4.1.2.2 Environmental Geologic Characteristics, Site 23

The candidate Site 23 is located in Sec. 11, T9S, R38E and is adjacent to the proposed Shell coal mining leases as shown in Figure 4.1.2-3. The topography of the general area is characterized by a series of relatively narrow, separated by narrow stream valleys occupied by Squirrel, Tanner, and Youngs Creeks and their lesser subsidiary drainages. (Reference 58a).

Stratigraphy

Four coal seams, averaging 10 to 48 feet in thickness, are the object of the proposed nearby Shell mining project. In some areas of the proposed mine, the seams split or converge to form thinner or thicker seams). The four coal seams are part of the Tongue River Member, which is the youngest (uppermost) unit of the Fort Union Formation.

The Wasatch Formation constitutes the uppermost bedrock unit at higher elevations in the western and northern portions of the Shell lease area and in the Wolf Mountains. The Tongue River Formation is the uppermost unit of bedrock in the southern part of the lease and along the valleys of Youngs, Tanner, and Squirrel creeks where erosion has removed the overlying Wasatch. Figure 4.1.2-3 illustrates the surficial relationship among the bedrock formations across the lease and the proposed siting area. Geologic units and formations significant to the site are tabulated in Table 4.1.2-2. (Reference 9).

Structure

The Shell coal lease and Site 23 are on the northern flank of the Ash Creek Anticline. This anticline causes the general southeasterly dip of regional bedding to be warped to the northeast at an average dip of 2 degrees throughout the general area. Prominent structural features on the lease include the clearly defined northeast and northwest lineation, consisting of fault-controlled topographic features. The northwest lineations are discernible as they are followed by Youngs,

FIGURE 4.1.2-3
GEOLOGIC MAP OF PROPOSED SHELL COAL MINING AREA

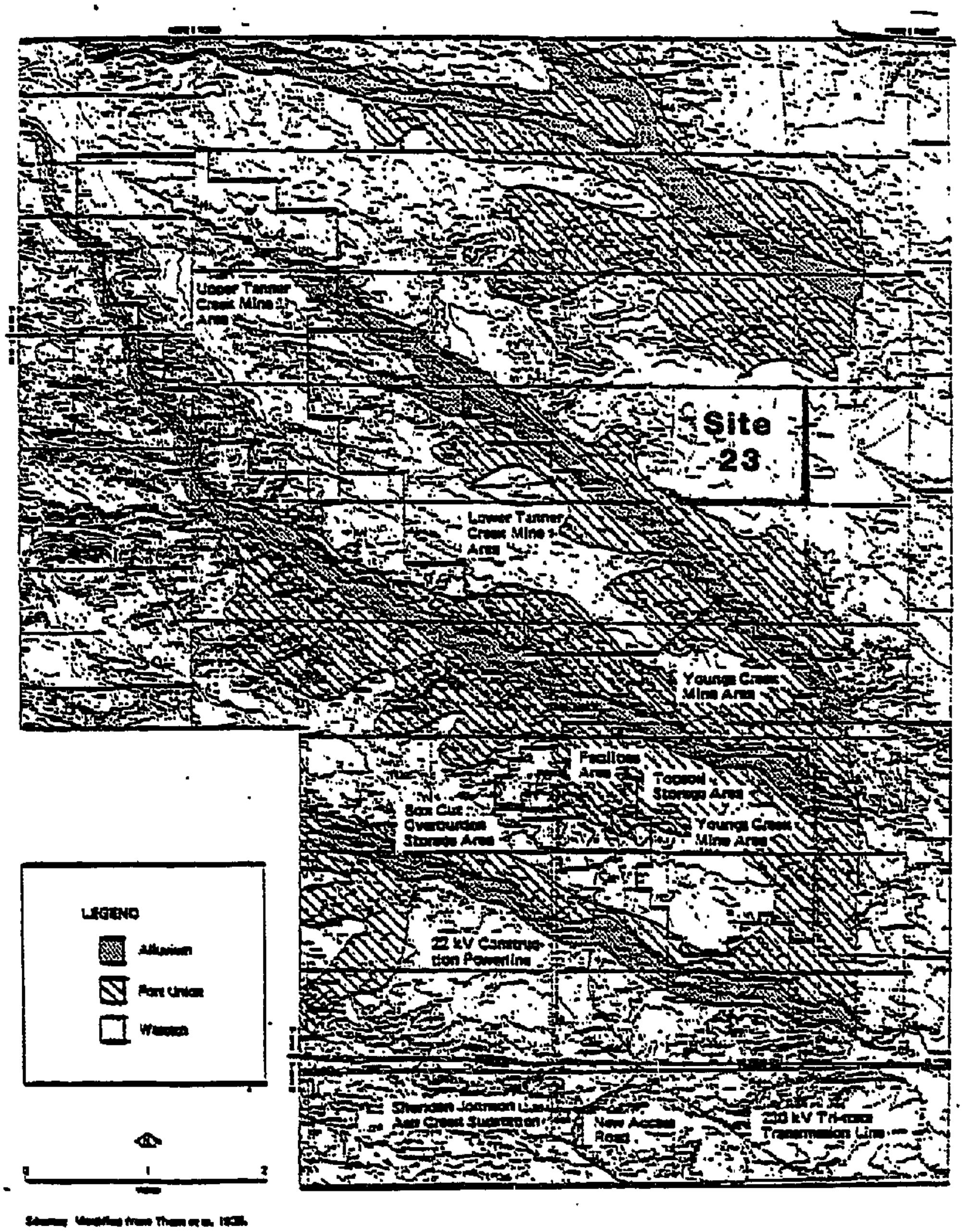


TABLE 4.1.2-2
GEOLOGIC UNITS OUTCROPPING IN THE CANDIDATE SITE 23 AREA

Stratigraphic Period	Stratigraphic Unit	Thickness (ft)	Character and Distribution
Quarternary	Alluvium	0-40	Detrital material along streams; detrived from adjacent upland areas. Includes lenticular beds of clay, sand, and gravel, and mixtures of these.
	Slopewash	0-20	Detrital material at base of slopes and above floodplain areas; generally poorly sorted. Rare, well-sorted sand or gravel lenses may be present.
Tertiary, Lower Eocene	Wasatch Formation	0-350	Clay, sandstone, and coal beds.
Tertiary, Paleocene	Fort Union Formation		
	-Tongue River Member	1,000-1,300	Beds of sandstone, shale, shaly sandstone, and coal. Few beds are persistent over several square miles.
	-Lebo Shale Member	100-300	Dark shale, bentonite, with minor sandstones and local, thin coal beds.
	-Tullock Member		Sandstone, coal and shale beds

Tanner, and Squirrel creeks. The northeast lineations, consisting of a series of northeast-southwest trending normal faults that transect the area, are not as obvious because they are masked by overlying undisturbed sediments. The down-dropped block is on the southeastern side of the faults, and strata on that side of the faults commonly dip abruptly into the faults. Several parallel faults in the southeastern part of the Shell lease area show apparent displacements ranging from 10 to 200 feet. Movement along these faults is assumed to have occurred in a steep to near-vertical plane. (References 9 and 53).

4.1.3 Water Environment

The existing natural water environment of the Crow Reservation is addressed in terms of both quantity and quality of surface waters and groundwaters primarily within the reservation boundaries.

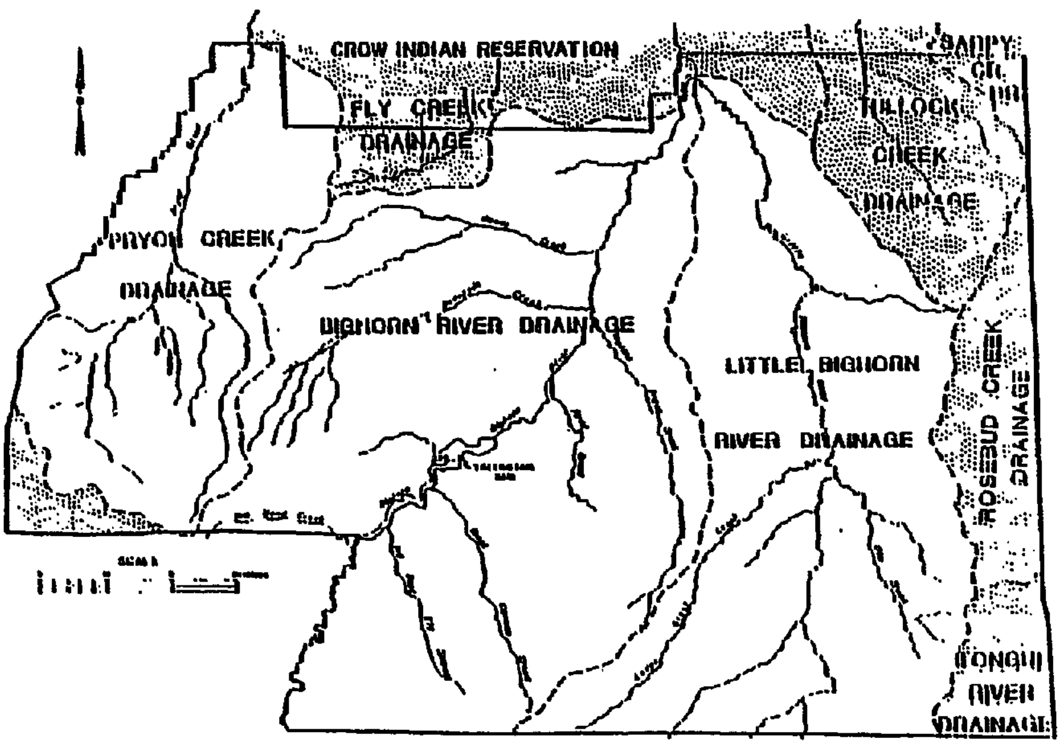
4.1.3.1 Water Resources

Surface Water Resources

The Crow Reservation, encompassing about 2.3 million acres, is located in the Yellowstone River Drainage. Lands within the reservation are drained by eight basins: Sarpy Creek, Tullock Creek, Rosebud Creek, Tongue River, Little Bighorn River, Bighorn River, Fly Creek, and Pryor Creek as shown in Figure 4.1.3-1. The Bighorn River, Little Bighorn River, and Pryor Creek drain most of the reservation and six of the eight candidate siting locations seriously considered in this study would be located within these drainages. All drainages on the reservation are located within the Yellowstone River Basin. The Little Bighorn River drainage, covering about 600,000 acres, drains most of the eastern part of the reservation. The lesser drainages on the eastern reservation boundary include Tullock Creek, Sarpy Creek, Rosebud Creek, and Tongue River. Tullock Creek drains to and joins the Bighorn River north of the reservation near Bighorn, Montana. Sarpy Creek drains north directly to the Yellowstone River. Rosebud Creek drainage consists of several small

FIGURE 4.1.3-1

CROW RESERVATION DRAINAGE BASINS



tributaries draining to Rosebud Creek east of the reservation. The three key tributaries of Squirrel Creek, Tanner Creek, and Youngs Creek in the Tongue River drainage originate in the Wolf Mountains in the southeast part of the Crow Reservation and drain southeast toward the Tongue River. (Reference 26).

The central part of the reservation is drained by the Bighorn River, the largest drainage on the reservation, encompassing a land area of approximately one million acres. The Bighorn River drains to and meets the Yellowstone River north of the reservation near Bighorn, Montana. Fly Creek drainage in the north-central part of the reservation drains north to the Yellowstone River near Pompeys Pillar, Montana.

The western part of the reservation is drained mostly by the Pryor Creek drainage. Pryor Creek drains directly to the Yellowstone River near Huntley, Montana. The extreme southwest corner of the reservation is drained by Sage Creek which is a tributary to the Bighorn River before it reaches the Crow Reservation.

Groundwater is available and has been developed for limited use throughout the Crow Reservation. In fact, groundwater constitutes the entire water supply for the Westmoreland Resources Absaloka coal mining operation in the northeastern part of the reservation. The major sources of groundwater on the Crow Reservation are the local deposits of alluvium and colluvium of recent (Quaternary) age and the sandstones, limestones, and coal beds of the bedrock formations underlying the reservation.

Based upon the primary candidate siting areas for the coal gasification plant, i.e. Sites 1 and 23, discussion of surface water resources emphasizes the following drainages: Bighorn River, Little Bighorn River, Pryor Creek, Youngs Creek, Little Youngs Creek, Tanner Creek, and Squirrel Creek. Discussion of potential groundwater resources is also limited to the aforementioned drainages with emphasis on resources in the area of the candidate sites.

Surface Water

Since a Lurgi coal gasification facility capable of producing a maximum of 250 MM SCF/D will require relatively large quantities of water (approximately 14,000 gpm or 31 cfs), the evaluation of surface water flow characteristics is limited to select reaches of the three principal streams (i.e., the Bighorn River, the Little Bighorn River, and Pryor Creek) plus direct withdrawal from Bighorn Lake behind Yellowtail Dam, since 100,000 ac-ft/yr in Bighorn Lake have been reserved for use by the Crow Tribe. For purposes of this feasibility study, both surface water quantity and flow variability are presented in general terms. If the proposed Crow synfuels project proceeds beyond the stage of this study, site-specific evaluations will have to be conducted. Additionally, this evaluation examines the quantity of water in the various streams and reaches and does not imply or convey the right to that water. Actual water rights to necessary quantities from the various streams or groundwater sources would have to be determined on a case-by-case basis. The Crow Tribe could change the point of diversion of the 100,000 ac-ft/yr of reserved water held in Bighorn Lake or possibly could exchange rights to water in the various rivers and creeks. However, such exchanges would have to be undertaken in compliance with applicable laws and regulations. A more detailed discussion of possible water rights issues is presented in the Legal Section in Volume III of this report.

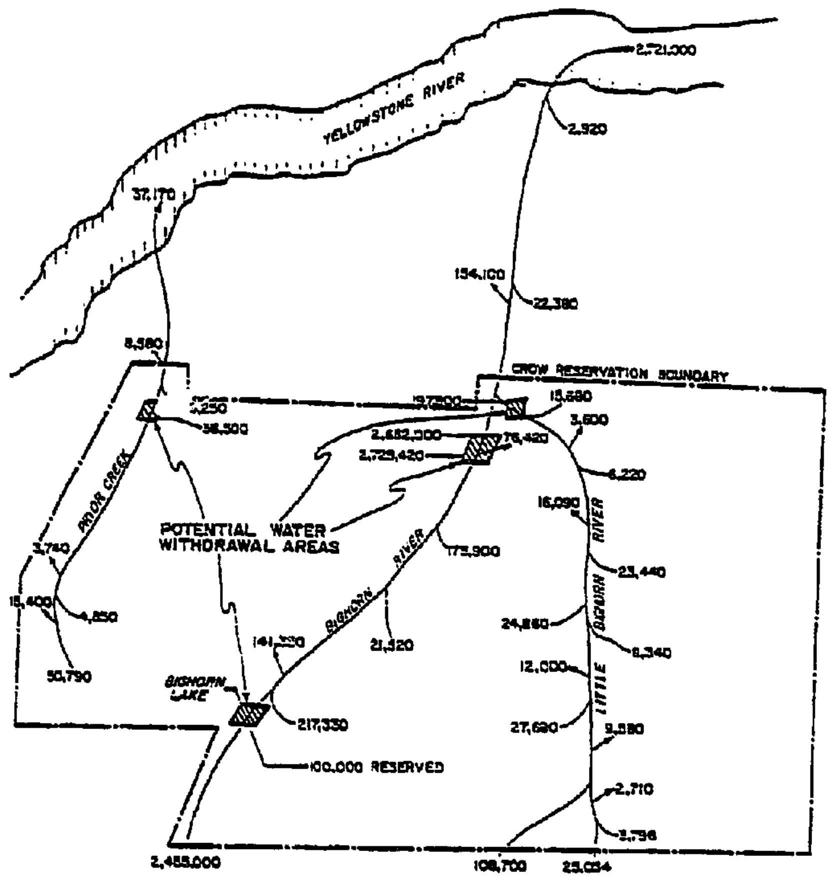
The relative magnitudes of flow in selected stream reaches on the Crow Reservation were developed for a Water Budget Study by the Soil Conservation Service in December 1974 and incorporated in a study by HKM Associates (HKM, October 1977). That water budget has been modified for use in this report and is shown in schematic form in Figure 4.1.3-2. The values presented in the figure are in ac-ft/yr and represent long-term average values at the time of the study (1974). The flow values, although average, show the relative magnitude of flows in respective streams. The flow quantity and variability of the various streams are discussed below. (Reference 26).

Little Bighorn River. The Little Bighorn River system originates in the Bighorn Mountains in Wyoming. Owl Creek, Pass Creek, and Lodge Grass Creek are key

FIGURE 4.1.3-2

MAJOR WATER RESOURCES, AVERAGE ANNUAL FLOW

(ac-ft)



Source: Modified Schematic HKM Associates, Section 4, Crow Sampling Program Results, October 1977.

tributaries to the Little Bighorn River on the Crow Reservation. The Little Bighorn River drainage contains about 1,030 square miles, approximately 88 percent of which is on the reservation. On the average, about 150,000 ac-ft/yr (207 cfs) of water flows onto the reservation from Wyoming in Lodge Grass Creek, Little Bighorn River, Pass Creek, and an unnamed tributary (HKM, October 1977). (Reference 26).

The reach on the Little Bighorn River nearest the identified potential coal gasification plant sites is immediately upstream of the confluence of the Little Bighorn River with the Bighorn River near Hardin, Montana. The average annual flow in the Little Bighorn River near Hardin, as estimated in the 1974 report by the Soil Conservation Service and as shown in Figure 4.1.3-2, is about 197,800 ac-ft/yr. The measured long-term average (June 1953 through September 1978) reported by the USGS is 235,500 ac-ft/yr (325 cfs) (USGS, 1978). (Reference 75).

The flow in the Little Bighorn River near Hardin is influenced by inflow from tributaries, upstream diversions for irrigation and storage in the off-stream Willow Creek reservoir (storage capacity about 23,000 ac-ft), and irrigation return flows. During the late summer, water for irrigation is released from the Willow Creek reservoir and influences the flow in Lodge Grass Creek and downstream in the Little Bighorn River.

The flow in the Little Bighorn River near Hardin peaks around May and June due to snowpack runoff. An example of the flow variability in the Little Bighorn River is shown in Figure 4.1.3-3. Over the four-water-year period shown (October 1974 through September 1978), the monthly flow varied from 25 percent to 581 percent (123 and 2,852 cfs, respectively) of the average flow of 490 cfs over that time period. The average flow of 490 cfs is 51 percent greater than the long-term average flow (June 1953 to October 1978) of 325 cfs as measured by the USGS (1978). (Reference 75).

