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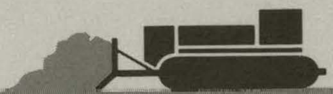

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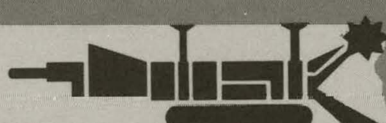
High Angle Mining System

Task Report—Definition of System Requirements
Contractor—FMC Corporation
Engineered Systems Division

December 1980

Contract No. U.S.D.O.E. AC01-80ET14257



U. S. Department of Energy
Assistant Secretary for Fossil Energy
Office of Coal Mining

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HIGH ANGLE MINING SYSTEM

Task Report – Definition of System Requirements

E. G. Brown

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Date Published – December 1980

Prepared under
Contract Number U. S. D. O. E. DE-AC01-80ET14257

U. S. Department of Energy
Assistant Secretary for Energy Technology
Solid Fuels Mining and Preparation

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CONTENTS

ILLUSTRATIONS

1.0 INTRODUCTION

The High Angle Mining System (HAMS) concept provides a means for safe, efficient, and profitable extraction of coal from seams varying widely in thickness and pitch. The HAMS concept would normally be employed to extract coal lying beyond the economic stripping limit of a surface mining operation.

This first report is submitted by the Engineered Systems Division of FMC Corporation in response to the Statement of Work, Task I-1, under U. S. Department of Energy Contract DE-AC01-80ET14257, which focuses on the definition of system requirements. More specifically, this task addresses a definition of practical performance requirements using the following stated goals as a reference point:

Performance Parameter	Goal
Angular capability	0 to 90 degrees
Depth capability	200 feet minimum
Recovery ratio/hole size and spacing	To be determined

The requirements developed are expected to be influenced by the amount and value of coal available for various seam pitches and thicknesses and where the emphasis of present and future mining will be. They are also expected to be influenced by the limits of technology currently available and the budget constraints of this project. The effects of all of these factors are difficult to assess immediately. It is anticipated that practical requirements will become clear during the early portion of the first phase. For now, at least, these requirements are better treated as goals.

As a beginning, available literature was reviewed in an attempt to estimate the available reserves for various ranges of seam pitch: 0 to 10 degrees, 10 to 25 degrees, and 25 to 90 degrees. The subjects of recovery ratio and highwall safety were also reviewed. To gain first-hand exposure to surface mining operations and the special problems associated with it, a task group visited each of three potential demonstration mines. These mines have moderate to steeply pitching seams and have expressed written interest in participating in the development and demonstration of a high angle mining system.

The results and observations made are touched upon briefly in the following summary and dealt with in more detail in the technical discussion. Conclusions and recommendations are contained in Section 4.0.

2.0 SUMMARY

2.1 CONVENTIONAL AUGERING LIMITS

The commonly accepted limits for conventional highwall coal augering are seam thickness from 2 to 8 feet, a pitch less than 10 degrees, and a penetration depth of from 150 to 200 feet. Recovery ratios for these conditions vary from 25 to 50 percent. One source found, for a limited sample base, an average recovery ratio of about 35 percent. The factors contributing to recovery losses were noted to be the following:

- Undersize augers for the seam being mined
- Hole depths less than maximum obtainable
- Excessive spacing between holes.

2.2 AVAILABLE RESERVES

An attempt was made to determine the reserves available by reviewing the literature. The information sources found and the approaches that have been used are discussed in Subsection 3.1.3.

The augerable reserve base for horizontal seams (0 to 10 degrees) between seam limits of 2 and 8 feet for a penetration depth of 200 feet has been estimated at 5 billion tons. This value may grow substantially if seams greater than 8 feet in thickness are considered.

An equivalent value estimated for coal residing in steeply pitching seams (25 to 90 degrees) is 234 million tons for a penetration depth of 150 feet (or 312 million tons for 200 feet). While no similar value for moderately pitching seams (10 to 25 degrees) has been found, most of the information necessary to make such an estimate exists.

It is interesting to note that the two mines visited near Kemmerer, Wyoming, are estimated to have a combined reserve base of more than 30 million tons for 200 feet of depth. This is a factor of six times their combined annual production of 5 million tons.

2.3 HOLE SIZE

Based on the early mining practices and experimental work conducted at one of the mines visited, very large, closely spaced holes are feasible, if the face opening is kept small. Multiple-pass boring produced holes about 12.5 feet wide, more than 50 feet high, and 500 feet deep with 12- to 14-foot thick webs.

Very large circular holes up to 20 feet in diameter with web thicknesses on the order of 25 to 50 percent of the hole diameter are believed to have been demonstrated in the Ohio River Valley by the Compton Auger Company. More detailed information on this will be pursued.

2.4 MINES VISITED

During the week of 17 November 1980, an FMC management group visited each of three potential demonstration sites. These are FMC's Skull Point Mine, Kemmerer Coal Company's Elkol-Sorenson Mine, both near Kemmerer, Wyoming, and the Cardinal River Mine near Hinton, Alberta. Nearby mines having similar conditions of moderate to steeply pitching seams were noted.

The Skull Point Mine contains multiple seams varying from 10 to 50 feet in thickness, with a composite thickness of about 100 feet. Seam pitch is about 21 degrees. At the economic stripping limit the highwall will be about 600 feet high and 7,200 feet long, though not all this area will be accessible at any one time. Reclamation will begin in 1986. Annual production is about 1 million tons.

The Elkol-Sorenson Mine is adjacent to the Skull Point Mine, but contains thicker seams up to 118 feet. Seam pitch is about 18 degrees. Composite seam thickness is about 300 feet. The highwall length potential is estimated at 2 miles. Annual production is 4 million tons.

The property was extensively mined by underground methods during the latter half of the century. Mining now and for the foreseeable future is exclusively by surface methods. Some of the old workings remain stable to this day. Entries uncovered in the main pit frequently withstand blasting of the overburden. The experimental multiple-pass boring alluded to in Subsection 2.3 was conducted at this mine. A discussion of this, the machinery, and the techniques involved, and an early stope-like/slusher coal mining technique is contained in Subsection 3.2.2.

The Cardinal River Mine produces coal from a single seam averaging 40 feet in thickness, but varying widely due to tectonic folding and faulting. Seam pitch also varies widely from horizontal to vertical. Mining is currently limited to surface methods but will gradually convert to underground methods at the economic stripping limit. Underground mining will employ the hydraulic technology so successfully developed by Kaiser in British Columbia. Hydraulic mining here will be enhanced by the coal's lower competency. Annual production is approximately 3 million tons of metallurgical coal committed to long-term export contracts.

2.5 CONCLUSIONS

- Angular Capability: The goal is the full range from 0 to 90 degrees, but this may be narrowed by need, technological risk, or cost factors.

- Depth Capability: The minimum depth of 200 feet is achievable.

- Recovery Ratio: Site-specific geological factors affect practical recovery ratios, which are expected to increase inversely with seam thickness.

3.0 TECHNICAL DISCUSSION

3.1 LITERATURE REVIEW

3.1.1 Definition of Terms

For the purpose of retaining some consistency with the literature and to avoid ambiguity, the following terminology is defined:

- Reserve

  Defined by the U. S. Bureau of Mines and the U. S. Geological Survey as "That portion of the identified coal resource that can be economically and legally mined at the time of determination."

- Augerable Reserve Base

  The total amount of in-place coal that can be legally and economically mined by augering methods. Usually lies beyond the economic stripping limit. Presently limited to the amount of coal residing in seams from 2 to 8 feet in thickness, pitching less than 10 degrees and for a depth of 150 or 200 feet.

- HAMS Reserve Base

  The total amount of in-place coal that can be legally and economically mined by the HAMS concept. Usually lies beyond the economic stripping limit. Presently unlimited in seam thickness or pitch to a penetration depth of 200 feet.

- Recovery Ratio

  The amount of coal recovered or recoverable (reserves) as a percentage of the reserve base.

Neither the augerable reserve base nor the HAMS reserve base include coal residing in highwalls after reclamation or after such coal has been otherwise rendered economically inaccessible by present standards.

3.1.2 Recovery Ratio

In 1974, the U. S. Bureau of Mines conducted a statistical survey of actual auger recovery ratios achieved for 14 eastern mines[1]. These varied from 25.5 to 43.7 percent, with a mean of 35.9 percent.

1. "Coal Recovery from Bituminous Coal Surface Mines in the Eastern United States, a Survey," U. S. Department of the Interior, Information Circular 8738.

The ideal recovery ratio was computed to be 63.6 percent. This was based on a seam height of 49.8 inches (the average of those surveyed), a maximum penetration of 150.8 feet, an auger hole diameter of 6 inches less than seam height, and a minimum rib thickness of 4 inches. The three major operating factors found to adversely affect recovery ratios obtained are quoted as follows:

- "Auger Undersize for Coalbed Thickness

  An average coal loss of 9.6 percent was attributed to this factor. Coalbed thickness is variable, and mine operators have a limited number of auger sizes. It is not practical or economical to have on hand a full range of auger sizes, or to frequently change augers when coalbed thickness is highly variable.

- Poor Average Depth of Penetration

  The coal loss attributed to this factor averaged 11.5 percent. The number of holes penetrating to the maximum depth depends to a large extent on the skill of the auger operator, but other factors such as thinning of the coalbed, hard partings, and roof falls can limit penetration. If the hole is not straight, penetration will stop when top or bottom rock or the void left by a previous auger hole is encountered.

- Excessive Spacing Between Holes

  This factor accounted for an average coal loss of 6.6 percent. It is a function of operator skill, highwall integrity, and roof support requirements."[2]

3.1.3 Reserve Base

A U. S. Bureau of Mines-sponsored report[3] in 1975 estimates the augerable reserve base in the U. S. to be 5 billion tons for a depth of 200 feet. Using a 25-percent recovery rate, the augerable reserve is estimated at 1.25 billion tons.

This reserve base was limited to coal residing in seams from 2 to 8 feet thick and less than 10 degrees in pitch. The amount was noted to be nearly equally split between the eastern and western coal regions with a trace falling in the central region. The practice of augering has been virtually limited to the eastern region.

---

2. "Coal Recovery from Bituminous Coal Surface Mines in the Eastern United States, a Survey," U. S. Department of the Interior, Information Circular 8738.

3. Ford, Bacon, and Davis, "Technology of Auger Mining," Bureau of Mines OFR 108-76.

A 1978 report prepared for the U. S. Bureau of Mines identifies the location of moderately pitching seams (8 to 25 degrees) within the continental United States.[4] Seams within this range were found to reside in 16 states as shown in Figure 1. Volume II contains detailed information regarding strippable reserves which are estimated at 23 billion tons. The information is tabulated by coal region, field, seam nomenclature, county, strippable reserves, pitch, thickness, quality, overburden characteristics, and areal extent. The subject of a HAMS reserve base was not addressed.

A 1979 study,[5] prepared for the U. S. Department of Energy by the same authors, surveyed reserves for steeply pitching seams (25 to 90 degrees). Seams within this range were found to be located within 18 states, as shown in Figure 2. The 1979 report contains a similarly detailed description of seams. It also contains for each state detailed maps that identify the boundaries of steeply pitching seams for each coal region. The total strippable reserves lying in steeply pitching seams are estimated at 67 billion tons. A HAMS reserve base is estimated at approximately 235 million tons, as shown in Table 1 taken from the same report. The calculated values were obtained from the estimated seam outcropping lengths and seam heights for a penetration depth of 150 feet. The extrapolated values, marked by an asterisk, were based on a judgmental estimate of steeply pitching seams as a percentage of a state's strippable reserve base.

3.1.4 Highwall Safety

Augering can be expected to reduce highwall integrity. However, where augering is anticipated, the final highwall can be prepared accordingly. The additional cost should be charged against the augering operations.

For multiple seams, benches can be positioned for seam access, and substantial berms can help protect the face from water seepage and the effects of icing. Augering should proceed as soon as possible. "Weather conditions often contribute to slope and highwall problems. Rainwater may seep into faults, joints, and other fissures, weakening the highwall by making the exposed surfaces in the cracks slippery. Cold temperatures create additional hazards when ground water freezes and expands in these areas. This expansion enlarges the gaps in the earth by exerting pressure against the walls of the fissure. The pressure is relieved when the rock on the exposed face of the highwall moves toward the pit, creating an even larger crack in the rock.

---

4. Skelly and Loy, "Development of Concepts for Surface Mining Moderately Pitching Coal Seams," Bureau of Mines OFR 61(1)79 and 61(2)79.

