173
4-20-81

(2)

Dr. 2557

FE-9120-T1

Sent out-118
NTIS- 25

UNDERSPOIL HAULAGE OF SURFACE MINED COAL

MASTER

Final Technical Report
Contractor—Dravo Corporation

February 1, 1980

Contract No. U.S.D.O.E. ET-76-C-01-9120
(formerly U.S.B.M. J0265056)

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

DISCLAIMER

Available from the National Technical Information Service, U. S. Department of Commerce, Springfield, Virginia 22161.

Price: Printed Copy A13
Microfiche A01

FE-9120-T1
Distribution Category UC-88

UNDERSPOIL HAULAGE OF SURFACE MINED COAL

Final Technical Report

Dravo Corporation

February 1, 1980

Contract No. U.S.D.O.E. ET-76-C-01-9120
(formerly U.S.B.M. J0265056)

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

TABLE OF CONTENTS

TABLE OF CONTENTS (cont)

TABLE OF CONTENTS (cont)

TABLE OF CONTENTS (cont)

TABLE OF CONTENTS (cont)

TABLE OF CONTENTS (cont)

LIST OF APPENDICES

LIST OF FIGURES

LIST OF FIGURES (cont)

LIST OF FIGURES (cont)

LIST OF TABLES

1. ABSTRACT

Underspoil haulage is defined as the transport of coal from the pit bottom by conveyor through a tunnel maintained under the spoil piles.

The main objective in promoting this study was to test, through engineering and economic analysis, the feasibility of constructing and operating this belt conveyor underspoil haulage system. Other continuous coal transporting concepts were also to be proposed to supplement underspoil haulage systems and to provide technical and economic comparisons to underspoil systems.

Four underspoil haulage systems for underspoil haulage of coal from a model strip mine were investigated and compared to more conventional truck haulage. Underspoil haulage showed itself to be economically favorable for coal thicknesses greater than 40 feet buried under 100 feet or more of overburden and mined at five million tons or more per year.

Secondary studies showed that several other continuous haulage methods are potential as alternatives to underspoil haulage or may be operable under criteria that are impractical for underspoil.

2. EXECUTIVE SUMMARY

Energy is the key word of the times. All civilizations are utterly dependent on usable energy in one form or another. The higher the degree of civilization or life quality, the higher the energy dependence. Present industrial and living requirements demand energy in concentrated form, produced at low cost, and environmentally clean. Coal is one of the most concentrated forms of energy while at the same time one of the most abundant. Discovering coal deposits is not the problem that discovering uranium and petroleum is. Converting the coal to usable energy presents no technological problems. Coal's production and utilization is primarily a matter of economics and economic decision making. The thrust of this study is, therefore, primarily oriented toward the economics of transporting surface mined coal from the pit.

2.1 Project Background and Purpose

Belt conveyor systems have long been available to transport bulk materials with a very high degree of efficiency. This efficiency is not only manifest in economic saving, but is also evident in energy utilization and conservation. Energy consumed in conveyor coal transport is generally coal generated electricity in contrast to scarce petroleum utilized by truck or other wheeled haulers.

Surface overland conveyors are commonly used for permanent or semi-permanent open-pit mining installations. These systems generally do not bring the coal or other minerals from the pit floor, but, rather receive their load from trucks outside the pit. Underspoil haulage is an attempt to bring the conveyors to the bottom of the pit in both strip and open-pit mines thereby gain the efficiency of conveyor transport for the maximum distance.

Underspoil haulage is defined as the transport of coal from the pit bottom, by conveyor, through a tunnel maintained under the spoil piles. These tunnels will remain in use through the reclamation of the mined lands without interference.

The concept of underspoil coal haulage was first proposed, for study, by the United Stated Department of Interior, Bureau of Mines in 1975. This study was performed by Dravo Corporation for the Bureau of Mines under Contract Number J0155151 and titled "Preliminary Engineering And Economic Evaluation of Underspoil Haulage In Area Strip Coal Mines". It was known as "Part I". Part II continues the investigation of this concept into three more phases. The U.S. Bureau of Mines initiated Phase I of Part II in 1976 to make a detailed feasibility study comparing underspoil haulage to truck haulage using a typical strip mining situation as a model. Phase II was intended to be an effort for locating a site-specific for a field trial of the underspoil concept as outlined in Phase I. Phase III would be the actual site-specific design, construction and test of the system. Part II was begun under the Bureau of Mines under Contract Number J0265056 in 1976, then with the creation of the U. S. Department of Energy, the project was removed from the Bureau of

Mines and transferred to the Department of Energy. Phase I of Part II was completed under the Bureau of Mines in February of 1977. Phase II of Part II was started in September of 1978 under the Department of Energy as Contract Number ET-76-C-01-9102. Phase III of Part II will not begin until a site is located for an actual system installation.

This report covers all investigations performed under both Phase I and Phase II of Part II. Phase II canvassing efforts did not produce a satisfactory field demonstration site as outlined by Phase I, consequently, the Department of Energy redirected the Phase II efforts to the goal of broadening the applicability of not only underspoil haulage concepts but also investigating other out-of-pit coal haulage systems. While a site for a field demonstration as outlined by the Phase I work was not located, two of the largest coal mining operations in the Powder River Basin did provide mining plans and criteria upon which modifications or innovations might be applied to the outlined system thereby producing broadened applications. Those companies are: AMAX Coal Company (Belle Ayre Mine) and ARCO Coal Company (Coal Creek Mine).

2.2 Project Summary

Both Phase I and Phase II have been incorporated into this final report. Should a Phase III be developed, it will subsequently produce it's own report.

2.2.1 Phase I

Underspoil coal haulage involves transporting coal by belt conveyors installed in tunnel structures buried by the advancing spoil piles produced during the strip mining of coal. These installations allow conveyor coal haulage from the pit floor without interference with mining and reclamation activities.

Four mining systems with three variations were developed as part of Phase I and a fifth system was developed during the site studies of Phase II. These systems were based on mining situations as they are found in the Powder River Basin of Wyoming and Montana. To provide a basis for the feasibility studies, six mine model situations were promulgated as they might occur in the Powder River Basin under two different coal thicknesses and three different overburden depths. The basic mine plan assumed for the comparison of underspoil haulage with conventional truck haulage is typical for the area.

Tunnel support under the heavy loading of loose spoil material involved highly detailed analysis and engineering. Three structure alternatives are proposed. Precast reinforced, concrete arches on cast-in-place concrete inverts, structural plate culvert with concrete invert; and steel arch/ liner plate installed on concrete invert slabs.

Detailed analysis of mining operations was made to insure that the underspoil system would not create inefficiencies in operation. Alternatives to underspoil haulage were analyzed also for comparison purposes. Total direct mining costs per ton of coal produced were determined for each of the four four original systems and their variations. Added to these costs for comparison purposes were System Five from Phase II and a thruspoil system detailed as an alternative. Each of these systems were analyzed under the two conditions of coal thickness and the three conditions of overburden depth.

The underspoil haulage mining system, designated "System No. 2", has been identified in this study to have an economic advantage over conventional shovel loading and truck haulage of coal for overburden depths of 100 to 200 feet, coal thickness of 30 to 70 feet, and mine production rates of 5 million tons or greater per year. As much as 8 percent reduction in direct mining costs per ton of coal can be achieved at the greater overburden depths and coal thicknesses. System No. 2 consists of dragline stripping, front-end loaders, extendible pit conveyors and underspoil conveyor for transport of coal from the pit bottom.

Extensive canvassing of mine companies was conducted in order to acquaint the surface mining community with underspoil haulage systems and advantages and to locate a mine willing to cooperate in a demonstration of the system. Twenty-four mines were contacted from among some seventy-nine possibilities. Of these, six expressed interest and three, Amax, Utah International Company, and Arco Coal Company examined in detail both System No.2 and adaptations generated to satisfy site-specific requirements of their condidate mines. All three of these companies decided against the underspoil haulage system and declined to participate in a demonstration program.

The principal reasons given for decisions against underspoint haulage and failure to locate a mine willing to participate in a demonstration program are:

1. High Capital Investment. Economic savings were considered to be insufficient to justify the high capital investment.

2. Inflexibility. The underspoil haulage system is considered to be a fixed installation and less flexible than a truck haulage system.

3. Multiple Seam Mining Incompatibility. Use of underspoil haulage with multiple seam mining presents a technical problem. An underspoil tunnel below the pit level might solve this problem.

4. Increased Regulations. The underspoil tunnel is similar to and underground coal mine slope and will be subject to the same regulations as an underground mine.

5. Unproved Technology. Underspoil Haulage is new, unproven, and is risky.

Underspoil conveyor haulage of coal from strip and open-pit mines is feasible with economic, operational, reclamation, and enviornmental advantages for thick seams, deep overburden, and high production rates. Economic advantages increase as thicknesses, depths, and production rates become greater than those studied under this contract. These increasing economic advantages coupled with less tangible ones such as less petroleum dependence, lower manpower requirements, and reduced dust and noise pollution, makes underspoil haulage a strong contender in the future selection of haulage systems for carrying coal from strip and open-pit mines.

2.2.2 Phase II

Phase II work consisted of developing a "Field Demonstration Plan". Using this plan, area strip coal mines were canvassed to discover interest in an installation of an in-mine prototype. Canvassing did not produce a site suitable for the test installation as it was outlined. However, one of the major Powder River Basin producers was interested in an adaptation of the underspoil concept to its mining plan for future development. This adaptation resulted in the development of System Five.

The Department of Energy requested that Dravo investigate other coal related and coal handling concepts as a supplement to the Underspoil Studies. Six underspoil related subjects were investigated: New BLM Coal Leasing Program; Comparison of Manpower Requirements; Comparison of Energy Consumptions; In-Pit Coal Haulage Systems; Dumping Ramp for Trucks; and Coal Elevating Systems and are dealt with in Section 3.3.

Reasons other than economics will probably prevail in the choosing between underspoil haulage and conventional truck haulage systems. Future conditions of labor and energy costs will certainly favor the belt conveying of coal, while current operations often favor continuation of truck haulage systems. Efficiencies and economics achievable with well planned conveyor systems can also be achieved with design alternatives to underspoil haulage that do not incur the expense of tunnel construction. Reclamation of mined land is another area where the positive advantages of underspoil haulage stand out.

Underspoil haulage of coal from strip and open-pit mines is feasible with economic, operational, and aesthetic advantages for seams thicker than 30 feet and overburden deeper than 50 feet on a five million ton per year basis. Greater production rates will further improve the economic advantages. Other less tangible advantages will be experienced in lower manpower requirements and petroleum dependence. Environmental considerations will also favor conveyor haulage and its limited dust and noise pollution.

It is the opinion of the author that several additional engineering studies should be considred that might produce valuable improvements in efficiencies in coal production. These recommendations all involve coal transportation along the pit floor and elevating it out of the pit. 1) Trackless trains offer the opportunity to combine semi-continuous in-pit coal haulage with continuous elevation and haulage out of the pit. 2) Advancing catenary conveyors would produce a method for advancing cable suspended belts in a thruspoil system as the trench is backfilled and reclaimed. 3) Portable Modular Conveyors, that can step-up benches, provide a possible method for elevating coal up a high wall with great flexability. 4) Bucket Elevator could be designed to raise the coal from a pit floor up an end high wall with no interference to spoiling and spoil reclamation. It might also follow a continuous coal loading unit such as a bucket wheel excavator and eliminate in-pit coal haulage.

3. UNDERSPOIL HAULAGE STUDIES

3.1 Phase I - Engineering and Economic Evaluation of Underspoil Haulage

3.1.1 Introduction

Underspoil Haulage is a term applied to transportation of coal from the pit to the surface in strip coal mines by belt conveyors through tunnels under the spoil piles. Transporting coal by conveyors is a well established technology. The extension of this haulage to the coal face in surface mines is a logical improvement in overall mine efficiency. Raising the coal up out of the pit is the major problem in a belt conveyor system for surface coal mining. The underspoil haulage approach avoids the steep inclines and the interference with mining and reclamation by burying the conveyor in a gently inclined accessible tunnel.

To evaluate the potential advantages of underspoil haulage conventional coal haulage by trucks was used for a basis for comparison. This system is designated as System No. 1.

Current reclamation requirements in most states emphasize close follow-up behind the mine advance. In Montana, for example, no more than two spoil ridges are permitted and truck ramps must be advanced at least once each year, necessitating major fill and road reconstruction work. Disposal of the spoil adjacent to the ramps by dragline is a problem. The rehandling of this material where ramps intersect the pit represents a substantial cost, especially when overburden depths exceed 100 feet. Where overburden is spoiled by truck, the long coal haulage ramps increase the haul distance around the pit substantially. Considering the costs and interference associated with overburden disposal and reclamation in conjunction with truck haulage, any system which eliminates ramps warrants investigation.

Underspoil haulage is a promising alternative to conventional haulage. The advantages of belt conveyors over trucks include lower manpower requirements, reduced congestion with increased pit safety and efficiency, and less extensive maintenance facilities. The potential of the underspoil conveyor concept lies in achieving these advantages without sacrificing the reliability and flexibility inherent in truck haulage.

Four mining systems with three variations were originally developed for economic comparison. System No. 5 was added later to broaden the applicability of the concept. Three different overburden and two different coal thickness were applied to each system to produce standarized mining models for a variety of situations. This report also summarizes cost trade designs as well as thruspoil haulage alternatives.

The mining systems evaluated are:

1. System No. 1 Conventional shovel loading and truck haulage. (Dragline Stripping)

2. System No. 2 — Front-end loaders, extendible pit conveyors, and underspoil coal haulage. (Dragline Stripping)

3. System No. 2A — Front-end loaders tramming coal to underspoil haulage system. (Dragline Stripping)

4. System No. 3 — Front-end loaders, shiftable pit conveyors, and underspoil haulage system. (Shovel Stripping)

5. System No. 3A — Front-end loaders, shiftable pit conveyors, and underspoil haulage system. (Dragline Stripping)

6. System No. 4 — Bucket wheel excavator loading, shiftable pit conveyors, and underspoil haulage system. (Shovel Stripping)

7. System No. 4A — Bucket wheel excavator, shiftable pit conveyors, and underspoil haulage system. (Dragline Stripping)

8. System No. 5 — Conventional shovel loading, truck haulage to a single underspoil conveyor. (Truck and Shovel Stripping)

Overburden depths of 50 feet, 100 feet, and 200 feet were investigated. Single coal seam thicknesses of both 30 feet and 70 feet were considered for each overburden depth.

Unit operations evaluated are: (1) topsoil removal, (2) overburden drilling and blasting, (3) overburden removal, (4) coal drilling and blasting, (5) coal loading, (6) coal haulage, (7) miscellaneous in-pit operations, and (8) spoil reclamation.

An evaluation of culvert/conveyor systems for use in 5 and 6-foot thick coal seams covered by 60-100 feet of overburden was also made. Both single and multiple coal seams were considered.

Several trade-off analyses were made. These include:

1. Coal haulage through the spoil rills by conveyors up ramps (both parallel and perpendicular to pit advance) and then hauled on top of spoil. This system is called "thruspoil" haulage.

2. Coal haulage over the spoil bank by steep elevating conveyors.

3. Underspoil tunnels driven in rock and covered trenches excavated below the pit floor to reduce structural loads. The term "tunnel" in this report applies to all underground conveyor conduits unless referred to as a bored or driven tunnel.

3.1.1.1 Feasibility Study Criteria

Design criteria used in this feasibility study are based on the contract requirements and on criteria previously established in the Preliminary Study. Mine site location and conditions were assumed in order to permit engineering and cost estimating to be consistent in evaluation of the various systems. The following criteria apply generally to all systems:

1. Mine Site. Powder River Basin of southeast Montana or northeast Wyoming.

2. Mine Type and Size. Area strip coal mine producing 5 million tons per year. The mine pit will be 2 miles long and the width at the bottom 100 feet plus extra width for a transverse pit conveyor, if required.

3. Overburden. Total of 50, 100, and 200 feet consisting of sedimentary rock overlain by 20 feet of unconsolidated overburden.

