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ECONOMIC ENGINEERING ANALYSIS OF U.S. SURFACE COAL MINES AND EFFECTIVE LAND RECLAMATION

BY

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FOREWORD

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ECONOMIC ENGINEERING ANALYSIS OF UNITED STATES SURFACE COAL MINES AND EFFECTIVE LAND RECLAMATION

by

Skelly and Loy, Engineers - Consultants

EXECUTIVE SUMMARY

Fossil fuel consumption in the United States increased markedly over recent years, and future demands expect to be even greater. Coal, this Nation's most plentiful natural fossil fuel, will play a key role in fulfilling these demands.

With expectations of increased coal exploitation, the U. S. Bureau of Mines authorized this project, the objectives of which were to prepare an authoritative report on current surface coal mining technology, to define current problems and possible solutions, and to project future developments necessary to assure adequate surfaced mined coal production to meet the Nation's future energy needs. These objectives were accomplished by an extensive review of available published literature and data gathering field visits to active surface coal mines throughout the country.

REGIONAL CHARACTERIZATION

In order to evaluate mining methodologies employed by industry, the United States was subdivided into four distinct regions where similar geologic and topographic conditions warrant similar mining practices. These regions, with encompassing states are:

Region I - Eastern Kentucky, West Virginia, Tennessee, and Virginia: characterized by steep slopes and contour mining along the outcrop of the coal.

Region II - Pennsylvania, Maryland, Alabama and Southeastern Ohio with rolling terrain and modified area and multiple cut contour mining.

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Region III - Western Kentucky, Illinois, Indiana, Ohio, Missouri, Oklahoma, Kansas, Arkansas, and Iowa: relatively flat terrain and thick overburden conducive to box-cut area mining.

Region IV - Montana, North Dakota, Colorado, Wyoming, New Mexico and Arizona: mostly shallow overburden and thick coal seams in a dry climate mined by area and open pit methods.

Mining techniques for each particular region were analyzed in detail from a unit operation viewpoint. Economics of alternative equipment choices and utilizations for various applications are presented.

Region I

In Region I, the steeped sloped contour mining portion of Appalachia, several mining techniques are currently practiced - Haulback or Lateral Movement, Mountain-Top Removal, and some Modified-Block Cutting. Lateral Movement Mining, a newly-developed method, was initiated as a means to eliminate one of the most critical factors inhibiting achievement of effective and productive reclamation in the steep hills and mountains of Region I, outslope overburden spillage. Basically, this contour mining consists of first excavating and storing an initial block cut of overburden material. After the initial block of exposed coal is removed, mining proceeds around the contour of the coal outcrop with overburden transported along the bench and selectively placed in mined out areas. This mining procedure incorporates production excavation and reclamation backfilling into a single operation, an ideal procedure for minimizing environmental disturbance.

Mountain-Top Removal is also a relatively new mining concept in this region. Serving as an excellent alternative to contour mining in hilly and mountainous areas, while using the same equipment, this method makes possible 100% coal recovery. The first cut, roughly parallel to the ridge, is executed in a box-cut manner, storing overburden in valleys and head-of-hollow areas. Successive cuts of overburden are placed in these fill sites as well as in mined out portions of the operation. After the mining is completed, the previously rugged mountain-top is totally transformed into a level or gently rolling expanse of land; the head of the pre-existing narrow hollow is transformed into a succession of crowned terraces, topped by a relatively flat, crowned fill bench area.

Region II

Although practiced to some extent in Region I, Modified Block-Cut Mining is more characteristic of Region II. A contour mining method, Modified Block-Cut Mining (sometimes referred to simply as Block-Cut) reduces spoil spillage on the outslopes, and creates few environmental disturbances. Similar to the haulback method, all spoil, except for the initial cut, is moved laterally along the bench. Overburden removal and reclamation backfill-regrading are accomplished in a single operation, facilitating reclamation, minimizing the exposure time of toxic materials, and making it easier to retain the original slope and shape of the mountain.

Another mining practice of Region II is Box-Cut Contour Mining. A box-cut is excavated along the contour of the coal outcrop, exposing portions of coal and leaving a low wall barrier in place. Spoil from the first contour cut is placed on the low wall barrier and eventually rolls down the outslope. Successive cuts are made into hillside with spoil placed in mined-out pits. Although practiced to a great extent in the past, present usage is limited, with future usage expected to be non-existent.

Modified Area Mining involves adaptation of box-cut area mining methods to the rolling and hilly terrain of Region II. Although similar to the Mountain-Top Removal Method of Region I, in that nearly 100% reserve recovery is obtained, major differences occur in: equipment usage; overburden removal and handling; final grading; and application in rolling terrain rather than steep slope mountains.

This technique is usually incorporated where a coal seam outcrops on opposite sides of a hill or ridge, with maximum overburden thickness through the hill being no greater than 150 feet. Modified Area Mining is also labeled hilltop removal, or ridge removal, and is accomplished by establishing an initial box-cut through the hill - exposing and removing coal from outcrop to outcrop. Successive cuts are taken with overburden from each new cut placed in the previous one. Regrading replaces the terrain to its near original contour, a major difference from Mountain-Top Removal.

Especially applicable to some abandoned contour strippings, Modified Area Mining can produce coal previously thought unrecoverable, and at the same time reclaim those orphan strip mines whose abandoned benches provide excellent storage areas for initial box-cut spoils.

Region III

Mining operations in Region III use Box-Cut Area or Modified Area Mining Techniques. A wide spectrum of equipment is employed, with basic stripping operations performed by draglines or stripping shovels. Generally, in areas where coals lie within 40 to 50 feet of the surface, stripping shovels are used because of their speed of operation, while thicker overburden (150' in some areas) necessitates use of large draglines. Due to high overburden to coal ratios and flat terrain, capacities of stripping equipment range upwards from 35 cubic yards. Area mines in this region generally proceed away from the central storage area or tipple, with cuts normal or parallel to the dip of the coal seam.

Box-Cut Area mining begins with an initial rectangular opening, casting overburden to one side. After removing exposed coal from this cut, an adjoining opening is made, placing overburden into the preceding mined-out cut. These parallel excavations are conducted until all reserves in the area are mined. Reclamation consists of regrading spoil ridges to near original contour and utilizing the area for agricultural or recreational purposes.

Region IV

Mining operations in Region IV commonly utilize area mining techniques and/or some form of open pit mining where coal seams are thicker. Basic stripping operations are performed by a wide range of equipment including shovels, draglines, scrapers, shovel-truck combinations, and front-end loaders. Overburden to coal ratios in Region IV can vary greatly, and sizes of stripping and coal loading equipment vary accordingly.

The extremely thick seams encountered in the West provide for implementation of a coal mining method totally different from any eastern technique, Open Pit Coal Mining. Seams greater than 70 feet thick present an entirely unique set of criteria to be analyzed. Open Pit Coal Mining in thick seams, or "Coal Quarrying," begins with uncovering a sufficient area of coal to allow extraction and provide an open area for future overburden placement. Initial overburden is spread and stored on adjacent land areas and revegetated. Coal thickness usually necessitates a benching operation for removal with loading shovels. "Quarry" expansion can proceed in most any direction from this initial point, usually along only one course at a time

until a limit is reached (natural barrier, property line, outcrop, etc.). Overburden material is trucked and dumped in mined-out areas of the pit, and later graded to a contour compatible with surrounding terrain.

Coal seams also dip very steeply in some portions of Region IV, necessitating use of different mining techniques to maximize coal production. Such seams may be either single or multiple, but in both cases, stripping follows the coal down-dip to increasingly greater depths. Where a number of steeply dipping coal seams overlie one another, the stripping procedures, overburden removal and reclamation in particular, vary somewhat. Removed overburden is cast on both sides of each strip cut above the highwall on the coal seam's down-dip side, and below the coal seam and partially covering the highwall of the cut which exposed the underlying coal seam. After coal extraction, reclamation consists generally of rounding the spoil banks and partially filling adjacent cuts. The resultant topography of the reclaimed area is gently rolling, although in overall perspective it is still representative of the land's approximate original contour.

EXPLORATION

Industry utilizes numerous exploration methods and procedures. Geologic setting and fund availability are important parameters considered when choosing the most advantageous program. Three basic exploration programs are normally utilized by the coal industry.

The simplest and least costly program involves geologic prospecting of coal outcrops supplemented by minimal drilling. The procedure is commonly employed in Appalachian regions where outcrops are abundant and coal bearing formations are well known.

A second program is random drilling. It is most effective in previously explored regions showing little geologic variability of coal thicknesses, quality, and overburden characteristics. A high degree of geologic predictability between informational control points is assumed.

The third program, one utilizing pattern drilling and statistical approaches, is employed when exploring virgin areas or areas showing high geologic variability between information control points.

Drilling is inherent with all three programs and may represent the most expensive segment of each. Therefore, it is advantageous to develop a drilling plan which yields maximum information from an optimum number of drill holes. Drill hole data provides the most usable information about coal and overburden characteristics.

Reconnaissance exploration using remote sensing and airborne geophysical surveying devices such as satellite and airborne photography, infrared imagery, side looking radar (SLAR), and gravity meters, can be used to outline structural basins, uplifts and regional faults and fracture zones. Satellite and high altitude aerial photography and infrared imagery, when used in conjunction with computers and photogrammetric density plotters, enable production of maps which are as accurate as U.S.G.S. 15' quadrangle maps.

Aerial photography is useful for midwestern and western mapping, while SLAR is an extremely effective remote sensing tool valuable in inaccessible, densely forested, or cloud covered areas (as frequently encountered in the Appalachian regions).

MINE PLANNING AND DEVELOPMENT

Successful surface coal mining operations depend on more than efficient production techniques. Proper development and good planning are essential to a profitable operation. Many factors must be considered before final layout and scheduling of an operation can be determined. These items include: geographic locations and features, geologic conditions, coal quality, environmental considerations, land acquisition, water rights, modes of available transportation, market, equipment and materials, and time for development.

Most prospective coal lands contain far more coal than is likely to be removed during a single mining operation. The factors affecting a decision as to the amount of coal to be extracted are complex; sufficiently complex that one knowledgeable miner may recommend a limited operation, while another would be inclined to open a large scale mine on the same property, basing their decisions on identical data. Mine development is an inexact science, and each potential mine must be evaluated with regard to its own unique conditions.

All factors influencing mine development must be analyzed in conjunction with each other to determine the economic size of a new mine, pit design and layout criteria, and equipment types and sizes. As previously stated, any two mining engineers given the same data base can design two distinctly different types of successful operations. An invaluable asset during planning procedures is past experience, which can save precious time in decision-making processes.

A precise mine design handbook which will solve all problems of mine planning can not be composed. However, certain basic procedures are usually followed to ensure proper and complete development of a successful mining venture. These items include mapping the area, mineral evaluation and right's acquisition, economic mine size determination, pit design and layout planning, and selecting equipment.

EXTRACTION AND RECLAMATION

As environmental regulations on surface coal mining have become more stringent, overburden handling has become more sophisticated. Whereas the original "shoot and shove" approach lacked planning but allowed quick coal recovery, today's miner is literally forced to perform a detailed analysis of his mining operation. In several respects this has helped miners realize a greater effectiveness and efficiency of their mobilized resources.

Eliminating abuses of the past requires comprehensive pre-planning and coordination of removal and replacement of overburden -- even to the extent reclamation alternatives dictate selection of extraction methods and equipment.

The geometric configuration of coal mined land has long been recognized as a source of physical and chemical pollutants as well as being visually displeasing. To a large extent, the public's unhappiness with past surface mining is based upon the negative visual impact of blighted landscapes whose color and texture are not harmonious with adjacent terrains. Today's backfilling, regrading, and revegetation practices do not create the "moonscapes" historically associated with strip mining, but do return the land to its near original, and sometimes better, condition.

TRANSPORTATION

Transporting the coal after removal is an important operation to be considered during mine planning. The five major forms of coal transport are: rail, waterways, conveyor, slurry pipelines, and trucks. Although waterways represent the least expensive method of transporting coal, the railroads remain the major transportation form, moving 376 million tons of coal in 1973. The railroads are plagued with problems of poorly maintained rail beds and rolling stock, plus a lack of expansion in railroad equipment. These problems, which must be solved if coal productivity is to significantly increase, emanate from the precarious financial condition of most rail carriers. Water requirement is the major problem to be solved with the transport of western coal via slurry pipeline.

Advanced designs of large storage facilities minimize the historical problems of coal storage, which included oxidation and spontaneous combustion. These modern facilities avoid problems of safety, economics, and environmental concern.

COAL PREPARATION

Coal cleaning has progressed from early hand picking practices for removal of gross refuse material to present technology capable of mechanically processing coal fines and slimes, permitting greater recovery of selected compositions. These technological advances were introduced with mechanization of mines and were stimulated by more stringent market quality requirements and increased coal production rates.

Coal markets have greatly influenced the degree of preparation required for coal produced from any particular mining operation. Traditionally, utility (steam) coal has been subject to less extensive preparation than has metallurgical coal. Although utility coal must have relatively uniform size, economic benefits accrued from extensive cleaning have not been sufficient to offset additional preparation costs. However, more complete cleaning of utility coal may be required with increased enforcement of sulfur dioxide emission limitations for power generating plants.

Three general stages of preparation are practiced within the coal mining industry. Coal preparation plants are individually grouped in

these stages according to degree of cleaning and unit operations. These stages are: Stage 1 - Crushing and Sizing (Basic Cleaning); Stage 2 - Hydraulic Separation (Standard Cleaning); and Stage 3 - Dense Medium Separation (Complete Cleaning).

SYSTEMS ANALYSES

Narrative case histories, discounted cash flow analyses (with complete equipment, manning, and materials listings), and sensitivity and risk analyses are presented in Chapter 9 for at least three representative mines within each Region. These case histories describe pertinent geographic, topographic, geologic and climatic conditions, in addition to detailed discussions of mining unit operations and auxiliary functions. Variations in unit operations provide a major basis for evaluating each mine's costs.

Computerized sensitivity and risk analyses are presented to depict the influence of various cost parameters on investment returns. Sensitivity graphs provided with each case history mine - Mine 2J is an exception - illustrate changes in return on investment (ROI) due to fluctuations in cash flow factors.

Possibly the most informative component of any detailed economic analysis of surface coal mining is definition of unit operations costs. Accurate knowledge of the integral parts leads to a better understanding of the total system. Thus, each of the case history mines is subdivided into basic unit operations costs which are listed in Table 9-108. To provide complete cost representation, all available charges are allocated to these operations.

CONCLUSIONS

Overburden stripping is by far the single most expensive unit operation per ton of coal extracted. This operation is usually the limiting or controlling function (determines production) in any mining operation - an exception is with thick coal seams, which result in coal removal being the controlling unit operation.

Considering an average cost per ton per foot (of overburden), Region I is the highest and Region IV lowest, with respective averages of

$0.14 and $0.02. Coal thickness is a major factor influencing stripping costs. However, the mining method and overburden characteristics are also extremely important. Mining technique may be the most significant factor in Regions I and II. Table 9-108 illustrates that cost per foot of overburden excavated is the lowest in Region II and greatest in Region I.

Data indicates the modified block technique provides the least expensive means of excavating overburden material. Several mine operators who employ two stripping methods stated that dozer and loader pits are the most economical. However, modified block mining operations are usually limited to low annual production. Thus, the technique has limited applicability.

Relating to economics, open pit and area mines are by far the most inexpensive for stripping overburden per ton of coal. Thus, operating costs per ton and coal selling prices (as determined by discounted cash flow analyses) are generally lower in Regions III and IV. Since many of these mines are producing sub-bituminous or low grade bituminous coal, it is imperative that mining costs should be significantly lower per ton of coal. Selling price is usually determined by calorific value, which results in reduced contract prices for many western surface mines.

Regional average total costs decrease in order from Region I to Region IV and represent all operating and capital expenditures. Discounted cash flow selling prices are indicative of this trend with highest minimum prices in Region I and lowest required prices in Region IV. Mining methods also follow the same regional pattern - open pit is least costly and truck haulback is the most expensive on a per ton basis. Since the fifteen case history mines are influenced by individual preferences and specific conditions, care should be taken to avoid overgeneralizing (concerning mining techniques and related costs). However, cost ranges and trends provide reasonable estimates to relate between methods and regions when considering input parameters.

RESEARCH RECOMMENDATIONS

It is obvious that to meet national production goals and maintain a productive environment, a concentrated research effort is needed. The Bureau of Mines, in compliance with the Federal Coal Mine Health

and Safety Act of 1969, is currently administering an extensive coal oriented research program. The Bureau is also administering non-coal contract programs that will in many cases provide positive transfer of technology.

In addition to current research being carried out by the Bureau and other agencies, several other research recommendations were developed through findings of this study:

- Feasibility of belt conveyor haulback mining should be evaluated.
- Feasibility of trench strip and auger mining should be evaluated.
- Definition of reclamation standards based on the ecologic norms for each region should be adopted.
- Development of a "rock picker" for removal of large rocks within the upper two feet of regraded overburden.
- Further research should be conducted to more fully define the subsurface water impacts for coal surface mining in the West.
- Definition and location of high pollution potential coals would be beneficial in reducing pollution control costs.
- Research into acceptable slime refuse disposal from Stage 3 coal preapration facilities should be conducted.
- Feasibility of adopting continuous miner loading machines to surface operations should be assessed.

Other research and development suggestions are listed in Chapter 10.

CHAPTER 2

INTRODUCTION

PURPOSE

With United States energy consumption increasing year after year, and the desire to be energy self-sufficient by 1985, our country's reliance on its coal reserves is paramount. Coal extraction techniques, particularly surface mining, need further research and development in order to fulfill future energy demands in the safest and most efficient way possible. This study, a part of the Bureau of Mines energy research program, reports on the current technology of coal surface mining in the United States, its current problems and possible solutions, and future developments necessary to assure adequate surface mined coal production. The purpose of the study is to prepare a coordinated, systematized, technical economic analysis of the surface coal industry, and through systems analysis techniques determine present bottlenecks and areas requiring research and development.

SCOPE

There exists, scattered throughout technical literature, a substantial body of information concerning the surface coal mining industry. Considerable research was conducted, and reports, publications, periodicals, and statistics were collected to form a basis for performing this study. The data search covered foreign as well as United States literature and included information from universities, libraries, research groups, government publications and consultants.

Coal surface mining techniques and methods are dependent on geographic location, geologic conditions and topography. In order to analyze current mining methodologies, the Nation was divided into four regions, where geologic and topographic conditions warrant similar mining techniques. These regions with encompassing states and general characteristics are:

Region I - Eastern Kentucky, West Virginia, Tennessee, and Virginia: characterized by steep slopes and contour mining along the outcrop of the coal.

Region II - Pennsylvania, Maryland, Alabama and Southeastern Ohio: characterized by rolling terrain and modified area and multiple cut contour mining.

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Region III - Western Kentucky, Illinois, Indiana, Ohio, Missouri, Oklahoma, Kansas, Arkansas, and Iowa: characterized by relatively flat terrain and thick overburden with box cut area mining.

Region IV - Montana, North Dakota, Colorado, Wyoming, New Mexico and Arizona: characterized by shallow overburden and thick coal seams in a dry climate with area and open pit mining.

Mining techniques characteristic of each particular region are described at length from a unit operational standpoint. Unit operations are outlined in detail with descriptions of alternative methods and equipment usage included. Flow diagrams represent interdependence of operations and indicate critical paths of the particular techniques.

Visits to selected mines in each region provided current information on characteristic mining methods. Case studies were performed and cost data developed to allow for comparison of alternative unit operations within a particular method. Systems analyses were performed on the case study operations to determine problem areas, if any, and to suggest areas in need of further research.

With coal consumption expected to increase in the future, surface mining will take on new demands and challenges. This study is designed to provide sound engineering and economic data for laying out efficient surface coal mines. Findings of the suggested research should provide additional criteria to assist mine planners and developers in designing profitable, efficient, and safe surface mining operations.

HISTORY AND TRENDS IN THE DEVELOPMENT OF SURFACE MINING

Coal surface mining had its beginning in 1866 at a mine near Danville, Illinois. Overburden was stripped with horse-drawn plows and scrapers, and hauled away by wheelbarrows and carts. Not until 1877 was the first mechanical device used to remove overburden material from a

coal seam. This new device, a steam shovel, was put to use on a seam previously worked by plows and scrapers near Pittsburg, Kansas (4).

Evolution of stripping equipment was slow. Until the 1920's surface mining accounted for only a minute percentage of total coal production in the United States. In these early years, however, significant design modifications to shovels and draglines opened the way for profitable surface mining operations. Introduction of alloy steels and aluminum in the early 1930's increased capability of designing larger capacity machines (4).

The percentage of total coal production produced by surface mining operations increased gradually from 1920 until World War II, when surface mining received its greatest boost. Demand for coal increased as a result of the war, and miners turned to surface production because it offered faster recovery with less manpower requirements.

During the years following World War II, improvements in machinery and techniques offered further advantages to surface miners. Improvements in overburden preparation, including introduction of ammonium nitrate-fuel oil explosives and rotary drilling, allowed greater productivity from stripping machines.

In 1956, a new era began for the strip mining industry. It was brought about with the introduction of gigantic stripping shovels and draglines (4). In order to match production capabilities of these larger machines, auxiliary equipment, such as dozers, loaders, scrapers, trucks, and haulers underwent considerable modification and enlargement.

Utilization of larger equipment has been the trend in the past few years. However, a leveling-off in size has temporarily occurred. Operating efficiencies have decreased with introduction of some of the larger machines, and improvements in current designs and efficiencies are the present trends (4).

In the early years of surface mining, major emphasis was placed on "recovery of the mineral," with little or no regard to "recovery of the land." Initial lack of concern for the environment caused increasingly stringent strip mine legislation. Reclamation has now become an integral part of most all surface mining operations, and has caused some major revisions in mining techniques, particularly in the East. Current practice is to incorporate reclamation with the mining sequence, and not regard it as a separate operation.

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The goals of Project Independence will have a serious impact on the entire coal industry. In order to meet those goals, the coal industry, by 1985, should be producing between 1.2 and 2 billion tons of coal per year. This will mean doubling the current production rate.

In order to fulfill energy needs by 1985, the National Academy of Engineering, in a study published in May, 1974, set forth the following requirements for the coal industry:

"... Develop 140 new 2 million tons per year Eastern Underground mines.

... Develop 30 new 2 million tons per year Eastern Surface mines.

... Develop 100 new 5 million tons per year Western Surface mines.

... Recruit and train 80,000 new Eastern coal miners.

... Recruit and train 45,000 new Western coal miners.

... Manufacture 140 new 100 cubic yard shovels and draglines.

... Manufacture 2,400 continuous mining machines."

These are goals for the coal industry, which means increased production from existing mines, plus development of many new operations. Surface production is expected to continue to increase in the upcoming years -- particularly in Western coal fields, where thick seams, shallow overburden, and low sulfur content provide attractive criteria for future development.

The percentage of coal production related to surface mining increased steadily from the mid-1950's until about 1969, when the Federal Coal Mine Health and Safety Act was enacted. After 1969, underground production fell off markedly, and surface mining gained predominance in total production percentage at 50.7%. With new improvements in surface mining techniques, and abundance of strippable reserves available (especially in Western states) surface mining will continue to account for most coal production in the United States.

LOCATION AND DESCRIPTION OF U. S. COAL RESERVES

It has been estimated there are over 1770 billion tons of total coal and lignite reserves in the United States (fig. 2-1). Of this reserve base, over 145 billion tons are reported strippable, with an estimated 111.5 billion tons of low sulfur content (fig. 2-2).

Tables 2-1 and 2-2 have been prepared to show distribution of coal reserves in major surface mining states, according to study regions. Sulfur content of coal has recently become an important parameter in evaluation of a coal deposit for mining. Recent government restrictions in sulfur content have seriously limited high sulfur coal markets, while at the same time opened new and more attractive markets for low sulfur fuels. Table 2-1 shows estimated strippable reserves, in major surface mining states, according to sulfur content, based on 1968 U.S. Bureau of Mines figures. Coal reserves by rank are indicated for major surface mining states in Table 2-2. (Figures for Tables 2-1 and 2-2 do not agree because Table 2-2 was derived from 1974 data while Table 2-1 included information from 1968 statistics only.)

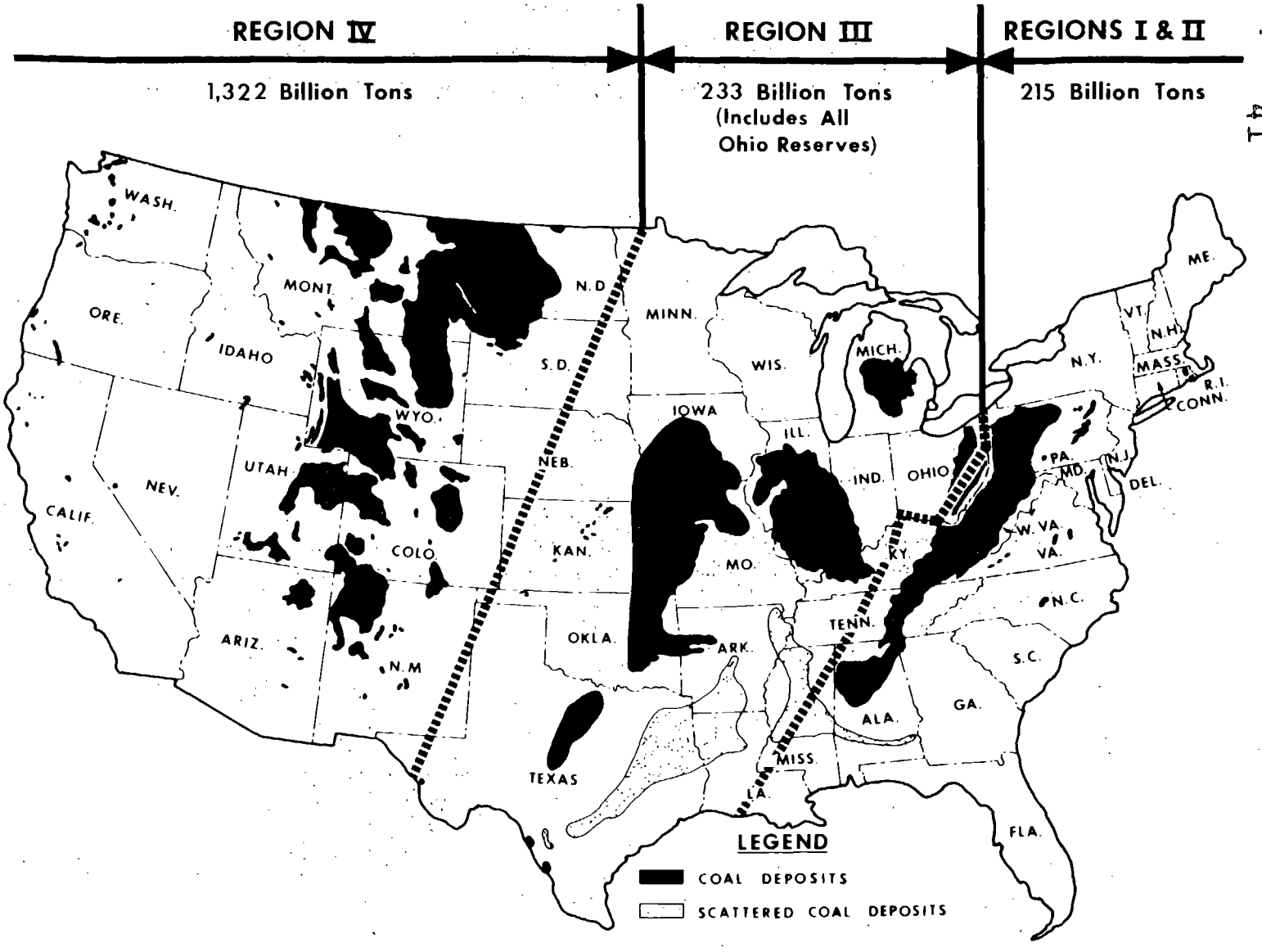
ACTIVE U. S. SURFACE COAL MINES

The 1973 Annual Report of the Mining Enforcement and Safety Administration (M.E.S.A.) lists 3,117 Active Coal Mines in the United States for 1973 (5). The Bureau of Mines, Department of Statistics lists 4,744 active coal mines for the same year. The breakdown of these statistics are shown below:

TABLE 2-3

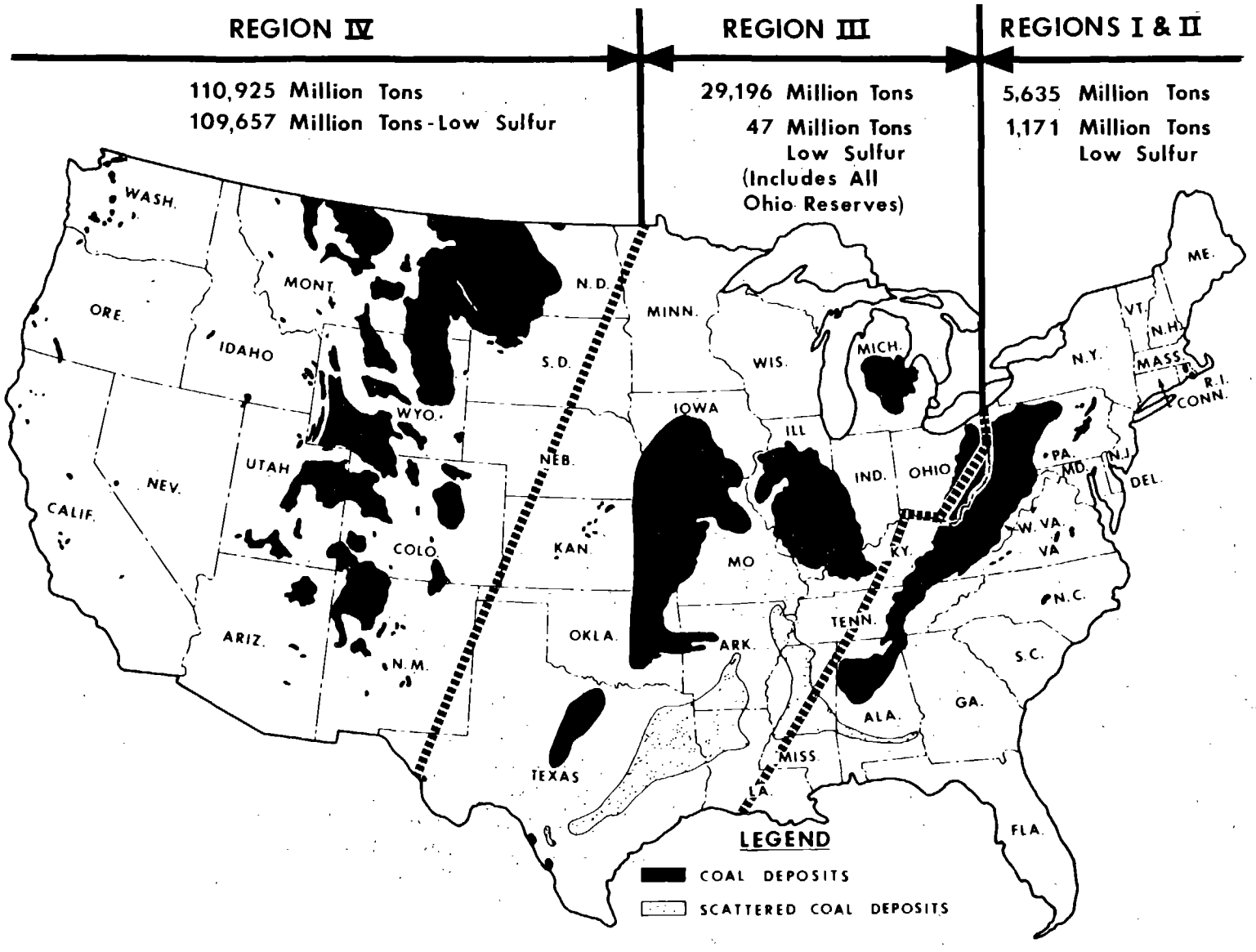
ACTIVE COAL MINES IN U.S.A. - 1973 (Average)

U.S.B.M.		M.E.S.A.	
Underground	1,737	Underground	1,425
Strip	2,309	Surface	1,692
Auger	698		3,117
	4,744		



TOTAL COAL RESERVES OF THE CONTERMINOUS UNITED STATES

Figure 2-1



STRIPPABLE COAL RESERVES WITH LOW SULFUR ESTIMATES OF THE CONTERMINOUS UNITED STATES

Figure 2-2

TABLE 2-1

STRIPPABLE RESERVES BY SULFUR CONTENT

REGION	STATE	STRIPPABLE RESERVES (Millions of Short Tons)			
		SULFUR CONTENT			TOTAL
		LOW (<1%)	MED.(1%-2%)	HIGH(>2%)	
I	E. Ky.	532	189	60	781
	Tenn.	5	43	26	74
	Va.	154	99	5	258
	W. Va.	1,138	669	311	2,118
	Sub-Total	1,829	1,000	402	3,231
II	Alabama	33	74	27	134
	Maryland	0	8	13	21
	Penna.	0	225	527	752
	Sub-Total	33	307	567	907
III	Arkansas	28	118	28	174
	Kansas	0	0	375	375
	Ill.	0	80	3,167	3,247
	Indiana	0	293	803	1,096
	Iowa	0	0	180	180
	W. Ky.	0	0	977	977
	Mo.	0	0	1,160	1,160
	Ohio *	0	126	907	1,033
	Okla.	10	44	57	111
	Sub-Total	38	661	7,654	8,353
IV	Arizona	387	0	0	387
	Colorado	476	24	0	500
	Montana	6,133	764	0	6,897
	N. Dakota	1,678	397	0	2,075
	New Mex.	2,474	0	0	2,474
	Wyo.	13,377	65	529	13,971
	Sub-Total	24,525	1,250	529	26,304
	TOTAL	26,425	3,218	9,152	38,795

* Includes Southeastern Ohio in Region II.

Adapted From Reference No. 2-10 (Sulfur Breakdown Not Available In 1974 Figures)

TABLE 2-2

COAL RESERVES BY RANK

REGION	STATE	TOTAL MINABLE RESERVE BASE (Millions of Short Tons)					STRIPPABLE RESERVES (Millions of Short Tons)				
		ANTHRACITE	BITUMINOUS	SUB-BITUMINOUS	LIGNITE	TOTAL	ANTHRACITE	BITUMINOUS	SUB-BITUMINOUS	LIGNITE	TOTAL
I	E. Ky.	0	12,917	0	0	12,917	0	3,450	0	0	3,450
	Tenn.	0	987	0	0	987	0	320	0	0	320
	Va.	138	3,512	0	0	3,650	0	679	0	0	679
	W. Va.	0	39,590	0	0	39,590	0	5,212	0	0	5,212
	Sub-Total	138	57,006	0	0	57,144	0	9,661	0	0	9,661
II	Ala.	0	1,955	0	1,027	2,982	0	157	0	1,027	1,184
	Md.	0	1,048	0	0	1,048	0	146	0	0	146
	Penna.	7,120	23,880	0	0	31,000	90	1,091	0	0	1,181
	Sub-Total	7,120	26,883	0	1,027	35,030	90	1,394	0	1,027	2,511
III	Ark.	96	537	0	32	665	0	231	0	32	263
	Illinois	0	65,665	0	0	65,665	0	12,223	0	0	12,223
	Indiana	0	10,623	0	0	10,623	0	1,674	0	0	1,674
	Iowa	0	2,885	0	0	2,885	–	–	–	–	–
	Kansas	0	1,388	0	0	1,388	0	1,388	0	0	1,388
	W. Ky.	0	12,624	0	0	12,624	0	3,904	0	0	3,904
	Mo.	0	9,488	0	0	9,488	0	3,414	0	0	3,414
	Ohio*	0	21,077	0	0	21,077	0	3,654	0	0	3,654
	Okla.	0	1,294	0	0	1,294	0	434	0	0	434
	Sub-Total	96	125,581	0	32	125,709	0	26,922	0	32	26,954
IV	Ariz.	0	0	350	0	350	0	0	350	0	350
	Colo.	28	10,097	4,745	0	14,870	0	870	0	0	870
	Mont.	0	1,384	99,212	7,131	107,727	0	0	35,431	7,131	42,562
	N.D.	0	0	0	16,003	16,003	0	0	0	16,003	16,003
	N.M.	2	1,777	2,615	0	4,394	0	250	2,008	0	2,258
	Wyo.	0	4,524	46,704	0	51,228	0	0	23,674	0	23,674
	Sub-Total	30	17,782	153,626	23,134	194,572	0	1,120	61,463	23,134	85,717
	TOTAL	7,384	227,252	153,626	24,193	412,455	90	39,097	61,463	24,193	124,843

* Includes Southeastern Ohio in Region II.

Adapted From Reference No. 2-12

45 The statistical difference is caused by two factors: First, the agencies use different methods in gathering field information, and second, the agencies use different methods in defining a coal mine operation.

GATHERING FIELD DATA

M.E.S.A. is charged with the responsibility of inspecting all active U.S. Coal mining operations for compliance with the Federal Coal Mine Health and Safety Act of 1969. Periodic field inspections are coordinated through nine M.E.S.A. District Offices. All information is forwarded to Denver, Colorado, and entered into a computer. Information is updated each week and includes the number of employees and annual production for each mining operation.

Bureau of Mines uses industry and state agencies as information sources for field data.

DEFINING MINING OPERATIONS

M.E.S.A. defines a surface coal operation as one mine if all pits are:

- owned by the same company
- supervised by the same superintendent
- located in the same county

Bureau of Mines uses state mining permits as a source of tallying mining operations.

DISCUSSION

The 1973 statistical difference between agencies for deep mine operations is not significant. However, in the surface mine category, M.E.

S.A. lists 1,692 surface mines for 1973 while Bureau of Mines lists 3,007 strip and auger operations. The major reason for the discrepancy is different agency definitions of a surface mine. Using the Commonwealth of Pennsylvania as an example, there are, by the M.E.S.A. definition, 356 surface mining operations for 875 strip pits. These pits require 715 state mining permits (plus 17 auger permits) therefore Bureau of Mines would list 732 strip and auger mines.

SUMMARY

Both M.E.S.A. and Bureau of Mines list approximately the same number of deep mine operations. However, a large statistical difference exists between agencies as to the number of "surface mine operations."

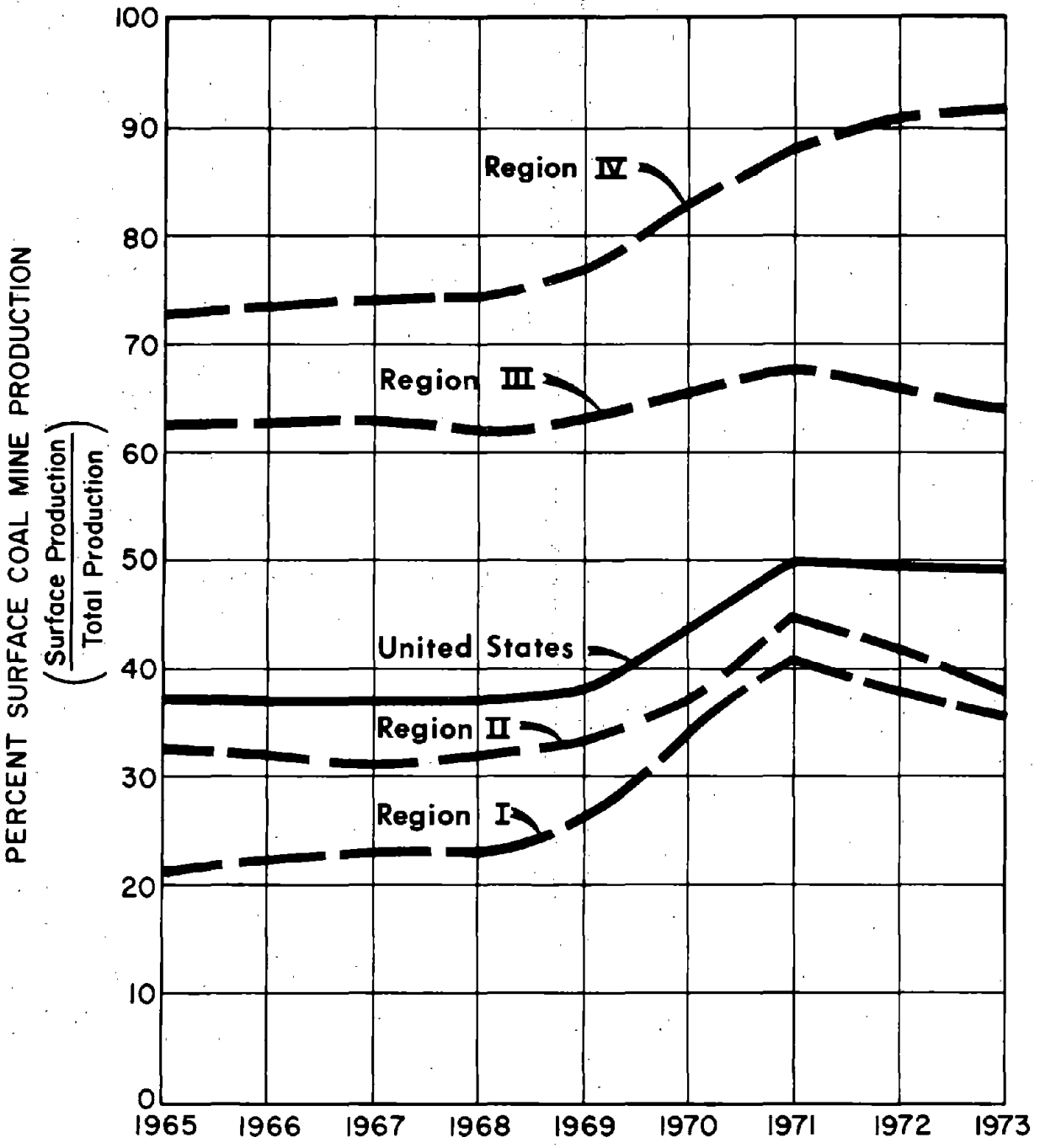
Using State permits as a measure of mining operations results in an inflated statistic, since many states issue more than one mining permit number for an operation on a single tract of land, and may require an additional permit for augering the same strip pit.

The number of deep mine operations is increasing in 1974, however, most operations with less than four men are non-permit, part-time operations representing less than 1% of production and employment for the deep coal mine industry.

If errors in field data gathering techniques are corrected, a reasonable estimate for the number of legitimate surface and deep mines in the United States as of January 1974, would be 1800 and 1600 respectively, with at least a 10% rate of increase in each category projected for 1974. These statistics were derived using the definition of a single surface mine as: An operation on single or adjacent pieces of property. Augering in an active strip pit was not counted as a separate operation.

Surface mines currently account for 50.7% of total coal production as opposed to 31.4% only a decade ago. In terms of production tonnage this represents an increase from 195 million tons in 1966 to 280 million tons in 1973 (1973 tonnage is preliminary).

Figure 2-3 shows the regional growth of surface mining while Table 2-4 examines individual state production. The rapid growth of coal production in western states is clearly evident in this table.



REGIONAL GROWTH OF SURFACE MINING

Figure 2-3

TABLE 2-4

PRODUCTION STATISTICS - 1973

Region	State	Total No. of Coal Mines	Total No. of Surface Mines	Total Production (Short Tons)	Surface Production (Short Tons)	Size Range of Surface Mine Production (Short Tons)		% Change Surface Production (8yrs) $\frac{Tons_{73} - Tons_{66}}{Tons(66)}$
						MAX.	MIN.	
I	E. Ky.	358	127	68,857,000	26,455,348	2,468,750	10,000	-
	Tennessee	60	39	10,100,000	3,411,765	400,000	62,000	+ 32%
	Virginia	102	18	35,500,000	4,745,580	1,030,072	45,000	- 18%
	West Va.	445	139	115,560,000	18,061,420	1,103,043	1,561	+ 5%
	Subtotal	965	323	230,017,000	52,674,113	-	-	+ 23%
II	Alabama	57	46	19,793,000	11,629,907	921,236	40,768	+ 118%
	Maryland	14	13	1,600,000	1,136,933	145,457	28,441	+ 43%
	Pennsylvania	335	222	82,250,000	26,968,411	2,620,000	3,650	+ 5%
	Subtotal	406	281	103,643,000	39,735,251	-	-	+ 25%
III	Arkansas	4	4	458,000	400,414	184,000	30,242	+ 133%
	Illinois	48	26	57,450,000	28,943,529	4,296,663	54,026	- 20%
	Indiana	23	21	24,263,465	24,095,558	4,064,910	54,649	+ 56%
	Iowa	9	7	1,500,000	496,472	95,280	46,853	- 35%
	Kansas	3	3	1,085,012	1,078,831	725,451	140,009	- 4%
	W. Ky.	55	28	52,329,000	29,113,686	5,290,991	74,614	-
	Missouri	7	6	4,669,072	4,669,072	1,227,939	498,120	+ 30%
	Ohio*	196	165	45,064,000	27,724,130	3,911,698	439	+ 9%
	Oklahoma	9	8	2,137,615	2,137,615	894,891	100,588	+ 155%
	Subtotal	354	268	188,956,164	118,659,307	-	-	+ 9%
IV	Arizona	2	2	3,246,500	3,246,500	3,246,500	3,246,500	-
	Colorado	19	5	6,254,000	2,701,405	1,076,120	106,798	+ 67%
	Montana	5	5	10,688,109	10,688,109	4,253,681	312,785	+3,149%
	N. Dakota	8	8	6,928,630	6,928,630	1,726,000	160,657	+ 96%
	New Mexico	3	2	8,777,347	7,852,610	7,389,321	463,289	+ 232%
	Wyoming	16	12	14,910,792	14,477,138	2,895,000	400,421	+ 308%
	Subtotal	52	34	50,805,378	45,894,392	-	-	+ 302%
	TOTAL	1,778	907	574,196,542	257,738,063	-	-	+ 32%

* Includes Southeastern Ohio in Region II.

HEALTH AND SAFETY AT SURFACE COAL MINES

HISTORY

Regulation and inspection of coal mines was the responsibility of the individual states until 1941 (when the first Federal Law was enacted as a result of public clamor for a reduction in mine accidents). Regulation and degree of enforcement varied from state to state, depending largely upon the importance of the industry in the particular state. Most mining laws were aimed at prevention of accidents, with little or no attention given to health measures.

Disasters occurring in a state usually resulted in new regulations or a strengthening of existing ones. Unfortunately, the number and severity of accidents were directly proportional to tons mined, with an occasional temporary improvement following a disaster or serious accident.

In 1941, the first Federal Coal Mine Safety Act was passed by the United States Congress. This act required the Bureau of Mines to prepare a mining code applicable to all states. A force of 107 inspectors was hired and extensively trained in the new code, as well as in first aid and mine rescue and recovery operations. The Federal Inspectors were responsible for inspecting mines, but lacked any enforcement power. Any hope for improvement in mining conditions and practices was largely dependent upon persuasive ability of the inspector; however, his findings could be published in local newspapers. In some instances hazards were corrected by an operator to avoid unfavorable publicity related to his mine.

A series of explosions in the nineteen-fifties aroused sufficient indignation to force the Congress to authorize Federal Inspectors to enforce certain provisions of the code, expecially explosion prevention measures, such as improved ventilation, gas detection, rock-dusting and electrical equipment maintenance. However, enforcement powers or mandatory regulations were not mentioned for surface mines, even though strip mining operations were increasing in number and size, with a corresponding increase in accidents. Subsequently, very little change in mining codes and enforcement occurred until November 20, 1968 when a disastrous explosion at Farmington, West Virginia claimed the lives of seventy-eight miners. This catastrophe aroused the public and the United Mine Workers' organization, and more stringent mine safety enforcement was demanded of the Congress.

For several years, studies had been conducted by the United States Public Health Service, and other investigators both here at home and abroad on the effects of breathing coal dust. These studies showed that exposure to excessive coal dust could cause lung impairment and premature disability in miners. Investigators also determined that exposure to excessive noise was detrimental to the health of workers.

After exhaustive hearings on the entire field of mine health and safety, and consideration of testimony supplied by numerous experts, Congress enacted the Federal Coal Mine Health and Safety Act of 1969. This Act embodied the most comprehensive mine legislation ever conceived in the field of industrial health and safety. The new Act specifically required that the Secretaries of the Departments of Interior and Health Education and Welfare prepare health and safety regulations to cover every facet of underground and surface mine operations. In addition, the Act imposed severe monetary penalties for each infraction of the law found by a Federal Inspector, and the penalty of mine closure until hazards were corrected.

HEALTH

The Mandatory Health Standards for Surface Mines as required by the Act became effective on March 28, 1972. These standards set forth limits for respirable dust, airborne contaminants, noise, and requirements for bathing facilities, sanitary toilets and drinking water. Included with the standards were prescribed methods for sampling airborne dust and other such contaminants, as well as a prescribed method for noise measurement. All necessary data, devices to be used for above measurements and tests, interval of testing, and reporting procedures required were defined.

Certainly, all of the standards are important to assure healthful working conditions. However, control of dust and other airborne contaminants, as well as elimination of noise are priority items.

Prior to July 1, 1972, each operator of a surface mine was directed to collect an accurate sample of the amount of respirable dust in the atmosphere to which each miner was exposed. The sampling procedure required that an approved sampler be attached to each worker and operated continuously for an entire shift. The sampling had to be supervised by a

person with practical coal mine experience. This includes knowledge of equipment employed at a mine, knowledge of the care and operation of the sampling devices used and the filters contained therein. He must have satisfactorily completed an approved course in sampling and evaluation of respirable coal mine dust concentration with the prescribed sampling devices.

If the initial sample established a concentration of less than one milligram of respirable dust per cubic meter of air, the operator was then required to take one sample during each ensuing twelve-month period. However, if the initial sample contained more than one but less than two milligrams of respirable dust per cubic meter of air, resampling was required on a six-month basis.

Initial samples containing more than two milligrams of respirable dust per cubic meter of air caused the mine operator to receive a Notice of Violation from the Mine Enforcement and Safety Administration requesting additional sampling until satisfactory conditions were attained.

All such dust samples, together with a complete identification card showing name of mine and its number, person sampling and his Social Security number, sampling device used, length of sampling period, occupation of the worker, must be mailed to the Pittsburgh Field Health Group, MESA for weighing. Results are subsequently sent to the mine operator.

Approved samplers presently in use are the MSA, by Mine Safety Appliances Company; Unico, by the Bendix Corporation and the MRE, developed by the Mining Research Establishment of the National Coal Board, London, England.

The noise standard requires noise at a work site for a full eight-hour shift be kept at, or below, ninety decibels. Multiple noise exposure is computed by adding the total time exposure at each specified level divided by the exposure permitted at that level, and the result must not exceed one. The device used to test noise is the General Radio Noise Level Meter.

Bulldozers and front-end loaders were found to be the machines

requiring most effort to control noise. Control measures include acoustically-treated operator cabs and exhaust mufflers which have shown a reduction of eight and ten decibels, respectively. Personal ear protective devices are used to a limited degree where other corrections do not suffice, or for short duration exposure.

SAFETY

Mandatory safety regulations for surface mines and surface work areas of underground mines are very comprehensive. They cover: surface installations, thermal dryers, mechanical equipment, electrical equipment, trailing cables, grounding, surface high-voltage distribution, low and medium-voltage alternating current, ground control, maps, manhoisting, auger mining, loading, haulage, stripping, drilling, trolley wires and trolley feeder wires, slope and shaft sinking, concrete, concrete forms, shoring, steel erection, explosives and blasting. These regulations are comprised of several hundred items, some with numerous subparts, in order not to miss a possible hazard, and hopefully to eliminate all accidents. Supplementary and explanatory tables, charts and other information are included to assist the mine operator in attaining compliance with the regulations. It would be virtually impossible to assign a degree of importance to any section of the safety code, since each and every standard is the result of a hazard which did or could cause injury.

In recent years, machinery has accounted for most of the accidents at strip operations -- with bulldozers and front-end loaders as the main offenders. Undoubtedly, the installation of rollbars in conjunction with seat belts will reduce the number of injuries from this source. Berms or guardrails along the outside edge of inclined roadways should assist in reducing the number of accidents from equipment leaving the roadway and rolling down an embankment.

Table 2-5 shows injury statistics for strip mines from 1968 through June 1974. These indicate a generally favorable trend, although not a consistent decrease, which should occur as a result of the effort being expended by federal, state and company safety personnel.

TABLE 2-5 U. S. Surface Mine Injury Statistics - 1969-74

	1969	1970	1971	1972	1973	to June 1974
Fatals by type	28	29	22	21	16	15
Haulage	3	4	3	6	4	1
Machinery	14	11	12	8	8	11
Electrocution	1	2	1	3	0	2
Falls or slides of coal or overburden	2	7				
Other fall materials	2	1				
Slips or falls of persons	1					
Handling materials	1	2		1		
Mine fires	2	1				
Explosives		1		1		
Slide of highwall				1		
Burns				1		
Off mine property					3	
All other	2		6		1	1
Fatal frequency	.66	.64	.39	.34	.29	.51
Disabling injuries	995	1375	1587	1102	1125	547
Disabling rate	22.47	26.23	26.93	19.92	19.39	16.15
No. of strip mines	1715	2292	2456	1474	1215	1039

Source: U. S. Dept. of Interior, Mine Enforcement Safety Administration

The Mining Enforcement and Safety Administration has two other divisions which perform vital services in the overall safety effort; namely, Education and Training and Technical Support.

EDUCATION AND TRAINING

The Education and Training Division is involved in a multitude of activities aimed at upgrading the knowledge of mine personnel and officials in health and safety. During 1973, about 300,000 miners and mine officials received training in one or more of the following subjects: methane and other gas detectors, self rescuers, roof and rib control, flame safety

lamps, ventilation, electrical qualification, fundamental principles, job safety analysis, explosives, first aid, mine rescue, health provisions of Public Law 91-173.

A Mine Health and Safety Academy is being erected at Beckley, West Virginia to train mine inspectors for both coal and metal-non-metal mines since no such training center is available. This facility will relieve veteran inspectors from training duties and permit use of their full time for mine inspection.

In order to reach the most persons in the shortest time, MESA instructors train and certify State and company instructors to teach the various health and safety courses.

In Pennsylvania, a 45-hour course entitled "Integrated Surface Mining and Reclamation Techniques" funded by the U.S. Office of Education and developed by the Pennsylvania State University, with technical assistance from MESA and in coordination with representatives of the State, Environmental Protection Agency, the Bureau of Mines, and the Department of Health Education and Welfare is intended for use by surface mine operators to emphasize health and safety in stripping and reclamation.

TECHNICAL SUPPORT

The Technical Support Organization, headed by an assistant administrator of MESA, became operational in 1972 and is composed of three major centers: The Pittsburgh Technical Support Center, The Denver Technical Support Center and the Health and Safety Analysis Center. Technical support provides engineering consulting services to the mining industry on related health and safety problems. When these problems are complex, technical investigations are made, followed by recommendations for corrective action. Examples of the work performed by this agency include testing and approval of: electrical and diesel equipment for performance elimination of toxic exhaust gases, gas-testing devices and portable lights for use in explosive atmospheres. Other work includes: ventilation surveys, testing of machine cabs and rollbars to determine their reliability, electrical surveys of dusty areas, advice on explosives and blasting.

The Health and Safety Analysis Center collects and compiles accident statistics and then analyzes them to determine trends. When an upward trend in a certain category is found, all available reports on accidents in this category are studied to determine a possible cause. This particular approach to the prevention of accidents may well be a long sought after breakthrough in mine safety work.

SUMMARY

Health and Safety considerations at surface coal mines have received increased emphasis over recent years. Federal restrictions on noise and dust exposures for mine personnel have reduced some of the health hazards to miners. However, achievement of the 90 decibel noise limitation is proving to be very difficult and costly. Machines designed and purchased to meet the noise standard do not, and operators are immediately faced with the problem of revising new equipment.

Establishing a "Safety First" Policy in a coal surface mine is a difficult task. Safety conscious miners have shown that safe operations are not impossible, however, as the disabling injury rate has been steadily decreasing over the past several years. On the other hand, the fatal accident frequency has shown a marked increase for 1974 – a puzzling problem for safety engineers.

GENERAL INFORMATION

Equipment utilization in coal surface mining is changing constantly. With recent increases in coal demands and more stringent environmental controls, miners are experimenting with new machines and equipment applications to satisfy government regulations and increase productivity. During the 1960's the trend toward larger stripping machines was halted with erection of 220 cubic yard walking draglines and 200 cubic yard shovels. In recent years, manufacturers have concentrated on enlarging and refining related support equipment, including loading shovels, wheel front-end loaders, dozers, and haulage vehicles. Pan scrapers are frequently appearing in various mining operations for topsoil removal, coal loading, and hauling. Interchange of unit operational equipment and purchase of versatile machines has become common practice.

EQUIPMENT UTILIZATION

Basic unit operations of surface coal mining include topsoil removal (Table 2-6), overburden preparation (Table 2-8), overburden removal (Table 2-8), coal loading (Table 2-9), coal hauling (Table 2-10), regrading and backfilling (Table 2-11), and revegetation (Table 2-12). Throughout the country, these operations are practiced using wide variations in equipment applications. The tables that follow reveal these various applications, indicating several equipment considerations for different parameters of operation.

Unit operation descriptions of practiced mining techniques are included in Chapter 3. These characterizations outline advantages and disadvantages of alternative equipment choices in relation to characteristics of the particular region and mining technique under discussion.

To avoid repetition of numerical comparison data under unit operation discussions, tables comparing performance, design criteria, and operation of various equipment performing similar functions are presented here.

TABLE 2-6

EQUIPMENT RATING-TOPSOIL REMOVAL

LEGEND

1. Should be considered
2. May be considered
3. May be considered under certain conditions
4. May be considered special situation

A. High
B. Moderate
C. Low

		Dozers	Front-End Loaders	Scrapers			Dragline	Shovel & Truck	Bucket Wheel Excavator	Front-End Loader & Truck
				Elevating	Full-Power	With Push Tractor				
Topsoil Thickness	0-2'	1	1	1	1	1	3	–	–	1
	2'-5'	1	1	1	1	1	3	4	3	1
Haul Distance	0-300'	1	1	2	2	1	3	–	–	–
	300'-500'	2	2	1	1	1	4	–	3	–
	500'-1000'	–	–	1	1	1	–	4	–	3
	1000'-1500'	–	–	1	1	1	–	4	–	2
	1500'-5000'	–	–	2	2	2	–	4	–	1
Flexibility Under Varied Field Conditions	good	A	A	A	A	A	A	A	B	A
	fair	A	A	A	A	A	A	B	B	B
	poor	B	B	B	B	B	A	C	C	C

TABLE 2-7

EQUIPMENT RATING–OVERBURDEN PREPARATION

LEGEND 1. Should be considered 2. May be considered 3. May be considered under certain conditions 4. May be considered special situation A. High B. Moderate C. Low		Tractor–Ripper	Drills		
			Percussion	Rotary	Jet Piercing
Composition of Overburden	Very Consolidated	3	1	1	2
	Moderately Consolidated	1	1	1	1
	Slightly Consolidated	1	2	2	2
	Unconsolidated	1	4	4	4
Depth of Overburden	0–30'	1	1	1	1
	30'–60'	2	1	1	1
	60'–90'	3	1	1	1
	>90'	3	1	1	2
Mobility	-	A	A	A	B
Flexibility Under Varied Field Conditions	Good	A	A	A	A
	Fair	A	A	A	A
	Poor	A	A	A	B
Hardness of Rock	Very Hard	3	1	1	2
	Moderately Hard	2	1	1	1
	Soft	1	1	1	1

TABLE 2-8

EQUIPMENT RATING-OVERBURDEN REMOVAL

LEGEND 1. Should be considered 2. May be considered 3. May be considered under certain conditions 4. May be considered special situation A. High B. Moderate C. Low		Dragline	Shovel	Shovel & Truck Comb.	Front-End Loaders	Dozers	Front-End Loader & Truck Comb.	Bucket Wheel Excavator	Scrapers		
									Elevating	Full Power	With Push Tractor
Thickness	0-30'	2	1	1	1	1	1	1	1	1	1
	30'-60'	1	1	1	2	2	2	1	1	1	1
	60'-100'	1	1	2	3	3	3	2	2	2	2
	>100'	1	2	3	4	4	4	2	3	3	3
Characteristics	Poor Fragmentation (Blocky-Large Breakout Force)	3	1	1	3	1	3	-	-	-	-
	Moderately Blocky	2	1	1	2	1	2	-	2	2	2
	Good Fragmentation (Low Breakout Force)	1	1	1	1	1	1	3	1	1	1
	Unconsolidated	1	1	1	1	1	1	1	1	1	1
Transport Distance	50'-150'	1	1	-	1	1	-	2	-	-	-
	150'-300'	1	-	2	1	1	-	1	-	-	-
	300'-500'	2	-	1	2	2	3	1	3	3	3
	500'-1000'	-	-	1	-	-	1	-	1	1	1
	>1000'	-	-	1	-	-	1	-	1	1	1
Coal Seam Support Characteristics	Good (Hard)	1	1	1	1	1	1	1	1	1	1
	Moderate	1	2	2	1	1	1	2	1	1	1
	Poor (Soft)	1	4	4	2	2	2	4	1	1	1
Segregation Capability	-	A	C	A	A	B	A	A	A	A	A
Production Capability	-	A	A	B	A	A	B	A	A	A	A
Flexibility Under Varied Field Conditions	Good	A	A	A	A	A	A	B	A	A	A
	Fair	A	B	B	B	A	A	B	A	A	A
	Poor	A	C	C	C	B	B	C	B	B	B
Mobility	-	B	B	B	A	A	A	C	A	A	A

TABLE 2-9
EQUIPMENT RATING-COAL LOADING

LEGEND
1. Should be considered
2. May be considered
3. May be considered under certain conditions
4. May be considered special situation

A. High
B. Moderate
C. Low

		Shovels	(Rubber Tired) Front-End Loaders	High Lift (Tracks)	Backhoe	Scrapers: Self-Loading Full-Powered	Scrapers: Elevating	Scrapers: Under-Powered With Tractor	Bucket Wheel Excavator
Coal Seam Thickness	1'-3'	2	1	1	2	1	1	1	4
	3'-5'	1	1	1	3	1	1	1	3
	5'-10'	1	1	1	-	2	2	2	2
	10'-25'	1	2	2	-	3	3	3	1
	> 25'	1	3	3	-	4	4	4	1
Fragmentation or Ease of Digging	Soft or Highly Frag.	1	1	1	2	1	1	1	1
	Moderately Frag.	1	1	1	3	2	2	2	3
	Hard or Low Frag.	1	3	2	-	4	3	4	-
Floor Conditions	Very Soft	4	1	1	2	1	1	1	3
	Moderate	1	1	1	2	1	1	1	2
	Hard	1	1	1	2	1	1	1	1
Mobility	-	B	A	A	B	A	A	A	B
Flexibility Under Varied Field Conditions	Good	A	A	A	A	A	A	A	B
	Fair	B	B	B	A	A	A	A	B
	Poor	C	B	B	B	B	B	B	C
Production Requirements	High	1	1	3	3	1	1	1	2
	Medium	1	1	1	2	1	1	1	1
	Low	1	1	1	1	1	1	1	1

TABLE 2-10

EQUIPMENT RATING - COAL HAULING

LEGEND

1. Should be considered
2. May be considered
3. May be considered under certain conditions
4. May be considered special situation

A. High
B. Moderate
C. Low

		Trucks					Scrapers					
		Off Road			Highway							
		End Dump	Bottom Dump	Trailer End Dump	End Dump	Trailer End Dump	Full Power	Elevating	Under Powered W/Tractor	Conveyor	Train	Pipeline
Material	Rough-Blocky	1	–	1	1	1	–	–	–	–	1	–
	36 inch size	1	–	1	1	1	–	–	–	2	1	–
	24 inch size	1	2	1	1	1	1	1	1	1	1	–
	Fines	1	1	1	1	1	1	1	1	1	1	4
Length of Haul	300'-500'	1	2	2	2	2	2	2	2	4	–	4
	500'-1000'	1	1	1	1	1	1	1	1	4	–	4
	1000' - 1500'	1	1	1	1	1	1	1	1	4	–	4
	1500'-5000'	1	1	1	1	1	1	1	1	3	–	4
	5000'-10,000'	1	1	1	1	1	3	3	3	2	2	3
	10,000' - 15,000'	1	1	1	1	1	–	–	–	1	1	3
	>15,000'	1	1	1	1	1	–	–	–	1	1	2
Condition of Road	Good	1	1	1	1	1	1	1	1	–	–	–
	Wet, Soft	1	1	1	2	2	3	3	3	–	–	–
Type of Haulage Roads	Mine Roads Only	1	1	1	2	2	1	1	1	–	–	–
	Combination: Mine & Public	2	2	2	1	1	4	4	4	–	–	–
Daily Production Rate	High	1	1	1	1	1	1	1	1	1	1	4
	Medium	1	1	1	1	1	1	1	1	2	2	4
	Low	1	1	1	1	1	1	1	1	–	–	–
Flexibility Under Varied Conditions	Good	A	A	A	A	A	A	A	A	B	C	–
	Fair	A	A	A	A	A	A	A	A	B	C	–
	Poor	A	A	A	B	B	B	B	B	C	C	–
Maximum Adverse Grade	+3%	1	1	1	1	1	1	1	1	1	1	1
	+5%	1	2	2	1	2	1	2	2	1	2	1
	+10%	2	3	3	2	3	2	2	2	1	–	2
	+15%	3	–	–	3	–	2	3	3	1	–	2
	+20%	–	–	–	–	–	3	4	4	2	–	3
	>+20%	–	–	–	–	–	4	–	–	3	–	3

TABLE 2-11

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EQUIPMENT RATING - REGRADING AND BACKFILLING

LEGEND 1. Should be considered 2. May be considered 3. May be considered under certain conditions 4. May be considered special situation A. High B. Moderate C. Low		Dozers	Graders	Scrapers	Draglines	Front-End Loader	Front-End Loader & Trucks
Spoil Configuration	High Peaks	1	–	2	2	3	3
	Moderate Peaks	1	3	1	2	1	2
	Low Peaks	1	1	1	2	1	1
% Spoil Rehandled	> 75%	1	–	1	2	2	1
	75% – 50%	1	–	1	2	1	1
	50% – 25%	1	–	1	3	1	1
	< 25%	1	2	1	–	1	1
Transport Distance	50'–150'	1	2	1	2	1	–
	150'–300'	1	–	1	2	1	–
	300'–500'	2	–	1	–	2	4
	500'–1000'	–	–	1	–	–	1
	> 1000'	–	–	1	–	–	1
Final Surface Contour	Flat & Smooth	1	1	1	–	3	–
	Flat & Rough	1	2	1	2	2	–
	Steep & Smooth	1	–	–	–	3	–
	Steep & Rough	1	–	–	2	2	–

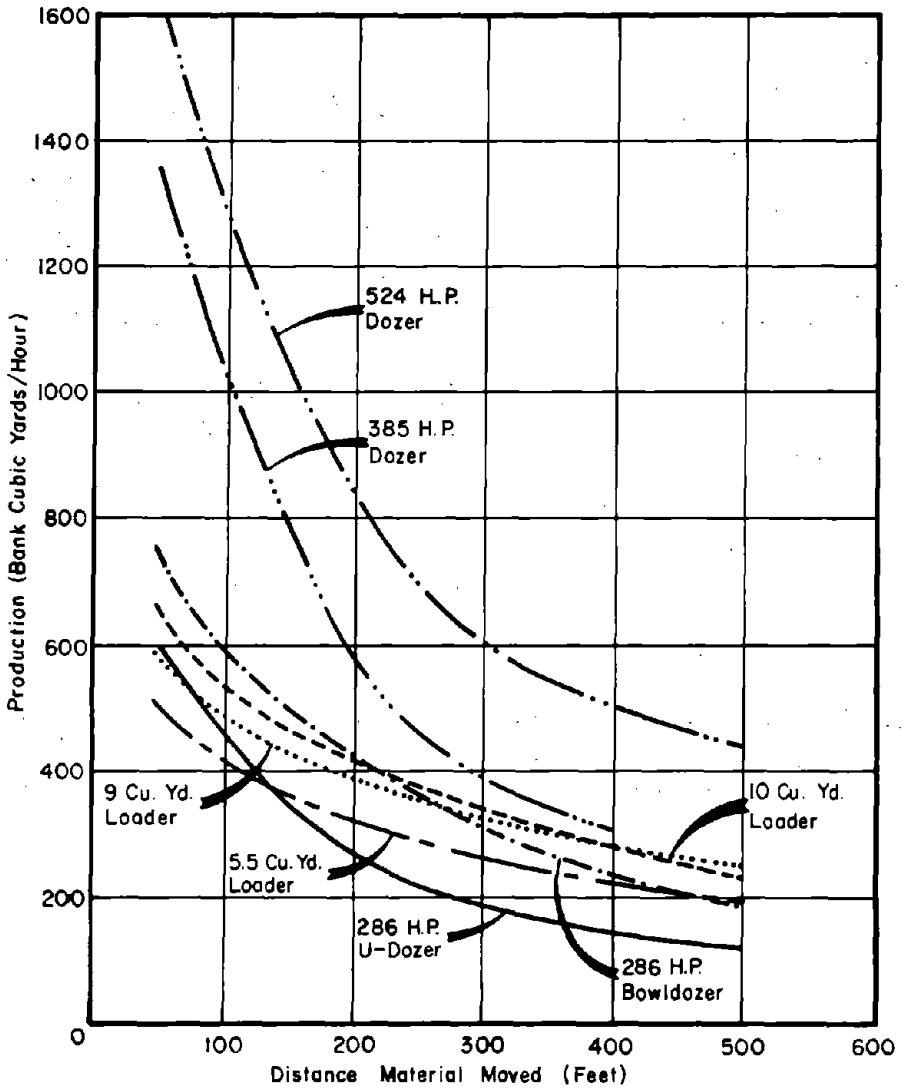
TABLE 2-12

EQUIPMENT RATING - REVEGETATION

LEGEND 1. Should be considered 2. May be considered 3. May be considered under certain conditions 4. May be considered special situation A. High B. Moderate C. Low		Airplane	Hydroseeder	Broadcast	Drill Seeding	Disc & Row Planting	Hand Planting or Spreading	Mulching Machine
Acreage	< 3	-	1	1	1	1	3	1
	3-10	-	1	1	1	1	4	1
	10-25	-	1	2	1	1	-	1
	25-50	3	1	2	2	2	-	1
	> 50	2	1	3	4	3	-	1
Seed Mixture	Grasses	1	1	1	1	3	3	-
	Crops	-	3	2	1	1	3	-
	Seedlings	-	-	-	-	1	2	-
Mulching	-	-	1	-	-	-	3	1
Fertilizer & Lime	-	1	1	3	1	1	3	-

Due to their high mobility and versatility, dozers - track and wheel, and front-end loaders are enjoying increased usage in the surface mining industry. Dozers and loaders can be used economically in almost any situation where material transport is required up to distances of about 500 feet. However, loaders are used in load and carry operations up to 1,000 feet.

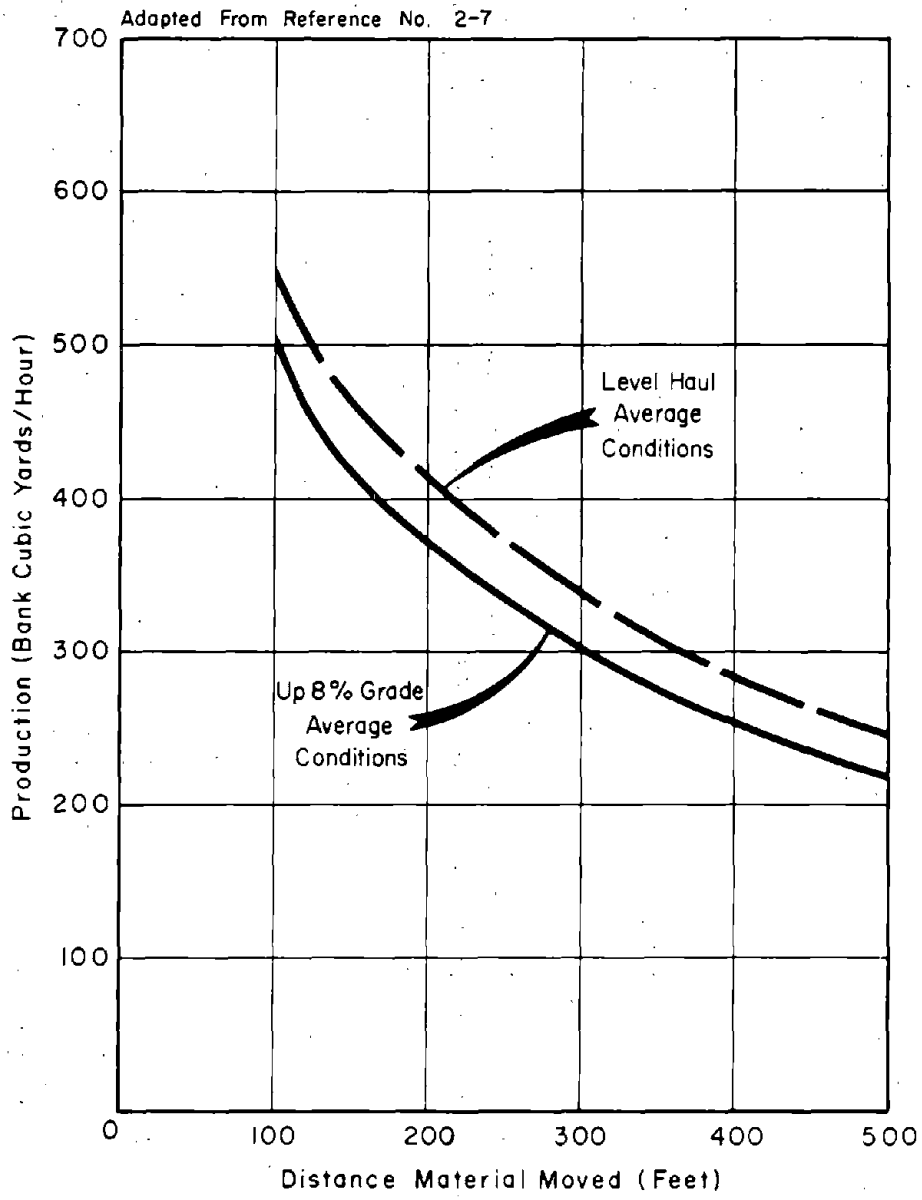
Figure 2-4 presents production comparisons of various sizes of dozers and loaders.



GENERALIZED PRODUCTION COMPARISON FRONT END LOADERS VS. BULLDOZERS

Figure 2-4

Figure 2-5 shows there is little difference in loader performance under average conditions for haul grades ranging from 0 to 8%.



EFFECT OF GRADE ON WHEEL LOADER STRIPPING PERFORMANCE

Figure 2-5

A major concern of front-end loader operation is the static tipping load (as this is the maximum transport load) (2). Table 2-13 presents major loader manufacturers and models with tipping load limitations.

TABLE 2-13

STATIC TIPPING LOAD LIMITATIONS FOR VARIOUS FRONT-END LOADERS

Loader Manufacturer	Model	Bucket Capacities (cu yd)	Static Tipping Load Straight Ahead (lbs)
TEREX	72-21	2 to 3	15,400
	72-21s	2 to 3	14,500
	72-31	2½ to 5	19,800
	72-31s	2½ to 5	19,200
	72-41	3 to 5	21,800
	72-51	3½ to 6	27,200
	72-71	6½ to 12	51,800
	72-81	9 to 18	75,800
TROJAN	1700	1 3/4	13,120
	1900	2	15,000
	2000	2½	19,380
	2500	3¼	24,960
	3000	3 3/4	28,650
	4000	4½	35,600
	6000	6	45,576
INTERNATIONAL HARVESTER	H-60B	1½ to 3½	13,200
	H-65C	2 to 4½	18,200
	H-80	3 to 6	22,000
	H-90E	3½ to 7	27,900
	H-100C	4¼ to 8½	35,000
	560	6½ to 12	54,000
	H-400B	10 to 20	81,000
MICHIGAN	35 AWS	1 to 2	7,500
	45B	1½ to 2	12,000
	55B	2 to 3½	14,950
	75B	2½ to 4	19,780
	85	3 to 5	24,200
	125	3½ to 6½	29,600
	175B	4½ to 6	34,730
	275B	6½ to 8	49,000
	475B	10 to 22	101,000
	675	24 to 36	165,000
CATERPILLAR	920	1½ to 1 3/4	12,000
	930	1 3/4 to 2¼	13,370
	950	2½ to 3½	16,750
	966C	3½ to 4½	23,000
	980B	4½ to 5½	32,580
	988	6 to 7	40,900
	**988	6 to 7	38,570
	992	10	81,900
ALLIS-CHALMERS	*545	2	13,050
	*605	2½	15,900
	*645	3	19,200
	745	4	26,200
	745H	4½	30,920

Adapted From Reference No. 2-2

* Series B
** Cushion Track

Rubber tired and/or track mounted dozers are essential elements of any surface mining venture. Horsepower, weight, and capacity are important considerations for dozer applications. Table 2-14 presents these characteristics for both dozer types.

TABLE 2-14

CHARACTERISTICS OF RUBBER TIRED AND TRACK TYPE DOZERS

Dozer Type	Horsepower	Approx. Weight (Dozer Only) Tons	Capacity Loose Cubic Yards/Hour
Track	180	18.2	458
	270	29	628
	385	40	889
	524	65	2100
Rubber Tired	300	32	366
	400	41	562

Adapted From Reference No. 2-11

Track type dozers are being challenged by their up and coming rubber-tired counterpart. However, some applications will still remain the duty of track machines. Table 2-15 shows comparative dozer applications.

TABLE 2-15

BULLDOZER SELECTION CHART FOR RIPPING AND DOZING APPLICATIONS

Job	Ground Condition	Rubber Tired Dozers			Track Dozers			Remarks
		Small	Medium	Large	Small	Medium	Large	
Clean up Around Small Shovel	Friable	X			X			No Ripping
			X					Minimum Ripping
	Hard Friable					X		Hard Ripping
		X			X			No Ripping
			X			X		Medium Ripping
				X		X		Hard Ripping
	Hard Jagged				X			No Ripping
						X		Medium Ripping
							X	Hard Ripping
Clean up Around Large Shovel	Friable		X					No Ripping
			X					Minimum Ripping
			X			X		Medium Ripping
	Hard Friable		X					No Ripping
			X			X		Medium Ripping
				X		X		Hard Ripping
	Hard Jagged					X		No Ripping
						X		Medium Ripping
							X	Hard Ripping
Waste Dump Dozing Capabilities	Friable and Hard Friable	X						9 (26 Ton Trucks)
			X					32 (59 Ton Trucks)
				X				> 32 (50 Ton Trucks)
	Hard Jagged				X			9 (26 Ton Trucks)
						X		32 (59 Ton Trucks)
	Wet Muddy				X			90 to 180 Tons/Hour
						X		270 to 720 Tons/Hour
							X	> 720 Tons/Hour

Adapted From Reference No. 2-11

Stripping; Draglines - Shovels

The merits of dragline vs. shovel have been debated for many years, with neither machine "winning". In recent years however, dragline construction has surpassed shovel construction. Each new mine must be evaluated according to its own particular needs, and equipment designed accordingly.

Major manufacturers of shovel and draglines are presented in Table 2-17. The Table lists the boom and dipper capacities for each model.

Estimations of shovel and dragline output can be calculated using the criteria set forth by Henry Rumfelt, "Computer Method for Estimating Proper Machinery Mass for Stripping Overburden," Mining Eng. Vol. 13, May 1961: Table 2-16 shows the estimated output of a shovel and a dragline using the criteria.

TABLE 2-16

ESTIMATED SHOVEL OUTPUT (AMO)

Dipper Size (cu yd)	D
Dipper Factor	80%
Dipper Load, (cu yd) bank measure	0.8D
Cycle Time (sec)	56
Passes per hour	64
Theoretical hourly output (cu yd) bank measure	51D
Scheduled monthly hours of operation	720
Theoretical monthly output (cu yd), bank measure	36,800D
Monthly expected operating factor	85%
Expected actual output (AMO) per month (cu yd) bank measure	31,200D

TABLE 2-16 (cont'd.)

ESTIMATED DRAGLINE OUTPUT (AMO)

Bucket Size (cu yd)	B
Bucket Factor	80 %
Bucket Load (cu yd), bank measure	0.8 B
Cycle Time (sec)	58
Passes per hour	62
Theoretical hourly output (cu yd) bank measure	49.5 B
Scheduled monthly hours of work	720
Theoretical monthly output(cu yd) bank measure	35,800B
Monthly expected operating factor	85%
Expected actual output(AMO)per month(cu yd) bank measure	30,400B

SHOVEL-TRUCK COMBINATIONS

Shovel-truck combinations are becoming more popular due to select placement of overburden in eastern mines and haulage of overburden in western open pit mines. Optimum shovel-truck combinations are presented in Figure 2-6. These combinations also apply to coal loading and hauling.

Stripping Scrapers & Dragline

Wheel tractor scrapers are becoming more economically comparable with draglines for overburden removal due to improvements in scraper design and capabilities. The three general types of scrapers are elevating, conventional and tandem-powered. Basic evaluations are:

Conventional - The single engine conventional unit is the most versatile of the three types for the widest range of conditions. Its operating costs are generally lower than the other two types and when haul conditions do not include steep grades, high rolling resistance or poor underfoot conditions, it is the most economical unit.

Elevating - The primary applications of elevating scrapers are on short to medium length, level haul roads with low to medium rolling resistance. Its flexibility and ability to work without the aid of a pusher unit make it especially applicable in mines where production requirements call for a limited number of scrapers in a given area. Its "work-along" capability also eliminates the possibilities of scraper pusher mismatch and bunching of scrapers and pushers.

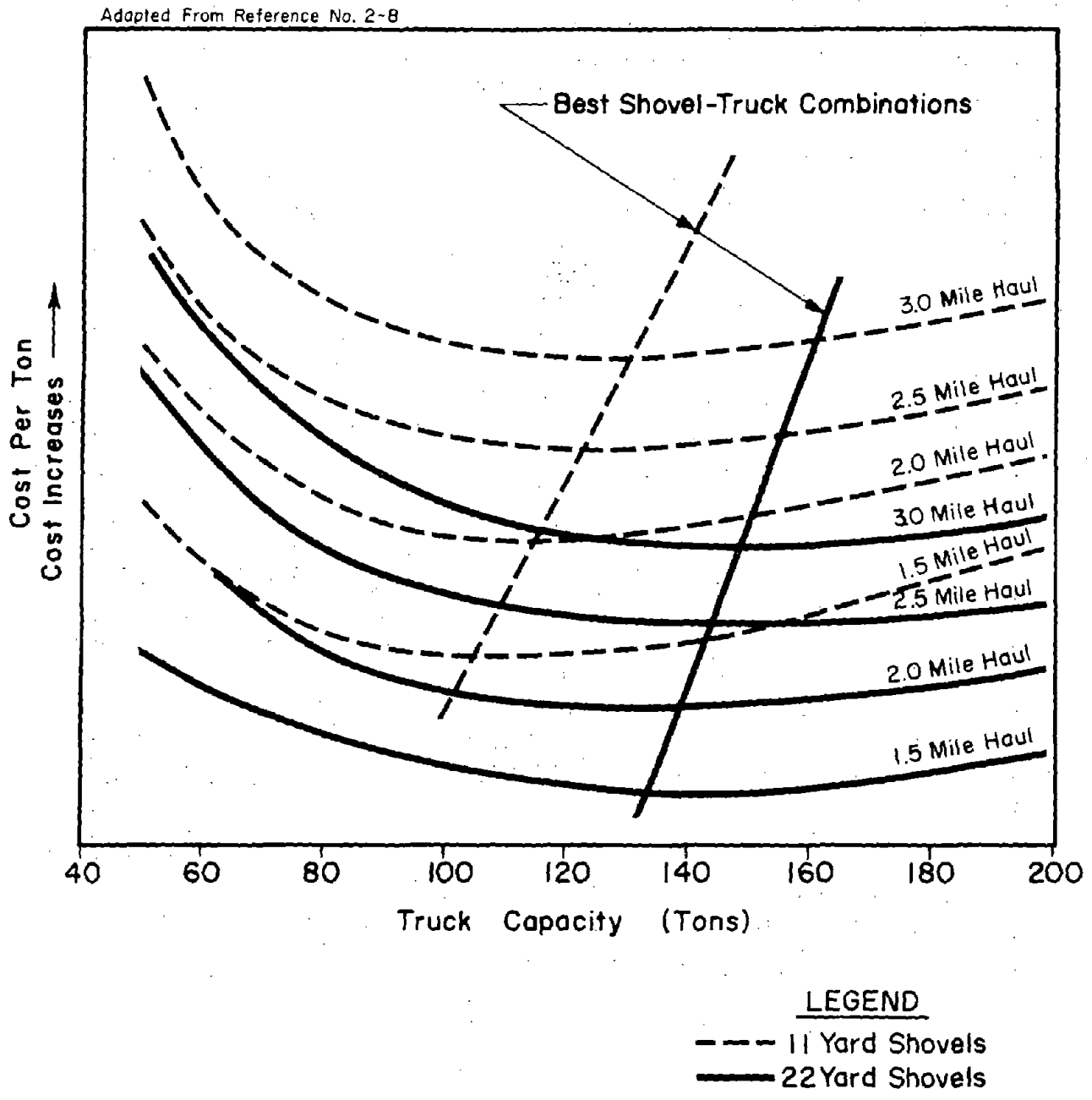
TABLE 2-17

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CHARACTERISTICS FOR VARIOUS SHOVELS AND DRAGLINES

Manufacturer	SHOVELS			DRAGLINES		
	Model	Boom Length (ft)	Dipper Capacities (cu. yd.)	Model	Boom Length (ft)	Dipper Capacities (cu. yd)
Harnischfeger P & H	1400	32	4½ to 5			
	1400 DE	32	4½ to 6			
	1500	35	5 to 7			
	1500 DE	35	5 to 7			
	1600	35	6 to 14			
	1600 DE	35	6 to 14			
	1900 AL	40	11 to 18			
	1900 CL	46	16			
	2100 B	44	12 to 20			
	2100 BL	44	13 to 25			
	2300	50	18 to 30			
	2800	55	20 to 40			
Bucyrus-Erie	110-B	36	4 to 10	480-W	175	18
	150-B	37½	4½ to 12	800-W	195	27
	190-B	41½	6½ to 14	1260-W	235	40
	195-B	41½	8 to 17	1300-W	260	45
	280-B	50	10 to 20	1350-W	285	50
	295-B	50	15 to 25	1370-W	285	60
	550-B	95	16 to 17	1500-W	285	65
	950-B	95	22	1570-W	285	75
	1050-B	123 to 180	26 to 45	2560-W	275	90
	1650-B	135	70	2570-W	310	110
	1850-B	150	90	4250-W	310	220
	1950-B	170 to 200	105 to 130			
	3850-B	200 to 210	115 to 140			
Manitawoc	4600 (standard)	44	7	4600	90 to 140	15 to 18
	4600 (hi-lift)	72	5	3900	70 to 100	6 to 10
Marion	111-M	32 to 35	3½ to 8	7400	160 to 235	9 to 14
	151-M	38 to 60	7 to 12	7500	180 to 260	10 to 20
	181-M	45½ to 57	8 to 16	7620	200 to 300	20 to 35
	184-M	45 to 70	7 to 18	7820	225 to 300	35 to 45
	185-M	42 to 57	11 to 20	7920	225 to 325	40 to 60
	192-M	51 to 66	12 to 26	8000	250 to 325	45 to 65
	251-M	52	20 to 35	8050	250 to 325	50 to 70
	5761	170	75	8200	250 to 325	60 to 75
	5860	180	80	8400	275 to 350	60 to 80
	5861	200	90	8750	275 to 350	80 to 115
	5900	210	105	8850	275 to 350	110 to 140
	5960	190	150	8950	275 to 350	140 to 160
Page				736	200	20
				740	210	30
				752	225	45
				752 LR	265	40
				757	285	54
				857	255	50
				762	300	54
				862	300	68

Adapted From Reference No. 2-2



OPTIMUM SHOVEL-TRUCK COMBINATIONS

Figure 2-6

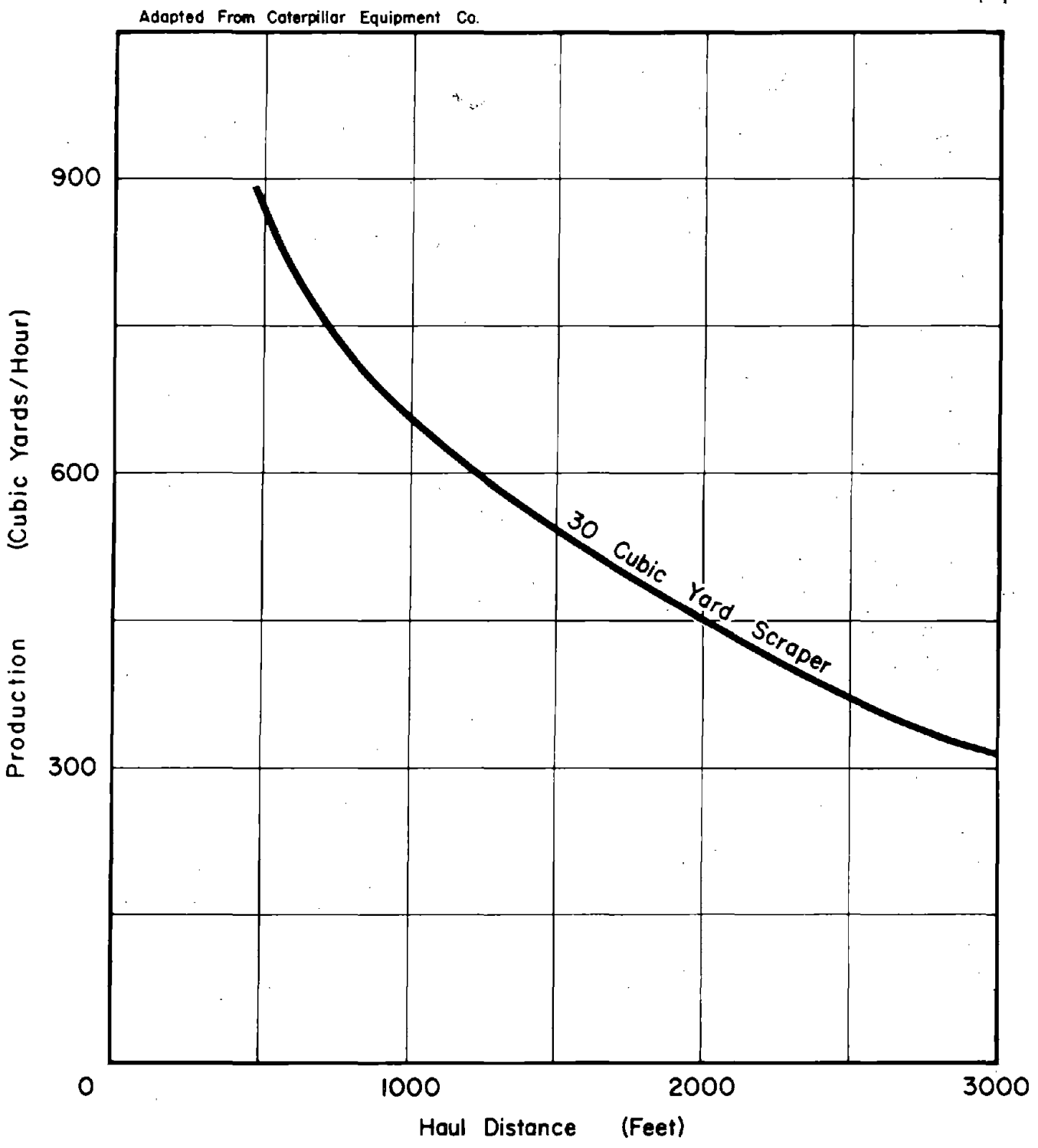
Tandem-Powered - The twin engine scraper's advantages of improved weight to horsepower ratio, tractor, traction and retarding ability are especially important under adverse conditions. The push-pull concept incorporates two tandem-powered scrapers equipped with push blocks and a special hook and bail arrangement. With this system, the second scraper push loads the lead scraper, which, when loaded, pulls the second unit through its loading cycle. The push-pulls retain all the advantages of tandem-powered scrapers, but avoid the possibilities of pusher-scraper mismatch and bunching since no push-tractor is needed. When necessary the push-pull can work independently as the standard tandem-powered scraper.

By contrast, the traditional use of the dragline has its own advantages. For instance, they can sometimes lower the cost of stripping overburden on large, long-life properties. With continuous years of high usage they can handle rock as well as dirt, and can stack overburden high at relatively little extra cost. The dragline, however, has its disadvantages: it is expensive, difficult to move, has a limited casting range, and requires support equipment for benching, clean-up and rehandling. It represents a sizable capital investment that easily reaches into millions of dollars. In addition, efficient dragline operation usually requires blasting.

Table 2-18 shows the average comparison of three general system types using scrapers, dragline, and dragline-scraper combination.

This table reveals scrapers or scraper-dragline combinations are relatively more efficient than dragline systems. Costs are based on overburden removal, loading and hauling only.

Figure 2-7 shows the average production capacities of a 30 cubic yard scraper, based on haul distances. Production efficiency is the highest for haul distances ranging from 500 feet to 1,500 feet. For haul distances less than 500 feet, scrapers become very inefficient due to congestion.



PRODUCTION CAPACITY - SCRAPER

Figure 2-7

TABLE 2-18

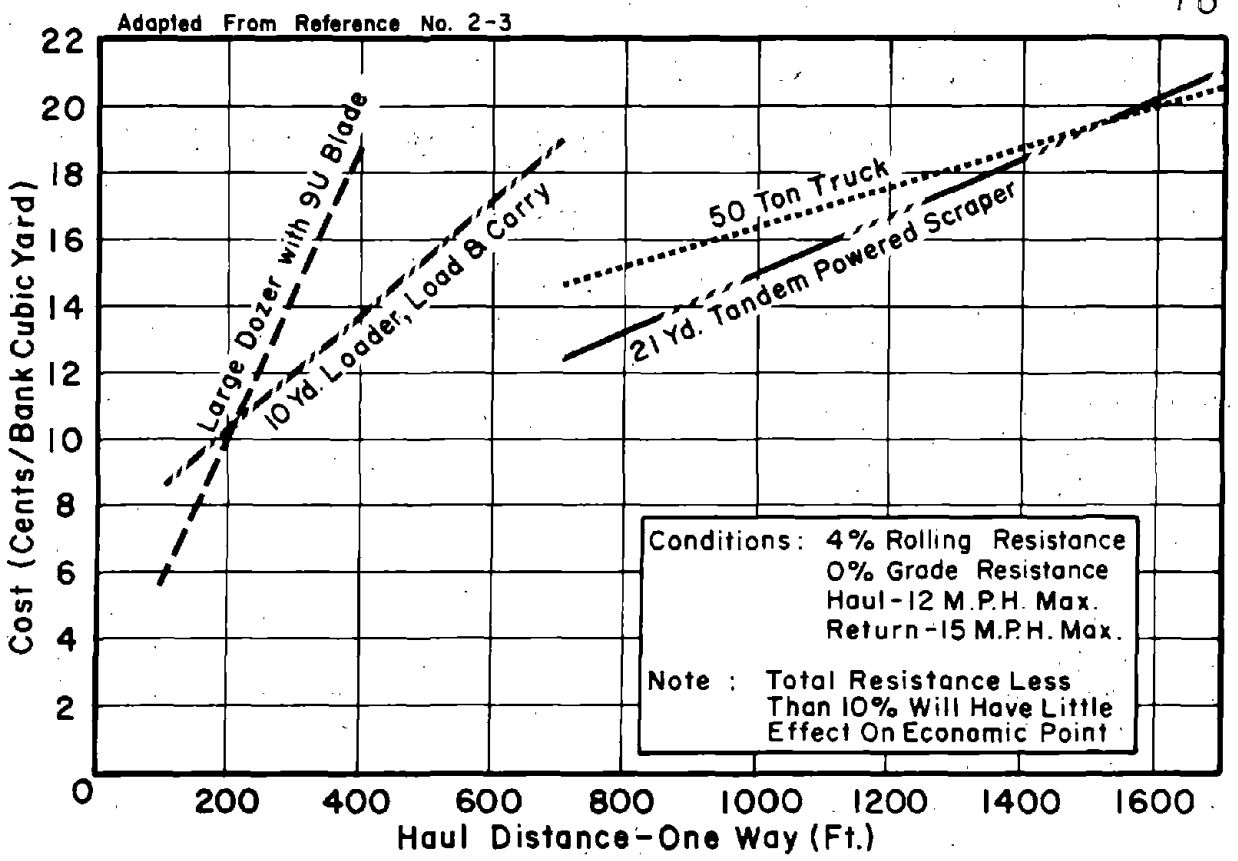
COST COMPARISON-SCRAPERS AND DRAGLINES				
Description	Scrapers			Dragline
	Elevating	Conventional W/2 Push Tractors	Push Pull	
Average Cost/BCY 70' Cut Working Alone	$ 0.086	$ 0.100	$ 0.087	$ 0.140 $ 0.180
Average Cost/BCY 120' Cut Working In Combination With Scrapers Removing Top 1/3 Of Overburden	$ 0.105	$ 0.110	$ 0.105	$ 0.140 to $ 0.180

HAULAGE

The major factor affecting hauling equipment cost is haulage distance. Figure 2-8 represents a general comparison of four major equipment types.

Analysis of Figure 2-8 shows that dozers and loaders are only economical for haulage distances ranging from 100 to 200 feet, and 200 and 500 feet, respectively. Haulage distances greater than 500 feet cause the cost per cubic yard for dozers and loaders to increase rapidly.

As haulage distances increase to 700 feet and higher, use of trucks or scrapers become more economical. Comparatively speaking, the cost of using scrapers is less for distances of 700 to 1,300 feet. Costs for trucks and scrapers are relatively the same for distances greater than 1,300 feet.



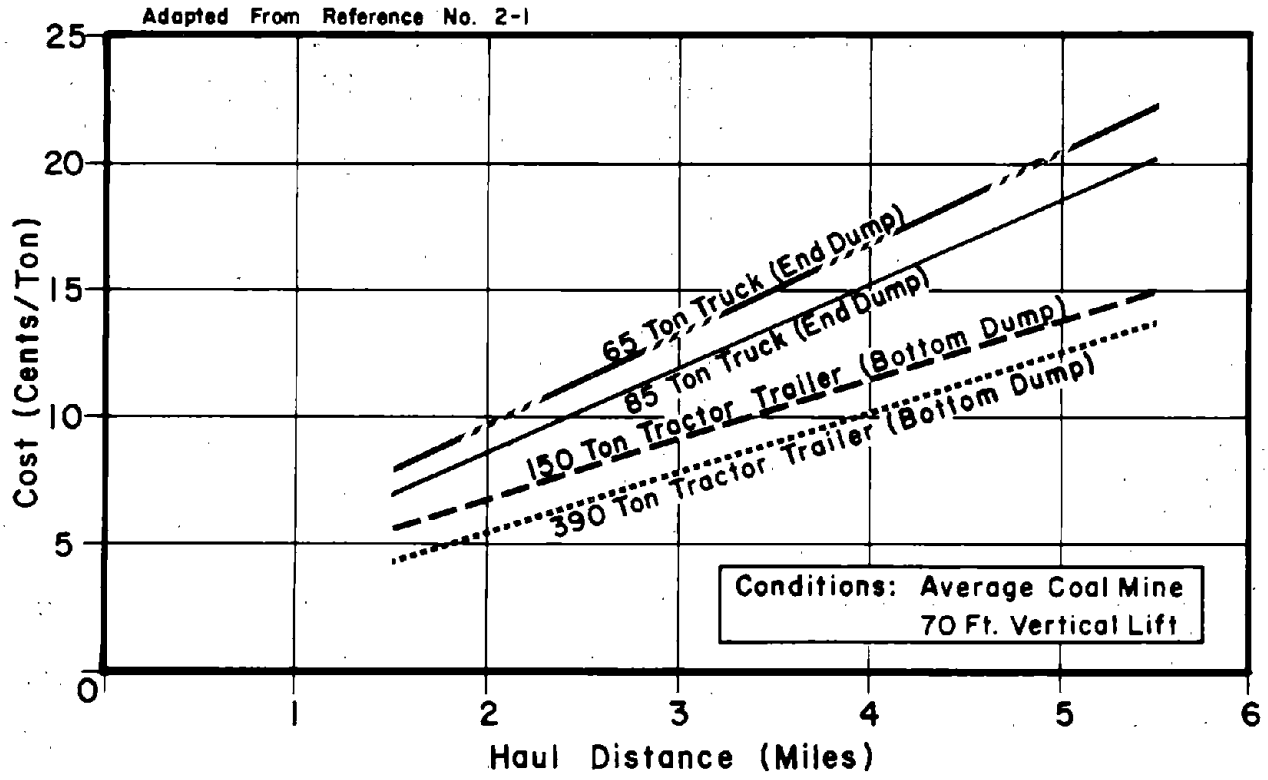
LOADING & HAULAGE COSTS OF REPRESENTATIVE EQUIPMENT

Figure 2-8

The relative operating cost difference per cubic yard between truck sizes does not change much with haul distance, as shown in Figure 2-9.

The differences in cost are related more to type than to size. The haulage cost for two-axle rear dumps, however, increases faster with haul distance when compared to tractor-trailers. The different cost rate change is due to faster increasing tire cost with distance for two-axle trucks.

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INFLUENCE OF DISTANCE ON TRUCK HAULAGE

Figure 2-9

EQUIPMENT MANUFACTURERS

Renewed national interest in coal mining will hopefully encourage new companies to enter the field of mining equipment manufacturing. Table 2-19 is a partial list of established manufacturers of surface coal mining equipment. The list indicates major types of mining equipment available through each company.

TABLE 2-19

MANUFACTURERS OF SURFACE COAL MINING EQUIPMENT

Manufacturing Company	Location City — State	Bucket - Wheel Excavators	Drilling Equipment	Bulldozers	Draglines	Loaders	Scrapers	Shovels	Trucks	Augers
Allis Chalmers	Milwaukee, Wisconsin			X		X	X			
American Hoist and Derrick Company	St. Paul, Minnesota				X	X				
American Poclain Corporation	Piscataway, New Jersey					X				
American Standard Company - WABCO	Peoria, Illinois						X		X	
Barber - Green Company	Aurora, Illinois					X				
Bucyrus Erie Company	South Milwaukee, Wisconsin	X	X		X			X		
J. I. Case Company	Racine, Wisconsin			X		X				
Caterpillar Tractor Co.	Peoria, Illinois			X		X	X		X	
Clark Equipment Company	Benton Harbor, Michigan			X	X	X	X	X		
Dart Truck						X			X	
Davey Compressor Co.	Kent, Ohio		X							
Eaton Corporation	Cleveland, Ohio					X				
Euclid, Incorporated	Cleveland, Ohio								X	
Gardner-Denver Company	Dallas, Texas		X							
General Motors Corp. - Terex Division	Hudson, Ohio			X		X	X		X	

TABLE 2-19 CONTD.

MANUFACTURERS OF SURFACE COAL MINING EQUIPMENT										
Manufacturing Company	Location City — State	Bucket – Wheel Excavators	Drilling Equipment	Bulldozers	Draglines	Loaders	Scrapers	Shovels	Trucks	Augers
Harnischfeger Corporation	Milwaukee, Wisconsin							X		
Ingersoll Rand Company	Philipsburg, New Jersey		X							
Insley Manufacturing Corporation	Indianapolis, Indiana					X				
International Harvester Co.	Chicago, Illinois			X		X			X	
ISCO Manufacturing Co.	Kansas City, Missouri								X	
John Deere	Moline, Illinois			X		X	X			
Joy Manufacturing Co.	Pittsburgh, Pennsylvania		X							
Mack Trucks Incorporated	Allentown, Pennsylvania								X	
Manitowoc Engineering Co.	Manitowoc, Wisconsin				X			X		
Marathon Letourneau Co.	Longview, Texas					X				
Marion Power Shovel Company, Incorporated	Marion, Ohio		X		X	X		X		
Massey-Ferguson Industrial and Machinery Company	Akron, Ohio			X		X				
McDowell-Wellman Engineering Company	Cleveland, Ohio					X				
Mobil Drilling Company, Incorporated	Indianapolis, Indiana		X							
Northwest Engineering Co.	Green Bay, Wisconsin				X			X		

TABLE 2-19 CONTD.

MANUFACTURERS OF SURFACE COAL MINING EQUIPMENT										
Manufacturing Company	Location City — State	Bucket - Wheel Excavators	Drilling Equipment	Bulldozers	Draglines	Loaders	Scrapers	Shovels	Trucks	Augers
Owatonna Manufacturing Company	Owatonna, Minnesota					X				
Page Engineering Company	Chicago, Illinois				X			X		
Salem Tool Company	Salem, Ohio									X
Sanderson Cyclone Drill Company	Orrville, Ohio		X							
W. J. Savage Company	Knoxville, Tennessee					X				
Schramm, Incorporated	West Chester, Pennsylvania		X			X				
Smith International Incorporated	Newport Beach, California		X							
Sperry - New Holland	New Holland, Pennsylvania					X				
Unit Rig and Equipment Company	Tulsa, Oklahoma								X	
V. C. Industries Incorporated	Cleveland, Ohio					X				

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CHAPTER 3

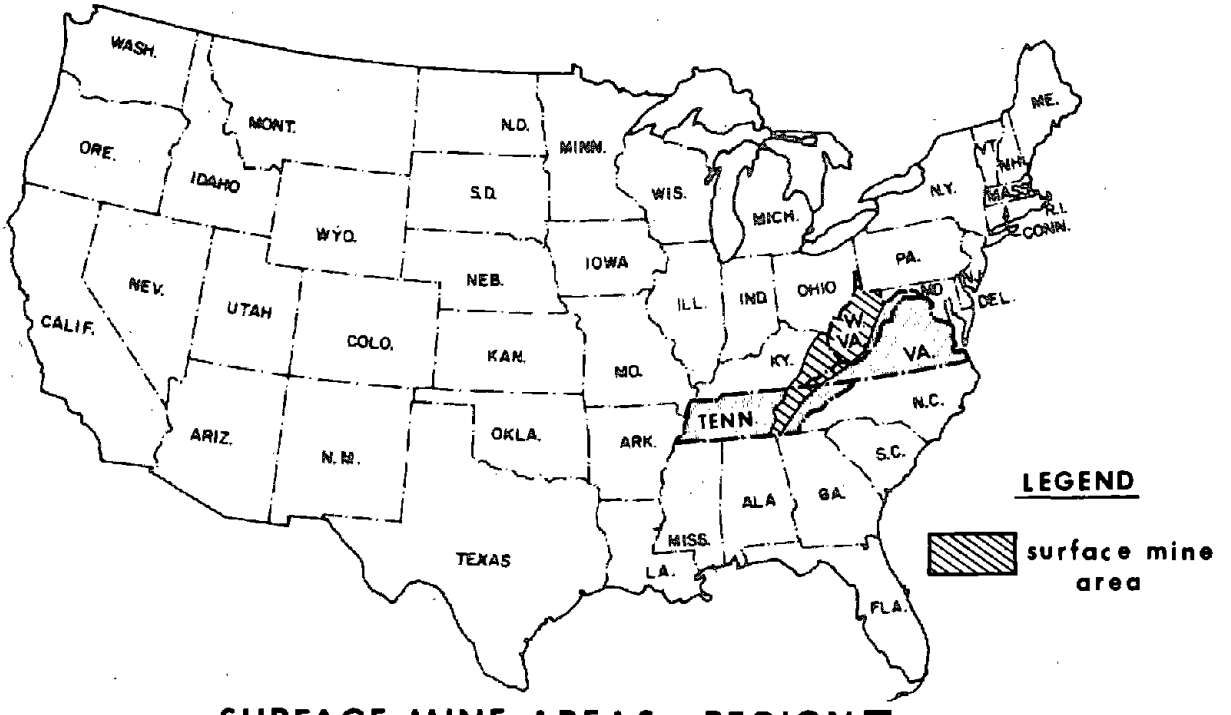
CHARACTERIZE GEOGRAPHIC REGIONS AND TYPES OF MINING



REGION I

CHARACTERISTICS

Region I encompasses eastern Kentucky, Tennessee, Virginia and West Virginia, the central core of the Appalachian Coal Basin.



SURFACE MINE AREAS - REGION I

Figure 3-1

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This bituminous coal region is a major, elongated depositional basin containing a series of local, parallel, northeast-southwest trending synclinal basins, occasionally offset by faulting. Erosion of sedimentary strata by dissecting streams has produced a series of steeply sloping valleys and ridges. The greatest differences in altitude occur closest to the long axis of the basin, with valley and ridge gradients generally decreasing along the basin's short axis as the topography grades into rolling hills. Higher quality soils are found in the well drained, moderately sloping areas of this extensive woodlands region.

Coal bearing strata is thickest along the eastern margin of the Appalachian Basin, becoming progressively thinner to the west. Overburden consists of shales and blocky sandstones, many of which are acidic in the northern portions of the basin. Field investigators found that surface miners strip an average 55 feet of overburden, ranging from zero outcrop up to a maximum of 100 feet during mining.

Many thinly bedded coals exist in this region, reflecting a static depostional environment. Their distribution was controlled by a wide variety of local structural and erosional conditions; therefore, occurrences and qualities of these seams are also variable. The exception is the Pittsburgh seam, a highly persistent, medium sulfur and ash coal. It underlies approximately 6000 square miles of the North Central Appalachian Basin, and consistently averages approximately 6 feet in thickness. Although the higher quality coals generally occur southeast of West Virginia's NE-SW trending hinge lines, the Pittsburgh, found NW of the hinge line, is one of the Nation's most valuable resources. Coals from all four of eastern Kentucky's reserve districts are of high quality, averaging 12,900 - 13,900 BTU, 3.9 - 7.4% ash and 0.65 - 1.0% sulfur (11). However, seam thicknesses are variable, and most of the important seams contain shale partings. Analyses of coals from Tennessee's two main coal fields range from 10,980 - 14,380 BTU, 1.2 - 19.0% ash, and 0.5 - 6.8% sulfur. Many of these coals are hard and blocky and contain partings. Good coking coals can be found here as well as in Virginia's only important coal producing region, the Southwest Virginia Field. Ash values of coals from the Southwest Virginia Field are usually below 8%, but can range from 1.2 - 19.4%, with heat values ranging from 12,320 - 15,000 BTU, and sulfur content ranging from 0.3 - 3.7% (see Coal Chart Table 3-1).

Climatic conditions vary most in the State of Virginia where both

maritime and continental conditions exist. Climate of the Southwest Virginia Field is similar to eastern Kentucky and eastern Tennessee. Southwest Virginia experiences a mean annual precipitation of 42 to 48 inches and a mean annual temperature of 54°F in this sharp ridge - deep valley area. Heaviest precipitation falls during the summer months, causing flash flooding and landslide threats. The same dangers exist in the mountain regions of eastern Kentucky where a 3 inch storm rainfall is common and occasionally, 6 inches of rain can fall in a 24 hour period. Mean annual precipitation varies from 50 inches in the south to 36 inches in the north, with mean annual temperatures varying accordingly, 59°F in the south to 54°F to the north.

A drop in temperature of 3° F per 1000 feet ascent in altitude is experienced in Tennessee, where up to 5000 feet differences in altitude can be encountered. Mean annual temperature varies from 62°F in the southwestern part of the state to 45°F in the eastern mountains. Moist air from the Gulf of Mexico distributes 48 to 56 inches of precipitation annually over most of Tennessee, the exception being an annual 76 inches of precipitation in parts of the southeast.

Greatest seasonal variations in Region I occur in the state of West Virginia. Average minimum winter temperatures range from 20°F in the central and northeast mountains to 30°F in the southern regions. The average summer temperature is 85°F except in the mountain areas, which are 5 - 10°F cooler. West Virginia's mean annual precipitation is also variable, with 50 to 60 inches of moisture falling in the central regions, 40 inches in the western regions, 30 inches in the east-central region, and 40 inches to the extreme east.

BASIC MINING METHODS ENCOUNTERED

Conventional Contour Strip Mining

Region I has been characterized throughout the years by its widespread use of contour strip mining in hilly or rolling country. In contour stripping, an initial cut is established along a hillside at the point where the coal is exposed or outcrops. Successive cuts are then made into the hill, discontinuing the operation at a specific stripping ratio,

TABLE 3-1

REGION I

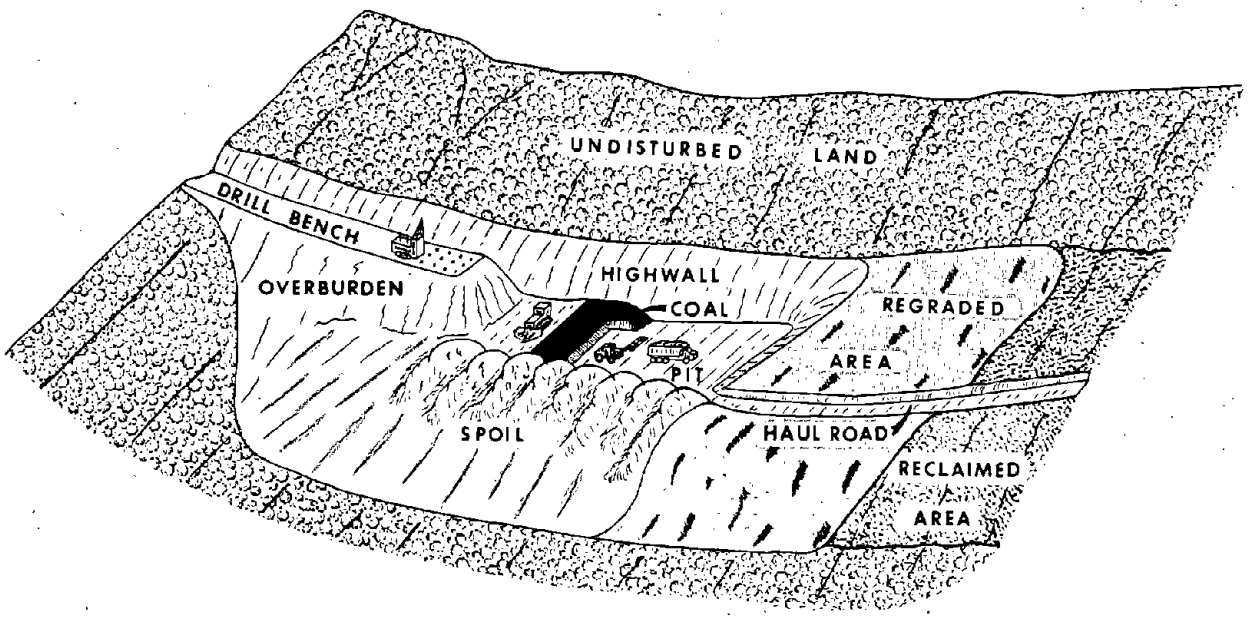
STATE	COAL BEARING AREAS	RANK	B.T.U. (X 1000)	ASH (%)	SULFUR (%)	MOISTURE (%)
E. Ky.	Hazard Reserve District	Bituminous	13.1 - 13.8	3.5 - 6.5	0.6 - 0.9	2.1 - 4.8
	Upper Cumberland River Reserve District	Bituminous	13.2 - 14.2	3.9 - 6.0	0.7 - 0.9	3.5 - 4.8
	Big Sandy Reserve District	Bituminous	12.3 - 13.9	3.9 - 11.0	0.6 - 1.3	3.6 - 7.3
	South Western Reserve District	Bituminous	13.2 - 13.9	4.4 - 6.0	0.7 - 0.8	3.5 - 4.8
Tenn.	Northern Field	Bituminous	11.7 - 14.4	1.2 - 18.2	0.6 - 4.8	0.8 - 7.4
	Southern Field	Bituminous	11.0 - 14.3	4.0 - 19.0	0.5 - 6.8	1.4 - 5.1
Va.	Southwest Virginia Field	Bituminous	12.3 - 15.0	Usually Below 8% 1.2 - 19.4	0.3 - 3.7	0.9 - 5.5
	Valley Fields	Semi-bituminous to Semi-anthracite	11.2 - 12.5	12.8 - 26.3	0.4 - 1.6	0.7 - 4.8
	Richmond Basin	Bituminous to Semi-anthracite	-	-	-	-
W. Va.	Northern Field	Bituminous	10.8 - 15.0	7.0 - 14.0	1.1 - 3.0	-
	Southern Field	Bituminous	12.0 - 15.6	4.0 - 14.0	0.5 - 1.5	-

TABLE 3-1

COAL CHARACTERISTICS

GEOLOGIC CHARACTERISTICS
Variable Seam Thicknesses, Contains Partings.
Fault Zone - Variable Seam Thicknesses, Contains Partings.
Highly Variable Seam Thicknesses, Contains Partings. Some Cannel Coal.
Scattered Irregular Shale Partings In Coal Seams.
Coals Hard & Blocky, Clay & Shale Partings, Cannel Coal Rider, Some Coking Coal.
Coals Generally 3-4' Thick - Approaches 120' Thick When Squeezed in Faulted Areas.
Coals Vary From Hard Splint To Soft Friable Coal. Good Coking Coals.
Seams Generally Thin and Unminable, But Some Reach 4 feet or More in Thickness.
Synclinal Basin Cut by Faults - Coking Coals; Some Coals Altered to Natural Coke (Anthracite) by Dike Intrusions.
Thin Persistent Seams, Pittsburgh Seam Has By Far The Greatest Production.
Number and Thicknesses of Coals Increase Southeasterly From NE - SW Trending Hinge Line Through The State.

the point where it is no longer economically feasible to further remove overburden. This stripping ratio compares overburden thickness to coal thickness, with the limit being determined in most instances by physical limitations of excavating equipment. Depending on thickness, continuity, slope and quality of the coal seam, type and conditions of overburden encountered, size of mine area, and return per ton of coal mined, this ratio can be as high as 30:1 and still provide a profitable operation using this mining technique.



TYPICAL CONTOUR STRIP METHOD

Figure 3-2

Contour stripping produces a long, sinuous band of strip mined land around an entire hillside. This band is characterized by a bench or shelf on the hillside where the coal has been removed, bordered on the inside by a highwall and downslope by piles of spoil material (See Figure 3-2). Prior to recent enactment of strict environmental mining regulations in West Virginia and Kentucky, much of this spoil material remained on the natural slope below the bench, creating severe erosion and landslide conditions. This material, indiscriminately cast over the bench, resulted in high quality overburden being covered with low quality and often toxic material, which when exposed to air and water would produce severe acid mine drainage pollution. Since resultant outslope material was not conducive to the growth of cover crops, further erosion problems ensued. Due to this method of overburden disposal, aesthetically displeasing and structurally unstable highwalls were also left to erode and cause subsequent pollution problems. However, with recent legislation prohibiting the storage of spoil material on the downslope this mining method will have no future utilization. It is included in this discussion for background and basic information only.

Unit Operations

Contour stripping primarily utilizes the unit operations of Clearing and Grubbing, Overburden Preparation, Overburden Removal, Coal Loading, Coal Hauling, Augering, Regrading and Backfilling, and Revegetation. A description of these operations follows.

Clearing and Grubbing

The proposed affected area is usually cleared of vegetative cover by timbering and/or by removal with a dozer. Dozers push this material downslope to the projected toe of the spoil pile to create a brush dam which helps to stabilize the spoil bank and filter sediments. This unit operation is not always necessary, and in some instances is eliminated, wherein all vegetative material is simply buried in the spoil during overburden removal.

Overburden Preparation

This is accomplished by two methods when necessary - drilling and blasting, and ripping. Drilling and blasting requires drill benches to be established first by a dozer. Mobile, truck mounted or crawler mounted, vertical drills are used to prepare seven to ten inch holes for blasting. The drill pattern varies, according to the type and depth of overburden and is usually over designed, so that "shooting" will throw material off the bench. To avoid excessive costs of dynamite and other explosives, most miners use ANFO (Ammonium Nitrate-Fuel Oil) as the primary blasting component.

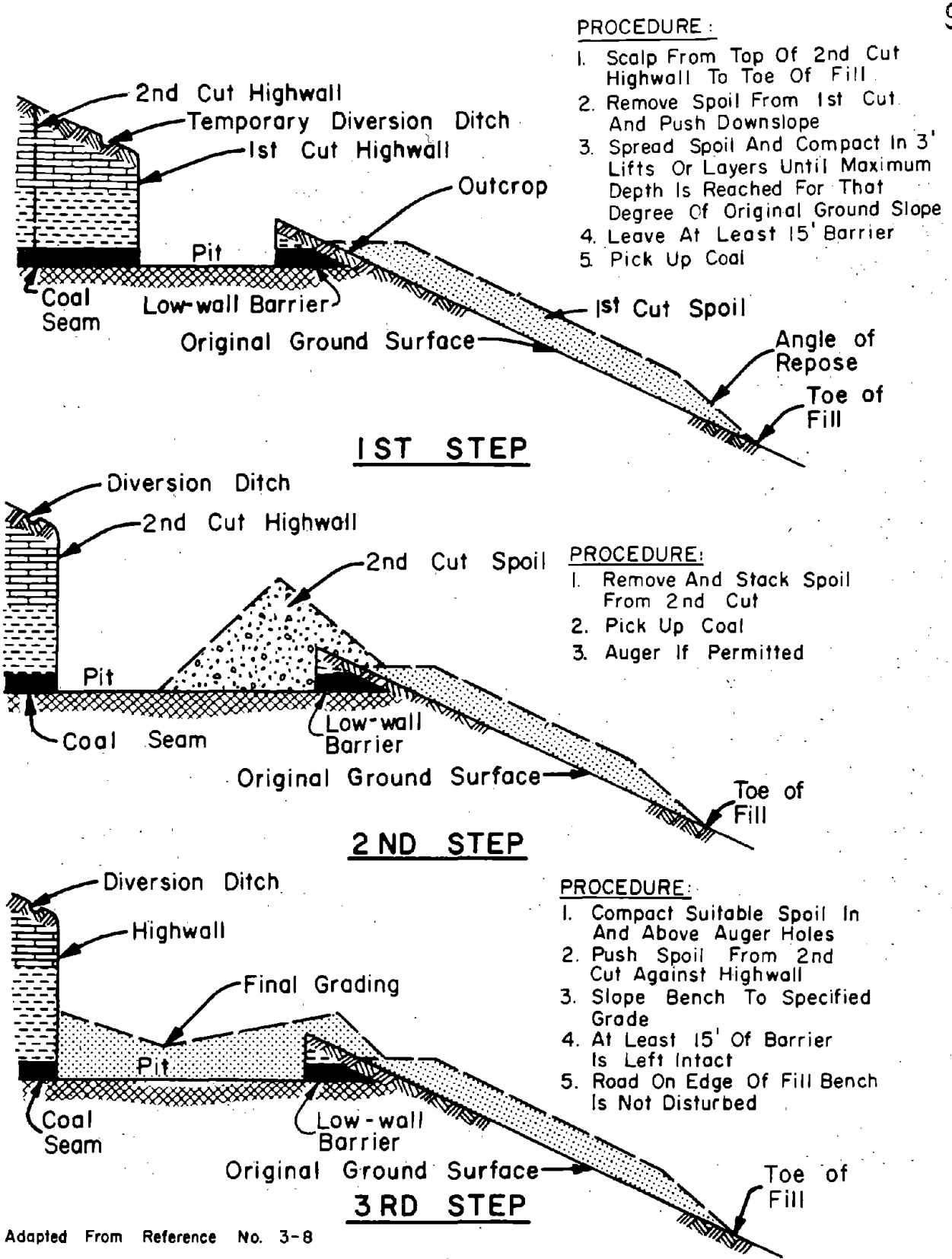
Ripping overburden is more desirable than blasting, when practical, as it eliminates the need for drill rigs, explosive trucks and extra personnel. Dozers equipped with rear-mounted or front-mounted ripper attachments do the job of overburden preparation where the overburden is predominantly shales and clays ("easy digging" material).

Overburden Removal

Only two types of equipment are generally used for stripping: dozers and front-end loaders (rubber tired or track). As can be observed by now, the dozer is essential to this mining method. Dozers and loaders can remove the spoil from the coal, and cast it over the edge of the bench on the downslope. This indiscriminate casting causes serious environmental damage, and has been outlawed or strictly controlled in many states. Variations of somewhat controlled spoiling on the outslope are parallel fill (Figure 3-3) and 7^{o} storage angle (Figure 3-4) slope reduction techniques.

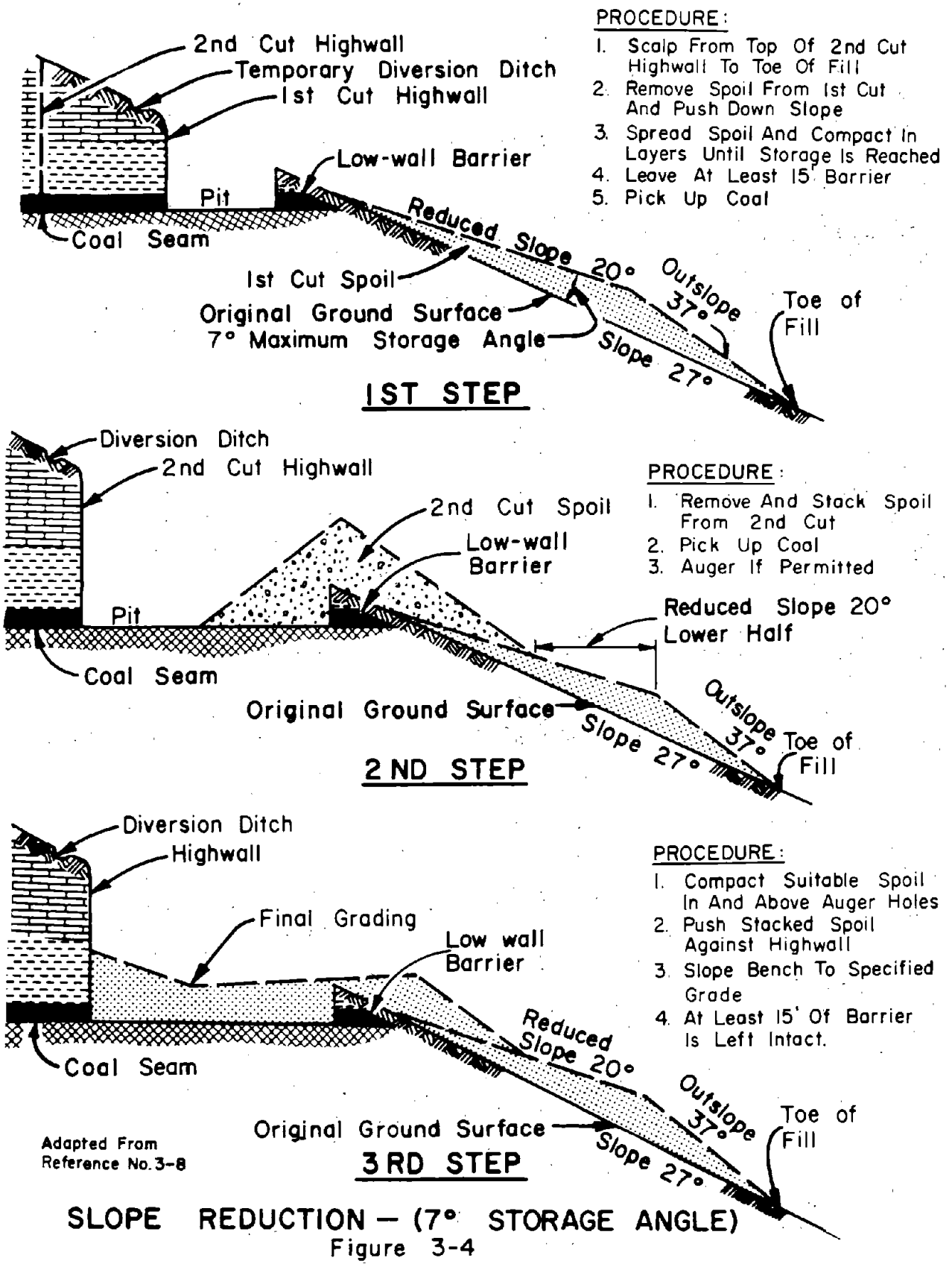
Coal Loading

Coal loading can be accomplished by the same loader used in the stripping process. However, when the coal is too hard or too thick for effective loader use, shovels are employed as a substitute provided the underclays can support them. In some cases, dozers rip the coal



Adapted From Reference No. 3-8

SLOPE REDUCTION-(PARALLEL FILL)
Figure 3-3



Adapted From Reference No. 3-8

SLOPE REDUCTION — (7° STORAGE ANGLE)

Figure 3-4

for ease of loading and if extremely hard coal is encountered, blasting may be necessary.

