 6-3



BHP MINERALS INTERNATIONAL INC.

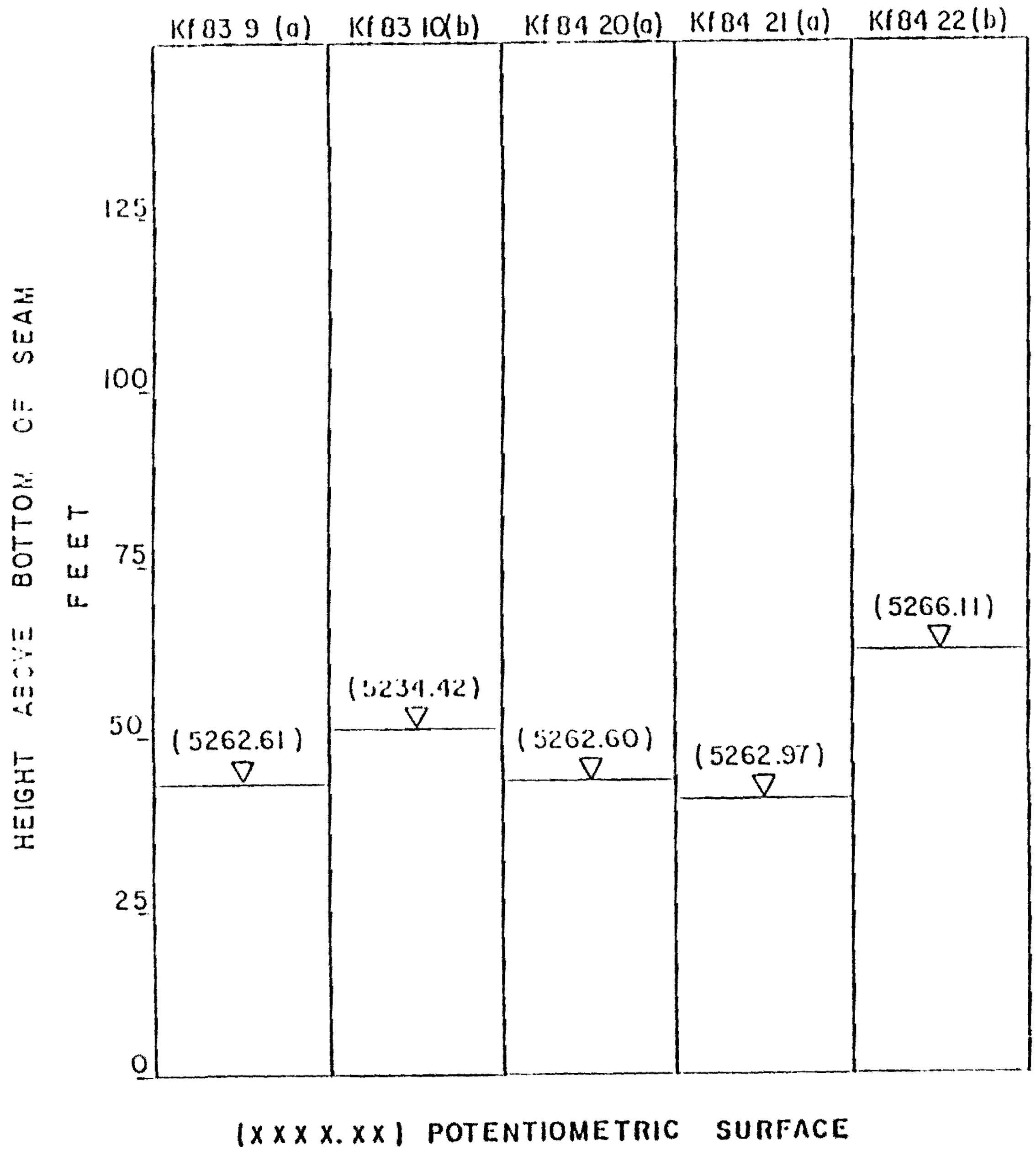
NAVAJO MINE

FRUITLAND, NEW MEXICO

VERTICAL HEAD–
NO. 8 SEAM

REV.	REVISION	DRAFT	ENGR
1	REVISION BLOCK REMOVED CONFIDENTIAL STATEMENT, MOVED FIGURE NO. TO TITLE BLOCK.	GGA	[illegible]

DRAWN BY J.GOLBE	SCALE NONE	FIGURE [illegible]
APPROVED BY	DATE 11-14-84	
DRAWING NO. 80-2000-04	LOCATION NO	



BHP MINERALS INTERNATIONAL INC.

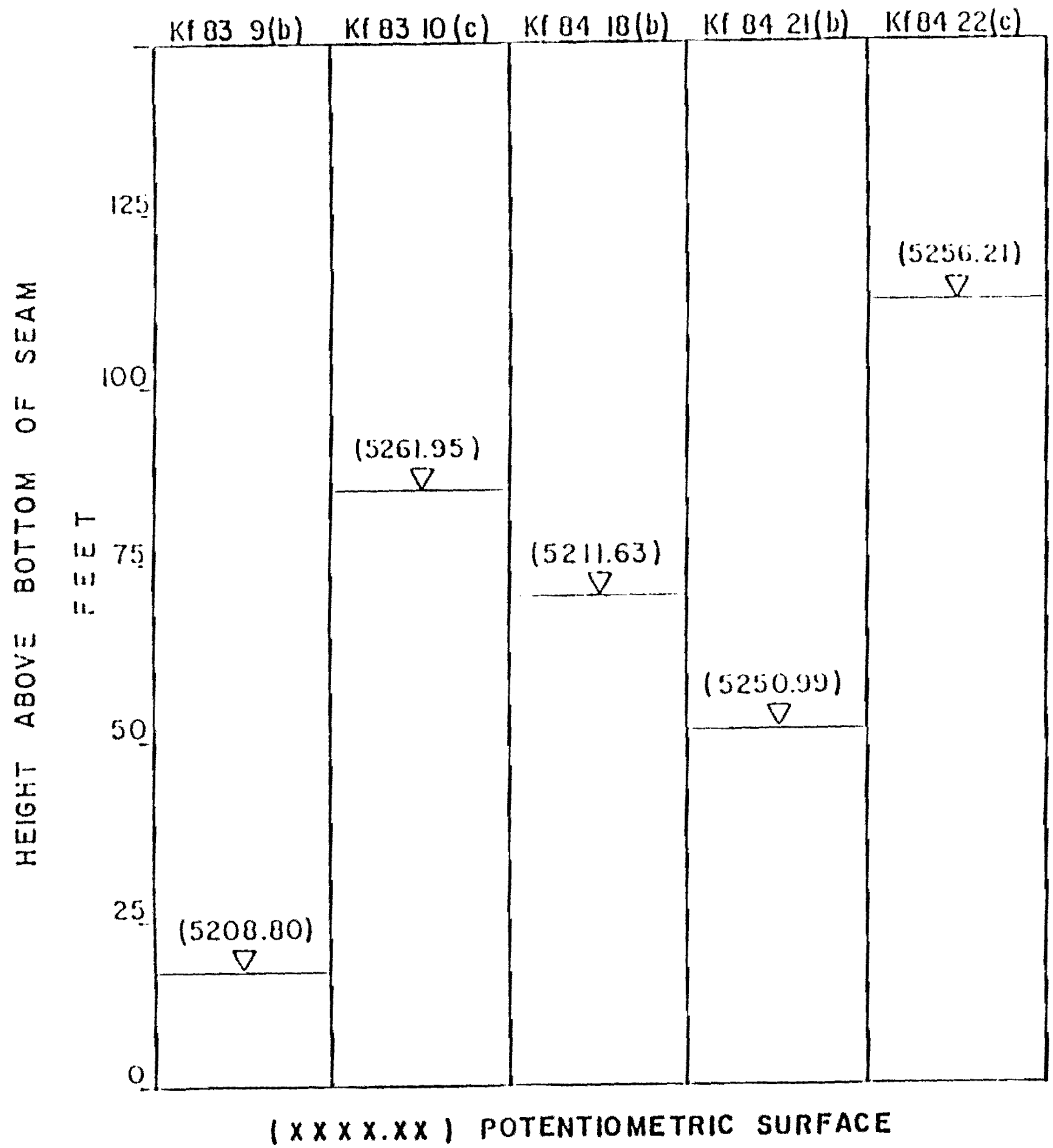
NAVAJO MINE

FRUITLAND, NEW MEXICO

VERTICAL HEAD-
NO. 7 SEAM

REV.	DATE	REVISION	DRAFT	ENGR
1	6-4-8	REVISION BLOCK, REMOVED CONFIDENTIAL STATEMENT, MOV-ED FIGURE NO. TO TITLE BLOCK.	GGA	[illegible]

DRAWN BY J. GOLBE	SCALE NONE	FIGURE 6
APPROVED BY	DATE 11-14-84	
DRAWING NO. 80-2000-03	LOCATION NO	



BHP MINERALS INTERNATIONAL INC.

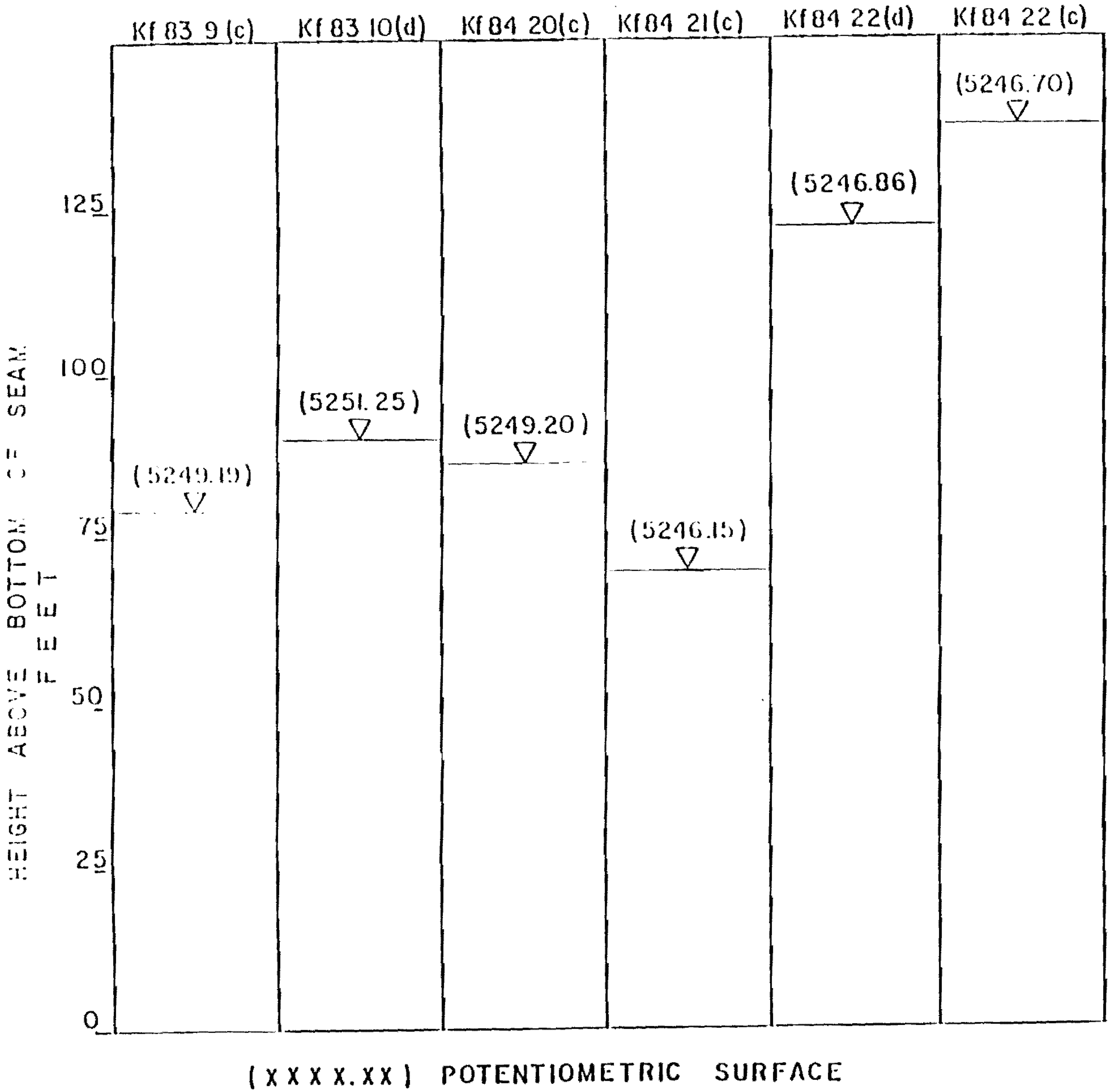
NAVAJO MINE

FRUITLAND, NEW MEXICO

VERTICAL HEAD– NO.4 – NO. 6 SEAMS

REV	DATE	REVISION	DRAFT	ENGR.
1	[illegible]	PUT REVISION BLOCK ON REMOVED CONFIDENTIAL STATEMENT MOVED FIGURE NO. TO TITLE BLOCK.	GGA	[illegible]

DRAWN BY J. GOLBE	SCALE NONE	FIGURE 6–6
APPROVED BY	DATE 11-14-84	
DRAWING NO. 80-2000-02	LOCATION NO	



BHP MINERALS INTERNATIONAL INC.

NAVAJO MINE

FRUITLAND, NEW MEXICO

VERTICAL HEAD –
NO. 2 – NO. 3 SEAMS

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DRAWN BY J. GOLBE	SCALE NONE	FIGURE 6-7
APPROVED BY	DATE 11-14-84	
DRAWING NO. 80-2000-01	LOCATION NO	

As seen on EXHIBITS 6-2 through 6-5, flow direction for the Fruitland Coal Seams is basically toward the east, with fluctuations near recharge/discharge areas (see APPENDIX 6D for report). Information used to support APPENDIX 6D are referenced in APPENDIX 6F. Flow gradients range from 0.001 to 0.02 ft/ft with steeper gradients observed in apparent discharge areas, (e.g., San Juan River).

Potential recharge areas include outcrop locations to the north and south along the subcrop and outcrops in stream channels. Discharge occurs at the contact with the San Juan River alluvium. Since the entire area has been disturbed by mining activities, it is impossible to obtain pre-mining or undisturbed data. However, from the potentiometric surface maps, it can be deduced that the pre-miming condition in the disturbed area was similar to conditions of areas to the east.

The analysis of the aquifer testing conducted on the coal seams of the Fruitland Formation assumes that water flow to the well bore is horizontal and aquifer transmissivities are the same in all directions (isotropic conditions). Coal is not isotropic since there is preferential permeability due to fractures and flow often along vertical as well as horizontal streamlines. However, the assumption is not invalidated because the coal is consistently cleated and fractured. Therefore, the transmissivities calculated are indicative of the overall characteristics of the coal. Transmissivities, permeability and other discharge characteristics, along with piezometer information; are presented in TABLE 6-1.

TABLE 6.1 AQUIFER DISCHARGE CHARACTERISTICS

Revised 5/2/85

Well Name	Location	Casing I.D.	Total Depth Elev.	Total Depth Depth	type Test	Transmissivity	Permeability	Saturated thickness	Formation*	Remarks
SJKF84#3	N 2089324.18	2.0 in.	4990.18	120	(1)	1.42 ft2/d	0.08 ft/d	18.0 ft	No.8	Q=1 gpm; VCW=18.06 gal
	E 3355493.72				(2)	0.71 ft2/d	0.04 ft/d			Secondary Permeability
SJKF84#4	N 2086566.75	2.0 in.	5046.67	71	(1)	1.45 ft2/d	0.08 ft/d	18.0 ft	No. 8	Q=0.3 gpm; VCW=11.77 gal
	E 333233.40				(2)	1.03 ft2/d	0.06 ft/d			Secondary Permeability
SJKF 84#5	N 2084412.50	2.0 in.	5092	180	(1)	2.08 ft2/d	0.12 ft/d	18.0 ft	No. 8	Q=0.1 gpm; VCW=5.52 gal
	E 331410.00				(2)	0.07 ft2/d	0.004ft/d			Secondary Permeability
KF8420(d)	N 2017120.64	2.0 in.	5213.92	190	(1)	1.28 ft2/d	0.26 ft/d	5.0 ft	No. 7	Q=0.2 gpm; VCW=8.10 gal
	E 304307.65				(2)	0.01 ft2/d	0.002 ft/d			Secondary Permeability
KF8420(a)	N 2017128.35	2.0 in.	5163.78	240	(1)	0.12 ft2/d	0.012ft/d	10.0 ft	No. 2	Q=0.2 gpm; VCW=13.9 gal
	E 304306.50				(2)	0.009 ft2/d	0.001 ft/d			Secondary Permeability
KF8421(c)	N 2012188.62	2.0 in.	5219.66	75	(1)	9.08 ft2/d	1.82 ft/d	5.0 ft	No. 7	Q=0.5 gpm; VCW=6.12 gal
	E 302693.56				(2)	0.04 ft2/d	0.008 ft/d			Secondary Permeability
KF8422(b)	N 2009513.79	2.0 in.	5204.1	140	(1)	0.76 ft2/d	0.152 ft/d	5.0 ft	No. 7	Q= 0.13 gpm; VCW=9.94 gal
	E 307829.36				(2)	0.02 ft2/d	0.003 ft/d			Secondary Permeability
KF8422(c)	N 2009528.55	2.0 in.	5142.5	202	(1)	0.04 ft2/d	0.006 ft/d	7.0 ft	No. 4-6	Q=0.03 gpm; VCW=18.37 gal
	E 307841.20				(2)	0.01 ft2/d	0.0014 ft/d			Secondary Permeability
KF8422(d)	N 2009525.42	2.0 in.	5124.2	220	(1)	0.71 ft2/d	0.14 ft/d	5.0 ft	No. 3	Q=0.17 gpm; VCW=19.82 gpm
	E 307832.96				(2)	0.01ft2/d	0.002 ft/d			Secondary Permeablity
KF8422(e)	N 2009531.93	2.0 in.	5107.8	237	(1)	0.15 ft2/d	0.015 ft/d	10.0 ft	No. 2	Q=0.08; VCW=22.65 gal
	E 307820.38				(2)	0.01 ft2/d	0.001 ft/d			Secondary Permeability

* Fruitland (KF) Formation
(1) Standard Recovery
(2) Modified Recovery

\123r4fil\permits\c06_T6_1.WK3

Aquifer testing, as described previously, indicated extremely low transmissivity and permeability values. This situation is typical of other low yield systems in northwestern New Mexico. In some cases, the test well dewatered completely within a matter of minutes and recovery took place over several days. (e.g., KF84-22 (e)). Permeability and transmissivity values appear to be random over the permit area with no significant trends based on aquifer thickness or location.

6.2.2.1 No. 8 Coal Seam

For the No. 8 Seam, a mean transmissivity and permeability of 1.13 ft^2/day and 0.06 ft/day, respectively, were calculated for the mine area. FIGURES 6-8 through 6-10 provide the method of calculation of the aquifer characteristics of the No. 8 Coal Seam. EXHIBIT 6-2 shows the potentiometric surface of the No. 8 Coal seam. Flow gradients range from 0.007ft/ft to 0.01ft/ft and flow velocities range from 1.12×10^{-2} ft/day. Flow is generally toward the east or downdip with discharge at the San Juan River and Cottonwood Arroyo subcrop areas.

6.2.2.2 No.7 Coal Seam

The No.7 Coal Seam has an average thickness of about five feet. The coal seam outcrops to the west of the permit area and extends from beyond Area III to the middle of Area II where it thins to less than one foot and eventually pinches out entirely. The No. 7 Coal Seam exhibits mean transmissivity and permeability values of 1.87 ft^2/day and 0.37 ft/day, respectively. FIGURES 6-11 through 6-13 provide the method of calculation and analysis of the No. 7 seam. EXHIBIT 6-3 shows the potentiometric surface of the No. 7 Coal Seam and indicates that the water table within it is essentially flat with no observable flow gradient. North of Area III, the No. 7 Seam was found to be dry in all exploratory drill holes within the permit area. The probable reason for this occurrence is that the No. 7 outcrop is above all potential recharge areas.

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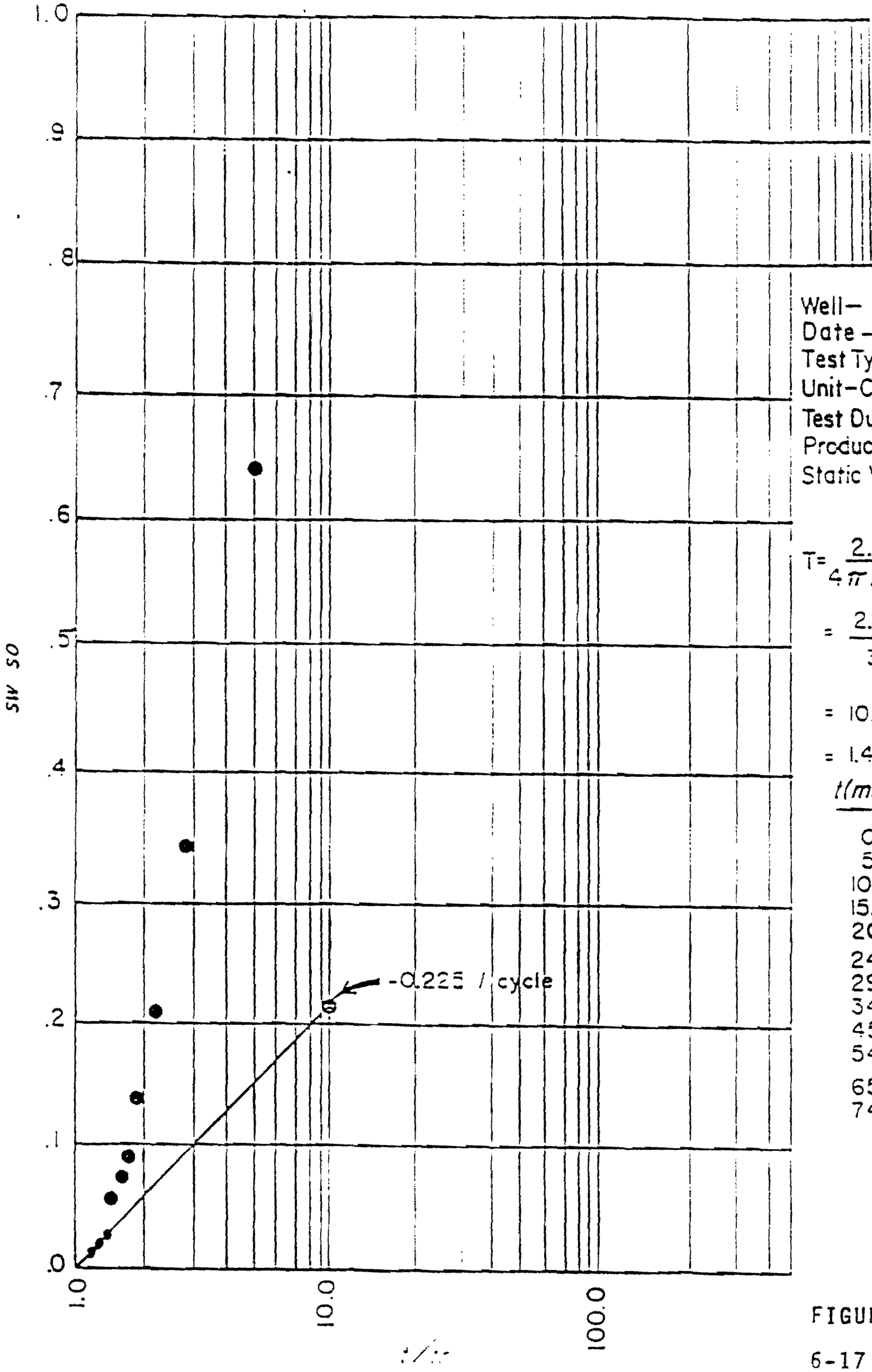


Well— SJKF 84 - 3
Date — 01 - 24 - 85
Test Type—Air life - Recovery
Unit—Coal Seam 8
Test Duration— 94.25 min.
Production— 1440.0 gpd
Static Water Level 9.32 ft.

$$T = \frac{2.30\,Q}{4\pi \Delta S}$$

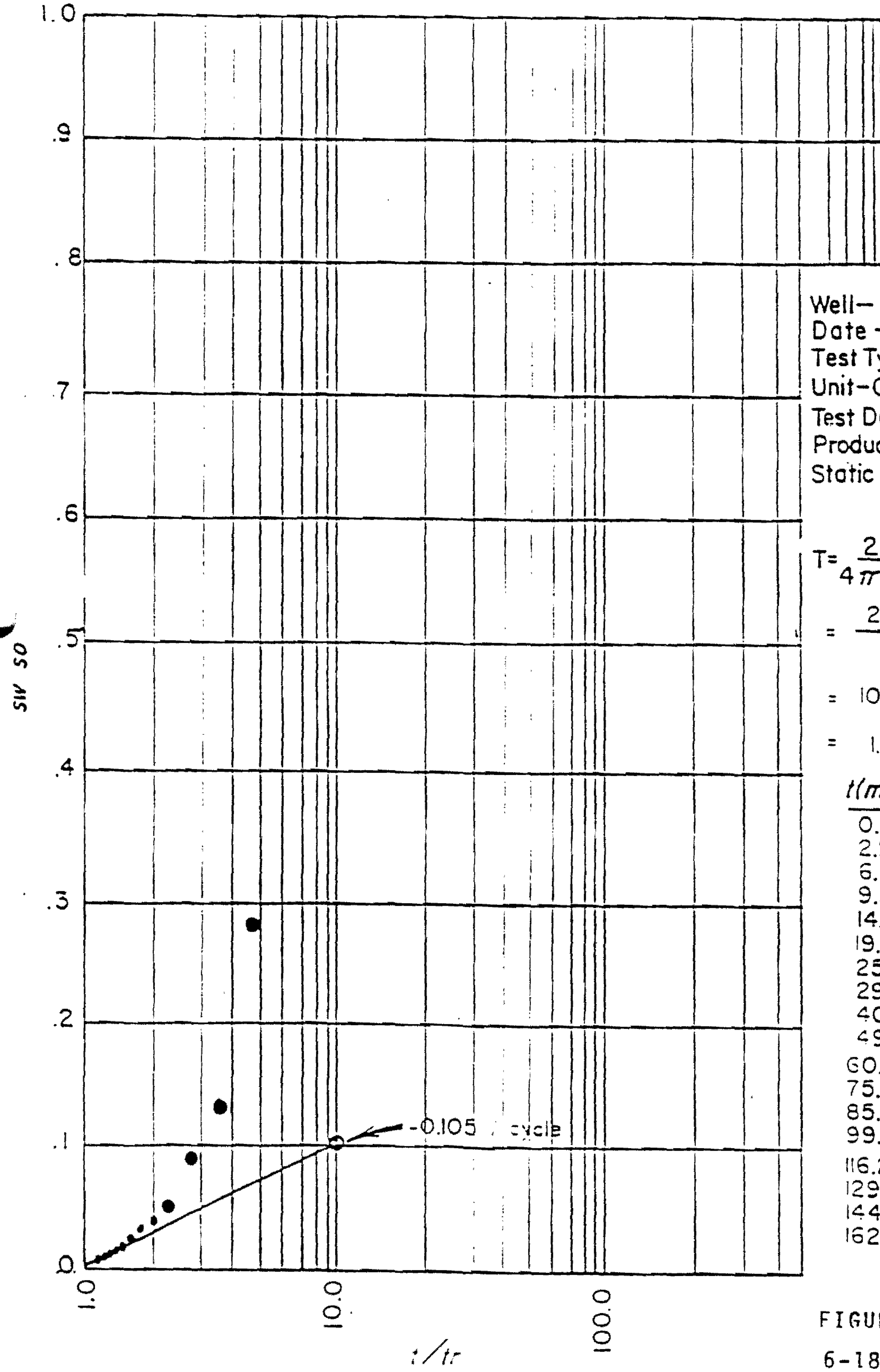
$$= \frac{2.30(1440)}{312.88}$$

= 10.59 gpd / ft

= 1.42 ft^2/ d

t(min.)	s(ft)	s'(ft.)
0.00	120.00	110.66
5.00	79.16	69.82
10.58	45.94	36.60
15.25	33.83	24.49
20.33	24.34	15.00
24.58	19.73	10.39
29.75	17.09	7.75
34.25	15.59	6.25
45.00	14.07	4.73
54.58	13.19	3.85
65.08	12.76	3.42
74.25	12.47	3.13

FIGURE 6-8



Well– SJKF 84 - 4
Date – 01 - 23 - 84
Test Type–Air life-Recovery
Unit–Coal Seam 8
Test Duration– 187.75 min.
Production– 432 gpd
Static Water Level 1.65 ft.

$$T = \frac{2.30\,Q}{4\pi \Delta S}$$

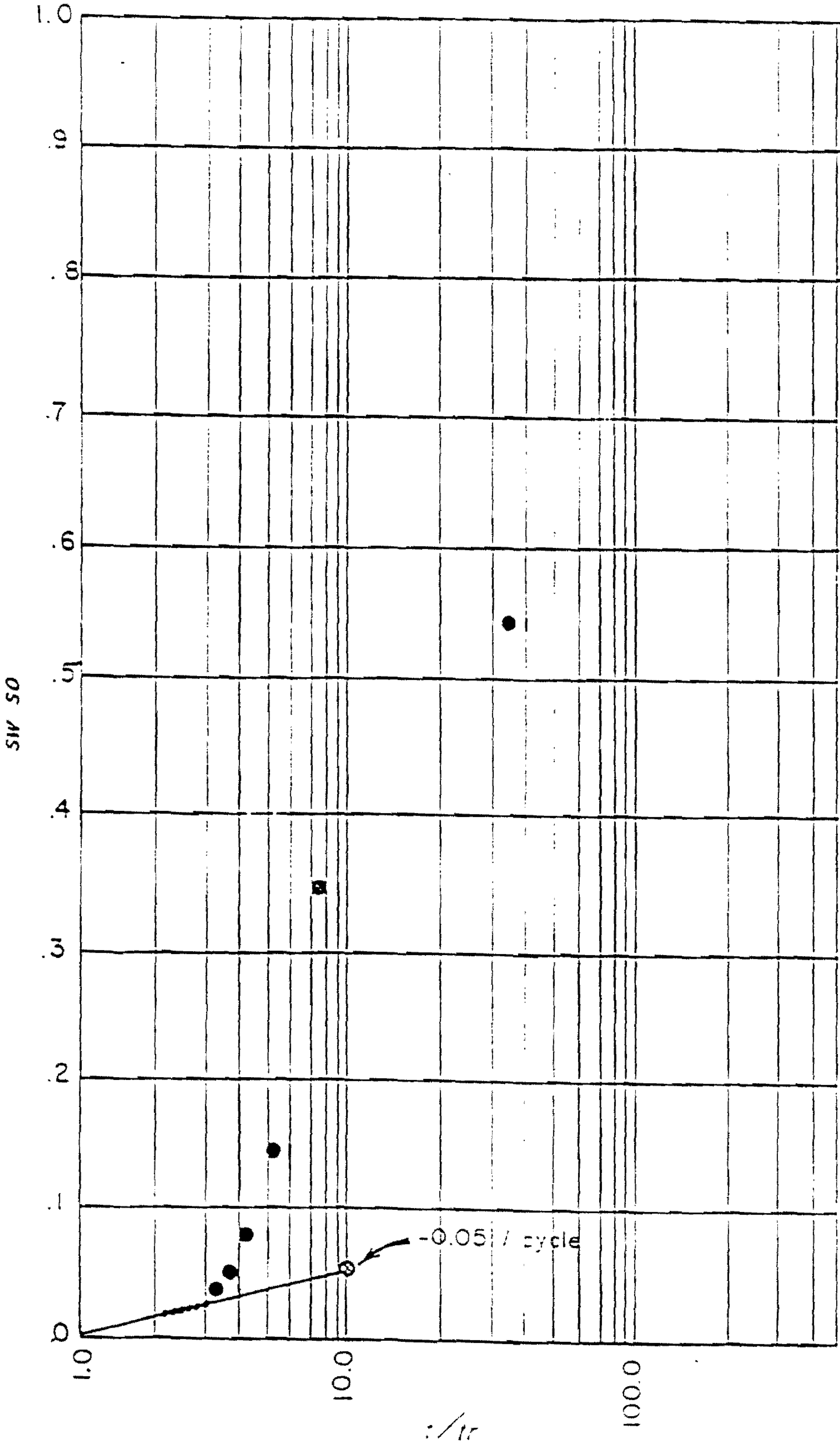
$$= \frac{2.30(432)}{91.51}$$

$= 10.86$ gpd / ft

$= 1.45\ ft^2 / d$

t(min.)	s(ft)	s'(ft)
0.00	71.00	69.35
2.25	53.28	51.63
6.75	21.85	20.20
9.50	10.59	8.94
14.58	7.53	5.88
19.25	4.85	3.20
25.33	4.42	2.77
29.50	4.07	2.42
40.42	3.57	1.92
49.92	3.28	1.63
60.00	3.03	1.38
75.33	2.84	1.19
85.75	2.67	1.02
99.58	2.52	0.87
116.25	2.41	0.76
129.33	2.34	0.69
144.58	2.23	0.58
162.75	2.13	0.48

FIGURE 6-9



Well— SJKF 84 - 5
Date—01 - 24 - 85
Test Type—Air life-Recovery
Unit—Coal Seam 8
Test Duration— 124.75 min.
Production— 144.0 gpd
Static Water Level 146.12 ft.

$$T = \frac{2.30\,Q}{4\pi \Delta S}$$

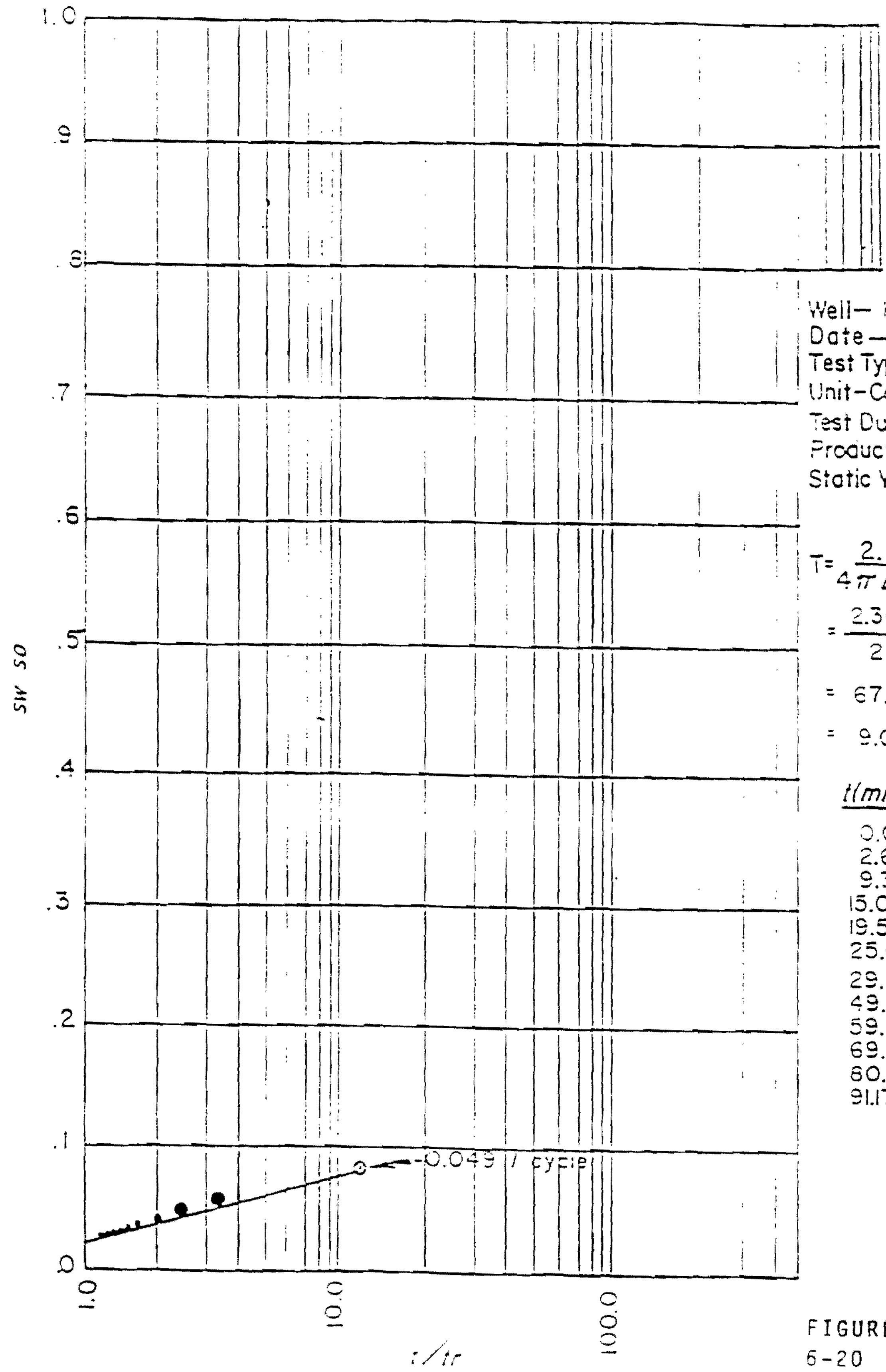
$$= \frac{2.30(144)}{21.24}$$

$= 15.59$ gpd/ft

$= 2.08$ ft^2/d

t(min.)	*s(ft.)*	*s'(ft.)*
0.00	180.00	33.88
2.08	164.31	18.19
10.50	157.26	11.14
15.25	151.05	4.92
19.58	148.67	2.65
24.50	147.60	1.48
29.67	147.16	1.04
34.67	146.95	0.83
39.42	146.80	0.68
44.67	146.78	0.66
49.75	146.70	0.58
54.50	146.63	0.51
59.75	146.61	0.49

FIGURE 6-10



Well— KF 84 - 21 (c)
Date — 01 - 21 - 85
Test Type—Air life-Recovery
Unit-Coal Seam 7
Test Duration— 111.67 min.
Production— 720 gpd
Static Water Level 36.02 ft.