4. Coal. Single near-horizontal seam with recoverable thicknesses of 30 and 70 feet.

5. Underlying Geology. Sedimentary rock with one foot of fire clay at bottom of coal seam.

6. Water. Ground water table at or below coal seam with surface water limited to storm run-off.

7. Reclamation. Requirements corresponding generally to those currently in effect in Montana and Wyoming.

Cost criteria established for this feasibility study are generally consistent with those in the Preliminary Study and reflect the assumptions described in the foregoing section. The following cost criteria apply to all systems.

1. Basis. All costs are end-of-1976 dollars.

2. Capital Costs. All engineering, mine development, and construction costs including major equipment and site facilities necessary to begin full-scale coal production are included in initial capital costs. Operating rates for equipment include depreciation to cover initial and replacement costs.

3. Operating Costs. The cost of all unit operations and related expense which constitute the total mine operation.

4. Method of Development. All earthwork including first box cut and road ramps or underspoil tunnel trenches performed by mine forces and equipment at cost.

5. Initial Construction. All civil, architectural, mechanical, and electrical construction performed under separate design-construct contract.

3.1.1.2 Feasibility Study Procedure

The limitations on available data necessarily effect the accuracy of the engineering and cost estimates. Considering the general nature of this study and its purpose for feasibility evaluation, efforts were concentrated on developing comparative costs which are representative rather than site-specific. A level of accuracy was maintained which reflects cost differences betweeen the various systems with sufficient accuracy to assure valid comparsions. This was done by the consistent use of identical input data from system to system wherever appropriate. Thus relative rather than absolute values are emphasized. The cost differences which indicate economic advantages and disadvantages are considered to be well within the 30% ± criteria established by the contract for preliminary capital and operating costs.

An essential phase of the detailed feasibility study was developed of background information. The primary sources of this information were mine visits, product research, and reviews of the Preliminary Study and current literature. Coal mining companies and manufacturers of equipment and tunnel support systems have been very helpful in providing practical advice, engineering data, and cost estimates. With the background information in hand and detailed procedure established, the work proceeded as a logical continuation of the Preliminary Study.

Seventeen coal mines were visited in Montana, Wyoming and Colorado during October and November 1976. Operations involved both single and multiple coal seams. Overburden stripping equipment included scrapers, shovels, and draglines. Coal loading equipment included shovels, front-end loaders, and one bucket wheel excavator. Two Arizona copper mines were visited to inspect large shiftable and extendible conveyors. A visit was made to one Wyoming uranium mine where several types of excavation equipment are in use.

Product research centered on belt conveyors including shiftable, extendible, and steep-slope types and on tunnel support systems. In addition, specifications and costs for all equipment required for the various cost estimates were reviewed with manufactures. Some twenty different sizes of excavation equipment are involved in the various combinations of overburden depth, coal thickness, and pit geometry required for specific conveyor arrangements.

A continuing review of current mining technology and requirements for safety, reclamation, and resource utilization are essential in developing new mining methods. The underspoil haulage concepts developed in the Preliminary Study were examined in light of the newest technology and regulations so that modifications could be made where appropriate.

Conventional design methods were used, consistent with the requirements for feasibility evaluation of a relatively complex combination of variables. This type of study does not lend itself to extensive computer application as most calculations are not repetitive. However, computer programs were used to advantage in the structural analysis of concrete tunnel arches and in the component selection and power requirements for the conveyor systems. Computer optimization of design variables was not considered justified in view of the limited amount and accuracy of input data available for a general study of this type.

3.1.2 Conceptual Design

3.1.2.1 General Idea

The choice of the Powder River Basin area as a hypothetical site for this study does not restrict its application to that region. However, the conditions prevailing there favor underspoil haulage, and the potential for near future surface coal mining probably matches that of any similar area in the United States (see Figure 1).

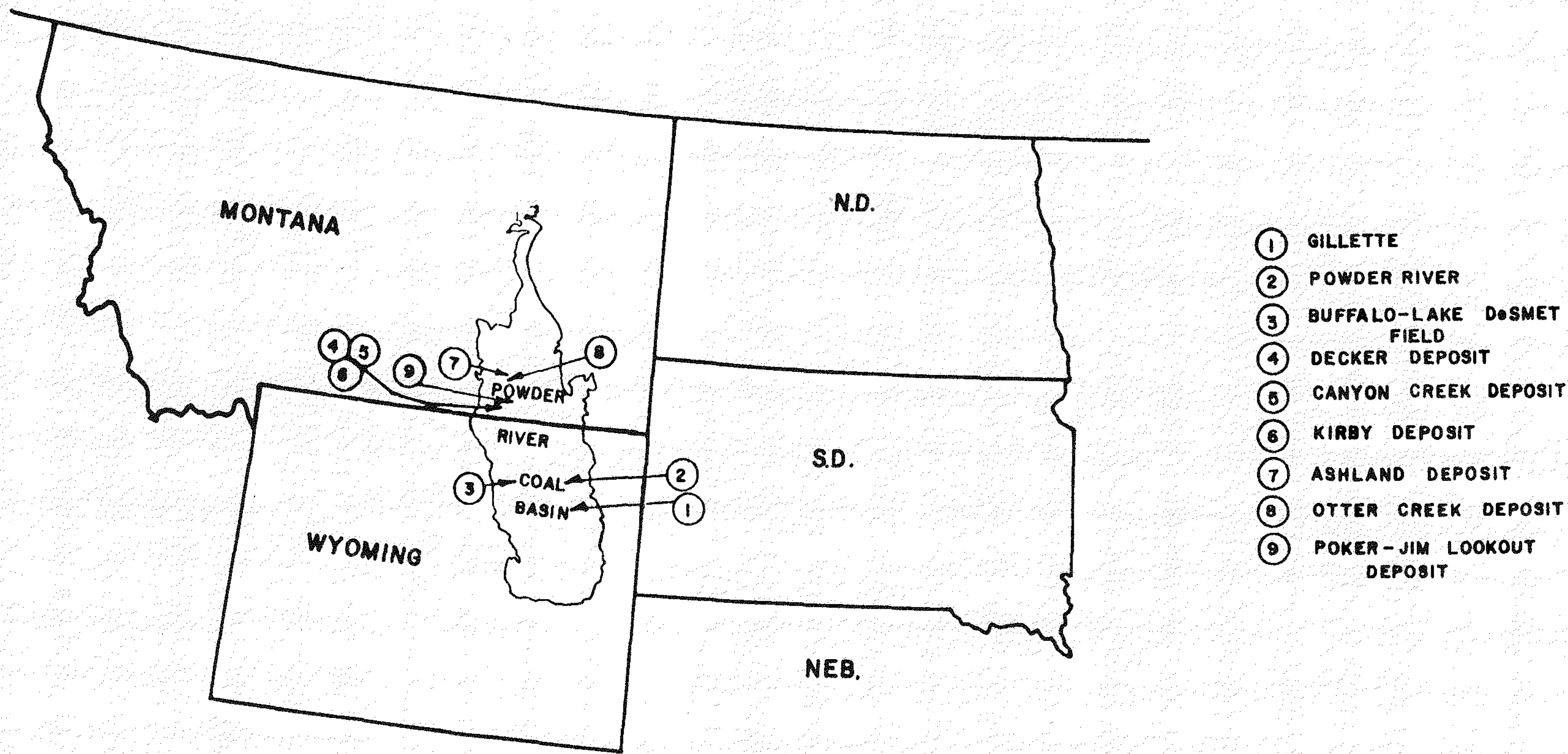
Conditions and mining methods assumed for study purposes are based on recent observations of major active mines in Montana and Wyoming as well as other United States coal fields. The study is considered applicable wherever similar conditions of overburden and coal are encountered.

3.1.2.2 Mine Layout

The basic mine plan assumed for the comparison of underspoil haulage with conventional haulage in the Preliminary Study has not changed. It consists of an area strip mine from which the coal is removed by excavating a sequence of parallel cuts. Each cut is approximately 2 miles long, corresponding to a lease holding which is two sections wide. The extent of the coal deposit normal to the pit is assumed adequate for a 20-year mine life at full production tonnage of 5 million tons per year. This dimension is 1.49 miles for 30 feet of recoverable coal and 0.64 miles for 70 feet of recoverable coal.

The pit is assumed straight for simplicity of analysis and consistency with complete mining of the rectangular block. Frequently, layout is dictated by topography, geology, or property considerations. As noted in the description of each underspoil system, certain pit conveyor arrangements lend themselves to a curved pit layout while others do not. If mine site conditions preclude a straight pit, this consideration becomes important.

Each cut is assumed to be 100 feet wide, a typical width in operations similar to those in this study. Actual pit width at the base of the coal



GEOGRAPHIC-GEOLOGIC LOCATION MAP

Figure 1

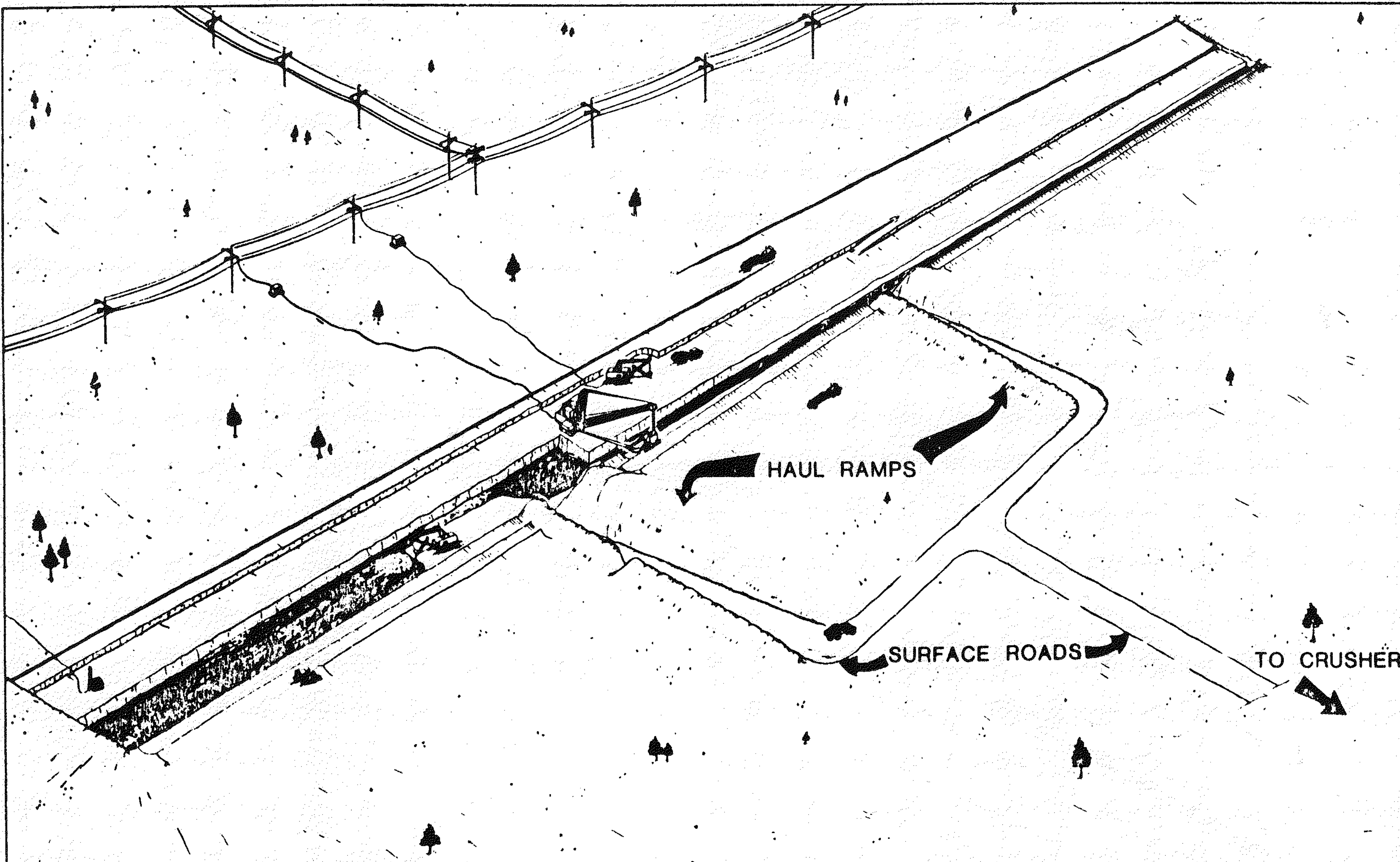
seam is thus 100 feet if additional space for pit conveyors is not required. This condition is typical for conventional truck haulage as maximum dragline stripping is realized when the turnover cut is cast to toe out against the base of the highwall. Relatively shallow overburden can be handled entirely by dragline, exposing successive 100-foot wide strips of coal and dumping the spoil in the previously mined-out cut. Where either overburden depth or required conveyor space prevents complete dragline turnover without rehandling, the study provides for bench excavation of the excess overburden by truck and shovel. Excavation operations are described in detail in Section 3.1.3, Mine Development and Operation.

The mine layout for conventional truck coal haulage, designated System No. 1, is shown in Figure 2. Two truck ramps enter the 2-mile long pit at equally spaced points to minimize total haul distance. This spacing of 2/3 mile is somewhat wider than the average observed in current mining operations of this type. The limitation to two ramps is based on the assumption that reclamation requirements necessitate advancing the ramps each year. The substantial cost of this filling, grading, and surfacing operation is thus minimized by wider spacing and fewer ramps. The ramps are sloped at 7%, a typical practice in the industry, and the minimum allowed by law in Montana. The surface roads leading to the storage area remain unchanged throughout the mine life.

The underspoil systems essentially involve replacement of each truck ramp with a tunnel conveyor, as shown in Figure 3. While each conveyor is designed for full mine capacity, only one operates at a time and a backup system is thereby available in the event of shut-down of one tunnel. The tunnels are spaced one mile apart to minimize pit conveying distance. Incline sections of the underspoil tunnels are sloped at 20% or 11.3 degrees. Conveyors in these tunnels receive the coal from the pit conveyors and transport it to the surface conveyor system. Advancing the tunnels and conveyors in 100-foot increments before backfilling allows the dragline to cast the spoil across the pit in each successive turnover cut. Systems using shovels for primary stripping backfill by trucks end-dumping from the spoil surface. Some protective fill around underspoil pit tunnels is recommended to cushion the effect of accidentally dropping or rolling a large boulder onto the tunnel.