5. Skelly and Loy, "Evaluation of High Angle Auger Systems," Draft Final Report for U. S. Department of Energy, Contract ET-77-C01-8914, Task Order 0071, April 1979.

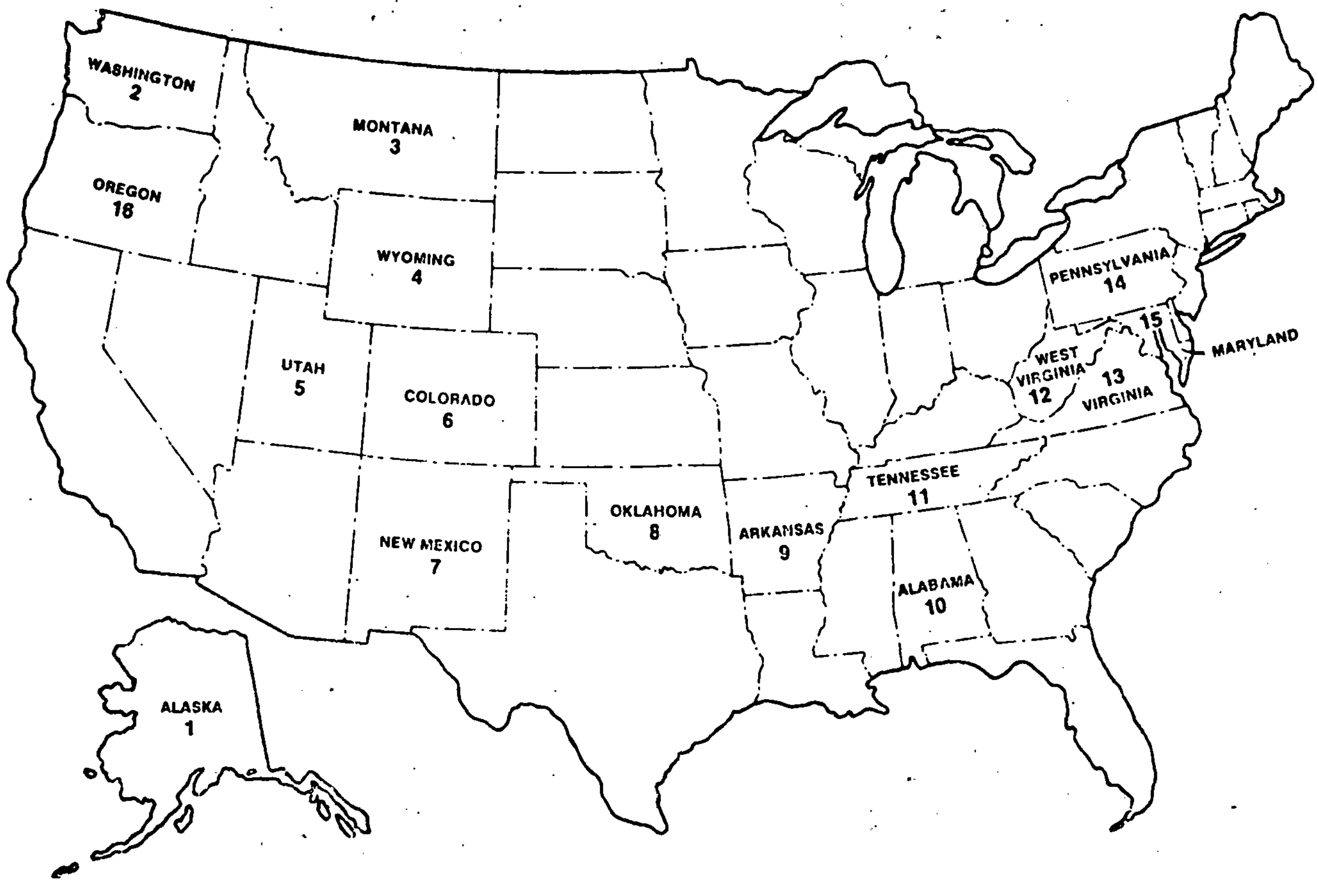

Figure 1 LOCATION OF MODERATELY PITCHING SEAMS (8 to 25 degrees)

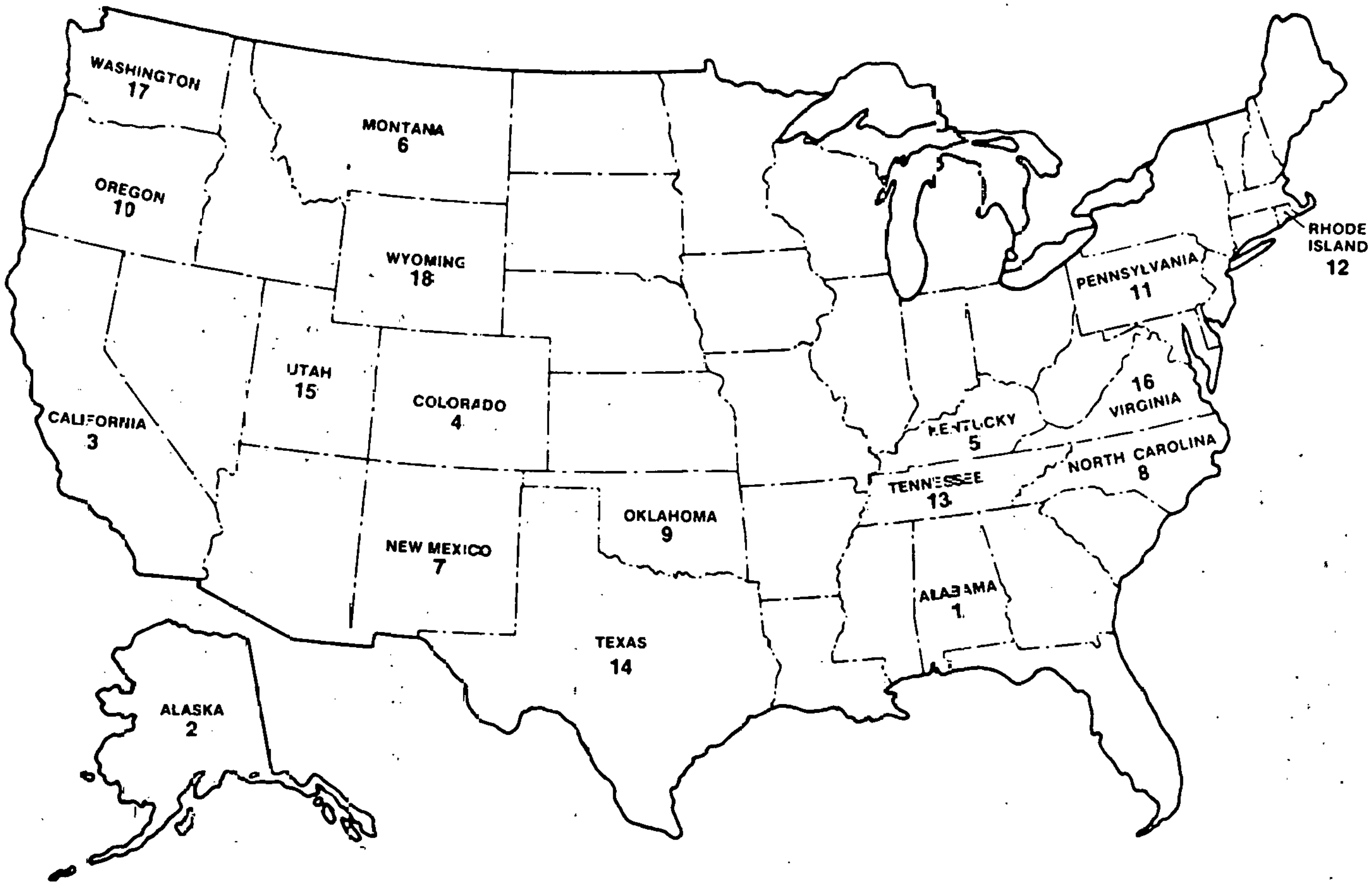

Figure 2 LOCATION OF STEEPLY PITCHING SEAMS (25 to 90 degrees)

The process is repeated when temperatures move above and below the freezing point in what is commonly called the freeze-thaw cycle, until the rock breaks free and falls into the pit."[6]

Table 1 ESTIMATE OF RESERVE BASE FOR STEEPLY PITCHING SEAMS (25 TO 90 DEGREES) BY STATE

State	Calculated reserve base
Alabama	* 46.4×10^6
Alaska	* 19.5×10^6
California	4.3×10^6
Colorado	* 19.5×10^6
Kentucky	* 4.2×10^6
Montana	18.7×10^6
New Mexico	9.7×10^6
North Carolina	2.1×10^6
Oklahoma	30.8×10^6
Oregon	* 1.2×10^6
Pennsylvania	* 12.4×10^6
Rhode Island	Trace
Tennessee	* 0.4×10^6
Texas	0.4×10^6
Utah	2.3×10^6
Virginia	27.0×10^6
Washington	* 21.0×10^6
Wyoming	14.7×10^6
Total	234.6×10^6 tons

* Extrapolated.

Special blasting techniques can leave the highwall in the best possible condition. "These methods include line drilling, presplitting, and cushion shooting, and involve drilling a row of closely spaced parallel boreholes along the final excavation line. With line drilling, the boreholes contain no explosives but create a plane of weakness allowing the blasted material to break cleanly along what will become the pit wall. The line of drill holes serves the same function as a row of perforations on a sheet of postage stamps, but in three dimensions rather than two. The presplitting method involves a similar line of boreholes along the excavation line, but these holes are loaded with a light explosive charge and are fired just before the primary charges. The cushion blasting technique involves shooting the lightly loaded row of boreholes after the main hole pattern is blasted. These methods are often used in mountain highway construction..."[7]

6. "Mine Safety and Health," MSHA Safety News Periodical, September-October 1980.

7. Ibid.

3.2 MINES VISITED

During the week of 17 November 1980 an FMC task group visited three potential demonstration sites: FMC's Skull Point Mine and the Kemmerer Coal Company's Elkol-Sorenson Mine both near Kemmerer, Wyoming, and the Cardinal River Mine near Hinton, Alberta, Canada.

3.2.1 Skull Point Mine

The Skull Point Mine is adjacent to and south of the Elko-Sorenson Mine. These two mines are located within the Hams Fork coal region and comprise the region's only active coal mines. This narrow region extends north from the southwest corner of Wyoming for more than 300 miles. The region is unique in that it falls within the overthrust belt, an area of intense activity for oil and gas exploration. Near an elevation of 7,000 feet in the eastern foothills of the Rocky Mountains, the weather can become quite cold in the winter. The seams mined are the Adaville formations which outcrop to the east and dip to the west. At the Skull Point Mine the dip angle is approximately 21 degrees. The Adaville formations include some 13 identifiable seams which thicken, thin, split, and coalesce over very short distances. These formations and the South Haystack area 17 miles south of the Skull Point Mine contain the only strippable deposits in the region.[8]

The Skull Point Mine pit will ultimately expose some 7,200 feet of highwall to a depth of 600 feet. Figure 3 shows the pit as it appeared a year ago. Figure 4 reflects the pit configuration as of November 1980. Figures 5, 6, and 7 show planned development through the year 1994. Some 17 million tons of strippable coal remain. Reclamation is planned to begin in 1986. Reclamation filling will begin at the north end of the pit and advance southward at approximately 450 feet per year. The original contour will not be restored, but the general drainage pattern will be maintained and contouring will be similar to that of the surrounding area.

Figure 8 shows cross sections looking north through the Skull Point property. Of principal interest are the lower two seams, Number 1 lower and Number 1 upper, separated by a 20-foot parting. The lower seam presently averages 22 feet in thickness and the upper seam 47 feet. The upper seam is slightly higher in quality than the lower, having a lower ash and sulfur content. The upper two seams of note average 32 feet in composite thickness. Moisture content averages 22 percent, fixed carbon 39 percent, ash 5 percent, sulfur 1 percent, and the heating value 10,000 Btu per pound. In situ density is about 80 pounds per cubic foot.

The mine is operated under contract by the Morrisson-Knudson Company, Inc. Mine management, staff, and union workers are employees of FMC and number about 100. The mine began producing in 1976. Production is currently 900,000 tons annually. Of this, 550,000 tons is shipped to FMC's Green River plant in Wyoming and used in the production of soda ash and phosphate chemicals. Another 200,000 tons is shipped annually to FMC's formcoke plant located near the mine. This is converted to 90,000 tons of coke and shipped to FMC's Pocatello plant in Idaho where it is used in the production of elemental phosporous. The balance of 150,000 tons per year is sold outside. All transporation away from the mine is by rail.

