SUPPORTIVE INFORMATION FOR USNRC
SOURCE MATERIAL LICENSE APPLICATION

FOR A RESEARCH AND DEVELOPMENT PILOT PLANT
THE CLEVELAND-CLIFFS IRON COMPANY

COLLINS DRAW PROJECT

CAMPBELL COUNTY, WYOMING

OCTOBER 1978

Prepared by

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for

THUNDERBIRD JOINT VENTURE PARTNERS

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Texas Eastern Nuclear
Pioneer Nuclear
Cleveland-Cliffs Iron Co.

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ACCOMPANYING FORM NRC-2

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SUPPLEMENTAL DATA SHEET for FORM NRC-2

THE CLEVELAND-CLIFFS IRON COMPANY

1.0 PROPOSED ACTIVITIES

The Cleveland-Cliffs Iron Company, as Manager of the Thunderbird Joint Venture, proposes to conduct a 100 gallon-per-minute pilot uranium in-situ solution mining test in the Pumpkin Buttes Area of Campbell County, Wyoming. This research and development project is designed to evaluate the technical viability and economic feasibility of extracting uranium from a mineralized zone 450 feet below ground level without removing the overburden or sinking a conventional mine shaft and with minimal, temporary surface and subsurface impact.

During the last seven years, in-situ solution mining has seen great progress and change. Solution mining is now a proven method for the recovery of uranium. At this time, there are at least seven commercial plants in operation in South Texas and several pilot plants operating in Wyoming, Colorado, and Texas, and more pilot plants planned for New Mexico and Utah. When geologic and hydrologic conditions are favorable, it is a viable method of mining. Development of solution mining technology may provide a technique for exploiting deposits which are not economic by conventional mining-milling, as well as providing an alternative mining method for deposits which are currently only economically marginal.

Commercial operations are reported to circulate through their plants from 250-2,500 gallons-per-minute of lixiviant, with levels of dissolved uranium ranging from 10-800 milligrams-per-liter, and controlling within their respective mine areas from 5-25 million gallons of leach solution. Most of these operations use alkaline lixiviants such as ammonium carbonate/bicarbonate or sodium bicarbonate/carbonate, with variations in pH and concentration.

The Thunderbird Joint Venture has several uranium deposits that are not exploitable by conventional means. An appraisal of one of these deposits, designated as the "Collins Draw Deposit," by numerous hydrological and metallurgical tests, indicates that a high pH, ammonium carbonate/hydrogen peroxide lixiviant should yield excellent recovery in a relatively short period of time, and hence, make commercial development of Collins Draw and many other deposits feasible.

1.1 Longevity of Operation

The operation of the pilot plant and well field is scheduled to start May 1, 1979 and last approximately thirty months. The first twelve-month period will emphasize the research data that is needed to evaluate potential commercial application. The final eighteen months are tentatively planned for demonstration of ground water restoration. If ground water restoration is demonstrated earlier in the program, then the

remaining time will be utilized for the collection of more research data and the preparation of a commercial license application for the Collins Draw Area.

Restoration of a mined out pattern area will commence as soon as practical. At this time, it is speculated that the length of time required to mine uranium from a pattern area is 2 to 3 months. Therefore, the first pattern could be in a restoration mode within 2 or 3 months after mining begins and the pattern could be fully restored before the end of the first twelve months.

1.2 Chemical and Physical Description of Ore Processing

The test lixiviant will be a water-based solution of ammonium carbonate and hydrogen peroxide. Laboratory tests have shown this lixiviant to be very effective in selectively reacting with the uranium in the mineralized zone, which is in the form of sooty pitchblende, to form a stable ammonium uranyl tricarbonate complex which is readily transported in solution to the recovery plant. The uranium in the pregnant lixiviant is separated from the lixiviant then concentrated, purified, precipitated, and dried in the recovery plant to form the final yellow cake product. The complete ore treatment process is discussed in Section 3.0.

The chemical and physical processing of the uranium depends on the chemical oxidation, in-situ, of the insoluble tetravalent uranium ion to the hexavalent uranium ion which then forms, in the presence of carbonate, a soluble uranyl tricarbonate complex for transport to the surface. Once the uranium is above the ground and in the recovery plant, the soluble uranyl tricarbonate complex is concentrated by ion exchange and precipitated to create the final yellow cake product. The yellow cake is then dried and shipped from the site in drums. There is no grinding or crushing of crude ore or product associated with the process and no tailings waste in the conventional sense.

1.3 Processing Rate

The recovery plant is designed for a liquid capacity of 100 gallons-per-minute (gpm) and a uranium production capacity of 25 to 300 pounds-per-day. Due to the anticipated great variability of uranium production per day, a large amount of flexibility was designed into the recovery plant to allow operations to continue over this very broad range, if the well field production will allow it.

1.4 Quantity to be Processed

Recovery of uranium from commercial solution mines is reported to vary from 40-95%. Recovery depends on the ore body size, grade, depth, the

water quality, several fluid flow parameters such as permeability and porosity, type of uranium mineralization, content of soluble interfering metals such as molybdenum and calcium, the metallurgical scheme, the mode of operation in the well field, and the quality of the operating personnel. Adequate uranium recovery depends on the right combination of the above factors.

Prior to research and development work, it is difficult to ascertain the quantity to be processed by the in-situ technique. However, the amount anticipated in plant design is 25 to 300 pounds-per-day.

1.5 Operating Plans and Schedules

The pilot plant will be capable of 24 hr-per-day, 7 day-per-week continuous operation and will be operated in this manner as often as possible. Two to four operators per shift are planned with additional supervisory and support manpower, as required, on day shift. The well field, which is equivalent to the mine area in a conventional operation, will be drilled in segments or patterns. The first pattern area will be operated until production is too low to continue operation of Pattern Number 1. The second pattern area will be ready to begin operation when the first area enters a restoration phase. Pattern Number 2 will be in operating mode and producing uranium while Pattern Number 1 is being restored. Depending upon results, additional patterns may be required to complete the pilot test and more than one pattern area may be in production at any one time, but the entire well field is not expected to exceed 1-1¼ acres. Approximately 1-1.3 million gallons of lixiviant will be controlled within any one pattern area during the production phase of the test.

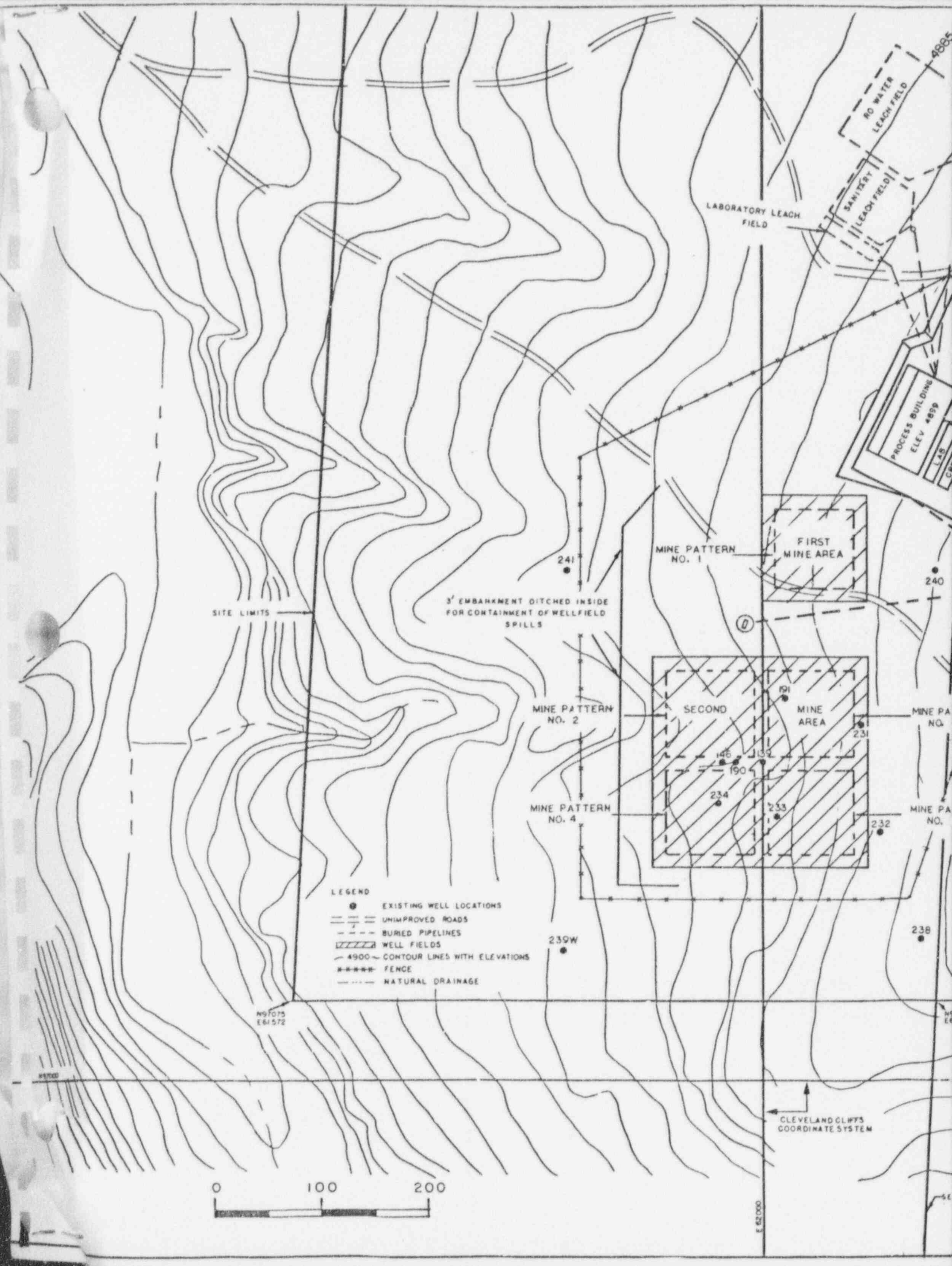
If permits and licenses can be obtained by February, 1978, test operations will commence on April 1, 1979, and last 12 to 30 months, depending upon the success of the research effort and time required to demonstrate restoration.

2.0 SITE DESCRIPTION

The site is located in Campbell County, Wyoming, approximately 85 miles northeast of Casper in the Pumpkin Buttes Area of the northern Powder River Basin. The complete surface plan is shown on Figure 1. Additional information regarding the land status is included as Appendix A.

2.1 Project Site - Disturbed Area

The total permit area requested is 23 acres (9.31 hectares) and direct surface disturbance will be approximately 3 acres (1.21 hectares). The well field area will encompass 1-1¼ acres (.51 hectares).



RO WATER LEACH FIELD
SANITARY LEACH FIELD
LABORATORY LEACH FIELD
PROCESS BUILDING ELEV 4899
LAB
FIRST MINE AREA
MINE PATTERN NO. 1
241
240
3' EMBANKMENT DITCHED INSIDE FOR CONTAINMENT OF WELLFIELD SPILLS
SITE LIMITS
MINE PATTERN NO. 2
SECOND
MINE AREA
191
231
146
190
132
234
233
232
MINE PATTERN NO. 4
LEGEND
EXISTING WELL LOCATIONS
UNIMPROVED ROADS
BURIED PIPELINES
WELL FIELDS
4900 CONTOUR LINES WITH ELEVATIONS
FENCE
NATURAL DRAINAGE
239W
238
N97075
E61572
CLEVELAND CLIFFS COORDINATE SYSTEM
0
100
200
E 62000

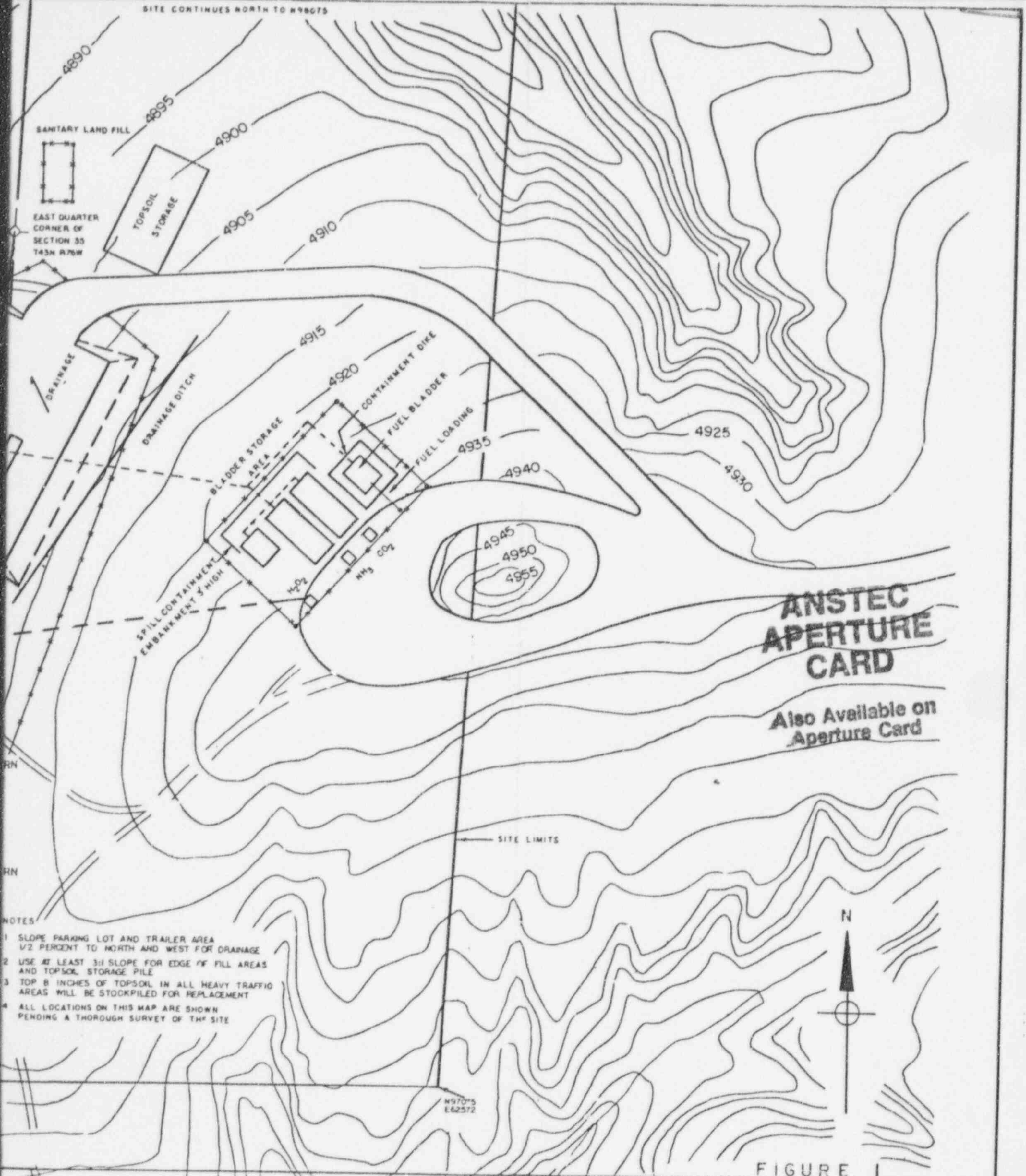


FIGURE 1

SURFACE SITE PLAN

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BEHRENT ENGINEERS
DENVER, COLORADO

2.2 Geography and Demography

2.2.1 Geography

The land on which the Collins Draw in-situ project will be developed is in southwestern Campbell County, Wyoming. A map of the overall area is shown as Figure 2. The project site is approximately 85 road-miles north of Casper, Wyoming, and approximately 65 road-miles southwest of Gillette, Wyoming.

The actual project site is included in the following township and sections as indicated on the location maps shown in Figure 3.

Township	Range
43N	76W
Sections	
#35	
#36	

The topography of the area is generally that of a rolling plain with surface drainage patterns trending away from a group of small mesas known as the Pumpkin Buttes. The Pumpkin Buttes (6,000 ft.) are considered the most prominent terrain feature of the Powder River Basin. The general elevations of the project area, excluding the Pumpkin Buttes, range from 4,800 feet to 5,400 feet.

The streams in this area show intermittent flow during normal years and are headwater drainage to the Powder River flowing toward the north and to the Belle Fourche River flowing toward the east. See Figure 4

2.2.2 Demography

The Cleveland-Cliffs' project site is located near the Pumpkin Buttes in southwestern Campbell County, Wyoming as shown on the Regional Setting Map, Figure 1. No other communities exist within 30 miles of the project area. The communities of Midwest, with an estimated population of 400, and Edgerton, with an estimated population of 600, are located approximately 35 miles southwest of the project in Natrona County. These communities, located approximately one mile apart, are situated in the historic Salt Creek Oil Field. The community of Wright, in Campbell County, is located approximately 40 miles east of the project area. It is being developed by the Atlantic Richfield Company for workers at a nearby coal mine; 1,800 residents are anticipated. Gillette, the county seat of Campbell County, is located approximately 65 miles northeast of the project area with a population of approximately 12,300. Casper, the county seat of Natrona County, is located 85 miles southwest of the

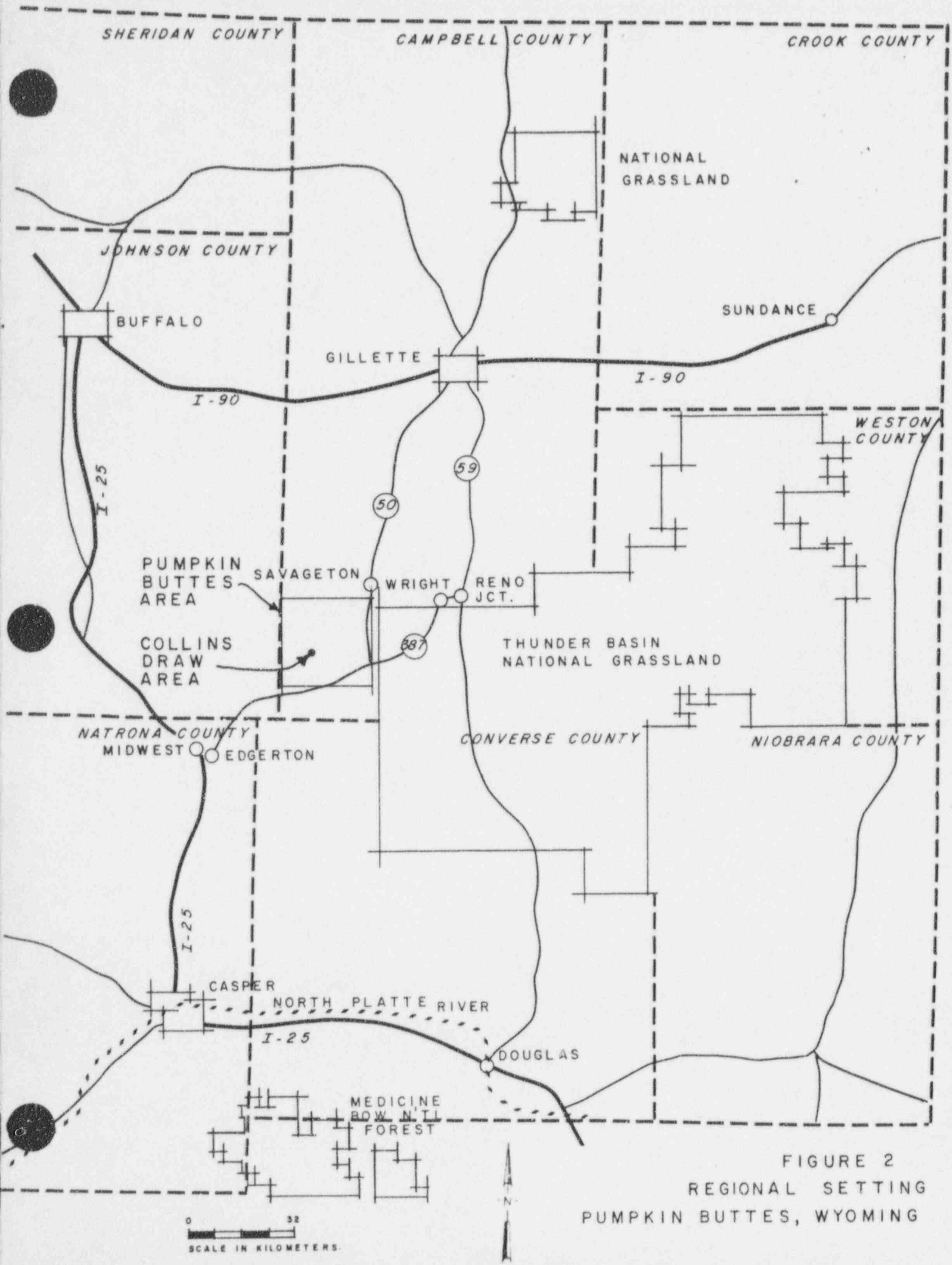
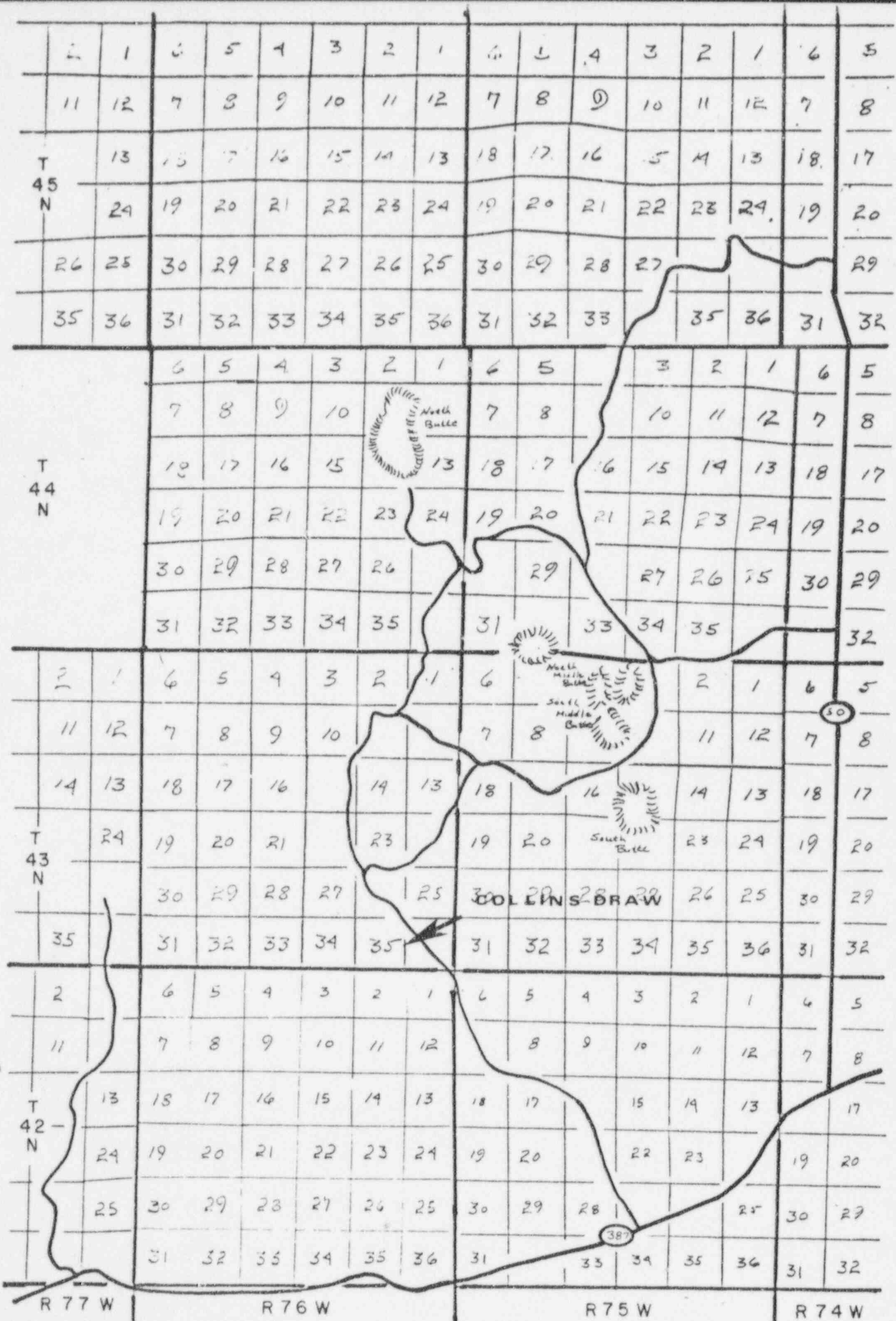
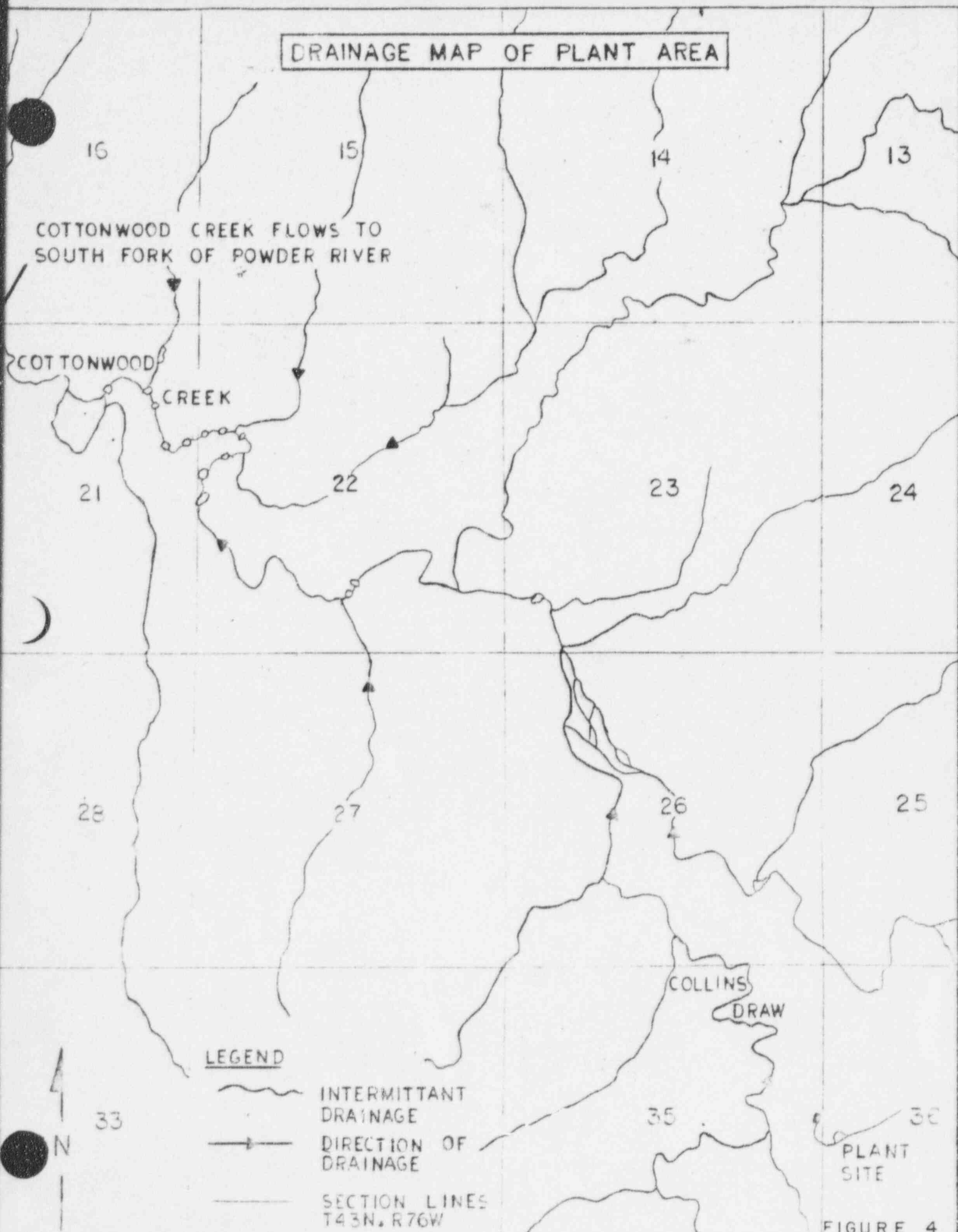


FIGURE 2
REGIONAL SETTING
PUMPKIN BUTTES, WYOMING



SECTION MAP
FIGURE 3


DRAINAGE MAP OF PLANT AREA
16
15
14
13
COTTONWOOD CREEK FLOWS TO
SOUTH FORK OF POWDER RIVER
COTTONWOOD
CREEK
21
22
23
24
28
27
26
25
COLLINS
DRAW
33
35
36
PLANT
SITE
N
LEGEND
INTERMITTANT
DRAINAGE
DIRECTION OF
DRAINAGE
SECTION LINES
T43N, R76W
SCALE: 1" = 2000'
FIGURE 4

project area and is a major retail and wholesale trade center for Wyoming. It has a population of approximately 50,000 and is considered by some to be the largest city in the state. All population approximations were made from the 1970 census and include the growth since that census.

Inasmuch as the above cities and towns will most likely provide the cultural environment for workers and their families at the uranium project, these are being continually surveyed to update all information about present and future social and economic conditions.

2.2.3 Land Use

Land of the project area was first used as habitat and space for large herds of grazing animals, principally the buffalo. In the mid to late 1800's, large livestock ventures were introduced into the Powder River Basin. English-controlled cattle ranches spread out over the land. These evolved into homestead ranches which, in the study area, average approximately 70,000 acres, including Taylor Grazing Land administered by the Bureau of Land Management. Livestock grazing and ranching has been the principal activity along with a scattering of cultivated use, primarily dry farming.

Industrial use has been introduced in the past 25 years. Uranium discoveries of the late 1950's set the stage for the future of that industry. Numerous gas and oil leases were issued in the past 10 years. Conversion of use is now taking place after almost 100 years of ranching.

Major land ownership remains in the hands of the ranching families and at this time will remain so, although leasing, rentals, and mutual agreements have taken place to accommodate the development of mineral resources.

2.3 Meteorology

The climate of the study area is directly influenced grossly by the major topographic features, the Coastal and Rocky Mountain Ranges. But, most specifically, it is influenced locally by the Big Horn Mountains which flank the western edge of the basin in which the project site lies. The mountain ranges are situated at right angles to the prevailing westerly air flow which affects wind, precipitation, and temperature patterns. Pacific air currents drop much of their moisture prior to entering eastern Wyoming. According to the Koppen Climate Classification System, the basin has a middle latitude steppes climate shut off by mountains from invasions of maritime air masses and is semi-arid with great annual temperature variations between summer and winter. The major weather stations for detailed information and analyses which

are available for the project site are located at Gillette and Douglas. Information from these stations is contained in Table 1. A comparison of available climatological data for some other selected stations located in proximity to the project area is made on Table 2.

2.3.1 Precipitation

Precipitation in the project area is influenced by its close proximity to the Big Horn Mountains. Generally, rates will diminish as weather moves in an easterly direction from the mountain and in a southerly direction down through the Powder River Basin. Northern Campbell County stations generally receive the greater amounts and those stations in Converse County to the south will receive lesser amounts of annual precipitation. Maximum precipitation occurs in spring and early summer, and a lesser peak occurs in the fall, usually in the form of early snowstorms. During the summer months, rain showers are frequent, but light, mean annual precipitation is shown on the isobar map, Figure 5.

Droughts are common. Adequate distribution of monthly rainfall for April, May, and June is critical for vegetative production and establishment. Although the average precipitation may exceed normal, frequently it does not occur during the critical period of the growing season. For this reason, mean values are at times meaningless when considering reclamation needs, especially when rainfall is often characterized by scattered thunderstorms.

The record 24-hour storm for the State of Wyoming occurred at Dull Center, located north of the project area in the east central portion of the Powder River Basin, which received 5-50 inches during a 24-hour period.

Rapid runoff from heavy thunderstorms caused flash flood conditions and contributed to extensive erosion and other damages. The Thunder Basin is aptly named owing to the frequent thunderstorms associated with the area. Severe hailstorms occur frequently and are often extremely destructive.

Snow is common from November through May but is generally light to moderate though several storms exceeding five inches can be expected annually. Heaviest storms leave ten to fifteen inches of snow. Winds frequently accompany or follow a snow storm and pile drifts several feet deep. Wind with snow quite often causes blizzard or near blizzard conditions for a few hours. Blizzards seldom last for any length of time in terms of days.

Isopluvial maps have been developed for maximum precipitation amounts that can be expected in 25-, 50-, and 100-year 24-hour storms. These

Table 1

Mean and Extreme Precipitation Totals (inches)
Gillette, Wyoming
For the 30-Year Period 1931-1960

Month	Mean monthly amount of precipitation	Greatest daily amount of precipitation	Year	Mean amount of snow/sleet	Maximum monthly snow/sleet	Year	Greatest daily snow/sleet	Year	Mean number of days with precipitation of .10 inch or more
Jan	0.63	0.70	1943	7.1	25.4	1943	6.0	1948	3
Feb	0.50	0.85	1954	5.6	20.4	1959	12.0	1953	2
Mar	1.06	1.60	1933	9.9	23.0	1944	18.0	1933	4
Apr	1.66	1.78	1941	6.3	20.0	1950	10.0	1933	5
May	2.22	2.00	1952	1.1	8.0	1950	8.0	1950	6
June	2.59	1.95	1947	0.1	4.0	1937	4.0	1937	6
July	1.24	1.70	1932	0.0	0.0	----	0.0	----	4
Aug	0.95	2.82	1960	T	T	1955	0.0	----	2
Sept	1.09	1.65	1951	0.5	4.0	1934	2.0	1949	3
Oct	0.71	0.78	1946	2.8	9.0	1932	7.0	1949	3
Nov	0.75	0.80	1945	7.1	23.0	1947	8.0	1956	3
Dec	0.61	0.80	1943	7.3	16.9	1955	7.0	1935	3
Year	14.00	2.82	Aug. 1960	47.8	25.4	Jan. 1943	18.0	Mar. 1933	44

Table 1 (Cont'd)

Mean and Extreme Precipitation Totals (inches)
Douglas, Wyoming
For the 30-Year Period 1931-1960

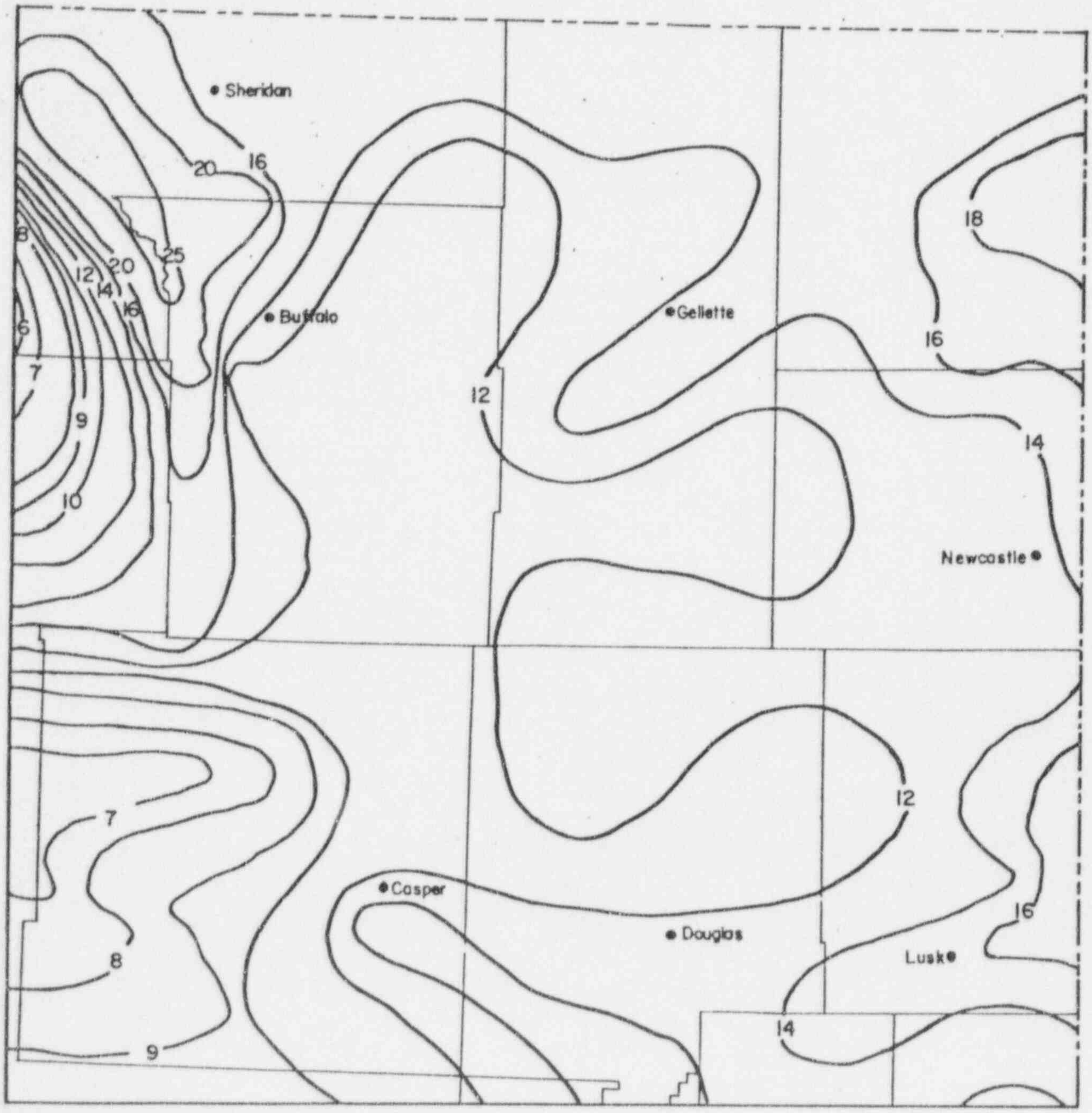
Month	Mean monthly amount of precipitation	Greatest daily amount of precipitation	Year	Mean amount of snow/sleet	Maximum monthly snow/sleet	Year	Greatest daily snow/sleet	Year	Mean number of days with precipitation of .10 inch or more
Jan	0.43	1.26	1949	6.0	24.0	1949	14.0	1949	2
Feb	0.53	0.64	1948	7.1	14.8	1948	8.0	1936	2
Mar	0.77	0.82	1954	8.0	29.7	1944	8.0	1954	3
Apr	1.82	2.16	1941	9.1	41.9	1945	22.0	1945	4
May	2.32	1.31	1942	2.0	17.5	1942	8.6	1957	6
June	1.83	1.68	1946	0.3	7.0	1951	7.0	1951	5
July	1.34	2.02	1933	0.0	T	1952	0.0		3
Aug	1.05	1.31	1947	0.0	T	1954	0.0		3
Sep	1.13	1.74	1938	0.1	2.0	1944	2.0	1944	3
Oct	1.11	0.84	1942	3.3	15.5	1949	8.0	1942	3
Nov	0.62	0.70	1956	6.7	23.9	1956	13.0	1956	3
Dec	0.55	0.75	1945	7.2	16.1	1945	7.5	1944	2
Year	13.50	2.16	Apr. 1941	49.8	41.9	Apr. 1945	22.0	Apr. 1945	39

Table 2

Comparison of Climatological Data for Selected Stations
Campbell and Converse Counties

Station*	Average Annual Precipitation (inches)	Average Annual Snowfall (inches)	Average January Temperatures (degrees F)			Average July Temperatures (degrees F)			Average Growing Season Based on 32° (days)	Elevation (feet)
			Max.	Min.	Ave.	Max.	Min.	Ave.		
Rocky Point	17.21	57.2	----	----	19.2	----	----	71.4	123	3,892
Recluse	14.73	42.9	----	----	14.9	----	----	71.1	118	4,200
Gillette	14.00	47.8	32.7	11.1	21.9	87.8	56.0	71.9	127	4,556
Rochelle	12.76	34.6	34.2	7.1	20.7	88.8	55.0	72.3	111	4,496
Dull Center	11.97	38.0	36.8	9.3	23.1	89.4	55.6	72.5	130	4,415
Douglas	13.50	49.8	35.7	10.7	23.2	86.1	54.3	70.2	121	4,853

*Stations are listed from north to south.



Source: By the Wyoming Water Planning Program In Cooperation with E.S.S.A. Weather Bureau State Climatologist, Wyoming.

FIGURE 5

Mean Annual Precipitation as of 1965
(In Inches)

frequencies are presented in Figures 6, 7, and 8. Probability occurrence within selected time periods is as shown in Table 3. To clarify use of Table 3, for any 100-year period, there is an 87 percent probability that a 50-year flood or rain will occur and a 63 percent probability that a 100-year event will occur.

Table 3

Probability That an Event of Given Recurrence Intervals Will be Equaled or Exceeded During Periods of Various Lengths

	Period Year				
	10	25	50	100	200
	Probability				
Recurrence Interval					
2	0.999	*	*	*	*
10	0.65	0.93	0.995	*	*
50	0.18	0.48	0.64	0.87	0.98
100	0.10	0.22	0.40	0.63	0.87
200	0.05	0.12	0.22	0.39	0.63

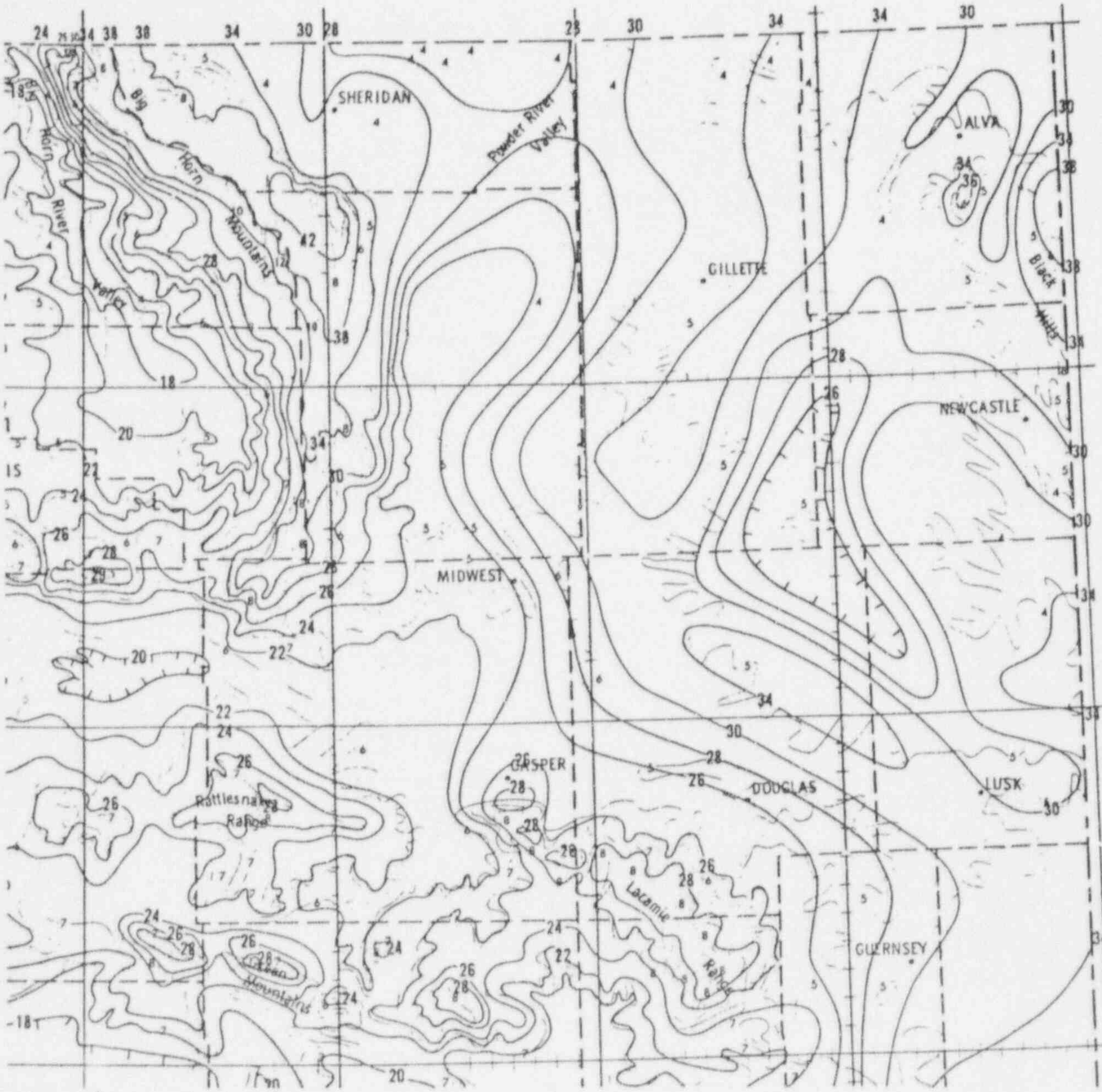
*In these cases probability can never be exactly 1, but for all practical purposes its value may be taken as unity.

2.3.2 Temperature

The project area has a relatively cool climate. The temperature range is wide between both summer and winter and daily maximums and minimums. The relative high elevation and dry air cause a rapid incoming and outgoing of solar radiation. January is usually the coldest month and July the warmest. Frequent changes between mild periods and cold spells are characteristic of winter weather.

During the winter, average daily minimums range between 5°F and 40°F. It is common, however, for temperatures to drop considerably below 0°F in December and February and for daytime temperature to rise to 50°F during mild periods.

The project area is particularly subject to cold air invasions from the north. During winter warm spells, chinook winds are common.



Prepared by :
U.S. Department of Commerce
For :
U.S. Department of Agriculture
August 1968

10 0 10 20 30 40
SCALE IN MILES

L E G E N D

—26— Isopluvials of Precipitation in Tenths of an Inch Annual.

FIGURE 6

25 – Year 24-Hour Precipitation

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For :
U.S. Department of Agriculture
August 1968

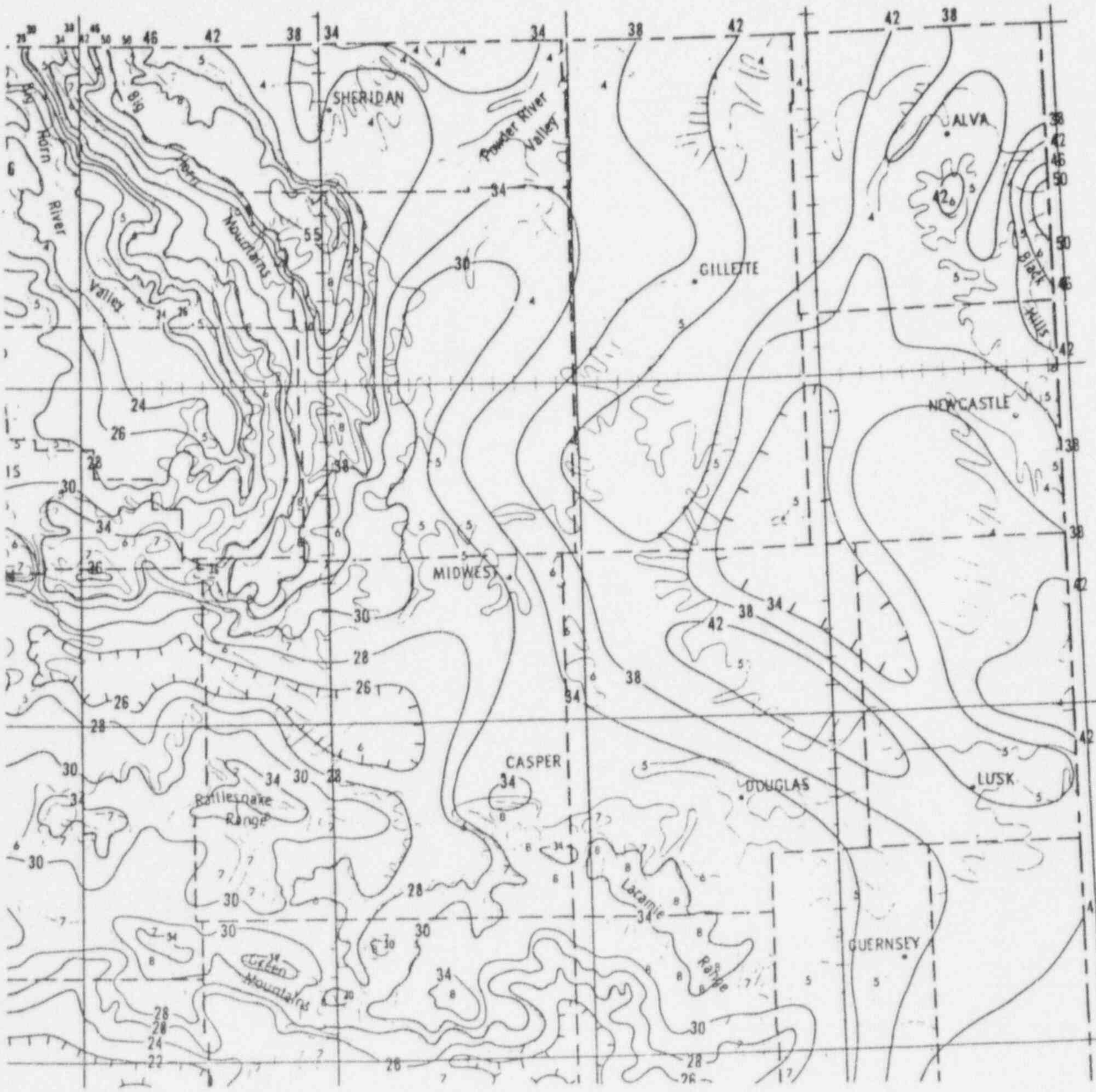
10 0 10 20 30 40
SCALE IN MILES

LEGEND

—26— Isopluvials of Precipitation in Tenths of an Inch Annual .