$$T = \frac{2.30\,Q}{4\pi \Delta S}$$

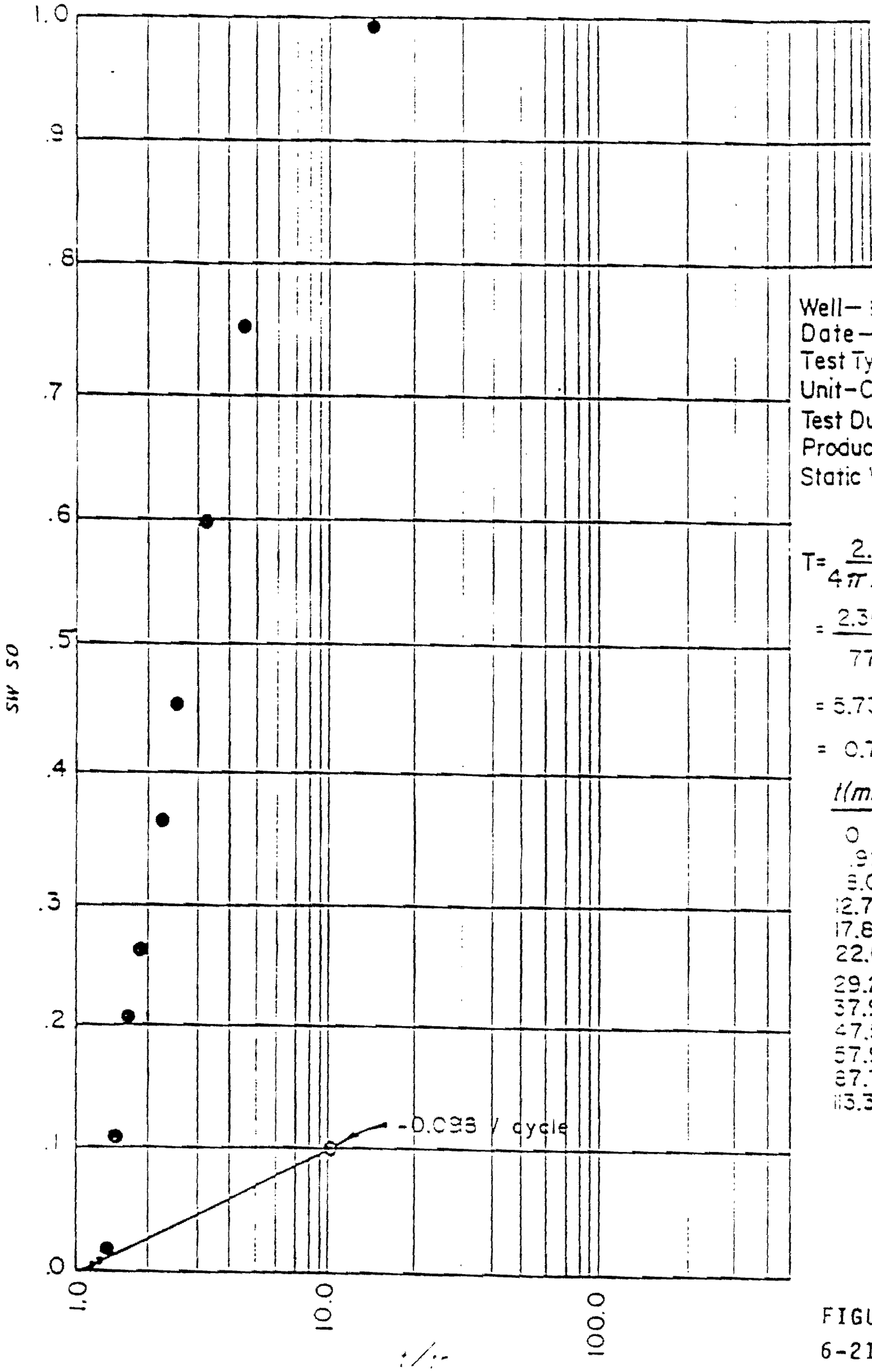
$$= \frac{2.30(720)}{24.37}$$

$= 67.95$ gpd/ft

$= 9.08\ ft^2/d$

t(min.)	s(ft.)	s'(ft.)
0.00	75.00	38.98
2.67	52.33	16.31
9.33	38.12	2.10
15.00	37.97	1.95
19.50	37.74	1.72
25.08	37.59	1.57
29.97	37.52	1.50
49.53	37.37	1.35
59.72	37.26	1.24
69.58	37.23	1.21
80.25	37.21	1.19
91.17	37.20	1.18
	37.16	1.14

FIGURE 6-11



Well— KF 84 - 22 (b)
Date— 11 - 14 - 84
Test Type—Air life-Recovery
Unit—Coal Seam 7
Test Duration— 140.33
Production— 192 gpd
Static Water Level 79.06

$$T = \frac{2.30\,Q}{4\pi \Delta S}$$

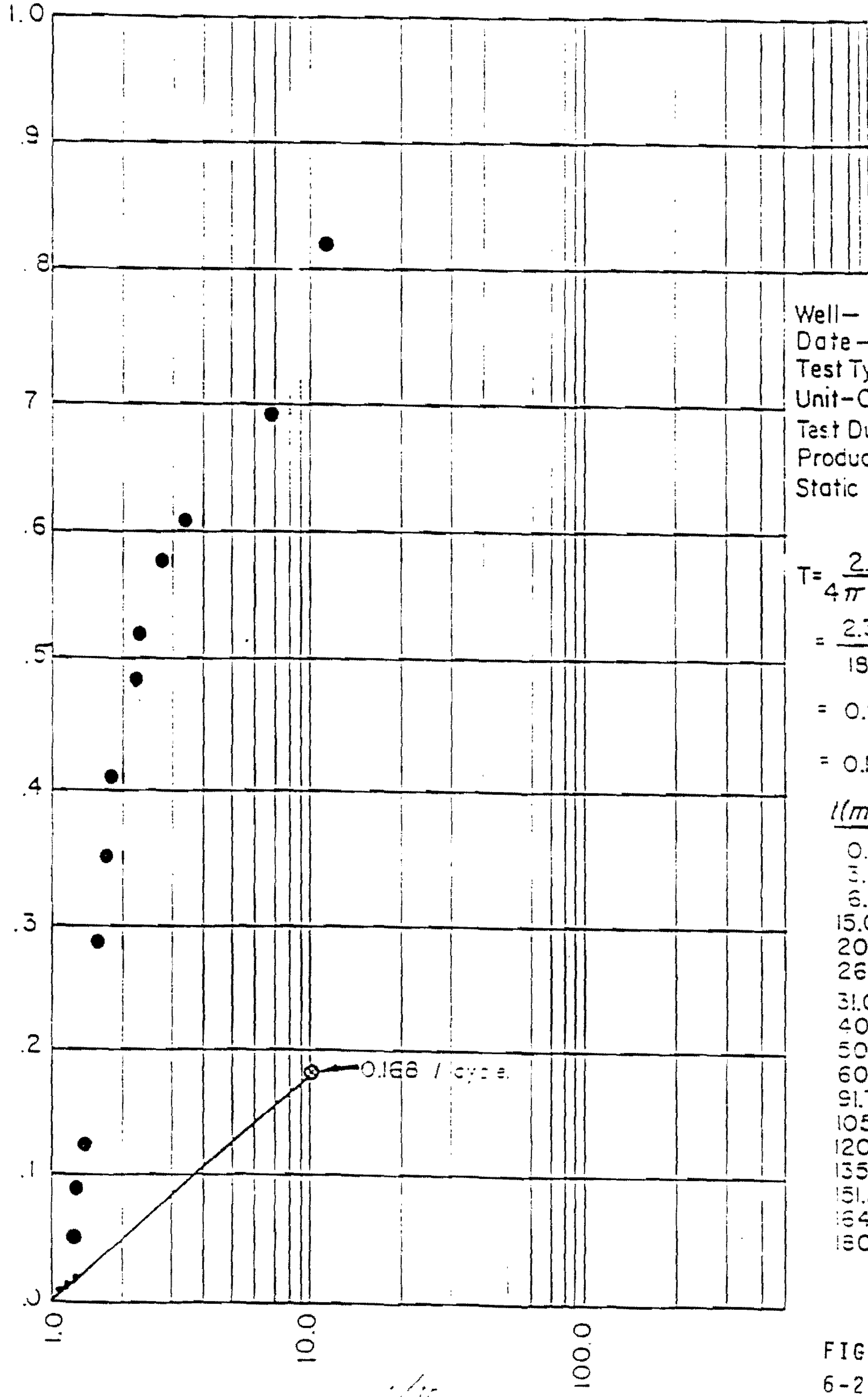
$$= \frac{2.30(192)}{77.10}$$

$= 5.73$ gpd/ft

$= 0.76\ ft^2/d$

t(min.)	s(ft.)	s'(ft.)
0	141.67	62.61
.92	140.53	61.47
3.08	128.03	48.97
12.75	116.64	37.58
17.83	108.26	29.20
22.67	101.63	22.57
29.25	95.49	16.43
37.92	91.98	12.92
47.58	86.41	7.35
57.92	81.24	2.18
87.75	79.53	0.47
113.33	79.13	0.07

FIGURE 6-12



Well— KF 84 - 20 (a)
Date — 01 - 22 - 85
Test Type—Air life-Recovery
Unit—Coal Seam 2
Test Duration— 215.08 min.
Production— 72 gpd
Static Water Level 154 ft.

$$T = \frac{2.30\,Q}{4\pi \Delta S}$$

$$= \frac{2.30(72)}{180.33}$$

$= 0.91$ gpd / d

$= 0.12$ ft^2 / d

t(min.)	s(ft)	s'(ft.)
0.00	240.00	85.43
3.50	224.41	69.84
6.17	213.31	58.74
15.00	207.92	53.35
20.17	204.01	49.44
26.15	199.80	45.23
31.08	196.74	42.17
40.50	189.98	35.41
50.17	184.22	29.65
60.00	178.57	24.00
91.75	166.19	11.62
105.08	162.49	7.92
120.58	159.40	4.83
135.75	157.89	3.32
151.58	156.18	1.61
164.75	155.20	0.63
180.08	154.85	0.28

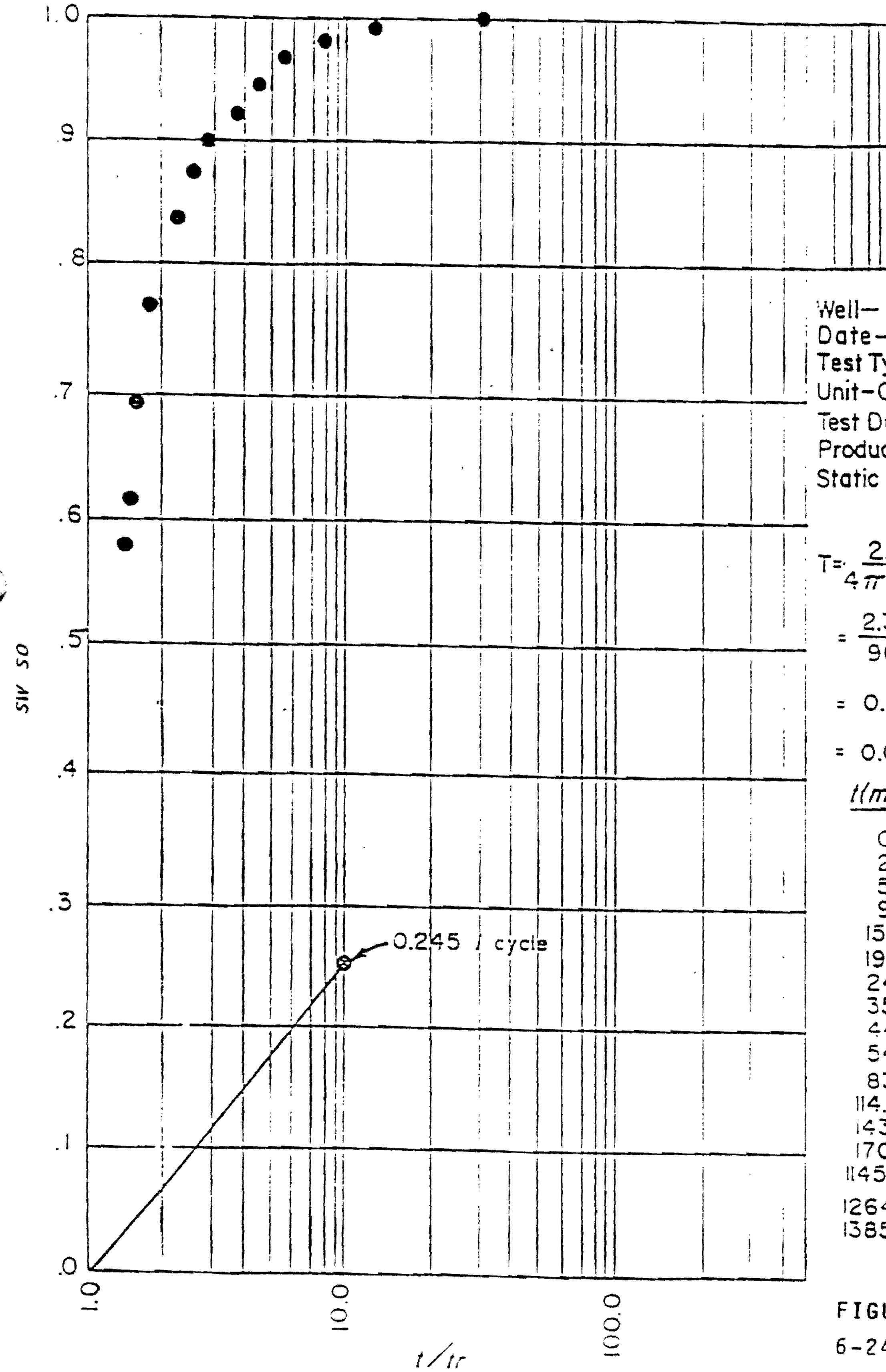
FIGURE 6-13

6.2.2.3 No. 4-6 Coal Seam

As was the case for the No. 7 Seam, the No. 4-6 Coal Seam extends from Area III to the south, and northward to just south of the North Area (Area I) where it thins out completely. FIGURE 6-14 shows the results of aquifer testing on the No. 4-6 Coal Seam. The No. 4-6 Coal Seam has an average thickness of seven feet and outcrops to the west of the permit area. No. 4-6 Coal Seam, as with the other coal strata, exhibits extremely low levels of transmissivity and permeability with values of 0.025 ft^2/day and 0.0037 ft/day, respectively. EXHIBIT 6-4 shows the potentiometric surface of the No. 4-6 Coal Seam. As observed, flow from the no. 4-6 Seam is both northeasterly and southwesterly toward the Cottonwood Arroyo discharge area. Flow gradients within the seam range from 0.0001 ft/ft to 0.001ft/ft and flow velocities range from 7.4 x 10^{-6} ft/day to 4.0 x 10^{-5} ft/day.

6.2.2.4 No. 2-3 Seam

The No. 2-3 Seam extends from Area III to the south, and northward to just above Area III, where the coal unit gradually thins and eventually disappears. The No. 2-3 Coal Seam an average thickness of 5 to 10 feet throughout Area III and outcrops to the west of the permit area. Secondary permeability predominates in the No. 2-3 Coal Seam with average transmissivity and permeability values of 0.16 ft^2/day and 0.00075 ft/day, respectively. FIGURES 6-15 through 6-17 provides the results of aquifer testings. EXHIBIT 6-5 shows the potentiometric surface on this seam. Flow from the No. 2-3 seam within the permit area is generally toward its discharge area in the Cottonwood Arroyo. The flow gradient is relatively flat (0.0003 ft/ft) with only two foot decline over a 7000 foot distance. This low gradient and permeability translates into a flow velocity of only 4.5 x 10^{-5} ft/day (0.01 ft/year).



Well— KF 84 - 22 (c)
Date— 11 - 14 - 84
Test Type—Air life-Recovery
Unit—Coal Seam 4
Test Duration— 1450.25 min.
Production— 48 gpd
Static Water Level 89.42 ft.

$$T = \frac{2.30\,Q}{4\pi \Delta S}$$

$$= \frac{2.30(48)}{961.51}$$

= 0.31 gpd / ft

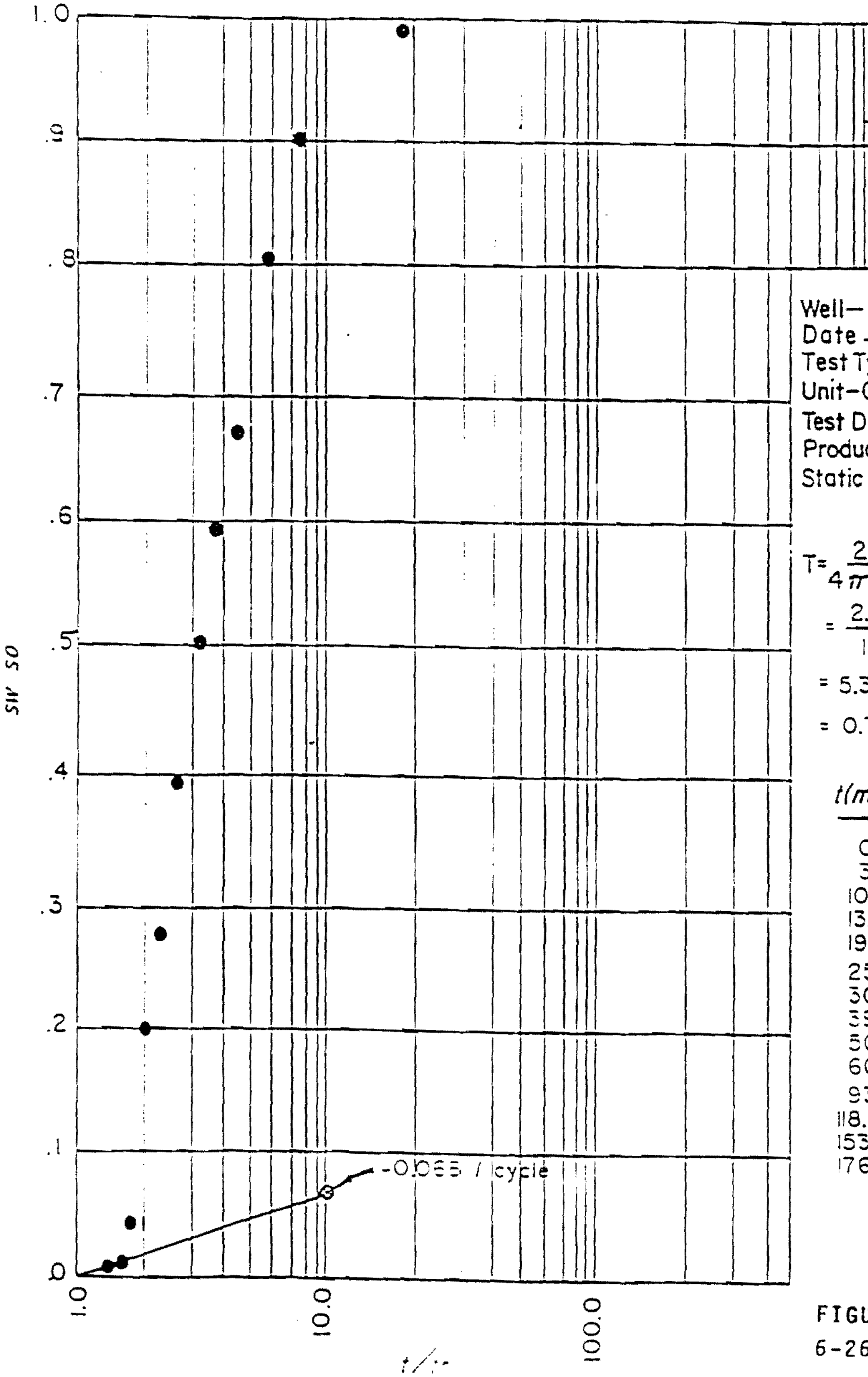
= 0.04 ft^2/ d

t(min.)	*s(ft.)*	*s'(ft.)*
0	204.18	114.76
2.25	204.18	114.76
5.08	203.17	113.75
9.92	201.71	112.29
15.02	199.97	110.55
19.67	197.94	108.52
24.75	196.17	106.75
35.08	192.17	102.75
44.83	188.83	99.41
54.50	185.53	96.11
83.58	176.89	87.27
114.00	168.52	79.10
143.50	161.42	72.00
170.33	156.22	66.80
1145.17	93.64	4.22
1264.33	92.98	3.56
1385.24	92.35	2.93

FIGURE 6-14

6.2.3 Quaternary Alluvium

Alluvial fill deposits occupying the valley bottoms of Chinde Arroyo, and the Cottonwood Arroyo, drainage have an average thickness of 10-15 feet. Chinde Arroyo has been mined through within the permit area and replaced with a temporary diversion structure (CHAPTER 11, Section 11.5.5). Cottonwood Arroyo, in Area IV North, contains alluvial deposits ranging from fine-grained wind blown sand to coarse-grained gravels. The Pinabete Arroyo, south of Area IV North and outside the permit boundary, is an ephemeral stream with a sandy channel bed. This is typical of ephemeral drainages of the southwest and it is estimated that transmissivity values will be similar to those found in other localities near the Navajo Mine (e.g., 218 ft^2/day, San Juan Coal Company, 1982). Generally, the direction of the flow gradient in the alluvial formations is towards the topograghic low areas in the adjacent washes. Groundwater may flow away from the washes during periods of peak flow. Water levels in the QA wells rise in the winter and spring during the period of low evapotranspiration and recharge from snow melt runoff. The water levels in wells begin to decline with the increase of evaporation during the summer. The lowest levels occur during the fall when there is little to no precipitation. Short term increases of the water levels occur during peak runoff caused by precipitation related flows. An exception to geohydrology characteristics of the QA is irrigation fluctuations occurring in alluvial well QAC-1 within the Chinde Wash. Monitoring well QAC-1 has the highest water levels occurring during the NAPI irrigation season April through October. These fluctuations can be correlated to increases in water quantity discharged from NAPI canals into the Chinde Wash.



Well— KF 84 - 22 (d)
Date — 11 - 14 - 84
Test Type—Air life - Recovery
Unit—Coal Seam 3
Test Duration— 241.58 min.
Production— 240 gpd
Static Water Level 98:44 ft.

$$T = \frac{2.30\,Q}{4\pi\Delta S}$$

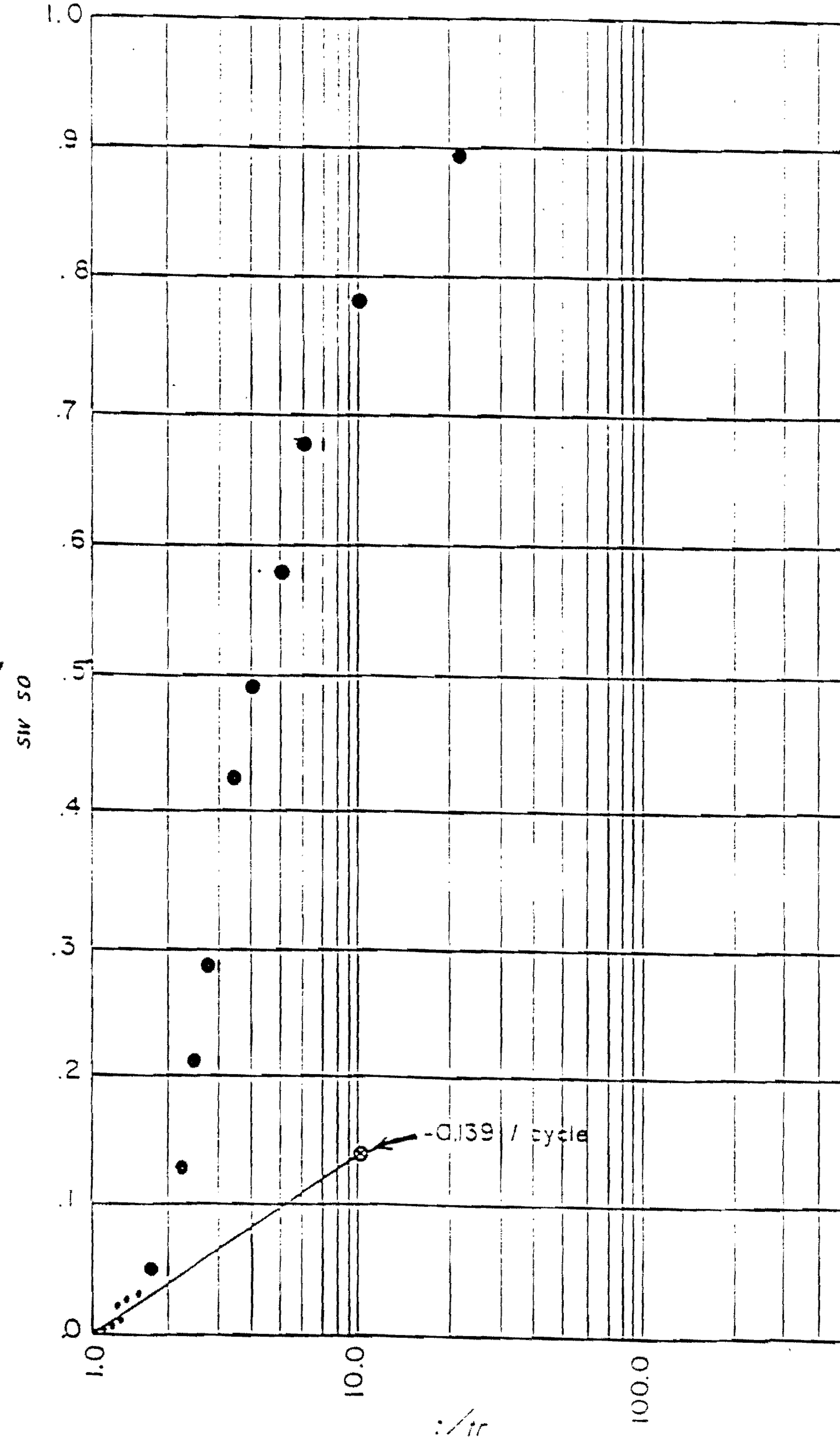
$$= \frac{2.30(240)}{103.92}$$

$= 5.31$ gpd

$= 0.71\ ft.^2/d$

t(min.)	s(ft.)	s'(ft.)
0	220	121.56
3.75	219.21	120.77
10.00	207.26	108.82
13.50	196.40	97.96
19.58	180.14	81.70
25.00	169.61	71.17
30.17	160.44	62.00
38.75	145.35	46.91
50.17	131.43	32.99
60.08	120.94	22.50
93.17	103.13	4.69
118.92	100.01	1.57
153.08	99.13	0.69
176.58	98.91	0.47

FIGURE 6-15



Well— KF 84 - 22 (e)
Date — 11 - 13 - 84
Test Type—Air life-Recovery
Unit—Coal Seam 2
Test Duration— 351.42 min.
Production— 120 gpd
Static Water Level 98.18 ft.

$$T = \frac{2.30\,Q}{4\pi\Delta S}$$

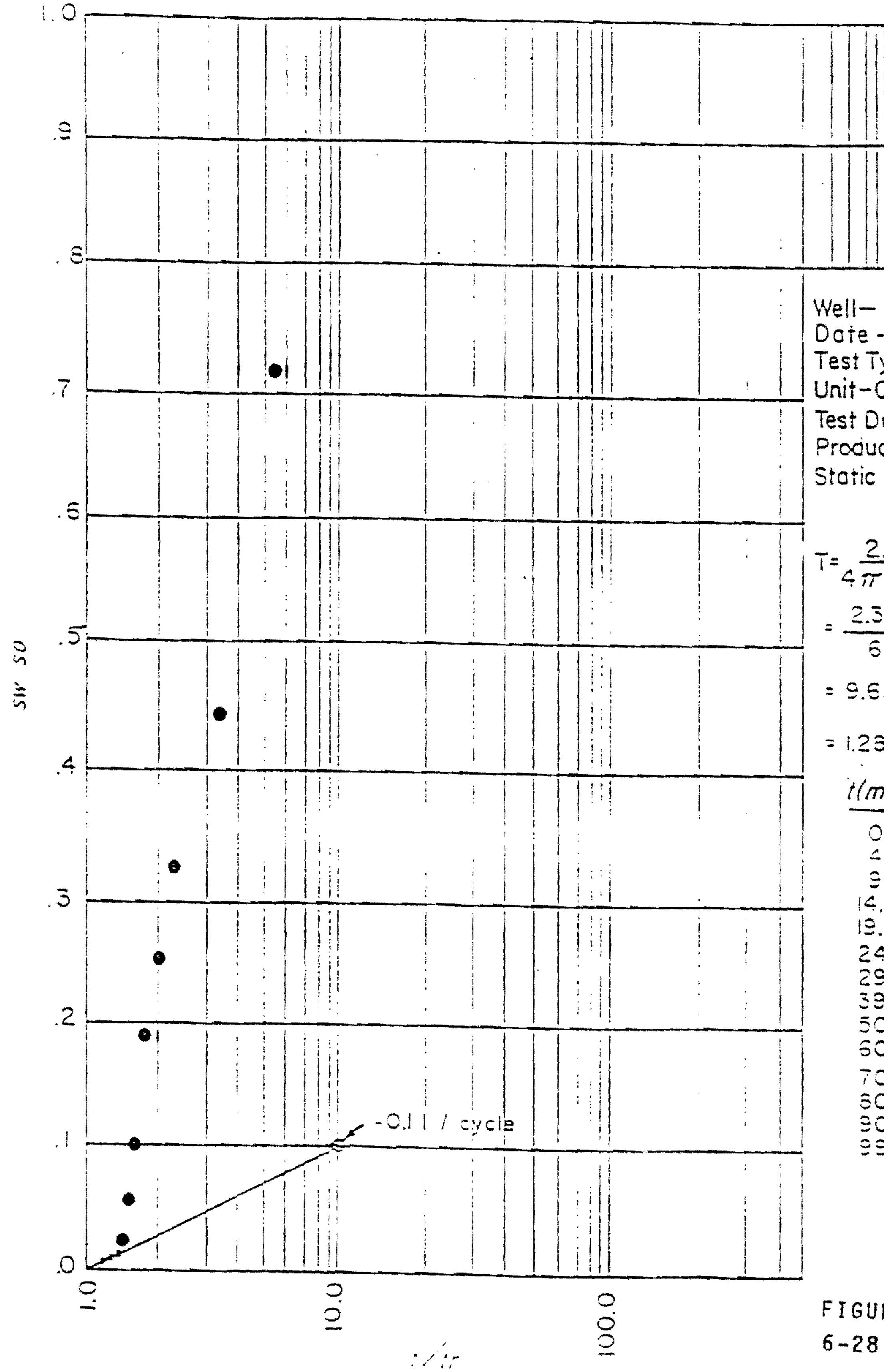
$$= \frac{2.30(120)}{242.41}$$

$= 1.13$ gpd

$= 0.15\ ft^2/d$

t(min.)	s(ft)	s'(ft.)
0.00	237.0	138.82
4.10	222.46	124.30
9.05	207.41	109.23
15.00	192.16	94.00
21.00	177.20	79.02
26.25	166.56	68.38
31.17	158.1	59.92
42.33	139.55	41.37
50.92	127.43	29.25
61.83	116.33	18.15
90.12	104.42	6.24
120.67	103.43	5.25
150.00	102.37	4.19
180.25	101.37	3.19
210.33	100.44	2.26
240.17	100.13	1.95
271.42	99.79	1.61

FIGURE 6-16



Well— KF 84 - 20 d
Date — 01 - 22 - 85
Test Type—Air life - Recovery
Unit—Coal Seam 7
Test Duration— 119.97 min.
Production— 288 gpd
Static Water Level 140.36 ft.

$$T = \frac{2.30\,Q}{4\pi \Delta S}$$

$$= \frac{2.30(288)}{68.61}$$

= 9.65 gpd / ft

= 1.28 ft^2/ d

t(min.)	s(ft.)	s'(ft.)
0.00	190.00	49.64
4.75	176.16	35.80
9.83	167.13	26.77
14.83	160.95	20.59
19.67	156.68	16.32
24.58	152.71	12.35
29.92	149.47	9.11
39.83	145.38	5.02
50.42	143.12	2.76
60.02	141.88	1.52
70.50	141.16	0.82
80.25	140.74	0.38
90.08	140.64	0.2
99.97	140.55	0.19

FIGURE 6-17

6.3 GROUNDWATER QUALITY

As previously stated, groundwater exists within the Pictured Cliffs Sandstone, in selected lenticular coal strata of the Fruitland Formation, and in the Chinde Arroyo and Cottonwood Arroyo alluvial deposits. In order to obtain representative baseline water quality information from the deposits, the piezometers were purged at least twenty-four hours prior to sampling. The piezometers were sampled, preserved, shipped and analyzed in accordance with EPA guidelines (Guidelines Estimating Test Procedures for the Analysis of Pollutants 40 CFR Part 136). The laboratory results are presented in TABLE 6-2 (Fruitland Formation) and also found in APPENDIX 6C , (Pictured Cliffs and Quaternary Alluvial Deposits). The results for each are briefly summarized below. The analytical information presented in TABLE 6-2 is a result of two years of data collected (1984 through 1985) and the values provided are averages.

Based on the limited seasonal water quality data available, it is evident that analytical parameters do not fluctuate seasonally within the bedrock water-bearing units. The lack of seasonality is typical for aquifers with very low transmissivities and constant static water levels.

6.3.1 Pictured Cliffs Sandstone

Water within the Pictured Cliffs is of poor quality and is classified as a sodium sulfate water type with high concentrations of chloride and abundant hydrogen sulfide gas evident during sampling. Generally, water quality increases toward the outcrop or recharge areas and quickly decreases down dip to near connate conditions. Since 1986, data has been submitted to the Office of Surface Mining (OSM) on a quarterly basis (see APPENDIX 6C for copies of analyses from 1975 to 1985).

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TABLE 6-2 GROUNDWATER QUALITY SUMMARY TABLE
(MG/L UNLESS OTHERWISE INDICATED)

Amended on 4/85

Element	SJKF84#2	SJKF84#3	SJKF84#4	SJKF#5	KF84-16	KF84-18(a)	KF84-18(b)	KF84-20(a)	KF84-20(b)	KF84 21(a)	KF84 21(b)
Aluminum (Al)	0.01	0.01	0.176	0.082	0.017	0.117	0.052	0.748	2.013	0.115	1.067
Arsenic (As)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001
Barium (Ba)	111	169	4.39	0.99	3.08	0.5	4.18	0.49	0.5	1.32	3.45
Boron (B)	1.23	1.43	1.57	1.23	1.37	0.58	0.63	0.49	0.53	0.36	0.13
Cadmium (Cd)	0.012	0.005	0.001	0.001	0.001	0.001	0.003	0.001	0.001	0.001	0.001
Calcium (Ca)	515	700	26.5	5.57	35	55	144	4.93	1.05	34.1	460
Chromium (Cr)	0.006	0.012	0.003	0.003	0.003	0.003	0.003	0.003	0.374	0.003	0.22
Cobalt (Co)	0.129	0.164	0.017	0.01	0.026	0.021	0.046	0.001	0.01	0.021	0.017
Copper (Cu)	0.003	0.002	0.009	0.007	0.005	0.007	0.006	0.007	0.009	0.009	0.007
Iron (Fe)	0.008	0.018	0.018	0.036	0.014	0.007	0.005	0.093	0.035	0.007	0.014
Lead (Pb)	0.017	0.014	0.01	0.105	0.013	0.004	0.009	0.002	0.017	0.022	0.069
Magnesium (Mg)	222	278	9.18	2.77	13.66	1.92	46.3	2.5	0.2	11	0.2
Manganese (Mn)	2.93	0.71	0.11	0.17	0.42	0.2	0.6	0.007	0.001	0.097	0.002
Mercury (Hg)	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Molybdenum (Mo)	0.01	0.001	0.01	0.01	0.001	0.01	0.027	0.017	0.001	0.01	0.021
Nickel (Ni)	0.06	0.098	0.01	0.01	0.01	0.01	0.01	0.013	0.01	0.01	0.013
Potassium (K)	56	61	13.5	11.1	20.6	18.3	28.4	10.4	16.8	12.1	70.7
Selenium (Se)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001
Silver (Ag)	0.002	0.002	0.001	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.001
Sodium (Na)	13456	15632	2642	1668	3498	2546	4019	992	1577	1901	2307
Vanadium (V)	0.102	0.1	0.05	0.1	0.1	0.1	0.1	0.101	0.05	0.05	0.05
Zinc (Zn)	0.08	0.05	0.05	0.05	0.05	0.005	0.05	0.05	0.065	0.05	0.05
Bicarbonate (HCO3)	774	552	2649	3090	2084	813	263	911	0	609	0
Carbonate (CO3)	0	0	276	230	106	36	35	320	180	56	0
Chloride (Cl)	23800	28200	2210	360	4500	3740	6050	700	1380	2860	2360
Cyanide (CN)	0.05	0.05	0.054	0.03	0.01	0.05	0.03	0.035	0.012	0.062	0.043
Fluoride (F)	0.92	0.97	1.08	2.07	0.88	0.86	1.08	1.93	1.64	0.94	0.91
Nitrate (N)	554	581	114	0.92	92.8	126	140	1.01	1.36	85.8	81
Phenols (-)	0.001	0.007	0.001	0.016	0.026	0.03	0.014	0.07	0.028	0.001	0.042
Phosphate (P)	0.77	0.67	0.15	0.15	0.15	0.15	0.15	0.15	1.32	0.15	0.15
Sulfate (SO4)	10	10	10	10	10	274	27	10	10	10	10
Sulfide (SO3)	0.05	0.05	0.025	0.2	5.75	0.025	0.025	0.025	0.025	0.025	0.025
SAR**	124.84	126.48	112.69	143.67	126.95	75.35	74.54	89.97	366.68	72.52	29.61
TOC-IR	10	6	17	25	14	14	6	37	12	11	18
OH	0	0	0	0	0	0	0	0	1214	0	2460
Conductivity*	46500	53000	10400	5900	13800	11500	18500	4240	10000	9050	16000
ph	7.03	7.29	8.06	8.12	7.74	7.73	7.85	8.8	12.06	8.23	12.2
Total Dissolved Solids	43035	50810	7370	4470	9920	7410	12410	2775	7515	5730	11925

TABLE 6.2 (continued)

Element	KF84-21(c)	KF84-22(a)	KF84-22(b)	KF84-22(c)	K84-22(d)	KF84-22(e)	(1)	(2)	(3)	(4)
Aluminum (Al)	0.068	0.185	0.05	0.033	0.035	0.056	5	-	5	20
Arsenic (As)	0.007	0.006	0.001	0.001	0.001	0.001	0.1	0.05	0.2	2
Barium (Ba)	0.66	0.5	1.32	2.86	4.1	4.37	1	1	-	-
Boron (B)	0.63	0.43	0.42	0.46	0.5	0.56	0.75	-	5	1.2
Cadmium (Cd)	0.001	0.001	0.001	0.002	0.001	0.001	0.01	0.01	0.05	0.05
Calcium (Ca)	14.6	11.9	45.8	44.4	27.4	26.8	-	-	-	-
Chromium (Cr)	0.003	0.003	0.003	0.003	0.003	0.003	.05	.05	1	1
Cobalt (Co)	0.027	0.01	0.023	0.028	0.023	0.028	.05	-	1	5
Copper (Cu)	0.003	0.008	0.005	0.006	0.006	0.006	1	1	0.5	5
Iron (Fe)	0.015	0.009	0.005	0.005	0.006	0.007	1	.03	-	20
Lead (Pb)	0.007	0.006	0.007	0.007	0.007	0.008	0.05	0.05	0.1	10
Magnesium (Mg)	14.9	4.55	13.6	16.6	18.7	18.3	-	-	-	-
Manganese (Mn)	0.38	0.28	0.32	0.14	0.16	0.13	0.2	0.05	-	10
Mercury (Hg)	0.001	0.001	0.002	0.001	0.002	0.001	0.002	0.002	0.01	-
Molybdenum (Mo)	0.01	0.01	0.01	0.01	0.01	0.012	-	-	-	
Nickel (Ni)	0.01	0.01	0.01	0.01	0.01	0.01	0.2	-	-	2
Potassium (K)	15	7.4	13.9	15.8	15.8	16.7	-	-	-	-
Selenium (Se)	0.001	0.001	0.001	0.001	0.001	0.001	0.05	0.01	0.05	0.02
Silver (Ag)	0.001	0.002	0.001	0.01	0.001	0.001	0.05	0.001	-	-
Sodium (Na)	2858	1247	2064	2716	2866	2890	-	-		
Vanadium (V)	0.05	0.05	0.05	0.05	0.05	0.05	-		0.1	1
Zinc (Zn)	0.05	0.05	0.05	0.05	0.05	0.05	10	5	25	10
Bicarbonate (HCO3)	753	919	620	553	680	781	-	-	-	-
Carbonate (CO3)	114	102	48	62	78	114	-	-	-	-
Chloride (Cl)	3980	320	3220	4070	3420	4300	250	250	-	700
Cyanide (CN)	0.03	0.083	0.01	0.09	0.01	0.01	0.2	0.2	-	-
Fluoride (F)	1.79	2.03	1.11	1.03	1.28	1.43	1.6	2.0	2.0	15
Nitrate (N)	394	0.53	75.7	158	77.4	58.5	10	10	100	-
Phenols (-)	0.001	0.004	0.001	0.001	0.001	0.001	.005	.001	-	-
Phosphate (P)	0.15	0.15	0.15	0.15	0.15	0.15	-	-	-	-
Sulfate (SO4)	184	2050	18	10	10	44	600	250	-	-
Sulfide (SO3)	36.8	1.4	0.025	0.025	0.025	0.025	-	-	-	-
SAR***	127.57	78.29	68.76	88.18	103.85	105.31	-	-	-	8-18
TOC-IR	5	11	11	14	6	6	-	-	-	-
OH	0	0	0	0	0	0	-	-	-	-
Conductivity	12600	5500	9700	12000	13000	12800	-	-	-	-
pH	8.08	8.41	8.05	7.86	7.94	8.1	6-9	5-9	-	4.5-9
Total Dissolved Solids	8505	4210	6125	8035	8610	8275	1000	-	3000	5000

*Units in umbros/cm at 25 degree Celsius

** Units in Meq/l

(1) New Mexico Groundwater Standard,
(2) Drinking Water Standard or Criteria,
(3) Stockwater Criteria,
(4) Irrigation Criteria, and
- No Criteria or standard exists.