Coal Hauling

Since most mines in this region are small, and preparation facilities rarely serve only one mine, coal is hauled from the pit with on-road type trucks (usually end-dump) having a capacity of 15-30 tons. Larger trucks are sometimes used, but care must be taken when establishing travel routes to avoid poor back roads and low capacity bridges.

Augering

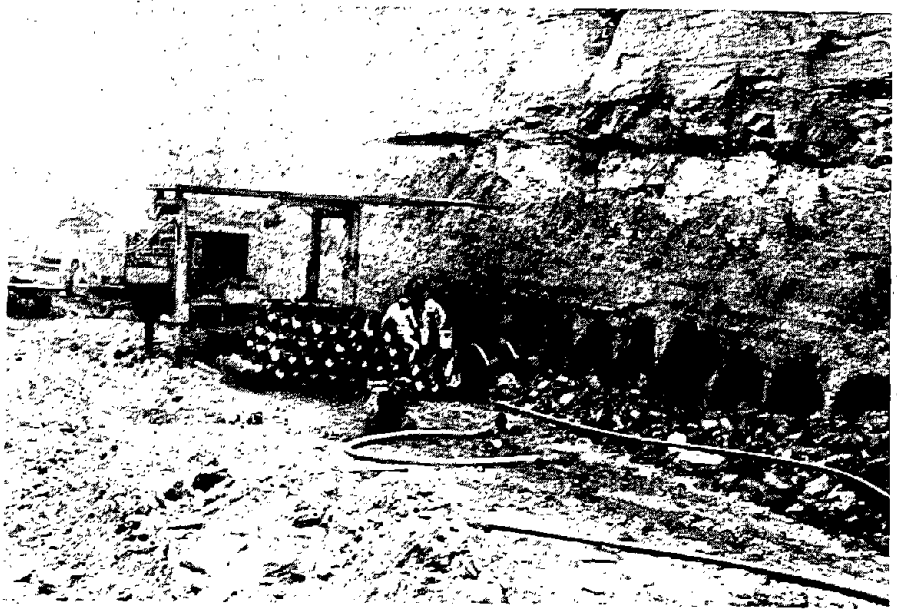
Whenever possible, coal is augered to gain maximum production from a pit where the limiting stripping ratio has been reached. Augering is horizontal boring, and coal is extracted in a manner similar to drilling (See Figure 3-5).

Auger cutting heads can reach sizes up to seven feet in diameter, but are limited to thickness of the seam. By adding more sections to a cutting head, holes can be drilled in excess of 200 feet. However, as holes become deeper, the auger sags, and eventually, material from the strata below is recovered. To avoid this occurrence as much as possible, holes are undersized by about 30%.

Although augering provides cheap coal for the current operators, it does have some disadvantages: (8)

- Augering usually provides poor recovery of the total reserve, as can be seen in Figure 3-6. Coal remaining between the holes, the extra 1/3 remaining within each hole, and the wedges remaining due to an irregular highwall, are all lost, with no forseeable chance of recovery.

- Alone, augering disturbs the least amount of surface area. However, access to abandoned underground mines is sometimes created which provides an exit or entrance for water - a

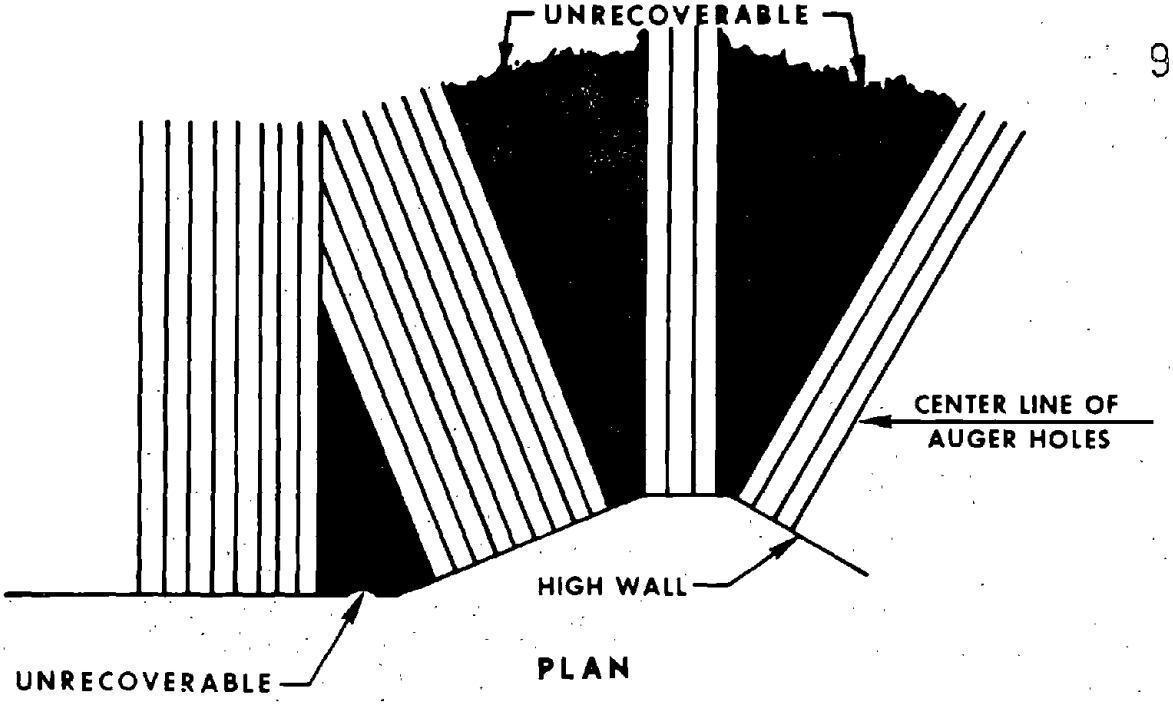


AUGER MINING
Figure 3-5

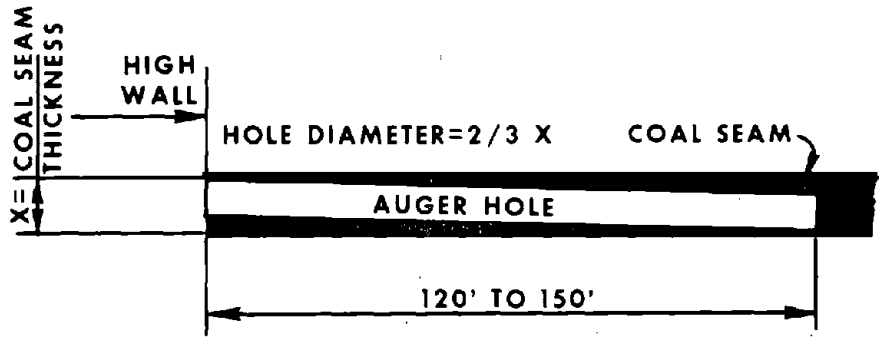
crucial source of acid mine drainage (AMD). Even if underground workings are not encountered, surface water can flow in and out of auger cavities, again, a source of AMD.

Regrading and Backfilling

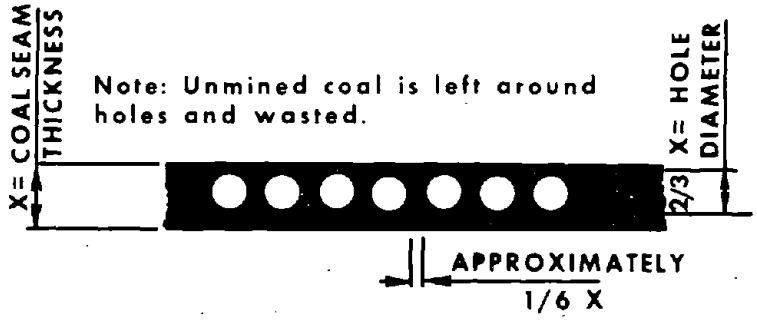
The primary regrading tool is, once again, the dozer. Pans have been used successfully for this purpose, but are not as versatile, therefore not as common. This operation is the last major effort, and is dependent upon all other procedures. Regrading and backfilling are fairly costly, due to excessive rehandling of the spoil, especially for con-



AUGER HOLE PATTERN - IRREGULAR HIGHWALL



LONGITUDINAL SECTION OF AN AUGER HOLE



SPACING OF AUGER
HOLES DRILLED FROM THE HIGHWALL

Adapted From
Reference No. 3-8

COAL LOSSES FROM AUGER MINING

Figure 3-6

tour grading. If stripping did not cast spoil on the outslope, the cost of regrading activities could be reduced (discussed later under Lateral Movement).

Reclamation procedures associated with this technique usually consist of highwall reduction, terrace backfill, and sometimes contour regrading. Illustrations of these techniques are shown in Chapter 6, Extraction and Reclamation.

Revegetation

Establishing growth on non-segregated regraded spoil is extremely difficult. Hydroseeding and broadcasting are common methods of seed application, usually contracted to outside companies. Various grasses, legumes and seedlings are applied (seedings are planted), along with occasional limestone treatment, fertilizers, and mulches. Further discussion of reclamation is included in Chapter 6.

Operation Relationships

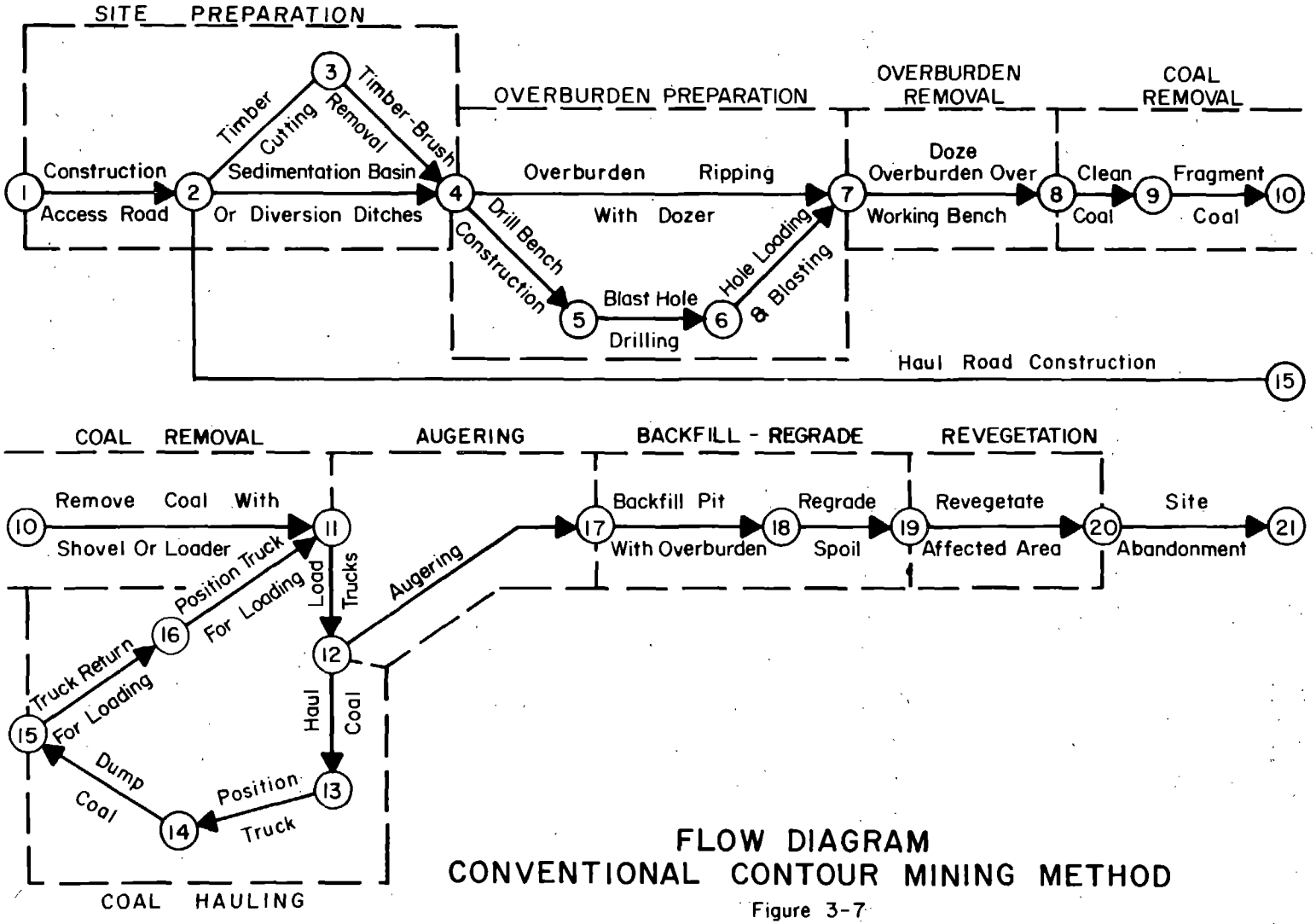
Unit operational activities of this mining method are related as shown in Figure 3-7. Production flow is linear, with no cyclic functions other than coal hauling.

Effects of Conventional Contour Strip Mining

Advantages

Benefits and advantages of conventional contour stripping over alternative methods are limited.

- Economic removal of some coals (thin seams of steam coal covered by massive sandstone) is permitted with this method when it would not be feasible utilizing other methods such as



FLOW DIAGRAM
CONVENTIONAL CONTOUR MINING METHOD

Figure 3-7

block-cut mining.

- It does not require complicated and time consuming pre-mining and reclamation planning, nor use of deck loading and other measures to obtain control of overburden blasting.

- Less capital expenditure for equipment (spoil haulage) is required.

Disadvantages

Its disadvantages, compared to those of alternative methods, are critical and, in some instances, have led to its use being banned or restricted.

- Resultant steep, unconsolidated outslopes produce serious erosion and landslide problems.

- Inherent in the technique is indiscriminate casting of spoil over the bench, often causing severe acid mine drainage pollution and inhibiting revegetation, compounding the erosion problem.

- Aesthetically displeasing, unsafe, and unstable highwalls are left as a legacy, from which further pollution problems emanate.

- It disturbs much more acreage (50%) than other steep slope methods.

- Bonding amounts and acreage fees are higher.

- The acreages stripped, as well as adjacent areas indirectly affected, have low land use potential.

Due primarily to these problems, the future use of conventional contour stripping, as described, is undoubtedly very limited. However, modifications of contour stripping such as slope reduction, parallel fill, box cut, modified block-cut, and particularly lateral movement and

mountain-top removal are already proving to be expedient replacements. With proper utilization of contour, terrace, swale, and other effective regrading and reclamation techniques, conventional contour mining may yet receive use in some areas if federal laws prohibiting casting of spoil over low wall slopes are not enacted.

Lateral Movement - Haulback - Controlled Placement Mining

This newly-developed mining method was initiated as a means to eliminate one of the most critical factors inhibiting achievement of effective and productive reclamation in the hills and mountains of Region I - problematic outslope spillage. Lateral movement is novel in that its basic concept had not been applied in areas of steep terrain until tested on the 65% slopes of West Virginia. Basically, this contour mining method is a modification of the block-cut, comprising a more delicate operation in order to effectively handle and dispose overburden material.

Selection of an adjacent hollow or low area (often times an old abandoned bench area whose reclamation could be improved by proper deposition of spoil material) for initial overburden disposal is the first consideration for beginning the operation. This space is essential to eliminate indiscriminate casting of first-cut material over the bench. If a hollow is utilized, then extensive pre-planning for proper construction of underdrains and terracing, must be implemented. In addition, this head-of-hollow fill can be utilized in conjunction with appropriately sloping access roads to form a conveyance system for mine water and surface runoff. Water can be diverted and channeled into rock drains preventing contact with spoil material and providing effective erosion control. The next step entails construction of a haul road on or below the predicted coal seam cropline. In addition to serving as an integral component in maneuverability of overburden handling, this roadway, situated on the crop bench, can aid in the prevention of water, rock, and overburden spillage down the outslope.

A great deal of pre-planning is involved in the next step: benching-down for blasting overburden at the point calculated to be the highwall limit. Stripping ratio limit incorporates the same considerations dealt with in contour mining: thickness, continuity, slope, and quality

of the coal seam; type, condition, and thickness of overburden encountered; size of mine area (including haulage distances); and return per ton of coal mined.

An additional factor is the resultant bench width and its capacity to allow efficient and expedient coordination and scheduling of the various procedures encompassed in the haulback method, thereby eliminating production delays. Spoil material generated by the initial benching-down process is then loaded and hauled to a previously-determined storage area with segregation of blackish shale, waste coal, and toxic and acid producing materials from those substances which are conducive to revegetation. Remaining overburden is carefully and precisely blasted using specialized techniques, such as deck loading, which will permit a subsequent interior cut, as well as prevent formation of an uncontrolled outslope area.

Following the blasting; excavation, haulage, and deposition are conducted parallel to the cropline. All movement of overburden is toward the mined out areas, thereby precluding possibility of having uncontrolled spillage on the outslopes. Spoils are segregated upon placement and regraded and revegetated as soon as possible. Concurrent reclamation associated with lateral movement allows for immediate revegetation and soil stabilization, further enhancing its value as an environmentally-sound method of mining.

Unit Operations

Haulback contour surface mining presents more operational difficulties and requires more production scheduling and planning than other contour methods. The unit operations of Clearing and Grubbing, Topsoil Removal, Overburden Preparation, Overburden Loading and Hauling, Coal Loading, Coal Hauling, Spoil Regrading, and Revegetation, must be closely coordinated because of their interrelationships.

Clearing and Grubbing

All marketable timber is removed prior to mining activities

(frequently by an outside contractor). Dozers are used to remove remaining vegetation which is either buried with toxic materials at the highwall or piled along the lower tree line.

Topsoil Removal

When topsoil is of sufficient quantity to require its removal, scrapers are employed. A typical haulback site has all aspects of mining occurring at the same time, permitting advance topsoil removal and reclamation placement in the same operation. Scrapers are well suited for this task since they are self-loading, have good maneuverability, and can unload, spread, and grade the topsoil in the reclaimed area.

Where scrapers are not available, dozers push topsoil onto piles, front-end loaders load haulage trucks, and the trucks dump the material in the reclamation area. This latter system ties up vital stripping equipment, impairing production capabilities. Topsoil segregation and replacement can be accomplished within the mining method. Topsoil removal includes excavation of a trench immediately below the coal outcrop to collect runoff water and rolling stones from the scalped area.

Overburden Preparation

Overburden preparation procedures are similar to those discussed under Conventional Contour Stripping, with the exception that blasting is very precise - designed to fracture, not cast. Accordingly, fewer drill holes are used, and less loading per hole is required. Deck loading and delayed blasting systems assist the miner in controlling overburden preparation procedures.

Ripping is preferable wherever possible.

Overburden Loading and Hauling

The term, "Haulback", is the key to this unit operation. Overburden is loaded and "hauled-back" to a mined out area. By initially removing an interior cut or "trough", as opposed to conventional exterior cuts along the cropline, no movement of overburden material toward the downslope side of the operation is necessary; thereby eliminating the chance of uncontrolled spillage on the outslope. As this interior cut is enlarged, the remaining outer portion of overburden is rolled inward.

There are, in use, three basic stripping equipment applications to Haulback mining: Front-end loader-truck (Figure 3-8), scrapers (Figure 3-9), and a combination of both (Figure 3-10).

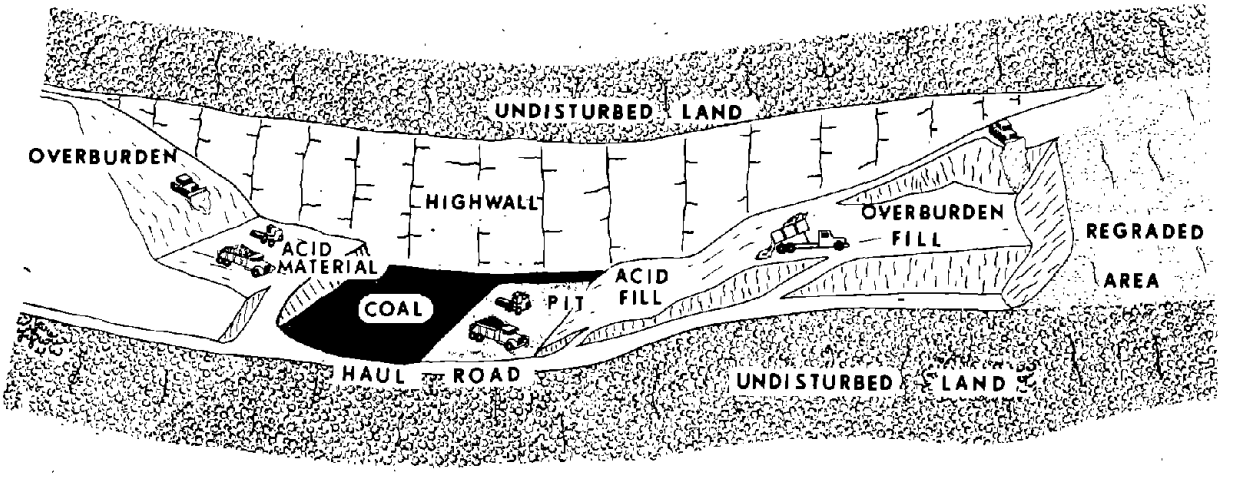
Front-End Loader-Truck

Front-end loader-truck combinations (Figure 3-8) work very effectively. Two loaders and two to four off-highway trucks can provide high production with this technique. However, traffic in the pit can become a problem with four haulage trucks. A rule of thumb application which could be inferred from actual visited operations is one large wheel loader and tractor dozer for every two haulage units.

Dozers push the overburden down to the loader, providing easy digging material for loading. Haul road and ramp construction for the overburden trucks are also performed by the dozer.

Segregation and deposition of spoil material can be controlled easily with truck usage. Lateral haulage by trucks gives flexibility to the process, thus permitting auxiliary operations, such as augering, to be conducted without interfering in the actual mining or reclamation process; the spoil can easily be hauled and deposited behind the auger operation.

If available, stripping shovels are used to load overburden trucks. However, with this technique, mobility is the key, and shovels are not known for their exceptional maneuverability. New operations employ



TYPICAL TRUCK HAULBACK METHOD

Figure 3-8

large loaders, while shovel usage occurs only by necessity (owning necessitates using). This is not to say shovels cannot be used - because they can, but front-end loaders have proven to be more successful where good overburden fracturing and moderately easy digging exist.

Advantages:

- Loader-truck combination offers the ultimate in select placement; specific loads can be dumped at specific points.
- With good conditions, production can quickly be increased with addition of another truck to the cycle.
- Little concern is given to the texture of material being transported, as trucks can haul nearly anything. No equipment changes or additions are required with variations in overburden.

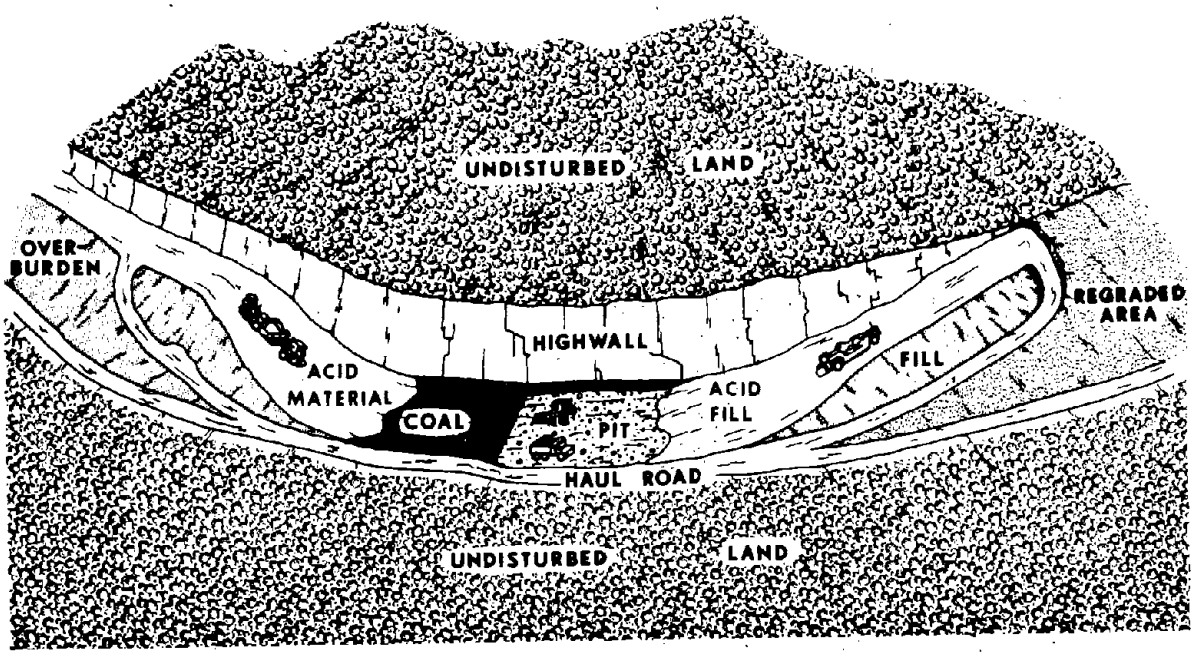
Disadvantages:

- Increasing the number of overburden trucks for greater production, also increases pit traffic which can cause congestion and production slow-downs.

- Mismatched loader-truck combinations do not allow for maximum production; as loaders may wait for trucks, or trucks may wait for loaders. Good timing and planning are essential. Spoil deposition is not smooth, and needs regrading and compaction. Much time is wasted by truck backing for dumping and loading.

Scrapers

Scrapers are also used for haulback contour mining (See Figure 3-9). Elevating scrapers offer good cost advantages over truck haulers on short haul distances associated with the haulback technique (10). Since scrapers can dig their own loads, transport that load at speeds up to 35 mph. and spread and compact the load in the dumping area, they are becoming increasingly popular in mining. Ripper dozers have greatly increased the range of scrapers, as shales and soft rock that previously resisted loading are now successfully loosened and removed. (The section on equipment in the introduction of this report gives more details on available scrapers.)



TYPICAL SCRAPER HAULBACK METHOD

Figure 3-9

Two to three scrapers can be used effectively with the haulback. Their one-step loading and hauling is usually supported by a ripper dozer which is also used for pushing during the loading operation. By using a push-pull arrangement, scrapers can sometimes eliminate the use of a pushing dozer.

Advantages:

- Less equipment in the pit. Scrapers can build and maintain their own haul roads, and need no loading machine.
- Little or no time is lost during loading or dumping, as no back-up is necessary. Unloading is not as precise as the truck system, but compaction is achieved with each pass of the scraper. If one scraper breaks down, production continues with others of the fleet. Such is not the case with a loader or shovel.
- Greater production/hour is achieved with short haul distances. Little or no regrading and compaction is necessary. Scrapers can accomplish both functions during unloading. Final scraper grade can be revegetated.
- Steep grades (20%) are no problem, even with a full load.

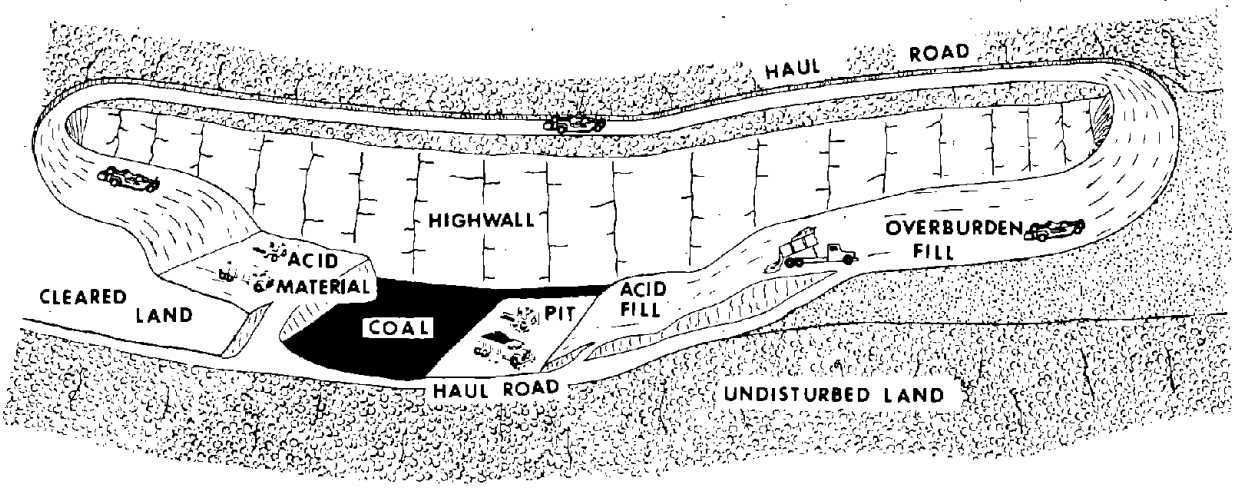
Disadvantages:

- With hard, blocky material, scrapers do not have the capabilities of loaders and trucks. Harder material necessitates use of pushing dozers, ripping, and push-pull combinations. However, elevating scrapers can load some of the more consolidated overburden with pushing aids.

Combination

A combination of the above variations is ideal (Figure 3-10). A scraper, removing less consolidated material near the surface, and loader-trucks excavating the blockier material near the coal, can be

very successful. Scrapers can traverse along the top of the highwall, and not interfere with pit congestion. Their grading capabilities can accomplish reclamation grading during final deposition of surface overburden, thus eliminating use of a dozer. On the other hand, loader-trucks can simply transport toxic, blocky material near the floor, thus not requiring trucks to traverse steep grades (for which they are not well suited). The access road on top of the highwall can also serve as a diversion ditch for pollution control.



TYPICAL TRUCK & SCRAPER HAULBACK METHOD

Figure 3-10

Coal Loading

As in most mining techniques in Region I, (Haulback is no exception) front-end loaders are becoming the primary coal loading machine. Their maneuverability and capability for overburden removal assistance during no-loading periods, make them well-suited for narrow pit, steep slope mining. Shovel usage is becoming less and less, and as shovels wear out, they are usually replaced with front-end loaders. Ripping or blasting is performed if coal characteristics warrant them.

Coal Hauling

Same conditions and methods apply as in Conventional Contour Stripping.

Augering

Augering can create problems with this technique. Although equipment and effects are similar to those noted in conventional contour stripping, the time requirement for augering is important. Auger delays can limit placement of overburden, thus limit production.

Regrading

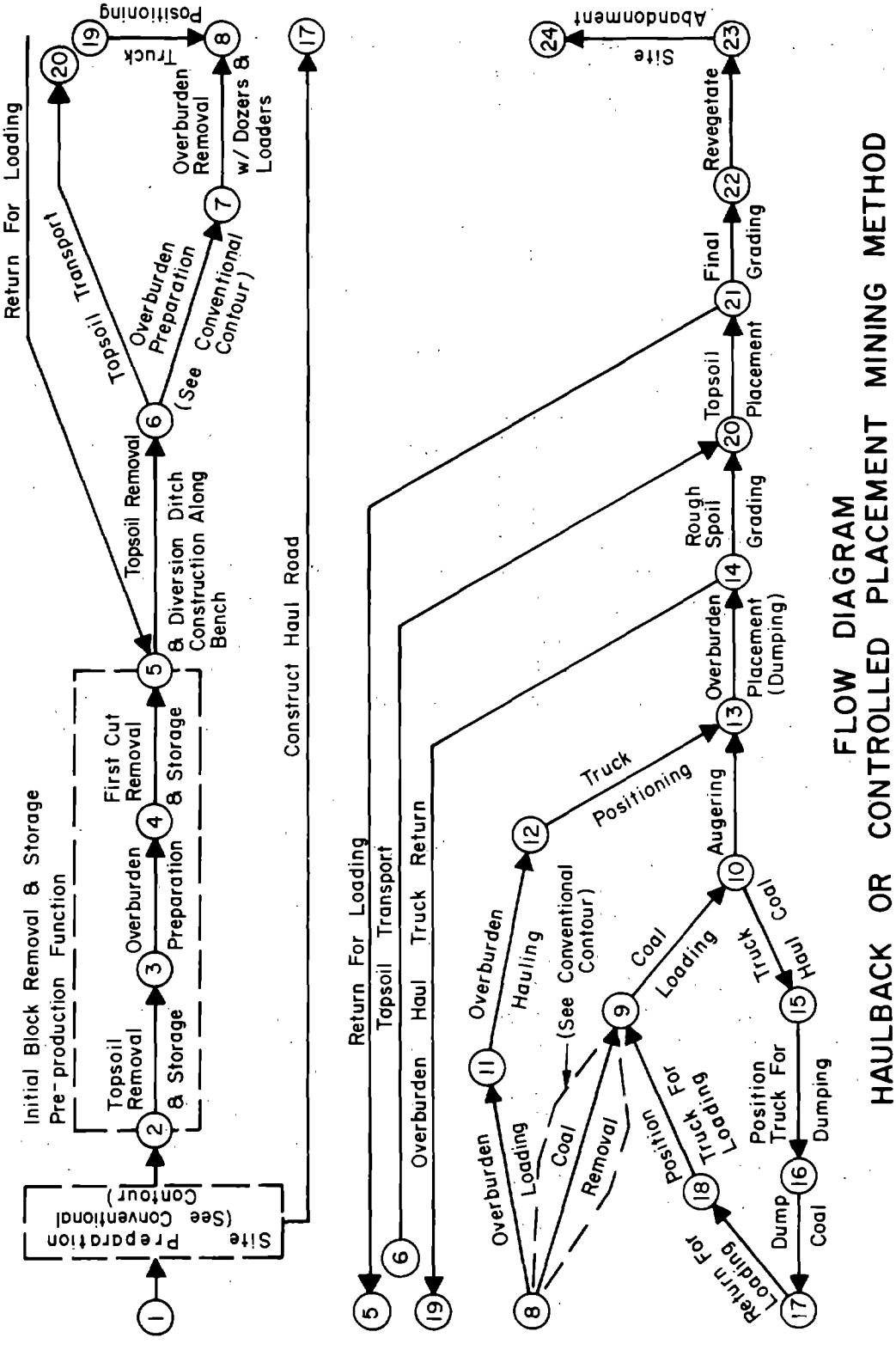
Dozers and graders usually regrade spoil material to near original contour, except when scrapers are used. Well dispersed overburden dumping can effectively reduce the efforts of regrading.

Revegetation

Identical to Conventional Contour methods, discussed in Chapter 6.

Operation Relationships

Production scheduling and operation flow for controlled placement techniques are much more complicated than Conventional Contour Mining (See Figure 3-11). Cyclical functions such as Topsoil Removal-Placement, Overburden Removal-Placement-Grading, and Coal Extraction-Hauling, complicate pit activities, and each can have a limiting effect on mine production.



FLOW DIAGRAM
HAULBACK OR CONTROLLED PLACEMENT MINING METHOD

Figure 3-11

Effects of Lateral Movement Mining

Substantial and profound are the benefits (when compared to conventional contour mining) affiliated with lateral movement, as demonstrated by its rapid increase in use and almost revolutionary effect on the coal mining business in the steep terrain areas of Region I.

Advantages

- Elimination of outslope spoil results in minimal erosion and no landslide problems.
- Contour regrading eliminates highwalls and their related aesthetic, safety, pollution and access problems.
- Segregation of topsoil (with inherent advantages of facilitating revegetation and inhibiting formation of acid mine drainage) is easily accomplished in this mining procedure.
- Concurrent reclamation practices are incorporated to further minimize environmental problems and to reduce the time required to return the land to productive use; also it accelerates releasing of permit bonds by State Agencies.
- Little or no disturbance to contiguous land, thus forming a buffer zone (especially that above the highwall and below the crop bench) which effectively alleviates detrimental erosion, subsidence, landslide, and aesthetic, as well as other offsite, effects.
- Reduction in disturbed land (50%) effectuates a decrease in bonding and revegetation costs.
- Minimal land disturbance and concurrent reclamation have caused a decrease in the number and size of sediment ponds (and related diversionary channelization structures), and have dramatically reduced required cleaning and maintenance.
- Ultimate control of backfilling is permitted. Each load of spoil can be segregated into an area that will least affect regrading and reclamation efforts.
- In some areas having extremely steep slopes and stringent laws pertaining to fill benches, lateral movement permits mining of coal resources which would not be excavated using alternative surface methods.

- The reclaimed land has an excellent potential for recreational activities and wildlife development, and its integrated road system provides unique access for forest fire control.
- Lateral movement permits a great deal of flexibility in the mining procedure, so that ancillary operations such as augering can be effectively implemented without impeding other integral processes.
- Overburden need be handled only once to achieve effective reclamation, whereas conventional contour mining requires overburden to be handled at least twice.

Disadvantages

Lateral movement does, however, entail some unfavorable conditions:

- Higher initial capital expenditures for the additional equipment required by this technique, and a decrease in rate of production, account for an approximate 30% increase in overall production costs.
- As with mountain-top removal, extensive pre-mining planning is necessary in order to properly schedule and execute the various phases, thereby eliminating dead time.
- If valley fill is utilized, additional planning is required for proper development of design plans and specifications.
- Thin coal seams cannot be economically recovered if overburden requires blasting.
- Complicated methods of drilling and blasting to maintain control of the overburden are time consuming.
- Feasibility is restricted to areas encompassing the requisite low area or hollow needed to appropriately handle and store excess overburden. Other pertinent considerations are type and condition of the overburden, haulage distance, and stripping ratio (not only for economical but also for practical feasibility, in that the resultant bench area must have the capacity to permit proper and efficient scheduling of production and reclamation processes).

Lateral movement has proven to be not only viable, but also an extremely effective alternative to conventional contour strip mining in

Region I. The significant environmental and social advantages associated with such controlled placement correspond to the times, appropriately reflecting the mood of not only the citizenry and its government, but also industry itself.

Mining operators will gradually improve upon these techniques and fully adapt their present practices to incorporate extensive premine planning. Hence, the practical disadvantages of lateral movement will be minimized. In addition, the monetary burden produced by initial capital expenditures and decreased production rate, though now only partially negated by reduced reclamation costs, will surely be further diminished in the future as environmentally unsound and less expensive reclamation procedures are outlawed or severely restricted.

Auxiliary Mining Operations

Operations other than production, auxiliary operations, require considerable emphasis by the operator, as they can at times be limiting factors in the mining cycle. The auxiliary systems include Equipment Maintenance, Site and Road Maintenance, Materials Storage and Handling, Pollution Control (Water and Dust), Power Distribution and Communications. Throughout Region I, these procedures vary slightly, with the exception of variations in Pollution Control techniques. The following descriptions of auxiliary operations and their importance to the mining cycle are common to all currently practiced mining methods within this region.

Equipment Maintenance

Equipment maintenance varies considerably from operator to operator, and depends on age of equipment, size of company, and available capital. Scheduling preventive maintenance is usually practiced to some degree at all sites. Daily or shift lubrication and inspections of all hoses, gauges, and oil levels, regular changes of oil and filters (every 100 hours), and periodic machine overhauls (every 5,000 - 8,000 hours) are typical segments of an effective preventive maintenance program. Operators trained in the basic functions of their machines per-

form daily checklists of maintenance items.

Even with a good preventive maintenance program, breakdowns still occur, thus requiring employment of a repair crew. Well equipped and trained personnel keep costly downtimes to a minimum, and can save costs and delays associated with manufacturer's servicemen.

Although reliable repair personnel and equipment are important to all mining operators, the importance assigned to maintenance systems changes substantially throughout the region. A well equipped maintenance crew for this region consists of welders, electricians, mechanics, greasers and oilers, and electric welders, cutting torches, pick-up trucks, mobile crane, lubricant truck, and central repair shop with machine tools. It is noted some facilities are better equipped than the above reference, although most sites are usually less equipped. Some have no maintenance program at all, aside from lubrication.

Site and Road Maintenance

Dozers, front-end loaders, and road graders find common usage for road and site maintenance. Graders, actually designed for road grading, are used extensively for haul road upkeep. Dozers construct new roads and repair severely damaged haul routes. When road conditions in the pit or plant area become troublesome, front-end loaders prove adequate because of their maneuverability and capability of transporting excess material.

Haul road maintenance does not end with grading. Use of water sprinkler trucks and road oil trucks keep dust controlled and haul arteries in condition. Heavily traveled areas are sometimes paved to reduce tire wear and general wear and tear on machines.

Materials Storage and Handling

Most all mining companies have buildings and/or trailers for storing supplies. Explosives and primers are stored separately, as required by law. Since deliveries of supplies are erratic, stocking

of frequently used materials, such as lime, ANFO, sheet steel, and forged and cast parts, has become common practice. One central supply store and warehouse usually serves a number of sites.

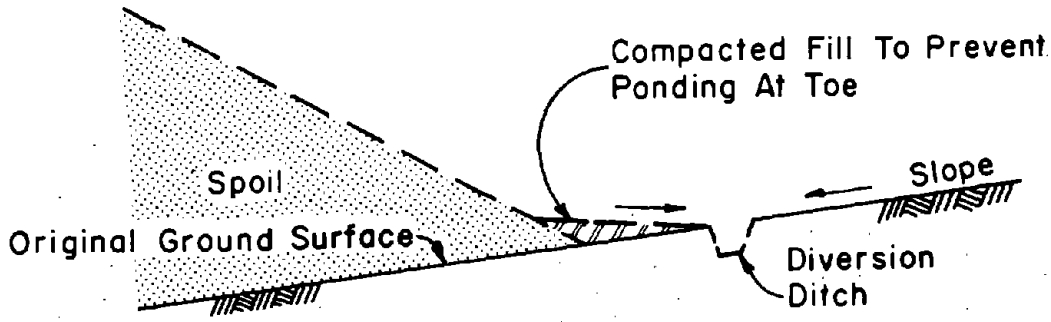
Pollution Control

Strip mining in Region I inherently produces water pollution threats, especially when using conventional contour stripping. Proper design, construction and maintenance of pollution control facilities can alleviate these threats, and maintain acceptable water quality in streams. Common control techniques applied with this mining method include water diversions, sediment basins, and acid neutralization.

The key to any pollution control program is to reduce the expense and difficulties of treatment. By using water diversion systems (ditches, flumes, pipes, trench drains and dikes) miners decrease the volume of water that needs treatment, thus reducing treatment costs. Diverted water is also kept from contact with acid producing materials, and is not permitted to pick up sediments from disturbed areas.

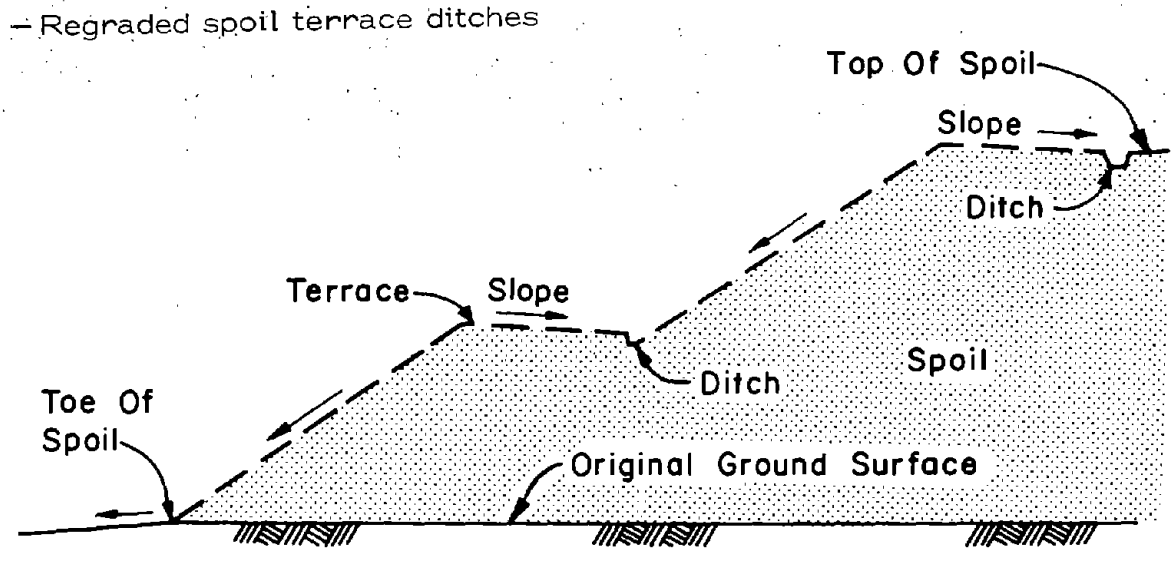
Ditch usage along the top of highwalls is similar in both Controlled Placement and Conventional Contour Mining, except when the top of the highwall is accompanied by an access road, which then substitutes as a diversion ditch. The edge of the haul road along the outcrop bench in Haulback Mining is also the edge of the affected area where surface drainage is directed to a ditch on the inside edge of access roads (graded roads) and then to a sump. By directing water to a single point, treatment can be accomplished much more easily. Techniques of neutralization and sedimentation control are similar in all mining methods in this region. The accompanying water handling sketches show the basic concepts involved.

- Drainage ditch on uphill side of spoil
  (See Figure 3-12)



Adapted From Reference No. 3-18

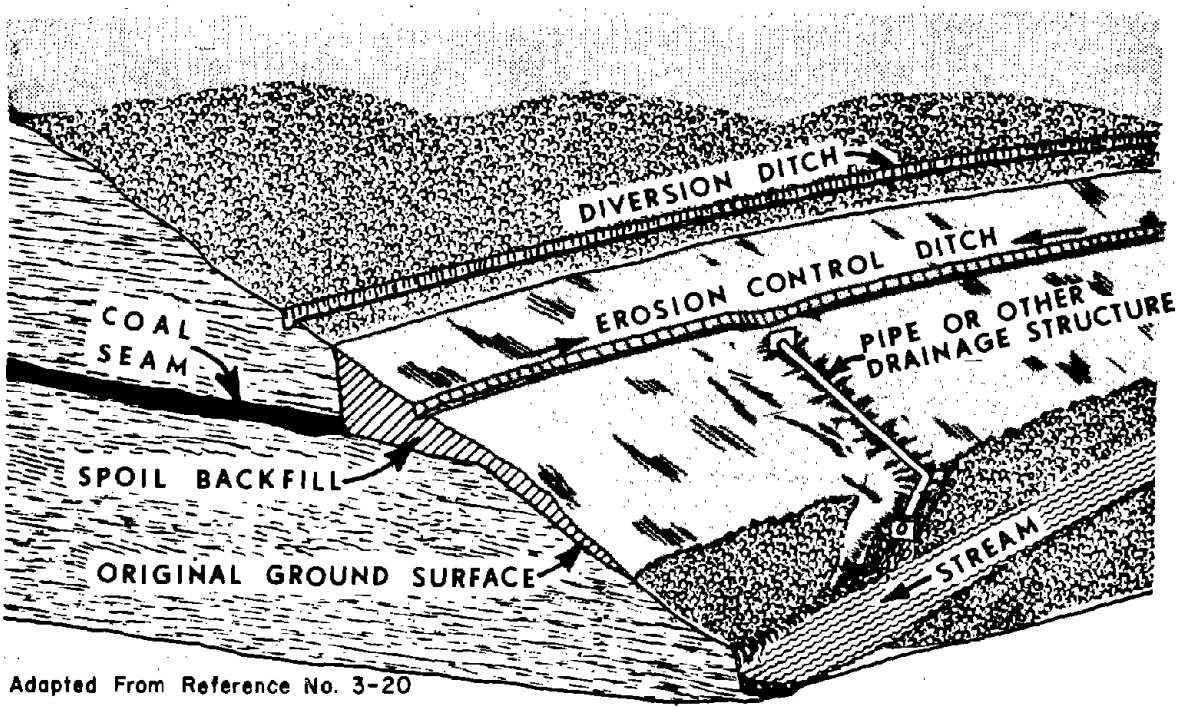
CROSS SECTION OF
DRAINAGE DITCH ON UPHILL SIDE OF A SPOIL PILE
Figure 3-12



Adapted From Reference No. 3-18

CROSS SECTION OF
DIVERSION DITCH ON TERRACE REGRADED SPOIL
Figure 3-13

- Reclaimed diversion applications

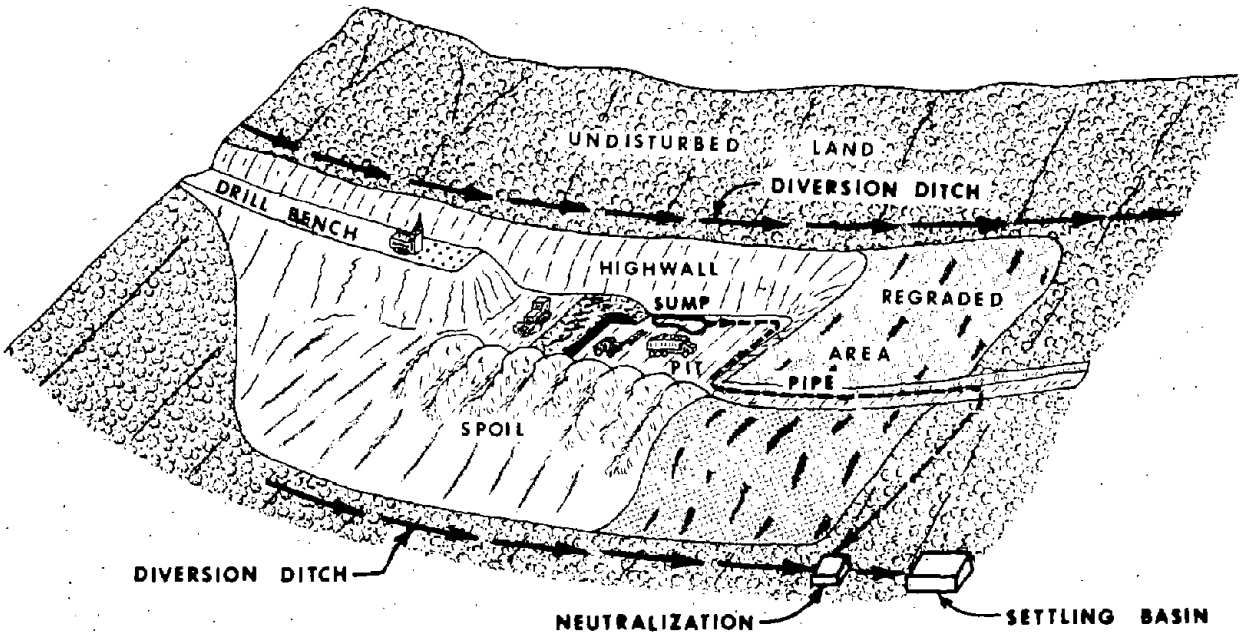


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WATER DIVERSION APPLICATION IN RECLAIMED AREA

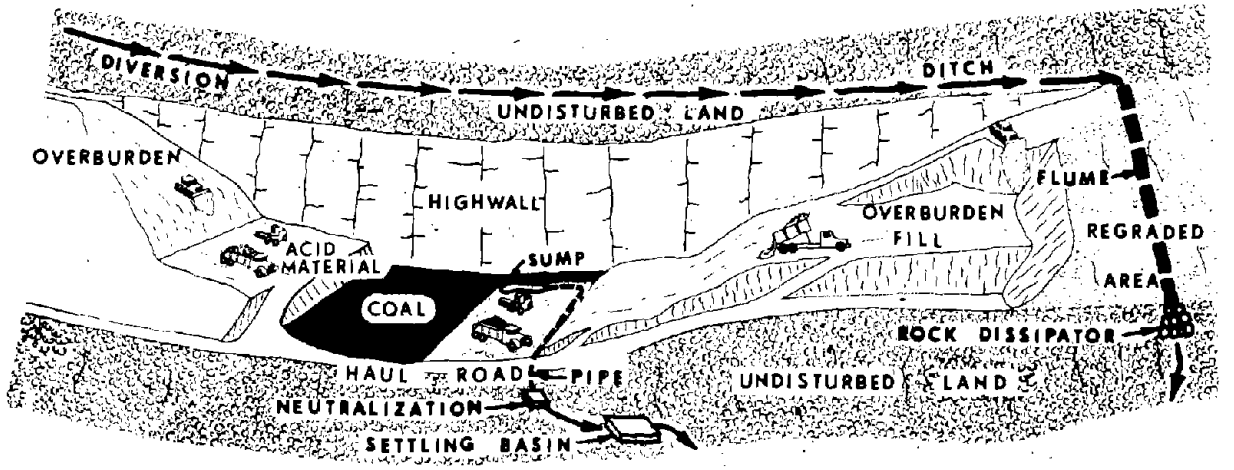
Figure 3-14

- Diversion ditch applications at active sites (See Figures 3-15 and 3-16)



TYPICAL CONTOUR STRIP METHOD
WATER HANDLING SYSTEM

Figure 3-15



TYPICAL TRUCK HAULBACK METHOD
WATER HANDLING SYSTEM

Figure 3-16

Region I, unfortunately, is plagued with the problem of acid forming materials occurring near and in coal seams. Surface mining, especially conventional contour stripping, exposes these materials to air and water, thus resulting in acid production. However by placing acid producing material at the base of the highwall and burying it with nontoxic material (which is characteristic of controlled placement methodology), the potential of acid production can be substantially reduced.

Seasonal runoff from the disturbed area and groundwater encountered in the pit usually contain a sufficient amount of acid to be rendered unacceptable for discharge. When this is the case, neutralization facilities are established, commonly using lime and soda ash treatment methods.

Large sophisticated plants are not common with surface mining in this Region. Treatment equipment is very mobile and uncomplicated, consisting of a barrel, pump and hoses for lime addition (Figure 3-17), or a simple chute with a basket of soda ash briquets for soda ash addition (Figure 3-18). Sizes of equipment vary according to water-flow and quality.

Sedimentation basins are very common, and occur in the treatment sequence as shown below.

Raw Water ⟶ Neutralization ⟶ Sedimentation Basin ⟶ Effluent

If pit dewatering is required, a basin is established for removing suspended solids from that flow. Runoff collection basins located at good collection points below the affected area remove sediments from seasonal site runoff. Design and size of these basins is in accordance with state guidelines and regulations, usually averaging about 0.2 acre-feet of volume per acre of drainage area. Common basin types in use include: (2)

- Excavations - Basins are excavated to provide sufficient detention time for solids removal.

- Earth Embankments - Embankments are constructed across waterways and swales, thus forming collection basins. Excavating behind the proposed embankment and using this material for

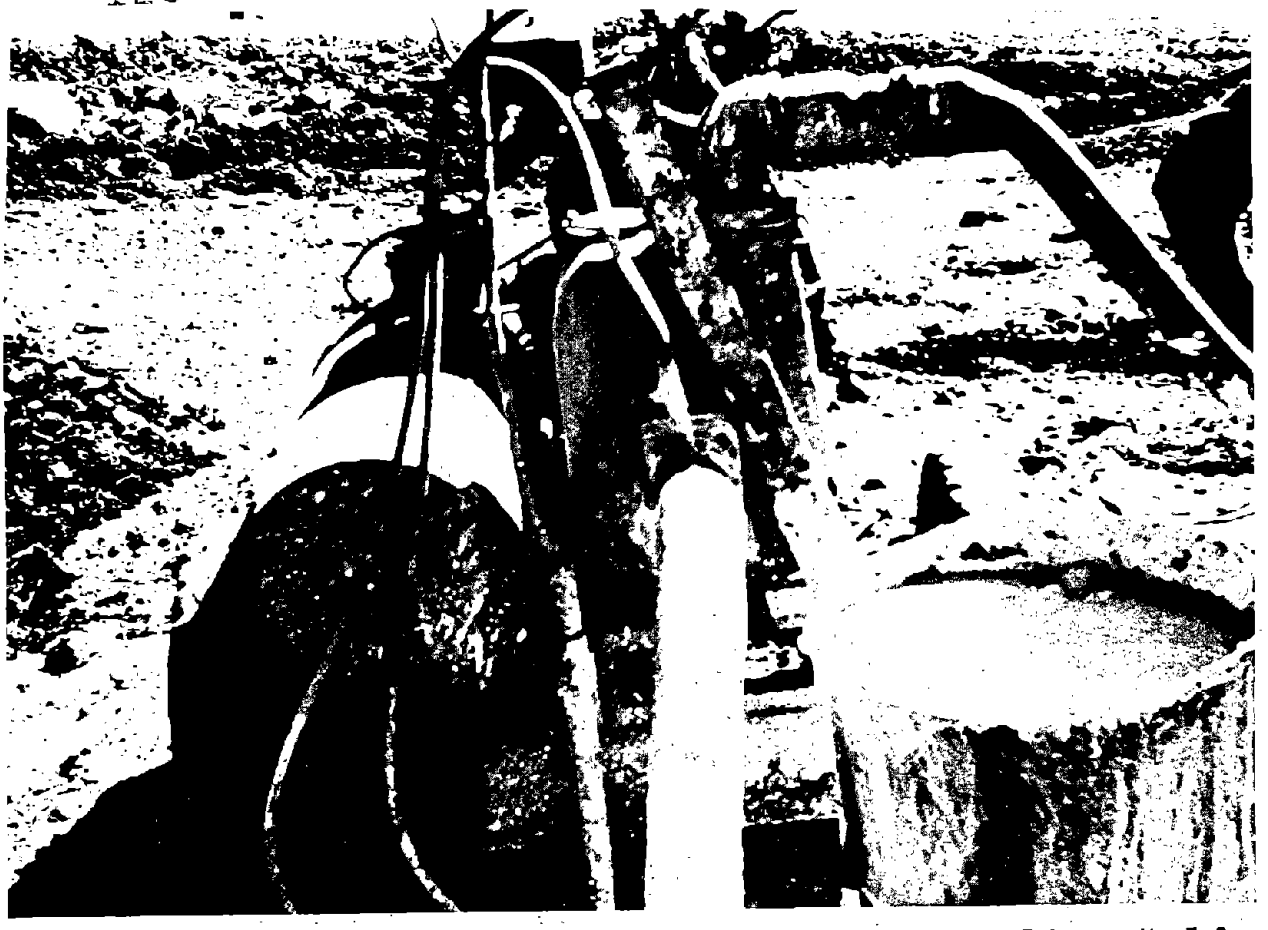
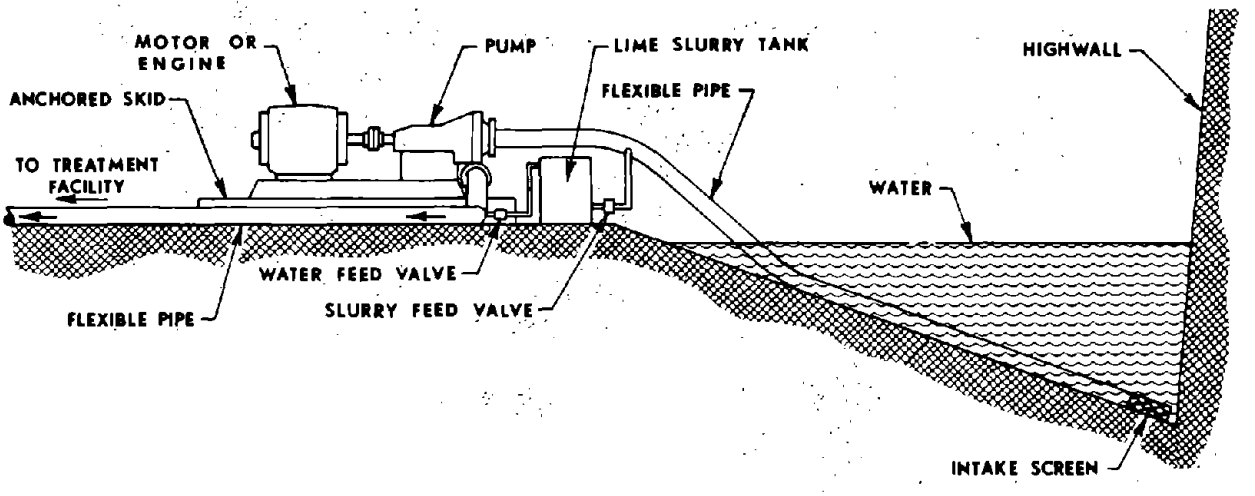
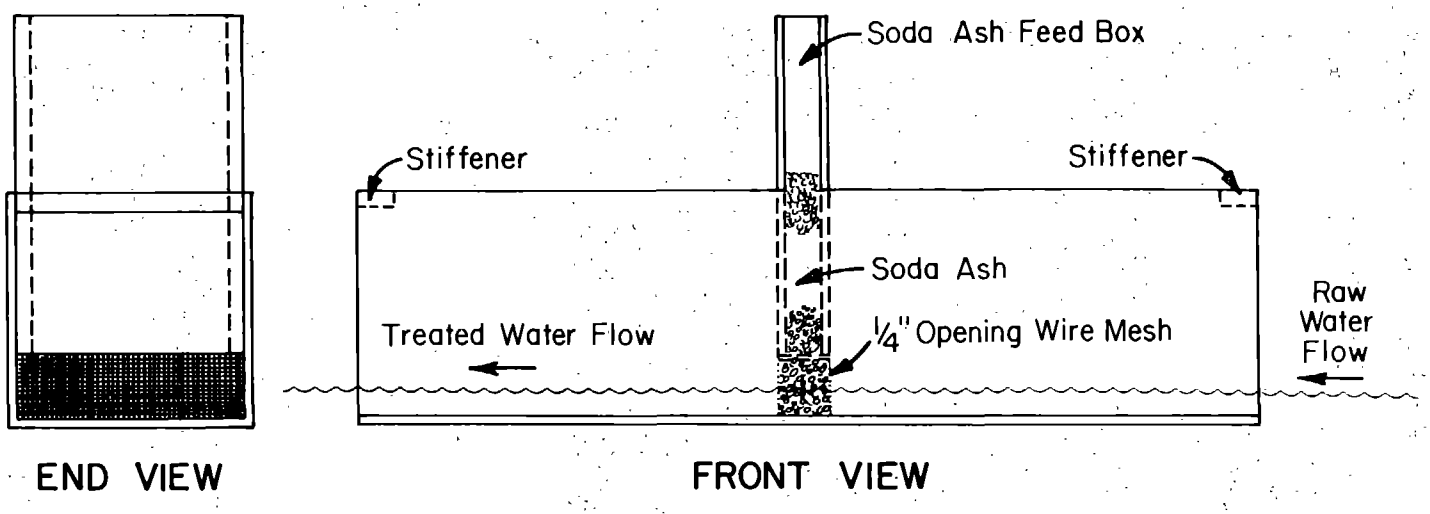


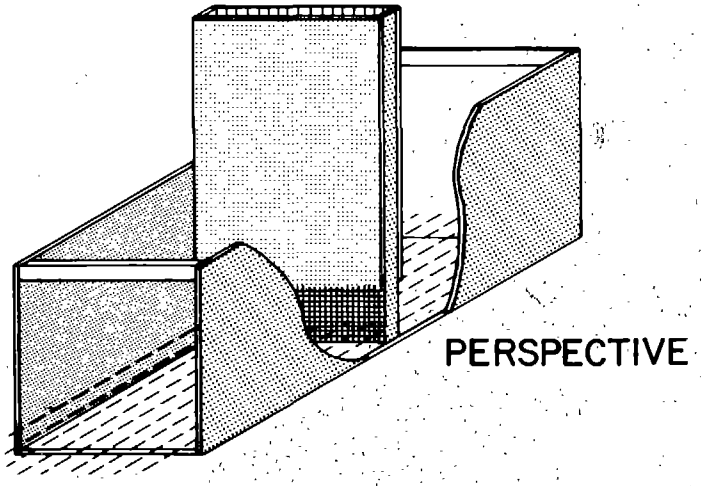
Photo From Reference No. 3-8



PORTABLE LIME SLURRY FEED SYSTEM

Figure 3-17





SODA ASH REACTOR

Figure 3-18

construction is common practice. If one basin cannot provide the required storage volume, a series of basins, with total storage equalling required storage, is used.

- Leaky Dam - Similar to a french-drain type structure, leaky dam basins momentarily stop runoff water to allow deposition of sediments before leaking through the dam.

- Gabion Walls - A variation of the leaky dam approach, gabion walls are steel wire baskets filled with broken rock. Gabion dams are built above-ground, with each end dead-manned into a virgin bank with steel cables through each rock basket layer. Water is not permanently retained by this structure, only slowed-down to permit settling of solids.

Dust control techniques, when used, involve utilization of water sprinkler trucks. These are tank trucks equipped with small attached gasoline water pumps for road wetting purposes. Improved road construction with road oil and paving, also indirectly assists in controlling dust generation.

Power Distribution

Very little high voltage electric machinery is used in mining the steep slopes of Region I. Electricity distribution is limited to offices, warehouses, tipples, and preparation plants. Typical utilization voltages are 120/240 V.

Fuel distribution (gasoline and diesel) consists of fuel delivery by the supplier to a central location, and distribution to sites by a fuel truck. Fuel trucks usually contain supplies of fuels and assorted lubricants. This is sometines considered part of the maintenance program. Smaller companies have suppliers deliver directly to the mine if possible.

Communications

Two way - private channel and citizen band radio systems are employed between the office, foremen, superintendents, and maintenance personnel at most mines. Furnishing pit equipment with radios is not common practice, but is a valuable way to maximize the use of all personnel, especially in emergency conditions.

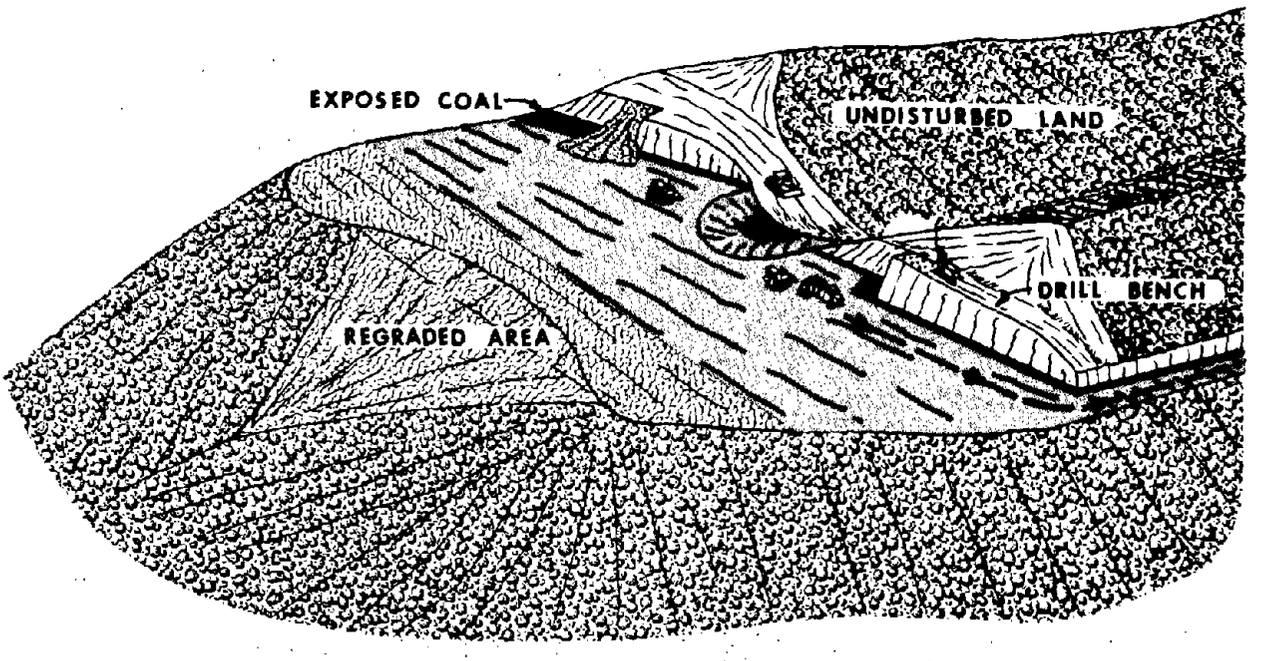
OTHER MINING METHODS ENCOUNTERED

Mountain-Top Removal and Valley Fill

This new method of mining, developed for use in mountainous terrain, originated in Region I. In 1967, after continuous research and a resultant realization that reclamation practices must be incorporated into the pre-mining planning and become an integral part of the actual mining process, the first large scale demonstration of the technique was successfully accomplished. Though not extensive, this technique is currently in use. Essentially, this method makes possible the total removal of overburden covering a coal seam, thus permitting 100% coal recovery (with the exception of outcrop barriers). Serving as an excellent alternative to contour mining in hilly and mountainous areas, using the same equipment (dozers, trucks, and front-end loaders), mountain-top removal is similar to area mining; it affects large blocks of land, rather than sinuous bands characteristic of contour methods (See Figure 3-19).

The first cut, roughly parallel to the ridge, is executed in a box-cut manner, isolating an undisturbed coal and overburden barrier of at least fifteen feet at the outslope. During the actual mining process, this barrier serves as a natural seal along the outcrop to retain surface and mine water within the operation; later it provides support for the backfilled overburden and helps confine ground water within the regraded spoil. The overburden excavated during the first cut is transferred to a storage area, usually a valley or head-of-hollow fill.

After the initial cut into the mountain top, coal is extracted and



TYPICAL MOUNTAIN-TOP REMOVAL-VALLEY FILL METHOD

Figure 3-19

mining proceeds in a series of cuts, parallel to the first and adjacent to one another, with concurrent reclamation following. Spoil from each new cut is placed in the adjacent excavated cut and in valley fills, until the entire mountain-top has been removed. However, most types of overburden rock, particularly tightly packed sandstones, substantially expand in volume after being blasted and moved. Therefore, a detailed regrading and overburden storage technique is needed to properly dis-

pose of this excess spoil, as well as that displaced from the initial cut.

Valley fill (or head-of-hollow fill), a method where spoil is placed in narrow V-shaped, steep-sided hollows free of underground mine openings or natural springs and located adjacent to the mining operation, is the technique most frequently employed in conjunction with mountain-top removal. In preparation for this procedure, vegetative cover is removed and rock drains are constructed where natural drains previously existed, forming a continuous conveyance system from the upper end of the hollow at the mined bench to a point several feet below the toe of the fill. This artificial drainage permits ground water and natural percolation to exit without saturating the fill, thereby greatly reducing the potential for landslide and erosion problems.(7) In addition, the overburden fill is built in compacted lifts or layers 4 to 8 feet thick, is terrace regraded with construction of some diversion ditches, and then is immediately revegetated and mulched, further minimizing the erosion potential of the steep outslope area.(8)

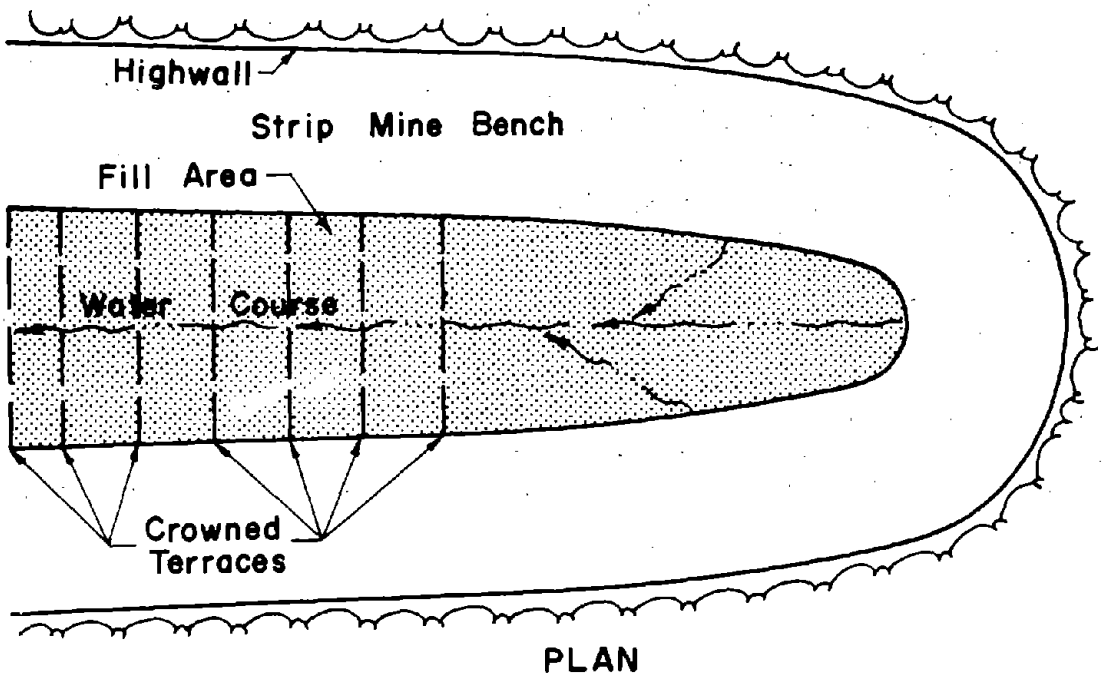
Other preliminary considerations in design criteria include the total amount of excess overburden generated by the mining operation, capacity of the hollow for fill material, total number of acres in the watershed above the proposed valley fill, expected drainage to be encountered, slope stability of the regraded fill, and prospective land use.

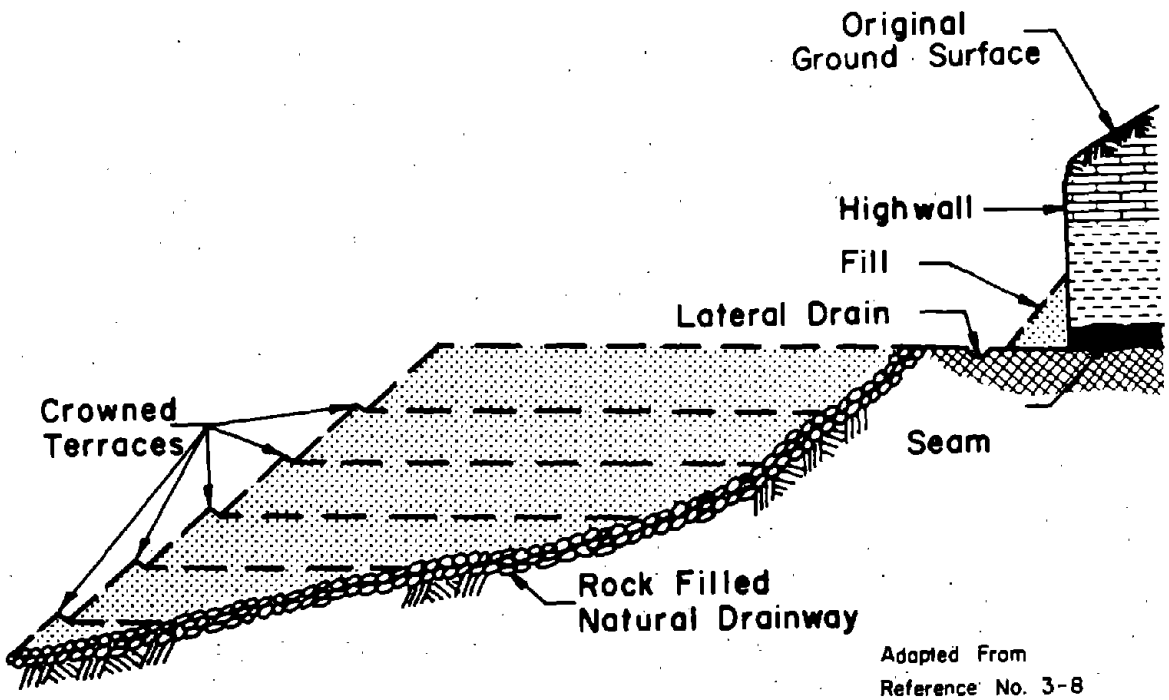
Effects of Mountain-Top Removal

After the mining is completed, the previously rugged mountain-top is totally transformed into a level or gently rolling expanse of land; the head of the pre-existing narrow hollow is transformed into a succession of crowned terraces, topped by a relatively flat, crowned fill bench area. Particularly significant and far-reaching are the aesthetic, economic, and pollution-related advantages of this new mining method and ancillary overburden storage technique.

Advantages

- Coal can be mined in many instances where underground methods would not be feasible, because of relatively thin seams, unsafe roof conditions, or the potential for critical surface subsidence.





CROSS SECTION OF
TYPICAL HEAD-OF-HOLLOW FILL

Figure 3-20

- Total resource recovery is made possible where coal seams lie near tops of mountains, ridges or knobs.
- Due to complete coal recovery, the reclaimed area will not be disturbed in the future by restripping operations.
- In areas of crippled economic growth, rugged mountain-tops and steep hollows are transformed into level or gently rolling land capable of agricultural, recreational, home, commercial, and indistrial development.
- Steep, unconsolidated outslopes of spoil are totally eliminated, reducing erosion and landslide potential.
- Highwalls are eliminated with total overburden removal and complete backfilling.
- Overburden can easily be segregated, including burial of toxic material and recovery of suitable subsoils and topsoils to facilitate proper revegetation.

Disadvantages

- Increased capital costs for the additional equipment.
- Extensive pre-mine planning is required to realize maximum production, and minimum costs:
  Incorporation of detailed planning to properly schedule the various phases and thereby eliminate dead time.
  Achievement of an accurate prediction of the total amount of overburden to be handled during the operation in order to alleviate unnecessary and improper handling of spoil.
- Additional planning incurred to accurately design the valley fill for appropriate drainage capacity and slope stability.
- Use of valley fill is restricted, being dependent upon its proximity to the location of the initial cut.

The future application of both mountain-top removal and valley fill should prove to be quite widespread throughout Region I where conditions permit. Its distinct benefits in comparison to conventional contour mining in hilly and mountainous regions far outweigh its disadvantages. As mining operators perfect these techniques and fully adapt their pre-mining planning to incorporate reclamation practices, the previously-mentioned disadvantages will become minimal. As with any other newly-introduced technique, experience gradually overcomes procedural

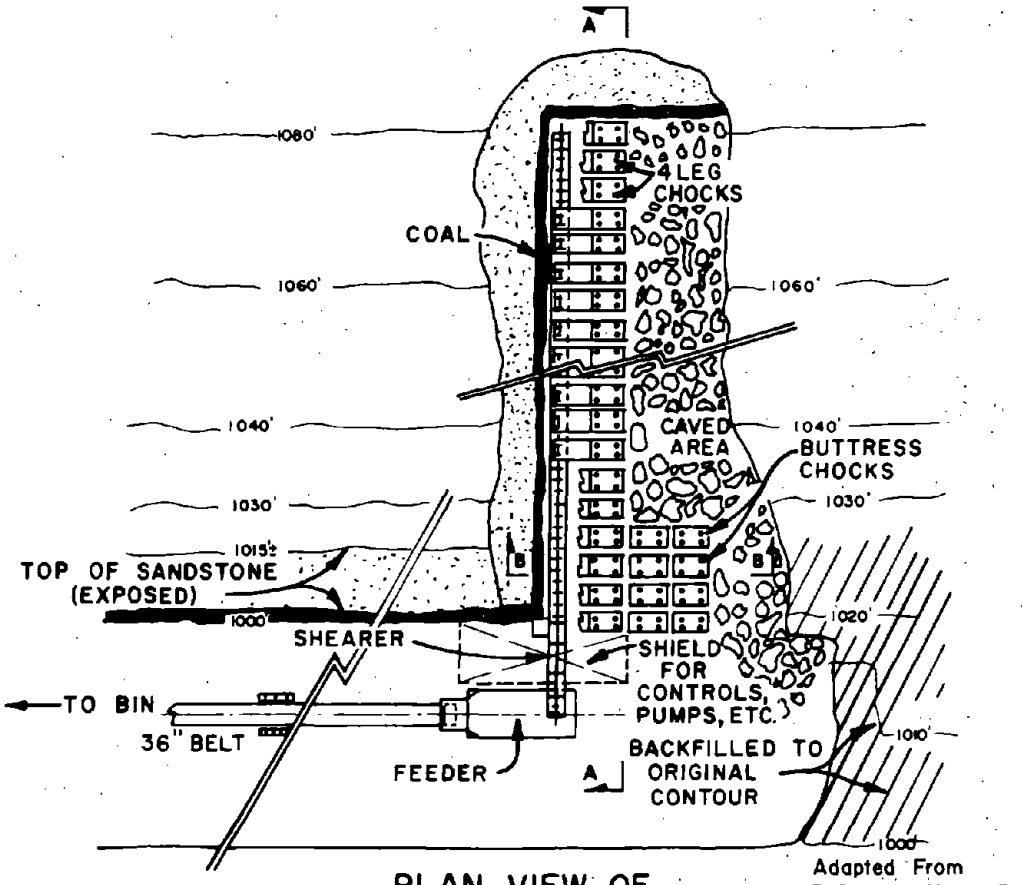
deficiencies, thereby resulting in a rapid increase in efficient management. In addition, the challenges posed by changing laws and increased environmental concern are adequately met and reflected by this mining practice. Opinions on aesthetics could be a major drawback against continuation of mountain top removal mining.

Longwall Strip Mining (5)

One of the unique mining methods presently being demonstrated in Region I is longwall stripping - a new surface mining technique employed to extract shallow-cover coal while minimizing enviromental degradation. This technique is patterned after the longwall mining system used extensively in European countries and successfully adapted in the early 1960's to United States underground coal mines.

Fundamentally, the process followed by this new mining system consists of cutting the coal by passing either a plow or shearer over the coal face. The severed mineral is transported from the mine by means of an armored chain conveyor with roof supports or jacks inserted along the working face to preserve roof integrity as mining progresses. Employment of conveyor shifting rams to move jacks and armored chain conveyor forward as the plow or shearer passes is most beneficial. After the self-advancing jacks move forward, the roof will collapse, resulting in the elimination of the voids or openings normally associated with mined out areas.

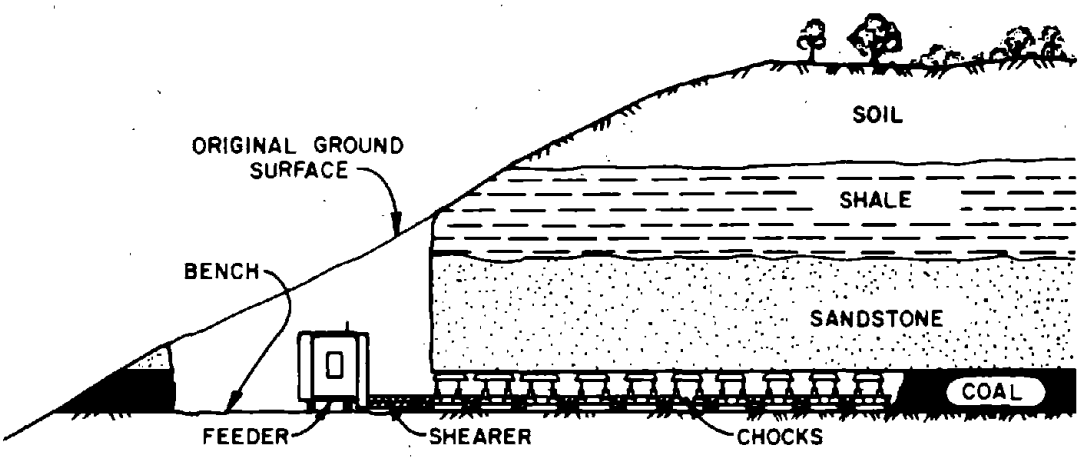
An alternative method of filling these voids is stowing rock or fly ash in the openings, thereby precluding the possibility of subsidence, as well as helping to solve the problem of waste disposal. Depending on thickness of the coal seam, type of cutter, depth and height of cut, cutting speed along the face, and ancillary transportation, production may reach 1000 tons per shift at present technological and development stages. Depending on site conditions, a three to five man crew (two shifts per day) is required to work underground with three to twenty men employed outside the mine. In addition, a five-man crew for maintenance is required. Longwall stripping does, however, have potential for remote operation, although some problems, such as dust interference with both radio and television controls, must first be resolved. Sketches of this technique follow in figures 3-21 and 3-22.



PLAN VIEW OF
LONGWALL STRIPPING SYSTEM
Figure 3-21

This technique requires preliminary work of preparing a narrow bench or outby opening about fifteen to twenty feet inside the coal outcrop. This outby serves a dual purpose: it is essential for removal of coal, and is a necessary barrier prohibiting emanation of drainage from the mine. Careful segregation of all displaced strata is employed in this task. In addition, construction of a small vertical trench from the outby opening into the coal seam is performed to accomodate insertion of longwall mining equipment. After advancement of the mining equipment and outby opening, immediate and total restoration can easily be

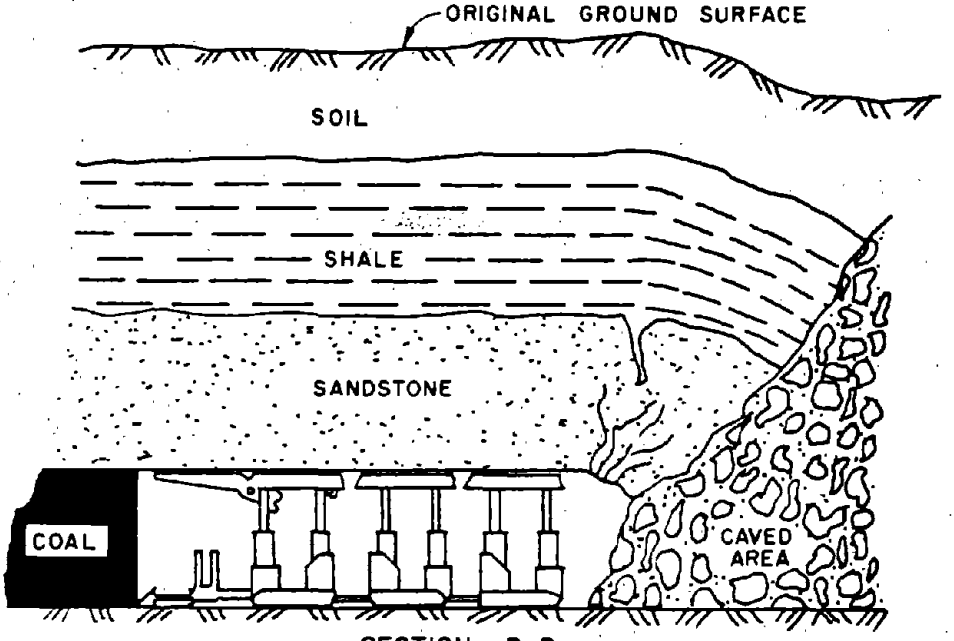
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Adapted From Reference No. 3-5

SECTION A-A

SECTIONAL VIEW OF LONGWALL STRIPPING SYSTEM ALONG HIGHWALL



Adapted From Reference No. 3-5

SECTION B-B

SECTIONAL VIEW OF LONGWALL STRIPPING SYSTEM ALONG HIGHWALL

Figure 3-22

achieved through simple backfilling and revegetation. After site selection and equipment procurement, set-up time for preliminary work is estimated to take about one month. However, a basic time delay is procurement of necessary equipment, which could take from eighteen to twenty-four months.

Effects of Longwall Strip Mining

Advantages

Advantages to be gained are optimistic. Economically, longwall mining appears to have lower production costs than normal underground mining methods, entails comparable initial capital costs, and allows for total resource recovery. Longwall stripping may serve as a valuable alternative technique to contour surface mining methods, often being practical in situations where neither overburden stripping nor underground mining methods are applicable; and it may be feasible for either area or contour mining. An extremely important consideration in today's society is miner health and safety. Hence, remote operation, a viable possibility for this technique, offers the ideal situation, where no one is required to work underground. While the actual mining progresses, a miner could operate the entire system from a totally enclosed cab outside the mine. When conditions demand maintenance and repair, the system could then be shutdown and needed repairs performed safely under jacks supporting the roof. In this way, problems related to surface and underground operations such as noise, dust, machinery-related accidents, fires, explosions, and cave-ins, could appropriately be avoided. Probably the most important advantage accuring to society, as well as to the miner, is the substantive possible environmental benefits associated with longwall stripping. Minimum disturbance to land and water resources seemingly should result in the following benefits:

- Only a small amount of land surface need be affected.
- With proper handling of overburden during construction of the trench, immediate and total restoration can easily be achieved.
- The outby opening can be utilized as a barrier to prohibit emanation of acid mine drainage into nearby waters.

- Any water encountered in the mine can promptly be channeled into appropriate treatment processes before discharge into public waterways.
- Total removal of the coal seam with either subsequent lowering of the overlying strata or utilization of stowing techniques will eliminate the voids necessary for water collection and drainage

Disadvantages

Disadvantages inherent in the longwall system of coal removal are higher production costs (as compared to conventional stripping operations), and restrictive specifications pertaining to overburden nature, composition, and thickness. At the present stage of technology, successful longwall stripping would most likely require a firm coal seam having a fairly consistent nature and a thickness of 48 to 72 inches, with a horizontal or slightly rising dip from point of outcrop. However, no certain prediction of requisite site conditions can be made until complete and thorough evaluations of demonstration sites are performed. Since the mining method is not perfected, expensive modification of existing equipment or the need for costly development of new equipment may be required. There is a definite possibility that even controlled subsidence could have deleterious effects on aquifers and on the course of underground water flow.

With the prospect of more stringent health, safety, and environmental regulations being adopted by state and federal agencies, longwall stripping should certainly become more economically competive with conventional surface mining methods. Although there is limited practical experience to date in operating an open-end face system as utilized in the longwall stripping process, it could become a practical method of the future and one which should be carefully evaluated by today's mining companies.

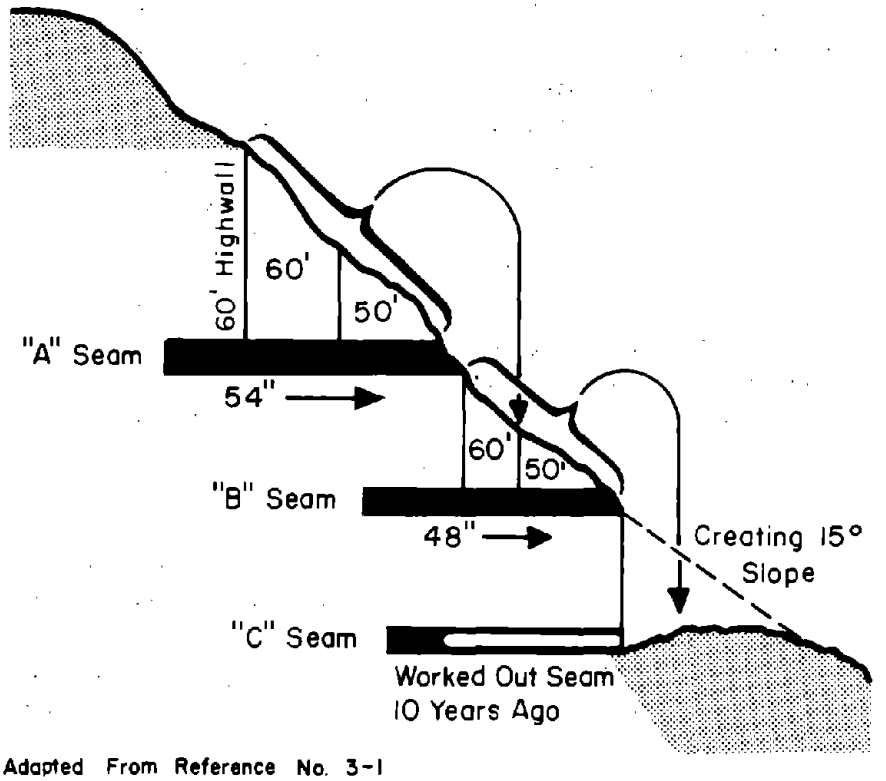
Multi-Seam Mining Methods

Before methods of multi-seam mining are described from actual

operations, geological clarification of a multi-seam setting is needed. Often a rider and main seam or bottom and top split(s) are separated by 20 to 25 feet or more of rock, and could be mined in one operation. In these cases the amount of material removed between seams is substantial and must receive the same consideration (drilling, shooting, loading-out) for removal and placement, as overburden from the larger cuts. When seams (two distinct coal layers) are separated by only one to two feet of material (a rock parting) this separation is often removed during coal loading and placed at the base of a spoil bank. Small separations such as this may develop into a distinct multi-seam configuration as the parting increases in thickness, but as such are not referred to as multi-seam. When seams have significant separation, and one seam's operation does not affect the other, this too would not be referred to as multi-seam operation.

There are advantages to mining more than one seam during the same time span. Exploration and proving of the seams' market value (quality) and reserves can be accomplished at less cost. Permit applications, set-up time and other phases of mining are dual purpose and reduce costs. More coal also offers alternatives in marketing and sale of the product. In addition to this, there is only a one-time disturbance and then final reclamation can be accomplished. This fact can also persuade surface, mineral and haul road owners to sign leases, and results in improved public relations.

The first typical multi-seam surface mining operation discussed and illustrated here was conducted in Kentucky. Two seams were being mined above a seam which had previously been worked-out and not reclaimed. The seams, from top to bottom, are referred to as seams "A", "B" and "C"; the lower "C" seam having been mined (See Figure 3-23). Two Caterpillar D-9's were used to clear and level the first cut area for overburden drilling directly above the "B" seam. Eight inch diameter holes were drilled on 10 foot centers, 40 feet deep, and loaded with 300 pounds of ANFO per hole. After shooting, D-9's and payloaders dozed and cast all "B" seam overburden down on the abandoned "C" seam pit floor. Coal was then loaded out of this first 60 foot cut into the "B" seam level. This operation was repeated; however, only part of the spoil was cast onto the lower-level, while the rest was hauled and pushed back into the first cut. Following removal of coal from this second "B" seam cut, the seam was augered. At this point, reclamation or slope grading started. The slope was con-



Adapted From Reference No. 3-1

MULTI-SEAM OPERATION
CUT-FILL-SLOPE PROCEDURE
Figure 3-23

toured 5 degrees toward the "B" highwall out to the edge and then down to the lower worked out bench of the "C" seam to a maximum slope of 15 degrees. After mining operations (conducted in the above manner) were completed on the "B" seam, the same operations were switched to the overlying "A" seam 60 feet above the "B" coal. The "A" seam was mined using the same basic procedures as before. The "B" seam bench, sloped in at 5 degrees, was used the same way the worked-out "C" seam bench was utilized. After all coal was stripped and augered the cuts were completely backfilled. After mining of the first cut was completed on the lower seam, mining of the upper seam began and proceeded at the same time.

Planting operations began on the lower 15 degree slope before mining of the upper seam. Planting was done at the best climate times using hydroseeding with perennial rye, fescue, and weeping lovegrasses to establish cover. Timothy and clover were planted later, with black locust and virginia pine seedlings planted on the slopes. Slopes not exceeding 15 degrees were utilized later for pasture lands.

Another multi-seam operation being conducted in 24 degree slope terrain was utilizing somewhat similar mining and reclamation methods. Three unmined seams were being mined, a 2 foot rider and 5 foot main seam underlain by another main 3 foot seam. Separations between the lower and upper two seams were 55 feet and 45 feet respectively.

Initially, all land surface to be affected was cleared of vegetative matter. This organic growth was placed in a windrow just below the toe of the lower seam spoil. Mining commenced on the lower seam, proceeding westward for 1,000 feet. Spoil removed from this cut was pushed over the side until the toe of the pile reached a horizontal line 20 feet below the seam mined. Remaining spoil was hauled to a previously mined out area.

After the coal was removed, all equipment was transferred to the original starting point to proceed eastward for 2,000 feet. During this time, auger mining was conducted in the western cut. As before, material not moved in the long eastern cut was either pushed over the side or hauled off-site for backfilling previously mined-out areas. When augering was complete in the western cut, eastern-cut spoil was no longer hauled off-site, but was used to backfill the western-cut until the highwall was covered. When mining was completed along the 2,000 foot eastern outcrop, all equipment returned to the starting point and moved up to the middle seam. Most spoil from the 45 foot highwall was pushed below on a bench left during lower seam mining; the remaining spoil was hauled off-site. Mining proceeded in a similar manner on this seam with one exception. Spoil from the eastern cut of the middle seam was hauled off-site for the first 500 feet and then afterwards hauled back in the western cut where augering was completed.

This mining operation is continuing and its success has not been totally evaluated.

Modified Block Cut

Although this technique is practiced to some extent in northern West Virginia, it is not considered characteristic of Region I. Detailed description of Modified Block Cut Mining is presented under Region II characterization.

REGIONAL RECOMMENDATIONS

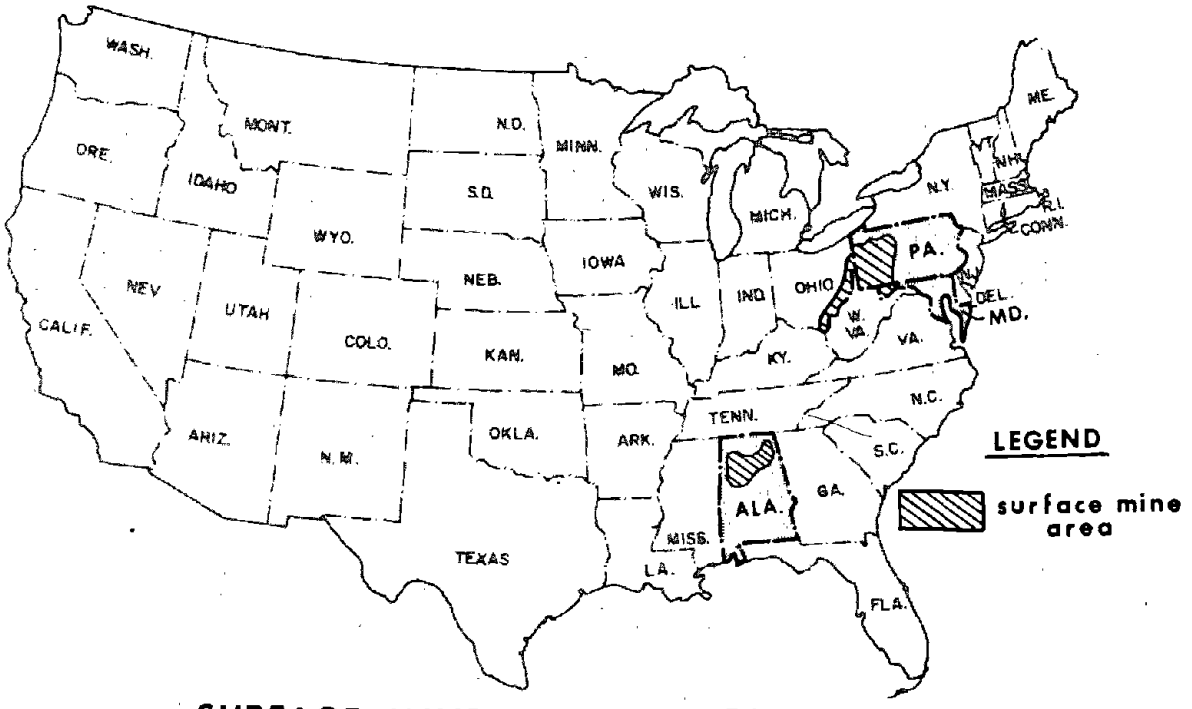
After careful analysis of mining methods practiced in this region, and evaluation of their environmental effects, Controlled Placement or Haulback techniques are recommended for maximum coal production with minimum environmental effects. Effective, preplanned use of front-end loaders, dozers, scrapers, and trucks can offer good coal production and excellent concurrent reclamation. That overburden removal and re-grading - backfilling of the pit to original contour are integrated operations is the major reason why this mining system reduces many of the environmental disturbances so inherent with other steep slope contour mining methods.

Another mining technique practiced in this Region recommended for use to increase coal production is Mountain-Top Removal-Valley Fill. However, extended usage is cautioned until full evaluations of environmental effects have been determined, although preliminary indications show little environmental disturbance.

REGION II

CHARACTERISTICS

Region II includes Pennsylvania, Maryland, Alabama and Southern Ohio, representing the northern and southern extremes of the Appalachian Coal Fields (See Figure 3-24). Although these states are disjointed, they share basic geographic characteristics inherent with the Appalachian Mountain chain and its coal beds. All coal lying within confines of the Appalachian mountains is bituminous, with the exception of a small lignite belt crossing lower Alabama along the Gulf coastal plain and the Pennsylvania anthracite fields.



SURFACE MINE AREAS - REGION II

Figure 3-24

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TABLE 3-2

REGION II

STATE	COAL BEARING AREAS	RANK	B.T.U. (X 1000)	ASH (%)	SULFUR (%)	MOISTURE (%)
Pa.	Main Bituminous	Bituminous	Increases from Avg. low of 14.7 in West to Avg. high of 15.8 in South-east.	Ash content varies for the coal seams in each field, generally any coal seam can range from a minimum of 4% to a maximum of 50%.	Mostly High Sulfur	Western ¼ ranges from 3% to 6%. Eastern 3/4 ranges from 2% to 4%.
	Georges Creek (Wellersburg)	Bituminous	15.8 Avg		Medium	2.0 - 4.0
	Broad Top	Bituminous	15.8 Avg		Medium	2.0 - 4.0
	North Central	90% Bitu-minous, 10% Semi-anthracite	Declines from high of 15.8 in the West-ern most fields to a minimum of 14.4 in the eastern most fields.		Low to Medium	2.0 - 4.0
	Northern Anthracite	Anthracite			Low to Medium	2.0 - 4.0
	Western - Middle Anthracite	90% Semi-anthracite 10% Anthracite			Low to Medium	2.0 - 4.0
	Eastern - Middle Anthracite	Anthracite			Low to Medium	2.0 - 4.0
	Southern Anthracite	Anthracite			Low to Medium	2.0 - 4.0
Md.	Georges Creek Basin	Sub-bituminous	12.5 - 14.5	5.1 - 15.5	0.6 - 4.2	1.3 - 4.8
	Upper Potomac Basin	Sub-bituminous	12.5 - 14.5	5.1 - 15.5	0.6 - 4.2	1.3 - 4.8
	Castleman Basin	Bituminous Sub-bituminous	12.9 - 14.2	5.3 - 14.1	0.8 - 4.2	1.7 - 5.3

TABLE 3-2

COAL CHARACTERISTICS

GEOLOGIC CHARACTERISTICS	
Series of broad, low, northeast - southwest trending anticlines and synclines. Dips generally less than 2° never greater than 8°. Folding is strongest in Georges Creek Field and Eastern Portion of Main Bituminous Field. No known significant geologic faulting except in an area constituting about 10% of the main Bituminous Field in the eastern most sector. Mineable seams generally average between 2' and 6'.	
Lies in the center of wide-deep structural basin. Secondary anticlines and synclines trending about north - south are prevalent. Dips are frequently as high as 30°. Coal seam thicknesses range from 2' to 5' and are often parted.	
No known faulting. Series of broad-low, northwest - southwest trending anticlines and synclines. Dips generally less than 2° and never more than 8°. Mineable coals vary in thickness from 2' to 7' and are often separated by numerous partings.	
Numerous geologic faults and subordinate folds. Dips in excess of 60° are common.	Contains two equal sized sub-basins within one large synclinal basin. Coal seams vary in thickness from 3' to 13'. Almost every seam is parted. Major partings range from 6" to 4' and vary for each seam.
	Two large adjacent synclinal basins and several smaller basins. Seam thicknesses vary from 3' to 15'. Only one seam in this field is not parted at all. The remaining seams contain partings ranging from 2" to 2'.
	Several closely clustered synclinal basins. Seam thicknesses vary from 4' to 22' and each seam may be separated by partings ranging from 6" to 3'.
	This field is made up of several highly faulted, closely spaced synclinal basins. Seam thicknesses range from 5' to 36' and can contain partings which vary between 3" and 7'.
Thick coal seams which contain shale and bone partings.	
Thick coal seams which contain shale and bone partings.	
Synclinal basin containing 12 coal seams. Syncline is symetric with 8°-10° dips on Meadow Mt. which are approximately double the dips on Negro Mountain.	

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TABLE 3-2

REGION II (CONTD.)

STATE	COAL BEARING AREAS	RANK	B.T.U. (X 1000)	ASH (%)	SULFUR (%)	MOISTURE (%)
Md. (Contd.)	Upper Youghiogheny Basin	Bituminous Sub-bituminous	12.0 - 13.5	9.6 - 15.5	0.8 - 3.6	1.9 - 3.3
	Lower Youghiogheny Basin	Bituminous Sub-bituminous	12.0 - 13.5	9.6 - 15.5	0.8 - 3.6	1.9 - 3.3
Ala.	Coosa Coal Field	Bituminous	13.7 Avg	9.2 Avg	1.9 Avg	2.1 Avg
	Cahaba Coal Field	Bituminous	13.6 Avg	7.3 Avg	1.0 Avg	2.9 Avg
	Plateau Coal Field	Bituminous	13.4 Avg	9.7 Avg	1.6 Avg	3.3 Avg
	Warrior Coal Field	Bituminous	13.4 Avg	8.7 Avg	1.5 Avg	2.7 Avg

TABLE 3-2

COAL CHARACTERISTICS

GEOLOGIC CHARACTERISTICS
Alternating layers of thin sandstone, shales, coals and clays found in synclinal basin. Rapid variation in coal seam thickness.
Alternating layers in thin sandstone, shales, coals and clays found in synclinal basin. Rapid variation in coal seam thickness.
Coals contain partings, thicknesses vary, seams are persistent. Steep dips in places.
Highly faulted and folded. Beds are of irregular thicknesses.
Minimum of 8 coal beds mined. Seams and clay, shale, and sandstone overburden are folded and eroded.
Basin structure, coals of various thicknesses, contain partings.

Pennsylvania and Maryland share the same geographic and geologic structure. Coals of Pennsylvania range through the Pottsville, Allegheny, Conemaugh, Monongehela and Dunkard Groups of the Pennsylvania and Permian Age. Some of the coal beds in the Broadtop Field of Pennsylvania frequently dip as much as 30 degrees, producing mining difficulties. Generally, the remainder of the beds in Pennsylvania and Maryland are flat-lying (with dips of 2 to 8 degrees) in broad northeast to southwest trending synclines and anticlines. Some significant faulting occurs in Centre, Clinton, Clearfield and Cambria counties of Pennsylvania.

Average Pennsylvania and Maryland coals have BTU values of 14,400 to 15,800, ash free moisture content from 0.5% to 12%, ash content from 4% to 20%, and sulfur from 0.5% to 4.5%. Lower mineable seams can be expected to have increased sulfur content, with 5 to 10% of the coal having high sulfur content and 25 to 30% having medium sulfur content. Coal thicknesses range from thin, one foot seams, to the usually thick seamed Pittsburgh coal, which has been known to reach twelve feet in some areas.

All mineable coals are found in a vertical range of 2,500 feet with an average separation of 40 feet. There are as many as forty mineable seams throughout Pennsylvania and Maryland. Overburden is generally common sedimentary clay, sandstone and shale. Some sandstones are massive consolidated units. Underclays associated with the Clarion-Brookville coals are important to the fire-brick industry, sometimes to the point that coal extraction is a secondary consideration. Acidic overburden associated with Clarion-Brookville and Kittanning coal seams does not usually facilitate good vegetation. However, the higher Freeport and Pittsburgh seams yield somewhat alkaline spoil material with good vegetation potential.

Most coal bearing areas of Pennsylvania and Maryland are mountainous woodlands suitable for wildlife, timber, and grazing, while some areas in Indiana and Armstrong Counties of Pennsylvania are suitable for dairy farming.

One-third of Alabama's coal production is for the coke market, while two-thirds of the production is for industrial (steam) and domestic uses. Most coal is high volatile bituminous with some beds of medium

to low volatile rank. Average characteristics of Alabama coal shows BTU values of 11,630 to 14,300; moisture content, 1.0% to 4.7%; ash, 2.5% to 16.6%; and sulfur, 0.4% to 3.9%.

The Calaba Field has 16 mineable beds in a formation some 9,000 feet thick; in many places these beds may be steeply inclined. Irregular seam thicknesses due to folding and faulting make mining in this field rather difficult. The Warrior Coal Field has seven coal groups with two to six productive seams. Some seams in this field have additional value due to the presence of underlying fireclay. Most seams average 1 to 7 feet thick with current production from the Black Creek, Mary Lee, Pratt and Brookwood groups. This field is the largest producer in the state, lying just south of the Tennessee River headwaters.

The Plateau field is in the northeast region of Alabama, which is also considered the lower reaches of the Appalachians. At least eight beds of coal have been mined with the Upper Cliff No. 1 and No. 2, Underwood, and Castlerock beds being the largest producers. Most coal currently comes from the Sand Mountain region. Overburden for this field consists of clays, shales and sandstones. The Warrior and Plateau fields are generally flat-lying to undulating beds with some western extremes of the Warrior field having overburden characteristics of the coastal plains.

Alabama has two major lignite belts; one along the Gulf Coastal Plain in formations of Tertiary Age, and another Northern belt that is of Cretaceous Age. Coastal Plain outcrops are a minimum of 12 feet thick with much of this belt 30 to 40 feet thick.

Since northern lignite is not presently considered valuable, no detailed exploration has been performed. These lignite belts are not major producers, primarily because most mining here is associated with captive steel or utility steam coal operations.

Topography in Alabama's coal fields ranges from the flat coastal plains, through the rolling plateau just southwest of the Tennessee River, to the beginnings of the Appalachian's in the northeast. The primary surface land use in this area is agricultural, with cotton, corn, sorghum, peanut and truck farms. Rainfall tends to be somewhat more consistent and suitable to farming interests in the southern regions.

Climatic conditions of Pennsylvania and Maryland coal regions are similar with somewhat milder conditions apparent in most of Maryland. Rainfall averages 36 to 48 inches per year with snowfall ranging from 20 inches in the southeast to 90 inches in McKean County, Pennsylvania. Temperatures range from a mean minimum of 39° F to a mean maximum of 86° F with record low of -42° F and a high of 111° F. Hurricanes have been known to directly affect Pennsylvania and Maryland weather on at least two occasions in recent years, with Hurricane Agnes in 1972 flooding all areas of these states. The predominant weather factor for the western reaches comes from the Great Plains of the United States and Canada, while eastern sections are influenced more readily by Atlantic coast storms.

Alabama is almost entirely influenced by coastal storms from the Gulf of Mexico. Generally the central portion of the state is somewhat drier than the northern reaches, which are influenced by the Great Plains weather. Rainfall ranges between 56 and 64 inches per year with severe hail storms common in the north during winter months. Snowfall can occur in the north, but is not a major factor. Mean minimum temperature is about 45° F with mean maximum at 80° F. Northeastern areas may experience 0° F readings for short time periods in the winter. Drought conditions occur statewide during July and August each year.

BASIC MINING METHODS ENCOUNTERED

Region II could be characterized as having the most variation in mining methodology. Methods range from conventional contour stripping in Alabama, to modified block cut in Pennsylvania through dragline and shovel usage in box-cut contour mining and modified area mining, to small area mines using dozers and loaders for excavation. The following state of the art descriptions of currently practiced methods indicate common applications of mining technology within the region.

Conventional Contour Strip Mining

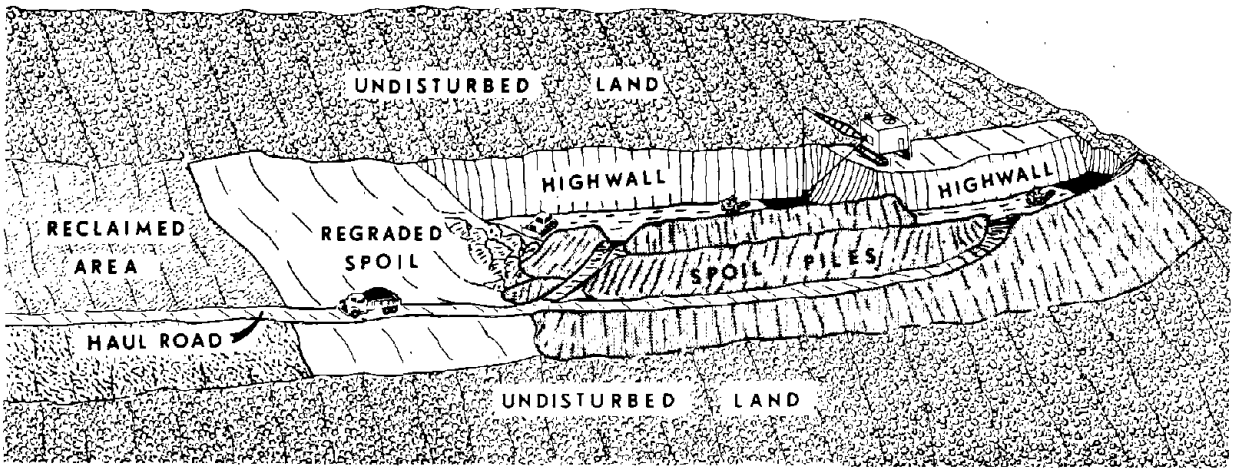
Though prohibited from use in Pennsylvania, Ohio and Maryland, conventional contour stripping (as described in Region I characterization) is still practiced to some extent in Alabama.

Box-Cut Contour Mining

As a variation of the conventional contour mining method, box-cut mining utilizes the concept of spoiling overburden material on the outslopes. All of the detrimental environmental effects associated with the conventional technique apply here also. Major differences between box-cut contouring and the conventional method stem from leaving a coal barrier 15 to 25 feet thick at the outcrop (depending on state laws). By leaving this barrier in place, water does not freely flow off the pit bench onto and through the spoiled overburden which could cause landslides and acid drainage problems. Another major difference is equipment utilization. Since a required coal barrier must be maintained, dozers and loaders have little major stripping application. Instead, draglines or shovels are used to uncover the coal seam.

The first cut is removed and placed directly on the low wall barrier along the contour of the outcrop line. The low wall assists in supporting a major portion of the spoiled material, as the remainder of swelled overburden rolls down the outslope (see figure 3-25).

This method finds little use in Pennsylvania, Ohio and Maryland, but is practiced to a greater extent in Alabama coal fields. Probable forthcoming legislation, prohibiting spoil placement downslope of the operating bench would outlaw using this type of mining (without modification).



TYPICAL BOX CUT CONTOUR METHOD

Figure 3-25

Unit Operations

Since box-cut contour mining is expected to have little future application, and since it is similar to the conventional contour method, emphasis is placed only on those unit operations that substantially differ from the conventional contour system, specifically: Overburden Preparation; Overburden Removal and Backfill-Regrading. Other auxiliary operations, such as Maintenance, Materials Handling and Storage, etc., are discussed at the end of this section as they apply to Region II mining methodologies.

Overburden Preparation

With a box-cut type excavation, blasting must be controlled to avoid fracturing the low wall barrier, as this would defeat the purpose of leaving it. Holes with 20 to 25 foot spacing are common with an average of 500 pounds of ANFO for every 50 feet of depth (this loading and spacing will vary according to material characteristics). Vertical, crawler or truck mounted percussion and rotary drills are commonly used. Roller-bit and drag rotary drills have good usage in

soft to medium hard rocks (shales and sandstones) while down hole percussion drills are better suited for hard rock conditions (14). Dozer ripping is practiced whenever possible to avoid drilling and blasting costs.

Overburden Removal

This unit operation is difficult to "characterize", as there are many variations.

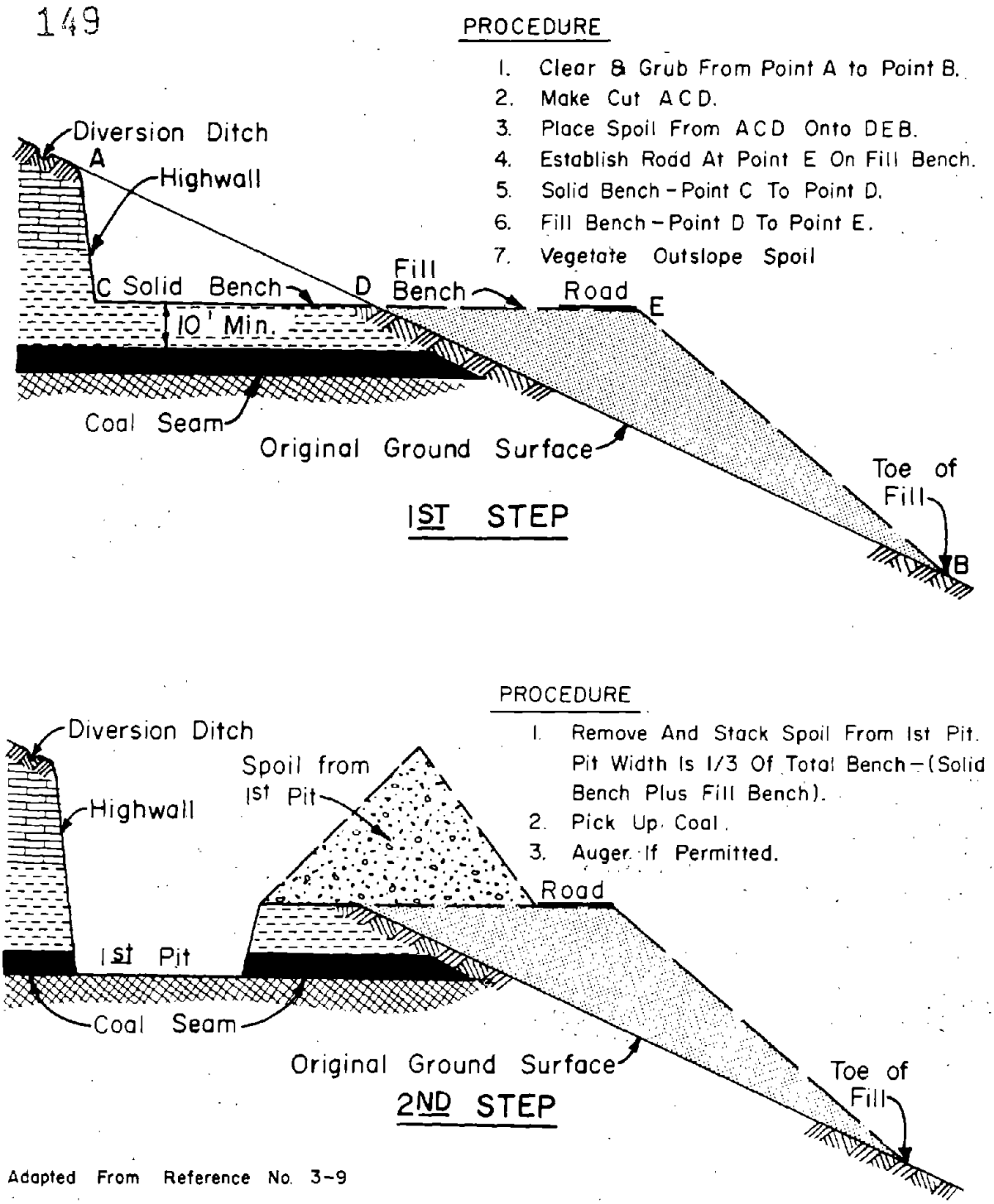
Typically, fractured overburden is removed from the first box-cut along the contour and placed on the low wall, with any excess material rolling down the outslope. Draglines and shovels, commonly used for this purpose, have bucket sizes ranging from 6 to 20 cubic yards. Draglines have better application where pit conditions are wet, and where spoil segregation is attempted. Both machines require support equipment for coal cleaning, while only draglines need working benches to be established.

Successive interior cuts are taken until a limiting highwall is reached, with spoil material cast into the preceding cut. Final spoil configuration resembles the box-cut area mine spoils of the Midwest, with mounds of material on the bench. This mounding permits easier regrading if a near original contour configuration is desired.

In steeply sloped areas, mounding spoil on the low wall produces serious landslide threats, which are somewhat overcome by using the slope reduction techniques shown in figures 3-3 and 3-4 of the conventional contour discussion. These reduced outslopes are usually graded and seeded as soon as possible to curtail erosion and reduce landslide problems.

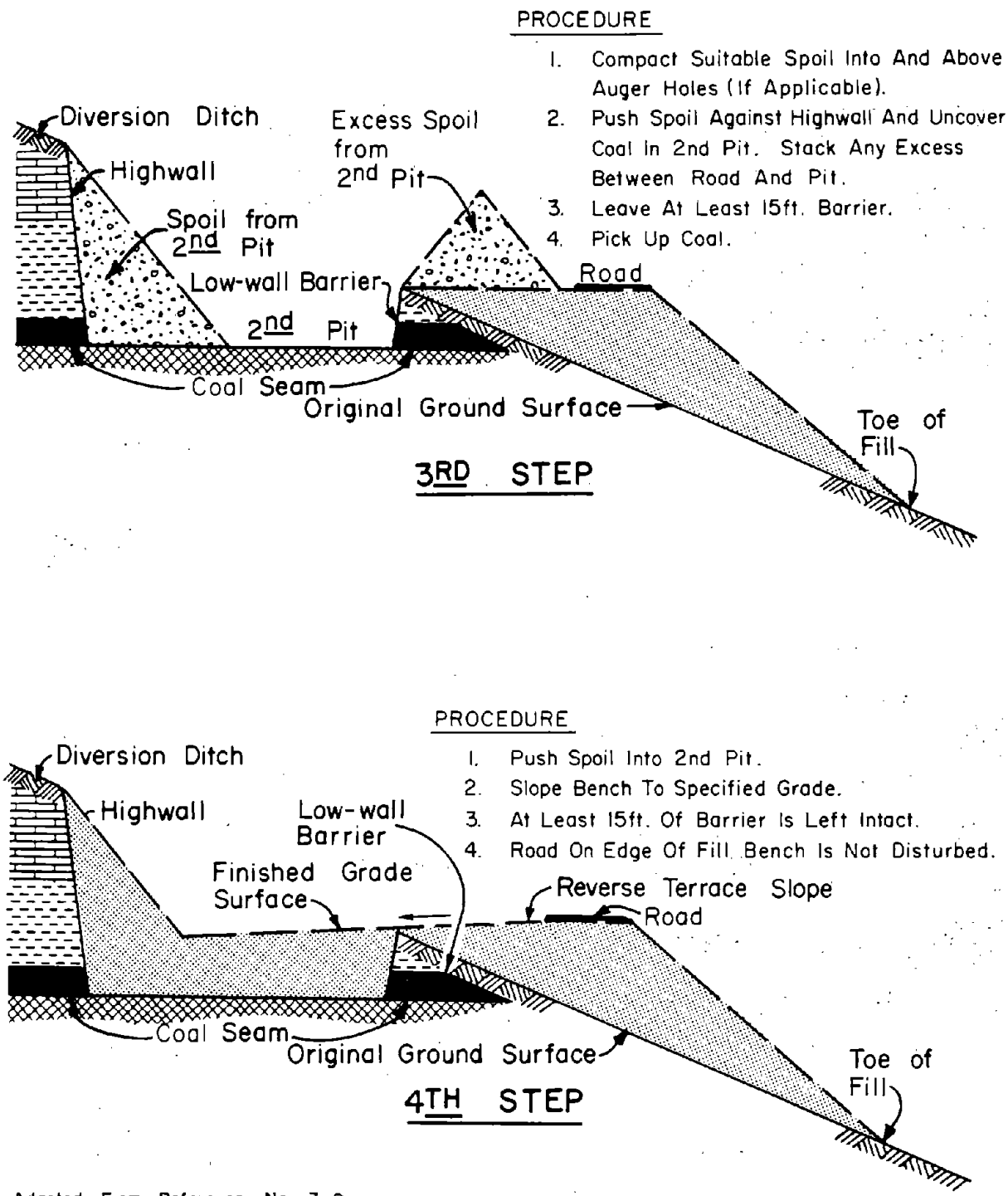
Another variation of the box-cut approach is the two-cut method. (8) (See figure 3-26a and 3-26b). This variation reduces the amount of overburden material on the outslope, thus reducing threats of slides. If spoil is vegetated immediately after placement and grading, erosion potential can be greatly reduced.

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Adapted From Reference No. 3-9

TYPICAL BOX-CUT METHOD (2 CUTS)
Figure 3-26A



Adapted From Reference No. 3-9

TYPICAL BOX-CUT METHOD (2 CUTS)
Figure 3-26B

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Backfill-Regrading

The sketches of the two-cut box cut method show that highwall elimination is accomplished with spoil material from the second cut. Final regrading thus results in a terrace effect. Dozers perform this final regrading procedure.

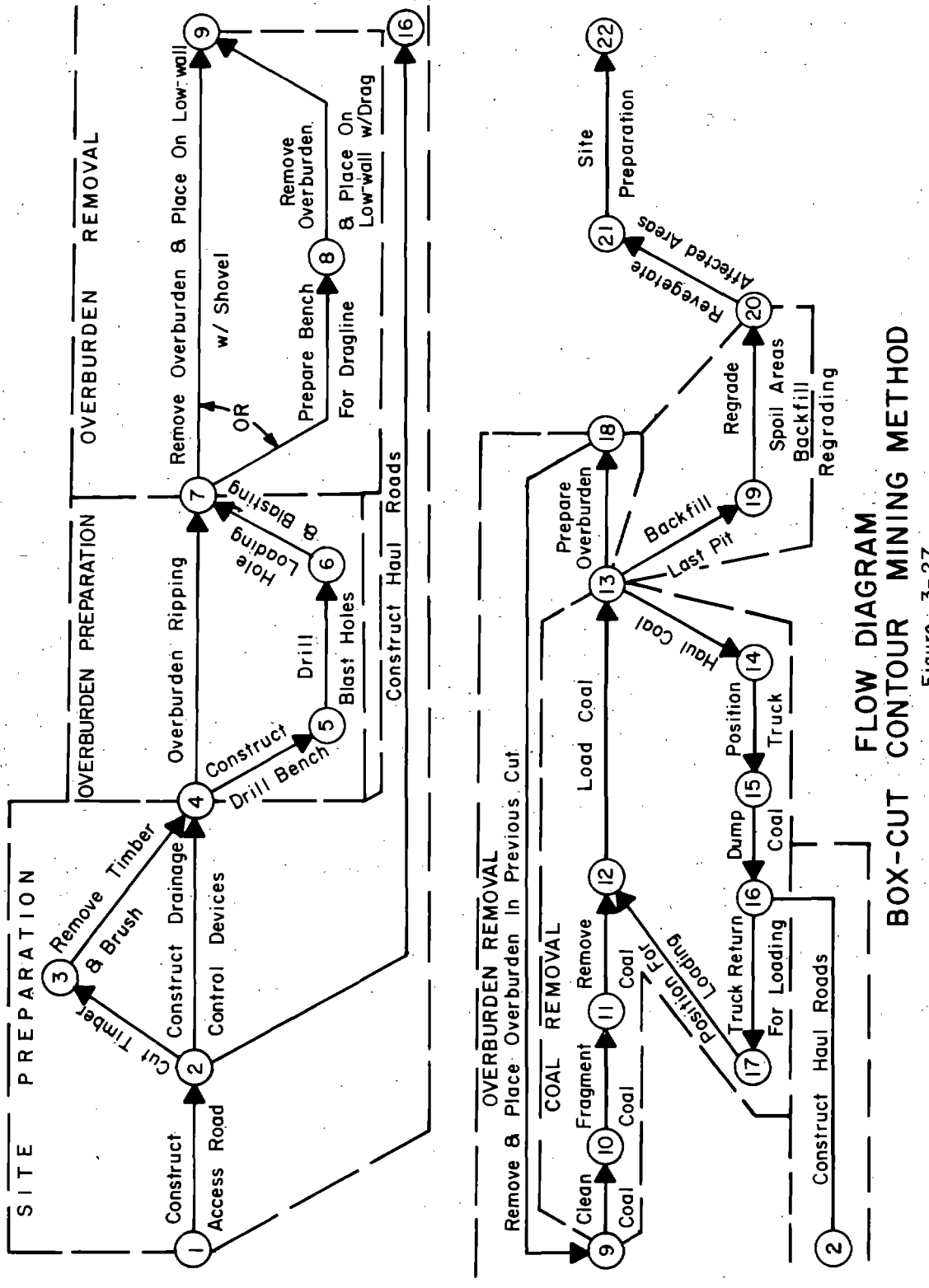
Box-cut contour mining can be regraded to near original contour, but excessive spoil rehandling costs usually result in terraced grades. Small draglines are often used to "pull-back" the cast material, while dozers take care of final grading procedures.