A flow duration curve based upon USGS data at the Little Bighorn River near Hardin for the period 1966 to 1979 is shown in Figure 4.1.3-4. The data show that 80 percent of the time the flow is about 150 cfs (108,400 ac-ft/yr) or greater. The

FIGURE 4.1.3-3

WATER FLOW VARIABILITY

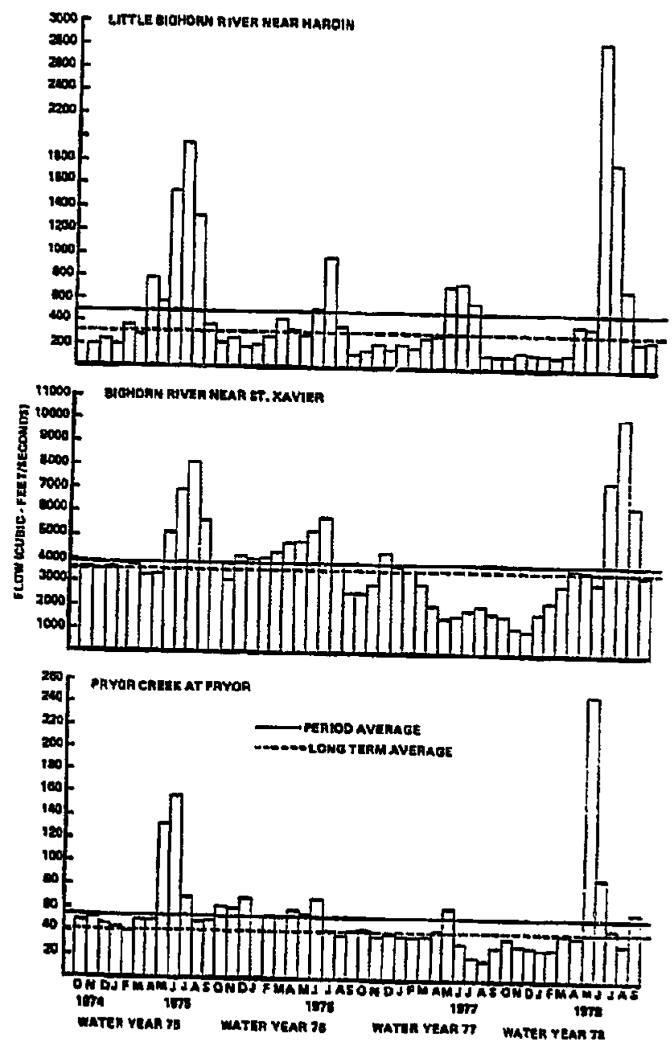
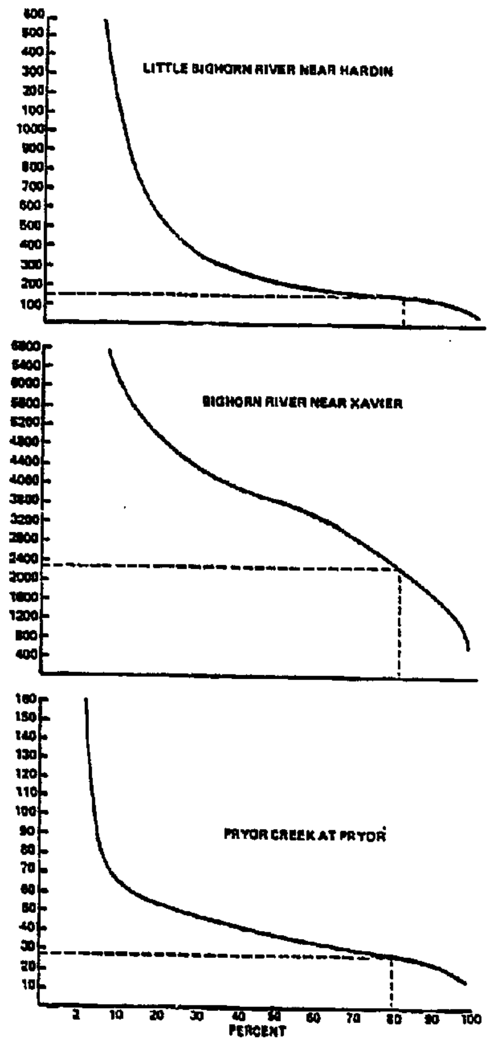


FIGURE 4.1.3-4
WATER FLOW DURATION



lowest mean flow in the Little Bighorn River for varying consecutive days between 1966 and 1979 is shown in Table 4.1.3-1. The lowest single-day flow during that period was 7.4 cfs in 1967. Irrigation depletions are particularly significant in water years exhibiting 80 percent change flows or worse. In 1961, the most severe current drought period for small watersheds, annual flow varied from 65,000 ac-ft at the state line to 67,120 ac-ft below Pass Creek to 51,000 ac-ft of yearly flow at Hardin. The Hardin gauge exhibited no flow on some days and approximately 10 cfs or less discharge for basically the entire July-August period (HKM, October 1977). (References 26, 75).

Bighorn River and Bighorn Lake. The Bighorn River drainage originates in the Absaloka and Wind River Mountains in Wyoming and is formed by the Wind, Little Wind, and Popo Agie rivers near Riverton. The Bighorn River drainage extends from its headwaters to its confluence with the Yellowstone River near Bighorn, Montana, encompassing a total of approximately 22,885 square miles. The reservation portion of the Bighorn River drainage is the largest on-reservation drainage covering about 1,340 square miles. The principal on-reservation tributaries to the Bighorn River include Soap Creek, Rotten Grass Creek, Beauvais Creek, and Windy Creek.
The average annual flow in the Bighorn River at the Montana-Wyoming state line, the southern boundary of the Crow Reservation, is shown in Figure 4.1.3-2 to be 2,455,000 ac-ft/yr. The flow entering Montana and the Crow Reservation in the Bighorn River is contained in Bighorn Lake which has a usable storage of 1.4 million ac-ft/yr. As previously mentioned 100,000 ac-ft/yr of water presumably has been reserved in Bighorn Lake for use by the Crow Tribe. Since Bighorn Lake represents a potential source of water for the coal gasification project, a record of monthly reservoir elevations is presented in Table 4.1.3-2 for water years 1967 through 1981 to illustrate the fluctuations in water level (DOI, Bureau of Reclamation, 1982). (Reference 65).

A minimum average monthly difference of 14.27 feet (0.39 percent) and a maximum average monthly difference of 11.6 feet (0.32 percent) from the 15-yr average elevation of 3621.15 feet are derived from the data shown in Table 4.1.3-2. Slightly higher values for average daily minimum and maximum deviations from the 15-year

TABLE 4.1.3-1

LOWEST MEAN DISCHARGE OF WATER

STATION NUMBER [illegible]

LOWEST MEAN DISCHARGE, IN CFS, AND RANKING, FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR ENDING MARCH 31

LITTLE BIGHORN RIVER NEAR HARDIN, MT.

YEAR	1	3	7	14	30	60	90	120	183	ANNUAL
1966	[illegible]	71.30	81.10 8	93.40 5	121.30	132.00 1	135.30 4	144.00 3	147.30 6	178.30
1967	[illegible]	[illegible]	[illegible]	[illegible]	19.40	35.00 1	42.13	50.00	97.30	100.00 1
1968	93.00 2	91.30	91.30	96.70 1	100.00 4	114.30	131.30 5	135.30 2	133.30 1	178.00 6
1969	70.30 6	70.00 5	90.00 7	99.30 7	134.30 6	147.00 9	156.30	162.00	183.30 9	440.00 11
1970	[illegible]	[illegible]	[illegible]	138.00 12	143.30 10	152.30 10	138.30 4	144.00 8	166.30 9	141.30 5
1971	100.30 11	105.00 11	119.00 12	143.30 13	149.00 11	173.30 12	189.30 12	270.00 12	212.30 12	394.30 12
1972	30.00 1	31.30 1	[illegible]	99.30 8	103.30 1	116.30 2	134.30 3	160.00	170.30	193.30 1
1973	107.00 13	112.30 13	117.00 11	135.30 11	134.30 7	139.30 8	141.30 5	153.00 4	161.30 4	278.30 3
1974	38.00 4	33.30 4	38.10 3	63.40 2	79.40 3	131.00 3	166.00 10	183.30 10	197.00 10	428.30 10
1975	[illegible]	[illegible]	43.30	109.30 10	194.30 13	170.00 11	177.00 11	194.00 11	198.30 11	415.30 9
1976	81.30 8	86.00 5	76.70 5	93.40 6	156.00 12	190.30 13	218.30 13	218.30 13	240.30 13	542.30 13
1977	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	115.30	101.30 9	100.30	137.30 8	318.30 4
1978	80.00 10	77.30 9	90.30 8	97.30 8	116.30 5	126.00	130.30 2	130.30 2	141.30 2	301.30 1
1979	120.00 14	123.00 14	144.00 14	153.00 14	197.00 14	208.00 14	232.30 14	244.30 14	287.00 14	743.30 14

STATION NUMBER [illegible]

LOWEST MEAN DISCHARGE, IN CFS, AND RANKING, FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR ENDING MARCH 31

BIGHORN RIVER NEAR ST. XAVIER, MT.

YEAR	1	3	7	14	30	60	90	120	183	ANNUAL
1966	180.00 3	160.00 1	190.30 1	238.00 1	323.30 1	683.00 2	1430.00 1	1790.00 3	1980.00 3	4310.30 10
1967	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1010.30 1	1060.30 1	1380.30 1
1968	112.30 1	188.30 2	1160.30 6	1910.00 7	2130.30 10	1330.00 6	3110.00	3330.00 9	1920.30 12	3300.30 10
1969	1700.00 13	1730.00 10	2880.00 9	2890.30 9	2200.30 8	2300.30 7	2900.30	3110.30 7	1420.30	4030.30 7
1970	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2300.00 1	2930.30 3	1080.30 5	3230.30 3
1971	323.00 5	328.00 5	328.00 4	327.00 4	1100.00 4	1730.00 5	2340.00 5	2230.30 4	3000.30 4	3490.30 4
1972	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3990.30 13	1860.30 14	4940.30 13
1973	1360.00 12	1770.00 11	2800.30 13	2870.30 13	3140.00 14	3180.00 12	3380.00 11	3490.30 11	1720.00 10	4270.30 9
1974	469.00 9	1390.00 3	1490.00 7	1700.00 6	1910.00 4	2770.00 8	3030.00 8	3450.00 10	3870.30 9	3920.00 6
1975	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3230.30 9	3440.30 8	4230.30 6
1976	1470.30 11	2320.00 14	2950.00 14	2970.00 14	3140.00 13	3300.00 14	3880.00 14	1820.00 13	3990.30 13	4880.30 12
1977	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1970.30 3	3320.30 3	3780.30 3
1978	382.00 6	831.30 7	897.00 3	180.30 3	910.30 1	1130.30 3	1210.00 2	1430.00 2	1040.00 3	2010.30 1
1979	640.00 6	723.00 6	1000.00 8	1290.00 8	2330.00 9	1340.00 13	1820.00 13	3800.30 12	1790.00 11	4790.30 13

STATION NUMBER [illegible]

LOWEST MEAN DISCHARGE, IN CFS, AND RANKING, FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR ENDING MARCH 31

BIGHORN RIVER AT BIGHORN, MT.

YEAR	1	3	7	14	30	60	90	120	183	ANNUAL
1966	300.30 2	383.00 2	863.00 1	879.00 1	910.00 1	1300.00 1	1800.00 1	1900.00 3	2300.30 3	4900.00 10
1967	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	391.30 1	1090.00 1	1800.30 1
1968	480.30 1	523.00 1	1040.00 6	1910.00 7	2300.30 9	2830.30 7	3120.00 7	3400.30 6	1900.30 11	3800.30 13
1969	1700.30 11	1730.30 10	2090.00 8	2150.00 6	2300.00 7	2890.00 9	3640.00 6	3110.30 8	1540.00 8	4820.00
1970	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3330.00 9	3310.30 7	1840.00	1880.30 3
1971	1080.00 9	1080.30 6	1240.00 5	1840.00 5	1820.00 5	2180.00 6	2430.00 4	2870.00 6	3130.30 4	4370.00 5
1972	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3900.00 12	4130.30 13	4330.30 14	5430.30 11
1973	1710.30 12	2470.30 13	2990.30 13	3030.30 12	3100.00 13	3220.00 12	3430.00 11	3090.30 10	3940.30 10	4340.00 8
1974	897.30 6	1230.30 3	1490.00 7	1320.00 3	1700.30 4	2830.30 8	3320.30 10	3720.30 11	3890.30 9	4470.30 9
1975	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3330.00 8	3540.30 9	3740.30 8	4370.30 9
1976	1230.30 10	2830.30 14	1040.30 14	3300.00 13	3230.00 13	3440.00 13	3880.30 13	4030.30 12	4280.30 13	5580.30 12
1977	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2400.30 3	2100.30 5	3410.30 3	3990.30 4
1978	900.30 3	887.30 6	861.00 1	964.30 1	1090.30 1	1320.30 1	1400.33 2	1340.30 2	1710.30 2	2810.30 1
1979	1020.30 7	1030.30 3	2770.00 13	3230.00 14	3430.30 14	3870.30 14	4130.30 14	4170.30 14	4180.30 17	5930.30 14

STATION NUMBER [illegible]

LOWEST MEAN DISCHARGE, IN CFS, AND RANKING, FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR ENDING MARCH 31

PRYOR CREEK AT PRYOR, MT.

YEAR	1	3	7	14	30	60	90	120	183	ANNUAL
1965	7.40 1	7.40 1	7.57 1	7.77 1	8.11 1	9.70 1	12.30 1	14.40 1	17.70 1	23.00 1
1966	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12.30 2	16.40 3	19.00	23.30 2	23.30 2
1970	11.00 4	12.30 4	13.30 4	13.30 4	16.30 4	20.00 4	23.30 4	23.40 4	26.70 3	21.30 3
1971	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	28.30	28.30	30.30	34.20	31.20
1972	13.30 3	13.70 3	13.40 3	17.20 3	19.20 3	21.40 3	23.70 5	23.00 5	30.10 4	37.20 5
1973	10.30 2	13.70 2	19.30 2	20.30 2	20.00 2	23.20 3	24.40 4	26.10	28.30 1	33.40 4
1974	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	27.70	31.40	34.10	38.40	67.40
1975	29.30 11	29.30 11	30.70 11	32.30 10	34.30 10	38.10 11	40.40 10	41.40 10	40.30 10	52.40 12
1976	[illegible]	[illegible]	[illegible]	12.10 12	18.30 12	39.00 13	53.00 12	58.40 12	50.30 12	72.00 12
1977	28.30 10	29.30 12	30.30 10	32.10 11	38.20 11	37.30 10	38.30 8	38.30 8	39.30 8	45.30 9
1978	11.00 4	11.30 3	16.70 3	13.30 3	15.00 3	19.30 3	22.30 3	24.70 3	27.30 4	33.40 5
1979	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13.00 3	43.30 11	48.30 12	49.70 11	71.00 11

TABLE 4.1.3-2

MONTHLY RESERVOIR ELEVATIONS - BIGHORN LAKE, WATER YEARS 1967-1981

PROGRAM RES070

RESERVOIR RECORDS STORAGE SYSTEM
MONTHLY RESERVOIR OPERATION RECORD

DATE RUN: OCT 30, 1981
PAGE 001

BUI - BIGHORN LAKE

BHID - MIDNIGHT RESERVOIR ELEVATION

UNITS: FEET

WATER YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	DAILY MINIMUM (FEET)	DAILY MAXIMUM (FEET)
1967	3583.28	3586.06	3578.48	3579.97	3582.79	3591.11	3592.69	3603.24	3652.84	3641.30	3635.58	3636.29	3573.30	3656.38
1968	3637.23	3636.37	3625.40	3607.17	3603.22	3598.02	3595.00	3586.52	3593.58	3597.31	3611.51	3611.58	3585.06	3637.65
1969	3612.51	3610.61	3605.14	3596.72	3594.75	3590.63	3604.07	3618.75	3634.27	3631.76	3621.68	3616.19	3589.93	3637.27
1970	3615.78	3616.38	3605.75	3590.26	3587.39	3600.71	3614.38	3630.97	3644.49	3635.64	3632.31	3636.18	3584.45	3644.49
1971	3638.07	3636.87	3628.62	3622.54	3622.02	3615.65	3603.07	3598.60	3622.01	3636.34	3633.35	3638.09	3591.16	3638.24
1972	3635.95	3630.27	3621.90	3617.03	3623.08	3623.61	3605.90	3602.26	3626.44	3631.47	3636.02	3637.76	3592.49	3639.42
1973	3637.01	3629.64	3626.63	3622.60	3618.84	3619.65	3625.31	3631.16	3631.46	3635.89	3632.84	3637.99	3618.03	3638.23
1974	3637.39	3628.62	3627.68	3625.19	3620.54	3612.96	3601.01	3606.60	3636.98	3634.93	3638.80	3636.64	3600.61	3639.80
1975	3634.01	3629.13	3621.62	3611.10	3600.91	3597.24	3599.03	3609.88	3627.02	3645.97	3637.08	3633.19	3597.17	3646.61
1976	3635.59	3628.15	3622.29	3616.35	3612.57	3604.82	3602.89	3601.77	3624.51	3620.61	3630.07	3633.28	3598.35	3635.61
1977	3630.37	3629.27	3626.09	3621.19	3616.53	3614.10	3618.96	3629.81	3633.45	3627.61	3624.47	3624.20	3613.83	3634.37
1978	3628.58	3631.01	3627.62	3620.43	3610.09	3603.07	3607.34	3640.11	3643.11	3644.27	3633.38	3635.41	3590.15	3648.60
1979	3635.65	3632.30	3624.49	3619.26	3613.07	3618.82	3621.21	3628.03	3637.78	3630.80	3629.23	3629.24	3611.87	3637.95
1980	3632.40	3634.37	3629.74	3622.69	3615.64	3610.70	3601.17	3614.16	3633.10	3635.90	3636.17	3637.08	3599.97	3639.16
1981	3631.78	3631.20	3626.38	3618.98	3612.28	3611.42	3610.69	3628.12	3641.07	3635.46	3634.71	3634.92	3610.33	3641.07
AVE.	3628.77	3626.02	3619.87	3612.76	3608.90	3607.50	3606.[illegible]	3616.14	3632.27	3632.76	3631.01	3631.87	3597.69	3641.14

average monthly elevation of 23.46 feet and 19.99 feet, respectively, are also evidenced from the data in Table 4.1.3-2.

The flow in the Bighorn River on the reservation is completely regulated by Bighorn Lake behind Yellowtail Dam. The long-term (October 1934 through September 1978) average flow in the Bighorn River near St. Xavier gauging station, located about 800 feet downstream from the Yellowtail Dam and afterbay, is 2,610,000 ac-ft/yr (3,603 cfs) (USGS, 1978). The principal tributaries to the Bighorn River are estimated to have a combined average annual flow of 50,000 ac-ft/yr which is only about 2 percent of the average annual flow in the Bighorn River. Therefore, it can be concluded that tributary inflow is negligible when compared to the annual average flow in the Bighorn River (HKM, October 1977). (Reference 26).