Within close proximity to the mine area, the water quality of the Pictured Cliffs varies significantly as indicated below:

	Range
Total Dissolved Solids	5200mg/l to 16960mg/l
Chloride	170 mg/l to 9000 mg/l
Sodium	1330 mg/l to 6100mg/l
Sulfate	1100 mg/l to 4750 mg/l
pH	6.8 to 9.1

Such large ranges in dissolved constituents are reflective of the low permeability and production rates of the Pictured Cliffs.

Water quality of the Pictured Cliffs Sandstone, as well as the Fruitland Formation discussed below, is poor, and does not meet standards and criteria for domestic and livestock use. Due to the low permeabilities, poor water quality and limited production, regional use is limited. Local use does occur in areas closer to the outcrop, however, it is restricted entirely to marginal livestock watering. For these reasons, the classification of the Pictured Cliffs and the Fruitland Formations as aquifers is questionable.

6.3.2 Fruitland Formation

TABLE 6-2 provides water quality summary for all the Fruitland Coal Seam piezometers. Water types vary between individual Coal Seams and are discussed separately in the following section.

6.3.2.1 No. 8 Coal Seam

The No. 8 Coal Seam water can be classified as a sodium bicarbonate – chloride type with high concentrations of calcium, manganese, nitrates and boron. Total dissolved solids range from 4,475 mg/l to 50,010 mg/l and pH averages 7.6 units. Generally, better water is observed closer to the mine area and extremely poor water is seen at potential discharge locations, e.g. San Juan River.

6.3.2.2 No. 7 Coal Seam

The No. 7 Coal Seam water is also classified as a sodium-bicarbonate-chloride type with high concentrations of carbonates, nitrates, and manganese. Total dissolved solids average 7,250 mg/l and pH averages 7.06 units.

6.3.2.3 No. 4-6 Coal Seam

The No. 4-6 Coal Seam water is classified as sodium – chloride type with high concentrations of calcium and potassium. Total dissolved solid concentrations average 9,100 mg/l and pH averages 9.01 units and was found as high as 12.20 units. Hydroxides were also present in concentrations of 2,460 mg/l.

6.3.2.4 No. 2-3 Coal Seam

The No. 2-3 Coal Seam is classified as sodium–chloride–bicarbonate type with high concentrations of nitrates. Total dissolved solids average approximately 7,000 mg/l and pH ranges between 7.8 and 8.2.

6.3.3 Quaternary Alluvium

As previously stated, within the permit area water occurs in the alluvial deposits of the Chinde Arroyo, Cottonwood Arroyo, drainages. Since 1986, data has been submitted to OSM on a quarterly basis (see APPENDIX 6C for copies of data from 1975 to 1985). Water quality within these fill deposits can generally be described as poor with total dissolved solid (TDS) concentrations at well QAC-1 (Chinde alluvium) ranging from 7,700 to 13,700 mg/l, with a mean of 12,340 mg/l. The elevated TDS is the result of high concentrations of sodium, sulfate and chloride, (sodium chloride-sulfate water type) which is typical of these ephemeral wash alluvial aquifers. The concentrations for the major ions are: sulfate ranges form 500-5,520 with a mean of 4,150 mg/l; sodium ranges from 1,410-4,460 mg/l with a mean of 3,669 mg/l; chloride ranges from 1,200-4,900 mg/l with a mean of 3,392 mg/l.

Weak seasonal correlation is evident at well QAC-1 for static water levels, pH sulfate and manganese; however, it does not appear to fluctuate consistently from year to year, and in some years no seasonality is apparent. Seasonal fluctuations in the water quality are related to the changes in water quantity, as recorded by changing static water levels. Generally the water quantity increases in the winter and spring during the period of low evapotranspiration and greater recharge from snow melt runoff. In Chinde Wash, discharge rates by NAPI may dictate to a larger degree fluctuations in water chemistry than seasonality.

It is not possible to determine seasonal water quality fluctuations in Cottonwood Arroyo alluvium due to the insufficient number of samples caused by frequent dry well conditions. Data to support seasonal fluctuations can be found in the annual and quarterly hydrology reports.

6.4 GROUND WATER USES

No impacts on existing water supplies are anticipated because project interaction with ground and surface waters is limited. The amount of groundwater which will flow into the pits from the Fruitland Formation will be small. During mining operations, water will not flow from the active mining area into the Fruitland or Pictured Cliffs formations. For a more extensive discussion of operational groundwater flow quantities and characteristics, see CHAPTER 11, OPERATION PLAN Section 11.6.2.

Surface water runoff will be diverted away from active mining operations or retained within the disturbed area. A water monitoring network (Section 6.6) and various water control measures (CHAPTER 11, Section 11.6.4) will be implemented throughout the life of the mine to ensure that impacts to surface waters are minimized.

6.4.1 Alternate Water Supply

While the chance of impacts to water resources outside the mine area will be minimal, an alternate water supply source is available for development by BHP should it become necessary. BHP has water rights on the San Juan River, which can be used to offset any adverse impacts to the State of New Mexico and present users. These rights will be maintained throughout the mining operation and a period thereafter, for retirement, if required, to any affected San Juan Basin water users.

Should it become necessary, BHP will develop water supplies of suitable quantity, quality and location, and provide an adequate distribution system to ensure that water supplies will be maintained at an equal or better condition.

Impacts on the hydrologic balance as a result of surface mining operations are discussed in more detail in CHAPTER 11, Section 11.6.

Table 6.4.1 lists wells adjacent to the Navajo Mine, which are not owned by BHP. Limited information is available about these wells, particularly water quality data. However, some water quality data is available for well QACW–2B. The data indicate that the water in well QACW-2B is a sodium sulfate water type and that no seasonal quality fluctuations are discernable.

The likelihood of impacts to these wells from mining is minimal, due to their distance from active mining.

Table 6.4.1. Non-Navajo Mine wells adjacent to the Lease Boundary (See Exhibit 6-1 for locations).

Well Number	Owner	Distance from lease boundary (miles)	Total Depth (ft)	Aquifer	Use	Construction	Water Quality Data
QACW-2B	BIA	¼	11	Cottonwood Alluvium	Livestock	Hand dug w/ hand pump	Available
13-14-6	Unkwn	1 ¾	Unkwn	Chaco Wash Alluvium	Livestock	Hand dug w/ hand pump	None
13-4-7	Unkwn	2	16	Chaco Wash Alluvium	Livestock	Hand dug w/ windmill	None
SJKF84 #5	Navajo Nation	1/8	181	Coal Seam #8	Originally to characterize #8 seam (plugged 6/94)	PVC	None

6.5 ALLUVIAL VALLEY FLOOR ASSESMENT

Major stream channels passing through the permit area were examined as part of a study by the New Mexico Bureau of Mines and Mineral Resources entitled "Identification of Alluvial Valley Floors in Strippable Coal Areas of New Mexico" (Love et al., 1981). In this report, the San Juan and Chaco river systems (among others) were investigated as part of a phase I study to distinguish "possible alluvial valley floors" from "lands clearly not alluvial valley floors" using guidelines released by OSM. No potential or possible alluvial valley floors were found in the permit area. Chinde Wash and Cottonwood Wash, the two largest drainages crossing the permit area, were specifically examined and found to be "clearly not alluvial valley floors". Adjacent drainages, including Pinabete Wash and Chaco Wash, were also found not to contain alluvial valley floors. OSM June 3, 1992, approved BHP's April 14, 1992 submittal for a negative determination for the two Washes. The only potential alluvial valley floors found near the permit area were along the San Juan River.

Most of the stream channels that pass through the permit area do not have adjacent alluvial deposits. Those few channels that do, such as Chinde Wash and Cottonwood Arroyo, are deeply incised, which acts to drain their adjacent alluvium of any groundwater. Surface flows in all of these streams are infrequent and typically occur only after precipitation events. Those flows that do occur are poor in quality with excessive levels of suspended and dissolved solids. Because of these factors, none of the streams within the permit area are considered to be capable of supporting any agricultural activity and therefore do not warrant any further study as potential alluvial valley floors. This finding is consistent with the conclusions of a phase I alluvial valley floor assessment done by Love et al. (1981) for the State of New Mexico.

6.6 GROUNDWATER MONITORING PLAN

6.6.1 INTRODUCTION

A description of the probable hydrologic consequences and the hydrologic regime are presented in CHAPTER 11, Section 11.6. In addition a description of the geology of the mine is provided in CHAPTER 5.0. The review of these sources of information coupled with the a review of the Groundwater Quantity and Groundwater Quality descriptions presented in Section 6.2 and 6.3 of this chapter are necessary for an understanding of the objectives, procedures, and rationale used to develop the Navajo Mine's groundwater monitoring program.

The hydrologic monitoring program at the Navajo Mine was implemented in 1983. The objective of the groundwater monitoring program is to monitor the groundwater quality and quantity that relates to the suitability of the groundwater for the current and approved post mining uses and the protection of the hydrologic balance. The program was developed to address the hydrogeologic monitoring requirements for surface coal mining and reclamation activities on Indian Lands. The purpose of the monitoring plan is to 1) generate hydrogeologic data of sufficient quality and quantity to support the objectives of the groundwater monitoring program and 2) to document the objectives, rationale, and procedures used for the collection of groundwater information. Quality assurance and quality control procedures, found in CHAPTER 6.0, APPENDIX 6-A of the PAP, are followed where applicable and support the objectives of the groundwater-monitoring program.

The groundwater monitoring program for the Navajo Mine is unique for several reasons. Monitoring sites are distributed over a large geographical area (i.e., 26.2 square miles) within which several discrete coal resources have been, are currently, or will be mined over an approximate 60 year period. The coal seams are very lenticular in nature and are mined in localized areas. Lands within the permitted area are classified as several different jurisdictional areas and the mine permit boundary abuts directly against the planned mining activities, which leaves little room for environmental monitoring locations outside of undisturbed lands. Furthermore, the development of a monitoring program is challenged by complex groundwater monitoring conditions such as unconfined and confined groundwater flow, naturally low water yielding formations with very poor water quality, and agriculturally impacted and unstable surface drainage channel conditions. In addition, the bedrock formations consist of alternating marine and nonmarine geologic formations that contribute elevated concentrations of dissolved constituents (e.g., sulfates, salts, and metals) to the natural groundwater quality (Stone et. al., 1983). Regionally the mine is located adjacent to the western boundary of the San Juan Basin in northwestern New Mexico, CHAPTER 5.0 contains additional geologic information. All these factors and conditions were evaluated and applied to the development of an effective groundwater monitoring plan at the Navajo Mine. The Navajo Mine was confronted with these factors coupled with technical developments in groundwater monitoring techniques and methods, as well as changing regulatory monitoring guidelines and requirements, when designing and implementing an effective groundwater monitoring program.

6.6.2 Objective

The objective of the Navajo Mine groundwater monitoring plan is to address the hydrologic monitoring requirements for the surface coal mining and reclamation activities at 30 CFR 777.13; 780.21a; 780.21I and 816.41 as well as comply with applicable U.S.EPA groundwater monitoring guidelines. The groundwater monitoring plan is used to define the following: 1) changes in the baseline conditions for groundwater quantity and quality; 2) to validate the Probable Hydrologic Consequences (PHC) results determined for mining and post mining periods (CHAPTER 11, Section 11.6); 3) assess the trends and magnitude and extent of any measurable impacts from mining or other sources to the hydrogeologic system; 4) determine the seasonal variability and define the ranges of variability; 5) define the degree of interaction between the groundwater and surface water systems; 6) determine when monitoring needs to be improved or when monitoring can be relaxed at sites; and 7) to provide site specific hydrogeologic data which will be utilized in bond release applications.

6.6.3 Background

The Navajo Mine groundwater monitoring program consists of (3) alluvial monitoring wells and (12) bedrock monitoring wells see TABLE 6-3 and EXHIBIT 6-1. Groundwater data has been collected annually and quarterly starting in 1983.

In general, the probable consequences of mining activities upon the quality and quantity of groundwater at the Navajo Mine is negligible. As discussed in CHAPTER 11, Section 11.6.2.2, groundwater quality is expected to generally improve (e.g., metal concentrations usually decrease while sulfate values increase) when natural groundwater flows through post mined pits and spoil materials. When groundwater travels through the coal seams, additional attenuation of selected chemical species is also documented, further reducing the potential impacts of mining on the regional groundwater quality.

In addition, the natural water quality of the Fruitland Formation is so poor and production is low, that regional use of this formation as a source of groundwater is nonexistent (Stone et. al., 1983). Mining activities are not expected to have a measurable impact on the human use of the groundwater (see CHAPTER 11, Section 11.6.2.4). Many constituents of the Fruitland Formation groundwater exceed Federal Drinking Water Standards (i.e., Maximum Contaminate Limits for Inorganic Chemicals, 40 CFR, Part 141). In most cases, the waters exceed the New Mexico Water Quality Control Commission standards and criteria for groundwater for fluoride, chloride, sulfate, total dissolved solids, and pH. Moreover, in many cases the groundwater quality exceeds New Mexico Water Quality Commission Standards and criteria for irrigation and livestock.

The only potential human health impacts of concern are to the San Juan River aquifer and this has been determined to be so small as to be unmeasureable (see CHAPTER 11, Section 11.6.2.4).

6.6.4 Geologic Units To Be Monitored

The two formations monitored as part of the Navajo Mine's groundwater monitoring program include the Quaterary formations and the Cretaceous coal seams within the Fruitland Formation.

6.6.4.1 Quaternary Formations

The quaternary formations consist of alluvial and eolian deposits found in the upland areas east of the permit boundary and within the arroyo drainage channels within and adjacent to the mine. These formations make-up the unconfined groundwater flow conditions monitored within and adjacent to the mine.

The quaternary deposits in the upland areas generally abut up against the eastern boundary of the mine lease and are used for agricultural activities (USGS, 1979). The deposits vary in the degree of saturation, but are generally saturated from the extensive agricultural activities along the eastern mine boundary. The upland deposits contribute appreciable amounts of groundwater return flows to the topograghically lower quaternary sediments within the arroyos. The upland quaternary formations are separated from the coal seams of the Fruitland Formation by the low permeability of the upper shales of the Fruitland Formation and therefore are not hydrogeologically connected to the coal seams. Moreover, the upland deposits along the eastern boundary are located hydrogeologically upgradient from the Navajo Mine's activities and are not and will not be impacted by mining activities. Therefore these upland quaternary deposits are not monitored.

The alluvial and eolian sediments found within the arroyos that pass through the Navajo Mine lease boundary are monitored by the alluvial wells adjacent to the arroyos. The arroyo deposits exhibit varying degrees of saturation along the drainage channel. The arroyo sediments are principally recharged by the upland deposits impacted by the agricultural irrigation activities of the Navajo Agricultural Product Industry (NAPI). Irrigation water is also directly discharged from the Navajo Indian Irrigation Project (NIIP) irrigation channels down the arroyo channels. Natural recharge contributions from meteoric precipitation to the arroyo sediments is limited because of the high evaporation rates in the region being a factor of seven times greater than the total precipitation at the mine (see CHAPTER 4, Section 4.1.1). The hydrologic regime of the quaternary formations is dynamic and will continue to be a changing hydrologic regime based on the changing agricultural activities.

6.6.4.2 Bedrock Formations

The coal seams within the Fruitland Formation at the Navajo Mine are the geologic units capable of transmitting groundwater away from the mining area. The Fruitland Formation coal seams are monitored because they are the formations that are disturbed by mining activities. The coal seams monitored are identified as the No. 2-3, No. 4-6, No. 7, and No. 8 coal seams. These coal seams are monitored by the bedrock wells shown on EXHIBIT 6-1. The coal seams within the Fruitland Formations generally strike north south and dip 1 to 2 degrees to the east-southeast toward the center of the San Juan Basin. Neither the coal seams nor the Fruitland Formation itself are considered significant as a groundwater resource because of their poor aquifer characteristics and water quality (Stone, 1983). The coal seams are monitored because they represent the zones of greatest hydrologic conductivity within the Fruitland Formation and therefore should facilitate the early detection of the potential migration of constituents.

The shale, mudstones, and siltstones of the Fruitland Formation act as aquatards or confining layers between the coal seams to potentially vertically migrating groundwater (see CHAPTER 11, Section 11.6.2.3). The potential for vertical permeability within the Fruitland Formation is limited. The presence of perched groundwater conditions within the coal seams and the absence of water in the adjacent interburden support this assertion.

The unit underlying the Fruitland Formation is a clean marine sandstone, the Pictured Cliffs Sandstone. The Pictured Cliffs Sandstone is a natural gas reservoir in the San Juan Basin (Stone et. al., 1983). The unit cannot be considered an aquifer because of its poor water quality and porosities (Stone et. al., 1983). The Pictured Cliffs Sandstone is hydrogeologically separated by an overlying ten to twenty-five feet of Fruitland Formation shale below the deepest coal seam mined. The layer of shale below the coal seam serves to restrict interconnected flow between the coal seam and the underlying Pictured Cliffs Sandstone. Underlying the Pictured Cliffs is an extensive thickness of the Lewis Shale.

6.6.5 Groundwater Flow Characteristics

The approximate groundwater flow directions, gradients, and movement rates are determined by precise groundwater level information collected from the alluvial and bedrock monitoring wells and the existing groundwater information in CHAPTER 6.0.

In general, the groundwater flow direction in the bedrock Fruitland Formation is from topographically high outcrop areas in the west to the east toward the center of the basin as well as towards lower outcrop areas to the north (i.e., San Juan River Valley) and to a minor extent the Cottonwood Wash to the south. The groundwater flow direction changes locally within the mine's major drainages (i.e., discharge areas). CHAPTER 11, Section 11.6.2.3.1 summarizes the coal seams, the general groundwater flow directions, and the potential discharge locations.

The general regional flow direction in the quaternary formations is from the topograghically elevated agricultural areas in the east towards the west and towards adjacent major dissecting drainages north and south. The major drainages impacted by the irrigation return flows are the Bitsui, Chinde, and Cottonwood arroyos.

The groundwater movement rates in the Fruitland Formations coal seams is judged to be no greater than 0.076 feet per day using worst case conditions (see CHAPTER 11, Section 11.6.2.2). The groundwater velocities when the Fruitland Formation is considered as one unit is much lower than the 0.076 feet per day.

The groundwater flow in the alluvial sediments is unconfined and fluctuates seasonally with the irrigation season. The hydraulic conductivities of the alluvial and eolian formations are generally estimated to range between 1 to 10 feet per day.

6.6.6 Monitoring Well Locations

While the chance of groundwater impact from mining remains remote, the following monitoring well locations were developed to collect water quality and quantity information to insure protection of the hydrologic balance.

The rationale used for the placement of the monitoring wells was based on historic groundwater information collected (see Section 6.2 and 6.3); spatial occurrence of the coals seams; the bedrock potentiometric surface maps; and locations of groundwater discharge and recharge areas. The (9) monitoring wells that are part of the Navajo Mine Monitoring Program are located within the mine lease boundary and are shown on EXHIBIT 6-7. Of these wells, (7) bedrock monitoring wells are installed in the Fruitland Formation coal seams with the remaining (2) wells monitoring the alluvial formations. The bedrock coal seams and Quaternary units and their associated monitoring wells are listed in TABLE 6-3. TABLE 6-3 provides the number of wells per unit monitored, the unit being monitored, and the frequency of monitoring. Access to each well site is made on existing roads.

The San Juan River alluvial aquifer is the most significant groundwater resource in the area. The water data collected from the bedrock wells in the northern area of the mine are utilized to monitor the water quantity and quality potentially flowing towards the San Juan River. The bedrock wells installed in the southern area of the mine monitor the potential impacts to the Cottonwood Wash. Wells located in the central area of the mine monitor groundwater flows towards the middle of the San Juan Basin. Hydrologic data provided in Section 6.3.2 describes the degree of saturation in each coal unit and spatial occurrence of the coal seams through out the mine.

The bedrock wells are utilized to estimate the hydrogeologic characteristics and the quality and quantity of groundwater in the four major coal seams downgradient of the mining activities. The information will also support hydrologic consequence predictions found in CHAPTER 11. The bedrock wells also provide information used to support potentiometric surface maps for each of the four coal seams. The existing potentiometric surface maps in the mine's current Permit Application

Package (PAP) were derived from data from the 12 bedrock wells and the information provided from the wells shown on EXHIBIT 6-6. The hydrogeologic data collected from the bedrock and alluvial wells will provide data that is used to assess the trends and magnitude and extent of potential impacts from mining or other sources to the hydrologic regime and the San Juan River alluvial aquifer.

The alluvial wells are located adjacent to the arroyos and monitor water quality within the alluvial sediments adjacent to the arroyos. The downstream alluvial monitoring well locations were selected to quantify the alluvial groundwater quality and quantity. The upstream alluvial location is monitored to provide upgradient background water quality and quantity information. In addition, the upstream water quality data will be used to detect constituents related to NIIP irrigation return flows and wastewater entering and flowing through the mine. The wells also provide data to characterize the hydrogeologic connection between surface water flows and the groundwater regime. The hydrologic connection information will be use to determine the characteristics of base flows within the arroyo sediments and the potential for impacts to the alluvial formation from NIIP flows. Generally, the arroyos are considered gaining channels. that is groundwater (i.e., irrigation return flows) are flowing towards the channel and recharging the alluvial sediments. The alluvial sediment cover usually conceals the evidence of discharge, and white salt or alkali deposits are the only evidence of groundwater discharge in these locations.

Table 6-3
Navajo Mine Groundwater Wells

Well Number	Owner	Location	Status	Date Installed	Well Case	Completed Depth (ft)	Aquifer Formation	Use
Bighan-1	BHP	E: 32203.63 N: 2067306.70	Non active	06/10/94	PVC 2"	35.00	Qal	Env.
Bitsui-1	BHP	E: 330254.76 N: 2081799.31	Non active	06/15/94	PVC 2"	73.00	Ash	Env.
Bitsui-2	BHP	E: 331199.69 N: 2082772.08	Non active	07/14/94	PVC 2"	120.00	Kf CS# 8	Env.
Bitsui-3	BHP	E: 33215.40 N: 2081610.27	Non active	07/14/94	PVC 2"	170.00	Kf CS# 8	Env.
Bitsui-4	BHP	E: 330338.30 N: 2082170.54	Non active	01/26/96	PVC 2"	76.00	Spoil	Env.
Bitsui-5	BHP	E: 33108827 N: 2082170.54	Non active	01/26/96	PVC 2"	65.00	Spoil	Env.
Bitsui-6	BHP	E: 330240.43 N: 2081972.15	Non active	01/26/96	PVC 2"	76.00	Spoil	Env.
Custer-1	BHP	E: 322494.27 N: 2075983.66	Non active	06/17/94	PVC 2"	15.00	Spoil	Env.
Custer-2	BHP	E: 323500.87 N: 2076001.28	Non active	06/16/94	PVC 2"	65.00	Ash	Env.
Custer-3	BHP	E: 323001.69 N: 2075501.48	Non active	06/17/94	PVC 2"	45.00	Ash	Env.
Custer-4	BHP	E: 327192.80 N: 2074351.27	Non active	06/21/94	PVC 2"	14.00	Spoil	Env.
Doby-1	BHP	E: 318972.80 N: 2059769.30	Non active	06/22/94	PVC 2"	51.00	Qal	Env.
Doby-3	BHP	E: 319412.95 N: 2058177.66	Non-active	08/28/96	PVC 2"	38.00	Qal	Env.
Doby-5	BHP	E: 319640.00 N: 2058175.00	Non active	08/28/96	PVC 2"	37.80	Qal	Env.
Doby-8	BHP	E: 319405.00 N: 2058175.00	Non active	08/28/96	PVC 2"	38.00	Qal	Env.
GM-17	BHP	E: 309800 N: 2013500	Non active	06/05/05	PVC 4"	20.30	Qal	Env.
KF83-1	BHP	E: 331600.00 N: 2080050.00	Non active	08/19/83	PVC 4"	147.00	Kf CS# 8	Env.
KF84-16	BHP	E: 334100.00 N: 2081500.00	Non active	01/01/95	PVC 2"	294.00	Kf CS# 8	Env.
KF84-18A	BHP	E: 318950.00 N: 2050180.00	active	05/01/84	PVC 2"	180.00	Kf CS# 4-6	Env.
KF84-18B	BHP	E: 318950.00 N: 2050180.00	active	05/01/84	PVC 2"	135.00	Kf CS# 8	Env.
KF84-20A	BHP	E: 304307.65 N: 2017120.64	active	03/06/84	PVC 2"	227.00	Kf CS#2-3	Env.
KF84-20B	BHP	E: 304319.22 N: 2017144.83	active	03/07/84	PVC 2"	187.00	Kf CS4-6	Env.

Table 6-3 cont.
Navajo Mine Groundwater Wells

Well Number	Owner	Location	Status	Date Installed	Well Case	Completed Depth (ft)	Aquifer Formation	Use
KF84-20C	BHP	E: 304310.70 N: 2017093.50	active	03/07/84	PVC 2"	187.00	Kf CS# 7	Env.
KF84-22A	BHP	E: 307822.16 N: 2009510.05	active	05/03/95	PVC 2"	126.00	Kf CS# 8	Env.
KF84-22B	BHP	E: 307829.36 N: 2009513.79	active	04/26/84	PVC 2"	142.00	Kf CS# 7	Env.
QAC-1	BHP	E: 310080.00 N: 2053200.00	active	01/01/84	PVC 2"	19.00	Qal	Env.
QACW-2	BHP	E: 287032.58 N: 2009420.7	active	n/a	PVC 2"	N	Qal	Env.
Watson-1	BHP	E: 32928.13 N: 2085893.97	Non active	06/08/94	PVC 2"	66.00	Ash	Env.
Watson-4	BHP	E: 328648.35 N: 2083899.52	Non active	06/07/94	PVC 2"	93.00	Ash	Env.

Kf = Cretaceous Fruitland Formation
CS# = Coal Seam Number
Qal = Quanternary Alluvium
n/a = not available

6.6.7 Well Construction

The alluvial and bedrock wells are constructed of two inch inside diameter flush joint threaded PVC. The screened interval of the wells generally consists of factory slotted PVC casing surrounded by silica sand. The wells completed in the Fruitland Formation were screened across the individual coal seams. The wells in the quaternary and bedrock formations are screened across the upper saturated zone. In most cases the wells are constructed with a bentonite seal above the sand pack and a cement bentonite grout to the surface. All the wells are surveyed from a designated point marked on the well casing and groundwater measurements are collected from this marked point only. The wells are protected with an outer metal casing with a locking cap and secured with an inner waterproof locking well cap. Wells are clearly marked in the field for identification and protection.

6.6.8 Sample Equipment

A dedicated bladder pump or a nondedicated centrifugal pump is primarily used for purging and sample collection. A bailer may be used for sample collection where appropriate on shallow alluvial wells or when pumping is not practical. Well QACW-2 is an existing hand dug alluvial well and a dedicated bailer is used for sample collection. These types of sample collection equipment are generally recognized as the best overall sampling devices for collection of water samples for the analysis of inorganic and organic constituents in groundwater (Barcelona et al., 1985b; Barcelona, 1988b; and USEPA 1986).

Water quality instruments which measure pH, conductivity, and temperature are used to determine the end point of well development; the basic chemistry of the groundwater; and compliance with regulatory guidelines (EPA, 1986). Field water quality instruments used to collect field parameters are calibrated before each sampling event. Water level measuring instruments are used to determine the static water level and total depth of the well to the nearest .01 of a foot from a consistent surveyed point on the well. Water level monitoring instruments are calibrated annually for accuracy. Calibration logs are kept for all applicable field instruments to document accuracy and performance. Field test kits may also be used in addition to laboratory analysis for parameters being evaluated that are physically or chemically unstable. Sampling and monitoring equipment is decontaminated between each sampling location to minimize cross contamination using a laboratory grade biodegradable phosphate free soap wash and a deionized water rinse. Decontamination, equipment operation, and calibration procedures are found in APPENDIX A - 6.

6.6.9 Well Monitoring

6.6.9.1 Frequency

The groundwater wells at the Navajo Mine are sampled at different frequencies based on the hydrogeologic characteristics of the formation being monitored. The quaternary monitoring wells are sampled on a quarterly frequency because of the high transmissivities that increase the hydrogeologic responsiveness of the alluvial formations. The bedrock wells on the other hand are sampled on an annual frequency because of the very low transmissivities of the coal seams. The quarterly and annual sampling frequencies will allow for the determination of seasonal and temporal changes to the quantity and quality of the hydrologic regime. Groundwater sampling of the alluvial wells is conducted in the last month of each quarter of the calendar year and Annual wells are sampled in the last month of the third quarter of the calendar year. The sampling frequency may be altered if analytical results indicate changes in the water quality or a need for additional or less information. Changes in sampling frequency will not be made without OSM approval.

6.6.9.2 Groundwater Level Measurements

Prior to well purging and sample collection at each well, static water level measurements are accurately measured to the nearest .01 of a foot (U.S. EPA, 1986). Water level measurements are collected from all the wells being sampled during each sampling event. The water level measurements provide a snapshot of the potentiometric surface at the time of sample collection.

6.6.9.3 Well Purging

Each well is purged of a minimum of two times the volume of groundwater that is standing in the casing prior to sample collection. Field measurements of pH, conductivity, and temperature are monitored in the field prior to well purging and after each purge volume until the groundwater field parameters have stabilized within approximately 10% between at least two successive measurements during purging. Stabilization of the field parameter measurements made in the purge stream will be considered evidence of satisfactory well development. An effort is made during purging and sampling to decrease the agitation of the water to minimize changes in water quality. The purging process will proceed at a pump rate that will not draw the water down to the pump intake. This will minimize sample alteration due to introduction of air into the sample collected.

6.6.9.4 Sample Collection

When the field parameter readings during the well purging process have stabilized, it will be assumed that the water being removed is representative of formational waters and a groundwater sample will be collected immediately. In cases where well production is very slow and does not allow for a minimum of two well purge volumes to be extracted the well is purged to near dryness once and samples are collected when sufficient water is available. Samples are collected at lower flow rate than purging in an effort to minimize sample agitation and therefore collection of a more representative sample. Field measurements of the pH, conductivity, and temperature of the sample collected for laboratory analysis are measured and documented in the field before submittal to the laboratory.

The samples collected from the wells are marked with the well number, sampling date and time, name of sampler's name, and mine. Samples are collected and preserved in the field following EPA guidelines found at 40 CFR, Part 136 Guidelines Establishing Test Procedures for the Analysis of Pollutants, TABLE II. The samples are then packed in ice, placed in a cooler, and delivered to the analytical laboratory. The samples will be submitted to the laboratory in sufficient time to meet the required EPA analytical holding times for chemical analysis found at 40 CFR, Part 136 Guidelines Establishing Test Procedures for the Analysis of Pollutants, TABLE II.

6.6.9.5 Quality Assurance Quality Control Samples

Additional samples are collected in the field for the purposes of field and laboratory quality assurance and quality control (QA/QC) measures and follow EPA guidelines (U.S. EPA, 1993). QA/QC samples collected include the following:

- Replicates (duplicates) to provide sampling and analytical precision data. Replicates are collected, numbered, packaged, assigned separate numbers, and submitted blind to the Laboratory. Replicates will be collected at a frequency of 10 percent of the total samples collected.

- Equipment blank samples are collected when sampling equipment is decontaminated and reused in the field. Equipment blanks provide a check for cross contamination during sample collection, verification of decontamination procedures, introduction of contaminates from sampling equipment, and a check on the laboratory. Metal free deionzed water is used for inorganic parameters. Blanks are collected, numbered, packaged in the same manner as other samples, and submitted blind to the laboratory. Equipment blanks will be collected at a frequency of 1 per sampling event.

- Lab QC samples are collected to perform laboratory QC analysis. Laboratories routinely perform matrix spike and lab duplicate analyses on field samples as a quality control check. One sample will be collected per sampling event and designated as a "Lab QC Sample" for the matrix spike and lab duplicate analyses. This is not an additional sample but merely additional volume of the same collected. QA/QC samples will be collected at a frequency of 20 percent of the total samples collected.

6.6.10 Parameter Selection

The parameters listed in TABLE 6-4 will be used for sample analysis of samples collected from bedrock and quaternary wells. The parameter list was developed based on the identification of potential sources of constituents, a review of Federal (i.e., Clean Water Act, NPDES programs) and

State of New Mexico (i.e., New Mexico, 1995) regulatory requirements for groundwater quality for human health, irrigation, and livestock; the Office of Surface Mining hydrologic information requirements; and historic groundwater data. The listed parameters will allow for the characterization ofgroundwater quality and evaluation of changes in groundwater chemistry.

6.6.11 Laboratory Analysis

A chain of custody (COC) accompanies all samples submitted to the laboratory for analysis. The COC lists the analysis requested and detailed sample information. The samples submitted to the laboratory are analyzed for the parameters on TABLE 6-4 in accordance to EPA approved analytical methodology and laboratory QA/QC procedures. Moreover, every effort will be made to meet the analytical holding times provided at 40 CFR, Part 136 Guidelines Establishing Test Procedures for the Analysis of Pollutants, TABLE II The analytical methods for all the samples collected are specified so that the chemical results will be of a known quality and comparable with previous laboratory data. Laboratory QA/QC procedures, guidelines, and QA/QC requirements are found in APPENDIX 6-A.

6.6.12 Data Management

The groundwater data collected is entered into an environmental database to accurately track and manage the data generated and develop a well history for water quality and quantity. Spatial variability in the hydrogeologic conditions requires that each well result be compared against its own sampling history. The monitoring data generated will include general field data, well and water quality field measurements, and water quality laboratory results. The field data collected is documented on field groundwater monitoring forms and later entered into the database management system. The data is evaluated and checked against historic groundwater concentrations for any anomalies or trends. Parameters that are determined to be outside the limits of historical values will be verified to determine if any errors occurred during sample collection, handling and/or analysis.

The data verification steps will include checking field and chain-of-custody forms to determine if irregularities occurred during the sample collection or handling and the laboratory data will be validated to determine if errors occurred in the sample analysis or reporting.

Generally, groundwater parameter concentrations do not change rapidly, any significant differences between the historic and new data collected might indicate potential errors in sample collection or analysis. If the differences cannot be explained, the well will be re-sampled to confirm the results. If a value is confirmed to be accurate and representative of the groundwater quality it will be reported to OSM.

6.6.13 Data Analysis

The data analysis goals are to identify changes in the hydrologic balance and to insure that groundwater quality and quantity is being maintained. To meet these goals various statistical analyses of the groundwater data will be performed based on the data collected. At a minimum standard statistical analyses (means, standard deviations, etc.) will be performed to assess the quality of water information and parameter specific time verse concentration plots will be performed to detect trends.

6.6.13.1 Groundwater Reference Criteria

Groundwater reference criteria were developed from the historic record of groundwater monitoring data collected through 2001 to aid in the evaluation of future groundwater monitoring data. The reference criteria were established for parameters that represent potential constituents resulting from mining associated activities as further discussed in CHAPTER 11, SECTION 11.6. The reference level for each criterion is the mean parameter concentration, determined through 2001, plus two standard deviations. Reference parameters and levels are listed in TABLE 6-5

6.6.13.2 Data Evaluation

Groundwater data will be evaluated and compared to reference criteria as a part of the Hydrologic Monitoring Report submitted twice during the permit term as discussed in CHAPTER 11, SECTION 11.6.6. Data evaluation will consist of comparing data to reference criteria and determining if analysis for additional parameters, to further evaluate potential sources of changing groundwater quality, will be required during subsequent groundwater monitoring collection periods.