8. Keystone Coal Industry Manual

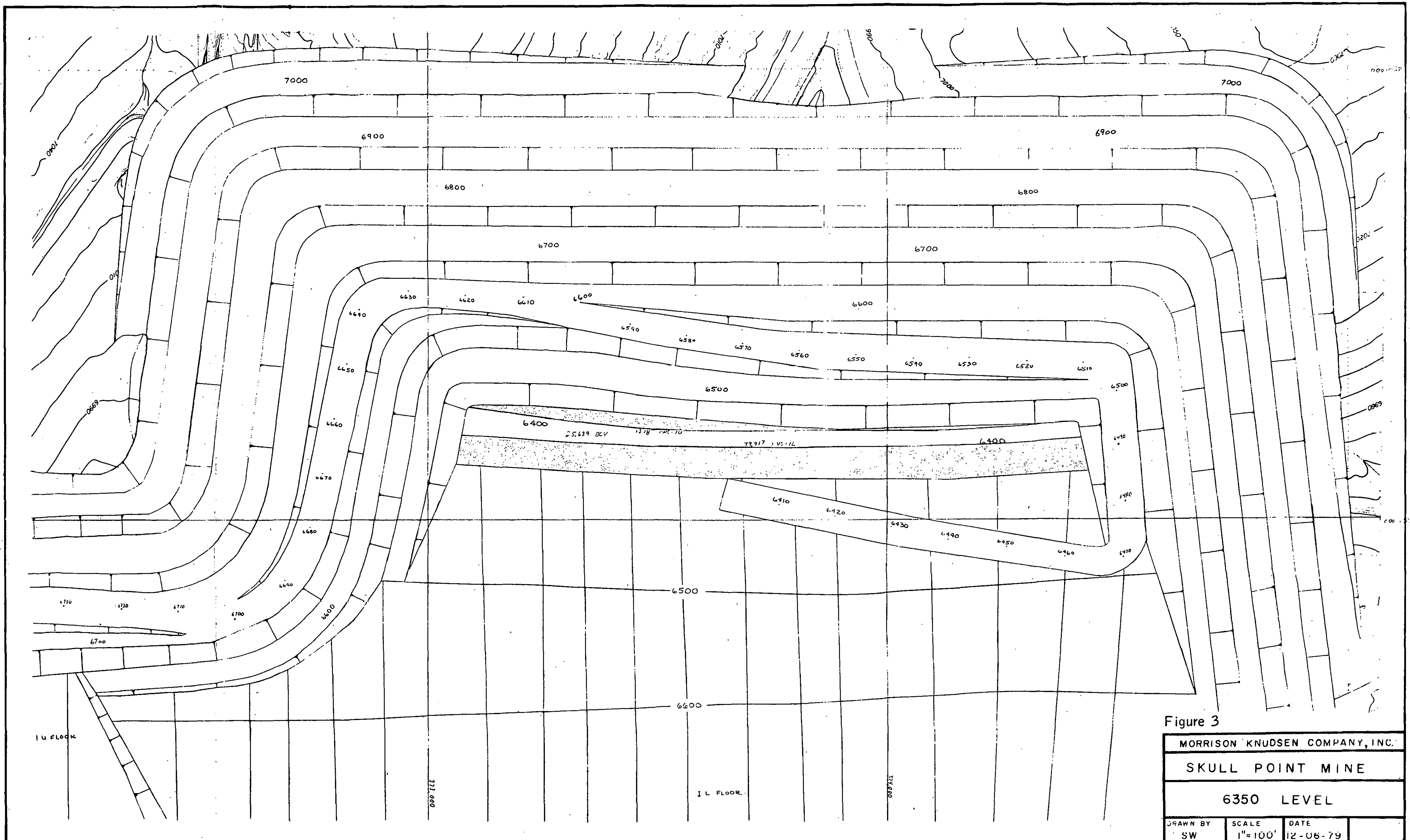
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Figure 3
MORRISON KNUDSEN COMPANY, INC.
SKULL POINT MINE
6350 LEVEL
DRAWN BY SW
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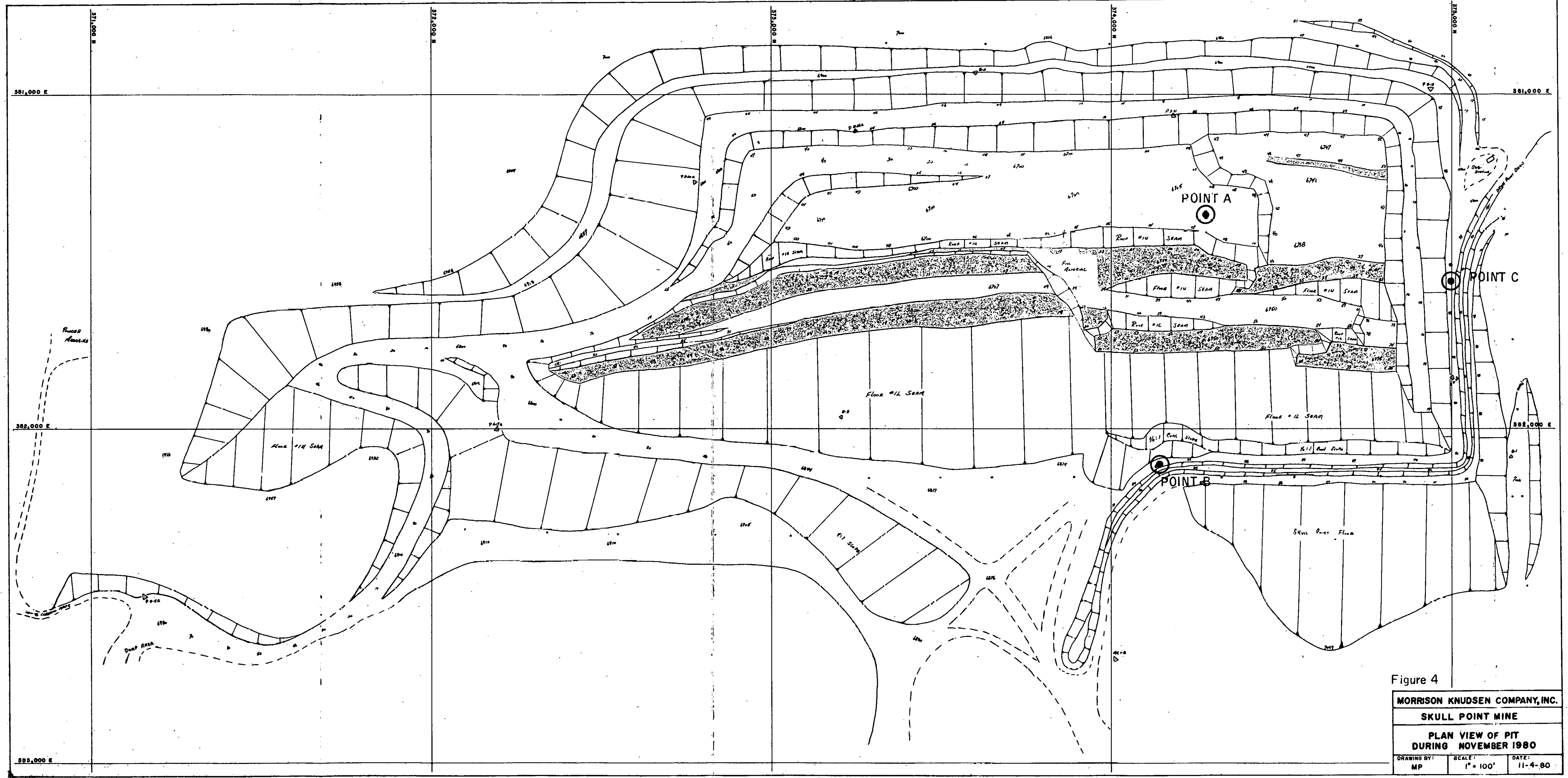
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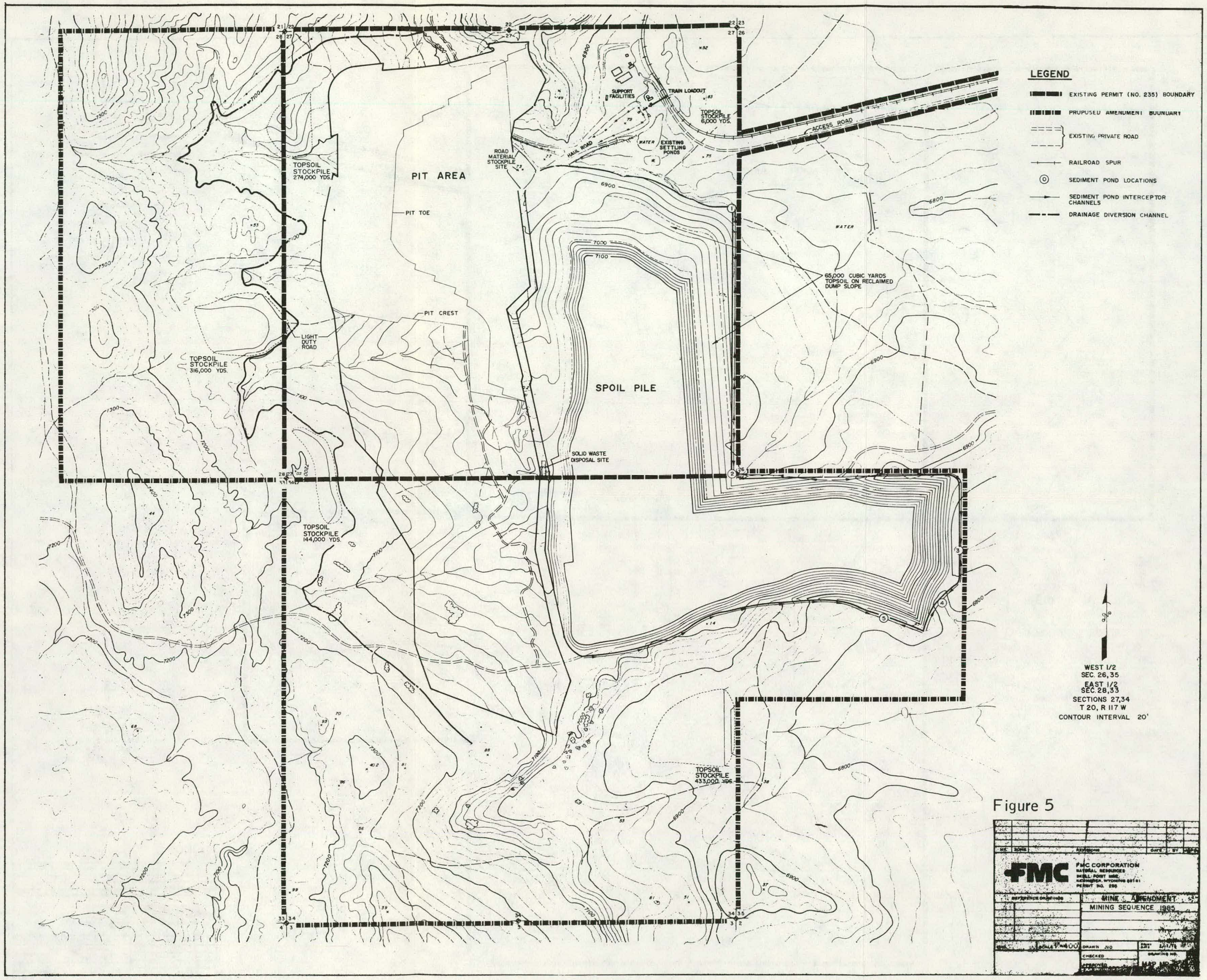
381,000 E
382,000 E
383,000 E
POINT A
POINT B
POINT C
Floor #12 Seam
Floor #14 Seam
Roof #14 Seam
Skull Point Floor
MORRISON KNUDSEN COMPANY, INC.
SKULL POINT MINE
PLAN VIEW OF PIT
DURING NOVEMBER 1980
DRAWING BY: MP
SCALE: 1" = 100'
DATE: 11-4-80