Operation Relationships

Unit operational activities are related as indicated in figure 3-27. Second cuts are dependent on coal removal from first cuts. Little pit scheduling is required with this method, since operations generally flow in a series pattern.

Effects of Box-Cut Mining

Problems of preventing spoil erosion, slide conditions, and resultant stream sedimentation, exist with any downslope spoil disposal technique. The surface overburden, often the better portion of the spoil, is cast downslope, leaving the lower materials with higher pollution potential on the bench. Spoil segregation, though difficult to accomplish using this mining method, would greatly assist current ailing revegetation attempts on regraded spoils. Terrace regrading (especially reverse slope or swale) is often used to reclaim box-cut contour mines. Although easily performed, the final reclamation grade induces water infiltration through toxic materials on the bench, causing acid mine drainage problems.



FLOW DIAGRAM
BOX-CUT CONTOUR MINING METHOD

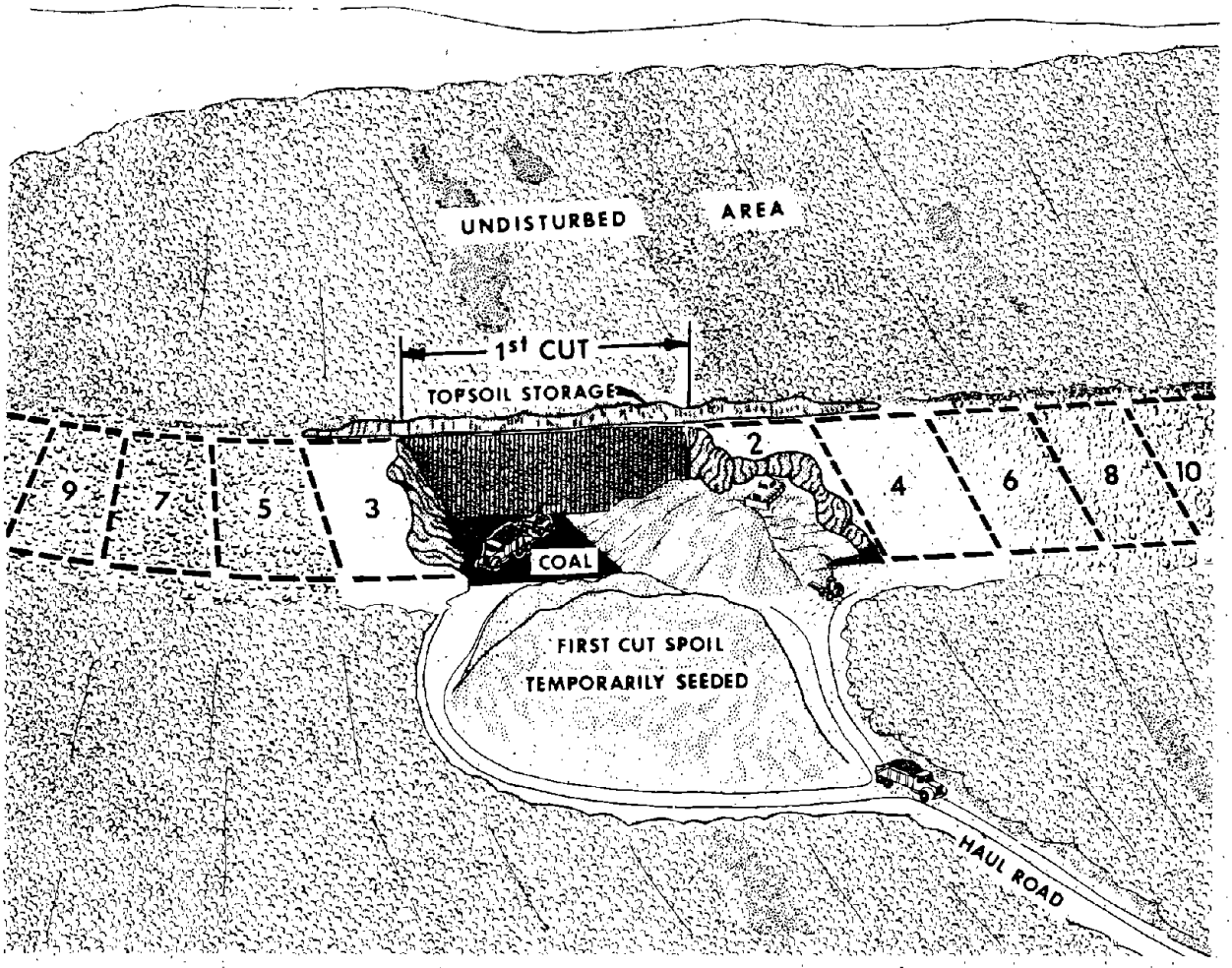
Figure 3-27

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Modified Block-Cut Mining

A contour mining method, Modified Block-Cut Mining (sometimes referred to as simply Block-Cut) reduces spoil spillage on the outslopes, and creates few environmental disturbances. Similar to the haulback method, all spoil, except for the initial cut, is moved laterally along the bench. The accompanying sketches illustrate the basic activities of this technique (See figures 3-28a and 3-28b).

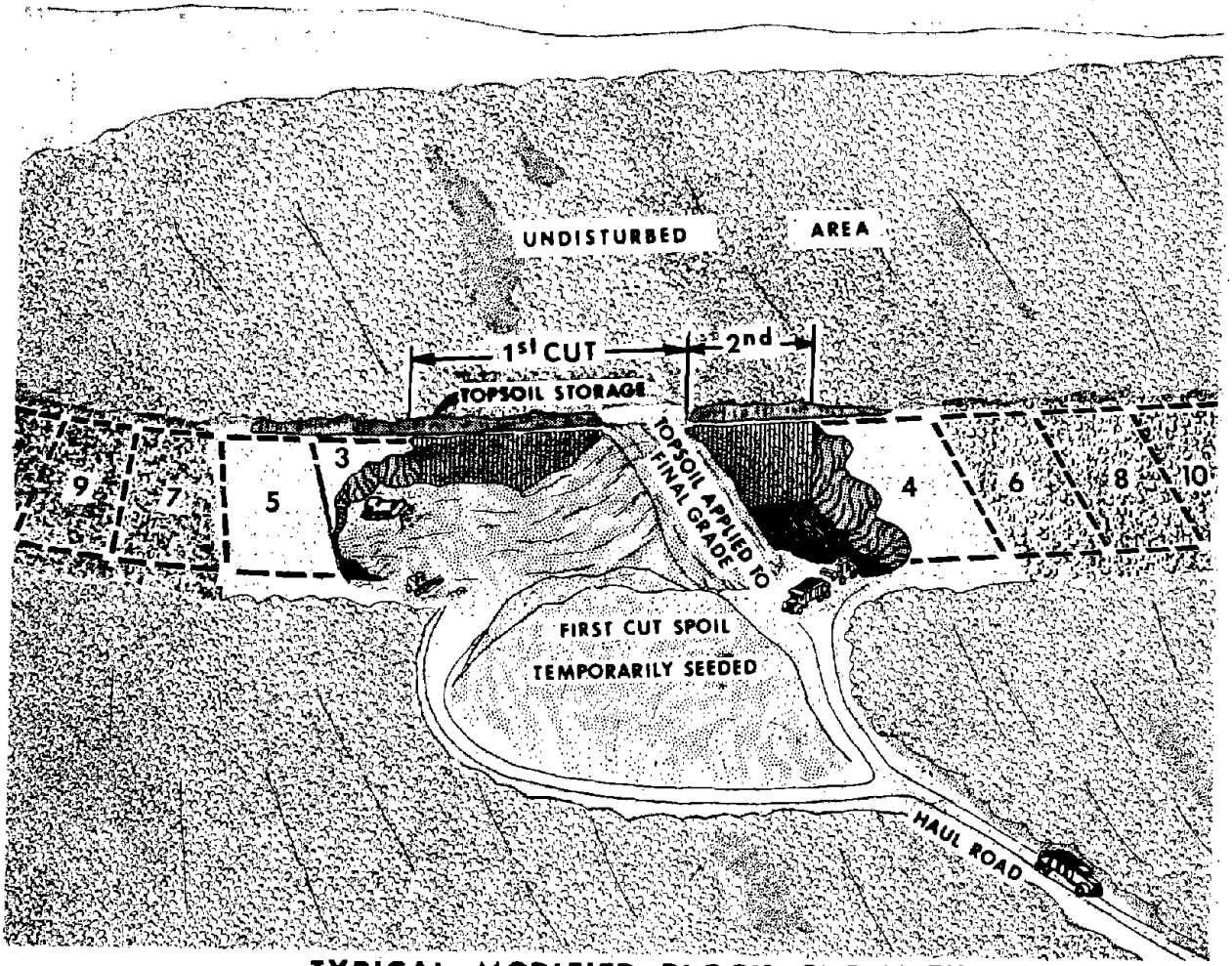
Initially, a box or block cut is excavated to the limiting highwall height, as close to the center of the mining permit area as possible,



TYPICAL MODIFIED BLOCK CUT METHOD
1st STEP

Figure 3-28A

leaving a 25 foot wide low wall barrier, with spoil carefully compacted, graded, and temporarily seeded on the immediate outslope. Coal from this initial cut is removed, after which overburden from cut No. 2 (approximately 1/3 to 1/2 as long as the initial cut) is placed in cut No. 1. When cut No. 2 coal is exposed and ready for loading, stripping of cut No. 3 begins and continues through No. 2's loading cycle, placing the spoil in the remaining portion of the initial cut. Regrading and revegetation of the first cut is then accomplished. Overburden from cut No. 4 is placed in No. 2 after coal is totally exposed in cut No.3, then No. 5 overburden is removed to No. 3, No. 6 to No. 4, etc., until completion. Reclamation grading is conducted as the final load of spoil is pushed into a mined out cut with revegetation of the graded



TYPICAL MODIFIED BLOCK CUT METHOD
2nd STEP

Figure 3-28B

blocks occurring as soon as weather conditions permit. Successive cuts become smaller and smaller as mining continues, thus minimizing the amount of overburden that must be hauled to fill the final pit.

Block cutting is becoming increasingly popular in moderate to steep slope conditions, especially in the Appalachian Region. The cuts are mined as units, thereby making it easier to retain the original slope and shape of the mountain.

At some sites, cut sequence proceeds in one direction only. This does not allow for continuous coal loading, but is applicable to small areas.

Unit Operations

Clearing and Grubbing

Wooded areas are timbered off, with brush piled in windrows at the lower edge of the limit of affected area, well in advance of mining.

Topsoil Removal

Dozers remove topsoil by pushing it uphill (on moderate slopes) to the top of the expected highwall limit, which allows for easy replacement after regrading and backfilling. In steeper terrain, topsoil is stockpiled on the low wall barrier until reclamation. Stacking topsoil material on the low wall does not contribute much to erosion because it is replaced on the regraded slope so quickly (16). Pan scrapers are generally not used in this technique.

Overburden Preparation

Practices discussed under the Haulback or Controlled Placement approach in Region I, also apply to this method.

Overburden Removal

Bulldozers and front-end loaders are most effectively used to move overburden along the blocks (16). Operating on the previously fractured overburden, these machines perform a "load and carry" operation by simply pushing and carrying the material to the adjacent vacant block. Spoil segregation is easily accomplished, with blocky acidic material buried at the base of the previous highwall. Rarely do more than four stripping machines operate at any one site (two dozers and two loaders). In some mines, where only one of each machine is employed (with the loader also being used for coal loading), coal production reaches 2000 tons/month (one shift operation).

Coal Loading

As blocks of coal become exposed, one of the stripping loaders remains behind to load coal while the rest of the fleet goes on to uncover the next block. When coal fracturing is required, one of the stripping dozers rips the coal prior to loading.

Coal Hauling

Similar to Region I, Modified Block-Cut mines of this Region are often scattered and usually do not have on-site preparation facilities. Therefore, coal is hauled in 20 to 30 ton capacity end-dump highway trucks. Outside contract hauling is common in Pennsylvania, Ohio and Maryland, and can cause major production delays by requiring the loader to wait for trucks, or by overloading the pit with too many trucks. Efficient scheduling is difficult with outside contract hauling.

Backfill-Regrading

Owing to the fact that overburden removal and pit backfilling are incorporated into a single operation, costs of reclamation regrading

are substantially reduced. Obviously, equipment usage is identical to that of overburden removal, for dozers and loaders final grade the spoil to contour as they deposit it. The only "extra" activity of final grading is replacement of the topsoil, with a dozer, either by pushing it upslope or downslope to cover the backfilled pit.

Revegetation

Broadcast and hydroseeding of various grasses and legumes provides excellent vegetative cover for soil stabilization and erosion control. Applying mulch, fertilizer and crushed limestone further enhances revegetation results. Replacement of original topsoil material provides an excellent base for plant growth.

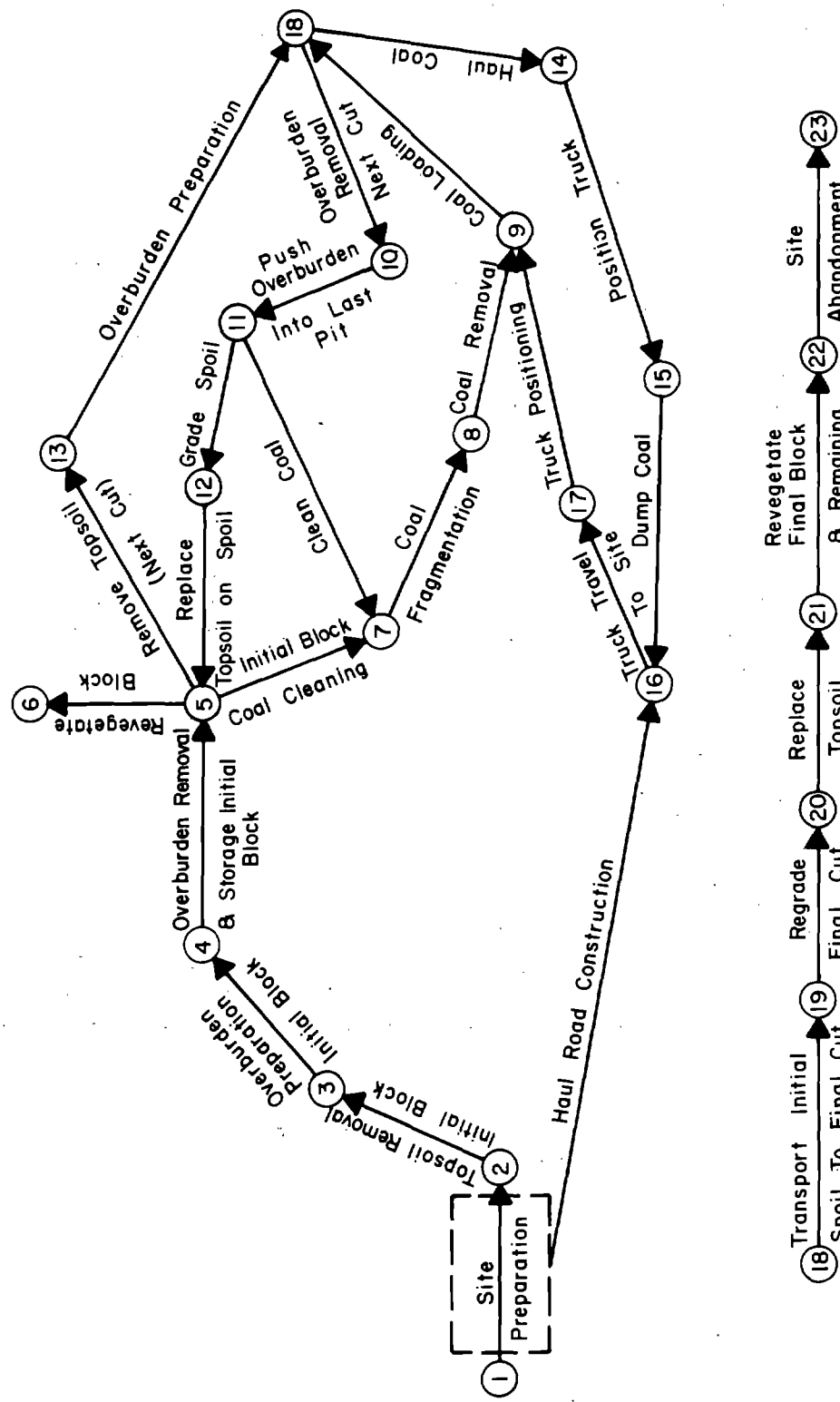
Operation Relationships

Efficient production scheduling is a difficult task with this technique. After initial cuts are made, unit operations integrate to form a complex array of cyclical operations, requiring precise timing and planning for continuous coal removal (See figure 3-29).

Effects of Modified Block Mining

Modified Block-Cut mining generally refers to small operations, where large stripping equipment is not utilized. The Modified Block approach, with alternating strip cuts on either side of a ridge, precludes the use of larger equipment applications (large draglines and shovels) because too much production time is wasted traveling between pits.

Environmental benefits and disturbances are similar to those listed for the Haulback method in Region I. They include:



FLOW DIAGRAM
MODIFIED BLOCK-CUT MINING METHOD

Figure 3-29

Advantages

- Aesthetically pleasing as no spoil is cast downslope during mining, and treelines above and below the working bench are maintained.
- Eliminates double handling of spoil.
- Low capital investment (2 machines can mine).
- Eliminates landslide problems.
- Retards acid formation with immediate burial of toxic materials.
- Highwalls are eliminated.
- Fast reclamation grading and replanting is accomplished.
- Minimizes erosion.
- Multi-seam mining is practical.
- Safety hazards are reduced by reducing exposed highwalls.
- Small disturbed area.

Disadvantages

- Small total coal production per year, but high tons/man-hour.
- Proper planning, design, and scheduling are necessary.
- Good location for initial spoil placement is required.

Modified Area Mining

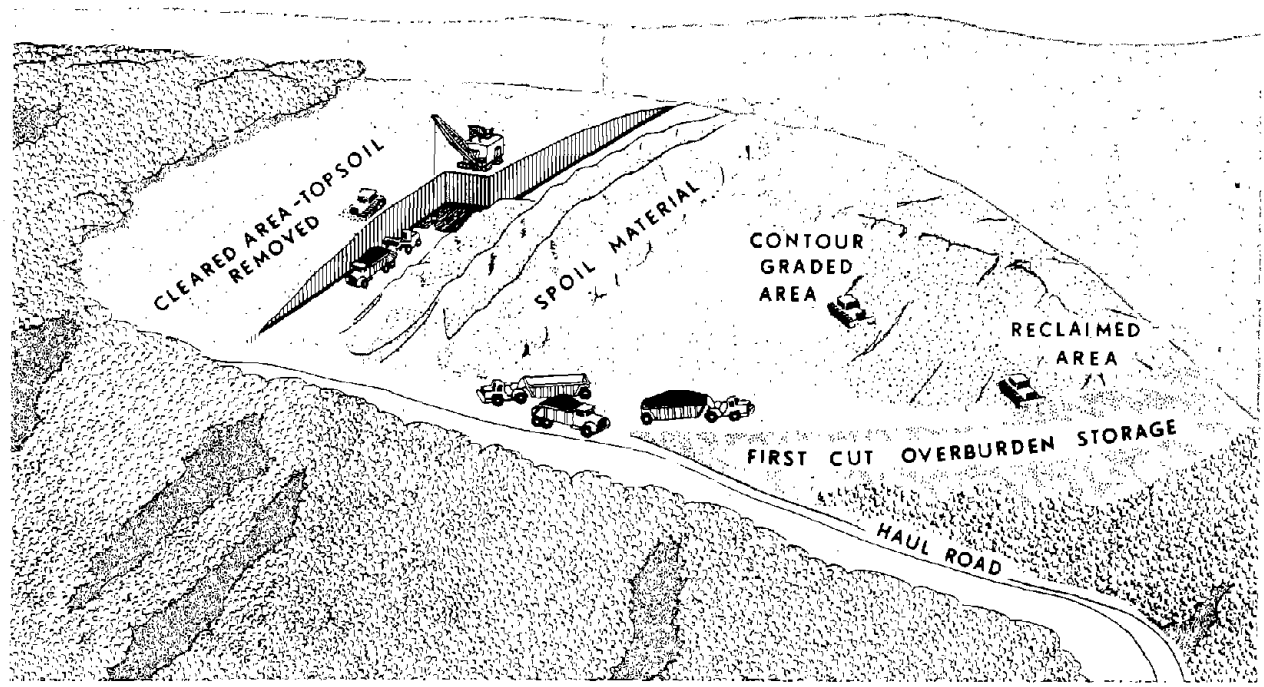
Modified Area Mining involves adaption of box-cut area mining

methods to rolling and hilly terrain.

Although similar to the Mountain-Top Removal Method of Region I, in that nearly 100% reserve recovery is obtained, major differences occur in: equipment usage; overburden removal and handling; final grading; and application in rolling terrain rather than steep slope mountains.

This technique is usually incorporated where a coal seam outcrops on opposite sides of a hill or ridge, with maximum overburden thickness through the hill being no greater than 150 feet. Modified Area Mining is also labeled hilltop removal, or ridge removal, and is accomplished by establishing an initial box-cut through the hill, exposing and removing coal from outcrop to outcrop. Successive cuts are taken with overburden from each new cut placed in the previous one. Regrading replaces the terrain to its near original contour, a major difference from Mountain-Top Removal (see figure 3-30).

Especially applicable to some abandoned contour strippings, Modified Area Mining can produce coal previously thought unrecoverable, and at the same time reclaim those orphan strip mines whose abandoned benches provide excellent storage areas for initial box-cut spoils.



TYPICAL MODIFIED AREA MINING METHOD

Figure 3-30

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Unit Operations

Mining unit operations that differ from those described in Box-Cut Contour and Modified Block discussions include: Topsoil Removal, Overburden Removal, and Regrading.

Topsoil Removal

First and second cut topsoil is removed by pan scrapers and stored on stockpiles for use in reclamation grading of the final cut. Topsoil from third and successive cuts is removed and placed directly on regraded spoil areas, thereby combining topsoil segregation and reclamation in a single operation. By temporarily seeding storage areas with a combination of quick cover grasses, topsoil erosion is eliminated.

Overburden Removal

Initial box-cuts are made near the point of a ridge or hill, or wherever first-cut spoil can be stored with minimal environmental effects. Draglines or shovels ranging in size up to 45 cubic yards are the primary stripping machines. However, due to their good spoil segregation capabilities, draglines find more common usage with this technique. Acidic or toxic material, when encountered, is placed on the floor of the previous cut and immediately buried with non-toxic spoil to reduce potential acid production. To allow for coal loading in the last exposed block of each cut, draglines or shovels travel back to the beginning of the pit before starting the next excavation.

When draglines are used in conjunction with abandoned contour mines, the last portion of overburden in a cut is removed and placed outside the end of the next successive pit on the abandoned bench to provide a working area for dragline operations. Spoil banks very much resemble those encountered with large area mines in the

Midwest, Region III. If cropline coal has not been stripped away by previous operations, low wall barriers remain, with no disturbance of land below the outcrop line.

Regrading

Spoil mounds are contour regraded with dozers, maintaining original slopes and ridge lines. Pan scrapers perform final grading as they deposit the topsoil. Topsoil removal from new areas and replacement on regraded areas is conducted in a single unit operation, thus eliminating materials rehandling and making the most efficient use of scraper capabilities.

Operation Relationships

Since Modified Area Mining is only a variation of Area Mining in the Midwest, Region III, interrelationships of unit operations will be identical to those shown in the discussion on Area Mining in Region III, Basic Mining Methods Encountered.

Effects of Modified Area Mining

Like Mountain-top Removal, Modified Area Mining provides nearly 100% coal recovery. With increasing coal demands, this technique may find greater usage in the near future.

Advantages

- By leaving outcrop low wall barriers, pit water is contained, reducing threats of water pollution.
- Segregation and burial of toxic overburden material is easily accomplished (with dragline usage), reducing acid production potential.

- Near total reserve recovery is accomplished.
- Side benefit of reclaiming abandoned mines (when applicable).
- Reclamation is concurrent with mining, reducing the amount of exposed overburden material and associated erosion potential.
- Topsoil erosion is minimized by direct placement on regraded areas.
- Aesthetics are maintained by regrading to near original contour.
- High production potential.

Disadvantages

- Initial cut must be stored and stabilized for future use in backfilling the final pit.
- Complete disruption of hilltop rock strata overlying the coal occurs, which could effect local groundwater movement.

Auxiliary Mining Operations

Road Maintenance

Road graders are used extensively for haul and access road maintenance, along with occasional adoption of dozers, pans and front-end loaders. Heavily traveled roadways receive semi-annual applications of road oil (or sometimes tar and chip paving). Normal usage routes are wetted daily in the dry summer months with sprinkler trucks, to minimize dust generation. During wet periods, crushed stone is applied to soggy areas to prohibit road rutting and reduce rolling resistance.

Equipment Maintenance

Most mining companies in this Region practice some sort of a preventive maintenance program, whether it be daily machine checklists performed by the operator, or scheduled service contracts conducted by the equipment suppliers. Periodic fluid changes (hydraulic, crankcase, and oil) and other minor tasks are accomplished with mine maintenance personnel, while major breakdowns require manufacturers' service crews. Most mine maintenance programs consist of: a central workshop for major repairs and overhauls; parts storage areas stocking frequently used or hard to obtain machine parts; welding trucks; mechanic trucks (equipped with a tow mechanism); several pick-up trucks; fuel and lubrication vehicles; small cranes (15 to 70 ton capacities); and qualified maintenance personnel (welders, electricians, mechanics, foremen, and laborers).

Materials Storage and Handling

As in Region I, central warehouses usually supply several mine sites. However, as sites become more scattered, separate storage areas are more practical, since travel time between mine and store is reduced. Major items in stock include fuel, lubricants, lime or soda ash, wire rope, tires, fuel oil, ammonium nitrate, dynamite, blasting caps, electric wiring, and numerous spare machine parts. Well-kept inventories usually have needed materials on hand for immediate distribution. With equipment parts in great demand and their long lead-times for delivery, spare items are ordered well in advance of their expected use; then stocked until needed. Some companies have a better parts inventory than their supplier, but it seems they "never have the right part at the right time."

Power Distribution

Fuel dispensing to major equipment involves delivery by a company-owned fuel truck from central storage facilities. Minor equipment usually travels to these facilities for refueling.

With use of electric draglines and shovels in this region, electrical distribution systems are required. Incoming voltage to mine substations can be as high as 33 K.V. (kilovolts), but is usually only 4.16 K.V. for pit distribution with cable ranging in size from No. 2 to 4/0. Whenever possible, portable substations are employed to avoid excessive ground cable runs to the pit. (See Power Distribution discussion in Region IV Characterization.)

Pollution Control

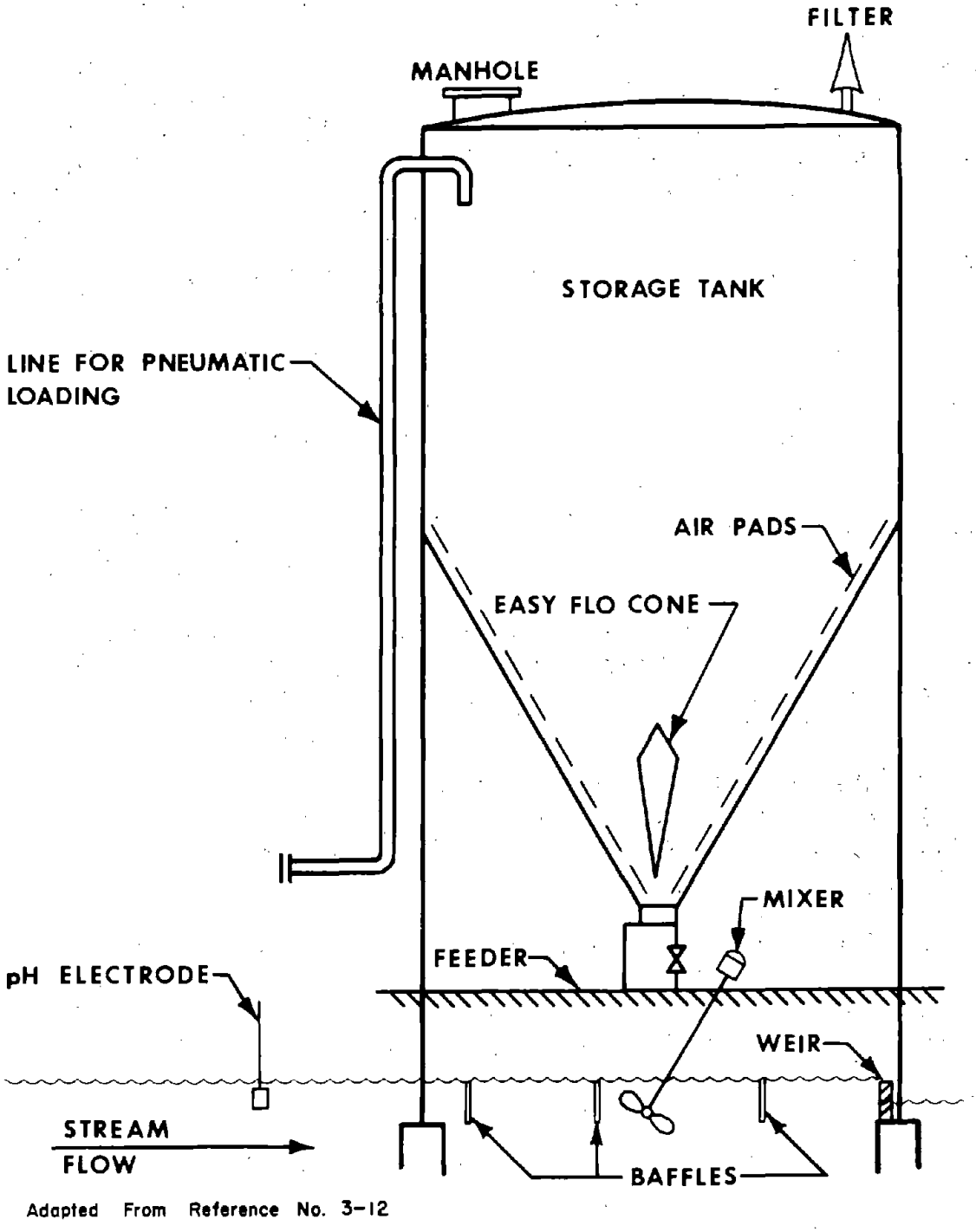
Diversion ditches and sediment retention structures, described in Region I, are used in this region also, with the exception that settling basins are usually in series of two or more, which is not always the case in Region I.

Neutralization techniques are very similar to Region I methods with application of automatic devices in some areas. See Figure 3-31.

Diversion ditch applications and overall water handling for box-cut mining are nearly identical to conventional contour stripping, with the exception that water collected in the pit must be pumped out from a collection sump.

Modified Block-Cut Mining utilizes diversion ditches along the top of the highwall to divert water from the site and ditches along the haul road to collect runoff water for removal of sediments (See Figure 3-32). Typical water handling systems for Modified Area Mining are shown in Figure 3-33.

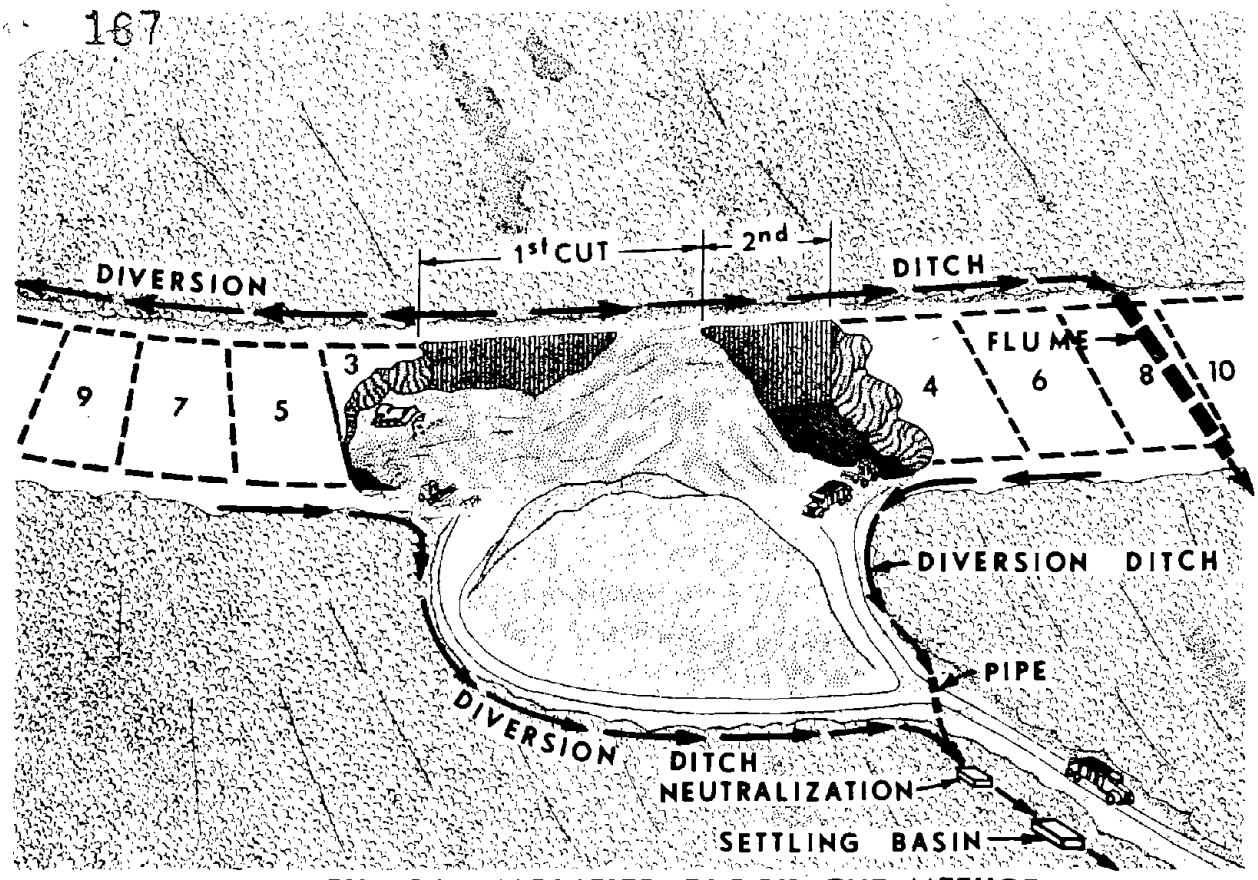
Pit collection sumps (20 feet x 30 feet x 5 feet average) are excavated in the strata beneath the coal seam, at the lowest point in the pit (either the low wall or highwall). As water collects in the sump, groundwater and/or surface runoff, it is automatically pumped via pipeline to neutralization and sedimentation facilities.



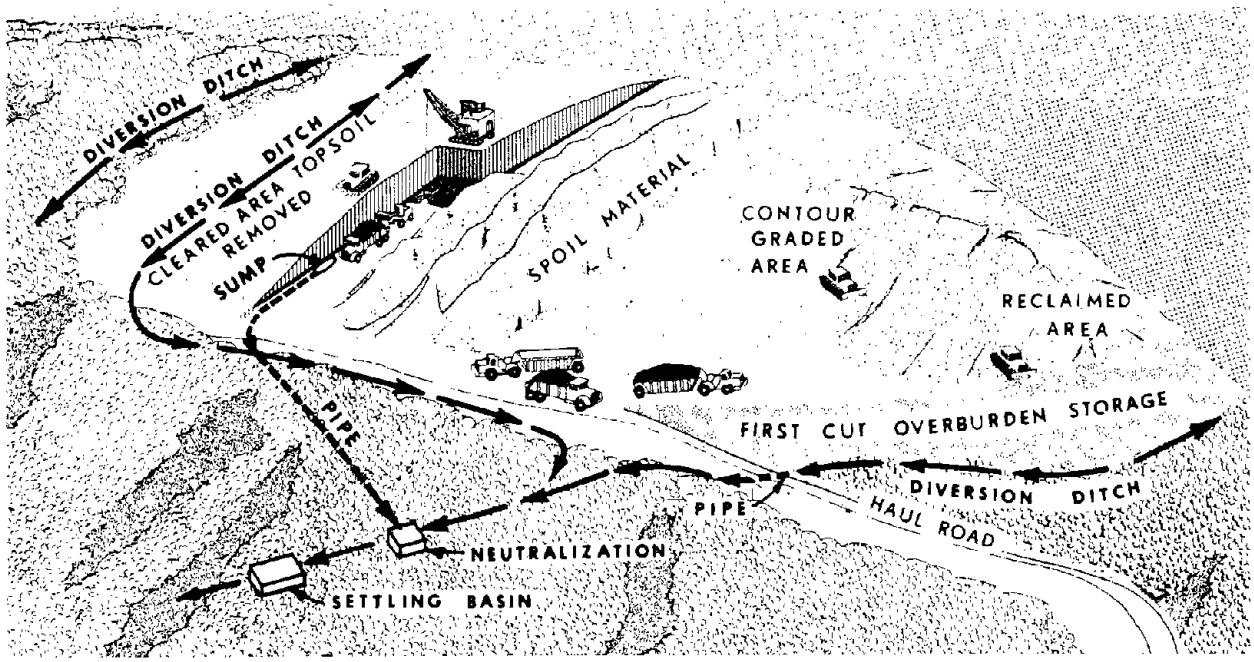
Adapted From Reference No. 3-12

AUTOMATIC LIMING DEVICE

Figure 3-31



TYPICAL MODIFIED BLOCK CUT METHOD
WATER HANDLING SYSTEM
Figure 3-32

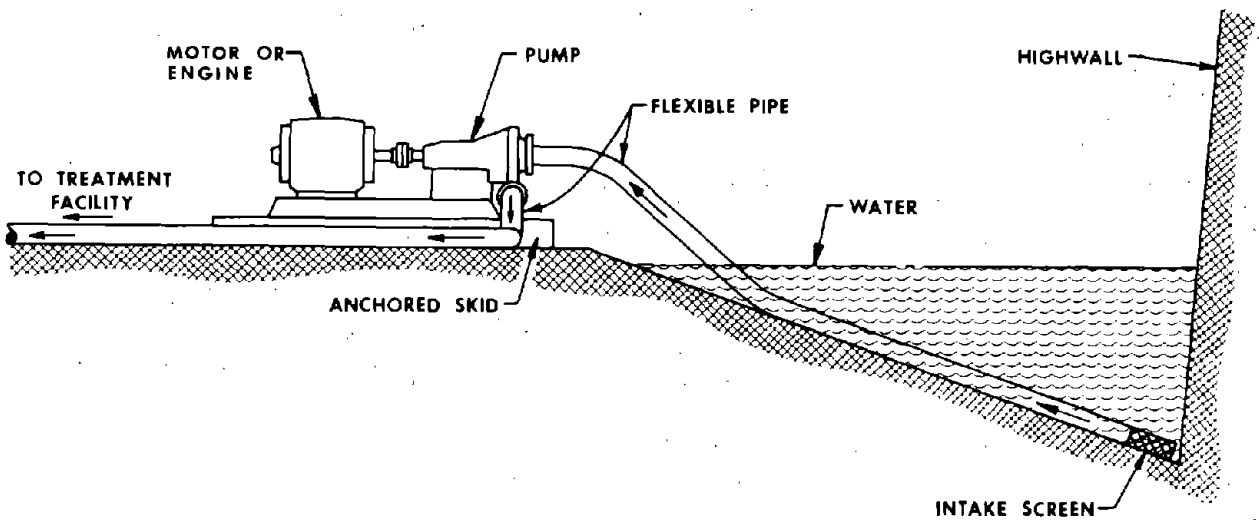


TYPICAL MODIFIED AREA MINING METHOD
WATER HANDLING SYSTEM
Figure 3-33

Sump volume and pump size are designed to insure that no flooding will occur in the pit. Surface pumps with submerged suctions are commonly used (see Figure 3-34).

Pit dewatering keeps the pit dry, thus minimizing wet, soggy floor conditions and water contact with acidic spoils. As the pit advances, sumps are reconstructed and water lines extended.

Controlling dust by oil and water applications to haul and access roads is common.



TYPICAL PIT SUMP

Figure 3-34

Communications

Radio equipped pick-up trucks, maintenance crews, and major stripping machines keep unproductive downtimes to a minimum by notifying the proper authority when a problem arises. Radio communication with the office can save valuable travel time for parts delivery, by simply requesting delivery from the warehouse.

OTHER MINING METHODS ENCOUNTERED

Block-Area Mining

In response to new coal markets, miners in Region II have developed a mining system which encompasses advantages and techniques of Modified Block-Cut mining to conditions almost applicable to Modified Area utilization. For the purpose of nomenclature, it is named Block-Area mining.

This "technique" uses equipment similar to that of Modified Block-Cut: dozers and front-end loaders. Limited to areas where maximum overburden depth is 40 feet, this system can economically remove coal seams as thin as one foot.

An initial block cut is established by dozing and carrying material to a mound adjacent to the cut. Toxic material is buried and the mound is stabilized with temporary vegetation. Similar cuts are made in sections 2, 3, 4, 5, etc., along the direction normal to the advancement of the face (see Figure 3-35). Coal is loaded immediately after blocks are exposed. Successive cuts 6, 7, 8 are then pushed into the mined-out area, with reclamation grading accomplished simultaneously (see Figure 3-36). Variations in cut sequence are many, but the important point is that, like the Modified Block-Cut technique, overburden removal and reclamation grading are integrated operations.

Advantages

- Economic recovery of thin seams.
- Reduction of pollution potential by burial of toxic substances, and immediate regrading.
- Minimal capital outlay for equipment.

- Low production costs ($/ton are lower with dozer-loader, Block Method than with drag) (16).
- Easy topsoil segregation.
- No separate spoil regrading procedures; reclamation concurrent with mining.
- Original contour is easily attained for reclamation.
- Higher production is easily accomplished by applying more equipment into a stepped-face type pit configuration (described in "An Analysis of Strip Mining Methods and Equipment Selection" - Research and Development Report No. 61, I.P. #7, by R. Stefanko, R. V. Ramani, and M. R. Ferko, page 115).
- One machine breakdown cannot stop operation.

Disadvantages

- Storage of initial block cuts until backfilling final pits could be a problem.
- Depending upon the block sequence used, water handling and coal hauling routes could also become problems.

REGIONAL RECOMMENDATIONS

With large variations of geologic-geographic conditions and production ranges of individual mines in this Region (3,000 to 1,000,000 tons/year), recommendation of a particular mining method that would maximize production and minimize environmental effects, is not practical. However, by incorporating basic principles into any technique practiced in this region, good production with little environmental disturbance can be achieved. Principles include:

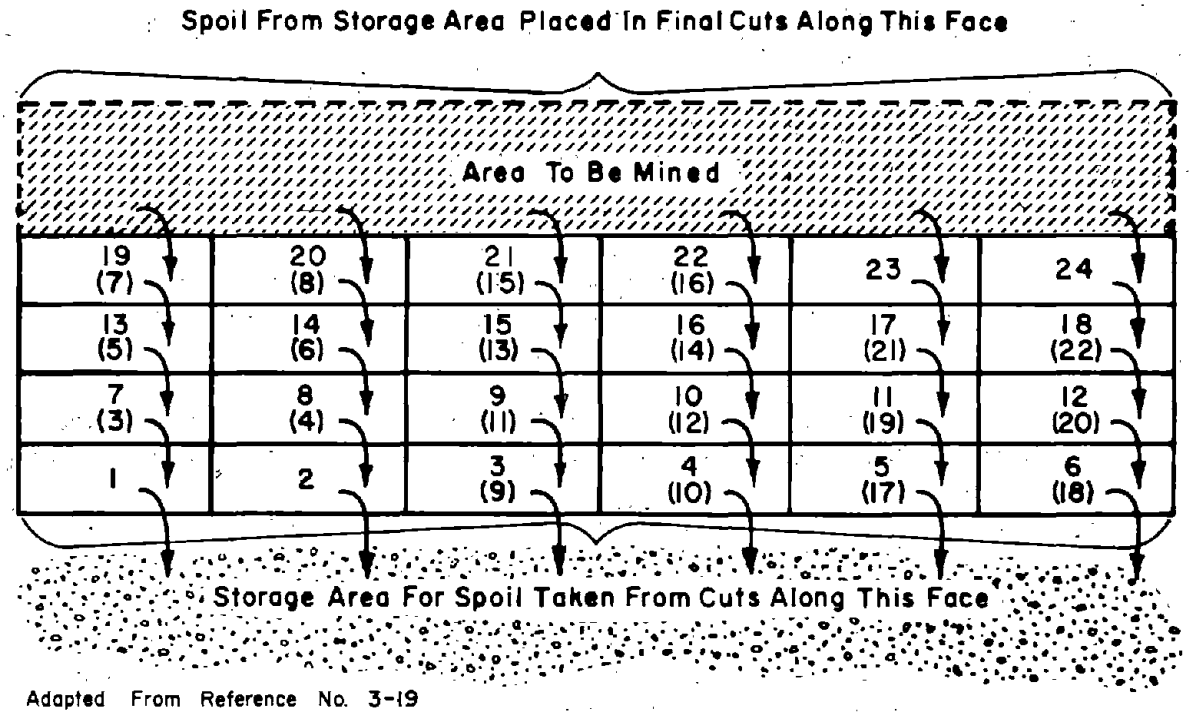
- Practice spoil segregation and immediate burial of toxic materials.

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- Where topsoil is of sufficient quantity and reasonable quality (Why conserve non-productive topsoils?) remove and re-apply on regraded spoils in one operation if possible.

- Incorporate as many production operations as possible into reclamation procedures, thus integrating unit operations.

- Have a pre-planned reclamation scheme which can easily be integrated with a feasible mining procedure. Near original contour grading is most acceptable in this region.



Adapted From Reference No. 3-19

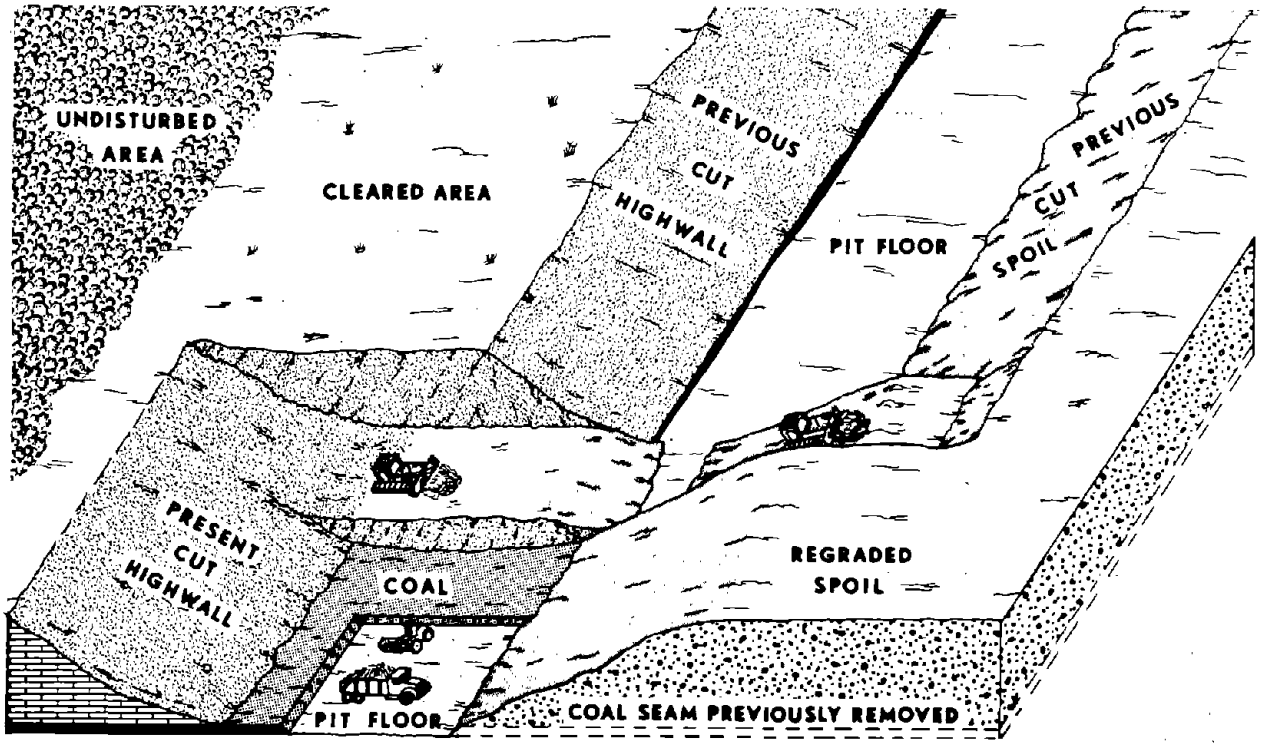
9 - Indicates Sequence Of Block Cuts

(11) - Indicates Alternate Sequence Of Block Cuts

BLOCK - AREA MINING

CUT PATTERN SEQUENCES

Figure 3-35



TYPICAL BLOCK-AREA MINING METHOD

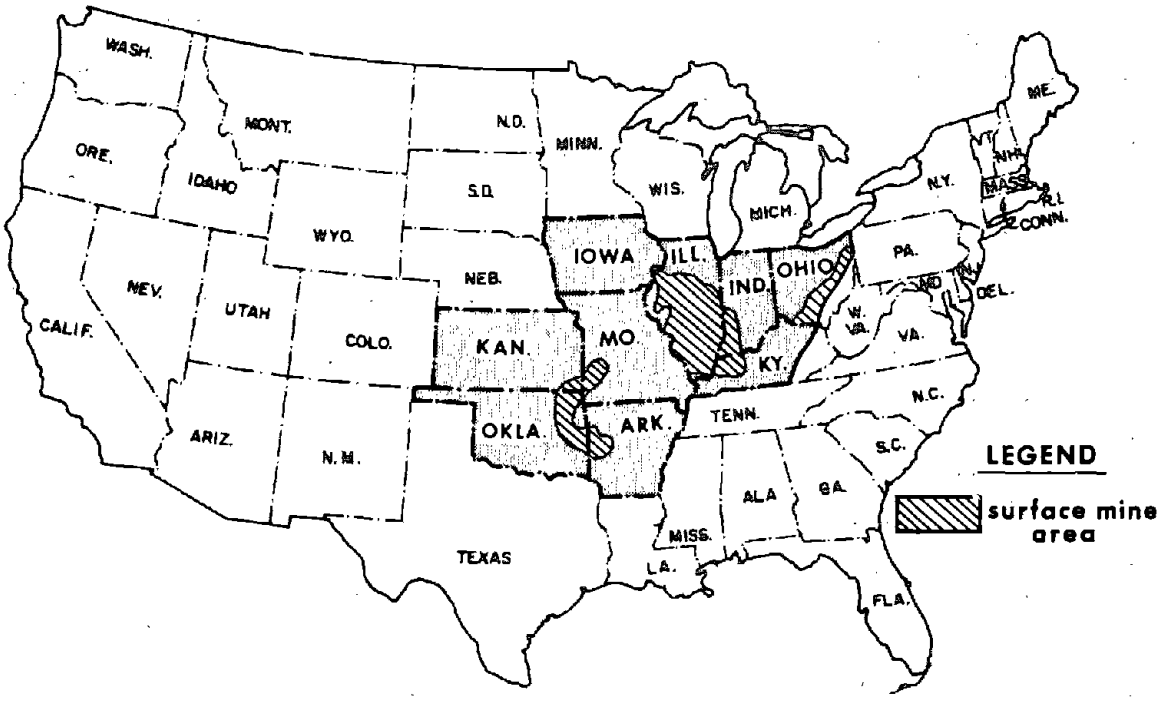
Figure 3-36

The three systems that come closest to meeting the above criteria are: Modified Block-Cut, Modified Area, and Block-Area Mining. In mountainous areas, Modified Block-Cut mining is recommended. Though not a high production (ton/year) method, low production costs and minimal associated environmental disturbances make its use attractive. Utilization of very large dozers and front-end loaders could increase future production, further enhancing this method's applicability.

In areas where conditions permit, and high production rates are desired, Modified Area Mining should be used. Environmental effects are few, and proper design and scheduling of unit operations can keep production costs low. Prior to adoption of the Modified Area technique for a particular area, consideration should be given to the Block-Area method, which offers all the advantages of Modified Block with large variations in production capabilities. Large scale Block-Area sites (many functioning blocks) can keep reclamation more concurrent with mining than Modified Area locations. With future development of larger dozers and loaders, Block-Area mining could replace the use of Modified Area methods.

CHARACTERISTICS

Region III includes the northwest portion of the Ohio coal field, the western Kentucky field, and all of Indiana, Illinois, Arkansas, Missouri, Oklahoma, Kansas and Iowa (Figure 3-37). The region has two distinct sub-regions with basic differences in climate and coal characteristics. Region III-A includes Ohio, west Kentucky, Indiana, Illinois, and has most of the region's known bituminous reserves. Region III-B includes Iowa, Missouri, Kansas, Arkansas and Oklahoma, and has both bituminous and lignite reserves.



SURFACE MINE AREAS - REGION III

Figure 3-37

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TABLE 3-3

REGION III

STATE	COAL BEARING AREAS	RANK	B.T.U. (X 1000)	ASH (%)	SULFUR (%)	MOISTURE (%)
Ark.	Shinn Basin	Bituminous	11.9 - 14.6	3.8 - 18.2	0.6 - 3.3	0.8 - 5.4
Ill.	Eastern Interior Coal Basin	Bituminous	11.0 - 15.0	10% Local variations of 2% - 3% common	Variable 0.5 - 6 3 - 4 Avg.	4 - 20
Ind.	Eastern Interior Coal Basin	Bituminous	10.9 - 11.6	6.3 - 12.2	1.16 - 3.31	10.0 - 15.5
Iowa	Western Region of Interior Coal Basin	Bituminous	9.2 - 10.1	14 - 18	3.0 - 6.0	17 - 19
Kan.	Southeastern Coal Field	Bituminous	10.4 Avg	20.4 Avg	3.9 Avg	6.0 Avg
	East Central Coal Field	Bituminous	8.7 - 12.2	6.7 - 15.7	5.1 - 9.9	7.4 - 15.3
	Northeastern Coal Field	Bituminous	-	-	-	-
	Cretaceous Lignite Area	Sub-bituminous Lignite	-	-	-	-
W. Ky.	Western Kentucky Coal Field	Bituminous	12.5 Avg	8.4 Avg	3.0 Avg	7.1 Avg
Mo.	Southwest District	Bituminous	10.1 Avg	22 Avg	4.8 Avg	-
	Tebo District	Bituminous	12.1 Avg	8.48 Avg	3.44 Avg	8.68 Avg
	Lexington District	Bituminous	-	-	-	-
	Bevier District	Bituminous	10.7 Avg	10.6 Avg	4.6 Avg	13.4 Avg
	Mendota - Novinger District	Bituminous	10.7 Avg	10.6 Avg	4.6 Avg	13.4 Avg

TABLE 3-3

COAL CHARACTERISTICS

GEOLOGIC CHARACTERISTICS
Coal thicknesses range from 2.5 – 7'. Partings range from 8" to 12".
BTU values systematically increase from NW to SE of basin. BTU values also increase at a rate of approximately 150 BTU/pound/100' depth in lower rank coals of Northern Illinois to 60 BTU/pound/100' depth of higher rank coals of Southern Illinois.
8 major seams interbedded with 1,500' of strata. Strata dips 25'/mile to West toward center of the basin.
Coals are Lenticular. Seams are rolling and of variable dip.
Relatively flat lying strata are free from faulting. Lies west of Ozark uplift. Prevailing dip is to northwest.
Uniform coal thickness, localized hardening and thickening. Very minor faults with little displacement.
Four coal seams ranging from 15" to 36". Most coals lie at depth and are not strippable.
Seams 12" to 36", flat lying. Area not developed.
Lies west of the Cincinnati Anticline. No. 9 seam is the most wide spread and persistent mineable seam, approximately 5' thick.
Flat lying, thin.
Thin coal, flat lying. Can reach as much as 30" in thickness.
Coals very thin and lie at depth.
Seam consists of 2 beds, thick upper separated from thin lower bed by a few inch thick clay and sand partings.
Seam consists of 2 beds, thick upper separated from thin lower bed by a few inch thick clay and sand partings.

TABLE 3-3

REGION III (CONTD.)

STATE	COAL BEARING AREAS	RANK	B.T.U. (X 1000)	ASH (%)	SULFUR (%)	MOISTURE (%)
Ohio*	Western Limit of Main Bituminous Field	Bituminous	12.4 Avg	8.78 Avg	3.25 Avg	5.7 Avg
Okla.	Northeast Oklahoma Shelf	Bituminous	13.2 Avg	7.6 Avg	3.3 Avg	4.9 Avg
	Arkoma Basin	Bituminous	13.5 Avg	8.5 Avg	2.3 Avg	3.4 Avg

* Includes Southeastern Ohio in Region II

TABLE 3-3

COAL CHARACTERISTICS

GEOLOGIC CHARACTERISTICS
Pottsville through Dunkard strata contain 21 major coal seams. Strata thins to the north and west.
Coals are 1' - 3' thick and dip to the N. W. from 1° - 3°.
Coals are 1.5' - 7.0' thick and occur in eroded folds that plunge southwest. Dips range from 3° - 90°.

Topography for the entire region consists of gently rolling hills and very flat plains. Most of this region is largely farm acreage in the northern reaches with grasslands or rangeland to the south. Soil conditions vary accordingly -- from extremely fertile in northern areas to relatively poor in the south central sections.

Region III - A Characteristics

Coals in this region range from knife-thin lenses to beds averaging 6 feet thick. Some localized areas are known to have up to 25 foot thick seams. There are 11 well defined beds of mineable coal, all medium to high volatile bituminous in rank (See Table 3-3). The quality of these coals varies between 9,700 to 13,100 BTU's, 0.4% to 6% sulfur, and 6% to 14% ash on an "as received basis." Pennsylvania and Permian Age stratigraphy, ranging from 280 to 1,000 feet thick, contains all of the coals of this sub-region. Illinois' reserves are the largest known high volatile bituminous reserves of the nation, with Kentucky and Indiana reflecting an eastern extension of the Illinois fields. The upper two or three seams are primarily extracted by surface mining operations, while most of the thicker deep seams are extensively deep mined. Mines from this sub-region produce more high quality coal per acre of disturbed land than any other area of the nation. Coal seams are relatively flat with dips of one to ten degrees and few major faults.

The eastern Ohio coal field is primarily Pennsylvanian Age (an extension of the Pennsylvania, Maryland, and West Virginia coal beds classified in Region II), which has eight mineable seams dipping one to eight degrees to the southeast, with few seams more than four feet thick. Somewhat more extensive faulting is encountered in this local area, due to the influence of the Appalachian Mountain chain just east of the field. Sporadic local areas with 20 to 25 feet of gray shale overburden yield low sulfur coals (0.5% S).

As stated earlier, this local area has some of the most fertile farmlands of the nation, with many grain and dairy farms. Due to relatively fault-free conditions and flat terrain, surface seepage and attending aquifer properties are not as unpredictable or as varied as the eastern coal provinces. Some acidic materials are encountered along the southern Indiana-Illinois border and on the western edges of the Ohio Appalachian coal fields.

Clays, shaley clays, red to gray variegated sandstones ranging from unconsolidated to massive, and some local shaley limestone conditions exist throughout the sub-region.

Climatic conditions for Ohio, Iowa, Indiana, Illinois and western Kentucky are generally characteristic of the middle temperate zone with four distinct seasons. Temperatures normally reach lows of - 10°F to highs of 100°F with an annual mean temperature of 42°F to 60°F. Frost lines range from 1 to 3 feet and snowfall up to 30 or 40 inches per year. Total precipitation varies from 36 to 50 inches yearly with storms producing 2 to 3 inches in 24 hour periods. Occasional storms can produce more than 5 to 6 inches per 24 hours. Temperatures do not cause major mining problems, but concentrated precipitation can cause heavy damage to newly revegetated areas and severe flooding in surface mining pits.

Region III - B Characteristics

Coal thicknesses in these states generally average from thin lenses to 3 feet. Localized conditions of 7 foot thick seams occur in Missouri coal fields. Coals in this sub-region range from lignites, and low to medium volatile bituminous coals in Oklahoma, Arkansas, and Missouri, to unusally high volatile, low sulfur coals along the middle border region of Oklahoma and Arkansas, (See Table 3-3). B.T.U. Values of 11,900 to 14,600, sulfur content of 0.6% to 4.5% and ash content of 3.8 to 18% are common. Low to medium volatile coals and lignite appear in Iowa, Kansas and northern Oklahoma with B.T.U.'s of 8,500 to 10,500, sulfur content 3% to 6%, and ash content 10% to 24%. A generalized stratigraphic column, representative of Oklahoma, ranges in thickness from 1,000 to 6,000 feet and contains nine mineable coal seams.

This region has a wider variety of surface characteristics and attendant uses than Region III-A. Parts of Iowa, Kansas and Missouri are very similar to Region III-A, while most of Arkansas, Oklahoma and lower Kansas experience a drier, sometimes semi-arid climate where the primary surface use is grassland or range. Topsoil in the lower reaches of the region is much more valuable, but at the same time more difficult to condition. Generally this material becomes a hard pan when severe rains prevail, and quickly de-waters in hot, dry conditions. Basic overburden composition includes grey, medium to hard sandstones. These strata are

nearly always alkaline in nature, with coals low in iron and acid, thus eliminating many of the acid and iron problems of eastern coal fields.

Climatic conditions of Missouri, Arkansas, Oklahoma and Kansas are typical of the Great Plains, except that this area is also influenced by storms from the Gulf of Mexico. Temperatures vary from lows of -20°F to highs of 105°F, with annual mean temperatures from 42°F to 76°F. Rainfall varies from 15 to 56 inches per year with storms generating as much as 10 to 12 inches per 24 hours. Snowfalls in Kansas are severe at times, with one major storm per season -- usually accompanied by high winds and drifting conditions. Tornadoes are common to the Region, usually resulting from weather conditions in the Gulf of Mexico.

BASIC MINING METHODS ENCOUNTERED

Area Mining

Mining operations in Region III use Box-Cut or Modified Area Mining Techniques. (Modified Area is discussed under Region II characterization). A wide spectrum of equipment is employed, with basic stripping operations performed by draglines or stripping shovels. Generally, in areas where coals lie within 40 to 50 feet of the surface, stripping shovels are used because of their speed of operation, while thicker overburden (150' in some areas) necessitates use of large draglines. Due to high overburden to coal ratios and flat terrain, capacities of stripping equipment range upwards from 35 cubic yards. Area mines in this region generally proceed away from the central storage area or tipple, with cuts normal or parallel to the dip of the coal seam.

Box-Cut area mining begins with an initial rectangular opening, casting overburden to one side. After removing exposed coal from this cut, an adjoining opening is made, placing overburden into the preceding mined-out cut. These parallel excavations are conducted until all reserves in the area are mined.

Unit Operations

Production unit operations for this characteristic mining method consist of Clearing and Grubbing, Topsoil Removal, Overburden Preparation, Overburden Removal, Coal Loading, Coal Hauling, Spoil Regrading, and Revegetation.

Clearing and Grubbing

Clearing and grubbing operations remove all large plant life and/or buildings. Most surface owners attempt to remove valuable timber prior to any mining operations. Dozers remove stumps and brush, usually piling it on heaps at some peripheral point from the proposed mine.

Topsoil Removal

An ideal topsoil removal system uses pan scrapers (push-pull arrangments) to strip topsoil ahead of mining and concurrently replace it on regraded spoils behind the operation. However, not all situations are ideal. Some miners simply place topsoil onto stockpiles with dozers and truck highlift combinations. Storage areas are temporarily seeded to prevent erosion and sedimentation.

Overburden Preparation

Overburden preparation actually begins with topsoil removal, by providing a suitable bench for drill rig operation. Drilling and blasting are commonly used to fracture the overlying strata, with hole sizes, grid spacings and loadings depending upon characteristics of the material. Vertical rotary and percussion drill units with bits up to 15" diameters are used, with grid patterns from 20' x 20' centers to 40' x 54' centers. Support equipment includes small dozers, nitrate trucks, fuel oil trucks and dynamite transport vehicles.

Some horizontal drilling and blasting is conducted, but is not common practice. This technique can be applied in shales where no hard layers of sandstones or limestones are present.

Advantages of horizontal drilling include: (14)

- No drill bench is required.
- Easy to supply with electricity, providing coal loading equipment is electrically powered.
- Lower drilling cost per foot.

Disadvantages:

- Not applicable to hard materials (limestones and sandstones.)
- More equipment in the pit, possible congestion.
- Must work on top of the coal, possibly causing coal losses.
- Fracturing of strata below coal may result.

Overburden Removal

Stripping shovels (up to 180 cubic yard capacities), draglines (up to 220 cubic yard), wheel excavators, dozers, scrapers, and front-end loaders are utilized throughout this region for overburden removal. Most common usage is attributed to draglines and shovels, with wheel excavators and pan scrapers finding application in special situations. A general description of the advantages and disadvantages of these major stripping machines is included below: (19)

Shovels

Shovels have greater application in tight or poorly fractured material than other machines, thus reducing the amount of overburden prepa-

ration necessary for excavation. In addition to blocky material, loose rocks can be loaded with good bucket fill efficiency. Low loading and dumping cycle times are also advantages for shovel operation because most of the material is loaded in an area directly in front of the machine, and dumped within a fairly short operating radius with 90 degree swings. Since shovels work on top of the coal, no working bench needs to be established. However, shovel tracks, designed for maximum rock wear, can destroy top portions of the seam.

Shovels are noted for their poor flexibility and maneuverability, and can have operations impaired by bank slides and groundwater infiltration into the pit. Support equipment consisting of highlifts, dozers, and/or front-end loaders are required.

Factors favoring shovel utilization are: (14)

- Lower investment cost/cubic yard.
- Lower downtimes.
- Lower power cost/cubic yard.
- Lower wire rope cost/cubic yard.

Draglines

Draglines operate from the top of the highwall, and can effect a greater reach and dumping radius than the shovel, which permits deeper overburden to be removed. Since draglines are not confined to the pit, maneuverability is somewhat greater, and problems with bank slides and water infiltration are eliminated. In uneven terrain, working benches need to be established for efficient operation -- requiring the services of a dozer. Greater fracturing of overburden material is required because draglines have little breakout power and do not perform well in blocky materials. Loading and dumping requires a high degree of operator skill, with cycle times somewhat higher than the shovel.

Advantages of dragline operation include: (14)

- Ability to handle and stock overburden that has poor stability.
- Not damaging to coal seam.
- Greater range makes this tool ideal for multi-seam excavations.
- Lower overall maintenance cost/cubic yard.

Wheel-Excavators

Bucket-wheel excavators (BWE's) have excellent applications in areas with unconsolidated overburden (soft layers of material, preferably earth or clay, sand or soft shales, requiring no bank preparation). As a continuous excavator, BWE's have no cycle times, with constant digging above, on, and below the working bench. Belt conveyors and stackers are used to distribute overburden onto spoil banks.

Advantages of BWE's are:

- Longer discharge radius than previous machines.
- Can be located on highwall bench or on the coal seam.
- Low cost belt conveyors are utilized.
- Lower power cost/cubic yard.
- Lower instantaneous power demands and no shock loadings.
- Good land reclamation tool-spoils are more regular in size, with excellent segregation capabilities.

Disadvantages:

- High downtimes due to complicated machinery.
- Little flexibility due to the great bulk of the machine.
- Cannot handle hard materials.
- Requires extensive clearing and grubbing procedures.
- Requires large maintenance force.
- High initial cost per production rate.

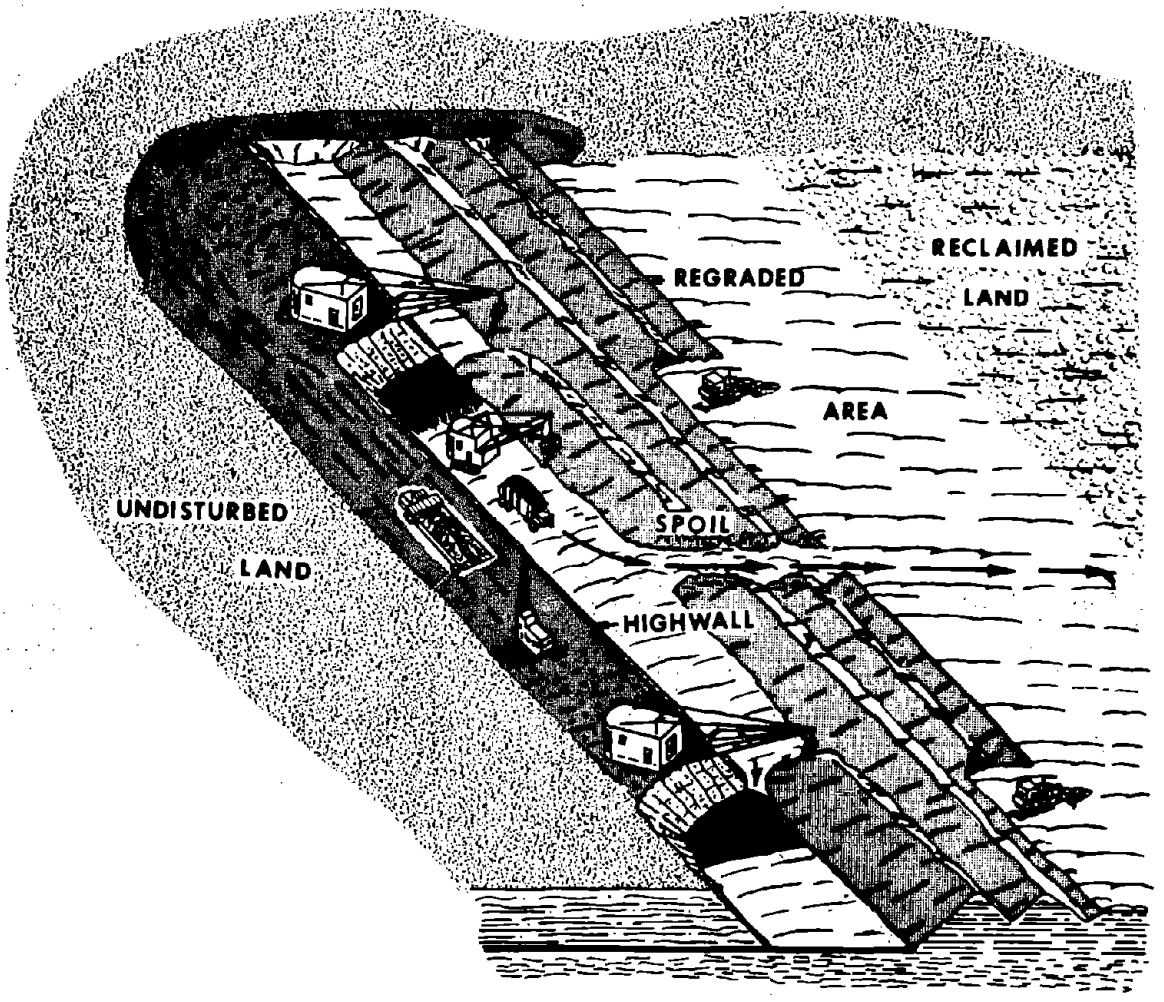
Pan Scrapers

Pan scrapers are somewhat limited to low practical stripping depths, but can be used very effectively alone, or in conjunction with ripping dozers to remove moderately consolidated overburden (6). Scrapers have excellent capabilities of spoil segregation, and can integrate reclamation grading and overburden into a single operation. High maintenance, especially tire replacement, is a major drawback of pan application. These machines are very useful in removing partings from a multiple seam operation. Production cannot begin to match other larger stripping machines, but low initial cost and low cost/cubic yard make this unit very adaptable to smaller operations.

Equipment Applications

Applications of these machines are extremely varied throughout the region. The following illustrations are basic pit layouts showing various equipment combinations and usages.

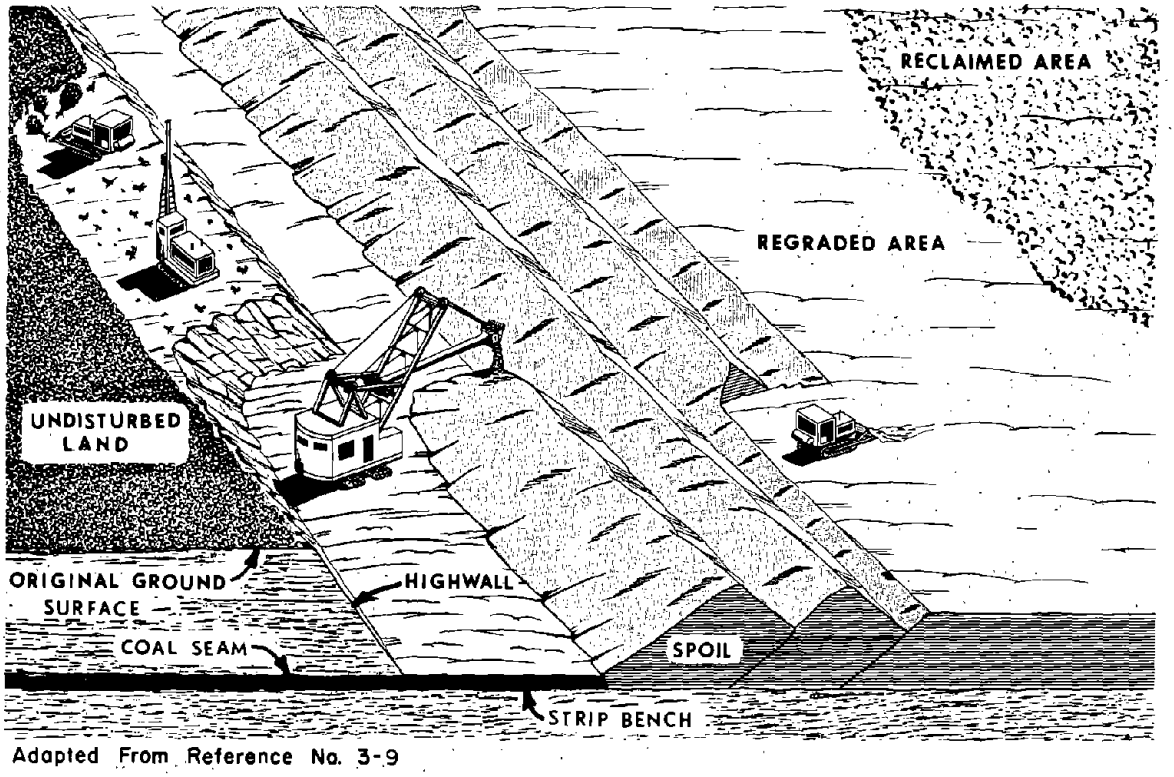
187 Basic area mining technique using the dragline as the major stripping machine (See Figure 3-38).



TYPICAL AREA MINING METHOD WITH TANDEM DRAGLINES

Figure 3-38

- Typical area mine layout indicates shovel removing overburden material. (See figure 3-39)

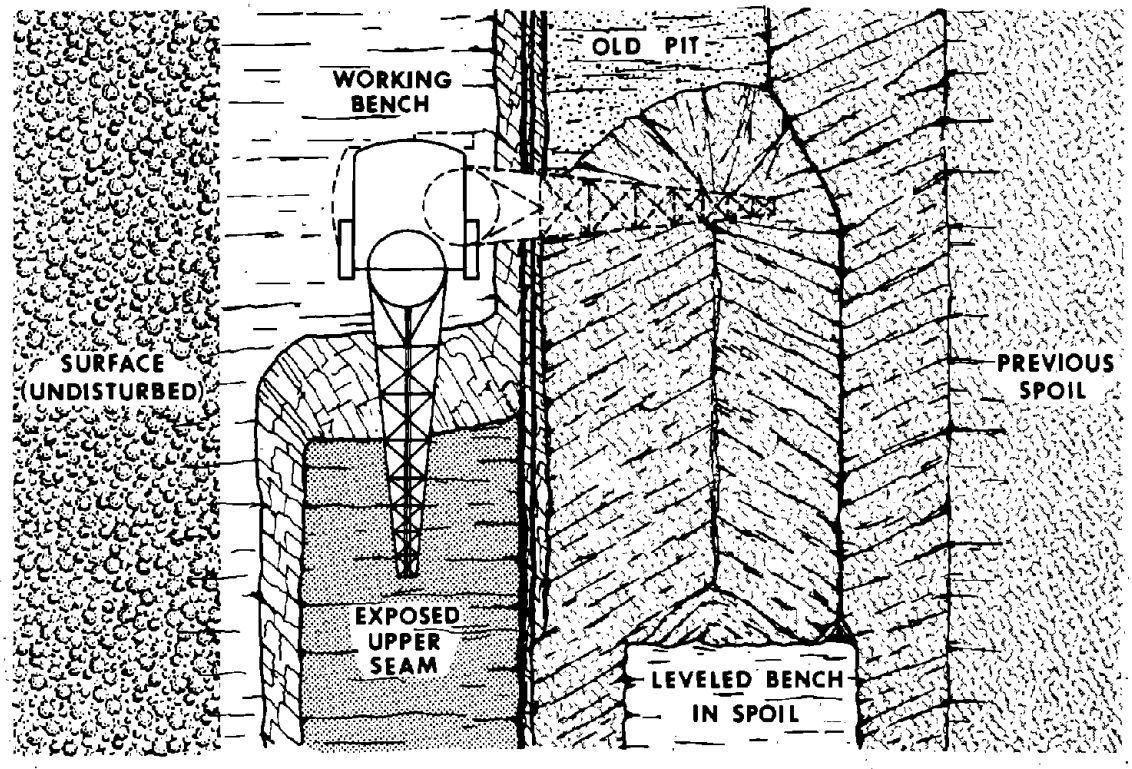


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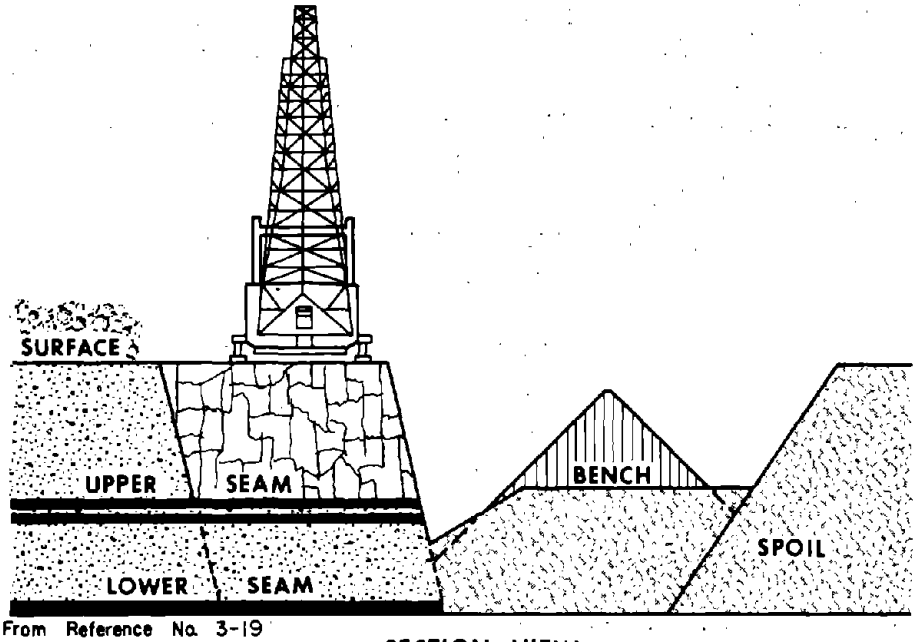
TYPICAL AREA MINING METHOD WITH STRIPPING SHOVEL

Figure 3-39

- Multi-seam mining with large dragline is shown. Top seam is exposed first, then dragline returns back down the pit on leveled spoil to remove the parting. (See figures 3-40a and 3-40b)



PLAN VIEW

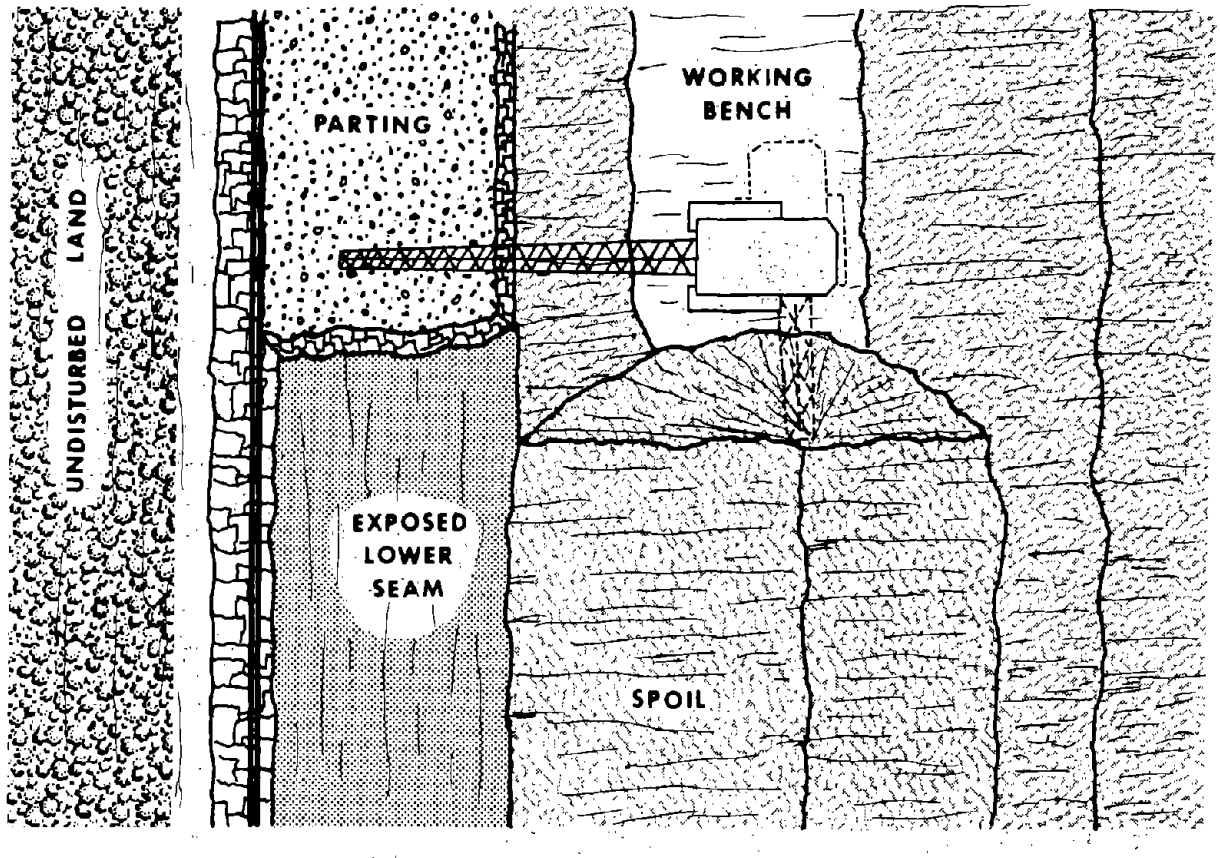


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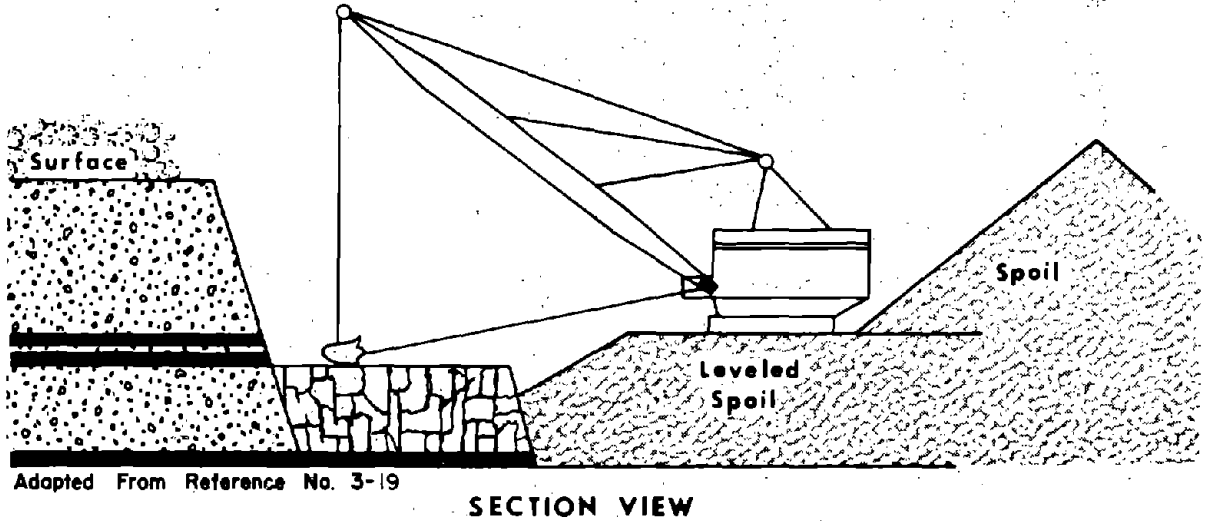
SECTION VIEW

MULTIPLE SEAM DRAGLINE OPERATION WITH UPPER SEAM EXPOSED

Figure 3-40a



PLAN VIEW



Adapted From Reference No. 3-19

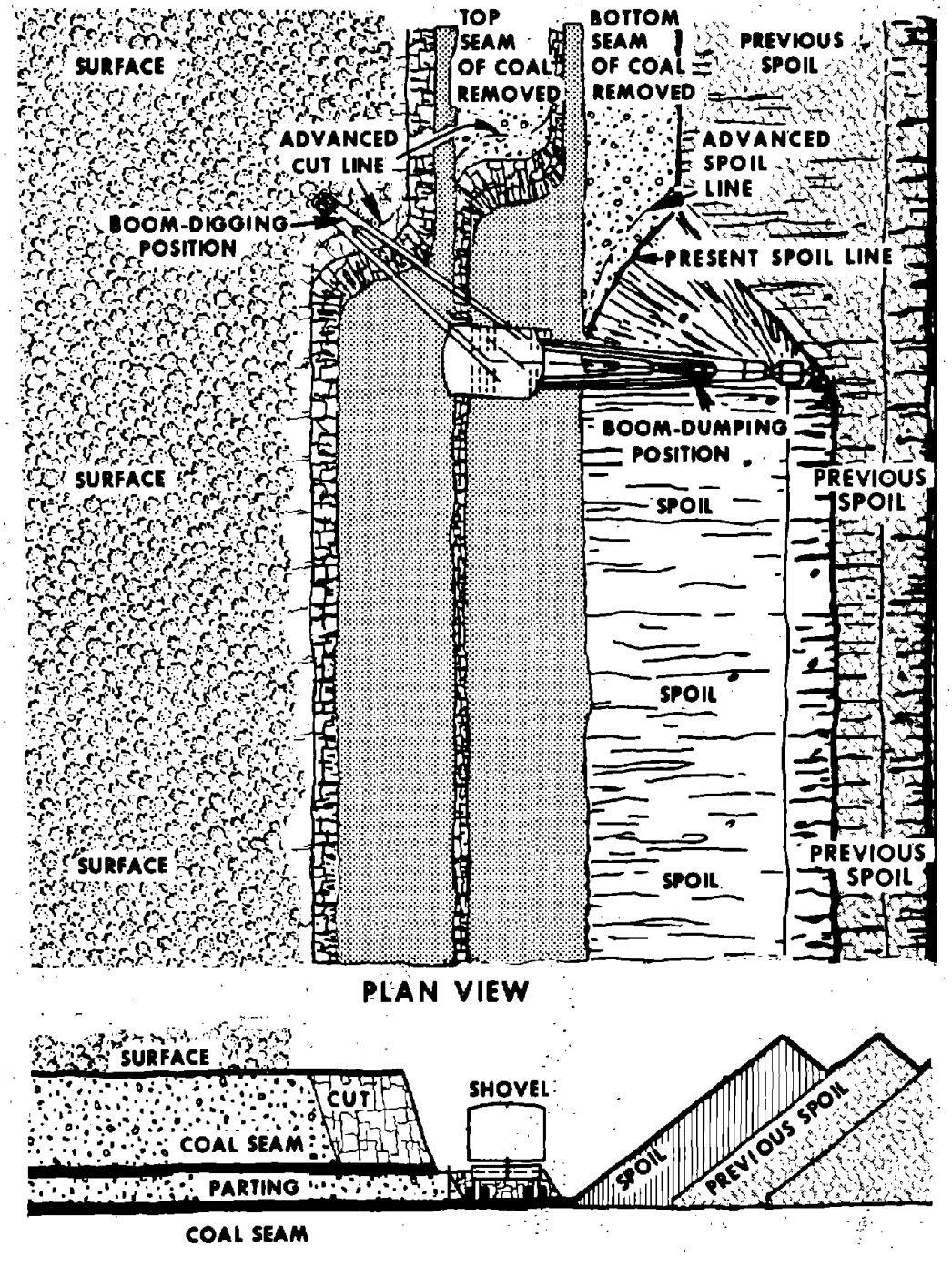
SECTION VIEW

DRAGLINE EXPOSING LOWEST SEAM FROM LEVELED SPOIL

Figure 3-40b

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- Multi-seam mining can easily be accomplished by a shovel, equipped with a variable pitch dipper. (See figure 3-41)

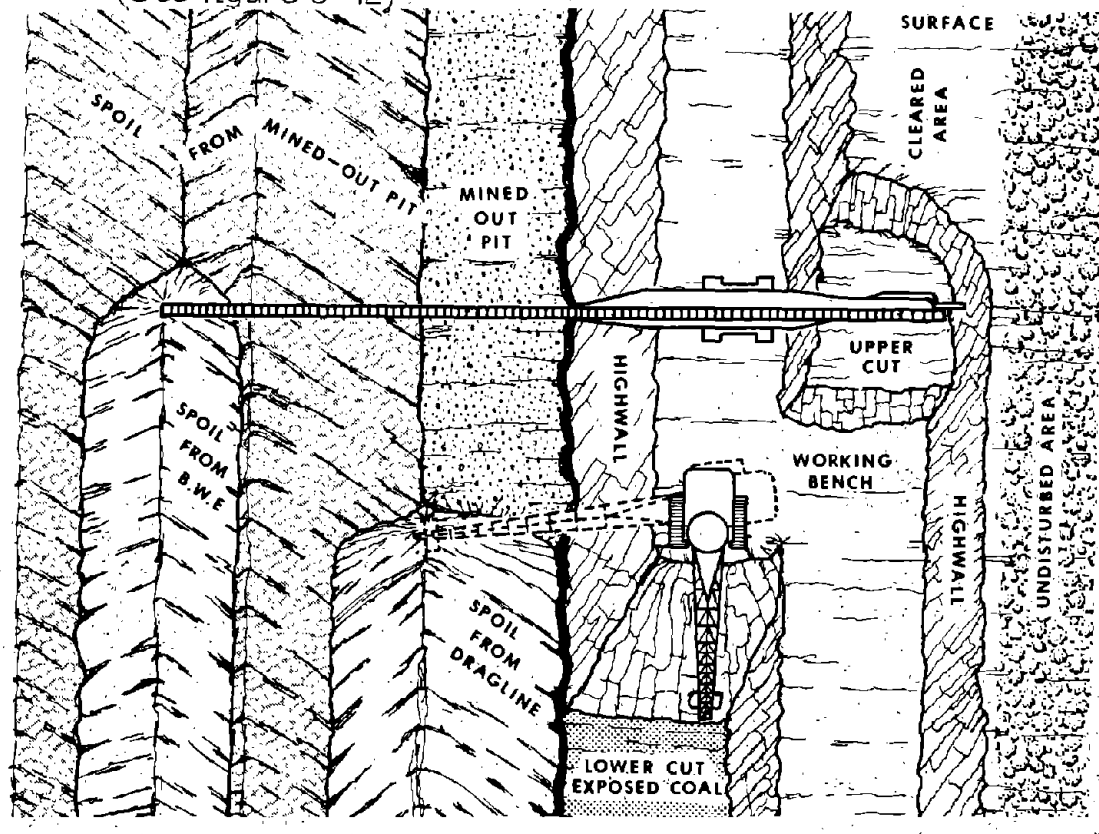


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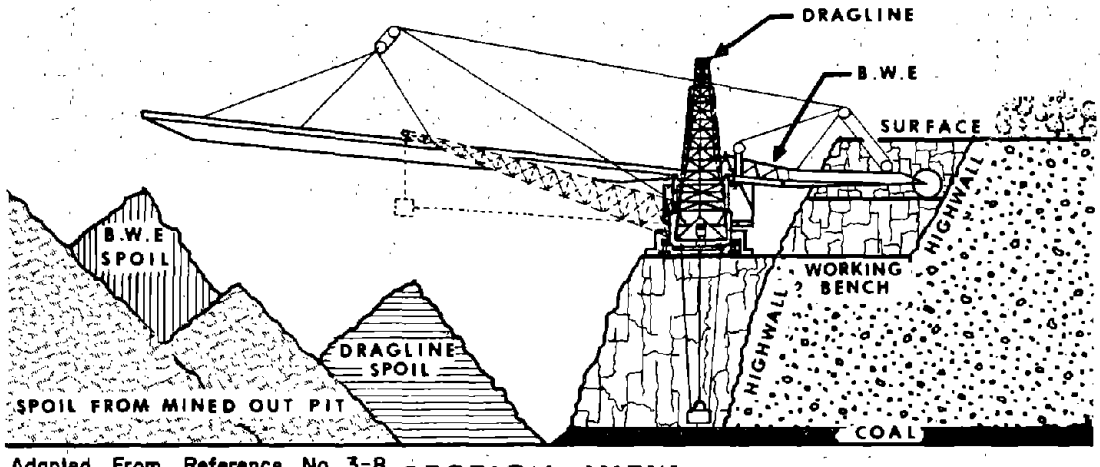
MULTISEAM STRIPPING OPERATION WITH A SHOVEL

Figure 3-41

- This layout represents a dragline - BWE tandem operation. 192
(See figure 3-42)



PLAN VIEW



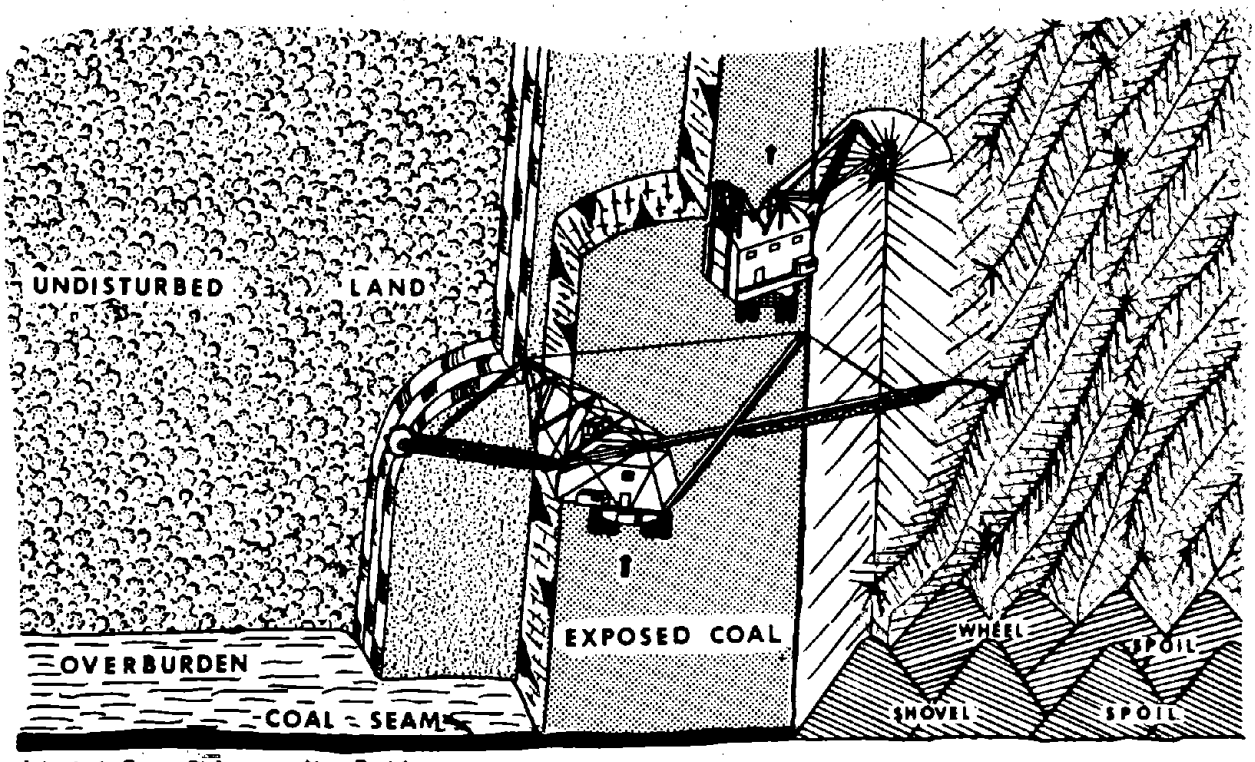
Adapted From Reference No. 3-8

SECTION VIEW

AREA MINING UTILIZING A BUCKET WHEEL EXCAVATOR AND DRAGLINE IN TANDEM

Figure 3-42

- Shovel - BWE combinations can be applied where conditions permit usage. (See figure 3-43)

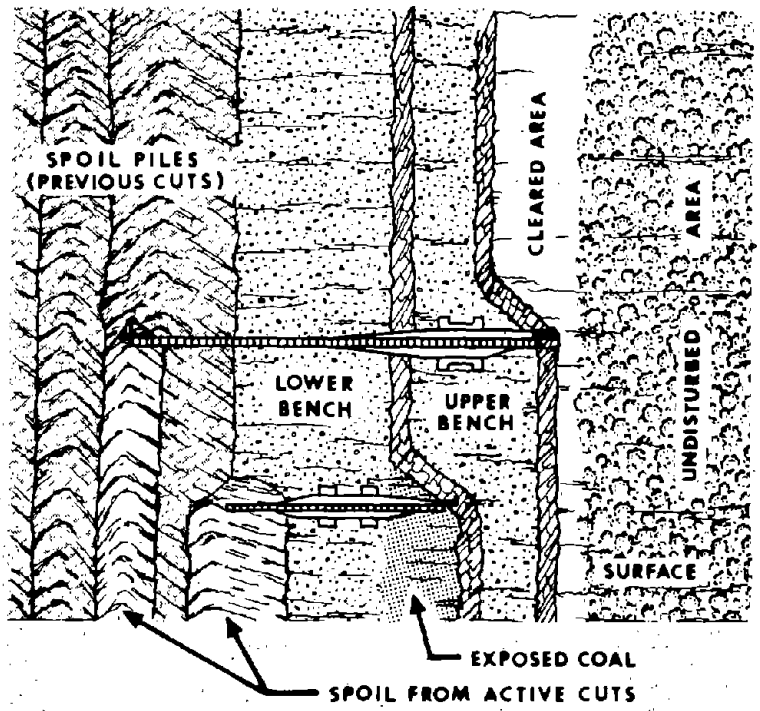


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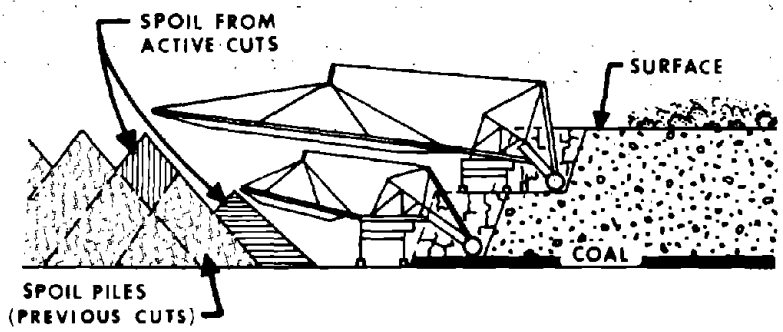
TYPICAL AREA MINING METHOD WITH BWE & SHOVEL

Figure 3-43

- In easy digging material, BWE's can be used very effectively. (See figure 3-44)



PLAN VIEW



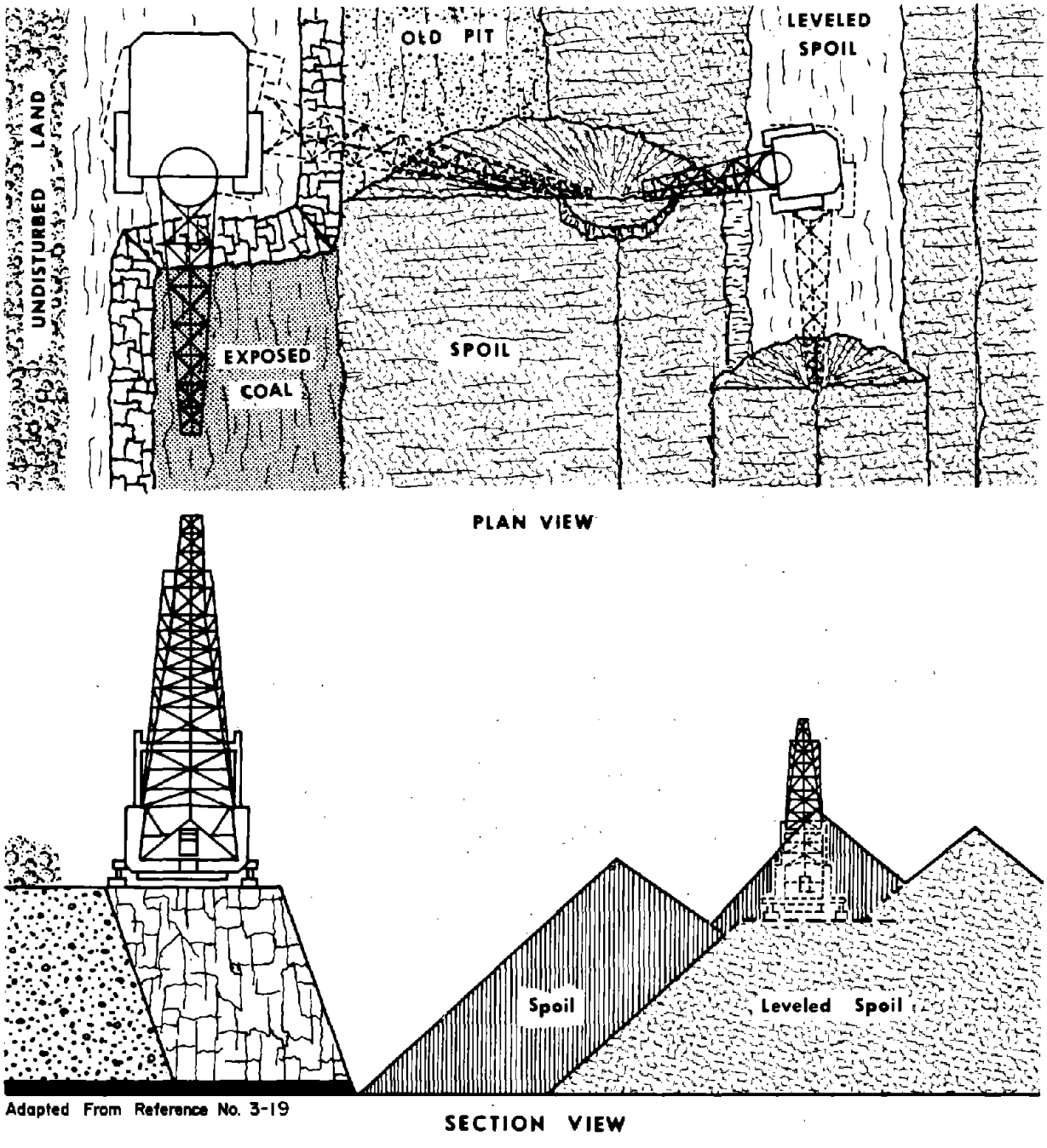
SECTION VIEW

Adapted From Reference No. 3-19

AREA MINING METHOD TANDEM BUCKET WHEEL EXCAVATORS

Figure 3-44

- Dragline with another pull-back dragline in spoil area allowing for greater spoil placement capacity of primary machine. (See figure 3-45)



Adapted From Reference No. 3-19

PULL-BACK DRAGLINE OPERATING IN SPOIL AREA

Figure 3-45

Coal Loading

Shovels, front-end loaders (rubber-tired) and highlifts (track type) accomplish the task of coal loading in many Midwest surface mines.

Electric and diesel powered shovels are most common in this region, requiring very little, if any, coal fracturing due to their high break-out force capacities (21). Although loading shovels are more commonly used at the present time, large front-end loaders, coupled with ripping dozers, may soon be favored as the prime loading combination. Comparisons of shovels versus front-end loaders from manufacturers' viewpoints follow (4).

Front-End Loaders

Advantages:

- Excellent mobility.
- Good blending capabilities.
- Good back-up and clean-up tool for shovel.
- Can perform other functions when not loading coal- (clean-up, stockpiling, road maintenance, etc.).
- Low capital cost, ideal for fast return on capital.
- Ideal in thin seam conditions.
- Annual costs are generally lower than a shovel.

Disadvantages:

- Excessive tire wear in difficult digging (however, ripping dozers can help alleviate this problem).
- Expected life is one-half that of a shovel.
- Loaders cannot work high faces.

- High tire costs.
- Bad floor conditions result in lower performance.

Loading Shovels

Advantages:

- Ability to handle coarse materials with larger breakout force.
- Smooth digging action.
- Low operating costs and maintenance requirements.
- Operator fatigue is less than with wheel loaders.
- Longer reach at the working face.
- Can work in close quarters.

Disadvantages:

- Lack of mobility.
- High initial cost.
- Cannot traverse steep grades.
- Support equipment required (usually wheel loaders).

Scrapers can also be used for coal loading but have found very little application in this region.

Coal Hauling

Unlike Regions I and II, each mine in Region III usually has its own coal preparation facility, thereby eliminating use of highway trucks. Off-highway vehicles, 35 ton to 150 ton capacities with end-dump or bottom dump features, find wide usage. Many companies are currently experi-

menting with various type units to determine which is more suitable to their needs.

Conveyor belt systems provide additional considerations for application within this Region. Advantages to belt installations include: continuous transport capability; manpower reduction; maintenance and equipment reduction; and low cost per ton. To date, conveyor systems are permanent in nature, requiring a long-range mining operation and stationary destination. Some progress is being made in mobilizing belt systems, which may provide for more expanded use in the future.

Regrading

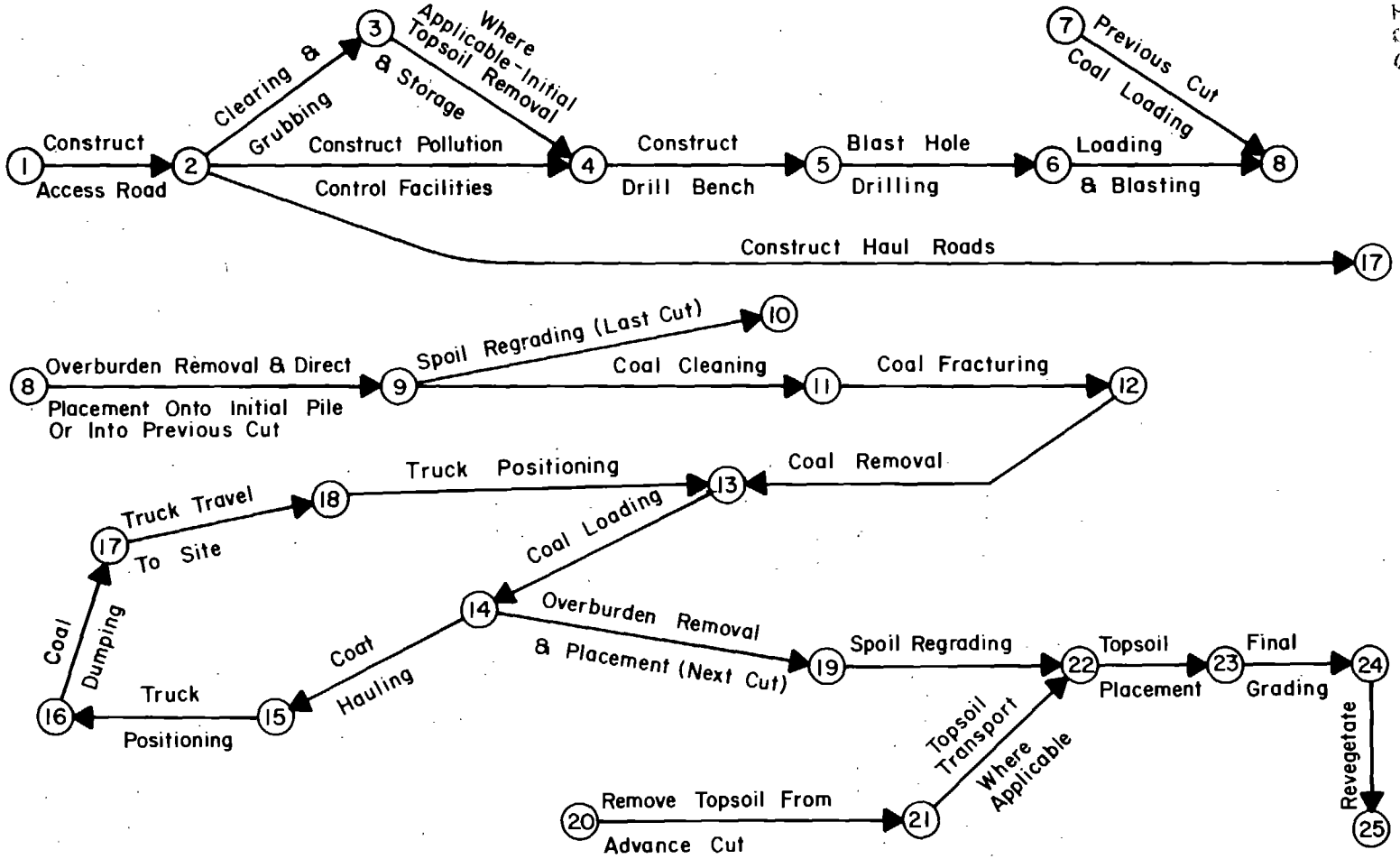
Progressive area mining makes the last cut condition very hard to eliminate, although highwall reduction methods have been used (See Chapter 6). Hauling all first-cut spoil to the last cut trench is not commonly practiced because of the very long hauls associated with area mining operations. All spoil cast by shovels or draglines is graded to even contours with final application of topsoil and grading by pans or end dump trucks and dozers.

Revegetation

A major portion of the land disturbed by surface mining in the Midwest is returned to some sort of agricultural use. When revegetating for pasture and grazing areas, broadcast applications of seed, fertilizer, and mulch are used with occasional sprigging of Bermuda grasses in Arkansas and Oklahoma. Some major coal producers are harvesting crops from reclaimed lands, providing additional income for use in offsetting reclamation costs for other sites.

Operation Relationships

After the initial box-cut is excavated, operational activity flow can be scheduled and conducted with little difficulty (See Figure 3-46). Most



FLOW DIAGRAM
AREA MINING METHOD
Figure 3-46

production difficulties occur at critical points in the mine layout, such as turns and curves.

Auxiliary Operations

Maintenance

Maintenance facilities and strict maintenance schedules are common in mines of large producers. Availability of factory service usually governs the extent of maintenance units and manpower. For example, basic lubrication and small parts replacement may be the only maintenance function in areas close to factory service, whereas a full range of maintenance supplies and personnel are necessary at remote mining operations. Maintenance and materials storage and handling are governed by these same parameters. Other maintenance characteristics are similar to those described in Region II.

Power Distribution

Electric power distribution is accomplished by a main power substation with dispersal to portable field stepdown transformers associated with each pit operation. (See Region IV for complete power distribution description.) Fuel oil distribution varies from a central pump site in more populous areas, to a series of fuel dumps strategically located throughout the mining operation. The latter is far more favorable due to elimination of a daily fleet of tank trucks.

Pollution Control

Drainage, dust and pollution control are operations governed by federal, state and/or local agencies. Drainage usually comes under state and local restrictions which differ widely over the Region. For example, mine water discharges in Arkansas and Oklahoma do not need to pass through settling systems, whereas many other states require at least one basin for suspended solids removal. Due to the flat topography

of this region, basins are usually excavated to the desired volume, using excavated material for dike or berm construction around the pond. Water encountered in the pit area is collected in a sump and directed via pipeline and diversion ditches to settling ponds (if required), see Figure 3-47. Dust control is maintained through periodic applications of water or road oil.

Road Maintenance

Road construction and maintenance are performed on an "as required" basis with road graders and dozers. Some mining companies are using semi-paved roads to eliminate downtime from tire repairs and road maintenance, and to decrease turnaround time for coal haulers.

OTHER MINING METHODS ENCOUNTERED

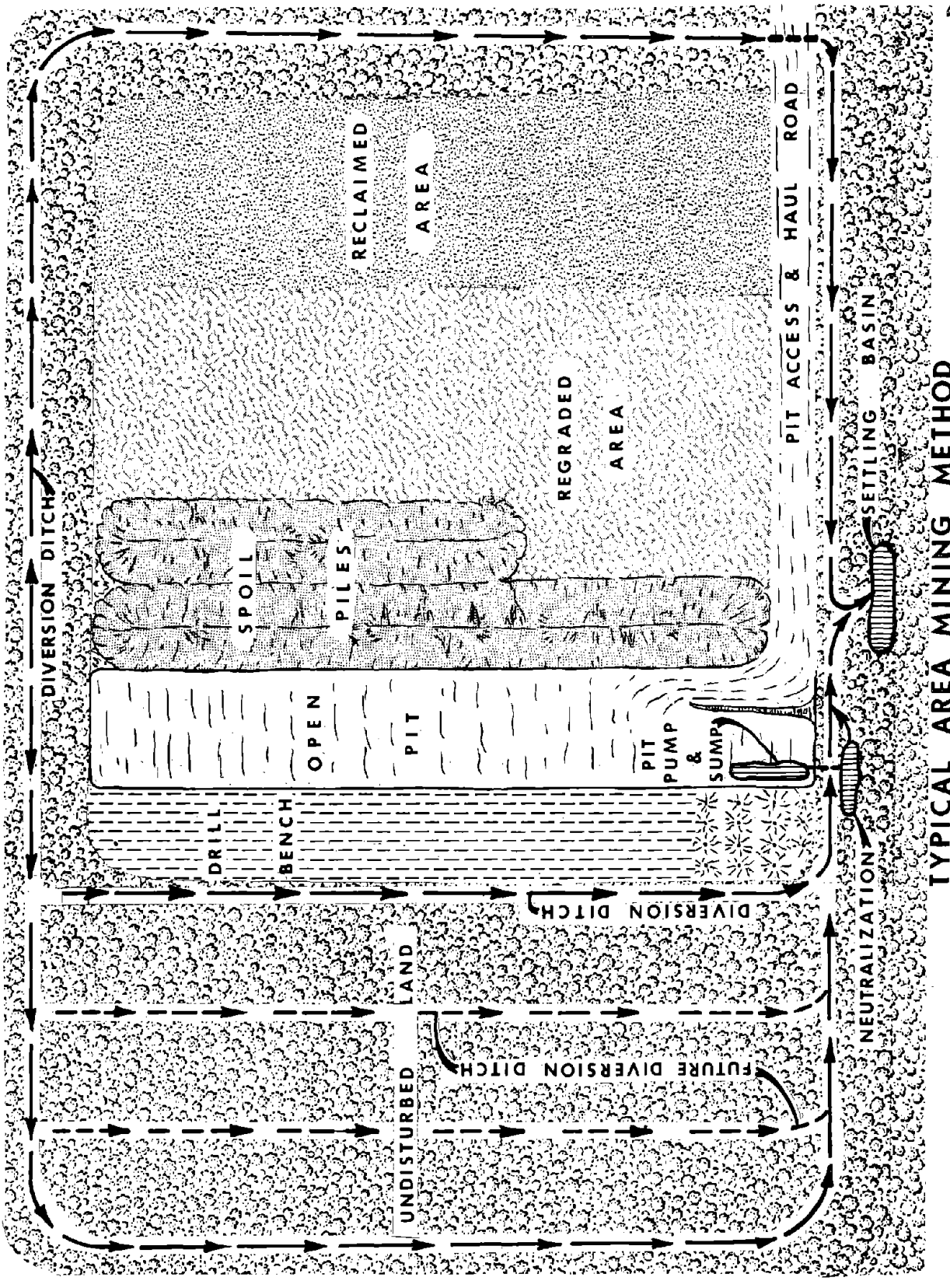
Block-Area

Some small mining companies in fringe areas use the Block-Area method, with overburden removal performed by high lifts, dozers, trucks, and pan scrapers. This technique, described in more detail in Region II "Characterization," offers good coal production with minimal capital investment. Although some variations exist with equipment usage, block size, and cut sequence in this region, the basic principles of block area mining are maintained. A variation of block cut sequence, practiced to some degree in the Midwest at smaller mines, follows (Figure 3-48).

The primary advantage of this technique is that it permits regrading and revegetation to be concurrent with stripping. Equipment utilization can also include draglines, although this is not usually desirable because of valuable production time lost due to numerous dragline moves.

Modified Area

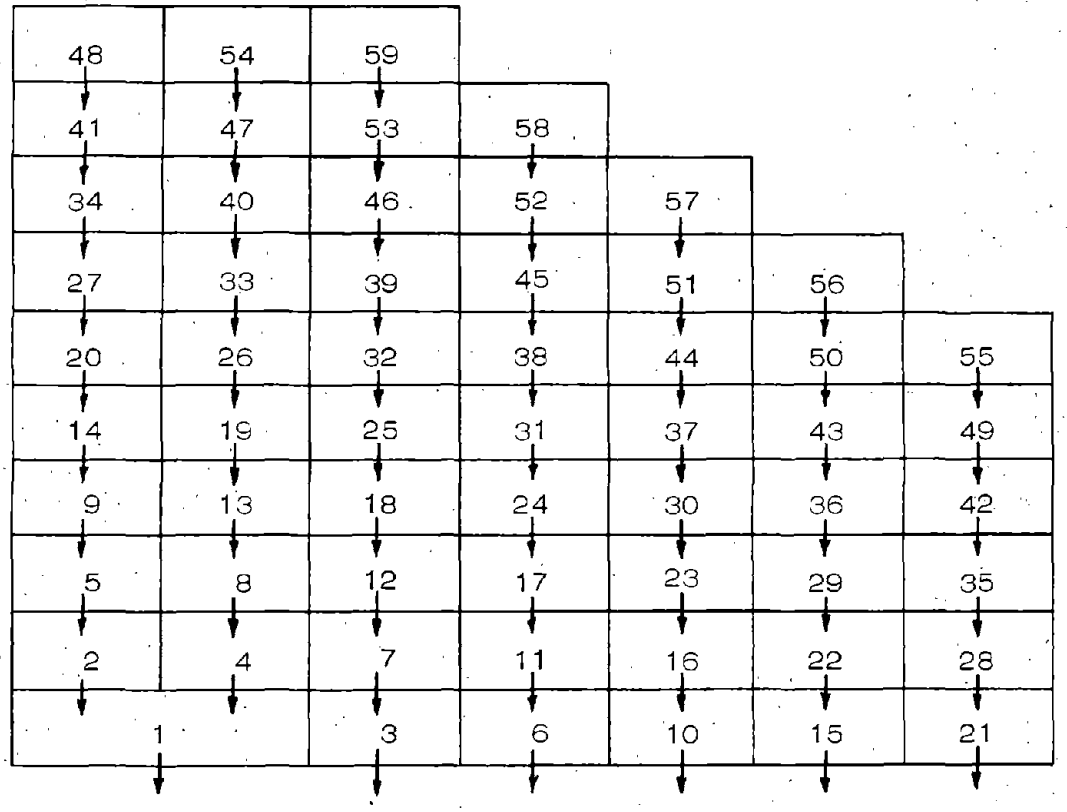
In hilly portions of northern Ohio, Modified Area Mining, as dis-



TYPICAL AREA MINING METHOD
WATER HANDLING SYSTEM

Figure 3-47

Adapted From Reference No. 3-19



→ Denotes direction of overburden movement.

CUT PATTERN FOR STEPPED FACE BLOCK-AREA MINING

Figure 3-48

cussed in Region II "Characterization" is practiced. The technique changes very little when adapted to this area, with full previous description of activities and operations applying to these Region III mines.

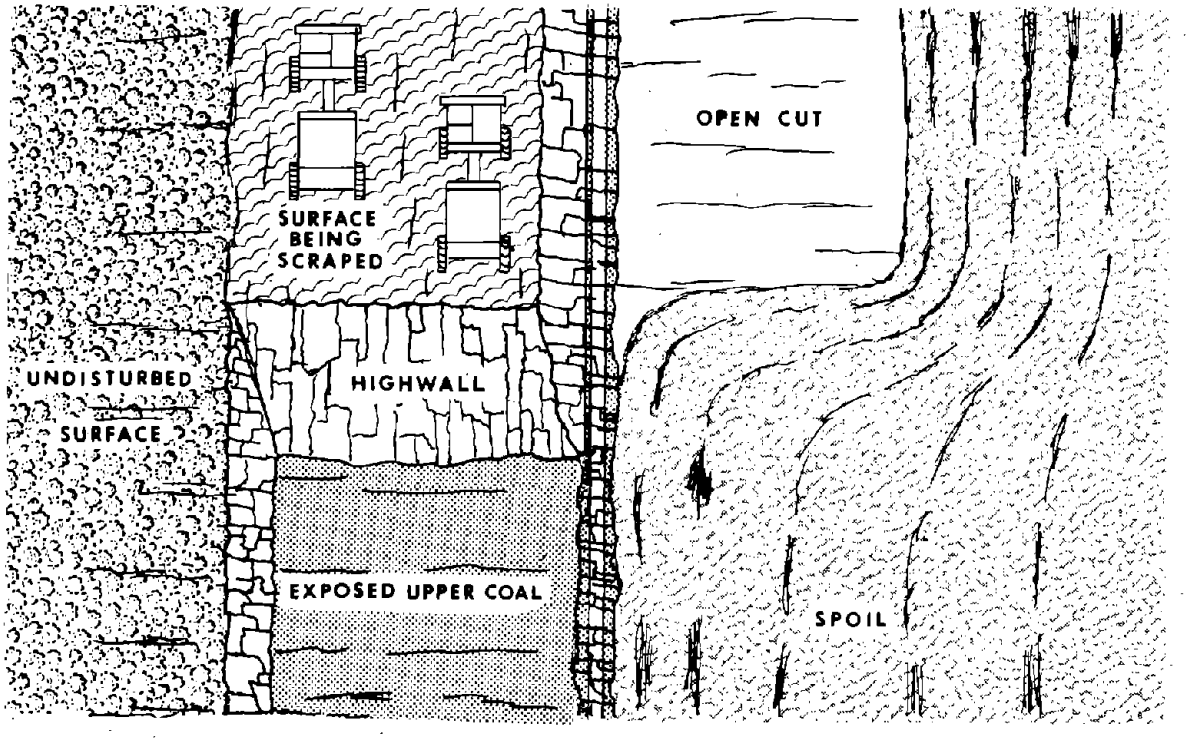
Multi-Seam Scraper Mining (Unique Operation) (19)

A unique mining operation employing five pan scrapers and five bulldozers as the major stripping equipment, was encountered in Region III. As a multi-seam operation, this system produces over 2 million tons per year of sub-bituminous coal (See Figure 3-49).

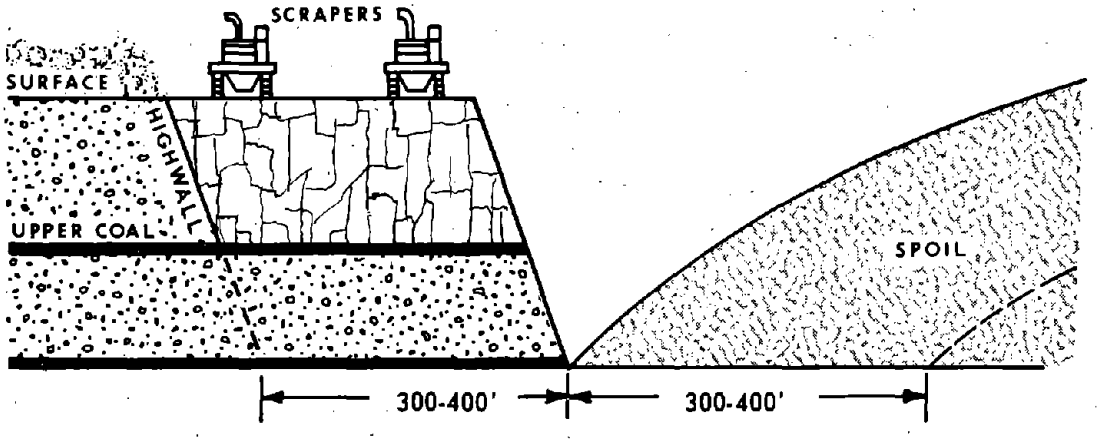
Pan scrapers begin the mining cycle by removing overburden above the upper seam, exposing coal in a pit approximately 300 to 400 feet wide for a length of nearly 1000 feet. Four and eight cubic yard diesel loading shovels begin loading the coal into nine 50-ton trucks for a 1¼ mile haul to the preparation plant. After the upper seam is sufficiently removed, several scrapers are assigned to remove the parting and expose the lower seam. One loading shovel then begins on the lower seam, working closely with the scrapers and dozers which remove the partings. The operation then becomes similar to an open pit scheme; the upper seam is worked as one bench and the lower seam as the second bench. The cycle is then repeated as scrapers work ahead of loading operations for the length of the cut. Once the cut is completed for the width of the property, another cut is initiated in the manner of a traditional area stripping operation.

"This is a gigantic earth moving system, and timing of equipment moves is critical. The scraper haul length is approximately 3500 feet, and overburden has been moved by this method to uncover seams up to 215 feet deep. Reclamation work is relatively easy using this method, because pans can dump uniformly and soils can be placed on top of the spoil. Stripping and loading are based on a 5-day week, two shifts each day (19)."

"Land reclamation begins by leveling spoil to a rolling contour and covering this leveled spoil with brown soils removed prior to stripping. Trees, including ponderosa pine, blue spruce, cottonwood and wild cherry, are planted in the spring. Reclamation at this mine is relatively easy and exceeds the state law requirement of leveling the spoil tops to a 15 foot width (19)."



PLAN VIEW



SECTION VIEW

Adapted From Reference No. 3-19

UNIQUE MULTIPLE SEAM SCRAPER OPERATION

Figure 3-49

This operation is ideal, in that spoil segregation and reclamation grading can easily be accomplished. Low initial equipment cost and flexible operation of stripping units offer other advantages. Although not well-suited for hard blocky overburden conditions, this technique shows promise for increasing coal production with reduced costs and reduced environmental effects.

RECOMMENDATIONS

Area strip mining has disturbed thousands of acres in the Midwest, with many acres left abandoned or only partially reclaimed. Current reclamation methods and policies, where grading and revegetation closely follow the mining operation, can return the land to near original contour, and minimize environmental disturbances. Without any area mined-land reclamation, future productive land use is precluded; water can become polluted with acid and siltation; and aesthetic values of the area can be disrupted. With adequate reclamation, cropland can be returned to farming, and range land can be restored for grazing.