When two (2) or more reference criteria are exceeded at any one well through four (4), consecutive sample collection periods, then a more detailed analysis of groundwater samples will be conducted during the next scheduled sample collection period. The detailed analysis will include dissolved iron, dissolved manganese, nitrate-nitrite, boron, and fluoride in addition to the approved suite of parameters listed in TABLE 6-4. The results from the detailed analysis will be reviewed with OSM to evaluate potential sources of changing groundwater chemistry and to determine if any measures should be taken. Analysis for the detailed suite of parameters will continue for the documented well until OSM approves a discontinuation of the expanded parameter suite or groundwater quality is below reference levels during subsequent sample collection periods.

6.6.13.3 Data Validation

Data validation is performed initially on a random selection of 10 percent of the total samples collected for laboratory analysis for each quarter. If problems are identified that may qualify the data unusable for its intended purposes 100% of the data will be validated for that quarter. The data validation will provide a check of the data to document the accuracy, precision, and completeness of the analyses performed. Data validation problems will be identified and explained to the extent possible. At a minimum, the following is checked, as part of the validation process, to insure that they meet the objectives of the groundwater plan:

- Documentation of sample collection , COC, and analysis,
- Transcription errors,
- Detection limits,
- Holding times and sample preservation,
- Comparison with blank samples,
- Matrix spikes and matrix spike duplicates,
- Laboratory duplicates for metals, and
- Field replicates.

6.6.14 Reporting

Groundwater monitoring results will be submitted on a quarterly basis to OSM. In addition, a detailed review of monitoring results will be submitted to OSM twice during the permit term. See CHAPTER 11, SECTION 11.6.6 for additional information.

TABLE 6-4

NAVAJO MINE

GROUNDWATER SAMPLING PARAMETER LIST

(BEDROCK AND ALLUVIAL WELLS)

CATEGORY	PARAMETER
GENERAL	Temperature
	Total Dissolved Solids (TDS)
	Conductivity
	pH
	Water level
WATER QUALITY	Calcium
	Magnesium
	Sodium
	Potassium
	Carbonate
	Bicarbonate
	Sulfate
	Chloride
METALS	Selenium

TABLE 6-5

Groundwater Monitoring Reference Criteria[1]

Monitoring Parameter[2/3]	Reference Criteria by Well[4]						
	KF84-20A	KF84-18A	KF84-20C	KF84-22B	KF84-18B	KF84-22A	QAC-1
Total Dissolved Solids (mg/l)	8,952	14,358	4,364	7,445	10,387	6,749	15,073
Magnesium (mg/l)	17.2	60.6	3.67	19.5	34.1	13.4	151
Potassium (mg/l)	21.3	42.1	9.91	33.0	58.9	50.9	28.4
Sulfate (mg/l)	385	348	1,267	64.1	107	3,333	5,651
Selenium (mg/l)	0.004	0.004	0.005	0.027	0.001	0.024	0.169

1. If two or more groundwater reference criteria are exceeded, at any one monitoring location, over four consecutive sample collection periods, then subsequent groundwater samples from that location will be analyzed for dissolved iron, dissolved manganese, nitrate-nitrite, boron, and fluoride in addition to the standard suite of parameters listed in Table 6-4, NM003E.

2. Monitoring parameters were selected because they are considered indicators for potential constituents resulting from mining activities as discussed in the Probable Hydrologic Chapter 11, Section 6, NM003E

3. Specific conductance, pH, calcium, sodium, carbonate, bicarbonate, and chloride are analyzed, in addition to monitoring parameters, to assess general groundwater chemistry and for determining water type. Reference criteria are not established for these parameters because they are not considered indicator parameters for potential source constituents.

4. Reference criteria are mean values plus two (2) standard deviations calculated from historic data collected through 2002. Detection values were calculated as the product of 0.5 and the detection limit.

TABLE 6-6

Analytical Methods and Detection Limits

PARAMETERS	EPA METHOD	DETECTION LIMITS
Temperature	170.1	0.2^0 C
Total Dissolved Solids (TDS)	160.1	10 mg/L
Conductivity	120.1	10 µmh/cm
pH	150.1	0.5 S.I. units
Water level	(*)	0.01 feet
Calcium	200.7	0.10 mg/L
Magnesium	200.7	0.05mg/L
Sodium	200.7	0.50 mg/L
Potassium	200.7	0.50 mg/L
Carbonate	310.1	2.00 mg/L
Bicarbonate	310.1	2.00 mg/L
Sulfate	300.0	1.00 mg/L
Chloride	300.0	1.00 mg/L
Selenium	270.3	0.01 mg/L

* RCRA Ground Water Monitoring Technical Enforcement Guidance Document, 1986

6.7 REFERENCES

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APPENDIX 6-A

QUALITY ASSURANCE AND QUALITY CONTROL
WATER QUALITY

(9/93)

QUALITY ASSURANCE AND QUALITY CONTROL (QA/QC) PROGRAM
WATER QUALITY

GENERAL REQUIREMENTS

BHP Minerals will contract with a single laboratory to provide water analytical services. If there is an anticipated change in laboratory, BHP Minerals will notify OSMRE within 60 days of the contract. If another lab is selected in the bidding process, OSM will be informed. BHP Minerals will coordinate planning, procedures and techniques of sampling programs with the contract laboratory.

SAMPLE COLLECTION, HANDLING, AND TRANSPORT:

1. Ground Water

Prepared sample kits and sampling instructions will be provided by the contract laboratory prior to sampling dates. The sample kits will be preserved and prepared according to the specified parameter lists in Tables 27.15 and 27.16 in Chapter 27 of the current approved PAP (NM-0003B). Water samples will be collected in a clean one gallon plastic bucket. At each site, the bucket will be thoroughly rinsed twice with distilled water before the sample is collected. The bottles from the prepared kits will be immediately filled. The samples will be packed in ice and transported expeditiously to the contract lab.

2. Surface Water

Surface water samples are automatically collected in clean and dry 1-liter polypropylene bottles. These are replaced when the bottles are filled. Samples are packed in ice and shipped expeditiously to the contract lab.

SAMPLE DOCUMENTATION FORM:

1. All samples submitted for analysis will be documented and kept on file. Instructions for type of analysis will be submitted to the laboratory with a list of samples being submitted for analysis. Time and date of sample and pertinent field data will be provided for all samples.

QUALITY ASSURANCE/QUALITY CONTROL PROGRAM ELEMENTS:

GENERAL

1. The contract laboratory must be EPA-certified or certified by other national or regionally recognized external accreditation;

2. A statement of qualifications of all laboratory personnel handling the samples and data will be provided to the company;

3. A detailed internal laboratory QA/QC program on all analytical work will be provided to the company;

4. All internal laboratory QA/QC data will be supplied to the company upon request;

5. A laboratory Standard Operating Procedure (SOP) outlining analytical procedures, calibrations, data reduction, etc. will be provided to the company for review;

6. If procedure modifications are made, the laboratory must describe the modifications in detail and supply the information to the company prior to an approved change.

DUPLICATE SAMPLING

Duplicate samples from five (5) monitoring wells will be submitted annually to the laboratory as blind samples. The sites will be selected in such a manner that within three years, a duplicate sample will be submitted once for all the wells listed in Table 27.11 of Chapter 27 of the approved PAP. Two (2) bottle sets from any one station will be filled, preserved and shipped in an identical manner. Furthermore, the location and other information given on the label will not reveal that the sample is a duplicate. This will provide a check for data precision, repeatability, and consistency from the laboratory.

LABORATORY

1. At least 20% of all samples will be run in duplicate;

2. At least 20% of all samples will be spiked for recovery;

3. 2-6 standards will be run for each set, depending on the given parameter;

4. Additional standards should be run throughout the series of samples at the rate of at least one (1) per 20 or less samples;

5. A standard and a blank will be run at the end of each set;

6. An EPA or NTIS traceable standard (known) will be run for each set of 20 or less samples;

7. All major equipment and balances will be under an inspection program;

8. The laboratory will at a minimum meet the laboratory procedures for the parameters listed in Tables 27.15-27.17 in Chapter 27 of the current approved PAP (NM-0003B) as outlined in "Methods for Chemical Analysis of Water and Wastes". Any modification to any of the methodology will be approved in advance.

ANALYTICAL QUALITY CONTROL

1. CATION-ANION BALANCE

   The formulas outlined in Method #1030 F in "Standard Methods for the Examination of Water and Wastewater" will be used to calculate cation-anion balance.

2. TDS RATIO CALCULATION

   The formulas outlined in Method #1030 F in "Standard Methods for the Examination of Water and Wastewater" will be used to calculate TDS ratio.

3. At a minimum, cation-anion balance will be used for laboratory data checks.

SAMPLE LOG MANUAL:

All samples delivered to the laboratory will be logged into the permanent record book, and the information will also be recorded on an internal lab information sheet (lab control sheet). This sheet will become part of the permanent files.

QUALITY CONTROL RECORDS MANUAL:

All quality control data will be maintained in the permanent records. The data for each parameter (i.e. duplicate and spiked samples, "known" and "unknown", audit samples and "splits") and their relationship to the +/- two (2) standard deviations will be kept in the chart form or other tabular to allow easy review of the control of the methods.

DATA ANALYSIS

The hydrology data will be statistically summarized and a trend analysis will be run on all the ground water and surface water parameters being analyzed. Further, the data will serve to determine background levels except the data generated as a result of the Navajo Indian Irrigation Project (NIIP) irrigation runoff. This data does not represent precipitation runoff.

REFERENCES

American Public Health Association. Standard Methods for the Examination of Water and Wastewater. 17th Edition or most current edition. Published jointly by: American Public Health Association, American Water Works Association, and Water Pollution Control Federation. Washington, D.C.

EPA. 1979. Methods for Chemical Analysis of Water and Wastes. EPA - 600/4-79-202. Cincinnati, OH.

APPENDIX 6-B

(copy of 1989 Appendix 12A)

WELL COMPLETION RECORDS

1985 Reorganization
Amended 10/89
12-A-1

WELL COMPLETION REPORT

Well Name (Kf83-1) Kf-1 Mine Navajo

Location Watson Pit (East)

County San Juan State New Mexico

Driller Jim Gay

Formation Fruitland/Kirtland TD 145

Drill Type Rotary

Drilling Fluid Injection Mist, 125' to 154'

Logs Rotary Cuttings; Geophysical logs: Gamma, Density, & Res.

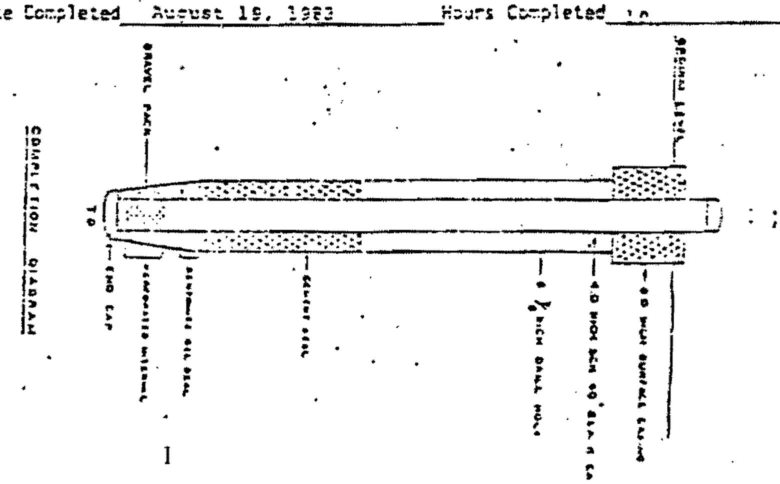
Hours Drilled 5

Note: Hole making 1 gal/min.

Completion Information

Casing Type	4" SCH. 40		
Casing Diameter	4"		
Perforated Casing	20' Slotted		
Blank Casing From	Top 0.0'	to	125'
Surface Casing From		to	
Perforated Casing From	125'	to	145'
Gravel Pack From	123'	to	145'
Gel Seal From	120'	to	123'
Cement Bottom Seal From	145'	to	154'
Cement Top Seal From	50'	to	120'
Packers Used (Y or N)		Centralizers Used (Y or N)	
Initial Water Level			
Elevation		Saturated Thickness	
Pump Installed		Air Lift Installed	
Pump Depth		Air Lift to TD (Y or N)	

Date Completed August 19, 1983 Hours Completed [illegible]



1985 Reorganization
Amended 10/89
12-A-2

WELL DRILLING REPORT

WELL NAME (Kf83-1) Watson Pit (East)   Kf - 1

DATE 8/18/83
PAGE 2 of 2

INTERVAL		WATER	LITHOLOGY	DESCRIPTION
0.0	7.0		Alluvial	Lt. Brown, shale, weathered
7.0	9.0		Shale	Gray, soft, oxidized
9.0	11.0		Sltstn	Lt. Gray, Very hard
11.0	12.0		Sandstone	Lt. Gray Hard
12.0	16.0		Shale	Gray, Soft
16.0	17.0		Sltstn	Lt. Gray, Very hard, Fine grained
17.0	36.0		Shale	Gray, Soft
36.0	37.0		Coal	Dull black, Shaley, Soft
37.0	47.0		Shale	Gray, Soft
47.0	48.0		Coal	Hard, Moist
48.0	50.0		Shale	Gray, Soft, Sandy
50.0	55.0		Shale	Gray, Soft
55.0	56.0		Coal	Hard, Moist
56.0	66.0		Shale	Gray, Soft
66.0	76.0		Sltstn	Gray, Moderately hard
76.0	104.0		Sandstone	Lt. Gray, Very hard (Damp @ 97')
104.0	105.0		Shale	Gray, Soft, Silty
105.0	106.0		Sandstone	Gray, Hard
106.0	107.0		Shale	Gray, Hard, Silty
107.0	112.0	5.0'	Coal	Hard, Lustre
112.0	128.0	16.0'	Shale	Gray, Soft
128.0	144.0	16.0'	Coal	Hard, Lustre, H_2S, H_2O bottom half @ less
144.0	154.0		Shale	Gray, Soft
154.0	155.0		Sandstone	PC Formation
				NOTE: Noticeable water invasion @ 112' dep
				also at 154' depth. Hole making wa
				less than 2 gallons per minute.

WELL COMPLETION REPORT

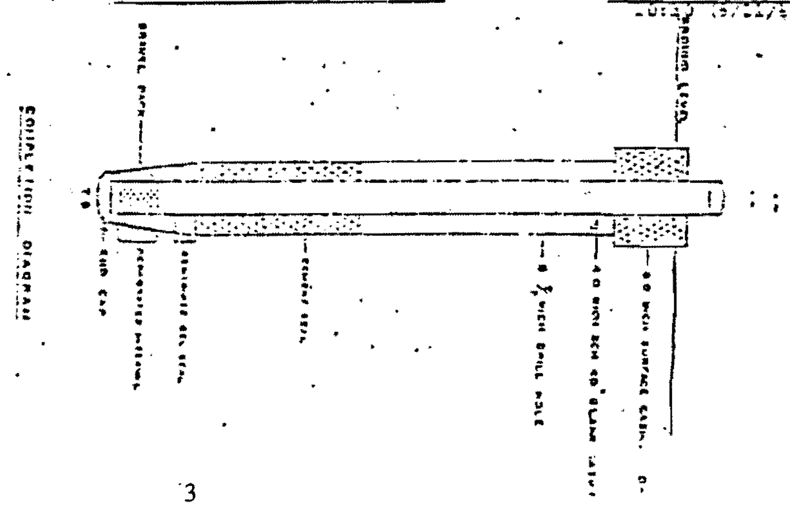
Well Name (Kf83-2) Kf - 2 Mine Navajo
Location Custer Pit
County San Juan State New Mexico
Driller Jim Gay
Formation Fruitland TD 172.0'
Drill Type Rotary
Drilling Fluid None
Logs Lithology, Geophysical
Hours Drilled

Note: No Water

Completion Information

Casing Type	4" SCD. 40		
Casing Diameter	4"		
Perforated Casing	18'		
Blank Casing From	0'	to	154'
Surface Casing From	0'	to	10'
Perforated Casing From	154'	to	172'
Gravel Pack From	152'	to	172'
Gel Seal From	150'	to	152'
Cement Bottom Seal From		to	
Cement Top Seal From	[illegible]	to	152'
Packers Used (Y or N)		Centralizers Used (Y or N)	
Initial Water Level	None		
Elevation		Saturated Thickness	
Pump Installed		Air Lift Installed	
Pump Depth		Air Lift to TD (Y or N)	

Date Completed August 22, 1983 Hours Completed 11:00 (8/19/83)
[illegible] (8/22/83)



WELL DRILLING REPORT

HOLE NAME (Kf83-2) Custer Pit Kf - 2

DATE 9-19-83
PAGE 2 of 2

INTERVAL		WATER	LITHOLOGY	DESCRIPTION
0.0	1.0		Alluvial	Blown sand, tan fine grained.
1.0	4.0		Shale	Gray, soft, clayey, oxidized.
4.0	10.0		Shale	Gray, soft, oxidized.
10.0	30.0		Sandstone	Lt gray, hard, oxidized, fine grained.
30.0	31.0		Shale	Gray, soft, sandstone interbedded.
31.0	37.0		Sandstone	Lt. gray, moderately hard.
37.0	51.0		Shale	Gray, soft.
51.0	56.0		Sandstone	Lt. gray, hard, fine grained.
56.0	71.0		Shale	Gray, slightly hard.
71.0	73.0		Coal	Hard, lustre.
73.0	90.0		Shale	Gray, soft.
90.0	92.0		Shale	Carbonaceous, dark, gray, soft.
92.0	103.0		Shale	Gray, soft.
103.0	107.0	5.0'	Coal	Hard, lustre.
107.0	108.0		Shale	Gray, soft.
108.0	149.0		Sandstone	Lt. gray, hard.
149.0	156.0		Shale	Gray, soft.
156.0	171.0	15.0	Coal	High grade, hard, lustre.
171.0	172.0		Shale	Gray, soft.

NOTE: No water found in well location.

WELL COMPLETION REPORT

Well Name (Kf83-3) Kf - 3 Mine Navajo

Location Doby Pit

County San Juan State New Mexico

Driller Jim Gay

Formation Fruitland TD 149'

Drill Type Rotary

Drilling Fluid None

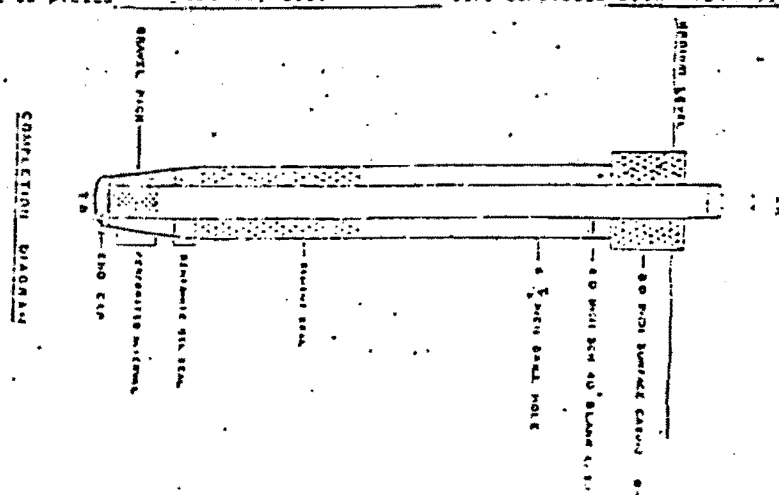
Logs Lithology and Geophysical

Hours Drilled 3 hours and 45 minutes

Note: No Water

Completion Information

Casing Type	4" SCD. 40		
Casing Diameter	4"		
Perforated Casing	14'		
Blank Casing From	Surface	to	135'
Surface Casing From		to	
Perforated Casing From	135'	to	149'
Gravel Pack From	133'	to	149'
Gel Seal From	131'	to	133'
Cement Bottom Seal From		to	
Cement Top Seal From	0	to	10'
Packers Used (Y or N)		Centralizers Used (Y or N)	
Initial Water Level			
Elevation		Saturated Thickness	
Pump Installed		Air Lift Installed	
Pump Depth		Air Lift to TD (Y or N)	
Date Completed	August 22, 1983	Hours Completed	11:00 (8/22/83) [illegible]



1985 Reorganization
12-A-6

WELL DRILLING REPORT

WELL NAME (Kf83-3) Kf - 3 Doby Pit

DATE 9/22/83
PAGE [illegible] OF [illegible]

INTERVAL		WATER	LITHOLOGY	DESCRIPTION
0.0	17.0		Alluvial	Blown sand, Tan, Fine grained
17.0	49.0		Sand	Lt. Brown, Soft, Oxidized, Fine grained
49.0	55.0		Shale	Gray, Soft
55.0	65.0		Sandstone	Lt. Gray, Very hard
65.0	70.0		Siltstone	Lt. Gray, Very hard
70.0	75.0		Sandstone	Lt. Gray, Very hard, Fine grained
75.0	86.0		Siltstone	Lt. Gray, Extra hard
86.0	110.0		Sandstone	Lt. Gray, Very hard
110.0	114.0		Shale	Gray, Moderately hard
114.0	130.0		Sandstone	Lt. Gray, Very hard
130.0	137.0		Shale	Gray, Slightly hard
137.0	148.0		Coal	H_2S
148.0	149.0		Shale	Gray, Soft
				NOTE: No water encountered in hole.

WELL COMPLETION REPORT

Well Name (Kf83-4) Kf - 4
Mine Navajo

Location Yazzie Pit

County San Juan
State New Mexico

Driller [illegible]

Formation Fruitland
TD 137

Drill Type Mayhew 1250 (Rotary)

Drilling Fluid -

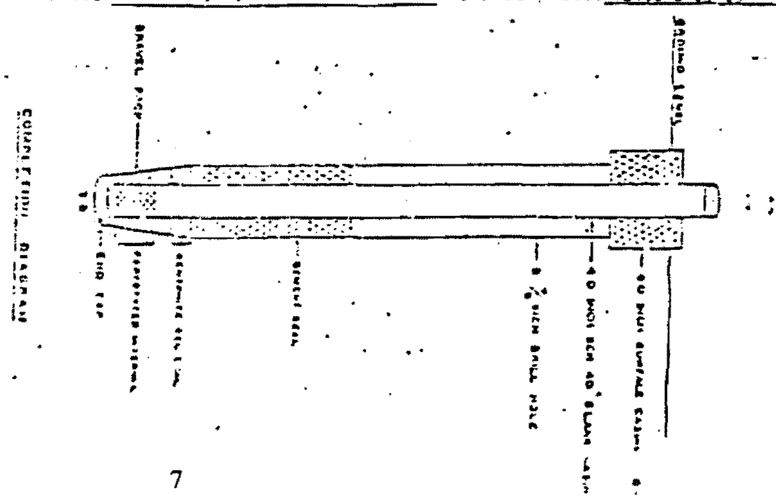
Logs

Hours Drilled

Water in well after 7 days; < 1 Gal./Min.

Completion Information

Casing Type Schedule 40 4" PVC
Casing Diameter 4"
Perforated Casing 4" Slotted
Blank Casing From 0 to 123
Surface Casing From 0 to 10
Perforated Casing From 123 to 133
Gravel Pack From 121 to 138
Gel Seal From 119 to 121
Cement Bottom Seal From to
Cement Top Seal From 59 to 119
Packers Used (Y or N)
Centralizers Used (Y or N)
Initial Water Level
Elevation
Saturated Thickness
Pump Installed
Air Lift Installed
Pump Depth
Air Lift to TD (Y or N)
Date Completed 8-23-83
Hours Completed 7:00/8-23-83 12:00/8-23-83



WELL DRILLING REPORT

WELL NAME (Kf83-4) Kf-4

DATE 9-23-83
PAGE

INTERVAL		WATER	LITHOLOGY	DESCRIPTION
0.0	1.0		Alluvial	Sandy, Shaley, weathered.
1.0	2.0		Shale	Lt. brown, soft, oxidized.
2.0	7.0		Sandstone	Lt. gray, hard, silty.
7.0	16.0		Shale	Gray, soft.
16.0	17.0		Sandstone	Lt. gray, hard, parting.
17.0	32.0		Shale	Gray, soft.
32.0	33.0		Coal	Thin, seam, dull black.
33.0	52.0		Shale	Gray, soft.
52.0	54.0		Sandstone	Lt. gray, hard.
54.0	55.0		Shale	Gray, moderately hard.
55.0	64.0		Sandstone	Lt. gray, hard, shale interbedded.
64.0	67.0		Shale	Gray, soft.
67.0	69.0		Sandstone	Lt. gray, very hard, silty.
69.0	72.0		Shale	Gray, soft, with hard S.S. interbedded.
72.0	85.0		Shale	Gray, soft.
87.0	99.0		Shale	Dark gray, carbonaceous, soft.
99.0	104.0		Shale	Gray, soft.
104.0	106.0		Sandstone	Lt. gray, very hard, silty.
106.0	109.0		Shale	Gray, soft.
109.0	117.0		Sandstone	Lt. gray, hard, silty.
117.0	127.0		Shale	Gray, soft.
127.0	137.0		Coal	
137.0	139.0		Shale	Gray, soft.
				NOTE: No water in hole.

WELL COMPLETION REPORT

Well Name (Kf83-9(a)) Kf-9A

Mine Navajo

Location Area III

County San Juan

State New Mexico

Driller Jim Gay

Formation Fruitland

TD [illegible]

Drill Type Falling

Drilling Fluid Injection (water)

Logs

Hours Drilled

Completion Information

Casing Type 4" schedule 40

Casing Diameter

Perforated Casing 4" slotted

Blank Casing From 0 to [illegible]

Surface Casing From to

Perforated Casing From 177 to [illegible]

Gravel Pack From 175 to [illegible]

Gel Seal From 172 to 175

Cement Bottom Seal From to

Cement Top Seal From to

Packers Used (Y or N) Centralizers Used (Y or N)

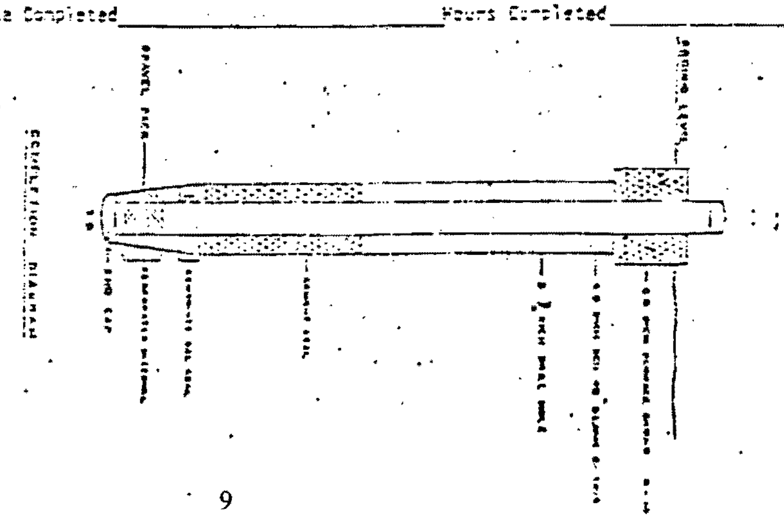
Initial Water Level

Elevation Saturated Thickness

Pump Installed Air Lift Installed

Pump Depth Air Lift to TD (Y or N)

Date Completed Hours Completed



[illegible]L NAME (Kf83-9(a)) Kf-9A

DATE 9/26/83
PAGE 1 OF 1

INTERVAL		WATER	LITHOLOGY	DESCRIPTION
				Same as 9c

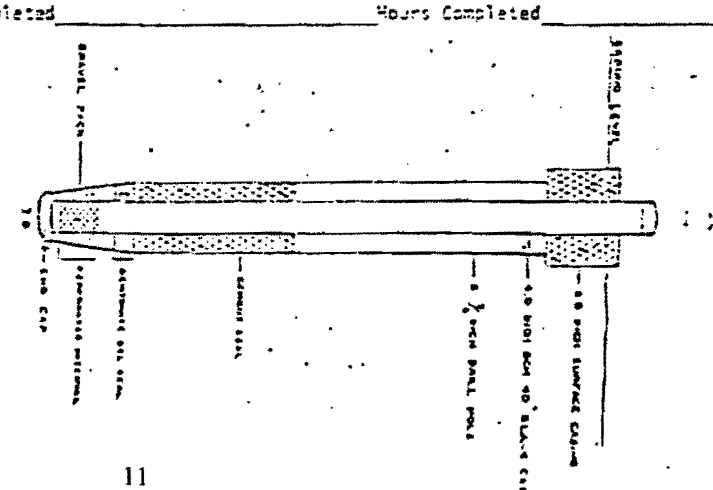
WELL COMPLETION REPORT

Well Name	(Kf83-9(b)) Kf-9B	Mine	Navajo
Location	Area III		
County	San Juan	State	New Mexico
Driller	[illegible]		
Formation	Fruitland	TD	213' Seam 2
Drill Type	[illegible]		
Drilling Fluid	Injection (water)		
Logs			
Hours Drilled			

Completion Information

Casing Type	4" schedule 40		
Casing Diameter			
Perforated Casing	4" slotted		
Blank Casing From	0	to	202
Surface Casing From		to	
Perforated Casing From	202	to	213
Gravel Pack From	200	to	213
Gel Seal From	195	to	200
Cement Bottom Seal From		to	
Cement Top Seal From		to	
Packers Used (Y or N)		Centralizers Used (Y or N)	
Initial Water Level			
Elevation		Saturated Thickness	
Pump Installed		Air Lift Installed	
Pump Depth		Air Lift to TD (Y or N)	
Date Completed		Hours Completed	

COMPLETION DIAGRAM



WELL NAME (Kf83-9(b) Kf-9B

DATE 8/26/83
PAGE 1 OF 1

INTERVAL	WATER	LITHOLOGY	DESCRIPTION
			Same as 9c

1985 Reorganization
12-A-13

WELL COMPLETION REPORT

Well Name (Kf83-9(c) Kf-9c — Mine [illegible]

Location Area [illegible]

County San Juan — State [illegible]

Driller Jim Gay

Formation Fruitland — TD [illegible]

Drill Type [illegible]

Drilling Fluid Injection (water)

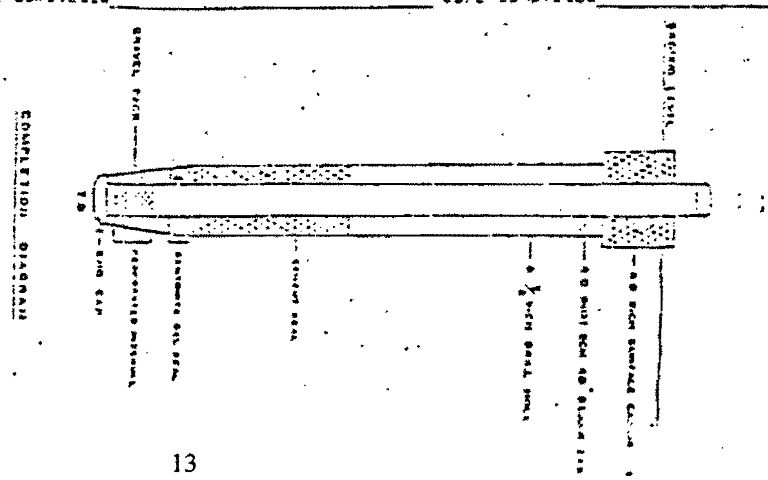
Logs

Hours Drilled

Completion Information

Casing Type 4" [illegible]
Casing Diameter
Perforated Casing 4" slotted
Blank Casing From [illegible] to [illegible]
Surface Casing From to
Perforated Casing From 226 to [illegible]
Gravel Pack From 224 to [illegible]
Gel Seal From [illegible] to 224
Cement Bottom Seal From to
Cement Top Seal From to
Packers Used (Y or N) — Centralizers Used (Y or N)
Initial Water Level
Elevation — Saturated Thickness
Pump Installed — Air Lift Installed
Pump Depth — Air Lift to TD (Y or N)

Date Completed — Hours Completed



1985 Reorganization
12-A-14

WELL NAME (Kf83-9(c) Kf-9c

DATE 8 /26/83
PAGE 1 of 1

INTERVAL		WATER	LITHOLOGY	DESCRIPTION
0.0	3.0		Shale	Light Brown, Soft, Sandy
3.0	12.0		Shale	Gray, Clayey
12.0	24.0		Shale	Gray, Soft
24.0	25.0		Siltstone	Light Gray, Very Hard
25.0	57.0		Shale	Gray, Soft
57.0	88.0		Siltstone	Light Gray, Very Hard
88.0	97.0		Shale	Gray, Soft
97.0	108.0		Sandstone	Light Gray, Hard
108.0	110.0		Siltstone	Light Gray, Very Hard
110.0	116.0		Shale	Gray, Soft
116.0	128.9	12.0	Coal	
128.0	149.0		Shale	Gray, Soft
149.0	157.0	8.0	Coal	
157.0	163.0		Shale	Gray, Soft
163.0	166.0		Siltstone	Light Gray, Very Hard
166.0	170.0		Shale	Gray, Soft
170.0	175.0		Sandstone	Light Gray, Very Hard
175.0	178.0		Shale	Gray, Soft
178.0	182.0	4.0	Coal	
182.0	186.0		Shale	Gray, Soft
186.0	187.0	1.0	Coal	
187.0	188.0		Shale	Gray, Soft
188.0	189.0		Sandstone	Light Gray, Hard
189.0	203.0		Shale	Gray, Soft, Silty Sand @ 191'
203.0	212.0	9.0	Coal	
212.0	227.0		Shale	Gray, Soft

Note: Water from 203' to 212' depth in coal beds

WELL COMPLETION REPORT

Well Name (Kf83-10(a) Kf-10A — Mine Navajo

Location Area III South

County San Juan — State New Mexico

Driller Jim Gay

Formation Fruitland — TD 184 — Seam 8A

Drill Type Failing 1250 (Rotary)

Drilling Fluid Injection (water)

Logs

Hours Drilled

Completion Information

Casing Type 4 " schedule 40 PVC

Casing Diameter

Perforated Casing 4 " slotted

Blank Casing From 0 to [illegible]

Surface Casing From to

Perforated Casing From [illegible] to 184

Gravel Pack From 170 to 184

Gel Seal From 166 to 170

Cement Bottom Seal From to

Cement Top Seal From to

Packers Used (Y or N) — Centralizers Used (Y or N)

Initial Water Level

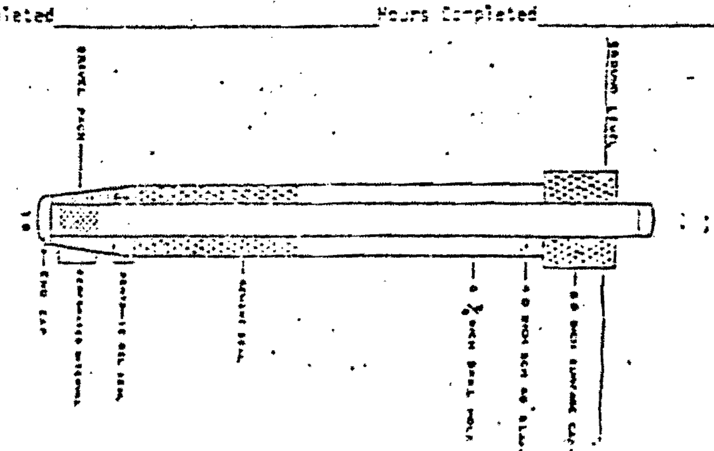
Elevation — Saturated Thickness

Pump Installed — Air Lift Installed

Pump Depth — Air Lift to TD (Y or N)

Date Completed — Hours Completed

COMPLETION DIAGRAM



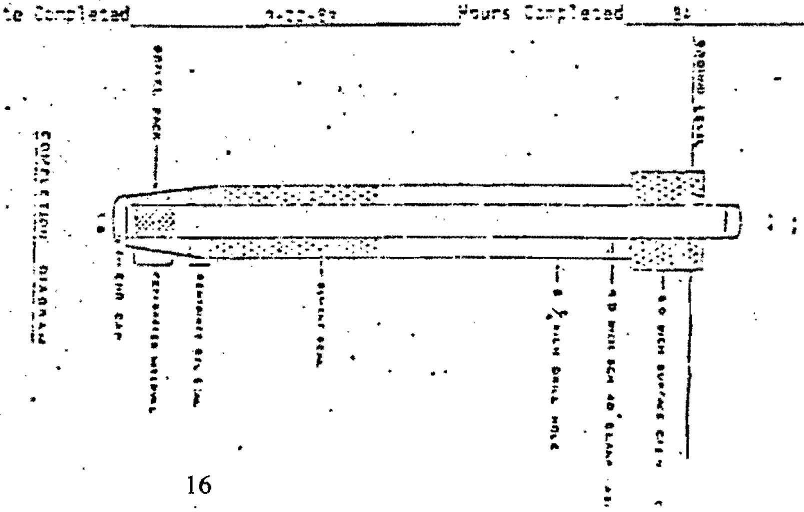
1985 Reorganization
12-A-16

WELL COMPLETION REPORT

Well Name	(Kf83-11) Kf-11	Mine	Navajo
Location	North end Watson		
County	San Juan	State	New Mexico
Driller	Jim V. Dev		
Formation	Kirtland/Fruitland	TD	130
Drill Type	Failing 1250 (Rotary)		
Drilling Fluid	H_2O (Injected) with Foam.		
Logs	Lithology - Geophysical		
Hours Drilled			

Completion Information

Casing Type	Schedule 40 PVC 4"		
Casing Diameter	7-7/8" Drill Bit		
Perforated Casing	Schedule 40 4" PVC		
Blank Casing From	0	to	~~55~~ 55
Surface Casing From	0	to	7
Perforated Casing From	55	to	130
Gravel Pack From	77	to	130
Gel Seal From	73	to	77
Cement Bottom Seal From	7	to	7
Cement Top Seal From	30	to	73
Packers Used (Y or N)		Centralizers Used (Y or N)	
Initial Water Level	-0-		
Elevation		Saturated Thickness	
Pump Installed		Air Lift Installed	
Pump Depth		Air Lift to TD (Y or N)	
Date Completed	9-22-83	Hours Completed	8



WELL DRILLING REPORT

DATE 9-21-83
PAGE

WELL NUMBER (Kf83-11) Kf-11

INTERVAL		WATER	LITHOLOGY	DESCRIPTION
0.0	15.0		Alluvial	River sand, tan, medium grained.
15.0	31.0		Gravel	Pebbles with 14" boulders.
31.0	33.0		Shale	Carbonaceous, dark gray, weathered, oxidized.
33.0	37.0		Shale	Gray, soft, with brown streaks.
37.0	42.0		Clay	Tan, soft, (tonstein).
42.0	85.0		Shale	Gray, soft.
85.0	97.0	12.0	Coal	
97.0	100.0		Shale	Gray, soft.