Allowing for inflows and diversions, the average annual flow in the Bighorn River in the reach of potential water withdrawal for the proposed plant is 2,652,000 ac-ft/yr to 2,728,420 ac-ft/yr (see Figure 4.1.3-2). The flow in the Bighorn River normally peaks during May, June, and July due to snowpack runoff. The flow variability in the Bighorn River below Yellowtail Dam at St. Xavier is shown in Figure 4.1.3-3. The variability is influenced by Bighorn Lake but, since the storage capacity of 1.4 million ac-ft/yr is only about 57 percent of the average annual inflow to the lake, a portion of the peak inflow spills over Yellowtail Dam. During the four-water-year period as shown in Figure 4.1.3-3, the average monthly flow ranged from 28 percent-267 percent (1,085 and 10,240 cfs, respectively) of the average flow of 3,838 cfs. The four-water-year average flow of 3,838 cfs is about 6 percent higher than the long-term average flow of 3,603 cfs. The flow duration curves as shown in Figure 4.1.3-4 show the flow to be 2,200 cfs or greater during 80 percent of the time for the period 1966 to 1979. The lowest mean flow in the Bighorn River at St. Xavier and near Bighorn, Montana, for varying consecutive days is shown in Table 4.1.3-1. The lowest single-day flow during that period was 112 cfs in 1968 in the Bighorn River at St. Xavier and 400 cfs in 1968 near Bighorn, Montana.

<u>Pryor Creek</u>. Pryor Creek originates in the Pryor Mountains on the Crow Reservation and flows north through the western edge of the reservation to its

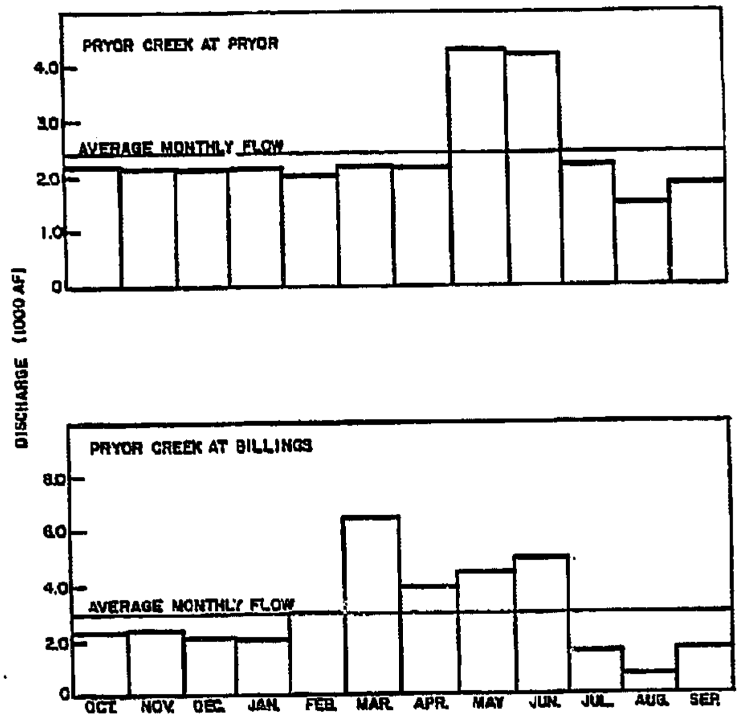
confluence with the Yellowstone River near Huntley, Montana. Five perennial streams are in the Pryor Creek drainage: East Fork Creek, Hay Creek, East Fork of Pryor Creek, West Fort Pryor Creek, and Pryor Creek. The Pryor Creek drainage covers approximately 610 square miles of which 75 percent is on the Crow Reservation.

The hydrologic characteristics of the upper portion of the Pryor Creek drainage are reported to be determined by a complicated hydrologic-geologic system (HKM, October 1977). Pryor Creek is a losing stream above the town of Pryor and changes to a gaining stream near Pryor. Below Pryor, Pryor Creek is a gaining stream throughout the reservation. (Reference 26).

The average annual flow in Pryor Creek nearest the candidate plant sites as shown in Figure 4.1.3-2 to be about 36,500 ac-ft/yr (50 cfs). Flow data in Pryor Creek near the northern boundary of the Crow Reservation are limited, but a USGS station near Billings, Montana, indicates the annual average flow for the years 1911 to 1924 and 1938 to 1953 to be 36,520 ac-ft/yr (HKM, October 1977). The long-term (1921 to 1924 and October 1966 to September 1978) annual average flow in Pryor Creek at Pryor is 30,570 ac-ft/yr (42.3 cfs) (USGS, 1978). Using available data, HKM Associates compared the monthly flow characteristics of the Pryor Creek stations at Pryor and near Billings (see Figure 4.1.3-5). The average monthly flow in Pryor Creek near Billings is higher than at Pryor and the station near Billings also experiences two flow peaks. The flow in Pryor Creek near Billings peaks in March and again in May to June. The March peak reflects a melting of lowland snow accumulation (HKM, October 1977). The flow in Pryor Creek at Pryor has a single peak in the May to June period and is similar to the flow characteristics exhibited by the Little Bighorn and Bighorn Rivers (see Figure 4.1.3-3). Pryor Creek, before its confluence with the East Fork Creek, is near candidate plant site 1A and, thus, the flow and flow characteristics in Pryor Creek at Pryor are taken as more representative of conditions at the potential water withdrawal site.

The flow variability in Pryor Creek at Pryor as shown in Figure 4.1.3-3. The monthly flow as shown in Figure 4.1.3-3 ranges from 35 percent to 459 percent (19.1 and 251

FIGURE 4.1.3-5
PRYOR CREEK MONTHLY FLOW VARIABILITY



cfs, respectively) of the four-water-year average monthly flow of 54.7 cfs which is 29 percent higher than the long-term average (June 1921 to September 1924, October 1966 to September 1978) of 42.3 cfs. A flow duration curve for the period 1968 to 1979 shows that the flow in Pryor Creek at Pryor is greater than 27 cfs during 80 percent of the time (see Figure 4.1.3-4). The lowest mean flow in Pryor Creek at Pryor, Montana, for varying consecutive days from 1968 through 1979 is shown in Table 4.1.3-1. The lowest single-day flow during that period was 7.4 cfs in 1968.

The four remaining perennial drainages evaluated in this study are located in the southeastern part of the reservation in an area proposed for Site 23, a candidate siting scenario adjacent to the Shell coal mining leases. Three of these perennial streams, Youngs Creek, Tanner Creek, and Little Youngs Creek drain the proposed Shell mine sites. The fourth drainage, Squirrel Creek, flows in a southeasterly course slightly north of the Site 23 area. All four drainages are tributary to the Tongue River. These streams flow in a southeasterly direction in deeply incised parallel valleys. The drainage basins in the mine areas are only about 2 miles wide and have an average topographic relief between valley bottom and uplands of 300 feet. The alluvial deposits in the valleys are generally less than 40 feet deep and 1000 feet wide. The approximate average width of alluvial deposits in Youngs Creek is 600 feet, and the average width in Little Youngs and Tanner Creeks is approximately 400 feet.

Thick clinker beds outcrop over much of the drainage basin of Little Youngs Creek and Youngs Creek but do not occur in the Tanner Creek drainage. The clinker beds control the flow regime of Youngs Creek and Little Youngs Creek to a large degree. The very porous and permeable clinker beds are the recharge area for many small groundwater flow systems which discharge to the creeks and maintain relatively high base flows of good-quality water in the creeks. The high infiltration rates in the clinkered areas greatly affect peak stream flows in the creeks relative to other streams in nonclinkered areas. The proposed mine site area also has a number of ephemeral tributaries that drain into the perennial streams.

The flow characteristics of Youngs Creek, Tanner Creek, and Little Youngs Creek have been investigated by Van Voast and Hedges (1974), Hedges et al. (1976) and Hydrometrics (1981). Morrison and Maierele also studied the surface flow characteristics of Youngs Creek (1974). Thompson and Van Voast have recently investigated the flow characteristics of Squirrel Creek (1981). Flow characteristics for the four streams are presented in Table 4.1.3-3. (References 9, 59).

Youngs Creek. Youngs Creek originates in the Wolf Mountains area and flows into the Tongue River in Wyoming just south of the Montana border. The base flow of Youngs Creek at the Crow Reservation boundary was estimated by Hedges et al. to be approximately 3 cfs, and the average annual flow was estimated at 5.3 cfs (1976). Approximately one-half of the base flow originates as groundwater discharge from the thick clinker beds west of the main stem of Youngs Creek in the Wolf Mountains. Two east-flowing unnamed tributaries were identified by Hedges et al. as the source of much of the base flow in Youngs Creek (1976). The base flow of Youngs Creek at the reservation boundary is also sustained by groundwater discharge from clinker beds south of the main stem. The largest spring in this reach, which issues forth at the base of the Anderson-Dietz clinker, is located in Sec. 27, T9S, R38E. Six ponds within the Youngs Creek drainage that are used primarily for stock watering have altered the natural base flow characteristics of the stream.

High-flow characteristics of the Youngs Creek drainage are poorly known. Peak discharges have been calculated for Youngs Creek by Morrison and Maierele (1977) and by Hedges et al. (1976) by the empirical methods of Johnson and Omang (1976) (Table 4.1.3-3). The calculated peak discharges most likely overestimate the actual peak discharges in Youngs Creek because the extensive clinker deposits in the Youngs Creek drainage were not accounted for in the empirical methods. The only known studies of runoff characteristics of streams in clinkered areas were conducted by Woessner et al. (1980) and by Andrews and Osborne (1979). They found that peak flows following thunderstorms in streams with similar drainage basins can be four times less in streams with extensive clinker deposits in the basin than in streams with only minor clinker deposits in the basin. (Reference 9).

TABLE 4.1.3-3

SURFACE FLOW CHARACTERISTICS AT CROW BORDER - YOUNGS CREEK TANNER CREEK, LITTLE YOUNGS CREEK AND SQUIRREL CREEK

Estimated Flow Characteristics at Crow Reservation Border	Youngs Creek, cfs	Tanner Creek, cfs	Little Youngs Creek, cfs	Squirrel Creek, [a] cfs
Mean annual flow [b]	5.3	1.4	1.1	5.6
Base flow	3.0	0.2	0.85	—
Peak discharge				
2 years	72 (54)	44	44 (33)	135
5 years	178 (141)	116	115 (193)	370
10 years	284 (227)	192	189 (153)	560
25 years	384 (365)	319	312 (250)	870
100 years	(495	—	(455)	—

[a] Squirrel Creek data are from MBMG Open File Report 84.
[b] Numbers in parentheses are from USGS-MDSL (1979c).

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Within the Crow Reservation, only two parties, Oscar Benson (a lessee from Shell) and the Bar-V Ranch, use surface water from Youngs Creek for irrigation purposes (Morrison and Maierele, 1974). The total land irrigated is approximately 120 acres. Benson draws water to an irrigation ditch in the northeastern quarter of Sec. 21, T9S, R38E, and the Bar-V Ranch operates a small storage reservoir with an approximate capacity of 150 ac-ft for irrigation in Sec. 17 and 18, T9S, R38E.

Tanner Creek. Tanner Creek originates east of the headwaters of Youngs Creek, east of the Wolf Mountains, and flows into Youngs Creek 1.5 miles east of the Crow Reservation boundary. The massive clinker beds formed by the burning of the Anderson and Dietz coal beds found in the Youngs Creek drainage basin are not found in the Tanner Creek drainage basin. Only minor clinker beds that were formed by the burning of the Smith and Roland seams occur in the Tanner Creek basin. The base flow of Tanner Creek was estimated by Hedges et al. (1976) to be only 0.21 cfs, and the average annual flow was estimated to be 1.4 cfs (Table 4.1.3-3). Most of the base flow is sustained by discharge from the Smith-Roland coal seam aquifers. Most of the flow in Tanner Creek occurs during spring snowmelt and after major spring and summer precipitation events. (Reference 59).

Little Youngs Creek. Little Youngs Creek originates in the Wolf Mountains and flows southeastward for about 11 miles until it flows into Youngs Creek. Clinker outcrops cover 42 percent of the drainage basin. The base flow of Little Youngs Creek was estimated by Hedges et al. (1976) to be 0.85 cfs above the stock pond in Sec. 2, T10S, R38E, and the average annual flow was estimated to be 2.3 cfs. The peak discharges in Little Youngs Creek calculated by Hedges in Little Youngs Creek calculated by Hedges et al. (1976) are very similar to peak discharges in Tanner Creek (Table 4.1.3-3). (Reference 59).

Squirrel Creek. Squirrel Creek drains an area of 49.8 square miles and is perennial across the entire study area. Its principal tributary, Dry Creek, rarely flows, however, partly because of numerous stock watering ponds that have been constructed along its course. Flow rates in Squirrel Creek are highly variable. High flows occur in late winter and early spring because of snowmelt (often augmented by rainfall). Lowest flows generally occur in late summer when precipitation events are infrequent, soil-moisture content is low, and evapotranspirative demands are still high. Low flows continue through the winter until snowmelt again occurs, thereby renewing the cycle. During the periods of low flow, stream discharge is maintained by seepage of groundwater from geologic materials. Springs are common in the headwaters area and provide the bulk of the low flow. The groundwater system has the capability of storing water during periods of snowmelt, precipitation, or high streamflow and then discharging it gradually to the watercourse. The gradual character of groundwater discharge maintains stream low flows at relatively constant levels.

Groundwater Resources

As previously noted, groundwater is available and has been developed for limited uses throughout the Crow Reservation. The quantity of groundwater available is highly variable and dependent upon location and the aquifer(s) from which the water is withdrawn. A study by Thorne Ecological Institute on coal development on the Crow Reservation briefly examined groundwater resources in the coal region, generally the eastern part of the reservation (Thorne, January 1979). A table prepared by Thorne, reproduced as Table 4.1.3-4, shows the general aquifers and range of yields on the Crow Reservation. More specific information on groundwater potential is given in Table 4.1.3-5. (References 52, 61).

Little Bighorn River. The alluvium and terrace deposits along the major stream beds on the Crow Reservation are the most readily available groundwater supplies. Both Quaternary alluvium and Pleistocene terrace deposits are found in the valley fill along the Little Bighorn River (see Figure 4.1.2-3). Water yields from the alluvium are estimated by Rocky Mountain Research Corp. to be 50 to 450 gpm. The high end of the range would require thick, saturated deposits having high permeability or the use of an infiltration/collection gallery system. Yields from the terrace deposits are shown in Table 4.1.3-4 to be less than 50 gpm. (Reference 52).

TABLE 4.1.3-4

GENERALIZED GROUNDWATER YIELDS[a]

Location	Quality	Yield[b] (gpm)
Alluvium valley bottoms	Fresh	Minor Source
Sandstone Aquifers Subsurface	Fresh	About 50[b]
Wasatch Formation (shallow)	Fresh	
Tongue River Member of Fort Union Formation	Fresh	
Limestone Aquifers Subsurface	Fresh	Up to 500[c]
Madison Formation (deep) Red River Formation	Saline	

[a]Thorne Ecological Institute, January 1979. More specific information on groundwater potential is shown in Table 4.1.3-5.
[b]50 gpm = 80 ac-ft/yr
[c]500 gpm = 800 ac-ft/yr

TABLE 4.1.3-5
STRATIGRAPHIC SECTION AND GENERAL AVAILABILITY OF GROUNDWATER

SOURCE: ROCKY MOUNTAIN RESEARCH, OCT. 1977

AGE			FORMATION NAME	WATER BEARING PROPERTIES	EXPECTED YIELDS	1/ USUAL QUALITY
QUATERNARY			VALLEY ALLUVIUM	WATER BEARING	** 50 - 450 GPM	FAIR TO GOOD
			RIVER TERRACE	WATER BEARING	LESS THAN 50 GPM	FAIR TO GOOD
TERTIARY	EOCENE PALEOCENE		WASATCH-FORT UNION FORMATION	WATER BEARING	*** LESS THAN 50 GPM	FAIR TO GOOD
			* ENTRUSIVE PYROCLASTICS	NON-WATER BEARING		
CRETACEOUS	UPPER		HELL CREEK FORMATION	WATER BEARING	*** LESS THAN 50 GPM	FAIR TO GOOD
			LENNEP SANDSTONE	WATER BEARING	LESS THAN 50 GPM	FAIR TO GOOD
			* BEARPAW SHALE	NON-WATER BEARING		
			JUDITH RIVER FORMATION	WATER BEARING	LESS THAN 50 GPM	POOR TO FAIR
			* CLAGGETT SHALE	2/ NON-WATER BEARING	2/ LESS THAN 50 GPM	POOR TO FAIR
			EAGLE SANDSTONE	WATER BEARING	*** LESS THAN 50 GPM	FAIR TO GOOD
		COLORADO GROUP	TELEGRAPH CREEK FORMATION	WATER BEARING	LESS THAN 50 GPM	FAIR TO POOR
			NIOBRARA FORMATION	NON-WATER BEARING		
			* CODY SHALE	NON-WATER BEARING		
			* CARLILE SHALE	NON-WATER BEARING		
			* GREENHORN FORMATION	NON-WATER BEARING		
			FRONTIER FORMATION	NON-WATER BEARING		
	LOWER		FRONTIER, TORCHLIGHT MEMBER	WATER BEARING	*** LESS THAN 50 GPM	POOR
			BELLE FOURCHE SHALE	NON-WATER BEARING		
			MOWRY SHALE	NON-WATER BEARING		
			MUDDY SANDSTONE	WATER BEARING	LESS THAN 50 GPM	POOR
			* THERMOPOLIS SHALE	NON-WATER BEARING		
			CLOVERLY FORMATION	WATER BEARING	*** LESS THAN 50 GPM	FAIR TO GOOD
JURASSIC			MORRISON FORMATION	WATER BEARING	LESS THAN 50 GPM	POOR TO FAIR
			SWIFT FORMATION	WATER BEARING	LESS THAN 50 GPM	POOR TO FAIR
			RIERDON FORMATION	NON-WATER BEARING		
			SUNDANCE FORMATION	WATER BEARING	LESS THAN 50 GPM	POOR
			* GYPSUM SPRING-PIPER FORMATION	NON-WATER BEARING		
TRIASSIC			* CHUGWATER FORMATION	NON-WATER BEARING		
			* DINWOODY FORMATION	NON-WATER BEARING		
PERMIAN			FOSTORIA FORMATION	WATER BEARING	LESS THAN 50 GPM	POOR
PENNSYLVANIAN			TENSLEEP SANDSTONE	WATER BEARING	*** 50 - 450 GPM	FAIR TO GOOD
			AMSDEN FORMATION	WATER BEARING	*** 50 - 450 GPM	FAIR TO GOOD
MISSISSIPPIAN			MADISON GROUP	WATER BEARING	*** 50 - 450 GPM	GOOD
DEVONIAN			JEFFERSON LIMESTONE	WATER BEARING	*** LESS THAN 50 GPM	GOOD
ORDOVICIAN			* BIG HORN DOLOMITE	NON-WATER BEARING		
CAMBRIAN			GALLATIN LIMESTONE	WATER BEARING	*** LESS THAN 50 GPM	POOR TO FAIR
			GROS VENTRE FORMATION	NON-WATER BEARING		
			FLATHEAD QUARTZITE	WATER BEARING	*** 50 - 450 GPM	GOOD
PRECAMBRIAN			METAMORPHIC & IGNEOUS ROCKS	NON-WATER BEARING		

* THESE UNITS MAY YIELD SOME WATER, BUT BECAUSE OF EXCESSIVE MINERALIZATION, DIFFICULTY OF DRILLING, MASSIVE STRUCTURE, EXCESSIVE DEPTH IN RELATION TO YIELD AND/OR HIGH ELEVATION OF OUTCROP AREAS, THESE FORMATIONS ARE NOT NORMALLY CONSIDERED AQUIFERS.