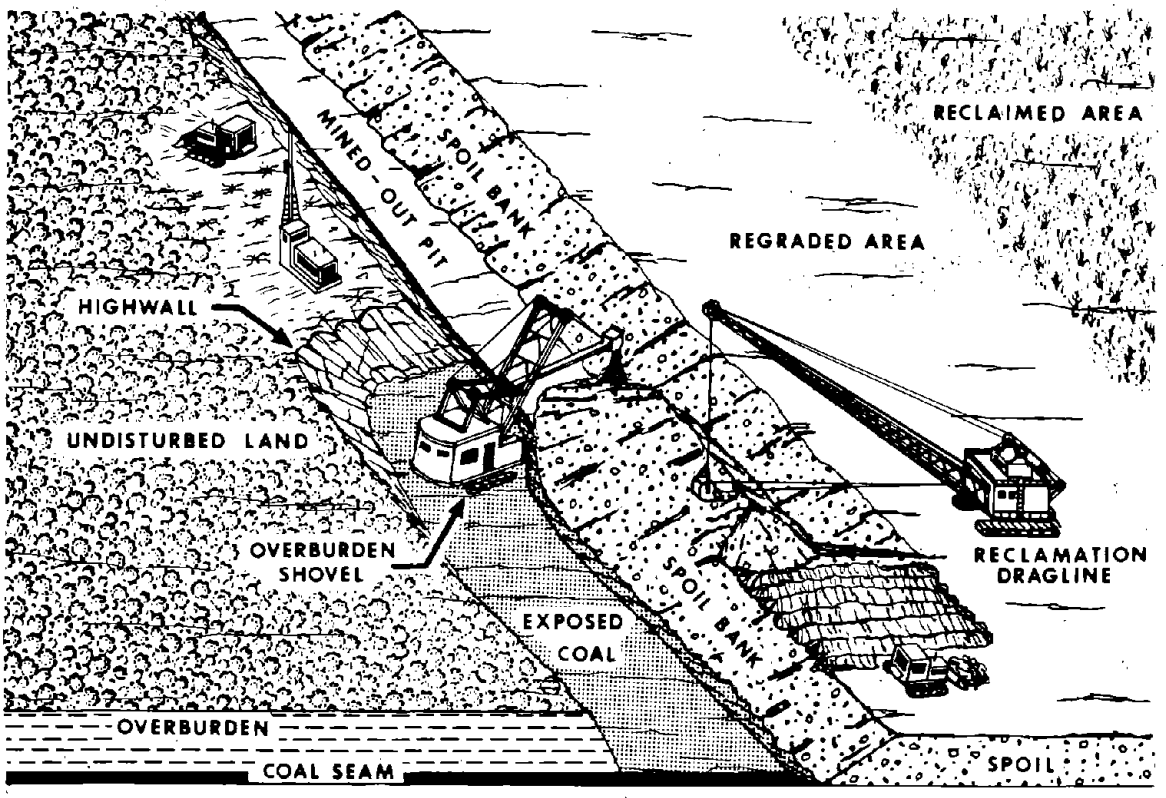
Environmental impacts of area mining, including changed water courses, ground water pollution, disruption of surface characteristics, and erosion and sedimentation can be minimized if reclamation procedures are concurrent with mining activities and if surface water flow is properly managed. Typical area mines have basic characteristics of at least one open cut and spoil ridge for the entire length of the coal tract. To reduce this acreage of disturbed land and economically maintain desired production levels has been a problem faced by mining engineers for many years.

Retreat mining is a process where mining begins at the furthest point to be mined in a coal tract and proceeds inward, toward a central point, usually preparation or loading facilities. Mining currently practiced in Region III begins at a central point and proceeds outward, thus reaffecting reclaimed areas with haul roads and overall mining activities. Retreat mining eliminates any necessity to go back and reclaim haul roads lying in reclaimed areas. Reclamation is a "once-and-done" activity providing immediate reuse of disturbed lands. Future use of this procedure can reduce environmental disturbances caused from haulage routes over spoils and reclaimed areas. However, large capital investments in land acquisition may limit use of this technique.

Block-Area stripping can provide immediate reclamation of disturbed areas with integrated stripping and regrading operations. Although not applicable to large stripping machines, high production levels can be achieved with several active blocks. Utilizing a "retreat mining" approach would eliminate disturbance of reclaimed areas with many haul routes associated with this technique.

Concurrent reclamation can also be accomplished in mines employing large stripping machines. The following illustration shows usage of a pull-back drag, maintaining reclamation grading to within 300' of active spoiling. Topsoil replacement (if applicable) and revegetation immediately follows the pull-back drag route.

Pull-back reclamation methodology, combined with retreat mining techniques could possibly minimize environmental disturbances and maintain high production advantages of large stripping equipment. (See figure 3-50)



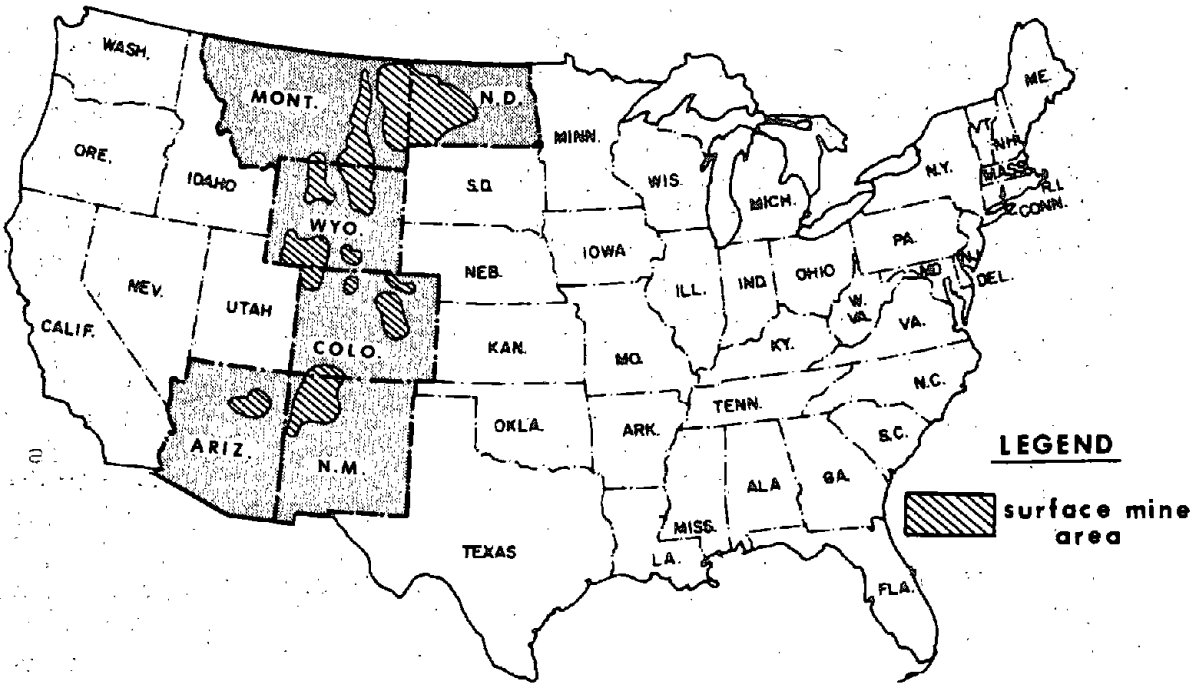
CONCURRENT RECLAMATION WITH A PULL-BACK DRAGLINE

Figure 3-50

REGION IV

CHARACTERISTICS

Region IV, which includes Arizona, Colorado, Montana, New Mexico, North Dakota and Wyoming, contains the largest potential coal reserves in the Nation, if not the world. Topography of the entire region varies from typical Great Plains to Rocky Mountain terrain. Surface land use is limited to agricultural needs, with primary emphasis on livestock. Some dry land farming is practiced in eastern Colorado and western North Dakota, in addition to localized irrigation farming throughout the region. Native vegetation in the coal bearing areas of the region is usually sagebrush or grasses, with some acreage in trees. Surface mine areas in Region IV are shown in Figure 3-51.



SURFACE MINE AREAS - REGION IV

Figure 3-51

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Climatic conditions are semi-arid due to the influence of the Rocky Mountain Range. Rainfall from Pacific frontal systems falls on the western slopes of the mountains, and occasional thunderstorms can be severe during the summer months. Most precipitation in the region is in the form of snow, with total accumulations of 100 inches recorded in northeast Arizona. In many of the more arid areas, snow melt runoff provides the largest percentage of surface water and is stored in large reservoirs where possible. Virtually all of Region IV has been eroded by wind and water for centuries, and is subject to flash floods causing further erosion problems. Temperatures vary from a mean minimum of 16°F to a mean maximum of 92°F in Arizona coal fields and from -15°F to 118°F in eastern Colorado.

The reserves that make Region IV so important range from lignite fields in North Dakota and Montana to high volatile bituminous coals in several other fields. Early mining in this region was restricted to that done by the native Indian tribes to meet domestic needs. Mining in this region has only recently been initiated on a large scale to meet the growing demand for low sulfur energy. State by state descriptions of the various coal basins that comprise Region IV are included in the following pages.

The Black Mesa field in Arizona's "Four Corners Region" is currently the state's only major producing area. Coal is mined from the Upper Cretaceous Wepo Formation. Beds are flat-lying to shallowly rolling with some broad synclines and anticlines, and tend to thicken toward the northern limits of the field. Stratigraphically, the Black Mesa field consists of the coal-bearing Dakota Sandstone, overlain by the Mancos Shale, the coal-bearing Mesaverde Group, which is sub-divided into the Toreva and Wepo Formations, and the York Point Sandstone. Six seams ranging in thickness from 5 to 28 feet lie within 1,700 feet of the surface in this area. There is still some debate between the Bureau of Mines and various coal industry factions as to the definition of the coal itself - sub-bituminous versus bituminous. BTU's are commonly 12,300 or greater, ash content is 9% or less, sulfur ranges from 0.4% to 0.9%, and moisture content "as received" ranges from 3.4% to 17.4%.

New Mexico's San Juan River Basin is an eastern extension of the above-mentioned Black Mesa field, and is also an important coal source. Characteristics of this coal are generally quite similar to those described for the Black Mesa coal.

Colorado, according to the U.S.G.S. and the Colorado Geologic

Survey, has eight major coal basins, two of which are extensions of previously mentioned Arizona and New Mexico fields. Geographic and geologic conditions are very diverse, with coal appearing in the Great Plains Province, the Southern Rocky Mountains, and the Wyoming Basin. This great diversity causes coal beds to vary from flat-lying and slightly faulted to steeply pitching and extensively faulted. Average Colorado coal generally exhibits a BTU range of 13,300 to 14,500, with some sub-bituminous units as low as 11,300, ash contents of 2.1% to 15%, moisture from 1% to 20%, and sulfur commonly less than 1%. Some coals have shown fixed carbons as high as 88%, but quantities of such coal are limited. The San Juan Basin is an extension of the Black Mesa field, as previously mentioned. The Raton Basin extends through south-central Colorado into New Mexico. BTU's in this basin range from 11,000 to 14,000, ash from 5.3% to 14.4%, sulfur from 0.4% to 1.3%, and "as received" moisture from 2.5% to 10.2%.

Eastern Montana and western North Dakota share the Nation's largest lignite and sub-bituminous reserves in the Fort Union Region. Various estimates indicate 32 billion tons of commercially recoverable lignite in North Dakota alone, while eastern Montana's lignite reserves, which have not been completely explored, have been estimated at between 16 and 20 billion tons. The southwest portion of the Montana field, in the area of the Powder River Basin, trends from lignite to sub-bituminous coal and has 20 billion tons of sub-bituminous reserves. Virtually all of these Montana and North Dakota reserves lie beneath less than 100 feet of cover. Most of the Fort Union Region north of the Missouri River is covered by glacial drift, while the southwestern portion of the region is covered by fine-grained clastic sediments of the Fort Union Group.

Central Montana's coal fields include the sub-bituminous north-central region and Bull Mountain Field and the following bituminous fields: Great Falls, Bridger, Stillwater, Silver Tip, Red Lodge, Livingstone-Trail Creek and the Blackfoot-Valier Area. Coal seams in these Montana fields vary in thickness from 5 to 90 feet and are generally level or slightly rolling. Lignites are characterized by 6000 to 7500 BTU's, 6.6% to 7.2% ash and 0.4% to 0.7% sulfur. Bituminous coal in these fields commonly shows 10,000 to 12,000 BTU's, 8% to 13% ash and 0.6% to 1.3% sulfur.

Wyoming coal reserves constitute approximately 20% of the Nation's total reserves, even though portions of the Green River Basin, Wind River Basin and Big Horn Basin are still unexplored. Most of the coal seams are

TABLE 3-4

REGION IV

STATE	COAL BEARING AREAS	RANK	B.T.U. (X 1000)	ASH (%)	SULFUR (%)	MOISTURE (%)
Ariz.	Black Mesa	Sub-bituminous Bituminous	12.3 Avg	8.9 Avg	0.6 Avg	9.7 Avg
Colo.	San Juan	Bituminous	10.4 - 13.7	4.8 - 15.9	0.53 - 1.0	2.0 - 10.8
	Uinta	Bituminous	10.9 - 13.0	3.7 - 10.9	0.45 - 1.1	6.8 - 12.2
	Green River	Sub-bituminous Lignite	9.9 - 10.7	4.0 -9.4	0.58 - 1.0	14.3 - 17.7
	Raton Basin	Bituminous	11.8 - 13.4	6.4 - 16.5	0.43 - 1.1	2.6 - 6.2
	Denver Basin	Sub-bituminous Lignite	7.8 Avg	10.4 Avg	0.49 Avg	23.6 Avg
	South Park	Sub-bituminous	9.8 Avg	1.3 - 6.4	0.47 -0.53	6.3 - 15.5
	North Park	Sub-bituminous	8.8 - 10.9	2.8 - 13.4	0.1 - 0.9	13.6 - 22.8
	Cannon City	Bituminous	10.1 - 12.0	4.6 - 17.7	0.3 - 1.1	5.4 - 15.0
Mont.	Fort Union	Sub-bituminous Lignite	7.6 Avg	6.2 Avg	0.46 Avg	-
	Bull Mountain	Sub-bituminous	11.0 Avg	7.5 Avg	1.0 Avg	-
	Red Lodge	Bituminous	10.0 Avg	13.4 Avg	1.0 - 1.3	-
	North Central Region	Sub-bituminous	9.1 Avg	11.5 Avg	-	-
	Blackfeet Valier	Bituminous	-	-	-	-

TABLE 3-4

COAL CHARACTERISTICS

GEOLOGIC CHARACTERISTICS
Nearly flat lying strata regionally warped into long broad synclines and anticlines.
Coal occurs in broad structurally simple basins which are locally complex, especially around the basin margins, because of folding faulting and igneous intrusions.
Relatively small, structurally complex basins.
As many as 5 - 8 strippable seams in Eastern Montana. Thicknesses range from 5' - 89'.
Basin structure contains 26 persistent, low sulfur coal seams.
Contains 8 coal seams - range 3.5' to 10' thick. Flat lying to a steep dip.
Coal found in the Eagle Sandstone and in Judith River formation ranges 2.5' - 7'.
Coals relatively thin, ranging 20" - 36".

TABLE 3-4

REGION IV (CONTD.)

STATE	COAL BEARING AREAS	RANK	B.T.U. (X 1000)	ASH (%)	SULFUR (%)	MOISTURE (%)
Mont. (Contd.)	Great Falls - Lewistown Field	Bituminous	10.2 Avg	Highly Variable	1.7 - 4.0	-
N. Mex.	San Juan Basin	Sub-bituminous Bituminous	9.9 Avg	16.8 Avg	0.64 Avg	11.33 Avg
	Raton Field	Bituminous	14.3 Avg	8.8 Avg	0.6 Avg	Moisture Free Analysis
N. Dak.	Fort Union Region	Lignite	6.0 - 7.5	4.4 - 8.0	0.2 - 1.4	33.5 - 43.8
Wyo.	Powder River Basin	Sub-bituminous Lignite	8.5 Avg	8.1 Avg	0.63 Avg	25.5 Avg
	Green River Basin	Sub-bituminous Bituminous	8.6 Avg	10.4 Avg	1.8 Avg	17.7 Avg
	Hams Fork Region	Sub-bituminous Bituminous	9.7 Avg	3.57 Avg	0.59 Avg	21.24 Avg
	Hanna Field	Sub-bituminous Bituminous	10.6 Avg	6.9 Avg	0.62 Avg	13.5 Avg
	Wind River Field	Sub-bituminous	-	-	-	-
	Bighorn Basin	Sub-bituminous Bituminous	10.6 - 11.5	5.6 - 9.7	0.45 - 0.85	10.4 - 14.2

TABLE 3-4

COAL CHARACTERISTICS

GEOLOGIC CHARACTERISTICS
Basin structure containing coals in the Morrison formation.
Asymmetric basin, strata dips steeply into basin on north and east sides.
Arcuate, shallow trough, few faults, dip of strata 2^{o} - 6^{o}.
Flat lying seams covered by semi - consolidated clays, glacial tills and gravel.
Gentle asymmetrical syncline bounded by mountain ranges on east and west. Relatively flat seams.
Divided into two structural basins by Rock Springs Anticline. Dips of 20^{o} occur at basin margins.
Highly folded and trust faulted - coal outcrops in long narrow belts.
Structural trough divided into 2 separate basins by a N.E. - S.W. trending anticline. Faulting is common.
Asymmetrical syncline with steepest slopes on north side. Minor faults and folds.
Broad structural basin. Dips of folds at basin, margins approach 50'. Coals are erratic and lenticular.

flat-lying or form broad, asymetrical synclinal basins between various ranges of the Rocky Mountains. Geology of the Wyoming coal strata is fairly simple except for a few areas of complicated major faulting.

Lignite reserves are limited to the northeastern Powder River Basin, but sub-bituminous coal is only absent in the State's Black Hills Region. Bituminous coal is found in the Black Hills, part of the Hanna River Basin, the Green River Region and the Big Horn Basin. Some high volatile coal is found in Hams Fork Region, and coal with weak to moderate coking properties occurs in that region's Kemmerer Field. Average values of Wyoming coals generally show BTU's of 11,000 to 14,000 for bituminous and 8,400 to 13,000 for sub-bituminous, ash contents of 1.4% to 17.2%, sulfur of 0.7% to 5.0% and moisture between 1.7% and 32.8%.

BASIC MINING METHODS ENCOUNTERED

Mining operations in Region IV commonly utilize area mining techniques and/or some form of open pit mining where coal seams are thicker. Basic stripping operations are performed by a wide range of equipment including shovels, draglines, scrapers, dozers, and front-end loaders. Overburden thicknesses in some areas are extremely small, and spoil material can be moved by scraper or front-end loader. Where coals lie within 40 to 50 feet of the surface, stripping shovels are best suited for fast, efficient operation, while thicker overburdens may dictate use of draglines. Overburden to coal ratios in Region IV can vary greatly, and sizes of stripping and coal loading equipment vary accordingly.

Area Mining

Area mining of lignite and sub-bituminous coals of the Fort Union Formation is practiced in the farm and pasture land of western North Dakota, eastern Montana, and northeastern Wyoming. Techniques and procedures, and unit operations utilized here are quite similar to those described for Region III. One primary distinction between the two regions is the stripping ratios, which are as low as 1:1 in parts of North Dakota and 4:1 in parts of Montana and Wyoming. Such minimal ratios are due to the combined benefits of shallow overburden and thick coal seams.

Unit Operations

Clearing and Grubbing

As previously mentioned, much of the land underlain by coal in Region IV is either farmland, pastureland, or semi-arid wasteland. Clearing and grubbing requirements are therefore extremely minimal, and there is virtually no associated timbering. This operation, when necessary, is accomplished by dozers.

Topsoil Removal

Topsoil removal and storage procedures are similar to those discussed in other regions, when practiced. Stockpiles are temporarily seeded to prevent erosion losses, but the semi-arid conditions do not promote exceptionally good cover growth.

Overburden Preparation

Overburden preparation procedures are quite similar in all areas of the region, being determined largely by the character of the overburden at the mine site. Typical preparation procedures include blast hole drilling with vertical rotary or percussion drills, loading with ANFO and shooting. In many cases, overburden preparation is not necessary due to unconsolidated conditions of overlying strata.

Overburden Removal

Western Area Mining, similar to mining in Region III, begins with an initial box cut, casting overburden to one side. Pan scrapers working in conjunction with 30 to 40 cubic yard draglines or 20 to 30 cubic yard shovels make effective combinations for overburden stripping. Relatively shallow overburden and thick coal seams allow direct placement of spoil in

adjacent, previous cuts using shovels or draglines with smaller buckets and booms than those in Region III. The lift and volume requirements of stripping equipment in Region IV are not as stringent as midwestern requirements. Overburden is generally unconsolidated or partially consolidated clay material overlain by sand or gravel. Consolidated sandstones and shales are found in western portions of this region.

After removing exposed coal from the first cut, an adjacent cut is made, and the overburden removed is placed in the adjacent previously mined out cut. Mining continues in a series of roughly parallel excavations to the limits of the mineable area. This is the typical area mining procedure, and is not altered by employment in thick seams mining.

Although overburden removal methods are similar to Region III, the demands put on equipment are different. While Region III requires large draglines to remove overburden, northeast Region IV requires slightly smaller equipment capacities.

Advantages and disadvantages of some of the major stripping equipment - shovels, draglines and bucket wheel excavators - were included in the Region III discussion, and will not be repeated here. However, since use of scrapers is an important overburden removal technique in this Region, expansion of previously presented information is in order. Scraper use in other Regions is frequently limited by practical stripping depths, a characteristic which is usually unimportant in this Region of generally shallow and poorly consolidated overburdens. Scrapers have excellent capabilities for spoil segregation, and can integrate reclamation grading and overburden removal into a single operation. They are also useful in removing partings in multiple seam and split seam operations. Under normal mining conditions, scraper overburden removal is more economical than any other commonly employed technique. Low initial and operating costs are primarily responsible for this. Overburden scraping in steeply dipping coal seams may also prove more economical than normal dragline use in similar situations.

There are also several disadvantages to scraper usage that must be considered. Production volume and speed cannot begin to match other larger stripping machines. Traction can be quite limited, depending on underfoot conditions and rock integrity, and rippers may be required to break the overburden for scraper pick-up and haulage. High maintenance, especially drive wheel tire replacement, can also become an important

economic factor.

Three basic types of wheel tractor scrapers are used in overburden removal. The first of these, the conventional, single engine scraper, is the very versatile and shows low operating costs. However, this scraper is ineffective in poor traction conditions and when subjected to high rolling resistances, necessitates use of a "pusher dozer" for efficient loading. The elevating scraper performs best on short to medium length haul roads, but they must be relatively level with minimal rolling resistance. Tandem powered twin engine scrapers have the greatest potential for effective, efficient overburden removal. These twin engine scrapers have a better weight to horsepower ratio than the other scrapers. Four wheel drive also gives these scrapers excellent traction. With special push blocks, and hook and bail arrangements, these scrapers can be used in tandem for "push-pull" scraping - one pushes while the other loads, then the full scraper pulls while the second one loads. This eliminates the need for extra non-production equipment such as push dozers.

Coal Loading

This unit operation probably represents the greatest variation between mining procedures in the study's regions. Coal seams are extremely thick in many portions of Region IV, and must be shot and loaded in benches (much the same as overburden is often stripped in benches in the other regions). Since the volume of coal to be loaded is much greater, there can be more variability in types of equipment suitable for loading. Equipment that can be utilized for coal loading in Region IV includes shovels, bucket wheel excavators, front-end loaders and self-loading scrapers. Selection of equipment for a specific site is dependent upon production capability and ability to load efficiently and economically. Advantages of coal loading equipment are summarized below:

1. Front-end Loaders
   Advantages
   - Excellent mobility
   - Good blending capabilities
   - Good back-up and clean-up tool for shovel
   - Multi-functional (loading coal, clean-up, road maintenance, stockpiling, etc.)

- Loader size can be easily matched to any truck size
- Low capital cost, ideal for fast return on capital
- Ideal in thin seam conditions
- Annual costs generally lower than a shovel

Disadvantages:

- Availability not as good as shovel
- Excessive tire wear in difficult digging
- High tire cost
- Expected life is half that of shovel
- Cannot work high faces
- Bad floor conditions decrease performance
- Lower capacity for digging, therefore coal must be shot harder

2. Loading Shovels

Advantages:

- Larger breakout force to handle coarse materials
- Smooth digging action
- Low operating costs and maintenance requirements
- Lower operator fatigue than with front-end loader
- Longer reach at working face
- Can work in close quarters

Disadvantages:

- Lack of mobility
- High initial cost
- Cannot traverse steep grades
- Support equipment required
- Sensitive to seam thickness - efficiency reduced if bucket does not fill in one pass through seam

3. Scrapers

Advantages:

- Self-loading
- Four-wheel drive minimizes traction problems
- Excellent mobility, maneuverability, carry ability, gradability

- Least sensitive to seam thickness of all loading equipment
- Self-contained; downtime on individual unit does not affect other units or operations
- Can blend coal by varying loading pattern
- Can be matched to other haulage systems such as truck or conveyor
- Can build compacted stockpile with no assistance

Disadvantages:

- Two-wheel drive units may have very high drive-wheel tire costs due to tractive efforts required to load unshot coal
- Suited only to short hauls due to poor gross weight/tire weight ratio
- Dust generator

4. Bucket Wheel Excavators

Advantages:

- Rapid, continuous production
- Conveyors, with electric drive, can be utilized

Disadvantages:

- Buckets cannot follow bottom of seam, therefore, use is restricted to thick coal seams
- Must work from base of coal - wet weather conditions may limit mobility of wheel and haulage vehicles

Coal Haulage

Coal haulage in Region IV is quite similar to that discussed for Region III, since each mining operation generally has its own preparation facility. This negates the need for highway haulage, permitting use of end or bottom-dump off-highway haulage equipment with capacities ranging from 35 to 200 tons. Since large scale surface mining in Region IV is relatively new, many companies are currently experimenting with various types and sizes of haulage units and conveyor systems to determine those best suited to their needs.

Regrading

Regrading of Region IV surface mines is quite similar (in many aspects) to area mining regrading described in other regions. The principal differences in Region IV regrading is the fact that the spoil volume may be much less than the volume of the pit or cut which must be reclaimed, due to relatively shallow overburden and thick coal seams. Regrading in such operations is generally limited to the minimum amount required to meet reclamation restrictions in mining permits. Spoil and topsoil are returned to strip pits and graded to approximate original topography using dozers and scrapers. This frequently leaves a gently rolling final grade, which may be below the elevation of the original land surface. Since the spoil is still graded into the undisturbed land surface, there is not a noticeable boundary following reclamation.

Revegetation

Revegetation techniques are unique in Region IV, as dictated by the semi-arid climatic conditions. Due to the dry conditions, much undisturbed land in this region is very sparsely vegetated, and after disruption, revegetation is extremely difficult. Mode of application of seed varies and no specific technique (aerial, drill, hand, hydro, etc.) is yet favored as more effective. Fertilizer and seeding mixtures have not yet been definitely established, since mining in this region was only initiated in recent years. Problems are encountered with destruction of newly developing vegetation by grazing wild and domestic animals on open range land. In addition, many arid mined areas require either irrigation or construction of some type of moisture retention devices (gouging, dozer basins, pits, snow fences, mulches, deep chiseling, effset listering and condensation traps) on the regraded surface. These too are still in experimental stages.

Bulldozers and pan scrapers regrade spoil piles to the approximate original land contour and pan scrapers restore topsoil if it was available for segregation. Five feet of A-horizon soil blankets much of North Dakota, and high yield wheat crops can be grown on reclaimed land there. Some mines reported high sodium clay overburden, creating some revegetation problems. It is often impossible to tell reclaimed land from

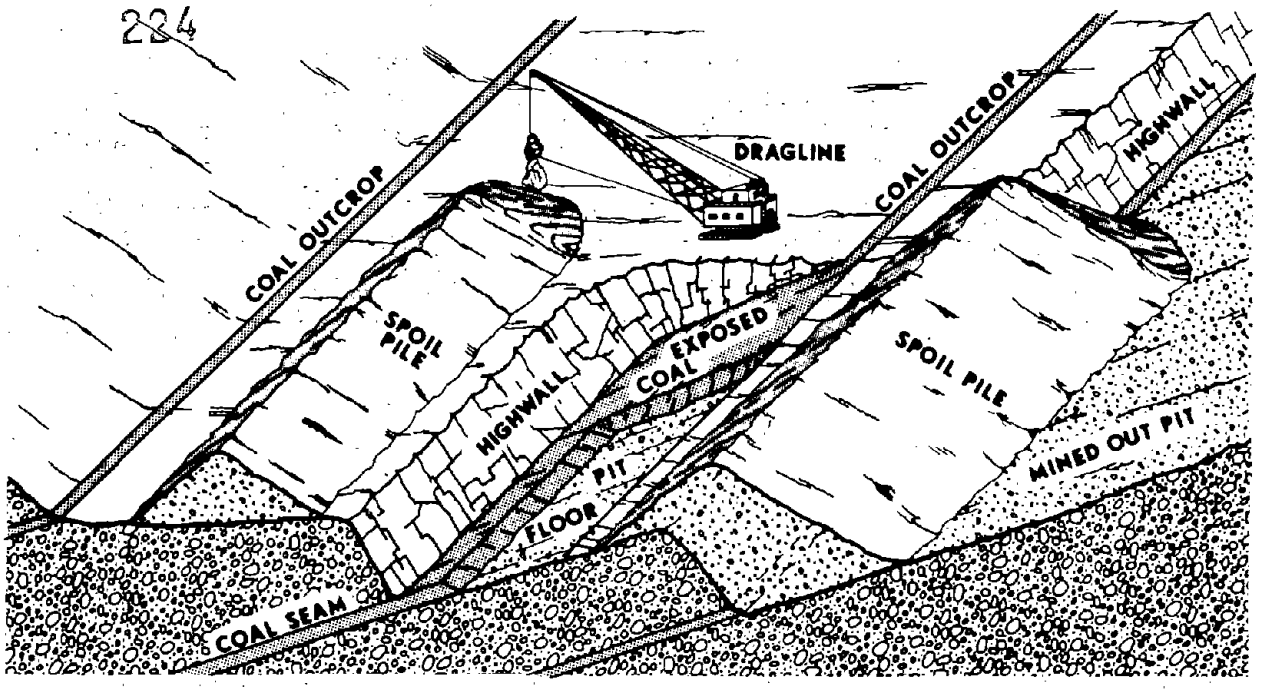
virgin farm land. However, in the semi-arid regions of Montana and Wyoming where wind and water erosion problems are severe, soil may already have been eroded from the mine site prior to mining. Revegetation of this disturbed land can be extremely expensive or impossible. Since coal mining is relatively new to Region IV, there are no definite or proven techniques for revegetation. State, Federal, University, and mine personnel are currently experimenting with reclamation and revegetation techniques in semi-arid regions.

Open Pit Mining - Dipping Seam

Coal seams also dip very steeply in some portions of Region IV, necessitating use of different mining techniques to maximize coal production. Such seams may be either single or multiple, but in both cases, stripping follows the coal down-dip to increasingly greater depths. The depth to which stripping can penetrate a steeply dipping seam is limited by the ultimate stripping ratio that can profitably be achieved. Where a number of steeply dipping coal seams overlie one another, the operating procedures, overburden removal and reclamation in particular, vary some-what. As shown in Figure 3-52, removed overburden is cast on both sides of each strip cut above the highwall on the coal seam's down-dip side, and below the coal seam, partially covering the highwall of the cut which exposed the underlying coal seam. After coal extraction, reclamation consists generally of rounding the spoil banks and partially filling adjacent pits. The resultant topography of the reclaimed area is gently rolling, although in overall perspective it is still representative of the land's approximate original contour. The rolling final topography is actually beneficial to native plant and animal life, because it offers protection from both wind and snow, which can be quite severe in many portions of Region IV.

Unit Operations

Equipment usage with this technique is identical to that of Area Mining, except that no stripping shovels can be used due to the dipping seams. Draglines perform the primary stripping function with support from dozers and pan scrapers. Bucket sizes are small, compared to the



TYPICAL OPEN PIT MINING METHOD (DIPPING SEAMS)

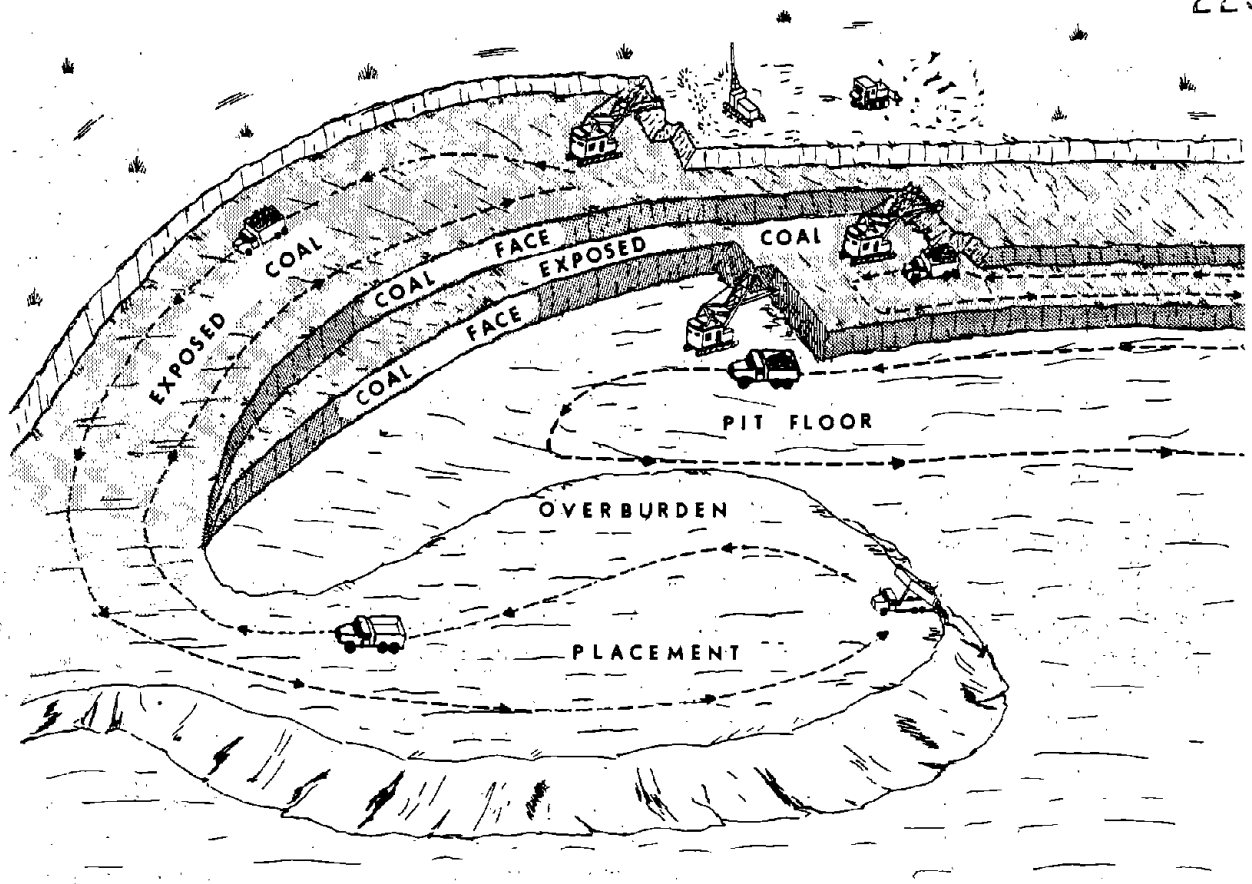
Figure 3-52

large machines of the Midwest. The term "open pit" applied to this method is commonly used throughout the west when referring to this type mine.

Open Pit Mining - Thick Seams

The extremely thick seams encountered in the West provide for implementation of a coal mining method totally different from any eastern technique, Open Pit Coal Mining (see Figure 3-53). Seams greater than 70 feet thick present an entirely unique set of criteria to be analyzed. Concentration must be placed more on the proper coal loading, hauling, and storage facilities than on overburden removal procedures. Overburden to coal ratios of 1:1 or less are not uncommon.

Open Pit Coal Mining in thick seams or "Coal Quarrying," begins



TYPICAL OPEN PIT MINING METHOD (THICK SEAM)

Figure 3-53

with uncovering a sufficient area of coal to allow extraction and provide an open area for future overburden placement. Initial overburden is spread and stored on adjacent land areas and revegetated. Coal thickness usually necessitates a benching operation for removal with loading shovels. "Quarry" expansion can proceed in most any direction from this initial point, usually along only one course at a time until a limit is reached (natural barrier, property line, outcrop, etc.). Overburden material is trucked and dumped in mined out areas of the pit, and later graded to a contour compatible with surrounding terrain.

Unit operations of this technique are identical to those of area mining with the exception of overburden removal practices. With this mining method, transporation of overburden material to a disposal point is common practice. Shovel-truck combinations and scrapers have proven to be well suited for this purpose, providing good flexibility and dependability. A major difference in this mining technique from other methods is that emphasis is placed primarily on coal removal, loading,

hauling and storage, rather than on overburden removal.

Effects of Coal Surface Mining Activities in Region IV

A major problem with surface mining in this region has been revegetation of disturbed areas. Semi-arid conditions do not promote vegetative growth, and where new cover growth can be established, grazing herds of antelope and deer can destroy nearly all revegetative efforts overnight.

Since coal surface mining activities, on a large scale, are at an early stage of development, long range environmental effects cannot accurately be determined at this point in time. A major concern of pending mining effects is the drastic change in area topography, 70 feet lower in some or more locations. If an operation causing this effect is permitted to extend the mine over a large area, visual aspects of this problem can be reduced or eliminated.

Hydrological effects of coal surface mining in this region have not been determined as yet. One possible advantage resulting from remaining mine depressions might be the collection of all precipitation that falls on the mined area in a centralized low point. This may serve to recharge groundwater in that vicinity or provide a water holding basin.

AUXILIARY OPERATIONS

Maintenance

Maintenance requirements for equipment utilized in Region IV operations are similar in all aspects to those described for Region III in which similar large equipment is operated.

Power Distribution

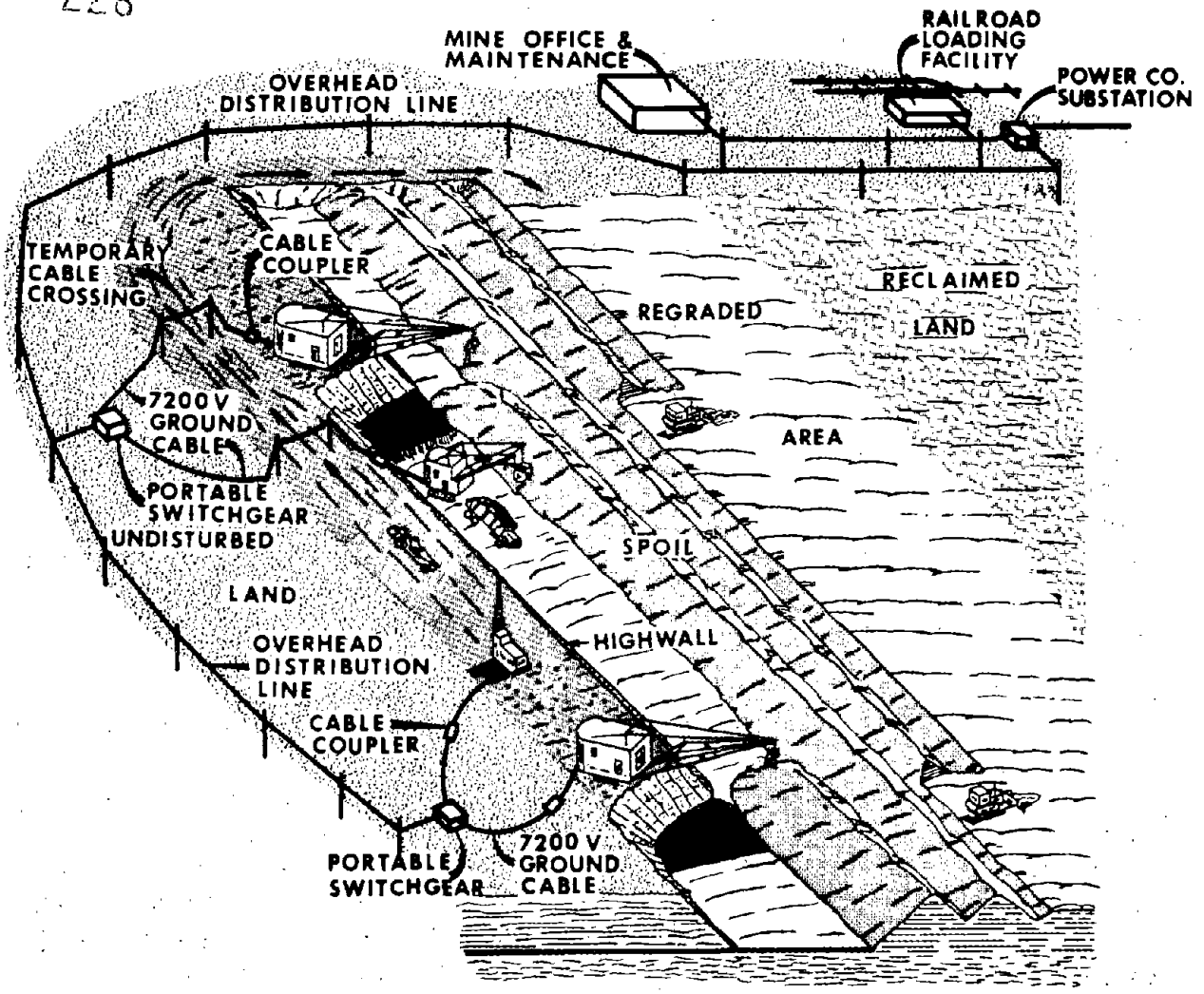
Primary voltage requirements for mining operations in Regions II, III and IV are determined by an engineering economic analysis of mine requirements and the utility rate structure. If the principal and operating costs of a high voltage substation (i.e. 33,000 volts) can be graduated over a period shorter than the predicted mine life, a higher receiving voltage can be justified. A typical example would be a 33 kilo-volt primary with a mine distribution voltage of 7200/4160.

Power distribution in the smaller mines of Region II normally is achieved with pole-mounted overhead construction to the pit area, where a portable substation connects to a ground cable. This ground cable is generally rated at 5 to 7 kilo-volts, with an impressed voltage of 4160/2400. The cable is then connected to a stripping machine (dragline or shovel) with a connected load of two to five thousand horsepower and a bucket capacity up to 25 cubic yards.

The large area and open pit operations in Regions III and IV have main power distribution systems with combinations of pole lines and ground cable lines. A typical large area mine electrical system is shown in Figure 3-54. This system contains a switchgear yard where the utility company terminates its facilities. If a higher receiving voltage were justified a transformation would occur at this point. Separate overhead lines are run to auxiliary buildings such as rail loading facilities and maintenance sheds. A transformer bank is set next to each building to reduce distribution voltage to a utilization level (i.e. 277/480 volts).

A separate overhead line is usually run along the edge of the mine property line, perpendicular to the open pit. This line is extended for about one mile beyond the pit, then runs parallel along its entire length. From this main line, laterals are run to the pit at intervals of several thousand feet, terminating in portable switchgear. Ground cables, which are usually in 1000 foot segments, are run from the switchgear to the heavy operating equipment. As the pits move laterally across-country, the lateral lines are shortened until the pit approaches the main pole line. This pole line is then moved farther from the pit to restart the cycle.

Stripping equipment capacities are generally over 25 cubic yards, and require distribution of 7200 volts. All heavy equipment converts the distribution system alternating current to direct current via large motor-



LARGE AREA MINE ELECTRICAL SYSTEM

Figure 3-54

generated sets located in the equipment housing. An added advantage of this power system is the ability to use synchronous motors in the conversion sets.

Pollution Control

Drainage, dust and noise pollution control are governed by Federal, State, and/or local agencies. Drainage discharge quality is generally controlled by state or local restrictions, and must be periodically monitored in some areas. Acid and iron concentration buildups are generally not associated with Region IV mining, but suspended and dissolved solids can

reach unacceptable levels. These problems are infrequent in Region IV due to the semi-arid climate, limited ground water, and high evaporation rates. Control of such discharge problems can be achieved through construction of settling and/or evaporation basins.

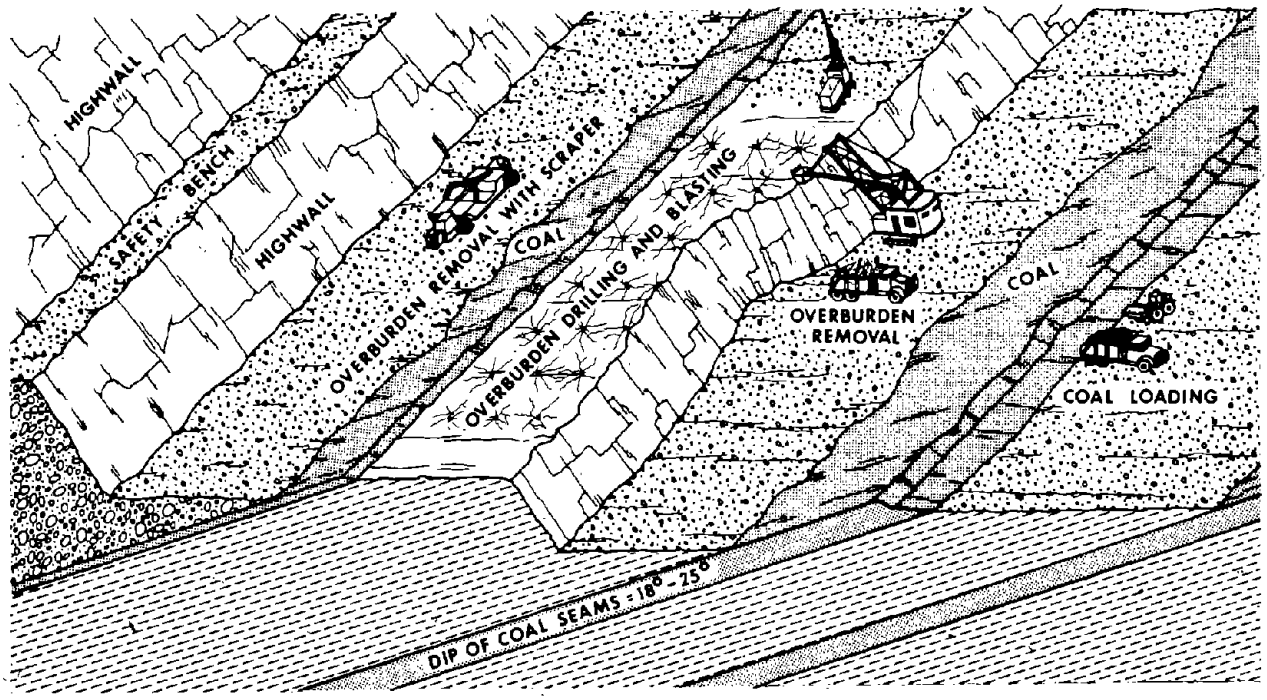
Dust control is a serious requirement in the semi-arid Region IV mine, and is accomplished with water or oil sprays on haul roads. Dust also becomes a problem when scrapers are used for either coal or overburden removal. Special water tanks can be fitted to the scrapers to control this dust.

Road Maintenance

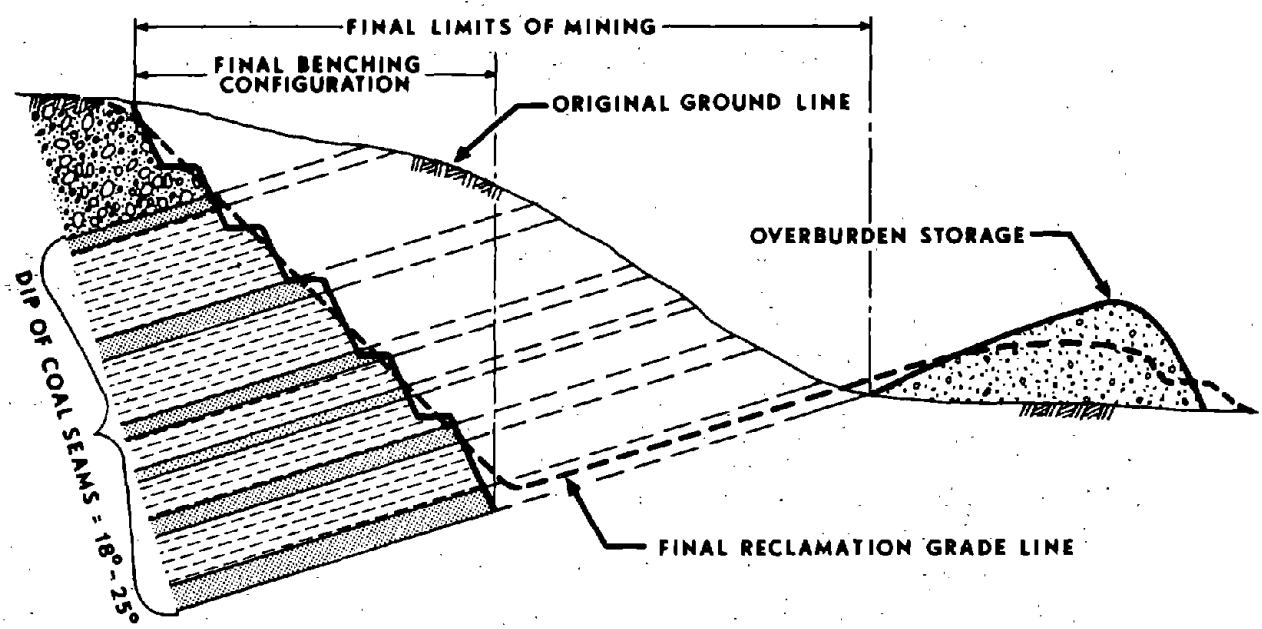
Road maintenance procedures in Region IV are much the same as those discussed for Region III.

UNIQUE MINING METHOD

The unique mining operation found in Region IV is a steeply dipping multi-seam operation with an ultimate highwall (after reclamation). This operation in Wyoming is similar in many respects to the dipping open pit operation previously described. In this case, however, there are 13 coal seams ranging from 4 to 93 feet in thickness located sufficiently close stratigraphically to one another to permit stripping of all seams. As Figure 3-55 shows, mining progresses along a series of steps or benches, one located at the level of each coal seam. Since the coals outcrop along the top of the ridge, the lower seam (this is the thickest and has the greatest BTU value) is mined first with progressive benching of overlying seams as encountered. The removal of overlying coals permits additional recovery of lower seams. This stripping cycle continues through all of the seams at the site. In this manner, the coal faces of each bench advance down-dip. Since the depth of overburden between each of the seams remains constant, downward development of this pit continues until the overall overburden ratio, (which is only influenced by the increasing depth of overburden above the uppermost seam), becomes too great to permit continued economical extraction.



PLAN VIEW



CROSS SECTION

UNIQUE MULTI-SEAM OPEN PIT MINING METHOD

Figure 3-55

When mining of such a segment of multiple seams has ceased, the configuration of the pit will resemble the cross section shown in Figure 3-55 - a series of benches on the high side, a single flat incline (representing the base of the lowest coal seam) on the low side, and a very large spoil outside the pit. The proposed "Super Pit" at this mine will be, when completed, approximately 6240 feet horizontally from lowest coal outcrop to highwall and 1770 feet deep. The volume of spoil in the pile adjacent to the pit will by that time be much too great to permit its return to the pit for contour grading. Reclamation of this segment will consist primarily of multiple highwall reduction and rounding of the spoil pile. Thus, the large open pit will remain essentially the same, with only some slope reduction on benches and minimal regrading.

Comparison of this steeply dipping multi-seam operation with any other mining technique or operation is extremely difficult, since it is specifically designed to maximize production in unique geologic setting. The obvious advantage of the technique is that it enables high production from a series of otherwise unmineable coal seams. The only potential disadvantage is the fact that the land will not be returned to original contour. However, this is not critical, since proper reclamation procedures will minimize environmental damages attributed to this mining technique. In addition, the remote geographic location of the mine is such that there are no major disadvantages to regrading in the manner described.

REGIONAL RECOMMENDATIONS

Recommendations for increased production with minimal environmental disturbance are hard to make or substantiate in Region IV, where large scale mining activities are extremely young. Mining and reclamation are at such an early stage in this region that their environmental effects have not yet been fully ascertained. Production techniques are still in experimental stages in many areas, since experience in thick seam mining is limited in this Nation. Thus, the only recommendations that can be proposed are very general and broad. Careful mining and reclamation planning, in conjunction with continued experimentation to determine better mining and reclamation procedures, are required to yield maximum production while maintaining acceptable environmental quality.

DISTRIBUTION OF ANTHRACITE RESERVES

Within the United States there are several states with notable anthracite coal reserves: Pennsylvania - 1.9 billion tons; Colorado - 456 million tons; New Mexico - 7.2 million tons; and Washington - 2.1 million tons.

About 90% of mineable anthracite lies within four fields of northeastern Pennsylvania. These fields are commonly referred to as the northern, eastern-middle, western-middle and southern and are located in the Valley and Ridge Province of the Appalachian Highlands, having a total area of about 480 square miles.

Each of these fields consists of elongated synclinal basins trending about N 70 degrees E. The basins or synclines resulted from downfolding of over 2,200 feet of rock containing up to 26 coal seams and reaching depths of 3,000 feet below the surface. Most of the coal lies in synclines protected from erosion by the Pottsville conglomerate and Pocono sandstones, two highly resistant rock units (3). The red Mauch Chunk shale and sandstone make a distinct horizon - marker and indicate the lower limit of all coal.

The northern coal field encompasses the Scranton and Wilkes-Barre region. Coal reserves occur here in a large, curved, canoe-shaped synclinal basin, 57 miles long and 7 miles wide with a relatively flat bottom and steep sides outcropping along the mountain ridges. Within 2100 feet of stratigraphic section are 13 major coal seams with 21 important splits.

On a local basis the northern field is highly complex, folding and faulting being quite intense. All lower seams dip or pitch from 60 to 80 degrees along the perimeter of the basin. Whereas at the center of the basin, seams are oriented horizontally to vertically and are occasionally over-turned. Frequent faulting produces offsets of rock strata and coal beds of up to 300 feet (3).

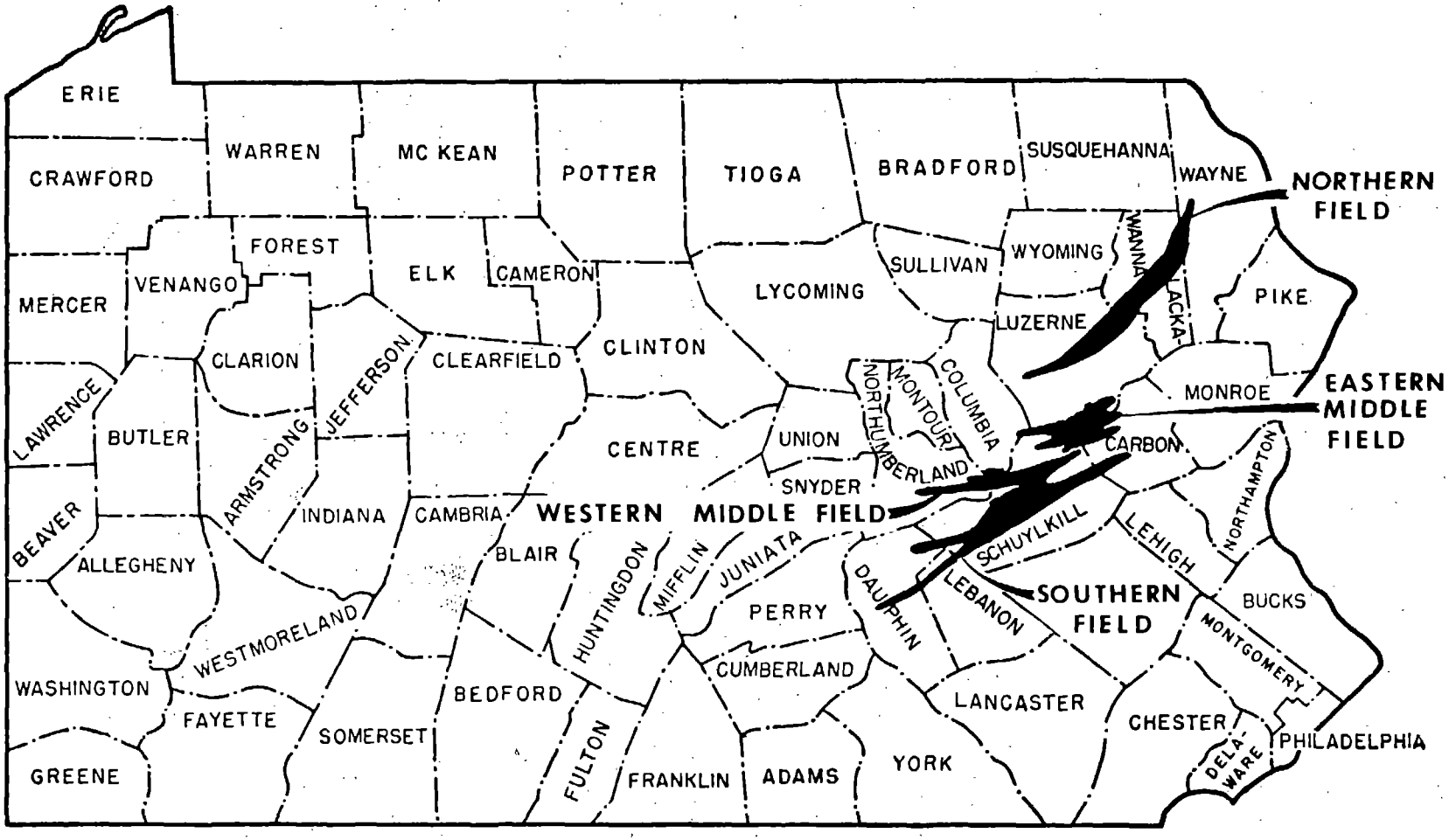
Individual coal seams vary somewhat in their mining characteristics and the analytical value of the coal. Within the northern field, most seams have an average thickness of seven to eight feet (11). Other

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than thickness, pitch of seam and continuity, friability of the coal is an important coal characteristic considered during mining. Most anthracite coal is of suitable mining quality. The range of Pennsylvania anthracite after simple cleaning and drying operations can approach 13,000 BTU. Although its BTU content is not as high as some Pennsylvania bituminous coal (14,000 BTU), its low sulfur content and BTU content compared with large western (Region IV) reserves makes Pennsylvania anthracite an important and environmentally attractive energy source, especially due to its proximity to large eastern markets and population centers. Typical analytical values for prepared anthracite coal are 82% fixed carbon, 10% ash, 13,500 BTU ("dry" basis) and 0.7% sulfur (11).

Past mining operations, geology, and environmental considerations dictate the immediate mining potential of the northern field. This field has been extensively mined with interconnecting workings that are largely inundated today. Massive water handling problems occur due to seepage or flow from adjacent abandoned mines. This fact along with treatment to acceptable water quality limits, prohibits economic extraction by deep mining (and some surface mining). Since mine workings along the sides and at the ends of the northern field are higher than workings in the center of the basin, flooding of the higher elevated mines produces seepage and transfer of mine water toward the center of the coal field, where continuous pumping is required to operate some surface mines. Although the bulk of the northern fields' coal reserves are available to deep mining methods, apart from environmental concerns and limitations, only bank (secondary processing) and small strip mining operations are currently active. Figure 3-57 shows relative importance of surface mining in the northern anthracite field.

The eastern-middle field, centered around the Hazleton area, consists of numerous long, narrow, east-west trending coal basins. The 13 major coal seams mined in this field, are deeply folded and complex in structure, have an average thickness of about 8 feet (and range from 4 to 30 feet in thickness (11). Analytical values for eastern-middle field coals are similar to the northern field coals. Average sulfur content for this and other remaining fields is about 0.62% and ranges from 0.3 to 1.7%. Since nearly all seams have been extensively deep mined over the past 150 years, very few underground mines are operating and most production comes from surface and bank mines. Drainage characteristics of the eastern-middle field are more compatible with surface mining



ANTHRACITE RESERVES OF PENNSYLVANIA
Figure 3-56

Type Of Mining	Annual Production Category (Tons)	Total Annual Production (Tons)	Number Of Companies	Total Number Of Employees	Productivity (Tons/man-day)
Deep	<500	0	0	0	0.0
	500-5,000	2,735	1	4	2.7
	5,000-10,000	0	0	0	0.0
	10,000-20,000	0	0	0	0.0
	20,000-50,000	0	0	0	0.0
	>50,000	164,153	1	222	3.1
SUBTOTAL =		166,888		MEAN =	3.0
Strip	<500	0	16	6	0.0
	500-5,000	0	0	0	0.0
	5,000-10,000	15,974	2	8	9.0
	10,000-20,000	17,211	1	81	3.8
	20,000-50,000	32,156	1	5	25.1
	>50,000	621,679	36	374	5.5
SUBTOTAL =		687,020		MEAN =	5.6
Culm Bank	<500	0	0	0	0.0
	500-5,000	11,463	3	10	14.5
	5,000-10,000	0	0	0	0.0
	10,000-20,000	19,367	1	7	89.3
	20,000-50,000	131,932	5	34	40.0
	>50,000	0	0	0	0.0
SUBTOTAL =		162,762		MEAN =	34.8
TOTAL =		1,016,670			

Adapted From Berger Associates

DISTRIBUTION OF MINING COMPANIES ACCORDING TO ANNUAL PRODUCTION

PENNSYLVANIA ANTHRACITE REGION

Figure 3-57

operations.

In the late 1800's long water level tunnels were driven into mountains at a point where they intercepted drainage from all higher coal seams mined (17). This eliminates some drainage problems for large active surface mining operations but caused degradation of streams. In the early 1970's production from the eastern-middle field was about 1.5 million tons annually, equivalent to the northern field, until early 1973, when with the closing of the largest mine in the northern field, the eastern-middle field became the larger producer. Figure 3-58 illustrates the relative importance of surface mining in the eastern-middle field as compared with other production methods.

The western-middle anthracite field encompasses the Mahanoy Shamokin region and contains many of the same major seams found in the eastern-middle field. All coal seams in this field (flat-lying in some areas and steeply pitching in others) are contained stratigraphically within 2,500 feet of rock (3). Coal seams in the Shenandoah and Mahonoy basins, including the Mammoth, are folded over upon themselves, doubling the thickness of mineable coal and achieving local thickness of 200 feet (3). Since coal basins in this field are almost totally beneath natural drainage channels, abandoned underground mines are inundated and mine pool overflows are a source of problems for deep pits (surface mines) which encounter flooded sections. About 18 seams or splits are mined in the western-middle field, most of which are six to seven feet thick and attain 14 to 15 foot thicknesses for the bottom split of the well known Mammoth Seam (13). Sulfur content ranges from 0.3 to 1.7% and averages about 0.6% (11). In the early 1970's annual production from the western-middle field was about two million tons. Considerable production decreases have occurred since 1970. Figure 3-59 indicates relative importance of production methods accounting for about 1.3 million tons annually.

The southern field is the largest of the four coal fields with an area of 200 square miles. This field is relatively long, extending from the Lehigh River Valley westward almost to the Susquehanna River. The 26 workable coal seams in the southern field lie within 2,200 feet of stratigraphic section. Portions of abandoned mine workings, surface and deep mines, are inundated and must be pumped to operate. Sulfur content averages about 0.68%, and ranges between 0.3 and 1.7%. The southern field seams are more deeply folded, consequently greater re-

EASTERN MIDDLE FIELD — 1973

Type Of Mining	Annual Production Category (Tons)	Total Annual Production (Tons)	Number Of Companies	Total Number Of Employees	Productivity (Tons/man-day)
Deep	<500	0	2	4	0.0 (1)
	500-5,000	4,184	2	7	3.4
	5,000-10,000	0	0	0	0.0
	10,000-20,000	0	0	0	0.0
	20,000-50,000	0	0	0	0.0
	>50,000	0	0	0	0.0
SUBTOTAL =		4,184		MEAN =	-
Strip	<500	0	2	17	0.0 (2)
	500-5,000	0	0	0	0.0
	5,000-10,000	0	0	0	0.0
	10,000-20,000	27,553	2	19	5.8
	20,000-50,000	26,466	1	25	3.6
	>50,000	810,680	3	253	9.7
SUBTOTAL =		864,699		MEAN =	-
Culm Bank	<500	491	1	6	54.6
	500-5,000	4,800	1	4	24.5
	5,000-10,000	0	0	0	0.0
	10,000-20,000	0	0	0	0.0
	20,000-50,000	69,153	2	9	38.5
	>50,000	349,849	2	26	83.7
SUBTOTAL =		424,293		MEAN =	49.8
TOTAL =		1,293,176			

NOTES: (1) No Backfilling
(2) Backfilling

Adapted From Berger Associates

DISTRIBUTION OF MINING COMPANIES ACCORDING TO ANNUAL PRODUCTION

PENNSYLVANIA ANTHRACITE REGION

Figure 3-58

WESTERN MIDDLE FIELD — 1973

Type Of Mining	Annual Production Category (Tons)	Total Annual Production (Tons)	Number Of Companies	Total Number Of Employees	Productivity (Tons/man-day)
Deep	<500	105	7	31	0.6 (1)
	500-5,000	28,397	12	46	3.3
	5,000-10,000	14,745	2	14	3.9
	10,000-20,000	46,635	3	26	6.7
	20,000-50,000	0	0	0	0.0
	>50,000	0	0	0	0.0
SUBTOTAL =		89,882		MEAN =	3.6
Strip	<500	96	1	42	0.2 (2)
	500-5,000	7,977	3	8	5.3
	5,000-10,000	6,327	1	3	5.9
	10,000-20,000	26,403	2	8	23.6
	20,000-50,000	49,254	2	20	9.2
	>50,000	504,311	5	310	7.9
SUBTOTAL =		594,368		MEAN =	7.2
Culm Bank	<500	303	2	7	2.6
	500-5,000	2,125	1	2	14.2
	5,000-10,000	0	0	0	0.0
	10,000-20,000	0	0	0	0.0
	20,000-50,000	72,928	2	6	60.5
	>50,000	580,760	4	41	107.0
SUBTOTAL =		656,116		MEAN =	95.1
TOTAL =		1,340,366			

Adapted From Berger Associates

NOTES: (1) Five Companies - No production
(2) Two Companies - Backfilling

DISTRIBUTION OF MINING COMPANIES ACCORDING TO ANNUAL PRODUCTION

PENNSYLVANIA ANTHRACITE REGION

Figure 3-59

serves of coal remain untouched by available mining methods. During the early 1970's, the southern field accounted for three million tons or 37.5% of all anthracite production. Figure 3-60 illustrates the relative importance of the various mining operations in the southern field, the region's greatest producer.

SOUTHERN FIELD —— 1973

Type Of Mining	Annual Production Category (Tons)	Total Annual Production (Tons)	Number Of Companies	Total Number Of Employees	Productivity (Tons/man-day)
Deep	<500	422	12	27	1.4 (1)
	500-5,000	46,684	20	69	4.6
	5,000-10,000	67,293	10	63	3.1
	10,000-20,000	95,360	7	53	6.5
	20,000-50,000	145,773	5	91	6.4
	>50,000	86,355	1	76	3.8
SUBTOTAL =		441,887		MEAN =	5.0
Strip	<500	0	5	22	0.0 (2)
	500-5,000	10,395	4	9	8.9
	5,000-10,000	14,322	2	7	9.3
	10,000-20,000	0	-	-	0.0
	20,000-50,000	167,025	6	104	9.6
	>50,000	947,096	3	351	10.9
SUBTOTAL =		1,138,838		MEAN =	10.1
Culm Bank	<500	0	-	-	0.0
	500-5,000	5,651	2	5	38.7
	5,000-10,000	5,121	1	0	0.0 (3)
	10,000-20,000	0	-	-	0.0
	20,000-50,000	273,760	9	38	43.2
	>50,000	777,648	8	132	30.6
SUBTOTAL =		1,062,180		MEAN =	33.1
TOTAL =		2,642,905			

NOTES: (1) Seven deep mines listed no product
(2) Backfilling
(3) Reported stockpile

Adapted From Berger Associates

DISTRIBUTION OF MINING COMPANIES ACCORDING TO ANNUAL PRODUCTION

PENNSYLVANIA ANTHRACITE REGION

Figure 3-60

ANTHRACITE MINING ENVIRONMENTS

Numerous anthracite coal seams are 8 to 15 feet thick and occasionally 25 to 100 foot seams have been surface mined (3). All mineable seams in the anthracite region have been surface mined at least once, and several large deposits have been mined three times by successively larger equipment.

The number (up to twelve adjacent seams) and thickness of steeply dipping coal seams do not permit original contour regrading, due to large backfill deficits created by the coal removed. Extensive removal of coal by deep mining for over 150 years has produced large void spaces, many of which have collapsed to the surface, causing major subsidence problems near population centers. Nearly all deep mines are interconnected by breaching barrier pillars for coal extraction and mine drainage controls. Before 1961, sufficient deep mining was conducted, along with pumping, to prevent migration and gravity discharge of mine water in the northern anthracite field. As deep mines were abandoned, mine pools began to elevate and flood some surface mining operations. Many coal seams which outcrop along the edge of the basins have been mined all the way to the surface, except for remaining coal pillars which have been strip mined. Occasionally these remaining pillars and overburden break loose and fall into the mine voids below. This is often referred to as a crop fall, which usually occurs more frequently with steeply pitching seams decreasing slightly in thickness toward the surface.

The abovementioned conditions are the combined results of past mining and geologic structure of the coal fields. All present and future surface mining operations are confronted with these conditions and must consider them when planning an operation. Considerations needed for mine planning are presented below:

- Completeness and accuracy of mapping, geology, hydrology, and past deep mine records.
- Percent of coal remaining in the form of pillars.
- Quality of coal is generally excellent, but may be poor on a local basis, or burned out in past mine fires.

- Knowledge of existence of flooded underground sections.
- Mine pool elevations and fluctuations in pool levels.
- Pumping rates required to hold mine pool levels low enough to permit surface extraction.
- Knowledge of barriers required to prevent flooding in towns, adjacent mining activities and the surface mine in question.
- Environmental or mining controls necessary to permit mining with regard to reclamation, acid materials placement, and treatment of mine drainage if required.
- The potential for a crop-fall caused by moving heavy equipment or shooting overburden material. This condition is almost non-existent in bituminous fields.
- Amount of overburden consisting of hard rock, glacial deposits and extent of groundwater interference.
- Pitch of the coal seam (which may be nearly horizontal to vertical) determines overburden thickness. Seams often dip or pitch 45 to 75 degrees.
- Minimum total quantity of coal which permits a profit, considering development, extraction, environmental controls and mine reclamation costs.
- Land use conflicts, public or private ownership, effects on surface streams.
- Sufficient capital investment, especially when large equipment is required.
- Availability of trained personnel.

ANTHRACITE SURFACE MINING

Previous deep and surface mining operations in the four fields have created high production costs for present surface mining operations since extraction of coal is restricted to mining stumps and some barrier pillars. Environmental controls necessary to conduct an operation acceptable to Pennsylvania State laws also add costs which must be passed on to the consumer. State reclamation laws have been adapted to conditions in the anthracite region and differ somewhat from laws for the state's bituminous fields. However, recent selling price increases in anthracite coal, which is in short supply, have helped offset high production costs.

Surface mining is confined to two basic methods employed in the four anthracite fields. The first (a continuation of previous conventional strip mining methods) uses electric and diesel walker and crawler draglines with capacities between seven and twelve cubic yards. Although both overburden and coal can be removed by dragline, the pitch of the seam usually determines if stripping of overburden is accomplished with a dragline or shovel. Steeply pitching seams (about 45 degrees or greater) usually require use of the dragline due to the depth of cuts. More shallow dipping seams permit use of shovels as well as draglines.

Stripping operations are usually confined to the edges of coal basins, where outcroppings of coal permit recovery after removal of minimum thicknesses of overburden. As greater depths are reached, surface operations encounter more void spaces as well as more overburden. Unless thick deposits of coal are uncovered in a short period of time, coal haulage (usually by truck) is not a continuous operation. When large, near-surface, pillars are being extracted, little foreign matter needs to be removed from raw coal during preparation. If void spaces are mined through where deep mining has occurred, rock, timber, and coal are extracted together. This requires extensive coal cleaning, but such extraction accounts for only 35 to 50% coal recovery. If thick seams are mined, this low percent recovery is usually profitable.

Overburden material removed in anthracite mining operations is extremely hard or well consolidated, compared with thin bedded sandstones and friable shales associated with bituminous coal fields. Such material requires extensive blasting and causes high wear on buckets and wire rope.

The second basic surface mining method utilized in the anthracite region is most accurately referred to as open pit mining. In addition to peculiar geologic conditions, the presence of deep mine water and pumping rates required to lower pool levels are factors determining open pit mining feasibility. There are currently two relatively large open pit operations in the anthracite region -- each employing different types of mining equipment and confronting vastly different mine water problems. The two open pit operations are located in the eastern-middle and southern coal fields having major geological similarities.

Within the southern field the Mammoth (bottom split), the Primrose and Orchard seams are relatively thick (15 to 100 feet) and deeply folded into a synclinal basin. The large open pit operation is conducted along the northwest flank where the Mammoth and Primrose seams dip 45 degrees to the southeast. The major seam mined in this pit, the Mammoth, is up to 100 feet thick which permits removal of overburden up to 800 feet thick containing additional coal. Stripping ratios range from 6:1 to 30:1 for overburden to coal removal. All coal seams surface mined have been previously deep mined and are normally flooded, requiring pumping to eliminate inundation problems. Several pumps remove about 5 billion gallons of mine water annually to hold mine-pool levels below a 700 foot elevation. Pumps are located in two mine shafts. One shaft has two 800 horsepower pumps and the other shaft has one 800 and one 1,000 horsepower pump.

After overburden has been drilled and shot, shovels load rock into trucks which haul this material to the end of the pit for dumping. Areas previously mined are used for dumping or concurrent backfilling. Haul roads, relative to most bituminous operations, are short in length and not as well traveled, especially for coal haulage. Dust is usually controlled by oiling or watering as required. These previously mined areas are also used for disposal of coal refuse material from preparation facilities. Exposed coal is placed on a stockpile by draglines, and shovels if conditions permit. Coal trucks are then loaded by front-end loaders or shovels for shipment to the tipple and coal preparation ares.

Occasionally 95% pure coal can be recovered; however, 40 to 50% is a more average recovery rate. Annual production from one large and one small pit is about 360,000 tons. The backfill deficit created by removal of large volumes of coal does not permit backfilling to original contour. The land surface is returned to its approximate contour, and

new elevations depend upon thickness and pitch of the seam mined and amount of overburden excavated. Type of revegetation performed on reclaimed land depends upon soil and slope conditions. If a revegetation plan does not exist for an area, test plots are usually planted to determine the best seed and fertilizer mixture.

The second large open pit operation, located in the Black Creek coal basin of the eastern-middle field (just north of Hazleton, Pennsylvania) is geologically similar to the first mine site. About 300 to 450 feet of overburden is excavated to recover remaining stumps and pillars of the Mammoth and Buck Mountain coal seams. Coal beds are downfolded into a relatively shallow synclinal basin with stripping ratios which permit economical mining. Overburden material, consisting of hard rock and glacial fill, is removed by large draglines (the largest in Pennsylvania) with capacities of 35 to 85 cubic yards. These machines are the primary earth movers in the operation.

Mining is currently proceeding in two separate large pits. In one pit an 85 cubic yard machine passes material to a 30 cubic yard machine to uncover the coal. In the other pit a 60 cubic yard machine passes overburden to a 30 cubic yard dragline which places only the finer material on a conveyor belt for haulage out of the pit. Removal of coal is accomplished with the dragline which places coal plus foreign material on separate stockpiles. Only 35 to 40% of raw coal material excavated is salable after cleaning and sizing.

Materials handling in this operation is improved with the use of an overburden conveyor belt system, and the construction of a drainage tunnel in the late 1800's contributed another economic advantage by eliminating pumping of deep mine workings.

Other than the above two basic mining methods, strip and open pit mining, several other surface mining operations employ large front-loaders. Production from future surface mining will, barring any technological breakthroughs, be confined to expanding the large open pit operations. More limited production will result from the smaller strip operations.

Future Outlook

Anthracite coal will continue to be available for surface mining until about the year 1995. Bank mined coal should be consumed before surface mining is complete. Deep mining will continue to play an important role in anthracite coal production beyond the year 2000; however, its expansion will be slight unless new mechanized deep mining methods are found. Surface mining methods have utilized the most modern equipment available. This is not the case for other mining methods which have remained unchanged for several decades.

Although expansion of the anthracite industry is possible from a geologic and technologic standpoint, unstable market conditions and availability of trained personnel are factors that will limit production. Both market and labor conditions affect investment incentive, and adequate financing is becoming increasingly more difficult to justify. New equipment is increasing in price, and operators from the bituminous fields are providing very competitive bidding. In some cases, used equipment from the anthracite region has been purchased by bituminous coal operators. Currently large operations are becoming more restricted to captive producers which can more readily afford the development cost or higher production cost independents cannot afford.

Consumption of Pennsylvania anthracite in the United States has decreased about 10% per year over the past four years. The greatest consumer use continues to be residential and commercial heating. In 1972, this consumption was nearly three million tons, or about one third of annual production. This use was followed by electric utilities, which consumed 1.59 million tons in 1972. Use of anthracite coal by utilities has not declined as much as other uses. Other categories of consumption include cement plants, coke-making, sintering and pelletizing. In late 1974 anthracite coal was high in demand and short in supply. Supply of home heating coal was low and some contracts filled in previous years could not be continued.

Bank production is expected to contribute significant production gains for the next 15 years. Surface mining, providing financial incentives exist, should begin to contribute more to the energy market before bank mining has depleted all available raw coal. Underground mining, in addition to financial incentive, will require technological

breakthroughs to increase coal production significantly.

Deep reserves are the most difficult and costly to extract and training of miners will also be required to assist their segment of industry. About 23% of all Pennsylvania's coal reserves are in the Anthracite Region; this includes nearly half of all Pennsylvania's low sulfur coal. The low sulfur and relatively high BTU value should produce some attraction for the anthracite market. Domestic energy sources, low in sulfur, are not high in supply and Pennsylvania's anthracite is likely to receive consideration in the future.

FOREIGN SURFACE COAL MINING ACTIVITIES

Most foreign coal mining activities involve underground mining methods. One exception is the surface mining operations being conducted in lignite fields of West Germany.

GENERAL INFORMATION

Sources of energy and other natural resources in Germany are not unlimited, therefore, very efficient and carefully made plans are developed before exploiting lignite (brown) coal reserves. More than a quarter of all West German electrical power production is derived from lignite reserves west of Koeln (15). Eighty-five percent of all lignite mined in West Germany is used for power production with the rest being converted into pressed-bricks (briquettes) for home heating in ten million households. Lignite mining has a strong influence on the economic development of the Koeln, Dusseldorf and Aachen areas (which possess energy intensive industries) (15). Other minerals mined from lignite sites include sand and gravel, pure quartz sands, and sulfur nodules. Additional materials are undergoing examination for possible use.

Future uses of lignite (brown-coal) will go beyond electrical power and briquettes. Brown coal's favorable physical and chemical properties (high reactivity, porosity, and low percentages of sulfur) will be major factors in determining future utilization. These properties permit its current use in: 1) reduction of iron ores; 2) electrochemical and electrometallurgical processes; and 3) as an absorbent medium for purification of blue gas water.

Development of high temperature reactors in the nuclear research plant in Juelich indicate that cheap process heat may be available for gasification of brown coal (15). Brown coal gas is also expected to have other uses which can replace some applications of natural gas and oil.

Germany has approximately 7.3% of the world's reserves of brown coal (90 billion tons). Sixty billion tons are in West Germany and

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the remainder is in Central Germany. Of the 60 billion tons, 55 are contained in the brown coal fields near Koeln and are known as the Rheinish Brown Coal Fields.

OPEN CAST MINING OF BROWN COAL

The Rheinish Brown Coal Fields cover an area of 965 square miles. Prior to 1945 numerous (about 25) shallow surface mines accounted for all brown coal production. Since World War II, new mining operations (6 in 1970) occupy larger areas (per mine) and mine deeper deposits than before. Overburden at some of the larger operations is up to 654 feet thick. Brown coal deposits are up to 500 feet thick.

In some areas of the Rhine River, eroded deposits cover the coal to depths of only 65 feet. At these points overburden to coal ratios are reduced to 0.3:1 and are the first coal deposits to be mined. Where uppermost coal deposits reach 650 foot depths, an average stripping ratio of 3:1 is encountered (along with sand and clay layers within the coal seam) (15). The main portion of the Rheinish Brown Coal Field is covered with several hundred yards of overburden where an average ratio of 6:1 exists.

Since 1955 the development of increasingly larger bucket wheel excavators (BWE) and matching auxiliary equipment (transport and disposal mechanisms) has made economic mining of greater depths possible. The world's largest open cast mine, Fortuna-Garsdorf (twice the size of the Kennecott Copper Mine), is currently being worked with 6 BWE's, each having a daily (20 hours) capacity of 130,794 cubic yards. The capacity of one BWE could cover a football field 80 feet deep in one day.

BWE's are extremely efficient in removing unconsolidated, or loose, overburden, as well as brown coal, due to their ability to select (within 2-4 inches - depending on the operator) and move material within the pit. The large BWE which weighs 7,400 tons requires an operator and loading supervisor in addition to maintenance personnel (15). The BWE has a height of 228 feet and a length of 654 feet.

The BWE can operate with the bucket wheel being held in either a raised or lowered position relative to the surface. The bucket wheel

can be raised from 80 to 150 feet and lowered 30 to 70 feet depending on the size of the BWE (15). The normal and most efficient operation position of the bucket wheel is the raised position. By changing the number and type of buckets on the wheel, a BWE is adjusted to the material. Material which sticks to metal surfaces is removed by a heavy chain net in the bottom of the buckets. Material which adheres to inner surfaces decreases the bucket's capacity.

The 100,000 cubic meter BWE's undergo inspection and maintenance every two weeks. Each three months more thorough inspections are conducted. After three years, an overhaul of the entire machine is conducted (some equipment observed in the mines has operated over 20 years).

Large capacity BWE's reduce the number of conveyor belts and transfer systems (along with smaller BWE's) which would otherwise be required to match the capacity of the larger machine. The BWE's working in the Fortuna-Garsdorf mine operate on benches with highwalls up to 150 feet high.

At Fortuna-Garsdorf construction of two new generation BWE's was observed. These BWE's are being constructed on the upper bench of the mine, and will be put into operation in 1975 at Fortuna-Garsdorf. This generation of BWE's will have a daily (20 hour) capacity of 260,000 cubic yards. The wheel has a diameter of 71 feet, supporting 18 buckets of 7.8 cubic yards capacity each. The BWE unit weighs 13,000 tons, has a height of 273 feet, a length of 720 feet and could load a 24 mile train of 100 ton cars each day (15).

BWE's in operation at Fortuna-Garsdorf can excavate and transfer coal and overburden material to trains and belt conveyors.

BELT CONVEYORS

Belt conveyors are becoming increasingly more popular in all of the large open cast mines. As deeper coal deposits are worked, extracted material is carried up from widely separated levels. The belt conveyor is a more adaptable and economic system for this purpose. One great advantage over rail traffic is its steeper gradient climbing efficiency, enabling it to be laid in a straight line over any terrain.

Space consuming ramps would be necessary to permit railway traffic to cope with the same task.

Belts used in German open-cast mines are made of rubber with steel wire rope reinforcement. They have widths of 7.25 feet, and run over supporting rollers at a speed of 12 mph with a capacity of 17,600 short tons per hour. Open cast mines in the Rheinish Brown Coal Fields employ 75 miles of conveyor belts. Some of the belt conveyors can be shifted to remain within loading distance of the BWE's loader. In 1976 belt widths of nearly 10 feet will be employed.

RAIL TRANSPORTATION

Rail transportation serving the Rheinbraun open cast mines is the most extensive private railway network in West Germany. For years it has been transporting about 100 million tons more than the total carried by the German Federal Railroad. Rheinbraun's rail network contains 324 miles of track.

Rails have special cross-sections which have been developed to withstand axle loads of more than 30 tons and weigh 129 pounds per yard. The rails are rated to carry locomotives hauling cars with a gross weight of 2,000 tons. Tracks are shiftable - they can be moved bodily by means of specially developed equipment into new positions to maintain a uniform excavating - to - loading distance as work proceeds in the mine.

Special electric locomotives have been constructed to haul large quantities of material. One hundred thirty-nine ton locomotives capable of hauling 2,000 tons are used in the mines. The latest electric locomotives developed are rated at 3,500hp (15). New locomotives have special electric circuits which permit them to operate nearly trouble free with a 12% improvement in efficiency. Increased electric savings permits this energy to be passed on and sold to 110 households.

Overburden is transported in 8-axle, 128 cubic yard capacity cars. One car has a gross weight of 240 tons and can be tipped sideways and emptied by a compressed air system within a few seconds. Brown coal is carried in four-axle, 90 ton capacity cars (15). When BWE's

are loading rail-cars the BWE loading operator controls movement of the train by a radio controlled link.

The main artery in the Rheinish Brown Coal Fields is a double track system over 26 miles long. This main route has branch lines to all the surface mines, briquetting plants, and power stations.

Large spreaders, with a capacity equal to the larger BWE's, are utilized to backfill excavated material. The Frimmersdorf open cast mine employs a spreader with a capacity of 196,191 cubic yards/day (15). These spreader machines are primarily used to reclaim mined-out areas. One spreader can dump overburden material on two benches as it proceeds across the mined area. Dumping can be conducted above and in back of areas which were filled when the boom carrying the belt was turned 180 degrees away from the direction the spreader is progressing.

Spreaders are supplied with overburden conveyed to them either by belt directly from the excavator, or rail-cars which dump their material in a long ditch where it is removed by a chain-bucket excavator on the back side of the spreader. Railroad tracks are moved periodically as work progresses. Two men operate a standard spreader which weighs 2,300 tons.

MINE SURVEYING

Traditional surveying equipment (theodolite, tape, level, etc.) is not used due to the vast areas being mined and the amount of time more conventional methods require. Consequently, aircraft are used to photograph the mines - taking pairs of photographs with 60% overlap. This displays the terrain in three dimensional format and contact prints of these photos present a clear indication of working conditions, and have on occasions revealed some ancient Roman ruins. Geodetic points on the ground are necessary for the correct interpretation of the stereo photographs.

During stereoscopic interpretation measured values of surface features are automatically registered on punched tape. With the aid of this data, computers calculate quarterly the quantities of overburden and coal moved.

GROUNDWATER REMOVAL

Surrounding overburden and lignite deposits are normally saturated with groundwater at levels being mined. Groundwater must be removed from surrounding overburden material and the water table level must be held below a level horizontal with the coal beds. To maintain low water table levels, drainage wells are placed at strategic points around mining operations.

Normally, drainage wells are dug to depths between 160 and 1600 feet, with an average well depth of 600 feet (15). Since the start of larger open cast mining operations, more than 1,815 wells have been drilled.

Submersible electric pumps with capacities from 0.7 to 1,165 cubic feet per minute raise water from these depths. The largest pumps in service measure 30 feet in length and weigh 12 tons. During visitation to one mine, 1,100 pumps were observed in service. On the average, 494 cubic feet (15.4 tons) of ground water are pumped for every ton of brown coal mined. In the event that groundwater still seeps into the mines at confined locations, special suction pumps, placed at 2 foot intervals, draw water out of the ground to eliminate the problem.

Existing waterways near drained areas are incapable of absorbing large quantities of pumped water. Therefore, a Koeln perimeter canal about 13.6 miles long was constructed (2). This was fed by small channels conveying water from each individual mine. The perimeter canal drained into the Rhein River, and was independent of rainfall run-off.

In addition to serving as a groundwater disposal, careful planning has provided high water level and flood protection for surrounding populated areas. High water levels in rivers adjacent to the perimeter canal are reduced by pumping water out of the rivers at a maximum rate of 351 cubic feet per second. Groundwater levels are checked constantly by the Rheinbraun Coal Company and river authorities. To date, there has been no justification for unfounded assertions that lowering of water table causes dehydration of the overlying vegetation.

About 200 million cubic yards of water presently are diverted each year from the mining areas near Koeln. This water is used for

public water supplies, surrounding industries, and lignite fired power stations. Make-up water for this area is currently averaging 260 million cubic yards per year (2). Future (1985 and beyond) demand is expected to exceed make-up and new storage capacities will be required. A partial solution to this problem will involve the Fortuna-Garsdorf Mine after it is abandoned. The backfill deficit is expected to provide a potential storage capacity of about 915 million cubic yards. Water required to fill this storage reservoir will come mainly from the Rhine River via a 12 mile long tunnel. Additional reservoir capacity will eventually be provided from the future Hambach open cast mine east of Fortuna-Garsdorf. This additional capacity should provide a 3.5% increase in water reserves, with water also being diverted from the Rhine River.

RELOCATION OF CITIZENRY

The density of villages in West Germany is such that advancement of large open cast mines usually conflicts with a few settlements. Villages then must be relocated to ground under which no significant deposits of brown coal exist. Relocation or construction of new villages provides for environmental improvements. Relocation of villages involves discussions with the Ministries of Land Government and the mining company.

Before mining activities commence, an opinion poll is taken to obtain local views on the best layout of their new village. If a person relocates to the new village, and wishes to improve upon their former dwelling, additional costs are paid by the owner. The coal company fully compensates home and land owners for every item (bush, tree, etc.), which will be lost in the mining operation.

In some of the new villages all homes were provided with flush toilets and bathrooms. Only 53 and 25 percent of the homes in older villages had flush toilets and bathrooms, respectively (15). In most villages average living space also increased 142 square yards, or about one third. Average living space in homes increased 50%. Eighty-five percent of the inhabitants in new dwellings preferred their new living conditions, and believed that the total advantages of new villages far

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outweighed the disadvantages of relocating.

RECLAMATION

Reclamation begins with stripping of fertile soil, predominantly loess, which is transported by rail and/or belt to areas backfilled with unconsolidated material. Backfilling of the unconsolidated overburden is accomplished with large belt spreaders. Loess, or topsoil, is spread with reclamation dozers or slurried.

Large impoundments are constructed to hold one to two meters of topsoil. Loess is mixed with water at a 1:1.5 ratio and pumped through pipelines over several miles to holding ponds. Water eventually disappears by absorption, evaporation or drainage.

Reclamation conforms to those uses desired by persons living and working in the Koeln area. Common land uses include: agriculture, forests, lakes and open fields. Whatever the final form may be, reclamation is always blended into a natural-type setting which cannot be distinguished from other surrounding areas.

Re-cultivation includes planting of 82% foliage trees, including 23 species, and 10% coniferous trees with 10 varieties. Poplars and willows account for approximately 2% of the plantings.

Wildlife is also abundant in reclaimed lands. A variety of game animals - wild pig, fallow deer, fox - live in recultivated areas. In addition, migratory birds, ducks and game fowl can be found. Fish are restocked yearly to provide added recreation to reclaimed mine sites.

As of 1973, Rheinbraun acquired 37,578 acres of land for mining purposes. Of this land, 11,596 acres were reforested, and 9,430 were reclaimed for agricultural purposes. In addition, 1,180 acres of surface waters were constructed, along with 2,000 acres for housing.

Currently, there is an increase in the number of acres being reclaimed annually for agricultural purposes. The cost of reclamation averages between $4,000 and $6,000 per acre, depending on land use.

OPERATION RHEINISHCHE BRAUNKOHLENWERKE AG
(Rhinebraun)

Mines

Frimmersdorf Surface Mine

Production statistics for:	1971	1972
overburden removed (10^6 tons)	47.7	53.9
coal removed (10^6 tons)	22.3	23.8

Fortuna - Garsdorf Surface Mine
(largest in the world)

Production statistics for:	1971	1972
overburden removed (10^6 tons)	68.4	74.4
coal removed (10^6 tons)	37.4	38.5

OPERATION BRAUMSCHWEIGISCHE KOHLEN - BERGWERKE

Mines

Helmstedt Surface Mine

Production figures	overburden removal started in 1973, no production to date

Treue Surface Mine

Production figures	1971	1972
coal (10^6 tons)	4.23	4.31
sulfur removed (tons)	1,975	29

Alversdorf Surface Mine

Production figures	1971	1972
coal (tons)	533,638	479,388
sulfur removed (tons)	7,507	4,056

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CHAPTER 4

EXPLORATION

GENERAL REMARKS

The act of searching for and defining new strippable coal deposits is relatively inexpensive when compared to exploration costs incurred by other extractive industries. The fact that the coal industry has not followed the lead of other mining industries in seeking legislation to allow all exploration expenditures to be tax deductible corroborates this point (5).

Locations of most coal deposits have been known for many years. New deposits are fewer and harder to find. A restrictive factor curtailing exploration is location of market relative to product. Prohibitive transportation costs render some high quality coal unmarketable. For example, existence of large low sulfur Alaskan coal reserves has been documented, and much larger reserves are suspected. However, an unstable coal market, long transport distance, and lack of feasible transportation have curtailed industrial exploration and development of these deposits.

Coal seams are found in sequence of sedimentary strata containing shales, sandstones, clays and limestones. Overlying beds affect coal quality because chemical constituents of overburden migrate downward and are incorporated in the coal. Post depositional deformation forces such as faulting, folding, and differential compaction and erosion affect continuity, consistency and overall distribution of the coal seam. Location and definition of coal deposits constitute the primary function of exploration programs. Analysis of information obtained from exploration programs aids miners in determining method and scale of mining and development and extent and type of coal preparation.

Analyses of coal samples obtained during exploration tell planning engineers whether coal preparation equipment is a requisite to coal marketing. If coal preparation equipment is necessary, coal quality data accumulated throughout exploration programs allows early equipment selection, design, and ordering.

Overburden thickness and characteristics determined from drill core analyses help planning and development personnel select stripping equipment. For example, pan scrapers can remove most overburden at many North Dakota mine sites, where unconsolidated and semi-consolidated clay material accounts for the majority of overburden. When mining follows directly after exploration, ordering equipment as early as possible

can avoid production losses resulting from equipment delivery delays. For many companies, prospecting for coal is a twofold operation -- exploring virgin lands, and examining known formations (4). In the latter case, exploration usually consists of simply accumulating and organizing second hand data.

BASIC EXPLORATION PROGRAMS

Industry utilizes various exploration methods and procedures. Geologic setting and fund availability are important parameters considered when choosing the most advantageous program. Three basic exploration programs are utilized by the coal industry.

The simplest and least costly program involves geologic prospecting of coal outcrops supplemented by minimal drilling. The procedure is commonly employed in Appalachian regions where outcrops are abundant and coal bearing formations are well known.

A second program is random drilling. It is most effective in previously explored regions showing little geologic variability of coal thicknesses, quality, and overburden characteristics. A high degree of geologic predictability between informational control points is assumed.

The third program, one utilizing pattern drilling and statistical approaches, is employed when exploring virgin areas or areas showing high geologic variability between information control points.

Drilling is inherent with all three programs and may represent the most expensive segment of each. Therefore, it is advantageous to develop a drilling plan which yields maximum information from an optimum number of drill holes. Drill hole data provides the most usable information about coal and overburden characteristics.

EXPLORATION METHODS AND EQUIPMENT

An initial step in any exploration program is a literature search. These searches are usually conducted to secure available oil, gas, and

water drill hole records, and geophysical survey data. When exploring virgin lands, paleotopographic maps and paleoenvironmental maps are particularly useful in determining if an area's geologic conditions were favorable for coal formation.

Topographic contour and geologic maps (U.S.G.S. 15' and 7.5' quadrangle) are commonly used as base maps. These are often supplemented with black and white aerial photographs.

Outline and reconnaissance core drilling is the most frequently used exploration method. Drill cores provide tremendous amounts of quantitative and qualitative information. Analysis of core samples yields essential data such as:

- physical and chemical character of coals and associated overburden
- presence of neutralizing and/or toxic units
- thickness and condition of topsoil
- geologic structure
- faulting and fracturing
- groundwater hydrology

The most popular drill pattern, the 660' (regional) and 330' (detailed) square grid, is not necessarily an optimum pattern for all situations. The square grid is best used in regions where coal beds are spatially more uniformly distributed. Distribution of coal seams and channel sands may be less uniform in other regions and may be oriented in preferred directions, thus not permitting effective use of square grid drilling. By consulting maps depicting ancient sedimentary control features and analyzing vector properties (such as grain size and orientation, current ripple, and sandstone crossbedding displayed in outcropping strata), preferred directions can be determined. Fewer drill holes are needed parallel to prominent vector directions and along the long axis of basin structures. More holes are needed perpendicular to these directions for optimum statistical evaluation of coal and overburden distributions.

New designs in diamond bit drill coring have reduced drilling time

per hole and have increased core recovery. Advances in air core drilling technology now allow nearly 100% core recovery, even through partially consolidated material (1). Water lines and water pumps which can cause environmental and freezing problems are eliminated.

Geometry of basement rock and overburden can be inferred by geophysical ground surveys using gravity meters, and seismic reflection and refraction surveys. Pattern intervals of approximately 400 feet normally give the detail required for regional exploration. Strong seismic reflection or refraction readings indicate thicknesses and structural features of prominent sedimentary units. Limestones are particularly good seismic reflectors and refractors (2), allowing mapping of secondary sedimentary control features such as major faults and folds within a basin. The position of limestone beds can be correlated, and the time of a structural happening can be related to the time of coal deposition. Exploration geologists and engineers use these beds when trying to correlate major coal seams which were displaced by deformational forces.

Reconnaissance exploration using remote sensing and airborne geophysical surveying devices such as satellite and airborne photography, infrared imagery, side looking radar (SLAR), and gravity meters, can be used to outline structural basins, uplifts and regional faults and fracture zones. Satellite and aerial photography and infrared imagery when used in conjunction with computers and photogrammetric density plotters, enable production of maps which are as accurate as U.S.G.S. 15' quadrangle maps.

Aerial photography is useful for Midwestern and Western mapping, while SLAR is an extremely effective remote sensing tool valuable in inaccessible, densely forested, or cloud covered areas (as frequently encountered in the Appalachian regions).

The Bureau of Mines Report of Investigations, RI 7680, "Forecasting the Properties of Coal Seams in Place," (3) describes how computer programming can be used to analyze drill hole data and to predict coal properties and overburden characteristics between drill holes. This Bureau report concluded the following:

1. Computerized, iterative grid interpolation techniques are useful and effective tools to forecast the between-sample-point values of coal seam attributes.

2. A measured property of coal can be represented as a surface over the area of mineable coal; the surface may be upgraded as more data becomes available to establish trends and spatial distribution patterns used in designing the mine and in planning optimal mining facilities.

3. Chemical properties of a coal seam in place may be forecast for a geographical region from relatively wide-spaced sample points.

4. Factors that can be used for product control, such as preparation characteristics, may be forecast for sections of a coal seam that are cored on approximately one-half mile centers.

5. Chemical properties of specific benches, or arbitrary cut-off points along the vertical axis of a seam may be forecast from drillcore data obtained on approximately one-half mile centers.

6. Factors related to a coal seam in place, such as overburden thickness, and composition, can be represented as surfaces over the area of interest. These surfaces are useful in planning optimal mine layouts.

REGIONAL EXPLORATION

In areas of the country having a long history of mining, specifically Regions I and II, many small companies dispense with drilling programs and geophysical techniques used for exploration. Guided by outcrop geology, minimal literature searches, and extensive mining background, they make judgments as to where the coal lies. In such cases, a minimum number of holes are drilled to satisfy state environmental regulations. Then 6" x 6" channel cuts and dozer contour face cuts are made to procure a sample for determination of marketable quality.

Limited exploration effort is one reason why many small companies incur financial difficulties. This was certainly the fate of one western Pennsylvania company. The miner was stripping coal from property formerly deep mined, and was making more than a marginal profit. Following an ancient stream deposit, he mined to the property edge; moved his equipment to another section not more than ¼ mile away, and followed

the same stream deposit. A combination of thick, hard, sandstone overburden and a lesser amount of coal caused bankruptcy and deterioration of his mining equipment. He had encountered an accretion bed sandstone of a paleostream (an ancient channel sandstone) overlying a partially deep mined coal deposit. Had he noticed: 1) the orientation of current ripples, crossbedding and fossil remains preserved in the outcropping sandstone and shale; and 2) performed a statistical frequency analysis on the data, he would have determined the paleostream's width, sinuosity and meander wavelength. He would then have been able to avoid the accretted sandstone channel deposits overlying the coal.

Different levels of exploration are required for the four study regions of the United States. Major oil companies have various areas classified as to how much geologic information is known. This is usually proportional to the density of oil, gas, and water well drill holes per region. Appalachian drill hole data is sparse, but where the geology can be seen in the abundant outcrops and extracted from old deep mine maps, less drilling is required. Drill hole data in parts of Region II and in Region III, especially around the Gulf States, is extremely good, due to extensive oil and gas exploration of years past. Available geologic data in Region IV is sporadic. Much of Region IV can be considered virgin land, particularly, Indian reservations and federal lands.

In Region I where contour mining is prevalent, regional exploration efforts emphasize contour prospecting by opening up contour faces with dozers, and punch mine exploration with dozers or backhoes. Old deep mine maps serve as invaluable sources of information. The limited amount of core drilling carried out is done to meet environmental regulations in Region I. More detailed exploratory work is accomplished by extracting 6" x 6" channel cuts from faces of contour exposures.

Regional exploration in Region II consists of historical data accumulation and core drilling on 1000 foot centers in areas of high uncertainty. Detailed work requires scrutiny of old deep mine maps and closer spaced drill patterns (ranging from 100 foot centers to 660 foot centers, with depths from 30 feet to 100 feet. Drilling required by regulatory agencies for monitoring water quality is also performed along with cropline coring.

Old oil, natural gas, and water well drill hole records are a primary source of information used in regional exploration in Region III. In addition, coal companies sink their own exploratory drill holes (commonly

on 660 foot centers). Detailed core drilling proceeds on 330 foot centers and holes are more closely spaced if anomalies appear. This is followed by punch mine bulk sampling, 6" x 6" channel cuts and core drilling at contour outcrops.

Region IV core drilling is usually initiated on one mile centers. In Northern areas where coal burned underground due to spontaneous combustion, drill patterns are tightened along the surface exposures of burn margins. Many surface mining companies find little if any need for detailed work, except in areas with steeply dipping beds or complex geologic settings, where drill holes are spaced closer. Studying the topography of this Region can provide much information about the continuity of underlying coal seams.

Pfleider (6) illustrates a full exploration sequence in the flow chart in Figure 4-1 and an exploration program applicable to study Region IV is presented in Table 4-1.

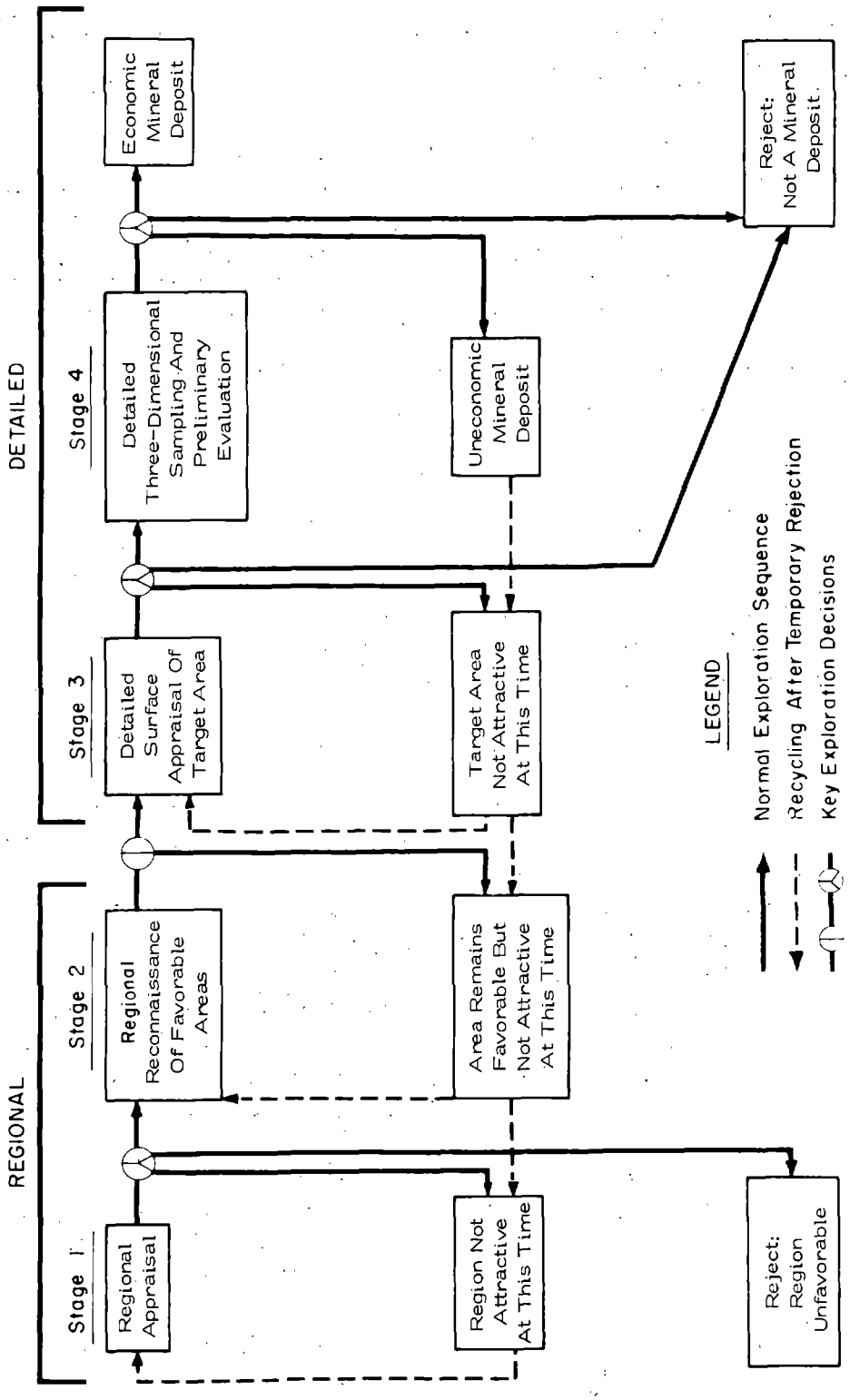
Region IV has become the most actively explored of all regions of the United States' mainlands. New markets, equipment with greater stripping capacities, and thick, low sulfur seams underlying shallow overburden make mining in Region IV lucrative. The following documented case histories are examples of recent efforts involved in the search for coal.

Case History No. 1

Company X decided to explore for coal on 90,000 acres of western land where no previous geologic mapping had been done. The area in question consisted of two distinct plateaus, the west side being 1000 feet higher than the eastern plateau. A preliminary field inspection indicated coal beds existed or had existed on both plateaus, as noted from massive clinker beds created by burning coal seams.

The initial phase consisted of drilling a number of holes on one-mile centers throughout the permit area. After initial drilling, it was noted that all coal (with the exception of several small remnants of coal seams on the upper plateau) had been completely burnt. Two small ten acre tracts, located within the prospecting permit on the upper plateau, were remnants of a 40 foot thick coal seam. Another 10 foot thick bed was found approximately 200 feet below the upper plateau, but escarpment

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Adapted From Reference No. 4-5

FOUR MAIN STAGES OF "FULL-SEQUENCE" EXPLORATION

Figure 4-1

TABLE 4-1

Adapted From Reference No. 4-5

OUTLINED REGIONAL AND DETAILED EXPLORATION PROGRAM

Exploration Stages		Search for a New Coal Deposit in Western U.S.A.
Stage 1	Regional Appraisal	O – Geologic Compilation for "marketing" area.*
Stage 2	Detailed Reconnaissance	F – Field check of sections containing coal seams.* F – Reconnaissance drilling for stratigraphy and coal thickness. F – Chemical and calorific check of outcrops or drill samples (not badly burned).
Stage 3	Detailed Surface Investigation of Target Area.	F – Field check of sections containing coal seams.
Stage 4	Detailed Three Dimensional Physical Sampling of Target Area.	F – Drilling* – Logging L – Mineralogical, chemical analyses and physical tests on samples, cores and cuttings.* F – Down-hole geophysical surveys. O – Reserves computations.* O – Preliminary valuation.* F – Investigation of water problems and water availability for plants.* F – Investigation of suitability of ground for plant, dump, and town sites. F – Punch mine to obtain bulk samples. L – Bulk tests.

LEGEND

O – Office study

F – Field investigation

L – Laboratory tests

* – Activity or method which is indispensable

between the two plateaus was too steep for the bed to be mined by stripping methods.

Initial drilling of the lower plateau located two coal beds that were separated by 150 feet of strata. Although both beds were extensively burnt, and no natural outcroppings could be noted, there was indication from initial drilling that there could be strippable reserves for both seams.

The second phase of drilling was restricted to the lower plateau. At the beginning of this phase, U.S.G.S. topographic maps (7½') were not available for the eastern portion of the permit area. To solve this problem, a base map was plotted for the lower plateau, and fitted to available topographic coverage of the upper plateau (western portion of the field). Two geodetic tri-stations were conveniently located on the edge of the upper plateau escarpment and were visible at nearly all positions on the lower level. Trisecting with a Brunton compass, it was possible to accurately locate the drill holes and supplemental control stations.

The drilling program was conducted with drill sites located on approximately one-quarter mile centers along the burn line (contact between the oxidized and unoxidized strata). The burn line was mapped as drilling progressed. On approximately one-half to one-mile centers, holes were drilled along the maximum recovery line. As preliminary topographic maps became available for the eastern portion of the permit area, the maximum recovery lines for the two beds were more accurately located.

After strippable reserves of the two seams were fairly well delineated, a coring program was initiated. Cores of the two seams were taken on approximately quarter-mile centers throughout the reserve area. A few more cores were required on the south end of the lease area to complete the final stage of the exploration program. Thus far, results concerning mining feasibility were positive.

Case History No. 2

Information for this western field was very limited. The area lacked natural outcrops due to the presence of a thick layer of glacial debris. Information was limited to reported coal thicknesses from one water well, one abandoned coal mine, and two or three second hand reported coal

thicknesses published in a U. S. Geological Survey Bulletin. After checking the latter, it was found that none of the so called outcroppings existed.

The initial program was to drill for coal-bearing portions of the permit area on half-mile centers, and then later on quarter-mile centers. It was soon realized that what coals did exist in the formation, were extremely lenticular and erratic. One hole was drilled within 200 feet of the abandoned coal mine. The two, eight foot thick seams at the mine site dwindled to two, one to three foot seams. The field was then determined to be uneconomical to mine, and the drilling program discontinued.

It was concluded too little information was available, where the coal seams were involved, to even acquire prospecting permits.

Case History No. 3

At this prospective mine site in Region IV, coal was found to occur in two separate members (Lithologically distinct portions of a geologic formation). Two coal bearing members, each of which contained as many as eleven seams, were divided by another member which was 400 feet or more thick. The coal seams were very lenticular and had a tendency to pinch out or thicken with rock partings in a few thousand lateral feet. (Unpredictable thickness of individual coal seams makes large scale mining nearly impossible).

A report was prepared for the property owner prior to the contractor's exploration efforts. It was a detailed report showing all coal mines, drill holes, surface and subsurface geology. From extensive study of geology and the report, the most favorable part of the property was outlined for further investigation.

Exploration drilling was planned to locate thirty million tons of mineable coal, either strip or underground. Drill holes were located in the center of each quarter-section on the virgin land. After the first twenty holes were completed, drill data was analyzed to confirm or eliminate possibility of mineable coal on the larger acreage parcels.

A total of 42 holes penetrated 28,315 feet and depths ranged from 300 to 1350 feet. The drilling covered 21 sections. Each hole, upon com-

pletion, was logged by a geophysical firm with a natural gamma, gamma-gamma density and resistivity log. Coal thickness and rock partings within the coal seams varying from 4 to 7 feet were logged; they did not correlate on half-mile centers.

It was proven through this drilling program that coal tonnages inferred in the report did not exist as mineable coal.

While it was impossible to estimate mineable tonnage without more extensive drilling, the unpredictable thickness and extent of the individual coal seams were very real clues to an unfavorable prospect.

Case History No. 4

Geology of the Cretaceous Mesaverde Formation is favorable for accumulation of western coal. An examination of the area to be explored revealed one small prospect, but an area of over 200,000 acres showed numerous coal seams had been burned at the surface. Very few unburned outcrops could be found. The obvious question was how much mineable coal remained.

A lease of 65,000 acres was negotiated after several years of drilling on prospecting permits.

The area was a massive topographic highland covering over 2 million acres. During Cretaceous time it was a structural basin and, as the sea retreated, was occupied by a massive swamp system. It was capped by the Mesaverde Formation, and all of the mineable coal formed in the middle member of the Mesaverde Formation.

When drilling started, no topographic or geologic maps were available and the area had not been surveyed. Drilling started and with favorable results, progressed southward.

To date, over 14,000 exploration holes 200 feet (or less) in depth have been drilled. One to five seams of coal from four to thirty feet thick have been found. Over 42 separate mining areas have been outlined by drilling and are thought to contain from 200,000 tons to 68 million tons of mineable coal.

At present, three prospect truck-mounted drills are working full-time with several years work remaining. About 26 percent of the total lease area will eventually be mined.

Numerous problems with burned coal, lenticular seams and faulting have been encountered and solved by careful exploration drilling.

After taking several hundred cores and numerous pit samples, it is expected the coal will average on a dry basis - 12,325 BTU, contain an ash of 8.9 percent or less, and sulfur of 0.6 percent or less.

DETAILED EXPLORATION

While regional exploration usually determines if and where a coal seam can be found, detailed exploration is an attempt to determine:

- tonnage of coal
- whether it is mineable
- consistency of quality

Detailed exploration requires closer spaced electronic sensory and/or drill hole patterns, and plotting of large-scale detailed maps.

Aerial photography can provide contour maps at almost any scale by photogrammetric techniques. A minimum of at least six ground control points are needed with 60% photograph overlap. Topographic, isopacheous, geologic, and geophysical anomaly maps are constructed and superimposed on one another to portray the geologic setting. Maps and results of permeability, porosity, washability, friability, moisture, ash, fixed carbon and sulfur tests provide the basis for major mining decisions.

Seismic prospecting, Induced Polarization (I.P.), and Differential Induced Polarization (D.I.P.) surveys are geophysical methods which help locate map positions for detailed exploration drilling programs. Seismic prospecting involves inducing an artificial shockwave into the earth (usually by detonating explosives). The shock waves are reflected and refracted off strata interfaces and the resulting wave patterns are recorded on an oscillograph.

Analyses of seismic data help locate depth and extent of mined deposits. Induced Polarization and Differential Induced Polarization involve placing electrodes in the ground and inducing an electric current. By varying the parameters of voltage and electrode spacing, depth and outline of coal deposits can be discerned. Since the chemical and physical differences between coal and other sedimentary strata are great, pronounced differences in their electrical responses are detectable. Accuracy decreases with depth of burial, but electrical responses are very accurate in outlining surface minable coal bodies. Geophysical surveys allow rapid investigation of large tracts of land.

In detailed exploration, depth of drill holes usually is less than 100 feet. Generally, drill hole spacings will narrow from 1 mile down to 1/16 mile centers from regional to detailed exploration. Pfleider (5) outlined in Table 4-2 some previous industry practices.

TABLE 4-2

EXAMPLES OF COAL DRILLING PRACTICES

Location Of Work	Hole Spacing			Sampling Method	Bit Type	Coring	Recovery (%)	Drill Media
	Exploration	Development	Mining					
Navajo Lease, New Mexico	1,000 ft. centers	-	-	Rotary drill Diamond drill offset holes	4½ in. dia. NX	- Coal bed only	- 95	Water
North Dakota	One-half mile	One-forth mile	50 feet	Churn drill Drillpipe	- -	- Coal bed only	- -	- -
Crows Nest, Fernie, British Col. 20 x 40 Mile Area	-	-	-	Outcrop - chip sample Adits chip samples Rotary Diamond drill	- - - -	- - - -	- - - -	- - Air-mud Mud

Adapted From Reference No. 4-5

Detailed drilling programs and field studies investigate:

- occurrences of coal seam pinch outs

- local variations in seam properties and thicknesses
- overburden thicknesses and properties
- partial erosion of coal seams
- thinning, thickening, sinuosity and distribution of channel sands

Data is gathered from reconnaissance geophysics (if applicable), known geology, continual literature searches, and statisitcial computer analysis. This data gives coal operators an increased degree of geological predictability, which helps minimize the expense and number of drill holes required to obtain accurate regional and detailed exploratory results.

Drilling and geophysical surveying are often performed for coal companies by specialized exploration firms. Drilling expenses vary with site access and supply of qualified drillers. Costs are highly variable on an intraregional basis. Core drilling (2½") costs identified in this study approximate $10.00/foot, and bore hole drilling (2½") costs approximate $7.00/foot. Exploration expenditures are reflected on a cost per ton basis in the "Summary of Case History Unit Operation Costs" in Chapter 9.

A scientific approach to exploration programming is less costly in the long run because the more exacting data obtained reduces the chance of investing and spending large sums of capital in a mining venture where sufficient coal reserves are nonexistent or are not mineable. The amount of engineering and field work required by any exploration program or method varies as both the intensity of the adopted program and the geologic complexity of the prospective area change.

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CHAPTER 5

MINE PLANNING AND DEVELOPMENT

FACTORS INFLUENCING DEVELOPMENT

Successful surface coal mining operations depend on more than efficient production techniques. Proper development and good planning are essential to a profitable operation. Many factors must be considered before final layout and scheduling of an operation can be determined. These items include: geographic locations and features, geologic conditions, coal quality, environmental considerations, land acquistion, water rights, modes of available transportation, market, equipment and materials, and time for development. All variables must be considered with reference to one another to establish sufficient criteria to plan and develop a successful surface coal mining venture.

Most prospective coal lands contain far more coal than is likely to be removed during a single mining operation. The factors affecting a decision as to the amount of coal to be extracted are complex; sufficiently complex that one knowledgeable miner may recommend a limited operation, while another would be inclined to open a large scale mine on the same property, basing their decisions on identical data. Mine development is an inexact science, and each potential mine must be analyzed with regard to its own unique conditions.

GEOGRAPHIC CONDITIONS

During preliminary stages of mine planning, attention is first focused on geographic conditions of the proposed site. These conditions, including topography of the area, altitude, temperature extremes, rainfall, general weather conditions, and natural boundary limitations all have an effect on design criteria.

In areas where abundant rainfall occurs, problems associated with surface drainage and treatment, haul road conditions and maintenance, and characteristics of wet overburden material must be considered. Dry areas present different types of problems, such as limited availability of water for processing coal and controlling dust.

Temperature extremes, along with varying atmospheric conditions, may cause increased maintenance on machinery and limit the number of available working days. Terrain topography, whether rough, rolling or

flat, is also an important consideration in ultimate pit design.

GEOLOGIC CONDITIONS

Geologic conditions, together with local topographic characteristics usually dictate the general type of pit acceptable for a proposed mine. Collection of sufficient geologic information may well be the key to a successful mining venture. All data gathered during exploration including structure contours of the coal seam, dip and thicknesses of the seam, outcrop (if any), locations of drill and core holes, ground water elevations, faulting and fracture traces, and variations in stripping ratios, should be plotted on a topographic map of the site area (Scale: one inch equals 500 feet for preliminary planning, or one inch equals 100 feet for detailed planning). This data should be readily available to the designing engineer for use in planning the pit layout. Several examples of how geologic structure coupled with topographic features affect a proposed mining plan are:

- Where dip of the coal seam is away from the terrain slope, stripping ratio will gradually increase, thereby limiting the number of possible cuts. This effect is of particular concern in areas where contour mining is practiced: Regions I and II.

- In rolling, hilly terrain, where the coal seam outcrops on opposite sides of a ridge, full seam recovery may be achieved by modified area mining, as opposed to contour stripping. The limiting factor of pit development in this case would be the maximum ridge height above the seam.

- In flat terrain where the coal seam is relatively horizontal, geologic - topographic structure ceases to be the primary limitation. Overburden thicknesses, equipment limitations, desired production and other considerations (to be discussed later) become major elements affecting pit design.

- A dipping seam in flat terrain can influence mine planning. Some underclays may promote sliding in spoil areas due to the angle of repose between spoil overburden and dipping underclays, not to mention the effect of developing a limiting highwall.

OVERBURDEN CHARACTERISTICS

Composition of material overlying the coal also presents important items to be considered in planning stages of a surface mine. Whether the overburden is toxic or neutral, porous or impervious, consolidated or unconsolidated, sand or clay, wet or dry, thick or thin, careful consideration must be given when selecting equipment and methods of extraction.

Proper handling of toxic and acid bearing materials is essential to prevent unnecessary acid production and pollution of the environment. Preventing acid production also reduces necessary water treatment requirements and associated costs. Special consideration should be taken when planning excavation procedures to permit segregation and isolation of pollution forming materials.

Porosity of overburden material, in place or spoiled, also influences pit design. In place porosity measurements aid in calculating the quantity of ground water infiltration to be expected, which is essential for proper design of water handling systems. Porosity of spoil can assist in determining whether pit drainage should be collected at the toe of the spoil or at the face. Collection of water at the toe of clay-type impervious spoils may result in sliding, whereas water collection at the toe of porous materials will permit infiltration into the bank and out of the pit area.

Consolidation is one of the most important characteristics of overburden affecting pit design. If material overlying the coal is consolidated, drilling and blasting requirements must be estimated and incorporated into the mining plan. Unconsolidated overburden does not require drilling and blasting, and offers a different set of criteria to be analyzed for selection of removal equipment: example, dragline or shovel if consolidated, and BWE (bucket-wheel excavator) if unconsolidated. Aspects other than drilling and blasting associated with consolidation, are highwall stability and stacking properties of cast spoil, both of which influence economical pit width (economical relating to minimum rehandling of spoil).

Moisture content of overburden, together with physical composition, can also have an effect on equipment selection and mine layout. Wet clay, for example, may cause problems by sticking to buckets, thereby limiting designed machine performance. In some cases, wet overburden may not be stackable, or even movable, by standard procedures. Dry spoil, on the other hand, may offer distinct advantages for one piece of

equipment over another.

Exploratory drilling and associated overburden analyses are keys to developing a successful mine venture. Enough emphasis should be placed on these analyses (described in Chapter 4) to develop representative profiles of overburden. Proper equipment selection, pit layout, and mine scheduling are all dependent on correct values of overburden characteristics obtained during exploratory drilling.

COAL CHARACTERISTICS

Although exploratory drilling provides essential data concerning characteristics of overburden, the main purpose is to establish extent and quality of a coal deposit. Expected coal quality is extremely important in developing or expanding any coal mine because the entire economic structure of a mine is dependent upon product return. Actual quality and thickness of the seam will determine limits of production expenses that will permit an attractive rate of return.

Coal characteristics influence mine planning and various mining unit operations. Whether coal is to be blasted, ripped, or simply loaded is important, and must be incorporated into coal fracturing and loading operations. Overburden removal procedures are also influenced by coal characteristics, such as capability of the coal seam to support overburden removal equipment. Thin seams may be loaded most efficiently by a front-end loader, while thicker seams might warrant use of a loading shovel. If coal quality is found to be variable over short distances, a mining plan may need to be designed which can produce different quality coals for selective blending.

The present importance of sulfur content has produced changes in mine development planning. Many rider seams (which are usually high in sulfur) routinely mined in the past, must now be wasted during mining. Selective loading of a coal seam to meet sulfur restrictions has become more common, especially in the East, where many coals have small bony streaks that did not significantly lower total BTU's when loaded with the entire seam. Now, these bony streaks must be carefully removed and wasted to hold sulfur within tolerable levels. Coal quality and market requirements also dictate the extent of coal preparation needed prior to marketing.

ENVIRONMENTAL CONSIDERATIONS

Preservation of environment is a universal consideration to be incorporated into all aspects of a proposed mine from exploratory drilling through reclamation and site abandonment. Every unit operation should be planned to provide a minimum of environmental disturbance, while maintaining a profitable production level. Protection of nearby stream quality and prevention of excessive dust generation are major aspects of environmental protection during life of a mine.

Nearby stream water quality can be affected by siltation and toxic discharges from the operation. Plans for water treatment facilities, including surface water diversion ditches, pit drainage channels, pit sumps and pump stations, water lines, neutralization facilities, settling ponds, and erosion and sedimentation control devices, are usually required by government agencies where a potential pollution threat exists. Care must be taken when designing these facilities to insure minimum costs of pollution control procedures while maintaining compliance with discharge criteria.

Preventing excessive dust generation has recently become an important segment of environmental protection procedures. Although dust control techniques do not influence design of the pit, adequate control measures must be incorporated into the schedule of mining activities. Dust originating from haul road usage is a major problem in surface mines and can usually be controlled by periodic wetting of the roads with water or road oil.

Forthcoming federal and existing state reclamation regulations present additional environmental requirements which must be adopted into a mining plan. The most economical method of accomplishing land restoration in any Region is to incorporate as many regrading and backfilling procedures as possible into actual mining operations, thus eliminating costly rehandling of spoil materials.

Planning reclamation into the mining schedule is a relatively new concept. In the past, regrading and revegetation were not considered to be a part of a surface mining operation, primarily because the selling price of coal could not justify additional expenses incurred during reclamation procedures. Recent environmental pressures have given rise to

new mining techniques and revised unit operations, such as spoil regrading and revegetation, which necessitate corresponding analyses during mine planning stages. In many instances, the entire pit layout is directed toward ease of reclamation rather than simply ease of coal extraction.

RESERVE ACQUISITION

Acquiring surface land and mineral rights, whether by purchase or lease agreements, is obviously a major consideration for a new mine. The amount of reserves obtained determine economic size of the operation. For example, a 20 million ton block of coal would not provide a sufficient mine life to warrant investment in a 5 million ton/year operation. However, this same 20 million ton reserve could be an ideal site for a one million ton/year or less size mine.

Total reserves required for initial investments need not be in one particular location, but should lie within a reasonable proximity to avoid non-productive travel times of stripping equipment. Control should be held over more lands than those intended to be mined in the near future, to provide areas for increased production warranted by unexpected increases in market demands. Any reserves in the mine area that are not mineable under current conditions, but which could become mineable in the future due to increased coal prices or improvements in extraction techniques, should be taken into account during mine development procedures.

Leasing is a very common method of acquiring sufficient reserves for mine development. The primary advantage being low initial cost of reserve acquisition, disadvantage being possible higher total cost over the life of the operation. Leasing typically covers items such as: term-duration of the lease, royalty rate - amount to be paid to the lessor per ton of coal produced ($/ton, or % income/ton), advance royalty - annual payment to be made prior to commencement of mining, termination clause - right to terminate the contract by payment of certain specified damages, land end-use clause - land use planned after mining (reclamation) as obligated by operator.

"The problem of future reserves of strip coal will not be as much one of scarcity as of availability. Studies by the Illinois State Geological

Survey indicate that in Illinois alone the coal lying under overburden thicknesses of 100 feet or less thick amounts to more than three times 3.5 billion tons. The problem, east of the Mississippi, at least, will be one of piecing together coal and surface rights to make a block sufficiently large for an economical operation." (3)

Caution must be taken to insure compliance with all local laws regarding land development, such as zoning. Usually zoning ordinances can be adapted to permit mining. Nonetheless, insurance of proper zoning should be secured prior to any detailed planning of a proposed mine.

WATER RIGHTS

If the coal to be mined requires wet preparation prior to marketing, or if dust suppression procedures necessitate water application, acquisition of water rights is an additional preplanning problem to be solved. Securing water rights in Regions I, II, and III is usually of little or no significance, while in Region IV it can be the predominant factor influencing development.

Local and State regulations regarding water usage rights vary considerably, particularly in the West. Therefore, determination of applicable laws and permits is a very important segment of water rights acquisition. Care must be taken to avoid infringement on another's rights while establishing those for the mine. If sufficient claim to water cannot be obtained to supply mine demands, purchase from adjacent holders may be required. It should be noted that water usage does not necessarily mean water consumption. Consumed water is that used water which is not returned to the source. Requirements and restrictions for usage usually dictate that water quality be maintained or improved, thus calling for design of water treatment facilities if pollutants or contaminants are introduced. Initial determination of mine water consumption should be compared to the amount of water available at or near the site. Changes in water usage requirements or searches for additional supplies may be necessary if planned consumption is greater than expected availability.

TRANSPORTATION

Transportation is a major consideration in coal mine development, more so in the West than in the East. Why design a mine for 5 million TPY (Tons Per Year) production when only a maximum of 3 million TPY can be transported? Thorough analyses of all available modes of transportation including rail, barge, truck, belt, and slurry pipelines should be conducted to determine the most efficient and economical means to distribute desired tonnages. Combining transportation modes may prove to be more satisfactory than relying on one particular distribution system.