WELL COMPLETION REPORT

Well Name (SJKF84-3) SJKF 84 No. 3

Location ¼SW ¼NW ¼NE Section 11 T29N, R15W

County San Juan | Mine Navajo

Driller Gay | State New Mexico

Formation Fruitland | TD 120

Drill Type Rotary

Drilling Fluid Air/H_2O/Mud

Logs Gamma-Gamma, Gamma-Density, Resistivity, Caliper, Lithology

Hours Drilled 12 4-17-84

Completion Information

Casing Type Sch 40 PVC

Casing Diameter 2.0 Inch ID

Perforated Casing 0.03 mm

Blank Casing From 000.0 to 098 (112-120)

Surface Casing From 000.0 to 126.0

Perforated Casing From 098.0 to 112.0

Gravel Pack From 095.0 to 120.0

Gel Seal From 092.0 to 096.0

Cement Bottom Seal From 000.0 to 092.0

Cement Top Seal From - to -

Packers Used (Y or N) N | Centralizers Used (Y or N) N

Initial Water Level 9.34

Elevation 5,110.18 | Saturated Thickness 14

Pump Installed N | Air Lift Installed Y

Pump Depth | Air Lift to TD (Y or N) Y

Date Completed 4-18-84 | Hours Completed 3

WELL COMPLETION REPORT

(SJKF84-3)

Interval	Water	Lithology	Description
000 to 020	Mud	Spud	Al, SD, Gravel @ 10 Ft.
020 to 025	Bl.Mud	Gravel	- to 26 Ft., St Surf. Csng - 8.0 Inch
025 to 030	Inj H_2O	SH	BCarb, w/Coal Str
030 to 035		AA	
035 to 036		Coal	
036 to 037		Coal	
037 to 038		Coal	
038 to 039		Coa	SHY
039 to 040		Sh	VCarb, Gry
040 to 045		AA	
045 to 050		AA	
050 to 055		AA	SD L 10%
055 to 060		AA	Slts
060 to 065		AA	Incr. Slts
065 to 070		SLTS	Vshy, Calc, Scarb
070 to 075		AA	Carb
075 to 080		AA	
080 to 085		AA	Carb
085 to 090		AA	
090 to 095		SH	VCarb
095 to 100		AA	Incr. Carb to Coal Str
100 to 101		Coal	
101 to 102		Coal	
102 to 103		Coal	
103 to 104		Coal	
104 to 105		Coal	
105 to 106		Coal	
106 to 107		Coal	
107 to 108		Coal	
108 to 109		Coal	
109 to 110		Coal	
110 to 111		Coal	
111 to 112		Coal	SHY
112 to 115		SH	VCarb, Gry
115 to 120		AA	Carb
		TD	4-17-84

WELL COMPLETION REPORT

Well Name (SJKF84-2) SJKF 84 No. 2

Location ¼SW ¼SW ¼SW Section 2 T29N, R15W

County San Juan

Mine Navajo

Driller Gay

State New Mexico

Formation Fruitland

TD 144.0

Drill Type Rotary

Drilling Fluid Air/H_2O/MUD

Logs Gamma-Gamma, Gamma-Density, Resistivity, Caliper, Litho

Hours Drilled 10½ 4-16-84

Completion Information

Casing Type Sch 40 PVC

Casing Diameter 2.0 Inch ID

Perforated Casing 0.03 mm

Blank Casing From 000 to 124.0

Surface Casing From - to -

Perforated Casing From 124.0 to 144.0

Gravel Pack From 122.0 to 144.0

Gel Seal From 118.0 to 122.0

Cement Bottom Seal From 000.0 to 118.0

Cement Top Seal From PAD to -

Packers Used (Y or N) N

Centralizers Used (Y or N) N

Initial Water Level 20.27

Elevation 5,129.22

Saturated Thickness 18.5

Pump Installed N

Air Lift Installed Y

Pump Depth

Air Lift to TD (Y or N) Y

Date Completed 4-17-84

Hours Completed 3

WELL COMPLETION REPORT

(SJKF84-2)

Interval	Water	Lithology	Description
000 to 020		SPUD	Col, All, Gravel @ 14 Feet
020 to 025		GSD	VFG, All
025 to 030		AA	Gravels @ 27 Feet DR LO 1 Ft/n
030 to 035		Gravel	Cobble
035 to 040		SD	VFG, Col, Qal, Incr. Dr, SSHY
040 to 050		SH	SHY, VCarb
050 to 055		AA	
055 to 060		AA	Carb, SD L10%
060 to 065		AA	
065 to 070		AA	SCarb
070 to 075		AA	
075 to 080		AA	
080 to 085		AA	
085 to 090		AA	Incr. Carb
090 to 095		Coal	VSHY, BNY
095 to 100		SH	VCarb to Carb
100 to 105		AA	
105 to 110		AA	SD Incre 05%
110 to 115		AA	Incr. SD
115 to 120		AA	Carb
120 to 125		AA	V Carb, Coal Str
125 to 130		AA	Incr. Coal Str
130 to 135		SH	VCarb
135 to 136		Coal	
136 to 137		Coal	
137 to 138		Coal	
138 to 139		Coal	
139 to 140		Coal	
140 to 141		Coal	
141 to 145		SH	VCarb
		TD	4-16-84

Circulate with clear water to TD

WELL COMPLETION REPORT

Well Name (SJKF84-1) SJKF 84 No. 1

Location ¼SW ¼NE ¼SE Section T39N. R15W

County San Juan

Mine Navajo

Driller Gay

State New Mexico

Formation Fruitland

TD 140.0

Drill Type Rotary

Drilling Fluid Air/H_2O/Mud

Logs Litho

Hours Drilled 12¼. 4-10 to 4-11. 1984

Completion Information Plugged to Surface

Casing Type ______

Casing Diameter ______

Perforated Casing ______

Blank Casing From ______ to ______

Surface Casing From ______ to ______

Perforated Casing From ______ to ______

Gravel Pack From ______ to ______

Gel Seal From ______ to ______

Cement Bottom Seal From ______ to ______

Cement Top Seal From ______ to ______

Packers Used (Y or N) ______ Centralizers Used (Y or N) ______

Initial Water Level ______

Elevation ______ Saturated Thickness ______

Pump Installed ______ Air Lift Installed ______

Pump Depth ______ Air Lift to TD (Y or N) ______

Date Completed ______ Hours Completed ______

WELL COMPLETION REPORT

(SJKF84-1)

Interval	Water	Lithology	Description
000 to 020	MUD	SPUD	Col, Qal, Gravel, Cobble, SH
020 to 025		ALL	FG, BRN
025 to 030		GRAVEL	Cobble, poss, H_2O Incr. GPM
030 to 035		AA	
035 to 040		AA	
040 to 045		AA	Incr. Cobble, NO H_2O
045 to 050		AA	
050 to 055		AA	
055 to 060		SD	S-P, VFG, Carb, Incr. DR
060 to 065		AA	
065 to 070		AA	Incr. Carb
070 to 075		AA	
075 to 080		AA	Incr. DR
080 to 085		AA	
085 to 090		AA	
090 to 095		AA	
095 to 100		AA	EOD 4-10-84
100 to 105		AA	
105 to 110		AA	
110 to 115		AA	
115 to 120		AA	
120 to 125		AA	
125 to 130		AA	
130 to 135		AA	
135 to 140		AA	TD

Set 15-Pound cement plug 000 - 140 from bottom coal seam not present.

WELL COMPLETION REPORT

Well Name (KF84-22(a) Kf8422 No. 8

Location Area IV, Cottonwood Arroyo, East of Burnham Road, N2009510.05, E307822.15

County San Juan

Mine Navajo

Driller Gay

State New Mexico

Formation Fruitland

TD 125

Drill Type Rotary

Drilling Fluid Air

Logs Gamma-Gamma, Gamma-Density, Resistivity, Caliper, Litho.

Hours Drilled 1½

Completion Information

Casing Type Sch 40 PVC

Casing Diameter 2.0 inch ID

Perforated Casing 0.03 mm

Blank Casing From 000.0 to 090.0

Surface Casing From - to -

Perforated Casing From 090.0 to 125.0

Gravel Pack From 085.0 to 125.0

Gel Seal From 082.0 to 085.0

Cement Bottom Seal From 000.0 to 082.0

Cement Top Seal From - to -

Packers Used (Y or N) N

Centralizers Used (Y or N) N

Initial Water Level 77.57

Elevation 5343.90

Saturated Thickness 24

Pump Installed

Air Lift Installed Y

Pump Depth N

Air Lift to TD (Y or N) Y

Date Completed 4-27-84

Hours Completed 1½

WELL COMPLETION REPORT

Well Name (KF84-22(b) Kf8422, No. 7

Location Area IV, Cottonwood Arroyo, East of Burnham Road, N2009513.79, E307829.36

County San Juan Mine Navajo

Driller Gay State New Mexico

Formation Fruitland TD 140

Drill Type Rotary

Drilling Fluid Air

Logs Gamma-Gamma, Gamma-Density, Resistivity, Caliper, Litho.

Hours Drilled 2 4-26-84

Completion Information

Casing Type Sch 40 PVC

Casing Diameter 2.0 inch Id

Perforated Casing 0.03 mm

Blank Casing From 000.0 to 134.0

Surface Casing From - to -

Perforated Casing From 134.0 to 140.0

Gravel Pack From 132.0 to 140.0

Gel Seal From 139.0 to 132.0

Cement Bottom Seal From 054.0 to 129.0

Cement Top Seal From 000.0 to 005.0

Packers Used (Y or N) N Centralizers Used (Y or N) N

Initial Water Level 79.06

Elevation 5344.10 Saturated Thickness 6.0

Pump Installed N Air Lift Installed Y

Pump Depth Air Lift to TD (Y or N) Y

Date Completed 4-25-84 Hours Completed 2

WELL COMPLETION REPORT

Well Name (KF84-22(c) Kf8422, No. 4

Location Area IV, Cottonwood Arroyo, East Burnham Road ,N2009520.55,E307841.20

County San Juan | Mine Navajo

Driller Gay | State New Mexico

Formation Fruitland | TD 2.02

Drill Type Rotary

Drilling Fluid Air

Logs Gamma-Gamma, Gamma-Density, Resistivity, Caliper, Litho. (Same as KF8422,NO.2)

Hours Drilled 2½

Completion Information

Casing Type Sch. 40 PVC

Casing Diameter 2.0 inch Id

Perforated Casing 0.33 mm

Blank Casing From 000.0 to 197.0

Surface Casing From - to -

Perforated Casing From 197.0 to 202.0

Gravel Pack From 195.0 to 202.0

Gel Seal From 193.0 to 195.0

Cement Bottom Seal From 118.0 to 193.0

Cement Top Seal From 000.0 to 005.0

Packers Used (Y or N) N | Centralizers Used (Y or N) N

Initial Water Level 89.42

Elevation 5344.60 | Saturated Thickness 5.0

Pump Installed N | Air Lift Installed Y

Pump Depth | Air Lift to TD (Y or N) Y

Date Completed 4-26-84 | Hours Completed 2½

WELL COMPLETION REPORT

Well Name (KF84-22(d) Kf8422, No. 3

Location Area IV, Cottonwood Arroyo, East of Burnham Road N2009525.42.E307832.96

County San Juan Mine Navajo

Driller Gay State New Mexico

Formation Fruitland TD 220

Drill Type Rotary

Drilling Fluid Air

Logs Gamma-Gamma, Gamma-Density, Resistivity, Caliper, Litho. (Same as KF8422 No.2)

Hours Drilled 2½

Completion Information

Casing Type Sch 40 PVC

Casing Diameter 2.0 inch Id

Perforated Casing 0.03 mm

Blank Casing From 000.0 to 213.0

Surface Casing From - to -

Perforated Casing From 213.0 to 220.0

Gravel Pack From 211.0 to 220.0

Gel Seal From 208.0 to 211.0

Cement Bottom Seal From 133.0 to 208.0

Cement Top Seal From 000.0 to 005.0

Packers Used (Y or N) N Centralizers Used (Y or N) N

Initial Water Level

Elevation Saturated Thickness 7

Pump Installed N Air Lift Installed y

Pump Depth Air Lift to TD (Y or N) Y

Date Completed 4-24-84 Hours Completed 2

WELL COMPLETION REPORT

Well Name (KF84-22(e) Kf8422, No. 2

Location Area IIV, Cottonwood Arroyo, East Burnham Road, N2009531.93. E307820.38

County San Juan

Mine Navajo

Driller Gay

State New Mexico

Formation Fruitland

TD 237

Drill Type Rotary

Drilling Fluid Air

Logs Gamma-Gamma, Gamma-Density, Resistance, Caliper, Litho

Hours Drilled 4

Completion Information

Casing Type Sch 40 PVC

Casing Diameter 2.0 inch Id

Perforated Casing 0.03 mm

Blank Casing From 000.0 to 227.0

Surface Casing From - to -

Perforated Casing From 227.0 to 237.0

Gravel Pack From 225.0 to 237.0

Gel Seal From 222.0 to 225.0

Cement Bottom Seal From 147.0 to 222.0

Cement Top Seal From 000.0 to 005.0

Packers Used (Y or N) N

Centralizers Used (Y or N) N

Initial Water Level 98.18

Elevation 53.44.80

Saturated Thickness 10.0

Pump Installed N

Air Lift Installed Y

Pump Depth

Air Lift to TD (Y or N) Y

Date Completed 4-23-84

Hours Completed 3

WELL COMPLETION REPORT

KF84-22(e)

Interval	Water	Lithology	Description
000 to 020		SPud	Cal, Shale, Brn, Sdy
020 to 025		Sh	Gry, SCarb
025 to 030		Slts	Shy, SCarb
030 to 035		AA	
035 to 040		AA	
040 to 045		AA	
045 to 050		SH	VSdy, Carb
050 to 055		AA	
055 to 060		AA	
060 to 065		AA	
065 to 070		AA	
070 to 075		SH	Carb
075 to 080		SH	VCarb, So Incr. 10%, Gry
080 to 085		AA	
085 to 090		AA	
090 to 095		Coal	
095 to 100		Coal	(No. 8B)
100 to 105		Coal	
105 to 110		SH	SCarb, Prt
110 to 115		Coal	
115 to 120		Coal	(No. 8A)
120 to 125		Coal	
125 to 130		SH	VCarb
135 to 140		Coal	(No. 7)
140 to 145		SH	VCarb, Coal Str
145 to 150		SH	Slts, VCarb
150 to 155		AA	Coal Str (1½ Ft)(No. 6)
155 to 160		Sh	VCarb, Gry
160 to 165		AA	w/ S Coal Str
165 to 170		AA	w/o Coal Str, VCarb
170 to 175		AA	VCarb
175 to 180		SD	VFG, S-P
180 to 185		SD	FMG, S-P, Fe Stn; Fr
185 to 190		SD	MG, Gloc, FR, Fe Stn
190 to 195		AA	Shy
195 to 200		SH	SSdy Incr. 10%, Blk
200 to 203		SS	Incre Carb
203 to 204		Coal	VShy

WELL COMPLETION REPORT

KF84-22(e)

Interval	Water	Lithology	Description
204 to 205		Coal	VShy
205 to 206		Coal SShy	
206 to 207		Coal Slty	
207 to 208		Coal Slty	
208 to 209		Coal	
209 to 210		Coal	
210 to 211		Coal	
211 to 213		Coal	
213 to 214		Coal	
214 to 215		Coal	
215 to 216		Coal	
216 to 217		Coal	
217 to 218		Coal	
218 to 219		Caol	Shy
219 to 220		Coal	Shy
220 to 225		SD	FG, S-P, Fe Stn
225 to 227		Coal	VShy
227 to 230		SH	VCarb, W/S Coal Str
230 to 231		Coal	
231 to 232		Coal	
232 to 233		Coal	(No. 2)
233 to 234		Coal	
234 to 235		Coal	
235 to 236		Coal	
236 to 237		SH	VCarb, Td

WELL COMPLETION REPORT

Well Name (Kf84-21(a) Kf 8421 No. 7

Location South Area III, Cottonwood Arroyo W. Burnham Road

County San Juan

Mine Navajo

Driller Gay

State New Mexico

Formation Fruitland

TD 75

Drill Type Rotary

Drilling Fluid Air

Logs Gamma-Gamma, Gamma-Density, Resistivity, Cal, Litho (all as 384-05)

Hours Drilled 1

Completion Information

Casing Type Sch 40 PVC

Casing Diameter 2.0 Inch ID

Perforated Casing 0.03 mm

Blank Casing From 000.0 to 069.0

Surface Casing From - to -

Perforated Casing From 069.0 to 075.0

Gravel Pack From 067.0 to 075.0

Gel Seal From 065.0 to 067.0

Cement Bottom Seal From 000.0 to 065.0

Cement Top Seal From - to -

Packers Used (Y or N) N

Centralizers Used (Y or N) Y

Initial Water Level 36.02

Elevation 5297.21

Saturated Thickness 6.5

Pump Installed N

Air Lift Installed N

Pump Depth

Air Lift to TD (Y or N) Y

Date Completed 4-27-84

Hours Completed Y

WELL COMPLETION REPORT

(KF84-21(a)

Interval	Water	Lithology	Description
			4-27-84 and 3-28-84

Log as Development Drill Site 384-05

WELL COMPLETION REPORT

Well Name (Kf84-21(b) Kf84 21 No. 4

Location South Area III, CTW Arr W. Burnham Road , N.2009864.48, E.300983.33

County San Juan

Mine Navajo

Driller Gay

State New Mexico

Formation Fruitland

TD 95.5 (170.0)

Drill Type Rotary

Drilling Fluid Air

Logs Lithology, Gamma-Gamma, Gamma-Density, Caliper

Hours Drilled 2½/Set Cement Plug 3-3-84

Completion Information

Casing Type Sch 40 PVC

Casing Diameter 2.0 Inch ID

Perforated Casing 0.03mm

Blank Casing From 000.00 to 083.0

Surface Casing From - to -

Perforated Casing From 083.0 to 095.5

Gravel Pack From 080.0 to 095.5

Gel Seal From 077.0 to 080.0

Cement Bottom Seal From 000.00 to 077.0 (095.5 to 170.0)

Cement Top Seal From - to -

Packers Used (Y or N) N

Centralizers Used (Y or N) N

Initial Water Level 45.48

Elevation 5292.97

Saturated Thickness 7

Pump Installed N

Air Lift Installed Y

Pump Depth

Air Lift to TD (Y or N) Y

Date Completed 3-10-84

Hours Completed 2½

WELL COMPLETION REPORT

(Kf84-21(b)

Interval	Water	Lithology	Description
000 to 020	Dry	Spud	Coal, (8B) Col, Carb Shale
	Dry		Hvy H_2S Coal at 16 ft - 18 ft
	Dry		PR (8A) Pr 1 ft 119-20 Coal
020 to 021		Coal	
021 to 025		SH	Gry, Sslty, SCarb
025 to 030		SH	VCarb, Gry
030 to 031		Coal	
032 to 033		Coal	
033 to 034		Coal	
034 to 035		Coal	
035 to 040		SH	Gry, SCarb, SSlty
040 to 045		AA	
045 to 050		SD	Slty, Carb, SHL 30%
050 to 055		SH	Incr. Carb, Na NOD
055 to 060		AA	
060 to 064		AA	Incr. Carb
064 to 065	Wet		
065 to 066			
066 to 067			
067 to 068			
068 to 069		SH	VCarb
069 to 070		AA	Incr. Slts, Incr. Carb
070 to 075		AA	Carb, SSlty
075 to 080	Damp	AA	
080 to 082		AA	Incr. Carb
082 to 083		Coal	
083 to 084		Coal	
084 to 085		Coal	
085 to 086		Coal	
086 to 087		Coal	
087 to 088		Coal	
088 to 089	↑ H_2O	SH	VSdy, NA NOD
089 to 090		AA	
090 to 100		SD	VShy, Na NOD
100 to 102	INS	AA	Incr. Carb
102 to 103		Coal	
103 to 104		Coal	

WELL COMPLETION REPORT

(Kf84-21(b)

Interval			Water	Lithology	Description
104	to	105		Coal	
105	to	106		Coal	
106	to	107		Coal	
107	to	108		Coal	
108	to	109		Coal	
109	to	110		Coal	
110	to	111		Coal	
111	to	112		Coal	
112	to	113		Coal	Incr. SH
113	to	114		AA	
114	to	115		SH	VCarb
115	to	120		AA	Carb
120	to	122		AA	
122	to	123		Coal	
123	to	124		Coal	
124	to	125		SH	VSdy, Carb
125	to	130		AA	VCarb
130	to	135	SH	SH	Slty, SCarb
135	to	140		AA	
140	to	145		AA	SDY-S-P
145	to	150		SD	S-P, VFG, SLTY
150	to	155		AA	
155	to	160		AA	
160	to	165		AA	
165	to	170		AA	TD

Set 15 Pound cement plug 75.0 - 170.0
Ream to 95.5

WELL COMPLETION REPORT

Well Name (Kf84-21(c) Kf 84 21 No. 2 - No. 3

Location South Area III, Cottonwood Arroyo, West Burnham Road

County San Juan

Mine Navajo

Driller Gay

State New Mexico

Formation Fruitland

TD 118

Drill Type Rotary

Drilling Fluid Air

Logs Cored - (Same as Kf 84 21 No. 4)

Hours Drilled 3½ 3-10-84

Completion Information

Casing Type Sch 40 PUC

Casing Diameter 2.0 Inch ID

Perforated Casing 0.03 mm

Blank Casing From	000.00	to	108.0
Surface Casing From	-	to	-
Perforated Casing From	103.0	to	118.0
Gravel Pack From	106.0	to	118.0
Gel Seal From	103.	to	106.0
Cement Bottom Seal From	000.0	to	102.0
Cement Top Seal From	-	to	-

Packers Used (Y or N) N

Centralizers Used (Y or N) N

Initial Water Level 49.74

Elevation 5223.80

Saturated Thickness 11

Pump Installed N

Air Lift Installed Y

Pump Depth

Air Lift to TD (Y or N) Y

Date Completed 3-9-84

Hours Completed 3

WELL COMPLETION REPORT

Well Name (Kf84-20(a) Kf 8420 No. 7

Location Lease Line Lowe Pit East. Area III.N2017093.50,E304310.70

County San Juan

Mine Navajo

Driller Gay

State New Mexico

Formation Fruitland

TD 1.90

Drill Type Rotary

Drilling Fluid Air

Logs Gamma-Gamma, Gamma-Density, Caliper (Litho. fr. Kf83, No. 9)

Hours Drilled 1.75 3-7-84

Completion Information

Casing Type Sch 40 PVC

Casing Diameter 2.0 inch ID

Perforated Casing 0.03 mm

Blank Casing From 000.00 to 178.5

Surface Casing From - to -

Perforated Casing From 178.5 to 190.0

Gravel Pack From 176.0 to 190

Gel Seal From 173.0 to 176.0

Cement Bottom Seal From 98.0 to 173

Cement Top Seal From 000.0 to 005.0

Packers Used (Y or N) N

Centralizers Used (Y or N) N

Initial Water Level 140.05

Elevation 5402.06

Saturated Thickness 8.0

Pump Installed N

Air Lift Installed Y

Pump Depth

Air Lift to TD (Y or N) Y

Date Completed 6-7-84

Hours Completed 2

WELL COMPLETION REPORT

(Kf84-20(a)

Interval	Water	Lithology	Description
			Log as Kf83, No. 9 3-7-34

WELL COMPLETION REPORT

Well Name (Kf84-20(b) Kf 8420 No. 4

Location Leaseline Lowe Pit East, Area III ,N2017114.83, E304319.22

County San Juan

Mine Navajo

Driller Gay

State New Mexico

Formation Fruitland

TD 215.5

Drill Type Rotary

Drilling Fluid Air

Logs All from Kf83 No. 9

Hours Drilled 2½ 3-7-84

Completion Information

Casing Type Sch 40 PVC

Casing Diameter 2.0 inch ID

Perforated Casing 0.03 mm

Blank Casing From 000.0 to 206.0

Surface Casing From - to -

Perforated Casing From 206.0 to 215.5

Gravel Pack From 204.0 to 215.5

Gel Seal From 200.0 to 204.0

Cement Bottom Seal From 125.0 to 200.0

Cement Top Seal From 000.0 to 005.0

Packers Used (Y or N) N

Centralizers Used (Y or N) N

Initial Water Level 91.77

Elevation 5402.02

Saturated Thickness 9½

Pump Installed N

Air Lift Installed Y

Pump Depth

Air Lift to TD (Y or N) Y

Date Completed 3-7-84

Hours Completed 3½

WELL COMPLETION REPORT

(Kf84-20(b)

Interval	Water	Lithology	Description
Log as Kf84 No. 9			Damp at 180 Ft, No. 7

WELL COMPLETION REPORT

Well Name (Kf84-20(c) Kf 8420 No. 3

Location Lease line Lowe Pit East, Area III , N2017120.64, E304307.65

County San Juan — Mine Navajo

Driller Gay — State New Mexico

Formation Fruitland — TD 240.0

Drill Type Rotary

Drilling Fluid Air

Logs Gamma-Gamma, Gamma-Density, Resistivity, Caliper

Hours Drilled 2¼

Completion Information

Casing Type Sch 40 PVC

Casing Diameter 2.0 Inch ID

Perforated Casing 0.03 mm

Blank Casing From 000.0 to 221.0 (236.0 - 240.0)

Surface Casing From - to -

Perforated Casing From 221.0 to 236.0

Gravel Pack From 219.0 to 240.0

Gel Seal From 215.0 to 219.0

Cement Bottom Seal From 140.0 to 215.0

Cement Top Seal From 000.0 to 005.0

Packers Used (Y or N) N — Centralizers Used (Y or N) N

Initial Water Level 154.57

Elevation 5401.78 — Saturated Thickness 15

Pump Installed N — Air Lift Installed Y

Pump Depth N — Air Lift to TD (Y or N) Y

Date Completed 3-6-84 — Hours Completed 2

WELL COMPLETION REPORT

(Kf84-20(c)

Interval	Water	Lithology	Description
			Log as Kf83 No. 9 8-19-84

WELL COMPLETION REPORT

Well Name (Kf84-18(a) Kf84 18 No. 8

Location SE Yazzie Highwall, Area II, N2050168.70, E318919.71

County San Juan   Mine Navajo

Driller Gay   State New Mexico

Formation Fruitland   TD 133.0

Drill Type Rotary

Drilling Fluid Air

Logs Lithology, Gamma-Gamma, Gamma-Density, Resistivity, Cal-(all as Kf8418 No.6)

Hours Drilled 1 5-1-84

Completion Information

Casing Type	Sch 40 PVC		
Casing Diameter	2.0 Inch ID		
Perforated Casing	0.03 mm		
Blank Casing From	000	to	119
Surface Casing From	-	to	-
Perforated Casing From	119.0	to	133.0
Gravel Pack From	117.0	to	133.0
Gel Seal From	114.0	to	117.0
Cement Bottom Seal From	000.0	to	114.0
Cement Top Seal From	-	to	-
Packers Used (Y or N)	N	Centralizers Used (Y or N)	N
Initial Water Level	112.25		
Elevation	5320.99	Saturated Thickness	14.0
Pump Installed	N	Air Lift Installed	Y
Pump Depth		Air Lift to TD (Y or N)	Y
Date Completed	5-1-84	Hours Completed	2

WELL COMPLETION REPORT

(Kf84-18(a)

Interval	Water	Lithology	Description
000 to 020		Spud	Col, Al, shale, brn
	Log as Kf 84 18 No. 6		
020 to 133		TD	

WELL COMPLETION REPORT

Well Name (Kf84-18(b) Kf8418 No. 6

Location SE Yazzie Highwall. Area II, N2050160.79, E318937.36

County San Juan Mine Navajo

Driller Gay State New Mexico

Formation Fruitland TD 181

Drill Type Rotary

Drilling Fluid Air

Logs Gamma - Gamma, Gamma Density, Resistance, Caliper, Lithology

Hours Drilled 1.75 5-1-84

Completion Information

Casing Type Sch 40 PVC

Casing Diameter 2.0 Inch ID

Perforated Casing 0.30 mm

Blank Casing From 000.0 to 150.0

Surface Casing From - to -

Perforated Casing From 150.0 to 181.0

Gravel Pack From 148.0 to 181.0

Gel Seal From 145.0 to 148.0

Cement Bottom Seal From 071.0 to 145.0

Cement Top Seal From 000.0 to 005.0

Packers Used (Y or N) N Centralizers Used (Y or N) N

Initial Water Level 105 Bgs

Elevation 5321.07 Saturated Thickness Var. Nos. 7,6,5

Pump Installed N Air Lift Installed Y

Pump Depth Air Lift to TD (Y or N) Y

Date Completed 5-1-84 Hours Completed 2½

WELL COMPLETION REPORT

(Kf84-18(b)

Interval	Water	Lithology	Description
000 to 020	Dry	Spud	Al, Col, Shale Brn at 10 ft.
020 to 025	Dry	Sh	Gry, Carb
025 to 030		AA	
030 to 035		AA	DECR Carb, slty
035 to 040		SD	VFG, Slty, Calc NOD, S Carb
040 to 045		SH	SD DECR 10% Carb
045 to 050		SH	Gry, S Carb
050 to 055		AA	
055 to 060		AA	Carb
060 to 065		AA	V Carb
065 to 070		AA	
070 to 075		AA	S Carb
075 to 080		AA	
080 to 085	Dry	AA	DECR Carb
085 to 090		AA	S Slty
090 to 095		AA	
095 to 100		AA	S Carb
100 to 105		SLTS	S Carb
105 to 110		SH	S Carb
110 to 115		SLTS	S Slty, Carb
115 to 118		SH	V Carb, Gry to Brn
118 to 119	Dry	COAL	
119 to 120		COAL	
120 to 121		SH	V Carb
121 to 122		AA	
122 to 123		AA	

WELL COMPLETION REPORT

(Kf84-18(b)

Interval	Water	Lithology	Description
123 to 124		COAL	Brn
124 to 125		COAL	
125 to 126		COAL	
126 to 127	Damp	COAL	
127 to 128	Damp	COAL	
128 to 129	Damp	COAL	
129 to 130	Damp	COAL	
130 to 131		COAL	Bny
131 to 132	Dry	SH	V Carb
132 to 135		AA	
135 to 140		AA	Gry
140 to 145		AA	
145 to 150		AA	
150 to 153	Dry	AA	INCR Carb
153 to 154		COAL	
154 to 155		COAL	
155 to 156	Damp	COAL	Shy
156 to 157		SH	Carb
157 to 160	Ins.	AA	V Carb
160 to 161		COAL	
161 to 162		COAL	
162 to 165		SH	V Carb
165 to 168		AA	
168 to 169		COAL	
169 to 170		COAL	

WELL COMPLETION REPORT

(Kf84-18(b)

Interval	Water	Lithology	Description
170 to 171		COAL	
171 to 175		SH	
175 to 180		AA	Sdy, S Carb
	TD		5-1-84

WELL COMPLETION REPORT

Well Name (Kf84-17) Kf 84 No. 17

Location NAPI, N2068744.6, E327371.48

County San Juan

Mine Navajo

Driller Gay

State New Mexico

Formation Fruitland

TD 310.0

Drill Type Rotary

Drilling Fluid Air

Logs Gamma-Gamma, G-D Res, Ltho Cal

Hours Drilled 4 5-22-84/5-23-84

Completion Information

Casing Type Sch 40 PVC

Casing Diameter 2.0 Inch ID

Perforated Casing .03 mm

Blank Casing From	000	to	276.0
Surface Casing From	-	to	-
Perforated Casing From	276.0	to	310.0
Gravel Pack From	274.0	to	310.0
Gel Seal From	270.0	to	274.0
Cement Bottom Seal From	195.0	to	270.0
Cement Top Seal From	000.0	to	005.0

Packers Used (Y or N)	N	Centralizers Used (Y or N)	N
Initial Water Level	242.00		
Elevation	5419.21	Saturated Thickness	23
Pump Installed	N	Air Lift Installed	y
Pump Depth		Air Lift to TD (Y or N)	Y
Date Completed	5-23-84	Hours Completed	2

WELL COMPLETION REPORT

(Kf84-17) Interval	Water	Lithology	Description
000 to 020	Ins.	SPUD	QA, Col, Wny Bla, Bln, QA,Col,WN BLN,BRN Sh @ 15 Ft, SHVCarb @ 18 Ft Brn, Fe Str, Gyps
020 to 025	DU	SH	Brn
025 to 030			SH GRR, Carb, Fe Stn
030 to 035		AA	BRN, SCarb
035 to 045		AA	Gry, SSlty
045 to 050		AA	Slty
050 to 055		Slts	Gry
0ff to 060		SH	Slty,Gry
060 to 075		AA	
075 to 080		SH	Gry, Carb
080 to 085		AA	
085 to 090		AA	
090 to 095		AA	SCarb
095 to 100		AA	
100 to 105		AA	Incr. Carb
105 to 110		AA	
110 to 115		AA	
115 to 120		AA	
120 to 125		AA	
125 to 130		AA	
130 to 135		AA	
135 to 140		AA	Decr. Carb
140 to 145		AA	
145 to 150		AA	SCarb
150 to 155		AA	
155 to 160		AA	
160 to 165		AA	Carb
170 to 175		AA	
175 to 180		AA	
180 to 185		SH	Gry, VCarb
185 to 190		AA	
190 to 195		AA	Carb
195 to 200		AA	SCarb SSlty
200 to 205		AA	
205 to 210		AA	
210 to 215		AA	

WELL COMPLETION REPORT

(Kf84-17) Interval	Water	Lithology	Description
215 to 220		AA	
220 to 225		AA	
225 to 230		AA	
230 to 235		AA	Carb
235 to 040		AA	
240 to 245		AA	
245 to 250		AA	
250 to 255		AA	
255 to 260		AA	
260 to 265		AA	
265 to 270		AA	
270 to 275		AA	
275 to 276	Dry	Coal	Bay
276 to 277		Coal	
277 to 278		Coal	Bay
278 to 279		Coal	
279 to 280		Coal	
280 to 281		Coal	
281 to 282		Coal	
282 to 285		SH	VCarb, Gry
285 to 290		SH	VCarb, Gry
290 to 295		Coal	
295 to 300		Coal	
300 to 305		Coal	
305 to 310		Coal	
310 to 315		Coal	
315 to 320		SH	VCarb
320 to 325		SH	Gry, SSlty
325 to 330		AA	
330 to 335		AA	
335 to 340		AA	Decr. Slty, SCarb
340 to 345		AA	
345 to 350		AA	
355 to 360		AA	
[illegible] to 365		AA	
365 to 370		AA	
370 to 375		AA	

WELL COMPLETION REPORT

(Kf84-17) Interval	Water	Lithology	Description
375 to 380		AA	
380 to 400			Set plug to 380, Rean 6¼ to 310.0 Set Casng 5-23-84

APPENDIX 6-C

(copy of 1989 Appendix 12B)

PICTURED CLIFF AND ALLUVIAL WATER QUALITY RECORDS

1985 Reorganization
12-B-1
COMMENTS:

WELL NO.: GM-18
LOCATION: Mouth of Cottonwood, Downstream
FORMATION: Alluvium
TOTAL DEPTH: Navajo Well

SAMPLED:	09/10/79	12/27/79	03/27/80
** Parameter:			
pH	-	-	-
Na	-	-	-
Ca	-	-	-
Mg	-	-	20.2
SO_4	1193.0	1260	1135
Cl	29.7	26.1	28.4
TDS	210.5	2135	2020
Al	0.35	0.15	0.18
As	0.0002	0.4	0.0002
Ba	0.04	0.03	0.02
B	0.11	-	0.01
Cd	<0.01	<0.001	<0.02
Cr total	0.01	0.01	0.02
Co	<0.01	0.02	0.02
Cu	<0.01	<0.005	<0.01
F	2.20	2.2	2.0
Fe	<0.01	0.1	0.04
K	-	-	-
Pb	0.09	<0.001	0.01
Mn	<0.01	0.01	0.02
Mo	0.02	0.03	0.03
Ni	<0.01	<0.005	<0.01
Se	0.001	0.0005	0.0008
Ag	<0.01	0.01	<0.01
Zn	<0.01	0.12	<0.01
NO_3 as N	0.85	<0.01	0.02
PO_4	-	-	-
U_3O_8	0.009	0.011	0.008
Fe^{tot}	0.01	-	0.02
Mn^{tot}	0.01	-	0.02
Hg^{tot}	0.00019	-	<0.000002
Temp. °C			
Conductivity (umhos/cm)			
Water Level (Ft. below LSD			
Cation/Anion Balance			

WELL NO.: GM-9

COMMENTS: 1985 Reorganization 12-8-2

LOCATION: Eastside of the Mine, Upstream Chinde

FORMATION: Alluvium

TOTAL DEPTH: 20'

SAMPLED:	09/10/79	03/27/80	09/23/80
** Parameter:			
pH	--	--	--
Na	--	--	--
Ca	--	--	--
Mg	--	--	44
SO_4	5440.	6565	440
Cl	227.	211	218
TDS	9235.	10060	830
Al	0.68	0.57	0.09
As	0.0008	0.0005	0.0008
Ba	0.26	--	0.14
B	0.51	0.3	0.11
Cd	<0.01	<0.01	<0.001
Cr total	0.04	0.03	0.004
Co	<0.01	0.02	<0.01
Cu	0.12	0.02	<0.01
F	1.60	1.8	1.38
Fe	0.04	0.06	46
K	--	--	--
Pb	0.43	0.03	0.014
Mn	0.06	1.02	0.19
Mo	0.07	0.08	0.03
Ni	0.02	0.02	<0.01
Se	0.002	0.0016	0.0006
Ag	<0.01	<0.01	<0.01
Zn	0.13	0.03	3.0
NO_3 as N	0.59	1.9	1.5
PO_4	0.005	--	0.24
U_3O_8	0.08	0.047	0.0019
Fe^{tot}	0.06	0.06	0.01
Mn^{tot}	0.90	0.96	--
Hg^{tot}	0.00019	0.0001	0.00004
Temp. °C			
Conductivity (umhos/cm)			
Water Level (Ft. below LSD			
Cation/Anion Balance			

WELL NO.: GM-17

LOCATION: Cottonwood Arroyo North Fork

FORMATION: Alluvium

TOTAL DEPTH: 20'