Figure 4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RAILROAD SPUR
SEDIMENT POND LOCATIONS
SEDIMENT POND INTERCEPTOR CHANNELS
DRAINAGE DIVERSION CHANNEL
PIT AREA
PIT TOE
PIT CREST
SPOIL PILE
TOPSOIL STOCKPILE 274,000 YDS.
TOPSOIL STOCKPILE 316,000 YDS.
TOPSOIL STOCKPILE 144,000 YDS.
TOPSOIL STOCKPILE 433,000 YDS.
TOPSOIL STOCKPILE 6,000 YDS.
LIGHT DUTY ROAD
ROAD MATERIAL STOCKPILE SITE
SUPPORT FACILITIES
TRAIN LOADOUT
HAUL ROAD
ACCESS ROAD
WATER
EXISTING SETTLING PONDS
65,000 CUBIC YARDS TOPSOIL ON RECLAIMED DUMP SLOPE
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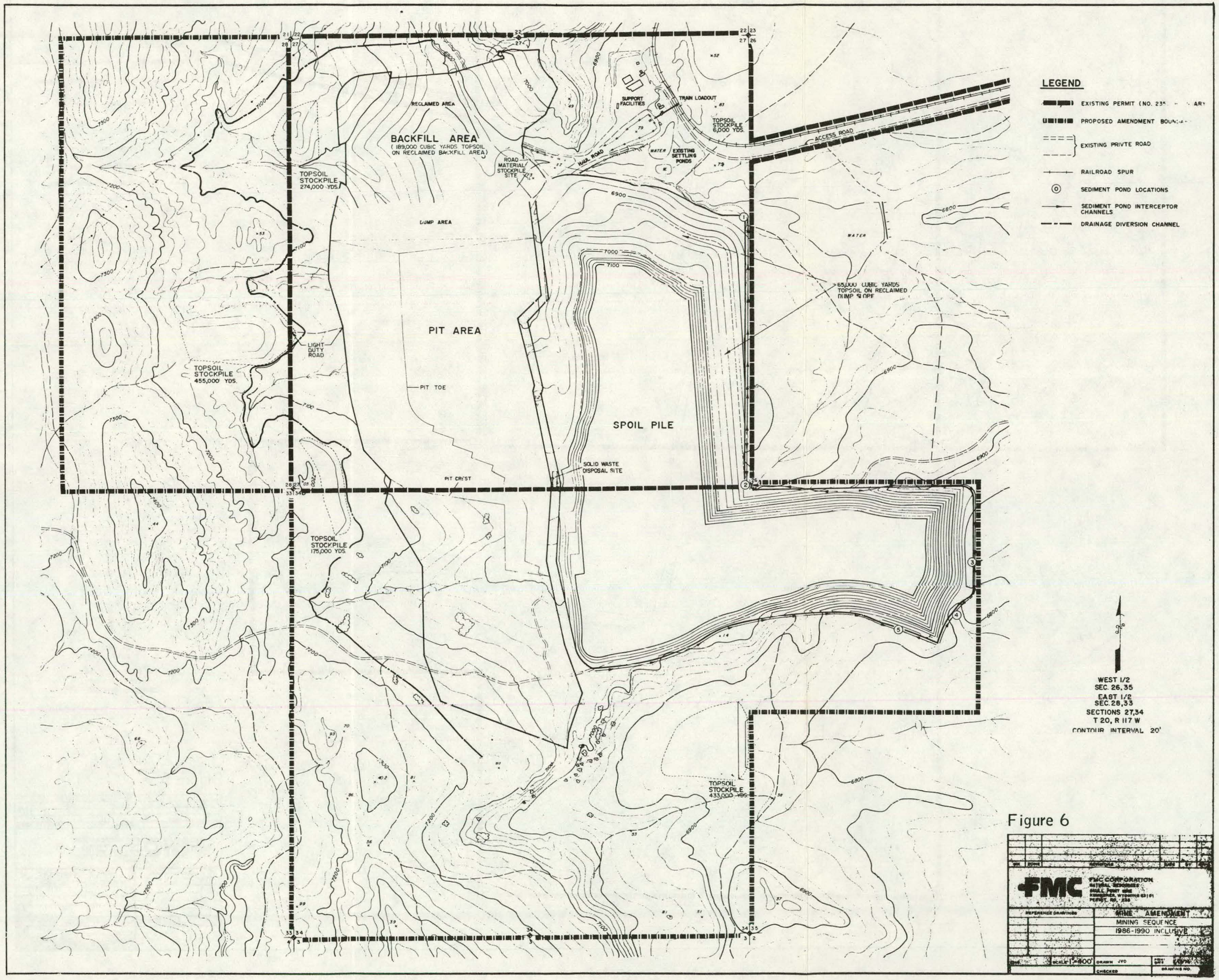
Figure 5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ROAD MATERIAL STOCKPILE SITE
SUPPORT FACILITIES
TRAIN LOADOUT
TOPSOIL STOCKPILE 6,000 YDS.
ACCESS ROAD
HAUL ROAD
WATER
EXISTING SETTLING PONDS
DUMP AREA
PIT AREA
LIGHT DUTY ROAD
TOPSOIL STOCKPILE 455,000 YDS.
PIT TOE
SPOIL PILE
65,000 CUBIC YARDS TOPSOIL ON RECLAIMED DUMP SLOPE
SOLID WASTE DISPOSAL SITE
PIT CREST
TOPSOIL STOCKPILE 175,000 YDS.
TOPSOIL STOCKPILE 433,000 YDS.
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EAST 1/2 SEC. 28,33
SECTIONS 27,34
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FMC CORPORATION
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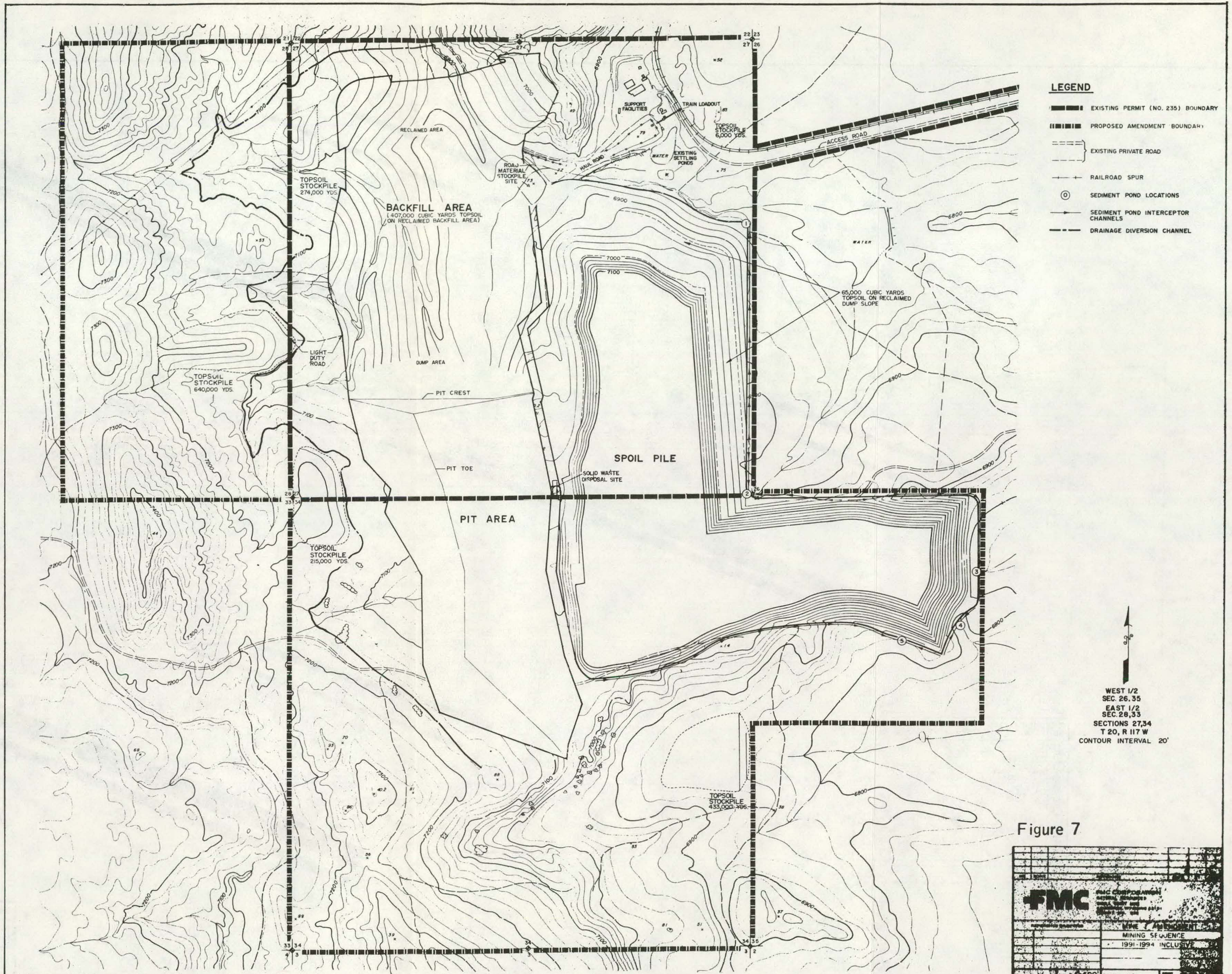
Figure 6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PROPOSED AMENDMENT BOUNDARY
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RAILROAD SPUR
SEDIMENT POND LOCATIONS
SEDIMENT POND INTERCEPTOR CHANNELS
DRAINAGE DIVERSION CHANNEL
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(407,000 CUBIC YARDS TOPSOIL ON RECLAIMED BACKFILL AREA)
RECLAIMED AREA
DUMP AREA
PIT CREST
PIT TOE
PIT AREA
SPOIL PILE
SOLID WASTE DISPOSAL SITE
65,000 CUBIC YARDS TOPSOIL ON RECLAIMED DUMP SLOPE
TOPSOIL STOCKPILE 274,000 YDS.
TOPSOIL STOCKPILE 640,000 YDS.
TOPSOIL STOCKPILE 215,000 YDS.
TOPSOIL STOCKPILE 433,000 YDS.
TOPSOIL STOCKPILE 6,000 YDS.
LIGHT DUTY ROAD
ROAD MATERIAL STOCKPILE SITE
SUPPORT FACILITIES
TRAIN LOADOUT
EXISTING SETTLING PONDS
ACCESS ROAD
HAUL ROAD
WATER
WEST 1/2 SEC. 26,35
EAST 1/2 SEC. 28,33
SECTIONS 27,34
T 20, R 117 W
CONTOUR INTERVAL 20'
FMC
FMC CORPORATION
MINE 7 AMENDMENT
MINING SEQUENCE
1991-1994 INCLUSIVE
SCALE 1"=400'
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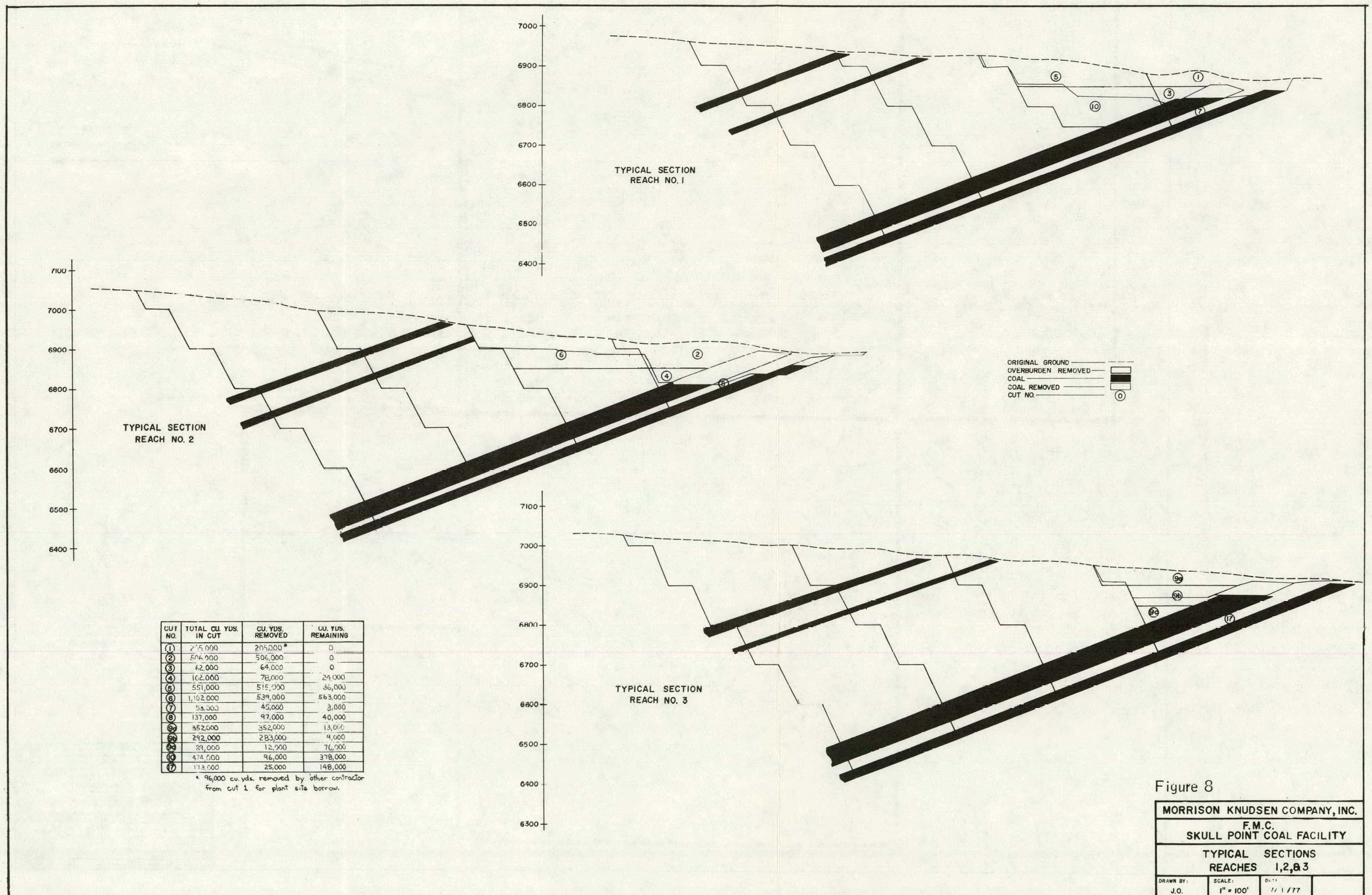
Figure 7