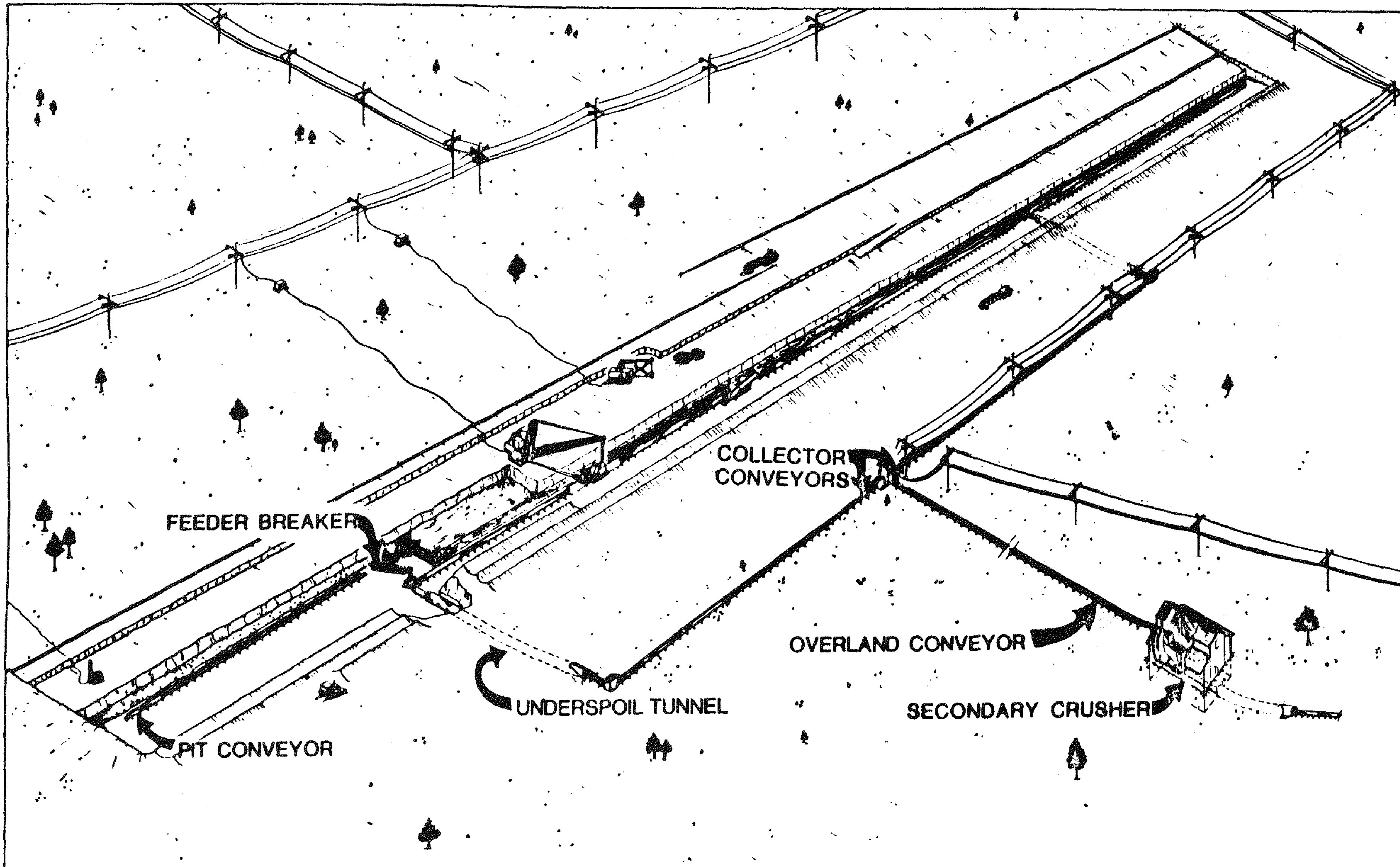
For purposes of comparison it is assumed that the storage area is located one mile beyond the common point where truck and conveyor systems would intersect at the ground surface outside the mine. As the pit moves away from the storage area, haulage distances increase. Operating costs are based upon one-half mile of mine advance measured normal to the first box cut. This represents the situation at average mid-life for the 20-year operation as an average for both the 30 and 70-foot coal seams. Under these conditions, the overall haul distance for operating cost comparisons is approximately three miles.

The study scope terminates with transporting the coal and with reclamation of the leveled spoil.



TYPICAL TRUCK HAULAGE

Figure 2



TYPICAL CONVEYOR HAULAGE

Figure 3

3.1.2.3 Underspoil Conveyor Systems

Efficient overburden removal is provided by large walking draglines supported by mining shovels to remove the deep overburden covering the area coal seams. Interference with this stripping operation must be avoided as must unnecessary delaying of mined land reclamation. Consequently, the least costly coal haulage system may not necessarily be the best. The optimum overall mine operation is the one which insures efficient and reliable coal haulage while minimizing interference with stripping, reclamation, and other costly operations.

Recognizing this cost relationship, the following criteria were used in evaluating various methods of tunnel support:

1. Reliability. Both structural adequacy to resist spoil loading stresses and redundancy to accommodate planned and unforeseen shut-down of one tunnel.

2. Installation Convenience. Simplicity which allows tunnel and conveyor extension by normal mine labor and equipment with minimal disturbance of mining operations.

3. Availability. Limitation to standard manufactured or easily fabricated components.

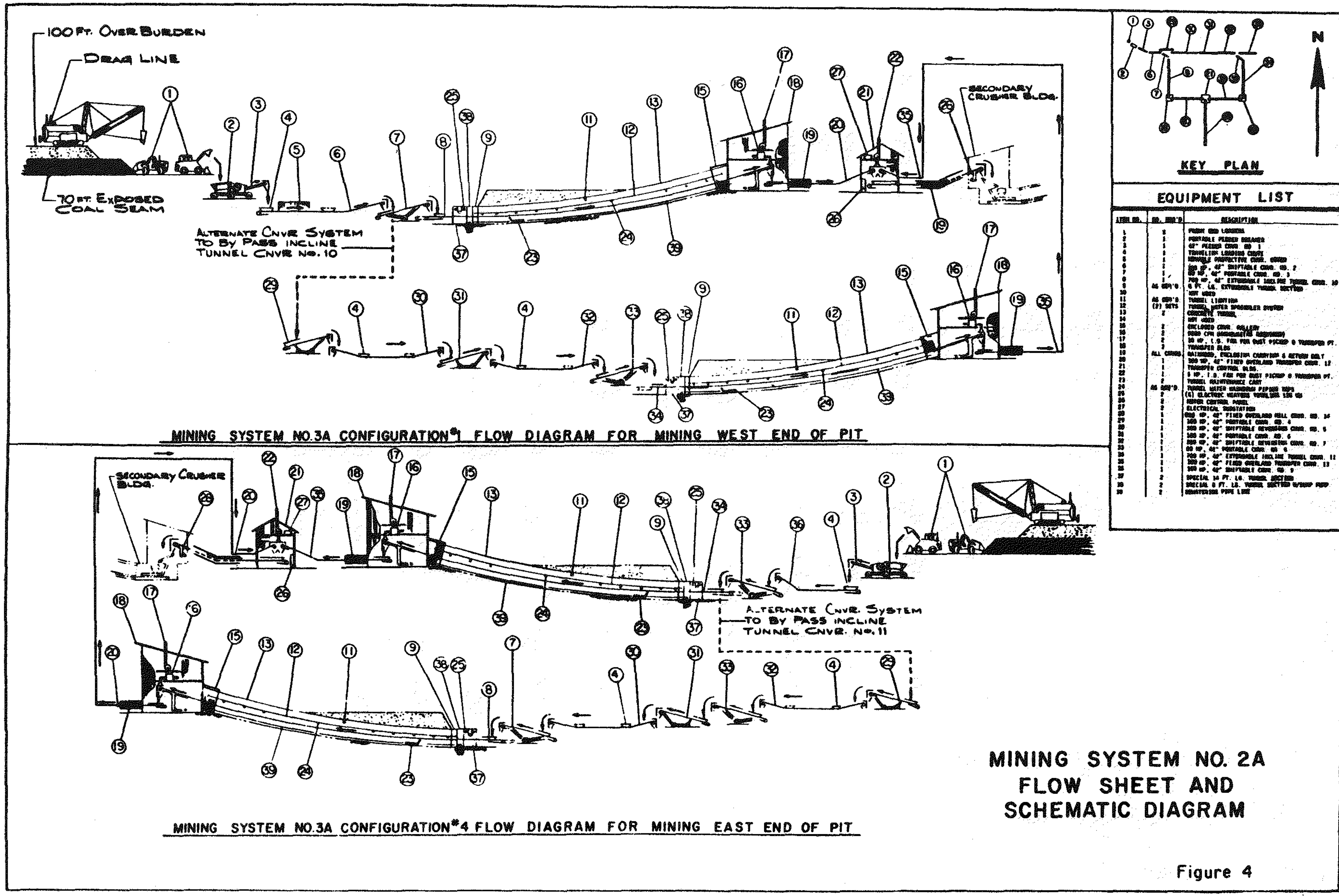
4. Flexibility. Sizing of tunnels and surface facilities to permit doubling mine tonnage at some future time.

5. Cost. Within the limits of the foregoing criteria, the total of capital and operating costs should be minimized.

Two underspoil conveyors are necessary to assure uninterrupted coal haulage, considering the time required to extend these conveyors and the occasional down-time to be expected with a single conveyor. While two conveyors in a single tunnel provide a degree of redundancy, the possibility of a mine shut-down due to tunnel failure still exists. Assuming this risk to be unacceptable, the concept of two conveyors in two separate tunnels was retained from the Preliminary Study. A typical flow sheet with primary conveyor flow and alternate bypass systems is shown in Figure 4.

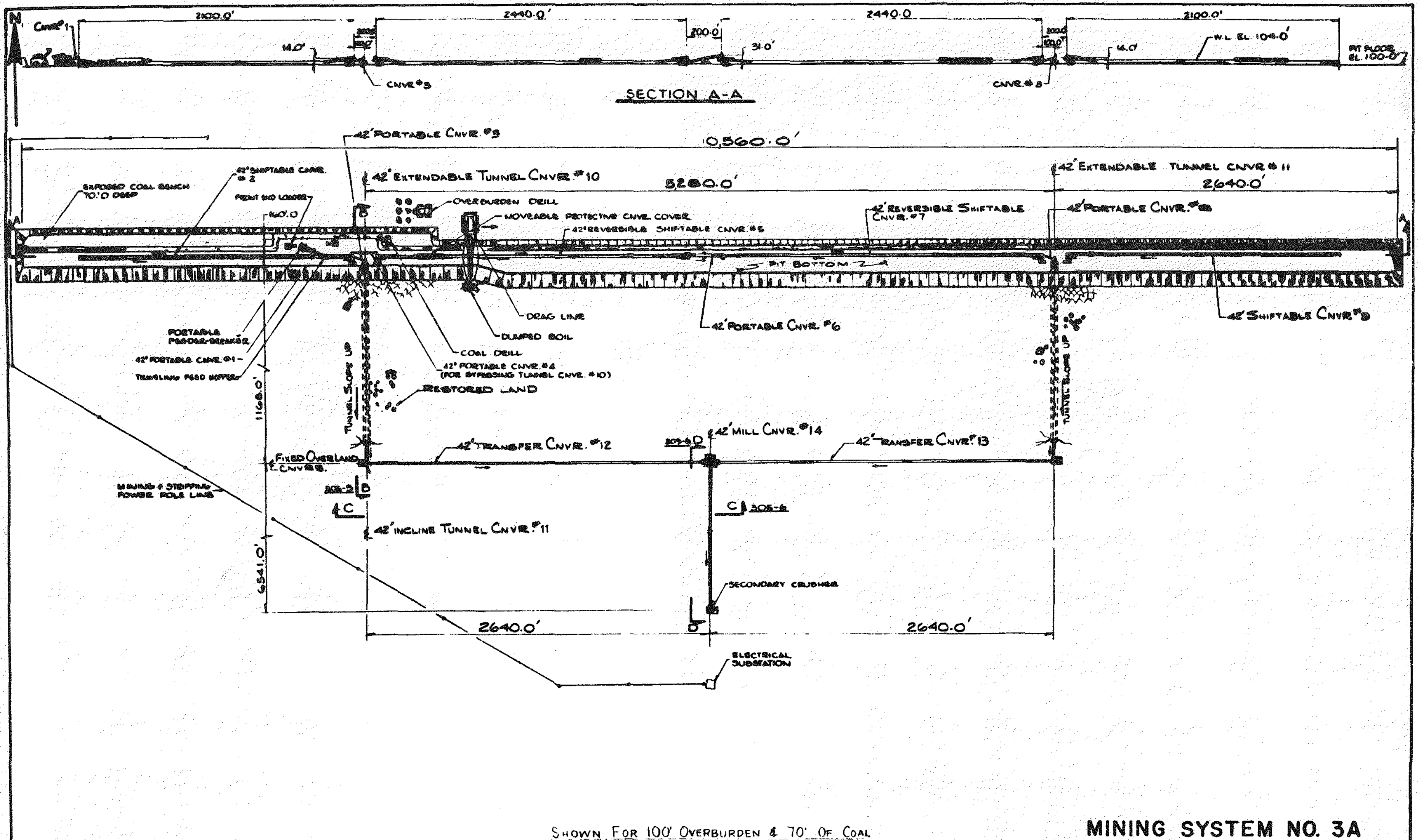
Locating the two tunnels side by side at the pit center could have economic advantages. This configuration reduces surface conveyor length and eliminates reversing pit conveyors to shift flow from one tunnel to the other. However, the possibility of losing both tunnels due to a single slide, flood, or explosion becomes less as the spacing is increased. Wider spacing also avoids interference during tunnel and conveyor extension work.

The logical spacing for two tunnels within a two-mile long pit is one mile. A typical layout is shown in Figure 5. The pit is divided into four equal lengths for standardizing the transverse conveyors. One half mile section can be served by a single shiftable conveyor. Each quarter



MINING SYSTEM NO. 2A FLOW SHEET AND SCHEMATIC DIAGRAM

Figure 4



MINING SYSTEM NO. 3A PLOT PLAN

Figure 5

of the pit can be operated independently, providing good flexibility in mine layout and operation. While additional tunnels would provide even greater flexibility and shorter pit conveyors, the cost of additional installations is not justified.

The shape of the tunnel cross-section will necessarily vary with the support method used. Several alternatives are feasible, the most economical depending on site conditions as discussed in the following section. Space requirements for the conveyor were carefully considered as there is a rapid increase in tunnel cost with increasing width. Ample area must be provided for the conveyor belt and all utility lines with space along one side for man clearance and passage of a small rubber-tired maintenance cart.

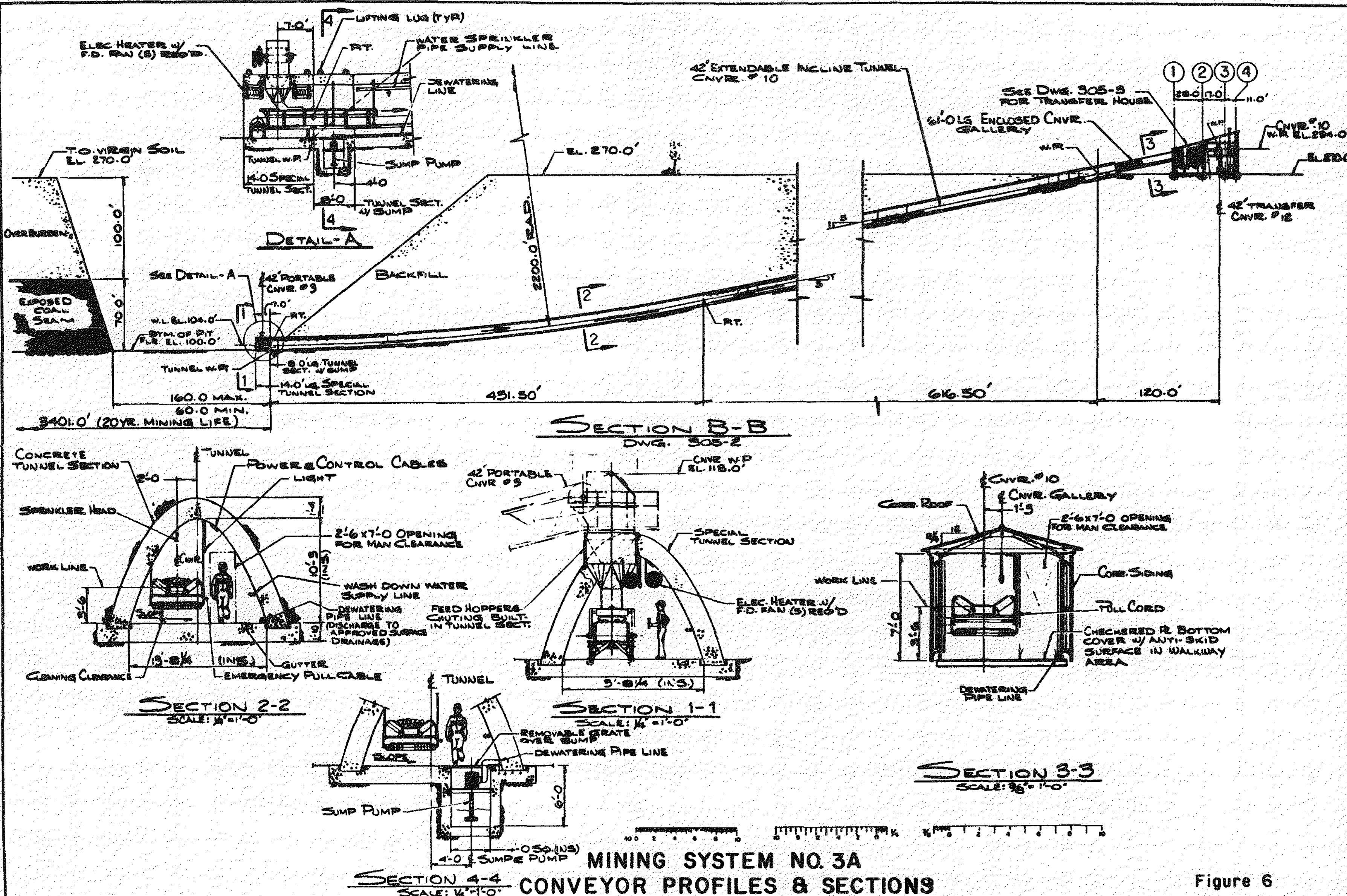
Details of the conveyor installed in a precast concrete arch and the tunnel cross-section are shown in Figure 6. The 42-inch wide belt has a design capacity of 5 million tons per year, but by replacing with a 54-inch belt and increasing belt speed approximately 15%, the conveying capacity can be doubled to 10 million tons per year. Space is adequate for the wider belt allowing the annual tonnage to be doubled without increasing operating hours or sacrificing the redundancy of the duplicate underspoil system. Both 12-foot diameter circular and the horseshoe shaped tunnels provide equivalent clearance.