MARKET FACTORS

The coal market, which has traditionally been unpredictable, is a determining aspect of mine development due to uncertainty alone. Large volume, long-term market contracts are often not available to insure a stable market for a high production mine. These long-term contracts can, however, be detrimental to future mine profitability because of inflationary costs of coal production. The attractive rate of return enjoyed at the outset of a contract may not be enough to offset mining costs during later years. Planning a mine during years of high demand and profitable prices should include analyses based on projected market slumps, to avoid unnecessary economic losses during those years. Degree of risk and speculation desired to be incorporated into a mining plan can only be determined by company financial officials. High risk or speculative ventures can provide very profitable ROI's (Return on Investments) or result in financial disaster; whereas a lower risk, conservative undertaking usually maintains a more consistent, though smaller, profit margin. Predicting future market trends is a difficult and important task during preplanning stages. Market forecasts for large mine endeavors tend to be conservative owing to associated large capital investments, while forecasts for smaller operations are usually more liberal because of the lower initial investment required.

EQUIPMENT AND MATERIALS

Another preplanning aspect, which helps influence size and layout of a mine, is determination of equipment and materials availability. Current or expected shortages of vital materials may cause design alterations which avoid use of those materials if possible. Special equipment desired for a new mine may take too long for delivery, so available alternative machines might be considered, along with revisions in desired procedure. Even though preferred machines or materials could be available in the future, rising costs may prohibit their use; this again necessitates investigation of a surrogate plan.

TIME FOR DEVELOPMENT

Developing a mine from initial conception until actual production takes years of research, planning and approvals. The numerous items which influence the amount of time consumed during this period include: exploration permits and associated environmental impact statements, land acquisition, detailed site drilling and evaluation, extensive federal, state and local permits, environmental impact statements for mining activities, many public hearings at all levels of government, equipment purchase and delivery, and site development which involves road and building construction. Although equipment selection and purchase is perhaps the most important aspect influencing success of a mine, obtaining proper permits and necessary approvals from all interested parties could prove to be the most important aspect influencing desired start-up dates.

Increasing mine development time can have only an adverse affect on mine economics. Capital invested during this time frame receives no return or interest until actual production commences. When mine start-up is delayed for any reason, whether it be equipment delays, permit denials, or whatever, favorable yearly cash flows become overdue, thereby reducing the expected ROI. A key to reducing excessive capital outlays that have no immediate returns is to plan a staged development program where mining begins early with initial production income being used to assist in offsetting costs of complete facilities installation.

CAPITAL

Opening new surface coal mines requires substantial capital investments, which are obtained from an existing mining company through re-investment procedures or borrowed from external financial sources. Re-investment of company funds usually disregards the concept of "opportunity cost," which means that a company ignores the possibility of gaining additional income from other highly profitable alternative uses; whereas borrowing the necessary capital imposes an additional charge to yearly cash flow until the loan is paid back. In any event, the project must be able to yield an attractive return on invested capital.

With requirements for environmental protection mounting and operating and production costs increasing yearly with current inflationary trends, profit margins in some corporations are being substantially reduced, limiting the amount of available re-investment funding. General uncertainty surrounding the future of the coal industry does not provide an attractive climate for obligating external financial resources into future coal mining ventures. Future industry profitability must be made more predictable in order to attract financing needed for increased coal production.

STEPS UNDERTAKEN IN DEVELOPING A MINE

All factors influencing mine development must be analyzed in conjunction with each other to determine the economic size of a new mine, pit design and layout criteria, and equipment types and sizes. As previously stated, any two mining engineers given the same data base can design two distinctly different types of successful operations. An invaluable asset during planning procedures is past experience, which can save precious time in decision-making processes.

No exact mine design handbook can be composed which will solve all problems of mine planning. However, certain basic procedures are usually followed to ensure proper and complete development of a successful mining venture.

MAPPING THE AREA

Mapping is usually the primary step in developing a surface mine operation. Topographic maps with scales of 1 inch = 500 feet, contour interval (C.I.) 10 feet, for preliminary design, and 1 inch = 200 feet, C.I. 5 feet, for detailed design, are usually employed for plotting pertinent information.

Mapping can be acquired by several methods; including, United States Geological Survey (U.S.G.S.) quadrangle sheets (enlarged to desired scales), conventional field surveys, and photogrammetric mapping. U.S.G.S. quadrangle sheets provide an adequate base where detail is not required, but are not considered extremely accurate, due to their scale and age (current information is not plotted). Conventional ground survey mapping is much more precise and can be produced at any scale. However, in rough terrain, conventional or plane-table surveying can become time-consuming and expensive. Aerial photography and associated photogrammetric mapping is gaining popularity in the mining industry because it is highly accurate, relatively inexpensive (compared to conventional surveying techniques), easily produced, available at any scale, and applicable to any type terrain. Aerial photography also provides a clear, concise, pictorial view of the site - before, during and after mining. Mining progress can readily be plotted with additional aerial photos. Contours can also be plotted directly over enlarged photographs.

Comparative costs of some topographic mapping techniques are given in Table 5-1.

MINERAL EVALUATION AND RIGHT'S ACQUISTION

Information gathered during exploration phases is plotted on prepared mapping, outlining the extent and quality distribution of the reserve. Other factors, such as iso-stripping ratio lines, locations of partings and dirt seams, and coal structure contours are included on the preliminary mapping.

Computer utilization supplies information on total reserve tonnages, economically recoverable tonnages, and in some cases can plot quality distributions. Expense and availability usually limit computer usage to

TABLE 5-1
COSTS OF CURRENTLY PRACTICED
TOPOGRAPHIC MAPPING TECHNIQUES

MINIMUM ACCURACY REQUIRED

Up to 50 Acres		50 – 100 Acres		100 – 500 Acres		1000 Acres	
1" = 2000	1" = 500'	1" = 2000	1" = 500'	1" = 2000	1" = 500'	1" = 2000	1" = 500'
U.S.G.S.							
No Additional Cost	$10 Minimum	No Additional Cost	$10 Minimum	No Additional Cost	7.2 mills/acre	No Additional Cost	7.2 mills/acre

MORE ACCURATE TECHNIQUES

Up to 50 Acres			50 – 100 Acres			100 – 500 Acres			1000 Acres		
1"=100' 2' C.I.	1"=200' 5' C.I.	1"=500' 10' C.I.	1"=100' 2' C.I.	1"=200' 5' C.I.	1"=500' 10' C.I.	1"=100' 2'C.I.	1"=200' 5' C.I.	1"=500' 10' C.I.	1"=100' 2' C.I.	1"=200' 5' C.I.	1"=500' 10' C.I.
Conventional Field Survey (Complete Mapping)											
$3000 total 50A.	$2500 total 50A.	$2250 total 50A.	$50/A. to $60/A.	$45/A. to $50/A.	$40/A.	$50/A. to $60/A.	$45/A. to $50/A.	$40/A.	Not Comparable With Photogrammetry		
Photogrammetry (Cost includes Aerial Photos, Ground Control, and Map Plotting)											
$900–1000 Min.	$900–1000 Min.	$900–1000 Min.	$14-16/A or $900–$1000 Min.	$13-14.5/A or $900–$1000 Min.	$900–$1000 Min.	$12.5/A to $14/A.	$10.5/A to $13/A	$8/A to $9/A	$9.5/A	$8.0/A	$7.0/A

larger mining companies.

After the location, extent, and quality of reserves are obtained, acquistion of mineral rights begins. Many variations of mineral ownership can occur within a coal tract, with as many variations in modes of acquistion. Some common methods of procuring sufficient reserves for a prospective operation are:

Fee - In some cases, companies find it more advantageous to purchase the surface and mineral rights, as opposed to lease agreements. Outright purchasing allows the developer to obtain positive control of the area, and eliminates annual payments and termination problems inherent in a lease. When the mine operation date is not in the near future, purchasing is considered favorable because it eliminates lease drafting problems and possible higher future costs.

Lease - When it is necessary to hold initial land acquisition costs to a minimum, lease contracts are employed. Although low initial cost is a primary lease advantage, total cost over the life of the mine is generally higher. Leasing contains clauses covering lease term, royalty rates ($/ton, %/ton), advance royalty, and termination.

Options - Another form of agreement which is used to minimize initial investment costs, is an option. Options allow the operator to maximize use of available capital by gaining control of sizeable areas for a time sufficient to prospect and determine feasibility of the site.

ECONOMIC SIZE DETERMINATION

Mine size (tons/year) is dependent on the amount of available reserves. Production is designed to permit a mine life that will allow reasonable depreciation of investment. Market predictions and transportation modes can also influence the projected mine size.

PIT DESIGN AND LAYOUT

Pit design and layout utilizes 200 scale (or 100 scale) contour map-

ping with iso-stripping ratio or iso-cost per ton lines, coal contours, geographic and cultural limits, water expectations, and overburden characteristics plotted to assist in planning.

Some steps and criteria associated with pit design include:

- Indication of ultimate economically permissible stripping ratio.
- Limits of available mine area.
- Selection of several pit or mine layouts.
- Evaluation of each preliminary design considering: economic pit widths in relation to overburden stacking properties and seam pitches; overburden characteristics at critical points (curves, entrances); blending capabilities from different areas; water handling system requirements; production cost estimates and problems; reclamation requirements.
- Selection of best design.

EQUIPMENT SELECTION

All types of equipment that are to be used with the chosen mining plan are listed according to their unit operation function. Any variations in usage that could occur and alternative equipment types for each unit operation are considered. In some areas of Region I and Region II equipment availability controls the mining plan and projected production rates, due to lack of capital for purchasing and lack of equipment to purchase.

Selection of equipment is the final stage of mine planning. Maximizing production while minimizing operating costs is the key consideration for proper equipment selection. Wrong decisions in this phase can offset much or all of the benefits of careful design and planning relating to pit layout and slope stability.

Major elements of proper equipment selection include:

- The required or permitted rate of coal to the plant or loading facility - T/Shift, T/Day, T/Week, T/Year.

- The tonnage or volume of overburden to be moved relative to the desired coal tonnage.
- Overburden characteristics: external overburden, internal partings, bony, hardness, abrasiveness, degree of fracturing, faulting or weathering, permeability, etc.
- Overburden segregation requirements.
- Distance, route, and elevation from the bank to spoil pile or discard area.
- Coal blending requirements for quality control.
- Coal haul distance and elevation changes.

The equipment selection process usually begins and concentrates on the major stripping machine: shovel, dragline, excavator, or loading and haulage combinations (scrapers, front-end loader-truck, shovel-truck, etc.). All equipment in other unit operations is designed in accordance with the overburden removal system. The charts included in the introductory section of this report discuss applications of alternative machines performing similar functions. When performing any equipment evaluation, experience in all its aspects, is of prime importance. Manufacturer's technical literature and specifications can be very useful, but should be used cautiously to ensure that all claims of production and functions relate to the mining conditions at the proposed site. Equipment suppliers can provide valuable technical assistance through use of computer programs. All the designer need do is fill in the blanks of prepared forms giving such data as haul road profiles and conditions, and desired tonnages, to receive a detailed set of figures on cycle times of various haulage units (produced by the manufacturer). Evaluation of the results from several suppliers can provide a sound basis for final selection.

After selecting the sizes and numbers of all equipment necessary for coal production, detailed specifications are written to ensure: (1)

1) That the equipment quoted by various manufacturers matches that which is requested and will perform the desired functions, and

2) That the various proposals submitted by the manufacturers are

in such a form to allow ready comparison of costs and capabilities.

Specifications can be written in two parts - equipment production requirements, and desired equipment options:

Equipment Production Requirements - includes descriptions of the desired function, performance capacity, power, weight, size, etc. as well as permissible tolerances.

Equipment Options - deals with descriptions of all desirable optional equipment items that permit better, safer, and/or cheaper operation, improved maintenance and reduced repair costs, and those items that are additions to the basic machine such as larger tires and engines. Requests for quotes on any other items, that the manufacturer feels would improve performance or operating costs, are also included. Suppliers are asked to describe any special features of their equipment which they think should be emphasized (1).

After receipt of the equipment proposals, careful analyses with respect to costs and technical compliance with requests are conducted, including:

- Capital costs (type payment required)
- Technical suitability
- Delivery and/or erection costs
- Delivery and/or erection dates
- Maintenance and repair considerations
  - Past Performance
  - Discussions with other owners
- Spare parts availability and costs
- Manufacturer's reputation
  - Technical servicing and/or training program
  - Warranty claims settlement

- Supplier or Dealer's reputation
  - Reliability

Equipment selection receives a great deal of mine development effort, as it is a primary element of a successful operation. Utilization of all available resources such as manufacturer's computer simulations and experienced mining engineers and equipment operators, help provide a sound basis for final decisions. If equipment is not matched according to size, production, and performance, inefficiency will result, leading to a lower return on investment than could be achieved by a machine better suited to the particular job.

COST ANALYSES

Inherent with mine planning, development, and decision-making are cost analyses for project or procedural evaluation. Examinations of sensitivity and risk assist mining engineers and management in selecting the most feasible approaches. This is done by determining effects on investment rates of return due to changes in one or more input variables such as coal price forecasts, operating costs and operation life. (See Chapter 9, Systems Analyses).

Economic analyses during development stages usually involve utilization of "Payback Period" or "Rate of Return on Investment" methods. The "Payback Period" technique, useful in preliminary evaluations, can serve to pick out high-profit projects that need no further sophisticated evaluation, or screen out exceptionally poor prospects to avoid unnecessary further capital expenditures. Payback emphasizes only the speed of recovery of initial outlay, not total project profitability. Rate of Return on Investment analyses are being used extensively and consist of two major types:

1) Accounting Method - Return is computed as the ratio of average net income to the average or net investment. This technique does not consider the time value of money, or the fact that income is variable, or the total economic life of the operation.

2) Discounted Cash Flow (DCF) - Return reflects the time value of

money and considers total cash investment and net cash return over the expected mine life.

The System Analysis section of this report deals more directly with applications and descriptions of these techniques.

New surface mining operations require very high capital investments of amortizable and depreciable items consisting of: (2)

Amortizable Items	Depreciable Items
Acquisition of property and mineral rights	Training
Exploration - drilling, sampling and analysis, reserve estimates, etc.	Access development
Development engineering - mapping, equipment selection, environmental impact statements	Power generation and transmission
Temporary preconstruction facilities	Plant facilities
Removal of civil and natural impediments to development	Site improvements
Deferred preproduction operational charges	Service and auxiliary facilities
Market research	Mining equipment purchase
	Water supply and drainage systems
	Escalation in cost of goods and services
	Coal transport facilities
	Taxes
	Contingencies and general expenses
	Replacement parts

Writing off these costs can be accomplished by various techniques and at various speeds. Slow cost write-offs are usually desired when firms which have no other income must defer deductions until they can be used against future project sales. Fast write-offs benefit a company by allowing them to deduct project development costs against incomes from other sources. Again, Chapter 9 discusses depreciation techniques and other cost analyses functions in more detail.

REGIONAL MINE DEVELOPMENT PROBLEMS

During implementation of this study, opinions were gathered con-

cerning seven major factors that were thought to notably influence mine planning and development. These factors were rated in order of importance on a scale from one to seven, with one being the most important. After separating the data into the study regions and combining the various opinions, a bar chart was produced to show their relative importance (Figure 5-1).

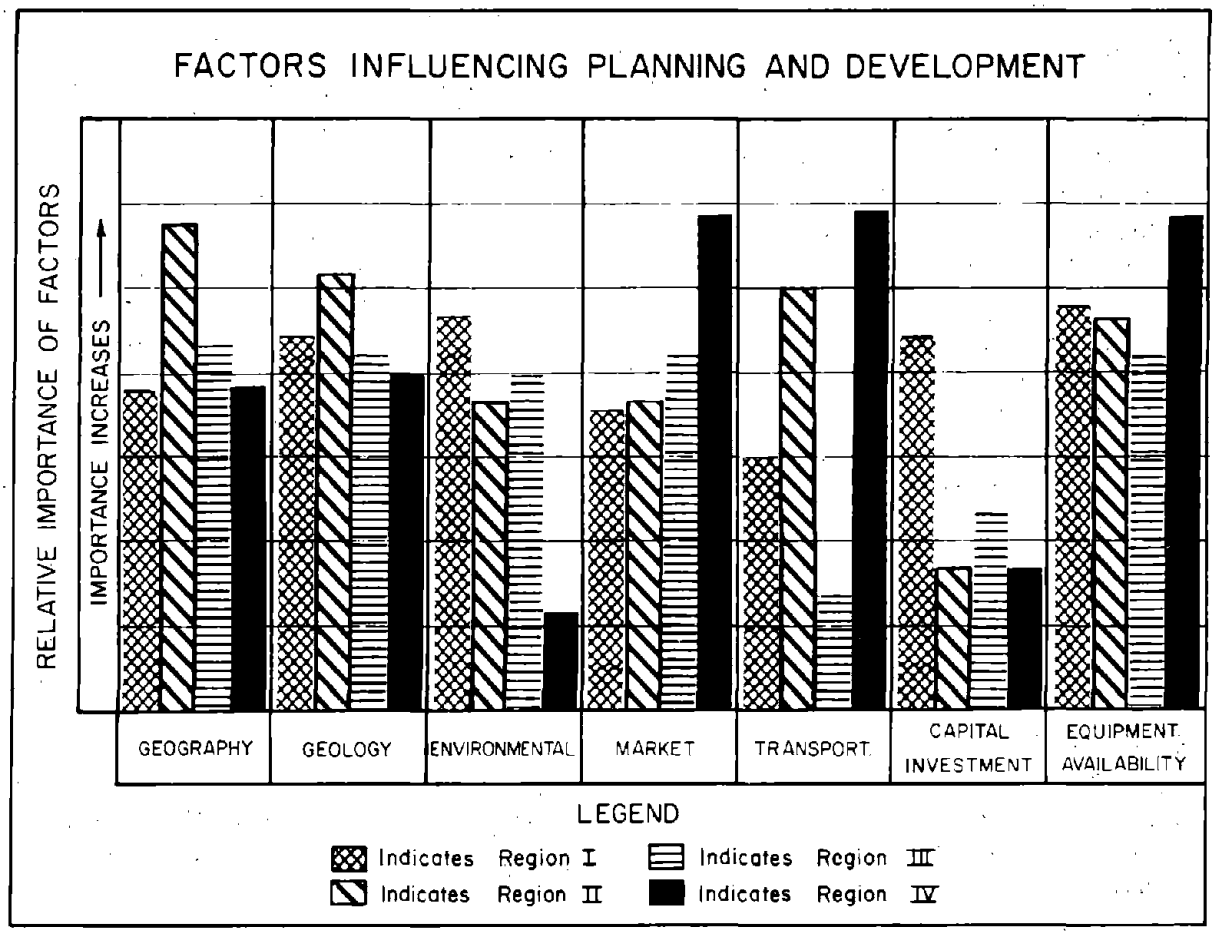


Figure 5-1

302 Discussions of this investigation on a regional basis follow.

REGION I

Operators and planners in Region I felt that transportation was probably the least important factor affecting planning and development. Rail lines and roads have already been established in most areas, eliminating a need for detailed transportation analyses. Naturally, geography and geology are important as they are key factors affecting actual pit design. Recently, however, other factors have gained more concern. New environmental restrictions have caused vast changes in production activities which require increased engineering and evaluation. These restrictions have also caused the use of new and different types of equipment, creating a new and increased equipment demand. Machine and parts availability, together with associated cost increases, present perhaps the most severe problem in this region. If by chance the equipment is available, financing is usually not, which is a major growing concern of the numerous small operations. Due to the usual short lives and small sizes of surface mine sites in Appalachia, detailed market research is not required. Current demands for coal prompt immediate production. Available sales usually outweigh available production.

REGION II

The combination of geography and geology was found to be the predominant concern in this region. The rolling terrain and folding seams together with overburden characteristics require much consideration during planning.

Rail lines were established during and after World War II in these areas to increase coal transportation capabilities. Unfortunately, as the demand for coal decreased, so did track maintenance and car availability. Now, with coal consumption on the rise again, the rail system is not yet capable of handling the increased loads. It is not uncommon for truck haulage of distances over 50 miles. General unavailability of mining equipment also proved to be a growing problem, as was the case throughout most of the nation. Environmental regulations and coal markets were of

lesser concern, although still important. Capital investment availability did not appear to be of major concern.

REGION III

Five of the seven factors influencing development in this region were found to have about the same magnitude of significance: geography, geology, environmental, market, and equipment availability. Capital investment had little effect, probably due to the presence of larger companies in the Midwest who can more readily obtain investment capital. Transportation facilities, largely rail and barge, are currently established, and do not seriously affect the planning stages.

REGION IV

Equipment availability, local coal markets, and product transportation seem to be the predominant factors in the West. Market and transportation problems go hand in hand; markets exist, but are far away and transportation is not always available to reach them competitively. In many instances, transportation and market limitations are such that production must be halted. Large markets must be obtained to help guarantee return of large capital expenditures required for western mines.

Geology and geography again play important roles when designing and evaluating the mining plan. For eastern miners going into the west for their first venture, new analyses and considerations present changes in past thinking.

Capital investments in new mines in Region IV are large, but at the present time do not predominate in importance.

Currently, environmental regulations regarding reclamation do not present serious planning and development problems. However, when mining and reclamation activities get into full swing, advance planning of reclamation procedures and future land use will play a key role in mine development.

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CHAPTER 6

EXTRACTION AND RECLAMATION

RELATIONSHIP OF OVERBURDEN REMOVAL PROCEDURES TO RECLAMATION PRACTICES

Handling of overburden governs the degree of successful reclamation. Just as the natural character of a mining site influences selection of extraction methods, the artificially induced conditions created during spoil deposition influence reclamation by:

1) Physical characteristics. Large stone and rocks on or near the surface impede seed bed preparation, and may sharply limit the vegetative species that can be planted. Grade and length of spoil slopes modify runoff and infiltration rates. Dark colored units on the spoil surface increase soil temperatures, impairing basic plant functions such as transpiration, respiration and photosynthesis.

2) Chemical composition. Presence and concentration of toxic particles (particularly pyrites, calcium and sodium salts) alter: spoil amendment requirements; seed bed preparation and plant selection; seed germination; and seeding vigor. Extremes of pH reduce or eliminate root hair absorption of nutrients such as potassium, phosphate and potash.

Selective overburden removal, segregation, and placement also reduces handling; decreases haulage distances for topsoiling and final grading and improves accessibility and maintenance of the reclaimed site.

Basic objectives of overburden removal and placement for improved reclamation results are:

- reduction of landslide and sedimentation potential
- elimination of toxic matter on spoil surface
- prevention of water pollution
- enhancement of visual quality

REGIONAL VARIABILITY AFFECTING OVERBURDEN HANDLING AND RECLAMATION ALTERNATIVES

As cited in other portions of this report, topography, overburden character and climatic conditions influence the manner in which spoils are reclaimed. For instance, reclamation practices followed in Region I are associated with presence of limestone or calcarious units over the coal. Steep topography requires strict adherence to control of slope gradient. Climatic conditions do not exert extraordinary influence.

In Region II rugged topography, coupled with presence of old underground mines filled with acid mine water, warrants special water pollution control measures. As in Region I, climatology of the area does not severely restrict reclamation.

Region III has a more gently rolling landscape with undulating hills. As such, control of slope gradient is not as critical. Although sulfur and pyrite content of the overburden is high, their effect is suppressed by abundant neutralizing units overlying the coal seams. Acid mine drainage problems are not as severe as those in Region II.

In Region IV, the arid to semi-arid climate becomes a primary mitigating factor in spoil handling and vegetative establishment. The difference in coal/overburden ratio also restricts backfilling and grading. Although sulfuric content of spoils is minimal, salinity and alkalinity levels often prohibit growth.

EFFECTS ON PRODUCTION AND COAL RECOVERY

As environmental requirements have become more stringent, overburden handling has become more sophisticated. Whereas the original "shoot and shove" approach lacked planning but allowed quick coal recovery, today's miner is literally forced to perform a detailed analysis of his mining operation. In several respects this has helped miners realize a greater effectiveness and efficiency of their mobilized resources.

A reduction of coal recovery and production can be attributed to specialized overburden and spoil handling. By their inherent nature, most present backfilling methods leave some recoverable coal intact (example:

low wall barriers). Backfills associated with retreat, haulback, and modified block cut mining sometimes involve placement of spoils on recoverable coal.

Administrative regulations which require backfilling within short distances of the pit reduce production. Decreased pit size causes:

- increased health and safety hazards
- congested pit conditions
- reduced equipment turning space
- decreased equipment efficiency

Provisions in proposed federal legislation would prohibit recovery of coal from previously mined lands. A major portion of surface mined coal has been, and still is, produced from previously mined sites. (It is for this reason that only 0.16 percent of United States land mass has been utilized by mining activities (7). Regulations such as the one just mentioned would serve to prevent recovery of significant amounts of this Nation's coal reserves.

RECLAMATION ECONOMICS

Discussion of specific reclamation costs are addressed by region and method in Chapter 9 - Systems Analyses.

ALTERNATIVE SPOIL HANDLING TECHNIQUES

Eliminating abuses of the past requires comprehensive pre-planning and coordination of removal and replacement of overburden -- even to the extent reclamation alternatives dictate selection of extraction methods and equipment.

Selection of appropriate backfill, grading, and planting methods involves several criteria. They include:

- inherent environmental site conditions
- adjacent land use
- local, state and federal environmental regulations
- technical feasibility
- equipment capability
- fiscal resource limitations

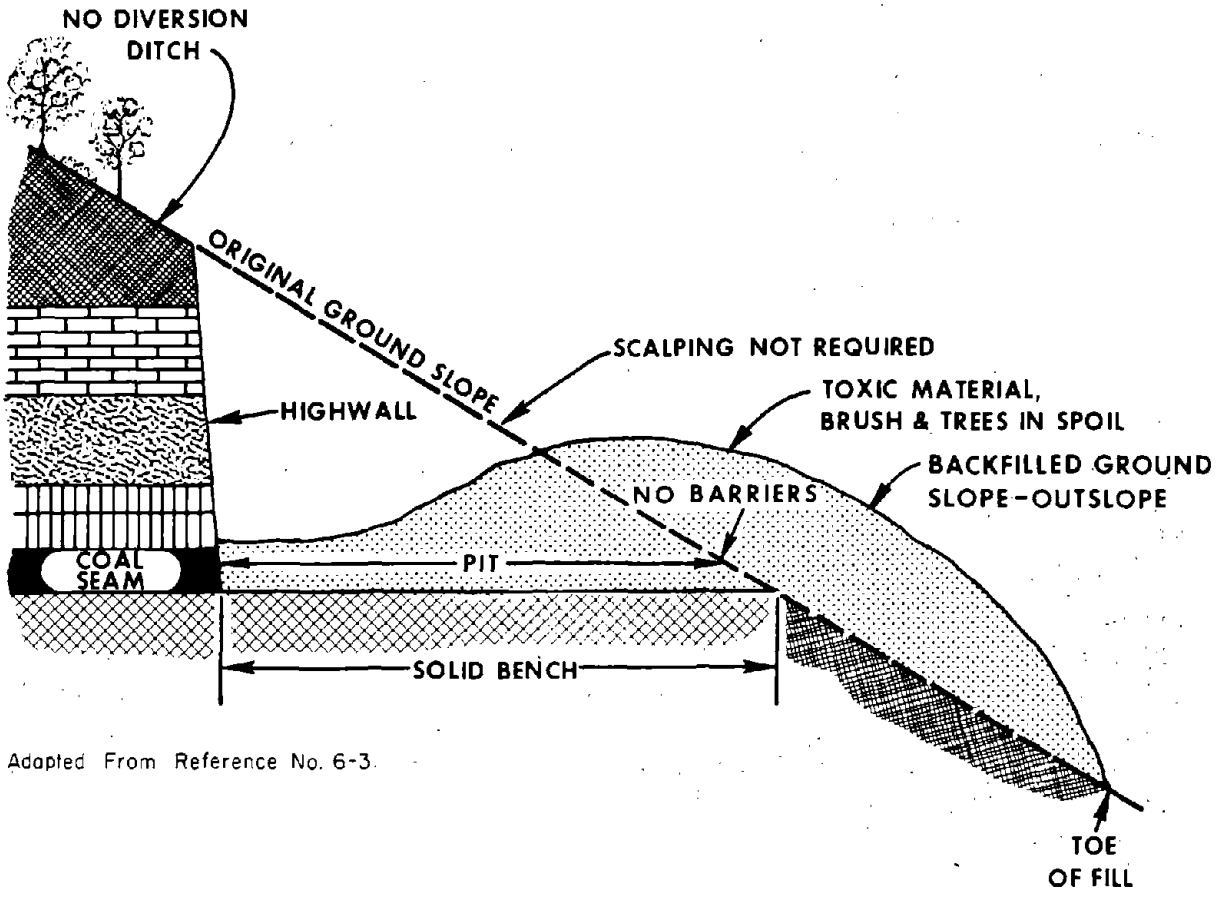
It is unusual for one technique to meet all of the above. A miner frequently finds that he must constantly adjust one or more techniques to meet his specific needs.

The geometric configuration of coal mined land has long been recognized as a source of physical and chemical pollutants as well as being visually displeasing. To a large extent, the public's unhappiness with past surface mining is based upon the negative visual impact of blighted landscapes whose color and texture are not harmonious with adjacent terrains. Today's backfilling and grading practices do not create the "moonscapes" historically associated with strip mining.

COVER THE PIT

One of the backfill methods first used in contour strip mines of the Appalachian and Interior Coal Basins consisted of simply covering the pit with unsegregated spoil. Although identified as a pollution control measure in initial strip mine legislation, its practice proved to be unsatisfactory in steep terrain and coals characterized by high sulfur content. Cover the Pit was often used with strike-off grading and the fill material covering the coal consisted of spoil taken from the ridge.

By itself, Cover the Pit does not comply with many state reclamation standards. Variations of this method are being used in open pit mines in Region IV.



Adapted From Reference No. 6-3

TYPICAL COVER THE PIT BACKFILL METHOD

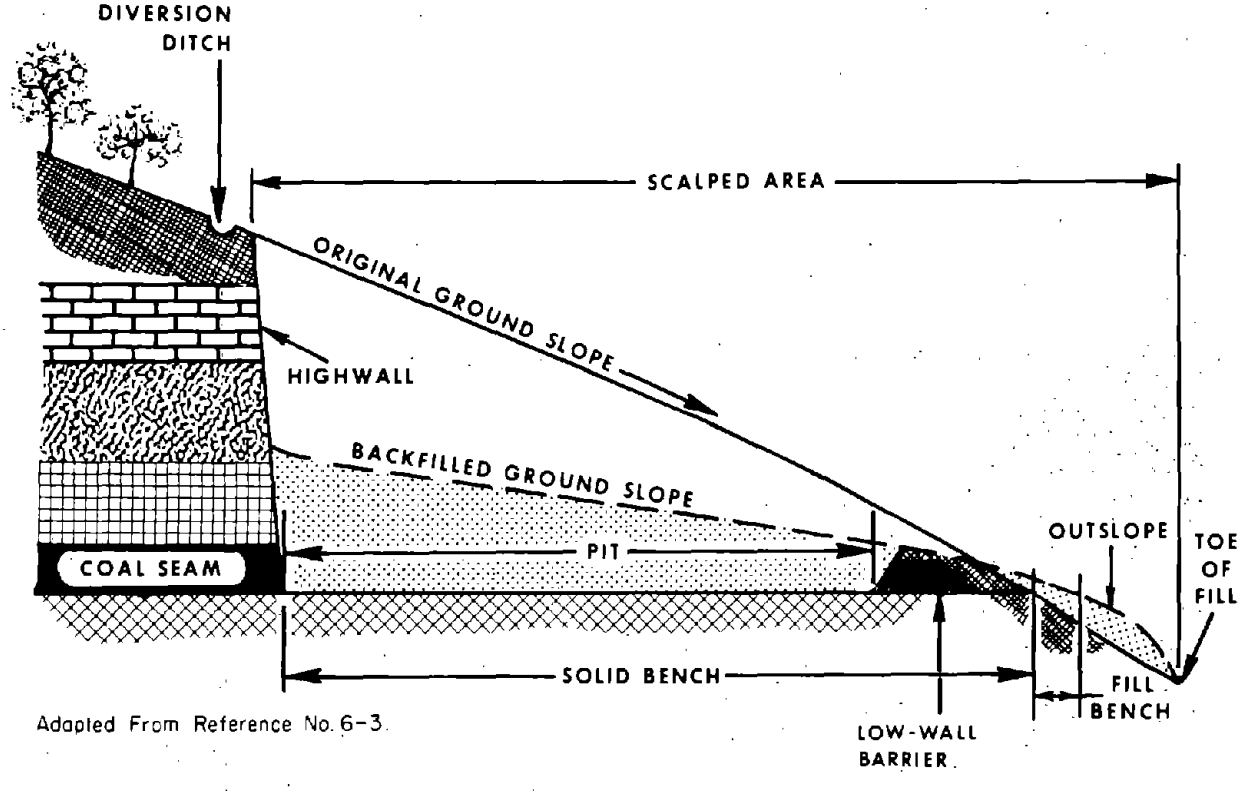
Figure 6-1

PASTURE BACKFILL

A vast improvement upon the previous technique is pasture backfill. This method entails distributing spoil over the pit and associated acid producing strata, with the resultant geometric configuration being

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amenable for pasturing purposes. This type of backfill has been employed extensively in contour and area mines in Appalachia and the Midwest with moderate success. A portion of the highwall is eliminated and fill spoil is sloped away from the highwall to create a gentle relief. Pasture backfill requires leaving coal in the low wall for improved pollution control.



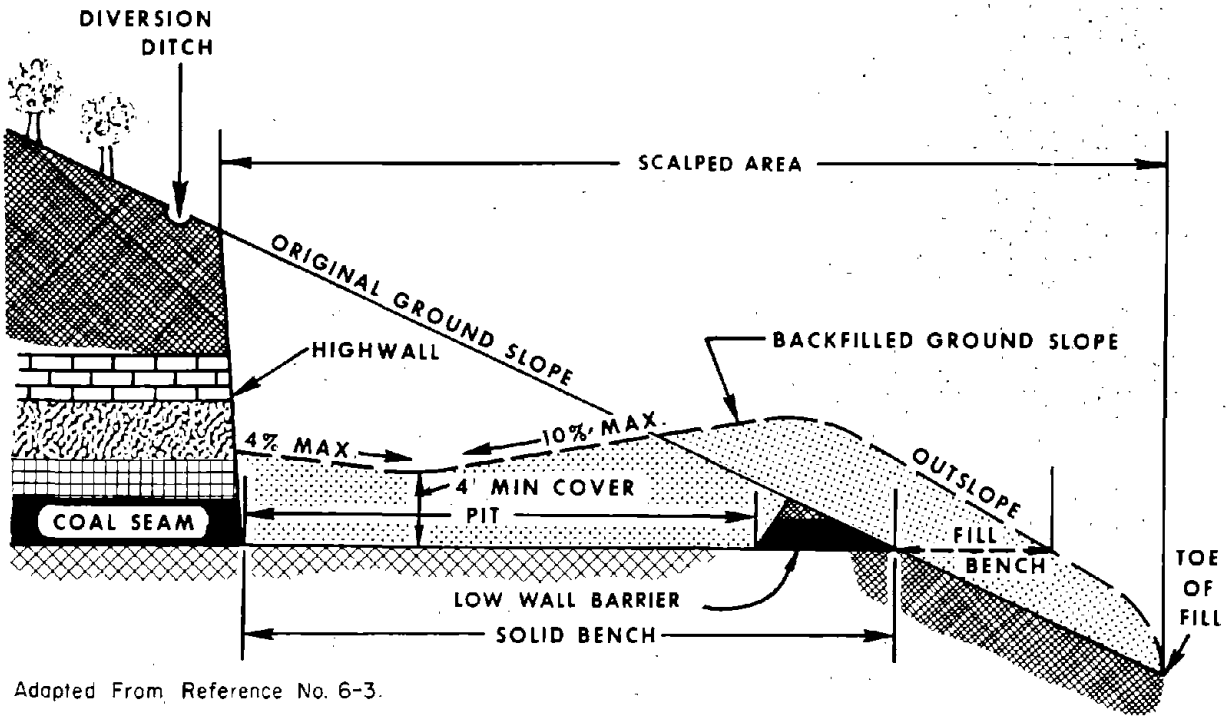
Adapted From Reference No. 6-3.

TYPICAL PASTURE BACKFILL METHOD

Figure 6-2

One of the least complex methods to execute in the field, the Georgia V-Ditch backfill is limited in use due to retention of the highwall and lack of acceptable surface grade. Much of the spoil is left in its mined position with only superficial grading to construct swales which convey water from the final cut. Upper portions of the highwall are left exposed and the regraded surface is generally uneven.

Effectiveness of this approach is dependent on the design and location of swales and water diversion channels. Steep slopes and collecting depressions create a potential for greater erosion and infiltration, unless the swales are properly located and conduct water flow to diversion channels. Coal is usually retained in the low wall.



Adapted From Reference No. 6-3.

TYPICAL GEORGIA V-DITCH (SWALLOW-TAIL) BACKFILL METHOD

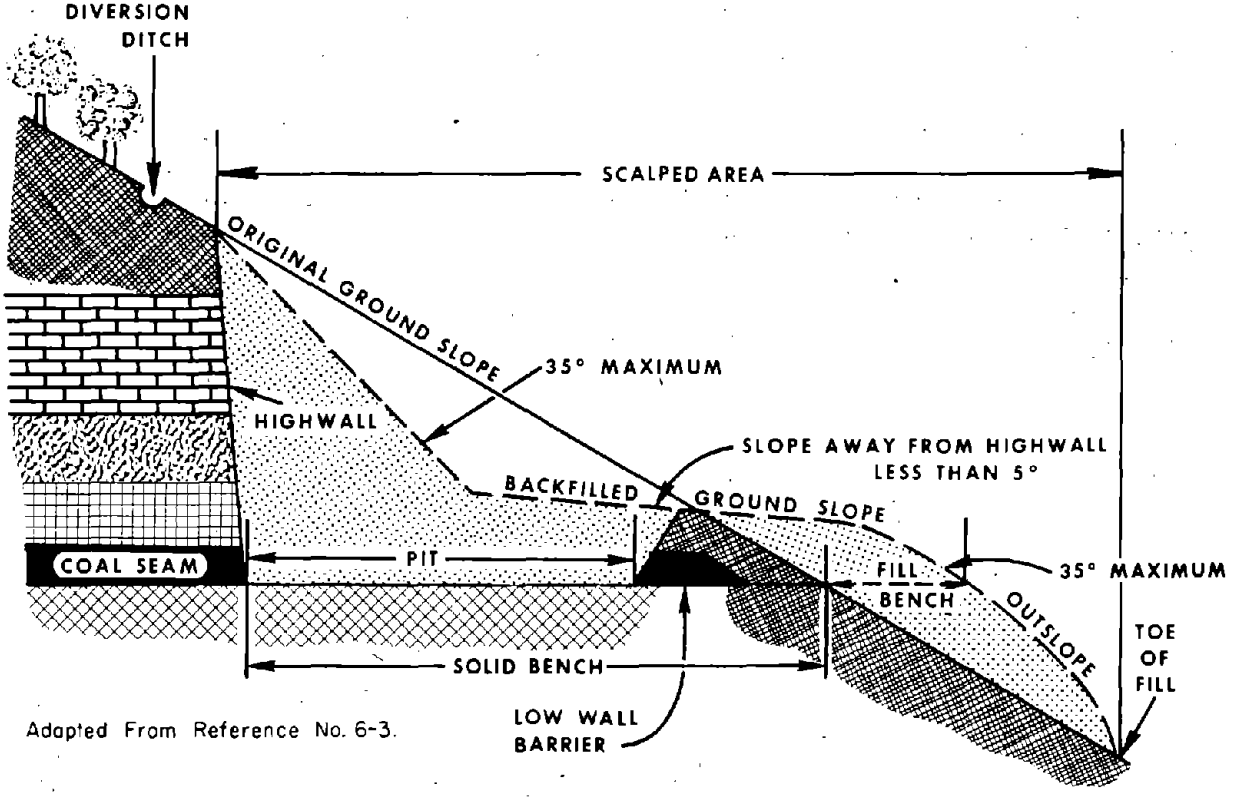
Figure 6-3

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TERRACE BACKFILL

Basically, terrace backfill consists of a gently sloping bench with a steep outslope (maximum grade of 35°). Fill material is deposited to eliminate the highwall, and the horizontal dimension of the terrace is graded away from the highwall. As previously mentioned, an extended outslope is inherent with this method. The outslope and steep slope at the highwall tend to be subject to erosion and landslides.

Terrace backfill presents an effective means of preventing quick runoff and increasing infiltration. Unlike contour backfilling, terracing requires less earth moving and has been used in steep terrain where contouring would not have been feasible.



TYPICAL TERRACE BACKFILL METHOD

Figure 6-4

VALLEY FILL (HEAD OF HOLLOW FILL)

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Just as its name implies, Valley Fill basically consists of filling the head of an adjacent valley with spoil. Valley Fill has been successfully used in West Virginia and Eastern Kentucky in conjunction with mountain-top removal. A complete discussion of Valley Fill can be found in Chapter 3 - Region I.

CONTOUR BACKFILL

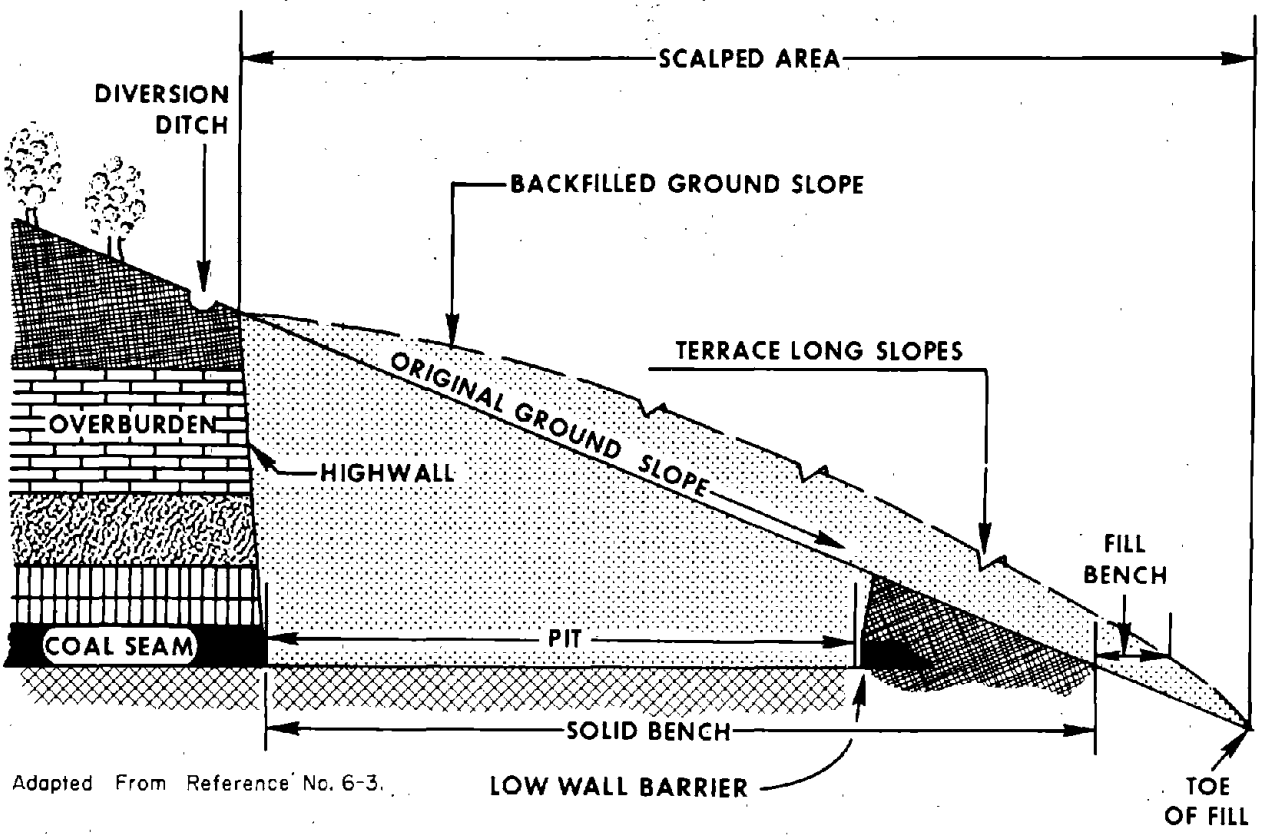
As environmental regulations became more stringent, modification of overburden removal and deposition practices resulted in development of the contour backfill. Inherent with this approach is successive grading of spoil ridges toward the final cut. The highwall is eliminated and the final grade approximates the profile of the site before mining. It is not unusual for post-mining configuration to be much better than before mining.

Contour backfilling although aesthetically very pleasing and technically feasible, warrants special precautions in its implementation. One particular disadvantage of the contour method is the tendency to create long gentle slopes which will erode extensively if a series of well designed terraces, diversions, and discharge outlets are not installed. Contour backfill also necessitates affecting approximately 30% additional land surface above the highwall in order to secure sufficient fill (unless the block cut extraction method is utilized) (3).

Use of the contour backfill is curtailed by availability of sufficient spoils. In Western coal fields, contour backfill is not always feasible due to the large volume of coal removed and small volume of overburden available as fill (See Figure 6-5).

HIGHWALL REDUCTION

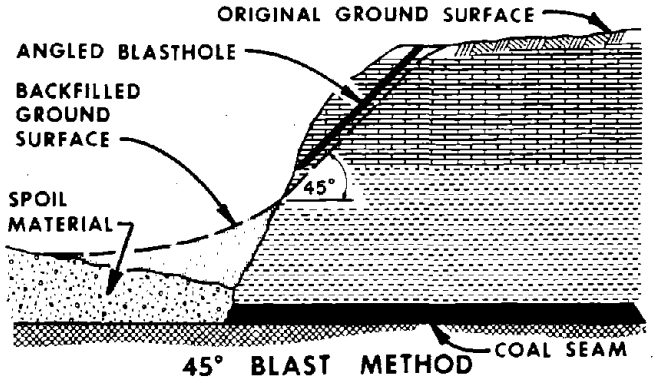
Highwall reduction is often used in combination with other mining and backfill techniques (example: Georgia V-Ditch or Terrace). Highwall reduction basically entails removal by blasting or grading the top edge, or

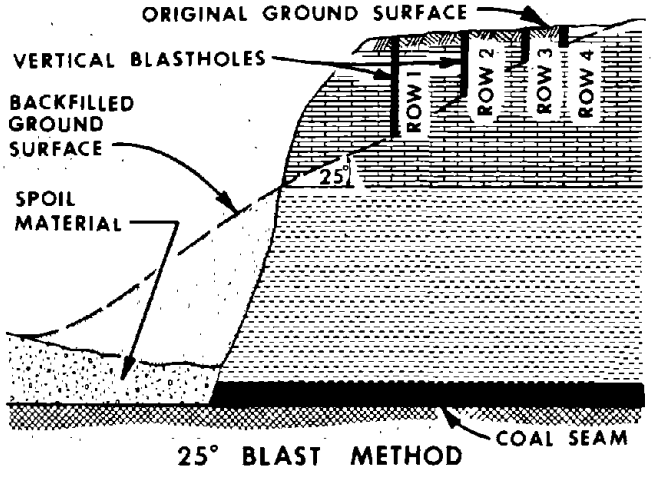


TYPICAL CONTOUR BACKFILL METHOD

Figure 6-5

lip, of the highwall. The loose rock is then cast down slope on the vertical face of the highwall and used as fill. This method is a viable water pollution and erosion control practice when used with above-slope diversions and slope revegetation.





Adapted From Reference No. 6-2.

HIGHWALL REDUCTION

Figure 6-6

SURFACE PREPARATION

In order to reduce compaction and erosion problems, grading should commence behind backfilling as quickly as possible. Surface grade is a major factor in conservation of spoil nutrients and moisture. Success of

plant survival is a function of the quality (character) of spoil micro-environments. These micro-environments are greatly affected by the physical shaping of the top few inches of the spoil surface.

TERRACING

Just as its name implies, terraces are constructed on the contour to control runoff, erosion, and sedimentation. It is particularly effective on erosive slopes. Most of the work can be accomplished with a dozer and an agricultural harrow. Terracing requires much precision in structuring and is often used with a series of small check dams and sediment ponds.

FURROW GRADING

Furrow grading incorporates collection of water and silt in a series of parallel furrows. As the ridges of the furrows weather, silt is collected in the middle of the furrow, gradually filling it. Since greater moisture and better nutrient medium collects in the middle of the furrow, vegetative size and density tends to be greater there. Furrow grading has been very successful on steep, erosive and toxic spoils in eastern and mid-western states (5).

GOUGING

Used primarily in arid to semi-arid climates, gouging creates shallow scooped-out depressions approximately 14 - 16 inches wide, 6 - 8 inches deep and 1 - 2 feet long. Initial results indicate gouging to be an effective surface water retention technique on gradual slopes and flat areas (3).

DOZER BASINS

Dozer basins are elongated depressions usually about 3 feet in depth and 25 feet in length. Constructed with an angled bulldozer blade, dozer

basins trap and retain large amounts of surface runoff. The basins have been quite effective in climates typified by draughty conditions and high intensity storms (3).

DEEP CHISELING

Although not considered as effective on a long term basis as the two techniques previously mentioned, chiseling does curtail erosion from low intensity storms. Chiseling loosens compacted spoils by creating a series of parallel slots 6 - 8 inches deep. The resultant seedbed is highly suited for broadcast seeding (3).

SEED BED PREPARATION

Organic composition of spoil is another major mechanism affecting vegetative growth. The practice of topsoiling greatly enhances regeneration of vegetation. By eliminating the presence of toxic salts in root-zone areas, the integrity of plant root hair tissue is maintained. (Toxic salts destroy the absorptive ability of root hairs.) Topsoiling also reduces application rates of lime, fertilizer and seed.

Mulches

Mulches such as hay and straw have proven to be very beneficial in: 1) insulating spoils against extreme spoil temperature; 2) increasing spoil moisture holding capacity; 3) reducing rainfall impact; 4) accelerating microorganism growth; and 5) reducing evaporation rates. Mulches, through the bacterial action of microorganisms, also increase the organic content of surface matter.

Lime & Fertilizer

Application of lime and fertilizer to improve soil productivity has been a long established practice by the agriculture industry. Its wide-

spread use by the coal industry is a relatively recent innovation.

One of the key elements in determining spoil supplement requirements is the methodology used in field sampling and laboratory analysis. Standard agricultural testing procedures are not usually suitable. Further research is needed to develop appropriate spoil testing procedures.

Neutralization of acid spoils with agricultural limestone is now commonly incorporated into most planting plans. For best results, liming must be done before actual seeding so that the lime reacts throughout the surface and root-zone horizons of the spoil. Successful maintenance of plant growth usually requires that additional lime be applied over a period of time.

Fertilizer provides the essential nutrients (nitrogen, phosphorous) usually absent in spoil material. Specific application rates vary greatly from site to site, but it has been found that the increased amounts of nitrogen will not eliminate the effects of insufficient amounts of phosphorous (1).

Fertilizer is usually applied at the same time as seeding or shortly afterward. In winter seeding, fertilizer is more appropriately spread in the spring during anticipated seed germination.

Fertilizer may be spread in wet or dry form. Caution must be exercised in fertilizing with a hydroseeder. The mixture of fertilizer, water and seed should be spread immediately and not be allowed to sit in the storage tank. In grass seed, the mixture of water and fertilizer form a salt solution which may damage seed coats. In legumes inoculated with nitrogen - fixing bacteria, salts from the solution may reduce effectiveness of the bacteria.

Fertilizer can also be spread in a dry-mix seed combination. Typical methods of application include aircraft, cyclone spreaders and bulk trucks.

Fly Ash

Not widely used, but certainly an alternative to lime and fertilizer is fly ash. It is a powdery coal waste product of electric power generation.

Although its chemical composition is determined in large part by the type of coal and processes used by the generating plant, fly ash has been demonstrated as effective in improving the micro-environments of spoils (1). In addition to elevating pH levels of acidic spoils, fly ash also increases moisture availability, air capacity and pore volume in spoils.

Some disadvantages of fly ash utilization include: 1) a deficiency in nitrogen, which must be supplemented with fertilizer; 2) presence of toxic boron levels; and 3) variability of pH. (Plantings using boron tolerant species for the first cover crop and their subsequent removal from the site, followed by plowing, has been an effective method in eliminating boron toxicity.)

Rates of application are determined by measuring the pH of equilibrated soil-water mixtures on a 1:1 weight basis. A basic application standard that has been used is that 1 inch equals 100 tons per acre.

Cost of fly ash application varies widely with terrain, spoil character, acreage, haulage distance, equipment capability, and environmental regulations.

Sewage Sludge

Applications of sewage sludge have been shown to be quite effective in reducing both acidity and alkalinity problems (4). Sewage sludge is particularly good for increasing the organic composition of spoils.

A limiting factor in sludge application is excessive nitrogen levels, which may pollute groundwater with nitrates, if spread too heavily. Sludge also contains nearly all trace elements which can be toxic if their concentrations are not controlled.

Qualification of sludge utilization can be based upon increased spoil fertility, water retention and improved soil structure.

Sludge may be spread in wet or dry form. Basic application methods include flooding, sprinkler and furrow irrigation and soil placement. In aqueous form, sludge may be transported using conventional pumps and pipes. Soil placement requires dry sludge. The cost of water removal

may be prohibitive in some instances to permit application with manure spreader or bulldozer.

REVEGETATION

SEEDING METHODS

Selection of seeding and planting methods is largly dependent upon slope gradient, size of area, time of year, seed bed condition, and site access. Other major considerations include availability of seed, equipment limitations, and environmental regulations.

Seeding with fixed wing airplanes and helicopters has been used in large acreages with very steep terrain. Airborne seeding, however, requires optimum weather conditions, and application rates of seed and fertilizer are typically greater than with conventional ground techniques.

Broadcast and row seeding with conventional farm drills is being increasingly practiced throughout the United States, particularly on recontoured lands. Tree planting, although not as extensive in recent years, is being done by mechanical planters and planting bars. In several states, seeding plans, seed bed preparation, and actual seeding is performed for coal companies through the contracted services of industry reclamation associations.

SPECIE SELECTION

Current reclamation practices are increasingly incorporating planting of grasses and legumes. Most coal operators are finding that quick growing herbaceous cover is essential for minimizing or reducing erosion. Much of this increase can be attributed to state regulations which require recontouring.

Specie tolerance to excessive pH, extreme soil temperature, deficient nutrients, and moisture are major aspects of specie selection.

In several instances, plantings for initial cover include legumes

and annual grasses. Secondary plantings are conducted later and usually consist of perennials. Unlike tree plantings, herbaceous vegetation requires much management to maintain growth.

At one time, woody vegetation was extensively associated with reclamation practices. Generally speaking, soil amendments were not applied and upon maturity, trees were sold as a marketable crop.

Their characteristic slow growth, however, does not provide the early ground stabilization so essential for steep slopes. Hence their exclusive use today is minimal. Instead, woody and herbaceous species are mixed to provide quick cover as well as long-term stabilization.

ENVIRONMENTAL IMPACTS

Until the early 1970's, pollution control measures practiced by the coal industry were minimal. The period since, however, has been marked by industry's active pursuit of improved mining and reclamation techniques. Much of this effort has been in direct response to legislative mandate.

STATE AND FEDERAL LEGISLATION

In some respects, goals of domestic energy self-sufficiency and protection of the environment are mutually exclusive. Many states having lands underlain with marketable coal are not being mined due to restrictions of spoil placement, steepness of grade and potential for acid formation. Current laws prohibit mining of reserves where technology has not been adequately demonstrated as being effective in eliminating pollution. Such restrictions not only prevent recovery of an urgently needed fuel, but also serve to limit incentive for field innovations by smaller miners.

In other instances, some states prohibit opening new surface mines on lands which are identified as possessing unique or irreplaceable beauty. Under proposed federal legislation any area under consideration for environmental analysis cannot be mined. Restriction of mining near public buildings, streams, transmission lines, pipelines, roads, property lines, and cemeteries reduces coal recovery. Regulations such as these remove

domestic energy reserves from our nation's energy bank or prolong their much needed recovery.

Legislated administrative requirements such as cash payment of mining fees, posting of surety bonds, and preparation of detailed maps and reports tie up operating capital. Sheer economics of administrative overhead often negate recovery of small reserves by independent coal operators. At the same time, large coal companies cannot justify the return on investment in mining such reserves.

Administrative regulations which require field inspection prior to final grading and planting often serve to disrupt effective environmental control. It is quite common for inspection delays to prevent miners from taking advantage of ideal grading and/or planting conditions.

Immediate backfilling requirements often prohibit or restrict recovery of other minerals uncovered in the overburden.

Current mining and reclamation practices have drastically reduced, and in many instances virtually eliminated, environmental abuses of the past. Caution must be exercised, however, so that today's cures do not create problems far worse than the original affliction.

Most existing state regulations have greatly altered the type of vegetation being used on mined lands. Past reclamation practices typically involved re-establishment of mixed hardwood trees in Regions I, II, and III. Noted increases of deer and bird populations have been correlated with forest-type reclamation in Regions II and III.

Because of the emphasis on water pollution control, almost all mined lands today are reclaimed to semi-agricultural standards via grasses and legumes. Wildlife requirements for food and shelter, (particularly from November to May) receive minimal consideration.

Grasses and legumes provide immediate cover, they also require long term management and care. Herbaceous vegetation does not create as many ecological niches as mixed forest cover, hence grasses are more susceptible to insect infestation. The lush green landscapes produced under current reclamation laws are not necessarily indicative of stable, productive, ecosystems.

In view of the world's food storage, the planting of row-crops such as corn, rye, oats, wheat, and soybeans certainly represent viable seeding alternatives. Immediate return on investment, production of food staples, and conservation of our natural resources are tangible benefits yet to be fully realized from reclamation.

Topsoil removal and replacement has not always resulted in the most beneficial growth medium being replaced on the regraded surface. Topsoiling requirements have actually prevented placement of more productive materials on the surface. Stockpiling has not always preserved the integrity of topsoil. Much more investigation needs to be conducted regarding the handling and stockpiling of topsoil.

Elimination of final cuts for water collection and storage is often another major shortcoming of legislated environmental ethics. In arid climates and states having polluted underground waters, retention of reservoirs can be an invaluable supplement to existing water supplies.

Restoration of original contour in flat, level lands, such as those found in Region IV, eliminate useful wind breaks for livestock. Swaling of regraded surface configurations would also increase collection of water from accumulated melting snow. Visual quality of the landscape would be enhanced by adding new dimension to otherwise repetitive landforms.

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CHAPTER 7

STORAGE AND TRANSPORTATION

One of the major constraints to development of the surface coal mining industry in all four regions is transportation from mine site to point of consumption. This section addresses the subject by first discussing equipment systems used in transport of coal. The role of coal storage is then examined. Finally, transportation trends in each region are discussed.

TRANSPORTATION EQUIPMENT SYSTEMS

Five major forms of coal transport are: rail, waterways, conveyor, slurry pipelines, and trucks. Combinations of these basic systems are used to transport coal from mine to point of consumption.

Most statistics compiled for interstate transportation of coal combine surface and deep mining production. These statistics are still important since the transportation problems to be overcome are common to both segments of the coal mining industry.

Railroad Systems

Railroad systems were used to move 376 million tons of bituminous coal in 1973. Eight companies accounted for 70% of the coal handled and 80% of the 1.4 billion dollar revenue generated by rail carriers (5). Table 7-1 summarizes bituminous coal handled and revenue received in 1973. This is attributed to better utilization of the unit train concept and an increase in average tons per car loaded from 74.7 in 1969 to 81.3 in 1973, as shown in Table 7-2.

Despite the 15% decrease in serviceable open top hopper cars, total tonnage of coal shipped by rail has increased during the past five years. Because of economics, unit trains now move more than 20% of total coal output.

The unit train concept was conceived by the Pennsylvania Power and

Table 7 - 1

Bituminous Coal Rail Carriers & Revenue - 1973

Coal Carriers	Originated Net tons x 10^3	Revenue - $ x 10^3
1) Penn Central	39,486	214,453
2) Norfolk & Western	67,609	295,881
3) Chesapeake & Ohio	49,605	187,397
4) Louisville & Nashville	48,692	110,290
5) Baltimore & Ohio	26,677	110,731
6) Southern	23,860	70,666
7) Illinois Central Gulf	27,074	56,910
8) Burlington Northern	24,711	89,997
9) All other railroads	68,364	289,263
TOTAL	376,078	1,425,588

Source: Association of American Railroads

Table 7-2 Coal Hopper Cars and Tons Loaded per Car

Year	Ownership	Awaiting Repair	Serviceable	Tons loaded/car
1969	394,204	16,054	378,150	74.7
1970	388,492	14,983	373,509	76.6
1971	386,482	14,479	372,003	77.8
1972	373,136	17,865	355,271	80.4
1973	354,608	19,280	335,328	81.3

Source: Association of American Railroads

Light Company and the Pennsylvania Railroad (Penn Central), as an instrument to reduce coal rail rates. Entire trains were dedicated for the sole purpose of transporting coal from mine loading points to electric generating stations. Unit trains range in size from 30 to over 100 cars, carrying

3,500 to 17,000 tons. Car size is sometines limited by rail bed design or condition.

The largest coal carrier in the country (originated plus transfer), Penn Central, must limit car capacity to 125 tons due to poor track conditions. Experimental car sizes have reached 240 tons, which illustrates significant lost potential for increasing capacities of unit trains at lower transport cost per ton.

With few exceptions, single track loading of unit trains is the rule, and is usually accomplished with an overtrack surge hopper. The hopper can be eliminated by running the train in a tunnel beneath the storage pile. Track setups usually provide for straightaway filling of the entire train when the road locomotive provides the power.

An example of advanced automatic railroading is the unit train operation at the Peabody Black Mesa mine in Arizona. Loading is automatic for a 73 car train with each car having a capacity of 122 tons. Loading time should not exceed 3 hours, while 20 minutes is required to unload at the power plant 78 miles away. Locomotives derive power from the first 50 K.V. railway system in existence. The entire train is automated, however, an operator rides in the cab of the lead engine to man controls in case of an emergency.

Although they are the major mode of transportation, railroads have not kept pace with present coal transportation needs. The railroad problem manifests itself in several forms; poorly maintained rail beds and rolling stock plus a lack of expansion in railroad equipment. These problems emanate from the precarious financial condition of most rail carriers. During the past decade part of the rolling stock problem was solved by customer owned rail equipment. The Pennsylvania Power and Light Company started this trend by owning and maintaining special unit-train cars operated by Pennsylvania Railroad crews (Penn Central). Today the electric utility industry is faced with serious problems in securing capital, therefore the railroads can no longer depend on this source of supply for rolling stock. Testimony presented at regional hearings of "Project Independence" indicates the railroad industry must expand equipment by approximately 8,000 locomotives and 150,000 hundred-ton hopper cars, with an estimated capital expenditure of six billion dollars. This expansion must take place by 1985 to move 1.2 billion tons of coal required in the "Project Independence" scenario.

The major environmental problem related to coal transport by rail

is wind loss in transit and open storage. The later is being solved by silo storage at rail transfer points. The transit wind loss problem is being attacked by use of more closed hopper cars, wind guards, water sprays, and surface treatment agents.

Water Systems

The inland waterway system in the United States is a network of over 25,000 miles of navigable water plus the Great Lakes and Coastal waterways, with coal representing over 20% of the total tonnage moved (5). Water is the least expensive method of shipping coal. Growth in water transport has been the result of improved navigation channels, improved towboats and barges, and changes in the electric utility industry (which is the major user of barge coal). As demand for electricity increased and generating stations became larger, the double advantages of cooling water and low cost coal transportation encouraged selection of sites on navigable waterways for many of the new power plants.

Barges

Barge coal is moved with equipment owned by coal producers, coal consumers, and independent barge lines. In recent years an increasing proportion of the transportation has been performed by independent barge lines. Barge companies move coal for a number of producers and consumers in the same area, and obtain advantages of scale and flexibility not attainable by a single producer or consumer. Barges are usually 1,000 to 1,500 tons capacity. The smaller size is well suited to work on western Pennsylvania and Upper Ohio Valley waterways. The 1,500 ton barge is used extensively on the Ohio, Mississippi, Illinois and Tennessee Rivers.

The point of interface between modes of transportation is a serious constraint to waterway coal transport. Barge unloading facilities have not kept pace with available technology. Continuous ladder unloader-conveyor systems are available that will eliminate this bottleneck to increased coal movement by waterway. Table 7-3 shows coal movement on each of the major waterways increasing. Orders have been placed for construction of over 1,000 additional coal barges, which is further evidence of increased

TABLE 7-3

INLAND WATER MOVEMENTS OF COAL, BY SHIPPING AREA
(Net Tons)

Shipping Area	1968	1970	1972
Allegheny River	1,737,999	1,476,072	1,367,834
Arkansas River	-	9,041	533,478
Big Sandy River	-	-	461,743
Black River	-	-	-
Cumberland River	128,250	72,900	-
Galveston Bay	-	875	-
Green & Barren Rivers	15,809,522	16,664,317	16,189,081
Gulf Intracoastal Waterway	1,481	1,164	2,835
Illinois River	4,836,856	6,090,937	5,477,126
Kanawha River	7,468,108	7,373,062	7,380,385
Lake Michigan	-	-	-
Mississippi River	7,353,150	6,636,141	9,497,995
Missouri River	-	-	-
Monongahela River	26,984,871	30,966,508	27,249,590
Ohio River	25,467,924	27,187,473	32,306,821
Huntington District	11,262,646	9,688,273	11,547,361
Louisville District	7,150,442	9,127,838	10,913,590
Pittsburgh District	7,054,836	8,371,362	9,845,870
Port of Chicago	2,315	7,463	11,715
St. Croix River	593	-	4,067
Tennessee River	4,956,655	5,509,102	8,235,166
Warrior River System	2,940,209	4,198,023	5,721,253
Willamette & Yamhill Rivers	-	-	66
Total	97,687,933	106,193,078	114,439,155

Source: U.S. Army Corps of Engineers

use of the inland waterway system.

Great Lakes

Another important aspect of coal transport by water is the Great Lakes system. In 1973 over 34 million tons of coal were handled on this system.

Soon new types of ships will be handling western coal on the Great Lakes. These ships will have a capacity of 62,000 tons and will be equipped with self-unloading facilities. An example of future trends on the Great Lakes system is the 180 million dollar, 25 year sale of western coal by Decker Coal Company to an electric utility plant near Detroit (2). Coal will be hauled to a terminal point at Superior, Wisconsin by 10,000 ton unit trains. It will be unloaded at a rate of 35,000 tons per hour and moved either to a ship loader or stockpile. This example illustrates the vast potential increase of coal handling by the Great Lakes system and unit trains in the development of western coals in Region IV.

Foreign Markets

Deep water transportation serves foreign markets for U. S. coal, including 1 million tons of anthracite. Approximately 50% of the anthracite is bound for Germany to heat buildings operated by the U. S. Armed Forces. In addition, over 55 million tons of bituminous coal was exported in 1974. Most of this coal was destined for steel producers such as Japan with a large portion passing through yards of the Norfolk and Western Railroad at Norfolk, Virginia. Most of this is high grade metallurgical coal from Region I. The yard can accommodate more than 11,000 hopper cars. Two major piers handle about 1,000 vessels a year.

Conveyor Systems

Demands of the coal industry for handling materials at higher rates and reduced costs have had a significant effect on recent belt conveyor technology. For example, twenty years ago the strongest commercially

available, fabric-reinforced conveyor belting had a tension rating of 50 pounds per ply-inch. Currently, fabric-reinforced belts are available with ratings of 350 pounds per ply-inch and steel cable reinforced belting is available with tension ratings of 3,000 pounds per inch of belt width. Use of belt conveyors over truck haulage also has the advantage of replacing equipment dependent on foreign petroleum products with equipment driven by electric energy produced with domestic coal.

Conveyors are now used for distances less than 10 miles, however, systems over 100 miles are being studied. Conveyor systems are used extensively at transfer points between mine and rail, rail and water, and between point of consumption and final overland mode of transport. Peabody's Black Mesa mines have already been cited for advanced transportation methods in the slurry pipeline and rail transport sections. The Kayenta mine at the Black Mesa complex is a dramatic example of overland conveyor use. In addition, this example illustrates the point that coal transport from pit to point of consumption is normally a combination of transport methods. At Kayenta a conveyor system moves coal supplied by 180 ton bottom-dump trucks at the mine site to a point 6½ miles off the mesa, where four coal silos are used to load a 50 K.V. automatic rail system. The three flight system has an operational capacity of 2,700 tons per hour. Only 450 horsepower per mile is needed as drive power because regenerative braking is employed enroute.

Shiftable belt systems with proven performance at large West German lignite operations are being studied and applied at U. S. surface operations. The equipment will be used to haul overburden and/or coal from the pit without being dismantled. Research has also been suggested to determine feasibility of substituting belt conveyors for trucks in certain haulback operations of Region I & II.

Slurry Pipelines

In 1957 the Consolidated Coal Company began operating a 108 mile coal slurry pipeline in Ohio. The slurry pipeline operated successfully for six years and transported 7,000,000 tons of coal. Operations ceased in 1963 when the Pennsylvania Railroad (Penn Central) offered substantially decreased rates to counter the "threat" to rail transportation of

coal (6).

During the past 10 years much research has been conducted on slurry pipeline systems. The Bechtel Corporation of San Francisco is engaged in research of coal slurry preparation, transportation, and utilization. Slurry preparation covers physical and chemical processing necessary to give the slurry characteristics required for hydraulic transport and utilization. Preparation involves size reduction and addition of liquid. Size reduction is accomplished with impactors, cage mills and rod mills. Coal is mixed with 50% water by weight and transported via pipeline to the point of consumption, where it is first decanted to a slurry of 35% water, and then dewatered in a two stage process of centrifuge and thermal drying. Resulting coal coke contains 25% moisture. Tests of direct evaporation have been conducted showing resultant heat loss due to latent heat of vaporization to be 5% of the coal's B.T.U. value (3).

An example of an existing coal slurry pipeline is the operation connecting the Peabody Black Mesa mine in Arizona with a power station in Nevada, a distance of 273 miles. Water for the 36 million dollar system is secured from deep wells. Coal from the mine is wet-ground to 8 mesh, slurried and placed in storage tanks. The slurry is pumped from four 630,000 gallon tanks to the pipeline system, which is capable of pumping 660 tons per hour of coal at 50% solids by weight. The flow rate is 4,200 gallons per minute at 4 miles per hour. Transit time is three days. Four pumping stations with driving horsepower of 1,500 to 1,750 are required for the 18" pipeline to transverse terrain that varies in elevation from 500 to 6,500 feet. The line is high pressure steel welded pipe carrying operating pressures that vary from 1,000 to 1,500 pounds per square inch. Slurry is delivered to 7.8 million gallon storage tanks at the power plant site where 75% of the water is removed. The resulting wet cake is dried and further pulverized for combustion.

Other slurry pipeline projects being considered include an 800 mile system from the Rocky Mountain area to the Pacific Northwest. This system would utilize methanol, produced from coal, as a liquid medium. In this manner, the entire slurry can be burned without a water-disposal problem.

Conventional slurry pipeline systems require a large quantity of water to operate, which is the major environmental problem. The "Project Independence" scenario previously mentioned calls for con-

struction of four new 25 million ton per year slurry pipelines to assist in transport of western coals. Based on a slurry of 50% water by weight, the annual water requirements would be 7.36×10^4 acre feet of water. This water requirement is derived as follows:

$$\frac{100 \times 10^6 \text{ tons} \times 2{,}000 \text{ lb/ton}}{8.34 \text{ lbs/gallon} \times 3.259 \times 10^5 \text{ gallons/acre.ft.}} = 7.36 \times 10^4 \text{ acre feet of water}$$

This water is to be taken from an area of the country already depleted by other forms of energy development such as oil shale, electric power generation and coal gasification. If coal slurry pipelines are to be utilized on a large scale, water use priorities must be established.

Trucks

Trucks are the most popular form of transporting coal from the surface mine pit to the next stop enroute to consumption. New designs trend toward larger tonnage sizes. Larger models include off-highway vehicles which were introduced about 10 years ago. A diesel engine drives an electric generator which, in turn, powers electric traction motors. Motors form the hubs of the wheels, and are fed electrically from the generator. High horsepower can be transmitted smoothly and efficiently since the design eliminates need for a differential, mechanical power transmissions and clutches. When driving downhill, the motors act as dynamic retarders and brake the truck. The power system can deliver up to 1,600 horsepower and payloads of 200 tons.

Bottom-dump tractor-trailers are gaining in popularity at large mine sites because they generally operate at a low cost per ton hauled. This is due to relatively low initial and maintenance costs, and ability to move large volumes of material for a given horsepower design. These vehicles are not suited to rough or hilly terrain or to operations requiring highway haulage.

All-wheel drive trucks solve the problem of difficult grades and tight turns. The diesel powered vehicle delivers power to a torque conventer, which delivers total power to a transmission. Equal traction at all four wheels is accomplished.

Tandem-drive dump trucks are being used for rugged up-and-down mountain climbing but the workhorse of the industry is still the standard 25 ton diesel powered dump truck.

Truck shipments of bituminous coal were approximately 68 million tons in 1973 (5). Pennsylvania and Ohio accounted for over 50% of this volume. The major environmental problem associated with truck transport is airborne particulates emanating from dirt roads used in hauling coal on or off the mining site. The conventional method of handling this problem is roadway wetting with a water truck. High rates of evaporation in arid sections of Region IV have compounded the problem. Special wetting agents are being mixed with water to decrease evaporation rates at these operations. Wind loss during highway transport by trucks has been significantly reduced with the aid of canvas covers. Some environmentalists view on-site haul roads remaining after post-mining operations as environmental damage. The Bureau of Mines will evaluate this issue in proposed research of area surface mining techniques.

STORAGE

Advanced technology in coal transportation methods make storage of coal an increasingly important part of coal handling systems at mines, preparation plants, railheads, and points of use. Better storage practices increase efficiencies of the surface mining industry for the following reasons:

- Allows different segments of the flow process from mine to consumer to operate independently with delays in one area not affecting the operation of the other;
- facilitates blending;
- allows prompt and economical loading of unit trains or barges;
- permits maximum shipping during good weather (i.e. Great Lakes);
- keeps coal on hand for domestic and truck trades;
- allows a preparation rate different from production rate.

Storage Problems & Solutions

Coal will heat spontaneously in storage due to its tendency to oxidize. This tendency is closely correlelated with its rank. The higher the rank, the less tendency to oxidize. Lignite and sub-bituminous coals are difficult to store without occurrences of spontaneous combustion, in contrast to anthracite which has never been known to ignite spontaneously (7).

The size-consist of coal in the pile is an important factor that will effect natural ventilation. Run-of-mine coal is difficult to store because of large percentages of fines mixed with lumps. This will not allow adequate removal of sensible heat as fast as it is liberated in the oxidation process. A chain reaction follows in that the oxidation rate is directly proportional to temperature.

Amount and size of pyrite present in stored coal will also affect oxidation rates. The union of pyrite (FeS_2) with water and oxygen results in the formation of iron sulfate and sulfuric acid, which is an exothermic reaction ($S^{--} SO_4$ + 217 k Cal/mole). If coal is stored in the open, rain may speed this reaction. Ironically, flooding with water to extinguish fires may, for the same reason, increase the rate of oxidation (1).

Presence of foreign materials, time in storage and the method by which the pile is constructed are factors that effect oxidation and spontaneous combustion. Complexity of the factors just cited make prediction of behaviors of storage piles difficult, however, coal can be safely stocked if the following precautions are taken: Storage areas should be dry with good drainage; the area should be free of all combustible material with low ignition temperatures; coal delivered to storage should be spread over the entire area in thickness of about one to two feet and compacted; stockpiles designed with reclaiming tunnels should contain adequate ventilating systems to reduce the hazard of an explosive atmosphere originating from an accumulation of methane and coal dust (8).

Rail Loading

The advent of unit trains created a problem of sufficient storage capacity for loading. Open storage was the most common method of accu-

mulating enough coal for unit train loadings. Conical piles fed by conveyor and situated over a reclaim tunnel were most popular, however all problems previously mentioned in this section manifest themselves with open storage. Silo storage has more recently replaced open storage in unit train loading. Single or cluster silos with standard capacities of approximately 10,000 tons are constructed of concrete or metal and work in conjunction with conveyor charging systems. Cluster silos can split car loading feed for blending, sizing, or separate handling of steam and metallurgical grade coals.

Water Loading

Barge loading of coal may be accomplished with the elevating boom type plant. If the river level fluctuates over a wide range, a spar barge system can be used. Unloading of barges is usually the concern of the coal consumer. Early barge unloadings were accomplished largely by whirler type cranes or clam shell buckets. The continuous bucket type systems are growing in popularity because of higher unloading rates and lower maintenance costs. Coal ships incorporate systems of rotary elevator belt unloaders or inclined belt unloaders.

Advanced Design

An example of large scale coal storage design trends is the Superior, Wisconsin terminal storage facility being built to store coal during periods when the Great Lakes are frozen. This system contains a high-line tripper for stockpiling and reclaiming coal in a dust free manner.

In summary, if proper methods and procedures of storage pile design are practiced, problems of safety, economics, and environmental concern, can be avoided.

REGIONAL TRENDS

Transportation of coal from the working pit of a surface mine to point of consumption varies greatly within each of the four regions surveyed

for this project. Therefore, care must be taken not to stereotype transportation methods within each region, however, general trends in coal transport will be discussed.

By far, the most popular means of transporting coal from the pit in Region IV is the bottom-dump diesel truck with electric powered wheels. The common size range is 120 to 180 tons, although one North Dakota lignite mine has utilized 200 ton models. These bottom-dump tractor trailers are used at the larger western mine sites because they have relatively low initial and maintenance costs, resulting in low cost per ton hauled. Most western mines have a terminal point at the periphery of the property. Trucks transfer coal to a conveyor system, which in turn transports coal to an adjacent power plant, slurry pipeline preparation plant, or rail loading facility. Conveyor systems range in length from less than 100 yards to more than 6 miles. One large western mine utilizes a unit train to transport coal from the pit area to a power plant located at the edge of the mine site. However, flat topography and high production rates are prerequisites for on-site rail usage. Therefore, widespread use of this method is unlikely.

Bottom-dump tractor trailers are not well suited for hilly or rough terrain, therefore Regions I and II rely heavily on conventional 25 ton diesel dump trucks. These trucks are also used because the majority of transfer points in Region I and II surface mines are located off-site--requiring transport on public roads. The surface mining industry in Regions I & II consists of large numbers of relatively low production pits on various sites, making individual mine transfer points impractical. Preparation plant or rail haulage transfer facilities usually serve several operations. Region III site transport is a combination of the methods discussed in the other three regions. Production rates and mine life expectancy are the two major factors that dictate practicality of mine site transfer in all four regions.

Transportation methods from the first off-site transfer point to point of coal consumption in each region is a decision based on availability of water or rail equipment. The most economical method to transport coal is by water. In ascending economic order other methods are: unit trains, slurry pipeline, shuttle train, and truck. Unfortunately water transport is limited to only portions of Regions I, II, & III. The rail systems in Regions I & II have deteriorated to the point that coal transport distances of over 300 miles by truck have been verified. The transportation equipment

section of this report contains statistics showing relative impact of waterway, slurry pipeline and rail transport in each region.

In 1970 the United States Bureau of Mines released Information Circular 8614, "Comparative Transportation Costs of Supplying Low-Sulfur Fuels to Midwestern and Eastern Domestic Energy Markets" (4). This circular contained a table of comparative costs for supplying high and low sulfur coal from selected producing districts to selected consuming regions. 1970 prices were used in the circular. Methodology used to derive the delivered coal prices is explained in Appendix B of the circular. The formula derived in Circular 8614 for transport distances less than 300 miles was:

$$\frac{\text{Cost of coal/ton}}{\text{B.T.U. Content/ton}} + \frac{103.5 + 1.124\,(\text{distance}) - 0.0081\cdot(\text{distance})^2}{\text{B.T.U. Content/ton}}$$

= Cost of coal at consumption point (cents/million B.T.U.)

The formula used for transport distances greater than 300 miles was:

$$\frac{\text{Cost of coal/ton}}{\text{B.T.U. Content/ton}} + \frac{33 + 0.38\,(\text{distance})}{\text{B.T.U. Content/ton}}$$

= Cost of coal at consumption point (cents/million B.T.U.)

L. W. Westerstrom of the Bureau or Mines was contacted and 1973 F.O.B. coal prices secured. Using Table B-1 of I.C. 8614, the average B.T.U. value per ton of coal in each producer district was secured and factored into the calculations. A revised table is shown in this report as Table 7-4.

In 35 of 42 cases the cost difference of supplying low versus high sulfur coal increased since the original B.O.M. study was released. This reflects a higher rate of cost increase for low sulfur western coal when compared to high sulfur coal mined in the eastern half of the United States.

This cost trend indicates an additional incentive to remove pyrite from eastern coals with advanced preparation methods rather than cross country transport.

TABLE 7-4

Comparative costs of supplying high and low sulfur coal from selected producing districts to selected consuming regions, 1973.

Producer district		Consumer Region: South Atlantic (Richmond, Va.) Cost of coal per million Btu[2] Low sulfur	High sulfur	Cost difference	Middle Atlantic (New York, N.Y.) Cost of coal per million Btu[2] Low sulfur	High sulfur	Cost difference	New England (Boston, Mass.) Cost of coal per million Btu[2] Low sulfur	High sulfur	Cost difference
16 and 17	Northern and Southern Colorado (Denver)	0.780	0.401	.379	0.800	0.348	.452	0.822	0.378	.444
18	Arizona and New Mexico (Albuquerque, N. Mexico)	0.493	0.401	.092	0.521	0.348	.173	0.544	0.378	.166
19	Wyoming (Cheyenne)	0.525	0.401	.124	0.536	0.348	.188	0.555	0.378	.177
20	Utah (Salt Lake City)	0.813	0.401	.412	0.822	0.348	.474	0.839	0.378	.461
21	North and South Dakota (Fargo, N. Dakota)	0.592	0.401	.191	0.605	0.348	.257	0.635	0.378	.257
22	Montana (Billings)	0.549	0.401	.148	0.557	0.348	.209	0.577	0.378	.199
23	Washington (Seattle)	0.910	0.401	.509	0.918	0.348	.570	0.939	0.378	.561

Producer district		Consumer Region: East North Central (Chicago, Ill.) Cost of coal per million Btu[2] Low sulfur	High sulfur	Cost difference	West North Central (St. Louis, Mo.) Cost of coal per million Btu.[2] Low sulfur	High sulfur	Cost difference	East South Central (Vicksburg, Miss.) Cost of coal per million Btu.[2] Low sulfur	High sulfur	Cost difference
16 and 17	Northern and Southern Colorado (Denver)	0.617	0.428	.189	0.595	0.298	.297	0.651	0.450	.201
18	Arizona and New Mexico (Albuquerque, N. Mexico	0.379	0.428	-.049	0.355	0.298	.057	0.339	0.450	-.111
19	Wyoming (Cheyenne)	0.378	0.428	-.050	0.364	0.298	.066	0.431	0.450	-.019
20	Utah (Salt Lake City)	0.685	0.428	.257	0.674	0.298	.376	0.714	0.450	.264
21	North and South Dakota (Fargo, N. Dakota)	0.352	0.428	-.076	0.402	0.298	.104	0.548	0.450	.098
22	Montana (Billings)	0.389	0.428	-.039	0.395	0.298	.097	0.496	0.450	.046
23	Washington (Seattle)	0.747	0.428	.319	0.761	0.298	.463	0.867	0.450	.417

[1] For methodology see appendix B of I.C. 8614. Cities in parentheses represent point of origin or destination for calculation of distance.

[2] Low-sulfur coal is from producer district given. High-sulfur coal given is least-cost-available high-sulfur coal (transportation cost + F.O.B. mine price) for each consumer region.

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CHAPTER 8

COAL PREPARATION

GENERAL

Coal cleaning has progressed from early hand picking practices for removal of gross refuse material to present technology capable of mechanically processing coal fines and slimes, permitting greater recovery of selected compositions. These technological advances were introduced with mechanization of mines and were stimulated by more stringent market quality requirements and increased coal production rates. Approximately 49 percent of United States' bituminous coal production (1971) was mechanically cleaned (1). Depending upon the degree of preparation and nature of the raw coal, preparation can: produce a uniformly sized product; remove excess moisture; reduce ash content; reduce sulfur content; and increase calorific value. It can also enable effective coal composition management.

Coal markets have greatly influenced the degree of preparation required for coal produced from any particular mining operation. Traditionally, utility (steam) coal has been subject to less extensive preparation than has metallurgical coal because the coke industry has the most stringent standards of all major coal consuming industries. Detailed preparation provides a uniform product with reduced sulfur and ash content important to coke plant, blast furnace, and foundry-cupola operations. Although utility coal must have relatively uniform size, economic benefits accrued from extensive cleaning have not been sufficient to offset additional preparation costs. However, more complete cleaning of utility coal may be required with increased enforcement of sulfur dioxide emission limitations for power generating plants. Responsibility for controlling stack emissions will be placed on electric and mining companies. Generating stations will eventually be required to install scrubbers or similar equipment for sulfur removal from gases, or the mining companies will be forced to supply a clean low sulfur coal.

Three general stages of preparation are practiced within the coal mining industry. Coal preparation plants are individually grouped in these stages according to degree of cleaning and unit operations.

STAGE 1: CRUSHING AND SIZING - BASIC CLEANING

This stage of coal cleaning is basic and involves only crushing and

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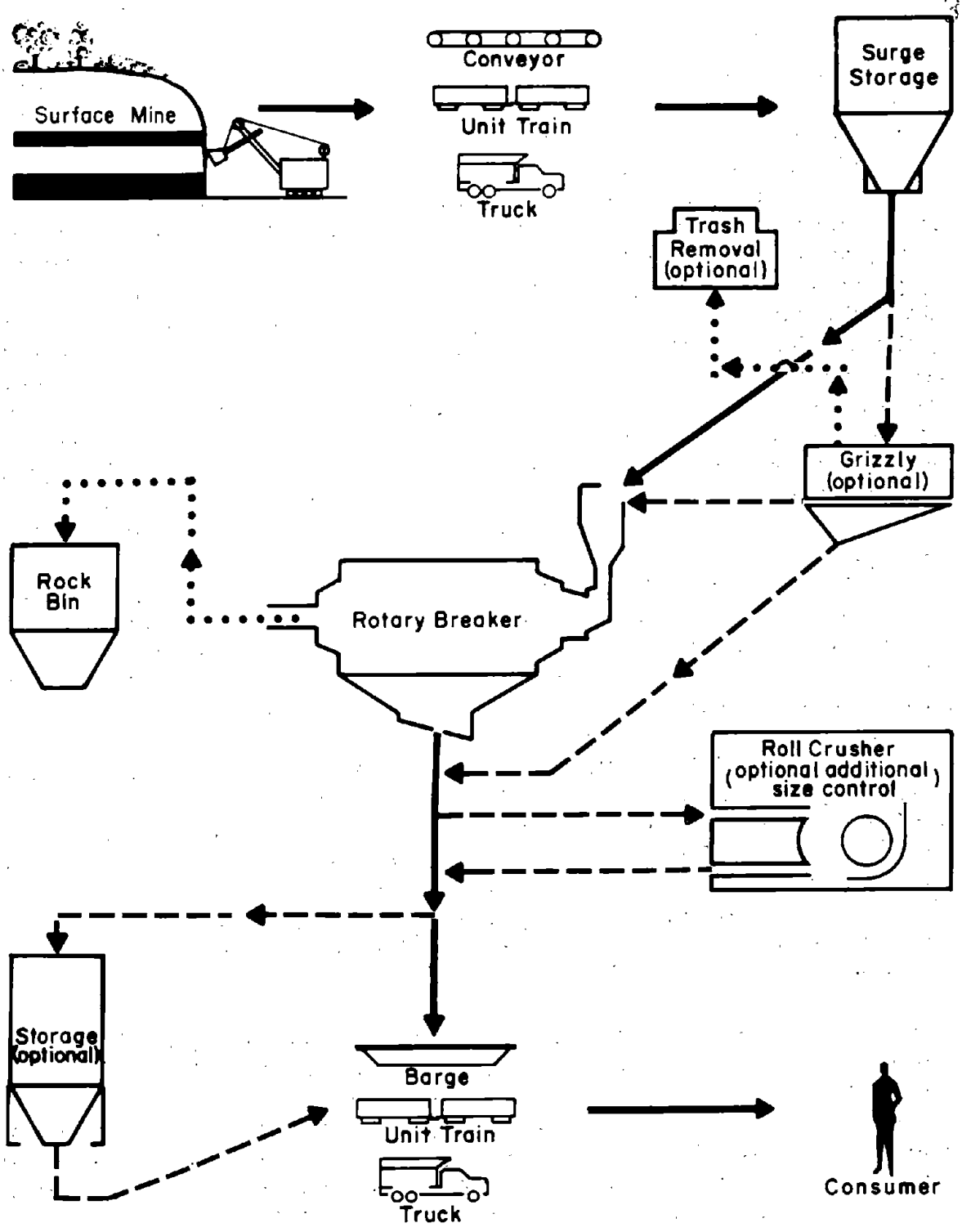
sizing. Preparation plants grouped in this stage always perform primary crushing, and in many instances secondary crushing is also employed to effect further size control. The two major objectives in Stage 1 preparation are: 1) a reduction of raw coal to uniform market sizes; and 2) segregation of refuse material which usually appears as reject from the first screening. Since these goals are accomplished with removal of only large refuse material, Stage 1 cleaning plants achieve maximum calorific recovery (approximately 95 percent clean coal) but minimal improvement in ash and sulfur contents.

Equipment used in this cleaning process is common to all stages of preparation. A variety of comminution units are employed, including single and double roll crushers, rotary breakers, hammer mill and ring crushers, and pick breakers. Rotary breakers (Bradford breakers) serve a dual function by breaking coal to a predetermined top size and removing refuse and trap iron. Thus, this particular comminution unit receives wide use throughout the coal industry.

Screens are usually employed in conjunction with crushers to provide additional segregation or sizing of coal. Moving and stationary screens are available to accomplish desired sizing. The most common screens are punched plate and woven wire vibrating screens.

Flow paths of coal and refuse within a typical Stage 1 preparation plant are shown in Figure 8-1. This flow diagram illustrates the location of standard and optional equipment in an entire cleaning system. A water circuit is not included in plant design because Stage 1 preparation is usually a dry process. Lack of plant process water limits water pollution potential to surface runoff near the plant and from refuse disposal areas. Proper planning and maintenance can usually ameliorate pollution at these locations.

Noise and dust associated with all preparation processes present the principal health and safety problems. To prevent possible hearing damage, plant operators are furnished with ear plugs or similar devices and additional protection is afforded by minimizing contact time in areas having high noise levels. Dust is reduced by enclosing coal crushing and transfer locations. The Health and Safety section of this report outlines all dust and noise measurement procedures.



STAGE I - COAL PREPARATION PLANT
Figure 8-1

STAGE 2: HYDRAULIC SEPARATION - STANDARD CLEANING

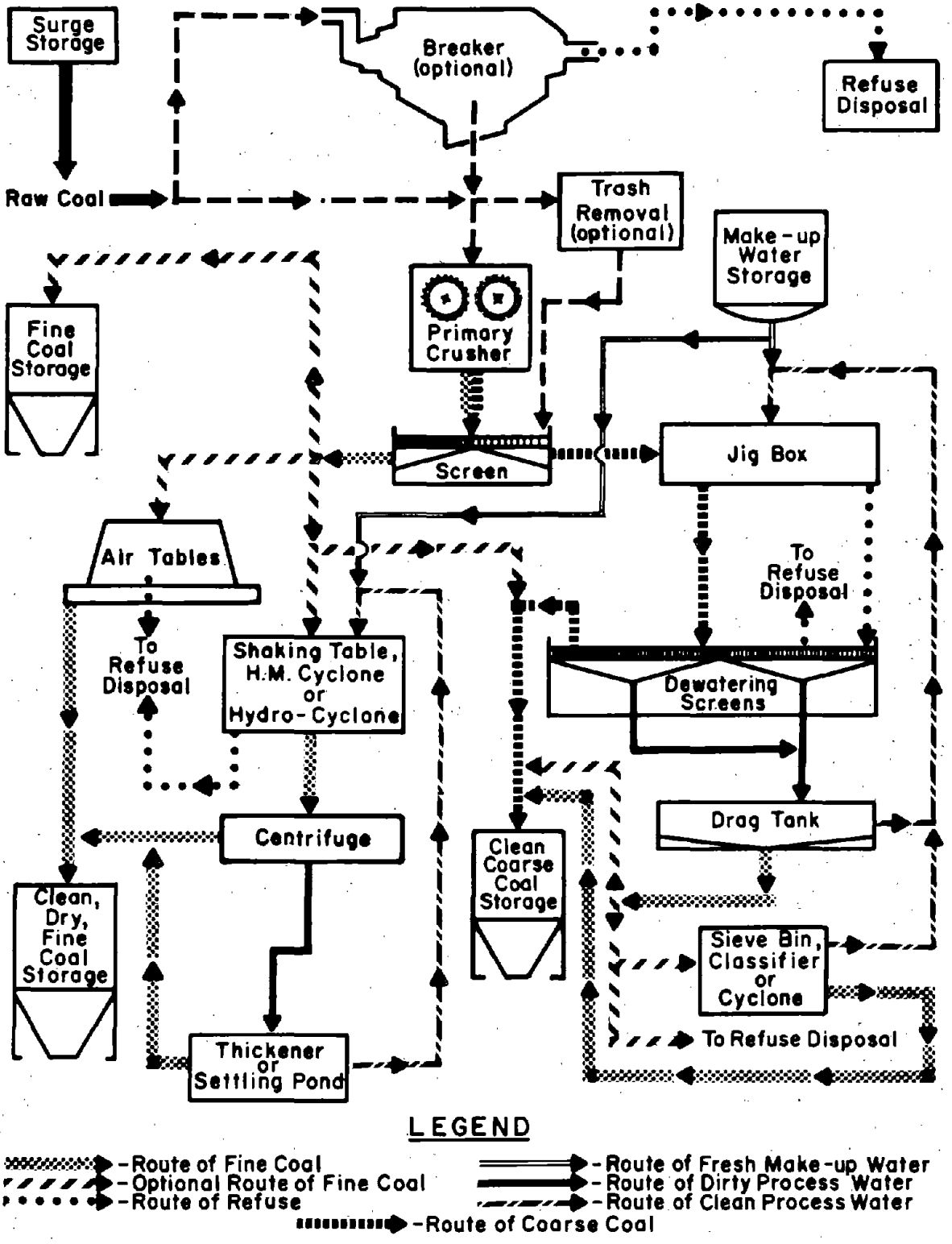
Stage 2 coal preparation is a standard system that has provided a clean coal product ideal for the utility coal market. This process typically incorporates comminution and sizing to about 3 to 4 inches top size, and optional by-pass of 3/8 inch material. Coal cleaning is accomplished by jigs using a pulsating fluid flow, inducing particle stratification via alternate expansion and compaction of a bed of raw coal. Density segregation is effected with dense impurities in bottom layers and clean coal in upper layers of the particle bed. A primary objective of Stage 2 preparation is removal of liberated mineral matter by cleaning at high gravity. This provides a uniform product with reduced ash and sulfur content. Coal preparation plants employing this system accrue a high calorific recovery with some inherent loss of combustible material (85 percent clean coal recovery). Percent recovery is a function of how dirty the coal is initially.

Dry fine coal cleaning circuits utilize air cleaning tables. A thermal dryer may be incorporated to reduce moisture in advance of air cleaning because excessive moisture can lower the efficiency of air cleaning processes. Fine coal cleaning circuits employ shaking tables, hydrocyclones, or heavy media cyclones for cleaning fines, and extreme fines are by-passed to refuse or blended with coarse coal. Mechanical drying (centrifuge) is usually required with wet cleaning of fine coal. Thermal dryers are used for fine clean coal only when necessary.

Fine coal is usually not cleaned and is directly blended with coarse clean coal. However, Stage 2 preparation plants can be modified to include a fine coal circuit for cleaning (3/8 inch) material. Cleaning of fine coal involves either wet or dry processing and provides additional quality control.

Unit operations in Stage 2 preparation plants are: Primary crushing; sizing; gravity separation of coarse coal; dewatering of clean coal and refuse; and removal of fines from process waters. The following equipment is frequently employed to perform individual unit operations: single or double roll crushers and vibrating screens for comminution and sizing; jigs for gravity separation; vibrating screens for dewatering; and drag tanks and thickeners or settling ponds to remove coal fines.

Material transfer and equipment locations for a Stage 2 preparation



STAGE 2-COAL PREPARATION PLANT

Figure 8-2

plant are shown in Figure 8-2. Since most preparation utilizes wet processing, degradation of process water will undoubtedly occur. Suspended solids are the greatest pollutant, and inclusion of a fine coal cleaning circuit intensifies this problem. Closed water circuits with either thickeners or settling ponds to remove fines ameliorate most of the water pollution problems.

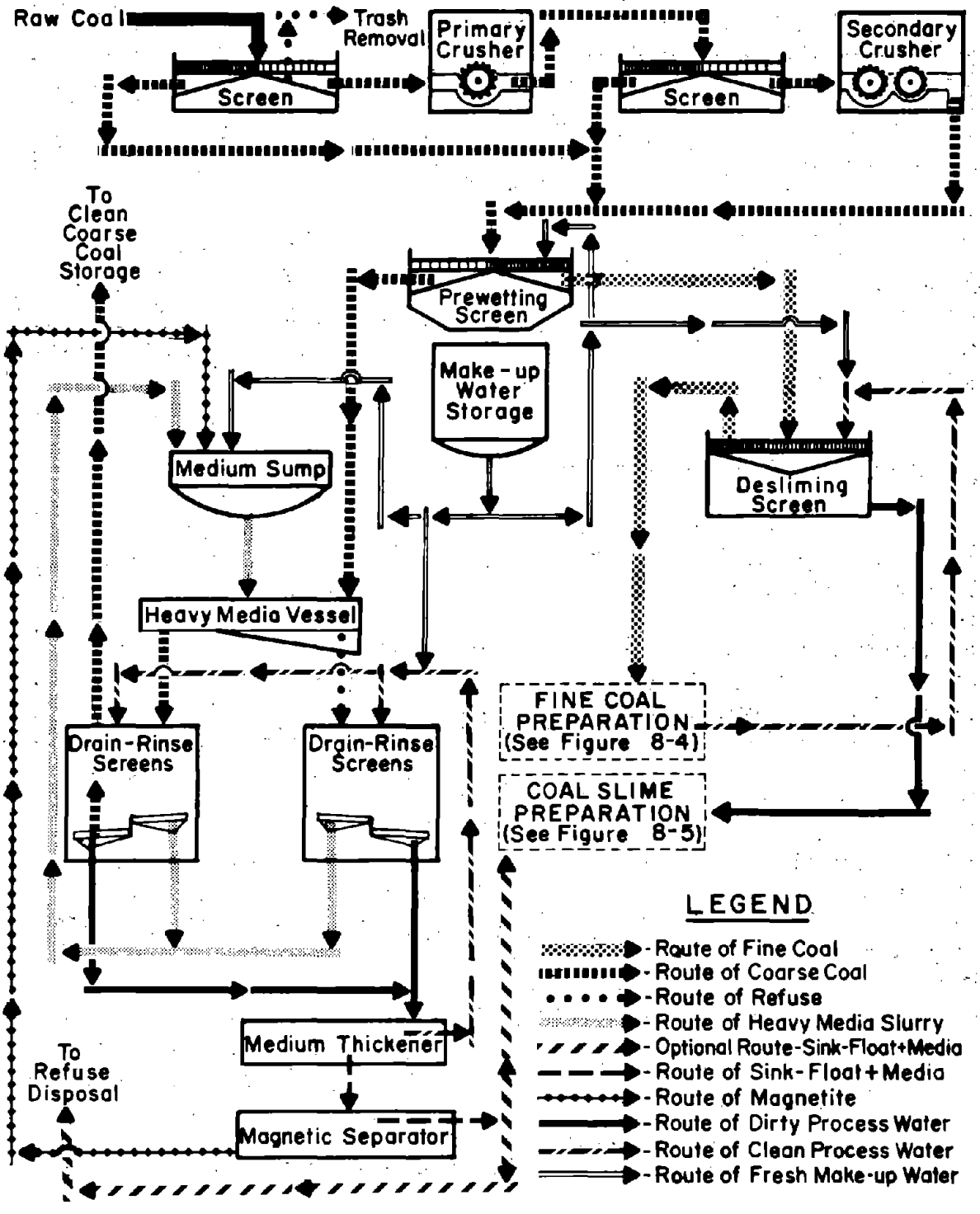
A majority of Stage 2 preparation plants surveyed during this study had closed water circuits. In addition, pH control was occasionally used to limit acid concentration. This usually involved addition of lime to make-up water. Treatment of these small quantities of make-up water is less costly than treatment of larger quantities of recycled water.

STAGE 3: DENSE MEDIUM SEPARATION - COMPLETE CLEANING

Coal preparation plants grouped in Stage 3 provide complete and sophisticated coal cleaning. Most metallurgical coal is subject to this detailed preparation, resulting in a superior quality, uniform product having reduced ash and sulfur to meet prescribed specifications. Sized raw coal is cleaned in a Stage 3 preparation plant by immersing it in a fluid acting at a density intermediate between clean coal and reject. This produces a stratification of material according to specific gravity. Magnetite is the most common dense media employed for cleaning coal, although sand is still occasionally used.

These processes are predicated on a size reduction to attain the maximum liberation (freeing of particles) that can be economically justified. A resultant increased development of fine particles requires additional processes to achieve maximum coal recovery (approximately 70 percent), to meet water content specification of the clean coal, and to control the water circuit. Major unit operations involved in the complexities of Stage 3 preparation are: comminution; sizing; gravity separation; optional secondary separation; dewatering; heavy media recovery; and water control.

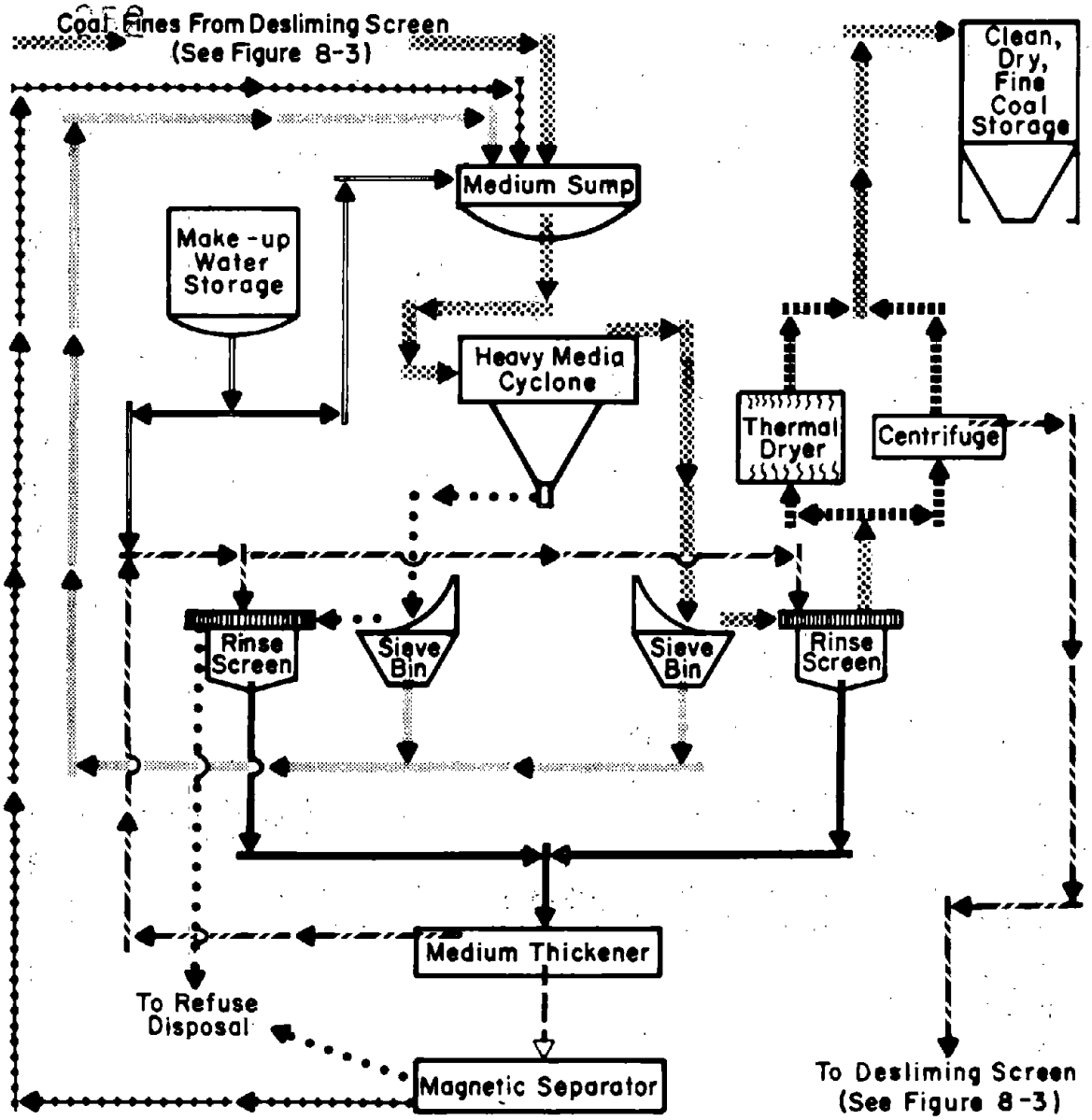
Equipment used in Stage 3 preparation plants varies according to product requirements and individual operator preferences based on raw coal characteristics. Comminution is primary crushing usually by a single roll crusher and secondary crushing using a double roll crusher. Material from the crushers is screened with topsize (1½ to 3/4 inches) going to



STAGE 3 - COARSE COAL PREPARATION PLANT

Figure 8-3

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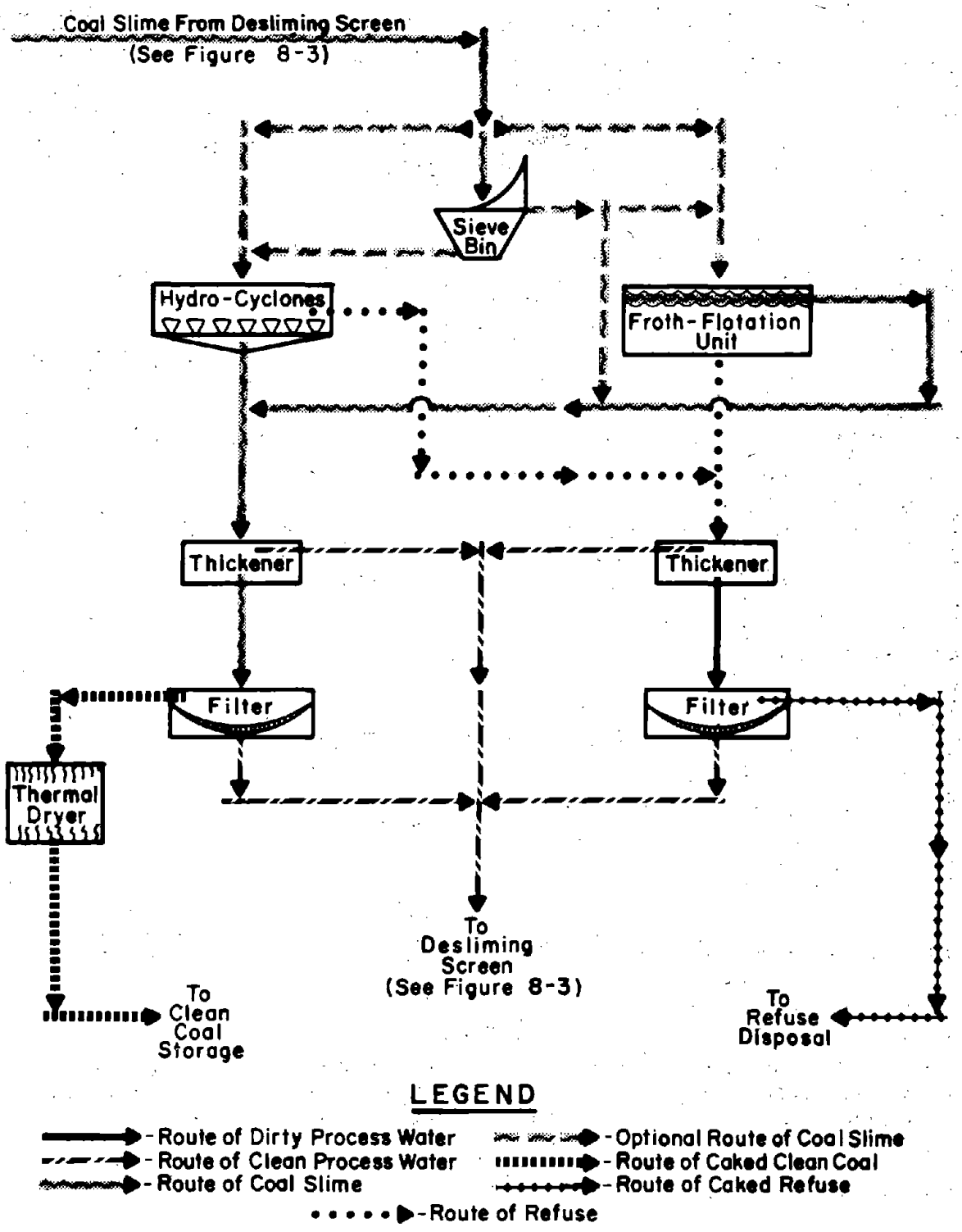


LEGEND

- Route of Sink-Float+Media
- Route of Magnetite
- Route of Dirty Process Water
- Route of Clean Process Water
- Route of Fine Coal
- Optional Route of Fine Coal
- Route of Refuse
- Route of Heavy Media Slurry
- Route of Fresh Make-up Water

STAGE 3 - FINE COAL PREPARATION PLANT

Figure 8-4



STAGE 3 - COAL SLIME PREPARATION PLANT

Figure 8-5

coarse coal cleaning and undersize to fine coal and slimes cleaning. Coarse coal separation is generally accomplished with heavy media vessels (1.35 - 1.45 gravities), and fine coal separation by heavy media cyclones (1.32 - 1.45 gravities). Slimes cleaning usually involves hydrocyclones and/or froth flotation cells.

Clean coarse coal and refuse from heavy media vessels are dewatered on drain and rinse screens. Dewatering of the fine coal and refuse from heavy media cyclones includes sieve bins and centrifuges as well as drain and rinse screens. Proper dewatering of slimes usually requires filtering and thermal drying. Thermal dryers are also occasionally employed to dewater fine coal from centrifuges. Since magnetite is a common heavy media used for coal separation, recovery and reuse of media is an economic necessity. The last process in a Stage 3 cleaning plant is removal of particulate matter from process waters by thickeners (sometimes settling ponds) prior to discharge or recycling. Figures 8-3, 8-4, 8-5, depict a typical Stage 3 coal preparation plant for coarse, fine, and coal slime recovery.

Most Stage 3 preparation plants have closed water circuits using thickeners to maintain acceptable loads of suspended solids in recycled water. Froth flotation commonly utilizes pH control because both product quality and recovery can be affected. Thus, lime is often added to make-up water to maintain a pH between 6.0 and 7.5 (2). As with Stage 1 and 2 preparation plants, Stage 3 plants require well planned disposal of refuse to minimize environmental degradation.

WASTE HANDLING AND DISPOSAL

Preparation plants produce two forms of refuse - solid and slurry - which require dissimilar handling and disposal methods. Common surface mining practice is to truck solid wastes to mined out pits with subsequent backfilling and revegetation. However, Stage 2 and 3 preparation plants which employ wet cleaning are responsible for disposal of slurry refuse.

Pipelines are the principal transport mechanism for slurry material. Lagoons, ponds or similar impoundments serve as disposal and dewatering sites that require careful planning to eliminate water pollution. Considerations include:

- sufficient storage area for the waste
- drainage control including infiltration and surface run-off (compaction, basin lining, diversion trench)
- if necessary treatment plan for dry drainage
- establishment of a final reclamation plan following mine abandonment-compacting, layering, topsoil cover, neutralization (for acid conditions), and revegetation.

COAL PREPARATION COSTS

Plant type and capacity are the major factors determining the capital and operating costs associated with coal cleaning. Results of a survey that included over fifty preparation facilities indicate initial plant costs range from 0.3 million to 25 million dollars - capacities varied from 50 to 1,500 tons per hour. The low figure represents small Stage 1 plants while the higher cost is associated with Stage 3 preparation facilities. Cost data is presented in the Systems Analyses Section of this report (Table 9-108). This represents total costs allocated to coal preparation as a unit operation within the individual case history mines.

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Chapter 8 - COAL PREPARATION

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2. Sokaski, M., H. F. Yancey, A. W. Deuerbrouck, and E. R. Palowitch. Wet Concentration of Fine Coal. American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York, Ch. 10, 3rd ed., 1968, pp. 10-1 - 10-90.

3. Truax-Traer Coal Company (Pinckneyville, Illinois. A Division of Consolidation Coal Company). Control of Mine Drainage from Coal Mine Mineral Wastes: Phase I Hydrology and Related Experiments. U. S. Environmental Protection Agency, Washington, D. C., Water Pollution Control Research Series 14010 DDH, August, 1971, 148 pp.

CHAPTER 9

SYSTEMS ANALYSES

GENERAL

This chapter presents detailed systems analyses of mining within each of the four regions, defined in previous report chapters: Region I - West Virginia, eastern Kentucky, Tennessee, Virginia; Region II - Pennsylvania, Maryland, Alabama and southeastern Ohio; Region III - Midwestern states; Region IV - Western states. Case histories, discounted cash flow (with complete equipment, manning, and materials listings), sensitivity, risk, and computer simulations were all closely evaluated and comprised the data base for deriving systems analyses.

Narratives are presented for at least three representative mines within each Region. These case histories describe pertinent geographic, topographic, geologic and climatic conditions, in addition to detailed discussions of mining unit operations and auxiliary functions. Unit operations differing from those described as typical for a Region (Chapter 3), are noted in the narratives. Variations in unit operations provide a major basis for evaluating each mine's costs. Major problems and production delays are mentioned because they lend much insight into cost parameters.

Detailed discounted cash flow analyses were performed for each mine using information obtained from personnel during mine visitation. In instances of data gaps regarding equipment and material costs, manufacturers' suggested retail prices were used. Thus, equipment prices reflect economics for the period of this study and all wages are those effective October, 1974, in accordance with the Bituminous Wage Agreement of 1971. Exceptions are mines that pay more than union rate in order to retain highly qualified and experienced mine personnel. Since most portions of the cost analyses do include costs developed through consideration of materials input, it should be understood that final results represent typical operations rather than exact reflections on the case study mines.

The following formulas and symbols were used with annual discounting tables to determine a coal selling price:

$$P = R \times \frac{(1 + r)^n}{r(1 + r)^n}$$

P = total capital requirements

359 R = present value of P due in 20 years (15 years for Mine 4E) at 15% compound interest

r = 15%

n = 20 years (15 years for Mine 4E)

Depletion = 10% of total sales not exceeding 50% of gross profit

Federal Income Tax = 50% of taxable income

Annual Cash Flow = net profit + depreciation and depletion

Coal selling prices reflect market values necessary to acquire a 15% return on capital invested at a particular operation. Although this is higher than the traditional 12% minimum return, present inflationary conditions necessitate 15% being a minimum. Some mining companies indicate a need for returns as high as 30%. Underlying factors include: lack of available capital; high interest rates; payment for large equipment prior to delivery; unknown final purchase prices on delivered equipment; escalating cost of operation supplies coupled with shortages; and uncertain impacts of pending federal legislation.

Computerized sensitivity and risk analyses are presented to depict the influence of various cost parameters on investment returns. The computer programs are listed in Appendix 3. Sensitivity graphs provided with each case history mine - Mine 2J is an exception - illustrate changes in return on investment (ROI) due to fluctuations in the following cash flow factors:

- exploration and development construction costs
- indirect costs
- equipment costs
- labor costs
- operating costs
- selling price and production

These linear functions can be used for cost planning to determine where tightest controls are necessary. In addition, the effects of pending labor or equipment cost increases can be studied in relation to rate of investment (ROI).

Results of separate risk analyses are given for Regions I and II. Insufficient responses to risk related questions in conjunction with undefined factors (such as inflation and penalty clauses in long term coal market contracts), negate risk analyses for Regions III and IV. However, probability distribution graphs are included to illustrate risk involved with mining in Regions I and II and risk factors are discussed for Regions III and IV.

CASE HISTORY - MINE 1A

Mine 1A of Region I is located in eastern Kentucky, where the virgin land is steep forested hills with streams dissecting and draining the area. The area experiences approximately 49 inches of rainfall per year with a mean temperature around 59°F. Temperature usually varies from 0°F to 100°F. Flash flooding can be a problem in eastern Kentucky.

Mine 1A is a large multi-pit operation which extracts the upper, lower and middle Hance seams. Seam thicknesses are 18 inches, 22 inches, and 40 inches respectively. The Hance seams are relatively flat lying, consistent seams of bituminous coal. Having 12,200 BTU, 10-13% ash, and 1.0% sulfur content in the raw state, the coal requires only hand picking of "slate material" and primary crushing before it is shipped to electric power plants.

An average of 70 feet of sandstone and shale must be stripped before the upper Hance seam can be removed. A 12 foot shale parting separates the upper and middle Hance while 18-20 feet of sandstone, shale and limestone overlie the lower Hance. The lower Hance has a thin shale parting, but both coal and parting are loaded together. The generally thick bedded overburden is fractured due to the proximity of a fault zone.

Formerly in private ownership, Mine 1A is now owned and operated by a construction company. The company's regional exploration procedures consist of core drilling test holes and, where possible, dozers expose the coal seam to obtain a bulk sample for quality determination. Very little detailed exploratory work is performed. The purpose of any detailed work here is simply to secure a coal sample and determine its quality and thickness. A full time crew employed solely for exploratory work consists of: a geologist; engineer or foreman; a driller and driller's helper; and a dozer operator.

All property is leased and royalty payments are made for mineral extraction. Geography (steep hills) and geology (faulted area) influence planning and development of the mine most directly. Past mining experience in the area and equipment availability strongly influence the final selection of the mining method and equipment to be used.

This multi-pit operation produces 1.75 million tons of coal per year. The mining process is initiated with quality timber being cleared

from undisturbed areas and the remaining scrub timber dozed away and later buried in refuse pits. Access and haul roads are built, and where feasible, topsoil is stockpiled.

If sufficient room for stockpiling soil is not available, the soil is discarded. Currently, tests are being made to see if scrub timber can be shredded or chipped and spread over regraded areas as a mulch.

Benches are constructed using dozers, and overburden is drilled and shot on 18 foot x 21 foot centers. Holes (9 inches and 10 5/8 inches) are loaded with ammonium nitrate, the ratio of blasting agent to overburden is 0.8:1.

Shovels and front-end loaders (assisted by D9 dozers when necessary) remove overburden down to the first seam and load it into rear dump trucks. The refuse is hauled away from the pit area and dumped in the head of hollows. Sometimes delays are encountered when shovels and loaders must wait for returning haul trucks. A dragline must remove overburden above the second and third seams because shovels and loaders do not have the depth and lift capabilities. Spoil material is placed into a parallel mined out cut. This entire operation combines truck haulback, mountain top removal and head of hollow fill techniques (see figure 3-8, 3-19, and 3-20).

Fragmentation of the coal is usually unnecessary, but when required, the coal is ripped with dozers. Front-end loaders load coal into 25 ton rear dump trucks which haul the coal to two primary hoppers. It takes approximately 3.5 minutes to load the coal trucks, and the trucks must wait about two minutes before they can be loaded. The coal is crushed and refuse is hand sorted. A conveyor belt transports the raw coal to stockpiles where it is then loaded into unit trains enroute to power plants.

Pan scrapers and dozers regrade the land to a gently rolling topography. An average of 8-10 inches of topsoil is spread over the area. Fescue, Rye (30-50 pounds/acre) and fertilizer (300-500 pounds/acre), are applied to the regraded area by broadcast and hydroseeding methods. A hydro-mulch and wood chips are also applied as a soil conditioner.

The major problems at this operation are shortages of ANFO and equipment parts, especially forged and cast parts. Recent shut-

downs of small foundries failing to comply with air pollution standards in the region have left a small parts supply gap that has not been filled by the larger foundries. For example, a washer that could not be obtained for a front-end loader kept the machine down for over a month.

TABLE 9-1
EQUIPMENT COST SUMMARY - MINE NO. 1A

Topsoil Removal and Reclamation	Capacity	Quantity	Total Cost
Cat. (992) Loader	10 C.Y.	3*	$308,700 (35%)
I.H. (400) Loader	10 C.Y.	3*	308,700 (35%)
Hank Euclid (R-75) Rear Dump	45 C.Y.	4*	315,000 (35%)
Hank Euclid (R-50) Rear Dump	-	4*	240,750 (35%)
I.H. Payhauler-Rear Dump	-	4*	210,000 (35%)
Cat. (D-9) Bulldozer	-	8*	536,760 (35%)
A.C. (HD-41) Bulldozer	-	1	225,000
Cat. (Twin D-9) Bulldozer	-	1	250,000
(4004 Tractor, John Deere 700 Tractor, Hydroseeder, Broadcast Seeder)	-	1 Ea.	202,000
			$2,596,910
Overburden Stripping			
Robins Drill	9"	7	$1,330,000
Bucyrus - Erie Drill	10 5/8"	1	425,000
Chicago Pneumatic Drill	10 5/8"	1	425,000
Marion (7820) Dragline	43 C.Y.	1	4,800,000
Page (728) Dragline	13 C.Y.	1	820,000
Lima-Ohio (2400) Dragline	7 C.Y.	1	600,000
Bucyrus-Erie (88-B) Shovel	6 C.Y.	1	450,000
Marion (183-M) Shovel	8 C.Y.	1	650,000
Cat.(992) Loader	10 C.Y.	3*	573,300 (65%)
I.H.(400) Loader	10 C.Y.	3*	573,300 (65%)
Hank Euclid (R-75) Rear Dump	45 C.Y.	4*	585,000 (65%)
Hank Euclid (R-50) Rear Dump	-	4*	447,110 (65%)
I.H. Payhauler-Rear Dump	-	4*	390,000 (65%)
Cat. (D-9) Bulldozer	-	8*	996,840 (65%)
Explosive Truck	-	5	50,000
			$13,115,550

TABLE 9-1 (Contd.)

Coal Removal and Loading	Capacity	Quantity	Total Cost
Cat. (988) Loader	6 C.Y.	2	$278,000
Cat. (980) Loader	6 C.Y.	1	104,000
I.H. (560) Loader	6 C.Y.	1	100,000
			$482,000
Coal Haulage (Contract out at $0.90/ton-Contractor pays wages.)			
Maintenance			
Mechanics Truck	-	6	$132,000
Welding Truck	-	4	56,000
			$188,000
Exploration			
Drill	-	1	$100,000
Cat. (D-9) Bulldozer	-	2	383,400
Cat. (D-8) Bulldozer	-	1	137,000
			$620,400

Total Cost of Equipment = $17,002,860

* Same equipment used for different operations.

TABLE 9-2
MANNING TABLE - MINE NO. 1A

Topsoil Removal and Reclamation	Total	Cost Per Year
Loader Operator	12*	$ 79,695 (35%)
Truck Driver	24*	132,248 (35%)
Dozer Operator (D-9)	16*	106,260 (35%)
Dozer Operator	4	75,900
Revegetation Equipment Operator	4	66,385
		$ 460,488
Overburden Stripping		
Driller	18	$ 298,733
Driller's Helper	18	287,100
Shooter	10	165,963
Shooter's Helper	10	159,500
Explosive Truck Driver	10	165,963
Dragline Operator	8	151,800
Dragline Oiler	8	139,590
Shovel Operator	4	75,900
Shovel Oiler	4	69,795
Loader Operator	12*	148,005 (65%)
Truck Driver	24*	245,602 (65%)
Dozer Operator (D-9)	16*	197,340 (65%)
		$2,105,291
Coal Removal and Loading		
Loader Operator	4	$ 66,385
Coal Preparation		
Prep Plant Operator	1	$ 16,596
Prep Utility Men	1	15,950
Picker	4	62,975
		$ 95,521

TABLE 9-2 (Contd.)

Coal Haulage	Total	Cost Per Year
Contract Haulage (Contract out at $.90/ton - Contractor pays wages)		-
Auxiliary Operations		
Mechanic	6	$ 104,693
Mechanic's Helper	6	95,700
Welder	4	66,385
Utility Men	4	62,975
		$ 329,753
Exploration		
Driller	1	$ 16,596
Driller's Helper	1	15,950
Dozer Operator	3	56,925
		$ 89,471
	Total Labor =	$3,146,909
Administrative		
Geologist	1	$ 15,000
Engineer	1	15,000
Secretary	3	23,400
Office Personnel	10	208,000
	Total Supervision =	$ 261,400
	Total Labor and Supervision =	$3,408,309

* Same people used for different operations.

TABLE 9-3
TOTAL ESTIMATED CAPITAL REQUIREMENTS - MINE NO. 1A

Exploration, Power Facilities, Site Preparation, Buildings and Roads		$ 3,500,000
Unit Train Loading Facilities		1,800,000
Mining Equipment		17,002,860
	Total Direct =	$22,302,860
Field Indirect (2% of Total Direct)		$ 446,057
Engineering		315,000
Overhead & Administration		1,704,155
	Subtotal =	$24,768,072
Contingency (10% of 24,768,072)		$ 2,476,807
	Subtotal =	27,244,879
Fee (2% of 27,244,879)		$ 544,898
Total Mine Cost (Base Insurance Tax) =		$27,789,777
Interest During Construction (3% of 27,789,777)		$ 833,693
Working Capital		3,324,496
	Total =	$31,947,966

TABLE 9-4
ESTIMATED WORKING CAPITAL - MINE NO. 1A

Direct Labor, 3 months		$ 852,077
Payroll Overhead, 3 months		298,227
Operating Supplies, 3 months		1,627,332
Indirect Costs, 3 months		371,911
Fixed Costs, 0.5% of Insurance Base		138,949
Miscellaneous		36,000
	Total =	$ 3,324,496

TABLE 9-5
ESTIMATED ANNUAL OPERATING COSTS - MINE NO. 1A

Direct Cost			
Labor			$ 3,146,909
Supervision			261,400
	Subtotal	=	$ 3,408,309
Operating Supplies			
Fuel			$ 964,200
Lubricants			38,568
Explosives			2,786,100
Parts, Materials & Miscellaneous			2,720,458
	Subtotal	=	$ 6,509,326
Auxiliary Cost			
Contract Coal Hauling			$ 1,575,000
Power			300,000
Communications			30,000
Union Welfare			1,750,000
Payroll Overhead			1,192,908
Health & Safety			52,500
Royalty			700,000
Strip License & Reclamation Fee			55,300
	Subtotal	=	$ 5,655,708
	Total Direct Cost	=	$15,573,343
Indirect Cost: 15% of Labor, Supervision, and Operating Supplies			$ 1,487,645
Fixed Cost: Taxes and Insurance 2% of Mine Cost			555,796
Depreciation			2,029,305
	Total Operating Costs	=	$19,646,089

TABLE 9-6
DEPRECIATION SCHEDULE - MINE NO. 1A

Item	Quantity	St. Line Deprec./Yrs.	Yearly Charge
Caterpillar (992) Loader	3	10	$ 88,200
International (400)Loader	3	10	88,200
Caterpillar (988) Loader	2	10	27,800
Caterpillar (980) Loader	1	10	10,400
International (560)Loader	1	10	10,000
Allis Chalmers HD-41 Bulldozer	1	10	22,500
Cat. (D9) Bulldozer	10	10	191,700
Cat. (Twin D9) Bulldozer	1	10	25,000
Cat. (D8) Bulldozer	1	10	13,700
Marion (7820) Dragline	1	20	240,000
Page (728) Dragline	1	20	41,000
Lima-Ohio (2400) Dragline	1	20	30,000
Bucyrus-Erie (88-B) Shovel	1	20	22,500
Marion (183-M) Shovel	1	20	32,500
Robins (9") Drill	7	20	66,500
Bucyrus-Erie (10 5/8") Drill	1	20	21,250
Chicago Pneumatic (10 5/8") Drill	1	20	21,250
Drill (Exploration)	1	20	5,000
Hank Euclid (R-75) Rear Dump	4	6	150,000
International Payhauler Rear Dump	4	6	100,000
Hank Euclid (R-50) Rear Dump	4	6	114,642
Explosive Truck	5	6	8,333
Mechanics Truck	6	6	22,000
Welding Truck	4	10	5,600
Ford 4004 Tractor	1	10	4,000
John Deere 700 Tractor	1	10	3,600
Hydroseeder	1	10	5,100
Broadcast Seeder	1	10	7,500

TABLE 9-6 (Contd.)