CUT NO.	TOTAL CU. YDS. IN CUT	CU. YDS. REMOVED	CU. YDS. REMAINING
1	205,000	205,000*	0
2	506,000	506,000	0
3	62,000	64,000	0
4	102,000	78,000	24,000
5	551,000	515,000	36,000
6	1,102,000	539,000	563,000
7	55,000	45,000	3,000
8	137,000	97,000	40,000
9a	352,000	352,000	13,000
9b	292,000	283,000	9,000
9c	89,000	12,000	76,000
10	474,000	96,000	378,000
17	173,000	25,000	148,000

* 96,000 cu. yds. removed by other contractor from cut 1 for plant site borrow.

Figure 8

Twelve and one-half million cubic yards of overburden have been stripped to date. The stripping ratio of overburden to coal is 5.2:1 (cubic yards per ton). FMC prepares the blast holes, which are contractor loaded. Overburden removal employs a 17-cubic-yard, 750-horsepower electric shovel, and five 120-ton trucks. Coal removal employs a 16-cubic-yard front-end loader and three 50-ton trucks. Overburden removal is conducted on a three-shift basis. Coal is mined on a single-shift basis. Coal is not cleaned but fed directly to a 4,300-ton-per-day (single-shift) tipple for loading into 100-ton rail cars. A coal sample is taken from each car and tested for Btu, ash, and sulfur content.

The highwall is maintained at an average angle of 55 degrees with 60-foot-wide benches spaced at 100-foot vertical intervals. Water seepage occurs all along the highwall and is collected in a sump at the bottom of the pit. This is pumped up to a 180-acre-foot settling pond area near the mine entrance. Current pumping rates are 150 gpm, but this is expected to increase to 400 to 600 gpm as the pit develops. In winter, seepage tends to freeze to the face of the highwall. Figures 9, 10, and 11 show various views of the Skull Point operation.

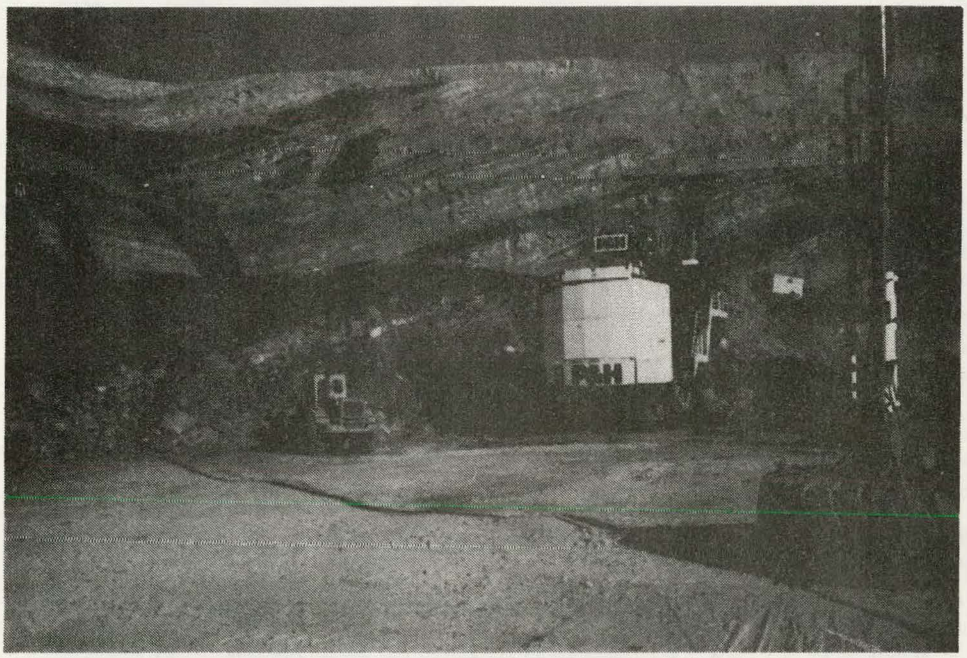


Figure 9 STRIPPING OVERBURDEN, LOOKING NORTHWEST FROM PIT FLOOR (POINT A, FIGURE 4)

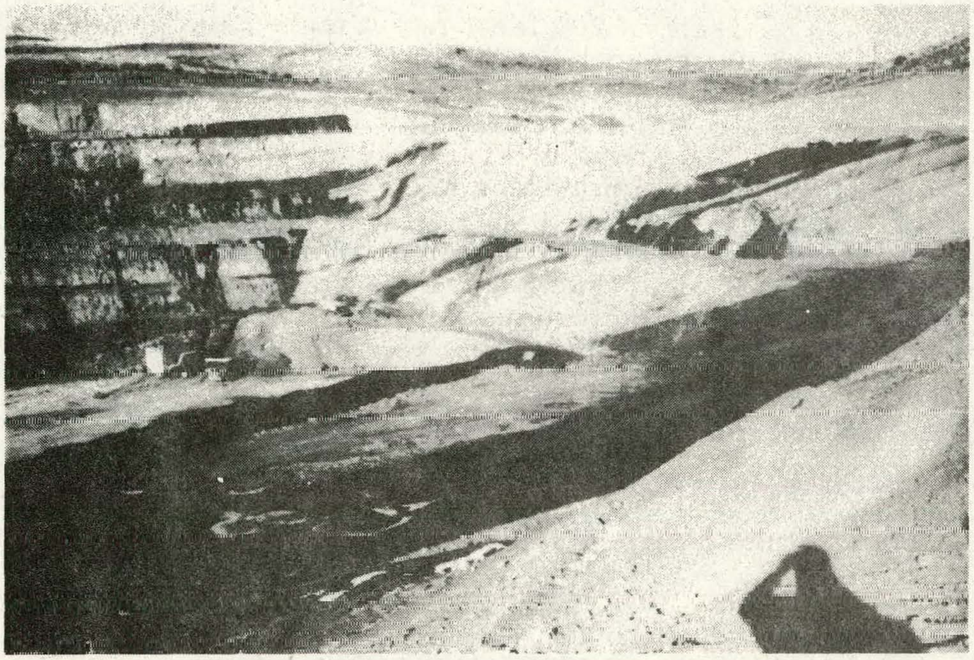


Figure 10 STRIPPING OVERBURDEN, LOOKING NORTHWEST FROM PIT EDGE (POINT B, FIGURE 4)

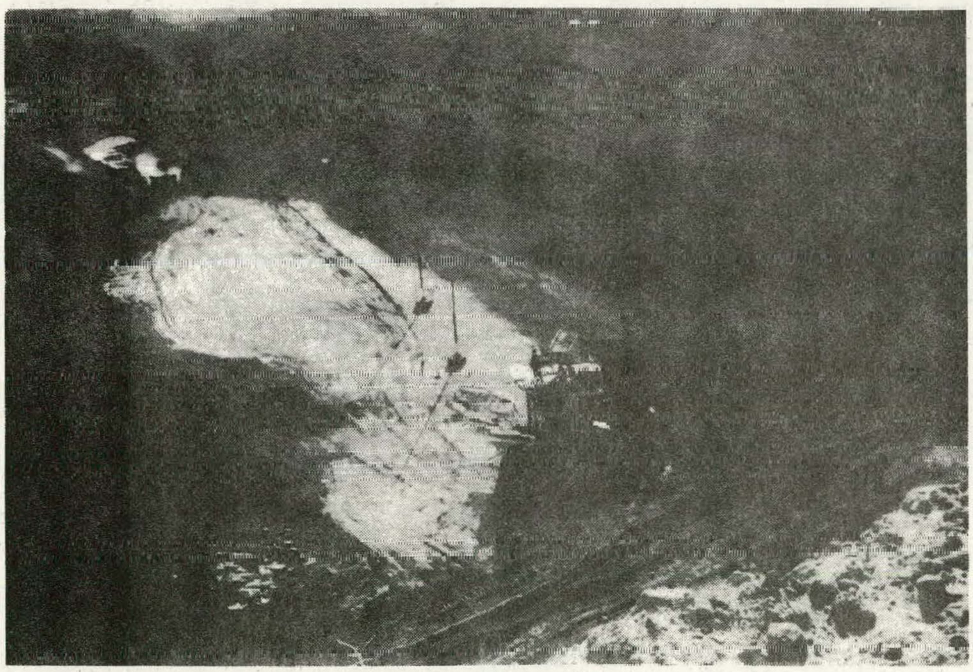


Figure 11 STRIPPING OVERBURDEN, LOOKING SOUTHWEST FROM NORTH HIGHWALL (POINT C, FIGURE 4)

The reserve base, for a depth of 200 feet, is estimated at 5.75 million tons in the highwall. This is based upon an average composite seam thickness of 100 feet for a distance of 7,200 feet. An additional 1.8 million tons are available in a 40- to 50-foot-thick outcropping seam to the south of the pit. This seam is estimated to outcrop for a distance of 5,000 feet. Skull Point does not presently plan to mine this area.

Regarding the development of HAMS concepts, it was recommended that seam augering proceed from upper to lower seams in such a manner as to minimize structural disturbance to the unmined seams. The use of hydraulic backfilling with a water-sand-limestone mixture was also discussed. This procedure would help stabilize the highwall and permit recovery of coal left in the webs between holes; however, the feasibility and economy of this procedure remains to be proven.

Nearby surface mines known or likely to have moderate to steeply pitching seams are listed in Table 2.

3.2.2 Elkol-Sorenson Mine

Conditions and mining methods at the Elkol-Sorenson Mine are similar to those at the adjacent Skull Point Mine, except for the element of scale. Annual production is in excess of 4 million tons. The Adaville Number 1 seam, which parts to the south, converges and thickens here to a maximum of 118 feet. The dip is a little less, averaging 18 degrees. The coals here are the highest in the basin and average 300 feet in composite thickness. The reserve base for this thickness for a potential highwall length of 2 miles is 25 million tons.

In the past, considerable underground mining was conducted on the property. Currently, it is exclusively strip mined. The old Conroy Mine was closed in 1926, and the Elkol Mine was abandoned in 1954. The entries of the Elkol Mine still stand even though little timbering was used. Parts of the Conroy Mine in the Number 1 seam are frequently uncovered in the main pit. These still remain open and frequently withstand overburden blasting. These reports are indicative of the competency of the area's coal and are very encouraging.

Once the old shafts are opened, spontaneous combustion becomes a problem in old loose coal. Areas free of loose coal do not pose much of a problem. One such area was seen in the south highwall adjacent to the Skull Point pit, where smoke was billowing out of an old shaft. Similar oxidation occurring naturally was observed in an outcropping seam at the southern extremity of the Skull Point Mine. It was noted, that as a minimum, highwall openings should be sealed off upon completion. Methane gas is reported to be virtually nonexistent.

Mine personnel related an unusual (for coal) underground technique that had been practiced at the Elkol Mine. It can be described as a stope-like process employing "slusher" scraping. A level haulage entry was driven cross-dip near the floor of the seam, which in this case was about 100 feet thick. At right angles to the entry, rooms were driven upward cross-seam, at an angle of 45 degrees for a distance of about 150 feet. These rooms were enlarged to about 30 feet wide and were separated from the previous room by 20 feet of coal.