The inclined tunnel profile, as shown in Figure 7, is sloped at 20% or 11.3 degrees to facilitate construction, minimize coal spillage, and permit access by the wheeled maintenance cart. The pit bottom section follows the coal seam through rolls and dip seams by cutting and filling to avoid sudden slope changes. Tunnel space heaters reduce cold-start horsepower and permit a single belt for the inclined and horizontal underspoil sections. The maximum belt length, investigated in this study, is 9,462 feet at 30-foot coal thickness and 20-year mine life. A transfer point at the base of the incline was avoided by a vertical curve.

Underspoil haulage can be divided into three areas: pit conveyors, underspoil conveyors, and surface conveyors. The pit conveying methods differ with each system and are described under Section 3.1.4, Alternative Systems. The underspoil and surface conveyors, on the other hand, are identical for all systems and vary only slightly with overburden and coal thickness. Underspoil conveyor details are shown in Figure 6 and surface conveyor details in Figure 8.

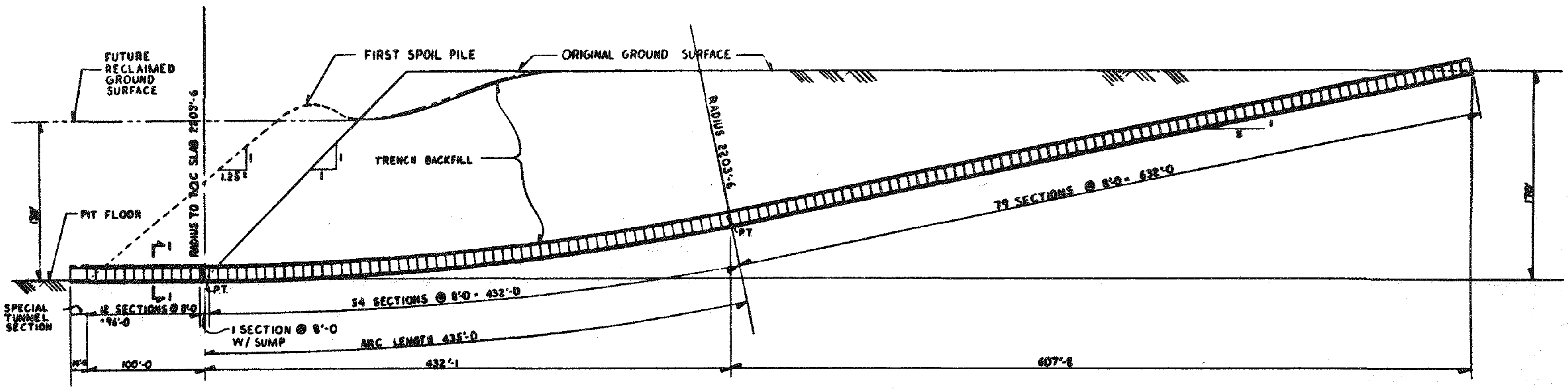
All conveyors are sized to handle full mine production of five million tons per year from a single coal face and over a single belt line. The following design details are common to all systems:

Conveyor Structure:	Steel stringer, fully enclosed (surface to pit)
Belt Type:	Steel cable with vulcanized splices
Belt Width:	42-inch
Belt Speed:	810 feet per minute
Idlers:	35 degrees at 4-foot centers
Loading:	100%



MINING SYSTEM NO. 3A
CONVEYOR PROFILES & SECTIONS

Figure 6



NOTE:
EXTENSIONS FOR SUCCESSIVE CUTS ALTERNATE BETWEEN 12 AND 13 STANDARD 8-FT. SECTIONS TO KEEP 100-FT AVERAGE. 14-FT. END SECTION IS RELOCATED WITH EACH EXTENSION.

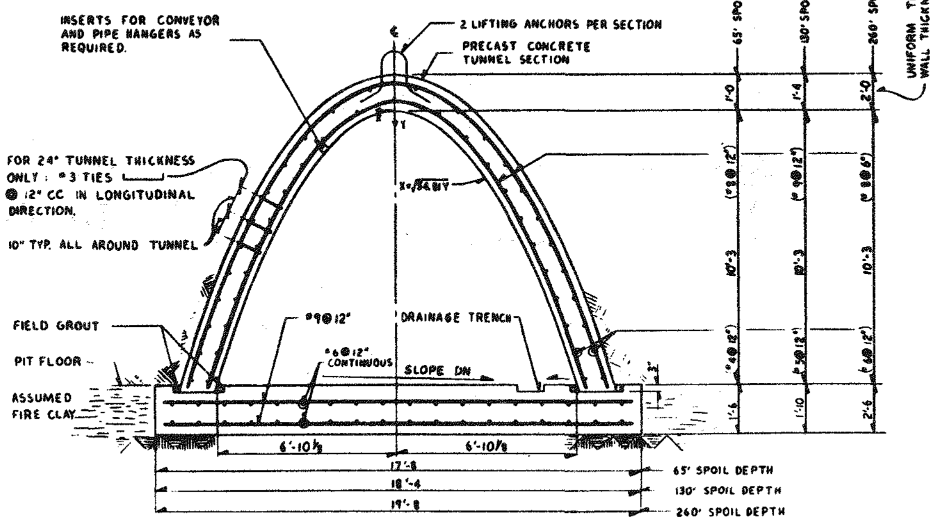
PROFILE
INITIAL TUNNEL CONSTRUCTION
1" = 40'-0

NOTES:

TABLE OF THICKNESS COMBINATIONS

OVERBURDEN THICKNESS	COAL SEAM THICKNESS	TOTAL THICKNESS	SPOIL THICKNESS
50'	30'	80'	65'
100'	30'	130'	130'
200'	30'	230'	260'
50'	70'	120'	65'
100'	70'	170'	130'
200'	70'	270'	260'

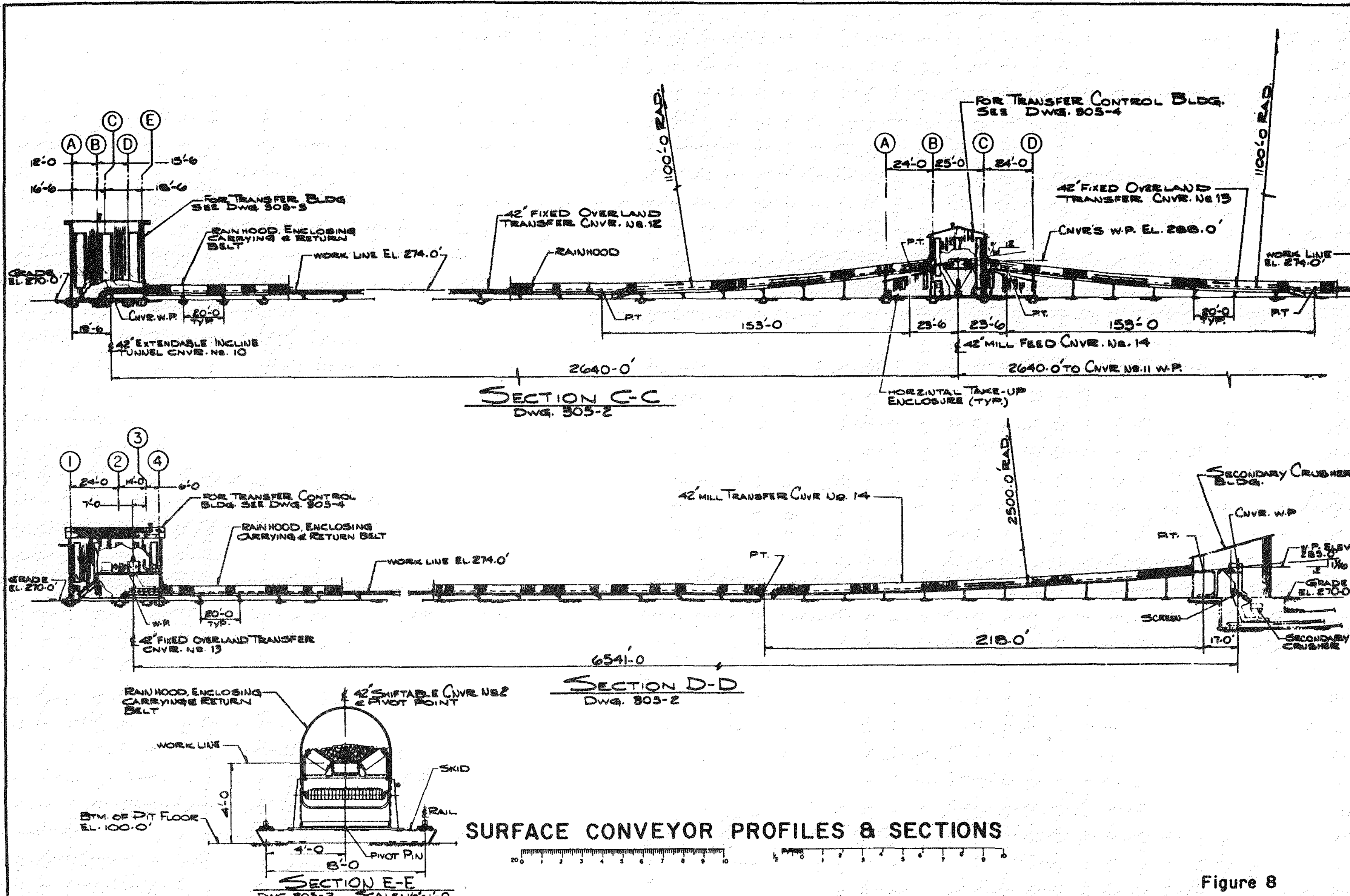
1. PROFILE SHOWN IS FOR 100' OVERBURDEN AND 70' COAL SEAM. SPOIL DEPTH FOR 100' OVERBURDEN IS 130'.
2. INITIAL TUNNEL CONSTRUCTION IS CUT AND COVER IN TRENCH. TUNNEL BELOW MINE SPOIL IS POSITIVE PROJECTING IN AN EMBANKMENT. SPOIL ADJACENT TO TUNNEL IS NOT COMPACTED DURING CONSTRUCTION.
3. SPOIL UNIT WEIGHT = 120 PCF
f'_c = 5000 PSI , f_y = 60 KSI



SECTION 1-1
½" = 1'-0

MINING SYSTEM NO. 3A
TUNNEL PROFILE & DETAILS

Figure 7



SURFACE CONVEYOR PROFILES & SECTIONS

Figure 8

Incline Slope:	20 percent
Operating Hours/Year:	3,500 (two 7-hour shifts, 250 days/year)
Required Capacity:	1,429 tons/hour
Available Capacity:	1,819 tons/hour (able to start in load conditions at 40°F)

The assumption of seven operating hours in an eight-hour shift is considered adequate to cover both unscheduled down-time and start-up, as such systems normally exceed 90% availability. The difference between required and available capacity represents a 27% reserve to provide for downtime in coal loading. As back-up equipment is included for all coal loaders except the bucket wheel excavator, this belt capacity is considered adequate. Should overall system availability be less than assumed, additional hours or higher belt speed would be necessary.

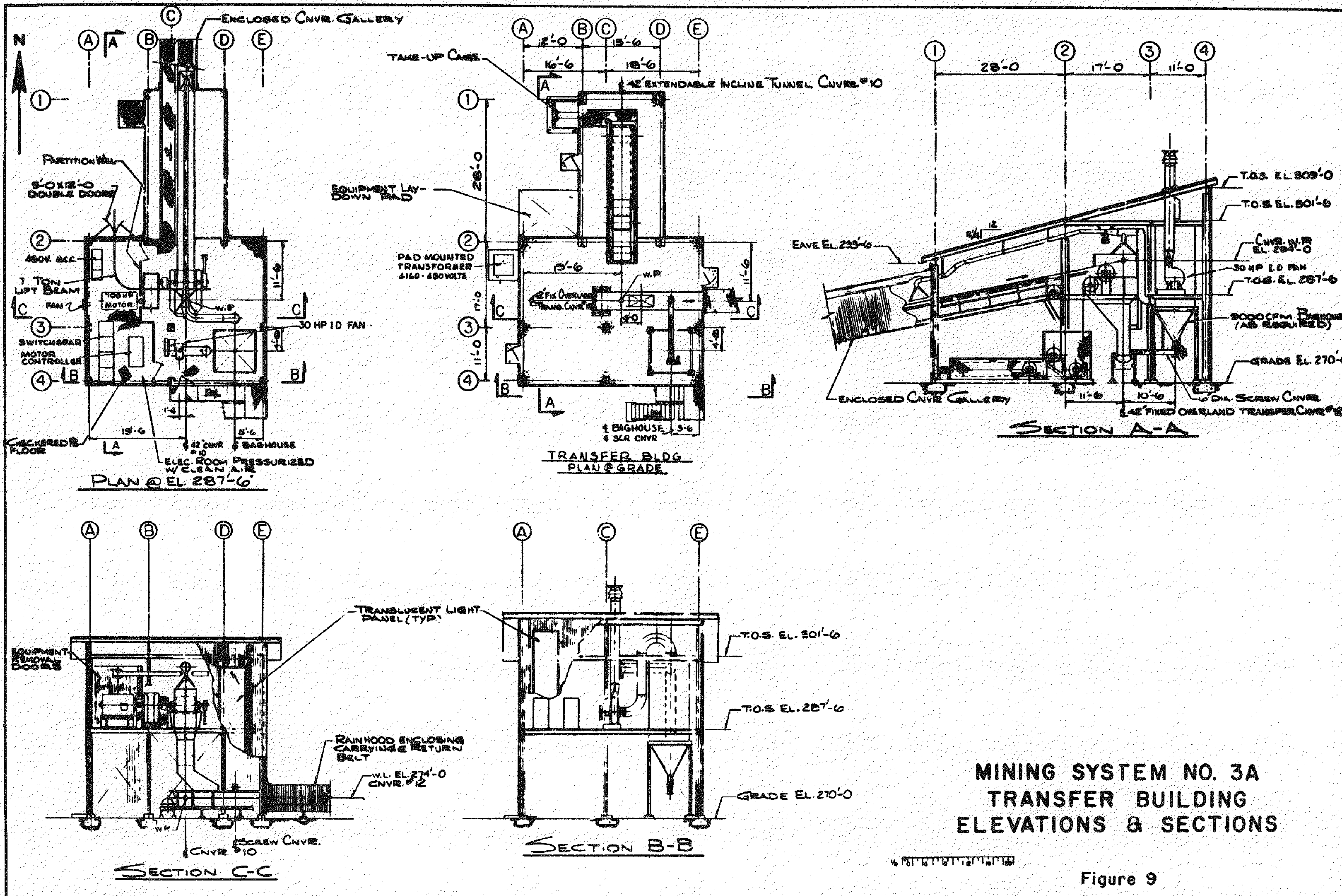
The conveyor capacity can be doubled by increasing belt width to 54 inches and belt speed to approximately 950 feet per minute. This speed remains well within current technology for steel cable belt and permits a future increase in annual production rate to 10 million tons through the existing tunnels and surface facilities.

Each underspoil conveyor receives coal from the pit system at the tunnel portal. The portal section is specially fabricated to house the tunnel heaters and to support the feed hopper into which the pit conveyors discharge. This section is reused with each 100-foot extension of the underspoil system. The underspoil conveyor drives are located in the two permanent transfer buildings on the surface. These buildings contain lift beams for replacement of motors and drivers. Details are shown in Figure 9.