** LARGER YIELDS MAY BE OBTAINED IN LOCAL AREAS OF THICK, SATURATED DEPOSITS OF HIGH PERMEABILITY, OR BY INSTALLING COLLECTOR GALLERIES OR WELL-POINT SYSTEMS IN AREAS OF THINNER DEPOSITS.

*** THESE FORMATIONS MAY CONTAIN CONFINED WATER UNDER ARTESIAN PRESSURE, AND WELLS PENETRATING A COMPLETE SATURATED SECTION OF THESE FORMATIONS MAY PRODUCE MORE THAN THE YIELD INDICATED HERE. SOME AREAS MAY BE TIGHTLY CEMENTED AND PRODUCE LESS THAN INDICATED HERE.

1/ GOOD – USUALLY SUITABLE FOR MOST PURPOSES.
FAIR – SUITABLE FOR MOST PURPOSES EXCEPT DOMESTIC USES AND IRRIGATION OF CERTAIN SOILS
POOR – EXCESSIVELY MINERALIZED AND NOT SUITABLE FOR MOST USES.

2/ PARKMAN SANDSTONE MEMBER OF CLAGGETT MAY BE WATER BEARING.

The exposed bedrock formations in the Little Bighorn River drainage near Hardin, Montana, are in the Montana and Colorado Groups of Cretaceous age. The Parkman Sandstone is the uppermost exposed formation and aquifer in the Montana Group. In the Little Bighorn Valley near Hardin, wells are completed into the Parkman Sandstone at depths of less than 200 feet (Rocky Mountain Research Corp., October 1977). Other potential aquifer formations in the Montana Group include the Eagle Sandstone and the Telegraph Creek Formation. All potential aquifer formations in the Montana Group are estimated to yield less than 50 gpm. The potential for water yield from formations in the Colorado Group appears to be minimal except for the Cloverly Formation which is estimated to yield up to 50 gpm (Rocky Mountain Research Corp., October 1977). (Reference 52).

The deeper Tensleep Sandstone, Amseden Formation, and Madison Limestone bedrock Formations are potential aquifers capable of yielding 50 to 450 gpm of water, but they are estimated to be at depths as great as 5,000 feet in the Hardin area. Both shallow alluviums and deeper bedrock formations have the potential to yield water in the Little Bighorn River drainage near Hardin. Yields are estimated to be 50 to 450 gpm (80 to 720 ac-ft/yr), but site-specific detailed work would have to be performed to define the actual extent of the resource.

Bighorn River. Like the Little Bighorn drainage, alluvium and terrace deposits are found along the major streambeds in the Bighorn River drainage and water yields would be in the same range; i.e., 50 to 450 gpm. Potential plant site areas adjacent to the Bighorn River would be located on Pleistocene terrace deposits underlain by shale formations of the Colorado Group.

Moving west away from the major rivers and the alluvium and terrace deposits, the exposed bedrock formations are those of the Colorado Group, consisting principally of shales that exhibit very low aquifer potential. The Cloverly Formation in the Lower Cretaceous series is a potential groundwater source underlying the potential site areas near the north-central reservation boundary, but they may be overlain by 2,000 feet or more of shale.

In the western part of the Bighorn River drainage along the northern reservation boundary, formations in the Montana Group overlie the Colorado Group. The sandstone formations of the Montana Group could serve as aquifers, but the potential yield would likely be very low due to the limited area of recharge and possibly limited formation thickness.

Potential candidate sites away from the Bighorn River would be located on shales of the Colorado Group or, if far enough west, possibly on limited sandstones of the Montana Group. More specifically, Site 1, one of the most promising candidate siting areas, is overlain primarily by two of the lower members of the Cody Shale formations, the Carlile and Niobrara, in the Colorado Group, as previously discussed in Section 4.1.2. Since pertinent well data are not available at the Site 1 location, the drill test data developed by Woodward-Clyde Consultants (1981) slightly north of Site 1 are somewhat indicative of the groundwater potential in that area. (Reference 82).

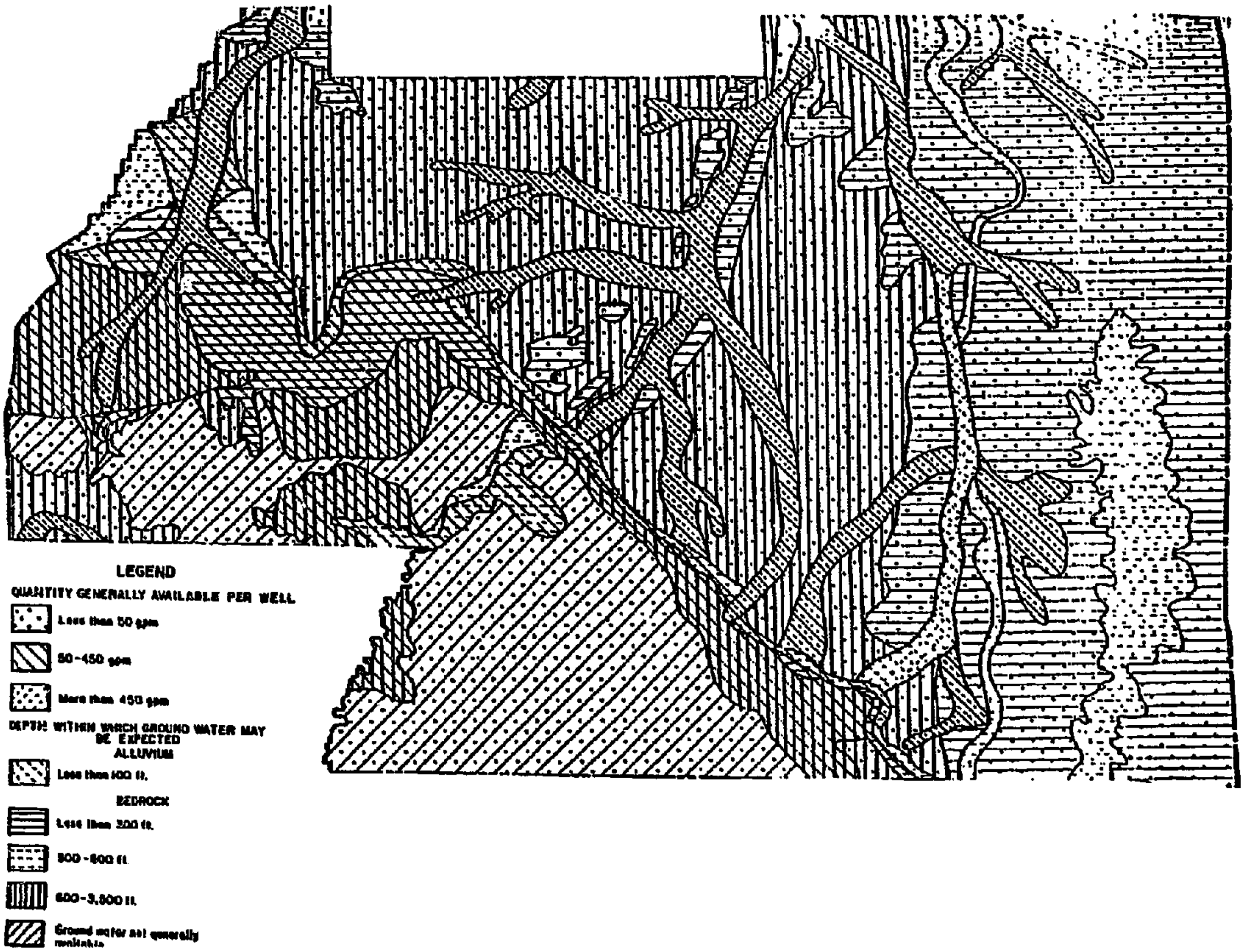
Briefly, the Woodward-Clyde drill test data from slightly north of Site 1 showed stiff to very stiff clays over the Carlile and Niobrara shale bedrock at depths of 3 to 7 feet. No free water was found in any of the test holes drilled to 20 feet. Additionally, the Cody Shales are generally considered to be poor sources of groundwater—capable of yielding 50 gpm or less and to occur at depths of 600 to 3,500 feet as shown in Table 4.1.3-5 and as shown in Figure 4.1.3-6. (Reference 52).

Pryor Creek. Alluvium and terrace deposits are generally absent from the streams in the Pryor Creek drainage. The Colorado Group is the predominant bedrock exposed in the central portion of the drainage. Formations of the Montana Group are exposed and overlie the Colorado Group in the extreme northern part of Pryor Creek drainage (see Figure 4.1.2-2 of Section 4.1.2).

The most western potential plant site (Site 1A) along the northern reservation boundary might be in the Pryor Creek drainage. If so, it would be located on the Montana Group where sandstone formations may serve as potential, though limited, groundwater sources.

FIGURE 4.1.3-6

GROUNDWATER POTENTIAL ON THE CROW RESERVATION



Source: Rocky Mountain Research, 1977.

The major water-bearing strata in the southeastern section of the Crow Reservation in the Site 23 area are the alluvial deposits within the Squirrel Creek, Youngs Creek, Tanner Creek, and Little Youngs Creek valleys, the major coal seams, associated clinkers, and sandstone beds in the Tongue River Member of the Fort Union Formation; the Hell Creek and Fox Hills Formations; the Fall River Formation; and the Madison Group as shown in Table 4.1.3-6. (Reference 8).

All domestic and stock wells in the proposed facility siting area derive water from either the alluvial deposits or the coal seams, clinkers, and sandstone beds in the Tongue River Member. Water yields from these aquifers are typically in the range of 1 to 10 gpm; and although larger yields could be obtained from deeper aquifers, the cost of obtaining water from these aquifers is very high.

The near-surface aquifers in the area have been studied by the Montana Bureau of Mines and Geology from 1971 through March 1980. The results of these investigations are summarized by Van Voast and Hedges (1974) and by Hedges et al. (1976, 1980). The near-surface aquifers in the vicinity of the Decker mines, Spring Creek mine, and the proposed Pearl mine site are described by Van Voast (1974), Van Voast and Hedges (1975), USGS-MDSL (1977, 1979 a-c), and Hedges et al. (1980). The deep aquifers are also discussed by Woessner et al. (1980). (Reference 59).

Alluvial Deposits. Alluvial deposits exist in the valleys of Squirrel Creek, Little Youngs, Youngs, and Tanner creeks. The alluvial deposits are lithologically variable, containing lenticular deposits of fine sand, silt, clay, and clinker gravels. The deposits vary in thickness and are reported by Hedges et al. (1976) to be as deep as 40 feet. Thompson and Van Voast (1981) have depths of up to 60 feet in Squirrel Creek valley. The width of alluvial deposits is generally less than 1,000 feet. Near the Crow Reservation boundary, the width of alluvial deposits averages 400 feet in both the Little Youngs Creek and Tanner Creek valleys, and averages 600 feet in the Youngs Creek valley. (References 8, 9).

Tongue River Member. The Tongue River Member of the Fort Union Formation is composed of several major coal seams, interbedded sandstone, siltstone and shale,

TABLE 4.1.3-6

MAJOR WATER-BEARING STRATA IN THE SHELL YOUNGS CREEK AND TANNER CREEK MINING AREAS

Geologic Unit	Age	Approximate Depth to Unit (ft)	Thickness (ft)	Description of Water-Bearing Unit	Well Yields (gpm)	TDS (mg/1)
Alluvial Deposits	Quaternary	0	0-40	-	10-100	500-2000
Tongue River Member	Tertiary	0-150	1000-13000	Coal, sandstone, clinker	2-30	500-4000
Hell Creek and Fox Hill Sandstone	Upper Cretaceous	2000	200	Sandstone	1-80	1000
Fall River Formation	Lower Cretaceous	3500	200	Sandstone	1-50	-
Madison Group	Mississippian	9000	1100	Limestone and dolomite	10-2000	1000-2000

Note: Ft = feet, gpm = gallons per minute, TDS = total dissolved solids, mg/1 = milligrams per liter.

Source: Bureau of Indian Affairs, February 1981.

and clinker beds. The major coal seams—the Smith, Anderson, Dietz, and Canyon—and their associated clinkers are the principal water-bearing units in the Tongue River Member. Locally thick sandstone beds between the coal beds are water-yielding, but the sandstones occur as discontinuous lenses that appear to be isolated bodies with very limited hydraulic connection (USGS-MDSL, 1977). (Reference 8).

The interburden between the coal seams generally has a hydraulic conductivity that is several orders of magnitude lower than the conductivity in the coal beds. As a result, there is only limited hydraulic connection between adjacent coal seams. The Tongue River Member can conveniently be divided into four main hydrogeologic units as shown in Figure 4.1.3-7: Smith-Roland, Anderson-Dietz, Canyon-Wall, and Lower Tongue River Member. These hydrogeologic units include the coal seams and the interburdens; but, because of the generally low-hydraulic conductivity of the interburden, it is assumed that on a regional scale transmissivity in the hydrogeologic units is only a function of transmissivity in the coal beds as shown in Table 4.1.3-7. (Reference 8).

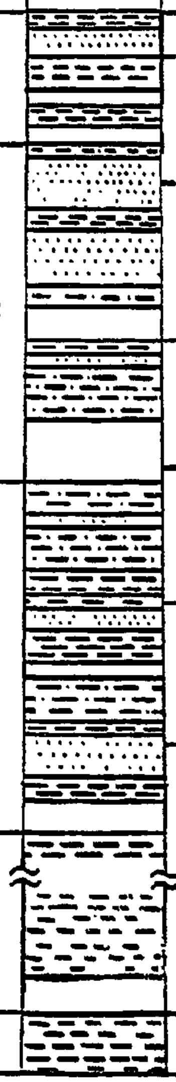
Smith-Roland Unit. The Smith coal seams are the major aquifer in the Smith-Roland unit. The Smith seams have a combined average thickness in the mine site areas of about 20 feet. In the northwestern part of the Tanner Creek mine site, the two seams merge, but in the eastern part of the area as much as 50 feet of interburden separates the two coal seams. The Smith coal seams are not an important regional water-bearing unit because their areal continuity is restricted by the deeply incised topography and the coal seams are relatively thin. North of Youngs Creek, in the proposed Tanner Creek mine area, the Smith seams are an important local aquifer as illustrated in Figure 4.1.3-7. South of Youngs Creek, the Smith coal seams occur only in the uplands and the seams are generally not saturated (Hedges et al. 1976). The transmissivity of the Smith coals has not been determined in the field. However, the transmissivity of the combined Smith seams is estimated to average 25 square feet/day.

Anderson-Dietz Unit. The Anderson and Dietz coal seams and associated clinkers form a continuous unit that extends from the Wolf Mountains on the west to the

FIGURE 4.1.3-7

GENERALIZED CROSS SECTION OF FORT UNION FORMATION, YOUNGS CREEK MINE AREA, CROW RESERVATION

Hydrogeologic Units	Lithology	Depth (ft) Below Top of Tongue River Member	Coal Seam Terminology: Matson and Blumer	Coal Seam Terminology: Shell	Coal Seam Terminology: Decker Coal Co.
Smith-Roland Unit		0	Roland		
			Smith	C, D	
Anderson-Dietz Unit		100			
		200	Anderson	G	Seams Merged D-1 Coal
		300	Dietz No.1 and 2	M	
Canyon-Wall Unit		400			
			Canyon	O	D-3 Coal
		500			
			Wall(?)	R	D-4 Coal
Lower Tongue River Member Unit					
		1200			



Sources: Matson and Blumer 1973, plate 31; Hedges and others 1976; Van Voast 1974. Lithology adapted from Hedges and others 1976.

Tongue River on the east as shown in Figure 4.1.3-8. The combined Anderson and Dietz coal seams have a thickness of 60 to 100 feet. In the Wolf Mountains, the Anderson and Dietz coal seams are merged, but to the east the Anderson splits from the Dietz. Along Youngs Creek near the Crow Reservation border, the Anderson seam averages 20 feet in thickness, the Dietz seam averages 53 feet in thickness, and about 200 feet of interburden separates the seams. About 3 miles east of the Crow Reservation border, the seams merge to form a combined seam about 80 feet thick (Matson and Blumer, 1973). Farther to the east, near the Tongue River, a thin seam called the Dietz No. 2 separates from the combined Anderson-Dietz seam. (Reference 8).

The western and southern extent of the Anderson-Dietz unit is defined by thick clinker beds that formed when the coal seams burned as shown in Figure 4.1.3-9. Some of the clinker beds are adjacent to the Anderson and Dietz coal seams, but many of the clinker beds found in the drainage basin of Little Youngs Creek and Youngs Creek have been isolated by erosion. Extensive clinker beds formed by the burning of the Anderson and Dietz coal seams are also found along the Tongue River Reservoir and in a large area north of the Decker Creek and Spring Creek mines (Baker, 1928). (Reference 8).

On the basis of seven pump tests run in the Youngs Creek and Tanner Creek mine areas, the transmissivity of the Anderson and Dietz coal seams was calculated by Hedges et al. (1976) to average 70 square feet/day and range 17 to 180 square feet/day. The transmissivities of these coal seams in the Pearl mine site area were reported to average 43 square feet/day and to range from 0.6 to 180 square feet/day. The relatively high transmissivities reported for the coal seams are the result of well-developed fracture systems within the coal seams.