FIGURE 7

50 – Year 24-Hour Precipitation



Prepared by:
U.S. Department of Commerce
For:
U.S. Department of Agriculture
August 1968

10 0 10 20 30 40
SCALE IN MILES

LEGEND

—26— Isopluvials of Precipitation in Tenths of an Inch Annual.

FIGURE 8

100 – Year 24-Hour Precipitation

Summers are generally mild with short periods of temperatures exceeding 100°F; nights are cool despite high daytime readings.

Mean and extreme temperature information for Gillette and Douglas weather stations is contained in Tables 4 and 5.

2.3.3 Wind

Studies of wind flow patterns indicated that Wyoming is usually covered by Pacific air with short periods of cool air masses from Canada. Seldom does air from the Gulf of Mexico extend this far north.

Wind is a significant factor in Wyoming's climate; the prevailing winds are westerly. The high elevation and large expanse of rolling plains in the basin result in high average annual wind, especially during the colder months from November through March. Winds often reach 30 to 40 miles per hour with occasional, higher gusts. These rates are from spillage through the lower mountain passes of cold air trapped in the Great Basin of the southwest. Surface wind velocity and direction data are greatly influenced by local situations and, therefore, reliable only for the immediate vicinity of the data collection point. The only detailed wind information of long-term value was compiled at the Sheridan weather service station and the variability of patterns makes extrapolation difficult.

More information concerning winds, inversions, and related data is included in the Air Quality Section 2.3.6.

2.3.4 Humidity

Average relative humidity is usually quite low. During warmest periods, the humidity drops to 25-30 percent, and, conversely, during low temperature periods rises to 65-75 percent.

2.3.5 Evapotranspiration

Relative humidity, temperature, and wind influence evapotranspiration rates. Evapotranspiration is important in terms of effect on water supply and vegetative growth, especially where available water is marginal.

Transpiration rates have a distinct annual fluctuation responding mainly to mean temperatures. During the winter months when precipitation rates exceed evapotranspiration, water will be available for recharge to soil water storage. From late spring through fall, evapotranspiration greatly exceeds precipitation; stream flow becomes intermittent and

Table 4

Mean and Extreme Temperatures (°F) for Gillette, Wyoming
For the 30-Year Period 1931-1960

Month	Means			Extremes				Mean Degree Days**	Mean Number of Days			
									Maximum		Minimum	
	Daily Maximum	Daily Minimum	Monthly	Record Highest	Year	Record Lowest	Year		90° and Above	32° and Below	32° and Below	0° and Below
(a)	30	30	30	30		30			30	30	30	30
Jan.	32.7	11.1	21.9	62	1953+	-32	1949	1336	0	12	30	6
Feb.	35.8	13.4	24.6	67	1932	-40	1936	1131	0	10	27	5
Mar.	42.3	19.8	31.1	78	1943	-23	1960	1051	0	6	28	3
Apr.	55.2	30.4	42.8	84	1936	-12	1936	666	0	1	18	*
May	66.1	40.1	53.1	95	1934	11	1954	375	*	*	5	0
June	75.4	47.8	61.6	104	1954	29	1943	168	2	0	*	0
July	87.8	56.0	71.9	107	1931	39	1956	22	15	0	0	0
Aug.	86.2	54.2	70.2	106	1949	35	1936+	25	13	0	0	0
Sep.	75.0	44.4	59.7	98	1959+	14	1942	217	3	*	2	0
Oct.	62.0	34.7	48.4	89	1957	-1	1935	524	0	*	12	*
Nov.	44.3	22.1	33.2	73	1931	-26	1959	954	0	5	26	2
Dec.	36.9	16.0	26.5	69	1939	-23	1932	1194	0	10	30	4
Year	58.3	32.5	45.4	107	July 1931	-40	Feb. 1936	7663	33	44	178	20

(a) Average length of record, years
* Less than one-half
\+ Also on earlier dates, months, or years
** Base 65° F; values computed from mean temperature

Source: U.S. Department of Commerce, Weather Bureau, Climatological Summary.

Month	Mean: Daily Maximum	Mean: Daily Minimum	Mean: Monthly	Extremes: Record Highest	Extremes: Year	Extremes: Record Lowest	Extremes: Year	Mean Degree Days**	Mean Number of Days: Maximum: 90° and Above	Mean Number of Days: Maximum: 32° and Below	Mean Number of Days: Minimum: 32° and Below	Mean Number of Days: Minimum: 0° and Below
(a)	30	30	30	30		30			30	30	30	30
Jan.	35.7	10.7	23.2	65	1953	-35	1959	1296	0	9	29	7
Feb.	39.1	14.1	26.6	69	1954	-38	1936	1075	0	7	26	4
Mar.	45.7	20.7	33.2	76	1953	-27	1956	986	0	5	27	2
Apr.	57.0	30.1	43.6	86	1952	-13	1936	642	0	1	17	*
May	66.8	39.0	52.9	93	1934	13	1954	388	*	*	4	0
June	77.6	48.2	62.9	102	1931	29	1947	144	4	0	*	0
July	86.1	54.3	70.2	106	1931	36	1959	22	13	0	0	0
Aug.	84.1	52.2	68.2	100	1954+	33	1939	34	8	0	0	0
Sep.	74.3	42.1	58.2	98	1960	20	1945+	234	2	0	3	0
Oct.	61.4	31.4	46.4	86	1958+	0	1935	577	0	*	16	*
Nov.	47.1	19.9	33.5	74	1953+	-23	1952	945	0	5	26	2
Dec.	37.6	13.6	25.6	68	1941	-27	1932	1221	0	7	29	5
Year	59.4	31.4	45.4	106	July 1931	-38	Feb. 1936	7564	27	34	177	20

(a) Average length of record, years

* Less than one-half

\+ Also on earlier dates, months, or years

** Base 65° F; values computed from mean temperature

Source: U.S. Department of Commerce, Weather Bureau, Climatological Summary.

Table 5

Mean and Extreme Temperatures (°F) for Douglas, Wyoming
For the 30-Year Period 1931-1960

runoff is low. Irrigation is necessary to grow high-yield crops. The area has an annual deficit precipitation-evaporation budget, shown in Figure 9, which varies from -9.5 inches at Douglas to -12.10 inches at Dull Center.

2.3.6 Air Quality

The project area is located within the Wyoming Intrastate Air Quality Region as designated by the Wyoming Department of Environmental Quality - Air Quality Division. Because the project area is located in the Powder River Basin and since the basin is considered a homogenous climatological area, the air quality of the basin has been used for the basis of this research and development application.

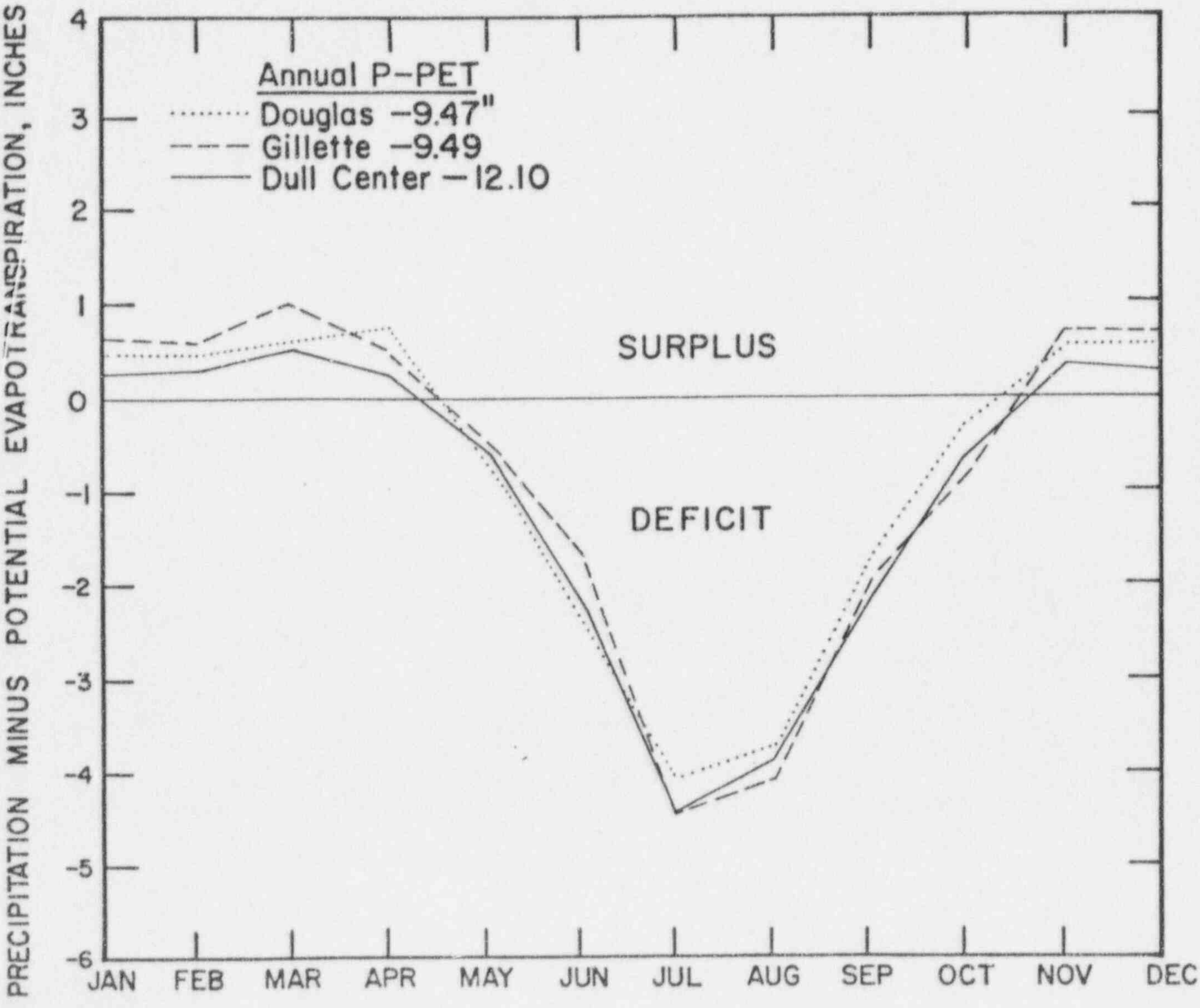
Winters in the basin are fairly constant, frequently reading high velocities, thereby causing significant atmospheric flushing. Wind direction varies from season to season but is generally dominated by prevailing westerlies. The north-south oriented Big Horn Mountain Range on the west side of the basin modifies the westerlies to more dominant northwesterly and southwesterly wind flows, and then local topography will further modify direction.

The basins prevailing dry air causes low-level nocturnal inversions to form frequently, especially during the winter. Such inversions are usually dissipated shortly after sunrise due to rising temperatures and increased wind speeds. In general, low-level inversions occur from 40 to 55 percent of the time in fall and winter and from 30 to 40 percent in spring and summer.

The potential for air pollution is influenced by mixing heights and average wind velocities in these mixing layers. Data taken from a recent study (E.P.A. 1972) indicate that the basin has mean mixing heights and corresponding wind speeds near the values shown on Table 6 for annual and seasonal periods of the year.

The data show a large directional variation of mixing heights between morning and afternoon. Seasonal variations of morning mixing heights in the basin are small while those of the afternoon are rather large. Shallower mixing heights are less effective in diluting or dispersing pollution that is released within the mixing layer.

Wind speeds in the afternoon are typically higher than morning values while summer speeds are less than those in winter. The higher wind speeds, of course, are more effective in transport and diffusion of pollutants.



Annual precipitation — evapotranspiration moisture budget.

FIGURE 9

Table 6

Powder River Basin Estimated Mean Mixing Heights and Wind Speeds*

Type of Data	Annual		Winter		Spring		Summer		Autumn	
	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
Mixing heights (feet)	980	6,560	980	3,610	1,310	8,530	980	9,840	820	6,230
Wind Speed (MPH)	11	16	11	13	12	18	9	15	9	15

* Average values for the basin.

(AM-morning; PM-afternoon; MPH-miles per hour)

Source: EPA, Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution Throughout the Contiguous United States (January 1972), figures 1-20.

A combination of shallow mixing heights and low wind speeds inhibits dispersion of pollutants. Therefore, it is significant to note that the greatest pollution potential in the basin occurs during the winter when both morning and afternoon mixing heights and wind speeds are relatively low. During this period, inversion may form for extended periods of time and create the potential for serious air pollution problems.

Upper level (above 500 feet) inversion may result in stagnant air conditions that last for several days, particularly during the winter. This region can be expected to have an average of 40 stagnation-episode days per year, and an average of 15 of these episodes lasting at least two consecutive days (EPA 1972). Episode conditions lasting at least five days occur on an average of four times per year. Some recent temperature soundings observations indicate that a persistent inversion may exist over the area during most of the winter and most of each spring.

Unstable atmospheric conditions are characterized by large variations in wind direction and result in effective dispersion of effluents with the greatest ground level concentrations in close proximity to the effluant source. Conversely, stable atmospheric conditions are characterized by small variations in wind direction and result in slow effluent dispersion with lower ground level concentrations in close proximity to the source. Frequency distributions of atmospheric stability for Moorcroft, Wyoming, show that neutral conditions (Class D) are most common while very unstable conditions (Class A) occur less than one percent of the time (NOAA Environmental Data Service, 1973). (See Figure 10.)

2.4 Hydrology

2.4.1 Surface Water

The site of the proposed project is on a gently sloping hillside which faces westerly and drains to Collins Draw. Surface runoff is presently cutting two young channels into the hillside on which the project is to be located.

Collins Draw is an intermittent (or possibly ephemeral) stream which flows in a northerly direction along the west edge of the project area to join Cottonwood Creek about 1.8 stream miles downstream and about 1 mile northwest of the project site. Cottonwood Creek is a tributary of the Dry Fork of the Powder River which flows westward to join the Powder River. Figure 6 is a Drainage Map of the area.

The meandering channel of Collins Draw has a bottom width of one to two feet and where the channel is well defined, it is about six feet deep

Source: USDC, NOAA Environmental Data Service, Monthly and Annual Wind Distribution by Pasquill Stability Classes, Moorcroft, Wyoming, 1973

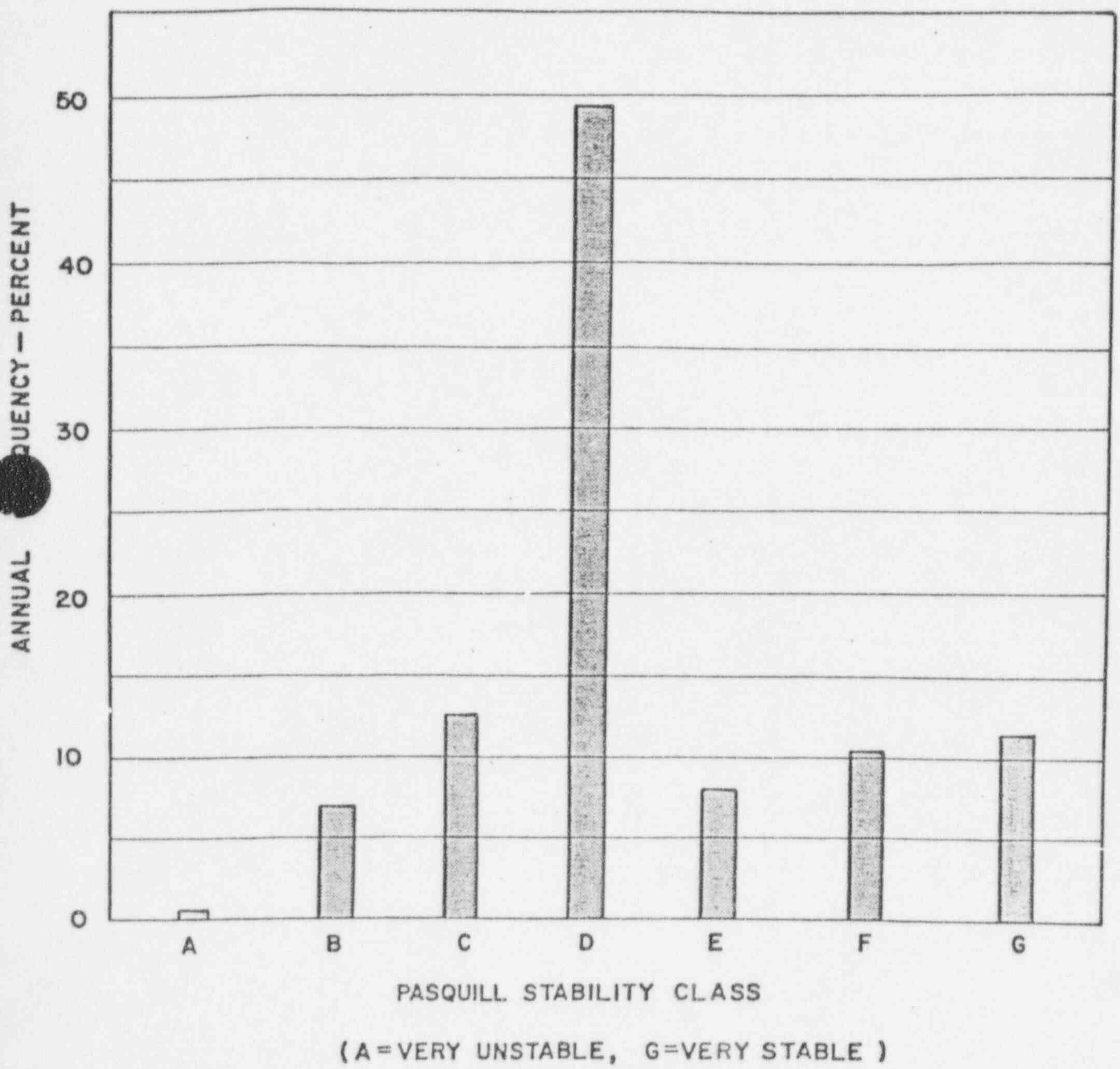


FIGURE 10

STABILITY FREQUENCY

MOORCROFT, WYOMING

1/50 7/52

with a top width of 50 feet. As is typical of many valleys in the Powder River Basin, the landowners have placed dams and spreader dikes along the channel to spread the flood waters over the flood plain to provide irrigation of native hay lands.

Beginning at the project site, the channel of Collins Draw and downstream, the channel of Cottonwood Creek, are marked by large (up to 5' diameter) cottonwood trees. Cottonwood trees are phreatophytes so their presence indicates a perched water table is close to the ground surface along the channel.

While there is considerable use of the waters that flow in Collins Draw and Cottonwood Creek, there is only one adjudicated water right and that is a 20 acre-foot stock reservoir on Collins Draw upstream from the project site.

There are numerous spreader dams and dikes along the channels, but no major storage facility which would control flows which occur as a result of large precipitation events. There are no major storage facilities below the project site on Collins Draw or streams it flows into within Wyoming.

A topographic map of the planned test site and immediate vicinity is attached as Figure 11.

2.4.2 Ground Water

The research and development project site is located adjacent to Collins Draw in the south-central part of the Powder River Basin on the boundary of section 35 and 36 of Township 43 North, Range 76 West.

The mineralized sand at the site lies in the Wasatch Formation which begins at the surface and attains a depth of over 1,500 feet. The Wasatch Formation is the only unit which can be affected by the pilot project. Our studies have accordingly focused on the regional and local hydrology pertinent to this formation and site.

The Wasatch Formation in the Powder River Basin is very close to a balanced recharge-discharge system. Water levels therefore exhibit only minor seasonal fluctuations.

Using data available in the literature together with site specific measurements by Cliffs and others, a regional piezometric surface map for the basin was constructed. The gradient at the site from the regional map was computed to be .006 foot/foot. This compares very favorably with a gradient of .008 foot/foot calculated from the local piezometric surface obtained from wells at the site. The local gradient and

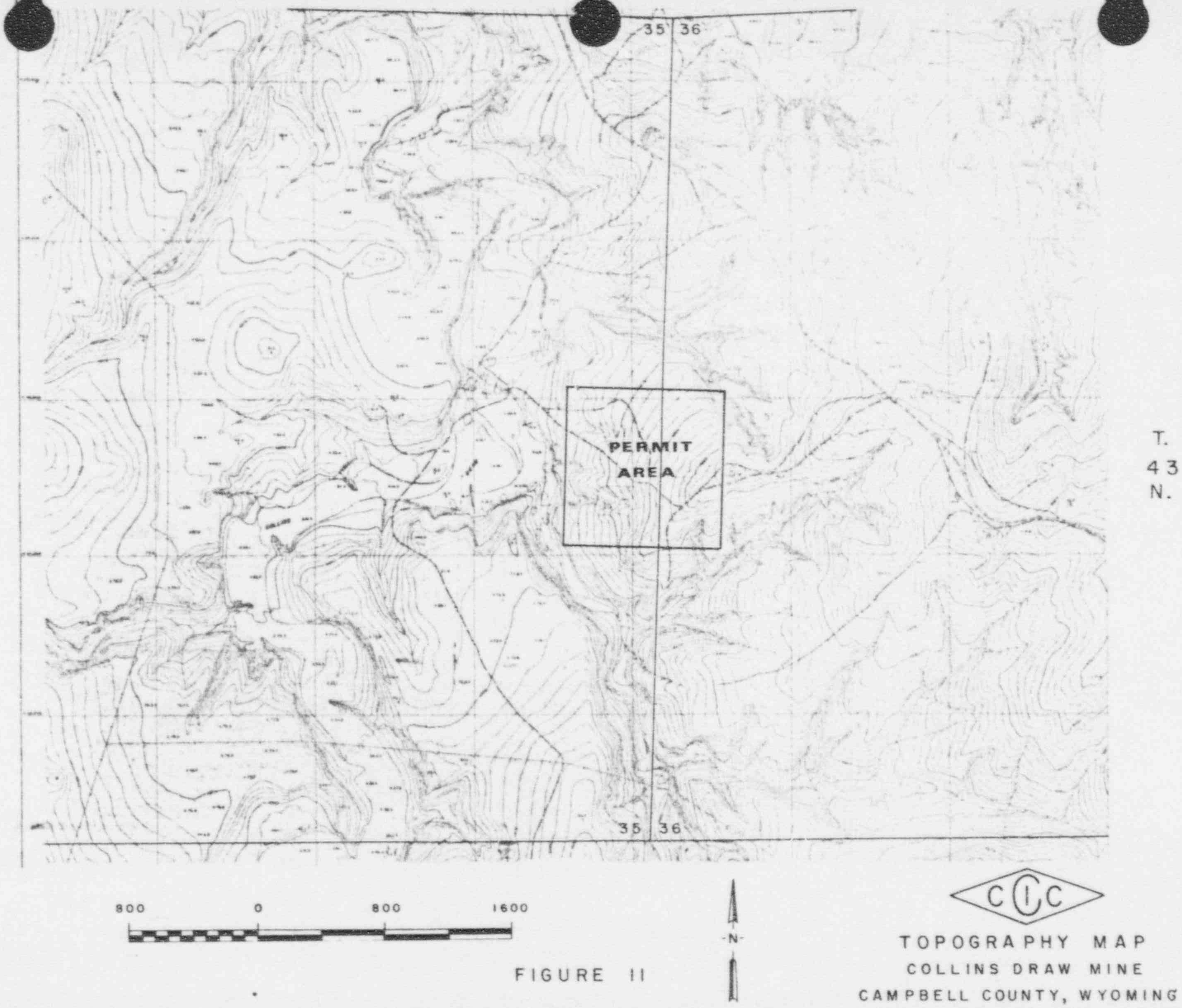

35
36
PERMIT
AREA
35
36
T.
43
N.
800
0
800
1600
N
TOPOGRAPHY MAP
COLLINS DRAW MINE
CAMPBELL COUNTY, WYOMING
84/803/EV-LA-XX-8/1

FIGURE 11

hydrologic properties combine to yield a ground water flow of 6.3 feet/year in a direction 19° west of north at the site. Local water levels over a period of 18 months fluctuate on the order of a few tenths of a foot.

Wells used in Cliffs' study have an average well efficiency of 80% and were thus in excellent condition for hydrologic testing. Seven pump tests were performed by The Cleveland-Cliffs Iron Company under the direction of Mr. Jerry Laman. Water level measurements were carried out using pressure transducers sensitive to ±.01 psi changes.

The aquifer has an average thickness of 52 feet and a porosity of 28% with the top of the sand 431 feet below the surface.

Assumptions used in analytic solutions to obtain the hydrologic properties of the aquifer were satisfied to a high degree of accuracy.

Average hydrologic properties over all wells for the Collins Draw Site were 192 gpd/ft. for transmissivity and 1.7×10^{-4} for storage coefficient. An impermeable boundary was detected at 240 feet from the pumped well running in a north-south direction. No recharge or discharge boundaries were detected.

Mean directional permeability using all wells in test 7 was found to be:

Major transmissivity 307 gpd/ft.
Minor transmissivity 111 gpd/ft.
Direction of major transmissivity - E 31°S

The hydrologic tests conducted at Collins Draw had a radius of influence of 485 feet.

Overlying monitor well 230 was used to check for leakage. No measurable water level changes were detected during the tests. Furthermore, drawdown data were checked against Hantush's Leaky type curves. Matches were obtained only on the limiting non-leaky curve. This indicates the absence of leakage and good vertical confinement.

Appendix B contains the hydrology report prepared by Dr. C. R. McKee.

2.5 Geology

The Collins Draw in-situ leach test is proposed for a typical "Wyoming roll front" sandstone-type uranium deposit. The host sandstone bed is one of many in a depositional sequence known as the Wasatch Formation.

2.5.1 General Geology

The Wasatch Formation was deposited during the Eocene epoch of the Tertiary period, considered to have been about 60 million years ago. The formation is part of an accumulation of sediments which was eroded from surrounding mountains, carried out by streams, and deposited in the area now known as the Powder River Basin. This basin-filling process emplaced several thousand feet of alternating sandstone, claystone, and coal beds. About 2,000 feet of these sediments are distinguished by a number of red colored beds and have been designated as the Wasatch Formation.

The individual sandstone beds were deposited by meandering streams, in areas with stream-like patterns in widths varying from a few hundred feet up to several miles. Thicknesses of the beds vary from a few to as much as 250 feet. The thick, extensive sand beds are major aquifers while the thin sands tend to be of limited lateral extent and are of little hydrologic significance.

2.5.2 Geological Detail at Collins Draw In-Situ Site

Discrete sandstone beds of the Wasatch can be identified individually and traced laterally through information derived from drill holes. A system of nomenclature to reference these sandstone beds has been devised. The system consists of a simple letter or number designation; e.g., A Sand, B Sand, etc. in ascending sequence and #1 Sand, #2 Sand, etc. in descending sequence from a reference plane.

The various sandstone members and intervening claystones investigated by drilling are depicted on the accompanying cross sections shown on Figures 12 through 15. The uranium host sand, #1, occurs at a depth of approximately 425 feet and has an average thickness of 50 to 55 feet. Above the #1 Sand, and separated by 11-52 feet of claystone is the A-B Sand. This is a coalescence of the individual A and B Sands into a single unit averaging 220 feet thick. The shallowest major sand, the C Sand, overlies the A-B with a 26-41 foot claystone separation.

Features to a depth of 113 feet (34.4 meters) below the #1 or host sand have been determined from drill holes in and near the test site. Next below the #1 Sand, separated by 10-16 feet of claystone, is a sandstone bed about 12 feet thick and of limited lateral extent. It is denoted simply as the Stray Sand. Drill hole #V-143, 1,500 feet north of the test site, has a 30' sand (tentatively the #2) below the Stray Sand, being separated therefrom by 48' of claystone.

The major sandstone units are generally similar in composition but being fluvial or stream originated are very "junky" with many internal variations. These sandstones are composed mainly of quartz grains with

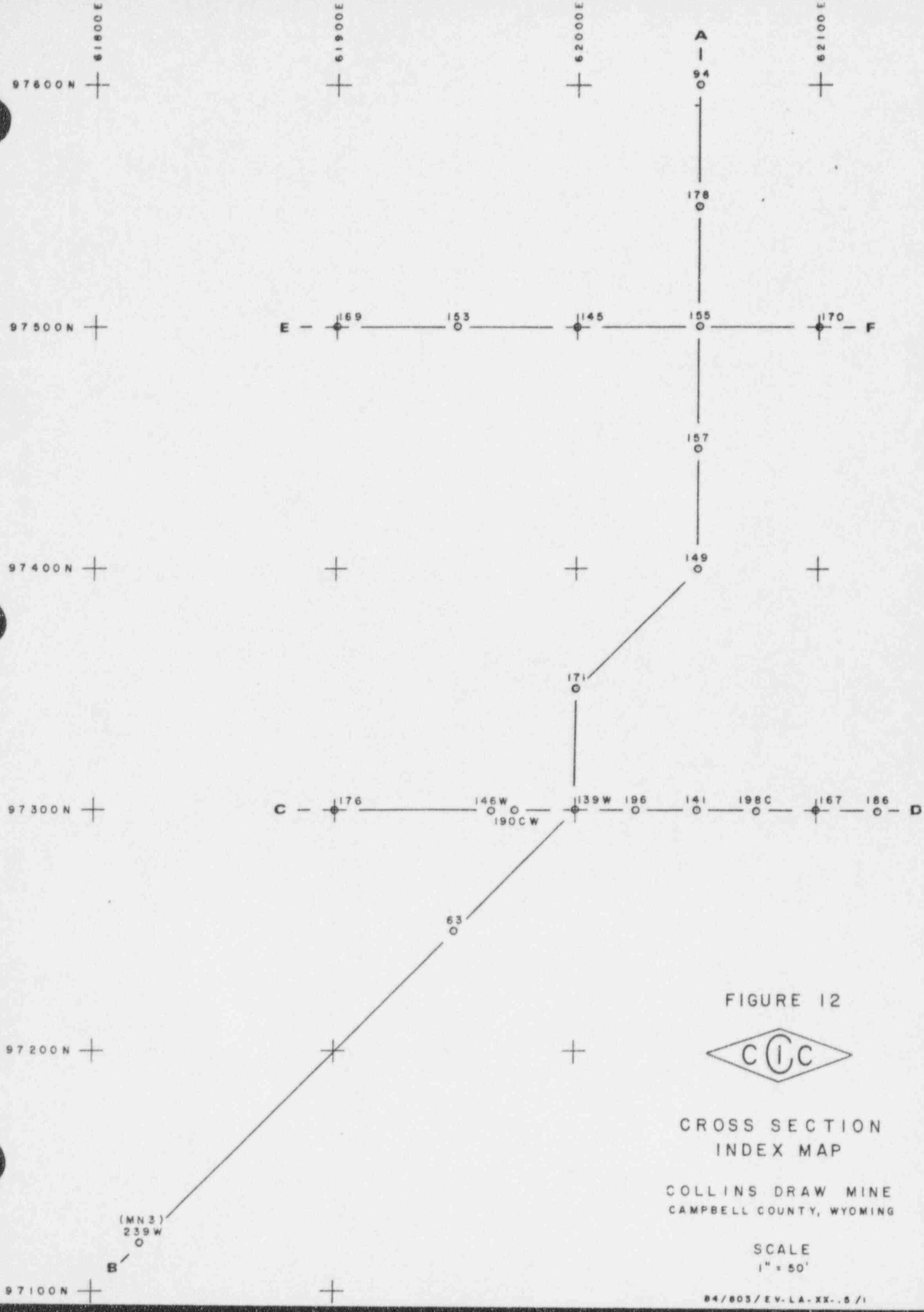


FIGURE 12

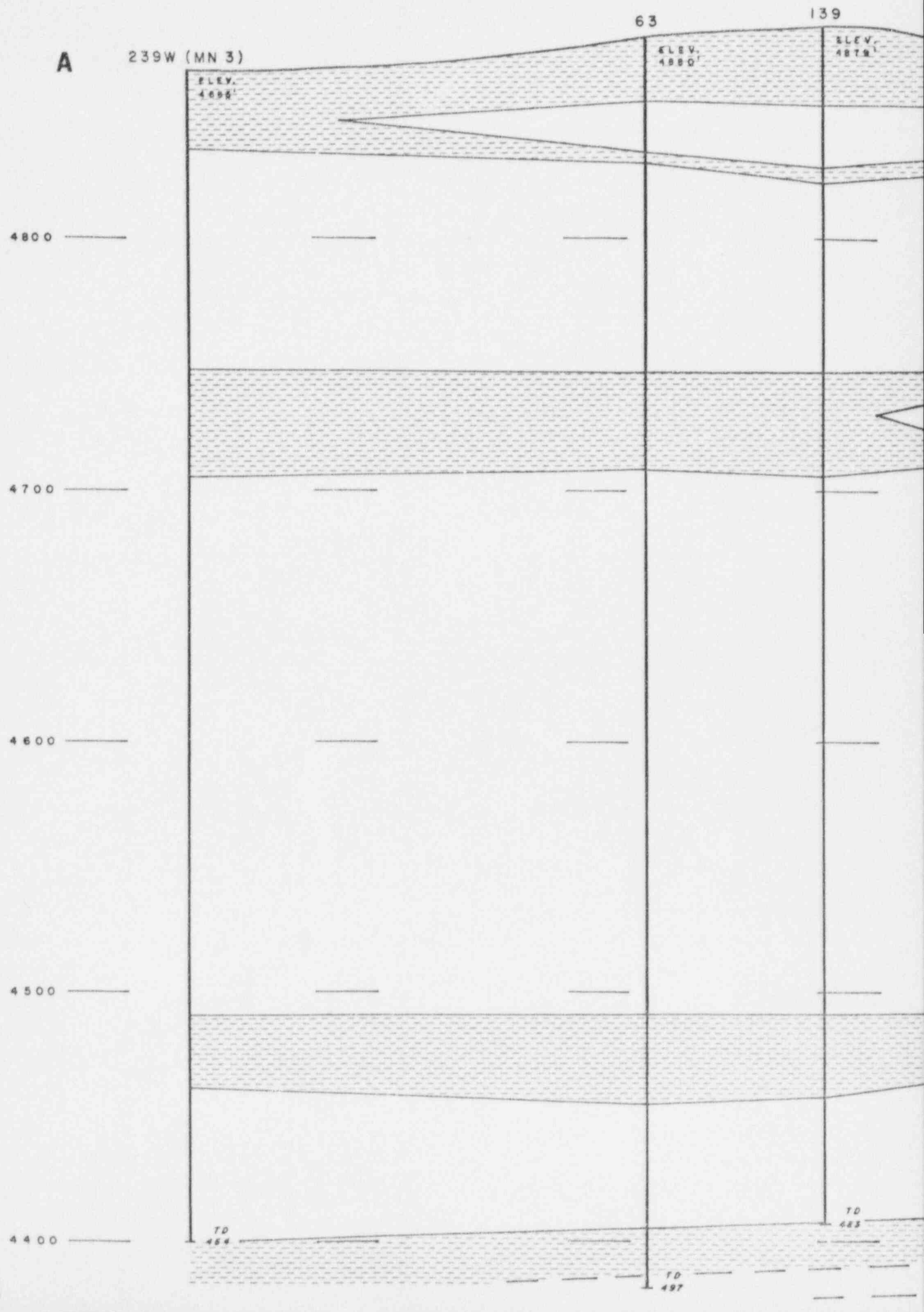
CIC

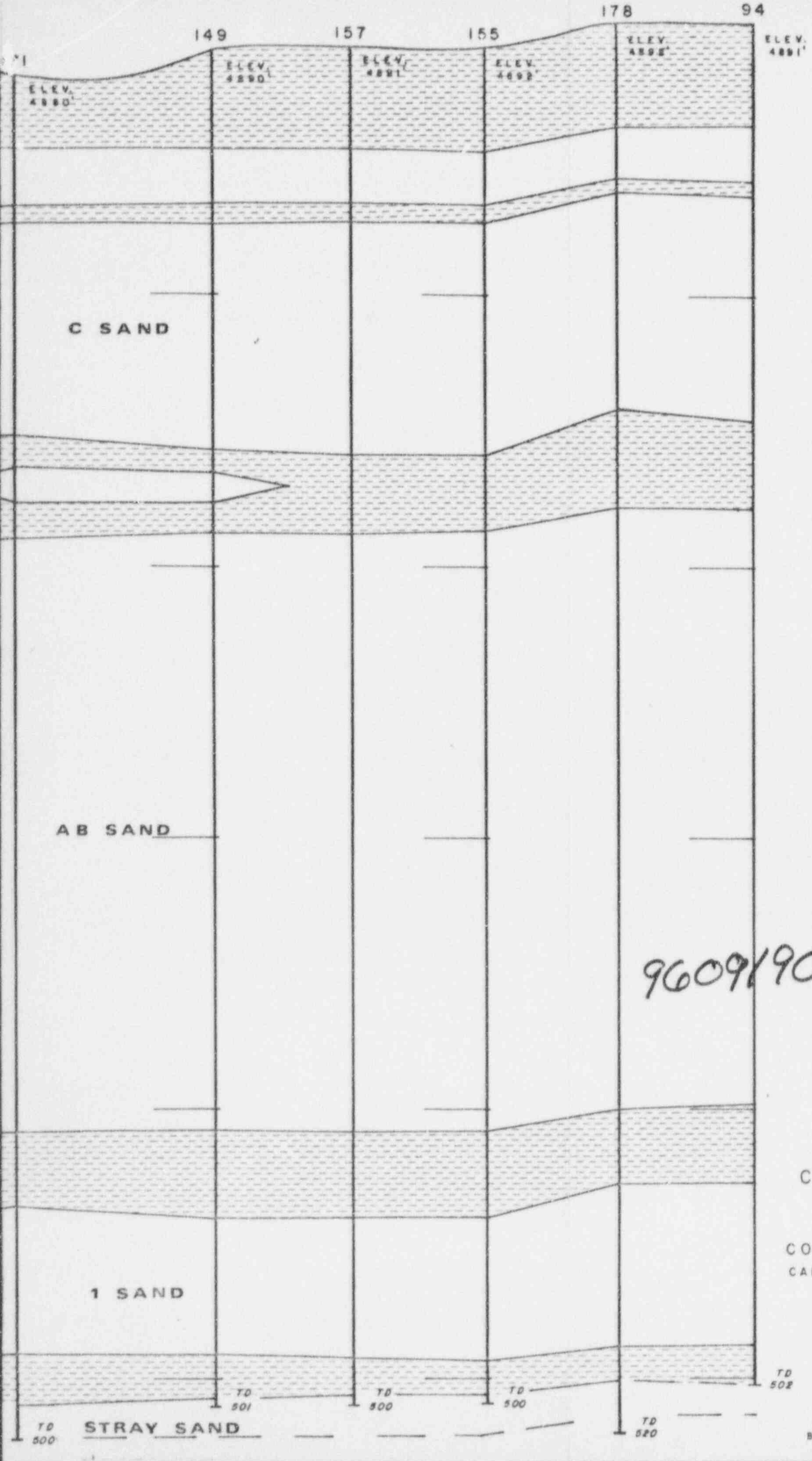
CROSS SECTION
INDEX MAP

COLLINS DRAW MINE
CAMPBELL COUNTY, WYOMING

SCALE
1" = 50'

84/803/EV-LA-XX-.5/1


A
239W (MN 3)
63
139
ELEV. 4880'
ELEV. 4879'
4800
4700
4600
4500
4400
TD 464
TD 483
TD 497



B

ANSTEC APERTURE CARD

Also Available on Aperture Card

9609190142-2

FIGURE 13

CCC

CROSS SECTION
A - B

COLLINS DRAW MINE
CAMPBELL COUNTY, WYOMING

SCALES
VERT. 1" = 500'
HORIZ. 1" = 500'

94/803/EV-LA-XX-8/1

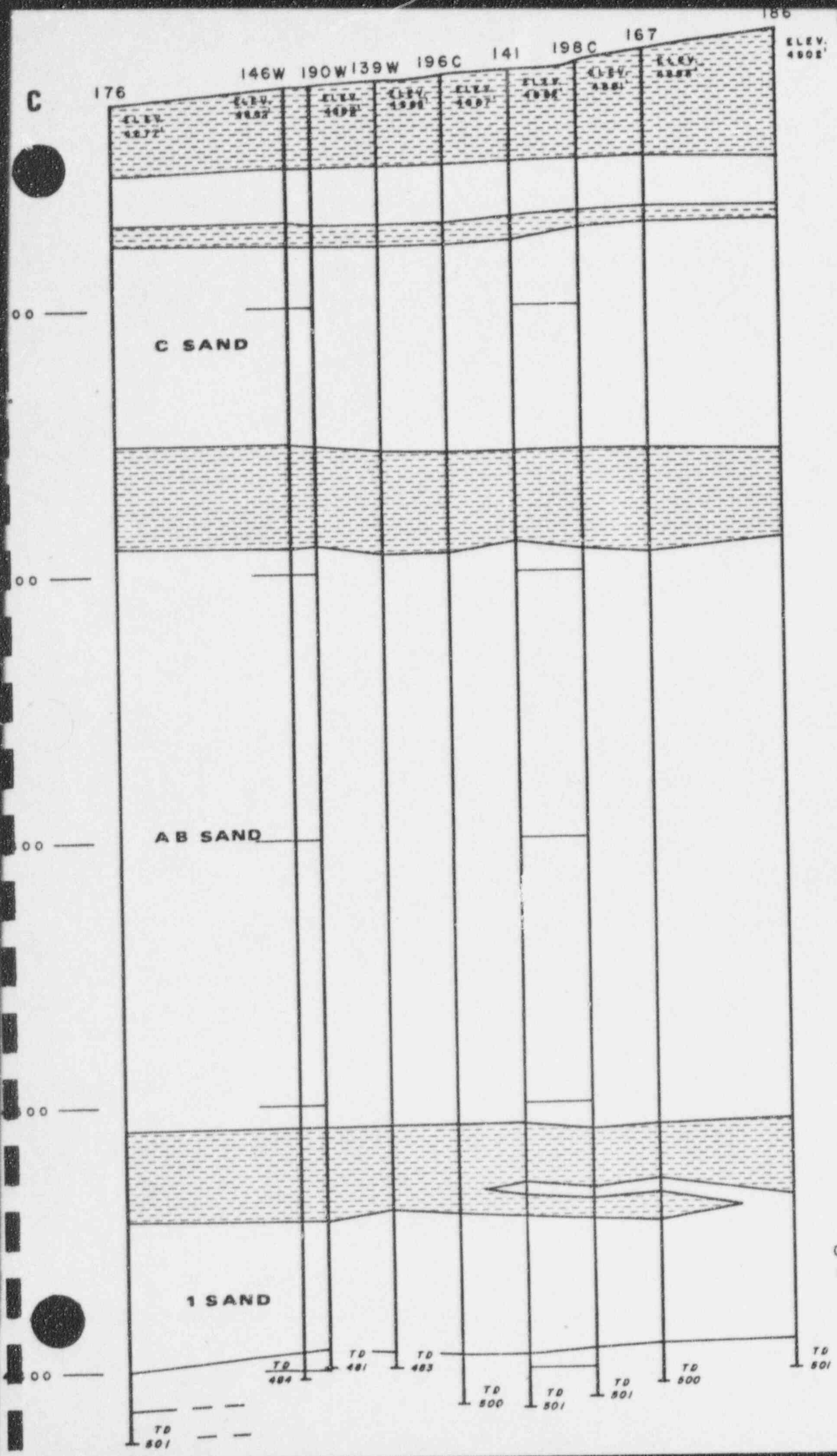


FIGURE 14

CCIC

CROSS SECTION
C - D

COLLINS DRAW MINE
CAMPBELL COUNTY, WYOMING

SCALES
VERT. 1" = 500'
HORIZ. 1" = 500'

84/803/EV-LA-XX-5/2

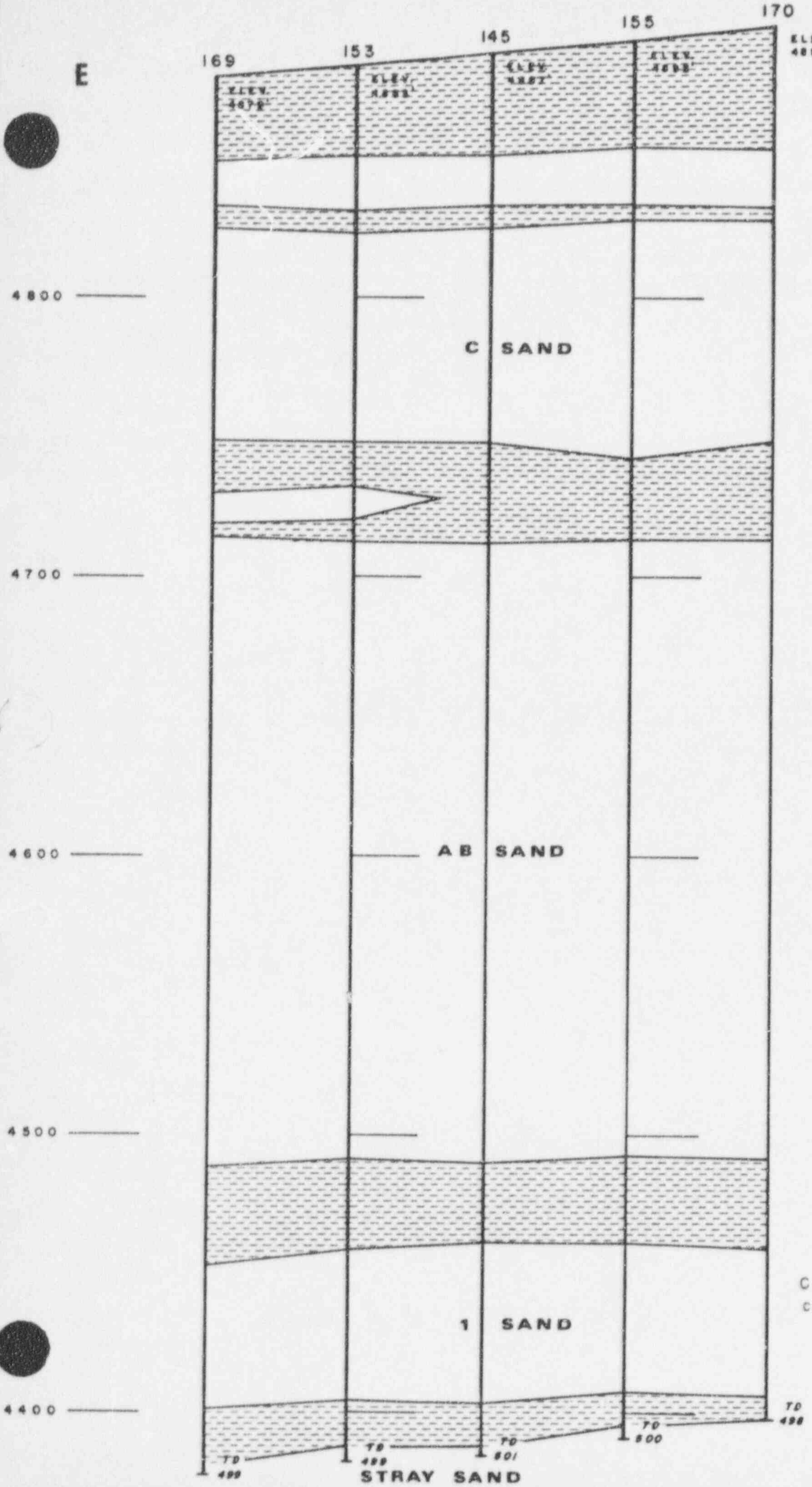


FIGURE 15

CICC

CROSS SECTION
E - F

COLLINS DRAW MINE
CAMPBELL COUNTY, WYOMING

SCALES
VERT. 1" = 500'
HORIZ. 1" = 500'

C4/803/EV-LA-XX-8/3

accessory feldspar grains and interstitial clay. The quartz grains vary from fine to very coarse grained in size and are rounded to angular in shape. They are "dirty," having interstitial clay in cases comprising as much as 25-30% of the total volume. From 5 to 25% of the individual grains are feldspar, placing the sandstone in the feldspathic to arkosic category. The natural color is gray but has been locally altered to yellow, brown, or red by chemically active formation water. The sandstones exhibit fair to good porosity and permeability. The individual sandstone beds are separated by gray claystone which contains considerable silt.