COMMENTS:
1985 Reorganization
12-B-3

SAMPLED:	09/10/79	03/10/80	09/24/80
** Parameter:			
pH	--	--	--
Na	--	--	--
Ca	--	--	--
Mg	--	128	160
SO_4	9308	9280	9290
Cl	104	103	1.5
TDS	15210	14490	15020
Al	0.63	0.45	0.43
As	0.0003	0.00002	0.00006
Ba	0.18	0.04	0.06
B	0.29	<0.01	0.28
Cd	0.01	<0.01	<0.001
Cr total	0.03	0.01	0.013
Co	0.02	0.01	< 0.01
Cu	0.02	0.06	0.07
F	0.27	0.4	0.35
Fe	0.03	0.35	18.0
K	--	--	--
Pb	0.33	0.05	0.22
Mn	<0.01	2.26	2.3
Mo	0.05	0.05	0.14
Ni	0.03	< 0.01	0.02
Se	<0.001	0.0025	0.0028
Ag	<0.01	0.01	<0.01
Zn	0.34	0.11	0.57
NO_3 as N	1.06	1.0	0.7
PO_4	<0.005	--	0.01
U_3O_8	0.025	0.020	0.021
Fe^{tot}	0.06	0.05	0.25
Mn^{tot}	0.08	1.78	--
Hg^{tot}	0.00015	0.00007	0.00005
Temp. °C			
Conductivity (umhos/cm)			
Water Level (Ft. below LSD			
Cation/Anion Balance			

WELL NO.: GM-18

COMMENTS:1985 Reorganization
12-B-4

LOCATION: Mouth of Cottonwood Downstream

FORMATION: Alluvium

TOTAL DEPTH: Navajo Well

SAMPLED:	06/12/80	09/25/80	07/15/81
** Parameter:			
pH	-	-	DRY
Na	-	-	NO
Ca	-	-	SAMPLE
Mg	-	75.0	
SO_4	2335	3750	
Cl	0.7	3	
TDS	3960	6160	
Al	0.36	0.53	
As	0.007	0.0004	
Ba	0.03	0.06	
B	0.11	0.23	
Cd	0.01	<0.001	
Cr total	0.02	0.018	
Co	0.01	<0.01	
Cu	<0.005	0.02	
F	2.10	3.12	
Fe	0.04	0.67	
K	-	-	
Pb	0.008	0.005	
Mn	0.37	0.53	
Mo	0.02	0.13	
Ni	< 0.005	0.01	
Se	0.003	0.5	
Ag	0.08	< 0.01	
Zn	< 0.005	0.021	
NO_3 as N	0.18	0.6	
PO_4	-	-	
U_3O_8	0.010	0.022	
Fe^{tot}	0.25	0.04	
Mn^{tot}	0.40	-	
Hg^{tot}	<0.00005	0.00003	
Temp. °C			
Conductivity (umhos/cm)			
Water Level (Ft. below LSD			
Cation/Anion Balance			

WELL NO.: GM-17

COMMENTS: 1985 Reorganizatio
12-B-5

LOCATION: Cottonwood Arroyo North Fork

FORMATION: Alluvial

TOTAL DEPTH:

SAMPLED:	03/09/82	06/25/82	09/29/82
** Parameter:			
pH	7.1	7.1	6.1
Na	4710	4690	4720
Ca	310	290	350
Mg	150	140	140
SO_4	9810	9640	9760
Cl	42	120	120
TDS	15900	15600	16000
Al	0.06	0.04	0.04
As	< 0.0001	< 0.0001	0.0002
Ba	0.25	0.32	0.06
B	0.13	0.30	0.66
Cd	< 0.0001	< 0.0001	< 0.001
Cr total	0.10	0.08	0.04
Co	< 0.01	< 0.01	< 0.01
Cu	.0035	0.0044	0.034
F	0.60	0.1	0.10
Fe	0.10	< 0.01	0.48
K	26	26	24
Pb	< 0.01	<0.01	<0.01
Mn	2.7	2.1	1.78
Mo	0.02	0.02	0.02
Ni	<0.01	<0.01	<0.01
Se	<0.0001	<0.0001	<0.0001
Ag	<0.0001	<0.0001	<0.002
Zn	0.09	0.05	0.03
NO_3 as N	1.3	1.1	1.18
PO_4	<0.01	0.01	<.01
U_3O_8	0.001	.001	0.000684
Fe^{tot}	10.0	7.7	1.33
Mn^{tot}	3.8	2.5	2.99
Hg^{tot}	<0.000005	<0.000001	<0.05
Temp. °C	15.7°	15:2°	15.4°
Conductivity (umhos/cm)	15.1	14.4	14.2
Water Level (Ft. below LSD	18.40'	18.15'	17.3'
Cation/Anion Balance	-02	-0.00	-0.32

WELL NO.: GM-17

COMMENTS: 1985 Reorganization
12-B-6

LOCATION: Cottonwood Arroyo North Fork

FORMATION: Alluvium

TOTAL DEPTH: 20'

SAMPLED:	07/15/81	09/17/81	12/15/81
** Parameter:			
pH	6.9	6.7	6.6
Na	4320	4490	4530
Ca	380	400	380
Mg	160	150	150
SO_4	9380	9560	8950
Cl	98	130	430
TDS	15300	15200	15700
Al	0.06	<0.1	0.12
As	<0.0001	0.0008	0.0008
Ba	0.2	0.1	0.28
B	0.31	0.16	0.08
Cd	<0.002	<0.002	<0.002
Cr total	0.03	0.04	0.06
Co	<0.01	<0.01	<0.01
Cu	0.03	0.042	0.03
F	0.3	0.2	0.5
Fe	<0.01	0.08	0.1
K	25	26	24
Pb	<0.02	<0.01	<0.01
Mn	<0.01	0.12	1.02
Mo	0.02	<0.02	0.03
Ni	<0.01	<0.01	<0.01
Se	0.0004	0.0002	<0.00001
Ag	<0.002	<0.002	<0.002
Zn	0.04	0.04	0.04
NO_3 as N	0.57	1.03	4.56
PO_4	0.04	0.02	0.03
U_3O_8	0.00029	0.00041	0012
Fe^{tot}	0.62	0.14	4.75
Mn^{tot}	0.08	0.76	1.75
Hg^{tot}	.000139	<.00010	.00001
Temp. °C	16.7°	16.7°	14.1°
Conductivity (umhos/cm)	0.85	13.9	13.5
Water Level (Ft. below LSD	6.15'	15.65'	16.1'
Cation/Anion Balance	0.64 6	-0.88	-0.84

WELL NO.: GM-10

COMMENTS: 1985 Reorganization
12-3-7

LOCATION:

FORMATION:

TOTAL DEPTH:

SAMPLED:	03/04/82	06/24/82	09/29/82
** Parameter:			
pH	7.1	6.9	6.45
Na	1890	1850	3490
Ca	600	560	760
Mg	220	230	250
SO_4	3110	3740	4090
Cl	2200	1600	4190
TDS	8710	8330	13,200
Al	0.09	<0.01	0.05
As	0.0002	<0.0001	0.0001
Ba	0.46	0.30	0.10
B	0.38	0.85	1.30
Cd	<0.0001	<0.0001	<0.001
Cr total	<0.01	<0.01	0.05
Co	<0.01	<0.01	<0.01
Cu	0.02	0.0033	0.030
F	1.1	0.60	0.7
Fe	0.31	0.40	0.07
K	12	11	15
Pb	<0.01	<0.01	<0.01
Mn	0.79	0.54	0.92
Mo	0.04	<0.01	<.01
Ni	<0.01	<0.01	<0.01
Se	0.00010	<0.0001	<0.0001
Ag	0.00010	<0.0001	<0.002
Zn	0.61	0.41	4.06
NO_3 as N	0.32	0.15	0.10
PO_4	<0.01	<0.01	<.01
U_3O_8	0.0013	0.0016	0.000005
Fe^{tot}	6.5	11	9.24
Mn^{tot}	0.80	0.81	0.94
Hg^{tot}	<0.000005	<.000001	0.000014
Temp. °C	9.7°	18.3°	17.4°
Conductivity (umhos/cm)	7.4	8.0	18.6
Water Level (Ft. below LSD	--	--	--
Cation/Anion Balance	±1.0	0.62	-0.13

WELL NO.: GM-10

COMMENTS: 1985 Reorganization
12-B-8

LOCATION:

FORMATION:

TOTAL DEPTH:

SAMPLED:	07/13/81	08/16/81	12/14/81
** Parameter:			
pH	6.8	6.9	6.8
Na	1130	1120	1120
Ca	490	490	500
Mg	210	220	220
SO_4	3180	3200	2770
Cl	660	720	960
TDS	6260	6130	6080
Al	0.06	0.1	0.07
As	$\leq$0.0001	.0001	0.0005
Ba	0.67	0.25	0.38
B	1.33	0.79	0.53
Cd	$\leq$0.002	$\leq$0.002	$\leq$0.002
Cr total	0.03	0.06	0.13
Co	$\leq$0.01	$\leq$0.01	$\leq$0.01
Cu	0.008	0.187	0.024
F	0.9	0.8	5.8
Fe	0.95	0.03	0.05
K	9.4	10	10
Pb	$\leq$0.02	$\leq$0.01	$\leq$0.01
Mn	0.32	0.27	0.57
Mo	$\leq$0.01	$\leq$0.02	0.06
Ni	$\leq$0.01	$\leq$0.01	$\leq$0.01
Se	$\leq$0.0001	$\leq$0.0001	$\leq$.00001
Ag	$\leq$0.002	$\leq$0.002	$\leq$ 0.002
Zn	0.77	1.24	2.42
NO_3 as N	0.62	1.16	0.62
PO_4	0.03	0.02	0.02
U_3O_8	0.00018	0.000240	0.0008
Fe^{tot}	17.1	37	70
Mn^{tot}	0.41	0.73	2.50
Hg^{tot}	0.000166	$\leq$0.00010	$\leq$0.00001
Temp. °C	19.9°	19.2°	14.9°
Conductivity (umhos/cm)	5.2	4.8	4.5
Water Level (Ft. below LSD	--	--	--
Cation/Anion Balance	--	--	--

WELL NO.: GM-10

LOCATION: West of Mine Area in Chinde Wash

FORMATION: Alluvium

TOTAL DEPTH: Navajo Well

COMMENTS:
1985 Reorganization
12-3-9

SAMPLED:	06/12/80	09/23/80
** Parameter:		
pH	-	-
Na	-	-
Ca	-	-
Mg	-	215
SO_4	2920	3580
Cl	380	2130
TDS	5270	9130
Al	0.44	0.80
As	0.001	0.0005
Ba	0.03	0.06
B	0.76	0.96
Cd	<0.005	<0.001
Cr total	0.03	0.03
Co	0.02	0.02
Cu	<0.005	0.01
F	0.71	0.72
Fe	0.32	3.52
K	-	-
Pb	0.009	0.009
Mn	0.82	0.87
Mo	0.03	0.15
Ni	0.005	0.02
Se	0.002	0.2
Ag	0.14	0.01
Zn	0.31	5.3
NO_3 as N	1.33	2.0
PO_4	-	-
U_3O_8	0.011	0.015
Fe^{tot}	1.69	0.06
Mn^{tot}	0.90	-
Hg^{tot}	0.00006	0.00016
Temp. °C		
Conductivity (umhos/cm)		
Water Level (Ft. below LSD		
Cation/Anion Balance		

WELL NO.: GM-10

COMMENTS: 1985 Reorganization 12-B-10

LOCATION: West of Mine Area in Chinde Wash

FORMATION: Alluvium

TOTAL DEPTH: Navajo Well

SAMPLED:	09/10/79	12/27/79	03/27/80
** Parameter:			
pH	-	-	-
Na	-	-	-
Ca	-	-	-
Mg	-	-	-
SO_4	2657	2880	2915
Cl	417	858	613
TDS	5010	6075	5660
Al	0.56	0.31	0.51
As	0.0002	0.0002	< 0.0002
Ba	0.15	0.05	0.03
B	0.79	-	0.7
Cd	<0.01	0.005	0.01
Cr total	0.03	0.03	0.02
Co	<0.01	0.04	0.02
Cu	0.01	0.02	<0.01
F	0.79	0.6	0.9
Fe	0.02	3.0	3.47
K	-	-	-
Pb	0.27	<0.001	0.01
Mn	0.32	0.47	0.61
Mo	0.04	0.06	0.06
Ni	0.02	0.02	0.01
Se	<0.001	0.0005	0.0008
Ag	<0.01	0.05	0.01
Zn	0.56	0.48	0.39
NO_3 as N	0.45	0.20	0.3
PO_4	-	-	-
U_3O_8	0.009	0.011	0.01
Fe^{tot}	0.05	-	1.34
Mn^{tot}	0.45	-	0.58
Hg^{tot}	0.00022	0.00003	0.00011
Temp. °C			
Conductivity (umhos/cm)			
Water Level (Ft. below LSD			
Cation/Anion Balance			

WELL NO.: GM-18

COMMENTS: Dry No Sample

1985 Reorganization
12-B-11

LOCATION: Downstream Cottonwood

FORMATION: Alluvium

TOTAL DEPTH:

SAMPLED:	09/17/81	12/15/81	03/09/82
** Parameter:			
pH	DRY	DRY	DRY
Na	NO	NO	NO
Ca	SAMPLE	SAMPLE	SAMPLE
Mg			
SO_4			
Cl			
TDS			
Al			
As			
Ba			
B			
Cd			
Cr total			
Co			
Cu			
F			
Fe			
K			
Pb			
Mn			
Mo			
Ni			
Se			
Ag			
Zn			
NO_3 as N			
PO_4			
U_3O_8			
Fe^{tot}			
Mn^{tot}			
Hg^{tot}			
Temp. °C			
Conductivity (umhos/cm)			
Water Level (Ft. below LSD			
Cation/Anion Balance			

WELL NO.: GM-18

LOCATION: Cottonwood Arroyo Downstream

FORMATION: Alluvium

TOTAL DEPTH: Navajo Well

COMMENTS: 1985 Reorganization 12-B-12

SAMPLED:	06/25/82	09/29/82
** Parameter:		
pH	DRY	DRY
Na	NO	NO
Ca	SAMPLE	SAMPLE
Mg		
SO_4		
Cl		
TDS		
Al		
As		
Ba		
B		
Cd		
Cr total		
Co		
Cu		
F		
Fe		
K		
Pb		
Mn		
Mo		
Ni		
Se		
Ag		
Zn		
NO_3 as N		
PO_4		
U_3O_8		
Fe^{tot}		
Mn^{tot}		
Hg^{tot}		
Temp. °C		
Conductivity (umhos/cm)		
Water Level (Ft. below LSD		
Cation/Anion Balance		

WELL NO.: GM-9

COMMENTS: 1985 Reorganization 12-B-13

LOCATION: Chinde

FORMATION: Alluvium

TOTAL DEPTH: 20'

SAMPLED:	03/09/82	06/25/82	09/29/82
** Parameter:			
pH	DRY	DRY	DRY
Na	NO	NO	NO
Ca	SAMPLE	SAMPLE	SAMPLE
Mg			
SO_4			
Cl			
TDS			
Al			
As			
Ba			
B			
Cd			
Cr total			
Co			
Cu			
F			
Fe			
K			
Pb			
Mn			
Mo			
Ni			
Se			
Ag			
Zn			
NO_3 as N			
PO_4			
U_3O_8			
Fe^{tot}			
Mn^{tot}			
Hg^{tot}			
Temp. °C			
Conductivity (umhos/cm)			
Water Level (Ft. below LSD			
Cation/Anion Balance			

WELL NO.: GM-9

COMMENTS: Well Went Dry

LOCATION:

1985 Reorganization
12-B-14

FORMATION: Alluvium

TOTAL DEPTH: 20'

SAMPLED:	07/15/81	09/17/81	12/14/81
** Parameter:			
pH	DRY	DRY	DRY
Na	NO	NO	NO
Ca	SAMPLE	SAMPLE	SAMPLE
Mg			
SO_4			
Cl			
TDS			
Al			
As			
Ba			
B			
Cd			
Cr total			
Co			
Cu			
F			
Fe			
K			
Pb			
Mn			
Mo			
Ni			
Se			
Ag			
Zn			
NO_3 as N			
PO_4			
U_3O_8			
Fe^{tot}			
Mn^{tot}			
Hg^{tot}			
Temp. °C			
Conductivity (umhos/cm)			
Water Level (Ft. below LSD			
Cation/Anion Balance			

APPENDIX 6-D

(copy of 1989 Appendix 12C)

SOLUTIONS TO OSMRE CONCERNS AND DEFICIENCIES RELATED TO THE GROUNDWATER SECTIONS OF THE NAVAJO MINE PERMIT APPLICATION PACKAGE

SOLUTIONS TO OSMRE CONCERNS AND DEFICIENCIES RELATED TO THE GROUND WATER SECTIONS OF THE NAVAJO MINE PERMIT APPLICATION PACKAGE

SUBMITTED TO
BHP UTAH INTERNATIONAL, INC.

SUBMITTED BY
BILLINGS & ASSOCIATES, INC.
ALBUQUERQUE, N.M.

NOVEMBER 1987

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1.0 INTRODUCTION

Billings and Associates, Inc. (BAI) was retained by BHP Utah International, Inc. (UII) to address Permit Application Package (PAP) deficiencies as defined by the Office of Surface Mining, Reclamation and Enforcement (OSMRE). These deficiencies were originally presented in a Request For Proposal letter from Ron Baldwin (UII) on May 18, 1987. Additional deficiencies and a more detailed description of OSMRE concerns were then submitted in a July 8, 1987 letter from UII to BAI. The tone of the detailed deficiencies presented in the July 8, 1987 letter was harsh. It is important for UII and BAI to understand the tone of this letter. The OSMRE must understand that topics such as "realistic determination of PHC" will always be based somewhat on judgement and experience. Where appropriate, we have attempted to bolster OSMRE judgement by technical analysis using numerical models and analytical calculations. However, the basic concept that must be understood by OSMRE is that geohydrologic characteristics, hyrologic setting and mine layout are the controlling factors and not an analytical and/or numerical analysis. If the OSMRE does not grasp this concept, additional studies, testing, analysis and data collection may be encountered.

It is therefore proposed that the approach to be utilized should be short, to the point, while only stressing the important criteria. What is critical, and only that, should be emphasized. For example, forget pumping times for aquifer test information. Rather, stress what are reasonable permeabilities for the units. Forget construction of wells east of the permit area. Rather, what is the general direction of ground-water flow and why is it important. Forget testing to determine storativity. Having test-derived, localized values of storativity is not critical. The use of guidelines in the selection of storativity is commonplace amongst hydrologists and reasonable values can be choosen and incorporated into all calculations. More importantly, permeabilities, saturated thicknesses and the mine layout control effects, not storativity.

2.0 LOCATION

UII's Navajo Mine is located on the western flank of the San Juan Basin approximately fifteen miles west of Farmington, New Mexico. The San Juan Basin is a structural depression lying at the eastern edge of the Colorado Plateau covering approximately 30,000 square miles of northwestern New Mexico and southwestern Colorado. The statigraphic dip throughout the greater part of the area is only 1 to 3 degrees towards the center of the basin with steepening towards the outcrop areas where a monocline can be observed encircling two thirds of the basin.[2]

3.0 FORMATION OF STRATIGRAPHIC UNITS

During the late Cretaceous geologic time period the shoreline of a vast shallow inland sea shifted back and forth across the basin and ultimately receded. Alternating marine and nonmarine sediments were deposited resulting in the following stratigraphic column in the vicinity of the lease area: *Lewis Shale, Pictured Cliffs Sandstone, Fruitland Formation* and the *Kirtland Shale*[2]. Ground-water flow paths in Cretaceous rocks within the lease area are north to northwest towards the San Juan River (see Figure 1).[8]

The *Lewis Shale* results from an offshore deposition of mud with streaks of fine grained sand, silt and limestone. The beach and nearshore deposits of mud and silt are represented as the *Pictured Cliffs Sandstone.* Coastal swamp deposition consisted of organic material, organic-enriched mud and silt, and the occasional accumulation of brackish-water shells. Deltas, estuaries and open lagoons in this environment intercepted local deposition, resulting in horizontally discontinuous coal deposits existing in what is known today as the *Fruitland Formation.* Flood plain deposits consist of fluvial and lacustrine sediments in the low areas adjacent to the coastal swamps and fluvial sediments predominantly composed of sand in the high areas away from the coastal swamps. These deposits are represented in the *Kirtland Shale*.[1]

4.0 UNIT DESCRIPTION AND CHARACTERISTICS

The *Lewis Shale* is greenish-gray shale with local streaks of yellowish calcareous shale. The thickness is 76 to 475 feet.[2]

The *Pictured Cliffs Sandstone* can be divided into an upper massive sandstone bed and a lower thin layer of interbedded sandstone and shale. The thickness is 25 to 281 feet[2] and is about 110 feet in the permit area.[1] Permeability is on the order of 0.007 feet per day.[2] Using a storativity value of $1.0E^{-06}$ times the aquifer thickness, a confined storage coefficient on the order of $1.0E^{-04}$ is obtained.[10] This value is consistent with previous testing conducted in the Pictured Cliffs Sandstone which yielded values on the order of $3.0E^{-04}$.[11] An unconfined storage coefficient of 0.1 is reasonable for this formation and represents a minimum porosity acceptable. If the unconfined storage coefficient were increased, the net effect would be to reduce the PHC.

The *Fruitland Formation* consists of horizontally discontinuous coal seams and interbedded lithological units. These units are sandstones, siltstones, shales, limestones, and carbonaceous sandstones, siltstones, and shales.[1] Sandstone is generally more abundant in the lower part of the formation with the upper being predominantly siltstone and shale (i.e., *Fruitland* overburden). The thicker coal beds are in the lower third of the formation and are generally noncorrelative and discontinuous. One coal zone (Fruitland Zone) and two coal beds Fruitland 1 (Fr 1) and Fruitland 2 (Fr 2) are identified in the *Fruitland Formation*.[5] The Fr 1 coal bed is generally above the *Pictured Cliffs Sandstone* and dips less than one degree to the east. The thickness is generally greater than ten feet and diminishes in all directions to the point of being absent in the east-central part of the Kirtland quadrangle[5] (the USGS quadrangle adjacent to the east of the quadrangle containing the permit area). The Fr 1 is overlain by the Fr 2 coal bed. The two beds are separated by a rock interval varying from 6 to 20 feet. The Fruitland 2 also dips less than one degree to the east. The thickness is generally greater than five feet and diminishes in all directions. It is absent in the southeast and northwest parts of the Kirtland quadrangle[5]. Although these coal beds are correlated and mapped as consistent layers for simplicity, they are actually several different coal beds that are lithostratigraphically equivalent but not laterally continuous[5]. Transmissivity of the coal seams and interbedded lithologic units range from 7 to 130 feet squared per day[2], for an average of 70 feet squared per day. Using a combined coal seam and interbedded lithologic unit thickness of 60 feet and $1.0E^{-06}$ times unit thickness, a confined storativity of $6.0E^{-05}$ is obtained, with unconfined storativity assigned 0.1. Remaining coal seams constituting the Fruitland Zone, are less than five feet thick, and are generally noncorrelative and discontinuous.[5] Inasmuch as individual coal seams are not horizontally continuous, it is more sensible to consider the geohydrologic parameters of the coal and interbedded lithologic units as a single geologic unit rather than consider the individual seams. We have followed this approach.

Permeability of the *Fruitland Formation* as a whole, is from 0.004 to 0.04 feet per day using a transmissivity of 1 to 10 feet squared per day[2] and a thickness of 250 feet. Using a storativity value of $1.0E^{-06}$ times the aquifer thickness[10] (i.e., 250 feet), a confined storage coefficient on the order of $3.0E^{-04}$ is obtained. An unconfined storage coefficient of 0.1 is reasonable for this formation.

The lower member of the *Kirtland Shale* ranges from 271 to 1031 feet thick and is a grey shale with some beds of siltstone and sandstone. Permeability of similar rock types is on the order of $1.0E^{-04}$ feet per day.[9] The *Kirtland Shale* and the *Fruitland Formation* are often treated as one unit as they exhibit similar hydrologic properties.[1] Using a storativity value of $1.0E^{-06}$ times the aquifer thickness[10] (i.e., approximately 300 feet), a confined storage coefficient on the order of $3.0E^{-04}$ is obtained. Again, an unconfined storage coefficient of 0.1 is also reasonable for this formation.

5.0 GEOHYDROLOGIC SETTING

An investigation was conducted by the United States Geological Survey (USGS), in cooperation with the Bureau of Land Management (BLM), to obtain baseline geohydrologic information for evaluating the effects of strip coal mining within the *Fruitland Formation* in the San Juan Basin.[1] In their investigation, the USGS concentrated their efforts on four distinct geologic units; "*Pictured Cliffs Sandstone*", "*coal seams and interbedded lithologic units* of the *Fruitland Formation*", "*overburden* of the *Kirtland Shale and Fruitland Formation*", and the "*alluvium*" along the Chaco River. No deficiencies pertaining to the *alluvium* along the Chaco River were outlined by the OSMRE and are therefore not addressed further. Potentiometric values were obtained by the USGS from wells within the remaining three units. Contours were constructed by BAI from these values and are presented on Figures 2, 3 and 4. The regional ground-water flow direction of all three units trends north to northwest. A localized, northeasterly flow component is expected and indicated along outcrop areas, reflecting recharge into the units. This component conceivably exists for a short distance prior to becoming encompassed by the regional flow pattern to the north/northwest. This general flow direction is in agreement with other Cretaceous formations in the San Juan Basin (see Figure 1)[8].

Due to the close proximity of the mine to the recharge area, the saturated/unsaturated border of the *coal seams and interbedded lithologic units* of the *Fruitland Formation* parallels the eastern extent of the mine permit boundary striking approximately 10-15 degrees northeast (Permit Application Package [PAP], Exhibits 12-2 through 12-5). The formation material is essentially dry throughout the middle portions of the mine area. In the northern portion of the mine, the formation becomes artesian on the order of 20 feet. In the southern portion of the mine, artesian conditions on the order of 80 feet are found. Due to the stratigraphy, it is anticipated that the *Pictured Cliffs Sandstone* is artesian beneath the majority of the mine area, while the *overburden* of the *Kirtland Shale and*

Fruitland Formation is anticipated to have a saturated thickness on the order of a few feet throughout the mine area.

UII mining activity will excavate portions of the *Fruitland Formation*. Material to be excavated is bound by a shale layer beneath the bottom most coal seam. Beneath this shale layer lies the low-permeability *Pictured Cliffs Sandstone*, which overlies the low-permeability materials existing in the *Lewis Shale*. Materials to be excavated are bound above by portions of the *Fruitland Formation* and/or the low-permeability, lowest member of the *Kirtland Shale*. Given the discontinuity of the coal seams and the geohydrologic characteristics of the units, it is inappropriate and unrealistic to analyze individual coal seams as if they were separate aquifers. Rather, units to be potentially affected by mining activity should be considered in a manner similar to that described by the USGS: i.e., "*Pictured Cliffs Sandstone*", "*coal seams and interbedded lithologic units* of the *Fruitland Formation*" and the "*overburden of the Kirtland Shale and Fruitland Formation*". It is important to note "*coal seams and interbedded lithologic units* of the *Fruitland Formation*" are treated collectively as one unit by the USGS and by BAI. Similarly, hydrologic parameters such as transmissivity and permeability, should also be treated collectively.

6.0 SPECIFIC DEFICIENCIES AS DEFINED IN MAY 18, 1987 PROPOSAL LETTER

6.1 DEFICIENCY 21.a.-Koch Model

Two broad concerns were raised by the OSMRE concerning conclusions drawn by use of the Koch Model. The first dealt with determination of the Probable Hydrologic Consequences (PHC). The second dealt with Protection of the Hydrologic Balance (PHB). Both concerns center around two hydrologic events; 1) outward propagation of a stress (change in potentiometric surface or commonly termed "drawdown") resulting from flow into the mine area and, 2) transport of potential contaminants from the mine area into the subsurface environment. Determination of both PHC and PHB are dictated not by the analytical tool used, but by the geohydrologic characteristics, setting and the mine layout within those criteria. The hydrologic events, stress propagation and transport are controlled by the surrounding units. Thus it serves no purpose to argue over the suitability of the Koch model, another model can be used but the results will be similar.

A three dimensional, finite-difference, ground-water model was conceptualized and constructed to evaluate the hydrologic consequences due to stress propagation from pit inflow. From this analysis, it was concluded that stress propagation resulted in minimal impacts to the hydrologic regime as drawdowns of only 2 to 3 feet were computed adjacent to the mine area for the *"coal seams and interbedded lithologic units* of the *Fruitland Formation"*, less than 0.5 feet for the *"Pictured Cliffs Sandstone"* and less than 0.005 feet for the *"overburden Kirtland/Fruitland Formation"*. Detailed model input and output are presented later in this report.

Analytical techniques were used to evaluate the hydrologic event, transport of pollutants into the sub-surface environment. As is the case for propagation of stress, the controlling factor for transport is the geohydrologic characteristics of the surrounding units. A "worst case" conceptualization was incorporated into the analyses. Technical details pertaining to the analyses are presented later in this report. The effects on the nearest discharge point (i.e., the San Juan River) are that the earliest arrival for a pollutant is on the order of 240 years, and that the ratio of the pollutant flux to the 7-day, 10-year recurrence interval discharge of the river is on the order of 0.00021. Ratios of the flux to the average monthly flows of the river are on the order of 2 to 3 times smaller than the 7-day, 10-year recurrence interval discharge (i.e, 0.00021). Batch-leach test results concluded by UII and presented in the PAP indicate pollutants may not even occur. Based on these analyses the impacts due to transport are minimal and are in all probability not measureable.

Other points should be noted prior to presenting details on stress propagation and transport. Applying the term "aquifer" to the units in the lease area is a loose application of the word. The units are not aquifers, they are low permeability rocks that should actually be considered confining beds, aquitards or perhaps even aquicludes. Wells are not constructed in these units except when absolutely necessary for low yield stock wells and for supplying information for permit applications. It is inappropriate to consider these units as a multiple aquifer system. Mainly because they actually are not aquifers, but rather geologic units. Vertical permeabilities of similar Cretaceous-age units in the San Juan Basin have been modeled as being on the order of $1x10^{-07}$ feet per day[8]. Roughly three orders of magnitude smaller than the horizontal permeability of for example, the *Fruitland Formation* (which is low in and of itself).

Permeabilities of the units to be potentially affected by mining activity are too low for any significant hydrologic consequences to occur. Additionally, mine cuts will not expose sufficient saturated material (predominantly unconfined as mining progresses) for significant changes in the potentiometric surface to occur. The hydrologic balance is secured by the low permeabilities of the surrounding units and not by permeabilities resulting from deposition of waste material.

Stress Propagation

An impact-mode, three dimensional, multi-layer, finite-difference model (MODFLOW) [12] was conceptualized and constructed for evaluation of the stress propagation due to mining activity. Three layers in order of increasing depth were evaluated; 1)*overburden of the Kirtland Shale and Fruitland Formation*, 2)*coal seams and interbedded lithologic units* of the *Fruitland Formation*, and 3) *Pictured Cliffs Sandstone*. A 31 row by 11 column grid network was developed and overlain on the potentially affected area (see Figure 5). Constant head nodes were placed within layers 1 and 2 to simulate hydrologic effects due to mine excavation. Additionally constant head nodes were placed along the San Juan River and Morgan Lake to simulate mining effects at discharge/recharge locations. Individual node status for each layer and aquifer characteristics utilized are presented in Figures 6,7 & 8. Stratigraphic thicknesses and additional geohydrologic information has been previously discussed. A complete printout of model input and output is presented in Appendix A.

Conceptually, two factors are important to the simulation. First, as mining progresses, a stress is instantly propagated with the result being a rapid drop in the potentiometric surface, however small. Thus if the layer was confined initially (it is only in the extreme northern and southern sections of the permit area), unconfined conditions are caused very rapidly. Consequently, in the excavated area of Layers 1 & 2, the material was simulated as being unconfined from the start. Second, as previously discussed the unsaturated/saturated border roughly parallels the eastern extent of the mine boundary. Mining activity will not intercept saturated material until late in the mine life. We have simulated the PHC as if the mine intercepted saturated material for a total of 12 years. This has resulted in over-calculation of effects as it is doubtful that mining activity will encounter saturated material for even this length of time. One should note where the eastern extent of mining intercepts dry conditions, no impact can occur. This is the case over considerable extent of the mine. Where mining intersects partial saturation, the hydrologic consequences are restricted to the vertical extent of the saturated thickness.

Results of the simulation indicate very minimal effects are observed due to stress propagation. Maximum simulated drawdowns on the order of 0.0004 feet are calculated in the *overburden of the Kirtland Shale and Fruitland Formation* at approximately one and a half miles away from the mining activity. Simulated drawdowns of a maximum of 2 to 3 feet adjacent to the permit area and less than 0.5 feet approximately 15 miles from the permit area are calculated for the *coal seams and interbedded lithologic units* of the *Fruitland Formation*. Calculated maximum drawdowns of 0.5 feet or less are determined for the *Pictured Cliffs Sandstone*. Sources of water for pit inflow are predominantly derived from storage, with an approximate total of 4 acre-feet for the entire simulation (i.e., 12 years) being obtained from capture of surface water (Morgan Lake and the San Juan River). This surface water capture represents the maximum extent of hydraulic impacts on the San Juan River as requested through Deficiency 21.h.. Average inflow to the entire mine area is approximately 239 acre-feet/year (148 gallons/minute) over a total simulation time of 12 years. It should be noted that a moderate portion of this inflow will not actually be observed in the mine due to evaporation.

Transport of Mining Affected Ground Water

Several assumptions and conditions were incorporated into the "worst case" analysis. They are presented along with the calculations as follows. Assume there is no attentuation or dilution of the chemical constituents of mining-affected ground water as it travels on a migratory path through the *coal seams and interbedded lithologic units* of the *Fruitland Formation* towards the discharge point of the San Juan River. Assume further that the ground water migrated to the extreme northern edge of the lease area through a "dragline aquifer" and appeared at the permit boundary instantaneously, neglecting the time involved to fill and create a gradient in the spoil area. Finally, assume the flow path to the San Juan River is a direct northern line and is not easterly first until it becomes encompassed by the regional flow pattern. Constituents in the mining-affected ground water would therefore migrate at the same rate as the true pore velocity. Based on the above, a "worst case" scenario is presented for evaluation of potential water quality impacts to the San Juan River as requested through Deficiency 21.h..

Pore velocity of ground water is determined by[13]:

$$v=(kI)/n$$

where,
v=pore velocity (feet/day),
k=permeability (feet/day)=1.2 feet/day (69 ft^2/day /60 feet, average of reported values of coal seams and interbedded lithologic units),
I=hydraulic gradient (dimensionless)=0.0051 ft/ft (average gradient of coal seams and interbedded lithologic units as determined from Figure 3),

n=effective porosity= approximately 0.1 for a coal type, sandstone/shale unit[14].

Therefore,
pore velocity=v=0.06 feet day

From the northern edge of the lease area, the shortest distance to the San Juan River, is approximately one mile. The minimum amount of time required for mining-affected ground water to potentially reach the San Juan River is approximately 240 years.

The amount of flux through an aquifer can be estimated using Darcy's Law expressed as[13]:

$$Q=KIA$$

where,
Q=volume rate of flow, (ft^3/day),
K=hydraulic conductivity, (ft/day),
I=hydraulic gradient (dimensionless),
A=cross-sectional area through which flow occurs, (ft^2/day).

In this analysis, the pollutant is simulated as migrating in a due north direction directly towards the San Juan River. The cross-sectional area used represents a unit thickness of 60 feet, with a width of 2 miles normal to the direction of flow (i.e., in an east-west direction). The two mile width is slightly larger than the normal mine width. The cross-sectional area is therefore 633,600 square feet for the *coal seams and interbedded lithologic units* of the *Fruitland Formation* and a flux from the mine area entering into the San Juan River is approximately 3900 ft^3/day (0.05 cfs). It should be noted that a small portion of the mining affected ground water becomes diluted with the total flow from the formation before entering the San Juan River. However, the analysis will proceed as if dilution did not occur.

San Juan River base flow for the 7 day-10 year recurrence interval at the Farmington station is 290 cfs, and is 129 cfs at the Shiprock station[15]. The contact of the *coal seams and interbedded lithologic units* of the *Fruitland Formation* with the San Juan River is located approximately one third of the distance downstream from Farmington to Shiprock. Therefore, a representative 7 day-10 year recurrence interval discharge for the contact area is approximately 236 cfs. The ratio of mining-affected ground water to the 7 day-10 year recurrence interval discharge is calculated as 0.00021.

A similar analysis was conducted for average monthly flows along the San Juan River. USGS gaging station data for approximately 40 years were compiled for the stations at Shiprock and at Farmington. Interpolated average monthly flow at Fruitland (approximate location of coal seams with the San Juan River) was then computed based on these stations. All three locations are presented on Figure 9. The ratio of discharge from the *coal seams and interbedded lithologic units* to the flow at Fruitland is presented in the table below. This ratio represents the maximum quantity of mining-affected ground water that could be introduced into the San Juan River.

Ratio of Maximum Quantity of Mining Affected Water to Average Flow in San Juan River

Month	Ratio
October	$3.6E^{-05}$
November	$5.8E^{-05}$
December	$7.3E^{-05}$
January	$7.4E^{-05}$
February	$5.1E^{-05}$
March	$2.6E^{-05}$
April	$1.1E^{-05}$
May	$4.6E^{-06}$
June	$6.5E^{-06}$
July	$1.7E^{-05}$
August	$2.7E^{-05}$
September	$3.5E^{-05}$

Given the conditions described above (i.e., no dilution, no attentuation, direct flow path, instantaneous start time and closest possible start location to the discharge location) results above are grossly over-calculated. Additionally, batch-leach testing results concluded by UII and presented in the PAP indicate insignificant increases in pollutant concentrations within the spoil areas and that attentuation affects are present.

It should be noted that the permeability of the *coal seams and interbedded lithologic units* of the *Fruitland Formation* was used in the above transport analysis. Calculation of pollutant velocities as a result of vertical leakage, introduction via inter-tonguing and/or migration through other units would be significantly decreased if permeabilities related to these pathways were used. Permeability of the *coal seams and interbedded lithologic units* of the *Fruitland Formation* is approximately three orders of magnitude greater than the *Pictured Cliffs Sandstone* and two to four orders of magnitude greater than the *overburden Kirtland/Fruitland Formation.*

6.2 DEFICIENCY 21.c.-Storativity

Calculated effects on the hydrologic regime are relatively insensitive to reasonable values of storativity. The size of the storage coefficient depends on wheter the usint is confined or unconfined. If the aquifer is unconfined, the predominant source of water is from gravity drainage of the unit through which the decline in the water table occurs. In such an aquifer, the storage coefficient is virtually equal to the specific yield and ranges from 0.1 to 0.3[9]. If the quifer is confined, the water released from storage when the head declines comes from expansion of the water and from compression of the aquifer. Storativity of confined aquifers are frequently determined from the relationship $1x10^{-06}$ times the unit thickness[10]. Given commonly accepted values of storativity, three factors provide the majority of control on PHC and PHB. First, the permeabilities of the formations to be potentially affected are simply too low for a significant stress to propagate and/or pollutants to rapidly migrate. Second, the boundary of the saturated/unsaturated zone exists on the eastern edge of the permit area throughout most of the mine which provides for minimal interception of saturated material. Third, progression of mining causes the potentiometric surface to drop at each cut expanding the unconfined boundary of the formation, which provides a severe hampering of propagation of stress. In the PAP, the coal seams in the *Fruitland Formation* were treated as individual aquifers and the OSMRE requested investigation of storativity values. BAI contends that the *coal seams* and their *interbedded lithological units* of the *Fruitland Formation* should be treated as one unit. Using the relationship 1×10^{-06} times the thickness of the unit[10], a value of 2.5×10^{-04} was obtained for the *coal seams* and *interbedded lithologic units* of the *Fruitland Formation*. A value of 0.1 represents the unconfined portions of the unit[9].