Item	Quantity	St. Line Deprec./Yrs.	Yearly Charge
Exploration, Power Facilities, Site Preparation, Buildings, and Roads	-	20	$ 175,000
Unit Train Loading Facilities	-	20	90,000
Depreciation: Field Indirect, Engineering, Overhead and Administration, Contingency, Fee and Interest During Construction.	-	20	316,030
Interim Equipment Cost	-	20	70,000
		Total	= $ 2,029,305

TABLE 9-7

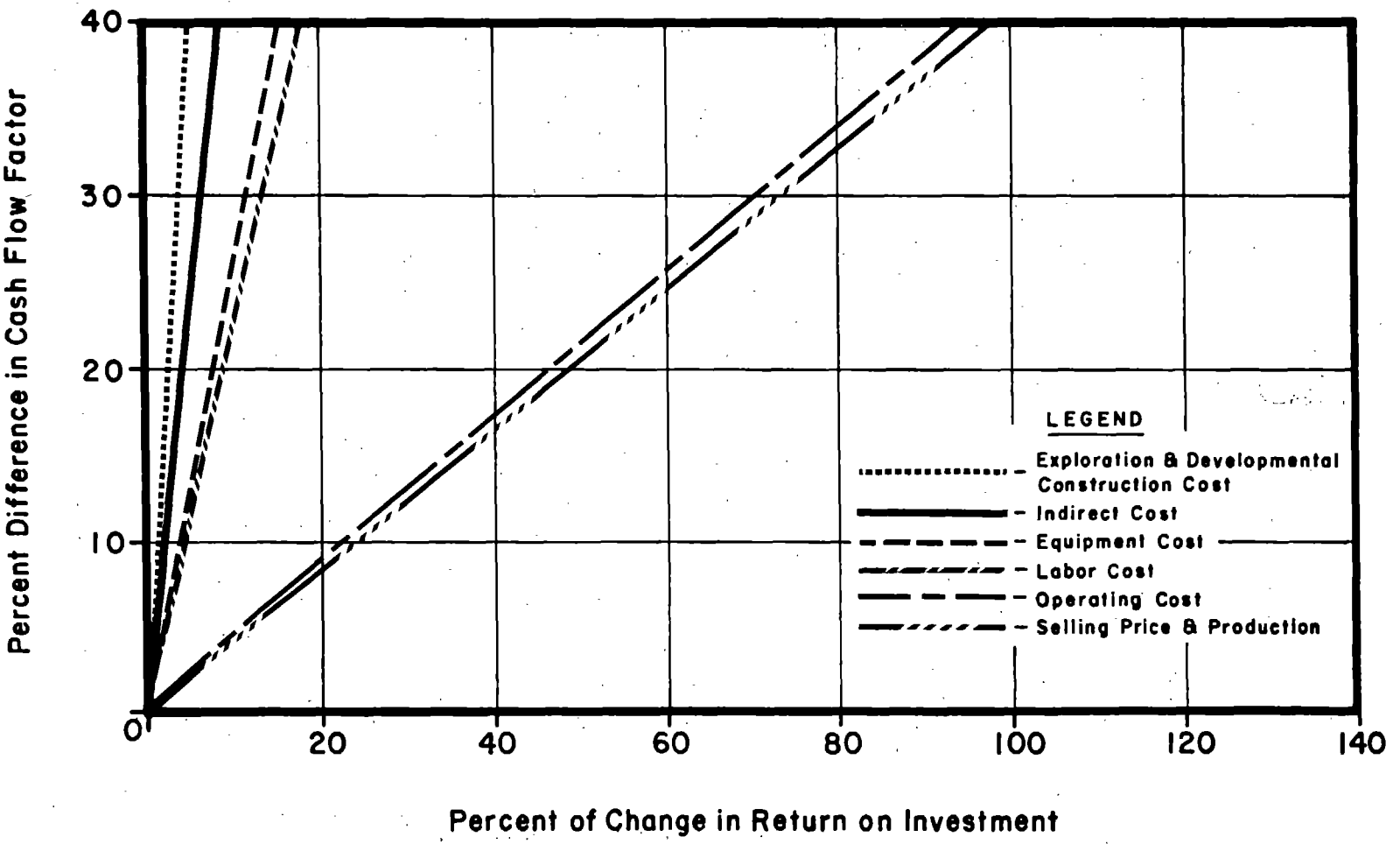
CASH FLOW ANALYSIS - MINE NO. IA

Year	Capital Investment	Cash Flow	Present Worth Factor At 15 Percent	Present Worth Capital Investment At 15 Percent	Present Worth Cash Flow Value At 15 Percent
0	$31,947,966	$-31,947,966	1.0000	$31,947,966	$-31,947,966
1	70,000	5,547,386	.8696	60,872	4,824,007
2	70,000	5,547,386	.7561	52,927	4,194,379
3	70,000	5,547,386	6575	46,025	3,647,406
4	70,000	5,547,386	.5718	40,026	3,171,995
5	70,000	5,547,386	4972	34,804	2,758,160
6	2,439,850	3,177,536	.4323	1,054,747	1,373,649
7	70,000	5,547,386	.3759	26,313	2,085,262
8	70,000	5,547,386	.3269	22,883	1,813,440
9	70,000	5,547,386	.2843	19,901	1,577,122
10	5,103,000	514,386	.2472	1,261,462	127,156
11	70,000	5,547,386	.2149	15,043	1,192,133
12	2,439,850	3,177,536	.1869	456,008	593,881
13	70,000	5,547,386	.1625	11,375	901,450
14	70,000	5,547,386	1414	9,898	784,400
15	70,000	5,547,386	.1229	8,603	681,774
16	70,000	5,547,386	.1068	7,476	592,461
17	70,000	5,547,386	.0930	6,510	515,907
18	2,439,850	3,177,536	.0808	197,140	256,745
19	70,000	5,547,386	.0702	4,914	389,426
20	-2,029,305	7,646,691	.0611	-123,991	467,213
			TOTAL	$35,160,902	0

R = $35,160,902 ÷ 6.2593	=	$ 5,617,386.00
Less depreciation	=	2,029,305.00
Depletion + net profit	=	3,588,081.00
Gross profit = 1.333 x $3,588,081	=	4,782,912.00
Sales = $19,646,089 + $4,782,912	=	24,429,001.00

Gross profit	4,782,912.00
Depletion	2,391,456.00
Taxable income	2,391,456.00
Federal income tax	1,195,728.00
Net profit	1,195,728.00

Annual cash flow = $1,195,728 + $2,029,305 + $2,391,456 =		$ 5,616,489.00
Selling price per ton = $24,429,001 ÷ 1,750,000 tons	=	13.96



SENSITIVITY GRAPH - MINE NO. 1A

Figure 9-1

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CASE HISTORY - MINE 1E

Mine 1E of Region I is located in Tennessee. The state's climate is topography related, with a general 3°F decrease in temperature per 1000 feet altitude ascended. Moist air from the Gulf of Mexico is responsible for warm humid summers and mild winters. Precipitation decreases from south to north, but this can be obscured by topographic effects. The average temperature of the coal region is approximately 45°F and the average annual rainfall is approximately 50 inches. Widespread flooding and local flash flooding during the winter and spring months of December through March can be a major concern, especially in the mountain regions and adjacent lowlands.

The area encompassing Mine 1E has typically steep hilled, densely forested, stream dissected terrain characteristic of much of Appalachia. This multi-pit operation extracts the Mason, Jellico, Winona and Rich Mountain seams. Thicknesses of these relatively flat-lying seams are 65, 54, 27 and 24 inches respectively. They undulate slightly and contain shale partings, but are consistent. With the average quality of the four seams being 12,200 BTU, 10% ash and 1% sulfur, this bituminous coal finds a waiting market at the electric power generating plants.

An average of 5 feet of topsoil and 40 feet of shale and overburden covers the coal. In places, massive sandstone lenses can be responsible for overburden thicknesses reaching as much as 80 feet.

Independently operated under new management, Mine 1E has begun to transform from a rather confused mining effort into an organized operation that shows economic promise. Previously, this mine consisted of a single pit where equipment worked in such close proximity that they were operating inefficiently. Currently, after sufficient exploratory work, permitting, and leasing, Mine 1E has expanded its operation in size and production with a decrease in equipment downtime. Because this region had been extensively mined in the past, little exploratory work was deemed necessary. Old drill core records were utilized and dozers made contour cuts to determine coal thicknesses. A series of 6 x 6 inch channel cuts were made across the face of the coal. An average sample from these channel cuts was used to determine the coal's quality.

If the coal quality analyses of the prospective area are promising, a program that plans at least two years ahead of the active mining is devised. To maximize hauling efficiency, especially in second and third cut areas, haul roads are short and close to the highways during winter months. Recent environmental regulations prohibiting casting of spoil from hilltops into adjacent valleys, and piling of spoil material on the outslopes, also influenced production methods and output. At Mine 1E, access roads remaining from previous mining activities in the area were improved. Trees were cleared and soil was isolated for future ground cover. Blasting of overburden is required and holes are drilled on 8 x 10 foot centers. The holes are loaded using the formula one pound of ANFO per cubic yard of overburden. This mine maintains a sufficient supply of ANFO so that an explosives shortage does not become an immediate problem.

Mine 1E comprises four locations, but coal is being extracted at only locations 2 and 3. Locations 1 and 2 are separated from locations 3 and 4 by a hollow. Location 1 is currently being reclaimed to conform to a gently rolling topography planned for the area. Spoil material from locations 2 and 3 is either pushed into the hollow (Head of Hollow Fill) with dozers, or front-end loaded into 25-ton rear dump trucks and hauled to the dump site. At location 4, the legal maximum of 1/3 of the spoil material is piled on the outslope, and the remaining 2/3 is trucked back to the dump site. This mining procedure (Truck Haulback with Head of Hollow Fill) is not only consistent with the overall reclamation plan, but minimizes gradients and distances of haul roads that must traverse the valley area enroute to the tipple (see figure 3-8).

Coal and bone partings are loaded separately by front-end loaders into 25 and 35 ton rear dump trucks. The trucks must travel an average of 5 1/2 miles over earthen haul roads to the tipple. Storage capacity of stockpiles at the tipple site is 50,000 tons, but spontaneous combustion can be a problem. Raw coal from the various pits is blended at the tipple before being loaded into railroad cars and shipped to electric power generating plants.

Disturbed land is regraded to a gently rolling topography, with pasture land and home development potential for post mining land uses, using dozers, front-end loaders and dump trucks. Topsoil is replaced and a home mixture of Serecea (15 pounds per acre), Lespedeza (15 pounds per acre), Kentucky 31 Fescue (35 pounds per acre), Locust seed (2 pounds per acre) and 1000 trees per acre are planted. The soil is also fertilized

(200 pounds per acre) and a hay mulch (100 bales per acre) is applied. Application of the various grasses and fertilizer is accomplished by hydroseeding with mulch applied by blower and trees hand planted. Application of seed, fertilizer and mulch is contracted out at $250/acre which does not include cost of materials.

Mine 1E experiences a variety of interrelated environment - production problems. Casting spoil over the outslopes has been disallowed by environmental regulations, and a partial valley fill - modified haulback method has been adopted. Changing of production methods to comply with environmental regulations, coupled with slow processing of permit applications (and poor attitudes of some local union employees), were the major problems cited. However, the new management expects resolution of these difficulties, as next year's coal production is projected at 500,000 tons, an increase of 150,000 tons.

TABLE 9-8
EQUIPMENT COST SUMMARY - MINE NO. 1E

Topsoil Removal and Reclamation	Capacity	Quantity	Total Cost
D-9 Bulldozer	-	9*	$ 576,000 (30%)
Overburden Stripping			
D-9 Bulldozer	-	9*	$1,152,000 (70%)
Cat. (988) Loader	6 C.Y.	4	556,000
Cat. (980) Loader	6 C.Y.	1	104,000
Cat. (950) Loader	-	2	123,000
A.C. (605) Loader	-	1	104,000
R.D.C. (16) Drill	5 1/8"	4	340,000
Truck	35 Ton	5	620,000
Truck	40 Ton	1	150,000
Truck	50 Ton	1	172,000
			$3,321,000
Coal Removal and Loading			
Cat. (988) Loader	6 C.Y.	2	$ 278,000
Cat. (980) Loader	6 C.Y.	1	104,000
			$ 382,000
Coal Haulage			
Mack Truck (Portion contracted out at $1.25/ton)	25 Ton	7	$ 560,000
Maintenance			
Steam Genny and Truck Unit	-	1	$ 10,000
Road Grader	-	1	60,000
			$ 70,000

TABLE 9-8 (Contd.)

Exploration	Capacity	Quantity	Total Cost
A. C. (HD-41) Bulldozer	-	1	$ 180,000
D-8 Bulldozer	-	1	137,000
			$ 317,000

Total Cost of Equipment = $5,226,000

* Same equipment used for different operations.

TABLE 9-9
MANNING TABLE - MINE NO. 1E

Topsoil Removal and Reclamation	Total	Cost Per Year
Dozer Operator	18*	$ 68,310 (30%)
Overburden Stripping		
Dozer Operator	18*	$ 211,140 (70%)
Loader Operator	16	248,400
Driller	4	54,320
Driller's Helper	3	39,150
Shooter	3	40,740
Shooter's Helper	3	39,150
Truck Driver	14	190,120
		$ 823,020
Coal Removal and Loading		
Loader Operator	3	$ 46,575
Coal Preparation		
None	-	-
Coal Haulage		
Truck Driver (Portion contracted out at $1.25/ton)	7	$ 95,060
Auxiliary Operations		
Maintenance Crew	2	$ 27,160

TABLE 9-9 (Contd.)

Exploration	Total	Cost Per Year
Dozer Operator	1	$ 15,525
Safety Man	1	12,883
		$ 28,408
	Total Labor =	$1,088,533
Administrative		
President	1	$ 25,000
Superintendant	1	20,000
Accountant	1	20,000
Foreman	4	80,000
Safety Engineer	1	15,000
Geologist	1	15,000
Secretary	1	7,500
	Total Supervision =	$ 182,500
	Total Labor and Supervision =	$1,271,033

* Same people used for different operations.

TABLE 9-10
TOTAL ESTIMATED CAPITAL REQUIREMENTS - MINE NO. 1E

Exploration, Power Facilities Site Preparation, Buildings and Roads		$ 50,000
Unit Train Loading Facilities		-
Mining Equipment		5,226,000
	Total Direct =	$5,276,000
Field Indirect (2% of Total Direct)		$ 105,520
Engineering		90,000
Overhead & Administration		635,517
	Subtotal =	$6,107,037
Contingency (10% of 6,107,037)		$ 610,704
	Subtotal =	$6,717,741
Fee (2% of 6,717,741)		$ 134,355
Total Mine Cost (Base Insurance Tax) =		$6,852,096
Interest During Construction (3% of 6,852,096)		$ 205,563
Working Capital		1,013,515
	Total =	$8,071,174

TABLE 9-11
ESTIMATED WORKING CAPITAL - MINE NO. 1E

Direct Labor, 3 months		$ 317,758
Payroll Overhead, 3 months		79,440
Operating Supplies, 3 months		454,255
Indirect Costs, 3 months		115,802
Fixed Costs, 0.5% of Insurance Base		34,260
Miscellaneous		12,000
	Total =	$1,013,515

TABLE 9-12
ESTIMATED ANNUAL OPERATING COSTS - MINE NO. 1E

Direct Cost		
Labor		$1,088,533
Supervision		182,500
	Subtotal =	$1,271,033
Operating Supplies		
Fuel		$ 252,000
Lubricants		10,080
Explosives		473,157
Parts, Materials and Miscellaneous		1,081,782
	Subtotal =	$1,817,019
Auxiliary Cost		
Contract Coal Hauling		$ 288,462
Contract Revegetation		7,500
Power		4,800
Communications		16,000
Union Welfare		250,000
Payroll Overhead		317,758
Health & Safety		2,250
Royalty		250,000
Strip License & Reclamation Fee		4,750
	Subtotal =	$1,141,520
	Total Direct Cost =	$4,229,572
Indirect Cost: 15% of Labor, Supervision, and Operating Supplies		$ 463,208
Fixed Cost: Taxes and Insurance, 2% of Mine Cost		137,042
Depreciation		717,316
	Total Operating Cost=	$5,547,138

TABLE 9-13
DEPRECIATION SCHEDULE - MINE NO. 1E

Item	Quantity	St. Line Deprec./Yrs.	Yearly Charge
D-9 Bulldozer	9	10	$ 172,800
Cat. (988) Loader	6	10	83,400
Cat. (980) Loader	2	10	20,800
Cat. (950) Loader	2	10	12,300
Cat. (605) Loader	1	10	10,400
D-8 Bulldozer	1	10	13,700
A.C.(HD-41) Bulldozer	1	10	18,000
Steam Genny & Truck Unit	1	10	1,000
R.D.C. (16) Drill	4	20	17,000
Truck (35-Ton)	5	6	103,333
Truck (40-Ton)	1	6	25,000
Truck (50-Ton)	1	6	28,667
Mack Truck (25-Ton)	7	6	93,333
Road Grader	1	10	6,000
Miscellaneous Equipment	-	-	-
Exploration, Power Facilities, Site Preparation, Buildings and Roads	-	20	2,500
Depreciation: Field Indirect Engineering, Overhead and Administration, Contingency, Fee, and Interest During Construction		20	89,083
Interim Equipment Cost		20	20,000
		Total = $	717,316
		= $	717,316

TABLE 9-14

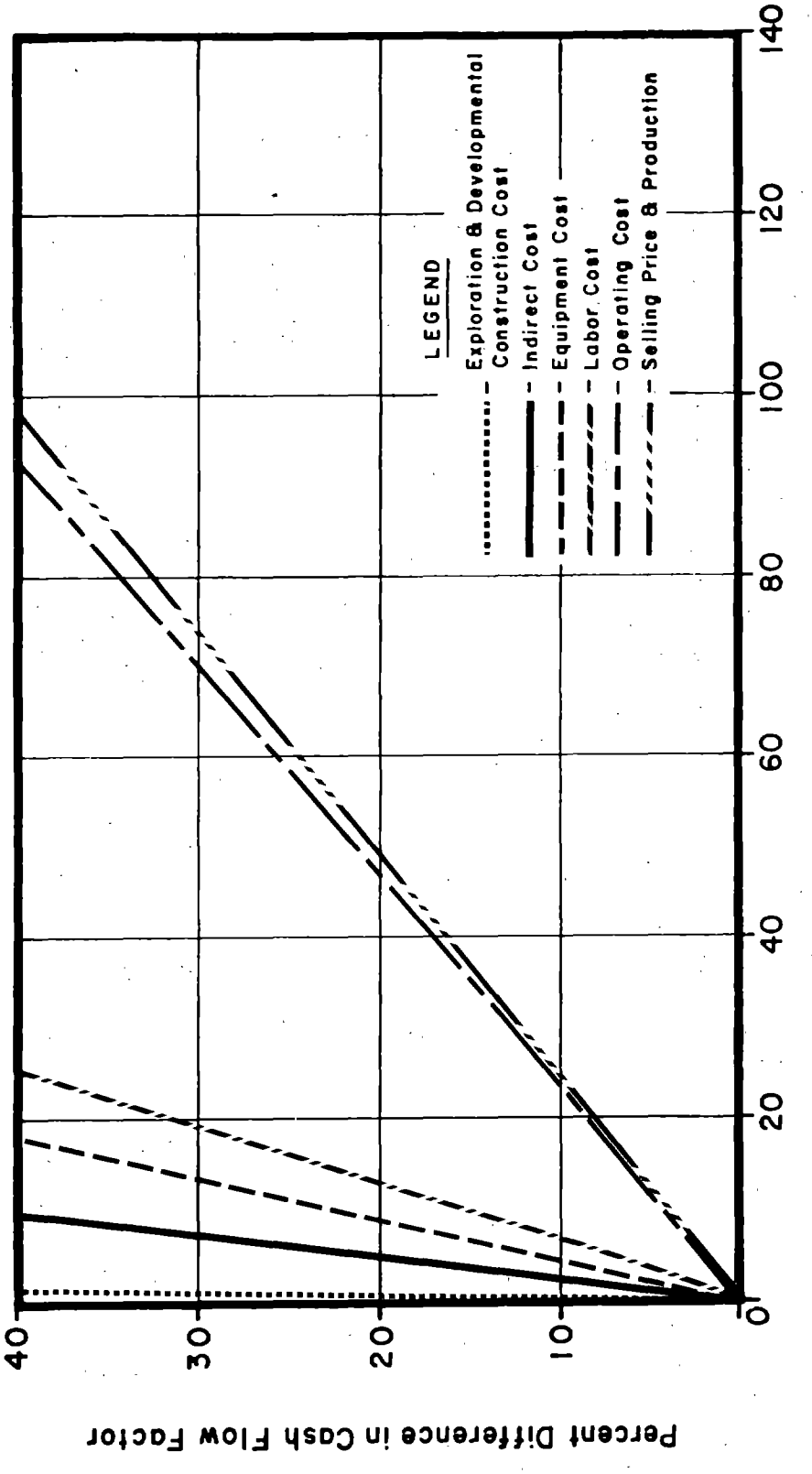
CASH FLOW ANALYSIS - MINE NO. IE

Year	Capital Investment	Cash Flow	Present Worth Factor At 15 Percent	Present Worth Capital Investment At 15 Percent	Present Worth Cash Flow Value At 15 Percent
0	$8,071,174	$-8,071,174	1.0000	$ 8,071,174	$-8,071,174
1	20,000	1,583,891	.8696	17,392	1,377,352
2	20,000	1,583,891	.7561	15,122	1,197,580
3	20,000	1,583,891	.6575	13,150	1,041,408
4	20,000	1,583,891	.5718	11,436	905,669
5	20,000	1,583,891	.4972	9,944	787,510
6	1,521,998	81,893	.4323	657,960	35,402
7	20,000	1,583,891	.3759	7,518	595,384
8	20,000	1,583,891	.3269	6,538	517,774
9	20,000	1,583,891	.2843	5,686	450,300
10	3,404,000	-1,800,109	.2472	841,469	-444,987
11	20,000	1,583,891	.2149	4,298	340,378
12	1,521,998	81,893	.1869	284,461	15,306
13	20,000	1,583,891	.1625	3,250	257,382
14	20,000	1,583,891	.1414	2,828	223,962
15	20,000	1,583,891	.1229	2,458	194,660
16	20,000	1,583,891	.1068	2,136	169,160
17	20,000	1,583,891	.0930	1,860	147,302
18	1,521,998	81,893	.0808	122,977	6,617
19	20,000	1,583,891	.0702	1,404	111,189
20	-717,316	2,321,207	.0611	-43,828	141,826
			TOTAL	$10,039,233	0

R = $10,039,233 ÷ 6.2593	=	$1,603,891.00
Less depreciation	=	717,316.00
Depletion + net profit	=	886,575.00
Gross profit = 1.333 x $886,575	=	1,181,804.00
Sales = $5,547,138 + $1,181,804	=	6,728,942.00

Gross profit	1,181,804.00
Depletion	590,902.00
Taxable Income	590,902.00
Federal Income Tax	295,451.00
Net profit	295,451.00

Annual cash flow = $295,451 + $717,316 + 590,902	=	$1,603,669.00
Selling price per ton = $6,728,942 ÷ 350,000 tons	=	19.23



SENSITIVITY GRAPH - MINE NO. IE

Figure 9-2

CASE HISTORY - MINE 1G

Mine 1G is located in Region I (West Virginia) in an area typified by moderately rolling hills of timber land. Using the modified block cut technique (see Figure 3-28), the bituminous Bakerstown seam is mined at a stripping ratio of 27:1. This consistent seam, with an approximately horizontal dip, averages about 27 inches thick. The coal, having about a 12,300 BTU, 14% - 16% ash, and 2½% - 4½% sulfur content, presently sells for $21 per ton delivered to the appropriate generating plant. Basic geology of the area is typical of hilly regions, with a maximum topsoil thickness of 6 inches and an average overburden thickness comprising 30 feet of sandstone and 30 - 35 feet of shale. The climate does not encompass any unusual conditions, therefore basic climatic problems pertaining to production delays simply evolve from periods of high rainfall, hindering machine mobility. This area averages about 44 inches per year of precipitation, with a range of temperatures from 20 to 95° F, averaging about 54°F.

Being one of four producing pits of a small independent operation, Mine 1G utilizes 2 shifts and a 6-day week in order to produce 85,000 tons of coal for its utility market. The active mine site encompasses approximately 30 acres with only 20 acres remaining to be affected, and an estimated coal reserve of 200,000 tons.

Due to the small amount of acreage involved and an obvious coal outcrop, no regional exploration was necessary. However, detailed exploration was conducted after obtaining a prospecting permit. This exploratory effort included employing dozers to construct roads to transport rotary drills to fifteen points per 50 acres (forming a criss-cross pattern over the acreage). Drilling was conducted to appropriate depths for determination of overburden and coal thicknesses. Dozers were then utilized to face-up the seam of coal. The entire exploration was performed in 9 man-days.

Based on favorable exploratory results, the planning and development stage was implemented. First, mineral and land rights were obtained with a subsequent agreement for royalty payments totalling $1.00 per ton of coal produced. Next, through evaluation of pertinent factors, the proposed size of the operation was determined. The most influential factors were, in order of importance, market, geology, environment, geography, transportation, capital, and equipment availability. Mining meth-

od (Modified Block Cut) and equipment (front-end loaders and dozers) selections were due mainly to overburden characteristics. All requirements necessary for obtaining a permit from the appropriate State agency were met. This included completion of a questionnaire pertaining to general information on the coal company, land and minerals to be affected, proof of legal right of entry, and a complete reclamation and mining preplan.

As stated previously, Mine 1G employs the Modified Block-Cut technique (described in the section on basic mining methods encountered in Region II) to achieve its 85,000 tons per year production rate. Site preparation comprises the first step in the mining procedure. For timber country, this step is initiated by clearing trees and other vegetation, followed by construction of access and haul roads. In this case, timber rights were sold to another party who was contracted to perform the grubbing operation. Treetops and other waste materials were separated and left for later burial in mine pits. A scraper was used to segregate, either below the crop of the coal or on top of the highwall, the minimal amount of topsoil generally found in the area.

After successful completion of this step, drilling and blasting of overburden was implemented through use of a 650 C.P. drill and a drill spacing pattern composed of 12 foot centers, hole sizes of 5 5/8 inches, average depths of 60 feet, and 300 pound loadings of ammonium nitrate. Two D-9 dozers and two front-end loaders then combine to remove the blasted overburden. In a precisely scheduled operation - to date no equipment delays have been experienced - the dozers are employed to push approximately half of the material from the top of the highwall toward the outslope area and then the front-end loaders are utilized to transfer the remaining overburden from the bottom of the cut in a direction perpendicular to the dozer movement. Haulage distance averages about 300 feet with spoil dumped into a previously mined-out pit area.

Next is the coal removal phase, consisting of coal fragmentation, loading, and haulage. Ripping of the coal takes place initially, with occasional inplace separation of bone partings performed by a front-end loader. Coal is loaded onto either the company's 20 ton International truck or trucks contracted to haul the coal 4½ miles to a nearby power plant. The 7 yard front-end loaders can usually dump four buckets into a haulage truck in approximately two minutes, and the transport makes a roundtrip to the plant site in about 45 minutes.

Contour regrading, the technique most often associated with Modified Block Cut, is executed at Mine 1G to adequately comply with strict state requirements. D-9 dozers are used in this process. In addition, all toxic spoil material is buried in the pit. Topsoil replacement averaging about 4 inches is performed by scrapers and dozers. A revegetation effort, in conjunction with the proper handling of toxic and topsoil material, has produced excellent revegetation results with: a seeding mixture of 15 pounds of birdsfoot trefoil, 20 pounds of Kentucky 31 fescue, and one bushel of either oats or wheat, 10-20-20 fertilizer averaging about 60 pounds per acre, and hay mulch averaging 2 tons per acre. Total reclamation costs incurred to create this pasture land average $1.84 per ton of coal produced (excludes topsoil removal).

Coal preparation and storage are not utilized in this mining operation. After removal, the coal is immediately transported by truck to the appropriate generating plant. Although exemption of coal preparation and storage facilities in the mining cycle decreases overall costs, the required transportation expenditures does, however, have an inflationary effect on mining costs.

Due to excellent maintenance programs, Mine 1G encounters few production delays. Each machine operator, as well as exceptionally qualified maintenance personnel, conducts extensive preventive maintenance on a daily basis. This has resulted in lower than average downtime for the major pieces of equipment such as scrapers (12%), dozers (12%), and front-end loaders (12%). In addition, since a coal preparation facility is not required and most coal haulage (80 percent) is contracted, related maintenance and downtime problems are minimized. However, Mine 1G does have the usual problem in obtaining ammonium nitrate (and sometimes fuel oil) for overburden blasting. It also experiences the customary delay when ordering spare parts. Unlike the company's other producing pits which experience severe acid mine drainage, Mine 1G has the compound problems of erosion and subsequent siltation. These are alleviated through use of sumps, diversion ditches, sediment ponds, and proper revegetation practices. Although the actual mining technique has not been changed nor has production been hindered by these environmental practices, mining costs have increased significantly.

TABLE 9-15
EQUIPMENT COST SUMMARY - MINE NO. 1G

Topsoil Removal and Reclamation	Capacity	Quantity	Total Cost
D-9 Bulldozer	-	2*	$ 96,000 (25%)
Scraper	14 C.Y.	1	(Leased)
			$ 96,000
Overburden Stripping			
D-9 Bulldozer	-	2*	$ 288,000 (75%)
C.P. (650) Drill	5 5/8"	1*	173,250 (99%)
Front-end Loader	7 C.Y.	2*	179,560 (67%)
Pick-up Truck	-	1	6,000
			$ 646,810
Coal Removal and Loading			
Front-end Loader	7 C.Y.	2*	$ 88,440 (33%)
Coal Haulage			
International Truck (Majority contracted out at $1.25/ton)	20 Ton	1	$ 50,000
Maintenance			
Crane (mounted on truck)	-	1	$ 20,000
Welder	-	1	2,400
Grader	-	1	61,000
Truck	-	1	12,500
			$ 95,900

TABLE 9-15 (Contd.)

Exploration	Capacity	Quantity	Total Cost
C.P. (650) Drill	5 5/8"	1*	$ 1,750 (01%)

Total Cost of Equipment = $ 978,900

* Same equipment used for different operations.

TABLE 9-16
MANNING TABLE - MINE NO. 1G

Topsoil Removal and Reclamation	Total	Cost Per Year
Dozer Operator	2*	$ 8,280 (25%)
Scraper Operator	1	16,560
		$ 24,840
Overburden Stripping		
Dozer Operator	2*	$ 24,840 (75%)
Driller	2*	28,678 (99%)
Loader Operator	2*	22,080 (67%)
Truck Driver	1	7,242
		$ 82,840
Coal Removal and Loading		
Loader Operator	2*	$ 11,040 (33%)
Coal Preparation		
None		
Coal Haulage		
Truck Driver (Majority contracted out at $1.25/ton)	1	$ 4,828
Auxiliary Operations		
Maintenance Crew	3	$ 31,382
Exploration		
Driller	2*	$ 290 (1%)
	Total Labor =	$ 155,220

TABLE 9-16 (Contd.)

Administrative	Total	Cost Per Year
President	1	$ 24,000
Secretary (Includes accounting services, and other responsibilities).	1	12,000
Total Supervision =		$ 36,000
Total Labor and Supervision =		$ 191,220

* Same people used for different operations.

TABLE 9-17
TOTAL ESTIMATED CAPITAL REQUIREMENTS - MINE NO. 1G

Exploration, Power Facilities, Site Preparation, Buildings and Roads		$ 30,000
Unit Train Loading Facilities		-
Mining Equipment		978,900
	Total Direct =	$1,008,900
Field Indirect (2% of Total Direct)		$ 20,178
Engineering		1,500
Overhead & Administration		20,000
	Subtotal =	$1,050,578
Contingency (10% of 1,050,578)		$ 105,058
	Subtotal =	$1,155,636
Fee (2% of 1,155,636)		$ 23,113
Total Mine Cost (Base Insurance Tax)=		$1,178,749
Interest During Construction (3% of 1,178,749)		$ 35,362
Working Capital		212,724
	Total =	$1,426,835

TABLE 9-18
ESTIMATED WORKING CAPITAL - MINE NO. 1G

Leased Equipment, 3 months		$ 16,500
Direct Labor, 3 months		47,805
Payroll Overhead, 3 months		11,951
Operating Supplies, 3 months		105,568
Indirect Costs, 3 months		23,006
Fixed Costs, 0.5% of Insurance Base		5,894
Miscellaneous		2,000
	Total =	$ 212,724

TABLE 9-19
ESTIMATED ANNUAL OPERATING COSTS - MINE NO. 1G

Direct Cost		
Labor		$ 155,220
Supervision		36,000
	Subtotal =	$ 191,220
Operating Supplies		
Leased Equipment		$ 66,000
Fuel		77,532
Lubricants		3,101
Explosives		124,800
Parts, Materials & Miscellaneous		150,840
	Subtotal =	$ 422,273
Auxiliary Cost		
Contract Coal Hauling		$ 85,450
Power		625
Communications		2,250
Union Welfare		-
Payroll Overhead		47,805
Health & Safety		3,030
Royalty		85,000
Strip License & Reclamation Fee		3,500
	Subtotal =	$ 227,660
	Total Direct Costs =	$ 841,153
Indirect Cost: 15% of Labor, Supervision, and Operating Supplies		$ 92,024
Fixed Cost: Taxes and Insurance, 2% of Mine Cost		23,575
Depreciation		218,500
	Total Operating Costs =	$1,175,252

TABLE 9-20
DEPRECIATION SCHEDULE - MINE NO. 1G

Item	Quantity	St. Line Deprec./Yrs.	Yearly Charge
D-9 Bulldozer	2	5	$ 76,800
C.P. (650) Drill	1	5	35,000
Pick-up Truck	1	3	2,000
Front-end Loader	2	5	53,600
International Truck (20 ton)	1	3	16,667
Crane (Mounted on Truck)	1	8	2,500
Welder	1	5	480
Truck	1	3	4,167
Grader	1	8	7,625
Exploration, Power Facilities, Site Preparation, Buildings, and Roads	-	5	6,000
Depreciation; Field Indirect, Engineering, Overhead, and Administration, Contingency, Fee, and Interest During Construction	-	20	10,261
Interim Equipment Cost	-	20	3,400
		Total = $	218,500

TABLE 9-21

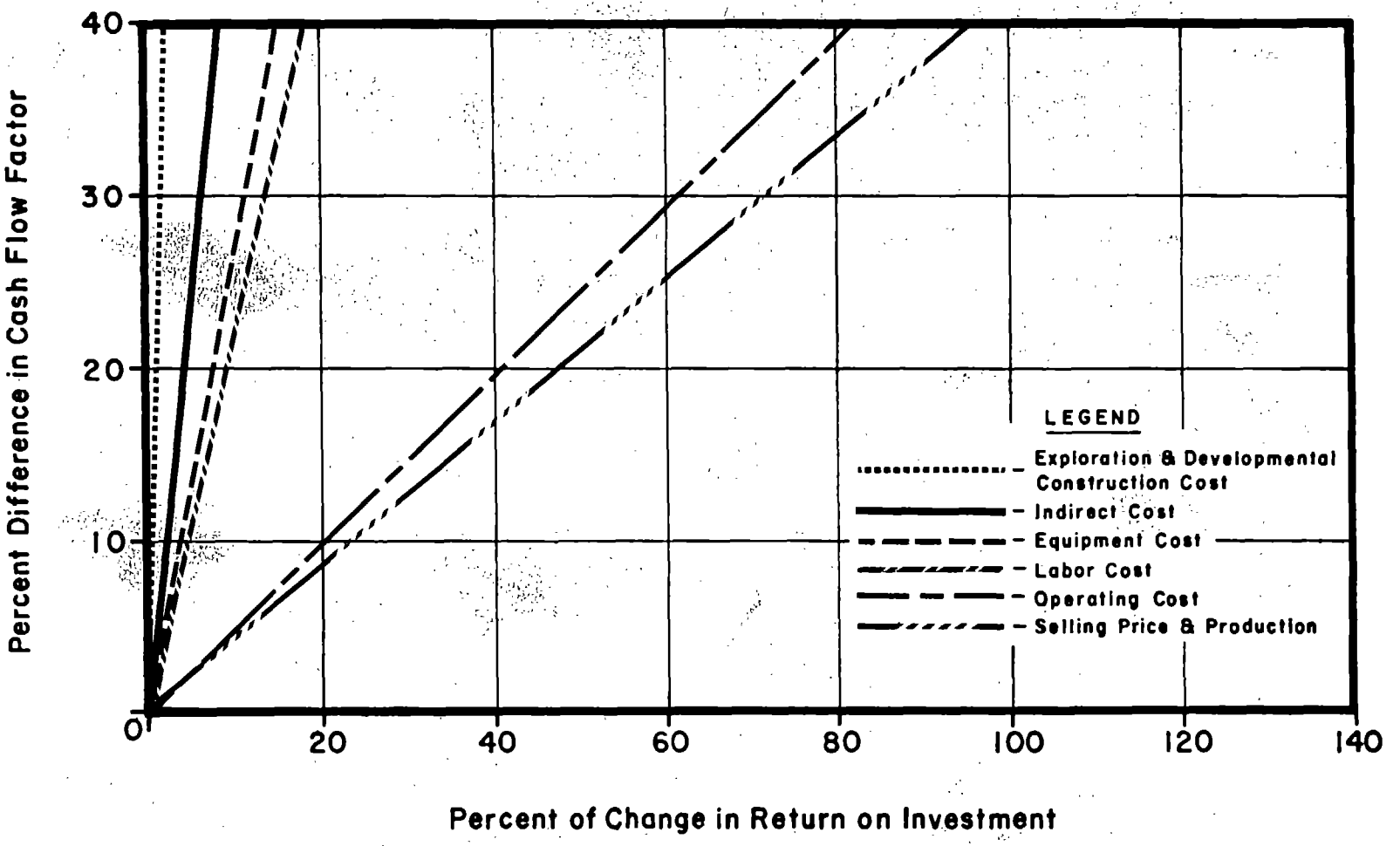
CASH FLOW ANALYSIS - MINE NO. IG

Year	Capital Investment	Cash Flow	Present Worth Factor At 15 Percent	Present Worth Capital Investment At 15 Percent	Present Worth Cash Flow Value At 15 Percent
0	$1,426,835	$-1,426,835	1.0000	$1,426,835	$-1,426,835
1	3,400	355,697	.8696	2,957	309,314
2	3,400	355,697	.7561	2,571	268,942
3	21,900	337,197	.6575	14,399	221,707
4	3,400	355,697	.5718	1,944	203,387
5	862,800	- 503,703	.4972	428,984	- 250,441
6	21,900	337,197	.4323	9,467	145,770
7	3,400	355,697	.3759	1,278	133,706
8	84,400	274,697	.3269	27,590	89,798
9	21,900	337,197	.2843	6,226	95,865
10	862,800	- 503,703	.2472	213,284	- 124,515
11	3,400	355,697	.2149	731	76,439
12	21,900	337,197	.1869	4,093	63,022
13	3,400	355,697	.1625	553	57,800
14	3,400	355,697	.1414	481	50,295
15	881,300	- 522,203	.1229	108,312	- 64,179
16	84,400	274,697	.1068	9,014	29,338
17	3,400	355,697	.0930	316	33,080
18	21,900	337,197	.0808	1,770	27,246
19	3,400	355,697	.0702	239	24,970
20	-218,500	577,597	.0611	- 13,350	35,291
			TOTAL	$2,247,694	0

R = $2,247,694 ÷ 6.2593	=	$ 359,097.00
Less depreciation	=	218,500.00
Depletion + net profit	=	140,597.00
Gross profit = 1.333 × $140,597	=	187,416.00
Sales = $1,175,252 + $187,416	=	1,362,668.00

Gross profit	187,416.00
Depletion	93,708.00
Taxable income	93,708.00
Federal income tax	46,854.00
Net profit	46,854.00

Annual cash flow = $46,854 + $218,500 + $93,708	=	$ 359,062.00
Selling price per ton = $1,362,668 ÷ 85,000 tons		16.03



SENSITIVITY GRAPH - MINE NO. 1 G

Figure 9-3

CASE HISTORY - MINE 2A

Mine 2A, located in Region II, is a typical dragline operation in Pennsylvania. The specific site terrain is a moderately sloping hill, with coal outcroppings on either side of the ridge. Earlier mining activities stripped the outcrop coal, leaving barren, unreclaimed benches along the contour. Vegetative cover on the hilltop consists of field grasses and scrub timber (of little, if any, lumber value). With the exception of two small drainage swales at the base of both slopes, no major streams, rivers, or lakes occur near the site.

Only one bituminous seam is mined at this location, the Lower Kittanning. Little seam undulation or rolling is apparent, with average dip being only 1^{o} to the Southeast. From drill logs, coal was found to be a fairly consistent 3½ feet thick, with no apparent partings. Post-preparation quality of 12,500 BTU, 8-10% ash, and 2-2½% sulfur, is sufficient to supply electric power utilities with steam coal (Jig cleaning is not included in mine costs).

Fortunately, at this site, overburden toxicity related to acid production is low. Ranging in thickness from 90 to 120 feet, composition of overlying material varies from 2 to 5 inches of topsoil and 20 feet of shaly clay near the surface. Yellow clays, buckwheat shales, sandrock and gray slate constitute the remaining overburden. Since this material is moderately thick bedded and consolidated with little fracturing, blasting is a necessary operation.

Climatic conditions do not create any unusual problems, other than muddy haul roads from rain, and ice problems in winter. Spring thaws and rains cause the most serious trouble, but road difficulties are overcome with good maintenance grading and crushed stone applications. Temperatures range from $90^{o}F$ highs in August, to $0^{o}F$ lows in January. Rain and snow account for about 39 inches of precipitation in an average year.

Mine 2A is only one of many sites operated by the parent company, a subsidiary of an even larger firm.

Having operated in this locale for many years, much information about coal geology, seam and location has been obtained through experi-

ence and knowledge of previously mined sites. Even with this past experience and knowledge, a regional diamond core drilling program is conducted every five years in areas of possible future expansion. Detailed site drilling with 100 to 500 foot air rotary hole spacing and 1,000 foot core spacing assists in verifying projected mineral occurrences. If findings are different than expected, holes are drilled at smaller intervals.

Mine planning and development was influenced primarily by geology, as the coal was known to exist and the 100 foot overburden thickness prohibited use of almost anything but a large dragline. Large market availability also prompted investment into a high production operation.

Regulations require Mine Drainage and Mining Reclamation Permits be issued by the Pennsylvania Department of Environmental Resources prior to commencement of mining. Mapping for these permits and for daily production usage was obtained with aerial photography, at scales of 1" = 100' and 1" = 400'. Production mapping has topographic contours plotted on enlarged aerial photos (ortho-photo maps).

"Modified Area Mining" described under Region II, Characterization of Mining, is the technique used at this site. The only difference being that contour stripping was conducted along the outcrop years ago. Production exceeds 500,000 tons/year.

Site preparation prior to excavation consists of timber removal, road construction, and benching for the dragline. All timber and brush not used for pulp, is buried in abandoned contour strip cuts, and backfilled by dozers. Dozers are also responsible for new haulroad construction (clearing and grubbing dozer) and dragline benching (dragline support machine).

With topsoil thickness averaging in excess of 8 inches, removal and reuse is necessary. Two push-pull pan scrapers remove the topsoil and deposit it on regraded spoil areas.

Drilling and blasting of overburden is essential for efficient dragline operation. Nine inch holes at 20 - 25 foot spacings loaded with ANFO are utilized for this purpose.

The major stripping machine is a 45 cubic yard walking dragline. Excavation proceeds in one direction only with overburden spoiled into the previous parallel cut. At the end of each 150 foot cut, the dragline walks back to the beginning before exposing more coal. This "walk" allows sufficient time to complete coal loading of the last exposure. Overburden removed from the last block in each cut is placed in the abandoned strip mine to provide a bench for use during excavation (Figure 9-4).

Coal loading into 22-ton highway trucks is accomplished by a rubber-tired front-end loader (6½ cubic yard bucket). Highlifts are occasionally used, but are usually restricted to cleaning the coal prior to loading. In the event that coal fragmentation is required, ripper dozers are used. The highway trucks haul coal 2½ miles where it is end dumped onto raw coal storage piles. Front-end loaders feed coal through the tipple, and conveyors transport the prepared coal to unit train loading facilities.

Final grading of affected areas with large dozers approaches the configuration of original contour. All signs of mining activities, including previously abandoned contour strippings, are erased. With reapplication of topsoil to regraded spoils, revegetation has been extremely successful. Post-mining land use usually consists of crop farming (oats, wheat, rye, corn) with 100% average yield by the third year.

No scheduled maintenance program is in effect with the exception of lubrication.

No variations in pollution control activities from those presented in Region II Characterization are practiced.

Major problems encountered at this operation concern the scarcity of maintenance parts (especially for the dragline), shortages of support equipment, and shortages of qualified personnel (professional and technical).

TABLE 9-22
EQUIPMENT COST SUMMARY - MINE NO. 2A

Topsoil Removal and Reclamation	Capacity	Quantity	Total Cost
Cat. (637) Pan Scraper	-	2	$ 618,000
A.C. (HD-41) Bulldozer	-	2*	236,500 (43%)
Hydroseeder	-	1	51,000
Tractor and Disc.	-	1	36,000
			$ 941,500
Overburden Stripping			
A.C. (HD-41) Bulldozer	-	2*	$ 236,500 (43%)
Chicago Pneumatic (T-750) Drill	-	1	190,000
Chicago Pneumatic (T-650) Drill	-	1	260,000
Marion (7820) Dragline	45 C.Y.	1	9,200,000
Dynamite Truck	-	1	13,000
Fertilizer Truck	-	1	60,000
			$9,959,500
Coal Removal and Loading			
A.C. (HD-41) Bulldozer	-	2*	$ 77,000 (14%)
Cat. (988) Loader	6 C.Y.	1	139,000
Highlift Michigan (75-A) Loader	6 C.Y.	1	72,000
			$ 288,000
Coal Haulage			
(Contract out at $.70/ton)			

TABLE 9-22 (Contd.)

Maintenance	Capacity	Quantity	Total Cost
Welding Truck	-	1	$ 14,000
Mechanic Truck	-	1	22,000
Pick-up Truck	-	1	7,000
Fuel Truck	-	1	30,000
Oil Truck	-	1	30,000
Grader	-	1	61,000
Crane	-	1	160,000
			$ 324,000

Exploration

(Contracted out at $65,093/year)

Total Cost of Equipment = $11,513,000

* Same equipment used for different operations.

TABLE 9-23
MANNING TABLE - MINE NO. 2A

Topsoil Removal and Reclamation	Total	Cost Per Year
Scraper Operator	2	$ 27,800
Dozer Operator	2*	10,350 (43%)
Hydroseeder Operator	1	1,509
Tractor Operator	1	1,509
		$ 41,168
Overburden Stripping		
Dozer Operator	2*	$ 10,350 (43%)
Driller	2	24,140
Driller's Helper	2	23,200
Dragline Operator	4	57,960
Dragline Oiler	4	53,300
Dynamite Truck Driver	2	24,140
Fertilizer Truck Driver	1	12,070
		$ 205,160
Coal Removal and Loading		
Dozer Operator	2*	$ 3,450 (14%)
Loader Operator	2	28,455
		$ 31,905
Coal Preparation		
None		
Coal Haulage		
(Contract out at $.70/ton)		
Auxiliary Operations		
Maintenance Crew	8	$ 112,322

TABLE 9-23 (Contd.)

Exploration	Total	Cost Per Year
(Contract out at $65,093/year)	-	-
	Total Labor =	$ 390,555
Administrative		
Superintendent	1	$ 25,875
Engineer	1	25,000
	Total Supervision =	$ 50,875
	Total Labor and Supervision =	$ 441,430

* Same people used for different operations.

TABLE 9-24
TOTAL ESTIMATED CAPITAL REQUIREMENTS - MINE NO. 2A

Exploration, Power Facilities, Site Preparation, Buildings and Roads		$ 1,250,000
Unit Train Loading Facilities		600,000
Mining Equipment		11,513,000
	Total Direct =	$13,363,000
Field Indirect (2% of Total Direct)		$ 267,260
Engineering		90,000
Overhead & Administration		220,715
	Subtotal =	$13,940,975
Contingency (10% of 13,940,975)		$ 1,394,098
	Subtotal =	$15,335,073
Fee (2% of 15,335,073)		$ 306,701
	Total Mine Cost (Base Insurance Tax)=	$15,641,774
Interest During Construction (3% of 15,641,774)		$ 469,253
Working Capital		531,367
	Total =	$16,642,394

TABLE 9-25
ESTIMATED WORKING CAPITAL - MINE NO. 2A

Direct Labor, 3 months		$ 110,358
Payroll Overhead, 3 months		38,625
Operating Supplies, 3 months		239,671
Indirect Costs, 3 months		52,504
Fixed Costs, 0.5% of Insurance Base		78,209
Miscellaneous		12,000
	Total =	$ 531,367

TABLE 9-26
ESTIMATED ANNUAL OPERATING COSTS - MINE NO. 2A

Direct Cost		
Labor		$ 390,555
Supervision		50,875
	Subtotal	= $ 441,430
Operating Supplies		
Fuel		$ 115,464
Lubricants		9,590
Explosives		83,630
Parts, Materials, & Miscellaneous		750,000
	Subtotal	= $ 958,684
Auxiliary Cost		
Contract Exploration		$ 65,093
Contract Coal Hauling		350,000
Power		150,000
Communications		16,000
Union Welfare		-
Payroll Overhead		154,500
Health & Safety		4,000
Royalty		250,000
Strip License & Reclamation Fee		5,500
	Subtotal	= $ 995,093
	Total Direct Cost	= $2,395,207
Indirect Cost: 15% of Labor, Supervision, and Operating Supplies		$ 210,017
Fixed Cost: Taxes and Insurance, 2% of Mine Cost		312,835
Depreciation		1,183,467
	Total Operating Cost	= $4,101,526

TABLE 9-27
DEPRECIATION SCHEDULE - MINE NO. 2A

Item	Quantity	St. Line Deprec./Yrs.	Yearly Charge
Cat. (637) Pan Scraper	2	5 yrs.	$ 123,600
A.C. (HD-41) Bulldozer	2	5 yrs.	110,000
Hydroseeder	1	5 yrs.	10,200
Tractor and Disc.	1	5 yrs.	7,200
Chicago Pneumatic (T-750) Drill	1	5 yrs.	38,000
Chicago Pneumatic (T-650) Drill	1	5 yrs.	52,000
Fertilizer Truck	1	3 yrs.	20,000
Dynamite Truck	1	3 yrs.	4,333
Marion (7820) Dragline	1	20 yrs.	460,000
Cat. (938) Loader	1	5 yrs.	27,800
Highlift-Michigan (75-A) Loader	1	3 yrs.	24,000
Grader	1	10 yrs.	6,100
Crane	1	10 yrs.	16,000
Welding Truck	1	3 yrs.	4,667
Mechanic Truck	1	3 yrs.	7,333
Pick-up Truck	1	3 yrs.	2,333
Fuel Truck	1	3 yrs.	10,000
Oil Truck	1	3 yrs.	10,000
Exploration, Power Facilities, Site Preparation, Buildings and Roads	-	20 yrs.	62,500
Unit Train Loading Facilities	-	20 yrs.	30,000
Depreciation: Field Indirect, Engineering, Overhead and Administration, Contingency, Fee, and Interest During Construction	-	20 yrs.	137,401
Interim Equipment Cost	-	20 yrs.	20,000

Total = $1,183,467

TABLE 9–28

CASH FLOW ANALYSIS – MINE NO. 2A

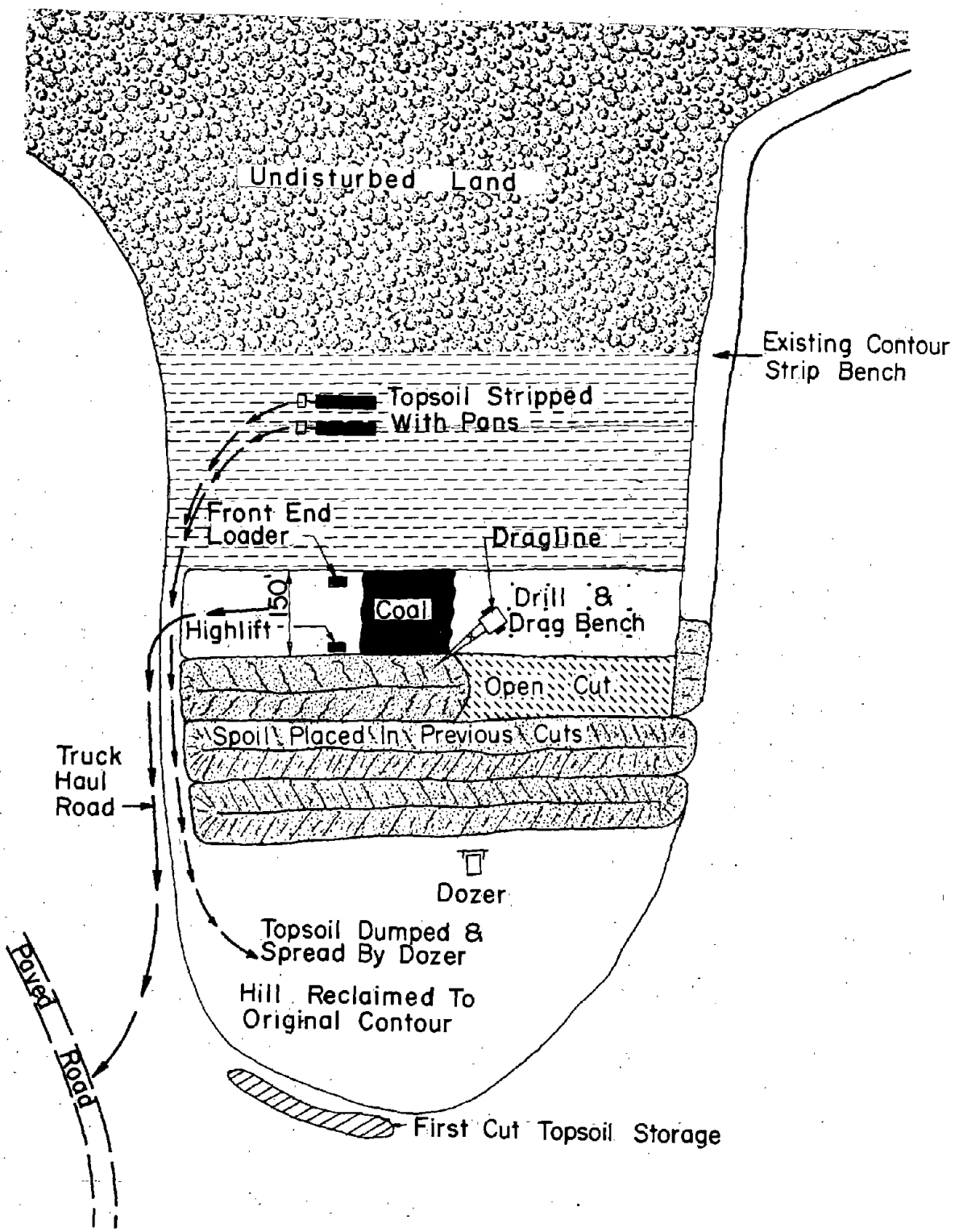
Year	Capital Investment	Cash Flow	Present Worth Factor At 15 Percent	Present Worth Capital Investment At 15 Percent	Present Worth Cash Flow Value At 15 Percent
0	$16,642,394	$- 16,642,394	1.0000	$16,642,394	$- 16,642,394
1	20,000	2,981,234	.8696	17,392	2,592,481
2	20,000	2,981,234	7561	15,122	2,254,111
3	268,000	2,733,234	6575	176,210	1,797,102
4	20,000	2,981,234	5718	11,436	1,704,670
5	1,864,000	1,137,234	.4972	926,781	565,433
6	268,000	2,733,234	.4323	115,856	1,181,577
7	20,000	2,981,234	.3759	7,518	1,120,646
8	20,000	2,981,234	.3269	6,538	974,566
9	268,000	2,733,234	2843	76,192	777,059
10	2,085,000	916,234	.2472	515,412	226,493
11	20,000	2,981,234	2149	4,298	640,667
12	268,000	2,733,234	.1869	50,089	510,841
13	20,000	2,981,234	1625	3,250	484,451
14	20,000	2,981,234	.1414	2,828	421,546
15	2,112,000	889,234	1229	259,565	109,287
16	20,000	2,981,234	1068	2,136	318,396
17	20,000	2,981,234	.0930	1,860	277,255
18	268,000	2,733,234	.0808	21,654	220,845
19	20,000	2,981,234	0702	1,404	209,283
20	-1,183,467	4,184,701	.0611	-72,310	255,685
			TOTAL	$18,785,625	0

R = $18,785,625 ÷ 6.2593 = $3,001,234.00
Less depreciation = 1,183,467.00
Depletion + net profit = 1,817,767.00

Sales = 1/0.55 (cash flow + 0.5 operating cost–depreciation)
Sales = 1.8181 [$3,001,234 + (0.5 × 4,101,526) – $1,183,467] = 7,033,374.00

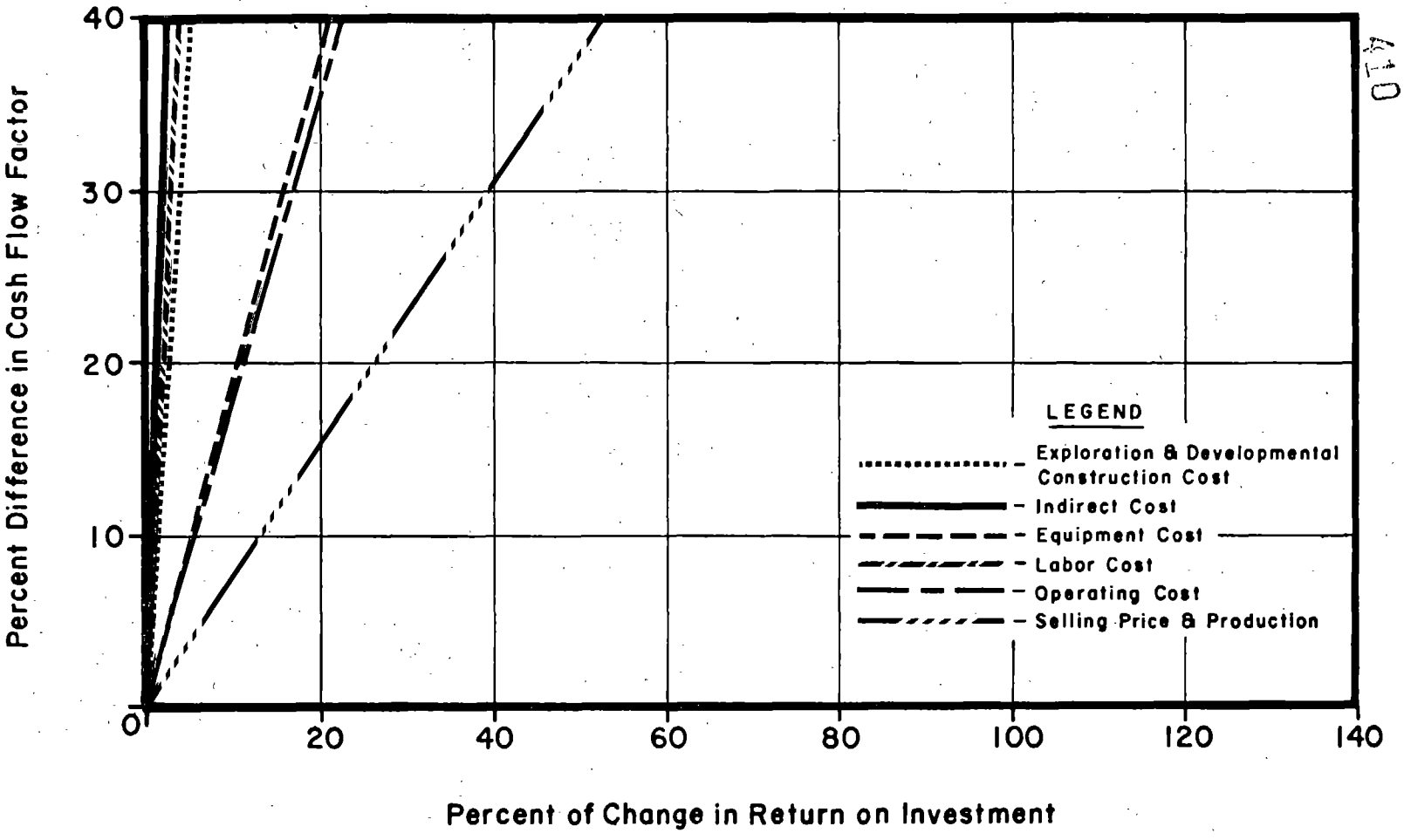
Sales	7,033,374.00
Operating Cost	4,101 526.00
Gross profit	2,931,848.00
Depletion	703,337.00
Taxable income	2,228,511.00
Federal Income Tax	1,114,256.00
Net profit	1,114,255.00

Annual cash flow = $1,114,255 + $1,183,467 + $703,337 = $3,001,059.00
Selling price per ton = $7,033,374 ÷ 500,000 tons = 14.07



MODIFIED AREA MINE

Figure 9-4



SENSITIVITY GRAPH - MINE NO. 2A

Figure 9-5

CASE HISTORY - MINE 2D

This mine is located in Region II, on the eastern extremes of the main bituminous field of Pennsylvania. Terrain varies from rolling hills to moderately mountainous, with major portions of the surface area in woodlands. Surface drainage is through various tributaries of the West Branch Susquehanna River.

Coals in the mine area include B-Seam (Lower Kittanning), the B'-Seam (Middle Kittanning) and the C-Seam (Upper Kittanning). These seams lie in flat to undulating beds of 24 to 38 inch thickness dipping generally to the southeast at 1^{o} to 5^{o}, and are of a high volatile bituminous rank. BTU's average 13,300 to 13,500, ash content - 10%, sulfur - 2% to 3%, with the primary use being steam generating coal. Some local value as home heating coal and limited value as metallurgical coal provide additional spot markets.

Overburden in undisturbed areas is generally 6 to 12 inches of topsoil and 10 feet to 12 feet clay and shale materials, with the remainder composed of red to red-gray sandstone. These rock units are massive, consolidated, and moderately hard with some layering in the topmost 6 feet. Much of this area has been previously contour stripped and in areas of marginal coal some old spoil must be removed. Most of this overburden is unconsolidated decomposed shale and sandstones units easily removed with dozers or loaders.

The climatic conditions of this area are typical of the upper temperate zone with annual precipitation of 43 to 51 inches and annual mean temperature $47^{o}F$. Monthly mean temperatures vary from 26^{o} to $70^{o}F$, and snowfall from traces to as much as 60 inches annually. Most surface mine operations are well up from valley floors, creating some travel problems during snows or sleet. Drainage of excessive pit waters during periods of high precipitation cause delays in coal loading due to State effluent discharge regulations. These delays are not often for periods of more than three days and do not usually affect overburden removal.

This mine is operated on an individual basis and is currently one of a number of independent operations producing coal for a larger sales organization. Each operation maintains an independent business status agreeing to provide a specified amount of coal to the sales facility annually. The

pricing and tonnage is usually determined on an annual basis with production capacities at or slightly above contract requirements. This structure allows for some independent sales of coal in occasional spot markets.

Exploration of these coal fields is not a major factor in this mining operation since the state geologic service has generated numerous maps of the coal fields, with attendant drilling records and historic data gathered from previous mining. Virtually all of the known bituminous reserves of Pennsylvania have been deep mined or strip mined to some extent since the early 1800's. Poor reclamation practices in the past left many exposed highwalls, sometimes completely encircling hillsides. Many small drift mines dot the bituminous fields, with maps available either from state agencies or various older mining interests. These factors have allowed relatively accurate visual assessment of coal reserves, and some air rotary holes are drilled to check possible fault conditions. State mine permit requirements mandate core borings; however, the borings are almost always minimal.

Mine planning and development is directly dependent on market conditions. This mine operation is small enough in terms of employees and annual production to allow the type of mobility needed to clean up marginal areas of coal, at the same time a more stationary operation is desirable. The present sales organization has, under lease or outright ownership, some 10,000 acres of disjointed tracts in the area. As equipment becomes available the operation can be moved easily. Environmental considerations are the next most important factors, due mostly to strict State codes. The codes place limits on disturbed area, pit widths and lengths, effluent discharges, erosion control, topsoil replacement and total affected area. Violation of any one of these codes can result in fines, shut-downs or permit cancellation. These regulations have forced the miner into more judicious use of time and materials with generally favorable results. Royalty payments are usually handled on a per ton basis with some surface owners requesting 7% to 10% of production.

Mapping and permits go hand in hand in that permit regulations require mapping for the initial permit, and continuous updating throughout the life of the mine. Mapping is accomplished by several means, the most common being aerial photography. Existing deep mine maps are sought to help in determining deep mine workings, and to eliminate the possibility of breaches and the varied problems these conditions can cause.

The current mining method can be classified as Modified Area Mining with reclamation to approximate original contour. Two pits are involved in production, one an area mine with defined trenching common to conventional area mines. The other is a clean-up operation, in which the operator is extracting all remaining C-Seam coal prior to completely mining the underlying B'-Seam.

The smaller clean-up operation has no method of segregation because the area had been previously stripped. The overburden is readily strippable, decomposed shales and topsoil that provide a suitable plant growth material. More stringent mining and reclamation requirements will be exacted when mining of the lower B'-Seam begins, with accepted standards of reclamation prevailing. Overburden movement and coal loading is accomplished with a Caterpillar 992 front-end loader and a Caterpillar 988 front-end loader. Overburden is pushed into old strip pits to expose small portions of coal remaining from the previous mining.

The larger operation runs the full course of mining unit operations, beginning with clearing and grubbing operations. Removal of valuable timber is performed by the surface owner, with subsequent removal of slashings and roots by the miner. Topsoil removal is the first full-scale operation performed by the miner; this is effected with dozers. Topsoil is usually pushed into stockpiles ahead of mining so that a suitable drilling bench is constructed. Topsoil stockpiles are later removed by front-end loaders and trucks to the reclamation portion of the operation.

Overburden drilling and blasting are performed by a sub-contractor on a per month basis. Currently a drill pattern on 15 foot centers; holes approximately 55 feet deep and nine inches in diameter are loaded with about 400 pounds of ammonium nitrate and fuel oil (ANFO) per hole. Delayed charges and hole loadings are set so that the overlying clays and shales are moved to the lower portion of the previous spoil castings by the blasting operation. Some fractured rock units also fall into the adjacent pit. The remaining in place sandstones are easily handled by the draglines of 5 and 6 cubic yards capacities working to a highwall of 45 to 55 feet, approximately 300 days per year.

Coal removal is performed by a Caterpillar 966, 4 cubic yard Caterpillar 988 or Caterpillar 992 front-end loaders, loading to 6 International Harvester 20 ton road trucks for hauling to a preparation plant approximately 17 miles away. These operations are performed about 50 hours per week, 50 weeks per year. No coal fragmentation is required, however

some segregation in the pit of the B-Seam coal takes place. This bony material is usually 4 to 6 inches thick and is buried during backfilling operations in accordance with state regulations. The sequence of operations are similar to those shown on Figure 3-30.

All coal is processed in a heavy media preparation plant built and operated by the parent sales organization. Current stockpile capability is about 250,000 tons raw and prepared, with a process capability of 180 tons per hour. Loading of prepared coal is done with front-end loaders and conveyor belts to unit trains, or front-end loaders to trucks.

Regrading is concurrent with mining and spoil piles are graded to approximate original contour by two D-9 dozers. Topsoil is placed on regraded areas by end dump trucks with final grading performed just prior to seeding operations. All seeding operations are performed in the spring and fall planting seasons by a contractor, usually under direction of the parent sales organization.

TABLE 9-29
EQUIPMENT COST SUMMARY - MINE NO. 2D

Topsoil Removal and Reclamation	Capacity	Quantity	Total Cost
D-9 Bulldozer	-	1	$ 191,700
D-8 Bulldozer	-	1	137,050
Cat. (992) Loader	10 C.Y.	1*	73,500 (25%)
Cat. (988) Loader	6 C.Y.	1*	34,725 (25%)
International Tandem-Axle Truck	20 Ton	1	50,000
Revegetation - (Contract out at $30,000/year)			
			$ 486,975
Overburden Stripping			
Cat. (992) Loader	10 C.Y.	1*	$ 220,500 (75%)
Cat. (988) Loader	6 C.Y.	1*	104,175 (75%)
Manitowac (4500) Dragline	6 C.Y.	1	812,000
Bucyrus-Erie (88-B) Dragline	5 C.Y.	1	450,000
Blasting (Contract out at $144,000/year)			
			$1,586,675
Coal Removal and Loading			
Cat. (966) Loader	4 C.Y.	1	$ 79,890
Coal Haulage			
International Tandem-Axle Truck	20 Ton	5	$ 250,000
Maintenance			
Pick-up Truck	-	2	$ 13,000
Fuel Truck	-	1	13,000
			$ 26,000

TABLE 9-29 (Contd.)

Exploration	Capacity	Quantity	Total Cost
(Contract out prior to mine development)			-
		Total Cost of Equipment =	$2,429,540

* Same equipment used for different operations.

TABLE 9 - 30
MANNING TABLE - MINE NO. 2D

Topsoil Removal and Reclamation	Total	Cost Per Year
Dozer Operator	2	$ 34,500
Loader Operator	2*	8,625 (25%)
Truck Driver	1	15,088
Revegetation (Contract out at $30,000/year)		
		$ 58,213
Overburden Stripping		
Loader Operator	2*	$ 25,875 (75%)
Dragline Operator	4	75,900
Dragline Oiler	4	69,796
Blasting (Contract out at $144,000/year)		
		$ 171,571
Coal Removal and Loading		
Loader Operator	1	$ 17,250
Coal Preparation		
None		
Coal Haulage		
Truck Driver	5	$ 75,437
Auxiliary Operations		
Maintenance Crew	2	$ 33,193

TABLE 9-30 (Contd.)

Exploration	Total	Cost Per Year
(Contract out prior to mine development)		-
	Total Labor =	$ 355,664
Administrative		
President	1	$ 25,000
Foreman	1	20,000
Secretary	1	7,500
	Total Supervision =	$ 52,500
	Total Labor and Supervision =	$ 408,164

* Same people used for different operations.

TABLE 9-31
TOTAL ESTIMATED CAPITAL REQUIREMENTS - MINE NO. 2D

Exploration, Power Facilities, Site Preparation, Buildings, and Roads		$ 85,000
Unit Train Loading Facilities		-
Mining Equipment		2,429,540
	Total Direct	= $2,514,540
Field Indirect (2% of Total Direct)		$ 50,291
Engineering		5,000
Overhead & Administration		5,000
	Subtotal	= $2,574,831
Contingency (10% of 2,574,831)		$ 257,483
	Subtotal	= $2,832,314
Fee (2% of 2,832,314)		$ 56,646
	Total Mine Cost (Base Insurance Tax)	= $2,888,960
Interest During Construction (3% of 2,888,960)		$ 86,669
Working Capital		173,012
	Total	= $3,148,641

TABLE 9-32
ESTIMATED WORKING CAPITAL - MINE NO. 2D

Direct Labor, 3 months		$ 102,041
Payroll Overhead, 3 months		6,000
Operating Supplies, 3 months		28,017
Indirect Costs, 3 months		19,509
Fixed Costs, 0.5% of Insurance Base		14,445
Miscellaneous		$ 3,000
	Total	= $ 173,012

TABLE 9-33
ESTIMATED ANNUAL OPERATING COSTS - MINE NO. 2D

Direct Cost		
Labor		$ 355,664
Supervision		52,500
	Subtotal =	$ 408,164
Operating Supplies		
Fuel		$ 102,950
Lubricants		4,118
Parts, Materials & Miscellaneous		5,000
	Subtotal =	$ 112,068
Auxiliary Cost		
Contract Revegetation		$ 30,000
Contract Coal Hauling		-
Contract Blasting		144,000
Power		700
Communications		5,000
Union Welfare		-
Payroll Overhead		24,000
Health & Safety		4,600
Royalty		90,000
Strip License & Reclamation Fee		15,300
	Subtotal =	$ 313,600
	Total Direct Cost =	$ 833,832
Indirect Cost: 15% of Labor, Supervision, and Operating Supplies		$ 78,035
Fixed Cost: Taxes and Insurance, 2% of Mine Cost		57,779
Depreciation		227,055
	Total Operating Cost =	$1,196,701

TABLE 9-34
DEPRECIATION SCHEDULE - MINE NO. 2D

Item	Quantity	St. Line Deprec./Yrs.	Yearly Charge
D-9 Bulldozer	1	10	$ 19,000
D-8 Bulldozer	1	10	13,700
Manitowac (4500) Dragline	1	20	40,600
Bucyrus-Erie (88-B) Dragline	1	20	22,500
Cat. (966) Loader	1	10	7,900
International Tandem-Axle Truck (20 ton)	6	7	42,857
Pick-up Truck	2	5	2,600
Fuel Truck	1	5	2,600
Cat. (992) Loader	1	10	29,400
Cat. (988) Loader	1	10	13,800
Exploration, Power Facilities, Site Preparation, Buildings and Roads	-	20	4,250
Depreciation; Field Indirect, Engineering, Overhead & Administration, Contingency, Fee, and Interest During Construction	-	20	23,048
Interim Equipment Cost	-	20	4,800
		Total	= $ 227,055

TABLE 9-35

CASH FLOW ANALYSIS - MINE NO. 2D

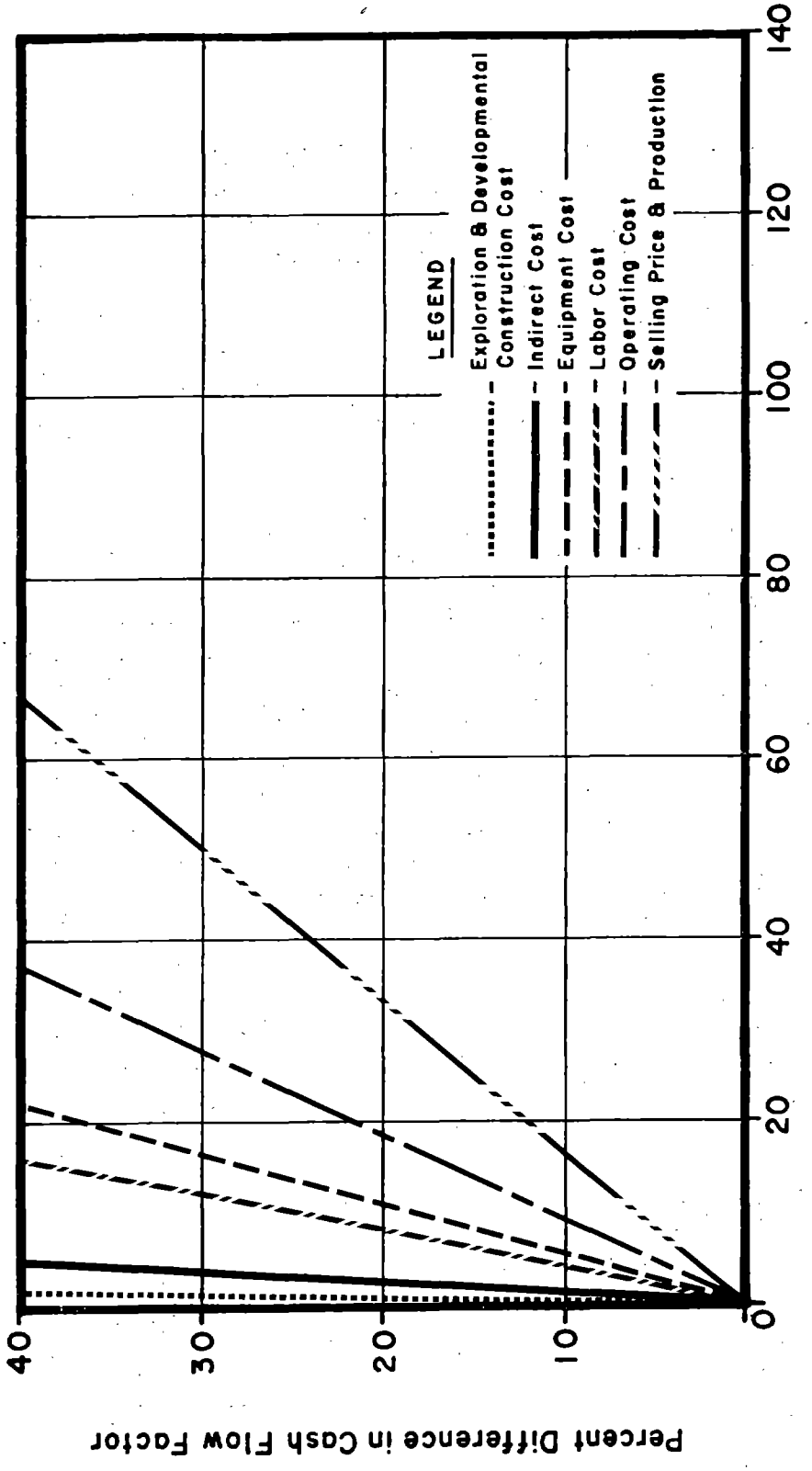
Year	Capital Investment	Cash Flow	Present Worth Factor At 15 Percent	Present Worth Capital Investment At 15 Percent	Present Worth Cash Flow Value At 15 Percent
0	$3,148,641	$-3,148,641	10000	$3,148,641	$-3,148,641
1	4,800	562,262	.8696	4,174	488,943
2	4,800	562,262	.7561	3,629	425,126
3	4,800	562,262	.6575	3,156	369,687
4	4,800	562,262	.5718	2,745	321,502
5	30,800	536,262	4972	15,314	266,630
6	4,800	562,262	.4323	2,075	243,066
7	304,800	262,262	.3759	114,574	98,584
8	4,800	562,262	.3269	1,569	183,803
9	4,800	562,262	.2843	1,365	159,851
10	868,800	-301,738	.2472	214,767	-74,590
11	4,800	562,262	.2149	1,032	120,830
12	4,800	562,262	.1869	897	105,087
13	4,800	562,262	.1625	780	91,368
14	304,800	262,262	.1414	43,099	37,084
15	30,800	536,262	.1229	3,785	65,907
16	4,800	562,262	.1068	513	60,050
17	4,800	562,262	.0930	446	52,290
18	4,800	562,262	0808	388	45,431
19	4,800	562,262	0702	337	39,471
20	-227,055	794,117	.0611	-13,873	48,521
			TOTAL	$3,549,413	0

R = $3,549,413 ÷ 6.2593 = $ 567,062.00
Less depreciation 227,055.00
Depletion + Net profit $ 340,007.00

Sales = 1/0.55 (cash flow + 0.5 operating cost-depreciation)
Sales = 1.8181 [$567,062+(0.5×$1,196,701)-$227,055] = $1,706,028.00

Sales	$1,706,028.00
Operating Costs	1,196,701.00
Gross profit	509,327.00
Depletion	170,603.00
Taxable income	338,724.00
Federal Income Tax	169,362.00
Net profit	169,362.00

Annual cash flow = $169,362 + $227,055 + $170,603 = $ 567,020.00
Selling price per ton = $1,706,028 ÷ 120,000 tons = 14.22



SENSITIVITY GRAPH - MINE NO. 2D

Figure 9-6

CASE HISTORY - MINE 2J

Mine 2J is in the main bituminous field of western Pennsylvania. The terrain is characterized by rolling hills with small patches of woods dotting an agricultural landscape of dairy farms. Surface drainage leads to the Allegheny River north of Pittsburgh, Pennsylvania.

Surface miners in this area extract coal from the Pittsburgh seam, which generally outcrops midway between the valley floor and the hill tops. The seam has a gentle southwest dip of approximately 2^{o}, and is a bituminous rank coal with a persistent thickness of five to six feet. The coal heating value from this mine varies between 12,000 and 13,000 BTU per pound with a sulfur content averaging 1% and an ash content of 18%. Large portions of this seam contain coal of metallurgical quality, however, over 60% of the product mined at this operation is steam coal, bound for electrical generating plants located within the county. The overburden consists of 12 inches of topsoil over a 15 foot section of thinly bedded sandstone. Slate and shale constitute the remaining overburden that varies in thickness from 30 feet to 70 feet at this site.

The annual precipitation averages 46 inches with a mean temperature of $45^{o}F$. The temperature extremes are -19^{o} to $101^{o}F$. State regulations require settling ponds for any excessive pit water drained from the operation. Quality or quantity of drainage water has not been a problem.

This operation is managed by a "family" type organization. The company is incorporated and simultaneously runs several relatively small operations in a two county area. Mining rights are secured from land owners in a checkerboard fashion. Rights are obtained to key plots of land varying in size from 10 to 100 acres by agreeing to royalty payments of $.75 to $1.00 per ton of coal removed. During the mining operation, attempts are made to secure mining rights to adjacent properties. If these attempts are successful, the mining plan is modified and permits are secured to extend the operation. The operation under study is a 15 acre site located on the periphery of a dairy farm. This field investigation was made during the ninth month of an estimated 24 month mine life. Production has been averaging 20,000 tons of coal per month. Most of the Pittsburgh seam at this location had been deep mined in previous years, therefore only 50% of the seam remains for surface mining recovery.

Exploration preceding this mining consisted of examining old deep mine maps to determine coal reserves and drilling six core borings to verify coal quality and overburden composition. Permits were filed and approved by the Commonwealth of Pennsylvania.

A scraper haulback operation was started by removing and stockpiling topsoil on the upper edge of the site. Scrapers with an occasional power assist from dozers removed most of the overburden from the initial pit. Blasting of overburden was not required at this site, however, scrapers could not handle about 20% of the bulky overburden. Trucks and front-end loaders handled this material. Overburden from the initial pit was stored on the lower edge of the site. Coal was pit loaded with front-end loaders to 25 ton dump trucks that transported the coal directly to a power plant 23 miles away. After the coal had been removed from the initial pit opening, the overburden removal advanced in the manner of a conventional haulback operation (see Figure 3-9).

When the coal has been removed from the final section of the advancing operation, the stored overburden and remaining topsoil is used to return the final section of the land to original contours. An independent contractor is employed to deposit two tons of lime and 300 pounds of 5-20-20 fertilizer per acre. The contractor then seeds the site with rye grass and crown vetch. Future land use will be grazing land. An inspection of one year old reclaimed mine sites close to this operation showed a high degree of success in returning land to original use.

Officials of the mining company reported no major operational problems indigenous to this mine other than equipment conjestion in the pit due to narrow working limits. Shortages of equipment, parts, and supplies were philosophically viewed as problems common to the entire industry and therefore did not represent a competitive disadvantage.

TABLE 9-36
EQUIPMENT COST SUMMARY - MINE NO. 2J

Topsoil Removal and Reclamation	Capacity	Quantity	Total Cost
D-9 Bulldozer	-	2*	Leased (35%)
657 Scraper	-	1*	Leased (35%)
Revegetation (Contract out at $1,200/year)			
Overburden Stripping			
D-9 Bulldozer	-	2*	Leased (65%)
657 Scraper	-	1*	Leased (65%)
Cat. (992) Loader	10 C.Y.	1	Leased
Coal Removal and Loading			
Cat. (988) Loader	7 C.Y.	1	Leased
Coal Haulage			
(Contract out at $1.80/ton)			
Maintenance			
Grader	-	1	Leased
Exploration			
(Contract out prior to mine development)			

Total Cost of Equipment = All Leased

* Same equipment used for different operations

TABLE 9-37
MANNING TABLE - MINE NO. 2J

Topsoil Removal and Reclamation	Total	Cost Per Year
Dozer Operator	4*	$ 25,116 (35%)
Scraper Operator	2*	12,558 (35%)
Revegetation (Contract out at $1,200/year)		$ 37,674
Overburden Stripping		
Dozer Operator	4*	$ 46,644 (65%)
Scraper Operator	2*	23,322 (65%)
Loader Operator	2	35,880
		$ 105,846
Coal Removal and Loading		
Loader Operator	2	$ 35,880
Coal Preparation		
None		
Coal Haulage		
(Contract out at $1.80/ton)		
Auxiliary Operations		
Grader Operator	1	$ 17,940
Maintenance Crew	4	67,600
		$ 85,540
	Total Labor =	$ 264,940

TABLE 9-37 (Contd.)

Exploration (Contract out prior to mine development)	Total	Cost Per Year
Administrative		
President	1	$ 25,000
Superintendent	1	20,000
Foreman	2	40,000
Engineer	1	15,000
Secretary	1	8,000
	Total Supervision	= $ 108,000
	Total Labor and Supervision	= $ 372,940

* Same people used for different operations.

TABLE 9-38
TOTAL ESTIMATED CAPITAL REQUIREMENTS - MINE NO. 2J

Exploration, Power Facilities, Site Preparation, Buildings and Roads		$ 33,000
Unit Train Loading Facilities		-
Mining Equipment		Leased
	Total Direct =	$ 33,000
Field Indirect (2% of Total Direct)		$ 660
Engineering		43,200
Overhead & Administration		120,000
	Subtotal =	$ 196,860
Contingency (10% of 196,860)		$ 19,686
	Subtotal =	$ 216,546
Fee (2% of 216,546)		$ 4,331
Total Mine Cost (Base Insurance Tax) =		$ 220,877
Interest During Construction (3% of 220,877)		$ 6,626
Working Capital		399,774
	Total =	$ 627,277

TABLE 9-39
ESTIMATED WORKING CAPITAL - MINE NO. 2J

Leased Equipment, 3 months		$ 51,300
Direct Labor, 3 months		93,235
Payroll Overhead, 3 months		23,309
Operating Supplies, 3 months		179,861
Indirect Costs, 3 months		40,965
Fixed Costs, 0.5% of Insurance Base		1,104
Miscellaneous		10,000
	Total =	$ 399,774

TABLE 9-40
ESTIMATED ANNUAL OPERATING COSTS - MINE NO. 2J

Direct Cost		
Labor		$ 264,940
Supervision		108,000
	Subtotal =	$ 372,940
Operating Supplies		
Leased Equipment		$ 205,200
Fuel		144,466
Lubricants		5,779
Explosives		-
Parts, Materials & Miscellaneous		364,000
	Subtotal =	$ 719,445
Auxiliary Cost		
Contract Revegetation		$ 1,200
Contract Coal Hauling		432,000
Power		-
Communications		-
Union Welfare		120,000
Payroll Overhead		93,235
Health & Safety		7,200
Royalty		120,000
Strip License & Reclamation Fee		33,000
	Subtotal =	$ 806,635
	Total Direct Cost =	$1,899,020
Indirect Cost: 15% of Labor, Supervision, and Operating Supplies		$ 163,858
Fixed Cost: Taxes and Insurance, 2% of Mine Cost		4,418
Depreciation		11,350
	Total Operating Cost =	$2,078,646

TABLE 9-41
DEPRECIATION SCHEDULE - MINE NO. 2J

Item	Quantity	St. Line Deprec./Yrs.	Yearly Charge
Exploration, Power Facilities, Site Preparation, Buildings and Roads	-	20	$ 1,650
Depreciation: Field Indirect, Engineering, Overhead and Administration, Contingency, Fee, and Interest During Construction	-	20	9,700
		Total = $	11,350

TABLE 9-42

CASH FLOW ANALYSIS - MINE NO. 2J

Year	Capital Investment	Cash Flow	Present Worth Factor At 15 Percent	Present Worth Capital Investment At 15 Percent	Present Worth Cash Flow Value At 15 Percent
0	$627,277	$-627,277	1.0000	$627,277	$-627,277
1	0	100,104	.8696	0	87,050
2	0	100,104	.7561	0	75,689
3	0	100,104	.6575	0	65,818
4	0	100,104	.5718	0	57,239
5	0	100,104	.4972	0	49,772
6	0	100,104	.4323	0	43,275
7	0	100,104	.3759	0	37,629
8	0	100,104	.3269	0	32,724
9	0	100,104	.2843	0	28,460
10	0	100,104	.2472	0	24,746
11	0	100,104	.2149	0	21,512
12	0	100,104	.1869	0	18,709
13	0	100,104	.1625	0	16,267
14	0	100,104	.1414	0	14,155
15	0	100,104	.1229	0	12,303
16	0	100,104	.1068	0	10,691
17	0	100,104	.0930	0	9,310
18	0	100,104	.0808	0	8,088
19	0	100,104	.0702	0	7,027
20	-11,350	111,454	.0611	-694	6,810
			TOTAL	$626,583	0

R = $626,583 ÷ 6.2593 = $ 100,104.00
Less depreciation = 11,350.00
Depletion + net profit = 88,754.00

Gross profit = 1.333 x $88,754 = 118,309.00
Sales = $2,0 78,646 + $118,309 = 2,196,955.00

Gross profit	118,309.00
Depletion	59,155.00
Taxable income	59,154.00
Federal Income Tax	29,577.00
Net profit	29,577.00

Annual cash flow = $29,577 + $11,350 + $59,155 = $ 100,082.00
Selling price per ton = $2,196,955 ÷ 240,000 tons = 9.15

CASE HISTORY - MINE 2K

This mine is located in Region II in the State of Ohio - an area characterized by gently rolling timber and pasture land interspersed with numerous small streams. The coal seam exclusively mined is Meigs Creek (No. 9), a bituminous rank seam whose consistent nature and thickness (averaging approximately 47 inches) provides ideal mining qualities to meet the ever-increasing demands of the utility market. The seam dips less than one degree to the North and has an average quality of 9,940 BTU's with 23% ash and 5% sulfur content. Interbedded shale (10' - 30'), limestone (2" - 8"), and sandstone (20' - 40') overburden ranges 30 - 100 feet in depth with an average thickness of approximately 80 feet. The topsoil, typical of that found in hilly regions, is limited, varying from 0 to 24 inches. The climatological conditions in this area are quite characteristic of the midwestern states: temperature ranges from minus 15° to 100°F, with 54°F as the average annual temperature; average precipitation is approximately 40 inches/year and is the primary climatological-related problem impeding machine mobility.

Mine 2K, one of eight active pits, is a captive mine annually producing approximately 600,000 tons for Ohio's utility market. Presently encompassing an active area of 500 acres, Mine 2K plans to affect approximately 4,500 remaining acres having estimated coal reserves of 7.2 million tons.

Regional exploration was performed prior to opening the study mine by several smaller operating companies utilizing air rotary drilling on two mile centers. The present miner conducted detailed exploration by drilling core borings on 3000 foot centers, ranging in depth from 80 to 250 feet. All coal samples were then analyzed for quality. Other critical parameters determined during exploration were thicknesses and composition of the coal and various overburden units.

Upon first implementation of the mine plan, the major factors influencing the proposed size of the operation were, in order of importance: capital, geography, equipment availability, geology, transportation, market, and environment. However, the growing concern over ecology and the subsequent increase in environmental regulations have dramatically changed the priority of environmental considerations; they are now second in importance, after capital.

The pre-mining planning stage also entailed development of preliminary mapping and fulfillment of other mandatory tasks for permit approval. Throughout the life of the mine, permit application procedures have varied, with additional requirements being stipulated in each successive law. Under Ohio's law, approval of a permit application is largely dependent upon the preparation of an extremely detailed map by a registered professional civil engineer or registered surveyor. Items covered by the map are: 1) exact location of the proposed mining activity; 2) all boundaries of land to be affected; 3) limits of adjacent or subadjacent deep mines; 4) names and locations of adjacent properties; 5) bodies of water; 6) roads; 7) railroads; 8) utility lines; 9) buildings; 10) oil and gas wells; 11) public works; 12) drainage plan of the area to be affected as well as surrounding areas; and 13) location of all test borings. Other technical information required includes: a description of the land to be mined, an estimate of the number of acres to be affected, an extensive report on the testing performed in the area, a complete and comprehensive pre-mining and reclamation plan, a cost estimate of reclamation performed (per acre). The permit application also requires the mining company to submit a license fee of one hundred fifty dollars, plus thirty dollars multiplied by the number of estimated acres to be mined, as well as a deposit of the appropriate amount of bond as prescribed by the Chief of the Division of Reclamation.

The principal mining method employed by Mine 2K is a variation of the Conventional Box Cut described in the section pertaining to Basic Mining Methods Encountered in Region II (Chapter 3). The first operation performed is site preparation. All trees, shrubs, and brush are grubbed and topsoil removed with dozers and pans. Topsoil is always stockpiled on either the edge of the outslope or on top of the highwall. In addition, dozers are employed in the construction of access and haul roads.

In the second operation, overburden is blasted, applying a 25 by 25 foot drill pattern with corresponding hole sizes and average depths of 10 5/8inches and 80 feet, respectively. The blasting agent generally used is ammonium nitrate with highly variable loadings, averaging 1,000 pounds per hole. (A maximum loading of 6,000 pounds per hole, as well as various specialized techniques (such as deck loading), have been employed.)

After blasting, pan scrapers and dozers make two initial cuts, averaging about eighty feet, in order to effect a straight highwall. The

displaced overburden is deposited along the low wall barrier. This process is continued following the contour of the hill. After these initial cuts, a 45 cubic yard shovel performs successive cuts into the hill. This process is discontinued at a specific stripping ratio, usually 20:1, restricted by either practical limitations of the excavating shovel or economic infeasibility. Shovel excavation follows the initial cuts made by the pans and dozers around the contour of the hill. Supporting equipment is also utilized in conjunction with the main excavator to keep the pit area clean, move cables when necessary, and remove overburden immediately above the coal seam (see Figure 3-26).

Coal removal usually serves as the third unit operation in the mining process. First, coal is fragmented by ripping (occasionally in-place separation of the bone partings must be performed with a rubber-tired dozer), and then loaded with an eight-yard shovel into 110 ton Dart trucks which haul the coal approximately three miles, finally dumping at a tipple area. After being crushed at the tipple, the coal is transported approximately 15 miles by unit train to a preparation facility and then transferred nearly 10 miles by conveyor belt to the appropriate generating plant.

After coal extraction has been accomplished within a given pit, the requisite reclamation effort is initiated. Within three months after removal of the overburden; backfilling, grading, and resoiling must be implemented. Generally, contour regrading is employed and, when possible, topsoil is replaced. These processes are accomplished through use of pan scrapers and dozers. All toxic spoil is, of course, buried in the pit to facilitate successful revegetation of the land. Within 12 months after the end of the license year or termination of the mining process (whichever comes first), this work must be completed and revegetation must then begin during the next appropriate season. Two basic elaborate seeding mixtures are utilized by Mine 2K to produce excellent revegetation results. One mixture, which is applied at 50 pounds per acre, is composed of birdsfoot trefoil, Kentucky blue grass, red top grass, orchard grass, perennial rye grass, alsike clover, and red clover. Fifty-nine pounds of an alternative mixture which consists of Kentucky 31 fescue, orchard grass, perennial rye grass, blue grass, red top grass, timothy, ranger alfalfa, red clover, ladino clover, sericea lespedeza, mammoth clover and alsike clover may also be seeded. General methods of application include employment of a drill, airplane, or hydroseeder. In addition, approximately 200 pounds/acre of fertilizer, as

well as 3 tons/acre of hay and straw mulch, is applied by either an airplane or conventional methods. Revegetation is achieved at an average cost of $750 - $1,000/acre through a combination of efforts by Mine 2K, an outside contractor, and the captor company to produce basic timber and pasture land, with crop farming being a viable possibility in some areas. Complete reclamation averages $5,000 per acre, which is higher than normal for this region.

Mine 2K, along with the other seven mines in the area, now utilizes a recently-converted Stage 2 preparation plant, processing approximately 1,700 tons per shift at a 7% reject rate. With the advent of the energy crisis and subsequent rising price of coal, it has become economically feasible to provide complete and sophisticated coal cleaning processes comprising coarse, fine, and coal slime recovery. As a result of the recent addition of a hydrocyclone and froth flotation for slime cleaning, the preparation plant utilized at this time may properly be classified as a Stage 3 plant. Operating and electric power consumption costs total $553,000 per year for the plant.

A stockpile having an approximate capacity of 250,000 tons and a conveyor belt system to serve as the transferring agency, is utilized at Mine 2K for coal storage. Due to reduced transportation rates by shipping unit train, storage has become an economic necessity. Its primary advantages are the following:

- It permits the preparation and production rates to differ and thereby precludes the possibility of any interdependence delays.
- It allows the mine and preparation plant to function independently with temporary cessations in one incapable of affecting the operating capacity of the other.
- It provides for prompt and economical loading of unit trains.

Actual transportation of the coal to its market facilities is accomplished by electric unit train owned and operated by the parent company and a conveyor belt provided by the captor company.

Basic problems in production-related activities pertain to material shortages, machine downtime, and machine delays. At the present time, the main shortages are occurring in such integral mining materials

as ammonium nitrate, antifreeze, and most of the major component parts for machinery. Along with these component machinery parts, there are numerous other mining-related parts and vital pieces of equipment which require as much as a six-month delivery delay. Poor road conditions and, at times, excessive precipitation combine to cause production delays by impeding machine mobility. In addition, there is excessive downtime due to a lack of preventive maintenance, although this is now in the process of being corrected. Production delays, especially during the coal removal operation, are also a problem because of the requisite movement of electrical cables that supply large shovels and draglines.

The critical environmental problem in this area is erosion with subsequent stream siltation. To prevent unnecessary erosion, Mine 2K utilizes diversion ditches to protect all spoil piles until successful revegetation takes place. Diversionary channelization is employed to convey all polluted waters into settling ponds before entering public waters. However, even with employment of contour regrading, elaborate seeding mixtures, fertilizer and mulch, and diversionary channelization, problems do occur in meeting the requirements of law as they pertain to erosion gully sizes. No acid problem has been encountered in this area to date.

TABLE 9-43
EQUIPMENT COST SUMMARY - MINE NO. 2K

Topsoil Removal and Reclamation	Capacity	Quantity	Total Cost
Cat. (D-9) Bulldozer	-	2	$ 383,400
Cat. (657-B) Pan	-	2	618,000
			$1,001,400
Overburden Stripping			
Bucyrus-Erie (50-R) Drill	10 5/8"	1	$ 400,000
Cat. (D-5) Bulldozer	-	1	57,600
Cat. (D-8) Bulldozer	-	1	137,000
Marion (5561-B) Shovel	45 C.Y.	1	1,900,000
Cat. (D-9) Bulldozer	-	1	191,700
Rubber-Tired (824-B) Bulldozer	-	1	170,000
Powder Truck	-	2	40,000
Bulk Truck	-	1	40,000
			$2,936,300
Coal Removal and Loading			
151-M Shovel	8 C.Y.	1	$ 820,000
Coal Haulage			
Kenworth-Dart Truck	110 Ton	2	$ 600,000
Maintenance			
Shop Equipment	-	-	$ 12,000
Welder	-	1	20,000
Other Equipment	-	-	Leased
			$ 32,000

TABLE 9-43 (Contd.)

Exploration	Capacity	Quantity	Total Cost
Ramrod II Core Drill	-	1	$ 260,000
Water Truck	-	1	25,000
			$ 285,000

Total Cost of Equipment = $5,674,700

TABLE 9-44
MANNING TABLE - MINE NO. 2K

Topsoil Removal and Reclamation	Total	Cost Per Year
Dozer Operator	4	$ 80,592
Scrapper Operator	4	80,592
		$ 161,184
Overburden Stripping		
Driller	2	$ 35,245
Driller's Helper	2	33,872
Dozer Operator	8	161,184
Shovel Operator	3	60,444
Shovel Oiler	3	55,582
Electrician	3	55,582
		$ 401,909
Coal Removal and Loading		
Shovel Operator	2	$ 40,296
Coal Preparation and Tipple		
Prep. Control Operator	1	$ 18,527
Prep. Utility Men	3	50,151
Tipple Attendant	2	33,872
		$ 102,550
Coal Haulage		
Truck Driver	4	$ 70,489

TABLE 9-44 (Contd.)

Auxiliary Operations		Total	Cost Per Year
Truck Mechanic		2	$ 37,055
Dozer Mechanic		3	55,582
Welder		8	148,219
Electrician		4	74,110
Machinist		3	52,867
Engine Rebuilder		3	52,867
Railroad Track Crew		3	52,867
Prep. Plant Crew		2	35,244
Utility Men		4	70,489
			$ 579,300
Exploration			
Driller	(Crew works	1	$ 3,524
Driller's Helper	20% of time	1	3,387
Engineer	at this pit)	1	7,300
			$ 14,211
		Total Labor	= $1,369,939
Administrative			
Mine Manager		1	$ 20,000
Secretary		1	7,500
Clerk		1	7,500
Operation Foreman		3	60,000
Maintenance Foreman		2	32,000
Engineer		1	15,000
Technical Assistant		1	11,000
Reclamation Foreman		1	15,000
Transportation Foreman		1	15,000
Superintendent		1	20,000
		Total Supervision	= $ 203,000

Total Labor and Supervision = $1,572,939

TABLE 9-45
TOTAL ESTIMATED CAPITAL REQUIREMENTS - MINE NO. 2K

Exploration, Power Facilities, Site Preparation, Buildings and Roads		$ 1,200,000
Preparation Plant		3,000,000
Unit Train Loading Facilities		1,500,000
Mining Equipment		5,674,700
	Total Direct =	$11,374,700
Field Indirect (2% of Total Direct)		$ 227,494
Engineering		600,000
Overhead & Administration		600,000
	Subtotal =	$12,802,194
Contingency (10% of 12,802,194)		$ 1,280,219
	Subtotal =	$14,082,413
Fee (2% of 14,082,413)		$ 281,648
Total Mine Cost (Base Insurance Tax)	=	$14,364,061
Interest During Construction (3% of 14,364,061)		$ 430,922
Working Capital		1,270,299
	Total =	$16,065,282

TABLE 9-46
ESTIMATED WORKING CAPITAL - MINE NO. 2K

Direct Labor, 3 months	$ 393,235
Payroll Overhead, 3 months	125,000
Operating Supplies, 3 months	540,225
Indirect Costs, 3 months	140,019
Fixed Costs, 0.5% of Insurance Base	71,820
Miscellaneous	-
Total =	$ 1,270,299

TABLE 9-47
ESTIMATED ANNUAL OPERATING COSTS - MINE NO. 2K

Direct Cost		
Labor		$ 1,369,939
Supervision		203,000
	Subtotal =	$ 1,572,939
Operating Supplies		
Leased Equipment		$ 7,500
Fuel		172,500
Lubricants		6,900
Explosives		906,000
Parts, Materials & Miscellaneous		1,068,000
	Subtotal =	$ 2,160,900
Auxiliary Cost		
Contract Reclamation		$ 500,000
Contract Coal Hauling		-
Environmental (Self Insurance)		10,000
Power		150,000
Communications		12,000
Union Welfare		660,000
Payroll Overhead		500,000
Health & Safety		18,000
Water		10,000
Royalty		120,000
Strip License & Reclamation Fee		50,300
	Subtotal =	$ 2,030,300
	Total Direct Cost =	$ 5,764,139
Indirect Cost: 15% of Labor, Supervision, and Operating Supplies		$ 560,076
Fixed Cost: Taxes and Insurance, 2% of Mine Cost		287,281
Depreciation		972,542
	Total Operating Cost=	$ 7,584,038

TABLE 9-48
DEPRECIATION SCHEDULE - MINE NO. 2K

Item	Quantity	St. Line Deprec./Yrs.	Yearly Charge
Cat. (D-9) Bulldozer	3	7	$ 82,157
Cat. (657-B) Pan	2	7	88,286
Bucyrus-Erie (50-R) Drill	1	10	40,000
Cat. (D-5) Bulldozer	1	7	8,229
Cat. (D-8) Bulldozer	1	7	19,571
Marion (5561-B) Shovel	1	20	95,000
Rubber-Tired (824-B) Bulldozer	1	10	17,000
Kenworth-Dart Truck (110 Ton)	2	10	60,000
151-M Shovel	1	20	41,000
Welder	1	10	2,000
Ramrod II Core Drill	1	10	26,000
Water Truck	1	7	3,571
Bulk Truck	1	10	4,000
Powder Truck	2	7	5,714
Exploration, Power Facilities, Site Preparation, Buildings and Roads	-	20	60,000
Preparation Plant	-	20	150,000
Unit Train Loading Facilities	-	20	75,000
Depreciation; Field Indirect, Engineering, Overhead and Administration, Contingency, Fee, and Interest During Construction	-	20	171,014
Interim Equipment Cost	-	20	24,000
		Total = $	972,542

TABLE 9-49

CASH FLOW ANALYSIS— MINE NO. 2K

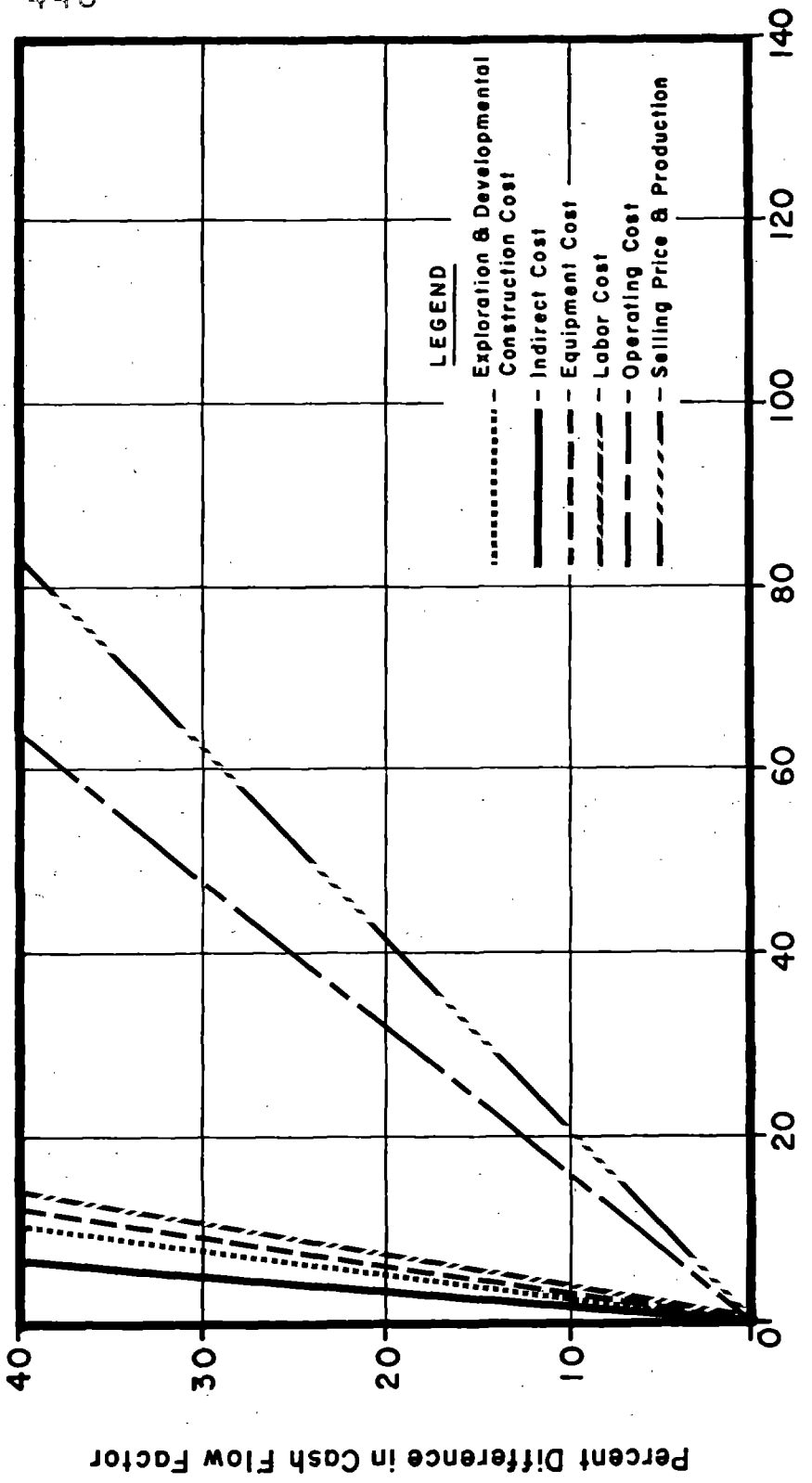
Year	Capital Investment	Cash Flow	Present Worth Factor At 15 Percent	Present Worth Capital Investment At 15 Percent	Present Worth Cash Flow Value At 15 Percent
0	$16,065,282	$-16,065,282	1.0000	$16,065,282	$-16,065,282
1	24,000	2,735,802	.8696	20,870	2,379,053
2	24,000	2,735,802	.7561	18,146	2,068,540
3	24,000	2,735,802	.6575	15,780	1,798,790
4	24,000	2,735,802	.5718	13,723	1,564,331
5	24,000	2,735,802	.4972	11,933	1,360,240
6	24,000	2,735,802	.4323	10,375	1,182,687
7	1,476,700	1,283,102	.3759	555,092	482,318
8	24,000	2,735,802	.3269	7,846	894,333
9	24,000	2,735,802	.2843	6,823	777,788
10	1,514,000	1,245,802	.2472	374,261	307,962
11	24,000	2,735,802	.2149	5,158	587,924
12	24,000	2,735,802	.1869	4,486	511,321
13	24,000	2,735,802	.1625	3,900	444,568
14	1,476,700	1,283,102	.1414	208,805	181,431
15	24,000	2,735,802	.1229	2,950	336,230
16	24,000	2,735,802	.1068	2,563	292,184
17	24,000	2,735,802	.0930	2,232	254,430
18	24,000	2,735,802	.0808	1,939	221,053
19	24,000	2,735,802	0702	1,685	192,053
20	-972,542	3,732,344	.0611	-59,422	228,046
			TOTAL	$17,274,427	0

R = $17,274,427 ÷ 6.2593	=	$ 2,759,802.00
Less depreciation	=	972,542.00
Depletion + net profit	=	1,787,260.00

Sales = 1/0.55 (cash flow + 0.5 operating cost-depreciation)
Sales = 1.8181 [$2,759,802 + (0.5 × $7,584,038) - $972,542] = $10,143,687.00

Sales	10,143,687.00
Operating Cost	7,584,038.00
Gross profit	2,559,649.00
Depletion	1,014,369.00
Taxable income	1,545,280.00
Federal Income Tax	772,640.00
Net profit	772,640.00

Annual cash flow = $772,640 + $972,542 + $1,014,369	=	$ 2,759,551.00
Selling price per ton = $10,143,687 ÷ 600,000 tons	=	16.91



SENSITIVITY GRAPH - MINE NO. 2K

Figure 9-7

CASE HISTORY - MINE 2M

Mine 2M is located in Pennsylvania's southwest plateau in Region II. Scrub timber covers this moderately steep-hilled, stream-dissected area. A 46" mean annual precipitation falls in this region, and temperatures range from a mean low of 19°F during the winter months to a mean high of 84°F during the summer.

The Lower Freeport seam totals 30" in thickness and contains intermittent shale partings up to 1' thick. This consistent seam is relatively flat-lying and undulates slightly. The Lower Freeport is a medium sulfur (2.4%) bituminous coal containing 13 - 14% ash and has a heat value of 12,500 BTU. Directly overlying the coal is a one-foot thick black slate. Total overburden thickness ranges from 18' to 85' and consists of iron stained interbedded fossile shales and broken sandstones. Topsoil cover is mostly nonexistent, but the weathered near-surface shales support vegetation.

Mine 2M is an independently owned, single pit operation. The Lower Freeport seam has been heavily mined for many years in this area. Guided by past mining experience and outcrop geology, the operator secured a property lease and the necessary exploration permits. No regional exploration was performed. Detailed exploration consisted of seven rotary air drilled holes, 80' to 100' deep on the 123 acre parcel of property. No pattern was planned. The purpose for drilling was to find the dip of the coal, determine type of overburden, and satisfy water permit stipulations.

The mine was planned to produce 25,000 tons of coal annually. The operator believes this is the most efficient size operation for the area. Major factors influencing productivity of the mine are: first, market; second, environmental considerations; and third, capital requirements. Contour stripping using a modified block cut was the mining method selected, as it satisfies the state's demands of concurrent reclamation backfilling and no casting of overburden over the low wall outslope (See Figure 3-28). Equipment was selected by experimental use of various pieces of machinery.

All earth moving and coal loading is done with a Caterpillar 980 front-end loader and a Caterpillar D8 bulldozer. Each box-cut along the

contour is 120 feet wide and 215 feet long. A 25 foot coal barrier is left on the low wall side to reduce the water pollution potential. Site preparation begins with the bulldozer clearing trees and building haul and access roads. What little topsoil is present is segregated and saved for revegetation. The overburden must be drilled and blasted; this work is contracted out. After the initial box-cut is made and the coal extracted, the area for the next cut is cleared of timber and pushed down into the center of the previous pit by the bulldozer. The front-end loader works the outside of the box-cut, pushing earth toward the highwall area where the bulldozer is working. The dozer crowds the overburden in toward the highwall, creating a series of benches. The dozer makes circular sweeps always pushing earth downhill and against the highwall. Almost all movement of overburden is in a downhill direction. When the coal is uncovered, the dozer rips the coal and the front-end loader chops it and loads it into contracted 25 ton coal haulers. The trucks dump at the coal buyer's tipple.

By backfilling overburden as described above, reclamation regrading proceeds along with the mining. A minimum of final regrading is left to be performed after the contour strip is completed. Working in this manner, periods of reclamation grading without coal production are eliminated and cost capital flows are evenly distributed. Backfilling is graded to contour and topsoil is redistributed evenly. Kentucky 31 fescue, tall fescues, and perennial rye grass are mixed with a 10-20-20 fertilizer and applied by a hydroseeder at the end of the stripping operation.

Raw coal is loaded in unit trains by bulldozer and front-end loader. Stockpile storage facilities at the loading site are able to store 60,000 tons of coal. No major problems were noted at this operation.

TABLE 9-50
EQUIPMENT COST SUMMARY - MINE NO. 2M

Topsoil Removal and Reclamation	Capacity	Quantity	Total Cost
Cat. (D-8) Bulldozer	-	1*	$ 6,853 (05%)
Cat. (980) Loader	4.5 C.Y.	1*	3,129 (03%)
Hydroseeder	-	1	51,000
			$ 60,982
Overburden Stripping			
Cat. (D-8) Bulldozer	-	1*	$ 123,344 (90%)
Cat. (980) Loader	4.5 C.Y.	1*	75,096 (72%)
Blasting (Contract out at $1.25/ton)			
			$ 198,440
Coal Removal and Loading			
Cat. (D-8) Bulldozer	-	1*	$ 6,853 (05%)
Cat. (980) Loader	4.5 C.Y.	1*	26,075 (25%)
			$ 32,928
Coal Haulage			
Mack (D-600) Truck (Contract out 50% of hauling at $1.75/ton)	23 Ton	4	$ 170,000
Maintenance			
Pick-up Truck (Contract Welding at $1500/year)	-	1	$ 6,000
Exploration			
(Contract out at $2,500/year)			-
		Total Cost of Equipment =	$ 468,350

* Same equipment used for different operations.

TABLE 9-51
MANNING TABLE - MINE NO. 2M

Topsoil Removal and Reclamation	Total	Cost Per Year
Dozer Operator	1*	$ 870 (02%)
Loader Operator	1*	497 (01%)
Hydroseeder Operator	1*	55 (01%)
		$ 1,422
Overburden Stripping		
Dozer Operator	1*	$ 16,332 (41%)
Loader Operator	1*	13,062 (33%)
Blasting (Contract out at $1.25/ton)		
		$ 29,394
Coal Removal and Loading		
Dozer Operator	1*	$ 828 (02%)
Loader Operator	1*	4,471 (11%)
		$ 5,299
Coal Preparation		
None		
Coal Haulage		
Truck Driver (Drivers are from another operation, they work 5 day/month each)	4	$ 13,752
(Contract out 50% of hauling at $1.75/ton)		
Auxiliary Operations		
Maintenance	2*	
(Contract Welding at $ 1500/year)		

TABLE 9-51 (Contd.)

Exploration	Total	Cost Per Year
(Contract out at $2,500/year)		-
		Total Labor = $ 53,786
Administrative		
Superintendent (20% of time at this pit)	1	$ 9,388
		Total Labor and Supervision = $ 63,174

* Same people used for different operations.

TABLE 9-52
TOTAL ESTIMATED CAPITAL REQUIREMENTS - MINE NO. 2M

Exploration, Power Facilities, Site Preparation, Buildings and Roads	$	3,300
Unit Train Loading Facilities		-
Mining Equipment		468,350
Total Direct =	$	471,650
Field Indirect (2% of Total Direct)	$	9,433
Engineering		3,000
Overhead & Administration		4,500
Subtotal =	$	488,583
Contingency (10% of 488,583)	$	48,858
Subtotal =	$	537,441
Fee (2% of 537,441)	$	10,749
Total Mine Cost (Base Insurance Tax) =	$	548,190
Interest During Construction (3% of 548,190)	$	16,446
Working Capital		30,858
Total =	$	595,494

TABLE 9-53
ESTIMATED WORKING CAPITAL - MINE NO. 2M

Direct Labor, 3 months	$	13,447
Payroll Overhead, 3 months		506
Operating Supplies, 3 months		10,256
Indirect Costs, 3 months		3,908
Fixed Costs, 0.5% of Insurance Base		2,741
Miscellaneous		-
Total=	$	30,858

TABLE 9-54
ESTIMATED ANNUAL OPERATING COSTS - MINE NO. 2M

Direct Cost		
Labor		$ 53,786
Supervision		9,388
	Subtotal =	$ 63,174
Operating Supplies		
Fuel		$ 14,926
Lubricants		597
Explosives		-
Parts, Materials & Miscellaneous		25,500
	Subtotal =	$ 41,023
Auxiliary Cost		
Contract Blasting		$ 31,888
Contract Coal Hauling		22,321
Contract Welding		1,500
Power		100
Contract Exploration		2,500
Communications		1,700
Water Treatment		150
Union Welfare		10,204
Payroll Overhead		2,025
Health & Safety		750
Royalty		51,020
Strip License & Reclamation Fee		1,325
	Subtotal =	$ 125,483
	Total Direct Cost =	$ 229,680
Indirect Cost: 15% of Labor, Supervision, and Operating Supplies		$ 15,630
Fixed Cost: Taxes and Insurance, 2% of Mine Cost		10,964
Depreciation		53,069
	Total Operating Cost =	$ 309,343

TABLE 9-55
DEPRECIATION SCHEDULE - MINE NO. 2M

Item	Quantity	St. Line Deprec./Yrs.	Yearly Charge
Cat. (D-8) Bulldozer	1	10	$ 13,705
Cat. (980) Loader	1	10	10,430
Hydroseeder	1	10	5,100
Mack (D-600) Truck	4	10	17,000
Pick-up Truck	1	6	1,000
Exploration, Power Facilities Site Preparation, Buildings and Roads	-	20	165
Depreciation: Field Indirect, Engineering, Overhead and Administration, Contingency, Fee, & Interest During Construction	-	20	4,649
Interim Equipment Cost	-	20	1,020
		Total = $	53,069

TABLE 9-56

CASH FLOW ANALYSIS - MINE NO. 2M

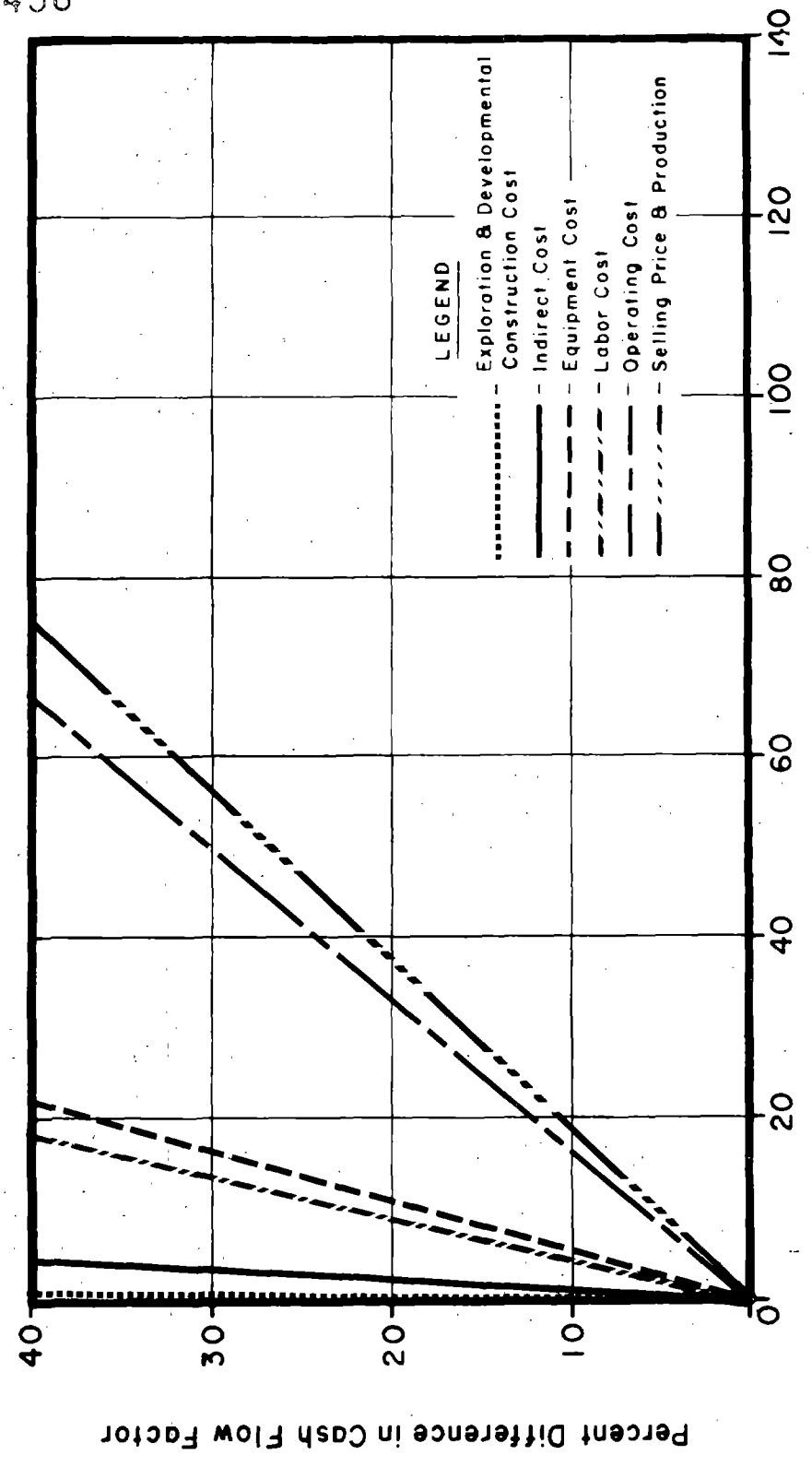
Year	Capital Investment	Cash Flow	Present Worth Factor At 15 Percent	Present Worth Capital Investment At 15 Percent	Present Worth Cash Flow Value At 15 Percent
0	$595,494	$-595,494	1.0000	$595,494	$-595,494
1	1,020	113,540	.8696	887	98,734
2	1,020	113,540	.7561	771	85,848
3	1,020	113,540	.6575	671	74,653
4	1,020	113,540	.5718	583	64,922
5	1,020	113,540	.4972	507	56,452
6	7,020	107,540	.4323	3,035	46,490
7	1,020	113,540	.3759	383	42,680
8	1,020	113,540	.3269	333	37,116
9	1,020	113,540	.2843	290	32,280
10	463,370	-348,810	.2472	114,545	-86,226
11	1,020	113,540	2149	219	24,400
12	7,020	107,540	1869	1,312	20,099
13	1,020	113,540	.1625	166	18,450
14	1,020	113,540	.1414	144	16,055
15	1,020	113,540	.1229	125	13,955
16	1,020	113,540	.1068	109	12,126
17	1,020	113,540	.0930	95	10,559
18	7,020	107,540	.0808	567	8,689
19	1,020	113,540	0702	72	7,970
20	-53,069	167,629	0611	-3,243	10,242
			TOTAL	$717,065	0

R = $717,065 ÷ 6.2593 = $114,560.00
Less depreciation = 53,069.00
Depletion + net profit = 61,491.00

Sales = 1/0.55 (cash flow + 0.5 operating cost-depreciation)
Sales = 1.8181 [$114,560 + (0.5 × $309,343) - $53,069] = $393,005.00

Sales	393,005.00
Operating Cost	309,343.00
Gross profit	83,662.00
Depletion	39,301.00
Taxable income	44,361.00
Federal Income Tax	22,181.00
Net profit	22,180.00

Annual cash flow = $22,180 + $53,069 + $39,301 = $114,550.00
Selling price per ton = $393,005 ÷ 25,510 tons = 15.41



SENSITIVITY GRAPH - MINE NO. 2 M

Figure 9-8

CASE HISTORY - MINE 3B

Surrounded by rolling hills of green pasture land, Mine 3B maintains an independent operation in the Ohio area of Region III. The bituminous seam mined is the Waynesburg (No. 11), dipping 1° northwest. Its consistent nature and thickness (34") and relatively shallow overburden (composed of 30 - 35 feet of shale and 5 - 10 feet of sandstone) provide excellent conditions for economical recovery utilizing the modified area technique. The quality of the Waynesburg coal (11,200 BTU's, 15 - 22% ash, and 1 - 2% sulfur content) makes it suitable for Ohio's utility market.

Climate in the area is similar to that of Mine 2K, with an average precipitation of 39 - 40 inches/year and an average annual temperature of 52°F with an annual range from -10°F to 90°F. No major climatological-related problems are encountered in this area; however, heavy rainfall and snow impede the mining operation.

One of six active pits, Mine 3B is a newly developed mine of moderate size, having produced approximately 70,000 tons since its five-month inception. This 50 acre mine will have affected 300 acres after completion and produced an approximate total of 750,000 tons. The preliminary regional exploration performed for this mine consisted of drilling 10 holes for each 50 acres. The primary factors examined were the rock formation of the overburden and their basic structural and chemical nature, as well as the thickness of the coal seam. Time and manpower consumed for this initial exploration entailed 24 man-days for each 50 acres explored. Subsequent to favorable findings, core borings were made immediately on 100 foot centers at an average depth of 45 feet. Additional expertise of a geologist was sought to analyze the borings and an engineer was employed to compute accurate acreage.

The planning and development effort encompassed many tasks and considerable time to meet stringent state requirements, as well as customary economical and methodological calculations and considerations. Initially, the problems of mineral rights and land ownership were resolved by leasing rights with resultant royalty payments of $1.25 per ton of coal produced by the mine. No water rights problems were encountered in this area.

Development of the proposed size of operation was achieved through

an appraisal of all pertinent factors. In decreasing order of importance, the following were the major influential considerations: capital, market, transportation, geography, environment, geology, and equipment availability. Through an evaluation of type and depth of overburden, the appropriate mining method (See Figure 3-30) and equipment (7 cubic yard dragline) were selected; in addition, these factors and the thickness of coal seam were incorporated with other mining-related conditions to determine a stripping ratio of 20:1. The task of acquiring approval for a strip mine permit from the Department of Natural Resources is similar to that developed and fulfilled by Mine 2K .

After permit approval, site preparation of the mine was initiated with construction of access and haul roads, now totalling approximately four miles. Clearing of vegetation and removal of topsoil composed the next step, with scrapers segregating topsoil from future spoil material through use of storage areas. Proper scheduling, good road conditions, daily maintenance, a road grade of less than 5%, and an average haul distance of no greater than 500 feet combined to achieve maximum efficiency.