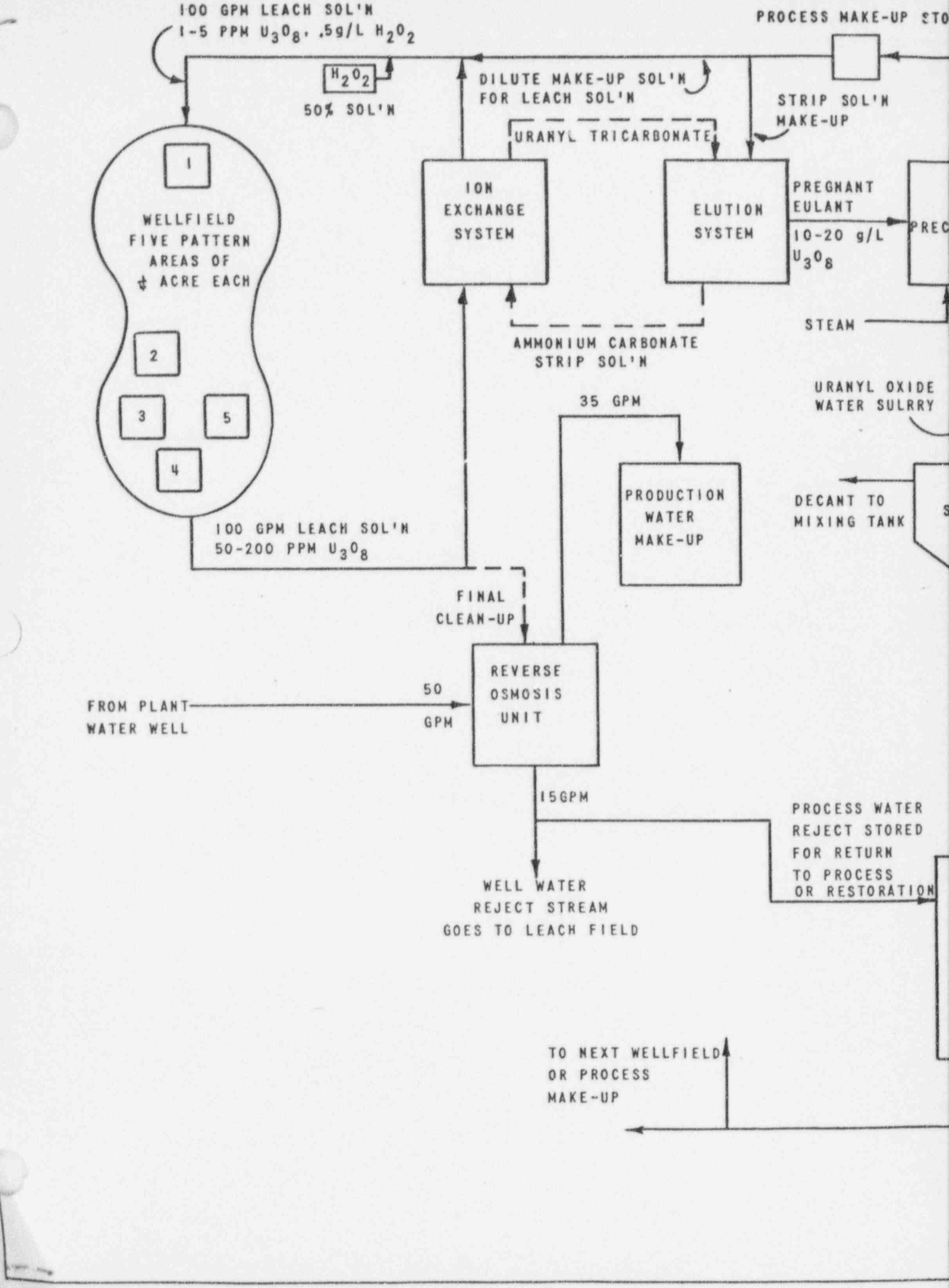
3.0 FACILITY DESIGN and CONSTRUCTION

The Cleveland-Cliffs Iron Company ("Cleveland-Cliffs"), Manager of the joint venture, has engaged Dr. R. H. Jacobson, of In-Situ Consulting, as Project Manager under the direction of J. Laman to design a 100 gallon-per-minute pilot facility. Dr. Jacobson was General Manager for Uranium Production of Intercontinental Energy Corp. (IEC) and was responsible for design and construction of their two commercial solution mining facilities in South Texas. He and Dr. C. R. McKee, of In-Situ Consulting, have engaged the Behrent Engineering Company to perform detailed design and aid in construction of the Cleveland-Cliffs' pilot research facility. The Behrent Engineering Company is experienced in detailed design of solution mining facilities and has performed detail design of two commercial plants for IEC and has been involved in design of several pilot plants. This team will be responsible to Cleveland-Cliffs for development of the pilot plant and for instruction in operating the solution mining facility.

The metallurgical process is designed to produce uranium with a minimum of waste disposal problems and to insure a safe working environment for all staff and employees. The pilot plant is basically a fixed-bed ion exchange system with a yellow cake precipitation and dryer circuit, as well as a water purification section. The plant is designed to recycle nearly all process water and to produce, as waste, a nonradioactive calcium sulfate/sodium chloride brine. The major components of the plant process equipment will be modular and skid mounted. The plant will be erected on an impervious pad, near the well field and housed in a building for year-around operation.

3.1 Metallurgical Process Description

The process schematic of the uranium recovery process with major material throughputs and compositions is shown on Figure 16. The plant layout is shown on Figure 17. The process description, beginning as the lixiviant is injected into the well field as described below.



100 GPM LEACH SOL'N
1-5 PPM U_3O_8, .5g/L H_2O_2
PROCESS MAKE-UP STO
H_2O_2
50% SOL'N
DILUTE MAKE-UP SOL'N
FOR LEACH SOL'N
STRIP SOL'N
MAKE-UP
URANYL TRICARBONATE
1
WELLFIELD
FIVE PATTERN
AREAS OF
¢ ACRE EACH
ION
EXCHANGE
SYSTEM
ELUTION
SYSTEM
PREGNANT
EULANT
10-20 g/L
U_3O_8
PREC
STEAM
AMMONIUM CARBONATE
STRIP SOL'N
2
3
5
4
35 GPM
URANYL OXIDE
WATER SULRRY
PRODUCTION
WATER
MAKE-UP
DECANT TO
MIXING TANK
100 GPM LEACH SOL'N
50-200 PPM U_3O_8
FINAL
CLEAN-UP
REVERSE
OSMOSIS
UNIT
FROM PLANT
WATER WELL
50
GPM
15GPM
PROCESS WATER
REJECT STORED
FOR RETURN
TO PROCESS
OR RESTORATION
WELL WATER
REJECT STREAM
GOES TO LEACH FIELD
TO NEXT WELLFIELD
OR PROCESS
MAKE-UP

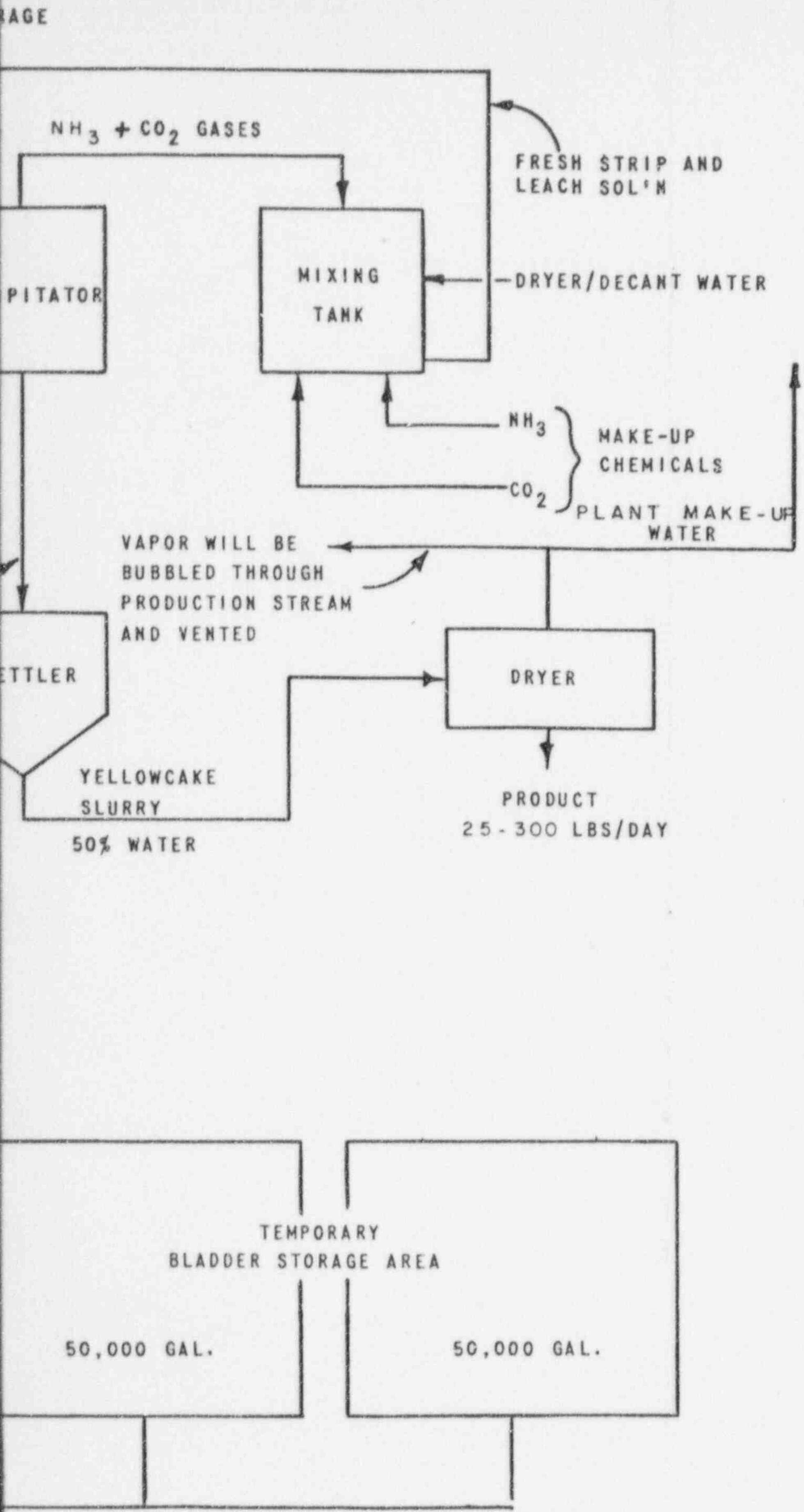
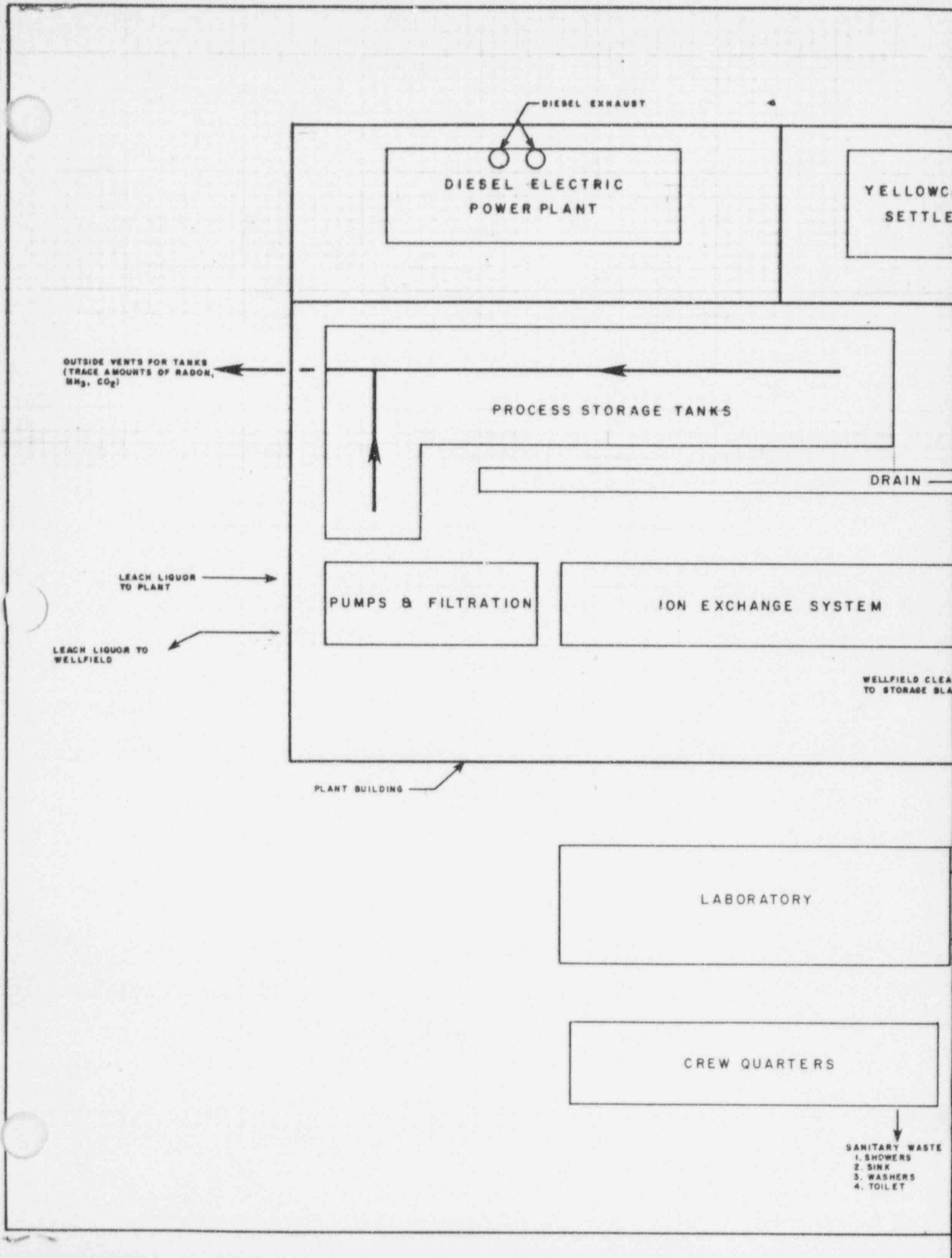


FIGURE 16

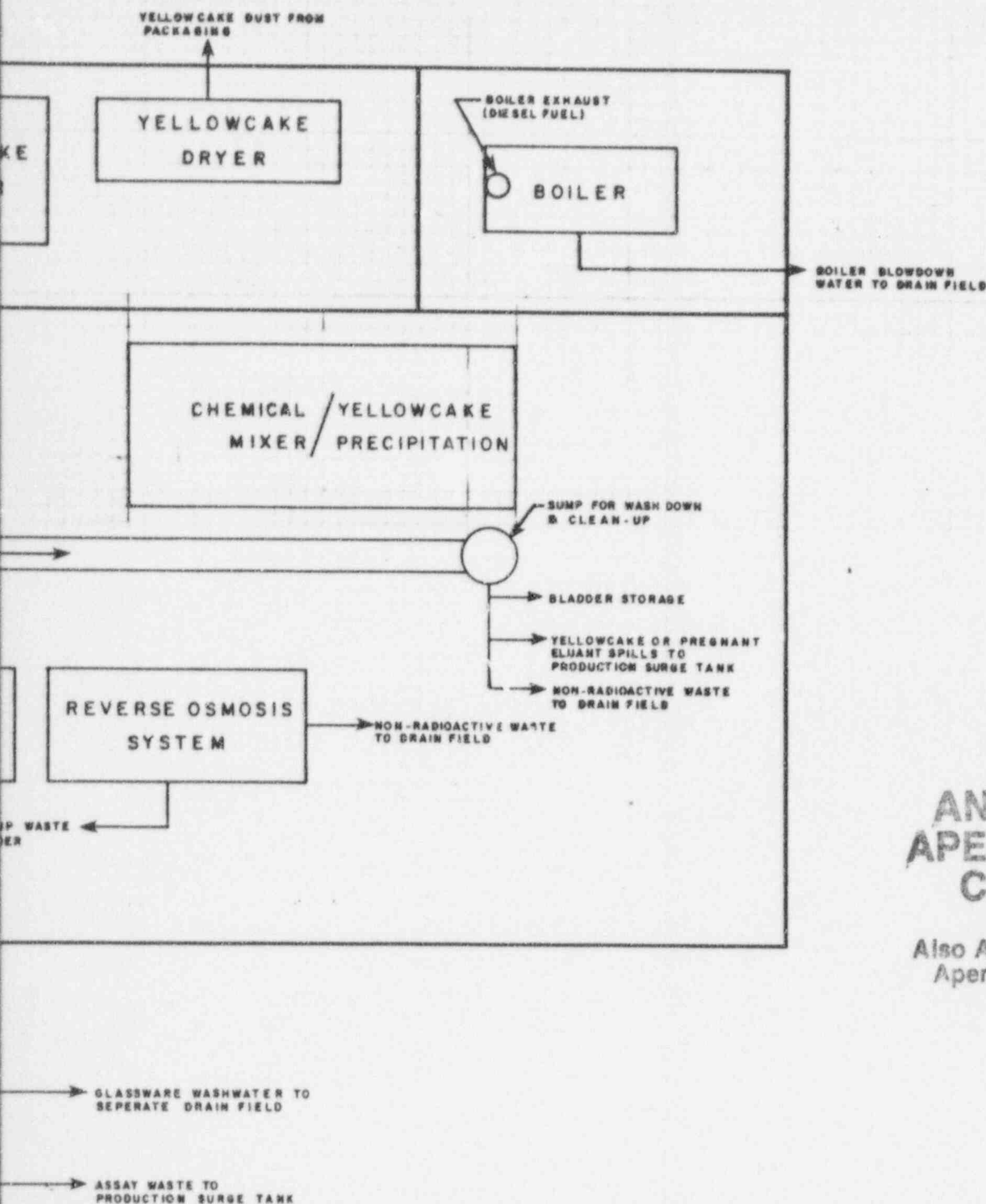
CIC

URANIUM RECOVERY
PROCESS SCHEMATIC

BEHRENT ENGINEERS
DENVER, COLORADO



DIESEL EXHAUST
DIESEL ELECTRIC POWER PLANT
YELLOWCA
SETTLE
OUTSIDE VENTS FOR TANKS (TRACE AMOUNTS OF RADON, NH3, CO2)
PROCESS STORAGE TANKS
DRAIN
LEACH LIQUOR TO PLANT
PUMPS & FILTRATION
ION EXCHANGE SYSTEM
LEACH LIQUOR TO WELLFIELD
WELLFIELD CLEA
TO STORAGE BLA
PLANT BUILDING
LABORATORY
CREW QUARTERS
SANITARY WASTE
1. SHOWERS
2. SINK
3. WASHERS
4. TOILET



NOTE: THE DRAIN FIELD WILL CONTAIN TRACE AMOUNTS OF U_3O_8 FROM PLANT WASH DOWN. MAJOR SPILLS WILL GO BACK TO PRODUCTION SURGE TANK.

NOT DRAWN TO SCALE

FIGURE 17

CIC

PLANT LAYOUT

BEHRENT ENGINEERS
DENVER, COLORADO
84/803/MU-LO-XX-0/1

J.K.T.

9609190142-4

Dilute ammonium carbonate and hydrogen peroxide will dissolve the uranium from a mineralized sand. This solution will be pumped by submergible pumps to a main header and on to a production surge tank. From there, the leach solution is pumped through an anionic exchange resin which has a strong affinity to the ammonium uranyl tricarbonate complex. Strong ammonium carbonate is used to strip the uranium complex from the resin. This eluant solution will contain 10-20 gms/liter of uranyl tricarbonate. The uranium is precipitated with heat producing a very pure uranyl oxide ($UO_3.2H_2O$), as well as gaseous ammonia and carbon dioxide. These gases are recovered and recycled to produce fresh strip solution for the eluant circuit. The uranyl oxide is pumped to a settling tank and from there to a rotary vacuum dryer heated by steam. The yellow cake is dried to less than 3% moisture and transferred to drums for shipment. All water vapor and any other gases from the dryer are collected and used as plant makeup water.

The unit operations within the plant are batch-type operations which have been designed to handle a continuous feed from the well field.

3.1.1 Well Field Operation and Restoration

The well field will be operated to model a segment of a full-scale commercial facility. This mode of operation will better train personnel for future commercial operation in the solution mining process and simultaneously obtain the best operating information for evaluation of the success of the test program.

Several pattern areas comprise the well field. Each pattern area is approximately 100 ft. x 100 ft. The number of wells inside any pattern area will vary according to spacing. Initially, well spacings of 20-40 ft. arranged in a staggered line drive geometry are planned. An outline of the well field area is included on Figure 1.

Fluid control inside the pattern areas will be achieved by close control of flow rates into and out of each well and by periodic use of standard computer programs which simulate fluid movements through sand.

The well field operation will begin with the introduction of approximately 500,000 gallons of water which have been purified by a reverse osmosis unit (R.O.) into a pattern area of approximately 100 x 100 ft. This water will be taken from a water well outside the mine area. This step will displace all calcium-laden formation water which will precipitate calcium in the formation in the presence of the ammonium carbonate leach solution and thus, reduce the overall formation permeability. The next step is the injection into each well in the first pattern area, the ammonium carbonate/hydrogen peroxide lixiviant. The lixiviant is then circulated to start the uranium leaching process.

Leaching of the uranium will continue in the first pattern area until a desired recovery is obtained. The first pattern area will be chosen in fairly low-grade ore in order to start restoration of the area after a 2-3 month period. The amount of lixiviant in this first pattern will be approximately one pore volume of 1-1.3 million gallons. After mining the uranium from the first area, the lixiviant is rapidly transferred to a second 100 x 100 foot area in high-grade ore. This new pattern area is also preconditioned with 500,000 gallons of R.O. water prior to lixiviant transfers. This lixiviant transfer will carry with it about 85-90% of the ammonium carbonate solution.

During the solution mining of the second pattern area, the water in the first area will be processed by reverse osmosis (R.O.). The concentrated ammonium carbonate solution in the R.O. reject stream will be transferred to the second well field, after first being incorporated as plant makeup water. Bladder storage will not be used until after the cleanup of the last pattern area. Good economy of plant and well field water will not increase significantly the amount of overall ammonium carbonate (approximately 45 tons) in process from the first to the last well field pattern.

This type of well field operation is important in determining the effect of detrimental ions (molybdenum, sulfate, etc.) that may build up in the lixiviant and interfere with the anionic resin exchange capacity and purity of the yellow cake. Another reason is to model, for cost evaluation, the best methods available for lixiviant conservation. The solution left in the last pattern area is the only surplus process water produced and will be concentrated by a special R.O. unit and several techniques tested for final disposal of process wastes (See Section 4.2).

During restoration of each pattern area, any lixiviant that may have started to migrate out of the well field will then be drawn back into the area and pumped to the R.O. unit. This rapid mining, transfer and R.O. cleanup eliminates the need for a deliberate process bleed stream. The technique has been tested in actual commercial operations. A bleed stream used in conjunction with the high pH ammonium carbonate process is detrimental to the operation because this practice would draw calcium laden water from outside the well field area into the process water causing calcium precipitation in the formation, wells, resin tanks, piping, flow instrumentation, etc.

It has been found in other solution mining operations that at high pH the ammonium carbonate solution will contain, during the life cycle of leaching a well field, only 2-4 ppm of dissolved calcium. Above a pH of 9.0, calcium on the clay and the ammonium ion in solution do not exchange. Therefore, rapid cleanup of the well field using an R.O. unit,

after transfer of leach solution from pattern area to pattern area is important, and the injection of ammonium-free R.O. water must quickly follow to minimize the exchange of any ammonium ion left over after transfer (the pH at this time is usually less than 8.5) from exchanging with calcium, sodium, potassium, etc. on clay minerals in the host sand. In summary, ammonium adsorbtion on clay (and ammonia desorbtion after cleanup) can be prevented by removing it as fast as possible once the pH drops below 9.0.

Once the ammonium ion in the ground water within the well field is reduced to acceptable levels with R.O. purification, which is a rapid process, the area is injected with several areal pore volumes of nearby formation water of low Eh and oxygen solubility. The area is then considered restored and the aquifer returned to very nearly its original condition.

The cost versus degree of water restoration should be accurately determined in this program.

3.1.2 Well Field Design

The well field design during this pilot program will vary according to computer modeling using on-site hydrologic parameters. Initially, the design will resemble a staggered-line drive. The well field will be kept in balance at all times. High quality flow meters which record both rate and quantity will be installed on each production and injection well. Distance between wells will vary from 20-40 feet.

Initially, all wells within each 100 x 100 ft. pattern area will be located within an 80 x 80 ft. zone. This is to test our ability to confine the leach liquor. Other wells may be completed between the pattern areas and the monitor wells to check for excursion.

3.1.3 Environmental Monitoring of Well Field Operations and Excursion Detection

The 1.25-acre well field area will be encircled with strategically placed monitor wells. These wells will be sampled once a month and analyzed on site for uranium, sulfate, ammonium, bicarbonate, and pH, etc. (carbonate will be calculated on the basis of bicarbonate and pH).

The well field operation (Section 3.1.1) describes how approximately 500,000 gallons of very pure reverse osmosis (R.O.) water are injected into each quarter acre pattern area prior to the introduction of leach chemicals. This R.O. water remains between the monitor wells and the well field. Any escape of lixiviant out of the area of leaching will push this R.O. water ahead. The first indication to the mine operator

that leach solution is migrating toward a monitor well will be indicated by a drop in sulfate and bicarbonate. Corrective action can then be taken by adjusting the pumping and injection rates in the pattern area, prior to the detection of excursion parameters. Tracers such as bromine may be added to the R.O. water to indicate movement of lixiviant out of the mine area.

A continuation of a possible excursion would be indicated by a rapid rise in sulfate and bicarbonate followed by an increase in pH and carbonate. A positive excursion would be indicated by a rapid rise in uranium values followed by a rapid rise of ammonium concentrations in the ground water.

A possible excursion will have many unmistakable indicators before it becomes a positive escape of uranium. Adjustments will be made in the well field upon the arrival and identification of the R.O. water front (possibly containing tracers).

In the event a positive escape is identified, the well field pattern will be changed such that the wells nearest the monitor well, where the escape was effected, will all become pumping wells to draw the escaping ions back into the well field pattern. When the monitor well returns to compliance and the excursion is over, operations will return to normal.

The Environmental monitoring, including placement of monitor wells, and excursion detection programs will involve the Wyoming Department of Environmental Quality and supplemental information will be forthcoming.

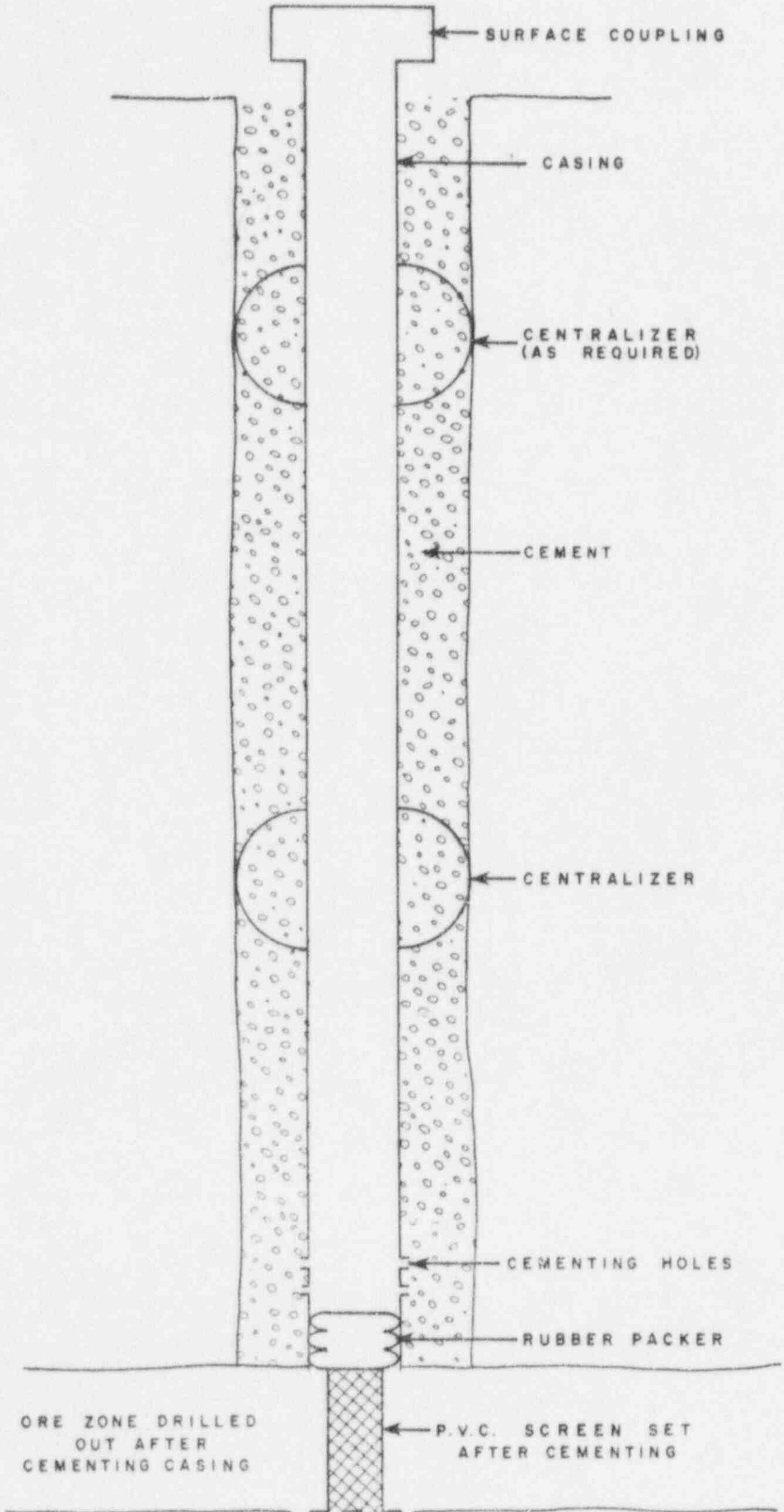
3.1.4 Well Completion

Well drilling and completion is a major cost factor in solution mining and several completion procedures may be tried in the pilot test.

Initially, the first series of wells will be drilled and completed using the technique shown on Figure 18. Basically, the procedure is to drill to the top of the mineralized sand, set the casing, and cement the annulus between the casings and the original hole wall. After the cement has set up, the mineralized sand zone is drilled out and the hole deepened until the underlying shale or siltstone is encountered. The sand interval can then be screened, if desired, using a telescoping screen and rubber packer.

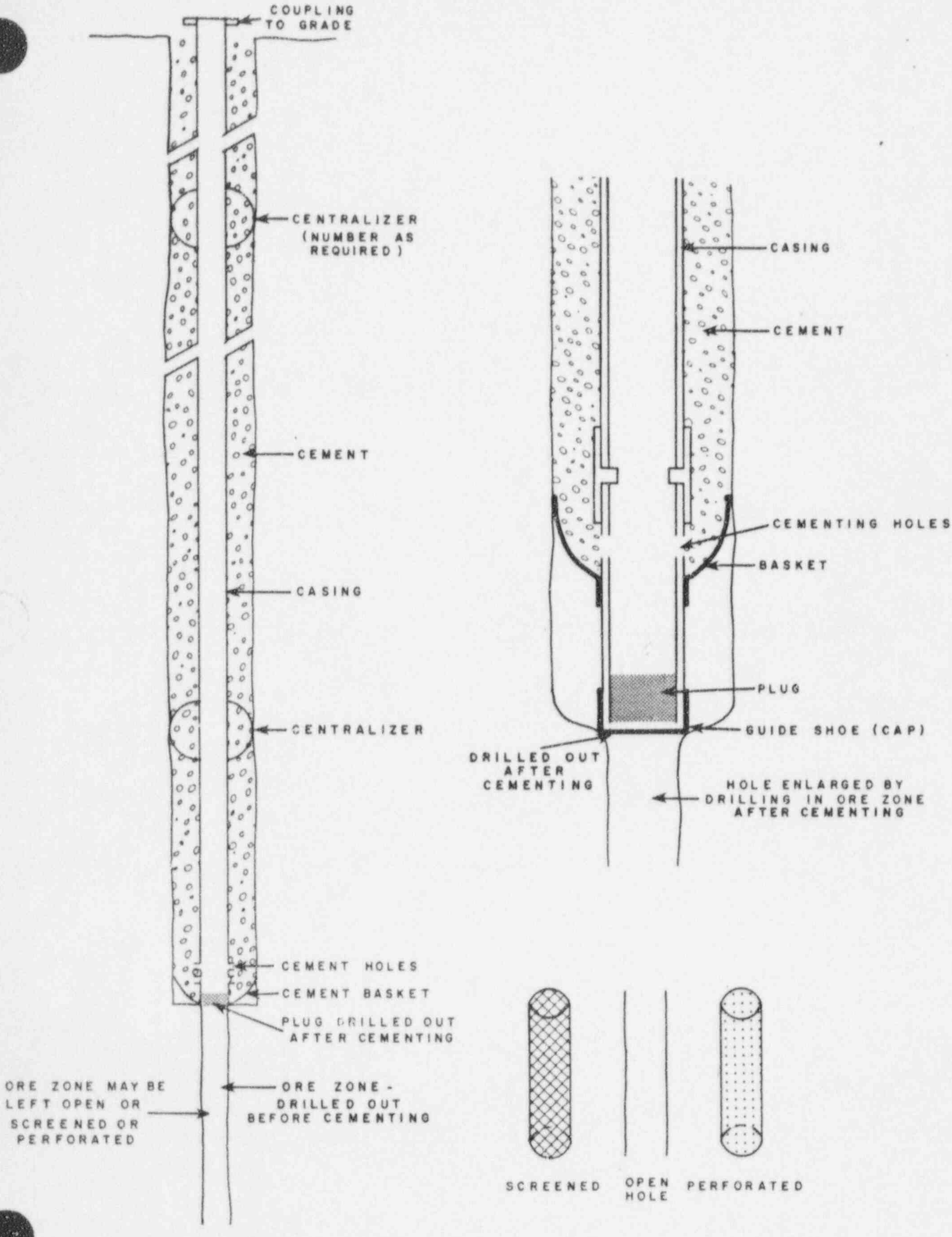
Other completion techniques which may be tried are shown on Figure 19.

Generally, these techniques involve drilling to the bottom of mineralized sand, setting casing with or without screen attached, and then cementing the annulus between the casing and hole wall with the aid of a



TYPICAL WELL COMPLETION

FIGURE 18



ALTERNATE WELL COMPLETION METHODS

FIGURE 19

cement basket designed to prevent cement from reaching the mineralized zone. This technique and modifications of it use less drill rig time and yield more down-hole logging information prior to the decision to case the hole and make a production or injection well.

Whichever drilling and completion procedure is being tried during the pilot test a trained geologist capable of identifying the mineralized zone and the overlying and underlying confining layers will be supervising the operation and on hand for all necessary decisions.

3.2 Major Equipment

Most of the equipment will be standard off-the-shelf items. A description of each major piece of equipment is given below.

A. Ion Exchange System

The ion exchange system will consist of a four column fixed-bed system. The resin tanks will be constructed of carbon steel with a rubber lining and will be rated for one hundred and fifty pounds-per-square-inch internal pressure. The system piping will be carbon steel with a protective liner. The resin will be strong base type anionic resin with a good affinity for the uranyl tricarbonate ion. The ion exchange system will be designed for a nominal loading flowrate of one hundred gallons-per-minute.

B. Precipitation System

The precipitation system consists of two tanks, a precipitator and a chemical mixer. The precipitator uses steam to heat the pregnant uranium solution and precipitate uranyl oxide. The chemical mixer is used to redissolve ammonia and carbon dioxide gases from the precipitator for later use as resin strip solution. The mixer will be a sealed atmospheric tank with no special features.

C. Dryer

The dryer system will consist of a rotary vacuum dryer, solid-vapor separation filter, vacuum pump, liquid-vapor separator and a dust control system for the unloading operation. The heat will be provided for the drying operation by a steam jacket around the dryer shell and rotor. The design batch-size of the dryer will be about 200-400 lbs. This type dryer is used in the pesticide industry and is designed to minimize or eliminate any product emissions.

D. Liquid Handling and Storage

1. Pumps Piping and Filters

Since this plant will be built in a modular fashion with the major equipment on separate skids, the piping consists mainly of connections between skids. This piping will consist of CPVC and PVC piping, valves and fittings with stainless steel pumps and instrumentation. The filters used will be cartridge type with stainless steel or rubber lined steel housings.

2. Liquid Storage Tanks

The batch nature of the metallurgical process requires the storage of process solutions. The storage tanks will be fiberglass and designed according to the specific use and sized to accommodate the process requirements.

3. Bladders

Rubberized storage bladders of the type used on construction of the Alaskan Pipeline will be used for this purpose. The plant will initially have 90,000-150,000 50,000 gallons of bladder storage capacity with the space available to add more bladders if necessary.

E. Reverse Osmosis System (R.O.)

The plant equipment will include a reverse osmosis water purification unit. This unit will be used to purify plant water and boiler feed, as well as for concentrating leach chemicals during restoration of the ground water in the well fields. A special R.O. unit will be used for final well field restoration to help concentrate the leach chemicals.

F. Support Equipment

1. Boiler

The plant steam boiler will be a 30-40 hp packaged unit skid mounted, complete with all instrumentation, insulation and valving. It will be inspected prior to use by the Hartford Boiler Insurance Company, of Hartford, Connecticut.

2. Generators

The electrical power for the plant will be supplied by diesel powered generators purchased as a skid mounted unit complete with switchgear, generators, and piping. The generator skid will be installed inside the building with plug-in type electrical connections to process equipment skids.

3. Chemical and Fuel Storage

The chemicals which are used in the process will be stored in tanks leased from the chemical supplier which will be properly designed for the specific chemical to be stored. These chemicals will be anhydrous ammonia, carbon dioxide, and 50% hydrogen peroxide. The fuel for the boiler and generators will be stored in a special fuel bladder with a containment dike surrounding it. The fuel for the lab and crew trailers will be stored in an LP gas storage tank leased from the supplier.

4. Air Compressor

The instrument and process air will be supplied by a small air compressor which will be purchased as a packaged unit.

3.3 Safety Instrumentation And Control System

The safety instrumentation, outlined below, is designed to safeguard against fluid handling accidents and electrical accidents. Additional safety precautions and instrumentation regarding radioactive exposure are discussed in Section 5.0.

A. Boiler

The boiler will be A.S.M.E. and National Board stamped. The boiler will be equipped with safety relief valves and blow-open safety door. The boiler will operate at a maximum of 60 psi.

B. Piping

All piping will be either schedule 40 or 80 PVC. Pipe runs will be in overhead pipe racks to protect against accidental abuse. Instrument flanges will be 200 lb. rated with others at 125 lb. A.S.M.E. The piping system will be designed to stand more pressure than the pumps will supply.

C. Pressure Tank (Uranium Precipitator)

The tank, piping, and flanges will meet A.S.M.E. standards. The steam system will be fitted with a 60 psi pressure relief valve.

D. Dryer

The dryer steam jacket will be fitted with a 60 psi pressure relief valve.

E. Storage Tanks

Each storage tank will be fitted with a high liquid level alarm and pump cutoff control to prevent overflow.

F. Electrical Boxes, Panel, and Wiring

All electrical wiring will be assembled according to the 1978 National Electrical Code to protect against electrical shock. A no-fault ground system will be incorporated throughout the plant electrical system.

G. Other Control Systems

The control system is as simplified as is practical. The process plant is manually operated. Electronic automation is used only for control of the boiler steam production. All flows into and out of the plant and well field, including electricity, fuel, and chemicals, are monitored as to rate and total accumulated consumption. During each shift, the operating personnel will have available the information necessary for a complete process material balance and/or fluid inventory.

Automatic controls in the process plant and well field may be evaluated after operating experience has been gained.

4.0 WASTE MANAGEMENT SYSTEM

The concepts of "zero discharge" are designed into this plant and operation, but the ultimate feasibility and success of this concept will depend upon the outcome of the test. Gaseous emissions are limited to building and tank ventilation for radon control, diesel engine exhaust, and minor amounts of evaporative loss from tanks. Liquid and solid wastes are minimized by good fluid management in the well field and by reverse osmosis technology, which yields a clean water product and a concentrated waste stream. The only planned discharge is a small volume,

non-radioactive reverse osmosis waste stream which will not leave the permit area but will be discharged into a specially designed drain field, much like a sanitary drain field. The location of this R.O. drain field is shown on Figure 1.

The composition of non-radioactive reverse osmosis waste is much like the natural ground water as the reverse osmosis unit merely separates water (H_2O) from the remaining constituents. However, during restoration of the well field, the reverse osmosis unit operation will include process waters from the well field composed of the remaining lixiviant and any impurities generated during leaching and the waste stream composition may change and may become slightly radioactive. Bladder-type storage of these restoration residues is planned to insure that proper handling of all the potential chemical and radiological constituents is assured. Nonradioactive wastes are generally routed to the sanitary landfill or to the drain fields. Radioactive wastes are accumulated in the bladder storage area for later treatment to concentrate the waste, generate by-products, and/or decontamination.

Due to the small scale of the operation and the unique process characteristics proposed for this research pilot plant, the amount of radioactive waste should be small and manageable. The levels of radioactivity should be low. Once the final radioactive wastes are analyzed, the project manager will work with the proper regulatory personnel to arrive at a feasible method for final disposal.

Figure 17 illustrates all potential waste sources and denotes their fate.

4.1 Gaseous

A. Dust Collection

The only area of the plant which will require dust control will be the yellow cake dryer. This area is separated from the major part of the plant. The water vapor which is drawn out of the dryer by a vacuum pump is passed through a solid-vapor separation filter to remove any fine particulate yellow cake. The water vapor passes through a liquid seal vacuum pump. This particular type of vacuum pump brings the water vapor in contact with water circulating through the pump, causing an excellent scrubbing action. Any uncondensed water vapor leaving the vacuum pump will be piped to contact it with leaching solution thereby preventing any escape to the atmosphere. The product discharged from the dryer will be loaded into steel drums. The dust generated during the drum filling operations will be contained by the use of a drum cover connected to the dryer with a flexible connection.

B. Ventilation Systems

1. Tank Vent System

All liquid storage tanks are completely sealed, under a slight positive pressure, and are vented into a common ventilation piping system which will be routed outside the plant. This air stream may contain a very minute amount of radon gas.

2. Dryer Room

The dryer room will be provided with an outside vent fan which will insure air flow from the main part of the plant through the dryer area.

3. Building Ventilation

The building will have a fan on one end and intake louvers on the other to insure a constant supply of fresh air.

C. Radon Gas

Radon gas may be detectable at very low concentrations in the production surge tank which collects the leach solution from the well field prior to pumping through the plant. This tank is located inside the plant building and is completely sealed, except for one vent, and has a slight positive air pressure from an air bubbler level indicator. This air pressure suffices to vent any radon gas to a common ventilation line which terminates outside the plant building.

All storage tanks are located inside the plant building and vented to the common ventilation line. The vents are necessary to balance atmospheric pressure while filling and draining the, otherwise, sealed tanks.

4.2 Liquid and Solids

Liquid wastes will consist of two separate reverse osmosis waste streams.

One reverse osmosis (R.O.) unit operation will be used to produce very pure water for plant makeup and steam heat. This water will originate from a water well <u>outside</u> the mine area. All calcium, sodium, sulfate, chloride, etc., ions will be essentially removed from R.O. product water. The brine waste stream from the R.O. unit will be pumped to a drain field designed specifically to adsorb all nonradioactive R.O.

waste water used in plant makeup. This waste stream can be considered the plant "bleed" stream. We estimate that this brine waste discharge to the drain field will be about 400-900 gallons-per-day.

A separate reverse osmosis unit operation capable of efficiently processing high TDS water will be used to restore the ground water in the last well field pattern. This R.O. waste stream will be stored temporarily in large rubberized bladders (See Section 4.2.1). As part of the research project, this R.O. waste will be evaluated as to the feasibilty of treatment to separate the radioactive from the nonradioactive compounds. All radioactive waste will be stored on site, either in drums or bladders, until a decision can be made concerning its absolute toxicity and determine an average daily amount that can be expected in a commercial scaleup.

The nonradioactive waste will consist of primarily a 10-30 gram-per-liter calcium sulfate/sodium chloride brine, with 0.5-2 milligrams-per-liter of ammonium carbonate, as well as trace amounts of the heavy elements such as uranium, vanadium, molybdenum, selenium, arsenic. This non-radioactive brine will be sent to the R.O. waste drain field.

4.2.1 Prevention of Discharge of Liquids and/or Solid Waste to the Environment

Large rubberized bladders (30-50 thousand gallon capacity) will be used instead of ponds for temporary storage of liquid wastes from the R.O. units. These bladder tanks will be surrounded by an embankment to confine any contained solutions leaking out and attempting to escape as surface water runoff. These large bladders have seen use militarily for fuel and water and were used extensively on the Alaskan Pipeline project for holding water, fuel, and brine solutions. They are readily available as off-the-shelf items in the 30-50 thousand gallon capacity. An extra bladder will be on site to allow transfer from any leaking bladder. These bladders can be easily repaired in the field.

Within the plant building, any liquid (lixiviant or pregnant eluant spills) or solid (yellow cake spills) wastes will be washed down with plant water to a sump and pumped to the production surge tank and processed again in the ion-exchange circuit.

The impervious plant floor will be designed to confine any other accidental spills or leaks, such as resin beads, lixiviant, etc.

4.2.2 Disposal of Liquid and Solid Wastes After Completion of The Project

Liquid wastes will consist of unused or reconstituted leach liquor, primarily from the last pattern area restoration. This solution will be

stored for future use, or treated to yield by-products, like fertilizer, molybdenum, vanadium, etc. Nonradioactive liquid wastes will be disposed of in the reverse osmosis drain field.

Solid wastes will consist of spent resin, charcoal, spent filter media, drill cutting, solid wastes from the assay lab., etc. Any nonradioactive solid wastes can be buried in the sanitary landfill. Radioactive wastes will be investigated as to their amenability and feasibility of decontamination and/or by-product generation.

Due to the scale of the pilot project and the nature of the process, only a modest amount of radioactive waste is anticipated and this waste is expected to exhibit low levels of radioactivity. If ultimately required, encapsulation or burial of this material in a suitable stratum (similar to conventional mill tailings stabilization) is possible. However, since this is a research pilot plant and the quantity and composition of the final radioactive waste is difficult to predict, all nondisposable radioactive wastes will be impounded and possible alternative solutions to the radioactive waste problem investigated at that time. Then, in conjunction with the Nuclear Regulatory Commission and the Wyoming Department of Environmental Quality, a final disposal plan will be developed. If no viable alternative solutions are developed, then the radioactive waste will be handled in a similar manner as conventional mill tailings.

4.3 Contaminated Equipment

The plant and well field will not contain any contaminated equipment such as wooden tanks, buildings, etc. All equipment is either steel, rubber or plastic and should not adsorb radioactive ions or particles to any significant level of detection. Decommissioning of the site will involve complete removal of all equipment, restoring the land contours, spreading topsoil and seeding the disturbed area. The roads to the area will be left in good condition, since they will continue to be used by local ranchers.