Induced draft fans in each transfer building provide ventilation in the tunnel in the direction of coal travel. Design capacity of the ventilation system is 6,000 actual cfm or approximately 60 fpm. A baghouse is provided in each building to insure dust compliance with emission standards. The ventilation system has been discussed with MSHA officials who consider it satisfactory in concept. Actual requirements should be reviewed with local authorities when specific conditions are known.

The underground spoil tunnels are provided with an automatic sprinkler system for fire protection. A separate wash water line permits periodic washing of the tunnels. The cost estimate includes allowance for a small maintenance cart in each tunnel. This cart would be fitted with a vacuum cleaner system for dust removal and would provide transportation for a mechanic with tools and spare parts.

Seepage water is not expected to be a serious problem in most western coal fields. However, provisions have been made to collect and remove wash water and ground water which enters the tunnels. The cost estimate allows for a flow of 100 gpm. The sizing of pumps and pipelines would be adjusted to suit actual site conditions. A pump sump is located at the base of incline and a dewatering line extends to the surface for discharge to



MINING SYSTEM NO. 3A
TRANSFER BUILDING
ELEVATIONS & SECTIONS

Figure 9

appropriate drainage channels or to a treatment system, if required. If mining is down dip a sump will be required in the end section of the tunnel. In the course of mining operations, similar sumps would be required at low points along the tunnels unless they are dry. Alternatively, scupper drains could be installed at intervals along the tunnels to allow drainage of wash water and localized wet spots into the underlying formations where they are sufficiently pervious to dissipate the water.

The conveyor systems are designed to protect operating personnel and equipment against injury or damage. Moving components such as drive equipment, tail pulleys, take-up pulleys, and counterweights are provided with guards or enclosures to comply with federal, state, and local codes. Conveyors are equipped with safety pull-cord switches along the walkway side for emergency use. Audible alarms are installed to warn personnel of conveyor start-up Chute overload plug switches at conveyor transfer chutes prevent injury or damage in the event of chute blockage. A blocked chute stops the feeding conveyor and all upstream conveyors are stopped by "zero speed" switches. These switches are also activated by belt failure, belt slip, or local power failure. Belt side travel limit switches prevent operation of misaligned belts. This arrangement of switches and interlocks permits monitoring and control of the entire conveyor system by a single operator located in the central control building.

3.1.2.4 Tunnel Support Methods

The uncompacted spoil which will be dumped in depths up to 260 feet over a conduit projecting above the pit floor will produce severe structural loading conditions. There is no known precedent for conduits of this diameter subjected to uncontrolled backfill. At the same time, there is no recognized method for accurately estimating such loads. Based on the essential requirements for a safe structure which can be extended with minimum disruption of mining operations, several alternatives were investigated. These include:

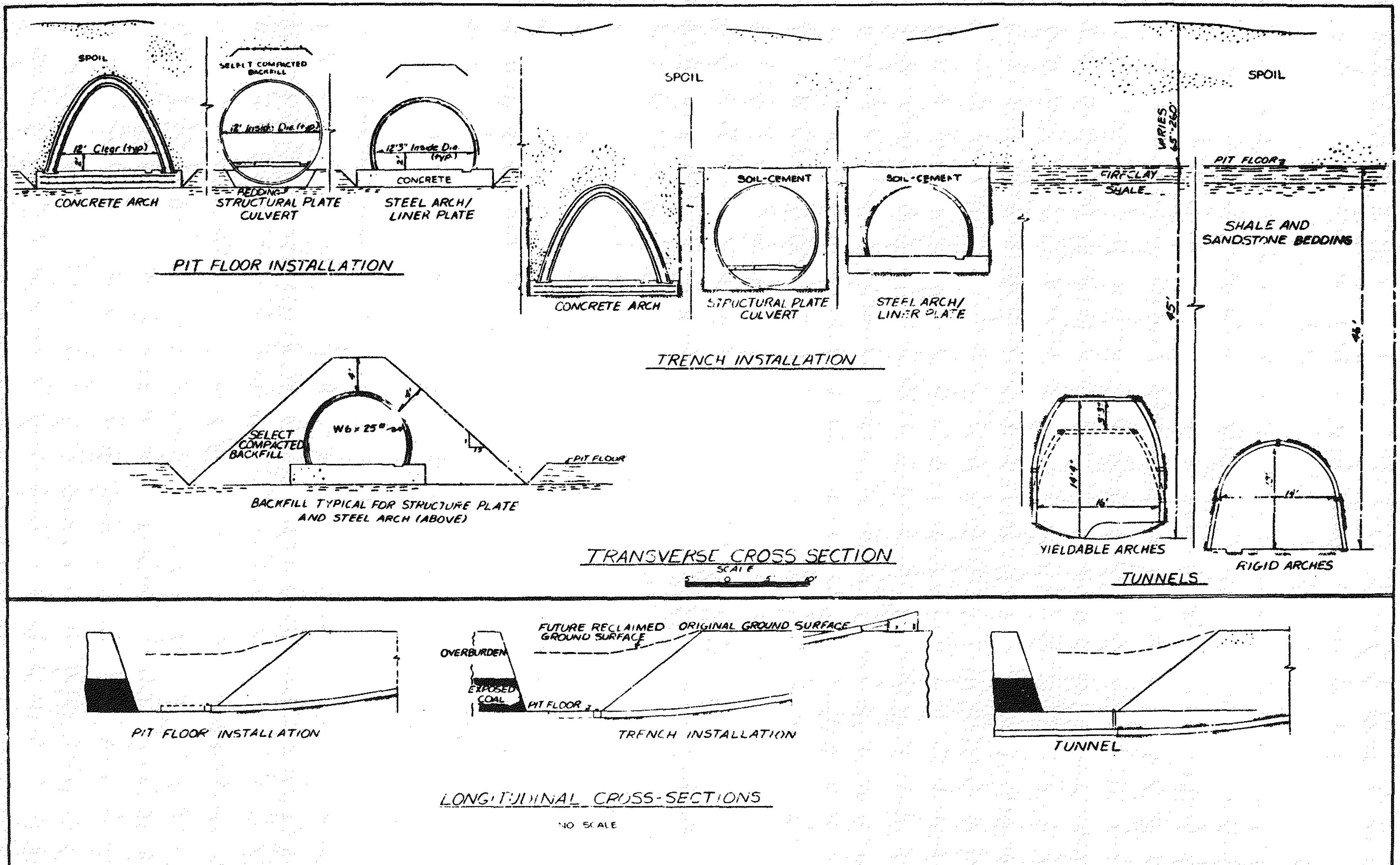
1. Precast reinforced concrete arch sections installed on a concrete invert slab.

2. Structural plate culvert with a concrete paved invert.

3. Steel arch/liner plate supports installed on a concrete invert slab.

These alternative support methods are shown in Figure 10.

Rigid culverts suspended in compressible fill will be subjected to dynamic loading caused by differential settling. This dynamic load will be added to the static load of the spoil material directly above. To insure the integrety of the tunnel structure a design load of 2 x static weight of fill was used for the reinforced concrete arches shown in Figure 7.



ALTERNATIVE TUNNEL SUPPORTS

Figure 10

Later analysis proved that this criteria was excessively conservative as arching of the high static column will compensate for this dynamic load. Using the conservative design factor of twice the static load and an assumed unit weight of 120 pounds per cubic foot of fill material, the vertical pressure on the tunnel due to a maximum spoil height of 245 feet over the arch is approximately 30 tons per square foot. This pressure will necessitate a 24-inch thick arch using 5,000 psi concrete and ultimate strength design methods which provide a safety factor of approximately 1.7. Design thicknesses for 130 feet is 16 inches and for 65 feet, 12 inches. The 12 inch thickness is controlled by casting and handling considerations rather than by stresses after installation.

The steel culvert and steel arch alternatives are flexible structures which tend to deflect and transfer a portion of the vertical load to the surrounding backfill. This arching action increases with greater compaction of the backfill around the sides of the culvert. If this backfill settlement is less than the crown deflection of the structure, vertical loads become less than the static soil weight. Potential cost savings due to the lighter loading is thus offset to some extent by the added expense of special backfill material and controlled placing and compaction.

Based on these considerations, several manufacturers of steel culvert and tunnel support were consulted in an effort to develop acceptable alternatives to reinforced concrete, particularly for the highest loads. Structural plate culverts, steel arch/liner plate supports, and ribbed and slotted steel place systems were investigated. Accurate evaluation of these systems is difficult in that loading on flexible structures is relatively indeterminate. With carefully controlled backfill, the various flexible steel systems in conventional weights are undoubtedly adequate for the lower range of spoil height. For higher spoil heights, their adequacy can best be determined by field tests, as detailed in the recommendations contained in this report.

A logical method of reducing vertical loads on buried conduits is trench installation. In effect the static load is distributed to the ground surrounding the trench much as it is distributed to compacted backfill surrounding a flexible projecting conduit. Further load reductions are obtainable by tunnelling in undisturbed ground below the pit. In view of the high costs and uncertainties associated with underspoil culverts which project above the pit floor, both trench installations and true tunnels in the underlying rock were investigated. These alterntives are discussed in Section 3.1.5 and illustrate in Figure 10. Trench designs were further investigated in the System Five study Section 3.2.3 of this report.

3.1.2.5 Surface Facilities

The surface road system for conventional haulage consists of two legs extending from the ramps over the spoils to a perpendicular connector which leads to the main haul road. All roads are 80 feet wide and are surfaced with local crushed clinker or scoria. The main haul road and connector are unchanged throughout the mine life. The parallel leg roads are extended annually with the ramps, requiring new surfacing material in addition to that required for maintenance.

The surface conveyor system consists of 42-inch steel cable belts similar to those in the underspoil system. Corrugated metal rain hoods and bottom pans enclose both the carrying and return belts. Two collector conveyors, each one-half mile long, run parallel to the pit from the transfer buildings to the central control building where they discharge to crusher conveyor. The entire conveyor system including pit conveyors is controlled by a single operator located in the central control building. All transfer points and all operating belts are monitored by electronic warning devices which signal stoppages or abnormal conditions to the control panel. Operating details are described in Section 3.1.3, Mine Development and Operation, and details of the central control building are shown in Figure 11.

As previously noted, the crushing facilities included in the comparative cost estimates provide for similar end-products from the various systems. Underspoil haulage systems include a pit feeder-breaker except where loading is by bucket wheel excavators which normally accomplish the equivalent of primary crushing. Thus, the surface facilities for the underspoil systems include only a secondary crusher whereas cost allowances are made for both primary and secondary crushing for conventional haulage. No allowance is made for storage or loadout of the crushed coal as this cost would be common to all systems.

The mine power distribution system for all cases studied was assumed to begin with 115,000 volt, three phase, 60 Hertz power delivered by the power company to a substation located at the central control building. The mine installs, owns and operates this main substation which regulates and transforms the incoming power for mine distribution.

The substation consists of the following basic equipment:

1. 115 KV incoming fused interrupter switch and lightening arrestors.

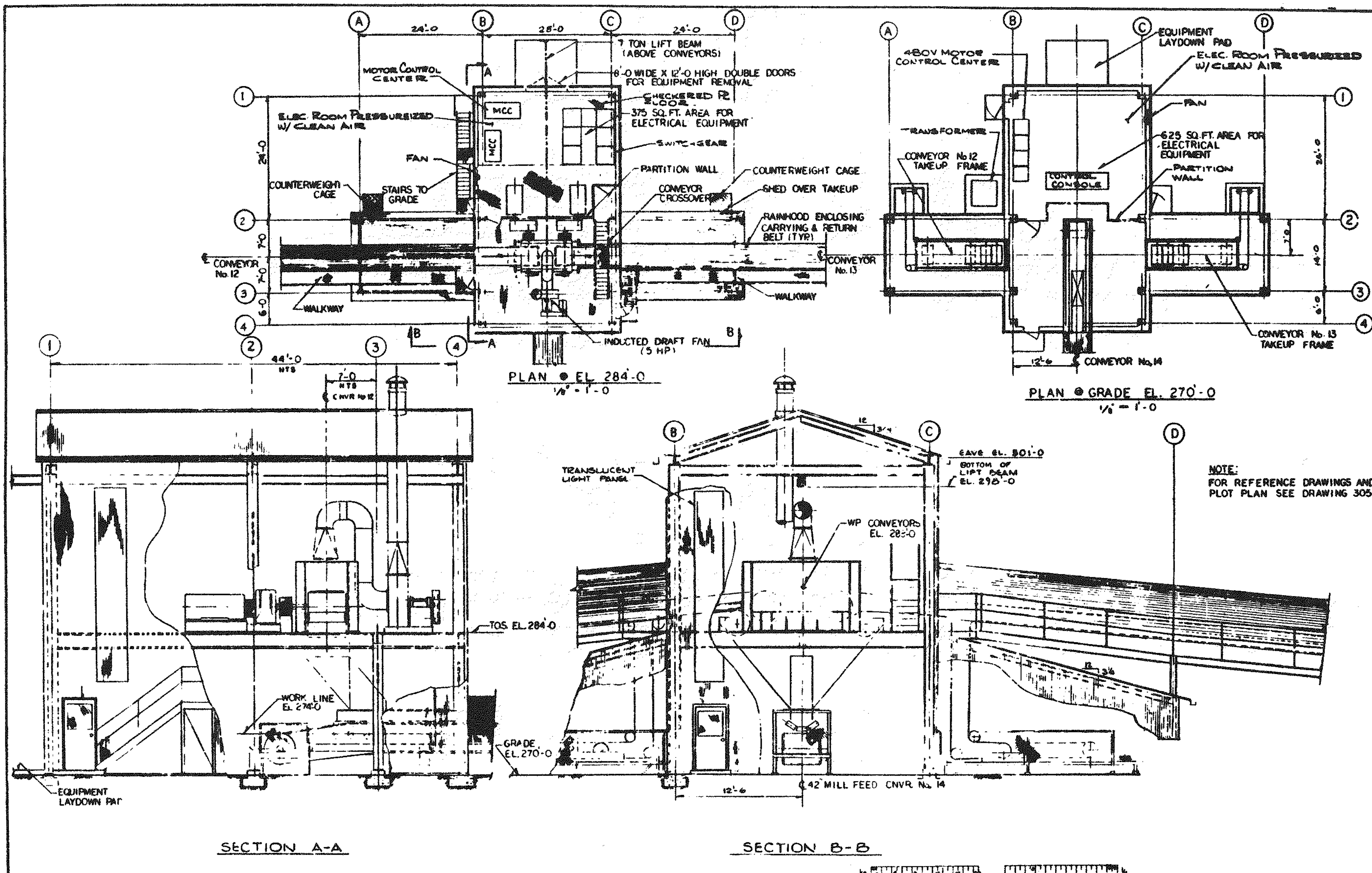
2. Main power transformer with load tap changer for ± 10% voltage regulation.

3. Primary and secondary current transformers for differential and overcurrent relaying and metering.

4. Potential transformers for undervoltage and phase sequence relaying and voltage regulation and metering.

5. Main secondary oil circuit breaker.

6. Substation bus.



MINING SYSTEM 3A–TRANSFER CONTROL BUILDING–ELEVATION & SECTIONS Figure 11

7. Grounding resistor for main power transformer.

8. Required metering, relaying and control devices.

9. Substation lighting and ground systems.

10. Fused disconnects for feeders to both the crusher loadout facilities and the underspoil and pit conveying systems.

11. Oil circuit breaker with overcurrent, ground fault and ground continuity relaying to feed the mining grid system for overburden excavators and drills.

The main substation secondary voltage was selected to match the terminal voltage requirements of the draglines and shovels. The main power regulating transformer was sized for each case based on the mining load plus an assumed 5,000 KVA requirement for both the crusher/loadout facilities and the underspoil and pit conveying system.

The mining grid is fed via a permanent line routed along the periphery to the rear of the property. A temporary mining grid is then installed from this permanent base line at 1/3 mile centers to the highwall side of the cut. As mining progresses, the grid system is moved back. Both the permanent supply line and temporary mining grid are of open pole line construction, three phase, four wire system, conductored with ACSR (aluminum conductor, steel reinforced). The grid system is tapped for feeds to the individual draglines and shovels and movable fused disconnect and pothead units employing portable mine trailing cable, type "SHD-GC" to each unit. Feeds to the drills is tapped using movable non-fused disconnects and a skid-mounted breaker to provide separate ground fault and ground continuity protection. Where voltage transformation is required from the grid to the device voltage, a transformer is included on the portable breaker skid.