Table 2 SUMMARY TABLE OF SURFACE MINES NEAR KEMMERER, WYOMING

Coal region	Company	Mine	Location	Annual tonnage stripped	Remarks
Hams Fork	FMC	Skull Point	Kemmerer, WY	900,000	21-degree by 10- to 50-foot seams
Hams Fork	Kemmerer	Elkol-Sorenson	Kemmerer, WY	4,000,000	13-degree by 10- to 100-foot seams
Hams Fork	Kiewit	South Haystack	Kemmerer, WY		Under development. Pitching seams likely.
North Park	Colowyo	Colowyo	Walden, CO	1,000,000	45- to 60-degree by 50- to 60-foot seams
North Park	Sigma	Canadian	Walden, CO	149,000	45- to 60-degree by 50- to 60-foot seams
Green River	Energy Fuels	Energy Mines Numbers 1, 2, and 3	Steamboat Springs, CO	4,100,000	10- to 16-degree by 4- to 8-foot seams
Green River	Empire Energy	Williams Fork	Craig, CO	242,000	Pitching seams likely
Green River	Bridger	Jim Bridger	Rock Springs, WY	5,175,000	Pitching seams likely
Hanna	Resource Exploration and Mining	Hanna Basin	Hanna, WY	900,000	Pitching seams likely
Hanna	Rosebud	Rosebud	Hanna, WY	2,709,000	Pitching seams likely
Hanna	Arch Mineral	Seminoe Number 1	Hanna, WY	2,500,000	40-degree seams
Hanna	Arch Mineral	Seminoe Number 2	Hanna, WY	2,800,000	>20-degree by 10- to 33-foot seams
Hanna	Arch Mineral	Medicine Bow	Hanna, WY	3,100,000	>20-degree by 4- to 60-foot seams

As shown in Figure 12, the haulage entry followed a clay parting approximately 12 feet from the seam floor, and the rooms terminated at another parting approximately 15 feet from the seam roof. All coal extraction was between these partings. The upper parting was most important as an indicator because the shale deposits overlying the seam were very weak. Once exposed and allowed to dry, they were very likely to fall.

A crosscut ventilation opening was made to the previous room near the upper parting. The floor of the rooms would be shot and benched down to the lower parting. A pulley, installed on the uppermost bench, called the Pioneer bench, would be used to attach a cable for a slusher bucket. Coal was slushed down dip and out the funnel-like opening to the haulage entry. At completion the rooms were closed off by a door in the funnel opening. This door was kept closed by a cable to the pulley on the Pioneer bench. Loose coal spalling from the ribs and roof would be recovered from time to time by opening the door and reinstalling the slusher bucket on the existing cable.

A wide variety of methods and machines have been used or experimented with at this mine. These include highwall augering with a conventional augering machine (Salem), a Joy 6CM ripper miner, and an experimental boring miner known as the Alkirk cycle miner. The Alkirk miner remains in fairly good condition in the mine's boneyard.

3.2.2.1 Alkirk Cycle Miner

The Alkirk cycle miner (Figure 13) is a crawler-mounted boring machine similar in size and configuration to the Goodman 429 and the Joy 2BT-2. The counter-rotating boring cutters are approximately 7 feet in diameter on 6-foot centers. The cutters are driven by a single 200-horsepower electric motor through right-angle drives at each end. A rotating roof trimmer bar is located just behind the cutters. This arrangement produced an oval hole approximately 7 by 12.5 feet. The maximum cutting rate is reported to have been 13 tons per minute.

The direction of rotation of the boring cutters tends to feed coal to the center of the machine to a gathering feeder conveyor referred to as a "gooseneck" (Figure 14). This unit was suspended between the tracks and consists of an endless belt of lightweight aluminum buckets over a rigid frame. It is powered by a pair of 30-horsepower electric motors.

The operator sat on a tractor-type seat on the right-hand side of the machine. No overhead protection was apparent. A small bidirectional auger drilled holes in both ribs. Arch-like lightweight aluminum roof support beams would be pinned in place behind the machine, to be removed again on the way out. The ventilation air duct, power cable, and water hoses were suspended from these beams by pulleys. These were not seen in the boneyard. The miner was withdrawn by winch at the completion of a hole, being apparently unable to negotiate the 18 degrees up slope. The machine also mounted a 15-horsepower pump to remove water that would otherwise collect at the bottom of the hole.

The gooseneck conveyor originally fed a 20-ton skip hoist car that nearly filled the bore hole. Since this virtually blocked the escape path for the underground miner operator, it was replaced by an extensible belt manufactured by Joy. Neither component was seen in the boneyard. At the surface, the extensible

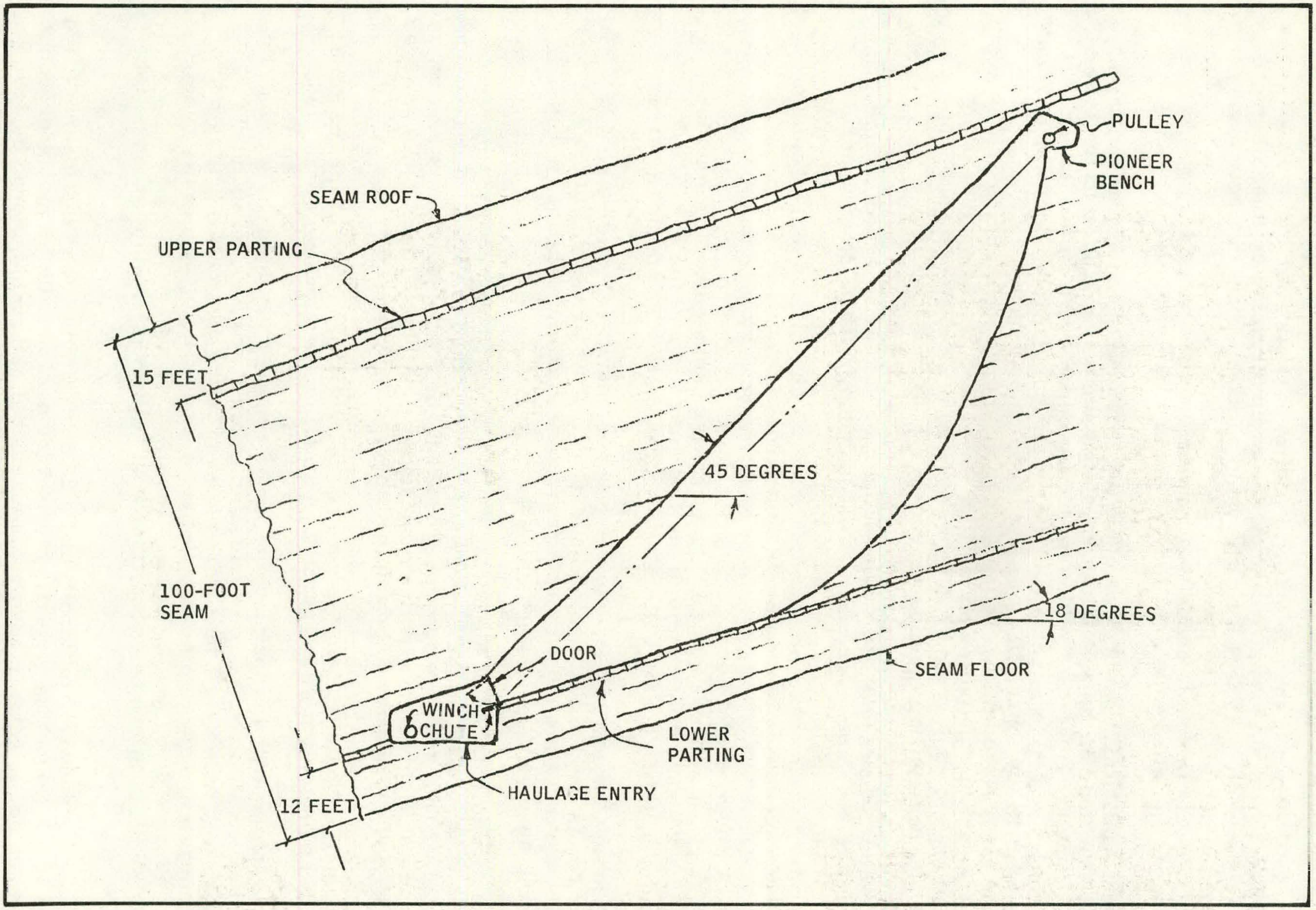


Figure 12 ROOM CROSS SECTION AT OLD ELKOL MINE

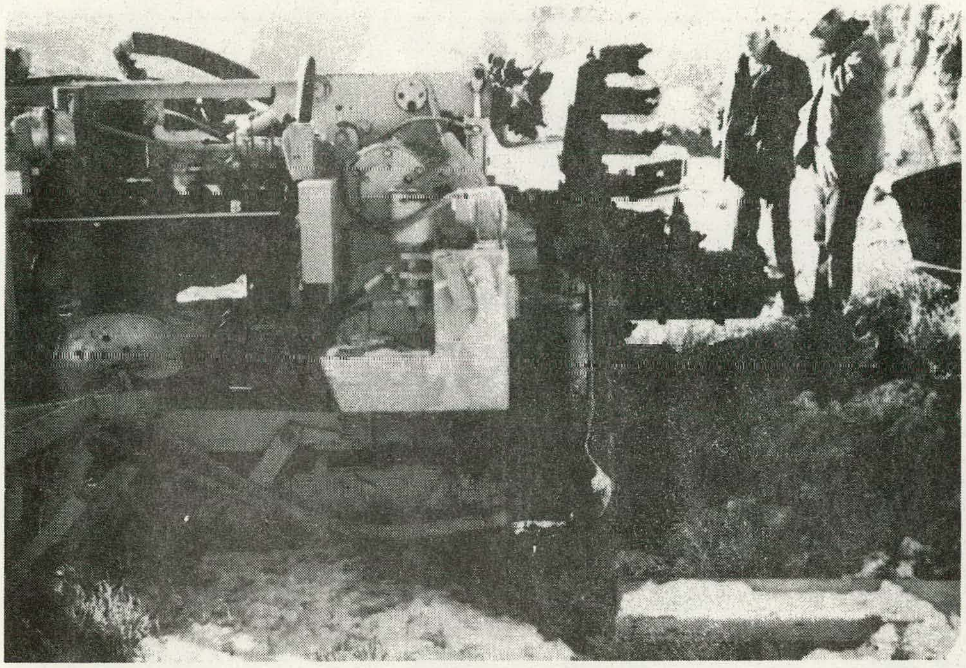


Figure 13 ALKIRK CYCLE MINER

Figure 14 GOOSENECK FEEDER, ALKIRK MINER

belt dumped onto a shorter belt section that loaded cut coal into a rather large hopper (Figure 15). The smooth belts would barely convey coal up an 18-degree incline. Coal was pushed upward by the gooseneck feeder. Coal would not convey with an empty feeder.

Figure 15 SURFACE HOPPER

The following information was taken from the nameplate:

Alkirk Cycle Miner Model TB-4, S/N 004

Manufactured by: Lawrence Machine and Manufacturing, Inc.
7911 10th Avenue
S. Seattle 8, Washington

U. S. Patent reissue 24,965 and other pending

Two smaller prototype versions intended for horizontal application were built. These were thought to have been tested in Alaska. Intended for coal mining, the U. S. Army Corps of Engineers reportedly used one to bore horizontal holes through permafrost exeeding 1,000 feet in length. The development of a later model known as the "Bootstrap Miner" is attributed to a faculty member of the Colorado School of Mines, and is believed to have been tested at the Thompson Creek Coal Co., near Redstone, Colorado. It had a self-sumping feature with an up-dip capability. The self-sumping capability was accomplished by pilot bore locking mechanisms that were integral with the centers of each of the boring cutters. Since the version built for Kemmerer was to be used down dip, where its weight and traction were sufficient, the self--sumping feature had been deleted. Of prime interest are the size and configuration of the stable holes produced during experimentation.

During the initial trials of the machine in the mid-1960's, the aluminum roof support arches were employed, and the miner was driven as far as 500 feet down dip. As confidence increased, use of the roof support beams, which were regarded to be of questionable value, was discontinued. They could not be recovered after multiple-pass boring experiments that will be described in a following paragraph.

The highwall in the demonstration area was more than 2 years old. Numerous freeze/thaw cycles had weathered and weakened the face. A large entrance shield, heavily constructed of steel, was found necessary. The shield extended 10 feet or so from the highwall to offer some protection from face slips.