5.0 OPERATION

The research pilot plant described in this application is part of a complete development program. In addition to investigating the technical aspects of uranium extraction by solution mining, the development of training procedures for personnel, and a radiation safety and monitoring program are planned. More details of these programs will become available as the complete staff for the pilot test is acquired. All required programs to insure personnel safety and radiation control will be in effect prior to plant start-up.

5.1 Corporate Organization

Figure 20 illustrates the chain of command for the control of the solution mining pilot project. Cleveland-Cliffs is the Manager of the joint venture and is responsible for carrying out programs approved by the joint venture.

5.2 Qualifications of Personnel Administering the Radiation Program

For the research plant, the radiation safety program will be administered by the project supervisory personnel. These people will have experience and training when they begin work or will be trained. Training is available through the Mine Safety and Health Administration (M.S.H.A.) and seminars, such as those offered periodically at the University of Texas Medical College regarding radiation health physics.

5.3 Radiation Safety Instructions

All employees and consultants engaged in operating the pilot plant will be issued radiation badges. These badges will probably be issued by the Life Science Group, Dosimetry Services, 26201 Miles Road, Cleveland, Ohio 44128, or an equivalent group. All personnel will be trained upon the proper use of this equipment.

All employees must wear hardhats, hardtoed shoes, and safety glasses. Respirators and safety gloves will be worn when handling either yellow cake spills or chemicals such as 50% hydrogen peroxide.

Radiation safety instruction will be included in the overall safety program to be developed for this project.

5.4 Security of Operating Areas

The entire plant and well field (approximately 6 acres) are enclosed by a fence and signs posted warning intruders to proceed with caution, etc. All equipment can be secured at the mine site either in the well field control station, or the Metallurgical Plant building. Gates entering the fenced areas can be locked.

The site will have at least two operators 24 hours a day, 7 days per week. Temporary quarters will be maintained at the site for those operators preferring low-cost living. Due to the nature of the pilot operation, its location, and its mode of operation, Cleveland-Cliffs does not intend to use security guards at the site, unless there is a major, long-term suspension of testing.

Yellow cake will be stored dry in 55 gallon steel shipping drums in a designated area within the metallurgical plant. It will be stored on

ORGANIZATIONAL CHART

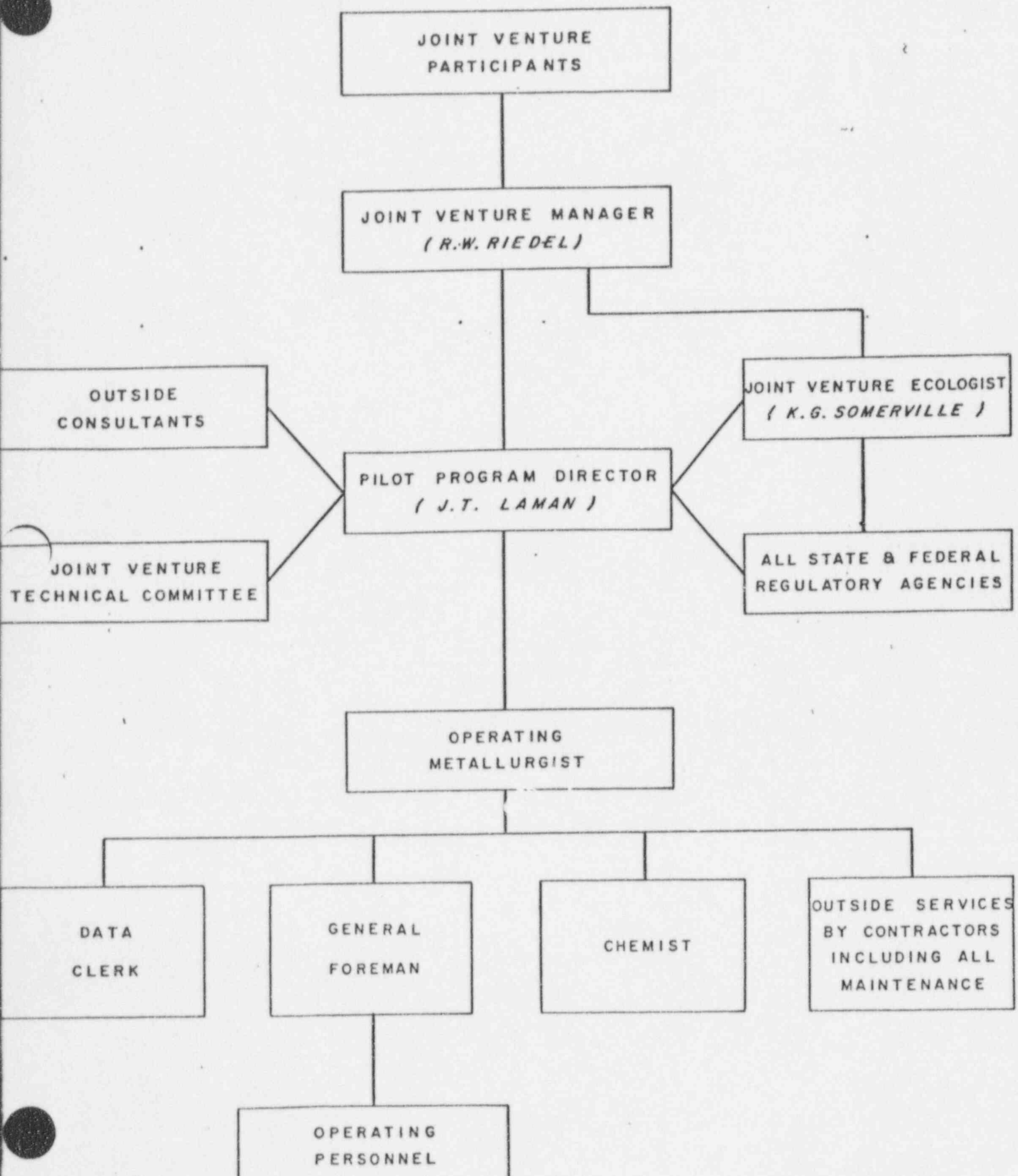


FIGURE 20

site until enough is available to ship by an authorized trucking company such as Tri-State, etc., who are experts in the transportation of yellow cake.

5.5 Radiation Safety Program

Cleveland-Cliffs will develop a radiation safety program and submit this program for approval at a later date.

6.0 ENVIRONMENTAL REPORT ADDENDUM

The proposed project uses a 100 gallons-per-minute research and development plant which is designed to assess the technical viability and economic feasibility of in-situ extraction of uranium. This solution mining method uses, and conserves, low-cost chemicals, such as anhydrous ammonia, carbon dioxide and hydrogen peroxide. The products of the leaching reactions are primarily water and water soluble ammonium uranyl tricarbonate. The process does not generate wastes in the sense of conventional mine-milling systems, as there is no overburden removal, mill tailings, or ponds. This process should have a very minimal environmental effect.

The proposed mining method should require only a small number of men (2-4 per shift plus supervisory and maintenance personnel on day shift) to operate. In effect, the "solution does the mining." This will, in the end, result in less impact to the outlying communities as well as the environment in the area of the test facility.

The proposed method of mining should have less impact on the surface of the site than would a small open pit or underground mine: less impact on the ore zone (the ore is left in place); less impact on the ground water aquifer (it is not removed); less impact on the ground water budget (it is only borrowed, not permanently removed); less impact on the atmosphere (virtually no gases or dust produced, if electricity were available no fumes from diesel power generation); less radiometric impact (only trace amounts of radon produced); less impact to personnel (no explosives, no breaking, crushing, grinding or transporting of solids). There is less impact to the environment after mining since virtually no detectable liquid or solid wastes are left behind (drill cuttings, etc., are buried).

6.1 Environmental Effects of Site Preparation and Facility Construction

The surface plan is shown on Figure 1. Approximately 3.86 acres will be disturbed and approximately 6 acres fenced. All topsoil stockpiling and surface reclamation will be in accordance with the rules, regulations and guidelines of the Wyoming Department of Environmental Quality - Land Quality Division. The complete reclamation plan and a brief ecological overview is included in Section 6.4.a.

The design is considering the short-term nature of this pilot research and development facility. Equipment will be modular and require minimum foundations. All foundations and/or impervious surfaces are designed for personnel safety and rapid dismantling whenever possible. Evaporation ponds for the storage of process water are not used.

Power lines and telephone lines are not planned because neither service will be available at the test site. However, if they do become available, power lines and a telephone line may become an environmental consideration.

Site preparation and facility construction can be listed as follows:

1. Road repair and upgrading;
2. Plant site leveling and foundation work;
3. Well field drilling;
4. Construction of pilot plant and building erection;
5. Construction of bladder storage area and chemical storage and refilling area;
6. Construction of sanitary waste drain field;
7. Construction of laboratory wash water waste drain field;
8. Construction of R.O. waste drain field;
9. Pipelines from well field to plant and from bladder storage area, chemical storage area to plant;
10. Fencing and lighting.

All phases of site preparation and construction and well field drilling will start as soon as the necessary permits are issued. Total time from start to finish is estimated to be two months. This short period of time should have little effect on the environment. The amount of material to move for leveling and to provide ditches and embankments (See Figure 1) to prevent spills is small. The plant will be located on nearly level ground. There is very little grass to be affected and no trees or scrubs to be moved, no creeks to be rerouted or bridged. The mine area is an open range used for grazing cattle and is located about 300 yards from a frequently traveled ranch road.

6.2 Environmental Effects of Facility Operation

The pilot facility will normally have 2-4 men at the plant and well field to operate efficiently. Noise generation at the site will be due mostly to diesel-powered electrical generators. Mufflers will be used to reduce this noise level as low as possible. Normally, solution mining facilities are quiet compared to other mining methods.

There will be no reason to operate outside the fenced area (approximately 6 acres) except to check monitor wells.

Ammonia, carbon dioxide, hydrogen peroxide and diesel fuel deliveries will be made to a separate area (See Figure 1) located about 200 feet from the plant building. Most chemical deliveries will be made about once every two months. Their effect on the normal environment and wildlife of the area will therefore be minimized.

The maximum number of vehicle trips due to crew changes is three per day. Miscellaneous vehicular traffic will be kept to a minimum.

6.2.a Radiological Impact on Man

Solution mining normally has very little radiological impact on the operating personnel. Wyoming Mineral Corporation, in their recently submitted Environmental Report for the Irigaray Project, stated that their pilot operation in Bruni, Texas showed an average whole body exposure of only 3.2 mr/man/year. The present occupational exposure limit (10 CFR, P20) for whole body exposure is 5,000 mr/man/year.

The nearest ranch house is located approximately two miles north of the test site. Radiological emissions from the plant, if any, are expected to be very small and should not affect people living at or near the ranch house. The source of potential radiological emissions is the tank and building ventilation system and the yellow cake dryer. Since this particular process uses a vacuum dryer rather than a calcine furnace stack, emission of yellow cake dust is completely eliminated.

6.2.b Radiological Impact on Biota Other Than Man

Radiological hazards to biota other than man will probably not be detectable.

6.2.c Effects of Chemical Discharges

The only chemical discharges that will be made will be as a nonradioactive brine to a shallow drain field. Therefore, the effects of these discharges to man and other biota will be minimized.

6.2.d Effects of Sanitary and Other Waste Discharge

Sanitary waste will be discharged to a septic system designed for the maximum number of employees who may be at the site at any one time. Other wastes such as garbage, paper, tin cans, etc., will be buried in a fenced landfill disposal pit.

6.2.e Radioactive Waste

Any radioactive wastes generated will be impounded either in cans or bladders and then investigated as to the viability of decontamination, by-product generation, or waste stabilization (similar to conventional mill tailings). Due to the scale of the operation and the nature of the process, this potential radioactive waste accumulation should be very small and readily manageable and not pose a hazard for either operating personnel or other people in the vicinity of the test.

6.3 Environmental Effects of Accidents

Primary sources of potential chemical or radiological release to the environment are: (1) plant area, (2) well field system, (3) product transportation, and (4) bulk chemical storage. Major environmental damage should be precluded by the scale of the operation, the nature of the chemicals, and the low level of radioactivity associated with this process.

6.3.a Plant Area

The plant floor will be an impervious material designed to facilitate the confinement and collection of any spills in the plant area. All spills will be returned to the process. The environmental effect of accidents in the plant area should be insignificant.

6.3.b Well Field System

Subsurface escapes of chemicals and the corrective action are discussed in Section 3.1.3. Failure in the surface piping system can result in releases of lixiviant chemicals and leaching products onto the surface. Well field spills will be contained by controlled drainage to a collection area where the fluids can be returned back to the process or impounded in the bladder area. Nonradioactive spills in the well field should have a minimal environmental effect as the main chemical, ammonia, is commonly used as a crop fertilizer. If these fluids should become radioactive, the containment procedure would be the same, but the surface soils may have to be decontaminated. The environmental effect,

after decontamination, should also be insignificant. Due to the low levels of radiation present, the effect on the environment during decontamination should be negligible.

6.3.c Transportation

The greatest potential hazard to the environment probably exists during the transportation of the dried yellow cake product. Standard packaging in containers approved by the Department of Transportation and the commissioning of experienced agents such as Tri-State Motor Transit, who are experts in the transportation of yellow cake, will be used to minimize the risk of accidental release of yellow cake. Specialty carriers, such as Tri-State, normally have spill prevention and spill clean-up procedures established in the event of an accident.

6.3.d Chemical Storage

The major bulk chemicals required in the process are ammonia gas, carbon dioxide gas, and hydrogen peroxide liquid. All bulk chemical storage will be outside the process building. Leaks or spills due to equipment failure will be quickly dispersed into the atmosphere and should not have a serious impact on air quality in the area.

The fuel oil, the primary fuel for the plant, will be stored outside the process building. The immediate area around the fuel oil storage will be designed to contain all leaks in the immediate area. Any spills will then be collected and returned to a storage vessel. Some hydrocarbon seepage into the ground can be expected, but proper surface restoration should alleviate this potential environmental effect.

6.4 Reclamation and Restoration of the Site

6.4.a Reclamation Plan

Reclamation will be accomplished, in general, to the rules, regulations, and guidelines of the State Department of Environmental Quality - Land Quality Division. Variances adaptable to Cliffs' area have been and will continue to be worked out with the Sheridan office of the Wyoming Department of Environmental Quality - Land Quality Division, Mr. Phil Dinsmoor, Vegetative Specialist.

The seed mix to be used at the Collins Draw site is one that should produce vegetation throughout the Pumpkin Buttes Area. Fifteen pounds of seed per acre is planned. The seed mix is as follows:

Western Wheatgrass	24%
Thickspike Wheatgrass	24%
Slender Wheatgrass	12%
Whitmar Wheatgrass	4%
Green Needlegrass	16%
Prairie Sandreed	4%
Blue Grama ('ass	4%
Pubescent Wheatgrass	4%
Smooth Brome Grass	4%
Sainfoin (Eski)	2%
Fourwing Salt Bush	x<4%

*Seed availability may alter mix slightly.

At the Collins Draw site there will be 3.86 acres of disturbed land that will need to be reclaimed when all phases of the operation have been completed. This acreage is made up of storage and processing areas, well fields and roads.

On all of the areas that will be disturbed, the top 8" of soil will be designated as topsoil. This topsoil will be stockpiled for future use in reclaiming the area after the site is abandoned.

The area for stockpiling the topsoil will be located no less than 200' away from the processing and storage areas. It will be stored in such a way that it is out of any drainage patterns so as to prevent contamination by any chemical spills.

The stockpile area will be 100' x 200' in dimension with signs erected around the perimeter designating it as a topsoil stockpile. The topsoil should be piled in this area in such a fashion that the slope has a ratio of at least 3:1.

After all topsoil has been stockpiled, it will be mulched with straw and disced before being seeded with the aforementioned seed mix. This will be done to establish a vegetation cover to hold the soil while it is being stored for the duration of the project. If necessary, water bars will be constructed on the slopes of the stockpile to control erosion caused by runoff of precipitation.

After operations have been completed and all structures have been removed, the disturbed sites will be recontoured to blend in with the surrounding topography. Topsoil will be distributed over the recontoured area with the use of graders and backhoes to a minimum depth of 6 inches.

Prior to seeding, the site will be prepared in the following manner. Fertilizer will be applied to the site if subsequent testing of the

topsoil deems it necessary. Straw will be used as a mulch and then the entire site will be disced to work the fertilizer and mulch into the soil, and to break up any chunks of soil and smooth the site for seeding. Water bars will be constructed in appropriate areas to minimize erosion and sedimentation.

The best planting time for most native grasses is in the late fall. This is true, because most native seed requires frost to crack the seed shell to allow germination. Some grasses will also do well if they are planted in the early spring while there is sufficient moisture in the ground. Taking this into consideration, Cliffs will do all seeding in the fall or early spring prior to April 15. All seeding will be done on the contour.

All roads into the area will be reclaimed with the exception of a 12' wide road allowing access to existing unimproved roads on the Brown Ranch. The road areas not included in the 12' access road will be plowed up and leveled, covered with topsoil and treated in the same manner as other reclaimed areas.

To protect the reclaimed areas, they will be enclosed by a barbed wire fence. This will protect the new vegetation from grazing stock until it can sustain itself under properly managed grazing. This enclosure shall remain in place for a period of 2 years or for a period to be determined by the administrator, permitee, and the landowner.

6.4.b Reclamation and Restoration of the Subsurface or Ground Water Aquifer System

Ground water restoration after mining will be accomplished primarily by the use of a large 50-100 gpm reverse osmosis system designed primarily to handle water of TDS levels as high as 30-40 gm/liter with a high reject level, 90-98%, and produce a minimum volume of waste water. The clean water from the R.O. unit will be returned to the aquifer system. The waste stream will be stored in the bladder storage area and later studies will be made to assess the feasibility of reprocessing and removing to a very low level the contained molybdenum, uranium, selenium, arsenic, radium, ammonia, and carbon dioxide, resulting in a nonradioactive, calcium sulfate/sodium chloride brine that may be disposed of in the R.O. waste leach field. Attempts will be made to concentrate and precipitate the nonradioactive heavy metals and to use the ammonia as a fertilizer in restoring the area.

If any radioactive wastes are discovered, the waste will be impounded and investigated as to the possibility of decontamination and by-product generation. However, in the event no acceptable alternative disposal method is developed, these low level radioactive salt brines will be stabilized in a manner currently acceptable for mill tailings.

When restoration of the ground water is complete, the ground water can be returned to its pre-mining use and will be near the original baseline conditions.

6.4.c General Ecological Overview

The Pumpkin Buttes Uranium District of Southwestern Campbell County is rangeland by classic definition. While juniper and cottonwood occur locally, the vegetation is characteristic of communities composed of low-growing shrubs and herbaceous plants adapted to the semi-arid condition of this district.

Throughout its successional development, large herbivores have influenced the composition of the vegetation dramatically. The district is well within the range of northern bison herds that roamed until the late 19th century. Since that time, the grazing nomads have been replaced with domestic livestock and ranching has continued to play a major role in rangeland development. The successional stages of vegetation development have been held in a seral stage for a long period of time by grazing animals, although conditions prior to the introduction of domestic livestock may be designated a "zootic climax."

Big sagebrush (Artemisia tridentata) is the shrub most characteristic of the better drained uplands throughout the district. The successional status of big sagebrush in this part of Wyoming has not been fully defined. Because of the nature of the understory of the big sage stands being composed of species common to the Northern Great Plains grassland, it is a high probability that the sagebrush is an invader into what should be grasslands. The theory for this invasion is based on the heavy grazing of desirable grasses by domestic livestock which resulted in the change of competitive position of sagebrush and permitted its establishment. However, since it appears that this region was grazed quite heavily by large herds of bison prior to the introduction of domestic stock, the over-grazing may be questionable as to explaining this theory.

Another view that has considerable merit is that big sage should not be considered an invader but rather a component of a transition vegetation type separating the Northern Great Plains grasslands (short-grass/mid-grass prairie) to the sagebrush eco-type which is predominant at this latitude over much of the western rangelands. This theory is compatible with current thinking in ecology which equates abrupt changes in vegetation only with equally abrupt changes in environment.

In this general area, a grassland decrease in elevation occurs from west to east, accompanied by an increase in annual precipitation and an increased length of growing season. The vegetational expression of this

complex environmental gradient is a big sage/short-grass community, which represents the ecotone between the two major vegetational zones, sagebrush zone of the west and the grassland zone to the east. The composition and structure of this standard vegetative association may vary from place to place, as controlled by broad environmental transitions, by site-specific factors and by use-history, including grazing and fire. The vegetation types and subtypes occurring in the area are described briefly below.

Big Sagebrush, Type I

The shrub layer of the sagebrush/grass community is composed almost exclusively of big sagebrush. The density of the sage layer varies from a few scattered plants, with a predominantly grass understory, to closely spaced or clumped short stands with little or no understory. In the latter, individual plant crowns do not touch. The height of the shrub layer is rarely over 18-24 inches.

The major understory species is blue grama (Bouteloua gracilis) which is almost everywhere. Taller growing grasses (mid-grasses) such as needleandthread (Stipa comata) and western wheatgrass (Agropyron smithii) are also abundant. These latter two species will vary in abundance from year to year, controlled by the variations in the moisture regime. Needleandthread is better adapted to dry-sandy soils, while western wheat is better adapted to clayey soils which hold available water.

Secondary grasses and sages include:

(1)	Sandberg bluegrass	(Poa secunda)
(2)	Prairie junegrass	(Koelaria cristata)
(3)	Threadleaf sedge	(Carex filifolia)
(4)	Indian ricegrass	(Oryzopsis hymenoides)
(5)	Green needlegrass	(Stipa viriduala)
(6)	Bluebunch wheatgrass	(Agropyron spicatum)
(7)	Cheatgrass	(Bromus tectorum)

Blue grama is most abundant in areas of heavy grazing, while Sandberg bluegrass, prairie junegrass and threadleaf sedge are rare or absent from areas of heavy grazing. Plains pricklypear (Opuntia polycantha) is widely distributed and may be abundant on ranges in any condition.

Silver Sagebrush, Type IA

A silver sagebrush shrub community is found on level to gently sloping flood plains of streams which run water during at least part of the growing season or on land which receives additional water from overflow.

Soils of these sites are deep, well drained and permeable, somewhat sandy or loamy, and usually not extremely saline or alkaline. Silver sage may form rather dense stands and grows two to three feet tall. The predominant grass is western wheatgrass. Needleandthread, Sandberg bluegrass, mat muhly (Muhlenbergia richardsens), blue grama, prairie junegrass, and threadleaf sedge are present to a lesser extent, particularly in areas of moderate to heavy grazing pressure. In lightly grazed areas, basin wildrye (Elymus cineias), green needlegrass, and several species of bluegrasses (Poa spp.) are present. Forbs are rather scarce. Occasionally, snowberry (Symphoricarpos spp.) is present.

Dry Meadow Grassland, Type II

Mixed throughout the region, scattered amongst the big sage areas "dry meadow" grassland does occur. In these areas, extreme hydrophytes are absent, and grasses such as prairie cordgrass, (Spartina pectinata), tufted hairgrass (Deschampsia caespatesia), basin wildrye, canada wildrye (Elymus canadensis), slender wheatgrass (Agropyron trachycaulum), bearded wheatgrass (A. canium), western wheatgrass (Agrophyron smithii), inland sedge (Carex interior), and mat muhly (Muhlenbergia richardsens) will be present along with a variety of mesophytic forbs, including licorice (Glycyrrhiza spp.), aster (Aster spp.), golden pea (Thermopsis spp.), meadowrue (Thalictrum spp.), starwort (Stellaria spp.), virginsbower (Clematis spp.), and yarrow (Archillea spp.). These meadows can be very productive and are often mowed for wild hay. Many of these areas are found included in many of the agricultural areas of the region.

Greasewood, Type III

Another shrub community is present along stream channels and on flood plains which receive additional water from overflow or runoff and where soils are moderately to strongly saline or alkaline. The shrub layer of this plant community is characterized by a moderate to heavy stand of black greasewood (Sarcobatus vermiculatus) with some scattered rubber rabbitbrush (Chrysothamnus nauseousus). Fourwing saltbush (Atriplex canescens), Gardner saltbush (A. gardneri) and winterfat (Eurotia lanata) also may be present on good condition sites. The understory is dominated by inland saltgrass (Distichilis spicata spp. stricta), squirreltail (Sitanion hystrix), and alkali bluegrass (Poa juncifolia) in grazed areas. Alkali sacaton (Sporobolus airoides) and Nutall alkaligrass (Puccinellia airoides) occur where high soil moisture exists into the growing season and where grazing is light.

The three major shrub communities (big sagebrush, silver sagebrush, and black greasewood) form a vegetative mosaic with several grassland communities. The uncertainty of the ecological status of the big sagebrush

and the preponderance of herbaceous species characteristic of the Northern Great Plains grasslands in big sagebrush shrubland have been discussed. Areas of big sagebrush in low density will have the appearance of grasslands and might be classified as such. Thus, a needleandthread-blue grama grassland type could be distinguished on loamy to sandy uplands and a western wheatgrass-blue grama grassland type on clayey uplands. The separation of shrubland from grassland, in this instance, is made on the density of big sagebrush. Whether certain areas exist where big sage density is limited by specific factors and which, therefore could be considered "true grassland," remains to be determined for the region.

An analogous problem may also be present with regard to the black greasewood shrub community, since stream channels and shrubs, where an inland-saltgrass-western wheatgrass shrubland type occurs, are also present. These are very similar to the black greasewood/inland saltgrass-western wheatgrass shrubland type, except for the complete absence of the shrub layer.

Nevertheless, plant communities where grasses and sedges are dominant do occur in the area under consideration. In general, these communities have rather distinctive site attributes, most important of which are high soil moisture conditions, or shallow, stoney soils or very sandy soils.

Juniper-Ponderosa, Type IV

Areas where trees are dominant are present. The most widely distributed type is Rocky Mountain juniper (*Juniperus scopulorum*). This vegetation type is well distributed over the slopes of the Pumpkin Buttes, the most dominant land mass of the area. It does have a scattering of ponderosa pine (*Pinus ponderosa*) along the very rim of each butte. Shrub species in the understory of the denser stands include skunkbrush (*Rhus trilobata*), creeping juniper (*Juniperus horizentalis*), and western snowberry (*Symphoricarpos occidentalis*). The herbaceous layer is composed mostly of grasses. Major species are green needlegrass, Sandberg bluegrass, prairie junegrass, and stoney hills muhly (*Muhlenbergia cuspidata*). More open stands will have silver sagebrush, green needlegrass, and sideouts grama (Boutelaua *curtipendula*) as the major understory species. On areas with coarser soils, bluebunch wheatgrass, little bluestem (*Andropogon scoparius*), and porcupine needlegrass (*Stipa spartea*) may be present.

APPENDIX A

L A N D   S T A T U S   R E P O R T

C O L L I N S   D R A W   M I N E   A R E A

Campbell County, Wyoming

September 29, 1978

The Cleveland-Cliffs Iron Company

TABLE OF CONTENTS

FOREWORD

In preparing the Land Status Report, the following sources of information were examined or consulted:

(a) The Bureau of Land Management

(b) Records of the State of Wyoming Land Office and State Engineer

(c) The Campbell County Land Records

(d) Records of the Campbell County Tax Assessor

(e) Highway Maps

(f) Various oil and gas companies having active exploration or drilling programs in the area of interest

(g) Records of private transactions of The Cleveland-Cliffs Iron Company with companies and individuals

(h) The card files of Petroleum Information Service

In preparing the Tract Summary Sheets, the following guidelines were used:

(a) The "SURFACE OWNER" column shows the ownership of the surface only.

(b) The "MINERALS OWNER" column shows ownership of the minerals and is subdivided in such a manner whereby the ownership of the mineral "Uranium" and "Oil and Gas" is separated and demonstrated individually from the ownership of "All Other Minerals" such as coal, etc.

(c) The "CLAIM OR LEASEHOLD INTERESTS" column shows ownership of any existing claims or leases affecting the mineral rights and is subdivided in such a manner whereby the ownership of a lease on "Uranium" or "Oil and Gas" is separated and demonstrated individually from the ownership of "All Other Minerals" such as coal, etc.

(d) The "ROYALTY OR O.R.R. INTERESTS" column shows ownership of a royalty interest in an existing lease called overriding royalty (ORRI); or, a royalty interest carved out of the base royalty of the mineral owner.

(e) The "ROW-EASEMENT & MISC." column shows ownership of surface leases, pipeline rights-of-way, utility easements, production payments, land purchase options, deaths and other facts considered pertinent to title interest.

The maps presented in this report are more or less schematic in nature and were not prepared from precise survey data; however, where specificity is required, the Tract Summary Sheets should always be consulted and the tract description thereon used.

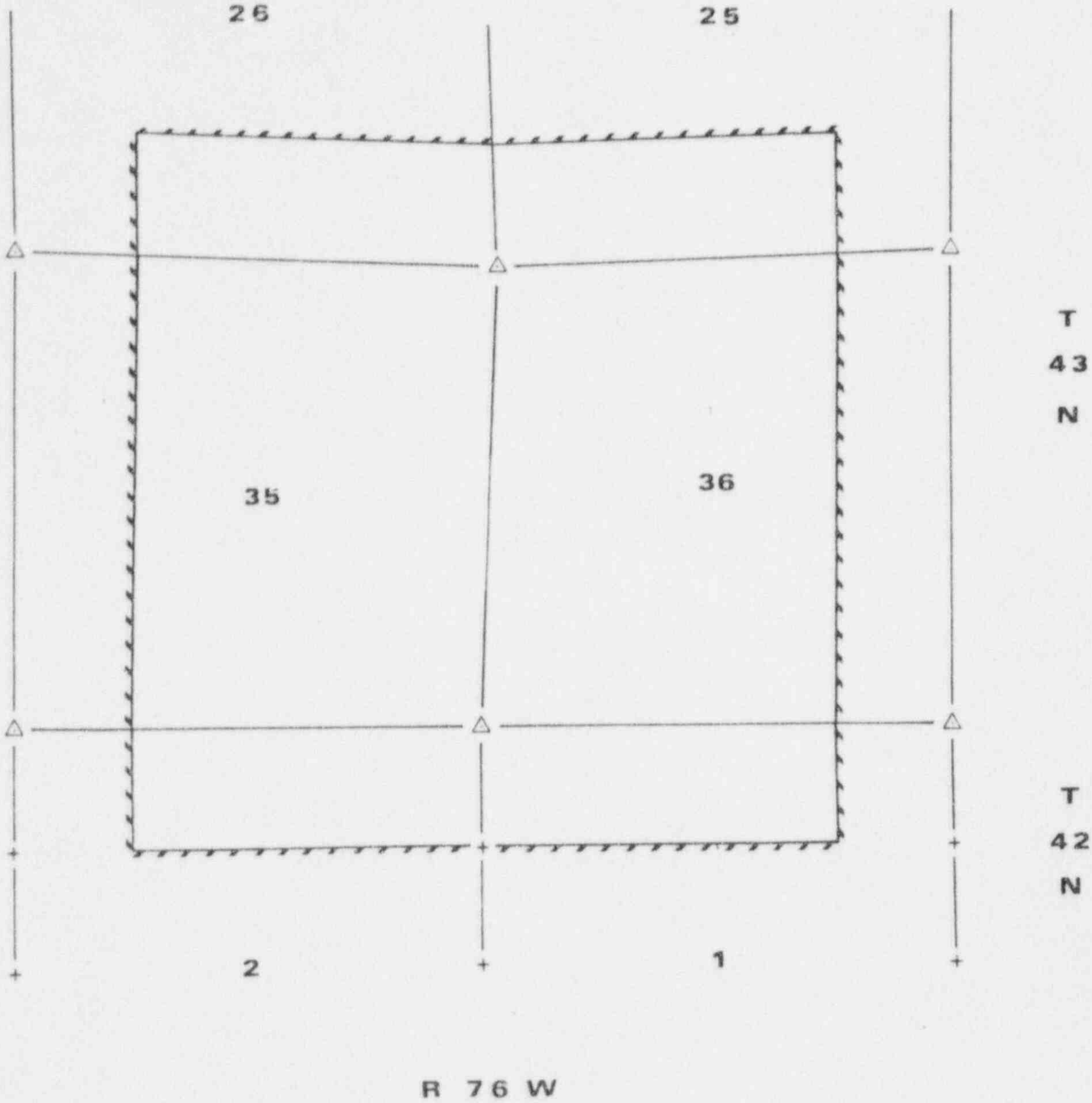
Only the legal entities of record in the Office of the Campbell County Clerk have been included in this report. Therefore, any unrecorded legal entities could not have been ascertained from such records or otherwise.

The date of this report is September 5, 1978.

R. A. Trost
Director of Land

Prepared under the supervision of R. A. Trost of The Cleveland-Cliffs Iron Company by:

D. L. Carpenter
P. O. Box 1819
Casper, Wyoming 82602



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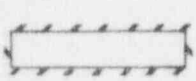
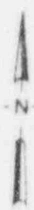

PERIMETER
AREA

The Cleveland-Cliffs Iron Company

CASPER, WYOMING



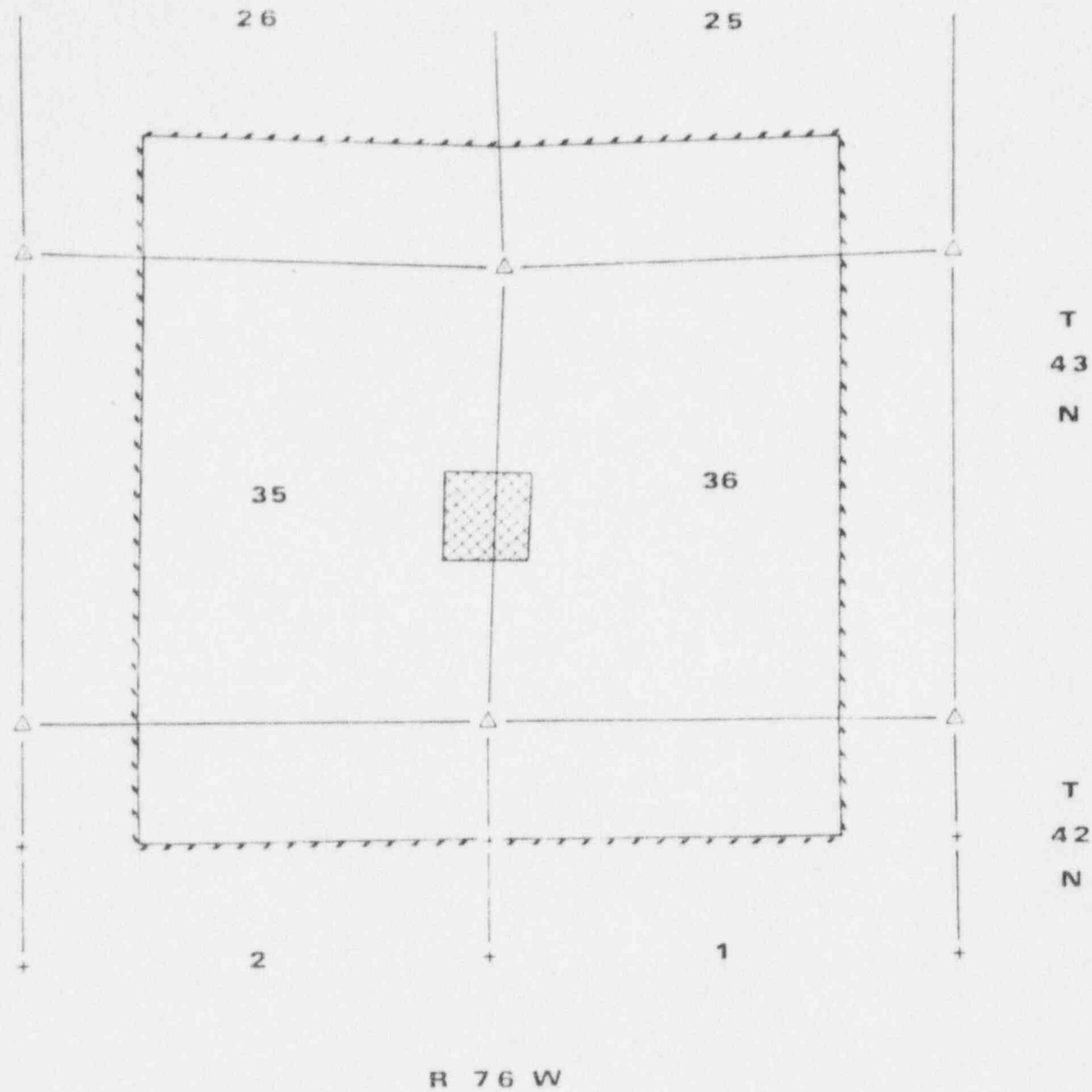
PERIMETER

AREA

COLLINS DRAW MINE
CAMPBELL COUNTY, WYOMING

1 - A

84/803 / EV-LA-XX-20 / 15 J.K.T.



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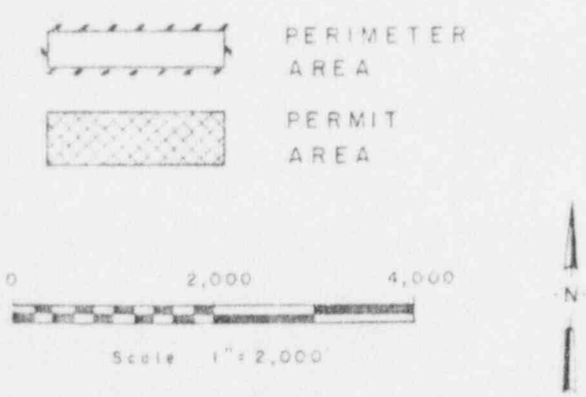


The Cleveland-Cliffs Iron Company

CASPER, WYOMING

PERMIT AREA WITHIN
PERIMETER AREA

COLLINS DRAW MINE
CAMPBELL COUNTY, WYOMING

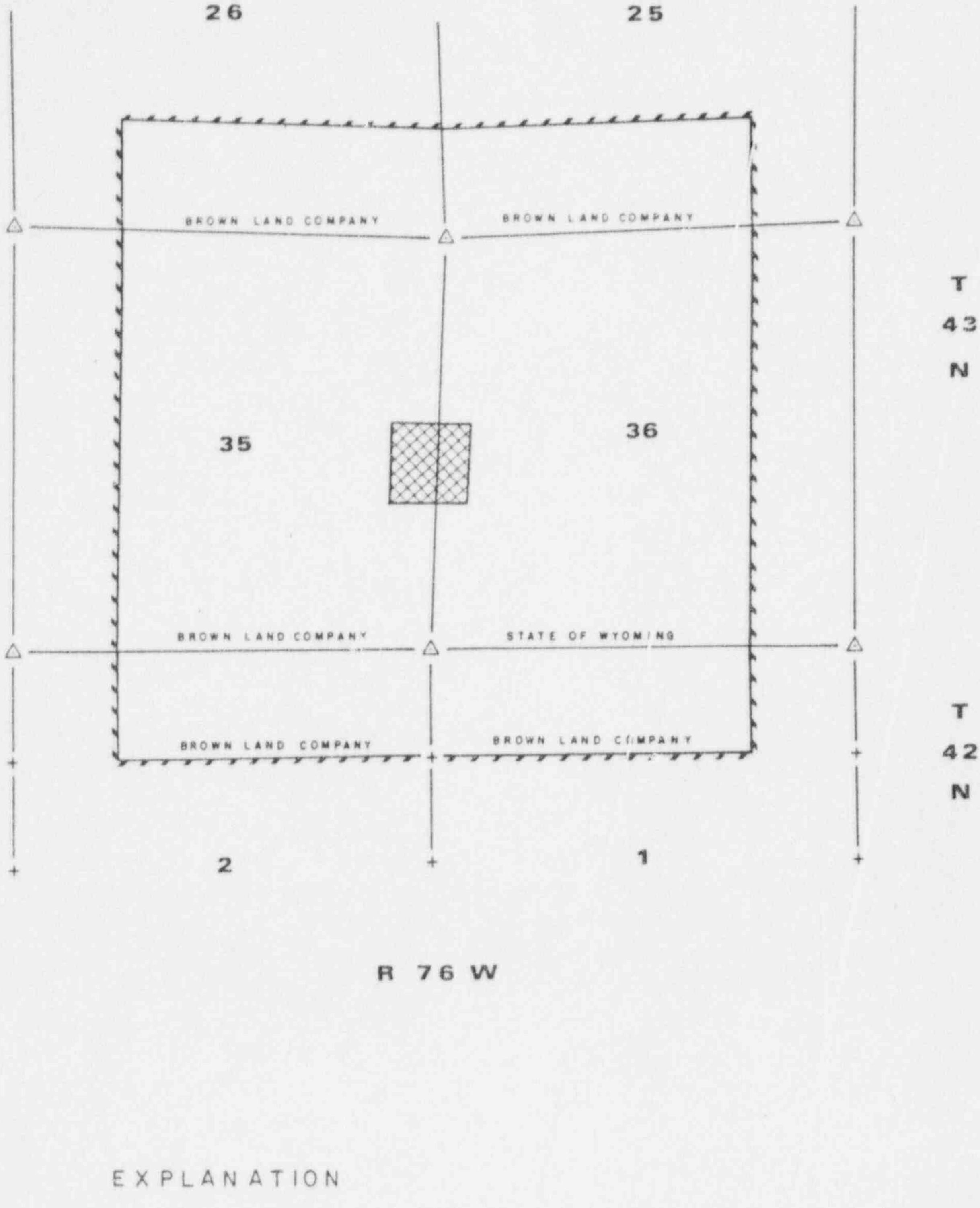
I-B

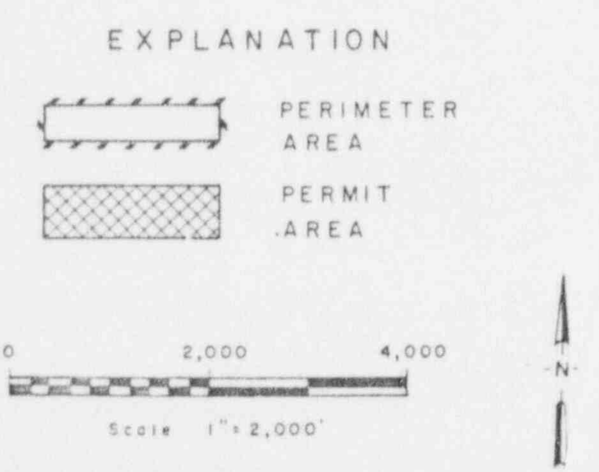
LEGAL LAND DESCRIPTION
OF PERMIT AREA

Commencing at the Northwest corner of Section 36, Township 43 North, Range 76 West, 6th P.M., thence south 01°59'39" west 2,340 feet along the east and west boundary line of Sections 35 and 36 to the point of beginning of this description, thence south 88°00'21" east 400 feet, thence south 01°59'39" west 1,000 feet, thence north 88°00'21" west 1,000 feet, thence north 01°59'39" east 1,000 feet, thence south 88°00'21" east 600 feet to the point of beginning, lying and being within Campbell County, Wyoming.

ACREAGE TABULATION

The acreage contained within the boundaries of the above description is approximately 22.96 acres.