The transmissivities of the Anderson-Dietz clinkers were estimated by Van Voast and Hedges to range 150 to 200 square feet/day in the Decker area (1975). The high transmissivities in the clinkers are the result of the baking and fusing of the sandstone, siltstone, and shale interburden and the subsequent collapse of this material into the void created by the burning of the coal. Clinkers are generally

TABLE 4.1.3-7

SUMMARY OF HYDRAULIC PROPERTIES OF MAJOR COAL SEAMS AND ALLUVIAL DEPOSITS

Geologic Unit	Transmissivity (ft^2/day) Average	Maximum	Minimum	Number Of Tests	Storage Coefficient (specific yield)
Smith	25	-	-	-	2×10^{-5} (0.01)
Anderson	30	80	3.3	4	2×10^{-5} (0.01)
Dietz	51	180	0.6	10	6×10^{-5} (0.01)
Anderson-Dietz	25	30	17	2	8×10^{-5} (0.01)
Anderson-Dietz Clinker	3300	-	-	1	(0.1)
Canyon	27	50	5	2	2×10^{-5} (0.01)
Wall	25	-	-	-	2×10^{-5} (0.01)
Rosebud	25	-	-	-	(0.01)
Alluvial Deposits	2500	4800	1300	6	(0.15)

Sources: Hedges et al. (1976), USGS-MDSL (1979c), Van Voastetal. (1976), Woessner et al. (1980).

<u>**FIGURE 4.1.3-8**</u>

<u>**MOVEMENT OF GROUNDWATER IN THE TONGUE RIVER MEMBER OF THE FORT UNION FORMATION**</u>

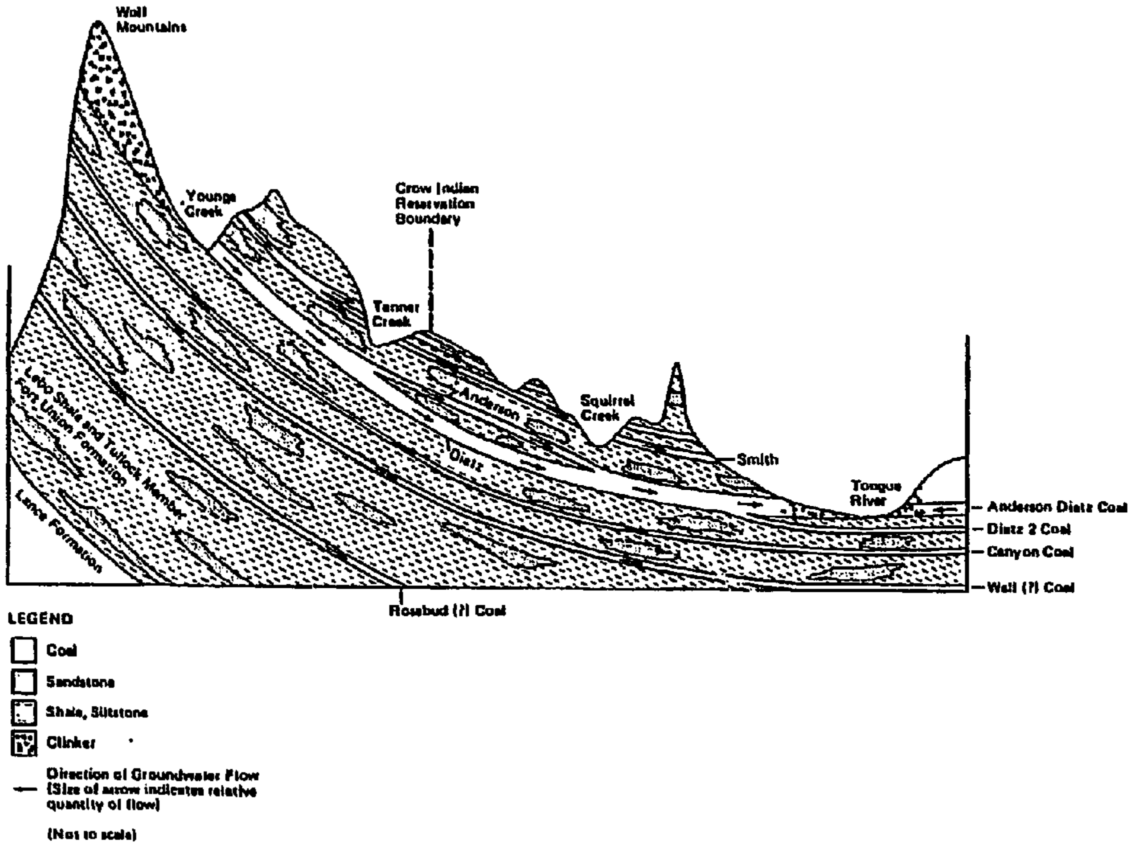
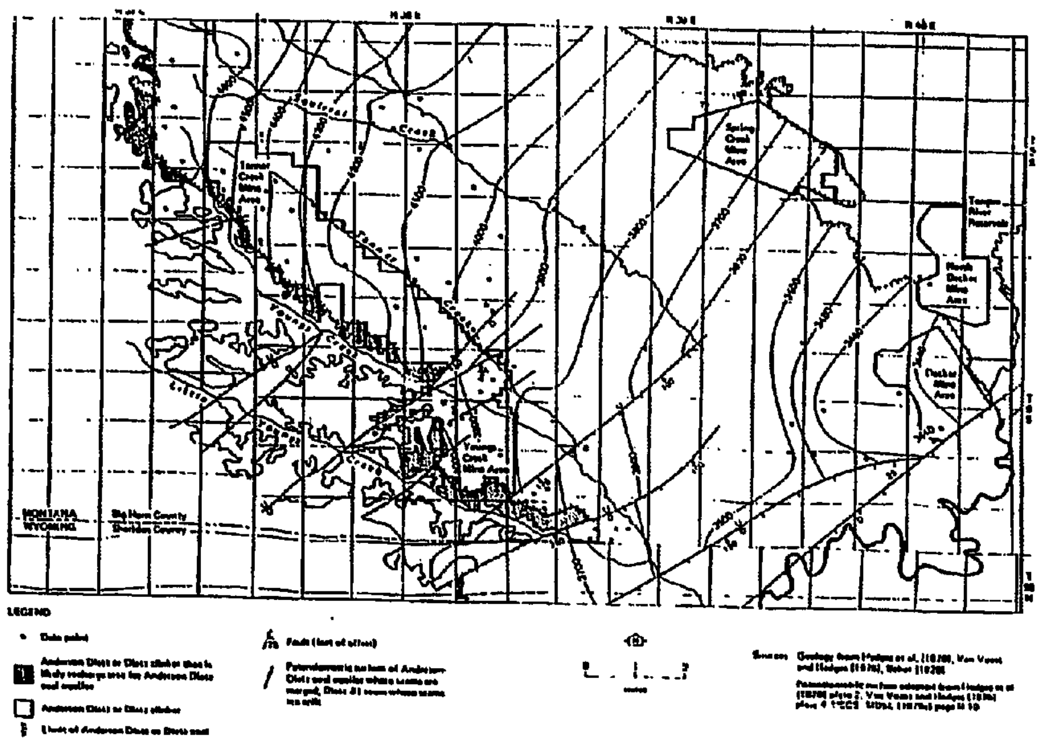


FIGURE 4.1.3-9

POTENTIOMETRIC SURFACE OF ANDERSON-DIETZ COAL AQUIFER



very fractured and very porous. Clinker beds are generally two to four times thicker than the coal seam that burned (Matson and Blumer, 1973). (Reference 8).

Canyon-Wall Unit. Two coal seams, which are each 10 to 30 feet thick, occur about 100 feet below the base of the Dietz coal seam. The two seams are separated by about 100 feet of interburden. The upper seam correlates with the Canyon seam of Matson and Blumer (1973), and the lower seam may correlate with the Wall seam. These two seams are continuous from the outcrop areas in the Wolf Mountains on the west through the Tongue River valley on the east. Hedges et al. ran two pump tests on wells completed in the Canyon coal seam, from which they calculated transmissivities for the coal of 5 square feet/day and 50 square feet/day (1976).

Lower Tongue River Member Unit. The basal 600 feet of the Tongue River Member contains only one major coal seam. This coal seam, which is 22 feet thick near Decker, is located near the base of the Tongue River Member, about 600 feet below the Wall coal seam (Baker, 1929). The interburden between the Wall coal seam and this basal coal seam is described in the log of Absarcka Oil and Gas Co. well No. 1 (Sec. 16, T9S, R40E) as shale, thin sandstone, shell lime, and thin coal. The basal coal seam may correlate with the Rosebud seam that is mined in the Colstrip area (Baker, 1929). The Lower Tongue River Member unit is probably continuous from the outcrop areas in the Wolf Mountains through the Tongue River valley. The transmissivity of the basal coal seam is probably similar to that of the other coal seams in the Tongue River Member (Woessner et al. 1980; Van Voast et al. 1977). (Reference 8).

Groundwater movement in the alluvial deposits along the major stream channels is parallel to the valleys. These alluvial aquifers are hydraulically connected with surface-water flows in the valleys. The alluvial aquifers are recharged directly by precipitation, stream flow, and seepage from bedrock aquifers. The quantity of groundwater flow in the alluvial aquifers is large in relation to the groundwater flow in the Tongue River aquifers. The quantity of groundwater flow in the alluvial aquifer along Youngs Creek across the reservation boundary was calculated to be in the range of 0.14 to 0.5 cfs. Flow in the alluvial aquifer along Tanner Creek across the reservation boundary was calculated to range 0.08 to 0.3 cfs, and the flow in the alluvial aquifer along Little Youngs Creek across the reservation boundary was calculated to range from 0.1 to 0.4 cfs.

An important local groundwater flow system exists in the Smith coal seams north of Youngs Creek in the Tanner mine site area. Groundwater recharges the aquifer at the outcrop areas of the Smith coals and their associated clinkers in the eastern part of the Upper Youngs Creek basin, and discharge occurs at numerous seeps and small springs in the headwaters of Tanner Creek and Squirrel Creek. The total flow in this system is less than 0.1 cfs.

One large groundwater flow system and several small systems exist in the Anderson-Dietz unit in the Shell mine site area. The continuous Anderson-Dietz coal seams and hydraulically connected clinkers function as a major flow system. Many small flow systems exist in the many clinker beds that have been hydraulically isolated from the major flow system by erosion of the Anderson-Dietz clinker and/or coal.

As shown in Figure 4.1.3-9, main groundwater flow movement is predominantly from the Wolf Mountains toward the Tongue River. The regional groundwater flow patterns are distorted by the large faults that occur along Youngs Creek and Little Youngs Creek, with displacement as large as 250 feet. The direction of groundwater movement in the vicinity of several of the faults is apparently parallel to the faults, suggesting that these faults act as barriers to flow. The major recharge areas for the flow system are the clinkered areas in the Wolf Mountains and the clinkered areas along Youngs Creek and Little Youngs Creek.

The quantity of water that moves through the Anderson-Dietz flow systems is not large. Total flow in the system across the Crow Reservation boundary in T9S is calculated to be in the range of 0.13 to 1.3 cfs. The best estimate of the flow rate is 0.3 cfs. Most stock and domestic wells in the region derive water from the Anderson-Dietz unit. Many of the thick clinker beds that outcrop in the Youngs Creek drainage are erosional remnants that are not connected with the main Anderson-Dietz groundwater flow system. Small groundwater flow systems exist within these hydraulically isolated clinker beds. The groundwater from these clinker flow systems discharges either as springs or seeps at the base of the clinker beds or as downward leakage to underlying strata. The underlying strata, the interburden layers below the Dietz coal seam, generally have a low hydraulic conductivity, and as a result most of the discharge occurs as springs and seeps. Groundwater discharge from these isolated clinker flow systems accounts for much of the base flow in Youngs Creek and Little Youngs Creek.

No available data were available to define the potentiometric surface in the coal seams underlying the Dietz seam. A continuous groundwater flow system most likely exists in both the Canyon-Wall and Lower Tongue River Member units from the Wolf Mountains to the Tongue River. The flow systems are most likely recharged at the outcrop areas in the Wolf Mountains and by downward leakage through overlying strata in the region east of the Wolf Mountains. Groundwater probably discharges from the system by upper leakage in the Tongue River valley. The quantity of water that moves through both units across the Crow Reservation boundary in T9S is probably less than that which moves through the Anderson-Dietz unit. One well in the region (Sec. 3, T9S, R40E) was completed in 1974 in the Canyon coal seam. This well, which was completed in 1974, flowed at the rate of 10 gpm, but 14 months later flowed at less than 1 gpm (USGS-MDSL, 1977).

Water Quality

The water quality in the particular river or stream is dependent upon the topographic features, soils, and geologic characteristics of the drainage. Water uses (including municipal, industrial, and agricultural, particularly irrigation return flows) can have an influence on water quality. Present municipal and industrial water uses on the Crow Reservation are limited and do not affect the water quality in tributaries on major streams. Irrigation return flow impacts the water quality in some tributaries but, since the tributaries provide only a small inflow to the major streams, there is not a significant change in water quality. Groundwater quality is dependent upon the geologic characteristics of the water-bearing formation, distance from the recharge area, the geologic characteristics of other formations the water may have traversed, and the initial quality of the recharge water.

Surface Water. The quality of surface waters in the Little Bighorn River, Bighorn River, and Pryor Creek on the Crow Reservation are generally good and suitable for all uses including municipal, agricultural, industrial, and wildlife resources. Surface waters within the above three basins are classified in the Montana Surface Water Quality Standards as either B-1 or B-2.* Waters classified as B-1 are "suitable for drinking, culinary and food processing purposes, after conventional treatment; bathing, swimming and recreation; growth and propagation of salmonoid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply" (State of Montana, October 1980). The B-2 stream classification is similar to the B-1 classification except water use for the propagation of salmonoid fishes is considered marginal. (References 43, 44).

Little Bighorn River. The Little Bighorn River at Hardin is a mixed-type water quality with dominant ions being sodium, magnesium, bicarbonate, and sulfate. The study by HKM Associates indicates that the tributaries originating on the reservation have a significant effect on the water quality of the Little Bighorn River with respect to suspended sediment, total dissolved solids, sodium, and sulfate (HKM, October 1977). (Reference 26).

The water quality stations on the Little Bighorn River, maintained since 1969, indicate that this water is the purest surface water to be found on the reservation. A compilation by HKM of available data in Table 4.1.3-8 shows that the water quality in the Little Bighorn River at Hardin meets primary drinking water standards and, with the exception of occasional excursions, also meets secondary drinking water criteria (1977). The water quality of the Little Bighorn River at Hardin is good and acceptable for all uses. (Reference 26).

*The reference to the Montana Surface Water Quality Standards is used to present a general view of the quality of water on the reservation and does not imply that state standards are applicable to waters within the exterior boundary of the Crow Reservation.

TABLE 4.1.3-8

WATER QUALITY CROW RESERVATION, VALUES IN (MG/L)

	Standard Or Criteria (mg/1)	Little Bighorn at Hardin	Bighorn River at St. Xavier	Bighorn River at Hardin	Pryor Creek at Pryor	Pryor Creek Near Boundary
Primary Drinking Water Standards						
Arsenic	0.05	-	0	0.0002	0.001 - 0.002	0.001 - 0.002
Cadmium	0.01	-	0	0.001 - 0.006	0.001	0.001 - 0.002
Chromium	0.05	-	0	0.001 - 0.019	0.01 - 0.023	0.01 - 0.024
Lead	0.05	-	0	0.01	0.01	0.01 - 0.012
Mercury	0.002	0.001	0	0.0002 - 0.007	0.0002 - 0.0003	0.0002 - 0.0007
Nitrate (N)	10.00	0 - 1.5	0 - 2.9	0.02 - 2.3	0.1 - 1.10	0.5 - 1.12
Selenium	0.01	-	-	0.001 - 0.0021	0.001 - 0.002	0.001 - 0.0021
Fluoride	1.4-2.4	0 - 0.7	0.1 - 0.8	0.37 - 0.7	0.31 - 0.53	0.43 - 0.5
Secondary Drinking Water Standards						
Ammonia	0.5	-	0 - 0.04	0 - 0.59	0.01 - 0.20	0.01 - 0.30
Boron	1.0	0.03 - 0.15	0.06 - 0.3	0.109 - 0.7	0.06 - 0.75	0.12 - 1.07
Chloride	250	1.0 0 8.2	3.4 - 19	3.4 - 19	0 - 6	9 - 15
Copper	.0	-	-	0.01 - 0.022	0.01 - 0.02	0.01 - 0.01
Iron	0.3	0 - 2.5	.0 - 0.30	0.02 - 0.95	0.08 - 0.76	1.09 - 5.5
Mangaˉnese	0.05	0 - 0.08	0 - 0.16	0.03 - 0.08	0.01 - 0.04	0.13 - 0.37
Sulfate	250	50 - 450	21 - 394	150 - 440	34 - 46	160 - 285
TDS	500	251 - 867	115 - 842	362 - 952	268 - 424	500 - 723
Zinc	5.0	-	- -	- -	0.01 - 0.079	0.01 - 0.51
pH	6.5-8.5	7.3 - 8.4	7.2 - 8.5	6.6 - 8.7	7.2 - 8.4	7.5 - 8.5

Source: HKM Associates, Adapted.

The waters of the Little Bighorn River also appear particularly suitable for irrigation. Values for specific conductance range 250 to 750 micromhos/cm and sodium absorption ratios are less than 1. These data indicate a medium salinity hazard and a very low sodium hazard based upon the classifications, shown as Figure 4.1.3-10, developed by the U.S. Salinity Laboratory staff (1954). (Reference 26).

Bighorn River. Water in the Bighorn River from St. Xavier to Bighorn is a calcium sulfate type. The water quality in the Bighorn River at St. Xavier and near Hardin is shown in Table 4.1.3-8. Data in the table show the water quality to be better than the primary drinking water standards at St. Xavier. However, primary standards of 0.002 mg/l and 0.01 mg/l for mercury and selenium, respectfully, have been exceeded at Hardin (see Table 4.1.3-8). Several other constituents have exceeded the secondary drinking water standards at both St. Xavier and Hardin on the Bighorn River. For example, sulfate concentrations are seldom less than 250 mg/l and concentrations in excess of 400 mg/l are common.