Webs between holes were maintained at 12 to 14 feet, and ventilation crosscuts were hand-excavated every 100 feet. Pressure tube ventilation advanced with the miner, and water spray was directed at the cutters.

Also described was a technique used for creating narrow, constant-width (12.5-foot wide) holes which gradually increased to more than 50 feet in height by multiple-pass boring. As shown in Figure 16, the entrance height was maintained at 7 feet. The first pass would start down dip near the seam floor and proceed cross-seam at a slight downward angle (less than 10 degrees). At approximately 500 feet of penetration, the first pass would intersect a narrow rock parting approximately 15 feet from the seam roof. At this point the miner would back to near the starting point, and a new starting bench would be shot into the floor for a second pass. This process would continue until a chamber resembling that shown on Figure 16 was completed.

The Alkirk miner was demonstrated off and on for 2 years. It was returned once to Seattle for modification. Federal inspectors required the submission of a safety plan which forced discontinuation of experimentation. Discontinuation would have occurred eventually, since the miner was plagued with breakdowns, and the impetus was by then clearly on surface mining.

3.2.2.2 Joy 6CM Miner

While the Alkirk miner was returned to Seattle for modification, a borrowed Joy 6CM ripper miner was experimented with for about 2 months. It was used with the same extensible belt. Although it would not cut quite as fast and had trouble gathering and feeding cut coal at an 18-degree down-dip angle, it was preferred over the Alkirk machine. It was easier to control and more reliable. The technique shown in Figure 16 considerably reduced the normal down-dip attitude to below 10 degrees, where gathering, feeding, and vehicle propulsion worked well.

3.2.2.3 Salem Auger

A 3- to 5-foot-diameter rotary auger, built by Salem was demonstrated in a 20-foot seam. It bored holes approximately 20 feet deep. The demonstration was short, less than a few weeks. The amount of coal produced was not impressive and created little interest.

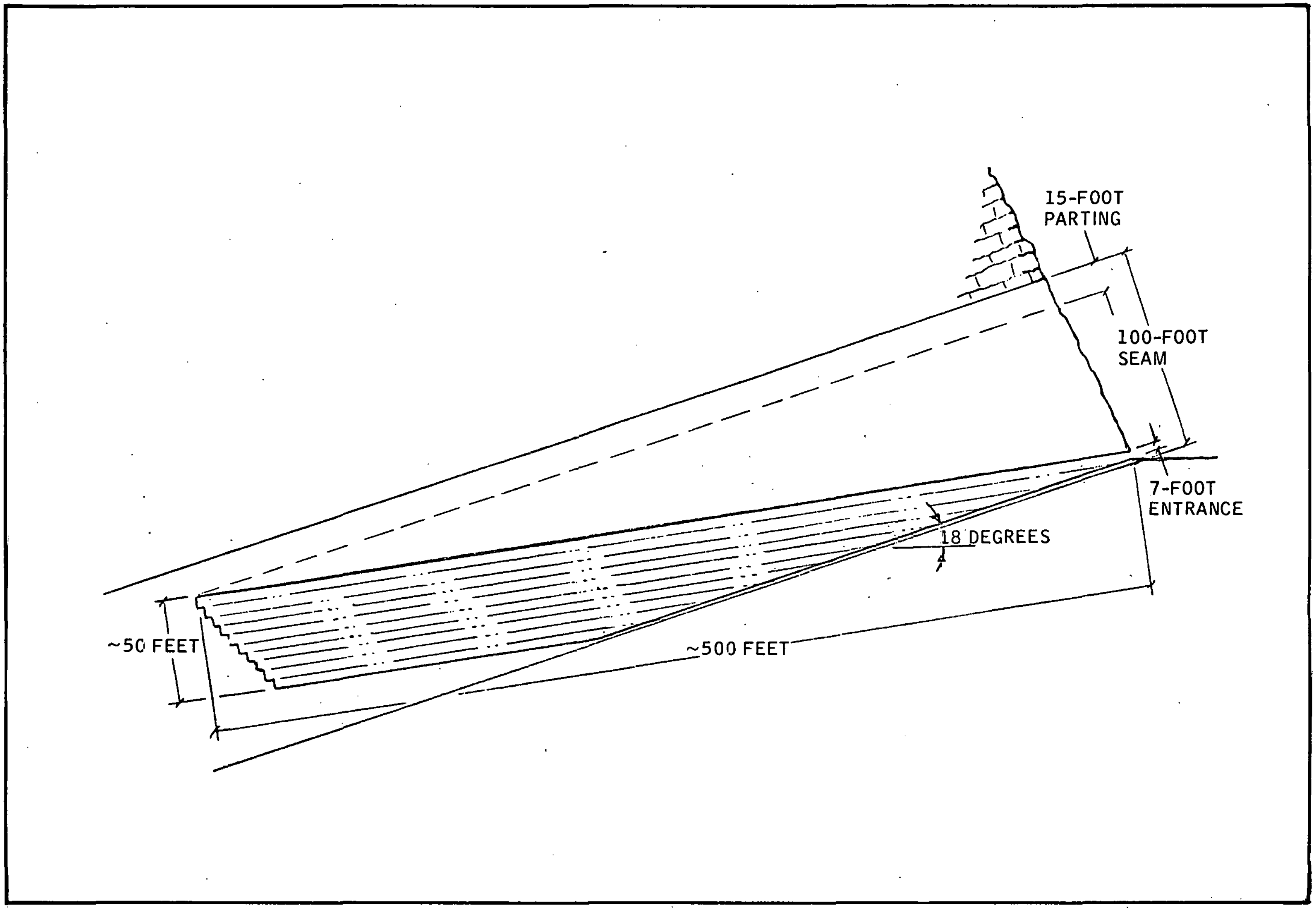


Figure 16 MULTIPLE-PASS BORING

3.2.3 Cardinal River Mine

The Cardinal River Mine is located about 26 miles south of Hinton, Alberta. It is operated by Cardinal River Coals, Ltd., which is jointly owned by Consolidation Coal and Luscar, Ltd., a family-owned consortium. It is situated in the eastern foothills of the Rocky Mountain range at an elevation of 5,500 to 6,400 feet.

Production is currently about 3 million tons per year of metallurgical coal. Of this, two-thirds is shipped to Japan, one-third to India, and a trace to Korea. All production is committed under long-term contracts. Forty-two million tons of coal is included in present planning. Total reserves are estimated at 300 million tons. The mine works three shifts a day, 7 days a week and employs about 600 union and 134 staff workers.

Seam thickness averages 40 feet but varies widely because of tectonic folding and faulting. Figure 17 shows cross sections of the seam. The dotted lines above ground level suggest seam portions that have been eroded away. The dotted areas indicate the extent of current strip mining. The average stripping ratio is 10:1. The operation employs draglines, shovels, front-end loaders, and haulage trucks.

The broken area of the underground seam indicates incomplete survey data. When the stripping limit has been neared, the operation will gradually convert to hydraulic underground mining, using present technology similar to that in use by Kaiser in British Columbia. The coal is very incompetent, which should enhance hydraulic mining.

The facility has a coal cleaning plant and thermal drier. Coal is preheated to 900^{o}F with diesel fuel and conveyed through a fluidized bed drier.

There were about twenty mines in the area, mostly underground, until the coal market dropped. Two local strip mines with similar conditions were identified. One is located in Coal Valley, approximately 45 miles to the northeast of the Cardinal River mine. It is jointly owned by Luscar, Ltd., and Alberta Energy Company. The seams there are flatter than at Cardinal River. It will produce about 3 million tons annually of steam coal under contract to Ontario Hydroelectric with the balance slated for export to Germany. A second operating mine is located about 60 miles to the northwest of Hinton, near Grand Cache, Alberta. It is known as the Smoky River Mine and is owned by McIntyre Mines, Ltd. It produces over 3 million tons per year of metallurgical coal, one-half by underground methods (continuous mining) and one-half by strip mining.