For the various underspoil systems, the power supply for pit conveyors, pumps, and lighting is delivered via the underspoil tunnels. As the coal drills, loaders, and feeder-breaker are all diesel powered, pit requirements for electric power are relatively simple. For conventional coal haulage, power to the pit for coal loading shovels, pumps and lighting is delivered via the mine grid.

A nominal allowance was made for the capital and operating costs of shop and office facilities. The allowance was included in order to develop a complete cost estimate for a typical mining operation. The facilities include warehouse, fuel and explosives storage. The cost estimate for these facilities is identical for all systems except that shop costs include an incremental increase to cover truck maintenance. This allowance was based on the total trucks required for each system, including coal and overburden.

3.1.3 Mine Development and Operation

3.1.3.1 General Idea

For cost estimating and scheduling purposes, the assumption was made that all excavation for mine development is performed by the operator and that all construction is by outside contractor. This is a customary practice where the major items of mining equipment for the new mine can be delivered in time or where suitable equipment is available from previous operations. Otherwise, initial stripping could also be done by contractor as the earthwork is similar to highway or railroad work and suited to conventional heavy construction equipment. The alternative to splitting up the work is, of course, for the owner to perform or manage all development, including construction.

Assuming concurrent excavation and construction, a development period of one to three years is required, depending primarily upon overburden depth involved in the first box cut. It should be noted that mine excavation equipment could be supplemented by contractor forces or rental equipment to reduce this period, but a minimum of one year would probably be required under the most favorable circumstances. This schedule is predicated upon the prior completion of all road, rail, and power facilities to the mine site. Such facilities would be required sufficiently in advance of the construction of support facilities such as the maintenance shop, fuel and explosives storage, and electrical distribution.

3.1.3.2 Initial Stripping

Following completion of any clearing required at the mine site, topsoil is removed from construction areas within the limits of the first box cut. Scrapers load and stockpile this material for use in later reclamation. An average topsoil depth of two feet and subsoil depth of three feet was assumed for purposes of this study.

Development costs were defined to include the removal of sufficient overburden so that full mine production can be achieved at the beginning of operations. The excavation therefore includes the two mile long box cut and additional bench excavation on the highwall side to permit coordinated stripping to continue with coal production. Excavation for haul ramps or the alternative cut-and-cover trenches for the underspoil tunnel inclines is also included. Stripping operations vary from system to system and with various combinations of overburden and coal thickness. The excavation plan and equipment estimated for each specific case is assumed to apply during development excavation. An allowance was made for additional costs involved in disposing of the first box cut spoil by stockpiling near the final cut along with later rehandling for filling or recontouring the final highwall and remaining haul ramps at the termination of operations.

3.1.3.3 Construction

Construction of the surface conveyors, transfer buildings and central control building would probably be done concurrently with the crushing, storage, and loadout facilities. Assuming spoil from the first box cut is stockpiled as described above, this excavation would not interfere with surface construction and could also be concurrent. The central control building would probably be one of the first items constructed as it houses the substation which serves the overburden drills and excavators. It also serves the 480 volt pit conveyors and would therefore be useful for temporary construction power.

The incline sections of the underspoil tunnels are cut-and-cover construction requiring sloping trenches similar to haul ramps but much steeper and narrower. As tunnel installation would normally progress up the incline, mining of coal in the portal areas would be completed before this construction starts. The design provides a 20% slope and 30-foot bottom width in the trench for construction a access by mobile equipment.

If the selected tunnel support system involves concrete or steel arch sections with a concrete invert slab, the invert can be placed directly from transit-mix trucks. This slab is monolithic with continuous long-supports embedded in the slab prior to setting arches. Alternatively the arches can be installed and the conveyor suspended as shown in Figure 6. The floor supports simplify construction; the suspended type simplifies cleanup during operation. In the case of reinforced concrete arches, precast sections 8 feet long are set into preformed keyways in the slab. The joint is then field grouted, completing the installation. In the case of steel arch/liner plate supports, the ribs have foot plates which are secured by bolts embedded in the invert concrete.

If a culvert-type tunnel is selected, special invert shaping and bedding is required. The conduit can be assembled in place or in preassembled sections. A paved invert is required inside the circular culvert alternative to facilitate cleanup and travel of the maintenance vehicle. This paving can be placed over a gravel levelling course inside the culvert after installation and before erection of the conveyor.

Backfilling requirements vary with the tunnel type as described in detail in Section 3.1.2.3. The reinforced concrete type can be backfilled by dumping selected spoil without compaction whereas the steel alternatives require selected backfill material, placed in horizontal lifts, and carefully compacted. Steel sections which deflect under load should be backfilled completely before installation of suspended conveyors.

As the pit conveyors are peculiar to each system, they are described in detail in Section 3.1.4, Alternative Systems. It is anticipated that the pit conveyors would be installed and placed in operation as soon as possible after mining begins. Extendable conveyors for System No. 2 would be utilized in the first box cut as the 120-foot portable sections can be brought in shortly after coal mining starts. Shiftable pit conveyors could not be installed until coal is removed from the initial box cut, probably by tramming with front-end loaders to the feeder-breaker at the nearest underspoil portal.

3.1.3.4 Overburden Excavation

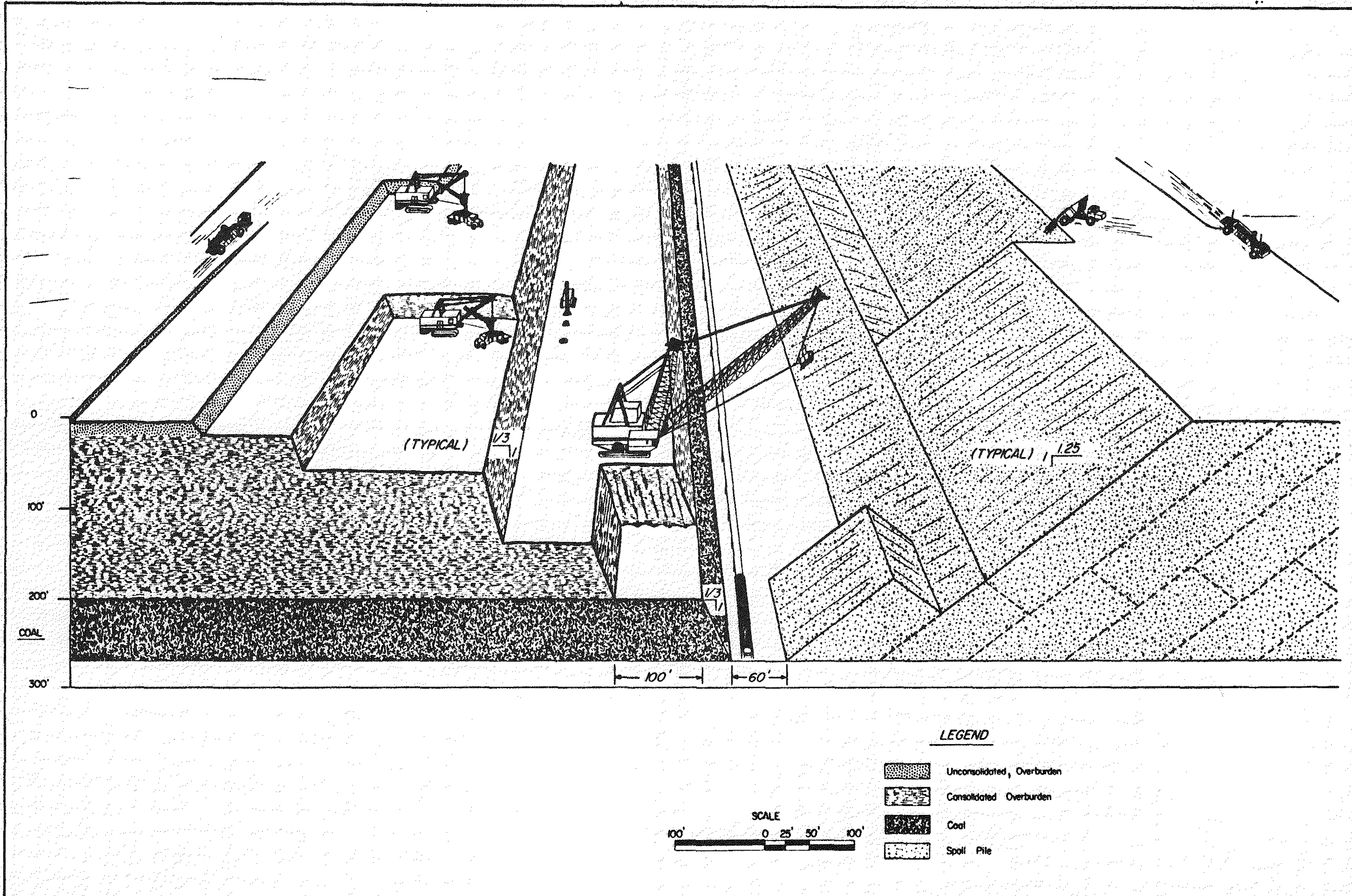
Overburden depths of 50, 100, and 200 feet were considered in this study. The upper 20 feet is assumed to be unconsolidated material composed of topsoil two feet thick, subsoil three feet thick, and the remaining 15 feet residual soil or highly weathered rock. Below the 20-foot depth the overburden is assumed to be relatively weak sandstone and shale, requiring light blasting for shovel or dragline excavation.

The four basic materials are excavated and placed as separate operations to retain the original vertical sequence. Figure 12 shows these various materials and the separate excavation operations for the maximum combinations of 200-foot deep overburden and 70-foot thick coal. The combinations of overburden depth and coal thickness studied represent stripping ratios varying from 0.77 to 7.19 cubic yards per ton. The annual overburden excavation corresponding to 5 million tons of coal ranges from 3,850,000 to 35,950,000 cubic yards.

Overburden blasting costs are based on current practice in western coal mines where overburden stripping is accomplished by shovel or dragline. Track-mounted electric drills were selected to suit production requirements for each case. Two drill patterns were used, depending on depth; 9-inch diameter holes on a spacing of 25 x 25 feet, and 12-inch holes on a spacing of 30 x 30 feet. A powder factor of 1/2 pound of prilled ANFO per cubic yard was assumed.

For cost estimating, the equipment for topsoil and overburden removal was selected to best suit each combination of overburden and coal thickness and each coal haulage system. After scraper stripping of the 5-foot surface layer the remaining 15 feet of unconsolidated overburden must be removed to permit drilling and blasting. The depth of overburden which can be cast directly to spoil depends upon space requirements on the pit floor for each coal haulage system. For example, systems using shiftable pit conveyors require a 60-foot wide lane between the highwall and spoil toe, which severely limits the height and volume of overburden which can be handled by dragline. Conventional truck haulage and underspoil systems which do not involve shiftable pit conveyors are better suited to dragline stripping as the spoil toe can extend to the base of the highwall. Highwall slopes are assumed to be 1/3 horizontal to 1 vertical, and spoil slopes 1-1/4 horizontal to 1 vertical.

Utilizing this geometry, the maximum height of dragline excavation was determined, assuming the use of currently available models up to 100 cubic yards in bucket size and 350 feet in boom length. Where overburden depth



OVERBURDEN EXCAVATION-SINGLE COAL SEAM

Figure 12

exceeds this dragline capability, power shovel-truck excavation is used to bench down to the dragline level. As shown in Figure 12, this benching operation involves all material not handled by the dragline or the scrapers. The alternative to shovel-truck operations would be rehandling by a second dragline on the spoil side of the pit. This pull-back operation would remove spoil from the primary dragline dump to create the extra spoil space required. A cost study was made which indicated this pull-back operation would generally be more costly than shovel-truck excavation for the study conditions. Spoil volumes are based on an average swell of 30%. Actual values would probably be less for the spoils and more for the rock materials with 30% a composite average.

The following overburden excavation equipment and availability factors were used for the various cases estimated:

Draglines	
Bucket sizes 16-100 cubic yards	85%
Shovels	
Shovel sizes 15-30 cubic yards	85%
(One, 12 cubic yard front-end loader for backup)	
Trucks	
End dumps 50-170 ton	80%
Scrapers	
Twin engine 30 cubic yards	80%

For this study work schedules are generally three 8-hour shifts, 300 days per year for draglines. Shovels and scrapers generally operate two shifts per day, 250 days per year.

3.1.3.5 Coal Excavation

This study is based on annual coal production of five million tons per year. Assuming two 8-hour shifts on coal operations, 250 days per year, a production rate of approximately 1,500 tons per hour is required. The mine plan for all systems is based upon single coal seams lying near-horizontal. For each overburden depth, recoverable coal seam thicknesses of 30 and 70 feet were investigated. In situ density of 80 pounds per cubic foot or 1.08 tons per cubic yard was used, swelling to 55 pounds per cubic foot for loading and haulage.

Coal blasting costs are based on typical data from western operations in bituminous and sub-bituminous coal. Track-mounted diesel drills, which simplify the electrical grid, drill 6-inch holes on an 18 x 18-foot pattern. A powder factor of 0.2 pounds of prilled ANFO per cubic yard was assumed for loading by shovel or front-end loader. For loading by bucket wheel excavator the powder factor was increased to 0.35.

Three types of loading equipment were included in the study: shovels, front-end loaders, and bucket wheel excavators. For conventional truck haulage, shovels were assumed to be the primary loader as they appear to predominate over front-end loaders in the mines visited. Front-end loaders were assumed for all underspoil systems except those specifically designed for bucket wheel excavators. This selection was made for several reasons:

1. Uniformity for comparison of various underspoil systems.

2. Flexibility to feed pit conveyor systems which lack the spotting manuverability of trucks.

3. Clean-up ability in close quarters where pit conveyors would restrict clean-up by a dozer working with a shovel.

4. Versatility to provide occasional pushing, pulling, and lifting in the installation of tunnel sections and the moving of conveyors.

Loading equipment is sized to produce the required 1,500 tons per hour with an allowance for availability based on operating records for each type of equipment under similar conditions. The following primary loading equipment and availability factors were used:

Power Shovel

One, 35 cubic yard shovel	85%
One, 12 cubic yard front-end loader for backup	

Front-End Loaders

One, 35 cubic yard loader	75%
One, 24 cubic yard loader	75%

Bucket Wheel Excavator

One, 3,600 ton per hour BWE	40%
One, 12 cubic yard front-end loader for backup	

This primary loading equipment is capable of working faces 30 feet high safely. Higher faces require bench excavation or dozing down of the upper material. For 70-foot coal seams, benching is assumed for shovel loading. For front-end loaders two tractor dozers are included to push the upper half of the coal over the face.

Coal trucks for conventional haulage are 120 ton haulers with spares to compensate for 80% availability.

3.1.3.6 Reclamation

Reclamation was considered as one of the unit operations for cost estimating purposes. As it influences mine development as well as operations, the general aspects which relate to all coal haulage systems are covered in this section.

The reclamation requirements assumed for this study are based upon current regulations in the states of Montana, Wyoming, and North Dakota. As reclamation law and its interpretation vary with time and location no effort was made to design around a specific set of regulations. However, the following requirements are generally representative of those currently in effect in the states mentioned and were used as a basis for the study.

1. Final grading will be to the approximate original contour.

2. Reduction of the final highwall by backfilling will be required. Spoil from the first box cut will be stockpiled in the vicinity and eventually placed in the final cut for this purpose.

3. Recontouring will be kept current, within two or three spoil ridges behind the active pit.

4. Haul ramps for conventional coal haulage will be at 7% grades and will be advanced annually by filling and resurfacing.

5. Topsoil will be removed ahead of mining operations and replaced to provide 2 feet of topsoil and 3 feet of subsoil over the recontoured spoils. Topsoil will be either directly placed or stockpiled and rehandled depending on operating conditions and season.

6. Revegetation including seeding, fertilizing, and limited mulching and sprinkling will be in accordance with current practice.

7. All facilities not suited to extended operations will be removed on completion of the 20-year mine life.

The cost estimates reflect the foregoing requirements and include detailed costs for the earthwork portion of reclamation as this work is effected to some extent by the haulage system. Revegetation is not effected by the system; and therefore, an identical cost allowance was made for all systems based on current reclamation work in the Powder River Basin.