Benching with dozers was executed prior to the next unit operation - blasting of overburden. A drill spacing pattern of 20' x 20', hole sizes of 7¼", and average depths of 40' were utilized together with primers, delay caps and 200 pound loadings of ammonium nitrate. Deck loading is sometimes employed. Two dozers and a 7 cubic yard dragline then perform the task of removing the shale and sandstone overburden.

Coal removal, loading, and haulage comprise the next stage of mining. Mine 3B employs a simple process utilizing a front-end loader for coal loading and five 18 - 20 ton trucks for transporting the coal four miles to a tipple area. Fragmentation of the coal is not required.

Contour regrading, the technique most often associated with modified area mining, is executed by Mine 3B to adequately comply with strict State requirements. Adequate replacement of topsoil (using scrapers) and burial of all toxic spoil to facilitate revegetation is also performed. The same time limits adhered to by Mine 2K must be met: all backfilling, grading, and resoiling must be initiated within three months after removal of overburden and completed within twelve months after the end of the license year, or termination of the mining process (whichever comes first); the revegetation process must then begin during the next appropriate season.

Mine 3B has accomplished excellent revegetation through the use of a cover crop (either wheat, rye, or oats - two bushels per acre) or a seeding mixture of 30% alfalfa, 15% white sweet clover, and 65% orchard grass and timothy (drill application). In addition, 300 - 400 pounds per acre of 20-20-20 fertilizer is usually applied by means of a spreader. Total costs incurred for this reclamation average $2.00 per ton of coal to create pasture land which has potential to yield a profitable corn crop (excludes topsoil removal).

Prior to marketing, Stage I preparation, consisting of crushing and sizing operations, is performed through hand-picking, breaking, and screening the coal, resulting in a reject rate of 2% per 1000 tons processed/operating day. This coal cleaning results in removal of only the gross mineral matter. Moderate costs have been incurred with a capital expenditure of approximately $100,000 for the initial plant, direct operating costs of $0.50 per ton processed, and power consumption costs totalling $400 per month.

Mine 3B utilized bin storage for its coal with appropriate loading being performed by front-end loaders. After preparation, the coal is transported by shuttle train, owned and operated by N. & W. Railroad; transportation is not included in the actual mining cost.

Some production-related problems are experienced by Mine 3B. Probably the most important are the modifications in the mining method demanded by environmental considerations. According to mine personnel, approximately 40 - 50% additional time has been required to mine due to the delays caused by: constructing two sediment ponds (½ acre each), daily pumping of water into these ponds, building of diversion ditches above the highwall, segregating of topsoil, covering of all toxic material, maintaining roads (dust control), and testing of soil and water quality.

The usual problems of obtaining critical materials such as ammonium nitrate and anti-freeze, and the time delay involved in acquiring most component machinery parts were also cited. In addition, breakdowns in loaders or tipple equipment impede production, though downtime is reduced by preventive maintenance measures such as hourly checks on all major pieces of equipment with oil changes made accordingly. No critical environmentally-related problems have been encountered to date.

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TABLE 9-57
EQUIPMENT COST SUMMARY - MINE NO. 3B

Topsoil Removal and Reclamation	Capacity	Quantity	Total Cost
Scraper	21 C.Y.	2	$ 320,000
TD-25 Bulldozer	-	1*	35,000 (25%)
D-9 Bulldozer	-	1*	47,750 (25%)
Disc & Tractor	-	2	20,000
Drill	-	1	2,200
Lime Spreader	-	1	2,800
			$ 427,750
Overburden Stripping			
TD-25 Bulldozer	-	1*	$ 105,000 (75%)
D-9 Bulldozer	-	1*	143,250 (75%)
Domey (125) Drill	7¼"	1*	107,800 (98%)
Dragline	7 C.Y.	1	700,000
			$1,056,050
Coal Removal and Loading			
M.F. (88) Loader	6 C.Y.	1	$ 120,000
Coal Haulage			
Truck	20 Ton	5	$ 250,000
Maintenance			
Welder	-	1	$ 10,000
Crane Truck	-	1	60,000
Miscellaneous	-	-	25,000
			$ 95,000
Exploration			
Domey (125) Drill	7¼"	1*	$ 2,200 (2%)
		Total Cost of Equipment =	$1,951,000

*Same equipment used for different operations.

TABLE 9-58
MANNING TABLE - MINE NO. 3B

Topsoil Removal and Reclamation	Total	Cost Per Year
Scraper Operator	2	$ 34,500
Dozer Operator	4*	20,700 (25%)
		$ 55,200
Overburden Stripping		
Dozer Operator	4*	$ 62,100 (75%)
Driller	1*	14,786 (98%)
Dragline Operator	2	41,400
		$ 118,286
Coal Removal and Loading		
Loader Operator	1	$ 15,088
Coal Preparation		
Prep Plant Operator	1	$ 14,477
Picker	2	28,404
		$ 42,881
Coal Haulage		
Truck Driver	5	$ 75,438
Auxiliary Operations		
Maintenance Crew	4	$ 66,385
Exploration		
Driller	1*	$ 302 2%)
	Total Labor	= $ 373,580

TABLE 9-58 (Contd.)

Administrative	Total		Cost Per Year
President	1		$ 10,000
General Manager	1		10,000
Accountant	1		10,000
Secretary	1		7,000
Lawyer	1		3,000
	Total Supervision	=	$ 40,000
	Total Labor and Supervision	=	$ 413,580

* Same people used for different operations.

TABLE 9-59
TOTAL ESTIMATED CAPITAL REQUIREMENTS - MINE NO. 3B

Exploration, Power Facilities, Site Preparation, Buildings and Roads		$ 120,000
Unit Train Loading Facilities and Preparation Plant		200,000
Mining Equipment		1,951,000
	Total Direct =	$2,271,000
Field Indirect (2% of Total Direct)		$ 45,420
Engineering		11,000
Overhead & Administration		50,000
	Subtotal =	$2,377,420
Contingency (10% of 2,377,420)		$ 237,742
	Subtotal =	$2,615,162
Fee (2% of 2,615,162)		$ 52,303
Total Mine Cost (Base Insurance Tax)	=	$2,667,465
Interest During Construction (3% of 2,667,465)		$ 80,024
Working Capital		350,541
	Total =	$3,098,030

TABLE 9-60
ESTIMATED WORKING CAPITAL - MINE NO. 3B

Direct Labor, 3 months		$ 103,395
Payroll Overhead, 3 months		36,188
Operating Supplies, 3 months		158,358
Indirect Costs, 3 months		39,263
Fixed Costs, 0.5% of Insurance Base		13,337
Miscellaneous		-
	Total =	$ 350,541

TABLE 9-61
ESTIMATED ANNUAL OPERATING COSTS - MINE NO. 3B

Direct Cost		
Labor		$ 373,580
Supervision		40,000
	Subtotal =	$ 413,580
Operating Supplies		
Fuel		$ 130,800
Lubricants		5,230
Explosives		182,400
Parts, Materials & Miscellaneous		315,000
	Subtotal =	$ 633,430
Auxiliary Cost		
Contract Coal Hauling		$ -
Power		6,000
Communications		2,400
Company Welfare		56,000
Payroll Overhead		144,753
Health & Safety		4,200
Royalty		175,000
Strip License & Reclamation Fee		1,600
	Subtotal =	$ 389,953
	Total Direct Cost =	$1,436,963
Indirect Cost: 15% of Labor, Supervision, and Operating Supplies		$ 157,052
Fixed Cost: Taxes and Insurance 2% of Mine Cost		53,349
Depreciation		486,957
	Total Operating Cost =	$2,134,321

TABLE 9-62
DEPRECIATION SCHEDULE - MINE NO. 3B

Item	Quantity	St. Line Deprec. Yrs.	Yearly Charge
Scraper	2	5	$ 64,000
Tractor & Disc.	2	5	4,000
Drill	1	5	440
Lime Spreader	1	5	560
TD-25 Bulldozer	1	5	28,000
D-9 Bulldozer	1	5	38,200
Drill	1	5	22,000
Dragline	1	5	140,000
M.F. (88) Loader	1	5	24,000
Truck	5	3	83,333
Welder	1	5	2,000
Crane Truck	1	5	12,000
Miscellaneous Equipment	-	5	5,000
Exploration, Power Facilities, Site Preparation, Buildings, and Roads	-	5	24,000
Unit Train Loading Facilities, and Preparation Plant	-	20	10,000
Depreciation; Field Indirect, Engineering, Overhead and Administration, Contingency Fee, and Interest During Construction	-	20	23,824
Interim Equipment Cost	-	20	5,600
		Total = $	486,957

TABLE 9-63

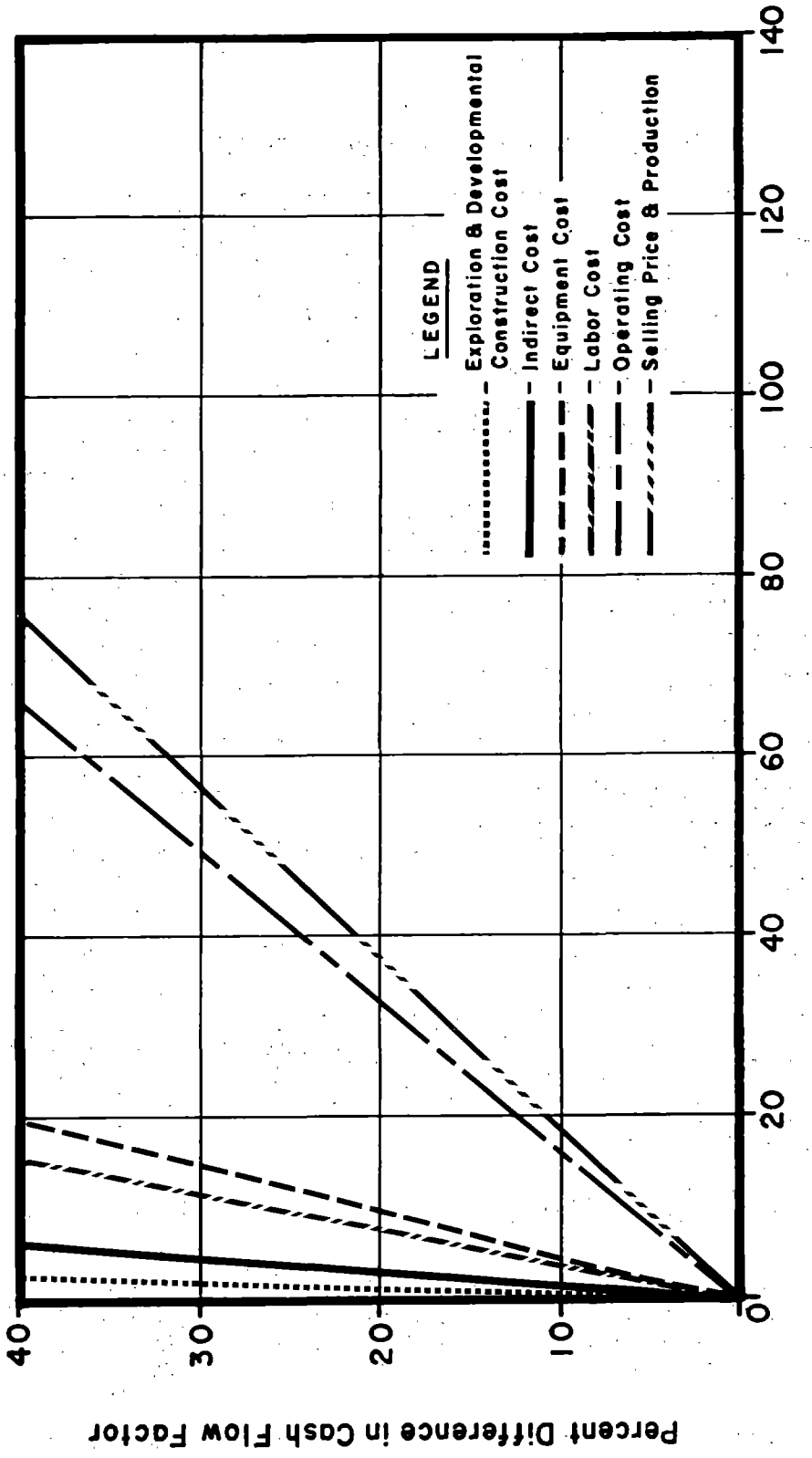
CASH FLOW ANALYSIS - MINE NO. 3B

Year	Capital Investment	Cash Flow	Present Worth Factor At 15 Percent	Present Worth Capital Investment At 15 Percent	Present Worth Cash Flow Value At 15 Percent
0	$3,098,030	$-3,098,030	1.0000	$3,098,030	$-3,098,030
1	5,600	812,945	.8696	4,870	706,937
2	5,600	812,945	.7561	4,234	614,667
3	255,600	562,945	.6575	168,057	370,135
4	5,600	812,945	.5718	3,202	464,842
5	1,826,600	-1,008,055	.4972	908,186	-501,205
6	255,600	562,945	.4323	110,496	243,361
7	5,600	812,945	.3759	2,105	305,586
8	5,600	812,945	.3269	1,831	265,752
9	255,600	562,945	.2843	72,667	160,045
10	1,826,600	-1,008,055	.2472	451,536	-249,191
11	5,600	812,945	.2149	1,203	174,702
12	255,600	562,945	.1869	47,772	105,214
13	5,600	812,945	.1625	910	132,103
14	5,600	812,945	.1414	792	114,950
15	2,076,600	-1,258,055	.1229	255,214	-154,615
16	5,600	812,945	.1068	598	86,822
17	5,600	812,945	.0930	521	75,604
18	255,600	562,945	.0808	20,652	45,486
19	5,600	812,945	.0702	393	57,069
20	-486,957	1,305,502	.0611	-29,753	79,766
			TOTAL	$5,123,516	0

R = $5,123,516 ÷ 6.2593	=	$ 818,545.00
Less depreciation	=	486,957.00
Depletion + net profit	=	331,588.00
Gross profit = 1.333 x $331,588	=	442,007.00
Sales = $2,134,321 + $442,007	=	2,576,328.00

Gross profit	442,007.00
Depletion	221,004.00
Taxable income	221,003.00
Federal Income Tax	110,502.00
Net profit	110,501.00

Annual cash flow = $110,501 + $486,957 + $221,004	=	$ 818,462.00
Selling price per ton = $2,576,328 ÷ 140,000 tons	=	18.40



SENSITIVITY GRAPH - MINE NO. 3B

Figure 9-9

CASE HISTORY - MINE 3D

This mine is located in southern Illinois, Region III. The surrounding topography represents typical Midwest terrain with 50% timberland, 25% pasture, and 25% marginal cropland. A small stream can be seen from the mine area, but poses no threat to the operation, or vice versa.

Two bituminous coal seams are mined at this site, the 5 foot thick Herrin (or No. 6) and the 3-3 1/2 foot thick Harrisburg (or No. 5). A thirty foot parting of fifteen feet of limestone and fifteen feet of shale separates these two consistent seams. With a combined post-preparation quality of 12,600 BTU, 11% ash, and 3.7% sulfur, these coals satisfy the requirements for utilization in steam power electric generators. The average overburden thickness of 40 feet (range 10 feet to 60 feet) is composed of 8 inches topsoil, 10 feet clay near the surface, 10 feet limestone, and 20 feet shale at the No. 6 seam. The effective average overburden thickness is 70 feet including the 30 feet of parting above the No. 5 seam. These moderately bedded rock systems are consolidated enough to warrant blasting.

The Midwest climate of this area (50° F average temperature and 35 inches average annual precipitation) causes the usual problems associated with weather (wet, muddy, haul roads; water in the pit; minor flooding; and freezing in the winter).

The reserves at this site were purchased with prior knowledge of availability. Detailed analyses of the deposit consist of drilling 660 foot center holes, then 330 foot center holes and even closer checks along the outcrop. One out of every ten holes is core drilled.

Both land and mineral rights ownership are retained by the company. This particular mine is only one of this firm's many operations.

Of the factors influencing mine planning and development, geography and equipment availability were most critical, with geology, environment, market, capital, and transportation of lesser importance (in decreasing order as listed).

Wooded land is timbered off with stumps removed by a dozer. No topsoil segregation procedures are conducted. Overburden prep-

aration consists of drilling 15 inch holes on a 35 foot x 40 foot grid pattern, and blasting with 1000 pounds of ammonium nitrate mixed with diesel fuel (ANFO) per hole. To avoid return passes of stripping machines, overburden and partings are removed on the same pass with a variable pitch dipper, 105 cubic yard stripping shovel. (See Figure 3-41). By sitting on the lower coal seam, the operator first strips the parting and stacks it at the toe of the spoil, to serve as a buckwall. Then material overlying the upper seam is removed and placed behind this buckwall.

Ripped coal is then loaded by shovels into 120 ton bottom dump coal haulers and taken to a hopper at the primary crusher. Crushed coal is stored in 8000 ton raw storage silos before cleaning, after which it is stored in 15,000 ton clean coal silos prior to unit train loading.

Reclamation regrading is conducted with crawler dozers and a small dragline to near original contours. By applying 200 pounds of 18-46-0 fertilizer and two bushels of wheat per acre, excellent crop revegetation is accomplished.

Diversion ditches and pumps direct water to settling ponds for removal of suspended solids prior to discharge.

Weekly "in-house" inspections and ground control monitoring receive major emphasis in health and safety considerations.

A complete scheduled maintenance program is conducted along with constant maintenance of haul roads.

Elimination of large rocks in the regraded spoil area is a major problem. Shovel stripping does not permit good segregation of material, therefore there is little control of topsoil material. Future regulations could require removal of any material greater than 24 inches in diameter from within two feet of the surface.

TABLE 9-64
EQUIPMENT COST SUMMARY - MINE NO. 3D

Topsoil Removal and Reclamation	Capacity	Quantity	Total Cost
D-9 Bulldozer	-	2	$ 383,400
TD-25 Bulldozer	-	1	160,000
NW (95) Dragline	4 C.Y.	1	400,000
			$ 943,400
Overburden Stripping			
Dynamite Truck	-	1	$ 30,000
Nitrate Truck	-	1	25,000
61-R Drill	15"	1	532,000
50-R Drill	10 5/8"	1	400,000
40-R Drill	9"	1	110,000
5900 Shovel	105 C.Y.	1	8,000,000
7500 Dragline	18 C.Y.	1	2,000,000
D-8 Bulldozer	-	3	411,000
824 Wheel Bulldozer	-	1	170,000
			$11,678,000
Coal Removal and Loading			
151-M Shovel	12 C.Y.	2	$ 820,000
D-9 Bulldozer/Ripper	-	1	197,000
D-8 Bulldozer/Ripper	-	1	137,000
D-7 Bulldozer	-	1	110,000
988 Loader	6 C.Y.	1	138,900
			$ 1,402,900
Coal Haulage			
Kenworth Dart Truck	120 Ton	6	$ 1,800,000

TABLE 9-64 (Contd.)

Maintenance	Capacity	Quantity	Total Cost
Grader	-	1	$ 50,000
Sprinkler Truck	-	1	30,000
Supply Truck	-	1	10,000
Pick-up Truck	-	2	14,000
Welding Truck	-	1	13,000
			$ 117,000
Exploration			
Drill	-	1	$ 110,000
Pick-up Truck	-	1	7,000
			$ 117,000

Total Cost of Equipment = $16,058,300

TABLE 9-65
MANNING TABLE - MINE NO. 3D

Topsoil Removal and Reclamation	Total	Cost Per Year
Dozer Operator	9	$ 180,835
Dragline Operator	1	17,222
		$ 198,057
Overburden Stripping		
Driller	9	$ 163,675
Driller's Helper	9	157,014
Drill Hand	9	155,111
Shooter	6	109,117
Shooter's Helper	6	104,676
Truck Driver	6	103,407
Shovel Operator	3	62,983
Shovel Oiler	3	57,905
Dragline Operator	3	62,983
Dragline Oiler	3	57,905
Dozer Operator	12	241,776
		$1,276,552
Coal Removal and Loading		
Shovel Operator	4	$ 68,890
Shovel Oiler	4	63,348
Dozer Operator	9	180,835
Loader Operator	3	52,721
		$ 365,794
Coal Preparation		
Prep. Plant Operator	1	$ 15,500
Prep Utility Men	1	14,202
		$ 29,702
Coal Haulage		
Truck Driver	12	$ 180,760

TABLE 9-65 (Contd.)

Auxiliary Operations	Total	Cost Per Year
Grader Operator	1	$ 17,222
Truck Driver	3	45,250
Welder	12	190,045
Electrician	9	166,747
Greaser	1	16,569
		$ 435,833
Exploration		
Driller	1	$ 15,063
Driller's Helper	1	14,477
Geologist	2	30,000
		$ 59,540
	Total Labor =	$2,546,238
Administrative		
President	1	$ 25,000
Vice President	1	25,000
Mine Superintendent	1	20,000
Maintenance Foreman	3	60,000
Foreman Superintendent	3	60,000
Engineer	1	15,000
Safety Engineer	1	15,000
Geological Engineer	1	15,000
Operations Manager	1	15,000
Maintenance Engineer	1	15,000
Accountant	2	30,000
Secretary	4	30,000
Clerk	3	22,500
	Total Supervision =	$ 347,500
	Total Labor and Supervision =	$2,893,738

TABLE 9-66
TOTAL ESTIMATED CAPITAL REQUIREMENTS - MINE NO. 3D

Exploration, Power Facilities, Site Preparation, Buildings and Roads		$ 2,000,000
Preparation Plant		7,500,000
Unit Train Loading Facilities		2,500,000
Mining Equipment		16,058,300
	Total Direct =	$28,058,300
Field Indirect (2% of Total Direct)		$ 561,166
Engineering		540,000
Overhead & Administration		1,417,248
	Subtotal =	$30,576,714
Contingency (10% of 30,576,714)		$ 3,057,671
	Subtotal =	$33,634,385
Fee (2% of 33,634,385)		$ 672,688
Total Mine Cost (Base Insurance Tax)	=	$34,307,073
Interest During Construction (3% of 34,307,073)		$ 1,029,212
Working Capital		2,297,097
	Total =	$37,633,382

TABLE 9-67
ESTIMATED WORKING CAPITAL - MINE NO. 3D

Direct Labor, 3 months	$ 723,435
Payroll Overhead, 3 months	248,019
Operating Supplies, 3 months	909,211
Indirect Costs, 3 months	244,897
Fixed Costs, 0.5% of Insurance Base	171,535
Miscellaneous	-
Total =	$ 2,297,097

TABLE 9-68
ESTIMATED ANNUAL OPERATING COSTS - MINE NO. 3D

Direct Cost		
Labor		$ 2,546,238
Supervision		347,500
	Subtotal	= $ 2,893,738
Operating Supplies		
Fuel		$ 624,975
Lubricants		25,230
Explosives		589,680
Parts, Materials & Miscellaneous		2,395,960
	Subtotal	= $ 3,636,845
Auxiliary Cost		
Contract Coal Hauling		$ -
Power		336,230
Communications		90,000
Union Welfare		2,400,000
Payroll Overhead		992,074
Health & Safety		50,000
Royalty		-
Strip License & Reclamation Fee		153,800
	Subtotal	= $ 4,022,104
	Total Direct Cost	= $10,552,687
Indirect Cost: 15% of Labor, Supervision, and Operating Supplies		$ 979,587
Fixed Cost: Taxes and Insurance, 2% of Mine Cost		686,141
Depreciation		2,204,900
	Total Operating Cost	= $14,423,315

TABLE 9-69
DEPRECIATION SCHEDULE - MINE NO. 3D

Item	Quantity	St. Line Deprec./Yrs.	Yearly Charge
D-9 Bulldozer	2	10	$ 38,340
TD-25 Bulldozer	1	10	16,000
NW (95) Dragline	1	20	20,000
Dynamite Truck	1	5	6,000
Nitrate Truck	1	5	5,000
61-R Drill	1	20	26,600
50-R Drill	1	20	20,000
40-R Drill	1	20	5,500
5900 Shovel	1	20	400,000
7500 Dragline	1	20	100,000
D-8 Bulldozer	3	10	41,100
824 Wheel Bulldozer	1	10	17,000
151-M Shovel	2	20	41,000
D-9 Bulldozer/Ripper	1	10	19,700
D-8 Bulldozer/Ripper	1	10	13,700
D-7 Bulldozer	1	10	11,000
988 Loader	1	10	13,890
Kenworth Dart Truck (120 ton)	6	6	300,000
Grader	1	10	5,000
Sprinkler Truck	1	10	3,000
Supply Truck	1	6	1,667
Pick-up Truck	3	4	5,250
Welding Truck	1	10	1,300
Drill	1	10	11,000
Exploration, Power Facilities, Site Preparation, Buildings and Roads	-	20	100,000
Preparation Plant	-	20	375,000
Unit Train Loading Facilities	-	20	125,000
Depreciation: Field Indirect, Engineering, Overhead and Administration, Contingency, Fee, and Interest During Construction	-	20	362,853
Interim Equipment Cost	-	20	120,000
		Total	= $2,204,900

TABLE 9-70

CASH FLOW ANALYSIS – MINE NO. 3D

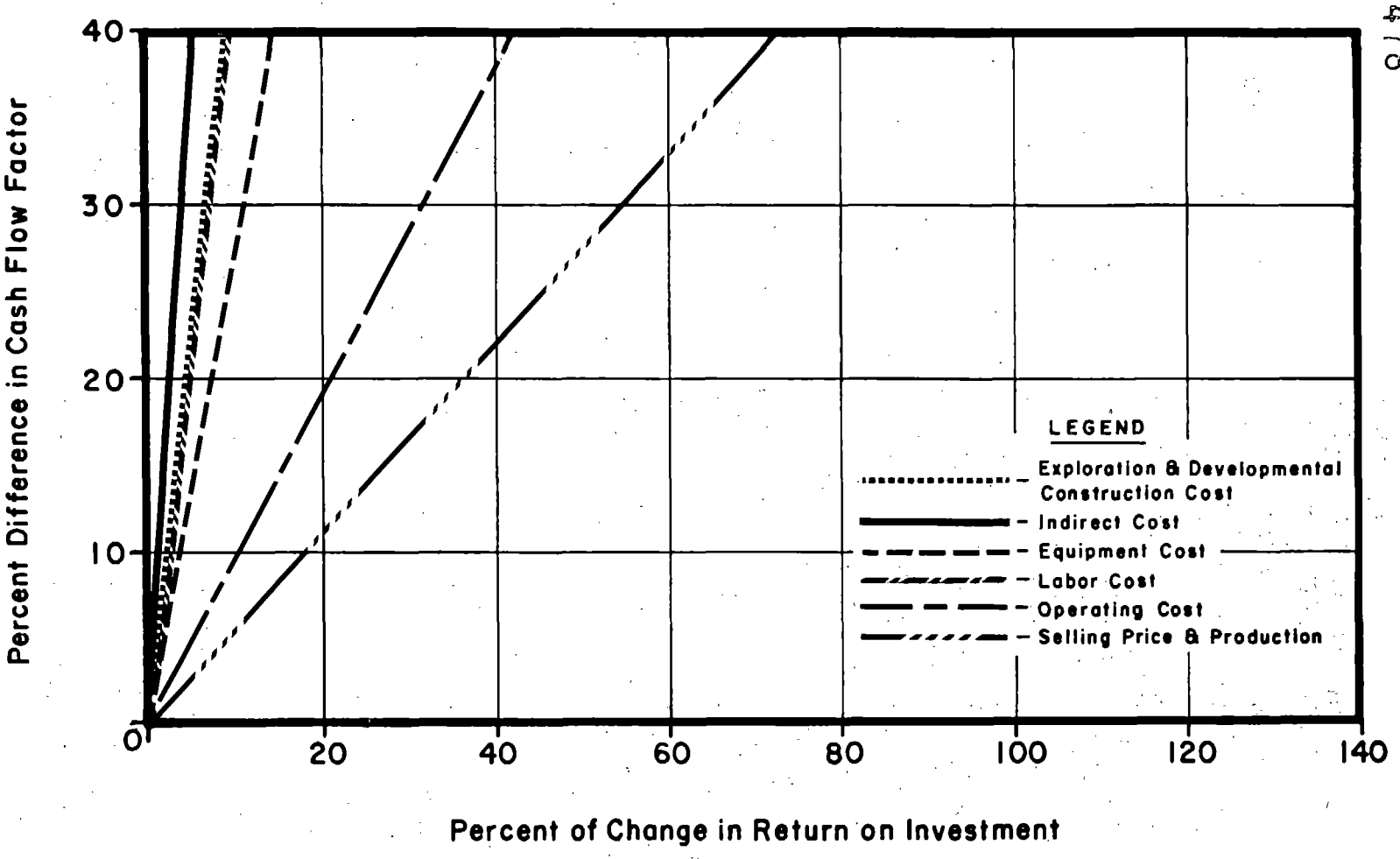
Year	Capital Investment	Cash Flow	Present Worth Factor At 15 Percent	Present Worth Capital Investment At 15 Percent	Present Worth Cash Flow Value At 15 Percent
0	$37,633,382	$-37,633,382	1.0000	$37,633,382	$-37,633,382
1	120,000	6,275,184	.8696	104,352	5,456,900
2	120,000	6,275,184	.7561	90,732	4,744,666
3	120,000	6,275,184	.6575	78,900	4,125,933
4	120,000	6,275,184	.5718	68,616	3,588,150
5	175,000	6,220,184	.4972	87,010	3,092,675
6	1,930,000	4,465,184	.4323	834,339	1,930,299
7	120,000	6,275,184	.3759	45,108	2,358,842
8	120,000	6,275,184	.3269	39,228	2,051,358
9	120,000	6,275,184	.2843	34,116	1,784,035
10	2,085,300	4,309,884	.2472	515,486	1,065,403
11	120,000	6,275,184	.2149	25,788	1,348,537
12	1,930,000	4,465,184	.1869	360,717	834,543
13	120,000	6,275,184	.1625	19,500	1,019,717
14	120,000	6,275,184	.1414	16,968	887,311
15	175,000	6,220,184	.1229	21,508	764,461
16	120,000	6,275,184	.1068	12,816	670,190
17	120,000	6,275,184	.0930	11,160	583,592
18	1,930,000	4,465,184	.0808	155,944	360,787
19	120,000	6,275,184	.0702	8,424	440,518
20	-2,204,900	8,600,084	.0611	-134,719	525,465
			TOTAL	$40,029,375	0

R = $40,029,375 ÷ 6.2593 = $6,395,184.00
Less Depreciation = 2,204,900.00
Depletion + Net Profit = 4,190,284.00

Sales = 1/0.55 (cash flow + 0.5 operating cost-depreciation)
Sales = 1.8181 [$6,395,184+(0.5×$14,423,315)-$2,204,900] =20,729,870.00

Sales	20,729,870.00
Operating Cost	14,423,315.00
Gross profit	6,306,555.00
Depletion	2,072,987.00
Taxable income	4,233,568.00
Federal Income Tax	2,116,784.00
Net profit	2,116,784.00

Annual cash flow = $2,116,784 + $2,204,900 + $2,072,987 = $ 6,394,671.00
Selling price per ton = $20,729,870 ÷ 3,000,000 tons = 6.91



SENSITIVITY GRAPH - MINE NO. 3D

Figure 9-10

CASE HISTORY - MINE 3L

Characterized as a typical Midwest area mine, Mine 3L is located in the southern Indiana coal fields of Region III. The surrounding area consists of gently rolling hills with pasture or crop vegetation and no nearby waterbodies. Coal geology of the sought-after 4.5 foot thick No. 5 seam indicates a dip .5% to S. W. with some undulations and no partings. This bituminous steam coal has post-preparation quality of 11,500 BTU, 8.5% ash, 3.5% sulfur, and 43% fixed carbon.

Overburden ranges in thickness from 15 feet to 120 feet (average 80 feet) and consists of 12 inches of topsoil and various thicknesses of shale, some sandstone and limestone, and a few thin coal seams. These rock units are fairly consolidated, and require blasting prior to removal.

Climatic conditions are typical of the midwest - 45 inches annual precipitation, $-5^{o}F$ to $110^{o}F$ temperature range ($55^{o}F$ average). No unusual problems are encountered relating to the climate. Of course, wet weather and cold temperatures affect the operation, as they would any earth moving activity.

Mine 3L is one of many mines operated by this company. As a large independent company, long term contracts with power utilities for coal sales are common.

Exploration for new reserves does not usually involve analysis of virgin, unexplored areas. Known coal bearing areas are examined for tract availability. After obtained, these areas are core drilled to estimate the available reserves at 10 acre minimum intervals. Augering outcrops yield large amounts of coal for testing and evaluation. Two full-time and one part-time drill rigs constantly search for new areas of possible mine development.

Mineral rights ownership varies even within the mine area. Some areas are entirely leased, others owned outright (surface and mineral), and others are surface leased while owning coal rights.

Although many factors influenced development of this mine, the large available market at the time of conception gave rise to this high production operation. Also huge amounts of reserves, 90 + million tons, insured coal availability.

Daily mine planning and State permit mapping are at scales of 1 inch = 100 feet and 1 inch = 400 feet, with aerial photography providing easy updating of production advancement for both parties (company and state).

Mine 3L is a typical box-cut area mine. The only site preparation required is construction of haul and access roads by dozers and road graders. For efficient operation of draglines, overburden is drilled and blasted on a 36 foot x 45 foot pattern with deck loading of holes using ANFO.

Two draglines are utilized at this site, one 100 cubic yard dragline for major stripping and one 65 cubic yard dragline for pullback work (See Figure 3-45)

Topsoil segregation and toxic material separation are performed with topsoil placed on top of old spoils, and toxic material placed in the bottom of old cuts.

Prior to loading with shovels into 90 and 100 ton off-highway bottom dump trucks, coal is fragmented by ripper-dozers. Length of haul to the plant ranges from 3-4 miles, depending upon the route taken. After being dumped into a hopper at the plant, coal is crushed, washed, screened, and moved by conveyor to unit train loading facilities.

Reclamation consists of regrading to near original contour (flat-slightly rolling terrain), and revegetating with grasses suitable for pasture grazing. Forty pounds/acre of seed and 250 pounds/acre of 20-40-0 fertilizer are applied by airplane (if sufficient acreage) or broadcast by hand.

All water encountered in the pit is collected in sumps and pumped to settling ponds for removal of suspended solids.

A future problem of this site is pending legislation that would call for the elimination of material greater than 24 inches in diameter from within two feet of the surface.

TABLE 9-71
EQUIPMENT COST SUMMARY - MINE NO. 3L

Topsoil Removal and Reclamation	Capacity	Quantity	Total Cost
D-9 Bulldozer	-	2*	$ 141,858 (37%)
D-8 Bulldozer	-	3*	152,126 (37%)
TD-25 Bulldozer	-	1*	51,800 (37%)
			$ 345,784
Overburden Stripping			
D-9 Bulldozer	-	2*	$ 241,542 (63%)
D-8 Bulldozer	-	3*	259,024 (63%)
TD-25 Bulldozer	-	1*	88,200 (63%)
61-R Drill	15"	2	1,064,000
Explosive Truck	-	2	12,000
2570-W Dragline	100 C.Y.	1	15,000,000
5761-W Dragline	65 C.Y.	1	6,300,000
500-W Shovel	13 C.Y.	1	1,500,000
			$24,464,766
Coal Removal and Loading			
BECO (150-B) Shovel	10 C.Y.	1	$ 750,000
BECO (100-B) Shovel	7 C.Y.	1	600,000
			$ 1,350,000
Coal Haulage			
Dart Bottom Dump Truck	90 Ton	3	$ 741,000
Dart Bottom Dump Truck	100 Ton	3	894,000
Euclid (R-35) Truck	35 Ton	1	124,000
Wabco (35) Truck	35 Ton	3	372,000
			$ 2,131,000

TABLE 9-71 (Contd.)

Maintenance	Capacity	Quantity	Total Cost
Lube Truck	-	1	$ 10,000
Grader	-	1	61,000
Water Truck	-	1	16,000
Welder Truck	-	1	12,000
Mechanic Truck	-	1	22,000
Pick-up Truck	-	3	18,000
Tire Truck	-	1	10,000
Fuel Truck	-	1	30,000
			$ 179,000
Exploration			
(22-HD) Joy Core Drill	-	1	$ 100,000
(50-B) Mobile Core Drill	-	1	400,000
(10-B) Skid Auger Drill	-	1	50,000
			$ 550,000

Total Cost of Equipment = $29,020,550

* Same equipment used for different operations.

TABLE 9-72
MANNING TABLE - MINE NO. 3L

Topsoil Removal and Reclamation	Total		Cost Per Year
Dozer Operator	12*	$	61,092 (37%)
Overburden Stripping			
Dozer Operator	12*	$	104,004 (63%)
Driller	4		60,253
Driller's Helper	4		57,907
Shooter	4		60,253
Shooter's Helper	4		57,907
Explosive Truck Driver	4		57,159
Dragline Operator	6		120,557
Dragline Oiler	6		110,860
Electrician	6		110,860
Shovel Operator	3		60,278
Shovel Oiler	3		55,430
Master Electrician	1		20,093
		$	875,561
Coal Removal and Loading			
Shovel Operator	4	$	68,890
Shovel Oiler	4		63,348
Electrician	4		63,348
		$	195,586
Coal Preparation			
Prep. Plant Operator	2	$	30,456
Prep. Utility Men	2		30,456
		$	60,912
Coal Haulage			
Truck Driver	20	$	285,792

TABLE 9-72 (Contd.)

Auxiliary Operations	Total	Cost Per Year
Laborer	20	$ 236,704
Mechanic	5	65,988
Mechanic's Helper	5	60,320
Welder	1	13,198
Welder's Helper	1	12,064
Machinist	2	26,395
Machinist's Helper	2	24,128
Grader Operator	4	57,408
		$ 496,205
Exploration		
Driller	3	$ 45,190
Driller's Helper	3	43,430
		$ 88,620
	Total Labor	= $2,063,768
Administrative		
President	1	$ 25,000
Vice-President	1	22,500
Secretary-Treasurer	1	20,000
Engineer	1	15,000
Technician	1	10,000
Draftsman	2	18,000
Geologist	1	17,500
Surveyor	1	12,500
Survey Crew	3	30,000
Secretary	5	40,000
Accountant	1	20,000
Foreman	3	60,000
	Total Supervision	= $ 290,500
	Total Labor and Supervision	= $2,354,268

TABLE 9-73
TOTAL ESTIMATED CAPITAL REQUIREMENTS - MINE NO. 3L

Exploration, Power Facilities, Site Preparation, Buildings and Roads	$ 2,700,000
Preparation Plant	5,000,000
Unit Train Loading Facilities	2,000,000
Mining Equipment	29,020,550
Total Direct =	$38,720,550
Field Indirect (2% of Total Direct)	$ 774,411
Engineering	259,200
Overhead & Administration	1,177,134
Subtotal =	$40,931,295
Contingency (10% of 40,931,295)	$ 4,093,130
Subtotal =	$45,024,425
Fee (2% of 45,024,425)	$ 900,489
Total Mine Cost (Base Insurance Tax) =	$45,924,914
Interest During Construction (3% of 45,924,914)	$ 1,377,747
Working Capital	2,393,588
Total =	$49,696,249

TABLE 9-74
ESTIMATED WORKING CAPITAL - MINE NO. 3L

Direct Labor, 3 months	$ 588,567
Payroll Overhead, 3 months	205,999
Operating Supplies, 3 months	1,114,010
Indirect Costs, 3 months	255,387
Fixed Costs, 0.5% of Insurance Base	229,625
Miscellaneous	-
Total =	$ 2,393,588

TABLE 9-75
ESTIMATED ANNUAL OPERATING COSTS - MINE NO. 3L

Direct Cost		
Labor		$ 2,063,768
Supervision		290,500
	Subtotal =	$ 2,354,268
Operating Supplies		
Fuel		$ 404,928
Lubricants		16,197
Explosives		1,310,400
Parts, Materials & Miscellaneous		2,724,514
	Subtotal =	$ 4,456,039
Auxiliary Cost		
Contract Coal Hauling		$ -
Power		477,921
Communications		60,000
Union Welfare		941,454
Payroll Overhead		823,994
Health & Safety		43,200
Royalty		720,000
Strip License & Reclamation Fee		207,950
	Subtotal =	$ 3,274,519
	Total Direct Cost =	$10,084,826
Indirect Cost: 15% of Labor, Supervision, and Operating Supplies		$ 1,021,546
Fixed Cost: Taxes and Insurance, 2% of Mine Cost		918,498
Depreciation		2,697,796
	Total Operating Cost =	$14,722,666

TABLE 9-76
DEPRECIATION SCHEDULE - MINE NO. 3L

Item	Quantity	St. Line Deprec./Yrs.	Yearly Charge
D-9 Bulldozer	2	10	$ 38,340
D-8 Bulldozer	3	10	41,115
TD-25 Bulldozer	1	10	14,000
61-R Drill	2	20	53,200
Explosive Truck	2	6	2,000
2570-W Dragline	1	20	750,000
5761-W Dragline	1	20	315,000
500-W Shovel	1	20	75,000
BECO (150-B) Shovel	1	10	75,000
BECO (100-B) Shovel	1	10	60,000
Dart Bottom Dump Truck (90 Ton)	3	10	74,100
Dart Bottom Dump Truck (100 Ton)	3	10	89,400
Euclid (R-35) Truck	1	6	20,667
Wabco (35) Truck	3	6	62,000
Lube Truck	1	6	1,667
Grader	1	10	6,100
Water Truck	1	6	2,667
Welder Truck	1	6	2,000
Mechanic Truck	1	6	3,667
Pick-up Truck	3	3	6,000
Tire Truck	1	6	1,667
Fuel Truck	1	6	5,000
(22-HD) Joy Core Drill	1	20	5,000
(50-B) Mobile Core Drill	1	20	20,000
(10-B) Skid Auger Drill	1	20	2,500
Exploration, Power Facilities, Site Preparation, Buildings and Roads	-	20	135,000

TABLE 9-76 (Contd.)

Item	Quantity	St. Line Deprec./Yrs.	Yearly Charge
Preparation Plant	-	20	$ 250,000
Unit Train Loading Facilities	-	20	100,000
Depreciation: Field Indirect, Engineering Overhead and Administration, Contingency Fee and Interest During Construction	-	20	429,106
Interim Equipment Cost	-	20	57,600
		Total =	$2,697,796

TABLE 9-77

CASH FLOW ANALYSIS - MINE NO. 3L

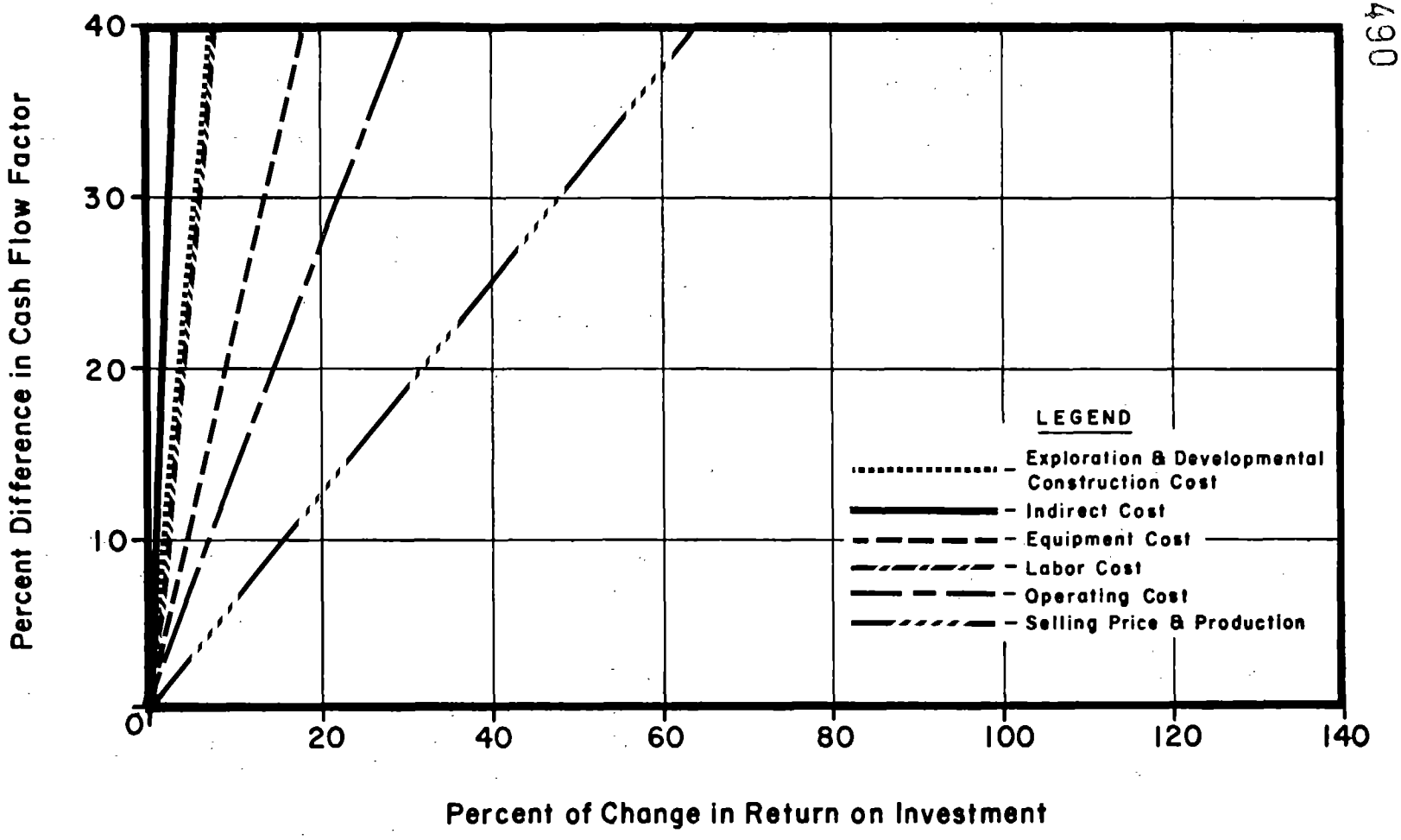
Year	Capital Investment	Cash Flow	Present Worth Factor At 15 Percent	Present Worth Capital Investment At 15 Percent	Present Worth Cash Flow Value At 15 Percent
0	$49,696,249	$-49,696,249	1.0000	$49,696,249	$-49,696,249
1	57,600	8,137,889	.8696	50,089	7,076,708
2	57,600	8,137,889	.7561	43,551	6,153,058
3	57,600	8,137,889	.6575	37,872	5,350,662
4	57,600	8,137,889	.5718	32,936	4,653,245
5	57,600	8,137,889	.4972	28,639	4,046,158
6	665,600	7,529,889	.4323	287,739	3,255,171
7	57,600	8,137,889	.3759	21,652	3,059,032
8	57,600	8,137,889	.3269	18,829	2,660,276
9	57,600	8,137,889	.2843	16,376	2,313,602
10	4,038,150	4,157,339	.2472	998,231	1,027,694
11	57,600	8,137,889	.2149	12,378	1,748,832
12	665,600	7,529,889	.1869	124,401	1,407,336
13	57,600	8,137,889	.1625	9,360	1,322,407
14	57,600	8,137,889	.1414	8,145	1,150,697
15	57,600	8,137,889	.1229	7,079	1,000,146
16	57,600	8,137,889	.1068	6,152	869,126
17	57,600	8,137,889	.0930	5,357	756,824
18	665,600	7,529,889	.0808	53,780	608,415
19	57,600	8,137,889	.0702	4,044	571,280
20	-2,697,796	10,893,285	.0611	-164,835	665,580
			TOTAL	$51,298,024	0

R = $51,298,024 ÷ 6.2593 = $ 8,195,489.00
Less depreciation = 2,697,796.00
Depletion + net profit = 5,497,693.00

Sales = 1/0.55 (cash flow + 0.5 operating cost-depreciation)
Sales = 1.8181 [$8,195,489 + (0.5 × $14,722,666) - $2,697,796] = 23,378,995.00

Sales	23,378,995.00
Operating Cost	14,722,666.00
Gross profit	8,656,329.00
Depletion	2,337,900.00
Taxable income	6,318,429.00
Federal Income Tax	3,159,215.00
Net profit	3,159,214.00

Annual cash flow = $3,159,214 + $2,697,796 + $2,337,900 = $ 8,194,910.00
Selling price per ton = $23,378,995 ÷ 1,440,000 tons = 16.24



SENSITIVITY GRAPH - MINE NO. 3L

Figure 9-11

CASE HISTORY - MINE 4E

Located in Colorado within Region IV, the area encompassing Mine 4E is characterized by rolling hills, sparsely vegetated with brush and aspen trees. Surface drainage emanates from the Rocky Mountains, and in the vicinity of this mine forms a small stream. Expansion of a smaller pit is being carefully considered to avoid stream siltation and infiltration into pit areas.

The Wadge and Fish Creek bituminous coals are extracted from two separate pits and sold on the utility market. Coal characteristics are: 11,000 BTU's; 7 to 10% ash; 0.3 to 0.6% sulfur; fixed carbon 35% (Wadge) and 45% (Fish Creek). Dipping approximately eight degrees, the Wadge varies from 7 to 10 feet thick and the Fish Creek averages 4 feet, while both maintain relatively consistent quality.

To effect coal removal, 50 to 70 feet of inter-bedded massive sandstone and thin bedded shales must be excavated from the Wadge, and 60 to 100 feet overlying the Fish Creek. Topsoil averages three to four feet thick and provides fair revegetation potential.

Climatic conditions vary with a normal temperature of 64°F with extremes ranging from -40°F to 95°F. Yearly precipitation averages 20 inches which includes 59 inches of snow. Much of the rainfall occurs as intense storms which cause short production delays. In addition, heavy snowfalls produce slick haulroad conditions that result in mine closures several days per year.

Mine 4E is an independent operation managed by a moderately large corporate structure. To date, mining has produced eight million tons of coal while disturbing seven hundred surface acres.

Since the coals are extremely consistent in thickness and quality, exploration efforts are limited to regional investigations. A field team of one geologist, a driller, and driller's helper explore prospective mine areas for five to six months per year. Outcrop geology and core borings are examined. An Ingersoll Rand drill is used to obtain the core on one mile centers - a minor amount of contract drilling is also performed.

Having established the extent of mineable coal through exploration

efforts, the initial step in planning and development is acquisition of mining rights. Although much of the land is owned by the mining company, Federal leases and fees ranging between $0.20 and $0.35 per ton are paid as mineral rights royalty. Another planning step involves mapping the mine area on U.S.G.S. topographic maps. These maps are then used to plot all mine facilities and in periodic up-dating of mining progress.

The present area mining method evolved as a traditional technique that has been continuously expanded by addition of new equipment at random, based on availability. Major factors influencing planned annual productivity include, in descending order of importance:

- market
- transportation
- geography
- capital
- equipment

The latter two factors have become increasingly important during the past year.

Access and haulroad construction comprise site preparation, while separate clearing and grubbing is not required due to sparse vegetation. Stripping operations are commenced by topsoil removal and storage via three dozers and two pan scrapers. The dozer and scrapers are also employed for spoil leveling and road work, with approximately 20% of the dozer time allocated to dragline benching.

Overburden material must be blasted to facilitate excavation. This is accomplished by drilling holes spaced 18 by 20 feet apart and loading each with 8 pounds of ANFO per foot (deck loading is used to provide added fragmentation of resistant sandstone units). Following blasting, the overburden is excavated with three draglines - the Wadge pit has a 14 cubic yard and a 21 cubic yard dragline operating in tandem producing 1,260,000 tons per year, while the Fish Creek pit employs an eight cubic yard dragline to recover 540,000 tons per year. Although both operations mine by area methods, the Wadge pit progresses along the coal dip slope with a series of parallel cuts perpendicular to the strike. The Fish Creek pit operates by the same general technique but all cuts traverse parallel to the coal strike.

Figure 3-38 illustrates the Wadge pit mining procedures. Both draglines move up and down the slope, casting spoil into the previously mined-out pit. One full strip takes approximately 30 days. Excessive overburden and a steep cliff at the coal crop define mining limits.

Coal removal is preceded by drilling (6 by 10 foot spacing) and blasting with four pounds of explosive per foot of coal. An electric shovel and front-end loader place coal into trucks which travel one mile from the Wadge pit to the tipple. Access is usually provided between the two dragline excavations to allow coal loading and haulage at either point with minimal road construction. The Fish Creek coal is loaded by a front-end loader onto trucks and carried 2.5 miles to the tipple (most of this haul road is paved). The tipple consists of a primary and secondary crushing plant (2500 tons per hour) with unit train loading facilities. Storage is minimal now but bins are being constructed in conjunction with new loading facilities.

Reclamation at Mine 4E consists of leveling spoil piles to original contour, replacing topsoil and revegetation. Twenty pounds of alfalfa and some fertilizer are applied to each acre by air spraying and seeders - drills have been more effective and will be used totally in the future. This vegetative cover is apparently better than the native brush, which only supports wildlife.

Major auxiliary operations are as follows:

- water diversion trenches above highwalls
- monitoring dust and noise
- watering haul roads
- performing preventive equipment maintenance - grease and oil coal haul trucks between shifts and analyze oil from dozers
- apply and rework gravel on roads
- maintain storage inventory of parts and supplies
- operate communications system with two way radios in all pick-ups and at the tipple and main office
- perform electrical services with a full-time electrician

The major production related problem at Mine 4E is a 25% loss in total production resulting from 50% down-time with the 21 cubic yard dragline. No significant environmental problems occur, although noise and dust monitoring do add to operating costs (a full-time safety engineer is employed).

TABLE 9-78
EQUIPMENT COST SUMMARY - MINE NO. 4E

Topsoil Removal and Reclamation	Capacity	Quantity	Total Cost	
Cat. (D-9) Bulldozer	-	3*	$ 345,060	(60%)
International (25) Bulldozer	-	2*	168,000	(60%)
Terex Scraper	10 C.Y.	2	260,000	
			$ 773,060	
Overburden Stripping				
Cat. (D-9) Bulldozer	-	3*	$ 230,040	(40%)
International (25) Bulldozer	-	2*	112,000	(40%)
Ingersoll Rand (40) Drill	7 7/8"	2	220,000	
Dragline	8 C.Y.	1	1,000,000	
Dragline	14 C.Y.	1	1,300,000	
Dragline	21 C.Y.	1	2,225,000	
Pick-up Truck	-	2*	6,700	(67%)
			$5,093,740	
Coal Removal and Loading				
Ingersoll Rand Drill	-	2	$ 110,000	
Shovel	6 C.Y.	1	450,000	
Hough Loader	10 C.Y.	2	588,000	
Pick-up Truck	-	2*	3,300	(33%)
			$1,151,300	
Coal Haulage				
Dart Truck	65 Ton	3	$ 600,000	
International Truck	35 Ton	2	248,000	
Cline Truck	45 Ton	4	600,000	
Euclid Truck	50 Ton	3	515,895	
Cat. (D-9) Bulldozer	-	1	191,700	
			$2,155,595	

TABLE 9-78 (Contd.)

Maintenance	Capacity	Quantity	Total Cost
Pick-up Truck	-	4	$ 20,000
Water Truck	-	2	60,000
Crane	55 Ton	1	80,000
Grader	-	1	60,000
Miscellaneous	-	-	300,000
			$ 520,000
Exploration			
Ingersoll Rand Drill	7 7/8"	1	$ 110,000
Pick-up Truck	-	2	10,000
			$ 120,000
	Total Cost of Equipment		= $9,813,695

* Same equipment used for different operations.

TABLE 9-79
MANNING TABLE - MINE NO. 4E

Topsoil Removal and Reclamation	Total	Cost Per Year
Dozer Operator	10*	$ 84,384 (60%)
Scraper Operator	2	28,130
		$ 112,514
Overburden Stripping		
Dozer Operator	10*	$ 56,256 (40%)
Driller	2	26,960
Driller's Helper	2	25,780
Shooter	2	26,960
Dragline Operator	9	167,670
Dragline Oiler	9	149,040
Truck Driver	2*	18,063 (67%)
		$ 470,729
Coal Removal and Loading		
Driller	2	$ 26,960
Driller's Helper	2	25,780
Shooter	2	26,960
Shovel Operator	1	14,650
Loader Operator	2	29,300
Truck Driver	2*	8,897 (33%)
		$ 132,547
Coal Preparation		
Dozer Operator	2	$ 28,130
Prep Plant Operator	2	26,960
Picker	2	20,040
		$ 75,130
Coal Haulage		
Truck Driver	12	$ 168,770

TABLE 9-79 (Contd.)

Auxiliary Operations	Total	Cost Per Year
Maintenance Crew	12	$ 175,800
Utility Men	8	80,160
		$ 255,960
Exploration		
Driller	1	$ 13,480
Driller's Helper	1	12,890
Drill Hand	1	7,480
Geologist	1	24,000
		$ 57,850
	Total Labor	= $1,273,500
Administrative		
President	1	-
Vice-President	1	-
Accountant	2	-
General Superintendent	1	-
Foreman	4	-
Safety Engineer	1	-
Secretary	2	-
	Total Supervision	= $ 300,000
	Total Labor and Supervision	= $1,573,500

* Same people used for different operations.

TABLE 9-80
TOTAL ESTIMATED CAPITAL REQUIREMENTS - MINE NO. 4E

Exploration, Power Facilities, Site Preparation, Buildings and Roads		$ 2,700,000
Preparation Plant		1,200,000
Unit Train Loading Facilities		1,800,000
Mining Equipment		9,813,695
	Total Direct =	$15,513,695
Field Indirect (2% of Total Direct)		$ 310,274
Engineering		500,000
Overhead & Administration		500,000
	Subtotal =	$16,823,969
Contingency (10% of 16,823,969)		$ 1,682,397
	Subtotal =	$18,506,366
Fee (2% of 18,506,366)		$ 370,127
Total Mine Cost (Base Insurance Tax)	=	$18,876,493
Interest During Construction (3% of 18,876,493)		$ 566,294
Working Capital		1,276,182
	Total =	$20,718,969

TABLE 9-81
ESTIMATED WORKING CAPITAL - MINE NO. 4E

Direct Labor, 3 months		$ 393,375
Payroll Overhead, 3 months		98,344
Operating Supplies, 3 months		524,695
Indirect Cost, 3 months		137,711
Fixed Costs, 0.5% of Insurance Base		94,382
Miscellaneous		27,675
	Total =	$ 1,276,182

TABLE 9-82
ESTIMATED ANNUAL OPERATING COSTS - MINE NO. 4E

Direct Cost	
Labor	$1,273,500
Supervision	300,000
Subtotal =	$1,573,500
Operating Supplies	
Fuel	$ 315,880
Lubricants	13,160
Explosives	665,740
Parts, Materials, & Miscellaneous	1,104,000
Subtotal =	$2,098,780
Auxiliary Cost	
Power	$ 122,300
Communications	30,000
Union Welfare	1,440,000
Payroll Overhead	393,375
Health & Safety	48,000
Royalty	504,000
Strip License & Reclamation Fee	3,000
Subtotal =	$2,540,675
Total Direct Cost =	$6,212,955
Indirect Cost: 15% of Labor, Supervision, and Operating Supplies	$ 550,842
Fixed Cost: Taxes and Insurance, 2% of Mine Cost	377,530
Depreciation	2,040,018
Total Operating Cost =	$9,181,345

TABLE 9-83
DEPRECIATION SCHEDULE - MINE NO. 4E

Item	Quantity	St. Line Deprec. Yrs.	Yearly Charge
Cat. (D-9) Bulldozer	4	4	$ 191,700
International (25) Bulldozer	2	4	70,000
Terex Scraper	2	4	65,000
Ingersoll Rand (40) Drill	3	5	66,000
Dragline	3	15	301,667
Ingersoll Rand Drill	2	5	22,000
Shovel	1	15	30,000
Hough Loader	2	5	117,600
Dart Truck	3	5	120,000
International Truck	2	5	49,600
Cline Truck	4	5	120,000
Euclid Truck	3	5	103,179
Pick-up Truck	8	3	13,333
Water Truck	2	5	12,000
Crane	1	10	8,000
Grader	1	10	6,000
Miscellaneous	-	10	30,000
Exploration, Power Facilities, Site Preparation, Buildings, and Roads	-	15	180,000
Preparation Plant	-	15	80,000
Unit Train Loading Facilities	-	15	120,000
Depreciation: Field Indirect, Engineering, Overhead and Administration, Contingency, Fee, and Interest During Construction	-	15	261,939
Interim Equipment Cost	-	15	72,000
		Total	= $2,040,018

TABLE 9-84

CASH FLOW ANALYSIS - MINE NO. 4E

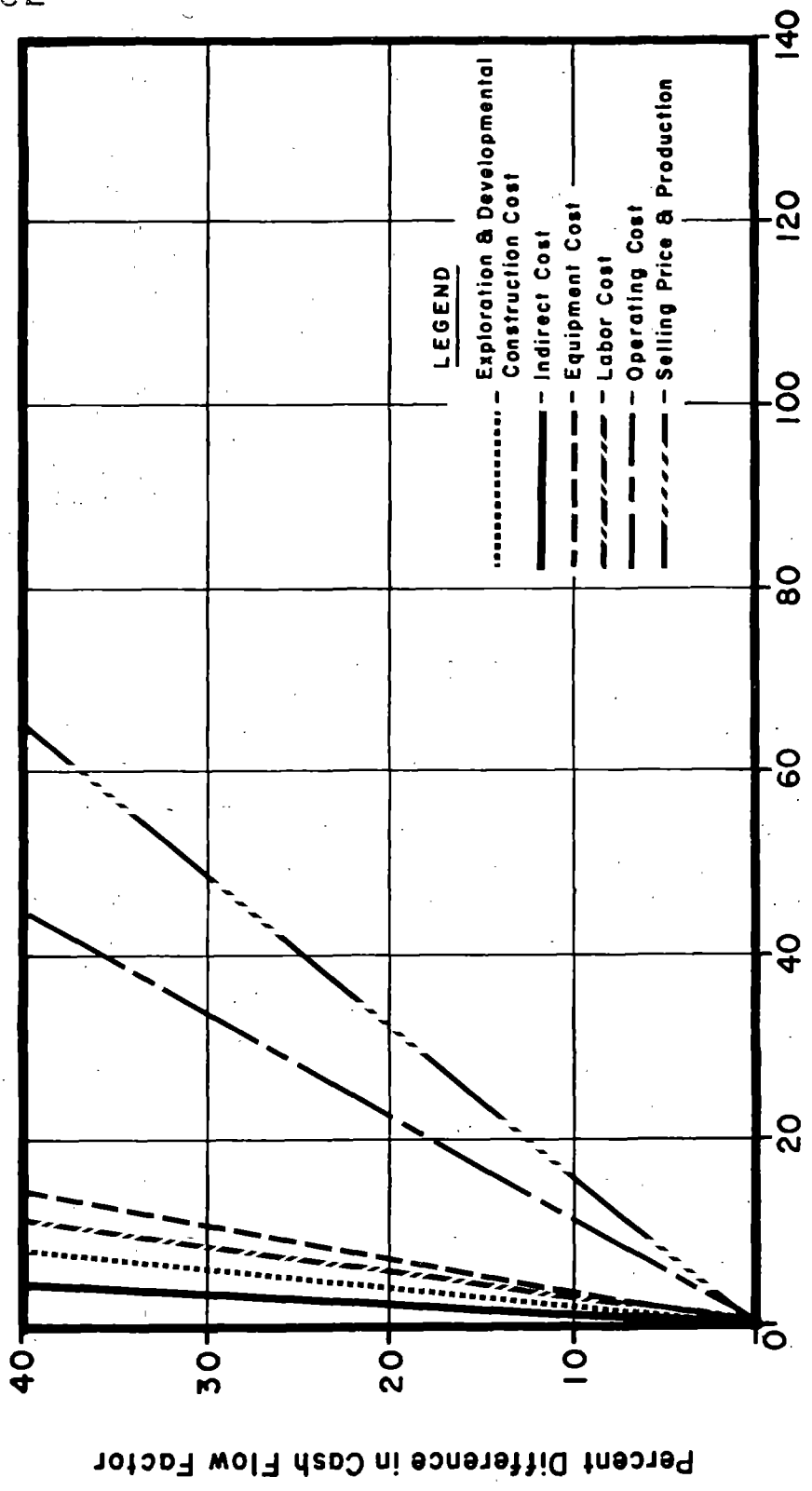
Year	Capital Investment	Cash Flow	Present Worth Factor At 15 Percent	Present Worth Capital Investment At 15 Percent	Present Worth Cash Flow Value At 15 Percent
0	$20,718,969	$-20,718,969	1.0000	$20,718,969	$-20,718,969
1	72,000	4,148,624	.8696	62,611	3,607,643
2	72,000	4,148,624	.7561	54,439	3,136,775
3	72,000	4,148,624	.6575	47,340	2,727,720
4	1,378,800	2,841,624	.5718	788,398	1,624,955
5	3,123,895	1,096,729	.4972	1,553,201	545,294
6	72,000	4,148,624	.4323	31,126	1,793,450
7	72,000	4,148,624	.3759	27,065	1,559,468
8	1,378,800	2,841,624	.3269	450,730	928,992
9	72,000	4,148,624	.2843	20,470	1,179,454
10	3,563,895	656,729	.2472	880,995	162,343
11	72,000	4,148,624	.2149	15,473	891,539
12	1,378,800	2,841,824	.1869	257,698	531,137
13	72,000	4,148,624	.1625	11,700	674,151
14	72,000	4,148,624	.1414	10,181	586,615
15	-2,040,018	6,260,642	.1229	-250,718	769,433
16			.1068		
17			.0930		
18			.0808		
19			.0702		
20			.0611		
			TOTAL	$24,679,678	0

R = $24,679,678 ÷ 5.8474 = $ 4,220,624.00
Less Depreciation 2,040,018.00
Depletion + Net profit 2,180,606.00

Sales = 1/0.55 (Cash flow + 0.5 operating cost - depreciation)
Sales = 1.8181 [$4,220,624 + (0.5 × $9,181,345) - $2,040,018] = $12,310,861.00

Sales	=	12,310,861.00
Operating Cost		9,181,345.00
Gross profit		3,129,516.00
Depletion		1,231,086.00
Taxable income		1,898,430.00
Federal Income Tax		949,215.00
Net profit		949,215.00

Annual cash flow = $949,215 + $2,040,018 + $1,231,086 = $ 4,220,319.00
Selling price per ton = $12,310,861 ÷ 1,800,000 tons = 6.84



SENSITIVITY GRAPH - MINE NO. 4E

Figure 9-12

CASE HISTORY - MINE 4H

This mine lies in south-central Wyoming. The area includes most western plateau terrain types, with the exception of mountainous areas. This basin has a geologic history of extensive and major faulting, and is evident in numerous hills and crop structures within a generally flat river basin. Vegetation is primarily sagebrush with trees almost non-existent. Antelope and jack-rabbits are common wildlife species and livestock grazing is the basic domestic land use. Surface drainage is usually loosely defined water courses or drainage along fault lines which trend northeast-southwest. Few impoundments are evident, most are small, usually located in remains of old strip mines. Storage capacities are usually small due to low infiltration conditions and small annual precipitation.

Geologic conditions in this area are among the most complex of the western mining states. Coal bearing rocks of the Cretaceous, Paleocene and Eocene Ages occur throughout the Basin. Present mining near Hanna involves the Ferris and Medicine Bow Formations of the Upper Cretaceous and Paleocene Ages. All six of the beds in this operation are in the Ferris Formation. For market purposes this coal is considered sub-bituminous in rank, although some areas of low grade bituminous coal are found. BTU values range from 9400 to 10,500, ash content averages 10% and sulfur is 0.4%. Bed thickness varies from 3 feet to 20 feet, with parting beds from 3 feet to 60 feet thick; most parting seams have large amounts of unmarketable coal. Bed dip can reach 40% with the average at 30%, strike of the basin is northeast to southwest trending and generalized dip is toward the northwest. Major faults of upwards to 300 feet have been traced through exploratory drilling and are considered widespread through the basin.

Overburden characteristics are typical of Cretaceous Age rock units. Topsoil is considered nonexistent; however, mining interests separate fine overburden as part of present State mining regulations. Some Wyoming clay is evident along with fragmented gray sandstone, and gray to white-gray shales. Most rock units are thin bedded, unconsolidated, moderately fractured, requiring moderate blasting prior

to removal. Vertical separation of coal beds can reach 100 feet to 150 feet with current mine highwall limit set at 150 feet. This depth usually intercepts a portion of the next higher cropline.

This mining operation was preceded by extensive and detailed field exploration, involving closely spaced air rotary and core drill samples, and extensive geologic studies.

Major factors in mine planning and development are equipment capability, reserve size, and geology, in that order. Equipment has been somewhat uniquely tested in this area, in large part due to the steeply tilted bed structure. Large draglines were chosen due to the uneven depth of overburden and wider casting arc. Mapping is related to the exploratory efforts of this operation and must be regarded as privileged data. Permits are becoming a problem due to environmental pressures being applied by State regulatory agencies. (Another division of this company currently has equipment available for mining another area being idled by a dispute over electric power transmission.)

A major consideration in this area is federally owned mineral rights and difficulties in obtaining lease agreements. As presently administered, this will have a major influence on present as well as future mining. In order for mining to compete in the energy field, production on a continuous basis is desirable. Current scattered public-private ownerships many times cause mine interests to skip or go around federally owned mineral reserves. While most interests recognize the need for control of these lands for the public good, instances are occurring which are counter-productive. This problem is not limited to the Hanna Basin, but is generally encountered throughout federal lands.

The mine is considered an open pit operation by the mining company with backfilling only to the extent that minimum permit requirements are met (in terms of gradients, spoil material cover, etc.). Due to the steeply pitched coal beds, a trench is opened with a low wall of about 20 feet to a highwall of nearly 150 feet. This trench is usually about one-half mile long. Overburden is cast to the mined-out side of the operation with these trends following the strike of the basin. On completion of coal removal all spoil piles are reduced into the pits, to properly cover gob materials and achieve sufficient slope grades. Completed grading yields a rolling ridge and valley network, generally

pleasing to the eye and of considerable value to livestock and wildlife (offering protection from high winds and cold temperatures, usually part of Wyoming winters). Completed vegetation contributes grasslands and livestock shelter to an area previously covered with sagebrush unsuitable for livestock.

Production in this mine approaches 3,000,000 tons annually - accomplished with one 60 cubic yard dragline, six 100-ton coal trucks, and supporting equipment. Site preparation is a minor item, with clearing and grubbing operations almost nonexistent and road construction relatively simple. Topsoil is removed and stockpiled with Caterpillar 633 and 657 scrapers, providing a drill and dragline bench. Drilling, when needed, is set up on a 35 x 35 foot grid using 12 1/4 inch holes varying in depth from 20 to 150 feet. A ratio of 2 1/2 yards of overburden to one pound of ANFO is usually followed. This yields a powder usage of about 480 pounds per 30 foot hole to about 4000 pounds for a 150 foot hole. Some deck loading techniques are employed usually in so-called "wet holes", but is not a common practice.

Overburden removal is accomplished entirely by a 60 + cubic yard dragline. Working depth varies from 30 feet to 150 feet, beginning operation after the pans have reached their limits.

Coal removal is accomplished by a 16 cubic yard electric loading shovel and a diesel wheel loader. Some coal fragmentation is used with a 10 x 10 foot drill hole spacing and ammonium nitrate mixed with diesel fuel as a blasting agent. Little, if any, in-place separation of partings is employed.

All coal is loaded to six, 100-ton coal haulers, with a 4 mile one-way trip to the preparation and storage facility. All coal removal and haulage operators work 300 days annually, 1 shift per day. Overburden stripping operators work 350 days annually, 3 shifts per day.

Raw coal is dumped into a hopper serving a Gunlock primary crusher, reducing mine run coal to a 6 inch consist. Secondary crushing is done with a McLanahan crusher to 2 inches x 0 gradation. This coal is stockpiled prior to loading on a unit train or run directly to unit trains.

Coal storage capacity is approximately 20,000 tons with a core feeder supplying a conveyor belt system to a loading tipple. To date no problems have occurred with the system, and spontaneous combustion, dust, and stockpile drainage do not exist. Transportation is supplied by Union Pacific railroad or coal customer cars, with markets in the mid-west power generation facilities.

Production problems seem to be related to equipment availability. The addition of another dragline will help this situation somewhat, but the lead time in acquiring this equipment is at best a 5 year program. Current market conditions require more coal production, with this producer finding support equipment such as D-9 dozers not readily available.

Environmental problems have hampered production in the past, usually resluting in a better environment at some additional cost. This seems acceptable to all parties concerned, but environmental restraints are now causing equipment down time during a period of full production necessity. This mine company has an investment in a new dragline and support equipment idled by a dispute over power transmission, after mine permits were issued. This, in addition to being counter-productive, is presenting financial problems to the company.

Federal mineral rights problems should be reassessed to eliminate unnecessary hop-scotch mining, thus reducing mining costs. These cost reductions could be realized by eliminating shut down and start-up time and mobilization costs.

TABLE 9-85
EQUIPMENT COST SUMMARY - MINE NO. 4H

Topsoil Removal and Reclamation	Capacity	Quantity	Total Cost
Cat. (633) Scraper	27 C.Y.	1	$ 180,000
Cat. (657) Scraper	40 C.Y.	2	618,000
Cat. (D-8) Bulldozer	-	1	137,000
Cat. (D-9) Bulldozer	-	1	191,000
			$1,126,000
Overburden Stripping			
Bucyrus-Erie (60-R) Drill	-	1	$ 475,000
Bucyrus-Erie (40-R) Drill	-	1	110,000
Marion (8000) Dragline	62 C.Y.	1	7,300,000
Explosive Truck	-	2	12,000
			$7,897,000
Coal Removal and Loading			
Marion (182-M) Shovel	16 C.Y.	1	$1,600,000
Dart (D-600) Wheel Loader	15 C.Y.	1	400,000
			$2,000,000
Coal Haulage			
Euclid Truck	100 Ton	4	$1,280,000
Cat. Truck	100 Ton	2	560,000
Euclid End Dump (Primarily Partings)	85 Ton	2	690,000
			$2,530,000
Maintenance			
Welder Machine	-	2	$ 24,000
Pick-up Truck	-	3	18,000
			$ 42,000

TABLE 9-85 (Contd.)

Exploration	Capacity	Quantity	Total Cost
Bucyrus-Erie (40-R) Drill	-	1	$ 110,000
Pick-up Truck	-	1	6,000
			$ 116,000

Total Cost of Equipment = $13,711,000

TABLE 9-86
MANNING TABLE - MINE NO. 4H

Topsoil Removal and Reclamation	Total	Cost Per Year
Scraper Operator	3	$ 41,400
Dozer Operator	4	55,200
		$ 96,600
Overburden Stripping		
Driller	6	$ 101,388
Driller's Helper	6	97,440
Shooter	3	50,694
Shooter's Helper	3	48,720
Dragline Operator	3	57,960
Dragline Oiler	3	53,298
Electrician	3	53,298
Explosive Truck Driver	6	96,180
		$ 558,978
Coal Removal and Loading		
Shovel Operator	4	$ 66,240
Wheel Loader Operator	2	33,120
		$ 99,360
Coal Preparation		
Prep. Plant Operator	2	$ 30,456
Prep. Utility Men	2	27,968
		$ 57,424
Coal Haulage		
Truck Driver	14	$ 202,776
Auxiliary Operations		
Maintenance Crew	16	$ 231,744

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TABLE 9-86 (Contd.)

Exploration	Total	Cost Per Year
Driller	1	$ 16,898
Driller's Helper	1	16,240
		$ 33,138
	Total Labor =	$1,281,020
Administrative		
Office Personnel	20	$ 322,500
	Total Supervision =	$ 322,500
	Total Labor and Supervision =	$1,603,520

TABLE 9-87
TOTAL ESTIMATED CAPITAL REQUIREMENTS - MINE NO. 4H

Exploration, Power Facilities, Site Preparation, Buildings, and Roads		$ 2,500,000
Preparation Plant		2,000,000
Unit Train Loading Facilities		500,000
Mining Equipment		13,711,000
		$18,711,000
Field Indirect (2% of Total Direct)		$ 374,220
Engineering		540,000
Overhead & Administration		786,435
	Subtotal =	$20,411,655
Contingency (10% of 20,411,655)		$ 2,041,166
	Subtotal =	$22,452,821
Fee (2% of 22,452,821)		$ 449,056
Total Mine Cost (Base Insurance Tax)	=	$22,901,877
Interest During Construction (3% of 22,901,877)		$ 687,056
Working Capital		1,421,777
	Total =	$25,010,710

TABLE 9-88
ESTIMATED WORKING CAPITAL - MINE NO. 4H

Direct Labor, 3 months	$ 400,880
Payroll Overhead, 3 months	140,308
Operating Supplies, 3 months	613,868
Indirect Costs, 3 months	152,212
Fixed Costs, 0.5% of Insurance Base	114,509
Miscellaneous	-
Total =	$ 1,421,777

TABLE 9-89
ESTIMATED ANNUAL OPERATING COSTS - MINE NO. 4H

Direct Cost		
Labor		$ 1,281,020
Supervision		322,500
	Subtotal =	$ 1,603,520
Operating Supplies		
Fuel		$ 437,400
Lubricants		17,496
Explosives		304,200
Parts, Materials & Miscellaneous		1,696,375
	Subtotal =	$ 2,455,471
Auxiliary Cost		
Contract Revegetation		$ 40,000
Contract Coal Hauling		-
Power		300,000
Communications		65,000
Union Welfare		1,500,000
Payroll Overhead		561,232
Health & Safety		90,000
Royalty		525,000
Strip License & Reclamation Fee		12,000
	Subtotal =	$ 3,093,232
	Total Direct Cost =	$ 7,152,223
Indirect Cost: 15% of Labor, Supervision, and Operating Supplies		$ 608,849
Fixed Cost: Taxes and Insurance, 2% of Mine Cost		458,038
Depreciation		1,883,597
	Total Operating Cost =	$10,102,707

TABLE 9-90
DEPRECIATION SCHEDULE - MINE NO. 4H

Item	Quantity	St. Line Deprec./Yrs.	Yearly Charge
Cat. (633) Scraper	1	5	$ 36,000
Cat. (657) Scraper	2	5	123,600
Cat. (D-9) Dozer	1	10	19,100
Cat. (D-8) Dozer	1	10	13,700
Bucyrus-Erie (60-R) Drill	1	10	47,500
Bucyrus-Erie (40-R) Drill	2	10	22,000
Marion (8000) Dragline	1	20	365,000
Explosive Truck	2	3	4,000
Marion (182-M) Shovel	1	20	80,000
Dart (D-600) Wheel Loader	1	10	40,000
Euclid Truck (100 Ton)	4	5	256,000
Cat. Truck (100Ton)	2	5	112,000
Euclid Truck (85 Ton)	2	5	138,000
Welder Machine	2	5	4,800
Pick-up Truck	4	3	8,000
Exploration, Power Facilities, Site Preparation, Buildings and Road	-	20	125,000
Preparation Plant	-	20	100,000
Unit Train Loading Facilities	-	20	25,000
Depreciation: Field Indirect, Engineering, Overhead and Administration, Contingency, Fee, and Interest During Construction	-	20	243,897
Interim Equipment Cost	-	20	120,000
			Total = $1,883,597

TABLE 9-91

CASH FLOW ANALYSIS - MINE NO. 4H

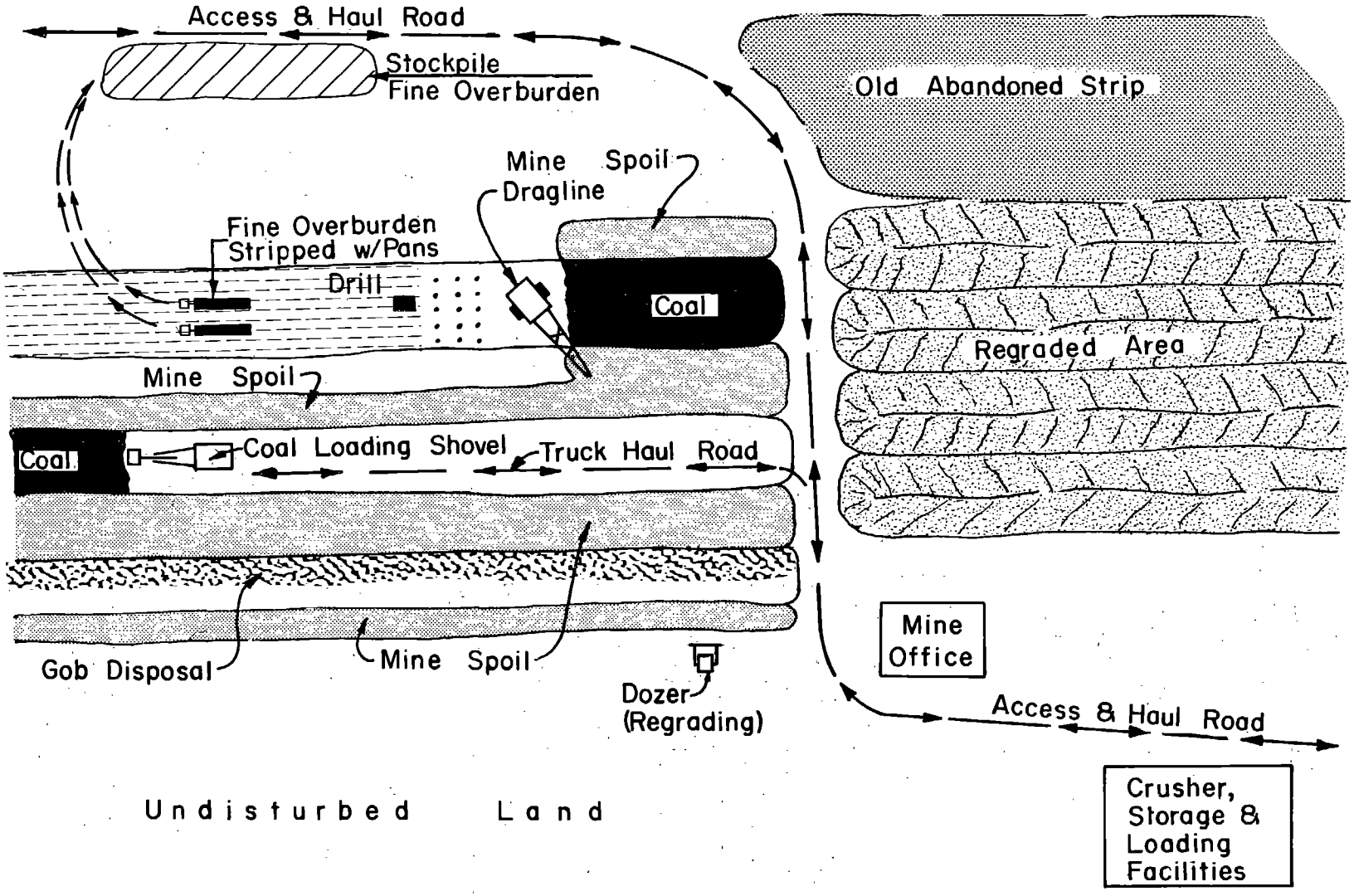
Year	Capital Investment	Cash Flow	Present Worth Factor At 15 Percent	Present Worth Capital Investment At 15 Percent	Present Worth Cash Flow Value At 15 Percent
0	$25,010,710	$-25,010,710	1.0000	$ 25,010,710	$-25,010,710
1	120,000	4,496,868	.8696	104,352	3,910,476
2	120,000	4,496,868	.7561	90,732	3,400,082
3	120,000	4,496,868	6575	78,900	2,956,691
4	120,000	4,496,868	.5718	68,616	2,571,309
5	3,472,000	1,144,868	.4972	1,726,278	569,228
6	120,000	4,496,868	.4323	51,876	1,943,996
7	120,000	4,496,868	.3759	45,108	1,690,372
8	120,000	4,496,868	3269	39,228	1,470,026
9	120,000	4,496,868	.2843	34,116	1,278,460
10	4,895,000	-278,132	2472	1,210,044	-68,754
11	120,000	4,496,868	.2149	25,788	966,377
12	120,000	4,496,868	1869	22,428	840,465
13	120,000	4,496,868	.1625	19,500	730,741
14	120,000	4,496,868	1414	16,968	635,857
15	3,472,000	1,144,868	.1229	426,709	140,704
16	120,000	4,496,868	.1068	12,816	480,266
17	120,000	4,496,868	.0930	11,160	418,209
18	120,000	4,496,868	.0808	9,696	363,347
19	120,000	4,496,868	0702	8,424	315,680
20	-1,883,597	6,500,465	.0611	-115,088	397,178
			TOTAL	$28,898,361	0

R = $28,898,361 ÷ 6.2593 = $ 4,616,868.00
Less Depreciation = 1,883,597.00
Depletion + Net Profit = 2,733,271.00

Sales = 1/0.55 (cash flow + 0.5 operating cost-depreciation)
Sales = 1.8181 [$4,616,868+(0.5×$10,102,707)-$1,883,597]= $14,153,226.00

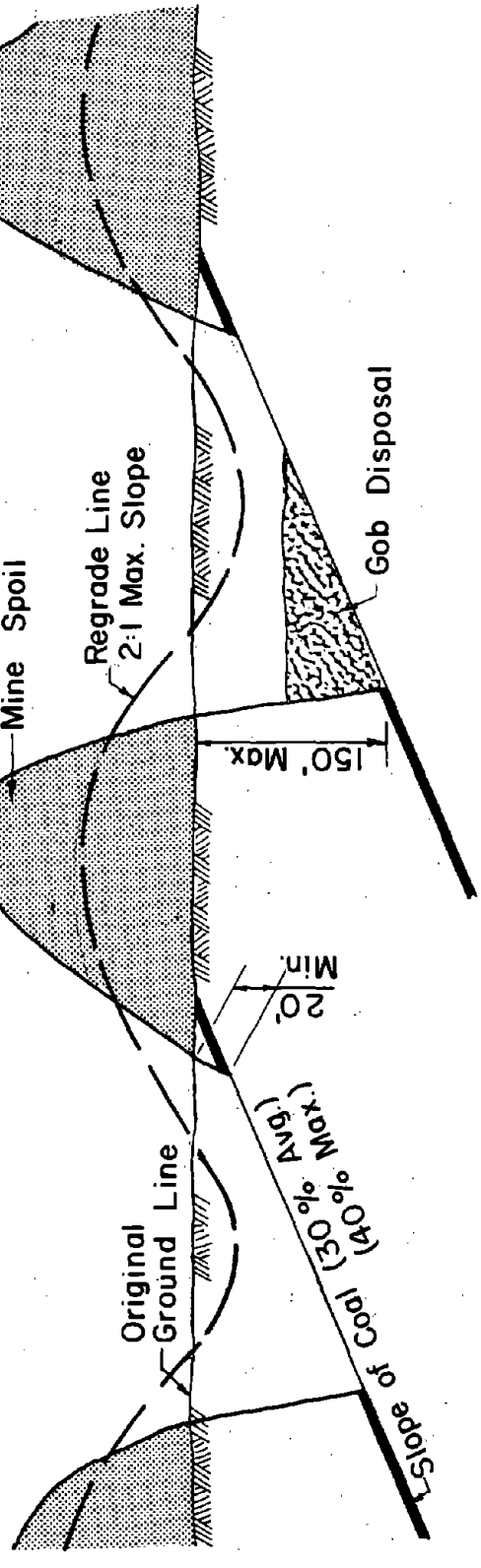
Sales	14,153,226.00
Operating Cost	10,102,707.00
Gross profit	4,050,519.00
Depletion	1,415,323.00
Taxable income	2,635,196.00
Federal Income Tax	1,317,598.00
Net profit	1,317,598.00

Annual cash flow = $1,317,598 + $1,883,597 + $1,415,323 = $ 4,616,518.00
Selling price per ton = $14,153,226 ÷ 3,000,000 tons = 4.72



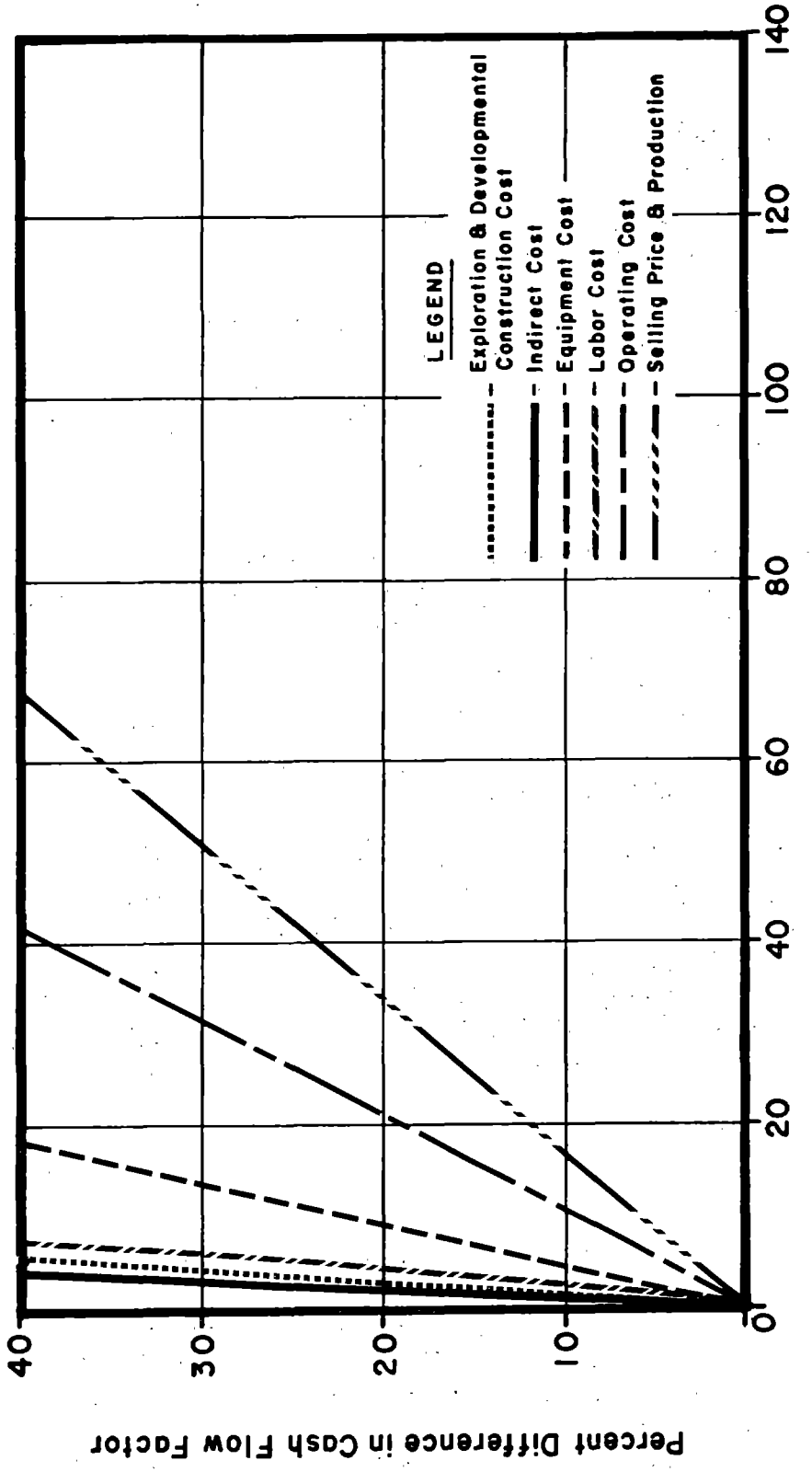
PLAN VIEW – MINE 4H

Figure 9-13



TYPICAL SECTION – MINE 4H

Figure 9-14



SENSITIVITY GRAPH - MINE NO. 4H

Figure 9-15

CASE HISTORY - MINE 4J

Mine 4J, an area mine representative of Region IV, is located in a flat area of sparse vegetation near a small river in eastern Montana.

This 5 million ton per year operation mines the 52 foot thick D-1 (Deitz) coal seam. Having zero dip, this consistent seam covers 3,800 acres with an estimated reserve base of over 1.2 billion tons. Being sub-bituminous in rank and having qualities of 9600 BTU, 3.7% ash and 0.33% sulfur, this coal provides good fuel for steam powered generating stations.

Rock units associated with the average 65 foot thick overburden material consist of some dandy alluvial fill, interbedded with clay, sandstone, and shale. Since these beds are fairly well consolidated, blasting is conducted.

Having a semi-arid climate (15 inches annual precipitation, 100°F High to -40°F Low temperatures), excessive dust generation during summer months is a major problem.

Mine 4J is a joint-venture operation supplying steam coal to utility markets. The low sulfur content of this reserve makes it extremely attractive during times of strict SO_2 regulation.

The mine is a result of exploration work which began 20 years ago. After noticing clinker and surface burns, several holes, (one per 500 acres), were sunk to establish thicknesses.

The major factor influencing development was the market. Reserves were obtained 20 years prior to mine opening. First, a market was established, then the mine was designed to fulfill the market.

Pan scrapers remove topsoil and store it at various locations on the property. The overburden above the coal seam requires blasting. The blast hole drill is capable of drilling 12 1/4 inch diameter holes 150 feet deep. However, a 30 foot spacing to the top of the coal is all that is necessary. The holes are then filled with ammonium nitrate mixed with diesel fuel (ANFO) and blasted. The overburden is removed from its original position with an all-electric dragline (equipped with a

41 cubic yard bucket and a 285 foot boom), and placed in previously mined cuts. The coal also must be blasted before it can be removed. Blast holes are 6 inches in diameter, and are spaced on 16 foot centers. By benching the seam into two 26 foot lifts, the coal can easily be loaded with 16 cubic yard electric coal loading shovels. The coal is hauled to the preparation plant by 70 ton bottom dump coal haulers.

The coal handling plant has the capability of crushing and conveying to storage 2000 tons per hour of mine run coal. Run of mine coal is crushed to a top size of 2 inches and is stored in two 13,000 ton capacity silos. Dust is held to a minimum through the use of enclosed conveyors and silo storage. If fugitive dust should become a problem, a water spray system installed at all potential point sources should control it.

The method used to load unit trains is known as "flood loading." Coal is conveyed from the silos to the floodloading building at a rate of 5,500 tons per hour. A unit train consisting of 100 railroad cars, each having a capacity of 100 tons, is loaded while it passes, without stopping, under the loading chute. An entire 10,000 ton trainload is loaded in approximately two hours. Coal loaded in railroad cars is electronically weighed and automatically sampled.

Reclamation engineers work with the State Department of Natural Resources, a local university, U. S. Soil Conservation Service and the U. S. Forest Service, well in advance of the mining operation in order to develop a reclamation plan that will be successful. Water that accumulates in the pit is directed to a settling pond to ensure removal of suspended solids prior to discharge. Extensive haul road wetting is conducted to prevent dust generation. The overburden is shaped to smooth contours by using large bulldozers. Topsoil is then replaced, fertilized and seeded. Test plots have been provided for the purpose of determining the best grasses, trees and shrubs to use for the revegetation program.

Problems of major importance involve control of fugitive dust (water applications consume 150,000 to 200,000 gpd), and re-establishment of vegetation on regraded spoils (dry climate and grazing herds of wildlife can destroy a young stand of plants).

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TABLE 9-92
EQUIPMENT COST SUMMARY - MINE NO. 4J

Topsoil Removal and Reclamation	Capacity	Quantity	Total Cost
Cat. (837) Scraper	-	2*	$ 268,000 (67%)
Cat. (D-9) Bulldozer	-	1	191,700
Hydroseeder	-	1	51,000
			$ 510,700
Overburden Stripping			
Cat. (837) Scraper	-	2*	$ 132,000 (33%)
Dragline	41 C.Y.	1	3,800,000
Cat. (D-9) Bulldozer	-	2	383,400
Drill	12¼"	1	475,000
Explosive Truck	-	1	10,000
Fertilizer Truck	-	1	60,000
			$ 4,860,400
Coal Removal and Loading			
Shovel	16 C.Y.	2	$ 1,980,000
Front-end Loader	-	1	150,000
			$ 2,130,000
Coal Haulage			
Cat. Truck	70 Ton	8	$ 1,600,000
Euclid Truck	120 Ton	1	340,000
			$ 1,940,000
Maintenance			
Grader	-	2	$ 120,000
Fuel Truck	-	1	10,000
Water Truck	-	1	60,000
			$ 190,000

TABLE 9-92 (Contd.)

Exploration	Capacity	Quantity	Total Cost
Drill	12¼"	1	$ 475,000
	Total Cost of Equipment		= $10,106,100

* Same equipment used for different operations.

TABLE 9-93
MANNING TABLE - MINE NO. 4J

Topsoil Removal and Reclamation	Total	Cost Per Year
Scraper Operator	4*	$ 28,704 (67%)
Dozer Operator	1	20,093
Hydroseeder Operator	1	6,276
		$ 55,073
Overburden Stripping		
Scraper Operator	4*	$ 14,352 (33%)
Dragline Operator	3	60,444
Dragline Oiler	3	55,582
Dozer Operator	6	120,888
Driller	3	55,582
Driller's Helper	3	50,808
Shooter	3	55,582
Truck Driver	6	103,016
		$ 516,254
Coal Removal and Loading		
Shovel Operator	4	$ 80,592
Shovel Oiler	4	74,110
Loader Operator	2	35,244
		$ 189,946
Coal Preparation		
Prep. Plant Crew	6	$ 84,000
Coal Haulage		
Truck Driver	18	$ 317,199

TABLE 9-93 (Contd.)

Auxiliary Operations	Total	Cost Per Year
Grader Operator	6	$ 120,888
Truck Driver	6	105,733
Maintenance Crew	32	480,000
		$ 706,621
Exploration		
Driller	2	$ 35,244
Driller's Helper	2	33,872
Drill Hand	4	66,460
		$ 135,576
	Total Labor =	$ 2,004,669
Administrative		
Office Personnel	46	$ 736,000
	Total Supervision =	$ 736,000
	Total Labor and Supervision =	$ 2,740,669

* Same people used for different operations.

TABLE 9-94
TOTAL ESTIMATED CAPITAL REQUIREMENTS - MINE NO. 4J

Exploration, Power Facilities, Site Preparation, Buildings, and Roads	$ 4,000,000
Preparation Plant	4,500,000
Unit Train Loading Facilities	3,500,000
Mining Equipment	10,106,100
Total Direct =	$22,106,100
Field Indirect (2% of Total Direct)	$ 442,122
Engineering	900,000
Overhead & Administration	800,000
Subtotal =	$24,248,222
Contingency (10% of 24,248,222)	$ 2,424,822
Subtotal =	$26,673,044
Fee (2% of 26,673,044)	$ 533,461
Total Mine Cost (Base Insurance Tax) =	$27,206,505
Interest During Construction (3% of 27,206,505)	$ 816,195
Working Capital	2,214,985
Total =	$30,237,685

TABLE 9-95
ESTIMATED WORKING CAPITAL - MINE NO. 4J

Direct Labor, 3 months	$ 685,167
Payroll Overhead, 3 months	240,000
Operating Supplies, 3 months	870,444
Indirect Costs, 3 months	233,342
Fixed Costs, 0.5% of Insurance Base	136,032
Miscellaneous	50,000
Total =	$ 2,214,985

TABLE 9-96
ESTIMATED ANNUAL OPERATING COSTS - MINE NO. 4J

Direct Cost		
Labor		$ 2,004,669
Supervision		736,000
	Subtotal =	$ 2,740,669
Operating Stripping		
Fuel		$ 315,360
Lubricants		12,614
Explosives		324,000
Parts, Materials & Miscellaneous		2,829,800
	Subtotal =	$ 3,481,774
Auxiliary Cost		
Power		$ 252,000
Communications		60,000
Union Welfare		4,000,000
Payroll Overhead		960,000
Health & Safety		300,000
Royalty		1,400,000
Strip License & Reclamation Fee		3,000
	Subtotal =	$ 6,975,000
	Total Direct Cost =	$13,197,443
Indirect Cost: 15% of Labor, Supervision, and Operating Supplies		$ 933,366
Fixed Cost: Taxes and Insurance, 2% of Mine Cost		544,130
Depreciation		2,240,716
	Total Operating Cost =	$16,915,655

TABLE 9-97
DEPRECIATION SCHEDULE - MINE NO. 4J

Item	Quantity	St. Line Deprec./Yrs.	Yearly Charge
Hydroseeder	1	5	$ 10,200
Cat. (D-9) Bulldozer	3	5	115,020
Dragline	1	20	190,000
Cat. (837) Scraper	2	5	80,000
Drill	2	5	190,000
Explosive Truck	1	3	3,333
Fertilizer Truck	1	5	12,000
Shovel	2	20	99,000
Front-end Loader	1	5	30,000
Truck (70 Ton)	8	5	320,000
Truck (120 Ton)	1	5	68,000
Grader	2	10	12,000
Fuel Truck	1	3	3,333
Water Truck	1	5	12,000
Exploration, Power Facilities, Site Preparation, Buildings and Roads	-	20	200,000
Preparation Plant	-	20	225,000
Unit Train Loading Facilities	-	20	175,000
Depreciation: Field Indirect, Engineering, Overhead and Administration, Contingency, Fee, and Interest During Construction	-	20	295,830
Interim Equipment Cost	-	20	200,000
		Total =	$2,240,716

TABLE 9-98

CASH FLOW ANALYSIS - MINE NO. 4J

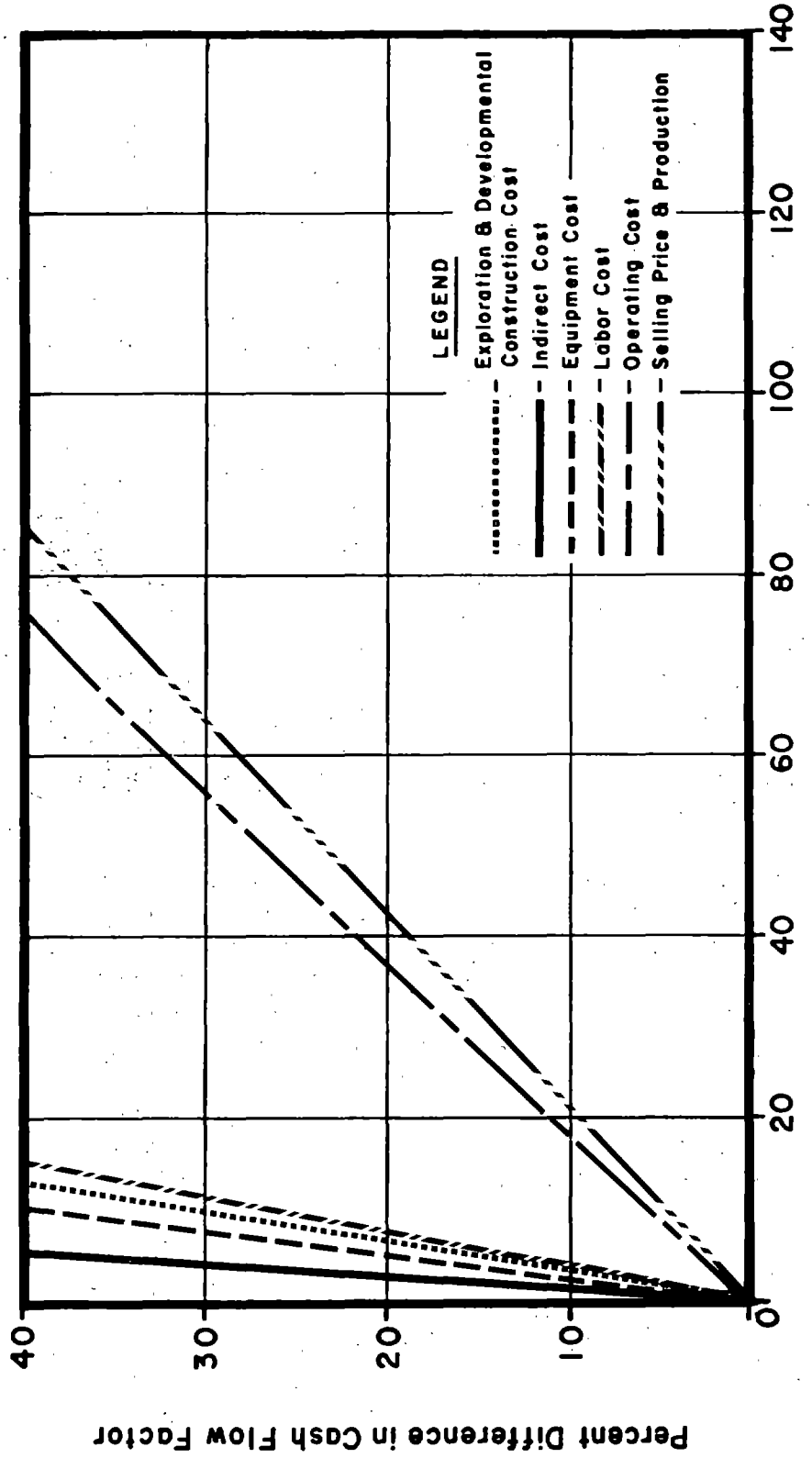
Year	Capital Investment	Cash Flow	Present Worth Factor At 15 Percent	Present Worth Capital Investment At 15 Percent	Present Worth Cash Flow Value At 15 Percent
0	$30,237,685	$-30,237,685	1.0000	$30,237,685	$-30,237,685
1	200,000	5,391,789	.8696	173,920	4,688,700
2	200,000	5,391,789	.7561	151,220	4,076,732
3	200,000	5,391,789	.6575	131,500	3,545,101
4	200,000	5,391,789	.5718	114,360	3,083,025
5	4,386,100	1,205,689	.4972	2,180,769	599,469
6	200,000	5,391,789	.4323	86,460	2,330,870
7	200,000	5,391,789	.3759	75,180	2,026,774
8	200,000	5,391,789	.3269	65,380	1,762,576
9	200,000	5,391,789	.2843	56,860	1,532,886
10	4,506,100	1,085,689	.2472	1,113,908	268,383
11	200,000	5,391,789	.2149	42,980	1,158,695
12	200,000	5,391,789	.1869	37,380	1,007,725
13	200,000	5,391,789	.1625	32,500	876,166
14	200,000	5,391,789	.1414	28,280	762,399
15	4,386,100	1,205,689	.1229	539,052	148,179
16	200,000	5,391,789	.1068	21,360	575,843
17	200,000	5,391,789	.0930	18,600	501,436
18	200,000	5,391,789	.0808	16,160	435,656
19	200,000	5,391,789	.0702	14,040	378,504
20	-2,240,716	7,832,505	.0611	-136,908	478,566
			TOTAL	$35,000,686	0

R = $35,000,686 ÷ 6.2593 = $ 5,591,789.00
Less Depreciation = 2,240,716.00
Depletion + net profit = 3,351,073.00

Sales = 1/0.55 (cash flow + 0.5 operating cost-depreciation)
Sales = 1.8181 [$5,591,789 + (0.5 × $16,915,655) - $2,240,716] = $21,469,762.00

Sales	$21,469,762.00
Operating Cost	16,915,655.00
Gross profit	4,554,107.00
Depletion	2,146,976.00
Taxable income	2,407,131.00
Federal Income Tax	1,203,566.00
Net profit	1,203,565.00

Annual cash flow = $1,203,565 + $2,240,716 + $2,146,976 = $ 5,591,257.00
Selling price per ton = $21,469,762 ÷ 5,000,000 tons = 4.29



SENSITIVITY GRAPH - MINE NO. 4J

Figure 9-16

CASE HISTORY - MINE 4K

Mine 4K of study Region IV is located in western North Dakota. This agriculturally oriented State has an average growing season of 110 days. Seventy-seven percent of the mean annual precipitation, approximately 18 inches, falls during the growing season, April to September. North Dakota's mean annual temperature is approximately 40°F. Although wind erosion is a problem in this plains state, the most important climatic factor is precipitation. The soil is of such high quality that only a minimal amount of precipitation is needed for good vegetative growth. Range grasses and farm crops cover a flat to gently rolling topography.

Three lignite seams totalling 20 feet in combined thickness are separated by two partings. These consistent seams occur in the Fort Union Formation and dip 2% to the southwest. This low sulfur and ash lignite, 0.5% and 6% respectively, finds its market at the electric power generating plants. Coal heat values range from 6300 to 7000 BTU. An unusual problem somewhat characteristic of this region is a high sodium clay overburden affecting the lignite quality. Sodium values in the coal can range from 0.5% to 12% and a 0.8% sodium slag shows up in power plant boilers. Zero to eight inches of topsoil covers the high sodium clay and scoria rock overburden to give an average combined thickness of sixty feet. However, the sodium condition is not a widespread problem at this site.

Exploration efforts started during the first quarter of the century. Since much information about an underlying coal seam can be deduced from topography, a minimum amount of core boring is performed. This mine relies on outcrop geology, and is guided by topographic interpretation and seam consistency. When drilling is done, no pattern is followed. Having nearly a half century of mining experience, and considering the geography and geology of the region, this mining company selected area mining as the most suitable coal extraction method. The planned two million ton annual production was strongly influenced by equipment and parts availability, environmental considerations, and capacity and quality of available transportation in the area.

Dozers and road graders are used to construct haul and access roads over the range land. Topsoil is removed with pan scrapers and is stockpiled and temporarily seeded if it is not to be replaced within 6 months. Since the overburden is unconsolidated, blasting is unnecessary. Two draglines work this multi-pit operation. Draglines were selected because

of their placement capabilities and nature of the overburden to be handled. They uncover the first seam, then move to another pit. Pits are very long, and the draglines try to maintain a 6 month coal exposure to avoid production loss due to dragline downtime. When the first seam of coal is extracted, the dragline returns and removes the partings. Both overburden and partings are placed directly into adjacent previous cuts, but some scoria is saved and used for haul road construction.

Due to the thickness of the coal seams, they must be blasted on 10 foot centers. ANFO (plus one stick of dynamite) is used in each 2 3/4 inch hole. Shovels load the coal into 65-ton bottom dump coal haulers which travel an average of two miles of haul roads enroute to the primary hopper. Delay time was noted when trucks must wait to be unloaded due to insufficient hopper capacity. The coal goes through a primary and secondary crusher before it is loaded out by unit train to the power plant. No storage facilities are available at the mine.

Disturbed land is regraded to original contour by dozers, and topsoil is replaced by pan scrapers and dozers to a uniform depth. State recommended native grasses - legumes, oats, barley, and warm and cold weather grasses - are drill seeded at the rate of 20 - 25 pounds per acre. Low nitrogen - high phosphate fertilizer (11:53) is applied to the regraded land surface. The amount of fertilizer per acre varies, and is determined from soil tests. Reclaimed land is restored to its pre-mining condition. Success of revegetation is generally good, with every effort being taken to cover all open areas as soon as possible with some type of vegetation to curb wind erosion problems and topsoil losses.

TABLE 9-99
EQUIPMENT COST SUMMARY - MINE NO. 4K

Topsoil Removal and Reclamation	Capacity	Quantity	Total Cost
Cat. (637) Scraper	-	2	$ 360,000
Cat. (D-9) Bulldozer	-	2	382,000
834 Bulldozer	-	1	225,000
TD-25 Bulldozer	-	1	140,000
D-120 Bulldozer	-	1	126,000
(Chisel Plow, Drill, Harrow and Tractor)	-	1 Ea.	100,000
			$1,333,000
Overburden Stripping			
Dragline	17 C.Y.	1	$1,480,000
Dragline	12 C.Y.	1	1,100,000
			$2,580,000
Coal Removal and Loading			
Robco Failing Drill	2 3/4"	1	$ 75,000
Hydraulic Drill	-	1*	20,833 (83%)
Bucyrus-Erie (110-B) Shovel	8 C.Y.	1	525,000
P & H (1400) Shovel	6 C.Y.	1	400,000
Bucyrus-Erie (71-B) Shovel	5 C.Y.	1	325,000
Cat. (920) Loader	1½ C.Y.	1	58,000
Self-Loading Scraper	-	1	310,000
			$1,713,833
Coal Haulage			
Euclid Truck	65 Ton	9	$2,025,000

TABLE 9-99 (Contd.)

Maintenance	Capacity	Quantity	Total Cost
Welding Machine	-	4	$ 48,000
Lube Truck	-	1	10,000
Pick-up Truck	-	3	15,000
Boom Truck	-	1	15,000
Water Truck	-	1	16,000
Grader	-	1	172,000
			$ 276,000
Exploration			
Hydraulic Drill	-	1*	$ 4,167 (17%)
Air Compressor & Water Truck	-	1	20,000
			$ 24,167

Total Cost of Equipment = $7,952,000

* Same equipment used for different operations.

TABLE 9-100
MANNING TABLE - MINE NO. 4K

Topsoil Removal and Reclamation	Total	Cost Per Year
Scraper Operator	6	$ 86,112
Dozer Operator	5	71,760
Revegetation Equipment Operator	1	14,352
		$ 172,224
Overburden Stripping		
Dragline Operator	6	$ 120,557
Dragline Oiler	6	110,860
		$ 231,417
Coal Removal and Loading		
Driller (Robco)	2	$ 25,608
Driller's Helper	2	24,604
Driller (Hydraulic)	1*	10,627 (83%)
Driller's Helper	1*	10,211 (83%)
Shovel Operator	3	43,056
Shovel Oiler	1	13,198
Loader Operator	1	14,352
Scraper Operator	1	14,352
		$ 156,008
Coal Preparation		
Prep. Plant Operator	1	$ 12,064
Coal Haulage		
Truck Driver	9	$ 112,975

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TABLE 9-100 (Contd.)

Auxiliary Operations	Total	Cost Per Year
Maintenance Crew	7	$ 92,383
Exploration		
Driller (Hydraulic)	1*	$ 2,177 (17%)
Driller's Helper	1*	2,091 (17%)
		$ 4,268
	Total Labor =	$ 781,339
Administrative		
Office Personnel	17	$ 272,000
	Total Supervision =	$ 272,000
	Total Labor and Supervision =	$1,053,339

* Same people used for different operations.

TABLE 9-101
TOTAL ESTIMATED CAPITAL REQUIREMENTS - MINE NO. 4K

Exploration, Power Facilities, Site Preparation, Buildings and Roads		$ 3,000,000
Unit Train Loading Facilities & Preparation Plant		2,000,000
Mining Equipment		7,952,000
	Total Direct =	$12,952,000
Field Indirect (2% of Total Direct)		$ 259,040
Engineering		360,000
Overhead & Administration		526,670
	Subtotal =	$14,097,710
Contingency (10% of 14,097,710)		$ 1,409,771
	Subtotal =	$15,507,481
Fee (2% of 15,507,481)		$ 310,150
Total Mine Cost (Base Insurance Tax)	=	$15,817,631
Interest During Construction (3% of 15,817,631)		$ 474,529
Working Capital		817,952
	Total =	$17,110,112

TABLE 9-102
ESTIMATED WORKING CAPITAL - MINE NO. 4K

Direct Labor, 3 months		$ 263,335
Payroll Overhead, 3 months		92,167
Operating Supplies, 3 months		299,010
Indirect Costs, 3 months		84,352
Fixed Costs, 0.5% of Insurance Base		79,088
Miscellaneous		-
	Total =	$ 817,952

TABLE 9-103
ESTIMATED ANNUAL OPERATING COSTS - MINE NO. 4K

Direct Cost		
Labor		$ 781,339
Supervision		272,000
	Subtotal =	$1,053,339
Operating Supplies		
Fuel		$ 136,500
Lubricants		5,460
Explosives		25,000
Parts, Materials & Miscellaneous		1,029,080
	Subtotal =	$1,196,040
Auxiliary Cost		
Contract Coal Hauling		$ -
Power		90,000
Communications		38,000
Union Welfare		800,000
Payroll Overhead		368,669
Health & Safety		20,000
Royalty		1,000,000
Strip License & Reclamation Fee		27,325
	Subtotal =	$2,343,994
	Total Direct Cost =	$4,593,373
Indirect Cost: 15% of Labor, Supervision, and Operating Supplies		$ 337,407
Fixed Cost: Taxes and Insurance, 2% of Mine Cost		316,353
Depreciation		1,173,583
	Total Operating Cost =	$6,420,716

TABLE 9-104
DEPRECIATION SCHEDULE - MINE NO. 4K

Item	Quantity	St. Line Deprec./Yrs.	Yearly Charge
Cat. (637) Scraper	2	6	$ 60,000
Cat. (D-9) Bulldozer	2	10	38,200
834 Bulldozer	1	10	22,500
TD-25 Bulldozer	1	10	14,000
D-120 Bulldozer	1	10	12,600
Chisel Plow, Drill, Harrow and Tractor	1 Ea.	10	10,000
Dragline (17 C.Y.)	1	20	74,000
Dragline (12 C.Y.)	1	20	55,000
Robco Failing Drill	1	20	3,750
Hydraulic Drill	1	20	1,250
Bucyrus-Erie (110-B) Shovel	1	20	26,250
P & H (1400) Shovel	1	20	20,000
Bucyrus-Erie (71-B) Shovel	1	20	16,250
Cat. (920) Loader	1	10	5,800
Self-Loading Scraper	1	10	31,000
Euclid Truck	9	8	253,125
Air Compressor & Water Truck	1	10	2,000
Welding Machine	4	10	4,800
Lube Truck	1	10	1,000
Pick-up Truck	3	4	3,750
Boom Truck	1	10	1,500
Water Truck	1	10	1,600
Grader	1	10	17,200
Exploration, Power Facilities, Site Preparation, Buildings, and Roads	-	20	150,000
Unit Train Loading Facilities and Preparation Plant	-	20	100,000
Depreciation: Field Indirect, Engineering, Overhead and Administration, Contingency, Fee, and Interest During Construction	-	20	168,008
Interim Equipment Cost	-	20	80,000
		Total	= $1,173,583

TABLE 9-105

CASH FLOW ANALYSIS - MINE NO. 4K

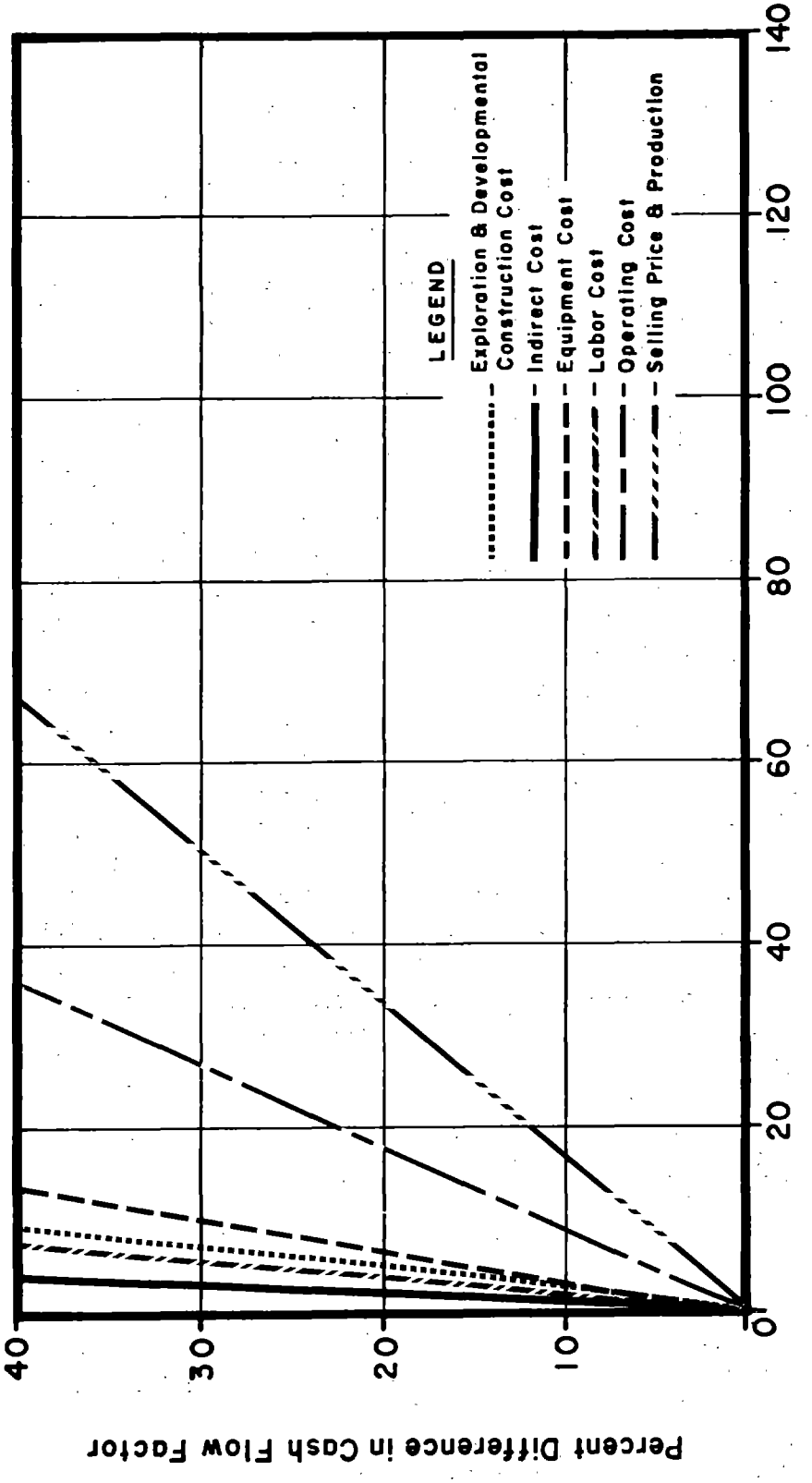
Year	Capital Investment	Cash Flow	Present Worth Factor At 15 Percent	Present Worth Capital Investment At 15 Percent	Present Worth Cash Flow Value At 15 Percent
0	$17,110,112	$-17,110,112	1.0000	$17,110,112	$-17,110,112
1	80,000	2,965,942	.8696	69,568	2,579,183
2	80,000	2,965,942	.7561	60,488	2,242,548
3	80,000	2,965,942	.6575	52,600	1,950,107
4	80,000	2,965,942	.5718	45,744	1,695,925
5	80,000	2,965,942	.4972	39,776	1,474,666
6	440,000	2,605,942	.4323	190,212	1,126,549
7	80,000	2,965,942	.3759	30,072	1,114,897
8	2,105,000	940,942	.3269	688,125	307,594
9	80,000	2,965,942	.2843	22,744	843,217
10	1,702,000	1,343,942	.2472	420,734	332,222
11	80,000	2,965,942	.2149	17,192	637,381
12	440,000	2,605,942	.1869	82,236	487,051
13	80,000	2,965,942	.1625	13,000	481,966
14	80,000	2,965,942	.1414	11,312	419,384
15	80,000	2,965,942	.1229	9,832	364,514
16	2,105,000	940,942	.1068	224,814	100,493
17	80,000	2,965,942	.0930	7,440	275,833
18	440,000	2,605,942	.0808	35,552	210,560
19	80,000	2,965,942	.0702	5,616	208,209
20	-1,173,583	4,219,525	.0611	-71,706	257,813
			TOTAL	$19,065,463	0

R = $19,065,463 ÷ 6.2593 = $3,045,942.00
Less depreciation = 1,173,583.00
Depletion + net profit = 1,872,359.00

Sales = 1/0.55 (cash flow + 0.5 operating cost-depreciation)
Sales = 1.8181 [$3,045,942 + (0.5 × $6,420,716) - $1,173,583] = $9,240,888.00

Sales	9,240,888.00
Operating Costs	6,420,716.00
Gross profit	2,820,172.00
Depletion	924,089.00
Taxable income	1,896,083.00
Federal Income Tax	948,042.00
Net profit	948,041.00

Annual cash flow = $948,041 + $1,173,583 + $924,089 = $3,045,713.00
Selling price per ton = $9,240,888 ÷ 2,000,000 tons = 4.62



SENSITIVITY GRAPH - MINE NO. 4K

Figure 9-17

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RISK ANALYSES

The tables and graphs in this section are a product of risk analyses which were performed in the following seven steps:

1) Major cost variables were determined for surface mining operations - initial capital; operating costs; coal selling price; market; and production.

2) Information concerning average, low and high variables values was solicited from mine managers and accounts.

3) Data obtained from literature and the preceding case history cost analyses was tabulated with step 2 information according to region and production.

4) All data was evaluated subjectively to establish average, low,and high variable values. Since most persons do not usually tend to list extreme values, a standard deviation was applied to the high and low values. Low STD = (Average - Low) ÷ 3; and High STD = (High - Average) ÷ 3.

5) A computer program was developed to perform the desired risk calculations (See Appendix 3). This program independently changed the five variables relative to their mean and standard deviations values by multiplying the standard deviations times random normal numbers (mean = 0 and STD = 1). Five hundred iterations were performed determining ROI's for each new set of variables.

6) Probabilities and distributions were plotted (Figures 9-18, 9-19, 9-20, and 9-21) from the computer output.

7) The results were examined to evaluate risk associated with mining at two production rates in Regions I and II.

TABLE 9-106

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RISK ANALYSES VARIABLES

REGION I - 50,000 TONS PER YEAR					
Variable	Low	Average	High	Low Standard Deviation	High Standard Deviation
Capital Investment	$500,000	$800,000	$1,500,000	$100,000	$233,300
Operating Cost / Ton	11.00	13.00	16.00	0.66	1.00
Selling Price / Ton	14.00	18.00	25.00	1.33	2.33
Market Tonnage	47,500	50,000	100,000	833	16,666
Production Tonnage	37,500	50,000	60,000	4166	3,333
REGION I - 150,000 TONS PER YEAR					
Variable	Low	Average	High	Low Standard Deviation	High Standard Deviation
Capital Investment	$1,000,000	$1,500,000	$3,000,000	$166,700	$500,000
Operating Cost / Ton	12.00	14.00	17.00	0.66	1.00
Selling Price / Ton	14.00	18.00	25.00	1.33	2.33
Market Tonnage	142,500	150,000	225,000	2,500	25,000
Production Tonnage	124,500	150,000	180,000	8,500	10,000

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TABLE 9-106 (CONTD.)