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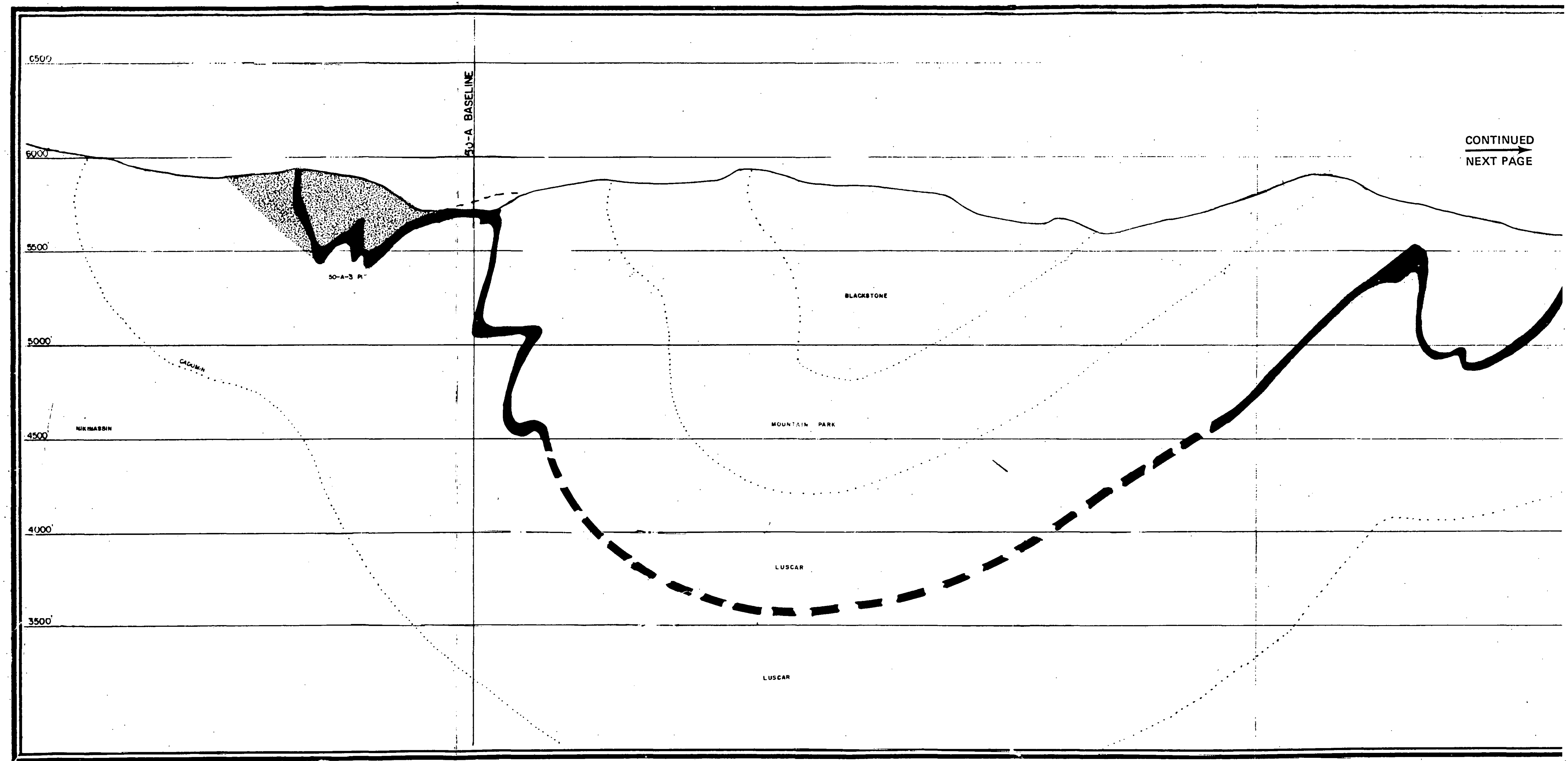
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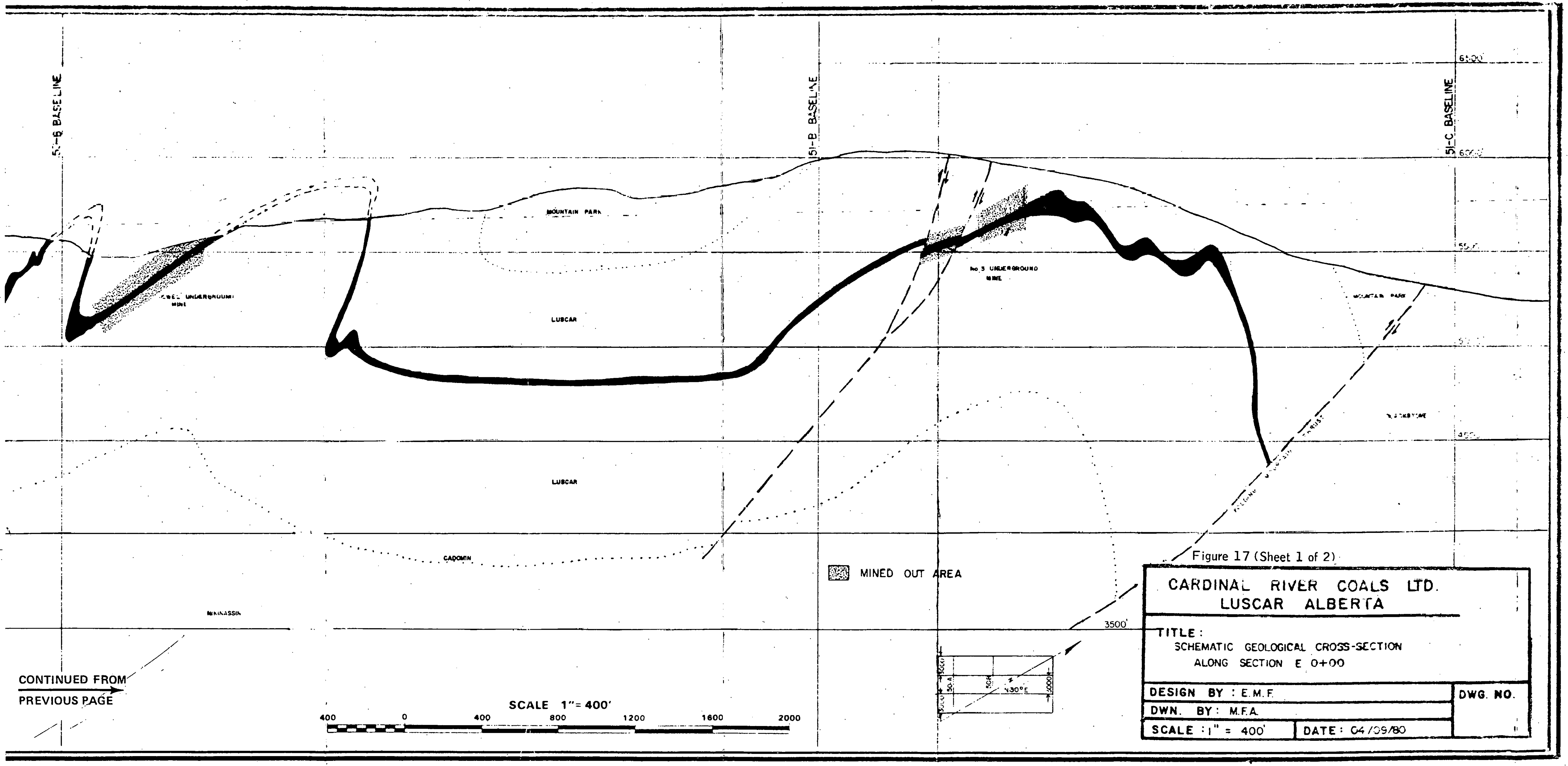
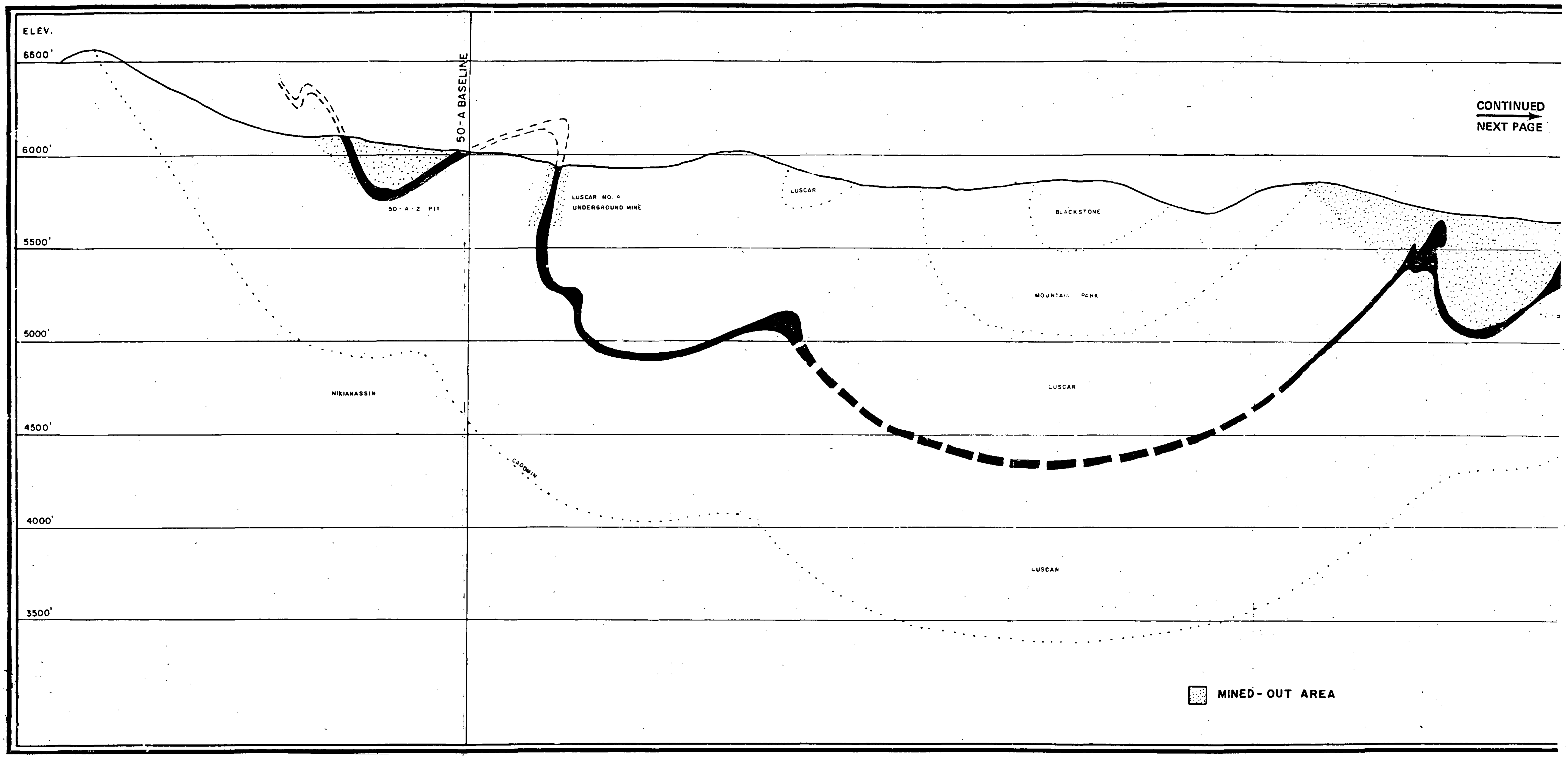


Figure 17 (Sheet 1 of 2)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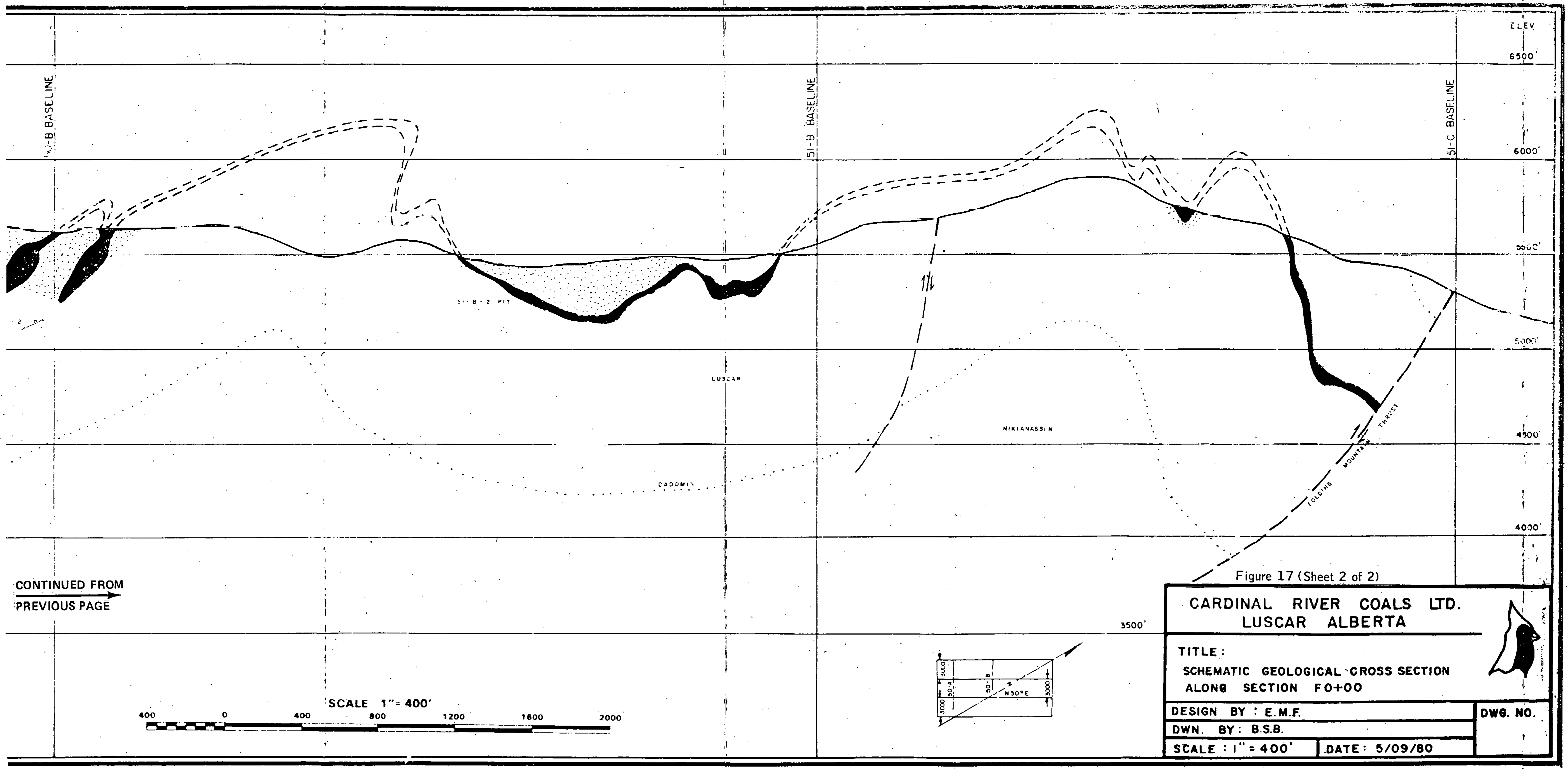

Figure 17 (Sheet 2 of 2)

4.0 CONCLUSIONS

It appears that a substantial portion of the available resource base resides in the lower range of seam pitches, say 0 to 10 degrees, and that the technology for mining these seam pitches is well developed. The technology, however, does not demonstrate very high recovery ratios on a sustained basis. Few approach 50 percent and are believed to average 35 percent. The mining of seams exceeding 8 feet in thickness can result in lower recovery ratios.

It also appears, because of the economics of stripping overburden and the amount of coal available, that most coal is currently produced from seams pitching less than 45 degrees. The more valuable, higher ranking grades, such as metallurgical coal and anthracite, are exceptions.

4.1 ANGULAR CAPABILITY

The goal, for the present, remains the full range of angular capability (0 to 90 degrees). The upper limit may be revised downward for any of the following reasons:

- The reserve base for very steep pitches is determined to be small.
- The number of strip mining operations being conducted in very steep pitches are few.
- The hardware concepts to be developed are unduly compromised for the balance of the range.

The lower limit may be revised upward if the concepts developed offer no clear advantage over existing hardware systems, especially if requirements for a horizontal operation compromise cost or performance for the balance of the range.

4.2 DEPTH CAPABILITY

The minimum depth goal of 200 feet is achievable. Some of the concepts to be developed may be inherently capable of 1,000 feet or more.

4.3 RECOVERY RATIO, HOLE SIZE, AND SPACING

Recovery ratio, hole size, and spacing, to a large extent, depend on geological factors affecting highwall face integrity and coal competency. The thicker the seam, the more difficult it becomes to achieve high recovery. Narrow and high-ceilinged excavations, coupled with small face openings, appear feasible in competent coal and may be the most promising approach to improve recovery. Another approach to improve recovery is to structurally fill the excavation with a water, crushed rock, and limestone mixture. The cost of this must be weighed against the additional amount of coal recoverable.