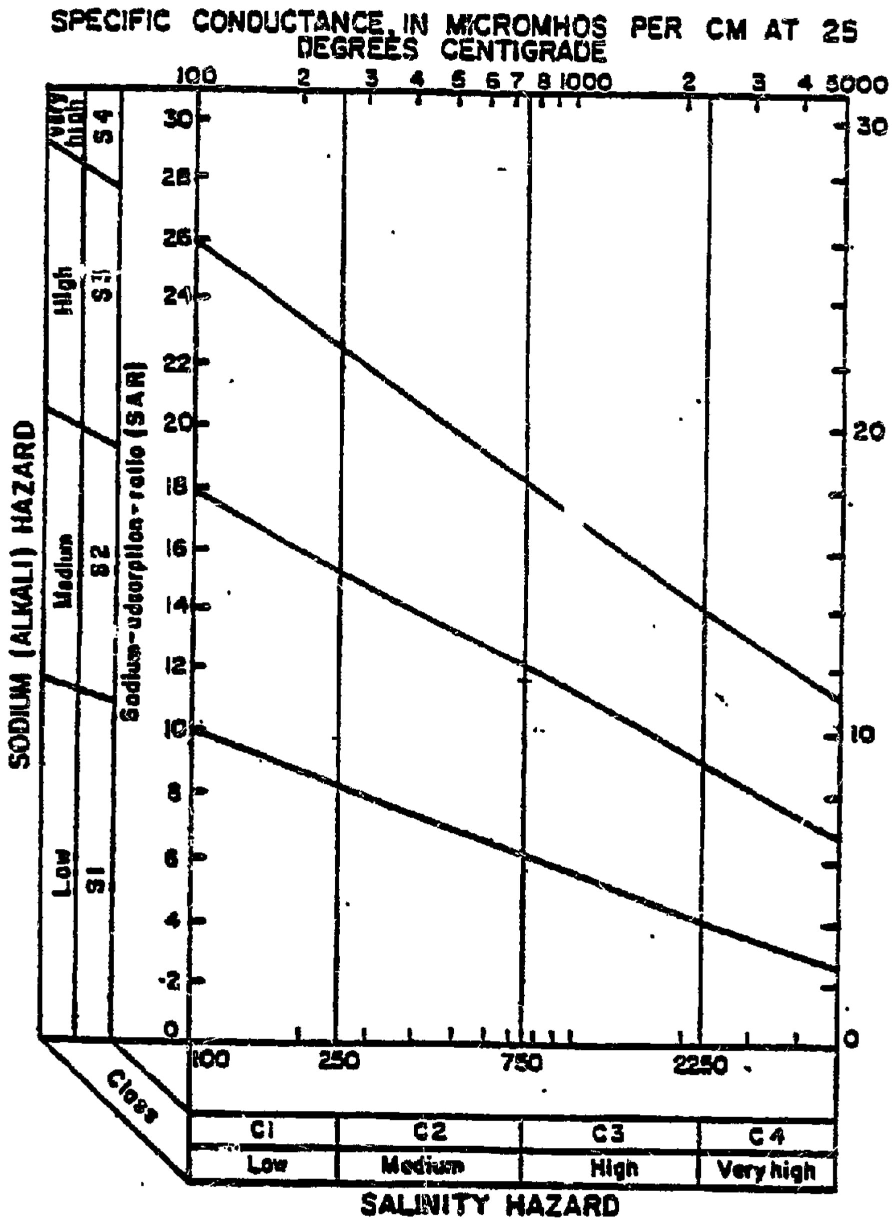
Total dissolved solids concentrations average in excess of 650 ppm, which is more than the recommended 500 ppm value. The concentration of dissolved manganese also has exceeded the recommended standard of 0.05 ppm. Turbidity values in excess of 5 units have been recorded.

The suitability of Bighorn River water for irrigation appears quite favorable. Sodium absorption ratio values seldom exceed 2.5 and specific conductance values average about 920 umho, indicating a medium to high salinity hazard yet a very low sodium hazard. Dissolved boron concentrations seldom exceed 0.15 ppm which is less than the 1 to 2 ppm value deemed hazardous.

The larger turbidity values experienced in the Bighorn River occur during spring runoff; however, tributaries below Yellowtail are notoriously heavy-sediment carriers. These are Beauvais Creek, Soap Creek, Rotten Grass Creek, and Woody Creek. USGS records on Beauvais Creek bear this out. Nevertheless, it may be concluded that water in the Big Horn River on the reservation can, with proper treatment, be made acceptable for all uses, including drinking water supply,

FIGURE 4.1.3-10

DIAGRAM FOR USE IN INTERPRETING THE ANALYSIS OF IRRIGATION WATER



irrigation, livestock watering, industrial use, and wildlife resources. (References 26, 75).

Pryor Creek. Limited water quality sampling performed in support of the EPA 208 Areawide Waste Treatment Planning program indicates a significant increase in the concentrations of sodium, sulfate, chloride, and total suspended sediment in Pryor Creek from the headwaters through the reservation to confluence with the Yellowstone River. As it passes through the reservation, Pryor Creek increases in hardness and changes from a calcium bicarbonate-type water at Pryor Gap to a mixed type consisting mainly of calcium, magnesium, sodium, sulfate, and bicarbonate at the northern reservation boundary. Water quality in Pryor Creek at Pryor and at the northern reservation boundary can be found in Section 4, Crow Sampling Program Results, Section 208 Water Quality Management Plan, prepared by HKM Consultants (October 1977). (Reference 26).

The limited data in Table 4.1.3-8 for Pryor Creek indicate the water quality to be better than the primary drinking water standards. The secondary drinking water criteria are exceeded on occasion, but the use of the water as a public water supply would not be precluded. The water in Pryor Creek between Pryor and the northern reservation boundary, while of poorer quality than water in the Little Big Horn and Big Horn Rivers, is acceptable with proper treatment for all uses.

Tongue River/Squirrel, Youngs, Tanner, and Little Youngs Creeks. The Tongue River is the major stream draining the Shell mining lease area and the candidate mine-mouth siting area designated as Site 23, since Squirrel, Youngs, Tanner, and Little Youngs Creeks are all tributary to the Tongue River. The surface water quality in the Tongue River Basin above the proposed project site is primarily affected by high quality snowmelt from the Bighorn Mountains, by irrigation in Wyoming, and by surface water and groundwater inflow. The water quality in the Tongue River above the Tongue River Reservoir is generally good as evidenced from the data presented in Table 4.1.3-9. (Reference 75).

The total dissolved solids (TDS) concentrations, especially the concentrations of calcium, magnesium, sodium, bicarbonate, and sulfate, tend to increase in the downstream direction. The lowest concentrations of TDS and of all major constituents can be expected during the high-runoff months of May, June, and July. A comparison of these chemical analyses and other trace element analyses for the Tongue River above and below the project area (Table 4.1.3-9) indicates that applicable Wyoming and Montana water quality standards for the Tongue River in this area would be met. EPA Primary Drinking Water Standards are also met. EPA Secondary Drinking Water Standards for iron (0.3 mg/l) are exceeded at Monarch, and the standards for TDS (500 mg/l), sulfate (250 mg/l), and iron and manganese (0.05 mg/l) are occasionally exceeded at the monitoring station near Decker. These waters are acceptable for most uses, including domestic supply and irrigation. The high hardness and bicarbonate values might require certain industrial users to provide treatment.

A limited number of water quality analyses have been published for the streams in the vicinity of candidate Site 23. However, selected analyses have been obtained for stations generally upstream and downstream of the Site 23 area on Squirrel, Tanner, Youngs, and Little Youngs creeks as presented in Table 4.1.3-10. In general, the water quality in Youngs and Little Youngs creeks is better than the water quality in Squirrel and Tanner creeks. The TDS concentration—and in particular the concentrations of magnesium, sodium, and sulfate—increase in the downstream direction. The water found in these creeks is good enough for most uses, although the high hardness and alkalinity values might require treatment for industrial use. Based on the available analyses, surface waters in Youngs and Little Youngs creeks meet Wyoming and Montana water quality standards, the EPA's Primary and Secondary Drinking Water Standards, and EPA's water quality criteria for freshwater aquatic life. The water in Squirrel Creek meets all of the standards except the Secondary Drinking Water Standard for TDS. Levels of TDS and sulfate exceed the Secondary Drinking Water Standards in Tanner Creek. (References 8, 59).

Groundwater. Generally speaking, the groundwaters available within the reservation are poorer quality than the surface waters. The geologic profile of the reservation

TABLE 4.1.3-9

WATER QUALITY IN THE TONGUE RIVER

ABOVE AND BELOW THE PROJECT AREA

Parameter[a]	Above Project at Monarch Average	Above Project at Monarch Range	Below Project at State Line Near Decker Average	Below Project at State Line Near Decker Range
Temperature (°C)	7.6	0 - 21.5	8.3	0 - 24
pH (units)	-	7.5 - 8.4	-	7.6 - 8.7
Specific Conductance (umhos/cm)	445	180 - 660	780	280 - 1700
Total Dissolved Solids	281	105 - 377	538	190 - 1320
Calcium	50	22 - 62	73	25 - 180
Magnesium	23	8.8 - 39	44	17 - 110
Sodium	16	3.1 - 32	39.4	8.6 - 98
Potassium	2.0	1.2 - 4.5	3.7	0.0 - 11
Total Hardness (as $CaCO_3$)	220	93 - 270	365	110 - 900
Carbonate	0	0 - 0	2	0 - 8
Bicarbonate	213	96 - 270	289	88 - 760
Sulfate	80	13 - 150	203	41 - 490
Chloride	2.2	0.8 - 3.9	5.8	2.1 - 18
Iron	0.413	0.160 - 0.800	0.943	0.160 - 0.1700
Manganese	0.25	0.20 - 0.40	0.63	0.30 - 0.90
(Nitrate + NO_2) as N	0.18	0.02 - 0.87	0.3	0.03 - 1.4
Fluoride	0.18	0.1 - 0.3	0.4	0.1 - 0.7
Dissolved Oxygen	10.5	8.9 - 12.4	10.6	8.1 - 13.2
Turbidity (NTU)	14	1 - 90	15.5	1 - 70
Suspended Solids	-	-	37	7 - 188
Iron, Dissolved	0.100	0.10 - 0.490	0.27	0.20 - 0.40
Flow (cfs)	624	60 - 1540	-	54 - 2200

Sources: USGS 1978, 1979.

[a]All units are milligrams per liter unless otherwise indicated.

TABLE 4.1.3-10

WATER QUALITY IN CREEKS NEAR PROPOSED SYNFUELS PROJECT SITE 23

Parameter[a]	Squirrel Creek Upstream	Squirrel Creek Downstream	Tanner Creek Upstream	Tanner Creek Downstream	Youngs Creek Upstream	Youngs Creek Downstream	Little Youngs Creek Upstream	Little Youngs Creek Downstream
Location	9S.38E.1	8S.38E.30	9S.38E.5	9S.39E.20	9S.37E.1	9S.38E.25	9S.36E.2	10S.38E.1
Date	09/25/75	09/25/75	09/23/75	09/23/75	08/17/72	08/16/72	09/10/72	09/10/72
Temperature(^{o}C)	8.5	8.0	13	6.0	20	19	11	11
pH (laboratory)(units)	8.1	8.2	8.1	8.2	8.3	8.5	7.6	8.3
Specific Conductance (field)(umhos/cm)	750	1010	880	1700	430	680	470	620
Total Dissolved Solids	433	637	518	1155	294	473	283	331
Calcium	72	69	73	94	51	54	55	40
Magnesium	55	87	67	142	30	60	22	39
Sodium	4.2	29	8.5	76	3.7	21	14	19
Potassium	4.1	5.7	4.5	8.5	4.0	11	3.4	6.5
Total Hardness (as $CaCO_3$)	405	528	460	818	252	383	228	259
Carbonate	0.0	0.0	0.0	0.0	0.0	10	0.0	0.0
Bicarbonate	420	451	400	511	287	366	281	286
Sulfate	78	210	155	566	23	114	28	65
Chloride	0.5	1.2	1.8	4.5	0.8	1.7	1.3	2.1
Iron	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.02
Manganese	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Nitrate (as N)	0.11	0.05	0.02	0.18	0.63	0.38	0.23	0.02
Fluoride	0.2	0.3	0.2	0.4	0.0	0.7	0.3	0.6
Flow (liters/sec)	14	47	6.8	6.2	40	63	5.4	4.8

Source: Hedges et. al. 1976.

[a]All units are milligrams per liter unless otherwise indicated.

shows a considerable number of shale formations which are highly mineralized. Groundwaters taken from the streambed alluvium (which represent most of the groundwater development) are reflective of the water quality in the stream but usually contain somewhat higher concentrations of dissolved minerals (Rocky Mountain Research, October 1977). (Reference 26).

Groundwater from unconsolidated alluvium and terrace deposit aquifers is hard and the predominant ions are sodium and sulfate. This groundwater is highly variable in mineral content and its suitability varies correspondingly. Groundwater from the unconsolidated deposits generally is suitable for either irrigation or domestic use, but in a few localities the content of dissolved solids exceeds 4,000 ppm and the water is undesirable for most purposes (HKM, October 1977). (Reference 26).

A study by the USGS published in 1976 examined the quality of water found in the alluvial and terrace deposits in the lower Big Horn River Valley (USGS, Hamilton, 1976). A summary of the water quality in alluvium and terrace deposits is shown in Table 4.1.3-11. (Reference 76).

A general indication of the chemical quality of groundwaters on the reservation may be obtained from Tables 4.1.3-12 and 4.1.3-13 which give results of tests of well water in the lower Big Horn River Valley. These tables also indicate the geologic source of the water or the particular alluvium or bedrock material from which waters in each instance were taken. Table 4.1.3-12 shows that the wells from the Cloverly Formation and the Parkman Sandstone are markedly better quality than the shallow wells drawing water from the terrace alluvial deposits. The same pattern shows up in the larger number of well samples reported in Table 4.1.3-13. The specific conductance values given in Table 4.1.3-13 are good indicators of total dissolved minerals. Many of the values shown are higher than the acceptable limit for either domestic or irrigation use. (References 27, 58a).

The results shown in Tables 4.1.3-12 and 4.1.3-13 are for the Big Horn River basin. Earlier tests, made about 1920, and reported by Thom and others (1935), were made on the Little Bighorn and Pryor Creek drainage basins. Results are generally

TABLE 4.1.3-11

RANGE OF CONCENTRATION OF SELECTED PARAMETERS IN SAMPLES TAKEN FROM ALLUVIA AND TERRACE WELLS, LOWER BIG HORN RIVER VALLEY, MONTANA

Parameter	Range of Concentration
Calcium	55- 524 mg/l
Magnesium	23- 282 mg/l
Sodium	14-1,706 mg/l
Carbonate & bicarbonate	300- 600 mg/l
Sulfate	202-4,400 mg/l
Chloride	11- 280 mg/l
Nitrate	0- 122 mg/l
Specific conductance	700-8,000 umhos/cm

Source: Hamilton and Paulson, 1976.

TABLE 4.1.3-12

CHEMICAL QUALITY OF GROUNDWATER IN THE LOWER BIG HORN RIVER VALLEY

Well Number[a]	Geologic Source[b]	Well Depth (ft)	Date of Collection	Tempera-ature (°C)	pH	Total Dissolved Solids (ppm)	Total Hardness as $CaCO_3$ (ppm)	Sodium Absorption Ratio (ppm)[c]
2S 32E 26a	Qt_2	21	10/11/21			1,230	449	4.4[c]
3S 33E 8bd	Q_2	28	08/25/80	11.1	7.1	7,240	2,190	12.0
3S 35E 18dc	Kp	120	12/19/45			1,890	67	33.3[c]
4S 32E 2aa	Qt_1	52	08/24/60	12.8	7.0	6,570	2,330	9.0
4S 32E 23dc	Qt_1	45	10/18/21			2,550	1,180	3.5[c]
4S 32E 23dc	Qt_1	30	08/24/60	12.2	7.0	2,500	1,390	2.3
4S 32E 36bd	Qt_1	35	04/15/60	10.0	7.3	3,390	1,310	5.9
4S 32E 36bd	Qt_1	38	04/15/60	10.6	7.1	1,810	982	2.3
4S 32E 36bd	Qt_1	38	08/24/60	11.7	6.9	2,530	1,440	2.3
5S 31E 35cc2	Kev	1,033	08/24/60	20.0	8.0	449	2	57.3
5S 31E 36db	Qt_1	44	04/15/60	8.9	7.5	806	304	3.7
5S 32E 11bb	Qt_1	35	04/15/60	10.1	7.1	5,850	2,300	7.0
5S 32E 20ba	Qt_1	47	04/15/70	8.9	7.2	1,270	712	1.9

[a]Well number is based upon the USGS numbering system which gives townships, range section, and location within the section.
[b]Geologic Source: Kev, Cloverly Formation; Kp, Parkman Sandstone; Qt_1 and Qt_2, terrace deposits 2 and 1.
[c]Sodium-absorption-ratio includes sodium plus potassium.