Additional testing to obtain localized storativity values is not technically justified as the results obtained would not alter the conclusion of minimal effects on the hydrologic regime. Using the previously described ground-water model (see Section 6.1) a sensitivity analysis of storativity was conducted. The confined storativity was decreased from its' original value by two orders of magnitude for all layers. Similarly, the unconfined storativity was decreased from a value of 0.1 to 0.05 for all layers. It should be noted that the size of storativity decreases implemented in this analysis are beyond the bounds of what would be considered reasonable values[9 & 10]. In decreasing storativity, the magnitude of stress propagation is increased. Thus, drawdowns are increased. Input and output for the storativity sensitivity analysis are presented in Appendix B.

Results of the sensitivity analysis indicate a maximum drawdown of approximately 1.5 feet outside of mining activity for the *overburden Kirtland/Fruitland Formation*. Drawdown within the majority of the modeled area is calculated as being less than one foot. For the *coal seams and interbedded lithologic units*, a maximum drawdown of approximately 4 feet is observed adjacent to the permit area, with values of approximately one-half to three feet observed throughout the rest of the modelled area. The *Pictured Cliffs Sandstone* yielded a maximum drawdown value of approximately 2.5 feet with the majority of drawdown values being on the order of 0.5 feet. A total of 10.3 acre-feet of water for the entire 12 year simulation was dervied from the surface sources; San Juan River and Morgan Lake. The above analysis demonstrates that conclusions pertaining to hydrologic consequences are insensitive to reasonable, and in fact even unreasonable, values of storativity. The sensitivity analysis also shows that if one argued that the selected values for storativity were too low, an increase in storativity would decrease the impacts to the hydrologic regime.

6.3 DEFICIENCY 21.d.-Aquifer Test Information

As presented in the PAP, individual coal seams were tested for hydraulic information. Inasmuch, as the individual coal seams in the permit area are generally noncorrelative, discontinuous, and interbedded with varying rock types (PAP, Chapter 11), they should not be considered as separate units for purposes of calculating hydrologic impacts. The USGS has purposely not considered individual coal seams in their evaluation of impacts in the Fruitland Formation and we concur. Tests conducted by other entities and by BAI on similar geologic units in northwestern New Mexico consistently yield the same conclusion; the units can be characterized by extremely low permeabilities. Except to again demonstrate permeabilities are low by considering overall well production and drawdown, the specific tests are of little value as individual tests. Additionally, the coal seams are not in of themselves seperate units, but rather are treated collectively with the *interbedded units* of the *Fruitland Formation*. Therefore, we recommend interpretaions and questions pertaining to individual coal seam tests should be disregarded for purposes of calculating hydrologic impacts and geochemical flux.

Tests reported by the USGS wherein the *coal seams* and *interbedded lithologic units* of the *Fruitland Formation* were treated as one unit, yielded a range of transmissivity values from 7 to 130 feet squared per day[2]. For this type of combined formation, these values are reasonable, expected, and are presented here for future use within the PAP. To the extent the coal seams are discontinuous, flow and stress propagation is controlled by the permeability of the interbedded lithologic units.

6.4 DEFICIENCY 21.e.-Potentiometric Surfaces

Ground-water flow paths in the Cretaceous rocks of the San Juan Basin are north to northwest trending towards the discharge point of the San Juan River[8](see Figure 1). Contours constructed by BAI using USGS data support a regional flow direction to the northwest for the *Pictured Cliffs Sandstone*, the *coal seams* and *interbedded lithological units* of the *Fruitland Formation*, and the *overburden* of the *Fruitland Formation* and *Kirtland Shale* (see Figures 2, 3 and 4). A localized northeasterly component near the outcrop is expected and indicated on the potentiometric surfaces previously submitted in the PAP (reference: Exhibits 12-2 through 12-5). These potentiometric surfaces represent individual coal seams and are not necessarily reflective of the unit as a whole. Consequently, certain hydrologic impact analyses should not be conducted utilizing these data (see Sections 5.0 and 6.3). The information from the PAP does identify the location of the saturated/unsaturated boundary within the individual coal seams. To that extent, the information is valuable (see Section 6.1). The unsaturated/saturated boundary information presented on Exhibits 12-1 through 12-5 (PAP, Chapter 12) have been collectively interpretated to identify a composite boundary for the *coal seams* and *interbedded lithologic units* of the *Fuitland Formation* as a whole (see attached Plate 1).

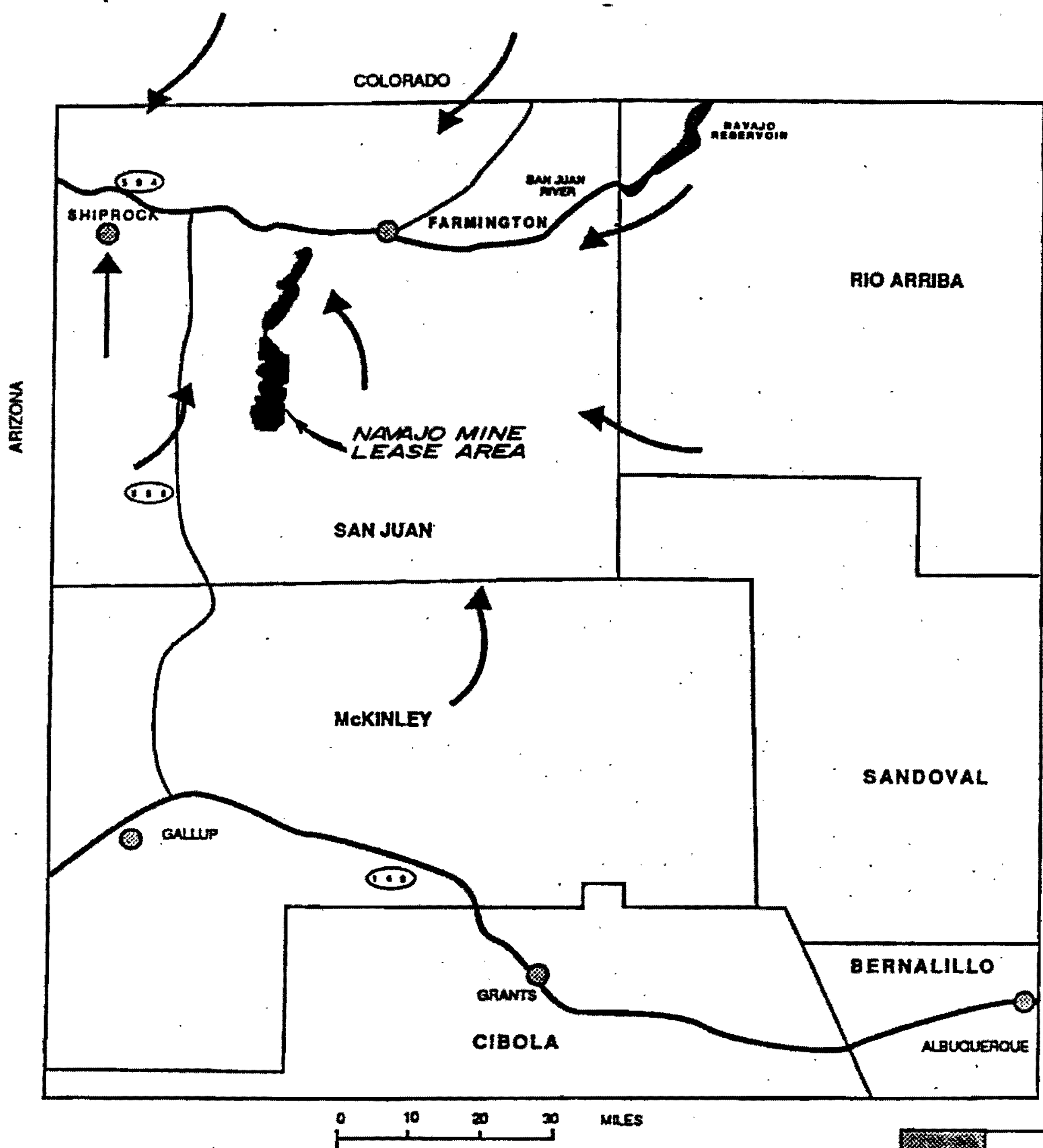
Eastern projection of the potentiometric surface should not be conducted for any large distance, based on the PAP potentiometric surfaces. However, projection is not necessary as USGS information allows for determination of the regional flow paths and gradients of the units involved. Similarly, it is not necessary to drill additional wells to the east because: a) the closest receptor is the San Juan River and it has been considered here; b) the analysis of hydrologic effects shows little effect to the east; c) the analysis of hydrologic effects shows essentially no contaminant could reach more than a mile east in reasonable time; d) high-production wells in these geologic units do not and can not exist to the east; e) available data show regional flow is not to the east; and f) these data, as expected match regional flow in geologically adjacent units of the basin.

6.5 DEFICIENCY 21.g.-Shallow Ground Water

Hydraulic impacts to the units beneath Area I and on Morgan Lake were simulated utilizing a ground-water flow model (see Section 6.1-Stress Propagation). These types of impacts were found to be negligible and probably unmeasureable. As such, hydraulic impacts in Area I North are not discussed further. In relation to transport and water quality impacts, the following is provided.

When Morgan Lake was first constructed, the major surface geologic feature in this area was the Pictured Cliffs Sandstone. Some alluvium was also present which, was used in the industrial area for fill material. Consequently, upon completion of Morgan Lake a localized recharge area developed with flow emanating from the lake to the sub-surface. As such, transport or migration of contaminants should not occur from the sub-surface to Morgan Lake. Any contaminants migrating to the San Juan River via the sub-surface from sources such as fuel tanks and coal stockpile runoff, would have to migrate through a minimum of the "worst case" geohydrologic conditions presented in Section 6.1. Given that the contaminant would have to migrate through the Pictured Cliffs Sandstone (i.e., lower permeability than the *coal seams* and *interbedded lithologic units* of the *Fruitland Foramtion*) first, the arrival time of the contaminant to the San Juan River would be greater than 240 years.

Additionally, UII has a current, valid NPDES permit which covers the Industrial Area - Area I North. Zero discharge has occurred since 1977 under this permit, and this will in all probability continue.



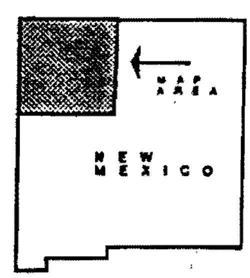


FIGURE 1: GENERALIZED PATTERN OF GROUND-WATER FLOW IN ROCKS OF JURASSIC AND CRETACEOUS AGE IN THE MIDDLE PORTION OF THE SAN JUAN BASIN
BHP-Utah International, Inc.
Billings & Associates, Inc. ALBUQUERQUE, NM
September, 1987 BAI

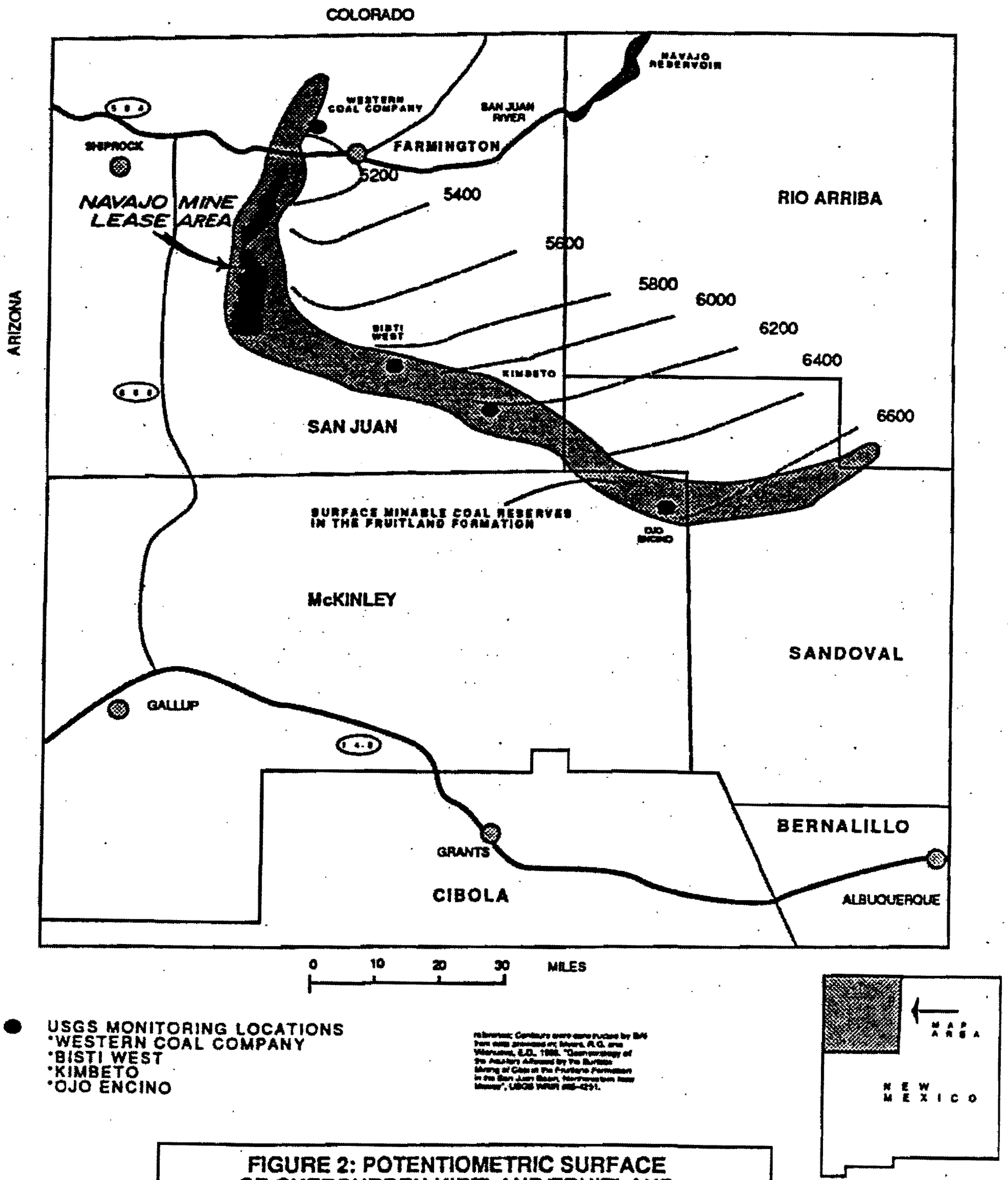
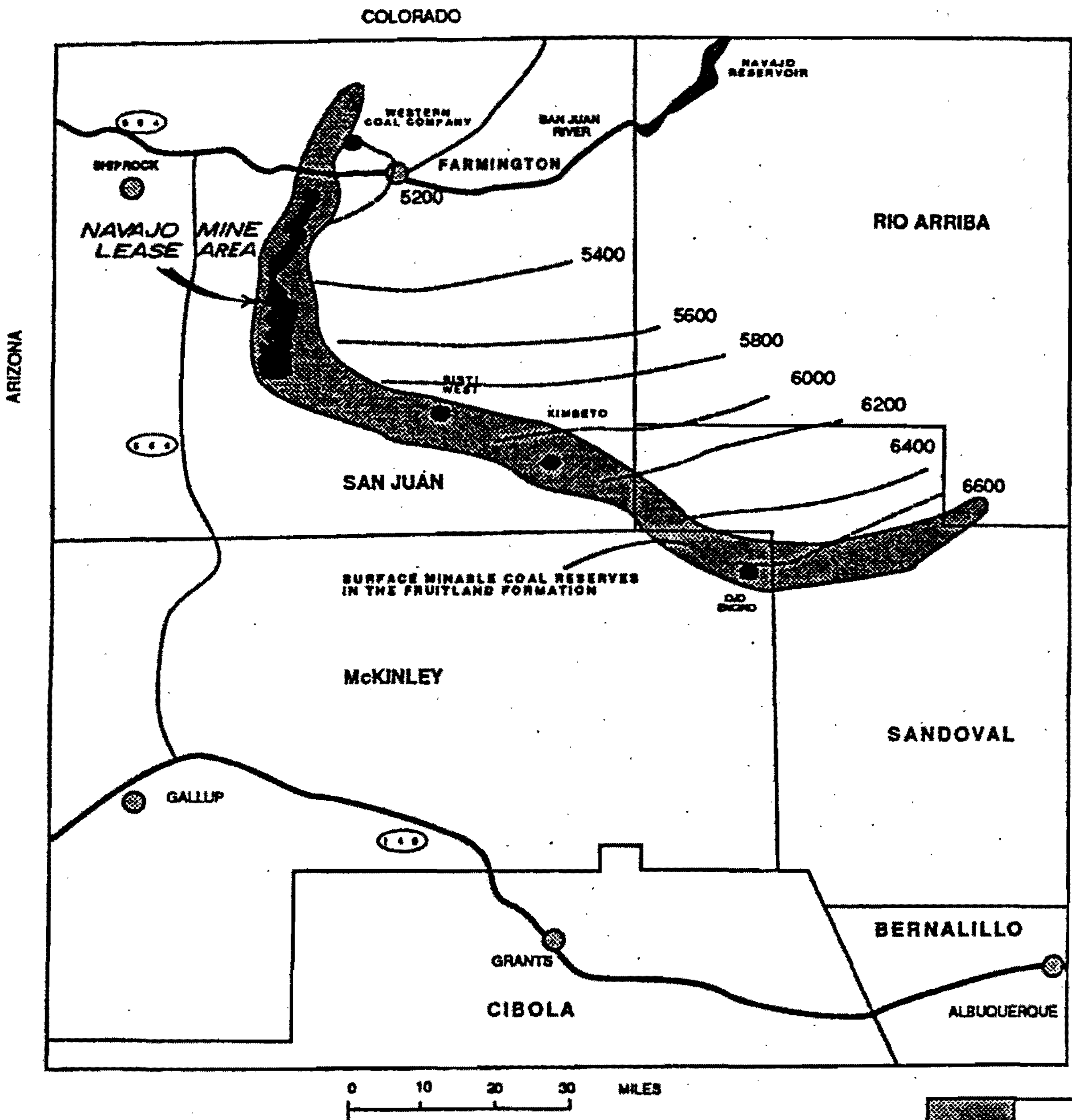


FIGURE 2: POTENTIOMETRIC SURFACE OF OVERBURDEN KIRTLAND/FRUITLAND FORMATION

BHP-Utah International, Inc.

Billings & Associates, Inc. ALBUQUERQUE, NM

September, 1987 BAI



● USGS MONITORING LOCATIONS
- WESTERN COAL COMPANY
- BISTI WEST
- KIMBETO
- OJO ENCINO

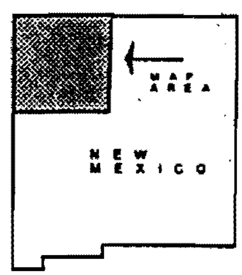


FIGURE 3: POTENTIOMETRIC SURFACE OF COAL SEAMS AND INTERBEDDED LITHOLOGIC UNITS

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Billings & Associates, Inc. ALBUQUERQUE, NM

September, 1987

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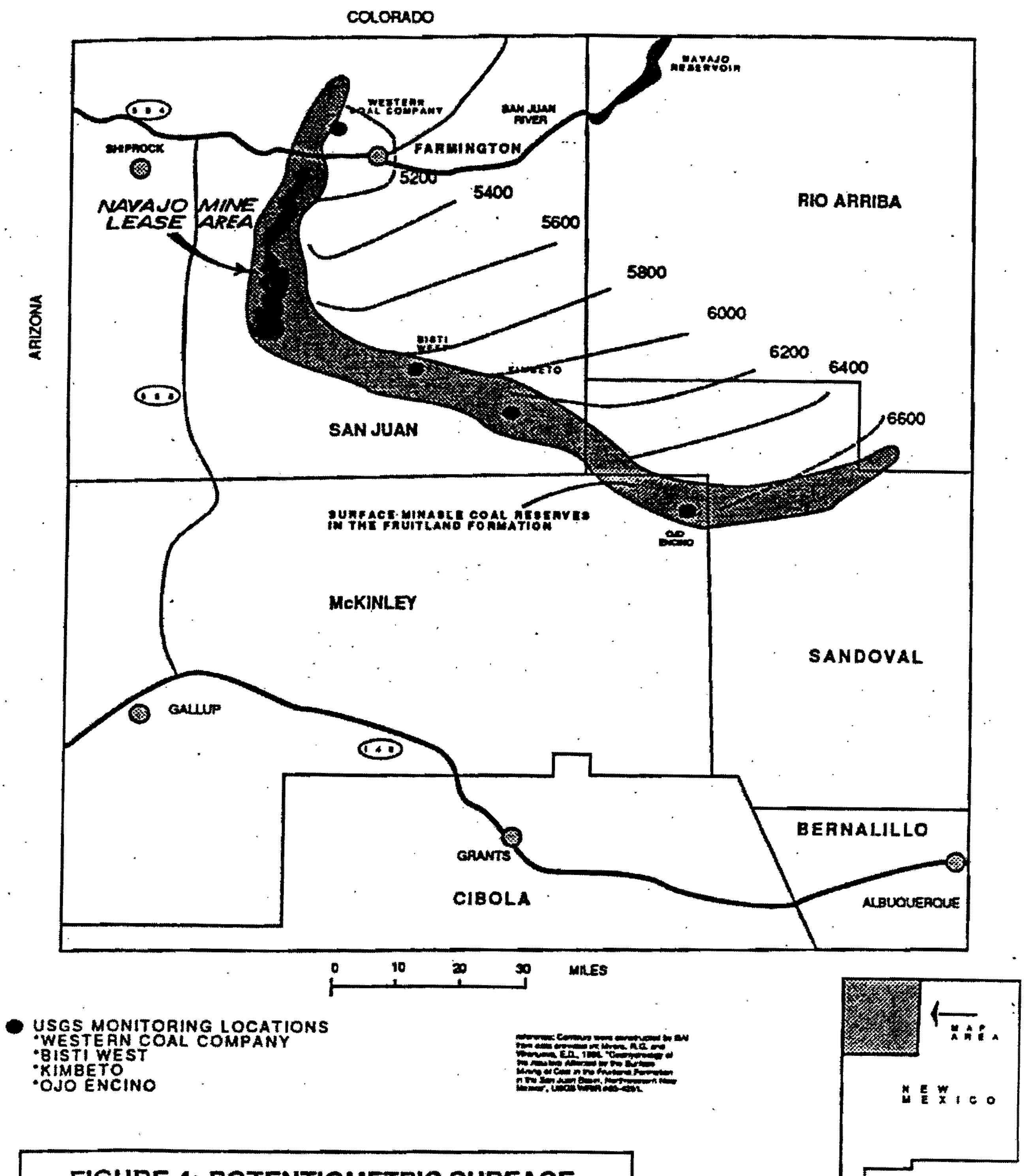

FIGURE 4: POTENTIOMETRIC SURFACE OF PICTURED CLIFFS SANDSTONE

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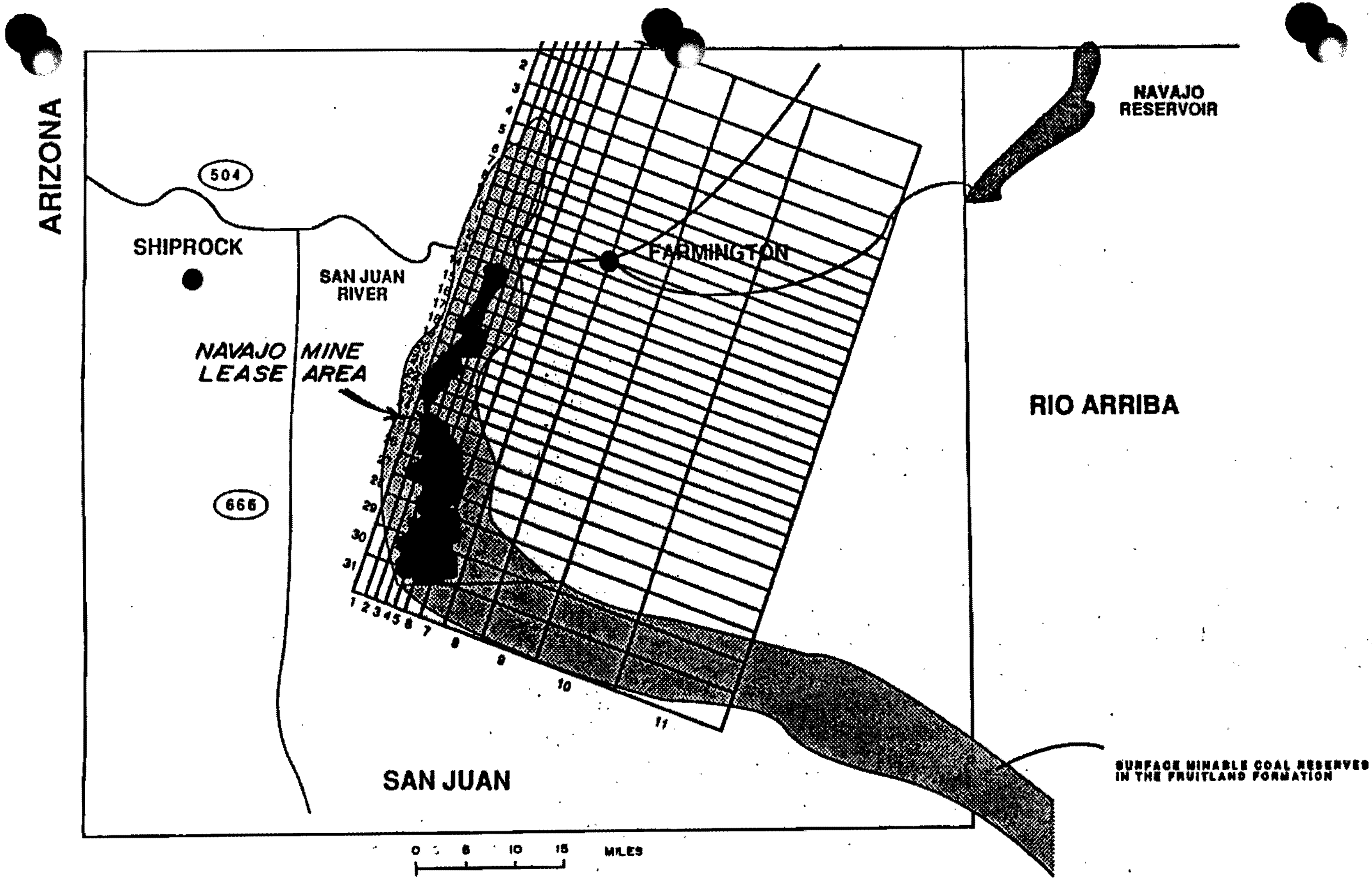

FIGURE 5: MODEL CELL NUMBERS AND GRID NETWORK

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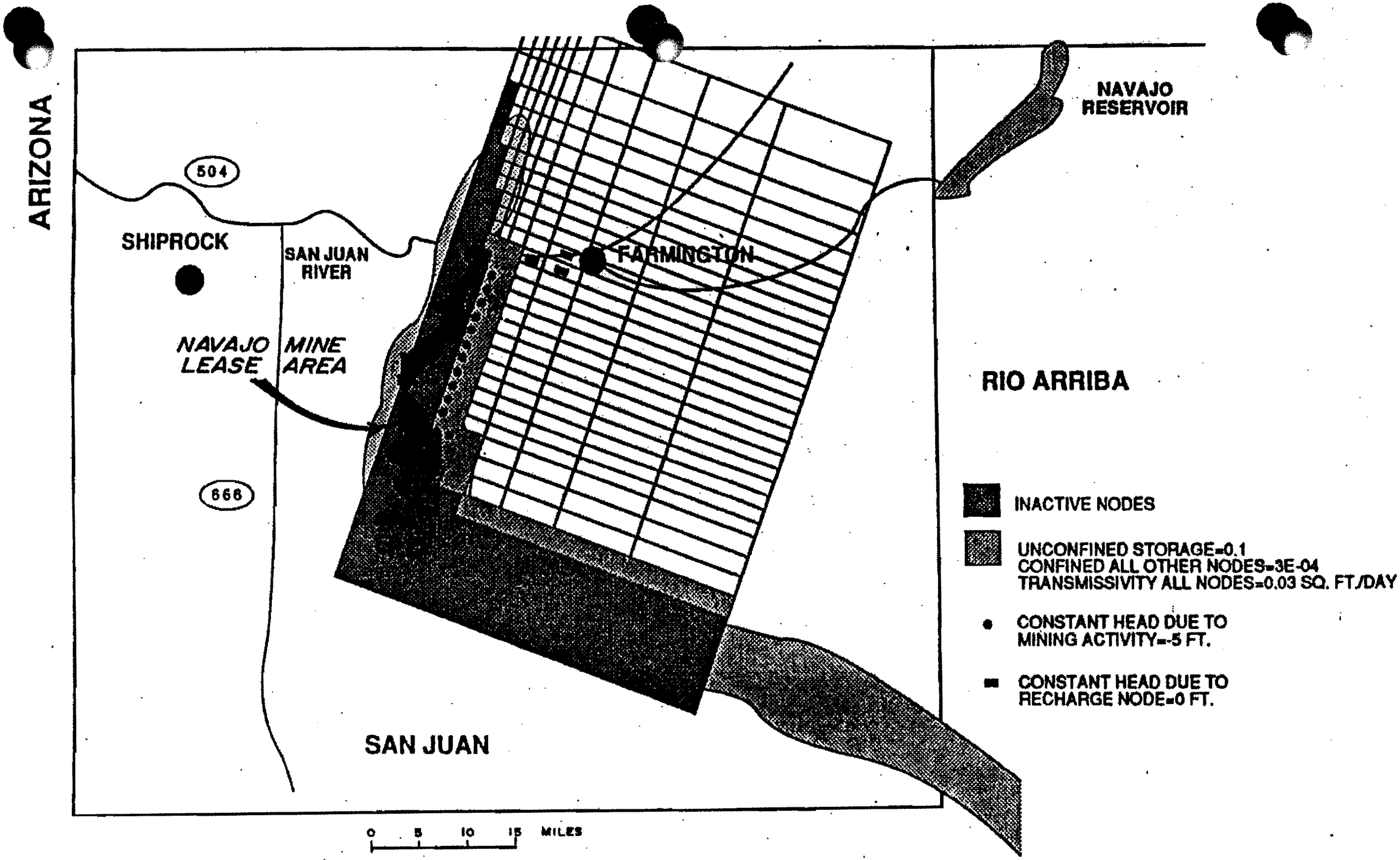

FIGURE 6: NODE STATUS-OVERBURDEN KIRTLAND/FRUITLAND

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SEPTEMBER, 1987

BAI

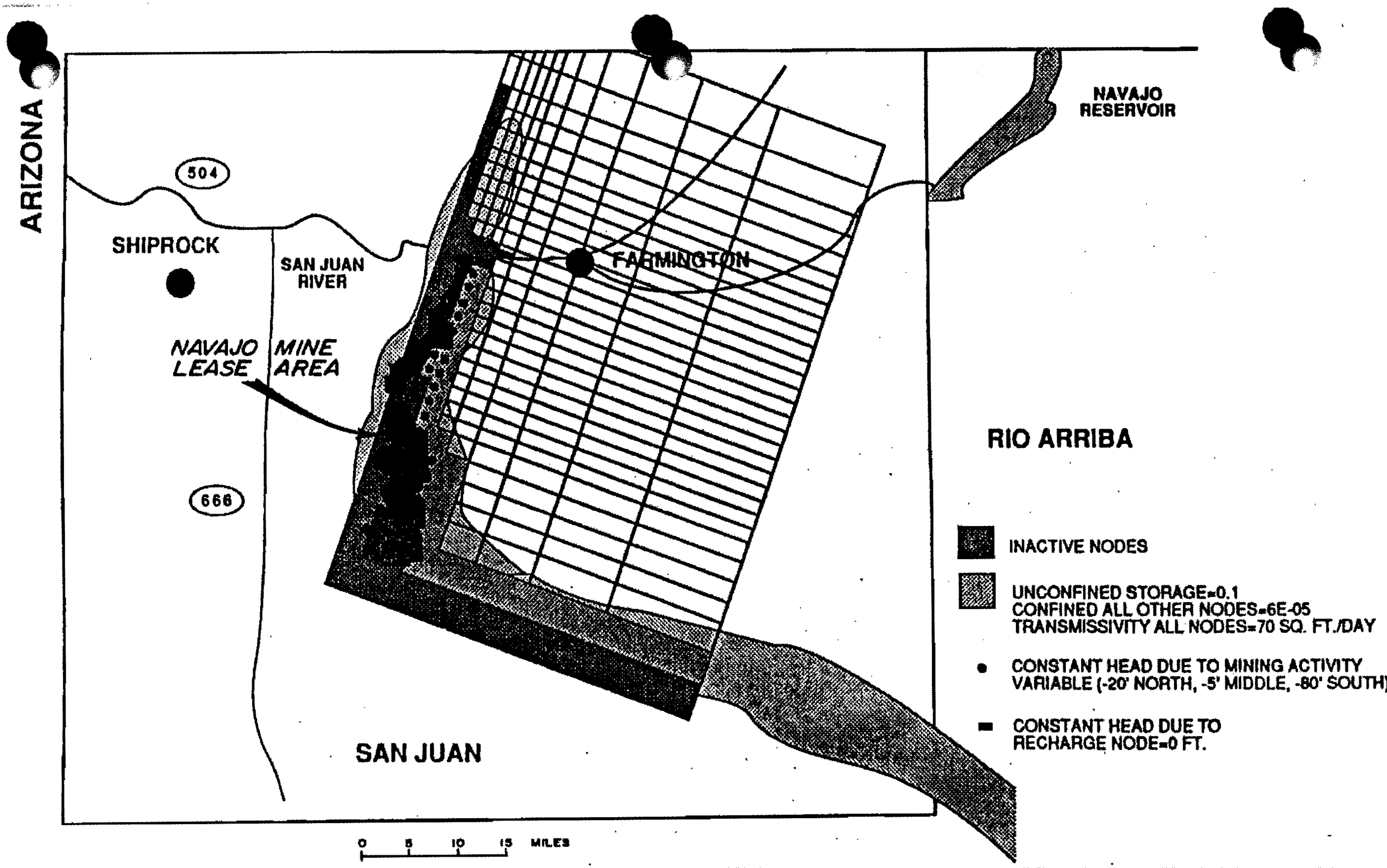

FIGURE 7: NODE STATUS- COAL SEAMS AND INTERBEDDED LITHOLOGIC UNITS

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SEPTEMBER, 1987 BAI

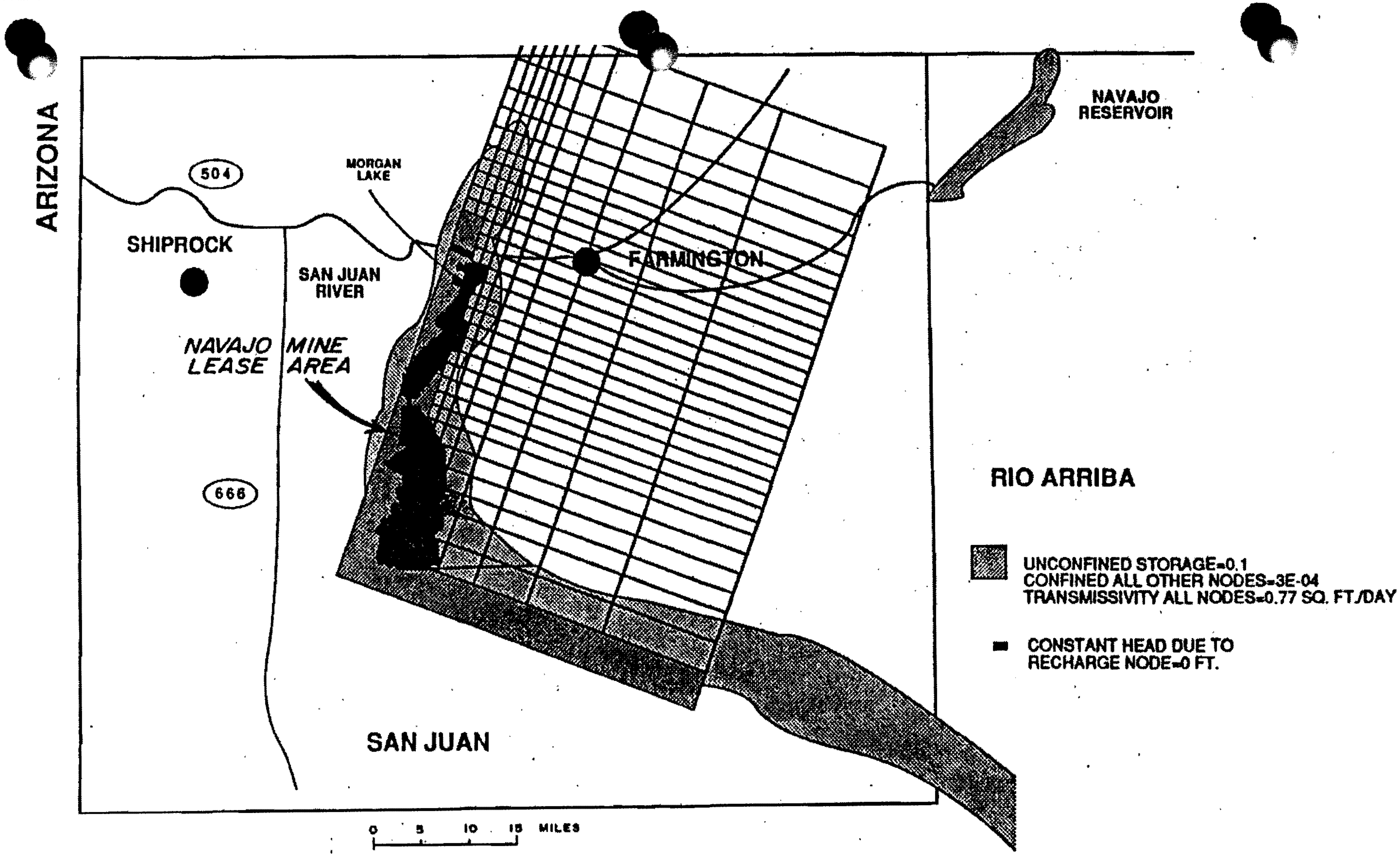

FIGURE 8: NODE STATUS-PICTURED CLIFFS SANDSTONE

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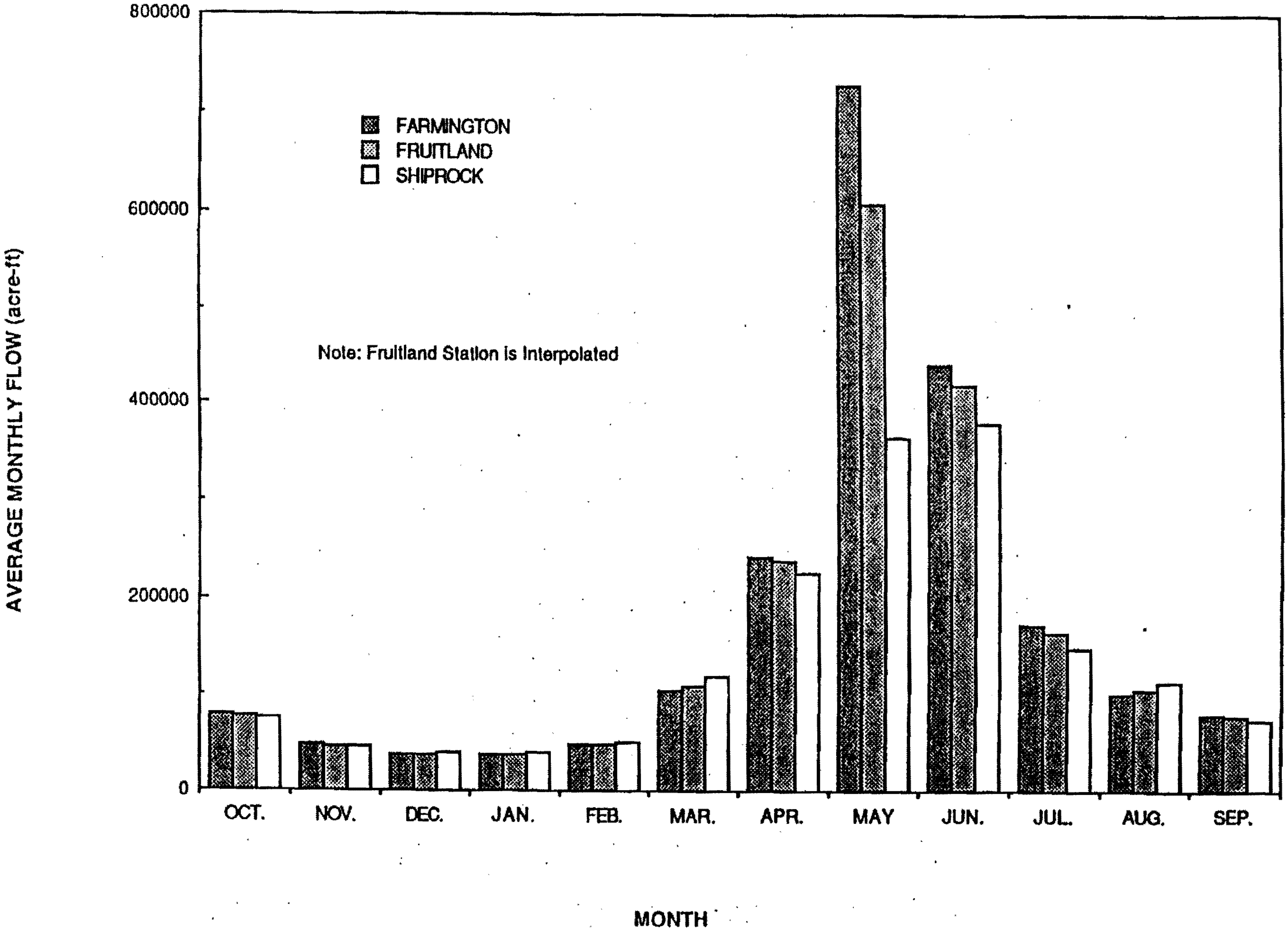
BILLINGS & ASSOCIATES, INC. ALBUQUERQUE, NM

SEPTEMBER, 1987 BAI

FIGURE 9. MONTHLY FLOW RATES-SAN JUAN RIVER



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APPENDIX 6-E

(copy of 1989 Appendix 12D)

WELLS ON AND NEAR THE PERMIT AREA

Appendix 12-D contains information pertaining to wells and springs that exist in and adjacent to the mine permit area. Where available, location, ownership, type and amount of water, depth of water, usage, well completion zone(s), well yield, well depth, and water quality information were collected. Information was compiled using an approximate border of the coal seam outcrops on the west to one mile east of the permit boundary extending north to the San Juan River.