RISK ANALYSES VARIABLES

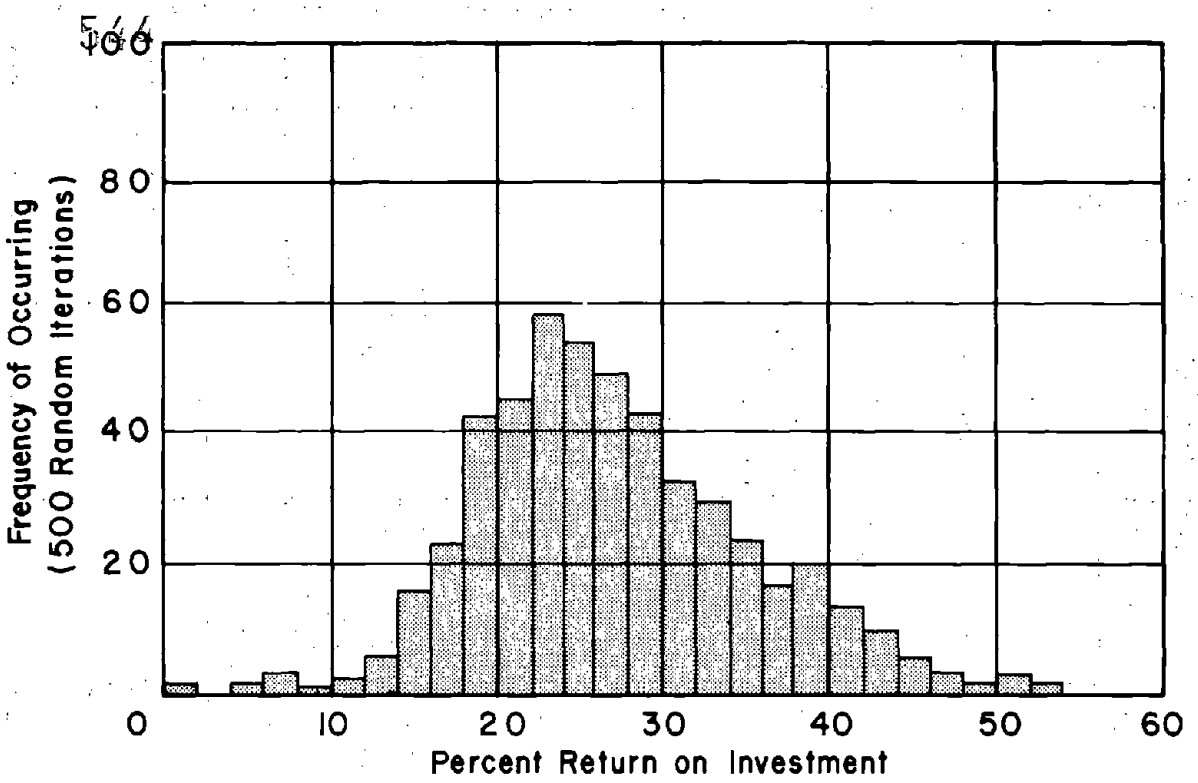
REGION II - 250,000 TONS PER YEAR					
Variable	Low	Average	High	Low Standard Deviation	High Standard Deviation
Capital Investment	$3,300,000	$5,000,000	$7,000,000	$566,666	$666,666
Operating Cost / Ton	8.00	10.00	14.00	0.67	1.33
Selling Price / Ton	14.00	18.00	25.00	1.33	2.33
Market Tonnage	237,500	250,000	375,000	4,167	41,667
Production Tonnage	167,500	250,000	415,000	27,500	55,000
REGION II - 600,000 TONS PER YEAR					
Variable	Low	Average	High	Low Standard Deviation	High Standard Deviation
Capital Investment	12,000,000	15,000,000	18,500,000	1,000,000	1,166,666
Operating Cost / Ton	8.75	11.00	14.00	0.75	1.00
Selling Price / Ton	14.00	18.00	25.00	1.33	2.33
Market Tonnage	570,000	600,000	900,000	10,000	100,000
Production Tonnage	318,000	600,000	798,000	94,000	66,000

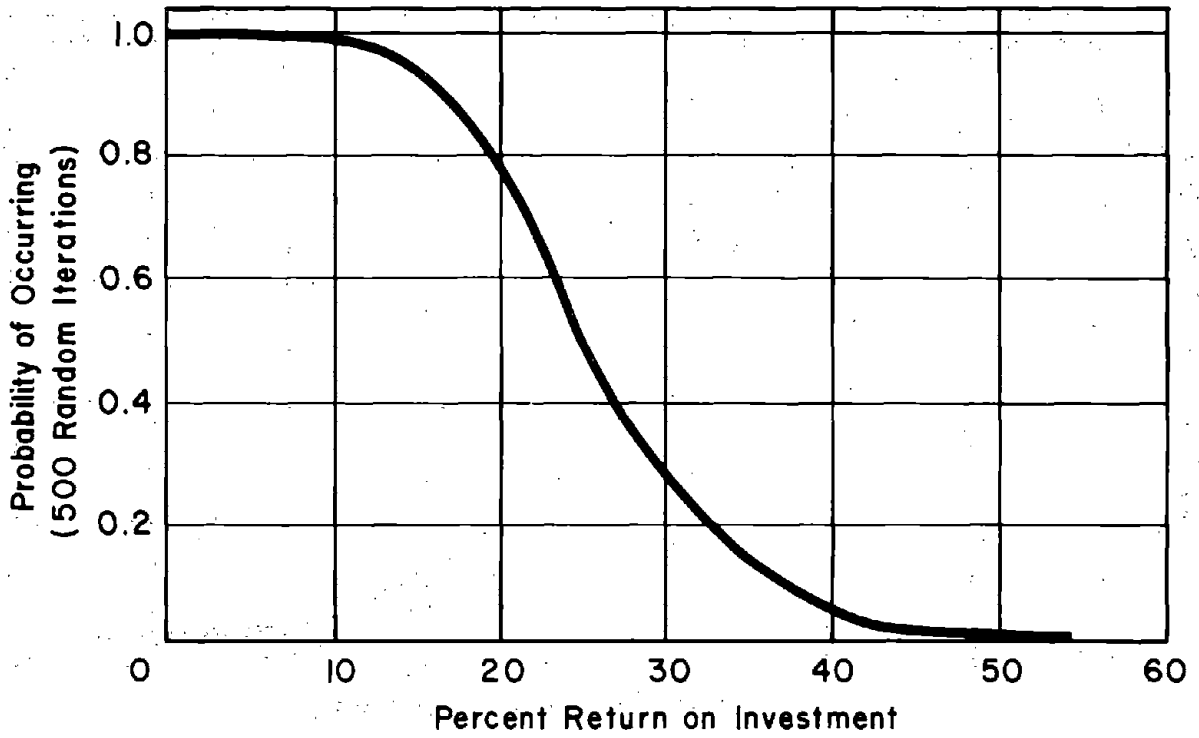
Data in Table 9-106 shows input to the risk analysis program. Variables reflect present market conditions, which are more favorable than in the recent past. Although some spot market coal prices have ranged between $40 and $70 per ton, the selling price variable represents present and potential near future short-term contracts and spot market. Figure 9-18 contains a histogram and a probability curve that shows the frequency and probability of obtaining any particular percent return on investment for a 50,000 ton per year surface mine in Region I. The frequency chart indicates 22 to 28% return is the most likely occurrence, while very few returns are less than 12 or greater than 44%. Considering 15% as an extreme minimum, examination of the probability curve reveals an 0.92 (92%) likelihood of receiving at least the minimum required return. However, chances of acquiring greater than 30% return on investment are only slightly more than 0.25 (25%).

Risk analysis graphs in Figure 9-19 illustrate conditions relating to 150,000 ton per year mines operating in Region I. Frequencies plotted on the histogram show a much larger grouping of ROI's with most values between 22 and 40% return on investment. Probability of obtaining the minimum return is about the same (0.92) as indicated for 50,000 ton per year operations. Since ROI's are more evenly distributed than in the previous analysis, the chance of receiving higher returns does not decrease as rapidly - the probability of a 30% return is approximately 0.57. Thus, it is apparent that opening a 150,000 ton per year surface mine has less risk than a 50,000 ton per year mine.

Analyses for Region II show slightly better assurance of achieving a 15% minimum return on investment - probability of 0.98 for a 250,000 ton per year mine (see Figure 9-20) and 0.95 for a 600,000 ton per year stripping operation (see Figure 9-21). In this instance, the smaller 250,000 ton per year operation is the most favorable. Although no range of ROI's is overwhelmingly dominant, the most frequent occurrences for the smaller operation are from 24 to 30% return. There is a fifty-fifty opportunity to obtain at least a 28% return, while the same probability occurs at 22% for a Region II - 600,000 ton per year mine. As indicated by the histogram (see Figure 9-21), approximately 250 of the 500 randomly generated ROI's are between 18 and 24%. This dominance of values is manifested by the sharp drop in the probability curve of larger operations.

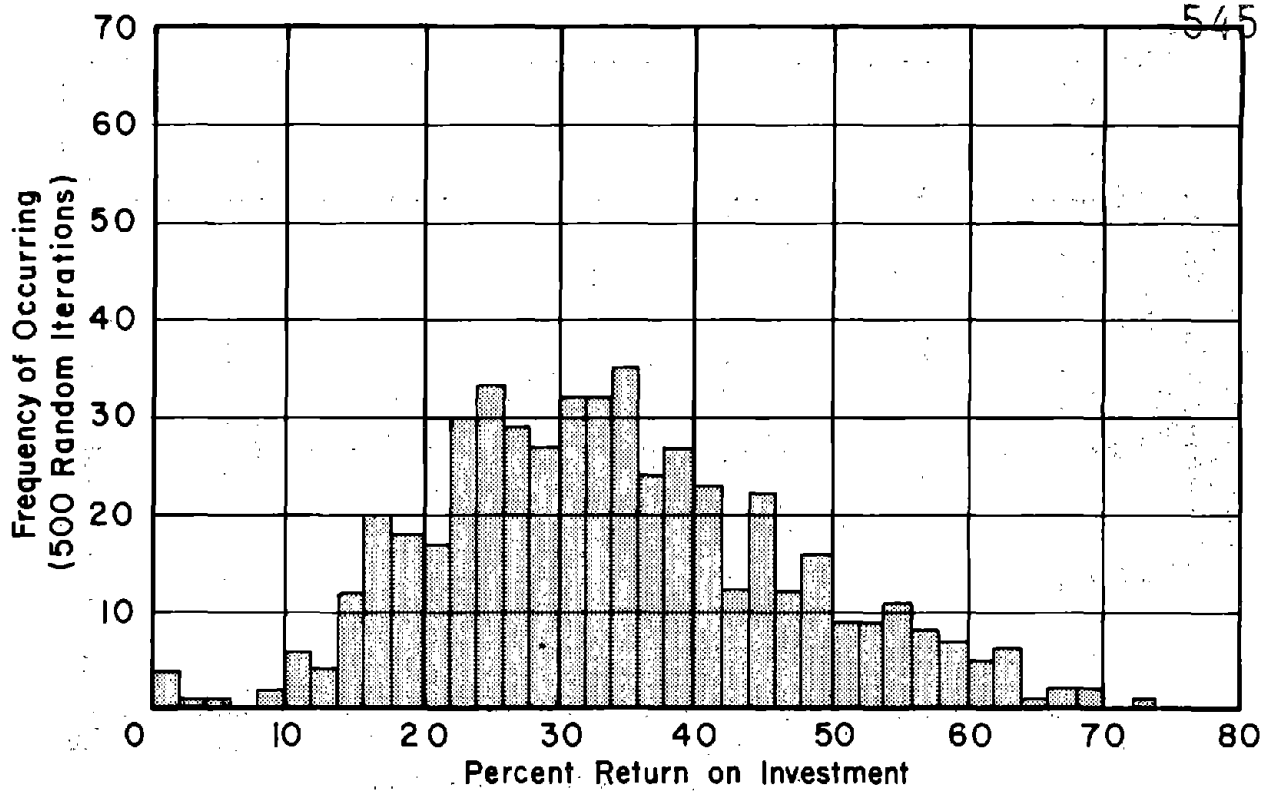
Comparing the four sizes of mines analyzed in Regions I and II,

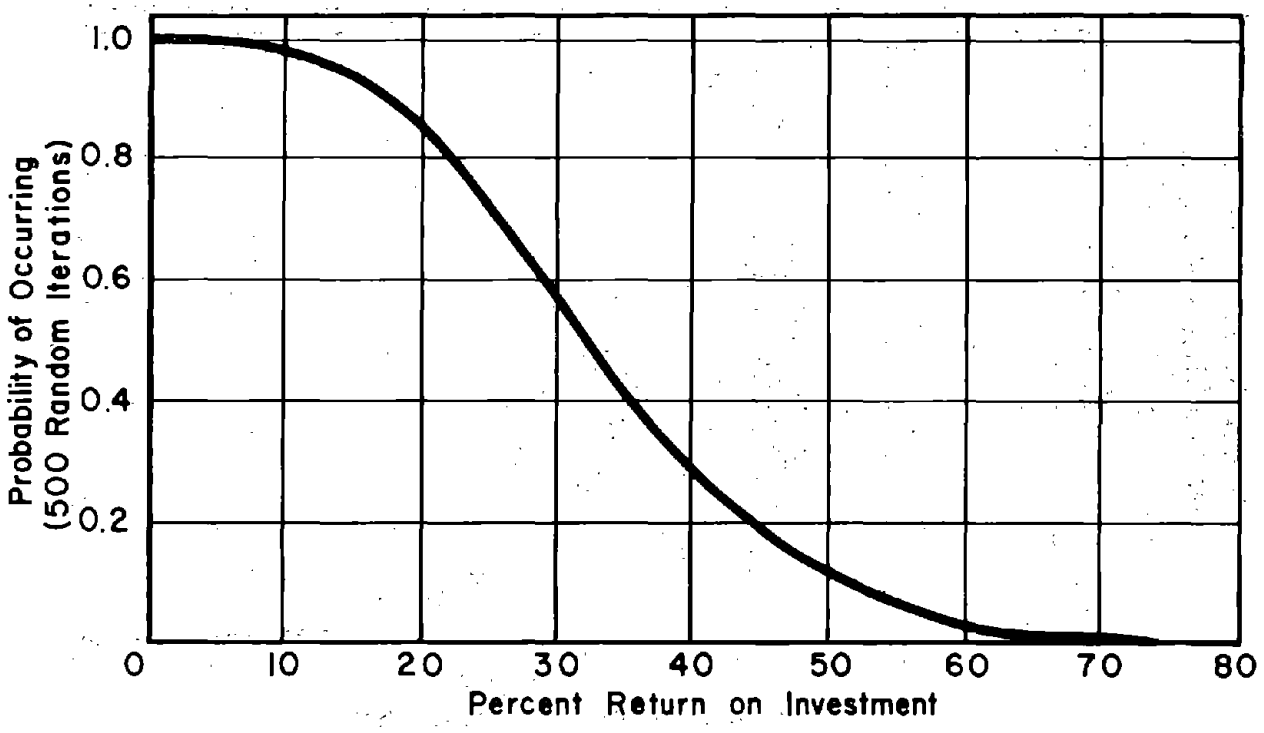




RISK ANALYSIS GRAPH
REGION I (50,000 TONS/YEAR)

Figure 9—18

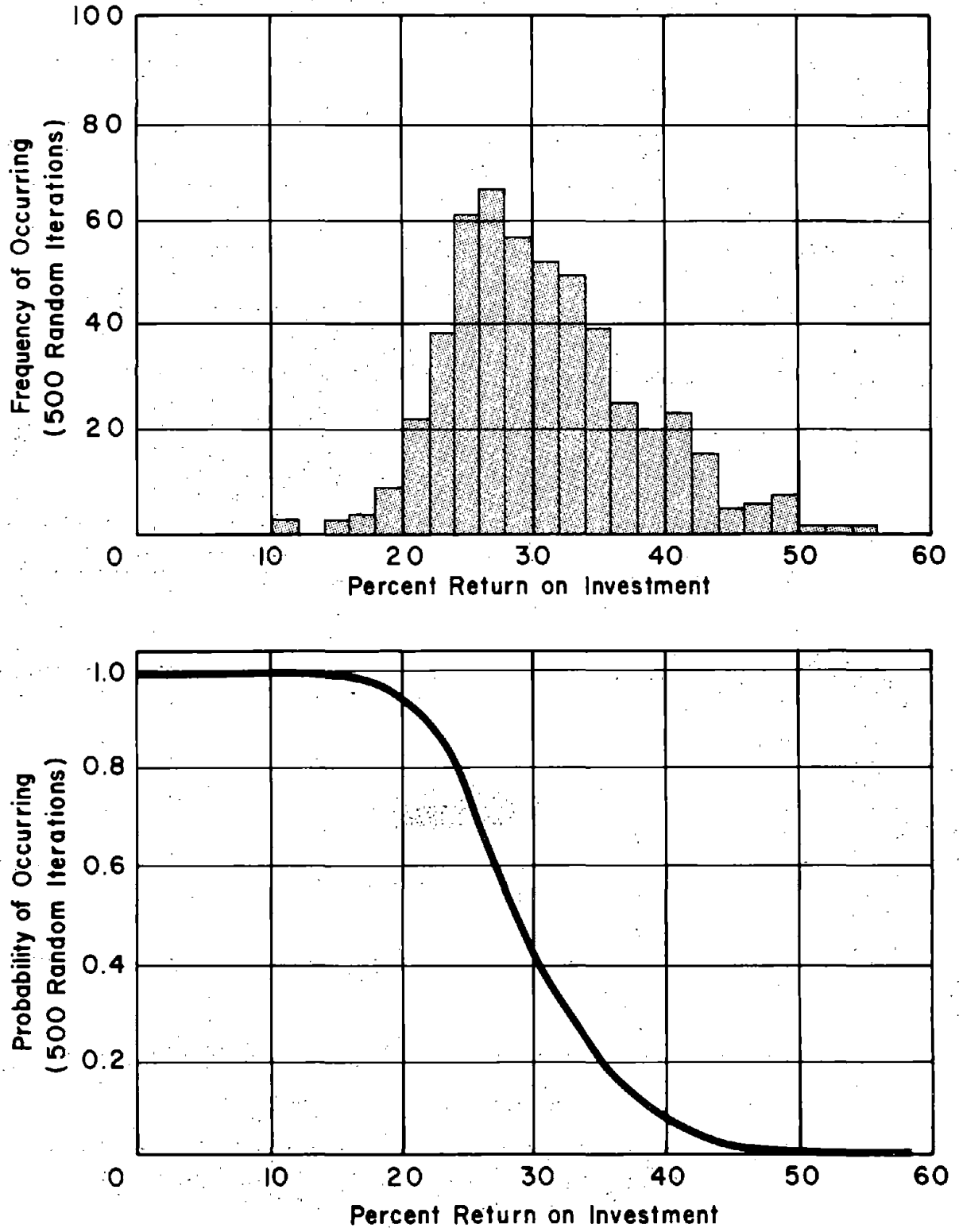




RISK ANALYSIS GRAPH
REGION I (150,000 TONS/YEAR

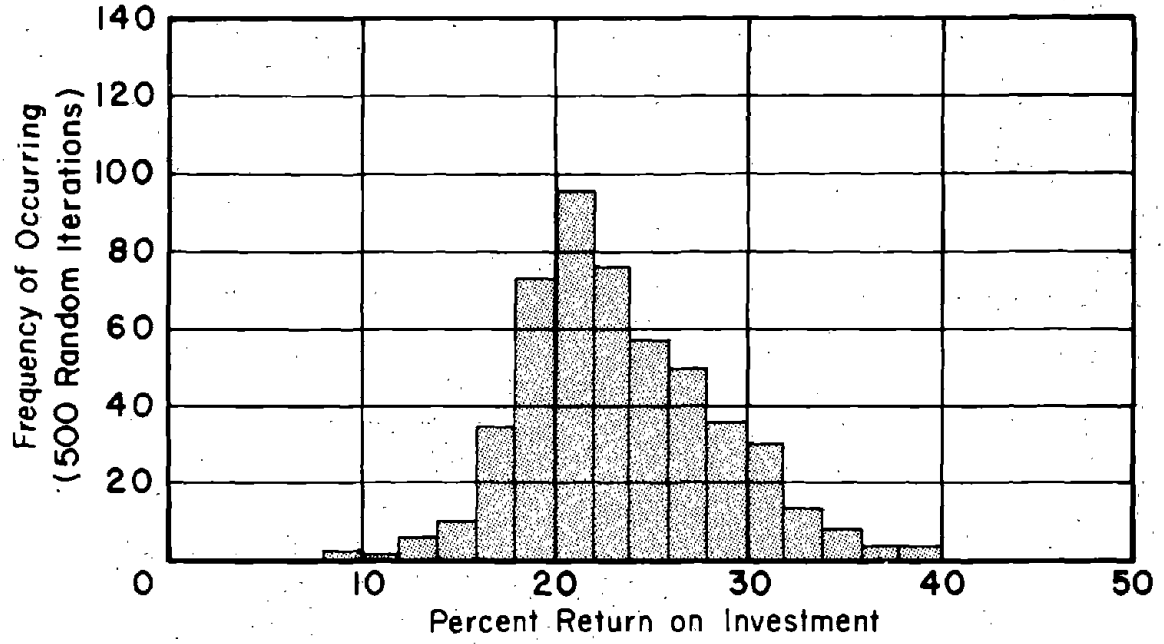
Figure 9-19

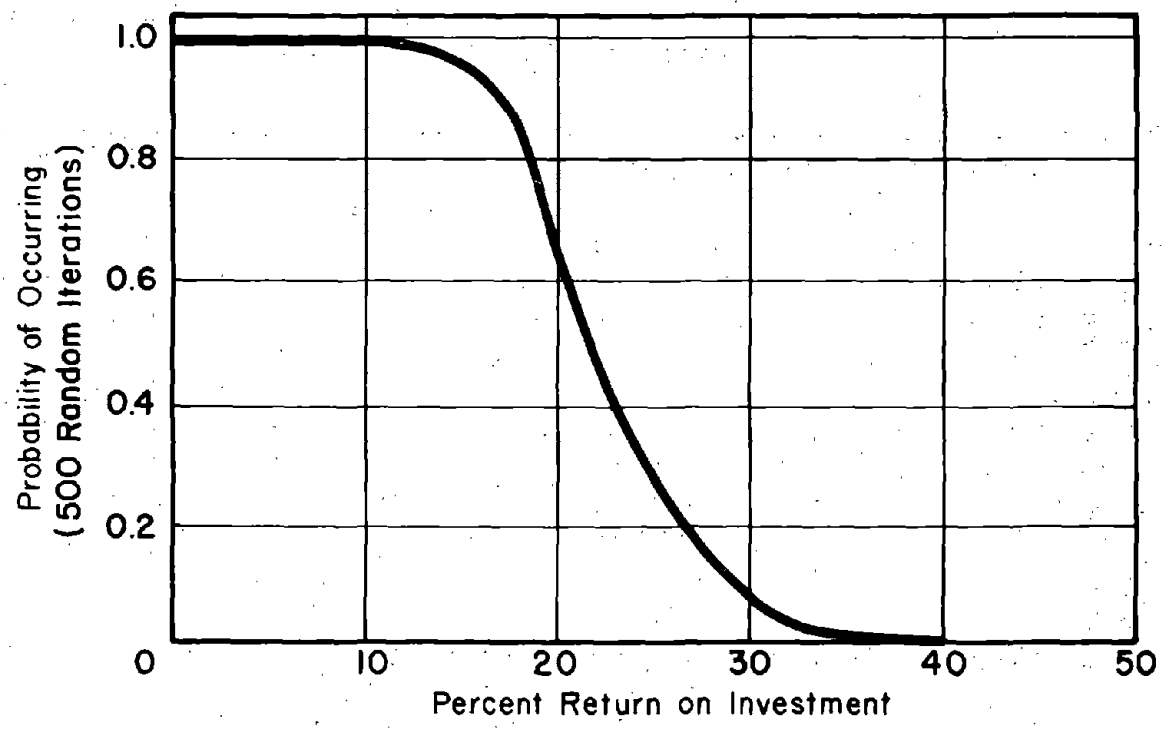
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RISK ANALYSIS GRAPH
REGION II (250,000 TONS/YEAR)

Figure 9-20





RISK ANALYSIS GRAPH
REGION II (600,000 TONS/YEAR)

Figure 9-21

a 250,000 ton per year operation is the best investment. This production is certain to provide the minimum return on investment with an excellent opportunity to receive significantly higher ROI. If the mining company is intent on acquiring much higher than 15% return, a 600,000 ton per year Region II mine is not a desirable investment - a 50,000 ton per year mine in Region I has similar drawbacks.

Table 9-106 provides insight for evaluating results of the computerized risk analyses. Careful study of this input data reveals that:

1) A 250,000 ton per year Region II mine has the best capital investment and production standard deviations with a much larger potential production increase from the normal.

2) The 250,000 ton operation has the least desirable range of operating costs, which show the greatest possible increase from the normal cost per ton.

3) Favorable speculative mining ventures follow the order indicated by the most favorable production variations - 250,000 ton per year Region II; 150,000 ton per year Region I; 50,000 ton per year Region I; and 600,000 ton per year Region II mines.

These observations concur with conclusions developed from the sensitivity analyses, (sensivity analyses are discussed in a following Systems Analyses Summary). Of the seven variables evaluated, production and selling price are the most sensitive. Since selling price is equal for all of the risk analyses, production is the most influential variable affecting return on original money invested. Although this is an apparent truth, it should be realized that risk is determined by numerous independently operating variables and that individual company practices are a major factor controlling each variable - thus partially influencing the risk.

Discussed in Chapter 4, exploration is an important unit operation of most surface mining systems. Insufficient definition of limits of coal and coal quality induces additional risk to mining ventures. Thus, it is imperative that exploration efforts accurately define marketability, consistency, quality and quantity of inplace coals prior to commitment of large sums of capital. Improper characterization of overburden material,

average coal thickness, and/or BTU value, can reduce sales (production and selling price) which are already illustrated as having the most direct contribution to the percent return on investment.

Risk associated with surface coal mining in Regions III and IV is more difficult to ascertain than in Regions I and II. Since most of the strip production in the midwest and west comes from large production operations, long term market contracts are imperative to insure coal sales. These contracts usually contain a renegotiation clause that permits periodic evaluation of increased mining costs and coal value. However, past contracts could not forecast present inflation or coal selling prices, and many companies are now committed to selling coal at prices below profit margins. In some cases, companies are breaking contracts and selling their coal to the same customer while being prosecuted for breach of contract.

Another clause usually included with long term coal market contracts provides for a penalty (paid by the mining company) if a prescribed tonnage is not delivered on time to the customer. Thus, for any complete and accurate analysis of risk in Regions III and IV, these contract variables should be incorporated. Unfortunately, most companies consider selling contracts confidential and are not willing to release pertinent features.

As discussed in the initial section of this chapter, uncertainities concerning pending federal legislation are a major risk factor deterring investment of capital. Investors and mining companies are wary of sinking large sums of money into expansion of existing facilities, or developing new operations, without knowing the impact legislative strictures will have on return on investments.

Other risk factors include: availability of equipment; final cost of major equipment; possible shortages of materials such as fuel, lubricants, explosives and spare parts. These risks are better realized by considering the following hypothetical case of a company opening a new mine with a long term contract.

Mine "Y" is planned to begin production 5 years from the present date (year 0). The major overburden excavation unit is a 75 cubic yard dragline which must be ordered now and paid for by the delivery date.

This dragline presently sells for $9,000,000, however, the final cost will reflect year 5 costs, which may be more than double the original value.

At year 5, the mine begins producing 500,000 tons per year with scheduled production increases by purchasing supplementary equipment in years 7 and 10. But a shortage makes it impossible to purchase required equipment. In addition, a shortage of critical parts and supplies has reduced the previous production rates. Thus, planned tonnages cannot be realized. What are the economic consequences?

- Mine "Y's" original contract clauses had not planned for the large increase in capital cost, and it is receiving lower than expected return on the original investment.

- Unless contract terms can be renegotiated, Mine "Y" must pay a penalty for not meeting required production tonnages.

- The scheduled production increases were to have escalated return on investment. However, lower returns are being realized.

- Mine "Y" is forced to abandon all operations!

Although the above example is probably an exaggerated circumstance, it does illustrate potential problems adding to risk associated with large mining operations. These and other uncertainities necessitate potential high ROI's to justify commitment of capital.

POLLUTION CONTROL

As discussed in Chapter 6 of this report, acid mine drainage occurs when water comes in contact with oxidized sulfuritic materials. Present and proposed environmental regulations require neutralization of this drainage as well as significant reductions of other pollutants (such as total iron and suspended solids). Treatment can significantly increase operational costs. From an economic viewpoint, it is imperative that the volume and concentration of polluted drainage be minimized. Surface water diversion is frequently employed to effect this goal. Water which becomes contaminated as a result of the mining operation is treated in some manner for neutralization and/or solids removal. Both functions - water diversion and treatment - may require substantial capital outputs. The range of these requirements will be briefly defined in the following discussion.

Various techniques are utilized to accomplish surface water diversion, including: 1) trenches along the highwall and uphill side of haul roads; 2) stream rechannelization; 3) intercepting water in low spots and pumping to avoid contact with potential pollutants; and 4) installation of drainage ditches in the actual strip cut to minimize contact with possible contaminants. Depending on local conditions, diversion ditches may range from simple earthen trenches to concrete channels.

Numerous factors enter into the cost of surface water diversion and vary widely across the United States. Rugged terrain, extensive forest cover, or rockiness all increase the cost of trenching. In areas of high permeability, trench construction may require the use of impermeable materials. The size of the operation is also an important consideration, since specialized trenching equipment can be justified for larger acreages, whereas smaller operations must use existing equipment.

Little reliable data could be obtained from the operators interviewed during this study on the cost of diversion ditches, since their construction is usually accomplished in conjunction with other operations. However, cost estimates derived through examination of construc-

tion records for similar operations indicate costs ranging from $0.75 to $2.50 per lineal foot for earthen trenches, depending on the degree of sophistication required. Average costs for this type of construction are in the neighborhood of $1.25 per lineal foot. Where more elaborate water diversion systems are warranted, as in permeable soils or highly fractured areas, costs of lined channels range between $10.00 and $20.00 per lineal foot. In addition to the cost of installation and maintenance, some expense can be incurred in reclaiming these trenches, although this cost is usually insignificant.

Typically the most costly aspect of water handling at surface mine sites is for water quality control. Depending on local conditions and effectiveness of other control measures, water quality may range anywhere from grossly polluted (with extremely high concentrations of acid, metals and/or suspended solids) to near drinking water quality. Mine drainage volumes also vary significantly between mine sites as well as between regions and seasons. Consequently, treatment facilities range from simple, home-made devices (such as a barrel filled with soda ash briquettes and crude earthen settling basins) to highly sophisticated neutralization plants with enormous settling ponds providing long detention times and several years of sludge storage capacity. The normal mode of operation for the surface mining industry is, however, toward more simplified mobile treatment facilities, because of the highly transient nature of these operations.

Since most surface mine treatment plants employ earthen settling basins, land requirements can become very significant. At some operations, very large settling basins and sludge storage areas have been formed by damming entire valleys. In most cases, however, treatment facilities are confined to land requirements of less than ten acres. Land costs are quite variable, depending on local and regional considerations, but generally range between $200 and $1500 per acre. Average costs can be estimated at about $400 per acre. Construction costs for sedimentation basins vary between $50 and $75 per acre of land affected by stripping with a mean of approximately $60 per acre. Additionally, the operator is faced with responsibility for reclaiming these areas upon completion of mining. Costs of sediment basin reclamation will range between $75 per acre for simple revegetation and $2000 per acre where topsoil replacement is required.

Neutralization plant costs are widely divergent due to numerous factors such as water quality and quantity, availability of reagents, mobility required, and anticipated life of the mine. Capital investment costs may range from $200 for a home-made soda ash briquette reaction action box, to more than $50,000 for a sophisticated lime feeder with automatic feed control and safety shut-down features. For the most part, a mobile neutralization unit can be fabricated to adequately handle discharge from most surface mines for under $5000. Operating costs of neutralization plants are a function of total acidity in acid mine drainage and volume treated. As a result, operating costs vary from 11 to 40 cents per thousand gallons treated per milligram per liter of hot acidity (3).

A very significant cost consideration for surface mine operations is the fact that recently proposed regulations will require mine operators to be responsible for water quality for a minimum of 5 years after completion of mining. If such action is required, an operator will have to maintain surface water diversion ditches, and possibly water treatment facilities, for many years after mining. This may require substantial capital outlays and must be addressed in the total mining plan.

HEALTH AND SAFETY

Pertinent features of the Federal Coal Mine Health and Safety Act of 1969 were delineated in Chapter 2. Noise and dust are principal health considerations while equipment is the major safety concern. Restrictions pertaining to these items represent additional costs in any mining operation.

Health regulations increase mining costs by virtue of the additional expenditures which must be made for specialized protection measures. They include:

- purchase, operation, and maintenance of dust and noise monitoring equipment
- collection, shipping, and testing of monitored samples
- purchase, operation and maintenance of specialized equipment and materials for dust control

(electrostatic precipitators, sprinkler trucks, dust-inhibiting chemicals.)

- purchase and frequent replacement of ear plugs, safety glasses, dust filtering masks, and hard hats

- modification of older equipment to meet current requirements

In addition to these health costs, the mining company must pay for safety features required for mobile equipment - backup horns, roll bars, seat belts, reinforced cabs, etc. Haul road grading and maintenance is also required with berm or guardrail construction where necessary.

Health and safety considerations are numerous and have a varying effect on individual mines. Health related costs provided by mine operators range from $20 per man each year (small mine) to $6000 per month at a 2 million ton per year operation. Safety equipment costs range from $250 per piece of equipment to 25% of new equipment purchase prices. One particular operator stated that health and safety regulations induce costs which represent an increase of 100% in total mining costs (an equipment study which may differentiate safety feature costs is presently being conducted for the Bureau of Mines). Health and safety figures listed in the case history operating cost tables reflect minor expenditures such as monitoring equipment and shipping charges. Most of these expenses are between 1 and 3% of the annual production costs.

Although health and safety factors increase capital and operating costs, related benefits can partially compensate mine operators. Fatal and nonfatal disabling accidents result in lost production due to mine closure and reduced manpower. A less tangible benefit is accured by more efficiency and productivity from employees working in a healthy and safe environment. Dials and Moore (1) developed a method for calculating loss of earnings due to fatal and nonfatal disabling accidents. This loss, as considered by Dials and Moore, is actually levied on the United States economy.

To determine lost earnings for the years 1970 through 2000. Dials and Moore used the following fraction:

$$\frac{(1) \times (2) \times (3)}{12 \text{ billion tons}} = \text{per ton cost of accidents in surface mining}$$

Where (1) is the total number of accidents 1970 - 2000; (2) is the average number of workdays lost per accident; (3) is the average daily earnings of coal miners; and 12 billion tons is the projected surface mining production for 1970 - 2000.

Applying projections of 69,000 nonfatal and 1,200 fatal accidents, and 52 and 6,000 respective lost days at $47 per day, the result was a total cost of 0.5 billion dollars or 0.042 dollars per ton lost earnings.

This illustrated example shows one possible technique for determining the cost of mining accidents. While 0.042 dollars per ton may not be a representative value, it does indicate potential benefits resulting from safety considerations which reduce accidents. If lost time due to sickness could be related to unhealthy working environments, similar production losses could be calculated. Again, a reduction in sickness can be considered a cost savings to the mining company.

SOCIAL ECONOMICS

An accurate assessment of the socio-economic aspects of surface mining requires evaluation of detailed data on a wide variety of interrelated factors including:

- existing land use
- population
- development potential
- environmental constraints
- economic needs
- real estate values
- potential land use
- labor force and employment

Due to the extreme complexity of these factors as they relate to specific locales, it is totally beyond the scope of this study to address this subject on anything but a cursory context. There are, however, basic considerations, similarities and/or differences between the study's four regions, which will be discussed.

Probably one of the most important socio-economic aspects of surface mining - common to all regions - is the industry's ability to manipulate large tracts of land, changing their surface configuration, physical properties and land use potential. Depending on specific site conditions this unique capability has varying degrees of significance. For instance, in Regions I and II, where contour mining is commonly practiced and level land is often at a premium, rolling topography can be regraded to form usable cropland, commercial building sites, recreational land or residential developments receptive to these land uses. Mountain top removal is especially receptive to these land uses.

On the other hand, Regions III and IV are generally characterized by plain lands with high dependency on livestock grazing and agriculture. Surface mining and subsequent reclamation can create catch basins for livestock watering or irrigation and can sometimes enhance cropland propagation by replacing inadequate surface material with more productive subsurface material. The economic returns of such alterations are difficult to assess on a general basis; however, for the purpose of discussion several pertinent examples can be illustrated.

In Appalachia (Regions I and II), surface mining is usually conducted in rural areas where land values are frequently less than the cost of reclamation. In such cases, the cost differential is difficult to justify on anything other than a negative basis; i.e., if left unreclaimed, surrounding property values (and taxbase) would suffer, as would downstream real estate values from the degradation of surface streams. Mining conducted on the fringes of urban areas, however, can realize significant economic gains if the land is properly reclaimed in accordance with some predetermined development plan (such as residential or commercial expansion). Realization of high capital gains from sale of reclaimed lands is more common in Regions I and II because of the higher population densities, and consequently, demand for such land.

Numerous attempts have been made to establish the socio-economic benefits of surface mine reclamation. Although most efforts have failed to accomplish this, a report recently completed for the Susquehanna River Basin Commission (4) has established methodology for assigning dollar values to such intangible factors as aethetics, land-use, and recreational utilization. While the information was derived specifically for abandoned mines in Pennsylvania, the methodology can be applied to any area and adapted to active mining. The study initially defines all of the activities or functions affected by sur-

face mining, including aesthetic degredation, water quality, timbering, agriculture, recreation, structural damages, taxes and land values. Dollar values are then developed based upon actual studies and supportive information. To illustrate the logic and rationale used in development of these cost factors, the following excerpt is presented:

AGRICULTURE

"There are numerous examples of strip mined land being restored specifically for agricultural use. The potential agricultural value of an acre of land depends upon many factors. These include rainfall rates, soils, material nutrients and soil reaction with regard to pH, slope, drainage or moisture capacity, and general agricultural economics. A very small percent of the land in the Anthracite and Broad Top Coal Fields is overlain by soils which are suitable for agricultural purposes. Special soil treatment could, however, increase this percentage factor not only for these areas but for others in the West Branch Susquehanna and the Tioga River Basin's coal beds as well. The least productive areas are usually forested or poor pasture land. The West Branch Susquehanna area is, relatively speaking, the most productive area and has many acres of land suitable for corn, grain, vegetables and pasture. The Tioga River Basin is not as productive as the West Branch sub-basin but does have areas suitable for hay, pasture, potatoes, small grain, and buckwheat."

"Historically, crop dollar values have fluctuated widely. Corn, alfalfa, wheat, and oats, for example, currently have gross average annual values per acre of $125, $100, $80 and $75 respectively. If crops are used as feed for beef, pork, eggs, poultry and dairy products, for example, this increases the average annual gross dollar value of about $100 per acre. Farmers and Pennsylvania State Univeristy College of Agriculture experts interviewed both agree that an average annual gross value of $100 per acre represents a realistic and probably conservative dollar evaluation of one acre of farm land per year. Consideration was given to the percentage of reclaimed lands which would be potentially suitable for agricultural purposes in each of the four sub-basins mentioned above. Land resource soil maps, agronomists, and agricultural experts with strip mine knowledge were consulted with regard to the percent of reclaimed strip mines which

could be utilized for agricultural purposes. A value of 2 to 3% was derived for the Broad Top and Anthracite areas and a value of 5 to 7% was decided upon for the West Branch Main Bituminous and North-Central Fields, as well as for theTioga River Basin. Most experts believed these percentage values were realistic and could, in fact, be increased if more money was spent on regrading and soil treatment. For benefit purposes, a minimum percentage value of two will be utilized for the Broad Top and Anthracite Fields and 5% will be applied to the remaining coal fields. An average annual gross crop value of $100 per acre will be used for the four sub-basins."

Similar techniques were utilized to establish realistic costs for each of the other factors defined. Social impacts and economic evaluations can be determined for each Region using similar techniques, despite the fact that severity and environmental problems will vary depending upon local conditions.

The economic welfare of Region III is primarily dependent upon livestock and agriculture. This trend will undoubtedly continue as the worldwide demand for food increases. Due to this fact, it becomes increasingly important to conduct reclamation toward the goal of increased crop productivity. Needless loss of prime agricultural land would have far reaching socio-economic implications. To exemplify this point, we can examine the current trends in real estate and crop prices. In the last five years, returns on an acre of soybeans alone have jumped from $100 to over $200 per acre and may continue to increase at that rate. Agricultural land is increasing at a similar rate. In 1970, an acre of the best farm land was valued at $900 per acre; current prices are in the range of $1400 to $1500 per acre. Conversely, there are numerous areas within these two regions which are not suitable for farming. Mining and well planned reclamation could boost local economics in these areas through improved land use opportunities such as recreational areas, fish hatcheries, woodlands, game habitat, and limited agriculture uses previously not possible.

The impact of western coal development must not be minimized. Almost overnight, boom towns have emerged to serve these rapidly expanding sub-bituminous coal fields. With this uncontrolled expansion have evolved numerous socio-economic problems such as critical shortages of housing, water, educational facilities, transportation networks, and retail markets. While these coal fields contain vast reserves which will

support the areas for many years to come, it must be realized that the coal deposits will eventually be depleted. Present planning efforts must, therefore, include provisions for future commercial development and financial stability.

Another very real socio-economic aspect of western coal development is the ability of the labor force and affected communities to adapt to the drastic change in the standard of living. Land-owners who were barely able to scrape a living from the typically low productive land have suddenly become millionaires, and laborers earning $40 per week now find themselves making many times this amount. While this would appear to be a blessing, most people are psychologically not prepared to cope with such windfalls. Thus, from a purely social standpoint, it would appear that the immediate impact of surface mining is more severe in the western coal fields (Region IV), where social structures are more delicate than in the well established eastern and mid-western fields. However, the economic base of Regions I, II, and III are highly dependent upon the coal industry despite the fact that social structures are more diverse and stable. Although coal development is in relative infancy in Region IV, it nevertheless comprises a very significant portion of the economy of all four regions. In order to stimulate economic stability in these areas, many of which are almost totally dependent upon the coal industry, it is imperative that land use planning be incorporated as an integral part of mining and reclamation plans. Alternative employment possibilities must be developed, land values and tax bases maintained and economic needs satisfied. In addition to long range implications, the immediate impacts of surface mining cannot be ignored. The surface mining industry employs over 38,000 people across the United States and is directly or indirectly responsible for employment of literally hundreds of thousands of other workers in support operations such as equipment, supplies, transportation, preparation facilities, laboratories and numerous other related activities (2).

As previously stated, an accurate assessment of all the socio-economic aspects of surface mining would involve a mammoth undertaking. The previous discussion is in no way intended to suggest that these factors constitute the entire spectrum of socio-economic considerations, but are presented merely to illustrate a few of the many important aspects that must be considered.

INCOME TAX DEDUCTION ALTERNATIVES

Federal income tax laws provide several major options to the mining industry for determining total taxable net profit. Since these alternatives can significantly reduce tax payments, it is important that each option is evaluated by mining companies. In addition to the major options, individual companies use equipment leasing, contracting (revegetation, coal haulage, etc.) and other techniques to accrue the most favorable tax write-offs for their particular operation and state. Following are brief descriptions and hypothetical examples to illustrate some of the pertinent tax alternatives.

DEPRECIATION

Depreciation represents the exhaustion of an asset over time from the combined effects of wear, tear, aging and obsolescence. Depreciation is required to correctly state the value of all assets; this is done by recording depreciation as an operating expense, usually on a monthly basis.

Depreciation affects company capital by increasing expenses, reducing income, and ultimately tax payments. The Internal Revenue Service has approved various depreciation methods, all of which may be classified as straight line or accelerated. Specific examples of straight line and accelerated depreciation, along with the corresponding affect on expenses, income, and taxes follow.

Straight Line Depreciation

Straight line depreciation results in uniform depreciation costs for all assets and is calculated by dividing the depreciable costs by the useful life span of the asset. Example: Given an asset cost of $100,000 and a useful life of 10 years, assuming no salvage value, depreciation per year would be $10,000 ($100,000 ÷ 10 years). Capital Effect: straight line depreciation does improve the capital position by reducing income and the corresponding taxes, but to a lesser degree initially than other techniques. It is the most popular depreciation method, but does not match depreciation to equipment performance (equipment usually performs more effi-

ciently when new).

Accelerated Depreciation

Accelerated depreciation results in increased initial depreciation costs. Double Declining and Sum of the Digits are examples of accelerated depreciation. Sum of the Digits will be used to explain accelerated depreciation. Sum of the Digits is calculated by multiplying the depreciable cost by a fraction whose numerator represents the remaining life of the equipment and denominator is the sum of the digits in the total life of the asset. Example: using the same $100,000 asset with a useful life of 10 years as in straight line, Sum of the Digits depreciation would be:

Year 1 Depreciation

$$\frac{10}{1+2+3\ldots\ldots\ldots+10} = \frac{10}{55} = 18.18\% \times 100{,}000 = \$18{,}180$$

Year 5 Depreciation

$$\frac{5}{55} = 9.09\% \times 100{,}000 = \$9{,}090$$

Year 10 Depreciation

$$\frac{1}{55} = 1.82\% \times 100{,}000 = \$1{,}082$$

Capital Effect: accelerated Sum of the Digits depreciates equipment faster in the early years, thus improving the capital position more than straight line depreciation. All accelerated depreciation methods match depreciation costs with asset performance better than straight line.

In order to better illustrate the specific effect of straight line and accelerated depreciation on expenses, income, taxes and available capital, an example is presented below for a ten year period in which the only variable is depreciation.

(Table 9-107):

Assumptions for 10 year period

Sales = $30 million per year
Expenses excluding depreciation = $25 million per year
Taxable income = $8 million per year
Tax Rate = 50 percent
Asset value = $20 million (salvage not considered)
Useful life = 10 years

Evaluation of the preceding examples show that additional capital is made available in the first five years by using an accelerated depreciation (sum of digits). This may be advantageous since production is often low during initial stages of mine development. However, the accelerated method is a disadvantage during the last years of equipment life, which are potentially low production years. Each company must carefully consider its particular needs to determine the best depreciation option.

DEPLETION ALLOWANCES

The acquisition (leasing), mining and restoration of coal bearing lands requires a sizable capital investment. Since these lands have less value after the coal is mined, depletion allowances were devised as a method to decrease taxable income by reflecting the exhaustion of coal deposits. This provides more capital for reinvestment and continued energy development.

The two types of depletion allowances are: 1) percentage depletion and 2) cost depletion. Both types segregate from income that portion representing return of invested capital. Companies choose the larger of the two to represent depletion allowance for a given year, and may change the method from year to year.

1. Percentage Depletion: The Tax Reform Act of 1969 continued to allow percentage depletion for coal mining. Thus, ten percent of gross income may be deducted from net income as the depletion allowance. However, this amount cannot exceed fifty percent of net income.

2. Cost Depletion: Cost depletion is used by companies with small taxable income and the formula is as follows:

$$\text{Cost Depletion} = \text{Remaining Investment} \times \frac{\text{Annual Production}}{\text{Remaining Reserves}}$$

The following example is presented to clarify these depletion techniques. Both methods are calculated for the same mine with year 1 economic data:

Example economic data:

Sales	$21,500,000
Cost Income Depreciation	$17,000,000
Taxable Income	$ 4,500,000
Land Lease/Mineral Royalty Costs	$ 1,400,000
Annual Production in Tons	$ 5,000
Total Tonnage Reserves	$ 50,000

Percentage Depletion Allowance - Year 1:

$21,500,000 x 0.10 = $2,150,000 but not to exceed 50% of Taxable Income (0.50 x $4,500,000 = $2,225,000). Therefore under the percentage depletion method the allowance would be $2,150,000.

Cost Depletion Allowance - Year 1:

$$\text{Cost Depletion} = \text{Remaining Investment} \times \frac{\text{Annual Production}}{\text{Remaining Reserves}}$$

$$\text{Cost Depletion } 1,400,000 \times \frac{5,000,000}{50,000,000} = \$140,000$$

The method of depletion used is determined by the company and can be changed on a yearly basis. In the above example, percentage depletion would be used since it reduced taxable income more than the Cost Depletion technique.

Other tax options exist, such as investment tax credit, minimum tax on tax preference, etc., but these are not significant to the mining

industry. Depreciation and depletion alternatives are utilized by most of the large companies and many smaller operations.

TABLE 9-107

ILLUSTRATION OF DEPRECIATION COMPARISON

Year	Depreciation Method	Sales	Expenses			Taxable Income	Taxes 50%	After Tax Income	Capital Improvement Accelerated Method
			Depreciation	Other	Total				
1	Straight	30,000,000	2,000,000	25,000,000	27,000,000	3,000,000	1,500,000	1,500,000	
	Accelerated	30,000,000	3,636,000	25,000,000	28,636,000	1,364,000	682,000	682,000	818,000
2	Straight	30,000,000	2,000,000	25,000,000	27,000,000	3,000,000	1,500,000	1,500,000	
	Accelerated	30,000,000	3,272,000	25,000,000	28,272,000	1,728,000	864,000	864,000	636,000
3	Straight	30,000,000	2,000,000	25,000,000	27,000,000	3,000,000	1,500,000	1,500,000	
	Accelerated	30,000,000	2,910,000	25,000,000	27,910,000	2,090,000	1,045,000	1,045,000	455,000
4	Straight	30,000,000	2,000,000	25,000,000	27,000,000	3,000,000	1,500,000	1,500,000	
	Accelerated	30,000,000	2,546,000	25,000,000	27,546,000	2,454,000	1,227,000	1,227,000	273,000
5	Straight	30,000,000	2,000,000	25,000,000	27,000,000	3,000,000	1,500,000	1,500,000	
	Accelerated	30,000,000	2,182,000	25,000,000	27,182,000	2,818,000	1,409,000	1,409,000	91,000
6	Straight	30,000,000	2,000,000	25,000,000	27,000,000	3,000,000	1,500,000	1,500,000	
	Accelerated	30,000,000	1,818,000	25,000,000	26,818,000	3,182,000	1,591,000	1,591,000	-91,000
7	Straight	30,000,000	2,000,000	25,000,000	27,000,000	3,000,000	1,500,000	1,500,000	
	Accelerated	30,000,000	1,454,000	25,000,000	26,454,000	3,546,000	1,773,000	1,773,000	-273,000
8	Straight	30,000,000	2,000,000	25,000,000	27,000,000	3,000,000	1,500,000	1,500,000	
	Accelerated	30,000,000	1,090,000	25,000,000	26,090,000	3,910,000	1,955,000	1,955,000	-455,000
9	Straight	30,000,000	2,000,000	25,000,000	27,000,000	3,000,000	1,500,000	1,500,000	
	Accelerated	30,000,000	728,000	25,000,000	25,728,000	4,272,000	2,136,000	2,136,000	-636,000
10	Straight	30,000,000	2,000,000	25,000,000	27,000,000	3,000,000	1,500,000	1,500,000	
	Accelerated	30,000,000	364,000	25,000,000	25,364,000	4,636,000	2,318,000	2,318,000	-818,000
TOTAL	Straight	300,000,000	20,000,000	250,000,000	270,000,000	30,000,000	15,000,000	15,000,000	-
	Accelerated	300,000,000	20,000,000	250,000,000	270,000,000	30,000,000	15,000,000	15,000,000	-

Accelerated = Sum of Digits * Excludes Depletion

THEORETICAL BACKGROUND FOR SYSTEMS ANALYSES

Techniques for analyzing industrial systems are numerous and have assorted applications. Certain of these techniques have been or are potentially useful in the surface coal mining industry. Selected for brief discussion is the following list of pertinent systems analysis techniques.

CASH FLOW ANALYSIS

This includes a variety of formulas and techniques for evaluating investment alternatives: time value of sums and series; time values of nonuniform series; time value of arithmetic series; annual cost; present worth; and discounted cash flow analyses of rate of return on investment. Each of these variations can be employed to analyze costs of mining ventures. Capital cost, operating cost, depreciation, and taxes are used to establish unit operation or equipment purchase impact on a given system.

The discounted cash flow analyses presented in this chapter serve as examples of cost analysis applications to the surface mining industry. Minimum coal selling price is calculated for each of the fifteen case history mines. This provides one basis of evaluating each operation and comparing different mines.

RISK ANALYSIS

Another method for evaluating economics, risk analysis is used to estimate potential returns on investment or other pertinent cost parameters. The technique involves establishing important cost variables influencing an operation, identifying possible co-ranges and average values, and performing numerous random determinations of new risk variables for input to cost calculations. Complexities of this technique require use of a computer.

Examples of risk analyses are illustrated by the analyses performed in this chapter. With many iterations of return on investment calculations, it is possible to show distribution and probability of achieving certain ROI's. Thus, this is a valuable tool for analyzing investment

considerations related to surface coal mining.

SENSITIVITY ANALYSIS

Many individual cost items formulate costs of a total system. As described for risk analysis, these parameters must be identified and valued prior to performing a sensitivity analysis. The basic method entails calculation of changes in total mining economics as a result of defined variations in each parameter.

Sensitivity analyses performed for case history mines shows the influence of seven variables on rate of return on investment. For these examples, a parameter is changed separately with all other values remaining constant. Studying sensitivity results indicate where tight cost controls are necessary and which variables can be increased with least change in ROI - for example, resource exploration can be intensified to reduce risk with little change in project ROI.

COMPUTER SIMULATION

This systems analysis technique has a variety of applications in the surface coal mining industry. Deterministic Simulation requires input of specific values for all essential parameters influencing production rates and/or costs of a system or its unit operations to be analyzed. Methodology involves programming individual components into a complete network representing the entire scope of operational functions and simulating operations for a defined period. Resultant data will show problem areas and production. Parameters can be changed to evaluate ways to improve the operation. For the surface coal mining industry, numerous simulations are available for studying the total mine, unit operations (such as coal loading and haulage and overburden excavation), or individual equipment performance. (Monte Carlo is another type of simulation which employs probability input data and random selection)(5).

A deterministic simulation analysis is exemplified by the computer programming of Mine No. 4E operations. Overburden removal, coal loading and coal haulage are simulated for one shift to determine ma-

terials handling rates. Since this analysis reflects a recent change in mining procedures, production projections can be compared with past data.

LINEAR PROGRAMMING

Linear Programming is one of many mathematical programming techniques. However, it is the most advanced of these techniques. This method deals with problems that contain linearly related variables - linear functions can be approximated for nonlinear relationships. All variables in a study problem are assigned mathematical functions which formulate an equation or series of equations representing the problem. Linear programming incorporates simulation and evaluates alternatives to arrive at the best possible solution. Production is maximized or costs are minimized to obtain ultimate results.

To illustrate use of linear programming, consider a mining problem involving blending coal from four mines producing different quality coals at different rates. Three markets are available, each requiring a specific quality coal with different selling prices. Linear programming can be used to determine blending and marketing rates needed for maximum sales or profit. Manula and Kin outlined a similar linear programming analysis (6).

CRITICAL PATH ANALYSIS

Basic procedures of the critical path method are definition of work items, times to complete each item, and determination of work sequence. A critical path is established showing each task that must be completed before another starts, which jobs can occur before another starts, and which jobs can occur concurrently with others. The resulting network is used to define the critical path which must be followed to complete the total job. By identifying the critical path, completion dates can be projected and noncritical items scheduled. (PERT, Program Evaluation and Review Technique, is a similar method that uses probabilities instead of actual times for critical path items.) Critical path analysis requires time studies or past experience for establishing task completion times.

A critical path analysis could be performed for an entire mining operation. Results could be used to reschedule non-critical (slack) jobs and increase the total mining efficiency.

CURRENT AND PROJECTED TRENDS

Only a few of the techniques described above have been frequently used in the surface coal mining industry. Small independent operations, common throughout Regions I and II, do not have the manpower to provide these more detailed systems analyses services. In addition, factors such as equipment availability and limited capital, and scarce materials dictate mining practices that are not always the most productive and/or economical. Probably the most frequently used methods in analyzing small to moderate mining operations are time studies and equipment fuel consumption rates. A continuing debate between proponents of the modified block method and supporters of truck haul-back mining has stimulated time studies and cost analyses pertaining to both mining techniques.

Larger companies characteristic of operations in Regions III and IV have used systems analyses techniques more extensively. In two ways this trend reflects the money available to large corporations: 1) more direct funds are available to finance detailed data collection and analysis; and 2) decisions are continuously being made pertaining to optional allocation of large sums of money and/or materials. Prior to committing funds for opening a new mine, expanding existing facilities, or changing mining procedures, systems analysts supply sufficient data to justify the decision. Simulation, linear programming and cost analyses (cash flow and risk) are all employed individually or collectively to aid in managment decisions.

Projected practices for future systems analyses applications in the surface coal mining industry indicate rapid increase - especially in Region IV. New and larger production operations are planned to supply our Nation's energy needs. These mines will be multi-pit operations located long distances from the point of consumption and will require careful planning and development of mining procedures, and coal transport systems to maximize profits and production. Linear programming and "Monte Carlo" simulations are systems analyses techniques valuable for this application.

Although a variety of systems analyses techniques have been de-

veloped or tested by research organizations, applications are restricted to other surface mining industries, including metals and phosphate mining. However, a transfer of technology is becoming a reality as noted during execution of this study. The following narrative illustrates transfer of technology by using a computer model formulated for large metal mines to simulate case history Mine No. 4E. This same simulator model is being applied in the Pennsylvania Anthracite Region and at a western bituminous operation that is considering mining with BWE's. Another large company in Region III may test the model for planning future mining operations and expansion.

COMPUTER SIMULATION - MINE NO. 4E

Mine No. 4E, as described in the case history narrative, is a two-pit operation producing 1.8 million tons annually. Overburden removal is accomplished in Pit No. 1 with 14 and 21 cubic yard draglines while an 8 cubic yard dragline excavates material in Pit No. 2. This mining company has recently converted to a three pit operation by transferring the 21 cubic yard dragline to a new location. Major equipment allocations now consist of:

1) Pit No. 1;
   overburden stripping - 14 cubic yard dragline
   coal loading - 10 cubic yard front-end loader

2) Pit No. 2;
   overburden stripping - 14 cubic yard dragline and D-9 dozer
   coal loading - 7 cubic yard shovel and 7 cubic yard front-end loader

3) Pit No. 3;
   overburden stripping - 21 cubic yard dragline
   coal loading - 10 cubic yard front-end loader

Computer out-put data (from OMPHS Model) listed in Appendix 3 show results of a single shift simulation of this new mining plan. Overburden excavation, coal loading and coal haulage rates and tonnages are provided. From input data representative of equipment performance, overburden characteristics, and haul road parameters, the computer program simulates mining operations, including equipment delays. Because

this program was initially developed for open pit metal mines, output terms are not representative of coal mines. Changes should include:

- Ore = Coal
- Waste = Overburden
- Ore body = Pit
- Bench = Individual unit operation

Total production from the combined pits was determined to be 6,033 tons per shift. Projecting this production rate (loading coal 6 days per week), for one year annual production is approximately 1.9 million tons. Thus, total production could increase by 100,000 tons over previous tonnages. In addition to production figures, equipment waiting times and equipment performances can be evaluated (numerous other uses are possible). If this information is available prior to initiating a new or expanding operation, decisions can be made to purchase additional equipment or replace existing units. The final result should be a more efficient and productive operation.

The brief analysis presented above illustrates potential benefits that can be accrued by the surface coal mining industry via effective transfer of technology. Each of the systems analysis techniques outlined in the beginning of this section can and should be employed to efficiently expand surface mining production.

SYSTEMS ANALYSES SUMMARY

Possibly the most informative component of any detailed economic analysis of surface coal mining is definition of unit operations costs. Accurate knowledge of the integral parts leads to a better understanding of the total system. Thus, each of the case history mines is subdivided into basic unit operations costs which are listed in Table 9-108. To provide complete cost representation, all available charges are allocated to these operations. Values listed in the last column - total cost per ton - are slightly higher than total operating costs because working capital is included as a planning and development cost.

Basic cost itemizing is performed by assigning costs of equipment, labor, supervision, energy consumption (fuel or electric), maintenance and supplies to individual unit operations. Factors such as operating shifts, downtime, energy consumption rates, and percent equipment use per operation are incorporated into subdivisions. To provide more complete understanding of certain costs, several breakdowns are presented. In addition, each unit operation is analyzed in the following discussions. Where appropriate, these discussions evaluate operations according to region, mining method and production.

EXPLORATION

Data in Table 9-108 indicate that exploration in Region I is the most costly per ton of coal mined (average $0.22 per ton) while Region II apparently requires the least exploration expenditures (average $0.09 per ton). However, further study shows mine size is also a controlling factor in influencing exploration costs. Unit exploration expenses increase with annual production until one million tons is reached, and then decline for mines producing three to five million tons per year. Since mine size is regionally differentiated, there is some interaction between region and production influences on exploration costs.

Variable quality and thickness of coals, coupled with steep terrain (which presents drill rig access difficulties), are some of the reasons for expected higher exploration costs in Region I. The exploration average unit cost for Region II is lower than expected, because two of the mines

perform only minimal exploration (that required to comply with state permit requirements). These small operations (Mines 2D and 2J) operate with low capital and overhead, and shift from location to location, mining available coal. Unlike the large companies, they can abandon a mine site (following reclamation) if coal quality or thickness becomes undesirable. An important reason for low exploration costs in Region IV (average $0.11 per ton) is associated with consistent, well documented, coal seams requiring minimal regional exploration.

PLANNING AND DEVELOPMENT

Pre-mining costs comprise an initial expenditure that is assigned a dollar per ton value by distributing expenses throughout the life of the mine. Construction of buildings, roads, and site preparation is usually a large portion of planning and development costs. These expenditure trends are similar to exploration cost trends. Examination of this data again shows Region I with the greatest planning and development cost per ton ($0.41 per ton), while Region IV has the lowest. In addition, unit costs tend to rise until mine sizes become larger than one million tons per year, and then decline.

Of the five case history area mines, four have relatively consistent planning and development expenses - Mine No. 3L is an exception. This may be indicative of surface topography and vegetation, which in this region ideally facilitate construction and site preparation. Rough topography and well established timber characteristic of Region I produce higher road construction and site preparation expenses. Another probable factor is that unit planning and development costs may be reduced as a result of increased in-house experience acquired by large companies (corporate structures). With numerous mines operating under similar conditions, past occurrences can be applied to new mines, reducing planning costs.

TOPSOIL REMOVAL AND RECLAMATION

Although generally considered separate unit operations, topsoil removal and land reclamation are interrelated and have overlapping efforts. Some mine operators recorded equipment usage time for both

TABLE 9-108

SUMMARY OF CASE HISTORY UNIT OPERATION COSTS

Region	Mine Code No.	Mining Method	Production 1,000 Tons/Year	Exploration Cost/Ton	Planning and Development Cost/Ton	Topsoil Removal and Reclamation Cost/Ton	Overburden Stripping			
							Cost/Ton	Cost/Ton-Foot	Avg. Over-Burden Depth (Feet)	Annual Cost/Foot of Over-burden
I	1A	Haulback & Mtn. Top Removal	1,750	$ 0.25	$ 0.53	$ 1.33	(D) $ 8.02	(D) $ 0.08	100	(D) $ 140,264
	1E	Truck Haulback	350	0.39	0.41	(C)(P) 0.99	(D) 11.58	(D) 0.19	60	(D) 67,564
	1G	Modified Block Cut	85	0.03	0.30	(C)(O) 2.88	(D) 8.41	(D) 0.14	60	(D) 11,910
II	2A	Modified Area	500	(A) 0.17	0.41	1.51	(D) 4.82	(D) 0.04	110	(D) 21,891
	2D	Modified Area	120	(A) 0.01	0.30	(C)(O) 2.15	(D) 5.33	(D) 0.12	45	(D) 14,203
	2J	Scraper Haulback	240	0.01	0.13	(C) 1.63	4.05	0.08	50	19,428
	2K	Box – Cut Contour	600	0.18	0.47	(B)(C)(N) 3.55	(D) 6.19	(D) 0.08	80	(D) 46,447
	2M	Modified Block Cut	25.5	(A) 0.10	0.25	0.78	6.52	0.13	50	3,323
III	3B	Modified Area	140	0.04	0.44	(O) 2.70	(D) 8.23	(D) 0.21	40	(D) 28,792
	3D	Area	3,000	0.08	0.18	0.44	(D) 2.52	(D) 0.04	70	(D) 108,066
	3L	Area	1,440	0.26	0.45	0.55	(D) 6.49	(D) 0.08	80	(D) 116,870
IV	4E	Area	1,800	0.15	0.27	(P) 0.64	(D) 2.01	(D) 0.03	70	(D) 51,600
	4H	Open Pit	3,000	0.08	0.13	(C) 0.42	(D) 1.42	(D) 0.01	100	(D) 42,717
	4J	Area	5,000	0.21	0.12	0.19	(D) 1.33	(D) 0.02	65	(D) 102,332
	4K	Area	2,000	0.02	0.17	0.79	0.80	0.01	60	26,422

LEGEND

(A) Exploration By Contract.
(B) Reclamation Grading By Contract.
(C) Revegetation By Contract.
(D) Overburden Fragmented By Drilling And Blasting.
(E) Coal Fragmented By Drilling And Blasting.
(F) Coal Fragmented By Ripping.
(G) All Coal Haulage By Contract.
(H) 65% Coal Haulage By Contract.

TABLE 9-108

SUMMARY OF CASE HISTORY UNIT OPERATION COSTS

Avg. Coal Thickness (Feet)	Coal Fragmentation and Loading Cost / Ton	Coal Haulage				Coal Loading Transport Facilities Cost / Ton	Coal Preparation Cost / Ton	Total Cost Per Ton	Mine Code No.	Region
		Cost / Ton	Cost / Ton-Mile	Roundtrip Haulage Distance (Miles)	Cost / Mile					
6.7	$ 0.17	(G) $ 0.90	(G) $ 0.08	11	(G) $ 2.25	(M) $ —	$ 0.32	$ 11.50	1A	I
14.2	0.52	(H) 2.10	(H) 0.18	12	(H) 4.38	(L) —	(L) —	15.99	1E	
2.3	(F) 0.84	(J) 1.49	(J) 0.17	9	(J) 3.31	(L) —	(L) —	13.95	1G	
3.5	(F) 0.52	(G) 0.70	(G) 0.14	5	(G) 3.08	0.13	(L) —	8.26	2A	II
7.8	0.38	1.88	0.06	34	1.11	(L) —	(L) —	10.04	2D	
5.5	1.14	(G) 1.80	(G) 0.04	46	(G) 0.98	(L) —	(L) —	8.74	2J	
3.9	(F) 0.34	0.53	0.09	6	9.72	0.28	1.20	12.75	2K	
2.5	0.90	(K) 3.64	(K) 0.09	40	(K) 2.09	(L) —	(L) —	12.19	2M	
2.8	0.67	2.48	0.31	8	6.19	0.07	0.75	15.37	3B	III
8.0	(F) 0.54	0.55	0.18	3	21.86	0.11	0.42	4.85	3D	
4.5	(F) 0.62	1.13	0.13	9	9.24	0.17	0.64	10.31	3L	
7.0	(E) 0.75	0.84	0.17	5	8.40	0.16	0.34	5.16	4E	IV
27.0	(E) 0.23	0.87	0.12	7.4	11.51	0.02	0.21	3.39	4H	
52.0	(E) 0.34	0.75	0.25	3	18.96	0.16	0.30	3.41	4J	
20.0	(E) 0.54	0.72	0.12	6	7.82	(M) —	0.21	3.23	4K	

LEGEND (contd.)

(J) 80% Coal Haulage By Contract.
(K) 50% Coal Haulage By Contract.
(L) Not Included In The Mining Cost.
(M) Included In Coal Preparation Cost.
(N) 10% to 15% Of Cost = Topsoil Removal.
(O) 35% to 40% Of Cost = Topsoil Removal.
(P) 45% to 50% Of Cost = Topsoil Removal.

operations, but opinions vary widely as to the point that defines the dividing line between topsoil removal and reclamation. Due to these uncertainties and an ever increasing coordination of efforts to achieve better concurrent reclamation, these operations are grouped as one unit in Table 9-108.

An important initial observation is that six of the 12 case history mines employ contractors to revegetate regraded spoil material. Several apparent advantages associated with contract seeding are: experienced contractors can insure better results; equipment expenditures are reduced (including maintenance); and storage space for seed and fertilizer is not required. However, a direct cost benefit can not be derived from the data available.

Large mines incur a lower topsoil removal cost per ton than do smaller operations. This may reflect thicker seams in the west; therefore, fewer acres are disturbed per ton of coal mined. Region IV, with thicker seams, shows the lowest average cost per ton for topsoil removal and reclamation ($0.51 per ton). The steeper topography associated with Region I and II mining presents erosion control and revegetation problems which add to reclamation costs. Mulching is virtually a necessity, along with diversion ditch construction and frequent reworking of erosional destruction occurring to regraded areas. This erosion problem is a major factor in conjunction with state reclamation enforcement. Mines 2K and 3B are both located in Ohio, and have experienced excessive reclamation costs because inspectors hold bonds until effects of erosion are reclaimed to their satisfaction. These mines frequently experience final reclamation costs greater than $5000 per acre.

OVERBURDEN STRIPPING

Overburden stripping is by far the single most expensive unit operation per ton of coal extracted. This operation is usually the limiting or controlling function (determines production) in any mining operation - an exception is with thick coal seams, which result in coal removal being the controlling unit operation.

Considering an average cost per ton per foot (of overburden), Region I is the highest and Region IV lowest, with respective averages of

$0.14 and $0.02. If mine No. 3B is excluded (this mine borders Region II), Region II is the second most expensive and Region III is the next to least costly. Here again coal thickness is probably a major factor influencing stripping costs. However, the mining method and overburden characteristics are also extremely important. Mining techniques may be the most significant factor in Regions I and II. Table 9-108 illustrates that cost per foot of overburden excavated is the lowest in Region II and greatest in Region I.

Although drilling and blasting increases total costs (only three mines do not require overburden fracturing), it is possible to examine stripping according to mining method. Data indicates the modified block technique provides the least expensive means of excavating overburden material. Several mine operators who employ two stripping methods stated that dozer and loader pits are the most economical. However, modified block mining operations are usually limited to low annual production. Thus, the technique has limited applicability.

Of the case history mines, Mine No. 1A, which operates with combined multi-seam truck haulback and mountain-top removal, is the most costly operation for excavating overburden (cost/foot). For this particular mine, economics are improved considerably as a direct result of combined coal thicknesses and rapid coal exposure. The cost per ton per foot is only $0.08. This emphasizes another important factor-rate of overburden removal. With more rapid removal of overburden, larger coal production rates can be realized. Thus, truck haulback (Mine No. 1E) shows the greatest cost per ton of coal mined.

Relating to economics, open pit and area mines are by far the most inexpensive for stripping overburden per ton of coal. Thus, operating costs per ton and coal selling prices (as determined by discounted cash flow analyses) are generally lower in Regions III and IV. Since many of these mines are producing sub-bituminous or low grade bituminous coal, it is imperative that mining costs should be significantly lower per ton of coal. Selling price is usually determined by calorific value, which results in reduced contract price for many western surface mines.

An additional observation reveals Mine No. 1E has relatively high stripping costs while topsoil and reclamation are comparatively low for Region I. Employing truck haulback with head of hollow fill reduced regrading expenses, but in doing so the cost of overburden excavation increased.

COAL FRAGMENTATION AND LOADING

Sixty percent of the case history mines require coal fragmenting prior to loading. Ripping is used for 33% of the operations with 27% fragmented by drilling and blasting. Every case history mine in Region IV uses drilling and blasting techniques to prepare coal for loading.

Costs per ton vary between and within regions; however, the range of values is small (cost per ton is $0.23 - $0.90 excluding extremes). Again Region IV accrues lowest fragmentation and loading expenditures per ton of coal mined, which in part reflects the thickness of coal seams. Economics do not significantly relate to mining methods, because techniques are characterized according to overburden removal practices. But equipment leasing does influence economics, as illustrated by Mine No. 2J. This coal loading operation is performed with a leased front-end loader and shows the highest cost per ton of coal extracted ($1.14) for fragmentation and loading. What must be considered, but is not reflected in the loading expense, is added available capital at year one. If invested wisely or used for another mining cost, this additional capital can more than compensate for yearly increases due to leasing. A regionally low total cost per ton may actually represent advantageous use of available funds.

COAL HAULAGE

Characteristic of Regions I and II, contract coal haulage is employed for all, or part of, production in a majority of the study mines. Contract haulage provides two important advantages: 1) small operations do not require large capital expenditures for coal trucks, and thus can pay for haulage directly from sales; and 2) maintenance facilities and parts inventory are reduced, which lowers the amount of capital tied up at any given time.

Although coal haulage expenditures are less per ton per mile in Regions I and II, greater roundtrip haulage distances tend to produce higher cost per ton values than occur in Region IV. In fact, a general relationship shows that incremental haulage expense does decline with increased haul distance.

Since mining in Regions I and II is conducted over a larger area within a given year, haulage from the pits to a tipple (or market point) requires greater travel distances than large mines working in one area. However, as a large mine matures haul distances will increase, unless retreat mining is used or the tipple is located at a central point. Large trucks, common in Regions III and IV, may also reduce expenses per ton transported.

In Regions III and IV, coal haulage is second only to overburden excavation on a cost per ton basis. Costs for topsoil removal and reclamation are second in Regions I and II, with coal haulage a close third.

COAL LOADING AND TRANSPORT FACILITIES

These values as listed in Table 9-108 represent operating costs of unit train loading facilities with initial construction costs spaced equally throughout the mine life. For Mines No. 1A and 4K, loading is from a hopper directly attached to a preparation plant and individual costs are difficult to separate.

In general, unit train loading facilities (or tipples) are only a small fraction of total mine expenses per ton of coal mines. In addition, transport costs are absorbed by the consumer (an exception is direct trucking to a nearby market), while coal selling prices represent a cost to mine and load on transport units. Coal transport is analyzed in Chapter 7.

COAL PREPARATION

Developed from minimal data pertaining to specific plants, coal preparation expenditures are determined from plant construction typical of the cleaning stage and processing rates. Operating costs include power consumption, labor, maintenance and materials purchase.

Mine 2K employs a Stage 3 preparation plant and incurs the highest cost per ton ($1.20). Cleaning of low sulfur western coals usually requires only Stage 1 preparation and averages $0.27 per ton of coal mined at the case history operations. As indicated in Chapter 8, future projec-

tions show more use of Stage 3 cleaning to meet quality controls. A detailed evaluation is required to determine preparation cost increases compared with increased coal value. Potential exists for coal cleaning expenses increasing as much as $2.00 per ton with more complete preparation.

TOTAL COST PER TON

Regional average total costs decrease in order from Region I to Region IV (excluding mine 3D, Region III is second) and represent all operating and capital expenditures. Discounted cash flow selling prices are indicative of this trend with highest minimum prices in Region I and lowest required prices in Region IV. Mining methods also follow the same regional pattern - open pit is least costly and truck haulback is the most expensive on a per ton basis. Since the fifteen case history mines are influenced by individual preferences and specific conditions, care should be taken to avoid overgeneralizing (concerning mining techniques and related costs). However, cost ranges and trends provide reasonable estimates to relate between methods and regions when considering input parameters.

In addition to information in Table 9-108, an examination of all systems analyses performed in this chapter provides some insight for better understanding of complete mining system economics. Sensitivity analyses show that tight controls must be maintained to insure required production rates with favorable operating costs. Since return on investment is generally least sensitive to exploration and development construction costs, exploration efforts should not be reduced as a cost cutting measure unless coal and overburden characteristics are well documented or extremely consistent. Proper exploration is a means of reducing risk with a minimum change in ROI. Figure 9-15 included with case history 4H shows a 20% change in exploration and developmental construction costs results in about 3% change to the ROI - Costs of exploration alone will probably produce less than one percent change in the ROI.

The following suggestions can reduce risk, increase profits and/or increase production from surface coal mines:

- place emphasis on exploration and characterization of the coal deposit

- use available systems analyses techniques such as simulation and linear programming to help plan new operations or expand existing facilities
- consider all tax options, including depreciation and depletion allowances
- employ linear programming, simulation, PERT and CPM analyses to determine equipment waiting times and other delays for maximizing production and return on investment
- evaluate leasing options to help alleviate initial capital investment shortages
- strip with two smaller draglines in place of larger inefficient equipment if technically feasible - mine operators and the computer simulation of Mine 4E indicate greater production with possible reduced costs
- use the modified area method for mining at medium to high production rates in Region II if topography is suitable
- mine via modified block technique when opening small production operations in Region I or II
- contracting coal haulage may reduce costs per ton in Region II
- more effective reclamation may be achieved by mining some moderately dipping seams in Region IV perpendicular to the strike

Results of systems analyses provide a basis for establishing research priorities. Overburden excavation is the most expensive unit operation and usually controls production rates. Thus, research efforts should be directed toward increasing efficiency and rate of overburden removal. New stripping equipment should be developed and existing equipment should be improved to minimize downtimes. Excessive mechanical delays experienced with large draglines and shovels reduce production immensely and increase operating costs (the sensitivity graphs indicate these two variables have the greatest influence on ROI's). Where feasible, careful consideration should be given to using BWE's for removal of unconsolidated

overburden. New equipment could incorporate certain BWE characteristics such as more continuous excavation without swing times for dumping.

Belt conveyor haulage of overburden is an excellent possibility for reducing stripping costs and increasing production in Regions I and II (see research and development recommendations in Chapter 10). With necessary equipment modifications, conveyor systems may also be advantageous in Regions III and IV. Belt haulage of coal in Regions III and IV is another area requiring research. As illustrated by Table 9-108 coal haulage is the second most costly unit operation in the west and midwest. In addition to offering transport at a potentially lower cost per ton, belt systems provide more continuous flow of material and eliminate many delays, such as turning and dumping times associated with truck haulage. Reduced operating costs will provide additional funds for increasing stripping equipment and thus increase total production.

Research priorities, after expediting overburden removal, should be directed toward providing more rapid coal loading. A machine similar to continuous miners used in underground coal mining could provide rapid continuous coal loading. Connected to a coal haulage belt conveyor system, this would facilitate continuous loading and haulage.

Topsoil removal and reclamation are also included with the highest expenses incurred by mining operations. Thus, research should concentrate on reducing reclamation costs while still meeting environmental requirements. Economics of retreat mining should be investigated for Regions III and IV. This would eliminate disturbances to reclaimed areas and allow farming or grazing to provide a supplemental income. Reclamation should be studied to further coordinate stripping, topsoil removal and placement with regrading efforts.

Systems analysis techniques are a valuable tool available to the mining industry. Research should be implemented to stimulate use of systems analysis for developing new large production mines in the west. With more accurate characterization of physical parameters - geologic, climatic, environmental, equipment related, etc. - linear programs can be developed to establish ultimate mining schemes. It should be possible to find the ideal production and total cost balance for a given mine.

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CHAPTER 10

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Although surface coal mining methods can be characterized in each of the four study Regions, equipment utilization and operating procedures vary significantly between individual mines. In Region I, Lateral Movement or Controlled Placement Methodology is used to successfully minimize environmental disturbances. However, truck haulback mining is one of the most expensive overburden excavation techniques commonly employed for surface coal mining. Development of more versatile machinery or implementation of conveyor overburden haulage systems should reduce costs and facilitate increased production rates.

Modified Block-Cut mining is Region II's substitute for the truck haulback technique. Utilizing dozers and loaders, this method provides the least expensive means to remove overburden commensurate with strict environmental regulation. Limited to small production mines, Modified Block-Cut mining will receive continued use, but it will not contribute significantly to the nation's total production. Characteristic of larger Region II operations, Modified Area mining provides an economical and environmentally favorable method for extracting coal at potentially greater rates than with Modified Block-Cut mining. Development of more efficient large draglines and shovels will minimize downtimes and increase production from Modified Area Mines.

Surface coal mining in Region III is solely characterized by area mining techniques. To achieve effective land restoration, reclamation efforts should be concurrent with mining. Of all the Regions, surface mining in Region III has the greatest potential post reclamation benefits. Properly planned, reclamation efforts can develop areas for productive crop farming to augment increasing world food requirements. However, many existing state laws limit coal recovery and implementation of viable reclamation alternatives. Water pollution control measures assume the primary emphasis in reclamation practices. Efforts should be directed toward establishing a productive ecosystem and attaining maximum coal recovery.

Only in its infancy, Region IV mining has not progressed far enough to fully evaluate extraction potential and environmental disturbances. Open Pit and Area Mining techniques facilitate high production removal of thick consistent coals. Compared with all other Regions, excavation

of overburden material in Region IV is by far the least expensive per ton of coal mined. With a more knowledgeable understanding of the ecosystem, Region IV will facilitate development of new large surface mines to help attain this Nation's energy self-sufficiency.

Installation of new mines and expansion of existing operations requires coordination of all unit operations involved in the total mining system. Exploration efforts should be complete and detailed (where required statistical techniques can be used to design and interpret drilling patterns and results) to reduce risk and assist with mine planning for selection of the most productive mining method and equipment. Systems analyses techniques should be employed to further reduce risk by insuring ultimate production goals with minimum operating costs. Linear programs are available to provide some of the necessary systems analyses services; however, research should be directed to expand existing capabilities. Time studies and computer simulation are tools available to periodically evaluate efficiency of unit operations and weak points within the total mining system.

In compliance with concern for environmental protection, topsoil removal and placement is being incorporated with regrading and revegetation. Although this coordination of efforts achieves desired results at lower costs than if the topsoil removal and reclamation were done separately, these two operations represent one of the larger unit operation costs per ton of coal mined. Productive land use should be considered as a partial supplement to reclamation expenditures. Timbering is a consideration for Regions I and II with crop farming a possibility in Region II and III. Pasture lands and water catches are potential benefits from mining in Regions III and IV. Retreat mining research may establish a feasible technique to reduce reclamation costs and facilitate early land use potential.

Overburden removal and placement is being modified to permit easier and more concurrent land reclamation. However, production goals must also be realized considering overburden excavation as the controlling factor. This unit operation is the most expensive per ton of coal extracted and should receive most careful consideration and planning. In addition, research should be concentrated on improving existing equipment and developing new equipment and mining practices to increase production and reduce costs.

While overburden excavation usually operates two or three shifts per day, coal removal is limited to one shift by the rate of coal exposure. The universal pit transport mechanism is the coal truck. Whether accomplished by small 25 ton trucks common to Region I or large 100 ton trucks in Region IV, coal haulage is an expensive unit operation. Conveyor haulage may be a partial remedy for large western and mid-western surface mines. For long distance coal transport, trucks and conveyor systems should be avoided. Available techniques for long distance transport are in ascending order of unit cost: water, rail,and slurry pipeline. The actual method employed may involve a combination of methods with the selection based on availability rather than economics. Capital assistance is needed from government to repair deteriorating rail systems and supplement a shortage of rolling stock. Also, national priorities must be established for water usage if large scale slurry pipelines are to play a significant role in the development of western coals.

Prior to market use, high sulfur coals of Regions I, II, and III will eventually require implementation of more Stage 3 preparation plants to help meet federal sulfur emission standards. These plants may involve construction expenditures approaching 30 million dollars, with increased operating costs. Slimes refuse disposal will also present added environmental problems. Higher selling prices must be realized to offset increased preparation costs. Research related to slimes disposal is also a necessity.

It is obvious that to meet national production goals and maintain a productive environment a concentrated research effort is needed,and coordinated mine planning is a virtual necessity.

BUREAU OF MINES RESEARCH PROGRAM

The Bureau of Mines, in compliance with the Federal Coal Mine Health and Safety Act of 1969, is currently administering an extensive coal oriented research program. In addition, the Bureau is administering non-coal contract programs that will in many cases provide positive transfer of technology. The Bureau issues a Mining Research Contract Review each month (1). A discussion of current contracts is included in that publication, describing the type of research and identifying the contractor. The first letter of each contract number indicates whether the project is - a grant (G), a Research and Development contract (H), or a Study and Supply contract (S). In-House research efforts by the Bureau are also presented.

CONTRACTOR RESEARCH

The research effort has two major thrusts: Mining Health and Safety, and Advancing Mining Technology. Projects are grouped in the following sub-categories:

Mining Health & Safety Research

- Dust Control
- Radon Control
- Noise Control
- Methane Control
- Industrial Hygiene
- Fires and Explosions
- Illumination
- Ground Control
- Industrial Safety
- Mine Communications
- Post Disaster
- Advance Mining Systems

Advancing Mining Technology

- Advancing Mining Systems

- Automated Continuous Roof Support
- Automated Longwall
- Oil Shale
- Surface Mining, Extraction, and Reclamation
- Surface Mining Equipment
- Underground Mining Technology
- Tar Sands

A survey of active contracts reveals thirteen projects with direct application for surface coal mining in areas of electrical system reliability, health and safety, mine planning, exploration techniques, production improvement, land reclamation, equipment selection, and engineering economics.

The survey also reveals additional projects with strong possibilities for technology transfer. The majority of these projects are primarily concerned with deep-mining, or non-coal operations, however, the scope of each covers a subject of concern in the surface coal mining industry.

IN-HOUSE PROJECTS

The Bureau of Mines historically has been one of the major proponents of in-house research for the coal industry. More recently the energy crisis catapulted this effort into a "Manhatten Project" approach for coal extraction and utilization technology.

Unfortunately Bureau policy does not encourage dissemination of information relative to concurrent in-house research. Work plans for each field operation center are printed but restricted to use within the Bureau (i.e. - work plans - FY' 75. Pittsburgh Mining & Safety Research Center). These work plans list each project objective, technology transfers, immediate goals, background and justification, and cooperating organizations. A survey of these work plans reveals many projects with direct application to surface coal mining. If the work plans were made available to contractors engaged in Bureau research projects, duplication of effort would be minimized. All inquires could be channeled through the contractor's Technical Project Officer to minimize interruptions and eliminate unauthorized requests for information.

OTHER RESEARCH

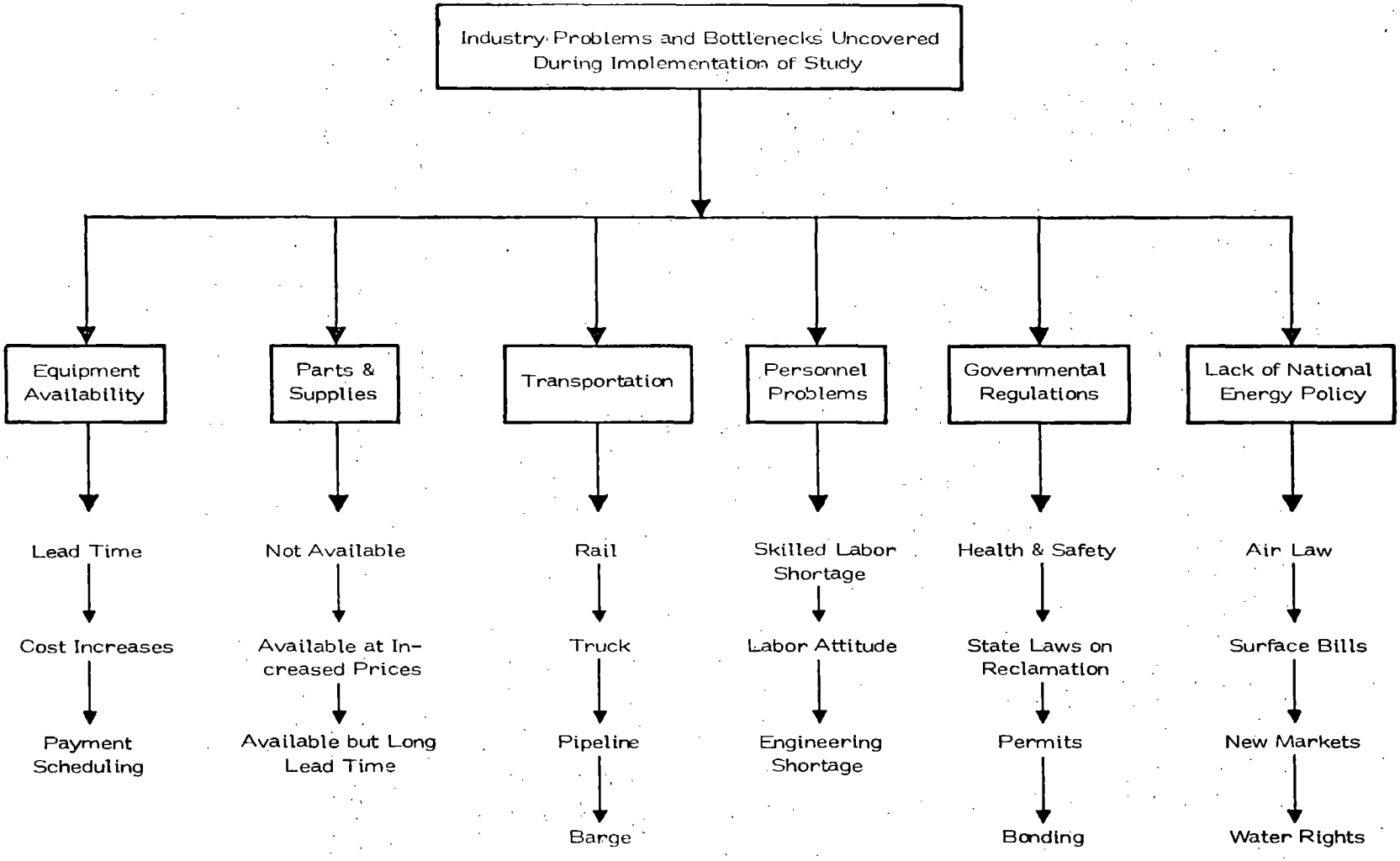
An Inventory of Current Energy Research and Development is a three volume report prepared for the Subcommittee on Energy of the Committee of Science and Astronautics, U.S. House of Representatives (2). A review of this report reveals numerous projects (listed with Appendix 1) with direct or related application to surface coal mining. Over 80% of these projects are addressed to environmental considerations, such as land reclamation and water quality. Less than 20% of this research effort is directed toward mining technology. These statistics reflect the emphasis placed on environmental issues before problems were focused by the current "Energy Crisis".

SUMMARY OF CURRENT RESEARCH PROGRAMS

An intensive national research effort is being conducted relative to environmental - energy issues; however, most of these projects do not propose solutions to the six major problem areas facing the surface coal mining industry today. Figure 10-1 illustrates these six problem areas:

- Equipment availability
- Parts and Supplies
- Transportation
- Personnel Problems
- Governmental Regulations
- Lack of National Energy Policy

Each area has several sub-categories, all of which have been illustrated and discussed in the report. An analysis of current projects listed in Appendix 1 shows a need for additional research directed toward several important problem areas discussed in detail in the following section - Research and Development Recommendations.



PROBLEMS AND BOTTLENECKS IN THE SURFACE COAL MINING INDUSTRY

Figure 10-1

RESEARCH AND DEVELOPMENT RECOMMENDATIONS

Resulting from field observations, data analysis, and findings of this study, the following list of recommended research projects is compiled. It is felt that effective execution of these recommended projects will benefit surface mining by increasing production and/or total recovery and reduce mining costs. The cost to implement these projects will vary according to individual levels of effort desired.

1) Feasibility of belt conveyor haulback mining should be evaluated. A project would entail determining technical and economic potential for transporting overburden material from an excavating machine to a mined out pit. To justify testing and use of the method, complete economic analyses should be performed and comparisons made with existing haulback or modified block-cut mining techniques. If determined feasible, belt conveyor haulback mining will facilitate increased production rates, additional recovery, and allow environmentally desirable reclamation.

2) An innovative application of existing mining technology, trench strip and auger mining provides potential for removal of thin mid-western coals that are covered by excessively thick overburden. This mining method involves excavating a box-cut trench (with draglines) for the length of a given property, followed by augering in both directions normal to the cut. A series of these procedures continue in a parallel sequence for the entire mine area. To contain drainage a barrier is left between each opposing set of auger holes, minimizing potential for acid mine drainage problems. Since this mining method will disturb less surface area with approximately 70 percent coal recovery, it deserves consideration for coals deemed unmineable either for economic or environmental reasons. Research efforts should define potential additional reserves and evaluate economic feasibility of trench strip and auger mining.

3) Definition of reclamation standards is a subject of extensive controversy. Within present context, several reclamation laws ignore application of fundamental ecological concepts.

In order to have uniform enforcement, many states established

inflexible "across-the-board" regulations. As a result, regional environmental variability was not considered. Coal operators are confronted with the perplexing problem of adjusting mining and reclamation activities to legislated requirements more often than to performing environmentally and economically sound work (Reclamation).

A viable alternative to current methods of establishing reclamation standards is to develop them based upon the ecologic norms for each Region - I, II, III, IV. By recognizing the inherent characteristics of each region, more realistic and effective reclamation could be achieved.

4) With legislation pending in the midwest that would limit the size of overburden material within the upper two feet of regraded spoils, a new or adapted piece of equipment which could "pick" oversized rocks from that zone will be very beneficial. "Rock Pickers" would eliminate regrading problems of materials segregation and gradation. In areas where reclamation involves agricultural cultivation, "rock picking" would reduce problems of broken plows, discs, and harrows. Research to design and test a "rock picking" device would greatly benefit agricultural reclamation procedures, not to mention possible applications to existing farmlands where large rocks present cultivating problems. A possible approach to large rock segregation could be adaptation of an elevating-scraper to incorporate a rake type mechanism instead of the current digging blades.

5) A major deterrent to development of western coal deposits is the uncertainty and concern about possible disruption of groundwater flow systems. Investigations should be conducted to determine if mining will disturb aquifers in given areas and available solutions. Possible solutions to be examined include: replacing coal with permeable scoria or other backfill; installing clay lining; or employing dewatering well systems. With adequate testing and documentation, this may help relax regulations and pressures presently preventing full scale development of western coals.

6) Preventing pollution of surface and groundwater systems is a major problem confronting many prospective surface mining opera-

tions. High costs for control and treatment of acid mine drainage reduce mining profits and discourage mining. Since not all coal seams are conducive to acid formation, there should be a study to determine the pollution potential of coal seams. Following classification of coal seams, mining could be encouraged in low pollution potential areas. The high pollution potential coals may then be more economically mineable in the future when improved treatment and abatement technology is available.

7) Existing state pollution control laws restrict mining of coal reserves for environmental purposes. All such laws should be reviewed to determine the amount of reserves restricted from mining. Where possible,solutions should be developed to permit extraction of these coals with minimal environmental disturbance.

8) Systems analyses techniques are valuable tools for planning and development of new and productive large surface mines. Although numerous linear programs and simulators are available for use by surface miners, there is a definite need to expand the capabilities and effectiveness of these techniques. All major physical parameters (geology, geography, climate, etc.) controlling production performances in each Region should be classified for computer programming. Operating parameters should be defined for all major equipment (related to regional physical factors) and each viable mining method should be programmed. The ultimate product of this multi-stage research effort should be a Regional computer program with the capability of selecting the equipment and mining method to achieve maximum production at least cost to the miner. Collection and review of existing data and systems analyses technique will provide an excellent starting point for this project.

9) Although coal preparation is a relatively small expense for most present surface mine operations, projected increased implementation of Stage 3 (detailed cleaning) preparation plants will produce a rise in cleaning costs per ton of coal mined. Slimes refuse disposal not only represents higher operating cost, but also poses a potential environmental problem. Lagoon disposal sites require extensive surface area and diligent construction planning to prevent contamination of surface and ground water systems. Research could begin with an assessment of current slimes disposal tech-

nology, environmental problems and costs. Following this evaluation, individual projects could be developed to design and test new disposal methods. These slimes disposal techniques should be concerned with lowering costs and beneficial use of slimes (usually there is sufficient coal content to sustain combustion).

10) Underground coal removal and loading machines operate on a continuous basis, with transfer of extracted coal to haulage units via conveyor belt. To date, the surface coal mining industry has experienced little application of any continuous coal removal equipment, with exception of a few experimental approaches with bucket-wheels in the west. In eastern surface coal mines, where thin coal seams are extracted, increased production and easier coal loading operations could possibly result by adapting underground coal methodology and equipment variations to surface operations. Decreased coal fragmentation requirements, continuous truck loading, and highwall coal recovery are some of the advantages that could result from this transfer of technology.

OTHER RESEARCH AND DEVELOPMENT POSSIBILITIES

- Develop more resistant products such as tires, drill bits, cables, bearings, etc.
- Employ more multi-stage drilling such as used in highway construction.
- Develop baseline data on ecologic norms of Regions I, II, III, and IV.
- Field investigations of long-term impacts of herbaceous vegetation for establishment of stable, productive ecosystems.
- Field investigations and demonstration of viable techniques in shaping Region IV spoil for reduction of wind erosion and increased moisture retention.
- Research to determine effects of topsoil stockpiling.
- Develop a viable substitute for ANFO.
- Experimental development of a more continuous overburden excavator incorporating desirable capabilities of BWE's with digging strength of shovels and draglines.
- Develop set of lesson plans and visual aids for introducing

courses in coal mining at University level.

- For all coal producing regions, make engineering economic analysis for various levels of pyrite removal by coal washing vs. post combustion removal of SO_2.
- Improve system of posting all research projects by: (1) Bureau; (2) Other Governmental Agencies (use of information retrieval system at each Technical Research Center, i.e. - system used in Gulf Oil Corporation Building in Pittsburgh, Pa.)

REFERENCES

Chapter 10 - CONCLUSIONS AND RECOMMENDATIONS

1. U.S. Bureau of Mines. Work Plans - Fiscal Year 1975, Pittsburgh Mining and Safety Research Center, Volume I - Mining.

2. Atomic Energy Commission - Inventory of Current Energy Research and Development, Volume I, Parts I and II, Series J, January 1974.

APPENDIX 1

CURRENT RESEARCH PROJECTS THAT RELATE TO THE SURFACE COAL MINING INDUSTRY

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RESEARCH PROGRAMS

Title: Developing a Pyritic System Mathematical Model - RF 296 1
Research Facility: Ohio State University, Department of Chemical Engineering
Sponsor: United States Department of Interior

Title: Jim Bridger Mine Land Reclamation Research Projects
Research Facility: University of Wyoming
Sponsors: Pacific Power and Light Company; Idaho Power Company

Title: Coal Acquisition Strategy Studies
Research Facility: Stanford Research Institute
Sponsors: Unspecified Industries

Title: Geochemistry of Strip Mine Overburden - Pilot Project
Research Facility: Ohio State Government, Department of Natural Resources, Division of Geological Survey
Sponsor: Same

Title: Improvement in Mining of Coal
Research Facility: Battelle Pacific Northwest Laboratories
Sponsor: Battelle Memorial Institute, Energy Program

Title: Remote Sensing of Strip Mine Pollution
Research Facility: National Aeronautics and Space Administration, Lewis Research Center
Sponsor: Same

Title: New Surface Mining Technology to Minimize Environmental Disturbance
Research Facility: Potomac Engineering and Surveying
Sponsor: United States Environmental Protection Agency

Title: Feasibility Study of a New Surface Mining Method
Research Facility: Potomac Engineering and Surveying
Sponsor: United States Environmental Protection Agency

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Title: Study of Sulfur Recovery from Coal Mine Refuse as a Profitable Means of Eliminating Acid Water Drainage from Coal Refuse Piles
Research Facility: Black, Sivalls, and Bryson, Incorporated
Sponsor: United States Environmental Protection Agency

Title: Water Quality Control in Mine Spoils
Research Facility: Colorado State University
Sponsor: United States Environmental Protection Agency

Title: Demonstration of Control of Acid Drainage from Coal Mine Refuse Piles and Slurry Areas
Research Facility: Consolidation Coal Company
Sponsor: United States Environmental Protection Agency

Title: Greene - Sullivan Demonstration Project (1B2040)
Research Facility: Indiana State Government, Department of Natural Resources and forestry
Sponsor: United States Environmental Protection Agency

Title: Hydrology Study
Research Facility: Montana State University; Peabody Coal Company
Sponsor: Peabody Coal Company

Title: Resource Allocation to Optimize Mine Drainage Pollution
Research Facility: Ohio State University, Engineering Experiment Station
Sponsor: United States Environmental Protection Agency

Title: State of the Art - Surface Mining Pollution Control
Research Facility: United States Environmental Protection Agency, National Environmental Research Center
Sponsor: Same

Title: Pre-Feasibility Report for Elk Creek Watershed
Research Facility: West Virginia State Government
Sponsor: United States Environmental Protection Agency

Title: Demonstration of Technique of Water Infiltration Control to Achieve Mine Water Pollution Control
Research Facility: West Virginia State Government, Department of Natural Resources
Sponsor: United States Environmental Protection Agency

Title: Dust Samplers and Their Reliability
Research Facility: Bituminous Coal Research, Inc.
Sponsor: Bituminous Coal Research, Inc.

Title: Mined-Land Reclamation Library and Technical Services
Research Facility: Bituminous Coal Research, Inc.
Sponsor: Bituminous Coal Research, Inc.

Title: Reuse of Treated Active Surface Mine Drainage for Revegetation Augmentation (1B2040)
Research Facility: Kentucky State Government Dept. of Natural Resources; Division of Reclamation;
Sponsor: U. S. Environmental Protection Agency

Title: Surface Mining Reclamation
Research Facility: National Academy of Sciences
Sponsor: Ford Foundation, Energy Policy Project

Title: Chemical Composition of Overburden Soils as Related to Coal Surface Mining Reclamation
Research Facility: Peabody Coal Co.
Sponsor: Peabody Coal Co.

Title: Hydrology, Erosion Control and Species Adaptation Research
Research Facility: Peabody Coal Co.; University of Arizona
Sponsor: Peabody Coal Co.

Title: Block Method of Strip Mining
Research Facility: Pennsylvania State University, College of Earth Mineral Sciences
Sponsor: Pennsylvania State University

Title: TVA Long Pit Strip Mining Reclamation Demonstration Project
Research Facility: Tennessee Valley Authority, Div. of Power Production
Sponsor: Tennessee Valley Authority

Title: Reclamation of Spoils Resulting from Surface Mining of Lignite
Research Facility: U. S. Dept. of Agriculture, Agricultural Engineering Research Division
Sponsor: U. S. Dept. of Agriculture, Agricultural Research Service

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Title: Surface-Mined Area Restoration Project
Research Facility: U. S. Dept. of Agriculture, Forest Service
Northeastern Forest Experiment Station
Sponsor: U. S. Dept. of Agriculture, Forest Service

Title: Reclamation on Spoil Banks from Strip Mining of Lignite and Western Coal - Managing Coal Wastes and Pollutants Project G-5
Research Facility: U. S. Dept. of Interior, Bureau of Mines, Grand Forks Energy Research Laboratory
Sponsor: U. S. Dept. of Interior, Bureau of Mines

Title: Mine Spoil Potentials for Plant Growth and Water Quality
Research Facility: West Virginia University Dept. of Plant Science
Sponsor: U. S. Dept. of Agriculture, Cooperative State Research Service

APPENDIX 2

COMPUTER

PROGRAMS

RISK ANALYSIS PROGRAM

```
      C     This Program Performs a Risk Analysis
    1       Real MU(10), P(10), SDL(10), SDH(10), PROB(80), ROI(500),
            CSH(500)
    2       Integer Count (80)
      C     Read the Variable Means
      C     I=1, Prod Cost; I=2, Production; I=3, Cap. Invest; I=4,
      C     Selling Price; I=5, Market
    3       Read, (MU(I), I=1,5)
      C     Read the Low Standard Deviation
    4       Read, (SDL(I), I=1,5)
      C     Read the High Standard Deviation
    5       Read, (SDH(I), I=1,5)
      C     Generate Random Variable Values
    6       IX=1
    7       S=1.
    8       AM=0.
    9       DO 101 J=1,500
   10       DO 100 I=1,5
   11       Call GAUSS (IX,S,AM,V)
   12       RN=V
      C     Test Random Normal Number for Neg., Zero, or Pos.
   13       If (RN) 20, 30, 40
   14    20 P (I) = MU(I) + (RN*SDL (I))
   15       If (J.GT.3) Go to 100
   16       Print, P(I)
   17       Go to 100
   18    30 P (I) = MU (I)
   19       If (J.GT.3) Go to 100
   20       Print, P(I)
   21       Go to 100
   22    40 P (I) = MU (I) + (RN*SDH (I))
   23       If (J.GT.3) Go to 100
   24       Print, P (I)
   25   100 Continue
      C     Calculate Cash Flow and Rate of Return
   26       If (P(5) .GE.P (2)) Go to 50
   27       P (2) = P (5)
   28    50 Sales = P (2) *P (4)
   29       Gross = Sales - (P(1) *P (2))
```

RISK ANALYSIS PROGRAM

```
30              If (Gross.LE.O.) Go to 300
31              Deplt = Sales *0.1
32              Taxin = Gross - Deplt
33              Z = Gross/2.
34              If (Deplt. GT.Z) Go to 302
35              Go to 303
36          302 Taxin = Gross/2.
37              Deplt = Taxin
38          303 Prof = Taxin/2.
        C       Estimate Depreciation
39              Depr = P (3) *0.06
40              Go to 270
41          300 Depr = P (3) *0.06
42              Taxin = 0.
43              Prof = Depr + Gross
44              CSH (J) = Prof
45              Print 33, Sales, Gross, Taxin, Prof, Depr.
46           33 Format ('-', F8.0, F13.0, F13.0, F13.0, F13.0)
47              Go to 275
48          270 Print 34, Sales, Gross, Taxin, Prof, Depr, Deplt
49           34 Format ('-', F8.0, F13.0, F13.0, F13.0, F13.0, F13.0)
50              CSH (J) = Depr + Prof + Deplt
51          275 ROI (J) = (CSH(J)/P (3)) *100.
52              Print 35
53           35 Format ('0', 27X, 'R.O.I.',7X, 'CASH')
54              Print 36
55           36 Format ('+', 27X, '______', 7X, '____')
56              Print 37, ROI (J), CSH (J)
57           37 Format (' ', 27X, F6.3, 5X, F8.0)
58          101 Continue
        C       Determine Distribution and Calculate Probabilities for ROI's
59              DO 103 I=1,80
60              Count (I) =0
61          103 Continue
62              Print 56
63           56 Format ('-', 'Count', 4X, 'Probability')
64              DO 102 J=1,500
65              R=0.
```

```
66              70 R = R + 2
67                 If (ROI(J).GT.R) Go to 70
68                 I = R/2.
69                 Count (I) = Count (I) + 1
70              102 Continue
      C            Determine Probability of Occurrence
71                 CUM = O
72                 DO 104 I=1, 80
73                 B Count = Count (I)
74                 Prob (I) = (500.-(B Count + CUM))/500
75                 CUM = B Count + CUM
76              104 Continue
      C            Print the Distribution and Probability of ROI, S
77                 DO 105 I=1, 80
78              105 Print 57, Count (I), Prob (I)
79               57 Format (' ', 13, F16.8)
80                 Stop
81                 End
```

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SENSITIVITY ANALYSIS PROGRAM

```
C       Program to Perform Sensitivity Analysis
        Real Orign (7), MIN10 (7), PLS10 (7), PLS20 (7),
        CAPVT (30), SALES (30), 10PERT (30), DEPRC (30),
        CSH (30), ROI (30), CHANG (30)
C       Read the Original Data:  I=1, Explr; I=2, Equip; I=3, Indir;
C       I=4, Opert; I=5, Prodt; I=6, Selpr; I=7, Labor
  150 Read, L
        If (L.EQ.2) Go to 450
        Read, N, (Orign (I), I=1,N)
        Read, W,X,Y,Z
        Deprc (1) = W
        Capvt (1) = X
        Sales (1) = Y
        Opert (1) = Z
C       Calculate Minus 10 Percent Variable Change
        DO 200 I=1,7
        MIN10 (I) = Orign (I) *0.90
C       Calculate Plus 10 Percent Variable Change
        PLS10 (I) = Orign (I) *1.10
C       Calculate Plus 20 Percent Variable Change
  200 PLS20 (I) = Orign (I) *1.20
C       Determine Capital Investment, Sales, Operating Costs, and
C       Depreciation
C       Change Due to Exploration: - 10 Percent, + 10 Percent, and
C       + 20 Percent
        CAPVT (2) = CAPVT (1) - (ORIGN (1) - MIN10 (1))
        DEPRC (2) = DEPRC (1) - ((ORIGN (1) - MIN10 (1))/20.)
        OPERT (2) = OPERT (1)
        SALES (2) = SALES (1)
        CAPVT (3) = CAPVT (1) + (PLS 10 (1) - ORIGN (1))
        DEPRC (3) = DEPRC (1) + ((PLS 20 (1) - ORIGN (1))/20.)
        OPERT (3) = OPERT (1)
        SALES (3) = SALES (1)
        CAPVT (4) = CAPVT (1) + (PLS 20 (1) - ORIGN (1))
        DEPRC (4) = DEPRC (1) + ((PLS 20 (1) - ORIGN (1))/20.)
        OPERT (4) = OPERT (1)
        SALES (4) = SALES (1)
C       Change Due to Equipment: - 10 Percent Etc.
        CAPVT (5) = CAPVT (1) - (ORIGN (2) - MIN 10 (2))
```

```
      DEPRC (5) = DEPRC (1) - ((ORIGN (2) - MIN10 (2))/20.)
      OPERT (5) = OPERT (1)
      SALES (5) = SALES (1)
      CAPVT (6) = CAPVT (1) + (PLS10 (2) - ORIGN (2))
      DEPRC (6) = DEPRC (1) + ((PLS 10 (2) - ORIGN (2))/20.)
      OPERT (6) = OPERT (1)
      SALES (6) = SALES (1)
      CAPVT (7) = CAPVT (1) + (PLS20 (2) - ORIGN (2))
      DEPRC (7) = DEPRC (1) + ((PLS20 (2) - ORIGN (2))/20.)
      OPERT (7) = OPERT (1)
      SALES (7) = SALES (1)
C     Change Due to Indirect Costs: - 10 Percent Etc.
      CAPVT (8) = CAPVT (1) - ((ORIGN (3) - MIN10 (3))/3.)
      DEPRC (8) = DEPRC (1)
      OPERT (8) = OPERT (1) - (ORIGN (3) - MIN10 (3))
      SALES (8) = SALES (1)
      CAPVT (9) = CAPVT (1) + ((PLS10 (3) - ORIGN (3))/3.)
      DEPRC (9) = DEPRC (1)
      OPERT (9) = OPERT (1) + (PLS10 (3) - ORIGN (3))
      SALES (9) = SALES (1)
      CAPVT (10) = CAPVT (1) + ((PLS20 (3) - ORIGN (3))/3.)
      DEPRC (10) = DEPRC (1)
      OPERT (10) = OPERT (1) + (PLS20 (3) - ORIGN (3))
      SALES (10) = SALES (1)
C     Change Due to Operating Costs: - 10 Percent Etc.
      CAPVT (11) = CAPVT (1)
      DEPRC (11) = DEPRC (1)
      OPERT (11) = MIN10 (4)
      SALES (11) = SALES (1)
      CAPVT (12) = CAPVT (1)
      DEPRC (12) = DEPRC (1)
      OPERT (12) = PLS10 (4)
      SALES (12) = SALES (1)
      CAPVT (13) = CAPVT (1)
      DEPRC (13) = DEPRC (1)
      OPERT (13) = PLS20 (4)
      SALES (13) = SALES (1)
C     Change Due to Production:  - 10 Percent Etc.
```

```
      CAPVT (14) = CAPVT (1)
      DEPRC (14) = DEPRC (1)
      OPERT (14) = OPERT (1)
      SALES (14) = ORIGN (6) *MIN10 (5)
      CAPVT (15) = CAPVT (1)
      DEPRC (15) = DEPRC (1)
      OPERT (15) = OPERT (1)
      SALES (15) = ORIGN (6) *PLS10 (5)
      CAPVT (16) = CAPVT (1)
      DEPRC (16) = DEPRC (1)
      OPERT (16) = OPERT (1)
      SALES (16) = ORIGN (6) *PLS20 (5)
C     Change Due to Selling Price:  - 10 Percent Etc.
      CAPVT (17) = CAPVT (1)
      DEPRC (17) = DEPRC (1)
      OPERT (17) = OPERT (1)
      SALES (17) = ORIGN (5) *MIN10 (6)
      CAPVT (18) = CAPVT (1)
      DEPRC (18) = DEPRC (1)
      OPERT (18) = OPERT (1)
      SALES (18) = ORIGN (5) *PLS10 (6)
      CAPVT (19) = CAPVT (1)
      DEPRC (19) = DEPRC (1)
      OPERT (19) = OPERT (1)
      SALES (19) = ORIGN (5) *PLS20 (6)
C     Change Due to Labor:  -10 Percent Etc.
      CAPVT (20) = CAPVT (1) - ((ORIGN (7) - MIN10 (7))/4.)
      DEPRC (20) = DEPRC (1)
      OPERT (20) = OPERT (1) - (ORIGN (7) - MIN10 (7))
      SALES (20) = SALES (1)
      CAPVT (21) = CAPVT (1) + ((PLS10 (7) - ORIGN (7))/4.)
      DEPRC (21) = DEPRC (1)
      OPERT (21) = OPERT (1) + (PLS10 (7) - ORIGN (7))
      SALES (21) = SALES (1)
      CAPVT (22) = CAPVT (1) + ((PLS20 (7) - ORIGN (7))/4.)
      DEPRC (22) = DEPRC (1)
      OPERT (22) = OPERT (1) + (PLS20 (7) - ORIGN (7))
      SALES (22) = SALES (1)
```

SENSITIVITY ANALYSIS PROGRAM

```
C       Calculate the Cash Flows and ROI's
        DO 300 J=1,22
        GROSS = 0
        GROSS = SALES (J) - (OPERT (J) + DEPRC (J))
        DEPLT = SALES (J) *0.1
        TAXIN = GROSS - DEPLT
        Z = GROSS/2
        IF (DEPLT.GT.Z) GO TO 250
        GO TO 260
  250 TAXIN = GROSS/2
        DEPLT = TAXIN
  260 PROFT = TAXIN/2
C       Calculate Cash Flow
        CSH (J) = PROFT + DEPRC (J) + DEPLT
        ROI (J) = (CSH (J)/CAPVT (J)) * 100
C       Determine Percent Change In ROI
        If (ROI (J) .GE.ROI (1)) Go to 50
        CHANG (J) = ((ROI (1) - ROI (J))/ROI (1)) * 100.
        GO TO 300
   50 CHANG (J) = ((ROI (J) - ROI (1))/ROI (1)) * 100
  300 CONTINUE
        PRINT DATA
        STOP
        END



        PRINT 3, L
    3 FORMAT ('1', 'Mine', 13)
        PRINT 33
   33 FORMAT ('0', 22X, 'Original Data', 8X, '-10 Percent,' 8X,
        ' + 10 Percent', 18X, ' + 20 Percent')
        PRINT 35
   35 FORMAT (' + ', 22X,'__________', 8X, '_____________',
        8X, '_____________', 18X, '_____________')
        DO 400 I=1,7
  400 PRINT 37, ORIGN (I), MIN10 (I), PLS10 (I), PLS20 (I)
   37 FORMAT ('0', F32.6, F21.6, F19.6, F19.6)
```

SENSITIVITY ANALYSIS PROGRAM

```
      PRINT 38
   38 FORMAT ('-',33X, 'CASH FLOW', 12X, 'R.O.I.,' 9X,
      '% CHANGE ROI')
      PRINT 39
   39 FORMAT (' + ', 33X, '________', 12X, '________,'
      9X, '____________________')
      PRINT 45
   45 FORMAT ('0', 5X, 'ORIGINAL')
      PRINT 40, CSH (1), ROI (1), CHANG (1)
   40 FORMAT (' ', F40.3, F20.3, F18.3)
      PRINT, '     EQUIPMENT'
      DO 12 I=2,4
   12 PRINT 40, CSH (I), ROI (I), CHANG (I)
      PRINT, '     INDIRECT COSTS'
      DO 13 I=5,7
   13 PRINT 40, CSH (I), ROI (I), CHANG (I)
      PRINT, '     OPERATING COSTS'
      DO 14 I=8,10
   14 PRINT 40, CSH (I), ROI (I), CHANG (I)
      PRINT, '     PRODUCTION'
      DO 15 I=11,13
   15 PRINT 40, CSH (I), ROI (I), CHANG (I)
      PRINT,'      SELLING PRICE
      DO 16 I=14,16
   16 PRINT 40, CSH (I), ROI (I), CHANG (I)
      PRINT, '     LABOR'
      DO 17 I=17,19
   17 PRINT 40, CSH (I), ROI (I), CHANG (I)
      GO TO 150
  450 PRINT, 'THE END'
      STOP
      END
```

SIMULATION OUTPUT - MINE NO. 4E

SHIFT 1 REPORT

SHIFT TIME = 360.00 MINUTE
TIME INCREMENT = 5.00 SECONDS

TRUCK PRODUCTION STATISTICS

ASSIGNED ORE BODY	TRUCK NUMBER	TRUCK TYPE	CAPACITY (TON)	LOADS ORE	LOADS WASTE	TONS ORE	TONS WASTE	TONS TAILING
14 Cu. Yd. DRAG 1- 1	1		50000.	0	0	0.0	0.0	0.0
BENCH TOTAL						0.0	0.0	0.0
10 Cu. Yd. F.E.L. 1- 2	2		54.	10	0	510.3	0.0	0.0
1- 2	3		54.	9	0	510.3	0.0	0.0
1- 2	4		54.	9	0	510.3	0.0	0.0
BENCH TOTAL						1530.9	0.0	0.0
SUBTOTAL PIT NO.1						1530.9	0.0	0.0
21 Cu. Yd. DRAG 2- 1	1		50000.	0	0	0.0	0.0	0.0
BENCH TOTAL						0.0	0.0	0.0
10 Cu. Yd. F.E.L. 2- 2	2		54.	12	0	623.7	0.0	0.0
2- 2	3		54.	11	0	623.7	0.0	0.0
2- 2	4		54.	11	0	623.7	0.0	0.0
BENCH TOTAL						1871.1	0.0	0.0
SUBTOTAL PIT NO.3						1871.1	0.0	0.0
8 Cu.Yd. DRAG 3- 1	1		50000.	0	0	0.0	0.0	0.0
BENCH TOTAL						0.0	0.0	0.0
DOZERS 3- 2	2		50000.	0	0	0.0	0.0	0.0
BENCH TOTAL						0.0	0.0	0.0
7 Cu.Yd. SHOVEL 3- 3	3		54.	6	0	343.2	0.0	0.0
3- 3	4		54.	6	0	343.2	0.0	0.0
3- 3	5		54.	6	0	343.2	0.0	0.0
3- 3	6		54.	6	0	286.0	0.0	0.0
BENCH TOTAL						1315.6	0.0	0.0
7 Cu.Yd. F.E.L. 3- 4	7		54.	6	0	343.2	0.0	0.0
3- 4	8		54.	6	0	343.2	0.0	0.0
3- 4	9		54.	6	0	343.2	0.0	0.0
3- 4	10		54.	6	0	286.0	0.0	0.0
BENCH TOTAL						1315.6	0.0	0.0
SUBTOTAL PIT NO. 2						2631.2	0.0	0.0
TOTAL PRODUCTION IN THE WHOLE SYSTEM						6033.2	0.0	0.0

TRUCK PERFORMANCE STATISTICS IN MINUTES

615

ASSIGNED ORE BODY	TRUCK NMBR	WAIT IN LINE	TIME TO LOAD	WAIT AT MILL IN LINE	TIME TO LOAD AT MILL	WAIT FOR DUMP-ORE	WAIT FOR DUMP-WST	TRAVEL LOADED	TRAVEL EMPTY
1 - 1	1	0.0	360.08	0.0	0.0	0.0	0.0	0.0	0.0
BENCH TOTAL		0.0	360.08	0.0	0.0	0.0	0.0		
1 - 2	2	0.0	92.83	0.0	0.0	0.0	0.0	13.50	13.50
1 - 2	3	10.58	84.67	0.0	0.0	0.0	0.0	13.50	13.50
1 - 2	4	21.83	81.67	0.0	0.0	0.0	0.0	13.50	13.50
BENCH TOTAL		32.42	259.17	0.0	0.0	0.0	0.0		
SUBTOTAL		32.42	619.25	0.0	0.0	0.0	0.0		
HRS/HR/TRUCK		0.0225	0.4300	0.0	0.0	0.0	0.0		
2 - 1	1	0.0	360.08	0.0	0.0	0.0	0.0	0.0	0.0
BENCH TOTAL		0.0	360.08	0.0	0.0	0.0	0.0		
2 - 2	2	8.25	112.67	0.0	0.0	0.0	0.0	9.25	9.17
2 - 2	3	16.58	114.42	0.0	0.0	0.0	0.0	9.25	9.17
2 - 2	4	27.17	104.67	0.0	0.0	0.0	0.0	9.25	9.17
BENCH TOTAL		52.00	331.75	0.0	0.0	0.0	0.0		
SUBTOTAL		52.00	691.83	0.0	0.0	0.0	0.0		
HRS/HR/TRUCK		0.0361	0.4804	0.0	0.0	0.0	0.0		
3 - 1	1	0.0	360.08	0.0	0.0	0.0	0.0	0.0	0.0
BENCH TOTAL		0.0	360.08	0.0	0.0	0.0	0.0		
3 - 2	2	0.0	360.08	0.0	0.0	0.0	0.0	0.0	0.0
BENCH TOTAL		0.0	360.08	0.0	0.0	0.0	0.0		
3 - 3	3	37.67	93.58	0.0	0.0	0.0	0.0	17.67	18.00
3 - 3	4	45.83	86.25	0.0	0.0	0.0	0.0	17.67	18.00
3 - 3	5	63.75	91.92	0.0	0.0	0.0	0.0	17.67	18.00
3 - 3	6	79.67	79.00	0.0	0.0	0.0	0.0	17.67	18.00
BENCH TOTAL		226.92	340.75	0.0	0.0	0.0	0.0		
3 - 4	7	44.08	87.17	0.0	0.0	0.0	0.0	17.67	18.00
3 - 4	8	48.83	86.00	0.0	0.0	0.0	0.0	17.67	18.00
3 - 4	9	64.42	85.42	0.0	0.0	0.0	0.0	17.67	18.00
3 - 4	10	81.92	82.17	0.0	0.0	0.0	0.0	17.67	18.00
BENCH TOTAL		239.25	340.75	0.0	0.0	0.0	0.0		
SUBTOTAL		466.17	1401.67	0.0	0.0	0.0	0.0		
HRS/HR/TRUCK		0.1295	0.3894	0.0	0.0	0.0	0.0		

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LOADER OUTPUT STATISTICS

ORE BODY 1 = PIT NO.1

LOADER NUMBER 1 14 Cu. Yd. DRAG LINE

MEAN CYCLE TIME = 95.0 SEC
DEV. CYCLE TIME = 60.0 SEC
MAX. CYCLE TIME = 180.0 SEC
MIN. CYCLE TIME = 45.0 SEC
CAPACITY OF BUCKET = 14.2 TONS

PRODUCTION STUDY

ORE EXCAVATED	0.0 TONS
WASTE EXCAVATED	2740.59 TONS
ACTUAL CAPACITY	457.19 TONS PER HOUR

TIME STUDY

CUT (MINUTES)	TRAM (MINUTES)	DELAY(WAITING) (MINUTES)	DELAY(MECH.) (MINUTES)	DELAY(OTHER) (MINUTES)
359.67	0.0	0.0	0.0	0.0

LOADER NUMBER 2 10 Cu. Yd. FRONT END LOADER

MEAN CYCLE TIME = 60.0 SEC
DEV. CYCLE TIME = 24.0 SEC
MAX. CYCLE TIME = 75.0 SEC
MIN. CYCLE TIME = 45.0 SEC
CAPACITY OF BUCKET = 6.3 TONS

PRODUCTION STUDY

ORE EXCAVATED	1600.16 TONS
WASTE EXCAVATED	0.0 TONS
ACTUAL CAPACITY	336.19 TONS PER HOUR

TIME STUDY

CUT (MINUTES)	TRAM (MINUTES)	DELAY(WAITING) (MINUTES)	DELAY(MECH.) (MINUTES)	DELAY(OTHER) (MINUTES)
285.58	0.0	74.00	0.0	0.0

ORE BODY 2 = PIT NO. 3

LOADER NUMBER 1 21 Cu. Yd. DRAG LINE

MEAN CYCLE TIME = 95.0 SEC
DEV. CYCLE TIME = 60.0 SEC
MAX. CYCLE TIME = 180.0 SEC
MIN. CYCLE TIME = 45.0 SEC
CAPACITY OF BUCKET = 21.3 TONS

PRODUCTION STUDY

ORE EXCAVATED	0.0 TONS
WASTE EXCAVATED	3961.77 TONS
ACTUAL CAPACITY	660.75 TONS PER HOUR

TIME STUDY

CUT (MINUTES)	TRAN (MINUTES)	DELAY(WAITING) (MINUTES)	DELAY(MECH.) (MINUTES)	DELAY(OTHER) (MINUTES)
359.75	0.0	0.0	0.0	0.0

LOADER NUMBER 2 10 Cu. Yd. FRONT END LOADER

MEAN CYCLE TIME = 60.0 SEC
DEV. CYCLE TIME = 24.0 SEC
MAX. CYCLE TIME = 75.0 SEC
MIN. CYCLE TIME = 45.0 SEC
CAPACITY OF BUCKET = 6.3 TONS

PRODUCTION STUDY

ORE EXCAVATED	1978.15 TONS
WASTE EXCAVATED	0.0 TONS
ACTUAL CAPACITY	330.61 TONS PER HOUR

TIME STUDY

CUT (MINUTES)	TRAN (MINUTES)	DELAY(WAITING) (MINUTES)	DELAY(MECH.) (MINUTES)	DELAY(OTHER) (MINUTES)
359.92	0.0	0.25	0.08	0.0

ORE BODY 3 = PIT NO. 2

LOADER NUMBER 1 8 Cu. Yd. DRAG LINE

MEAN CYCLE TIME = 35.0 SEC
DEV. CYCLE TIME = 7.0 SEC
MAX. CYCLE TIME = 55.0 SEC
MIN. CYCLE TIME = 25.0 SEC
CAPACITY OF BUCKET = 8.1 TONS

PRODUCTION STUDY

ORE EXCAVATED	0.0 TONS
WASTE EXCAVATED	4017.53 TONS
ACTUAL CAPACITY	670.21 TONS PER HOUR

TIME STUDY

CUT (MINUTES)	TRAN (MINUTES)	DELAY(WAITING) (MINUTES)	DELAY(MECH.) (MINUTES)	DELAY(OTHER) (MINUTES)
359.67	0.0	0.0	0.0	0.0

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LOADER NUMBER 2 **DOZERS**

MEAN CYCLE TIME = 60.0 SEC
DEV. CYCLE TIME = 40.0 SEC
MAX. CYCLE TIME = 150.0 SEC
MIN. CYCLE TIME = 50.0 SEC
CAPACITY OF BUCKET = 18.0 TONS

PRODUCTION STUDY

ORE EXCAVATED	0.0	TONS
WASTE EXCAVATED	4284.00	TONS
ACTUAL CAPACITY	714.66	TONS PER HOUR

TIME STUDY

CUT (MINUTES)	TRAM (MINUTES)	DELAY(WAITING) (MINUTES)	DELAY(MECH.) (MINUTES)	DELAY(OTHER) (MINUTES)
359.67	0.0	0.0	0.0	0.0

LOADER NUMBER 3 **7 Cu. Yd. SHOVEL**

MEAN CYCLE TIME = 60.0 SEC
DEV. CYCLE TIME = 20.0 SEC
MAX. CYCLE TIME = 90.0 SEC
MIN. CYCLE TIME = 30.0 SEC
CAPACITY OF BUCKET = 4.4 TONS

PRODUCTION STUDY

ORE EXCAVATED	1407.97	TONS
WASTE EXCAVATED	0.0	TONS
ACTUAL CAPACITY	235.26	TONS PER HOUR

TIME STUDY

CUT (MINUTES)	TRAM (MINUTES)	DELAY(WAITING) (MINUTES)	DELAY(MECH.) (MINUTES)	DELAY(OTHER) (MINUTES)
359.08	0.0	0.58	0.0	0.0

LOADER NUMBER 4 **7 Cu.Yd. FRONT END LOADER**

MEAN CYCLE TIME = 60.0 SEC
DEV. CYCLE TIME = 24.0 SEC
MAX. CYCLE TIME = 75.0 SEC
MIN. CYCLE TIME = 45.0 SEC
CAPACITY OF BUCKET = 4.4 TONS

PRODUCTION STUDY

ORE EXCAVATED	1390.37	TONS
WASTE EXCAVATED	0.0	TONS
ACTUAL CAPACITY	232.27	TONS PER HOUR

TIME STUDY

CUT (MINUTES)	TRAM (MINUTES)	DELAY(WAITING) (MINUTES)	DELAY(MECH.) (MINUTES)	DELAY(OTHER) (MINUTES)
359.17	0.0	0.0	0.17	0.0

FACE EXCAVATOR SUMMARY

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		PRODUCTION (TONS) ORE	WASTE	LOADING (MINUTES)	WAITING (MINUTES)	
ORE BODY 1						
BENCH 1	14 Cu. Yd. DRAG	0.0	2740.6	359.67	0.0	PIT NO. 1
BENCH 2	10 Cu. Yd. F.E.L.	1600.2	0.0	285.58	74.00	PIT NO. 1
SUBTOTAL		1600.2	2740.6	645.25	74.00	PIT NO. 1
ORE BODY 2						
BENCH 1	21 Cu. Yd. DRAG	0.0	3961.8	359.75	0.0	PIT NO. 3
BENCH 2	10 Cu. Yd. F.E.L.	1978.1	0.0	359.00	0.25	PIT NO. 3
SUBTOTAL		1978.1	3961.8	718.75	0.25	PIT NO. 3
ORE BODY 3						
BENCH 1	8 Cu. Yd. DRAG	0.0	4017.5	359.67	0.0	PIT NO. 2
BENCH 2	DOZERS	0.0	4284.0	359.67	0.0	PIT NO. 2
BENCH 3	7 Cu. Yd. SHOVEL	1408.0	0.0	359.08	0.58	PIT NO. 2
BENCH 4	7 Cu. Yd. F.E.L.	1390.4	0.0	359.17	0.0	PIT NO. 2
SUBTOTAL		2798.3	8301.5	1437.58	0.58	PIT NO. 2
GRAND TOTAL		6376.7	15003.9	2801.58	74.83	
STATISTICS-TONS/HR/B, HRS/HR/B		132.85	312.58	0.9728	0.0260	