TABLE 4.1.3-13

SPECIFIC CONDUCTANCE OF WATER FROM WELLS IN THE LOWER BIG HORN RIVER VALLEY

Well Number[a]	Depth (ft)	Geologic Source[b]	Specific Conductance (Micromhos at 25°C)
1S 34E 18bb1	20	Qal	3,500
1S 34E 19bb	10	Qal	1,300
2S 32E 12dd	55	Qt_2	1,600
2S 33E 2ba2	24	Qt_1	1,850
2S 33E 2bb	18	Qt_1	3,200
2S 33E 2cd	11	Qt_1	2,400
2S 33E 3bb	50	Qt_1	2,000
2S 33E 3cc	16	Qt_1	3,400
2S 33E 5bb	30	Qt_1	1,900
2S 33E 9dd	20	Qt_1	1,100
2S 33E 10bc	21	Qt_1	3,600
2S 33E 10cd			2,500
2S 33E 10dc	9	Qt_1	3,300
2S 33E 10dd	50	Qal	4,300
2S 33E 11ba	22	Qal	2,500
2S 33E 15ba	17	Qt_1	2,100
2S 33E 16ca1	9	Qt_1	1,250
2S 33E 18bb	55	Qt_1	1,400
2S 33E 20dc	26.2	Qal	2,000
2S 33E 29dc	11	Qal	1,950
2S 33E 32db	13	Qal	2,600
3S 32E 36dd	70		8,000[c]
3S 33E 5cd	20	Qal	6,200
3S 33E 8cd	28	Qt_1	7,520
3S 33E 8da			6,500
3S 33E 9ba	70	Qt_1	6,500
3S 33E 20ab			600
3S 33E 29ab	80	Qt_1	2,200
3S 33E 29bb	49	Qt_1	8,000[c]
3S 33E 30aa	49	Qt_1	8,000[c]

TABLE 4.1.3-13

SPECIFIC CONDUCTANCE OF WATER FROM WELLS IN THE LOWER BIG HORN RIVER VALLEY (Continued)

Well Number[a]	Depth (ft)	Geologic Source[b]	Specific Conductance (Micromhos at 25°C)
4S 32E 1ad	40	Qt_1	6,200
4S 32E 2aa	52	Qt_1	6,670[c]
4S 32E 12dd	56	Qt_1	8,000
4S 32E 13cc			4,000
4S 32E 23ad1	26	Qt_1	3,000
4S 32E 23dc	30	Qt_1	2,720
4S 32E 24aa	29		4,000
4S 32E 24cc	55	Qt_1	2,900
4S 32E 24dc	7	Qt_1	4,600
4S 32E 25bb	55	Qt_1	2,500
4S 32E 26ad	60	Qt_1	2,600
4S 32E 26bd	35	Qt_1	3,780
4S 32E 26da	45	Qt_1	2,800
4S 32E 35aa	38	Qt_1	2,600
4S 32E 35ab	34	Qt_1	2,000
4S 32E 36bd	38	Qt_1	2,690
4S 32E 36bd	66	Qt_1	2,500
4S 33E 6aa	60		2,600
4S 33E 6cc	50	Qt_1	5,900
4S 33E 7ab	70	Qt_1	1,900
4S 33E 7bb	66	Qt_1	3,800
4S 33E 7db	50	Qt_1	3,100
4S 33E 18ca	80	Qt_1	4,700
5S 32E 17cc	33	Qal	1,750
5S 32E 19da	32	Qal	2,300
5S 32E 20ba	47	Qt_1	1,640
5S 32E 29aa	65	Qt_1	1,400
5S 32E 30aa1	45	Qt_1	2,400
5S 32E 30aa2	25	Qt_1	2,000
5S 32E 30bb	8	Qal	2,300
5S 32E 30dd	60	Qt_1	2,400
5S 32E 31aa	37	Qt_1	3,200
6S 31E 11dc	30	Qt_2	1,000
6S 31E 16dc	395	Kcv	840

TABLE 4.1.3-13

SPECIFIC CONDUCTANCE OF WATER FROM WELLS IN THE LOWER BIG HORN RIVER VALLEY (Continued)

Well Number[a]	Depth (ft)	Geologic Source[b]	Specific Conductance (Micromhos at 25°C)
5S 31E 35bd	50		2,400
5S 31E 35cc2	1,033	Kcv	825
5S 31E 36ad	50		1,450
5S 31E 36db	44	Qt_1	1,180
5S 32E 2aa	38	Qt_1	3,100
5S 32E 2ad	43	Qt_1	5,900
5S 32E 9ba	25	Qt_1	2,200
5S 32E 10bc	100	Qt_1	2,300
5S 32E 10bd	45	Qt_1	2,300
5S 32E 11bb	35	Qt_1	6,030
5S 32E 16dd	80	Qt_1	1,800

[a]Well number based on USGS numbering system which gives township, range, and location within the section.
[b]Geologic source: Qal, Alluvium; Qt_1 Quaternary Terrace deposit 1; Qt_2, Quaternary Terrace deposit 2; Kcv, Cloverly Formation.
[c]Meter scale goes only to 8,000.
Source: Hamilton and Paulsen, 1968.

consistent with those shown in Tables 4.1.3-12 and 4.1.3-13—the waters from terrace deposits and shallow alluvium are highly mineralized, with the mineral content increasing from south to north on the reservation. Waters from the Cloverly, Parkmam, and Morrison formations are considerably better and usually within acceptable limits for domestic and irrigation use.

For example, water from the Parkman Sandstone of the Montana Group is characterized by extreme softness (low calcium and magnesium concentration) and very high sodium content. The principal anion is sulfate, although the concentration of bicarbonate equals that of sulfate. Thus, water from the Parkman Sandstone in the lower Little Big Horn River valley may be described as essentially a solution of sodium sulfate and bicarbonate. Water from the Cloverly Formation is similar in composition to water from the Parkman Sandstone, except that the percentage of bicarbonate plus the carbonate slightly exceeded the percentage of sulfate. Water from the Claggett Shale Member of the Cody Shale is similar to water from the Cloverly Formation, except the percentage of bicarbonate is almost double the percentage of sulfate. Although the water from these bedrock aquifers in the southern part of the area is suitable for domestic and industrial uses, its high percentage of sodium makes it undesirable for irrigation (HKM, October 1977). (Reference 26).

A well completed into the Colorado Group near the northern reservation boundary in the general area of candidate Sites 1 and 1A encountered water having a total dissolved solids content of over 24,000 ppm. The very high dissolved solids content makes such water generally unusable (Rocky Mountain Research, October 1977). (Reference 26).

The aquifers of Mississippian age—specifically the Mission Canyon or Madison Limestone—have not been tested on the Crow Reservation. A well drilled to the Madison at the Westmoreland Resources mine site, directly north of the reservation, and a well at Colstrip, northeast of the reservation, both encountered calcium sulfate-type water. A well in the Soap Creek oil field, west of the study area, also flowed calcium sulfate-type water from the Madison (BIA, Coal Development EIS).

(Reference 5).

Available analyses of groundwater quality in the alluvium of Youngs and Tanner creeks indicate high levels of several constituents, as shown in Table 4.1.3-14. Alluvial groundwater in Tanner Creek is considerably higher in TDS than Youngs Creek alluvial groundwater. Levels of magnesium, sodium, and sulfate are significantly elevated in Tanner Creek alluvial groundwaters. Magnesium is the primary cation in both groundwaters, bicarbonate is the primary anion in Youngs Creek groundwaters, and sulfate is the primary anion in Tanner Creek groundwaters. The levels of TDS and sulfate in both groundwaters are above EPA Secondary Drinking Water Standards. All EPA Primary Drinking Water Standards were met in all analyses, except for the slightly elevated lead concentrations found in Tanner Creek wells. Although the sodium absorption ratios of these waters are generally below the levels at which irrigation problems are expected to occur, the high sodium concentrations may cause problems if water is applied by sprinklers (Bouwer, 1978). In addition, industrial use of these waters, as well as waters from the coal bed aquifers, may be limited by the high hardness and bicarbonate levels. (Reference 8).

Groundwater quality in the coal seams is extremely variable, and TDS levels in the groundwater are significantly higher than TDS levels of surface waters as shown in Table 4.1.3-15. These waters can be characterized as a sodium bicarbonate type. A comparison of these and other data with the EPA Primary Drinking Water Standards indicates that all standards are met. However, test data have shown that Secondary Drinking Water Standards for TDS and sulfate are consistently exceeded. Thus, use of these waters for irrigation would be severely limited because of the high levels of TDS and sodium. The high levels of TDS and sulfate would also severely limit human consumption.

TABLE 4.1.3-14

WATER QUALITY IN THE ALLUVIUM

Parameter[a]	Youngs Creek	Tanner Creek[b] Average	Tanner Creek[b] Range
Date	03/05/76		
Location	9S.38 E. 25 dacc		
Temperature (°C)	9.5	7.0	- —
pH (laboratory) (units)	7.9	—	7.8 - 8.0
Specific conductance (u mhos/cm)	1370	2153	2000 - 2180
Total dissolved solids	928	1713	1540 - 1936
Calcium	91	135	110 - 150
Magnesium	98	201	179 - 220
Sodium	86	126	94 - 155
Potassium	9.4	12	-
Total hardness (as $CaCo_3$)	634	1167	1099 - 1210
Carbonate	0.0	0.0	-
Bicarbonate	592	559	500 - 617
Sulfate	321	940	814 - 1066
Chloride	4.9	6.8	3.7 - 10
Total alkalinity (as $CaCO_3$)	485	459	410 - 506
Iron	0.14	0.17	0.02 - 0.28
Manganese	0.01	0.03	0.01 - 0.07
Nitrate (as N)	1.59	0.59	0.23 - 0.90
Fluoride	0.7	0.3	0.2 - 0.4

[a]All units are milligrams per liter unless otherwise indicated.
[b]Sampled wells included 9S.38E.24cabc (10/15/72), 9S.39E.20bccd (9/4/76), and 9S.39E.20bccd (3/4/76).

Source: Hedges et al., 1976.

TABLE 4.1.3-15
WATER QUALITY IN THE COAL BED AQUIFERS

Parameter[a]	G Bed[b]		M Bed[c]		O Bed[d]	
	Average	Range	Average	Range	Average	Range
Temperature (^{o}C)	14.8	14.5-15.0	—	12-15	10.8	10.5-11
pH, units (laboratory)	—	7.5-8.3	—	7.8-9.1	—	8.0-9.4
Specific Conductance[e]	2940	1890-3990	1558	638-2440	1890	1460-2650
Total Dissolved Solids	2039	1310-2767	1167	393-1723	1249	888-1764
Calcium	41.2	8.4-74	26.3	3.5-99	4.7	4.4-5.0
Magnesium	72.7	6.4-139	52.2	0.2-208	3.6	1.6-7.3
Sodium	620	215-1025	319	20-521	401	365-638
Potassium	—	8.3	6.9	2.9-12	4.3	2.9-5.8
Total Hardness (as $CaCO_3$)	401	47-755	282	10-1116	27.0	18-43
Carbonate	0.0	0.0	21	0-58	50	0-79
Bicarbonate	1387	1016-1758	633	312-1017	870	810-926
Sulfate	581	332-829	404	17-975	257	21-630
Chloride	20	10-29	5	2.8-7.9	6.9	4.3-11.6
Total Alkalinity (as $CaC0_3$)	1138	833-1442	560	284-849	797	759-837
Iron	0.27	0.12-0.41	0.03	0.01-8.4	0.06	0.01-0.18
Manganese	0.02	0.01-0.04	0.02	0.01-0.11	0.01	0.01
Nitrate-N	0.39	0.02-0.75	1.17	0.02-3.48	0.66	0.07-1.78
Floride	1.80	0.7-2.9	1.5	0.3-3.4	2.3	1.7-3.1

SOURCE: Hedges et al. 1976.

[a]All units are milligrams per liter unless otherwise indicated.

[b]Based on analyses from the following wells (dates in parentheses): 9S.38E10 (3/18/76) and 9S.39E.29 (3/10/76).

[c]Based on analyses from the following wells (dates in parentheses): 9S.38E10 (3/17/76, 9S.38E.22 (4/25/73, 9S.38E.23 (4/18/72),
9S.38E24 (6/14/74), 9S.38E.24 (10/15/72), 9S. 38E. 25 (4/24/73), 9S. 38E.25 (6/11/73), 9S.39E.26 (4/23/73), 9S.38E.27 (6/13/74).

[d]Based on analyses from the following wells (dates in parentheses): 9S.38E.24 (4/26/73), 9S.38E.27 (6/12/74), and 9S.39E.29 (3/9/76).

[e] umhos/cm.

4.1.4 Physiography and Land Use

4.1.4.1 Site 1

The candidate plant Site 1 is located in the northwestern portion of Big Horn County, Montana, in the unglaciated part of the Missouri Plateau section of the Great Plains physiographic province. The area is a transition zone between the mountains in the west and the plains to the east. The Bighorn Mountains, with elevations of 9,000 feet above sea level are to the south. The Pine Ridge Hills are to the north. The Yellowtail dam is due south. The immediate area is characterized by hills, high gravel terraces, fans, and benches. They are mantled with gravelly mountain sediments, valley fill, loess, and reworked old alluvium. These materials are formed from weathering of shale and sandstone of the Colorado and Montana geologic groups.
This site is located on a relatively narrow and somewhat rounded natural divide that separates it into two drainage areas. Drainage area of the western portion of the plant site slopes to the northwest as part of the Yellowstone River drainage area. Fly Creek, a tributary of the Yellowstone River, passes through the northwest corner of the plant site and flows north. Drainage to the east is received by the Bighorn River. Onsite drainage in the eastern sector is due to an intermittent stream, the North Fork Two Leggins Creek. It flows eastward and empties into the Bighorn River. Elevation on Site 1 ranges from about 3,240 to 3,360 feet above sea level.

Approximately 960 acres will be occupied by the proposed synfuels plant. The existing land use for this site is for the production of winter wheat. The Montana Department of Agriculture reported in the 1980 annual Montana Agricultural Statistics that winter wheat yields were 26.1 bu/acre. The wheat is harvested in July and replanted in early September. The stubble field may be grazed in the interim.

4.1.4.2 Site 23

Candidate Site 23 is situated in the extreme southeastern corner of the Crow Reservation. It is located in an area of narrow stream valleys bordered by narrow, flat-topped plateaus. Ponderosa pine trees grow at the higher elevations. The area is on the eastern slope of the Wolf Mountains, thus the local drainage is mainly to the east. The site is situated on a flat-topped plateau. Immediate site drainage is to the southwest into Tanner Creek and the northeast drainage is received by Squirrel Creek. Dry Creek drains the eastern portion of the site. Site elevation varies from approximately 4,100 to 4,400 feet MSL.

The primary use of this area is for livestock grazing. It is used in part also by wildlife. The 1977 Soil Conservation Service (SCS) Survey indicates it can be utilized for pasture planting of alfalfa, crested wheatgrass, and pubescent wheatgrass. Approximately one section of the land will be occupied by the proposed plant.

4.1.5 Soils and Vegetation

4.1.5.1 Soils

The soil descriptions herein were derived from the U.S. Department of Agriculture Soil Survey of Big Horn County (1977). For the purposes of this report, the SCS data suffice. Soils series, mapping units, and soil classification descriptions are located in Appendix A-4. More intensive field studies and laboratory analyses are recommended as part of the preoperational monitoring program once a plant site is selected. Appendix A-4 contains the engineering properties of the two candidate sites. (Reference 55).

Soils in candidate Site 1 are young soils as indicated by small soil formation patterns, low fertility, and extremes in chemical and physical properties. They are formed in alluvium and in weathered parent material of shale, sandstone, and siltstone. Soils in the drier zones are formed from transported parent material. Glaciers, significant in soil formation in Montana, were not a factor in this particular area. The soil types presented in this section are generalized and the soil series identified are subject to change as more field data are collected. Likewise, the soil series and mapping unit description (Appendix A-4) depict typical aspects and should not be applied as actual onsite description. The soils of this site are typical of the gentle, undulating hills and terraces of Big Horn County. These soils are shallow to deep, nearly level to very steep, and gently undulating to hilly. They are found on fans, foot slopes, terraces, and sedimentary uplands. The heavy, fine-textured shallow clay soils on sedimentary uplands and hills are grayish-brown silty clay and light olive-gray clay. They are underlain by pale-olive clay at a depth of 18 in. Soils on terraces, fans, and foot slopes that are nearly level to strongly sloping are also clay with about 2 in. of gray-brownish silty clay underlain by pale-olive clay. Seven different soils series and 13 mapping units were found on the proposed site (Table 4.1.5.1 and Figure 4.1.5-1). Since the parent material is mostly clay, the soils are not very complex. Average annual precipitation is 10 to 14 in. and the frost-free period is 90 to 125 days. Although some of the area is classified as generally unsuitable for cultivation, the site is used for small grain growing. Dry land farming is practiced.

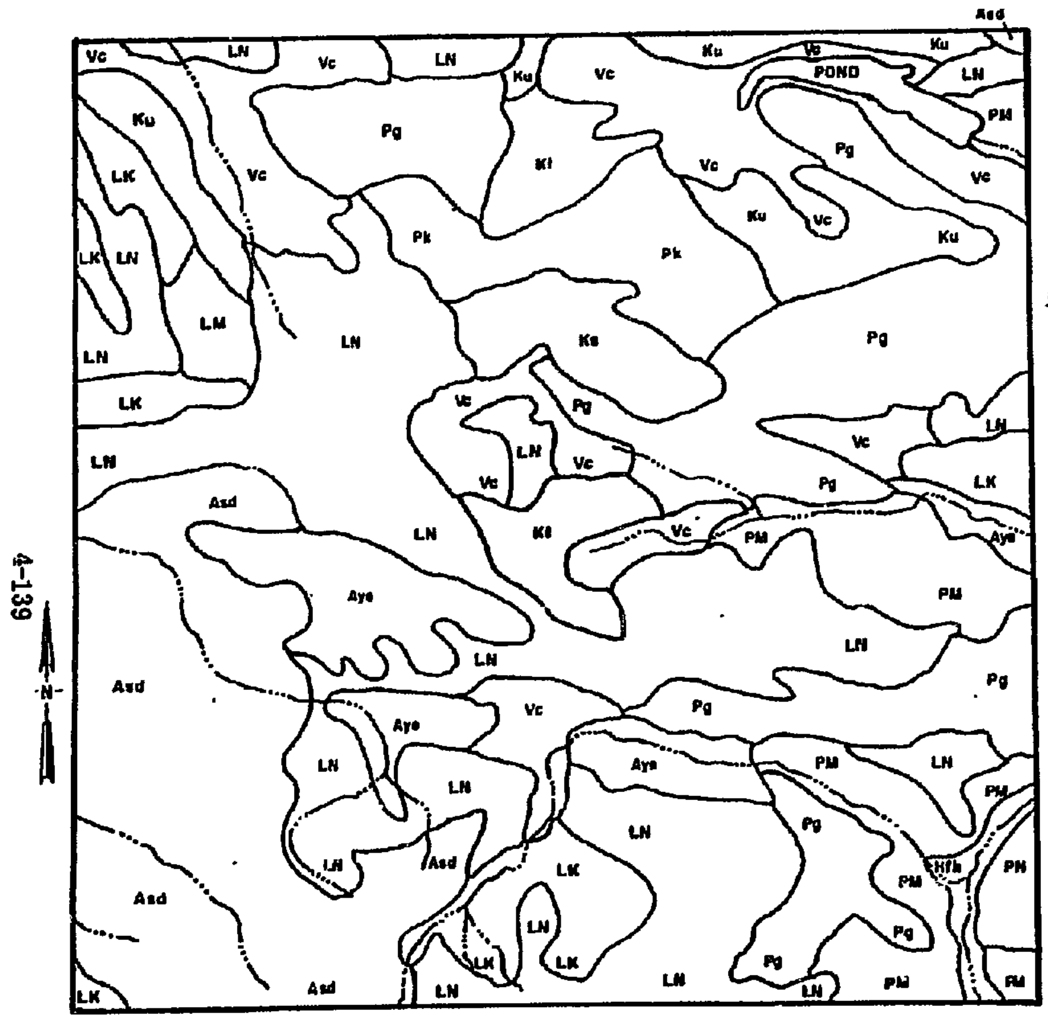
The soils along the pipeline, railroad, and roads are similar to the soil described above. The surface soils are about 3 in. deep with limited development and light in color. They are formed in alluvium and in material weathered from shale. The soil is low in organic matter and hard and massive when dry. The subsoils are 3 to 20 in. thick and composed of grayish-brown silty clay. The brown and silty clay loams are deeper and grayish-brown. The underlain material is pale yellow silty clay for the thin soils. The deeper soils are underlain by light brownish-gray silt loam or olive-gray silty clay loam. The soils are suitable for rangeland and dryland crops. Soils along the banks of the Bighorn River are 2 to 12 in. deep. Subsoils may be absent. The underlain material is usually light yellowish and pale olive clay or loam. These soils may be subject to flooding. Irrigated cropland is the usual land use. The more dissected parts along the river are shale escarpments that erode easily. Along the river channels are gravel bars, low islands, and eroded flood plains that are nearly barren. The alluvial material is mainly sand, loam sand, gravelly sand, and sands.