Generally, five data sources were examined; UII record (Chapter 12-PAP), Navajo Nation files, United States Geological Survey computer data base WATSTORE, New Mexico State Engineer files, and scientific publications. Due to stratigraphy in the area, the geologic units that could potentially be impacted (Chapter 12, PAP) and consequently those investigated were Alluvium, Kirtland Shale, Fruitland Formation and Pictured Cliffs Sandstone. A data base was developed from an area larger than that defined above to facilitate collection, tabulation and presentation. Development of these types of data bases typically require triangulation coordinates which include, but extend beyond the area of concern. Consequently, many of the wells/springs presented herein, lie outside the region defined above.

Tabulation of collected information is given in Addendum 12-D-A. The base map depicting the area from which well/spring information was obtained is shown on Figure 12-D1. Note that topographic features were obtained from USGS maps printed in 1980. Extension of the mine permit boundary exists southerly to approximately the bottom of T26N. Identified well/spring locations are presented on Figure 12-D2, with a BAI number of classification. Refer to Addendum 12-D-A for additional information on any particular well. UII well numbers are 95-143, and 157. Note that some well numbers may appear to be missing, as evidenced by well numbers 85, and 88, but no well number with 86 and 87. These wells are located outside of the map boundary of Figure 12-D1. Consequently, they were deleted from the original data base, which included an area even larger than that of Figure 12-D1.

No wells or springs have been ground truth checked. It is not known whether the wells/springs presented here are still in existence, or have been abandoned, plugged, or mined out. It has been our experience that, certainly within alluvial environments, such as the Chaco River area and tributaries (see Figures 12-D1 and 12-D2), it is not uncommon for wells to become plugged and/or abandoned.

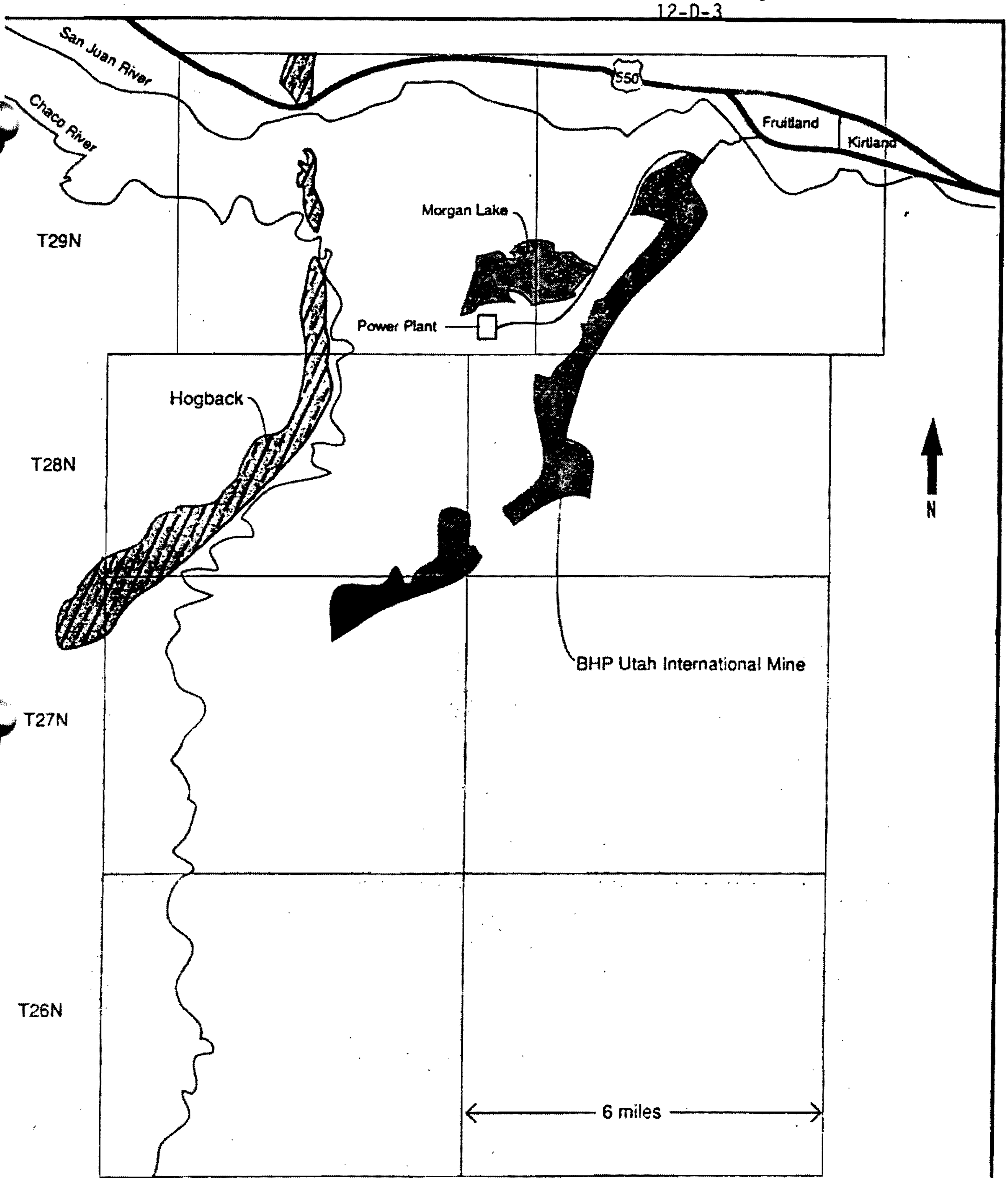

FIGURE 12 - D1

Base Map
BHP Utah International, Inc.
Billings & Associates, Inc. January, 1989

reference: base map and topographic features taken from USGS 1:100000 Farmington and Toadlena maps (USGS, 1980)

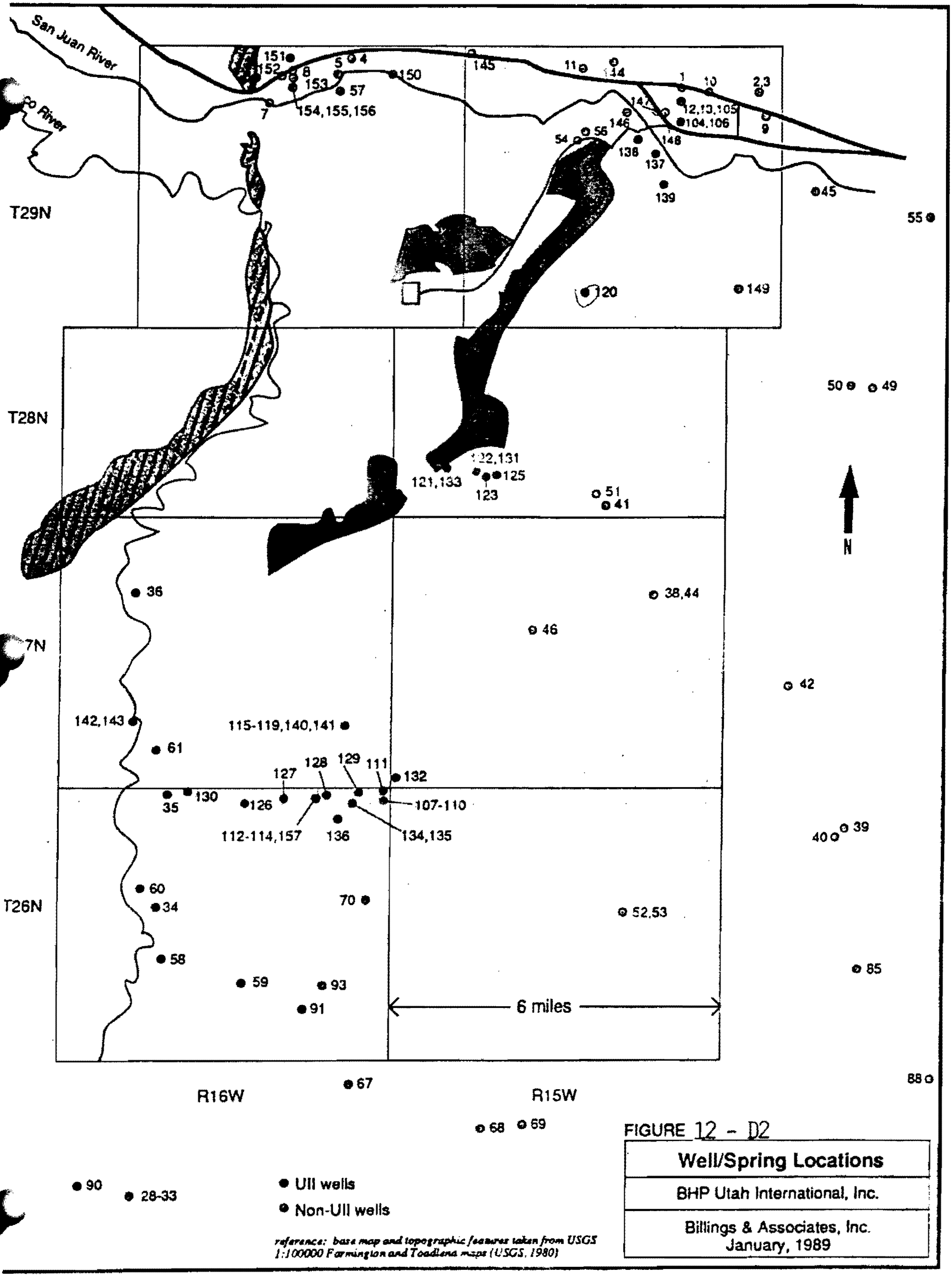

FIGURE 12 - D2

Well/Spring Locations

BHP Utah International, Inc.

Billings & Associates, Inc.
January, 1989

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APPENDIX 6-F
(copy of 1989 Appendix 12E)

SPECIAL CONDITION 11/89

The results of water-chemistry analyses are shown in table 2. The water is brackish. The specific conductance of the representative water samples ranges from 3,100 to 11,300 microsiemens per centimeter at 25° Celsius (microsiemens) (a calculated sum of approximately 2,200 to 6,800 milligrams per liter of dissolved solids). The dominant cation (fig. 7) in all samples is sodium. The dominant anion (fig. 7) is chloride except for samples from well 20, which is predominately bicarbonate, and well 29, which is predominately sulfate.

Transmissivities of the Pictured Cliffs Sandstone were determined from the results of slug tests and recovery tests after bailing from selected wells. These values ranged from 0.001 to 3 feet squared per day (Stone and others, 1983).

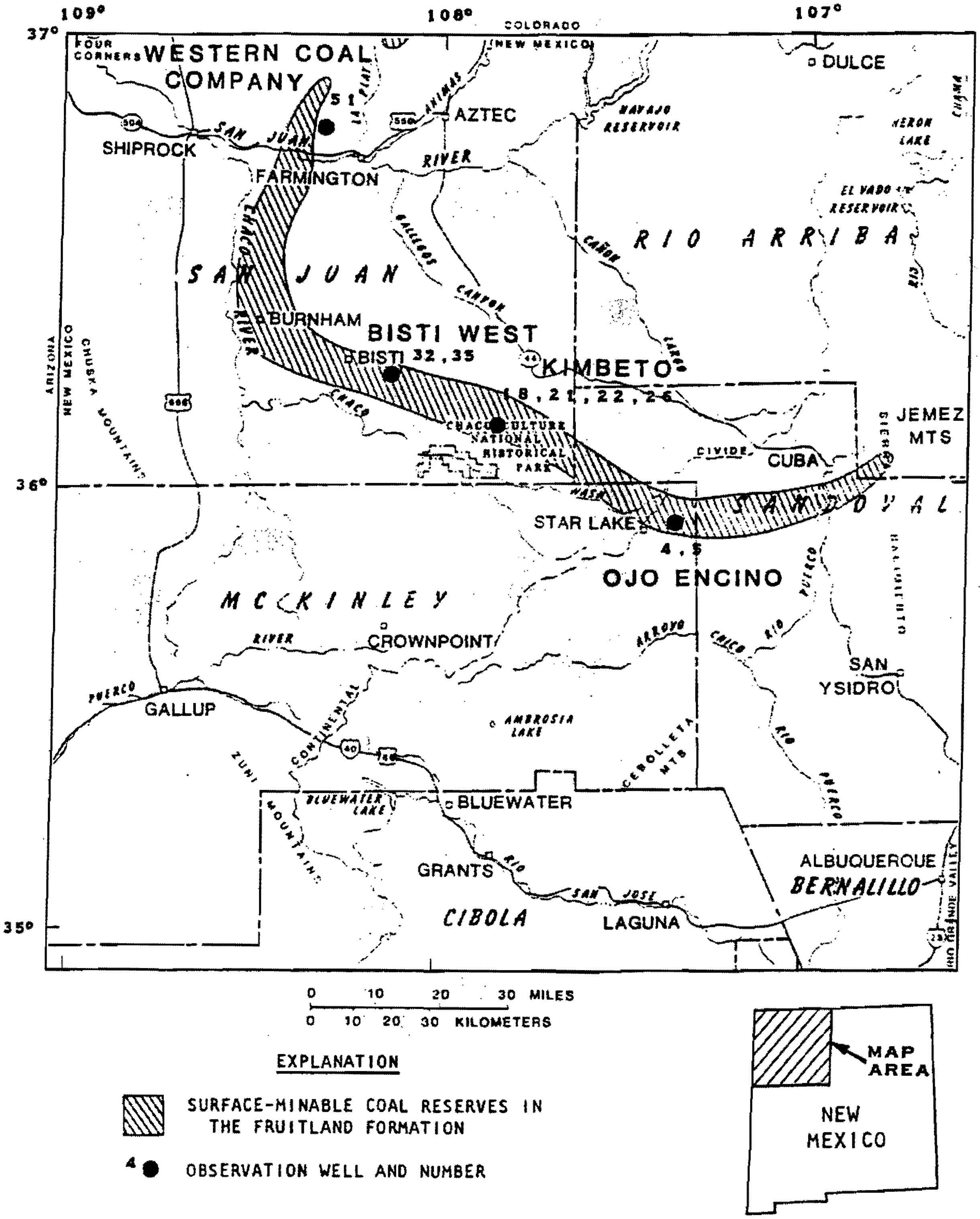
Coal Seams and Interbedded Lithologic Units of the Fruitland Formation (Late Cretaceous)

The Fruitland Formation overlies and intertongues with the Pictured Cliffs Sandstone and underlies the Kirtland Shale. The contact between the Pictured Cliffs Sandstone and Fruitland Formation is at the top of the massive sandstone underlying the lowermost coal bed. The contact between the Fruitland Formation and Kirtland Shale is at the top of the highest coal or carbonaceous-shale bed (Fassett and Hinds, 1971). The Fruitland Formation is composed of discontinuous, interbedded sandstone, siltstone, shale, coal, limestone, and carbonaceous sandstone, siltstone, and shale. The vertical lithology is somewhat consistent. The thin limestone beds composed of brackish-water pelecypod shells are in the lower part of the formation. The thicker coal beds are in the lower one-fifth to one-third of the formation. Sandstone generally is more abundant in the lower part of the formation. The upper part of the formation predominantly is siltstone and shale. The thickness of the Fruitland Formation generally is less than 300 feet within the study area (Fassett and Hinds, 1971).

Nine observation wells are completed in the coal seams and interbedded lithologic units of the Fruitland Formation (fig. 8; table 3). Water-level measurements for the period of record are shown in figure 9.

The results of water-chemistry analyses are shown in table 4. The water is brackish. The specific conductance of the representative water samples ranges from 1,900 to 13,000 microsiemens (a calculated sum of approximately 1,200 to 8,500 milligrams per liter of dissolved solids). The dominant cation in all samples is sodium (fig. 10). The dominant anion is bicarbonate for samples with specific conductances less than 5,000 microsiemens. The dominant anion for samples with specific conductances greater than 5,000 microsiemens is chloride, except for the sample from well 32, which is sulfate.

Transmissivities of the coal seams and interbedded lithologic units in the Fruitland Formation were determined from the results of slug tests and recovery tests after bailing from selected wells. These values range from 7 to 130 feet squared per day (Stone and others, 1983).



EXPLANATION

SURFACE-MINABLE COAL RESERVES IN THE FRUITLAND FORMATION

4 ● OBSERVATION WELL AND NUMBER

Figure 8.--Location of observation wells completed in coal seams and interbedded lithologic units of the Fruitland Formation.

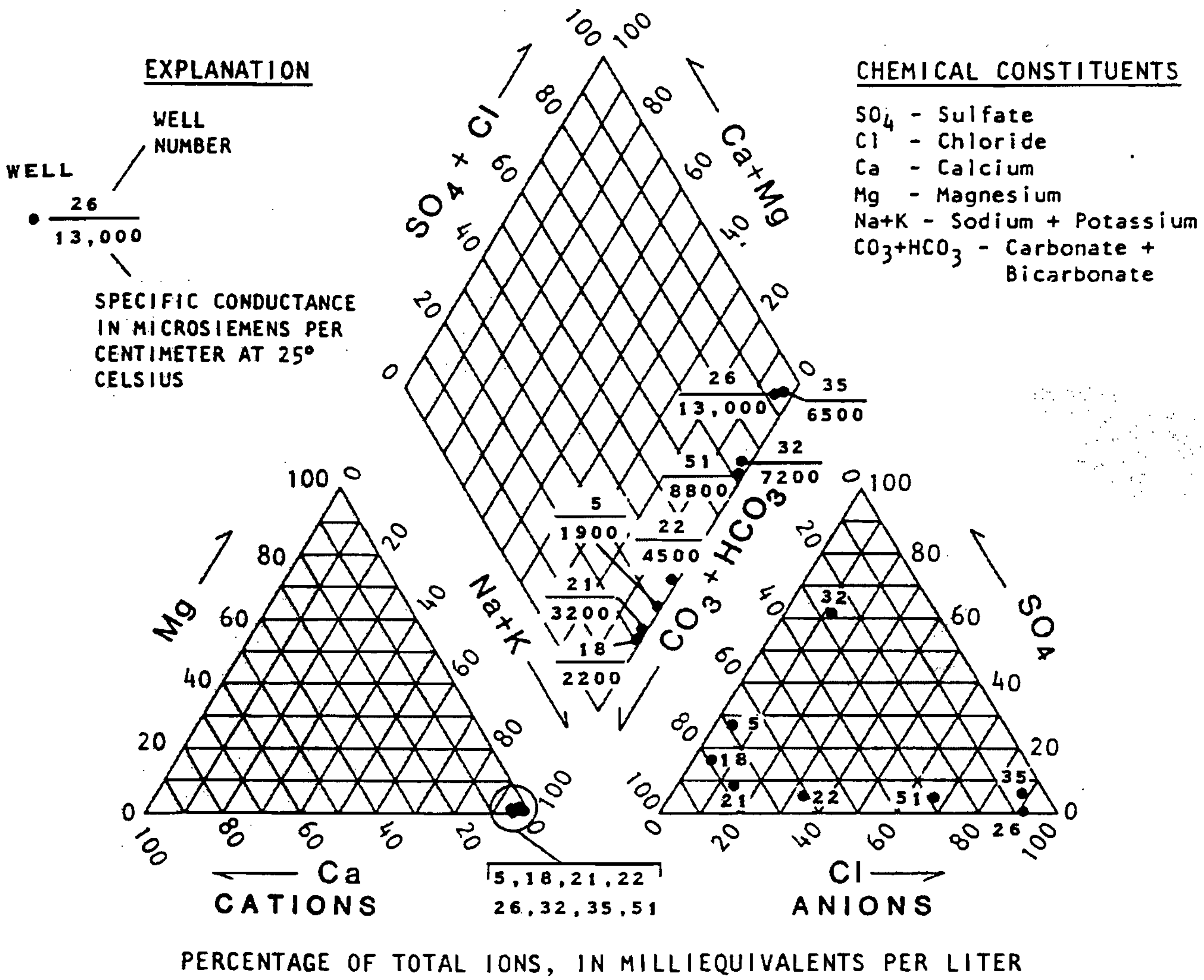


Figure 10.-- Representative chemical analyses of water from selected wells completed in coal seams and interbedded lithologic units of the Fruitland Formation.

Table 3. Records of observation wells completed in the coal seams and interbedded lithologic units of the Fruitland Formation

Number in figure 8	Station number	Date completed	Altitude of land surface (feet)	Well depth (feet)	Casing diameter (inches)	Water level (feet below land surface)	Date measured
4	355446107204801	10-11-78	6,621	250	2	33.90	10-11-78
5	355447107224301	11-11-78	6,675	240	2	68.00	07-25-79
18	360734107523101	09-08-77	6,300	292	1.5	92.78	11-16-77
21	360823107544001	05-10-77	6,330	250	1.5	115.41	08-17-77
22	360849107561801	05-31-77	6,290	225	1.5	86.80	08-17-77
26	361008107543901	07-22-77	6,280	373	1.5	68.30	08-16-77
32	361446108090801	08-23-76	5,920	148	2	62.70	03-02-77
35	361513108090701	08-04-76	5,925	162	2	84.14	03-02-77
51	364845108214201	11-15-77	5,370	715	2	158.85	02-22-78

LEGEND

- ◎ DOBY-1 — PROGRAM MONITORING WELLS
- KF84-21A — COMPLIANCE MONITORING WELLS
- NAPI SPRINGS
- □ 13-14-6 — NON-BHP WELLS
- △ NAPI DISCHARGE POINT — NAPI IRRIGATION DISCHARGE POINT
- ——— - PERMIT BOUNDARY

REV. No.	DATE	DRAFT. BY	REVISION DESCRIPTION	E.Q.	E.Q.	P.E.	RPLS	CHIEF ENG.
09-A	7-12-09	PJF	ADDED IBR EASTSIDE OF LOWE PIT AND SUBMITTED TO OSM FOR REVIEW.	Shawn Smith	YB			
D	12-10-01	PJF	REMOVED THE FOLLOWING WELLS CUSTER-1, 2, 3, 4, KF84, KP84, KF84-21A, QACW-1 AND SUBMITTED TO OSM FOR REVIEW AND APRROVAL.	AAY	MC		WB	
C	6-3-99	PJF	ADDED NON-BHP WELL AND NAPI SPRINGS, DISCHARGE POINTS AND SUBMITTED OSM FOR REVIEW AND APPROVAL.	AAY	MC		WB	
B	7-29-98	PJF	MID TERM SUBMITTAL TO OSM FOR REVIEW AND APPROVAL.	GW	MC		WB	
A	5-29-97	PJF	SUBMITTED TO OSM FOR APPROVAL.	GW	GW			

EXHIBIT 6-1

BHP BILLITON NAVAJO COAL COMPANY

NAVAJO MINE — SAFETY PAYS

P.O. BOX 155 FRUITLAND, NEW MEXICO 87416

WELL LOCATION MAP NAVAJO MINE MARCH, 1997

PREPARED BY GW/PJF	DRAWN BY PJF	SCALE 1" = 2000'
APPROVED BY	DATE MAR. 16, 1997	MYLAR LOC.

PATH: G:\Gs\OSM_SUBM\PER_PROG\CH_06-HYDROLOGY\PAP DATA\EXH 6-1.pro


UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
FRUITLAND QUADRANGLE
NEW MEXICO - SAN JUAN CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
NAVAJO RESERVATION BOUNDARY
MORGAN LAKE
NAVAJO INDIAN RESERVATION
UNSATURATED
SATURATED
5250
5230
5210
5190
5170
5150
5130
5110
A II
A III
A IV
A V
Southern Permit Boundary
N
CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL
LEGEND
IMPROVED DIRT ROAD
DIRT ROAD
PAVED ROAD
RAILROAD
MINE SITES
Drill Hole DRILL HOLE
WATER WELL
PIPELINE
5450 CONTOUR ELEVATIONS
x5356 ELEVATIONS
DEPRESSION
HIGH VOLTAGE POWER LINE
TAILINGS PONDS
BUILDINGS
A.P.S. PROPERTY LINE
Oil Well OIL WELL
RIVER
HOME SITES
PONDS
AQUEDUCT
KF84 NO. 22
PIEZOMETER
CONTOUR INTERVAL = 20 FT.
PERMIT BOUNDARY
UTAH LEASE LINE
AREA LOCATION
NAVAJO RESERVATION BOUNDARY
EXHIBIT 6-2
BHP MINERALS INTERNATIONAL INC.
NAVAJO MINE
FRUITLAND, NEW MEXICO
NO. 8 COAL SEAM
POTENTIOMETRIC
SURFACE
DRAWN BY J. GOLBE
SCALE: 1" = 2000'
APPROVED BY
DATE AUG. 1983
DRAWING NO.
LOCATION NO. MF-C6
REV. NO.
DATE
REVISIONS
APPROVALS
DRAFT BY:
ENGR.
CHIEF ENGR.
PROJECT MGR.
1
11 / 87
PUT REVISION BLOCK ON, CHANGED CO. NAME TO BHP-UII, REMOVED NUMBER IN TITLE BLOCK, CONFIDENTIAL STATEMENT ADDED SOUTHERN BOUNDARY
GG.
2
3-11-93
ADDED NEW EXH. NO., FORMER BLK A,B,C & D BOUNDARY AND CHANGE CO. NAME
PJF

EXHIBIT 6-3

REV. NO.	DATE	REVISIONS	DRAFT BY:	ENGR.	CHIEF ENGR.	PROJECT MGR.
1	11 / 87	PUT REVISION BLOCK ON, CHANGED CO. NAME TO BHP-UII, REMOVED CONFIDENTIAL STATEMENT, PUT EXHIBIT NUMBER IN TITLE BLOCK	CG			
2	9-11-93	ADDED NEW EXH. NO., FORMER BLK A,B,C & D BOUNDARY AND CHANGE CO. NAME	PJF			

BHP MINERALS INTERNATIONAL INC.
NAVAJO MINE
FRUITLAND, NEW MEXICO

NO. 7 COAL SEAM POTENTIOMETRIC SURFACE

DRAWN BY J. GOLBE	SCALE: 1" = 2000'
APPROVED BY	DATE AUG. 1983
DRAWING NO.	LOCATION NO. MF-C6


UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
FRUITLAND QUADRANGLE
NEW MEXICO–SAN JUAN CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
NAVAJO RESERVATION BOUNDARY
MORGAN LAKE
A I
A II
A III
A IV
A V
KF83 Nº5 (dry)
KF83 Nº7 (dry)
KF84-20 (b)
KF83-10 (c)
KF84-21 (b)
KF84-22 (c)
UNSATURATED
SATURATED
5210
5215
5220
5225
5230
5235
5240
5245
5250
5255
5230
Southern Permit Boundary
N
LEGEND
IMPROVED DIRT ROAD
DIRT ROAD
PAVED ROAD
RAILROAD
MINE SITES
Drill Hole
DRILL HOLE
WATER WELL
PIPELINE
5450
CONTOUR ELEVATIONS
x5356
ELEVATIONS
DEPRESSION
HIGH VOLTAGE POWER LINE
TAILINGS PONDS
BUILDINGS
A.P.S. PROPERTY LINE
Oil Well
OIL WELL
RIVER
HOME SITES
PONDS
AQUEDUCT
KF84-20
PIEZOMETER
CONTOUR INTERVAL = 5 FT.
PERMIT BOUNDARY
UTAH LEASE LINE
AREA LOCATION
NAVAJO RESERVATION BOUNDARY
EXHIBIT 6-4
BHP MINERALS INTERNATIONAL INC.
NAVAJO MINE
FRUITLAND, NEW MEXICO
Nº4, & 6 COAL SEAM POTENTIOMETRIC SURFACE MAP
DRAWN BY J. GOLBE
SCALE: 1" = 2000'
APPROVED BY JCH
DATE AUG. 1983
DRAWING NO.
LOCATION NO. MF-C4
REV. NO.
DATE
REVISIONS
APPROVALS
DRAFT BY:
ENGR.
CHIEF ENGR.
PROJECT MGR.
1
11 / 87
PUT REVISION BLOCK ON , CHANGED CO. NAME TO BHP-UII , PUT EXHIBIT NUMBER IN TITLE BLOCK , REMOVED CONFIDENTIAL STATEMENT , ADDED SOUTHER PERMIT BOUNDARY
GG
2
9-11-93
ADDED NEW EXH. NO., FORMER BLK A,B,C & D BOUNDARY AND CHANGE CO. NAME
PJF
CONTOUR INTERVAL 20 FEET

REV. NO.	DATE	REVISIONS	DRAFT BY:	ENGR.	CHIEF ENGR.	PROJECT MGR.
1	11/87	PUT REVISION BLOCK ON, CHANGED CO. CHANGED TO BHP-UII, PUT EXHIBIT NUMBER IN TITLE BLOCK, REMOVED CONFIDENTIAL STATEMENT, ADDED SOUTHERN PERMIT BOUNDARY	GG			
2	9-11-93	ADDED NEW EXH. NO., FORMER BLK A,B,C & D BOUNDARY AND CHANGE CO. NAME	PJF			


UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
FRUITLAND QUADRANGLE
NEW MEXICO – SAN JUAN CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
NAVAJO RESERVATION BOUNDARY
SJKF84-2
SJKF84 # 3
SJKF84 # 4
SJKF84 # 5
Kf 83-11
Kf 84-16
Kf 83-1
MORGAN LAKE
Kf 83-2 (Dry)
Kf 84-17 (Plugged)
CUSTER 6 (dry)
Kf 83-3 (Dry)
GM9
GM10
Kf 83-4
Kf 84-18 (a)(b)
Kf 83-8
Kf 83-9 (a)(b)(c)
Kf 84-20 (a)(b)(c)(d)
GM18
Kf83-10 (a)(b)(c)(d)
GM17
CWAP-3
CWAP-1
CWAP-2
Kf 84-22 (a)(b)(c)(d)(e)
Southern Permit Boundary
GM30
T4-1
N
LEGEND
IMPROVED DIRT ROAD
DIRT ROAD
PAVED ROAD
RAILROAD
MINE SITES
DRILL HOLE
WATER WELL
PIPELINE
CONTOUR ELEVATIONS
ELEVATIONS
DEPRESSION
HIGH VOLTAGE POWER LINE
TAILINGS PONDS
BUILDINGS
A.P.S PROPERTY LINE
OIL WELL
RIVER
HOME SITES
PONDS
AQUEDUCT
GM AND T4 WELLS
KF83-1 PIEZOMETER OR WELL LOCATION
PERMIT BOUNDARY
UTAH LEASE LINE
AREA LOCATION
NAVAJO RESERVATION BOUNDARY
3 | 9-11-93 | ADDED NEW EXH. NO., FORMER BLK A,B,C & D BOUNDARY AND CHANGE CO. NAME | PJF
REV NO | DATE | REVISIONS | APPROVALS: DRAFT BY | ENGR. | CHIEF ENGR. | PROJECT MGR.
1 | 11/87 | PUT REVISION BLOCK ON, CHANGED CO. NAME TO BHP-UII, PUT EXHIBIT NUMBER IN TITLE BLOCK, CONFIDENTIAL STATEMENT ADDED SOUTHERN PERMIT BOUNDARY | GG
2 | 1/89 | ADDED GM & T4 WELLS, ADD a,b,c,d,e DESIGNATORS TO Kf WELLS, CHANGE TO 5000', ADD WELL TO PIEZOMETER | JG | RHB
EXHIBIT 6-6
BHP MINERALS INTERNATIONAL INC.
NAVAJO MINE
FRUITLAND, NEW MEXICO
LOCATION OF WELL/ PIEZOMETER SITES
DRAWN BY J. GOLBE
SCALE: 1" = 5000'
APPROVED BY
DATE AUG. 1983
DRAWING NO.
LOCATION NO. MF-C6
CONTOUR INTERVAL 20 FEET

LEGEND

▼ 14	NPDES OUTFALL LOCATIONS
KF84-21A	COMPLIANCE MONITORING WELLS
△ CD-2A	SURFACE WATER MONITORING STATION
——— — — —	PERMIT BOUNDARY

NOTE: Outfall 16 ▼ displayed by Mining Operations, Pond CR-3 removed.

REV. No.	DATE	DRAFT. BY	REVISION DESCRIPTION	E.Q.	E.Q.	P.E.	RPLS	CHIEF ENG.
09-A	7-12-09	PJF	ADDED IBR EASTSIDE OF LOWE PIT AND SUBMITTED TO OSM FOR REVIEW.	Shawn Smith	YB			
F	2-28-07	PJF	ADDED NPDES-19, SOUTH DIXON PIT AREA AND SUBMITTED TO OSM FOR REVIEW.	DV	MC			
E	12-12-02	PJF	REMOVED THE FOLLOWING NPDES 3, 4, 5, 12, 14, 15, RELOCATED NPDES-9 TO BLOCK-C POND#2, NPDES-10 TO BLOCK-C POND#1 AND SUBMITTED TO OSM FOR REVIEW.	BS	MC		WB	
D	12-10-01	PJF	REMOVED THE FOLLOWING MONITORING STATIONS QACW-1, KF84-21A, KF84, KP84 KF83-1, KF84-16 AND SUBMITTED TO OSM FOR REVIEW AND APPROVAL.	AAY	MC		WB	
C	2-29-00	PJF	REMOVED THE FOLLOWING MONITORING STATIONS CS-1, CNS-1, CN-1 (COTTONWOOD WASH), NB-1, NB-2 (BITSUI AREA-NORTH) AND PROGRAM MONITORING WELLS DOBY-1, 3, 5 AND 8 (DOBY PIT)	AAY	MC		WB	
B	7-29-98	PJF	MID TERM SUBMITTAL TO OSM FOR REVIEW AND APPROVAL.	GW	MC		WB	
A	5-16-97	PJF	SUBMITTED TO OSM FOR APPROVAL.		GW			
				APPROVALS				

EXHIBIT 6-7

BHP BILLITON NAVAJO COAL COMPANY

NAVAJO MINE — SAFETY PAYS

P.O. BOX 1717 FRUITLAND, NEW MEXICO 87416

COMPLIANCE MONITORING WELL, NPDES OUTFALL AND SURFACE WATER MONITORING STATIONS LOCATIONS

PREPARED BY GW/PJF	DRAWN BY PJF	SCALE 1" = 2000'
APPROVED BY	DATE MAY 16, 1997	

G:\Gs\OSM_SUBM\PER_PROG\CH_06-HYDROLOGY\PAP DATA\EXH 6-7.pro