In line with the assumed topsoil requirements, the surface soils are removed and replaced in a 2-foot layer by scraper. The next 3 feet of material is likewise excavated by scraper and placed on the spoils ahead of the surface soil in order to keep the materials properly separated and sequenced. In the cost estimates these two excavation items are combined as the first unit operation, topsoil removal, in order to match the contract format and to isolate any system-specific costs. All subsequent reclamation costs including revegetation are included in the final unit operation, spoil reclamation.

It should be noted that clearing is not treated as a separate unit operation. The removal of trees and brush is generally insignificant in the mine areas visited in Wyoming, Montana, and New Mexico. The clearing of fences, abandoned structures and other man-made features is a site-specific cost which does not seem appropriate for this general study. However, it is certainly a cost to be considered when details are available for a particular mine.

3.1.4 Alternative Systems

3.1.4.1 General Description

This section is intended to present the essential features of each system. A brief description, a drawing, and a cost summary are included for conventional coal haulage and for each of the six underspoil alternatives investigated. Design details common to all systems are described in Section 3.1.2 and methods of development and operation in Section 3.1.3. A detailed comparison of system unit costs is made in Section 3.1.6. The Appendix 3.1.4 includes cost support data, indexed by system, to backup the cost summaries.

It should be noted that with the exception of the most favorable condition, 50-foot overburden and 70-foot coal, overburden removal is more costly than coal haulage. As overburden removal costs become a larger part of total mining costs, the effect of the coal haulage system upon overburden stripping becomes increasingly important. For this reason the method of overburden stripping used in estimating each coal haulage system for each combination of conditions is listed in Table 1 which follows. Except for Systems 3, 4, and 5 draglines are used throughout. Prestripping by shovel and trucks is performed where the combination of overburden depth, coal thickness, and conveyor space requirements exceed effective dragline reach. These criteria are described in Section 3.1.3.4.

TABLE 1

METHODS OF OVERBURDEN REMOVAL

Overburden Depth	50 Ft.		100 Ft.		200 Ft.	
Coal Thickness	30 Ft.	70 Ft.	30 Ft.	70 Ft.	30 Ft.	70 Ft.
System No. 1	DL	DL	DL	DL	S & DL	S & DL
System No. 2	DL	DL	DL	DL	S & DL	S & DL
System No. 2A	DL	DL	DL	DL	S & DL	S & DL
System No. 3	S	S	S	S	S	S
System No. 3A	DL	DL	DL	S & DL	S & DL	S & DL
System No. 4	S	S	S	S	S	S
System No. 4A	DL	DL	DL	S & DL	S & DL	S & DL

DL = Dragline
S = Shovel and Trucks

Note: Top 5 feet by scrapers in all cases.

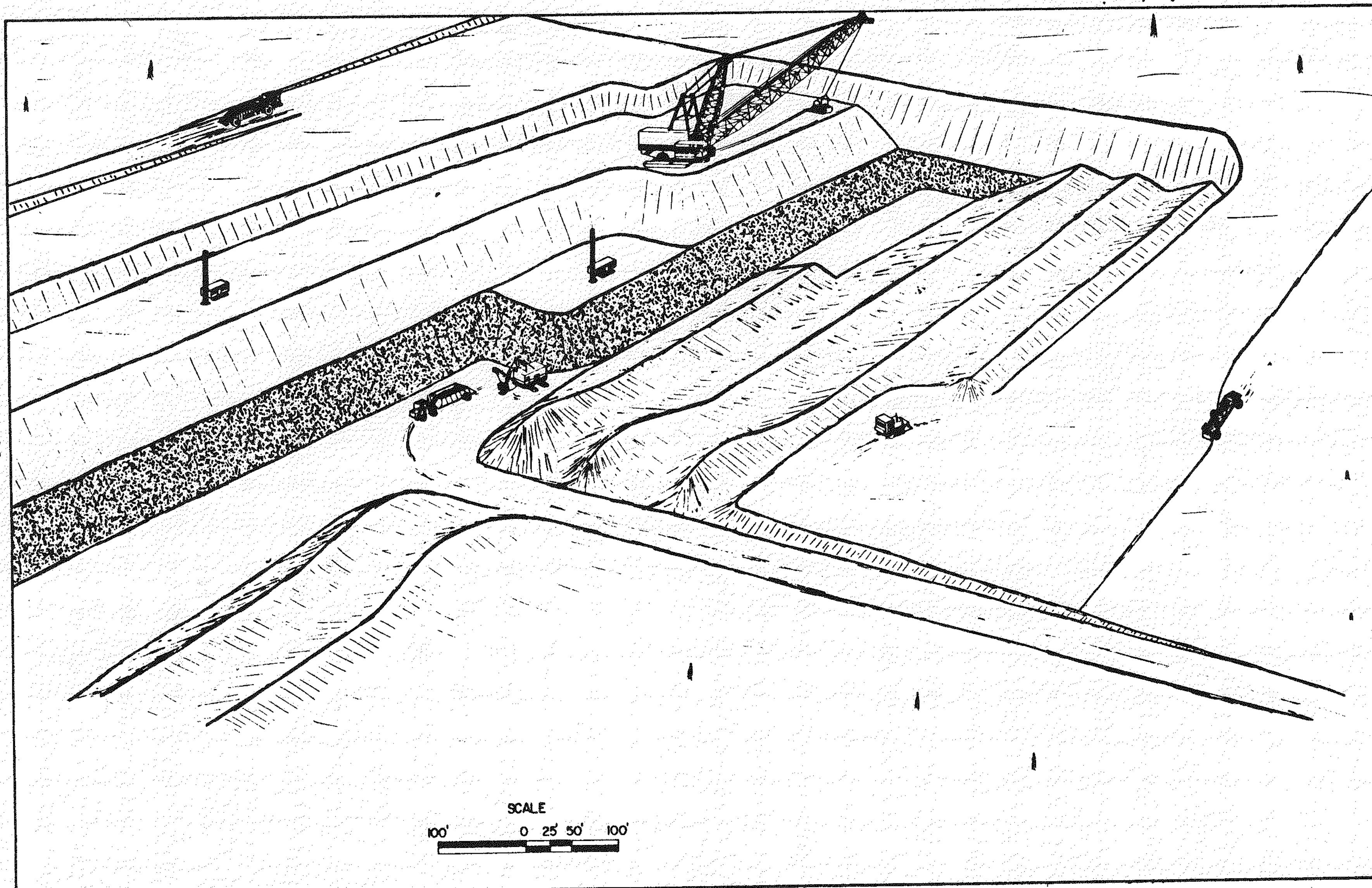
3.1.4.2 System No. 1

System No. 1 is the conventional coal haulage system currently found in most area strip mines. A typical layout is shown in Figure 13. Coal is loaded into trucks at the face by either a power shovel or front-end loaders. The trucks travel along the pit bottom, up the nearest ramp through the spoil, and on surface roads to a dump hopper at the crusher facilites.

The cost estimates are based on one 35 cubic yard shovel loading approximately, 1,500 tons per hour, two shifts per day. The 120 ton end-dump trucks haul approximately 3 miles at mid-life of the mine, this distance varying with coal thickness and pit depth.

Some advantages of truck haulage over conveyors are:

1. Flexibility. A truck fleet can move coal from several separate areas simultaneously and can be shifted quickly from one area to another to accommodate coal blending, lease holdings, or reclamation requirements.



CONVENTIONAL SHOVEL LOADING AND TRUCK HAULAGE (SYSTEM NO. 1) Figure 13

2. Versatility. Where both overburden and coal are hauled by truck, units can be shifted between overburden and coal to maintain balanced operations.

3. Reliability. Trucks tend to "get the job done" because they are understood and accepted by owners and operators as a proven means of haulage. Availability is poorer on a unit basis than are conveyors; however, replacement units can be brought into production to maintain good overall availability.

4. Efficiency. Loading efficiency can be maximized by precise spotting of trucks, and hauling efficiency can be maintained by adjusting the number of trucks to suit varying loader production and haul distance Selection between shovel or front-end loader can be made to suit site conditions.

5. Salvage Value. Truck and shovel or front-end loader combinations are well suited to operations of unknown duration as they are relatively saleable whenever mining terminates.

Disadvantages of truck haulage are considered to be:

1. Lower Coal Productivity. Compared with belt conveyors, trucks have relatively low availability and productivity due to mechanical failure and driver inefficiency. (This is offset by using spare trucks).

2. Interference with Stripping. Truck ramp entrances to the pit require "gapping the spoil" which usually involves expensive rehandling. Ramps extend haul distances for topsoil and any overburden hauled to disposal, and result in cross-traffic.

3. Interference with Reclamation. Truck ramps delay recontouring and revegetation. Annual advancing of ramps reduces this interference but the cost of filling and resurfacing is substantial.

4. Fuel Uncertainties. Both the cost and the continuous availability or diesel fuel for future operations is uncertain.

5. Labor Uncertainties. Rapid labor escalation and the shortage of trained drivers and mechanics in "boom" areas reduce the attractiveness of labor-intensive truck haulage.

Capital and operating costs developed in 1976 for a complete mining operation under six combinations of overburden depth and coal thickness are summarized in Table 2. These costs include all normal unit operations for a mine using truck haulage to produce five million tons of coal per year. Initial capital costs for System No. 1 increase rapidly with deeper overburden, reflecting larger volumes of development stripping and ramp excavation as well as more and heavier stripping equipment. Capital costs decrease slightly with thicker coal as the lower stripping ratio reduces initial investment in overburden excavators.

TABLE 2

CAPITAL AND OPERATING COSTS
System No. 1

Coal Thickness	30 Feet			70 Feet		
Overburden Depth	50 Feet	100 Feet	200 Feet	50 Feet	100 Feet	200 Feet
Total Initial Capital Cost	22,931,376	35,543,706	74,815,971	19,596,296	30,740,556	64,487,788
Operating Cost Per Ton of Coal						
1. Topsoil Removal	0.151	0.151	0.180	0.056	0.059	0.082
2. O.B. Drill & Blast	0.125	0.317	0.668	0.063	0.167	0.312
3. Overburden Removal	0.445	0.817	2.537	0.263	0.503	1.368
4. Coal Drill & Blast	0.097	0.102	0.102	0.099	0.097	0.101
5. Coal Loading	0.132	0.132	0.132	0.132	0.132	0.132
6. Coal Haulage	0.356	0.470	0.641	0.358	0.419	0.518
7. Misc. Pit & Oper.	0.035	0.035	0.035	0.035	0.035	0.035
8. Reclamation	0.143	0.143	0.085	0.056	0.056	0.060
9. General	0.043	0.043	0.043	0.043	0.043	0.043
10. Supervisory	0.213	0.213	0.213	0.213	0.213	0.213
Depreciation and I.T.I. on Capital Costs	0.162	0.259	0.559	0.183	0.299	0.751
Administration	0.190	0.268	0.520	0.150	0.202	0.362
TOTAL DIRECT COST	2.092	2.950	5.715	1.651	2.225	3.977

Several trends are noteworthy in the operating costs per ton of coal:

1. Topsoil removal costs, which include scraper load, haul, and dump of the 5-foot surface soils are inversely related to coal thickness.

2. Overburden removal costs for 50-foot depth at $0.45 per ton of coal ($0.29 per cubic yard of overburden) are for dragline casting of a single turnover cut. The unit costs of $0.82 ($0.27 per cubic yard) for 100-foot thickness is likewise dragline casting. The unit cost for 200-foot depth of $2.54 ($0.41 per cubic yard) includes both dragline casting and shovel loading with haul distances increased to allow for the coal haul ramps.

3. Coal loading costs of $0.13 per ton by power shovel are lower than those for conveyor systems which include front-end loader and feeder-breaker costs (bucket wheel excavator costs for System No. 4 and No. 4A). Benching is assumed for shovel loading 70-foot seams whereas dozers are required to push down to the front-end loaders for the underspoil haulage systems.

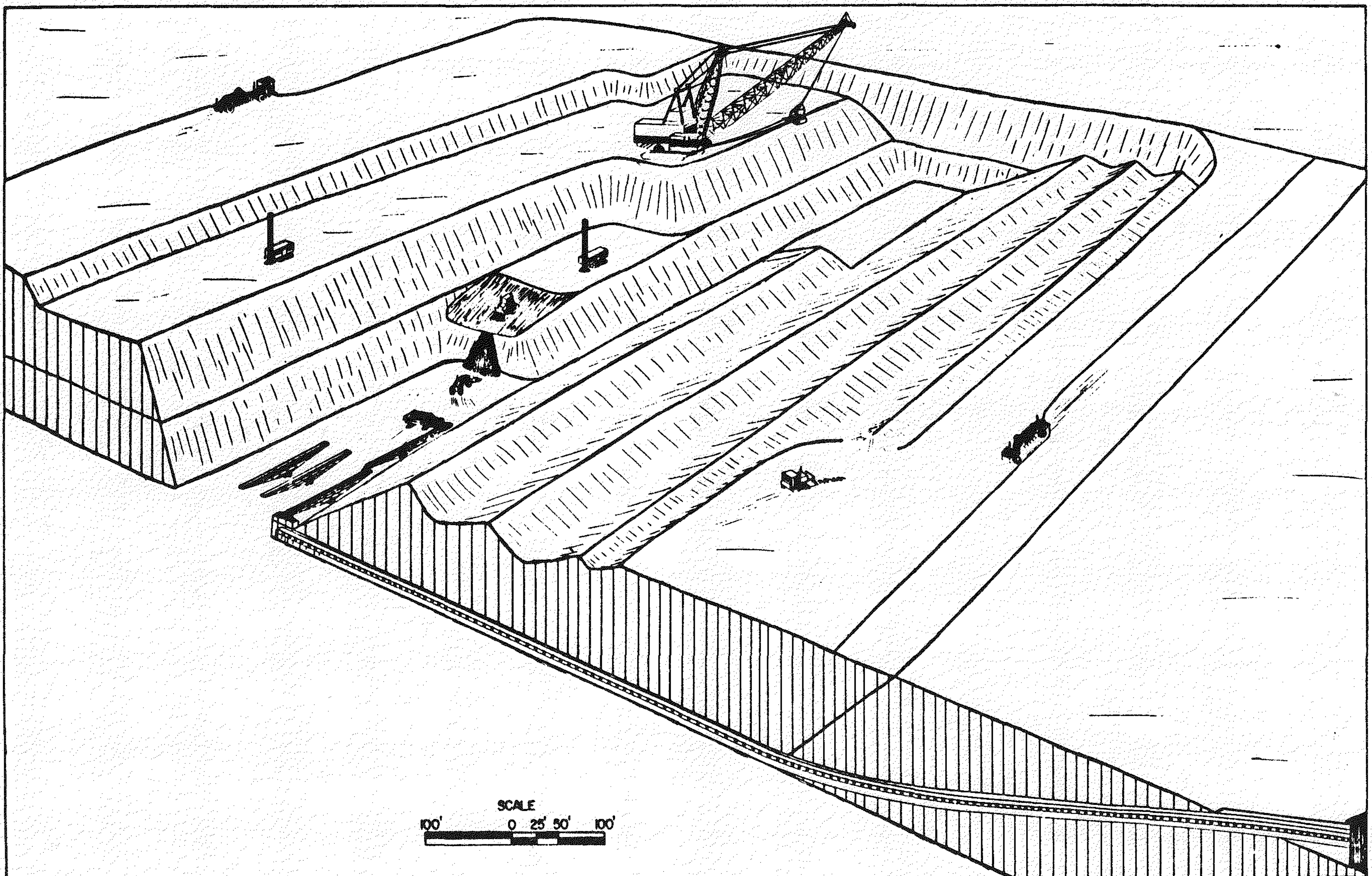
4. Coal haulage costs, by truck, increase with pit depth which is directly related to both overburden depth and coal thickness.

5. Relcamation costs reflect the additional surface area with thinner coal. They are also higher where overburden removal is entirely by dragline, as dozer costs for recontouring spoil ridges are included (Appendix 3.1.4).