Candidate Site 23 soils are shallow and moderately deep, gently undulating to hilly, and strongly sloping to very steep, well-drained soils. Shales outcrop on sedimentary uplands. Rock outcrops can also be noted on the site. The predominate soils are formed from calcareous clay loam and silty clay loam tablelands. Runoff is medium. Shallow drainages traverse the area, hence, the erosion hazard is moderate. The soil is suited to dryfarmed crops, hay, wildlife, recreation,

TABLE 4.1.5.1

SOILS OF PROPOSED PLANT SITE 1

Soil Series/Mapping Units	Acreage	Percent
Allentine Asd	373.8	14.6
Arvada Aye	145.9	05.7
Haverson Hfh	15.4	0.6
Kyle Ks, Kt, Ku	243.2	9.5
Lismas LK, LM, LN	793.6	31.0
Pierre Pg, Pk, PM, PN	683.5	26.0
Vananda Vc	284.1	11.1
Perennial Pond	20.5	0.8
Total	2,560	100



LEGEND

SERIES	MAPPING UNITS
Allentine	Asd
Arvada	Aye
Haverson	Hfh
Kyle	Ks, Kt, Ku
Lismas	Lk, LM, KN
Pierre	Pg, Pk, PM, PN
Vananda	Vc

Source: USDA, SCS, 1977

FIGURE 4.1.5-1

SOILS DISTRIBUTION, SITE 1, CROW RESERVATION

watershed, and rangeland grazing and is located in the 10 to 14 in. precipitation zone. The surface layer is light brownish-gray silty clay loam about 2 in. thick. The subsoil is grayish-brown, brown, and light olive-brown silty clay loam and silty clay about 11 in. thick. The substratum is light brownish-gray and pale olive silty clay loam, silty clay, and clay that contains a few shale chips in the lower part. Clay shale is at a depth of about 33 in. The site contains five soil series and seven mapping units (Table 4.1.5-2 and Figure 4.1.5-2). The soil series and mapping units are described in more detail in Appendix A-4.

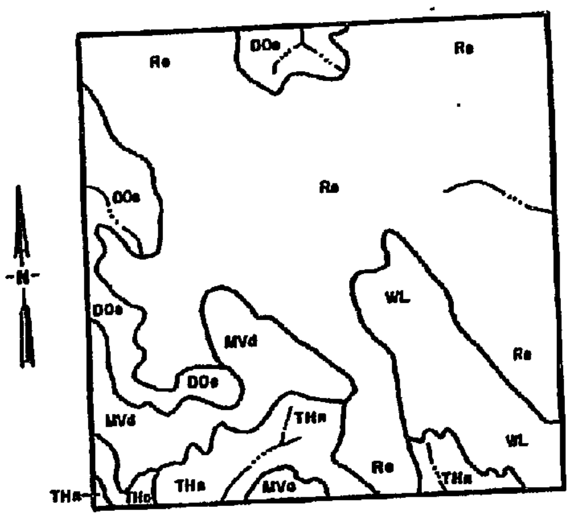
Approximately 690 acres will be occupied by the pipeline and access roads. The largest acreage to be affected will be the soils of the Korchea-Farnuf-Savage Association comprising about 269 acres. The soil association consists of deep, nearly level to steep, well-drained soils on flood plains, terraces, fans, and foot slopes (see Table 4.1.5-1). Korchea comprises about 40 percent of the association and is grayish-brown loam about 9 in. thick. It is underlain by light brownish-gray loam and silt loam. Farnuf soils comprise about 20 percent of the association and are very dark grayish-brown loam about 5 in. thick. The subsoil is grayish-brown and pale brown loam and silt loam. It is underlain by light yellowish-brown loam. Savage soils comprise about 20 percent of the association and are dark grayish-brown silt loam about 2 in. thick. The subsoil is grayish-brown silty clay loam and silty clay about 21 in. thick. It is underlain by olive silty clay. Twenty percent of the rest of the association is composed of other soil series. Management concerns of these soils are protection from spring flooding, proper irrigation, and erosion control. Irrigated crops are corn, sugar beets, small grain, and hay.

The Doney-Reeder-Wayden Association comprises about 193 acres of the pipeline and road easements. The association consists of moderately deep and shallow, gently undulating to very steep, well-drained soils on sedimentary uplands. The assoication is made up of about 30 percent Doney soils, 20 percent Reeder soils, 20 percent Wayden soils, and 30 percent of others. Doney soils are grayish-brown loam about 6 in. thick. They are underlain by light yellowish-brown and pale yellow loam. Shale and sandstone are at a depth of about 24 in. Reeder soils are dark grayish-brown loam about 4 in. thick. They are underlain by pale-brown clay loam and loam. Shale

TABLE 4.1.5-2

SOILS OF PROPOSED PLANT SITE 23

Soil Series/Mapping Units	Acreage	Percent
Doney DOe	60.8	9.5
Midway MVa, MVd	60.1	9.4
Renohill Re	398.1	62.2
Thedalund THn, THo	55.7	8.7
Wayden WL	65.3	10.2
Total	640	100



LEGEND

SERIES	MAPPING UNITS
Doney	DOe
Midway	MVa, MVd
Renohill	Re
Thedaland	THn, THo
Wayden	WL

Source: USDA, SCS, 1977.

FIGURE 4.1.5-2

SOIL DISTRIBUTION, SITE 23, CROW RESERVATION and sandstone are at a depth of about 30 in. Wayden soils are grayish-brown silty clay loam about 5 in. thick. The substratum is light brownish-gray silty clay loam. Shale is at a depth of about 19 in. The association management includes maintenance or improvement, rangeland vegetation, and control of erosion.

The Wayden-Regent Shale Outcrop Association comprises about 138 acres. It consists of shallow and moderately deep, gently undulating to hilly, and strongly sloping to very steep, well-drained soils and shale outcrop on sedimentary uplands. The association is composed of 40 percent Wayden soils, 25 percent Regent soils, 15 percent shale outcrop, and 20 percent other soils. Wayden soils' description is the same as above. Regent soils are grayish-brown silty clay loam about 3 in. thick. The subsoil is grayish-brown and pale olive silty clay loam about 13 in. thick. It is underlain by light gray silty clay loam. Shale is at a depth of about 26 in. Management of the soils includes maintenance or improvement of rangeland vegetation and control of erosion. The land use is range.

The Beauvais Association consists of deep, gently undulating to hilly, well-drained soils on terraces, fans, foot slopes, and loess-covered hills. The association (34 acres) is made of 40 percent Beauvais soil, 30 percent Colby soils, and 30 percent other soils. Beauvais soils are grayish-brown silty clay loam about 5 in. thick. They are underlain by light gray and light brownish-gray silty clay loam. Colby soils are grayish-brown silt loam about 5 in. thick. They are underlain by light brownish-gray silty clay loam. Soil management includes protection from spring flooding, erosion control, and maintenance or improvement of rangeland vegetation. The soils are suited for irrigation, although they are normally used for dry-farmed grain and range.

The Midway-Nunn Association consists of 34 acres. It is a shallow to deep, nearly level to steep, and undulating to hilly, well-drained soil on terraces, fans, foot slopes, and sedimentary uplands. The association is made of 45 percent Midway soils, 30 percent Nunn soils, and 25 percent other soils. Midway soils are light olive-gray silty clay loam about 2 in. thick. They are underlain by olive-gray silty clay loam. Shale is at a depth of about 11 in. Nunn soils are grayish-brown silty clay loam about 8 in.

thick. The subsoil is grayish-brown and light olive-brown silty clay and clay loam about 15 in. thick. It is underlain by stratified clay loam, silt loam, and sandy clay loam. The land use is range. Management concerns are maintenance or improvement of rangeland vegetation and control of erosion.

The Pierre-Lismas-Kyle Association is the smallest soil unit to be encountered along the easement—about 21 acres. These soils are shallow to deep, nearly level to very steep, and gently undulating to hilly, well-drained soils on fans, foot slopes, terraces, and sedimentary uplands. The association is comprised of 35 percent Pierre soils, 30 percent Lismas soils, 15 percent Fyle soils, and 20 percent other soils. Pierre soils are grayish-brown silty clay about 3 in. thick. They are underlain by pale olive clay. Clay shale is at a depth of about 29 in. Lismas soils are light olive-gray clay about 1 in. thick. They are underlain by light olive-gray clay. Clay shale is at a depth of about 18 in. Kyle soils are grayish-brown silty clay about 2 in. thick. The subsoil is olive-gray clay and silty clay about 8 in. thick. It is underlain by pale-olive clay. The main concerns pertaining to management are localized protection from spring overflow, erosion control, and maintenance or improvement of rangeland vegetation. The land use is mainly range, but the nearly level to sloping undulating Pierre and Kyle soils are also suited to dry-farmed grain.

4.1.5.2 Vegetation

Candidate Site 1 is used primarily for raising wheat. Because of the close relationship between plants, climate, and soils, range sites can be identified. A combination of soil group names and precipitation zones determines a specific range site. The predominant soils occupy the clayey range site, receiving 10 to 14 in. of precipitation annually. The soils are moderately deep to deep granular clay loam, silty clay loam, silty clay, sandy clay, and clay soils. Western wheatgrass, forbs, and green needle grass are predominant species. Other range sites encountered are Shallow Clay, Dense Clay, and Pan Spots. Appendix A-4 provides further discussion on range sites.

About 62 percent of Site 23 is categorized as Clayey range site. Therefore, the site is similar to Site 1. The land is primarily used as grazing land, and wildlife also inhabit the area. Other range sites are thin hilly and thin breaks. Appendix A-4 describes each range type. About half of the site is classified as being in good condition and the other half as fair (BIA, 1971). The average stocking rate for the area is 3.8 acres per animal unit.

As previously mentioned, the easement for the access roads, railroads, and water pipeline will encompass about 690 acres at Site 23. The majority of the disturbed land will affect the agricultural community. The principal grain crops that are grown in this area are winter wheat and barley. Most of the areas used for grain production are located on relatively level areas on dry uplands. The lands are not irrigated. The Riparian type, located near Bighorn River, consists of a diverse plant composition. The trees and shrubs are cottonwood, box elder, green ash, western chokecherry, and hawthorn. Understory shrubs and grasses are snowberry, wood's rose, Kentucky bluegrass, giant wildrye, streambank wheatgrass, and smooth brome.

The vegetation on the pipeline easement is not described in this report as it actually occurs on Site 23, and the vegetation types presented here should not be considered conclusive. The plant communities described in this report were derived from documents on other projects that are in close proximity to the Crow synfuels project and are, therefore, considered characteristic of the pipeline route. The vegetation information was obtained from studies of proposed coal development (Coennenberg and DePuit, 1979; Rocky Mountain Research Corp., 1977; U.S. Department of the Interior, 1981; and VIN, 1978). It is therefore recommended that a range vegetation inventory study should be conducted on the pipeline route. The inventory should include mapping of vegetation types, identification and listing of species, and measurement of density, composition, cover, and production. The vegetation types or communities are described in the following paragraphs. (References 52, 69, 77).

The information from the above studies was subsequently utilized to assess the vegetation presumed to be along the pipeline route. The route is situated in a transition zone between mixed prairie grassland and eastern Montana ponderosa pine forest. Therefore, the area represents a complex mixture of plant communities.

Riparian vegetation types indicative of drainages traverse the area frequently. The clayey areas are dominated by large sagebrush and the sandy areas by silver sage. The higher elevations with more precipitation consist of ponderosa pine and other trees.

The sagebrush-steppe type occurs on dry areas disturbed mainly by overgrazing practices. Formerly, they were grasslands. The sagebrush once established tends to inhibit other vegetation. Big sagebrush occupy the xeric sites which had retrogressed from sagebrush-grassland or grasslands. The sagebrush-grassland type has a higher diversity and density of other plants, mainly grasses. Where big sagebrush prevail one can find broom snakeweed, rubber rabbitbrush, and fringed sagewort. Grasses occur in small amounts. Grass species are western wheatgrass, sandberg bluegrass, and various annual grasses. In the case of the sagebrush-grasslands; bluebunch wheatgrass, prairie junegrass, and needlegrass occur. Shrubs and half-shrubs would include silver sagebrush. Silver sagebrush are more prevalent where more moisture is available. They can be found in the lowlands near drainages. Other plants in this community are cheatgrass, plains prickly pear, scarlet globemallow, Indian ricegrass, and sand dropseed. Plants that decrease under grazing pressure are prairie junegrass, plains bluegrass, sandberg bluegrass, western wheatgrass, sand dropseed, and Indian ricegrass.

The mixed shrub is similar in soil and available water conditions as the sagebrush type except the land was disturbed to a greater degree. The plant species are the same as those found in the sagebrush type. However, no single shrub species could dominate the area. Other plants occurring here are three-leaf sumac, green needlegrass, needle-and-thread, small soapweed, and curl-leaf mountain mahogany.

The mesophytic deciduous shrub-forb type occurs in the moist upland areas, small drainages, seep-spring areas, and in floodplain areas. The vegetation is varied and dense. The dominant plants are deciduous shrubs, some grasses, and forbs. Three subtypes are found in this community. The upland drainage-seep subtype is found along small drainages, seeps, and springs. Small trees and shrubs dominate these wet sites. They are snowberry, Wood's rose, chokecherry, American plum, and hawthorn. Kentucky bluegrass and western wheatgrass are the major subdominant grasses. Forbs include, but are not limited to, western yarrow, groundsel, horsemint, and wild licorice. The deciduous shrub-grassland subtype is found at higher elevations, since the precipitation is higher and/or moisture accumulates in the depressions. Dominant shrubs are prairie rose and snowberry. Grasses are green needlegrass, Idaho fescue, and needle-and-thread. The floodplain-mud flat subtype is adjacent to periodic flooding. The plant diversity is low. Grasslike plants and mesophytic shrubs are present.

The mid-short-grass prairie types are located on steep sidehills and on well-drained loam and coarse-textured soils. Two community subtypes are found. The loose, fine-textured soil areas have little bluestem, red three-awn, sideoats grama, blue grama, and threadleaf sedge. The shrubs are Porter fleabane, Hood's phlox, fringed sagewort, skunkbush sumac, and western snowberry. The sandy-loam or silt-loam soils are in concave slopes at the heads of ephemeral streams. The area is dominated by prairie sand reedgrass, a sod-former. Western ragweed, sand sagebrush, silver sagebrush, curlycup gumweed, Louisiana sagewort, and Fendler sunflower commonly occupy spaces among the prairie sandreed sods. The mid-short-grass prairie community is relatively stable due to limited grazing because of the steep topography.

The grassland types have the annual and perennial grass dominating. The community is characterized by a large variability in short- and mid-grass species. The perennial grasses are composed of western wheatgrass, bluebunch wheatgrass, needle-and-thread, green needlegrass, Kentucky bluegrass, sandberg bluegrass, prairie junegrass, and Idaho fescue. The dominant grasses that occur in a particular area depend on soil characteristics, aspect, available moisture, relief, and past land-use practices. Idaho fescue prefer high precipitation zones and/or north-facing slopes with wet depressions. Bluebunch wheatgrass dominate the drier slopes. Western wheatgrass and prairie junegrass concentrate on clayey soils, wet sites, and/or in areas consistently grazed. Needle-and-thread may co-dominate a site with bluebunch wheatgrass and western wheatgrass. Blue grama may become a common species on grazed areas in the drier areas. Big and silver sagebrush are common but in lower densities than the xeric areas. The perennial half-shrubs are fringed sagewort, cudweed sagewort, and broom snakeweed. The annual grass subtype occurs where overgrazing or disturbance has taken place and the area is invaded by the annual grasses. Often these areas are near drainages and creek bottoms. Perennial grasses may still be present. Invader grasses are usually Japanese brome and cheatgrass.

The Ponderosa-pine badlands community type are on uplands having rocky soils. Some pine and juniper stands are dense enough to qualify as forests, but usually they are limited to widely spaced savanna-like canopies or individual trees. Understory species vary according to soil and grazing conditions. Mildly grazed nonsaline sites exhibit an association of grasses similar to the mid-short-grass prairie community, dominated by little bluestem, sideoats grama, red three-awn, and bluebunch wheatgrass. Severely used areas or areas with substrates derived from clinker or shale produce an understory dominated by annual bromes, various thistles, and curlycup gumweed. Certain sites possess a well-developed browse-shrub community consisting of skunkbush sumac, western snowberry, Wood's wildrose, western chokecherry, red wildplum, and prickly currant. They form thickets on deep soils along ephemeral streams.

The deciduous riparian type is located near major stream courses offering a mesic environment. The diverse plant composition contains plants which could not survive under more xeric conditions on upland sites in semiarid regions. The overstory is typically dominated by broadleaved trees and large shrubs, which include plains cottonwood, box elder, green ash, western chokecherry, and hawthorn. Major understory shrubs and grasses include snowberry, Wood's rose, Kentucky bluegrass, giant wildrye, streambank wheatgrass, and smooth brome. In marshy sites, cattail and wiregrass become abundant.

Agricultural communities are divided into three types according to irrigation methods. Dryland croplands prevail on benchlands and hilltops. Crops are limited to dryland hay meadows or drought-resistant small grains (crested wheatgrass, Russian wildrye, sweet clover, trefoil, winter wheat, and winter barley). The irrigated lands produce alfalfa and mixed-grass hay. Common grass mixtures include timothy, orchard grass, smooth brome, Kentucky bluegrass, intermediate wheatgrass, and big bluestem. Common legumes in hay production include alfalfa, soinfoin, sweet clover, and trefoil. Areas that are flood-irrigated produce alfalfa, alsike and sweet clover, sainfoin, trefoil, and various other grasses. Corn silage may be grown under these conditions.

4.1.6 Wildlife Resources

4.1.6.1 Site 1 (Including Ancillaries and Right-of-Ways)

Information on the wildlife resources within the proposed areas of impact (Figure 4.1.6-1) is limited to winter aerial surveys conducted by the U.S. Fish and Wildlife Service since 1979. Although various off-reservation studies of wildlife resources have been conducted, primarily on Westmoreland Resource's lands (Tracts I, II, and III), no site-specific studies for the proposed area of impact have been conducted. Therefore, information presented can, at best, be considered preliminary pending future site-specific studies to document the extent of wildlife resources within the proposed area of impact.

Large Mammals

Antelope. Pronghorn antelope are typical inhabitants of the plains and grassland regions of Montana. The largest concentration of antelope (over 100 animals) reported during the winter of 1981 were located in the extreme northern portion of the reservation near Fly Creek (USFWS 1981) which is just west of the proposed area of impact. Grassland habitat appears to be the preferred year-round habitat as evident by the fact that 71 percent of all antelope sightings on Westmoreland's Tract III in 1975 occurred in grassland habitat which is typical of the proposed area of impact. Although documentation on the status of antelope (i.e., seasonal occurrence, population) within the proposed area is limited, available information suggests that concentration and population densities are highest during winter months. The important winter range of antelope is illustrated in Figure 4.1.6-2. (Reference 74).