The Cleveland-Cliffs Iron Company

CASPER, WYOMING

SURFACE

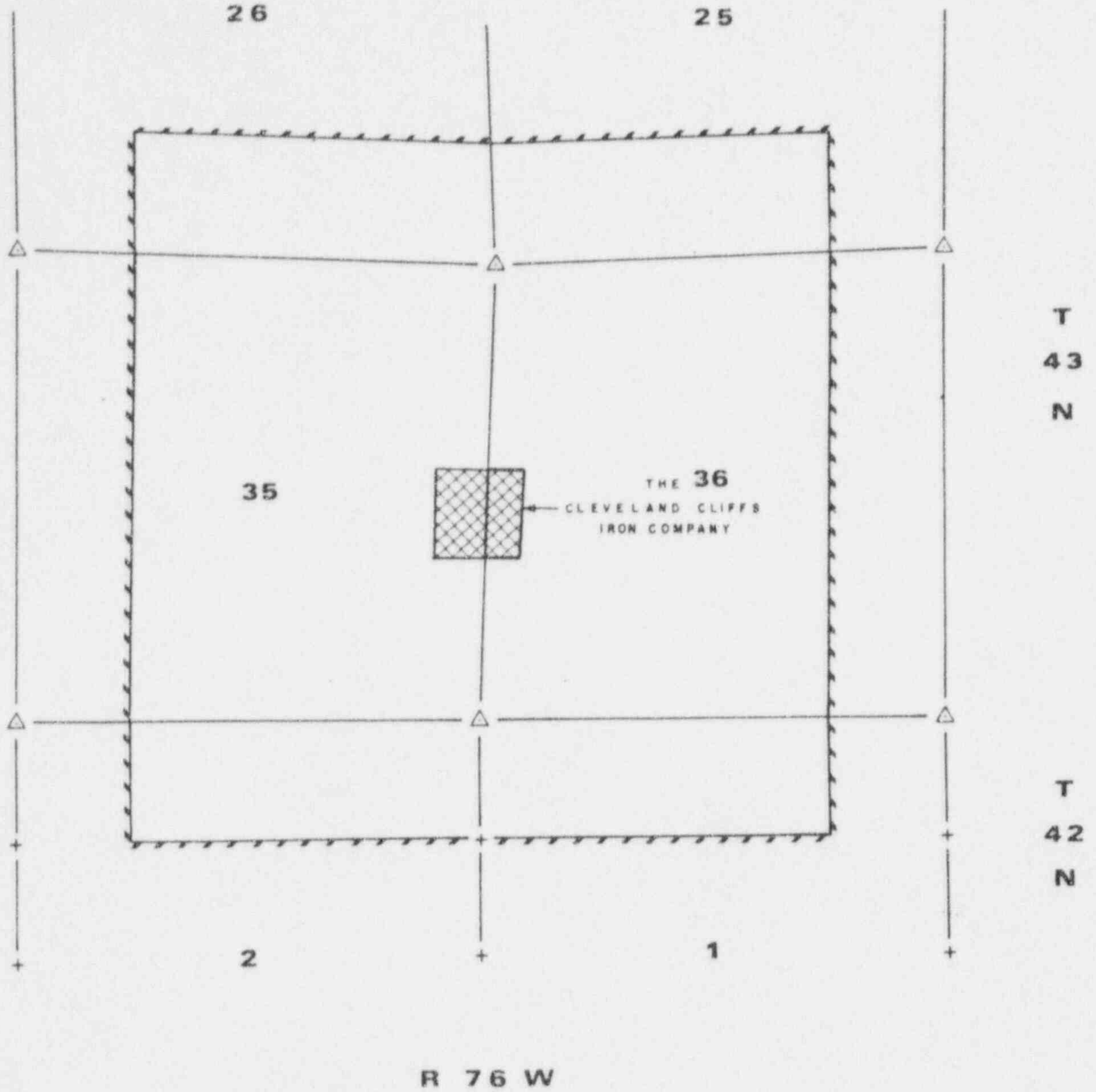
OWNERSHIP

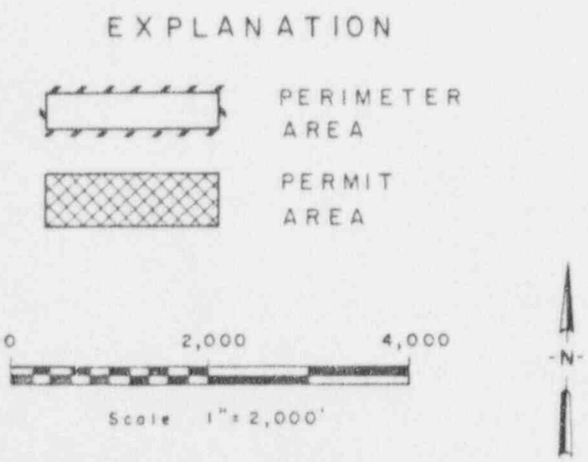
COLLINS DRAW MINE

CAMPBELL COUNTY, WYOMING

2 - A

84/803 / EV-LA-XX-20/8





The Cleveland-Cliffs Iron Company

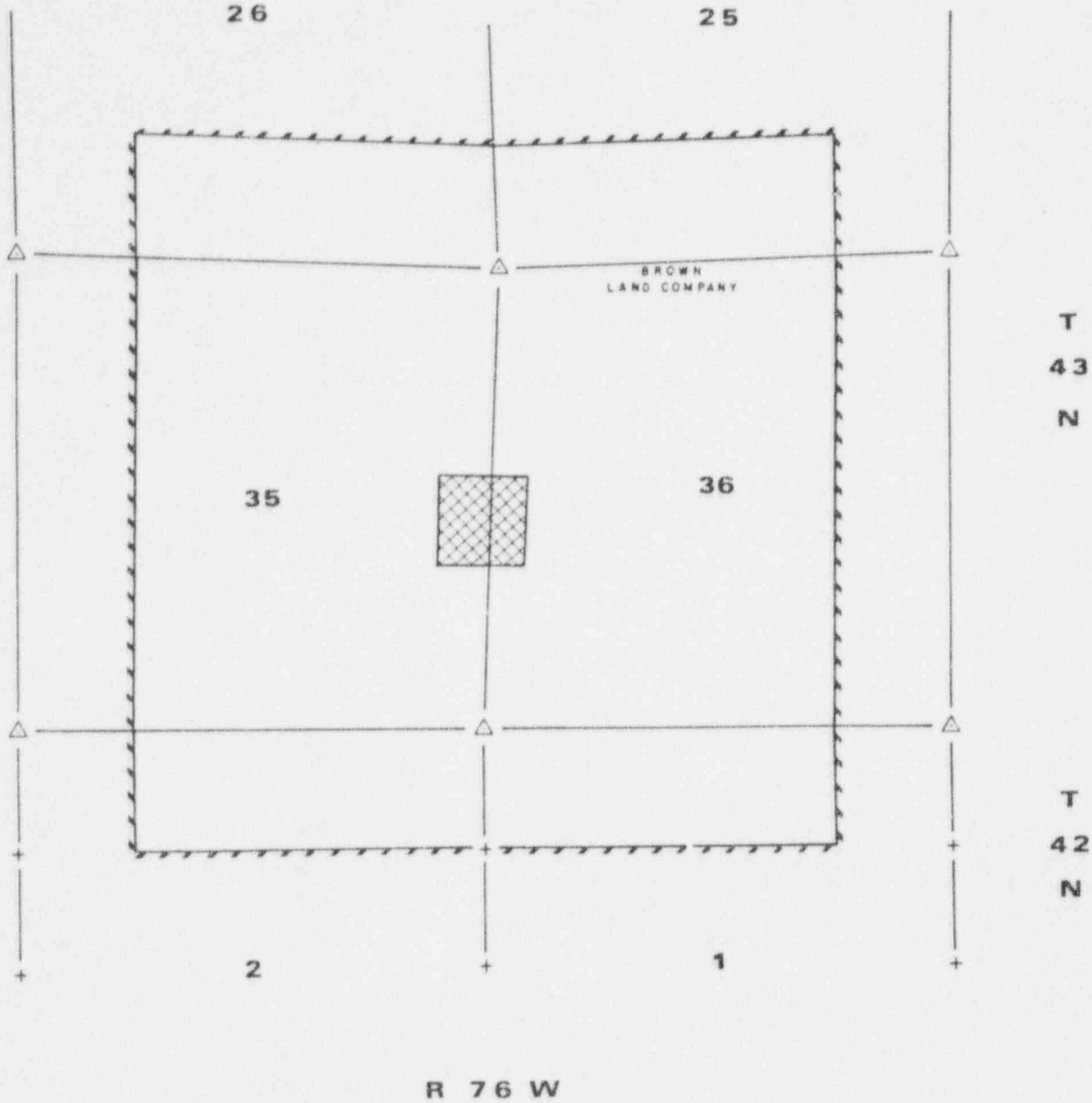
CASPER, WYOMING

SURFACE LEASE

COLLINS DRAW MINE
CAMPBELL COUNTY, WYOMING

2 - B

84/803/EV-LA-XX-20/9 JKT



EXPLANATION

PERIMETER AREA

PERMIT AREA

0 2,000 4,000

Scale 1" = 2,000'

N

2 - C

The Cleveland-Cliffs Iron Company

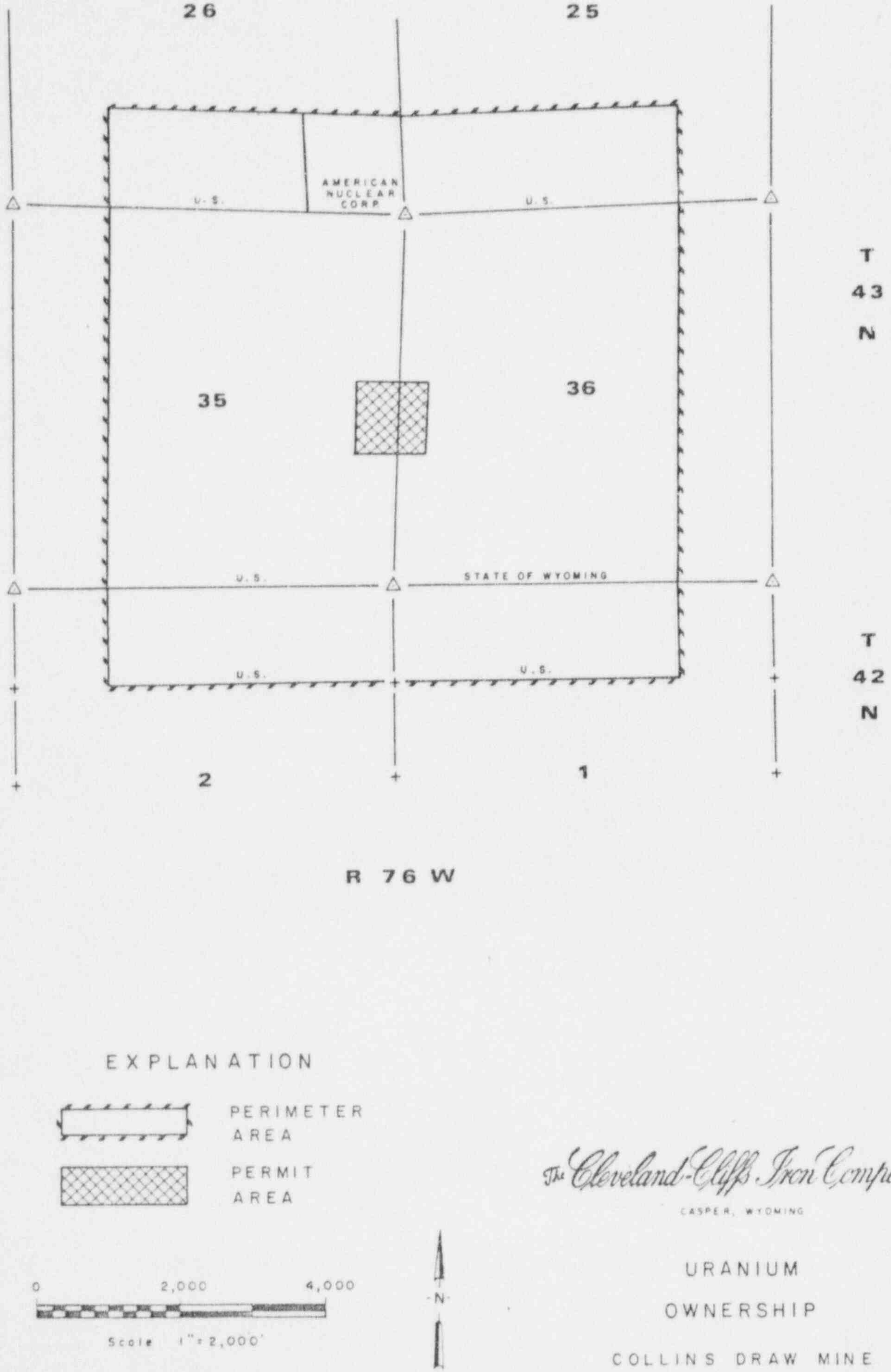
CASPER, WYOMING

GRAZING

LEASE

COLLINS DRAW MINE
CAMPBELL COUNTY, WYOMING

84/803/EV-LA-XX-20/10 J.K.T.



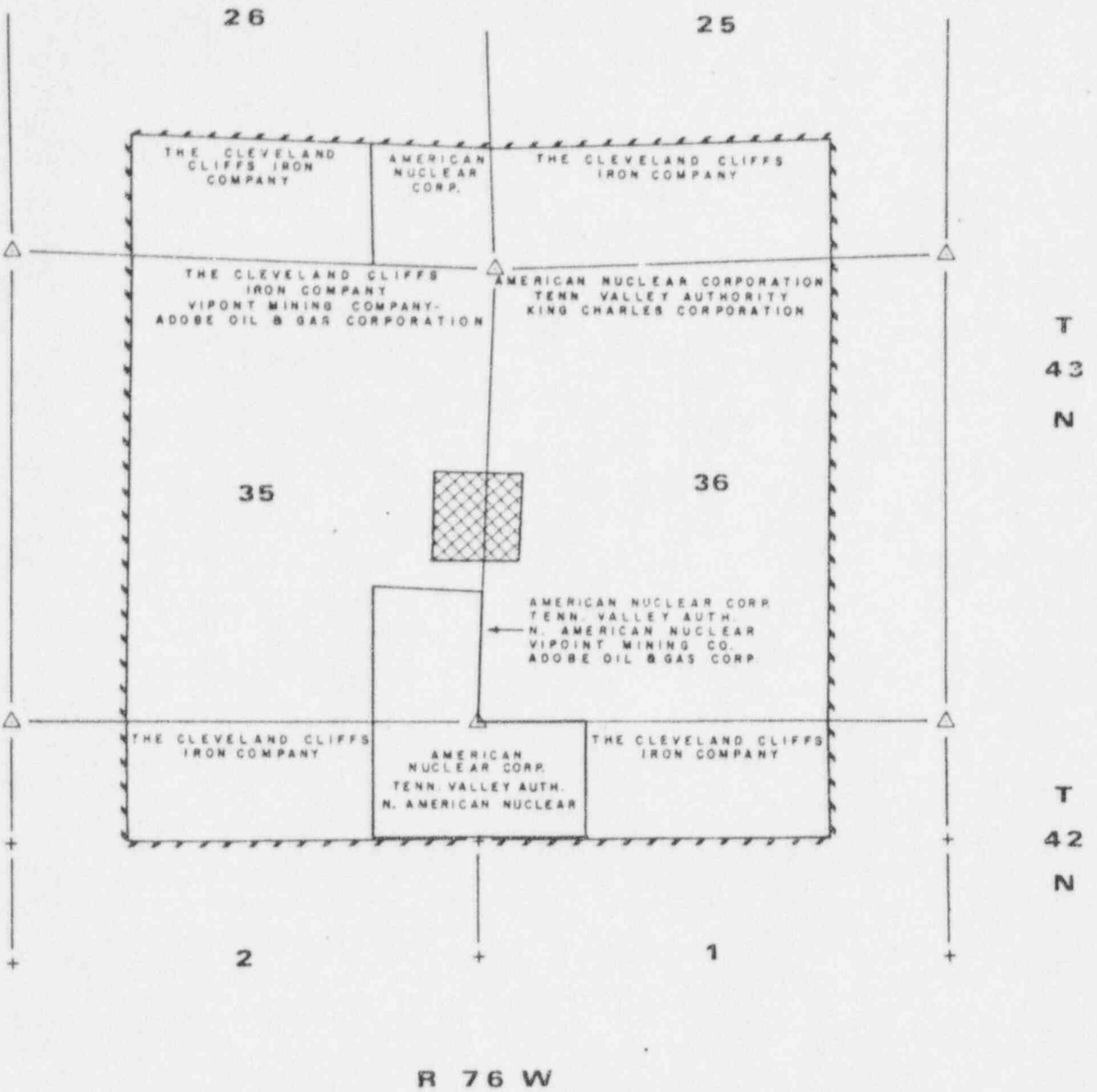
The Cleveland-Cliffs Iron Company
CASPER, WYOMING

URANIUM OWNERSHIP

COLLINS DRAW MINE
CAMPBELL COUNTY, WYOMING

3 - A

84/803/EV-LA-XX-20/4



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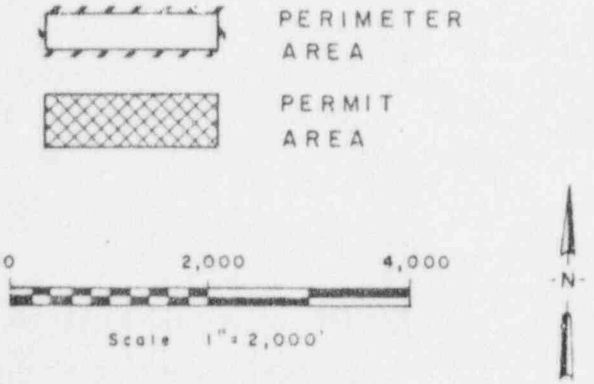


The Cleveland-Cliffs Iron Company

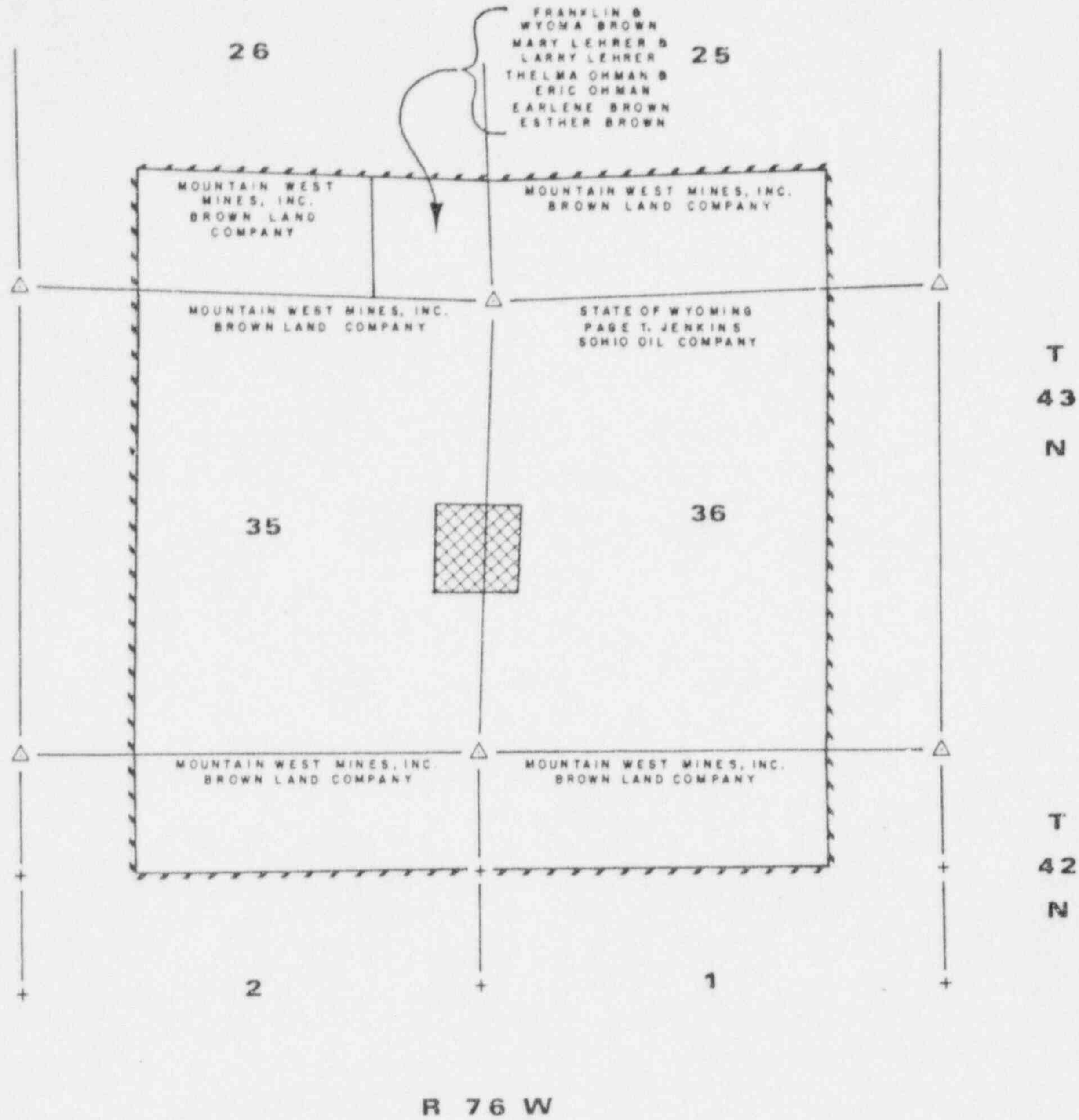
CASPER, WYOMING

URANIUM CLAIM OWNERSHIP
and LEASEHOLD INTERESTS

COLLINS DRAW MINE
CAMPBELL COUNTY, WYOMING

3 - B

84/803 / EV-LA-XX-20/3 JKT



EXPLANATION

PERIMETER AREA

PERMIT AREA

0 2,000 4,000

Scale 1" = 2,000'

-N-

The Cleveland-Cliffs Iron Company

CASPER, WYOMING

URANIUM

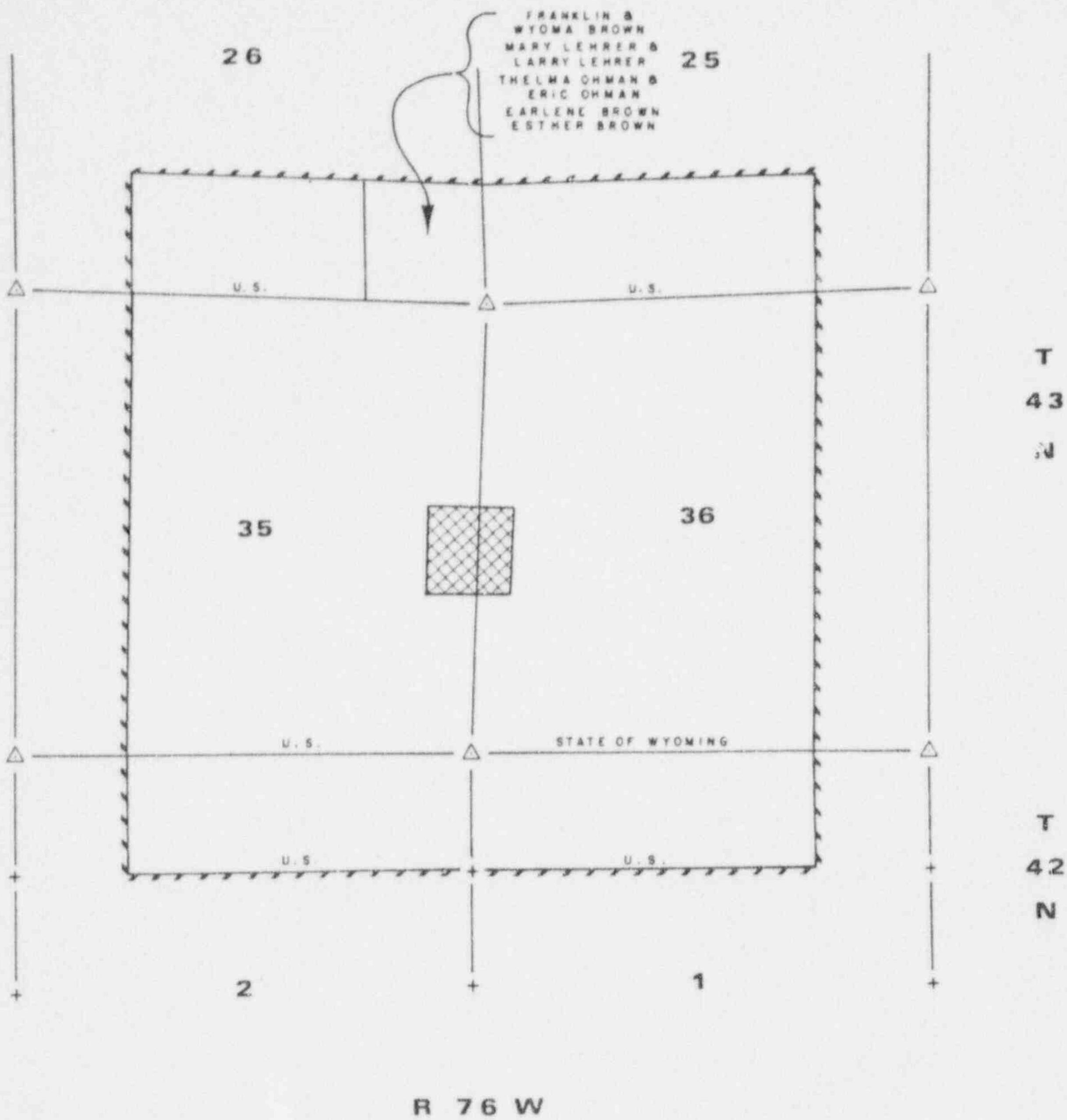
ROYALTY or O.R.R. INTERESTS

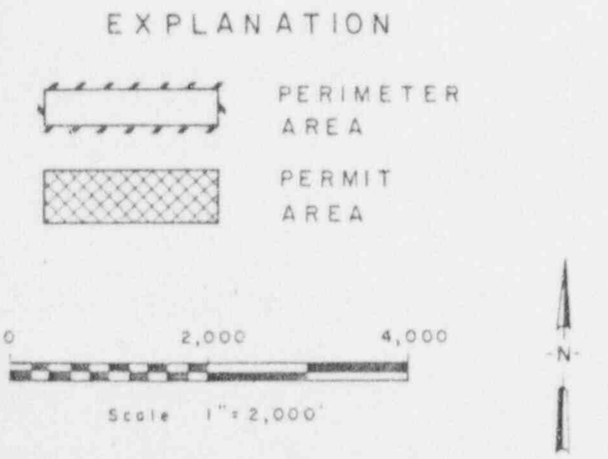
COLLINS DRAW MINE

CAMPBELL COUNTY, WYOMING

3-C

84/803 / EV-LA-XX-20 / 12 J.K.T.





The Cleveland-Cliffs Iron Company

CASPER, WYOMING

OIL & GAS

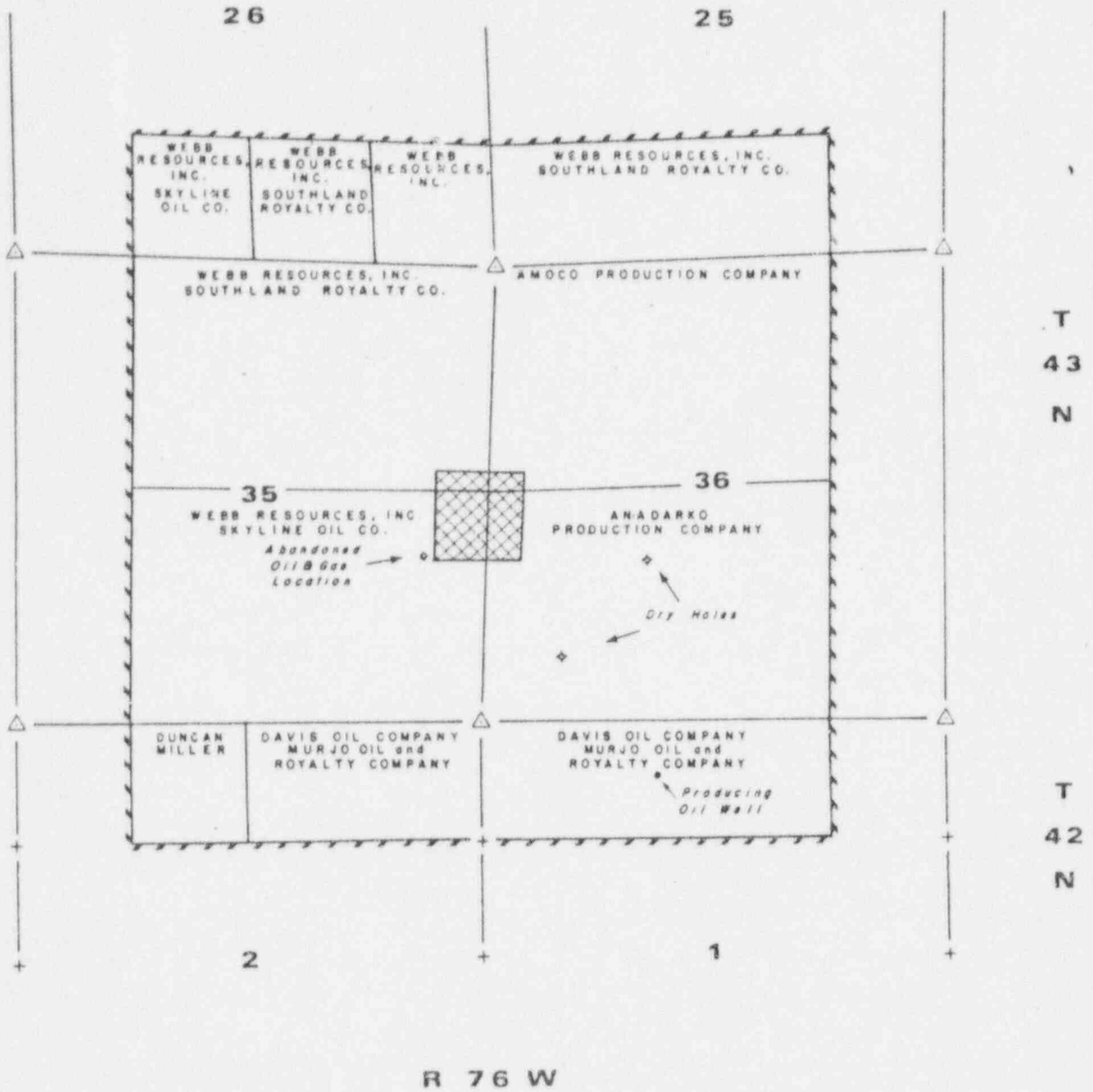
OWNERSHIP

COLLINS DRAW MINE

CAMPBELL COUNTY, WYOMING

4 - A

84/803/EV-LA-XX-20/2



EXPLANATION

PERIMETER AREA

PERMIT AREA

0 2,000 4,000

Scale 1" = 2,000'

N

The Cleveland-Cliffs Iron Company

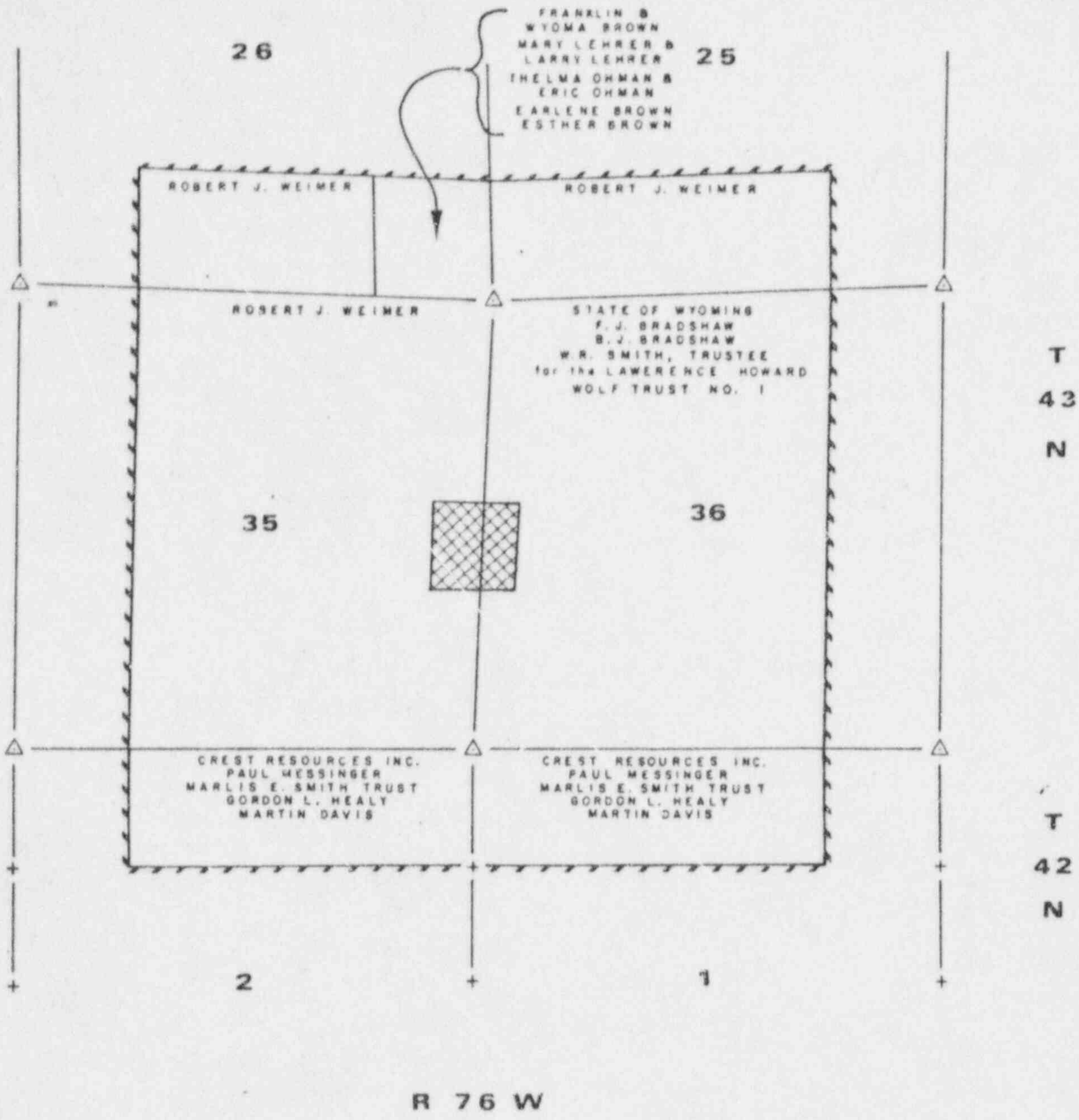
CASPER, WYOMING

OIL & GAS
LEASEHOLD INTERESTS

COLLINS DRAW MINE
CAMPBELL COUNTY, WYOMING

4 - B

84/803 / EV-LA-XX-20/1 J.K.T.



EXPLANATION

PERIMETER AREA

PERMIT AREA

0 2,000 4,000

Scale 1" = 2,000'

-N-

The Cleveland-Cliffs Iron Company

CASPER, WYOMING

OIL & GAS

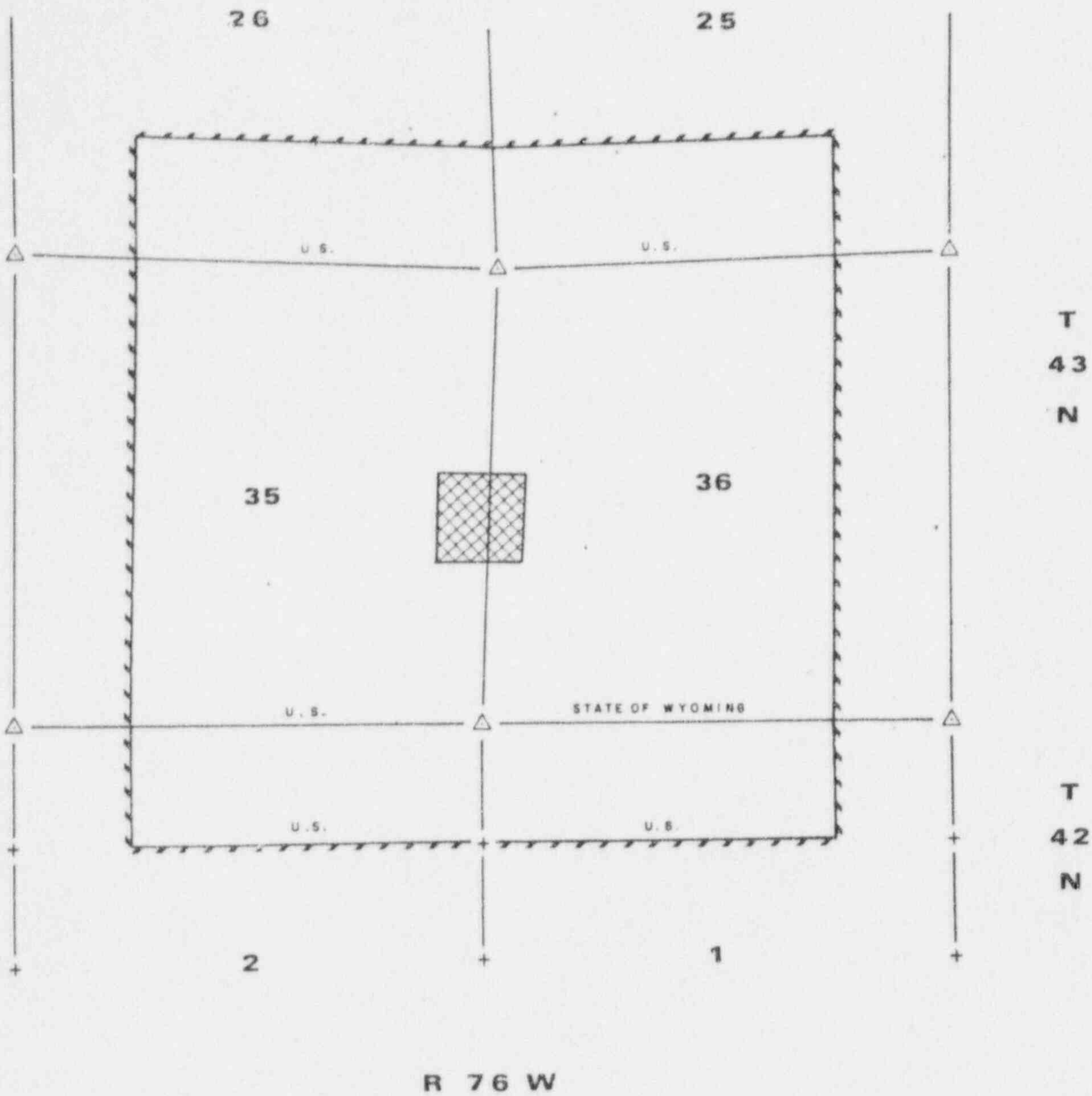
ROYALTY or O.R.R. INTERESTS

COLLINS DRAW MINE

CAMPBELL COUNTY, WYOMING

4 - C

84/803 / EV-LA-XX-20 / 11 J.K.T.



EXPLANATION

PERIMETER AREA

PERMIT AREA

0 2,000 4,000

Scale 1" = 2,000'

N

The Cleveland-Cliffs Iron Company

CASPER, WYOMING

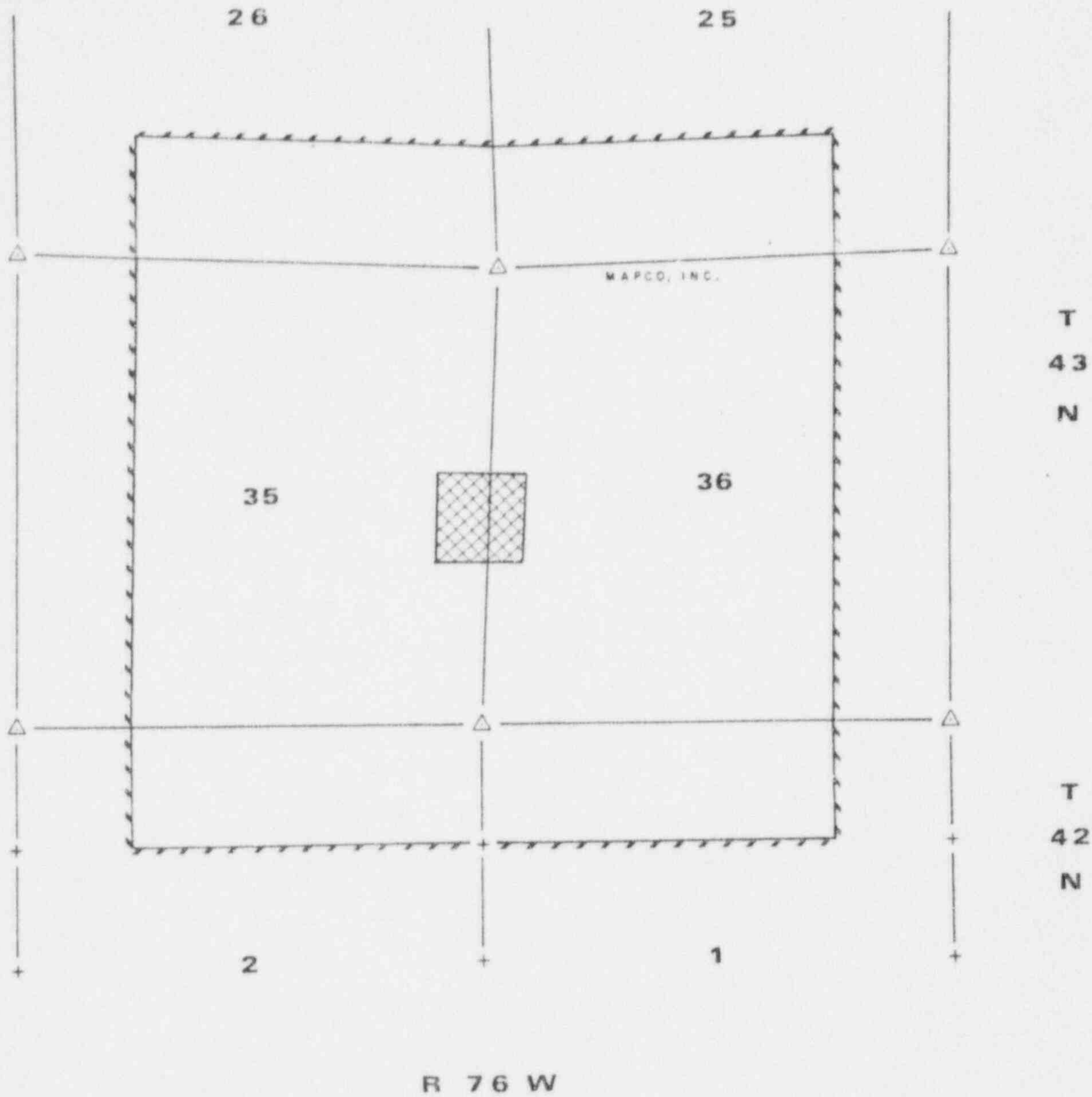
COAL OWNERSHIP

COLLINS DRAW MINE

CAMPBELL COUNTY, WYOMING

5 - A

84/803 / EV-LA-XX-20/6



EXPLANATION

PERIMETER AREA

PERMIT AREA

0 2,000 4,000

Scale 1" = 2,000'

N

The Cleveland-Cliffs Iron Company

CASPER, WYOMING

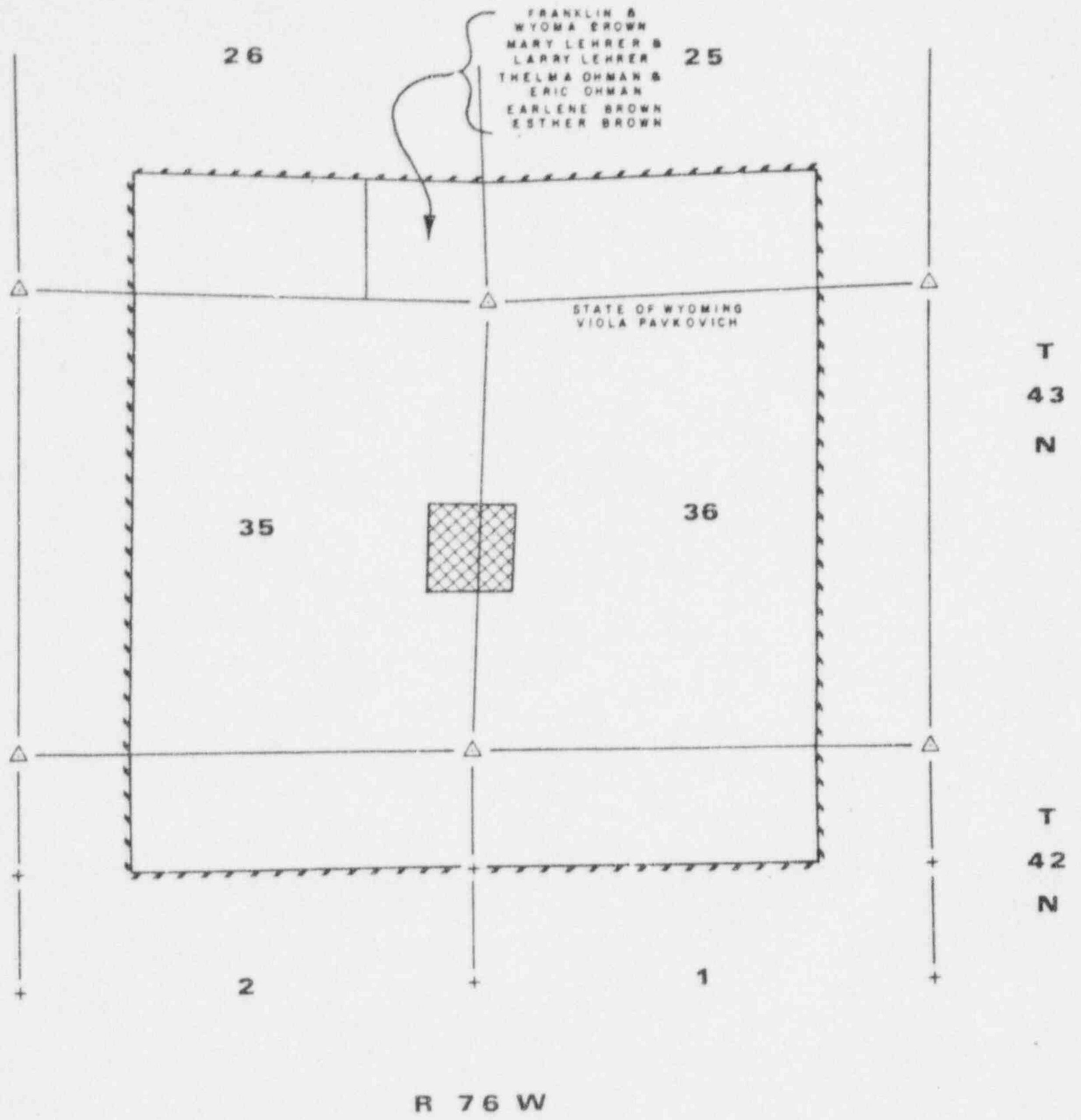
COAL

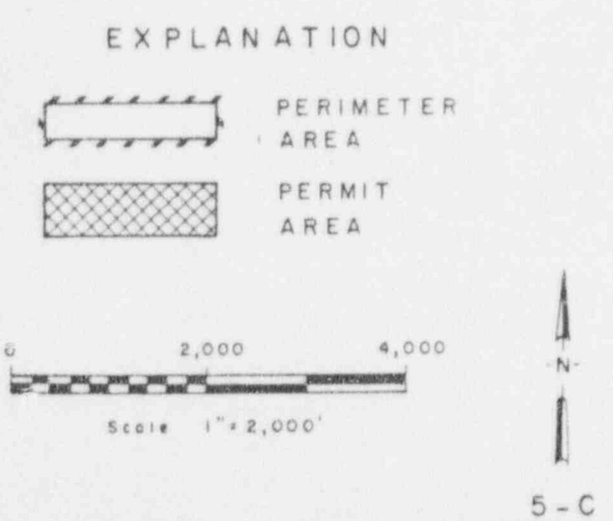
LEASEHOLD INTERESTS

COLLINS DRAW MINE

CAMPBELL COUNTY, WYOMING

84/803/EV-LA-XX-20/5





The Cleveland-Cliffs Iron Company

CASPER, WYOMING

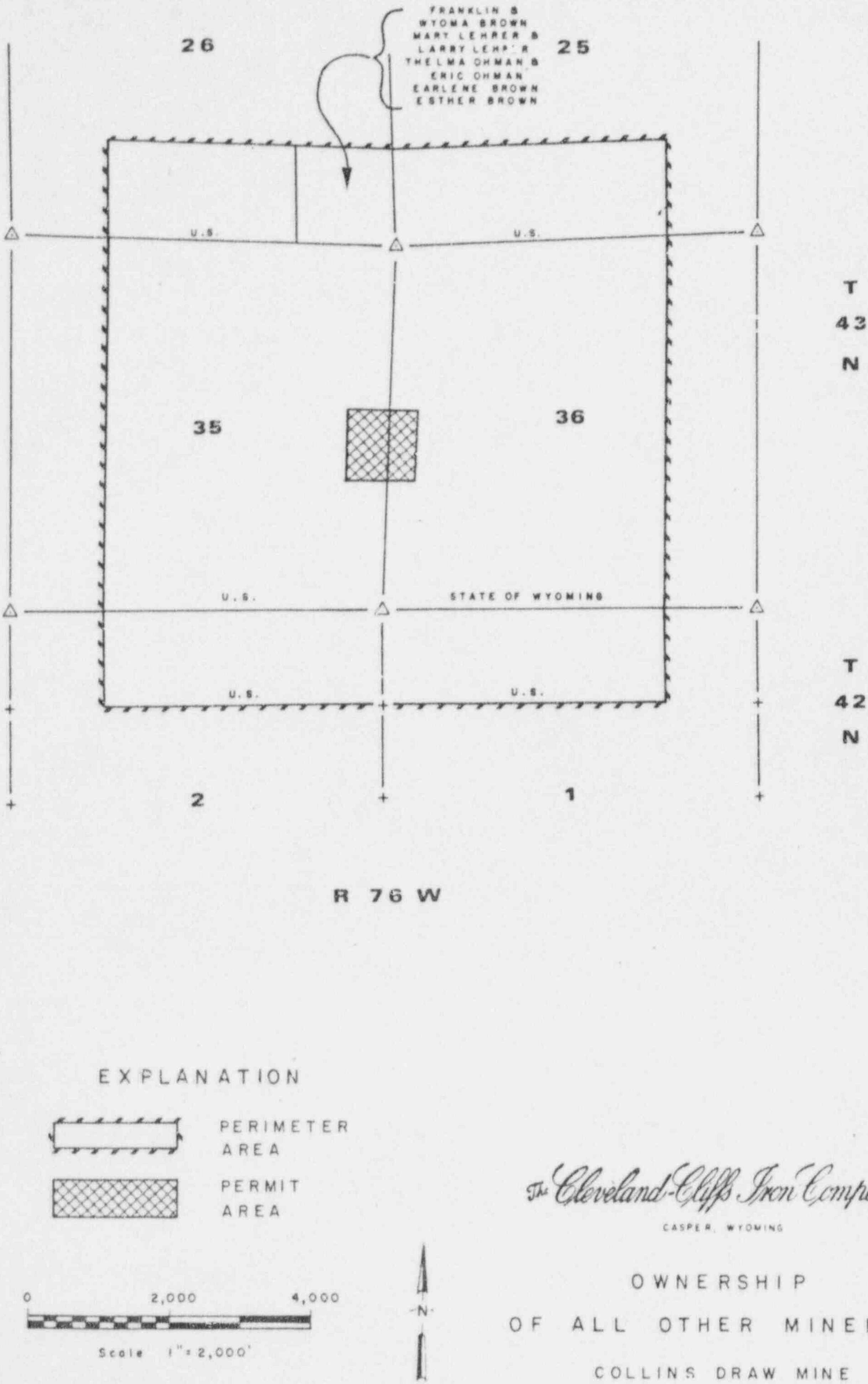
COAL

ROYALTY or O.R.R. INTERESTS

COLLINS DRAW MINE
CAMPBELL COUNTY, WYOMING

5-C

84/803/EV-LA-XX-20/13 J.K.T.



The Cleveland-Cliffs Iron Company

CASPER, WYOMING

OWNERSHIP

OF ALL OTHER MINERALS

COLLINS DRAW MINE

CAMPBELL COUNTY, WYOMING

6 - A

84/803/EV-LA-XX-20/7 J.E.T.

The Cleveland-Cliffs Iron Company

CASPER, WYOMING

SURFACE IMPROVEMENTS

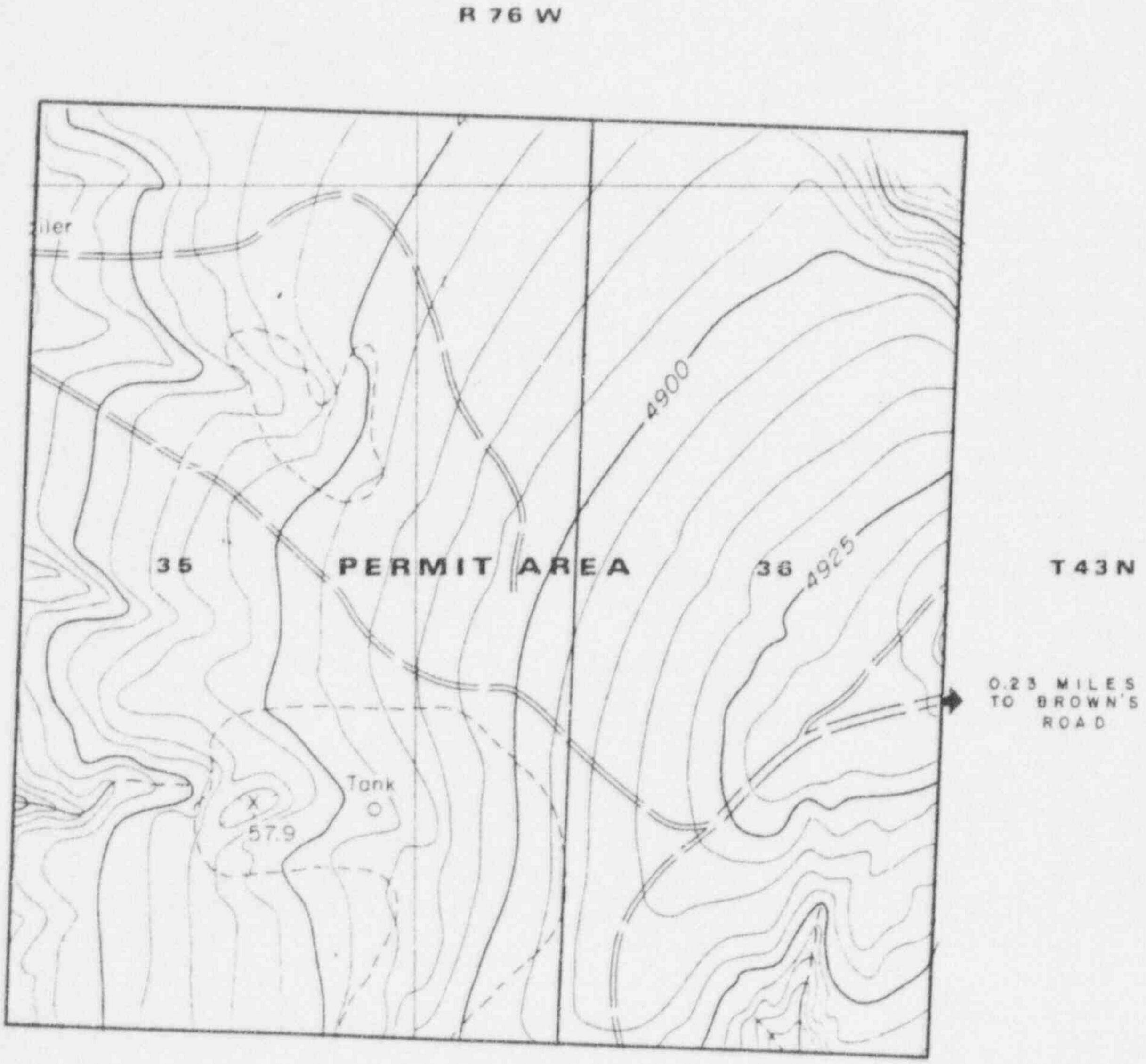
(ROADS & TRAILS)

COLLINS DRAW MINE

CAMPBELL COUNTY, WYOMING

7-A

84/803/EV-LA-XX-40/1



0 200 400

SCALE 1" = 200'

N

The Cleveland-Cliffs Iron Company

CASPER, WYOMING

DETAILED MAP OF
SURFACE IMPROVEMENTS
(ROADS & TRAILS)

COLLINS DRAW MINE
CAMPBELL COUNTY, WYOMING

7 - B

84/808 / EV-LA-XX-201

SURFACE OWNER(S)	MINERAL OWNER(S)	CLAIMS OR LEASEHOLD INTERESTS	ROYALTY OR ORR INTERESTS	ROW-EASEMENT & MISC.
Brown Land Company	Uranium: U.S.A.	Uranium: The Cleveland-Cliffs Iron Company American Nuclear Corporation Tennessee Valley Authority Vipont Mining Adobe Oil & Gas Corp. North American Nuclear	Uranium: Mountain West Mines, Inc. Brown Land Company	Uranium: None
Brown Land Company	Oil and Gas: U.S.A.	Oil and Gas: Webb Resources, Inc. Southland Royalty Co. Skyline Oil Co.	Oil and Gas: Brown Land Company Robert J. Weimer	Oil and Gas: None
Brown Land Company	All Other Minerals: U.S.A.	All Other Minerals: None	All Other Minerals: None	All Other Mins None

Sec. 35 T43N,R76W
Desc. E1/2, E1/2W1

SURFACE OWNERS(S)	MINERAL OWNER(S)	CLAIMS OR LEASEHOLD INTERESTS	ROYALTY OR ORR INTERESTS	ROW-EASEMENT & MISC.
State of Wyoming	Uranium: State of Wyoming	Uranium: American Nuclear Corporation Tennessee Valley Authority King Charles Corporation	Uranium: State of Wyoming Page T. Jenkins Sohio Oil Company	Uranium: None
State of Wyoming	Oil and Gas: State of Wyoming	Oil and Gas: Amoco Production Company Anadarko Production Company	Oil and Gas: State of Wyoming F. J. Bradshaw B. J. Bradshaw W. R. Smith, Trustee for the Lawrence Howard Wold Trust #1	Oil and Gas: None
State of Wyoming	All Other Minerals: State of Wyoming	All Other Minerals: Mapco. Inc.	All Other Minerals State of Wyoming Viola Pavkovich	All Other Mineral None Grazing Lease to Brown Land Compan Inc.

Sec. 36, T43N,R76W
Desc. W1/2, W1/2E1/

SURFACE OWNER(S)	MINERAL OWNER(S)	CLAIMS OR LEASEHOLD INTERESTS	ROYALTY OR ORR INTERESTS	ROW-EASEMENT & MISC.
Brown Land Company	Uranium: U.S.A.	Uranium: The Cleveland-Cliffs Iron Company American Nuclear Corporation North American Nuclear, Inc.	Uranium: Mountain West Mines, Inc. Brown Land Company	Uranium: None
Brown Land Company	Oil and Gas: U.S.A.	Oil and Gas: Davis Oil Company Murjo Oil & Royalty Company Duncan Miller	Oil and Gas: Crest Resources, Inc. Paul Messinger Marlis E. Smith Trust Gordon L. Healy Martin Davis	Oil and Gas: None
Brown Land Company	All Other Minerals: U.S.A.	All Other Minerals: None	All Other Minerals: None	All Other Minerals: None

Sec. 1, T42N,R76W
Desc. Lts. 2, 3, & 4

SURFACE OWNER(S)	MINERAL OWNER(S)	CLAIMS OR LEASEHOLD INTEREST	ROYALTY OR ORR INTERESTS	ROW-EASEMENT & MISC.
Brown Land Company	Uranium: U.S.A.	Uranium: The Cleveland-Cliffs Iron Company	Uranium: Mountain West Mines, Inc. Brown Land Company	Uranium: None
Brown Land Company	Oil and Gas: U.S.A.	Oil and Gas: Davis Oil Company Murjo Oil & Royalty Company Duncan Miller	Oil and Gas: Crest Resources, Inc. Paul Messinger Marlis E. Smith Trust Gordon L. Healy Martin Davis	Oil and Gas: None
Brown Land Company	All Other Minerals: U.S.A.	All Other Minerals: None	All Other Minerals: None	All Other Minerals: None

Sec. 2, T42N,R76W
Desc. Lts. 1, 2, & 3

SURFACE OWNER(S)	MINERAL OWNER(S)	CLAIMS OR LEASEHOLD INTERESTS	ROYALTY OR ORR INTERESTS	ROW-EASEMENT & MISC.
Brown Land Company	Uranium: American Nuclear Corporation	Uranium: The Cleveland-Cliffs Iron Company American Nuclear Corporation Tennessee Valley Authority	Uranium: Franklin & Wyoma Brown Mary Brown Lehrer & Larry Lehrer Thelma Brown Ohman & Eric Ohman Earlene Brown Esther Brown	Uranium: None
Brown Land Company	Oil and Gas: Franklin & Wyoma Brown Mary Brown Lehrer & Larry Lehrer Thelma Brown Ohman & Eric Ohman Earlene Brown Esther Brown	Oil and Gas: Webb Resources, Inc.	Oil and Gas: Franklin & Wyoma Brown Mary Brown Lehrer & Larry Lehrer Thelma Brown Ohman & Eric Ohman Earlene Brown Esther Brown	Oil and Gas: None
Brown Land Company	All Other Minerals: American Nuclear Corporation	All Other Minerals: None	All Other Minerals: Franklin & Wyoma Brown Mary Brown Lehrer & Larry Lehrer Thelma Brown Ohman & Eric Ohman Earlene Brown Esther Brown	All Other Minerals: None

Sec. 26 T43N, R76W
Desc. SE¼SE¼

SURFACE OWNER(S)	MINERAL OWNER(S)	CLAIMS OR LEASEHOLD INTERESTS	ROYALTY OR ORR INTERESTS	ROW-EASEMENT & MISC.
Brown Land Company	Uranium: U.S.A.	Uranium: The Cleveland-Cliffs Iron Company American Nuclear Corporation Tennessee Valley Authority	Uranium: Mountain West Mines, Inc. Brown Land Company	Uranium: None
Brown Land Company	Oil and Gas: U.S.A.	Oil and Gas: Webb Resources, Inc. Southland Royalty Co. Skyline Oil Co.	Oil and Gas: Robert J. Weimer	Oil and Gas: None
Brown Land Company	All Other Minerals: U.S.A.	All Other Minerals: None	All Other Minerals: None	All Other Minerals: None

Sec. 25 T43N, R76W
Desc. S½SW¼, SW¼SE¼
Sec. 26 T43N, R76W
Desc. SE¼SW¼, SW¼SE¼

DIRECTORY OF OWNERS OF VESTED INTEREST
WITHIN THE PERIMETER AREA

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United Bank Center, Suite 717
Denver, Colorado 80290

Anadarko Production Company
P. O. Box 1330
Houston, Texas 77001

American Nuclear
P. O. Box 2713
Casper, Wyoming 82602

Amoco Production Company
Security Life Building
Denver, Colorado 80212

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337 Pierpoint
Salt Lake City, Utah 84101

Brown Land Company, Inc.
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Earlene Brown
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Esther Brown
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Franklin & Wyoma Brown
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Gillette, Wyoming 82716

Crest Resources, Inc.
1050 17th Street, Suite 1814
Denver, Colorado 80265

Davis Oil Company
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475 17th Street
Denver, Colorado 80202

Marvin Davis
1100 Metrobank Building
475 17th Street
Denver, Colorado 80202

Gordon Healy
1100 Metrobank Building
475 17th Street
Denver, Colorado 80202

Page T. Jenkins
830 Midland Savings
444 17th Street
Denver, Colorado 80202

King Charles Corporation
P. O. Box 2713
Casper, Wyoming 82601

Mary Brown Lehrer & Larry Lehrer
903 Park
Ft. Morgan, Colorado 80701

Mapco, Inc.
1437 S. Boulder
Tulsa, Oklahoma 74119

Paul Messinger
1100 Metrobank Building
475 17th Street
Denver, Colorado 80202

Duncan Miller
P. O. Box 728
Boulder City, Nevada 89005

Mountain West Mines, Inc.
Box 308
Moab, Utah 84532

Murjo Oil & Royalty Company
P. O. Box 12666
Fort Worth, Texas 76116

North American Nuclear
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Casper, Wyoming 82601

Thelma Brown Ohman & Eric Ohman
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Savageton Route
Gillette, Wyoming 82716

Viola Pavkavich
1942 S. Cedar
Casper, Wyoming 82601

Skyline Oil Company
2000 University Club Building
Salt Lake City, Utah 84111

W. R. Smith, Trustee for the Lawrence
Howard Wolf Trust #1
P. O. Box 1715
Denver, Colorado 80201

Sohio Petroleum Company
Midland Building
Cleveland, Ohio 44101

Southland Royalty Company
Denver Club Building, Suite 1010
Denver, Colorado 80202

Tennessee Valley Authority
200 North Walcott
Casper, Wyoming 82601

United States Department of Agriculture
Bureau of Land Management
2515 Warren Avenue
Cheyenne, Wyoming 82001

Vipont Mining Company
6901 South Yosemite, Suite 208
Englewood, Colorado 80110

Webb Resources, Inc.
Suite 200, First of Denver Plaza
Denver, Colorado 80202

Robert J. Weimer
Rural Route 3, Box 470
Golden, Colorado 80401

State of Wyoming
Commissioner of Public Lands
Pioneer Building
Cheyenne, Wyoming 82002

EXHIBIT "A"

The Cleveland-Cliffs Iron Company

Offices 14th Floor Union Commerce Building

Cleveland, Ohio 44115

September 15, 1978

STATEMENT

The Cleveland-Cliffs Iron Company, Applicant, has not forfeited a bond posted with the Land Quality Division, Department of Environmental Quality, State of Wyoming, for reclamation purposes and that all the statements contained in the Permit Application are true and correct to the best of our knowledge.

THE CLEVELAND-CLIFFS IRON COMPANY

By [signature]
Vice President

Attest [signature]
Secretary

STATE OF OHIO)
: SS.
COUNTY OF CUYAHOGA)

On this 15th day of September, 1978, before me, a Notary Public in and for said County, appeared H. J. Leach and S. R. Curtis, Jr., to me personally known, who, being by me, duly sworn, did each for himself say that they are respectively the Vice President and Secretary of the Corporation named in and which executed the within instrument, and that the seal affixed to said instrument is the corporate seal of said corporation and that said instrument was signed and sealed in behalf of said corporation and H. J. Leach and S. R. Curtis, Jr., acknowledged said instrument to be the free act and deed of said corporation.

[signature]
Notary Public

JOHN E. LENHARD, Attorney
NOTARY PUBLIC - STATE OF OHIO
My commission has no expiration date.
Section 147.03 R.C.

EXHIBIT "B"

The Cleveland-Cliffs Iron Company

Offices 14th Floor Union Commerce Building

Cleveland, Ohio 44115

September 15, 1978

STATEMENT

The Cleveland-Cliffs Iron Company, Applicant, has the right and power by legal estate to mine the Permit Area. Applicant has located valid and subsisting lode mining claims covering the permit area and has acquired by surface agreement the right to mine the Permit Area from the surface owner.

THE CLEVELAND-CLIFFS IRON COMPANY

By H. J. Leach
Vice President

Attest S. R. Curtis Jr.
Secretary

STATE OF OHIO)
:SS.
COUNTY OF CUYAHOGA)

On this 15th day of September, 1978, before me, a Notary Public in and for said County, appeared H. J. Leach and S. R. Curtis, Jr., to me personally known, who, being by me, duly sworn, did each for himself say that they are respectively the Vice President and Secretary of the Corporation named in and which executed the within instrument, and that the seal affixed to said instrument is the corporate seal of said corporation and that said instrument was signed and sealed in behalf of said corporation and H. J. Leach and S. R. Curtis, Jr., acknowledged said instrument to be the free act and deed of said corporation.

John E. Lenhard
Notary Public

JOHN E. LENHARD, Attorney
NOTARY PUBLIC - STATE OF OHIO
My commission has no expiration date,
Section 147.03 R.C.

APPENDIX B

APPENDIX B

In-situ Consulting 1158 FRONTERA DR., LARAMIE, WY 82070 (307) 742-4539 (303) 573-7185

HYDROLOGIC EVALUATION

of

THE COLLINS DRAW RESEARCH AND DEVELOPMENT SITE

for

IN SITU URANIUM RECOVERY

by

J. T. Laman*, C. R. McKee, S. C. Way, R. Santoro

September 30, 1978

*(with Cleveland Cliffs Iron)

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ACKNOWLEDGEMENT

We wish to express our appreciation to Jim Copen of Cleveland Cliffs Iron for furnishing geologic data and interpretation.

1.0 SUMMARY AND CONCLUSIONS

The research and development project site is located adjacent to Collins Draw in the south-central part of the Powder River Basin on the boundary of section 35 and 36 of T43N, R76W.

The mineralized sand at the site lies in the Wasatch Formation which begins at the surface and attains a depth of over 1500 feet. The Wasatch Formation is the only unit which can be affected by the pilot project. Our studies have accordingly focused on the regional and local hydrology pertinent to this formation and site.

The Wasatch Formation in the Powder River Basin is very close to a balanced recharge-discharge system. Water levels therefore exhibit only minor seasonal fluctuations.

Using data available in the literature together with site specific measurements by Cliffs and others, a regional piezometric surface map for the basin was constructed. The gradient at the site from the regional map was computed to be .006 foot/foot. This compares very favorably with a gradient of .008 foot/foot calculated from the local piezometric surface obtained from wells at the site. The local gradient and hydrologic properties combine to yield a groundwater flow of 6.3 feet/year in a direction 19° west of north at the site. Local water levels over a period of 18 months fluctuate on the order of a few tenths of a foot.

Wells used in Cliffs' study have an average well efficiency of 80% and were thus in excellent condition for hydrologic testing. Seven pump tests were performed by the Cleveland Cliffs Iron Co. under the direction of Mr. Jerry Laman. Water level measurements were carried out using pressure transducers sensitive to $\pm$.01 psi changes.

The aquifer has an average thickness of 52 feet and a porosity of 28% with the top of the sand 431 feet below the surface.

Assumptions used in analytic solutions to obtain the hydrologic properties of the aquifer were satisfied to a high degree of accuracy.

Average hydrologic properties over all wells for the Collins Draw Site were 192 gpd/ft. for transmissivity and 1.7×10^{-4} for storage coefficient. An impermeable boundary was detected at 240 feet from the pumped well running in a North-South direction. No recharge or discharge boundaries were detected.

Mean directional permeability using all wells in test 7 was found to be:

Major transmissivity 307 gpd/ft.

Minor transmissivity 111 gpd/ft.

Direction of major transmissivity E 31°S

The hydrologic tests conducted at Collins Draw had a radius of influence of 485 feet.

Overlying monitor well 230 was used to check for leakage. No measurable water level changes were detected during the tests. Furthermore, drawdown data were checked against Hantush's Leaky type curves. Matches were obtained only on the limiting non-leaky curve. This indicates the absence of leakage and good vertical confinement.

A small bleed stream of .6 gpm is inherent to the project and will serve to further protect against solution excursion. The drawdown at one year at a distance of 2000 feet from the R & D site will be only 1 foot thereby giving rise to a very minimal impact on regional groundwater as opposed to more conventional methods of extraction such as open pit and underground mining.

We conclude that the hydrologic conditions at the site are favorable for insitu uranium extraction.

2.0 INTRODUCTION

The purpose of our report is to analyze the regional and local hydrology pertinent to the Collins Draw Insitu Uranium Pilot Site. The site is located in the south-central part of the Powder River Basin on the boundary of section 35 and 36 in T43N, R76W.

Collins Draw is a research and development project and involves only several small isolated patterns. Its effects in a regional sense will therefore be negligible. For this reason our study concentrates mainly on site specific hydrology and correlates these findings with general regional features such as the piezometric surface or water level contours.

Regional hydrologic information was gathered from published literature and Cliff's baseline wells. Site specific data was obtained from a total of seven pump tests and one injection test. They were conducted on the Collins Draw Property by the Cleveland Cliffs Iron Company from December 20, 1975 to November 17, 1976 under the direction of Mr. Jerry Laman. Test 7 was the largest and consisted of a seven well interference tests designed to investigate layering effects as well as directional permeability.

3.0 PREVIOUS INVESTIGATION

The work of Hodson, Pearl and Druse (1973) describing the water resources of the Powder River Basin is fundamental to our regional study. They summarize their findings as well as unify the efforts of many previous investigators. We have used their data to construct a piezometric surface map of the Basin. While the data presented in the report of Hodson et al consists of measurements prior to 1973, interpolated contours through Collins Draw are in excellent agreement with the water level observations recorded by Cliffs personnel. This is mainly due to the balanced recharge-discharge in the basin which precludes large annual fluctuations.

Another regional study was conducted by Wyoming Mineral Corporation and the Nuclear Regulatory Commission (NRC) for a commercial application at Irigaray Ranch. The findings were issued in an overall environmental impact statement by the NRC. This site is only 20 miles N-NW of the Collins Draw project.

The NRC report relies to a great extent on the previous study of Hodson et al. However, new site specific hydrologic data particularly water level measurements are included. This information together with that gathered by Cliffs was used to provide increased definition to the water table in the vicinity of the project.

4.0 REGIONAL GROUNDWATER

4.1 Geologic Setting

The Collins Draw project is located in the south-central part of the Powder River Basin. The formation is part of an accumulation of fluvial sediments eroded from surrounding mountains and deposited in the Powder River Basin. The uppermost 2000 feet of deposition contain a number of red colored beds and have been designated as the Wasatch Formation. The Wasatch Formation is exposed at the surface across most of the central part of the Basin and all of the site with the possible exception of thin alluvial deposits in adjacent dry stream beds. Site surface drainage is to the Powder River.

The following information refers to regional characteristics and is not site specific unless designated as such.

4.2 Aquifer Characteristics

In the subsequent discussion we briefly dispense with alluvial aquifers and discuss to a greater extent the water bearing properties of the Wasatch Formation. The deeper Fort Union is not discussed since at least 1500 feet of multiple confining layers separate the mineralized sands at Collins Draw from this formation. The potential for migration of lixiviant to this unit during the short duration of the operation therefore is extremely remote.

4.2.1 Alluvial Aquifers

Alluvial aquifers in the basin are only important in the vicinity of major rivers, such as the Powder and Belle Fourche, none of which are located near the site. For this reason we will omit a discussion of these aquifers in the present study.

4.2.2 Wasatch Formation

In general, aquifer zones in the Wasatch Formation are confined, although local water table or unconfined aquifers may occur in a few near surface layers. Yield from wells is highly variable and ranges from a few gpm in the northern part of the Basin to as much as several hundred gpm in the southern Powder River Basin. Water produced is from lenticular sandstone beds which vary considerably in areal extent, and to a lesser amount from jointed coal and clinker beds.

4.2.2.1 Sources and Sinks

The Powder River Basin is a relatively independent groundwater system. Recharge is determined mainly by geology and precipitation. Recharge to the Wasatch is along the front of the Bighorn Mountains and in the Black Hills with additional influx from precipitation over the remainder of the Basin. Discharge is by evaporation, seepage to springs, streams and rivers and by transpiration as well as pumpage. Principal natural discharge of water is along the Powder River and Little Powder River valleys and tributaries.

4.2.2.2 Seasonal Variation

Most groundwater development has been for stock and domestic use. Wells are usually drilled and developed to satisfy only these requirements. Hence it is not surprising to find that groundwater levels exhibit only minor seasonal fluctuations. This indicates that recharge and discharge, unlike many portions of the United States are approximately in balance. This is further substantiated by the small local water level changes observed by Cliffs at Collins Draw which will be presented in a later section.

4.2.2.3 Piezometric Surface and Regional Flow

Figure 1 depicts the regional piezometric surface for groundwater in the Wasatch formation of the Powder River Basin. The area shown consists of 486 townships (R67W-R84W and T31N-T57N). The area covers approximately 14400 square miles. Water level data from 91 well locations were used in constructing the water table. Pertinent well data are presented in Table 1. Ground level elevations for all wells were obtained by interpolating between contours on the standard U.S.G.S. topographic gradrangle maps. The depth to water was then subtracted from this elevation resulting in a water elevation referred to mean sea level.

The area given in the map is certainly greater than that usually given for studies such as the present one. However, the map does provide additional insight into groundwater movement and a better comparison between site specific

or local data and regional trends.

As evidenced by the map, the Powder River with its tributaries is one of the major controlling factors in the regional movement of water in the Wasatch. The movement of water is generally northward toward these drainage ways. Locally, especially in near-surface aquifers, movement of water is controlled by other drainages such as the Belle Fourche River.

The location of the pilot site in the regional map is also marked in Figure 1.

5.0 LOCAL GROUNDWATER

5.1 Local Aquifer Description

A map indicating three cross sections (A-B, C-D, E-F) is given in Figure 2. Three major water bearing sands are given in cross section in Figures 3 (A-B), 4 (C-D), and 5 (E-F). The uranium host or No. 1 sand is at a depth of 425 feet with an average thickness of 52 feet. Above this intended production sand is the AB sand which is a coalescence of two sands. This upper sand is separated from the production or No. 1 sand by a claystone confining layer ranging in thickness from 11 to 52 feet. The C sand is nearest the ground surface and is separated from the AB sand by a 26-41 foot claystone confining layer.

Features to a depth of 113 feet below the production aquifer (No. 1 sand) have been explored. Below the production aquifer is another 10-16 foot claystone layer. The water bearing sandstones appear to have a very limited lateral extent and lack continuity. Continuous units such as those overlying the production sand do not appear to be present to the depth explored.

The production aquifer can be further subdivided into three differing layers. The top unit in this aquifer has been termed the 1c layer and is approximately 15 feet thick. The next layer below it is termed 1b (20-25 feet thick), while the lowermost is the 1a (15 feet thick). The 1c and 1a layers appear to be cleaner and exhibited fair to good

porosity and permeability while 1b layer is more shaley and clayey and possesses lower porosity and permeability.

Features such as vertical confinement will be treated in the section reporting test results from the production aquifer.

5.2 <u>Local Piezometric Surface Map</u>

The local piezometric surface is given in Figure 6. The coordinates are North-East system and are given in feet with the origin of coordinates having the value 100,000N, 100,000E at the northwest corner of section 30 in R74,T43.

Some deviation of wells from the surface on the order of a few tenths of a foot are evident. We attribute these deviations to minor surveying errors. The surface has been accordingly drawn as approximately planar, since it has been our experience that groundwater tables over a small area invariably result in a planar surface.

The local gradient is approximately .008 feet/foot in a direction which is 19° West of North. This compares well with the regional gradient of .006 feet/foot computed from Figure 1. The direction of the local gradient is also in good agreement with the regional gradient at site in Figure 1.

5.3 <u>Local Groundwater Flow</u>

The well locations, water level data, and hydrologic properties (discussed in the next section) were input to a computer program. The program fits a least squares trend

surface through the data to obtain the local gradient as well as direction and magnitude of groundwater flow. The resulting values were .008 feet/foot with a flow of 6.3 feet/year in a direction of 18.9^{o} West of North. The flow is clearly negligible and will not cause any problems during the life of the insitu pilot field.

5.4 Local Water Level Fluctuations

Baseline water level fluctuation on several wells taken over a period of one and a half years is given in Figure 7. Water level changes are small and on the order of a few tenths of a foot, in agreement with previous statements regarding a balanced recharge-discharge system.

6.0 HYDROLOGIC TESTS OF THE LOCAL PRODUCTION AQUIFER

As mentioned in the introduction, a total of seven pumping tests and one injection test were conducted on the Collins Draw Property by Mr. Jerry Laman of the Cleveland Cliffs Iron Company. These were performed from December 20, 1975 to November 17, 1976. Test 7 involved the largest number of wells. Test 5 was run for the longest period. Accordingly, the bulk of our analysis concentrates on these tests. In the following we will discuss the well characteristics, test results, and vertical confinement.

6.1 Well Characteristics

All wells were drilled with mud down to the top of the production aquifer. Wells were then cased and cemented to the surface. After this the production aquifer was drilled. Extreme care was taken by the well drilling contractors and supervisory personnel to insure the least amount of formation wellbore damage from the drilling operation. To this end drilling in the production aquifer was done with foam to avoid mud infiltration and formation damage. The wells were developed by air jetting, and then left without screen to further minimize well losses.

It has been our experience that wells drilled in this manner have well efficiencies on the order of 80%. The majority of Cliffs wells exhibit well efficiencies of this magnitude.

Wells 139, 146 and 191 were cased with a light 6 5/8" steel casing. Well 190 was cased with 6" yellomine pipe. The remainder of the wells were completed with 5" yellomine casing.

All wells were completed through the entire production zone with the exception of wells 231 and 232. Wells 231 and 232 were completed in only the 1c or uppermost 15 feet of the production aquifer.

Relevant well data used in hydrologic testing are listed in Table 2. Well efficiencies are listed in Table 7.

6.2 Test Procedure and Instrumentation

An electrical conductance water level device with depth markings every 5 feet was used to measure initial water levels. The instrument is a simple battery operated device which can achieve excellent accuracy when properly used.

Pressure transducers were used to record water level during the various injection tests. The transducers are sensitive to pressure changes on the order of .01 psi. The transducer cables merge to a central switching box and digital readout meter. The pressure and hence water level in a given well is obtained by turning the switch to the well's transducer and recording its reading. The rapid nature of this mechanism allows collection of reliable data early in time when pressure changes were rapid.

Each transducer, switching box and digital meter were checked for reliability and sensitivity prior to commencing

the pump test.

Flow rate was measured by either a Badger or Carlin flow meter with an accuracy of ± 2%. Rates were held constant by manually adjusting a value to maintain a constant flow reading.

Since water levels decline rapidly during the initial stages of the test, water level readings were taken at short intervals. The time between readings increased gradually as pumping continued.

Collected drawdown data from earlier tests were plotted and analyzed. Preliminary tests and analyses provided the basis for determining the duration of the test to obtain the necessary radius of influence, to detect hydrologic boundaries near the test site.

6.3 Method of Analysis and Assumptions

Three methods were used to analyze the data. First the type curve method was used to check for leakage. Secondly, when we were assured no leakage was present the semi-log straight line method devised by Jacob was used. Jacob's method requires that the dimensionless parameter u given by

$$u = \frac{1.87\ r^2 s}{Tt}$$

be less than .01. In order to check this method we used Chow's technique which still allows a semi-log plot but is

not subject to any restriction on u. Hantush's partially penetrating type curves were used to examine the ratio of vertical to horizontal permeability in the deposit.

The following assumptions are made in the derivation of these solutions:

1. The formation is a confined aquifer.
2. The formation is homogeneous within the radius of influence.
3. The thickness of the aquifer is uniform.
4. The pumped well is of infinitesimal radius.
5. Water is derived simultaneously from storage with the change of pressure.

We made the following observations concerning the above assumptions in sequence. The assumption of confined condition was verified by water level measurements and well logs. The water levels are located at approximately 77 feet below the top of the surface (from water level measurements) and the top of the aquifer is located at approximately 431 feet below the ground surface (from well logs). The lack of measurable response in the overlying monitor well No. 230 in the AB sand further substantiate the existence of confining conditions.

A substantial number of tests and varying methods were applied to each well. The mean values for all tests applied to an individual well are given in Table 3. The average transmissivity is 192 gpd/ft. with maximum deviation of 15 to 18%. While some heterogeneity exists it does not appear to be of a nature which would prevent us from arriving at

good approximations for the hydrologic properties of the pilot site.

The assumption of uniform thickness is easily checked by referring to the list of thicknesses given in Table 2. From these values we obtain an average thickness of 52 feet with variation about the mean on the order of $\pm$ 10%. Fluctuations of this magnitude will not have more than a 10% effect on transmissivity values. This is because transmissivity is proportional to aquifer thickness.

With respect to assumption 4, the pumped well is obviously not of infinitesmal diameter. For our situation the drawdown in the pumped well is affected by the finite diameter of the well during the first 50 minutes of pumping (Papadopulos and Cooper 1967). Thereafter the finite wellbore diameter has negligible effect on the pumped well. No drawdown measurements were taken in the pumped well.

The effect of a pumped well having a finite well bore on an observation well has been examined by Wigley (1968). For our situation the error in an observation well 100 feet from the pumped well is approximately 2% after 5 minutes from the onset of pumping. For a well 50 feet from the pumped well at 5 minutes the percentage error between our solutions and the exact solution is a few hundredths of a percent. Errors due to the finite well bore radius of the pumped well are small and decline exponentially with increasing time. The effect of a finite well bore and well bore storage can therefore be safely neglected for observation wells used in

our study.

Assumption 5 that water is derived simultaneously from storage with a change in pressure is also satisfied. This is due to the fact that yielding of water from storage in a confined aquifer is an elastic phenomenon. As such the only delay that can occur in yielding water due to a pressure change at a given distance is the time for elastic equilibrium to occur. The time for this to occur is approximately 10 traversals of a stress wave over the thickness of the aquifer. Calculating the bulk modulus from the storage coefficient results in a value of 3.2×10^5 psi. The resulting wave speed is therefore approximately 4000 feet per second. Hence the required equilibrium time is .13 second. The delay of approximately .1 second between an applied pressure change and yielding of water from storage can for all practical purposes be regarded as simultaneous or instantaneous.

We therefore conclude that all assumptions required in the analysis are satisfied to a good approximation.

6.4 Radius of Influence

Essential to proper evaluation of an aquifer is to determine the area for which the results are valid. This naturally leads to the concept of radius of influence and its definition. A number of formulas are given by Bear et al (1968) for determining the radius of influence due to pumping. We prefer the

the formula given on page 406 of Bear et al because it has a natural analytic definition and can be directly related to the well function. In the gallon-day-foot system, the equation for radius of influence is

$$r_e = (.3Tt/S)^{\frac{1}{2}}/2*$$

where S is the storage coefficient. The above equation is derived from the long time logarithmic approximation to the well formation by finding the radius at which the drawdown is zero. When the value for r_e is substituted into the exact well function the drawdown will not be zero but instead have a finite value. The value depends on the hydrologic properties of the aquifer. In the present case the drawdown at r_e for test 5 is approximately 7.6 feet. Test 5 had a radius of influence of 485 which was the largest value attained since this particular test was run for the longest period.

There did not appear to be any systematic change in transmissivity values with increasing area of influence. The values from test 5 are in agreement with values from other tests having lesser radii of influence.

We conclude that tests conducted by Cliffs yielded values representative out to a distance of 485 feet from the center of well 146. An impermeable boundary was detected within this radius indicating that our criteria for the radius of

* The factor of 2 is included to account for the ficticious image well used in the analysis of boundary effects.

influence was correct.

6.5 Data Analysis

As mentioned in an earlier section, a total of seven pumping tests and one injection test were conducted by Cleveland Cliffs Iron Company. Results of all tests are summarized on a test by test basis in Table 4 and on a well by well basis in Table 5.

The amount of data involved is substantial. We have therefore chosen to report only the resulting parameters and methods used for tests 1, 2, 3, and 4, and instead confine this report to a detailed discussion of tests 5, 6, and 7. These three tests delineate the significant hydrologic properties of the production aquifer. Test 5 was run the longest in order to detect boundary effects. Test 6 was performed to analyze layering effects and the ratio of vertical to horizontal permeability. Test 7 was conducted primarily to determine directional permeability.

Where possible, three different methods were applied to the data. In the majority of cases the value of transmissivity agreed within 10 to 15%. Storage coefficient is more sensitive to the particular technique used and accordingly varied more widely.

Average values for all tests on a well by well basis are given in Table 3. The average value obtained for transmissivity was 192 gpd/ft. while the average storage coefficient (excluding well 190WC) was 1.7×10^{-4}. Well 190 was excluded

for the storage coefficient since its value is an order of magnitude larger than the mean. If it were included, we would have obtained 4.1×10^{-4}. The difference between the two averages is not great considering the variability usually attending storage coefficient measurements. We would however prefer to use the value of 1.7×10^{-4} for the Collins Draw Pilot Site. We now turn to a more detailed analysis of tests 5, 6, 7, and discuss them in numerical sequence.

6.5.1 Test Five (Hydrologic Barrier)

Test five was run for the longest period with the intent of establishing a large radius of influence and detecting any hydrologic boundaries within this radius. The radius of influence of this test was 485 feet.

Drawdowns in the observation wells were plotted against time on semi-logarithmic paper in Figure 8. Values of transmissivity and storage coefficient were computed using the early straight line portions of the drawdown curve before the boundary affected the slope of the curve. After 1000 minutes of pumping the rate of drawdown in the observation wells increased indicating the presence of a hydrologic barrier. The barrier could be a pinchout of the sand or transition to a significantly lower permeability.

Image well theory is used to locate the barrier by constructing circles around each observation well. The

diameter is calculated by selecting a point at which the drawdown from the pumped well is equivalent to that due to the ficticious image well on the other side of the boundary. Ideally all three circles share a common intersection. The boundary is then half the distance between the pumped well and point of intersection. In our case only two of the circles intersected indicating a boundary at 240 feet and lying either east or west of the property. An impermeable boundary running in a north-south direction is certainly consistent with the direction of local groundwater flow discussed previously.

The tests have established the location of a hydrologic boundary. Its location will be determined by conducting a more precise hydrologic test in the near future.

6.5.2 Test Six (Layering Effects)

Test six consisted of three wells (231, 232, 233). Wells 231 and 232 were completed in the uppermost 10 feet of the production sand.

Well 231 was the observation well while 232 served as the pumped well. The time drawdown response and match to the type curve is given in Figure 9. The best match was achieved with a ratio of horizontal to vertical permeability of unity. If the ratio of horizontal to vertical permeability were unity then partial penetration effects would be absent a distance of 1.5 times the aquifer thickness from the pumped well. In this case observation well

No. 231 was 1.7 times the aquifer thickness from the pumped well. This would still be sufficient to allow detection of permeability ratios for horizontal to vertical permeability of 3 or less. We would therefore conclude that this ratio lies between 1 and 3.

6.5.3 Test Seven (Directional Permeability)

In test 7, water level changes in six observation wells were monitored. Well 139 was pumped at a constant rate of 20 gpm. Transient drawdown data were first analyzed using Jacob's, Chow's and Hantush's methods. The results from Jacob's and Chow's methods are displayed in Figures 10 - 16. Matches against Hantush's type curves are given in Figure 17. Results for these analyses are listed in Table 4.

Papadopulos' method was initially used to determine the directional permeability of the formation. Papadopulos' method requires a minimum of three observation wells in three different directions from the pumped wells. In a homogeneous anisotropic medium any combination of three observation wells should yield identical results. However, most formations exhibit some heterogeneity as well as anisotropy. In this case anisotropy may be due to smaller scale features such as braided stream channels which can give rise to contrasts in permeability. Depending on their spacing and angular distribution, various combinations of wells can give different results. Some wells may be drilled into a localized feature which is

not representative of the region as a whole. Such features may include local higher or lower permeability zones. It is also possible that a higher permeability stream channel directly connects the pumped well with an observation well. Some representative three well combinations are given in Table 6. There are a total of 20 possible three well combinations.

Using a computer program, all the data from observation wells in test 7 were analyzed simultaneously using a least squares technique to arrive at an average orientation and directional transmissivity values. The results are:

Major transmissivity 307 gpd/ft.

Minor transmissivity 111 gpd/ft.

Geometric mean transmissivity 185 gpd/ft.

Direction of major transmissivity E 31°S

Storage coefficient 8.8×10^{-5}.

The geometric mean value of 185 gpd/ft. agrees within 4% of the previous single well average of 192 gpd/ft. Considering the variability in storage coefficient, this value is also in good agreement with the previous average of 1.7×10^{-4}.

6.5.4 Transmissivity Contours

To obtain a transmissivity distribution over the site the average values listed for each well in Table 3 were contoured. The results were given in Figure 18. The

variability of transmissivity is not large. However, there is a trend toward higher permeability at the center of the site.

6.5.5 Vertical Confinement

Well No. 230 was drilled into the sand overlying the production aquifer. No measurable drawdown was detected by Cliffs personnel. In addition to this, the results of test 7 were matched against Hantush's unsteady state type curve in Figure 17. No leakage was detected.

7.0 EFFECT OF BLEED STREAM

It is anticipated that a small bleed stream on the order of 200 to 900 gallons per day will be required during the operation of the pilot plant. This amounts to approximately .14 to .63 gallons per minute.

At one year the drawdown due to a 900 gpd withdrawal is 3 feet at 200 feet and only 1 foot at 2000 feet from the site. The impact is clearly negligible and much less than the drawdown which would be associated with alternative extraction methods such as open pit and underground mining.

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TABLES

TABLE 1

REGIONAL PIEZOMETRIC SURFACE DATA

Well Number *	Water Level (ft.)	Depth (ft.)	Quadrangle Name	Ground Elevation (ft.)	Water Elevation (ft.)
44-76-8 cdc	flowing (2 gpm)	760	Fort Reno, SE	4660	-
42-74-6 ac	185	225	South Butte	5370	5185
46-76-10 da	28	90	Savageton	4510	4482
47-76-26 cd	105	300	Bogie Draw	4810	4705
49-76-27 aaa	flowing (1 gpm)	1000	Morgan Draw	4170	-
46-75-9 bd	4	400	Savageton	4700	4696
47-75-13 bcc	34	355	Double Tanks	4730	4696
50-75-30 bd	150	400	Carr Draw	4340	4190
53-74-7 bcc	46	120	Truman Draw	4330	4284
50-74-31 cb	84	290	Jeffers Draw	4530	4446
49-74-13 db1	10	143	Four Bar J Ranch	4750	4740
46-74-9 cb	187	281	Savageton	4940	4753
40-74-21 ac	20	30	Coal Draw	5080	5060
38-74-13 db	40	160	Coal Draw	5175	5135
37-74-35 dc	70	118	Highland Flats	5400	5330
36-74-18 ca	27	35	Fifty Five Ranch	5870	5843
35-73-33 da	38	80	Gilbert Lake	5180	5142
36-73-27 bd	168	180	Highland Flats	5520	5352
38-73-17 ab	flowing (1 gpm)	515	Coal Draw	5120	-
39-73-24 caa	70	267	Coal Draw	4955	4885
43-74-25 da	30	177	Turnercrest	5125	5095
44-73-35 cc	45	205	North Star School	4910	4865
46-73-34 ccd	19	200	North Star School	4810	4791
46-73-6 ddd	22	233	North Star School	4900	4878
48-73-31 ad	79	305	Pleasantdale	4830	4751
52-73-25 dd	80	210	Rawhide School	4255	4175

* 1st numeral denotes township, 2nd numeral denotes range, 3rd numeral denotes section. Subdivisions within a section are labeled a,b,c, and d in a counterclockwise direction beginning in the northeast quarter (a - NE¼, b - NW¼, c - SW¼, d - SE¼). The first letter denotes the quarter section, the second letter, if shown denotes the quarter-quarter section,etc. A numeral n if shown indicates it is the nth well assigned a number in that quarter-quarter -...section.

46-78-18 dc	110	540	Provence Ranch	4525	4415
47-78-24 cb	flowing (1 gpm)	235	Bowman Flats	4195	-
51-78-32 bb	200	344	Bear Draw	4325	4125
51-79-16 ba	30	164	Floate Draw	4020	3990
50-79-19 bc	165	600	Pine Gulch	4170	4005
48-79-29 ca	125	390	Brown Ranch	4555	4430
43-79-20 dac	49	103	Soldier Creek	4565	4516
43-79-9 dac	30	85	Sussex	4495	4465
43-79-2 dd	68	270	Sussex	4490	4422
45-80-1 dac	39	141	Elaine Draw	4545	4506
47-80-16 ba	66	220	Brown Ranch	4635	4569
49-80-23 ac	4	145	Crazy Woman Ranch	4280	4276
50-80-26 ac	15	215	Buffalo, SE	4620	4605
49-82-2 bb	6	318	Buffalo	5117	5111
36-72-29 ba	50	400	Highland Flats	5250	5200
36-72-9 dd	180	212	Bill	5420	5240
43-72-16 cc	305	345	Turnercrest	5180	4875
43-72-18 bd	165	261	Turnercrest	5215	5050
45-72-15 ba	20	145	Reno Junction	4855	4835
45-72-10 bc	20	145	North Star School	4860	4840
46-72-34 bd	25	205	North Star School	4855	4830
46-72-1 bcc	30	90	Eagle Rock	4695	4665
48-72-24 cd	15	40	The Gap, SW	4635	4620
48-72-13 aa	58	122	The Gap	4615	4557
50-72-5 aab	55	120	Gillette West	4600	4545
50-72-4 ab	133	387	Gillette West	4560	4427
51-72-35 dd	4	305	Gillette West	4500	4496
50-72-8 bbb	160	380	Gillette West	4405	4245
51-72-29 bdd	30	34	Gillette West	4320	4288
51-72-22 cb	32	100	Rawhide School	4265	4233
49-71-18 dcc	48	204	The Gap	4650	4602
50-71-29 dca	166	263	The Gap	4675	4509
47-71-11 bcc	110	180	Coyote Draw	4630	4520
49-71-34 cb	24	114	The Gap, SW	4505	4481
45-71-2 aa	100	155	Neil Butte	4740	4640
44-71-10 dd	95	124	Hilight	4830	4735
34-70-5 db	55	149	Clausen Ranch	5160	5105

42-70-32 aaa	240	280	Teckla	4850	4610
42-70-5 ddd	110	233	Reno Reservoir	4780	4670
43-70-11 da	25	45	Piney Canyon, NW	4725	4700
44-70-28 cbc	110	261	Hilight	4865	4755
33-73-27 bdb	9	92	Orpha	5170	5161
57-79-25 cc	40	95	Box Elder Draw	4225	4185
55-79-30 bba2	150	200	Clearmont	4085	3935
53-79-7 bc	70	280	Julie Draw	3975	3905
52-79-12 cc	27	160	Floate Draw	4310	4283
52-80-1 ac	26	312	Julie Draw	4275	4249
53-80-18 ca2	46	143	Ucross	4083	4037
53-80-2 db	50	260	Julie Draw	4200	4150
54-80-24 bc	82	120	Clearmont	4060	3978
57-81-7 cb	80	510	Cedar Canyon	3700	3620
56-81-29 bd	190	378	Jones Draw	4080	3890
54-81-14 bc	47	110	ULM	4460	4413
52-81-13 db	12	246	Lake DeSmet East	4480	4468
54-82-29 ba	12	60	Buffalo Run Creek	4320	4308
56-82-35 aa	50	87	Jones Draw	3880	3830
54-83-3 bd	20	245	Buffalo Run Creek	4090	4070
53-83-7 dd	7	42	Story	5115	5108
54-84-11 ab	11	160	Big Horn	4130	4119
41-73-6 bb	40	120	Turnercrest	5020	4980
41-74-11 dd	0	–	Turnercrest	5090	5090
42-73-8 ca	180	450	Turnercrest	5240	5060
43-74-10 bd	150	290	Turnercrest	5160	5010
43-73-9 aa	110	152	Turnercrest	5080	4970
42-73-31 aa	65	210	Turnercrest	5120	5055

TABLE 2

Collins Draw Water Well Data
1-Sand
T43N R76W Sec. 35

Hole No.	Surface Coordinates N/S	Surface Coordinates E/W	Bottom Hole Coordinates N/S	Bottom Hole Coordinates E/W	Hole Depth (ft.)	Casing Depth (ft.)	Host Sand Top (ft.)	Host Sand Thickness (ft.)	Ground Elevation (ft.)	Top Casing Elevation (ft.)
139W	97300N	62000E	drift/5	36/max	485	430	426	52	4885.48	4886.73
146W	97300N	61965E	97297.39	61966.1	485	429	428	55	4883.03	4884.71
190WC	97300N	61975E	97301.6	61969.68	481	429.6	430	47	4883.41	4885.27
191WC	97359.5N	62017E	97369.67	62023.13	480	431	431	49	4883.08	4884.40
230W*	97275N	62050E	Not available		396	312	312	84	4890.06	4890.93
231W	97335N	62095E	97332.10	62085.68	488	438	438	50	4893.89	4894.78
232W	97240N	62110E	97243.34	62108.54	lc(457)	447	447	(10)	4899.63	4900.06
233W	97250N	62012E	97250.45	62010.46	487.5	429	426	52	4885.31	4887.34
234W	97260N	61960E	97263.95	61963.71	479.5	425	421	58.5	4880.15	4881.47

* Hole No. 230W is in the "A" sand.

TABLE 3

AVERAGE TRANSMISSIVITY AND STORAGE COEFFICIENT FOR EACH WELL

Well No.	Township-Range-Section	N/S Surface Coordinates	E/W Surface Coordinates	Average Transmissivity gpd/ft.	Average Storage Coefficient
139W	43 - 76 - 35	97300N	62000E	227	2×10^{-4}
146W	43 - 76 - 35	97300N	61965E	216	4.3×10^{-4}
190WC	43 - 76 - 35	97300N	61975E	187	2.1×10^{-3}
191WC	43 - 76 - 35	97359N	62017E	163	2.3×10^{-4}
231W	43 - 76 - 35	97335N	62095E	167	9.3×10^{-5}
232W	43 - 76 - 35	97240N	62110E	182	5.5×10^{-5}
233W	43 - 76 - 35	97250N	62012E	212	9.7×10^{-5}
234W	43 - 76 - 35	97260N	61960E	180	1.1×10^{-4}

Average transmissivity over all wells = 192 gpd/ft.

Average storage coefficient (excluding 190WC) = 1.7×10^{-4}

TABLE 4
History of pump tests, test by test
Collins Draw, Wyoming

Date	Test No.	Well No.	Transmissivity (gpd/ft.) Jacob's	Chow's	Hantush's	Storage Coefficient Jacob's	Chow's	Hantush's	Discharge (gpm)
		146W	258						33.2
12/20/75		139W	270						48.0
		139W	270						
7/15/76	1	139W	225						35.0
		139W	225						
		146	210	209		$8.23x10^{-5}$	$8.24x10^{-5}$		
7/30/76	2	139W	258						40.0
		146	235	209	209	$1.20x10^{-4}$	$1.49x10^{-4}$	$1.49x10^{-4}$	
		190	216	190	181	$2.24x10^{-4}$	$1.52x10^{-4}$	$3.17x10^{-4}$	
		191	182	150	144	$2.48x10^{-4}$	$1.81x10^{-4}$	$2.76x10^{-4}$	
7/30/76	3	190	243						35.0
		139	231	212	192	$3.02x10^{-4}$	$2.01x10^{-4}$	$2.45x10^{-4}$	
		146	234	221	178	$1.61x10^{-3}$	$1.06x10^{-3}$	$1.49x10^{-3}$	
		191	176	161	132	$3.08x10^{-4}$	$2.05x10^{-4}$	$2.50x10^{-4}$	
8/5/76	4 Injection well	139W	204						34.0
		146	204	187		$1.37x10^{-4}$	$1.29x10^{-4}$		
		190	169	146		$5.53x10^{-3}$	$7.09x10^{-4}$		
		191	243	175		$9.12x10^{-5}$	$1.23x10^{-4}$		
8/23/76	5	146	189						25.61
		139	194	178	184	$1.34x10^{-4}$	$1.62x10^{-4}$	$1.61x10^{-4}$	
		190	188	172	178	$2.86x10^{-3}$	$3.53x10^{-3}$	$3.53x10^{-3}$	
		191	186	178	148	$1.06x10^{-4}$	$1.08x10^{-4}$	$1.44x10^{-4}$	
11/5/76	6	232	183						
		231	173		134	$4.36x10^{-5}$		$6.0x10^{-5}$	
		233	271		220	$5.66x10^{-5}$		$5.47x10^{-5}$	
11/17/76	7	139	269	267					20.07
		146	186	172	192	$1.75x10^{-4}$	$2.40x10^{-4}$	$1.36x10^{-4}$	
		191	139	104		$4.15x10^{-4}$	$5.59x10^{-4}$		
		231	183	170	173	$1.10x10^{-4}$	$1.24x10^{-4}$	$1.25x10^{-4}$	
		232	186	170	190	$5.31x10^{-5}$	$6.51x10^{-5}$	$5.18x10^{-5}$	
		233	191	176	204	$1.24x10^{-4}$	$1.47x10^{-4}$	$1.02x10^{-4}$	
		234	180	169	190	$1.11x10^{-4}$	$1.29x10^{-4}$	$8.90x10^{-5}$	

Table 5
History of pump tests, well by well
Collins Draw, Wyoming

Well No.	Date	Test No.	Transmissivity (gpd/ft.) Jacob's	Chow's	Hantush's	Storage Coefficient Jacob's	Chow's	Hantush's
139	12/20/75		270					
			270					
	7/15/76	1	225					
			225					
	7/30/76	2	258					
	7/30/76	3	231	212	192	3.02×10^{-4}	2.01×10^{-4}	2.45×10^{-4}
	8/5/76	4	204					
	8/23/76	5	194	178	184	1.34×10^{-4}	1.62×10^{-4}	1.61×10^{-4}
	11/17/76	7	269	267				
146			258					
	7/15/76	1	210	209		8.23×10^{-5}	8.24×10^{-5}	
	7/30/76	2	235	209	209	1.20×10^{-4}	1.49×10^{-4}	1.49×10^{-4}
	7/30/76	3	234	221	178	1.61×10^{-3}	1.06×10^{-3}	1.49×10^{-3}
	8/5/76	4	204	187		1.37×10^{-4}	1.29×10^{-4}	
	8/23/76	5	189					
	11/7/76	7	186	172	192	1.75×10^{-4}	2.40×10^{-4}	1.36×10^{-4}
190	7/30/76	2	216	190	181	2.24×10^{-4}	1.52×10^{-4}	3.17×10^{-4}
	7/30/76	3	243					
	8/5/76	4	169	146		5.53×10^{-3}	7.09×10^{-4}	
	8/23/76	5	188	172	178	2.86×10^{-3}	3.53×10^{-3}	3.53×10^{-3}
191	7/30/76	2	182	150	144	2.48×10^{-4}	1.81×10^{-4}	2.76×10^{-4}
	7/30/76	3	176	161	132	3.08×10^{-4}	2.05×10^{-4}	2.60×10^{-4}
	8/5/76	4	243	175		9.12×10^{-5}	1.23×10^{-4}	
	8/23/76	5	186	178	148	1.06×10^{-4}	1.08×10^{-4}	1.44×10^{-4}
	11/17/76	7	139	104	No match	4.15×10^{-4}	5.59×10^{-4}	
231	11/5/76	6	173		134	4.36×10^{-5}		6.0×10^{-5}
	11/17/76	7	183	170	173	1.10×10^{-4}	1.24×10^{-4}	1.25×10^{-4}
232	11/5/76	6	183					
	11/17/76	7	186	170	190	5.31×10^{-5}	6.51×10^{-5}	5.18×10^{-5}

Table 5 (Continued)
History of pump tests, well by well
Collins Draw, Wyoming

Well No.	Date	Test No.	Transmissivity (gpd/ft.) Jacob's	Chow's	Hantush's	Storage Coefficient Jacob's	Chow's	Hantush's
233	11/5/76	6	271		220	$5.66x10^{-5}$		$5.47x10^{-5}$
	11/17/76	7	191	176	204	$1.24x10^{-4}$	$1.47x10^{-4}$	$1.02x10^{-4}$
234	11/17/76	7	180	169	190	$1.11x10^{-4}$	$1.29x10^{-4}$	$8.90x10^{-5}$

Table 6

Summary of Results, Papadopulos' method
Test 7, Collins Draw, Wyoming

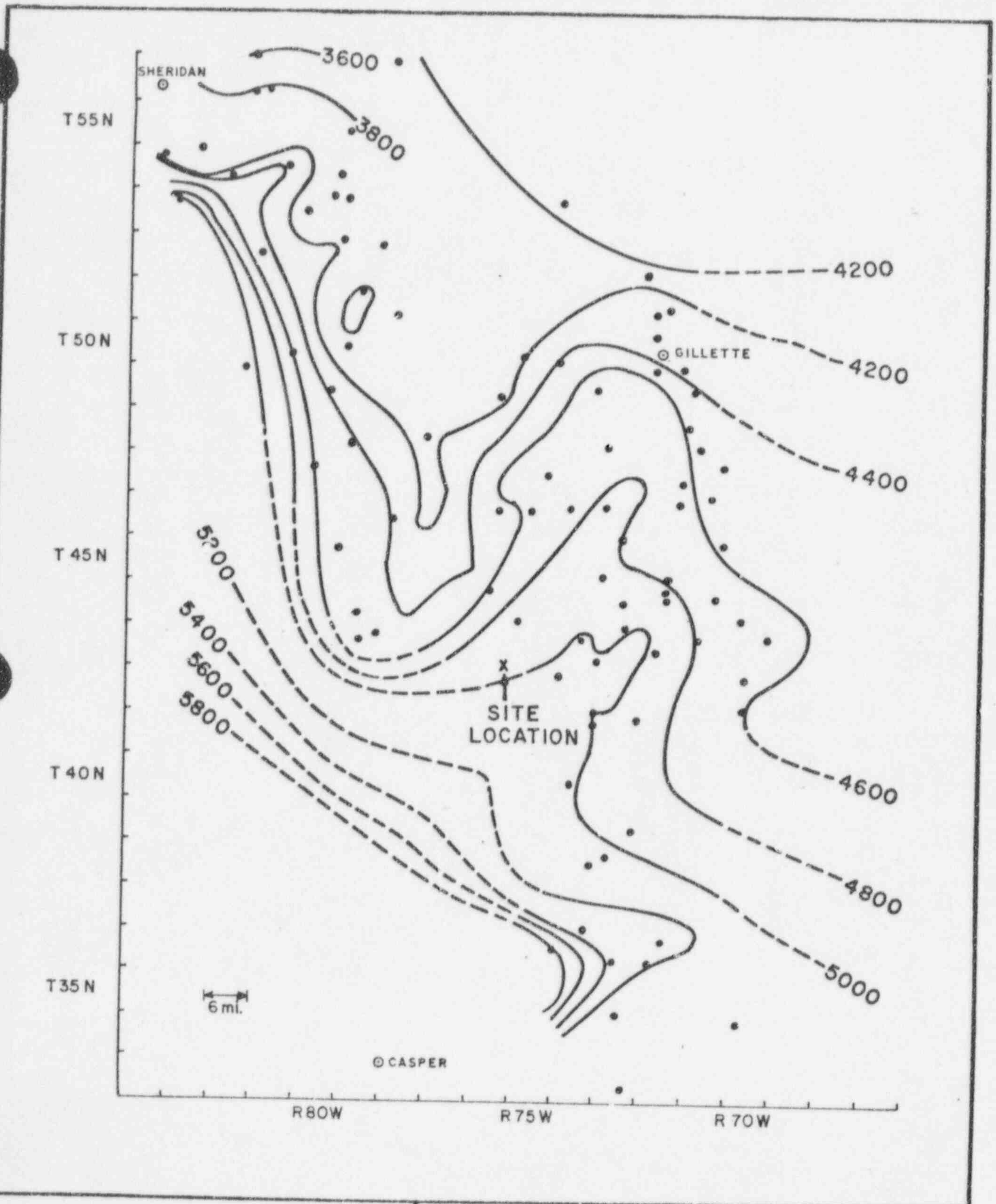
Well Nos.	Major Transmissivity (gpd/ft.)	Minor Transmissivity (gpd/ft.)	Direction of Major Transmissivity	Storage Coefficient
146,231,234	385	87	N 57°E	$2.05x10^{-4}$
146,231,233	600	58	N 30°E	$7.61x10^{-5}$
146,232,233	543	65	E 42°S	$1.02x10^{-4}$
231,232,233	329	106	E 26°S	$9.39x10^{-5}$
232,233,234	314	109	E 14°S	$8.14x10^{-5}$
146,233,234	260	132	N 19°E	$1.35x10^{-4}$
231,233,234	191	178	N 63°E	$1.17x10^{-4}$

Table 7

Well Efficiencies

Date	Test No.	Pumping Well	Discharge (gpm)	Time (minutes)	Observed Drawdown (ft.)	Theoretical Drawdown (ft.)	Well Efficiency
12/20/75		139	48	180	137	115.2	84%
7/15/76	1	139	35	120	114.9	73.5	64%
7/30/76	2	139	40	270	125	105	84%
11/7/76	7	139	20	470	74	59.5	80%
?		146	33.2	120	106.3	69.7	66%
8/23/76	5	146	25.6	1000	107	88.3	82%
7/30/76	3	190	35	181	160	147	92%

FIGURES



REGIONAL PIEZOMETRIC SURFACE

In·situ Consulting

PREPARED BY: R.S.	DATE: 9-27-78
CHECKED BY: C. R. M	DATE: 9/28/78
DRAWN BY ZIMMERGRAPHICS	FIGURE NO. 1

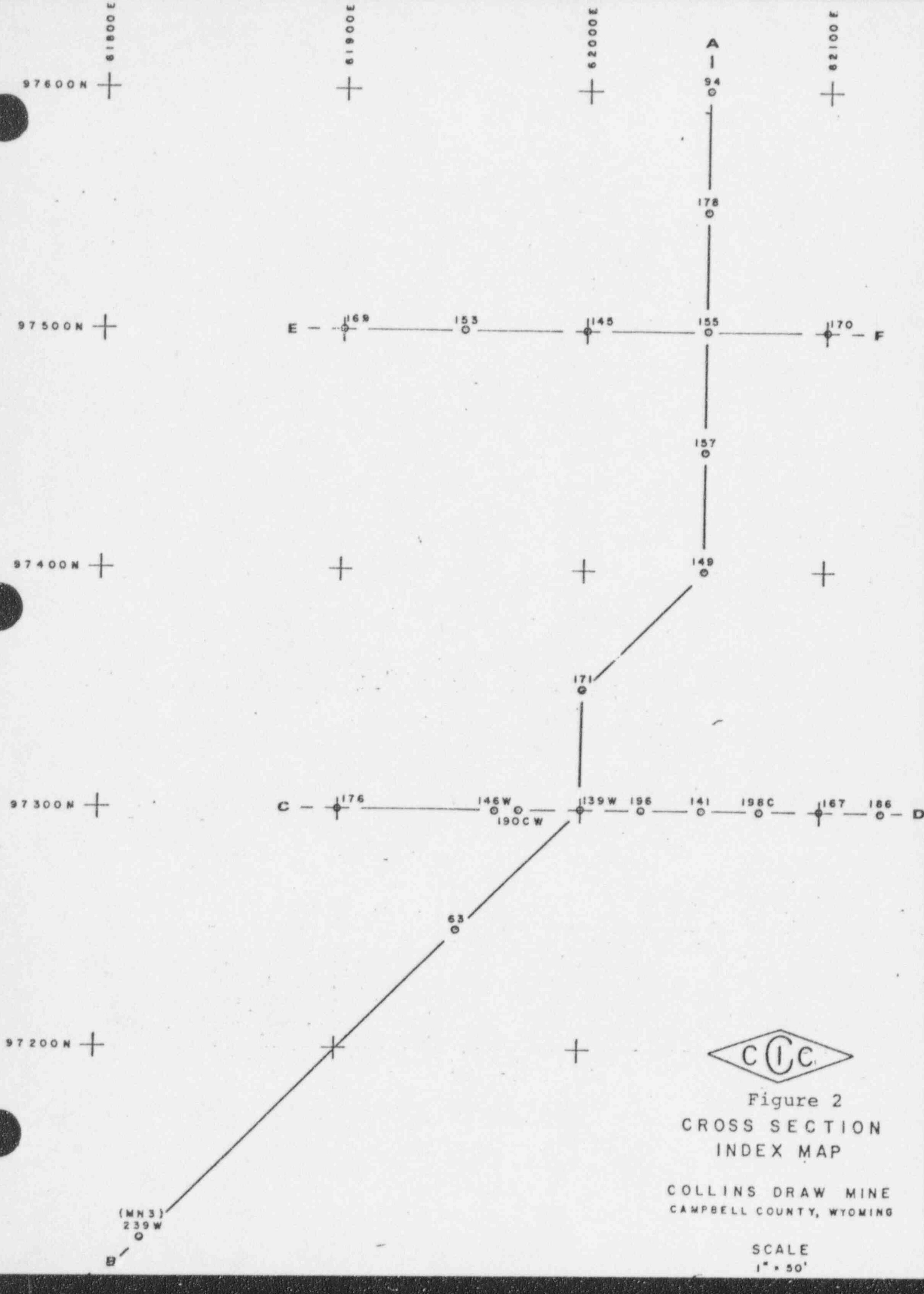
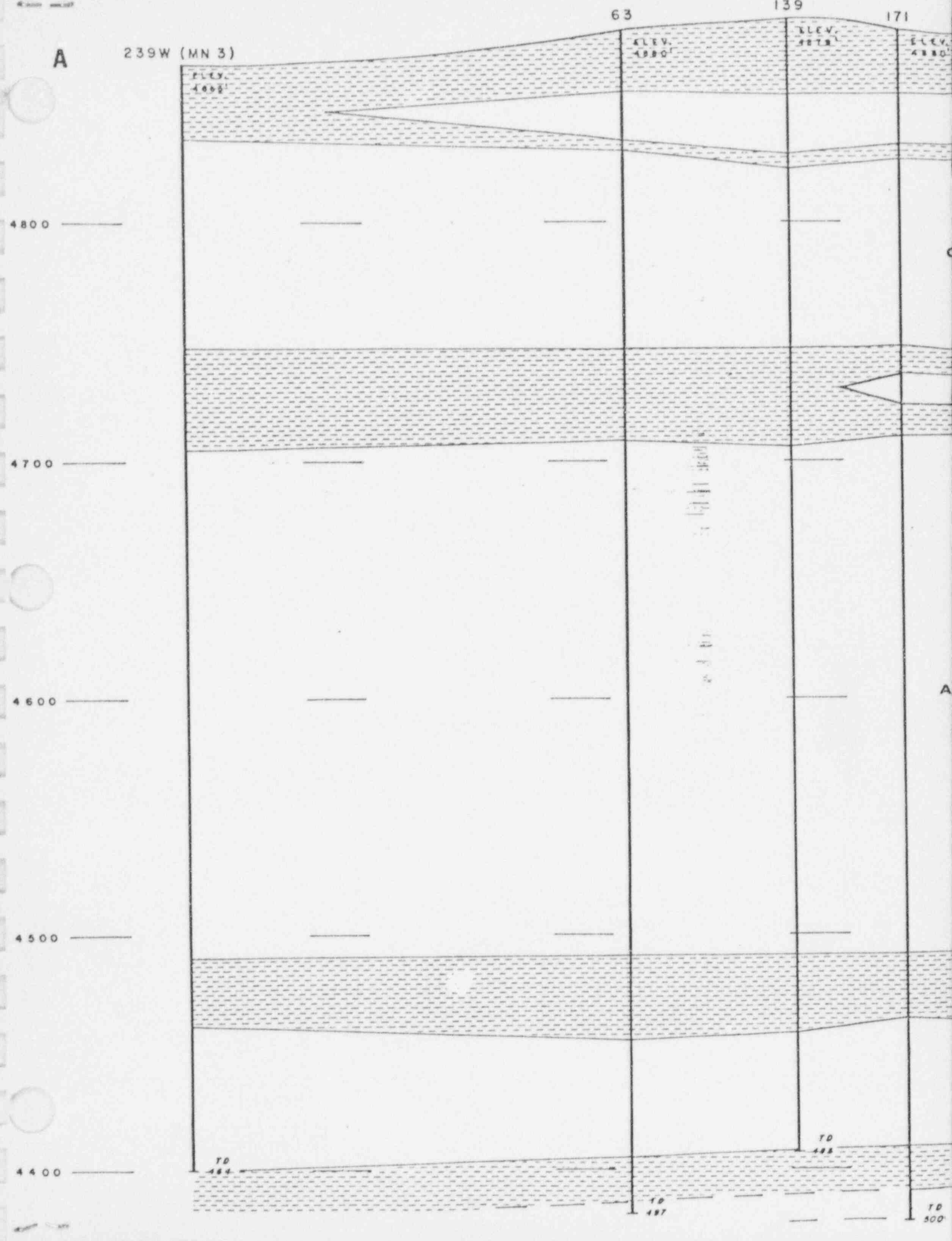


Figure 2
CROSS SECTION
INDEX MAP

COLLINS DRAW MINE
CAMPBELL COUNTY, WYOMING

SCALE
1" = 50'



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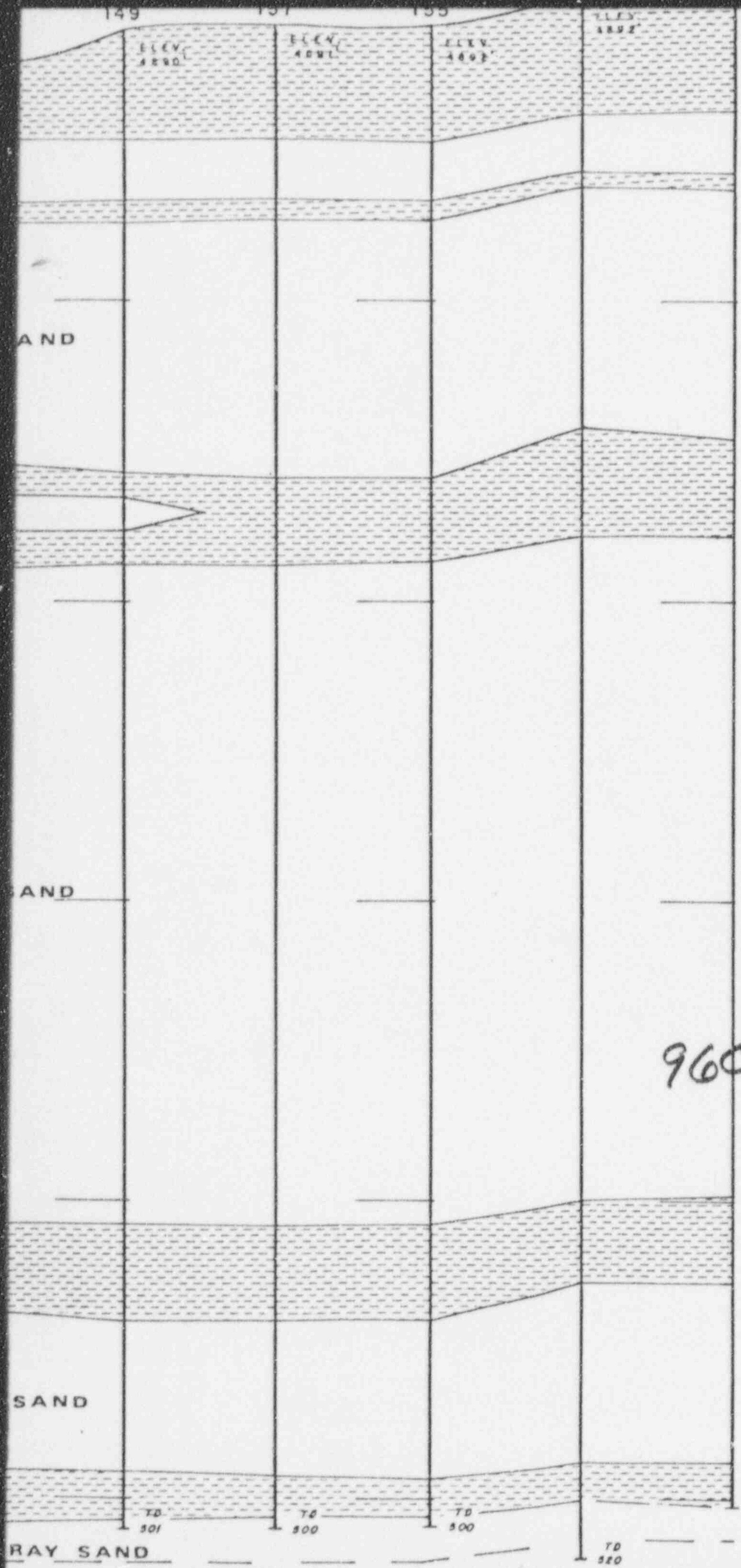
139
171
4800
4700
4600
4500
4400
A
TD
TD
TD
500'



9609190142-5

C I C

Figure 3
CROSS SECTION
A - B

COLLINS DRAW MINE
CAMPBELL COUNTY, WYOMING

SCALES
VERT. 1" = 500'
HORIZ. 1" = 500'

84/803/EV-LA-XX-8/1

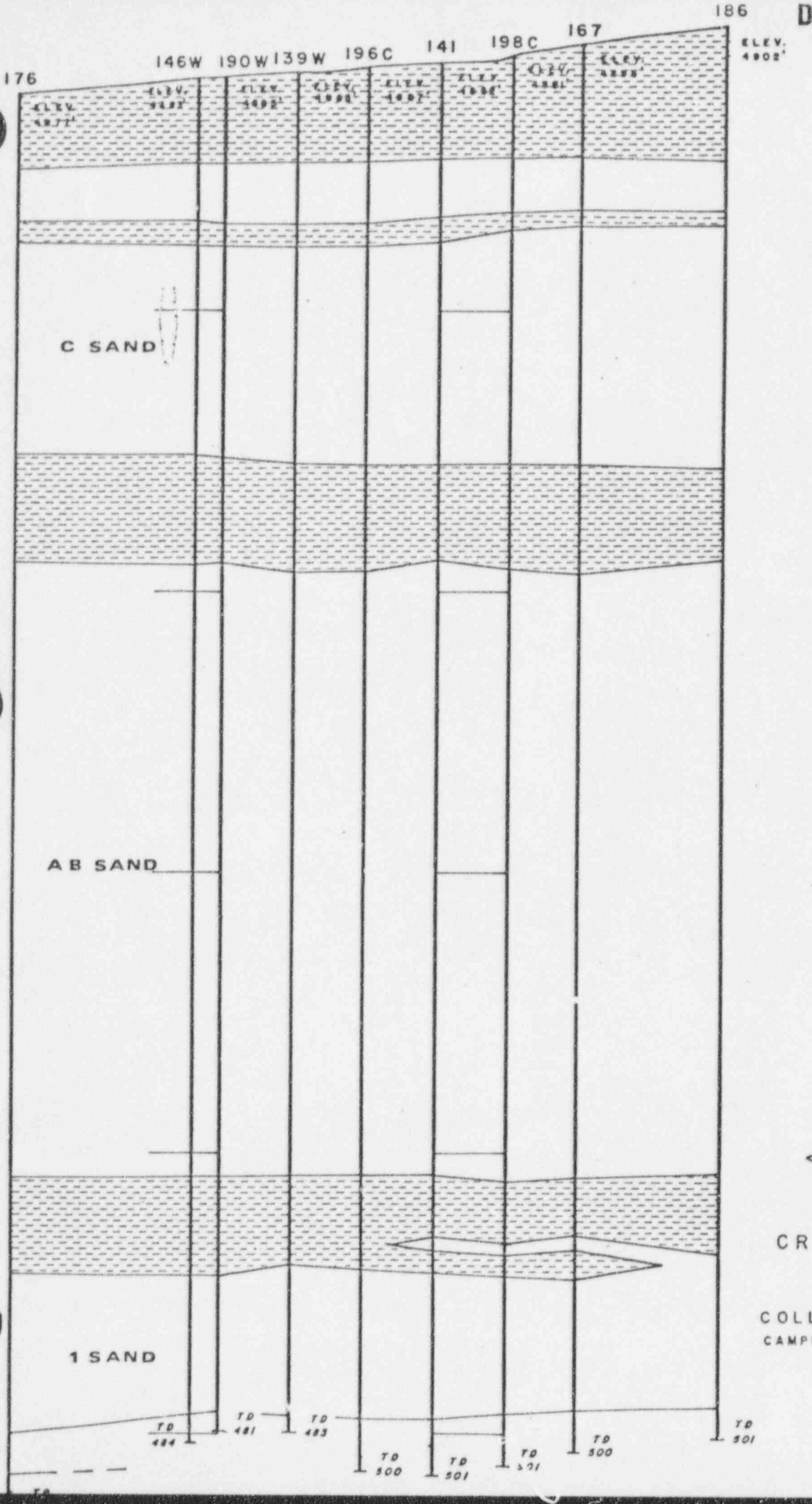


Figure 4

CROSS SECTION

C - D

COLLINS DRAW MINE

CAMPBELL COUNTY, WYOMING

SCALES

VERT. 1" = 500'

HORIZ. 1" = 500'

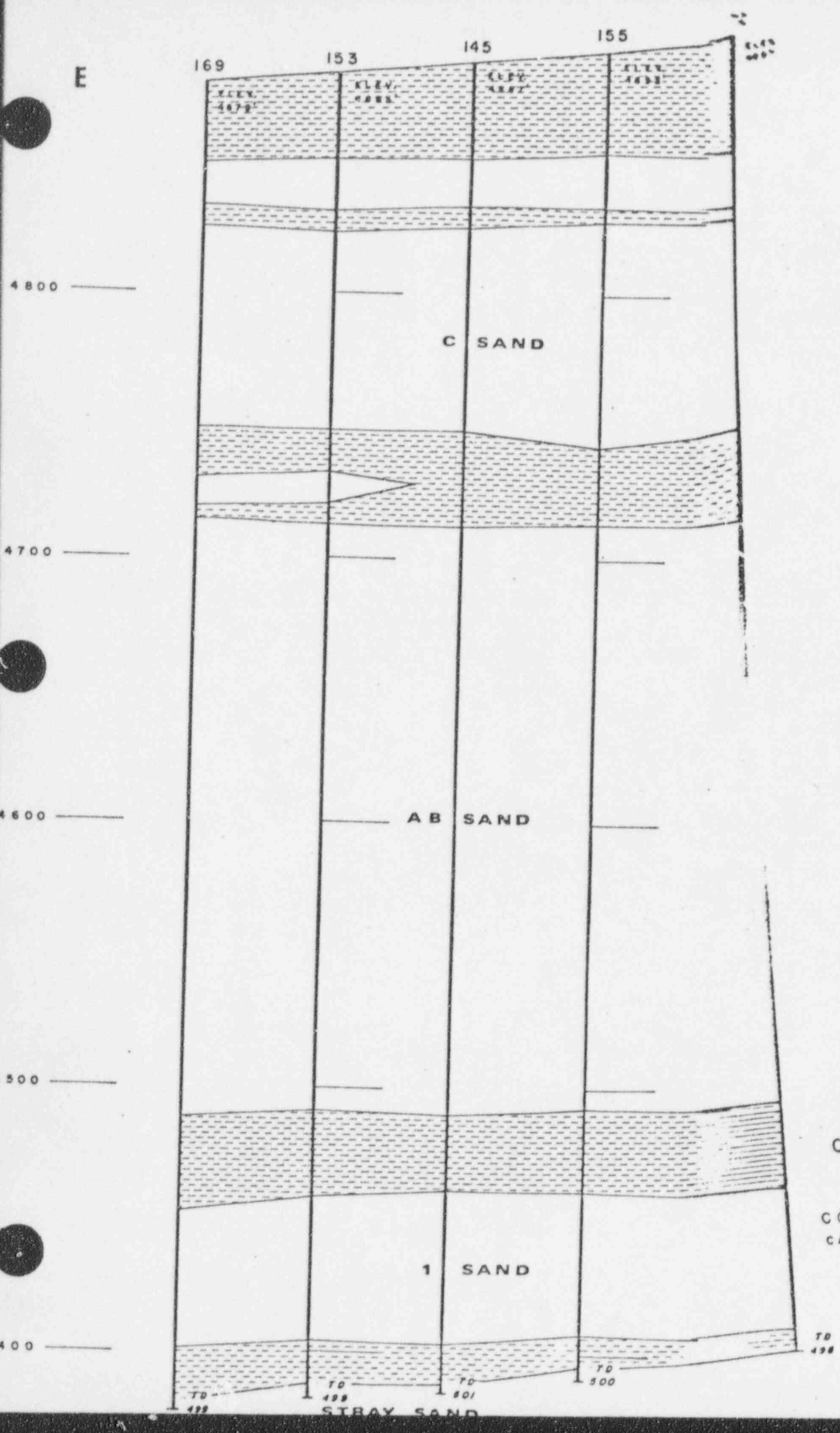
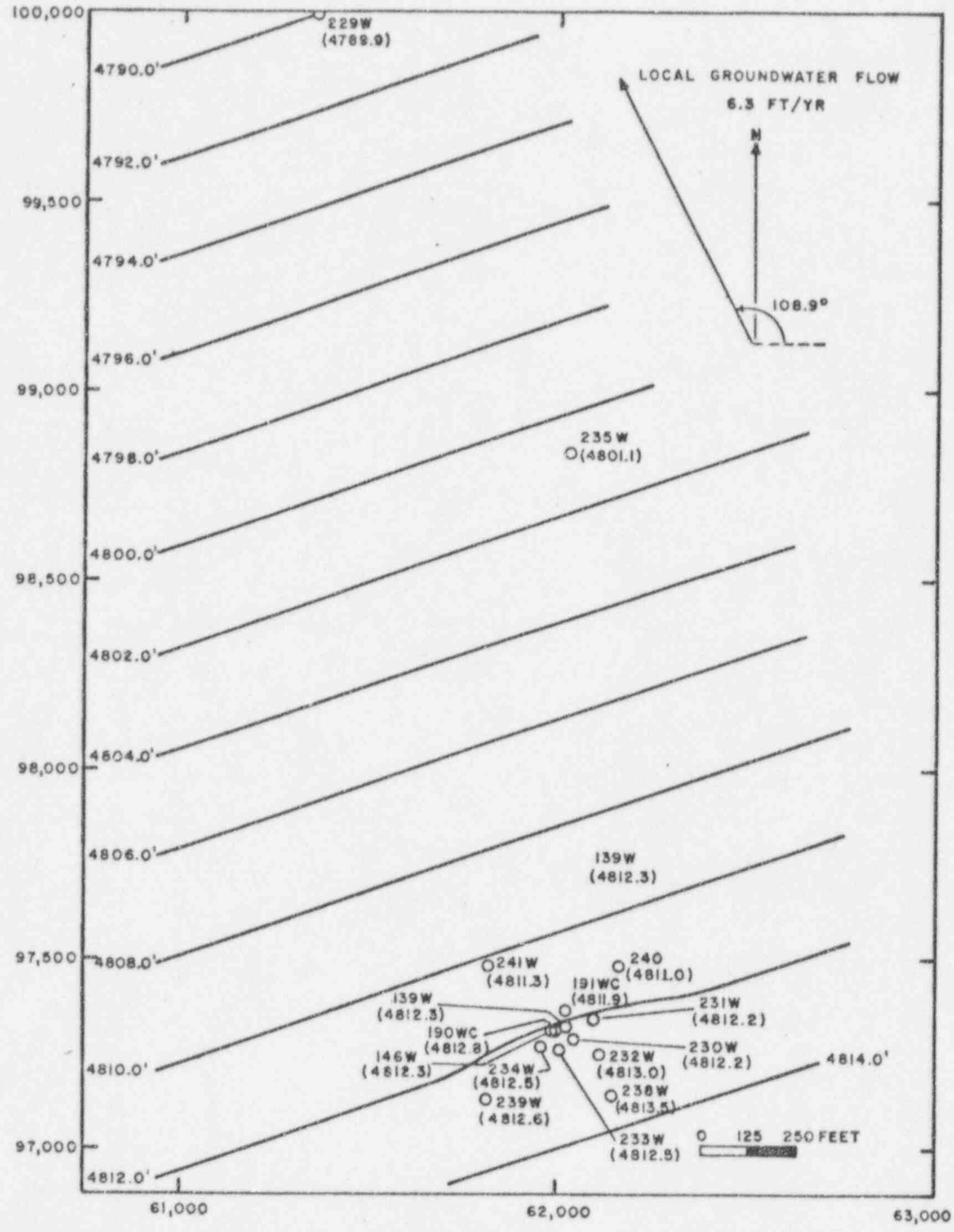


Figure 5
CROSS SECTIO
E - F

COLLINS DRAW MI
CAMPBELL COUNTY, WYOM

SCALES
VERT. 1" = 500'
HORIZ. 1" = 500'

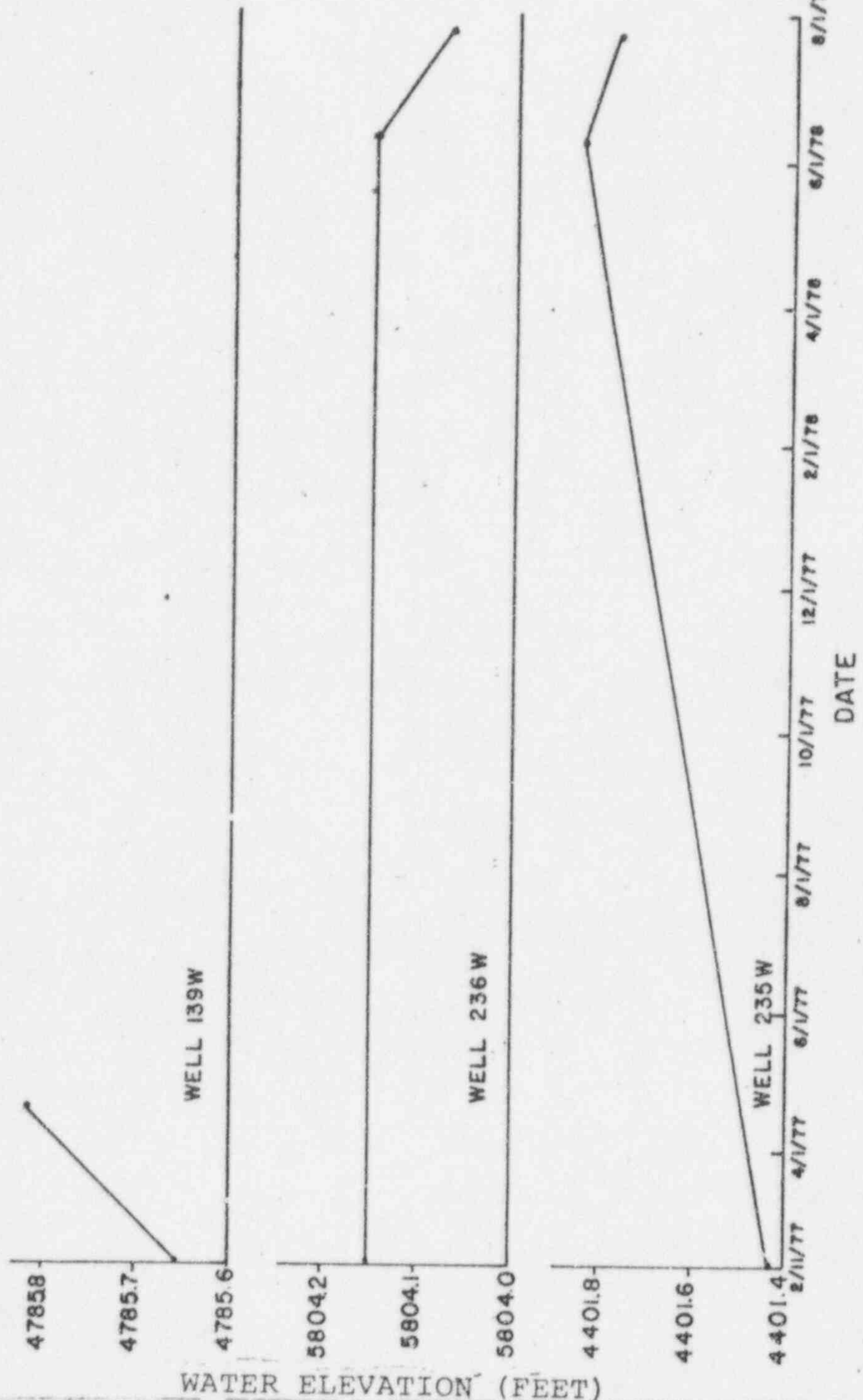
84/003/EV-LA-XX-5/3



PIEZOMETRIC SURFACE MAP

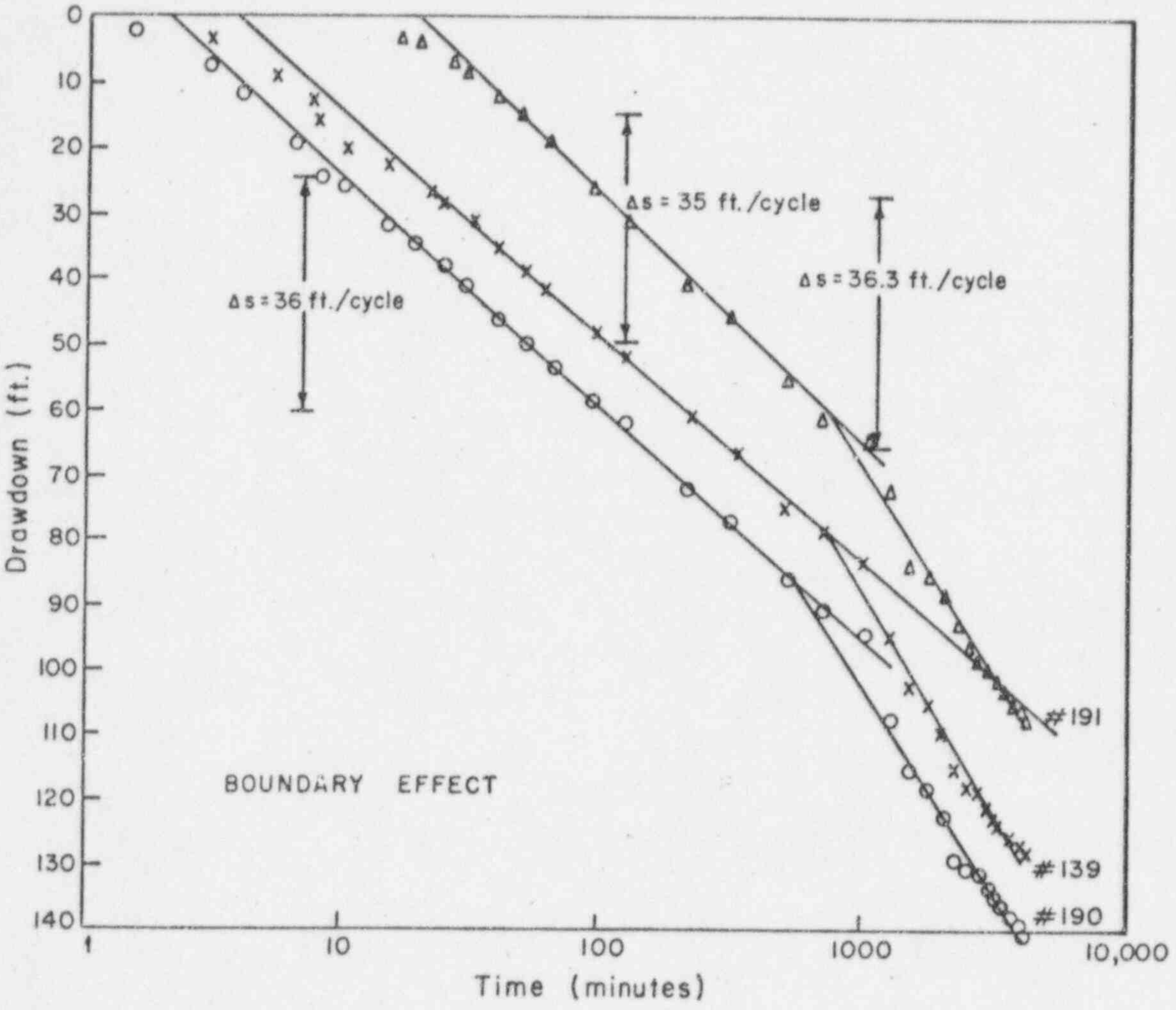
In-situ Consulting

PREPARED BY: R.S.	DATE: 9-27-78
CHECKED BY: C.R.M.	DATE: 9/28/78
DRAWN BY ZIMMERGRAPHICS	FIGURE NO. 6

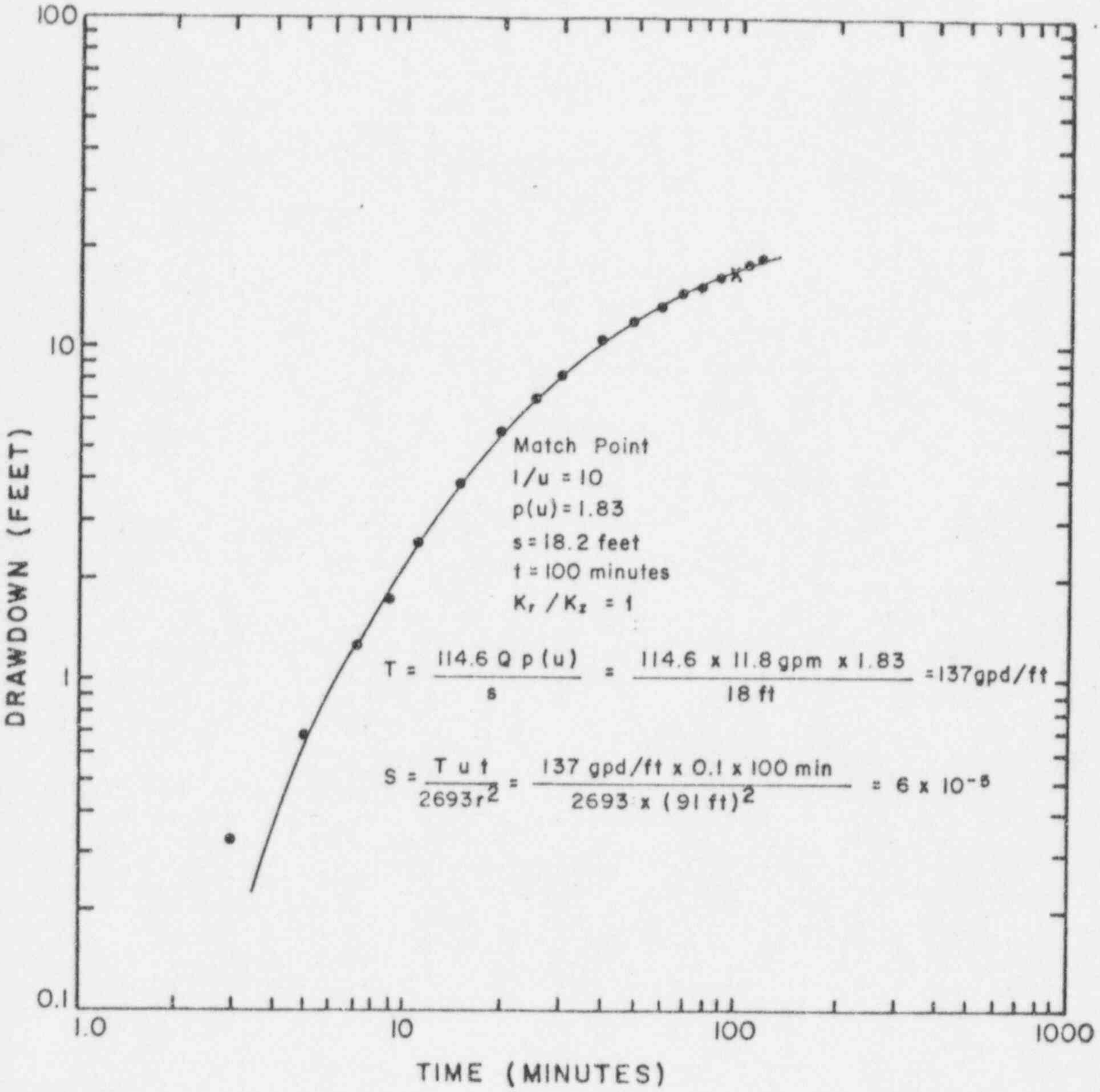


WATER ELEVATION VS. TIME
COLLINS DRAW

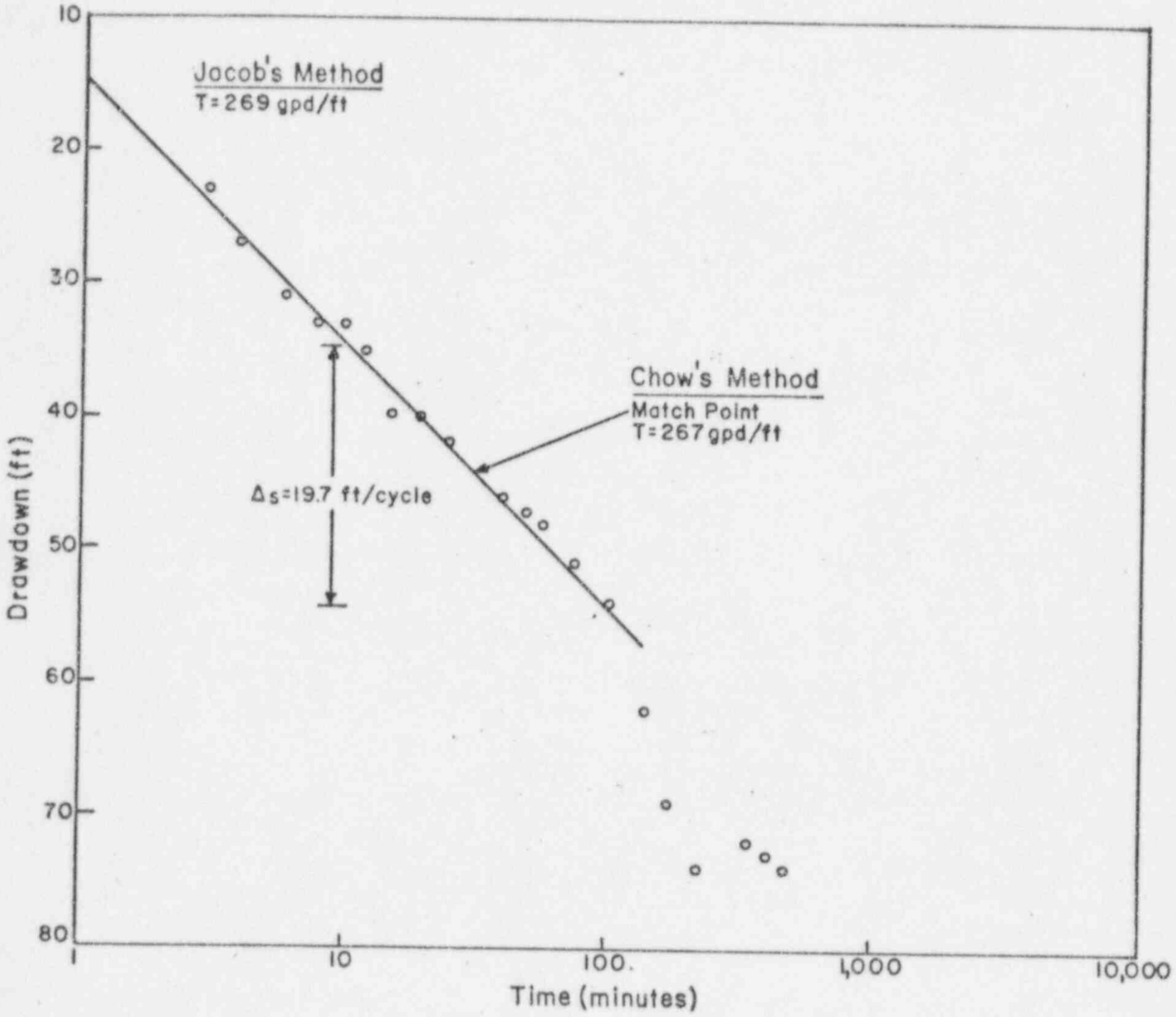
In-situ Consulting	PREPARED BY: R.S.	DATE: 9-27-78
	CHECKED BY: C.R.M.	DATE: 9/28/78
	DRAWN BY ZIMMERGRAPHICS	FIGURE NO. 7



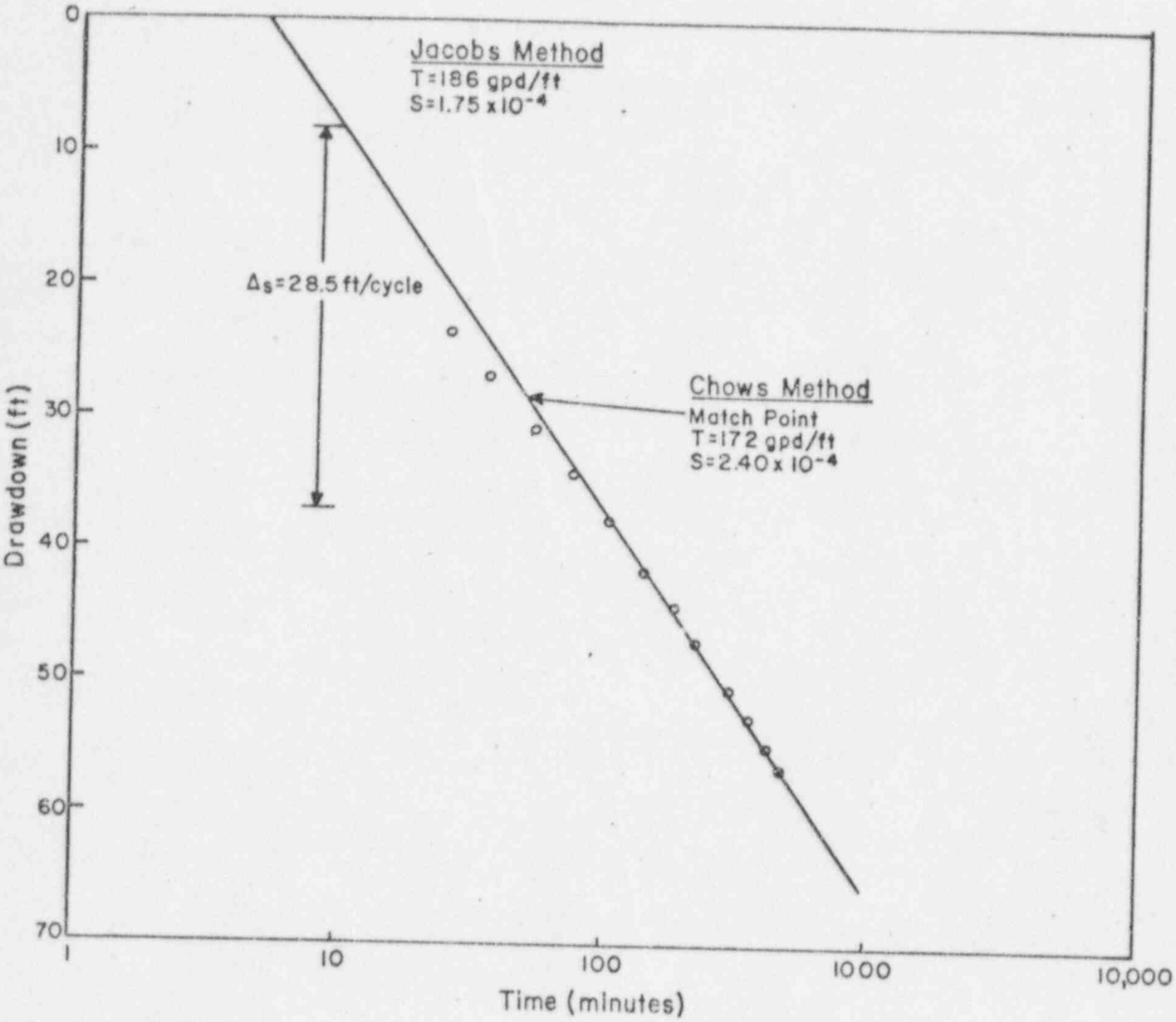
CLEVELAND CLIFFS IRON CO.	TEST 5 PUMPING WELL 146 Q = 25.6 gpm	
In·situ Consulting	PREPARED BY: T.W.	DATE: 9-27-78
	CHECKED BY: C.R.M.	DATE: 9/28/78
	DRAWN BY ZIMMERGRAPHICS	FIGURE NO. 8



CLEVELAND CLIFFS IRON CO.	HANTUSH'S UNSTEADY STATE TYPE CURVE OBSERVATION WELL NO. 231 TEST 6	
In-situ Consulting	PREPARED BY: T. W.	DATE: 9-27-78
	CHECKED BY: C. R. M	DATE: 9/28/78
	DRAWN BY ZIMMERGRAPHICS	FIGURE NO. 9

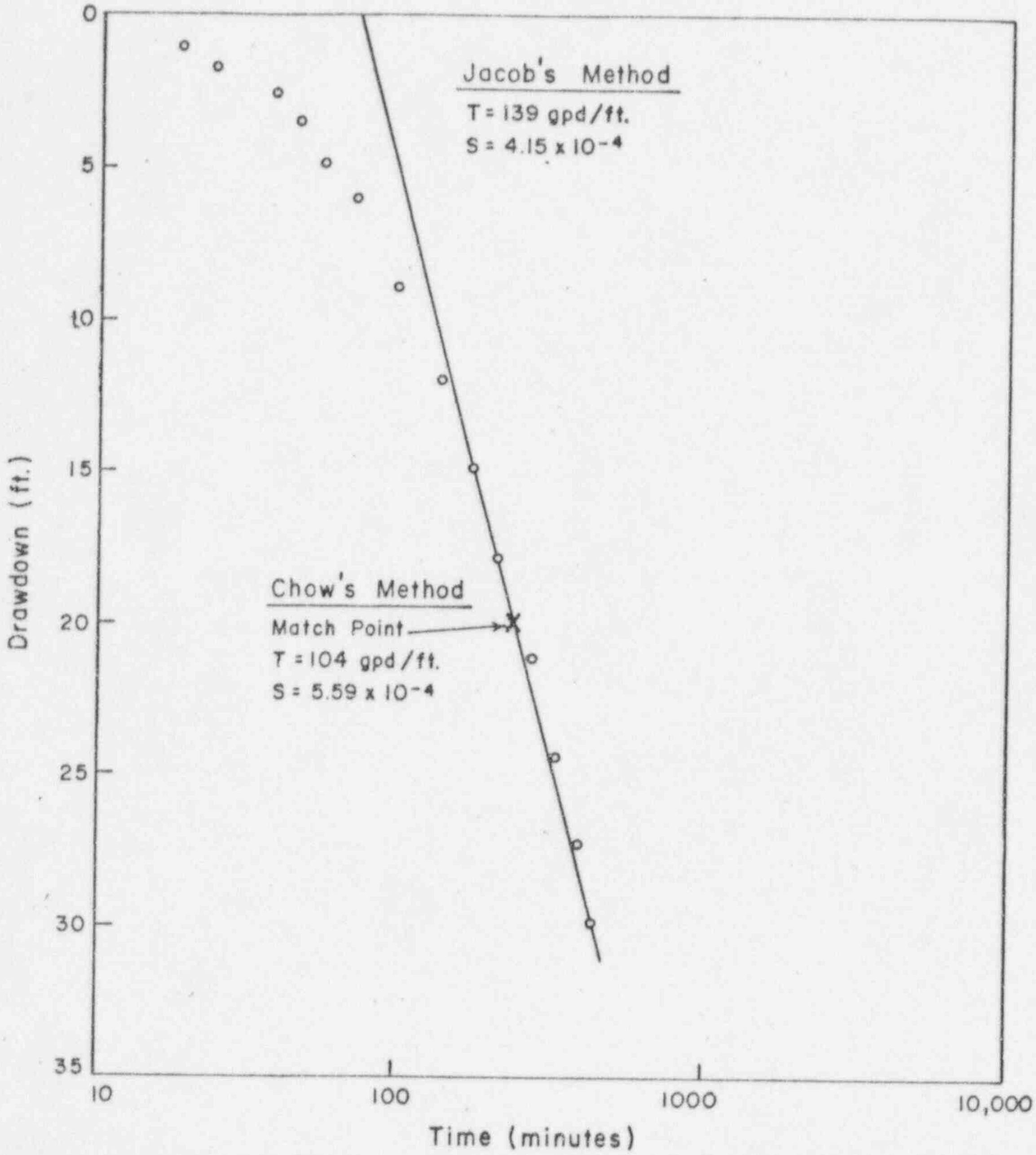


CLEVELAND CLIFFS IRON CO.	TEST 7 PUMPING WELL 139 Q=20 gpm	
In·situ Consulting	PREPARED BY: T.W.	DATE: 9-27-78
	CHECKED BY: C.R.M.	DATE: 9/28/78
	DRAWN BY ZIMMERGRAPHICS	FIGURE NO. 10

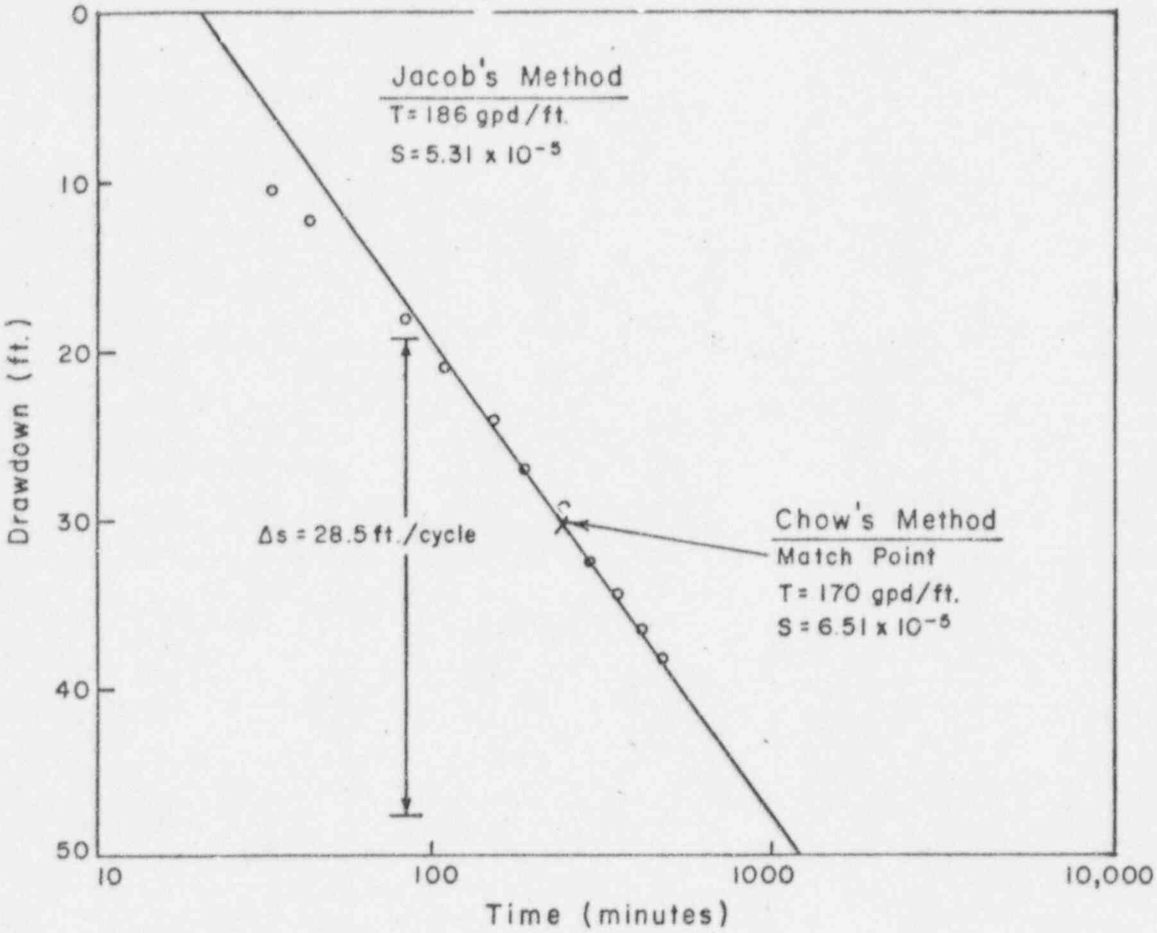


CLEVELAND CLIFFS IRON CO.	TEST 7 OBSERVATION WELL 146 PUMPING WELL 139 Q=20 gpm

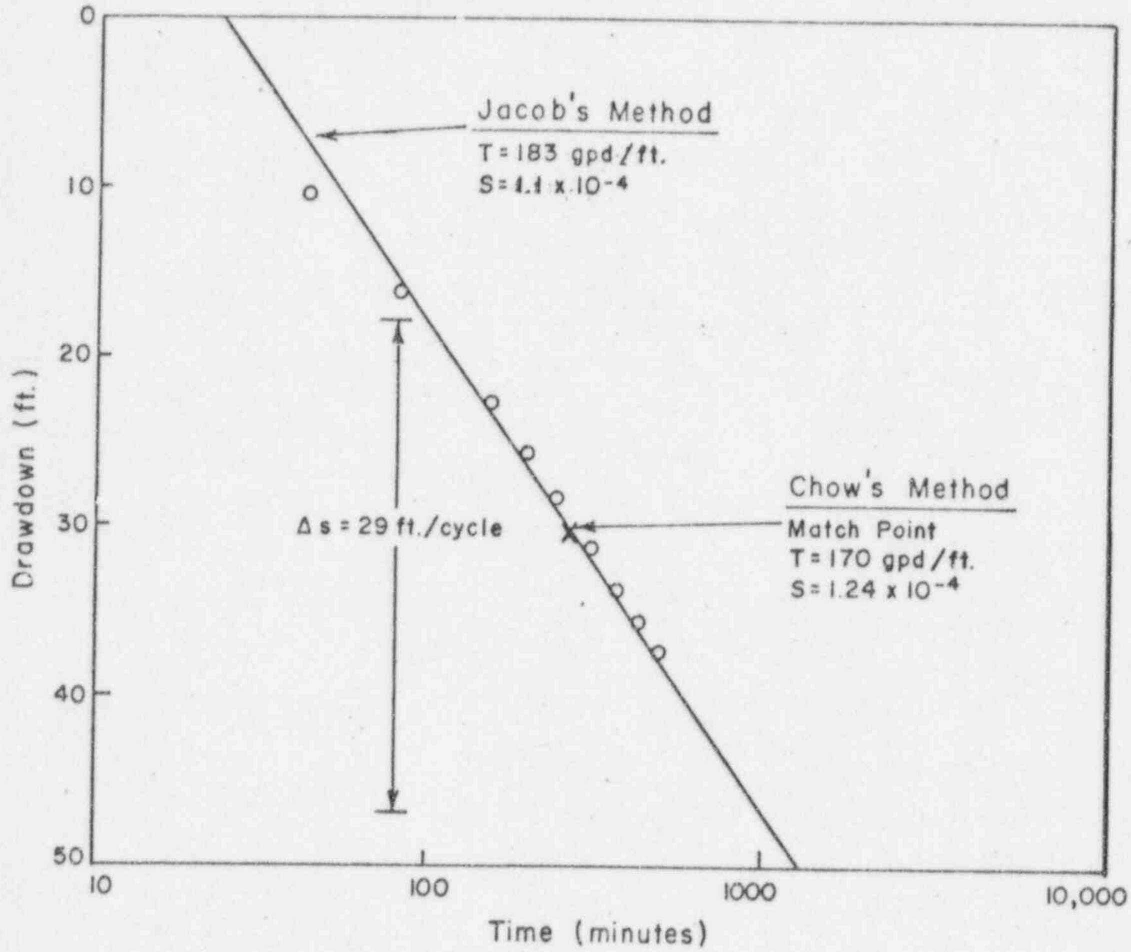
In·situ Consulting	PREPARED BY: T. W.	DATE: 9-27-78
	CHECKED BY: C. R. M	DATE: 9/28/78
	DRAWN BY ZIMMERGRAPHICS	FIGURE NO. 11



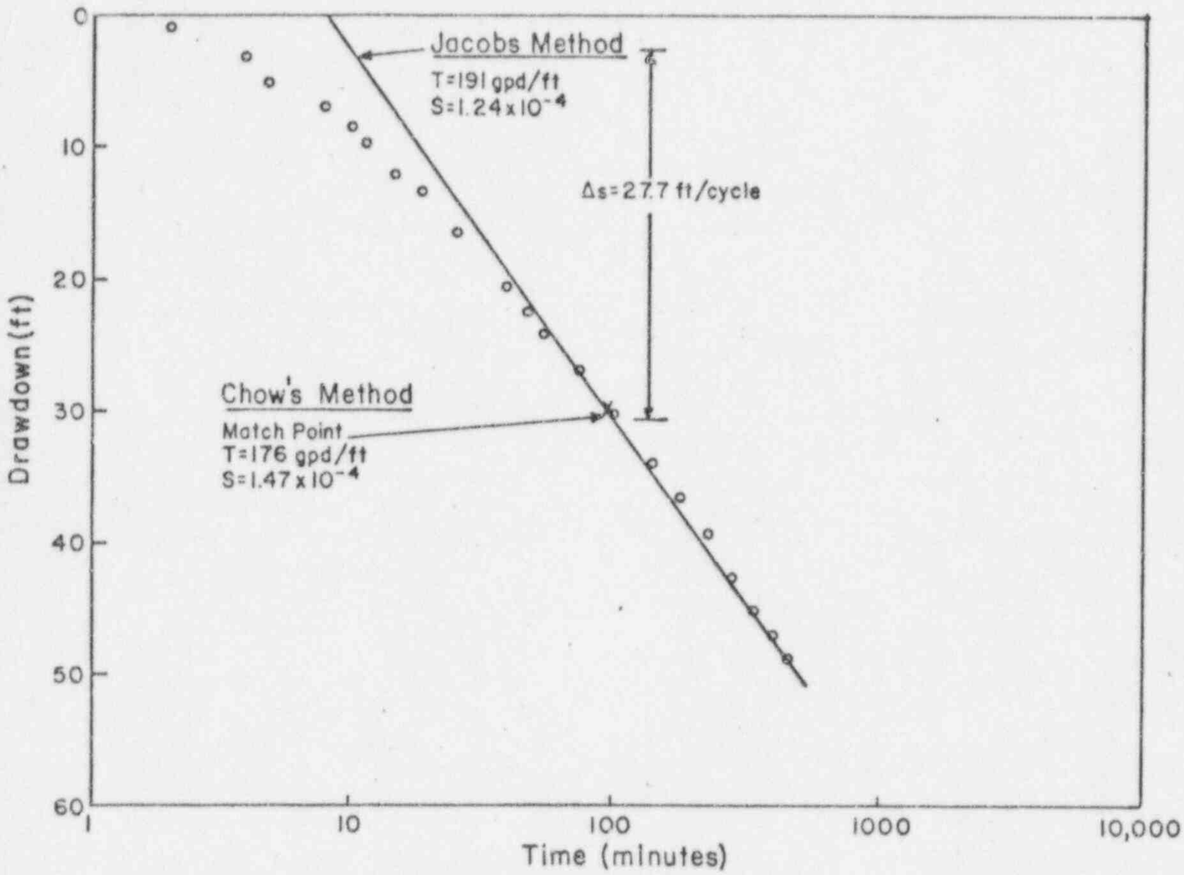
CLEVELAND CLIFFS IRON CO.	TEST 7 OBSERVATION WELL 191 PUMPING WELL 139 Q = 20 gpm
In·situ Consulting	PREPARED BY: T.W. — DATE: 9-27-78 CHECKED BY: C.R.M — DATE: 9/28/78 DRAWN BY ZIMMERGRAPHICS — FIGURE NO. 12



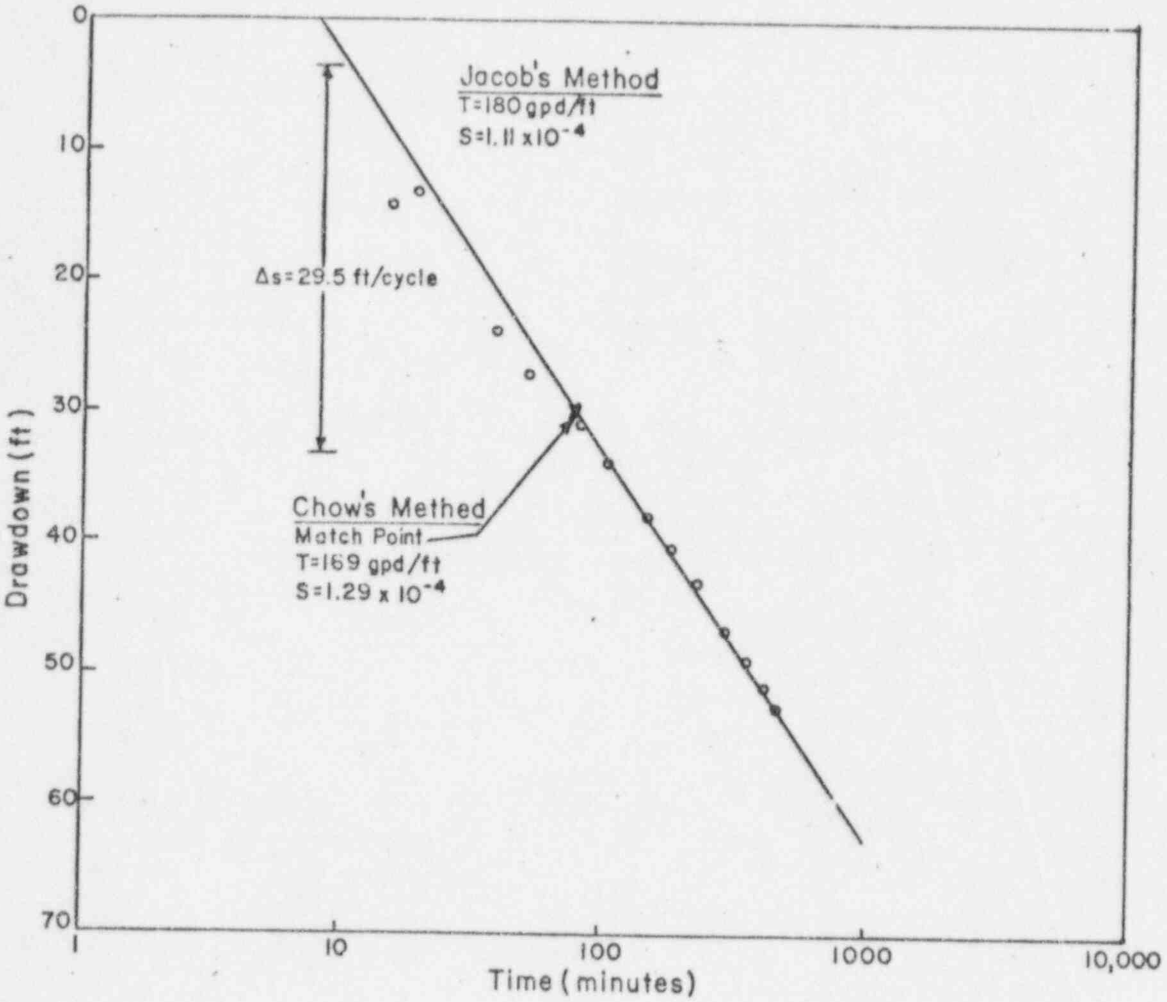
CLEVELAND CLIFFS IRON CO.	TEST 7 OBSERVATION WELL 232 PUMPING WELL 139 Q = 20gpm	
In-situ Consulting	PREPARED BY: T.W.	DATE: 9-27-78
	CHECKED BY: C.R.M.	DATE: 9/28/78
	DRAWN BY ZIMMERGRAPHICS	FIGURE NO. 14



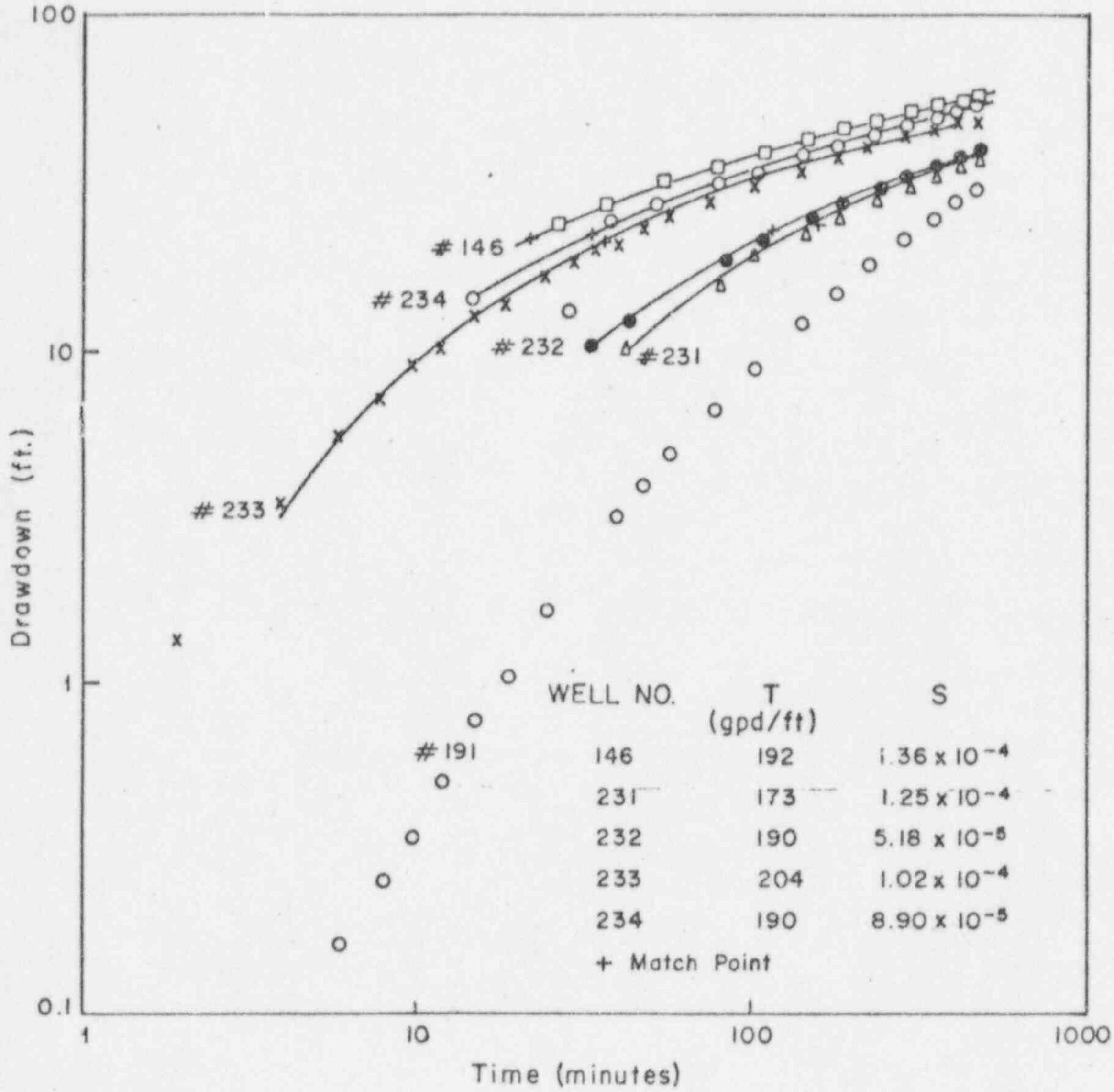
CLEVELAND CLIFFS IRON CO.	TEST 7 OBSERVATION WELL 231 PUMPING WELL 139 Q = 20 gpm
In·situ Consulting	PREPARED BY: T.W. — DATE: 9-17-78 CHECKED BY: C.R.M. — DATE: 9/28/78 DRAWN BY ZIMMERGRAPHICS — FIGURE NO. 13



CLEVELAND CLIFFS IRON CO.	TEST 7 OBSERVATION WELL 233 PUMPING WELL 139 Q=20gpm	
In-situ Consulting	PREPARED BY: T. W.	DATE: 9-27-78
	CHECKED BY: G.R.M	DATE: 9/28/78
	DRAWN BY ZIMMERGRAPHICS	FIGURE NO. 15



CLEVELAND CLIFFS IRON CO.	TEST 7 OBSERVATION WELL 234 PUMPING WELL 139 Q=20 gpm	
In-situ Consulting	PREPARED BY: T. W.	DATE: 9-27-78
	CHECKED BY: C.R.M	DATE: 9/28/80
	DRAWN BY ZIMMERGRAPHICS	FIGURE NO. 16



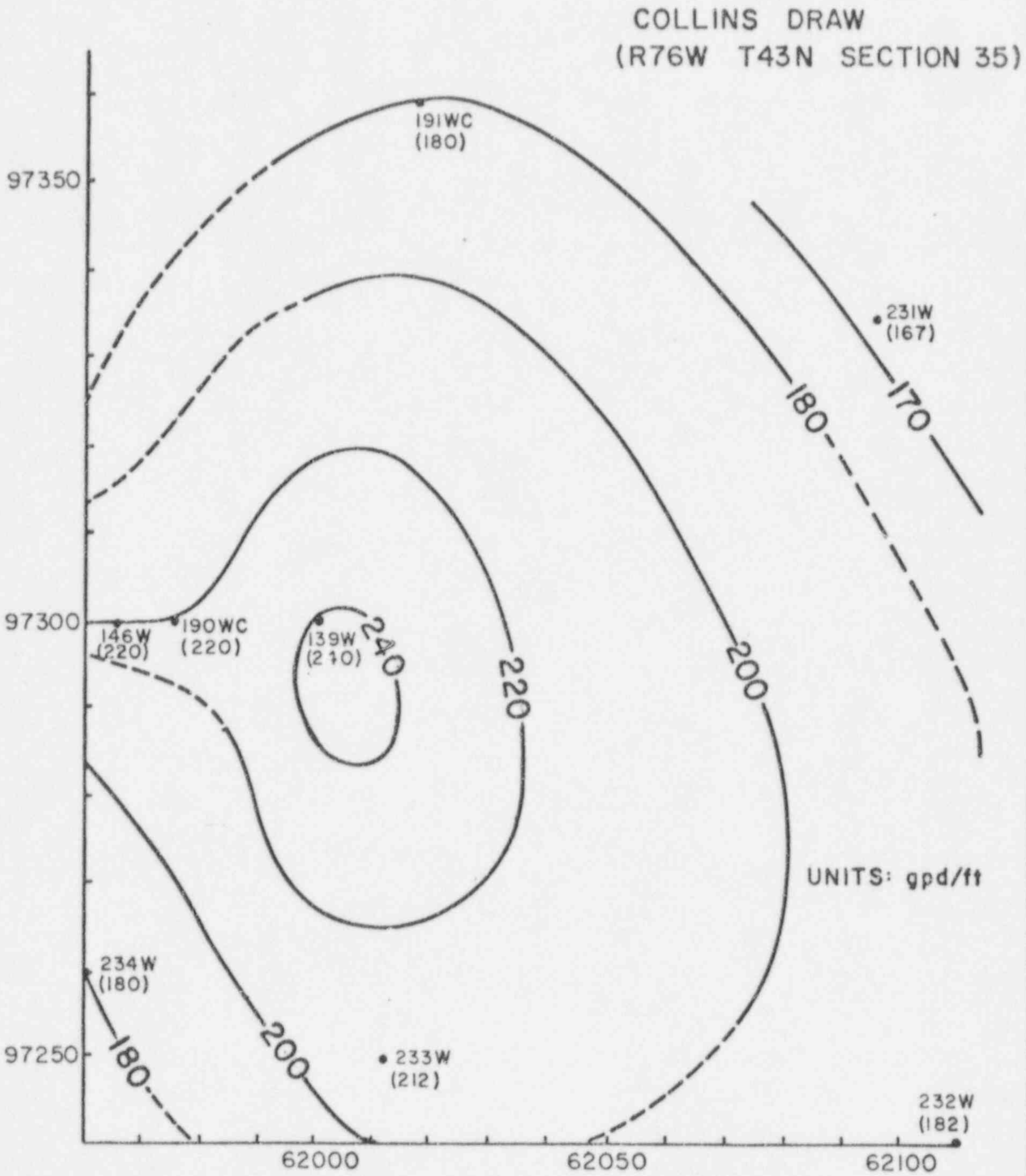
WELL NO.	T (gpd/ft)	S
146	192	1.36×10^{-4}
231	173	1.25×10^{-4}
232	190	5.18×10^{-5}
233	204	1.02×10^{-4}
234	190	8.90×10^{-5}

+ Match Point

CLEVELAND CLIFFS IRON CO.	HANTUSH'S UNSTEADY STATE LEAKY TYPE CURVE METHOD

In-situ Consulting

PREPARED BY: T. W.	DATE: 9-27-78
CHECKED BY: O. R. M	DATE: 9-28-78
DRAWN BY ZIMMERGRAPHICS	FIGURE NO. 17



TRANSMISSIVITY CONTOUR MAP

In·situ Consulting

PREPARED BY: T.W.	DATE: 9-27-78
CHECKED BY: C.R.M.	DATE: 9/28/78
DRAWN BY ZIMMERGRAPHICS	FIGURE NO. 18

Computations Accompanying Figures in Text

FIGURE 8

JACOB'S METHOD

WELL # 191

$T = \frac{264Q}{\Delta s}$

$= \frac{264 \times 25.61 \text{ gpm}}{36.3 \text{ ft}}$

$= 186 \text{ gpd/ft}$

$S = \frac{Tt_0}{4790 r^2}$

$= \frac{186 \text{ gpd/ft} \times 19.7 \text{ min}}{4790 \times (85.02 \text{ ft})^2}$

$= 1.06 \times 10^{-4}$

WELL # 190

$T = \frac{264Q}{\Delta s}$

$= \frac{264 \times 25.61 \text{ gpm}}{36 \text{ ft}}$

$= 188 \text{ gpd/ft}$

$S = \frac{Tt_0}{4790 r^2}$

$= \frac{188 \text{ gpd/ft} \times 2.05 \text{ min}}{4790 \times (5.3 \text{ FT})^2}$

$= 2.86 \times 10^{-3}$

WELL # 139

$T = \frac{264Q}{\Delta s}$

$= \frac{264 \times 25.61 \text{ gpm}}{35 \text{ ft}}$

$= 194 \text{ gpd/ft}$

$S = \frac{Tt_0}{4790 r^2}$

$= \frac{194 \text{ gpd/ft} \times 3.8 \text{ min}}{4790 \times (33.9 \text{ FT})^2}$

$= 1.34 \times 10^{-4}$

CHOW'S METHOD

WELL # 191

AT MATCH POINT

$s = 35 \text{ ft}$

$t = 160 \text{ min}$

$F(u) = 35/35 = 1.0$

$w(u) = 2.11$

$u = 0.074$

$T = \frac{114.6\, Q\, w(u)}{s}$

$= \frac{114.6 \times 25.61 \text{ gpm} \times 2.11}{35 \text{ FT}}$

$= 178 \text{ gpd/ft}$

$S = \frac{Tut}{2693 r^2}$

$= \frac{178 \text{ gpd/ft} \times 0.074 \times 160 \text{ min}}{2693 \times (85.02 \text{ ft})^2}$

$= 1.08 \times 10^{-4}$

WELL # 190

AT MATCH POINT

$s = 36 \text{ ft}$

$t = 21 \text{ min}$

$F(u) = 35/35 = 1.0$

$w(u) = 2.11$

$u = 0.074$

$T = \frac{114.6\, Q\, w(u)}{s}$

$= \frac{114.6 \times 25.61 \text{ gpm} \times 2.11}{36 \text{ FT}}$

$= 172 \text{ gpd/ft}$

$S = \frac{Tut}{2693 r^2}$

$= \frac{172 \text{ gpd/ft} \times 0.074 \times 21 \text{ min}}{2693 \times (5.3 \text{ ft})^2}$

$= 3.53 \times 10^{-3}$

WELL # 139

AT MATCH POINT

$s = 35 \text{ ft}$

$t = 38 \text{ min}$

$F(u) = 35/35 = 1.0$

$w(u) = 2.11$

$u = 0.074$

$T = \frac{114.6\, Q\, w(u)}{s}$

$= \frac{114.6 \times 25.61 \text{ gpm} \times 2.11}{35 \text{ ft}}$

$= 178 \text{ gpd/ft}$

$S = \frac{Tut}{2693 r^2}$

$= \frac{178 \text{ gpd/ft} \times 0.074 \times 38 \text{ min}}{2693 \times (33.9 \text{ ft})^2}$

$= 1.62 \times 10^{-4}$

FIGURE 10

JACOB'S METHOD

$$T = \frac{264Q}{\Delta s}$$

$$= \frac{264 \times 20.07\ gpm}{19.7\ ft}$$

$$= 269\ gpd/ft$$

CHOW'S METHOD

AT MATCH POINT

$s = 44\ ft$

$t = 30\ min$

$F(u) = 44/19.7 = 2.23$

$\Rightarrow w(u) = 5.1$

$u = 0.003$

$$T = \frac{114.6\ Q\ w(u)}{s}$$

$$= \frac{114.6 \times 20.07\ gpm \times 5.1}{44\ ft}$$

$$= 267\ gpd/ft$$

FIGURE 11

JACOB'S METHOD

$$T = \frac{264Q}{\Delta s}$$

$$= \frac{264 \times 20.07\ gpm}{28.5\ ft}$$

$$= 186\ gpd/ft$$

$$S = \frac{T t_0}{4790 r^2}$$

$$= \frac{186\ gpd/ft \times 5.2\ min}{4790 \times (34\ ft)^2}$$

$$= 1.75 \times 10-4$$

CHOW'S METHOD

AT MATCH POINT

$s = 2.87\ ft$

$t = 62\ min$

$F(u) = 28.7/28.5 = 1.01$

$\Rightarrow w(u) = 2.15$

$u = 0.07$

$$T = \frac{114.6\ Q\ w(u)}{s}$$

$$= \frac{114.6 \times 20.07\ gpm \times 2.15}{28.7\ ft}$$

$$= 172\ gpd/ft$$

$$S = \frac{Tut}{2693 r^2}$$

$$= \frac{172 \times 0.07 \times 62\ min}{2693 \times (34\ ft)^2}$$

$$= 2.40 \times 10^{-4}$$

FIGURE 12

JACOB'S METHOD

$T = \frac{264Q}{\Delta s}$

$= \frac{264 \times 20.07\ gpm}{42.5 ft - 4.3 ft}$

$= 139\ gpd/ft$

$S = \frac{T t_o}{4790 r^2}$

$= \frac{139\ gpd/ft \times 77\ min}{4790 \times (73.41 ft)^2}$

$= 4.15 \times 10^{-4}$

CHOW'S METHOD

AT MATCH POINT

$s = 20 ft$

$t = 260\ min$

$F(u) = 20/38.2 = 0.52$

$\Rightarrow w(u) = 0.9$

$u = 0.3$

$T = \frac{114.6\ Q\ w(u)}{s}$

$= \frac{114.6 \times 20.07\ gpm \times 0.9}{20 ft}$

$= 104\ gpd/ft$

$S = \frac{Tut}{2693 r^2}$

$= \frac{104\ gpd/ft \times 0.3 \times 260\ min}{2693 \times (73.41\ ft)}$

$= 5.59 \times 10^{-4}$

FIGURE 13

JACOB'S METHOD

$T = \frac{264Q}{\Delta s}$

$= \frac{264 \times 20.07\ gpm}{29 ft} = 183\ gpd/ft$

$S = \frac{T t_o}{4790 r^2}$

$= \frac{183\ gpd/ft \times 24.5\ min}{4790 \times (91.5 ft)} = 1.1 \times 10^{-4}$

CHOW'S METHOD

AT MATCH POINT

$s = 30 ft \quad t = 260 min$

$F(u) = 30/29 = 1.034$

$\Rightarrow w(u) = 2.22 \quad u = 0.063$

$T = \frac{114.6Q\ w(u)}{s}$

$= \frac{114.6 \times (20.07 gpm) \times 2.22}{30 ft} = 170\ gpd/ft$

$S = \frac{Tut}{2693 r^2}$

$= \frac{170\ gpd/ft \times 0.063 \times 260 min}{2693 \times (91.5 ft)^2}$

$= 1.24 \times 10^{-4}$

FIGURE 14

JACOB'S METHOD

$T = \frac{264Q}{\Delta s}$

$= \frac{264 \times 20.07\,gpm}{28.5\,ft} = 186\,gpd/ft$

$S = \frac{Tt_0}{4790r^2}$

$= \frac{186\,gpd/ft \times 20.5\,min}{4790 \times (122.44\,ft)^2} = 5.31 \times 10^{-5}$

CHOW'S METHOD

AT MATCH POINT

$s = 30\,ft$

$t = 283\,min$

$F(u) = 30/28.5 = 1.05$

$\Rightarrow W(u) = 2.22$

$u = 0.065$

$T = \frac{114.6\,Q\,W(u)}{s}$

$= \frac{114.6 \times 20.07\,gpm \times 2.22}{30\,ft} = 170\,gpd/ft$

$S = \frac{Tut}{2693r^2}$

$= \frac{170\,gpd/ft \times 0.065 \times 283\,min}{2693 \times (122.44\,ft)^2}$

$= 6.51 \times 10^{-5}$

FIGURE 15

JACOB'S METHOD

$T = \frac{264Q}{\Delta s}$

$= \frac{264 \times 20.07\,gpm}{27.7\,ft}$

$= 191\,gpd\ ft$

$S = \frac{Tt_0}{4790r^2}$

$= \frac{191\,gpd/ft \times 8\,min}{4790 \times (50.64\,ft)^2}$

$= 1.24 \times 10^{-4}$

CHOW'S METHOD

AT MATCH POINT

$s = 30\,ft$

$t = 96\,min$

$F(u) = 30/27.7 = 1.083$

$\Rightarrow W(u) = 2.3$

$u = 0.06$

$T = \frac{114.6\,Q\,W(u)}{s}$

$= \frac{114.6 \times 20.07\,gpm \times 2.3}{30\,ft}$

$= 176\,gpd/ft$

$S = \frac{Tut}{2693r^2}$

$= \frac{176\,gpd/ft \times 0.06 \times 96\,min}{2693 \times (50.64\,ft)^2}$

$= 1.47 \times 10^{-4}$

FIGURE 16

JACOB'S METHOD

$$T = \frac{264Q}{\Delta s}$$

$$= \frac{264 \times 20.07 \text{ gpm}}{2.95 \text{ ft}}$$

$$= 180 \text{ gpd/ft}$$

$$S = \frac{T t_0}{4790 r^2}$$

$$= \frac{180 \text{ gpd/ft} \times 7.7 \text{ min}}{4790 \times (51.15 \text{ ft})^2}$$

$$= 1.11 \times 10^{-4}$$

CHOW'S METHOD

AT MATCH POINT

$s = 30$ ft

$t = 80$ min

$F(u) = s/\Delta s = 30/29.5 = 1.02$

$\Rightarrow W(u) = 2.2$

$u = 0.067$

$$T = \frac{114.6\, Q\, W(u)}{s}$$

$$= \frac{114.6 \times 20.07 \text{ gpm} \times 2.2}{30 \text{ ft}}$$

$$= 169 \text{ gpd/ft}$$

$$S = \frac{T u t}{2693 r^2}$$

$$= \frac{169 \text{ gpd/ft} \times 0.067 \times 80 \text{ min}}{2693 \times (51.15 \text{ ft})^2}$$

$$= 1.29 \times 10^{-4}$$

FIGURE 17

HANTUSH'S METHOD

AT ALL MATCH POINTS $u = 0.1$ $\frac{1}{u} = 10$ $W(u) = 1.8$

WELL # 146

$$T = \frac{114.6\, Q\, W(u)}{s}$$

$$= \frac{114.6 \times 20.07\ \text{gpm} \times 1.8}{21.5\ \text{ft}}$$

$$= 192\ \text{gpd/ft}$$

$$S = \frac{Tut}{2693 r^2}$$

$$= \frac{192\ \text{gpd/ft} \times 0.1 \times 22\ \text{min}}{2693 \times (34\ \text{ft})^2}$$

$$= 1.36 \times 10^{-4}$$

WELL # 231

$$T = \frac{114.6\, Q\, W(u)}{s}$$

$$= \frac{114.6 \times 20.07\ \text{gpm} \times 1.8}{24\ \text{ft}}$$

$$= 173\ \text{gpd/ft}$$

$$S = \frac{Tut}{2693 r^2}$$

$$= \frac{173\ \text{gpd/ft} \times 0.1 \times 163\ \text{min}}{2693 \times (91.5\ \text{ft})^2}$$

$$= 1.25 \times 10^{-4}$$

WELL # 232

$$T = \frac{114.6\, Q\, W(u)}{s}$$

$$= \frac{114.6 \times 20.07\ \text{gpm} \times 1.8}{21.8\ \text{ft}}$$

$$= 190\ \text{gpd/ft}$$

$$S = \frac{Tut}{2693 r^2}$$

$$= \frac{190\ \text{gpd/ft} \times 0.1 \times 110\ \text{min}}{2693 \times (122.44\ \text{ft})^2}$$

$$= 5.18 \times 10^{-5}$$

WELL # 233

$$T = \frac{114.6\, Q\, W(u)}{s}$$

$$= \frac{114.6 \times 20.07\ \text{gpm} \times 1.8}{20.3\ \text{ft}}$$

$$= 204\ \text{gpd/ft}$$

$$S = \frac{Tut}{2693 r^2}$$

$$= \frac{204\ \text{gpd/ft} \times 0.1 \times 34\ 5\ \text{min}}{2693 \times (50.04\ \text{ft})^2}$$

$$= 1.02 \times 10^{-4}$$

WELL # 234

$$T = \frac{114.6\, Q\, W(u)}{s}$$

$$= \frac{114.6 \times 20.07\ \text{gpm} \times 1.8}{21.8\ \text{ft}}$$

$$= 190\ \text{gpd/ft}$$

$$S = \frac{Tut}{2693 r^2}$$

$$= \frac{190\ \text{gpd/ft} \times 0.1 \times 33\ \text{min}}{2693 \times (51.15\ \text{ft})^2}$$

$$= 8.90 \times 10^{-5}$$