3.1.4.3 System No. 2

System No. 2 incorporates underspoil haulage with extendible conveyors in the pit between the face and the tunnel conveyor. The layout is shown in Figure 14. Extendible conveyors with built-in belt storage were investigated in the Preliminary Study. Using this system and periodic splicing, each conveyor could be extended to a maximum length of one-half mile. Further review however indicates that separate portable conveyor flights, or modules, are preferable to this application. Front-end loaders, at the coal face, dump into the surge hopper of a high-capacity track-mounted feeder-breaker. Coal is broken to minus 6-inch lump size and discharged into a feed hopper mounted on the leading unit of portable conveyor string. The last flight of portable conveyors discharges into a similar hopper installed in the end-section of the underspoil tunnel.

The underspoil conveyor transports the coal to the surface where it is transferred to the one-half mile long collector conveyor. The central control structure houses a transfer point for both collector conveyors to feed the single overland conveyor and on to the secondary crusher and storage or loadout facilities. The underspoil and surface conveyors are identical for underspoil Systems No. 2 through 4A.



UNDERSPOIL HAULAGE SYSTEM NO. 2

Figure 14

The pit conveyors in System No. 2 are conventional wheel-mounted sections or flights approximately 120 feet long, Figures 15 and 16. They can be moved readily by front-end loader or tractor and can be turned around in the pit at access road entrances. They are fitted with a single axle and hitches at each end to facilitate positioning and turning. Levelling jacks are provided for final alignment on the pit floor. Each conveyor has its own drive and the system receives power from the underspoil tunnel. Belt width is 42-inches to match the remainder of the system which is designed to handle a maximum of 1,800 tons per hour. Average required capacity assuming 7 operating hours, 2 shifts, 250 days per year is 1,500 tons per hour.

As the portable conveyors are designed for full capacity and mobility, only sufficient units to serve a one-half mile section of pit, a total of 18 sections, are required (Figure 17).

These sections are parked in the pit for movement into line as the face advances away from the underspoil conveyor. Initially the feeder-breaker discharges directly into the tunnel end-section. When clearance for the first conveyor flight is available the feeder-breaker moves to the face. As the feeder-breaker does not require an operator, two full time ground men are sufficient to move, position, and align the feeder-breaker and pit conveyors. The combined capacity of the 36 and 24 cubic yard loaders is such that the smaller unit would normally be available as a prime mover when needed. Otherwise, a tractor can be used part-time and the moving can be done on the off shift. For the conditions studied, one section per shift would be required for a 30-foot coal seam and one section per day for a 70-foot seam. The cost estimates include an allowance for this tractor (Figure 18).

Advantages of System No. 2 over truck haulage are:

1. High Coal Productivity. Compared with trucks, belt conveyor systems have relatively high unit availabilty.

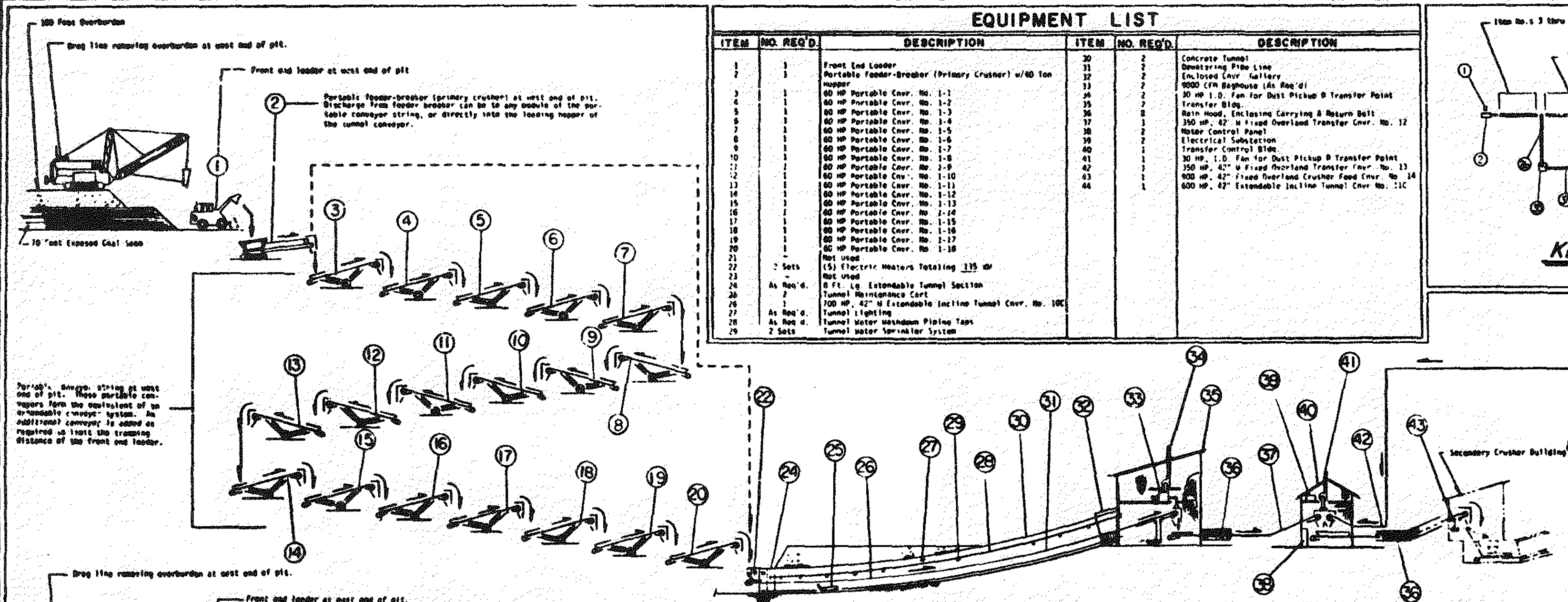
2. Fuel Uncertainties. The future cost and availability of electric power versus diesel fuel may favor conveyor haulage.

3. Low Interference with Stripping. The underspoil concept eliminates haul ramps which necessitate spoil rehandling and road resurfacing and increases overburden haul distances.

4. No Interference with Reclamation. Ramp elimination permits current recontouring, direct placing of topsoil, and uninterrupted revegetation. The surface haul roads are replaced by surface conveyors located outside the mined area.

5. Low Labor Dependence. Reduced requirements for truck drivers and mechanics favor conveyor systems in a labor-short market. This advantage is more pronounced where overburden trucks are not required as the need for truck maintenance shops and equipment can also be reduced or eliminated.

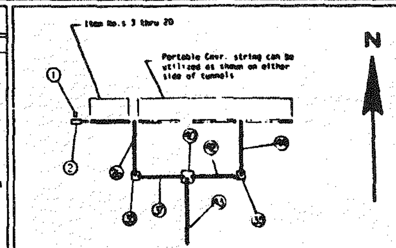
6. High Efficiency. Belt conveyors use less energy than trucks to do the same work.



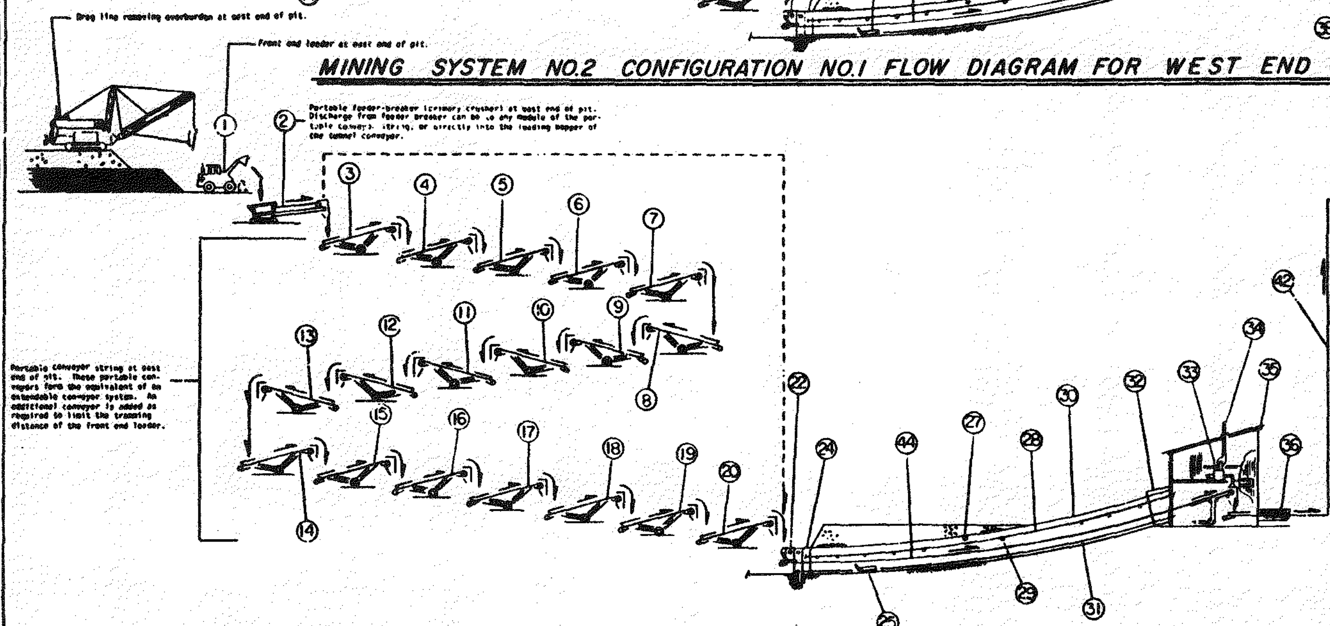
MINING SYSTEM NO.2 CONFIGURATION NO.1 FLOW DIAGRAM FOR WEST END OF PIT

EQUIPMENT LIST

ITEM	NO. REQ'D.	DESCRIPTION	ITEM	NO. REQ'D.	DESCRIPTION
1	1	Front End Loader	30	2	Concrete Tunnel
2	1	Portable Feeder-Breaker (Primary Crusher) w/60 Ton Hopper	31	2	Dewatering Pipe Line
3	1	60 HP Portable Cnvr. No. 1-1	32	2	Enclosed Cnvr. Gallery
4	1	60 HP Portable Cnvr. No. 1-2	33	2	9000 CFM Baghouse (As Req'd)
5	1	60 HP Portable Cnvr. No. 1-3	34	2	30 HP I.D. Fan for Dust Pickup @ Transfer Point
6	1	60 HP Portable Cnvr. No. 1-4	35	2	Transfer Bldg.
7	1	60 HP Portable Cnvr. No. 1-5	36	8	Rain Hood, Enclosing Carrying & Return Belt
8	1	60 HP Portable Cnvr. No. 1-6	37	1	350 HP, 42" W Fixed Overland Transfer Cnvr. No. 12
9	1	60 HP Portable Cnvr. No. 1-7	38	2	Motor Control Panel
10	1	60 HP Portable Cnvr. No. 1-8	39	2	Electrical Substation
11	1	60 HP Portable Cnvr. No. 1-9	40	1	Transfer Control Bldg.
12	1	60 HP Portable Cnvr. No. 1-10	41	1	30 HP, I.D. Fan for Dust Pickup @ Transfer Point
13	1	60 HP Portable Cnvr. No. 1-11	42	1	350 HP, 42" W Fixed Overland Transfer Cnvr. No. 13
14	1	60 HP Portable Cnvr. No. 1-12	43	1	900 HP, 42" Fixed Overland Crusher Feed Cnvr. No. 14
15	1	60 HP Portable Cnvr. No. 1-13	44	1	600 HP, 42" Extendable Incline Tunnel Cnvr No. 11C
16	1	60 HP Portable Cnvr. No. 1-14			
17	1	60 HP Portable Cnvr. No. 1-15			
18	1	60 HP Portable Cnvr. No. 1-16			
19	1	60 HP Portable Cnvr. No. 1-17			
20	1	60 HP Portable Cnvr. No. 1-18			
21	–	Not Used			
22	2 Sets	(5) Electric Heaters Totaling 135 KW			
23	–	Not Used			
24	As Req'd.	8 Ft. Lg. Extendable Tunnel Section			
25	2	Tunnel Maintenance Cart			
26	1	700 HP, 42" W Extendable Incline Tunnel Cnvr. No. 10C			
27	As Req'd.	Tunnel Lighting			
28	As Req'd.	Tunnel Water Washdown Piping Taps			
29	2 Sets	Tunnel Water Sprinkler System			



KEY PLAN

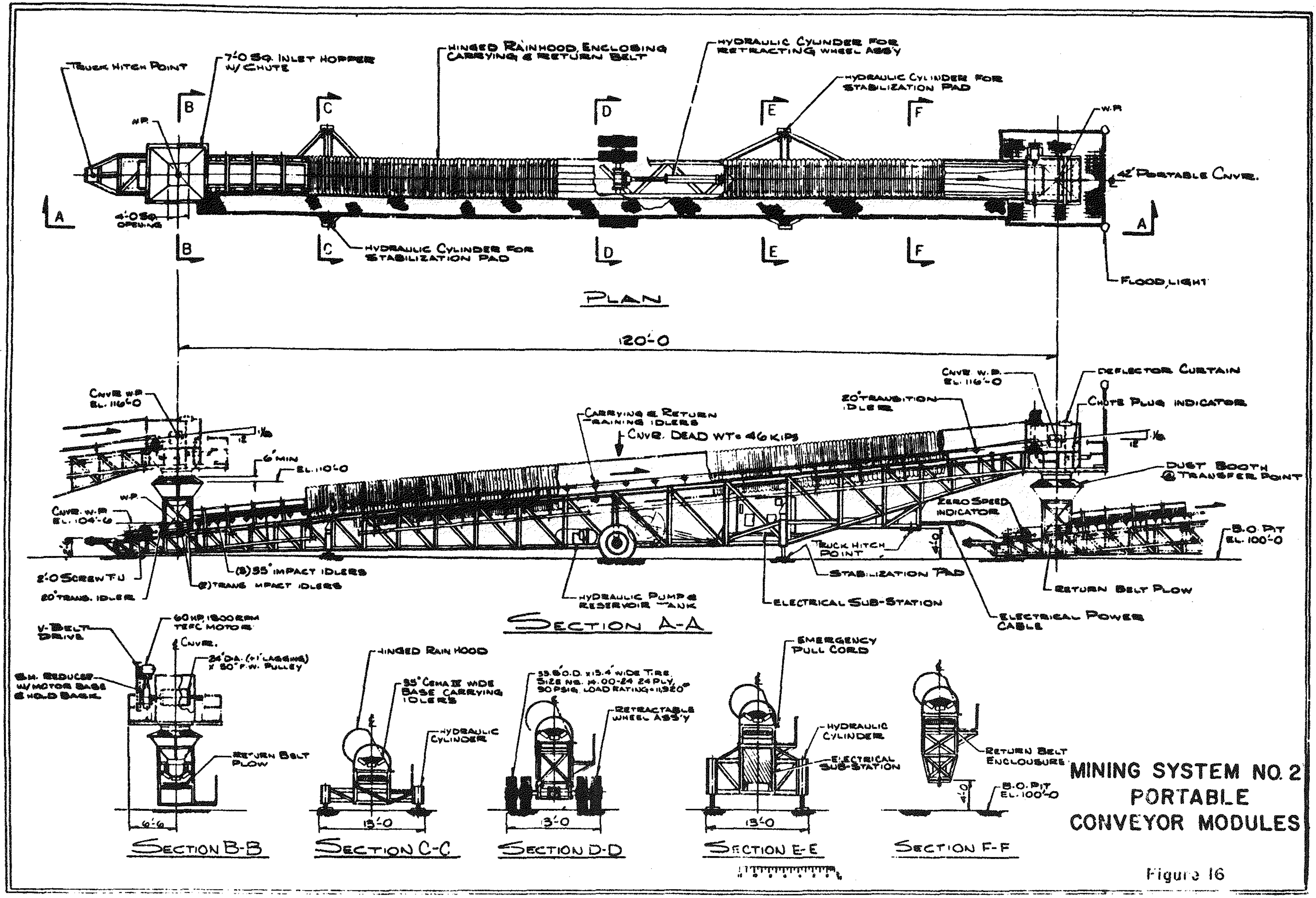


MINING SYSTEM NO.2 CONFIGURATION NO.4 FLOW DIAGRAM FOR EAST END OF PIT

Note:
For Plot Plan and Reference Drawings See DWG. 305-1Q

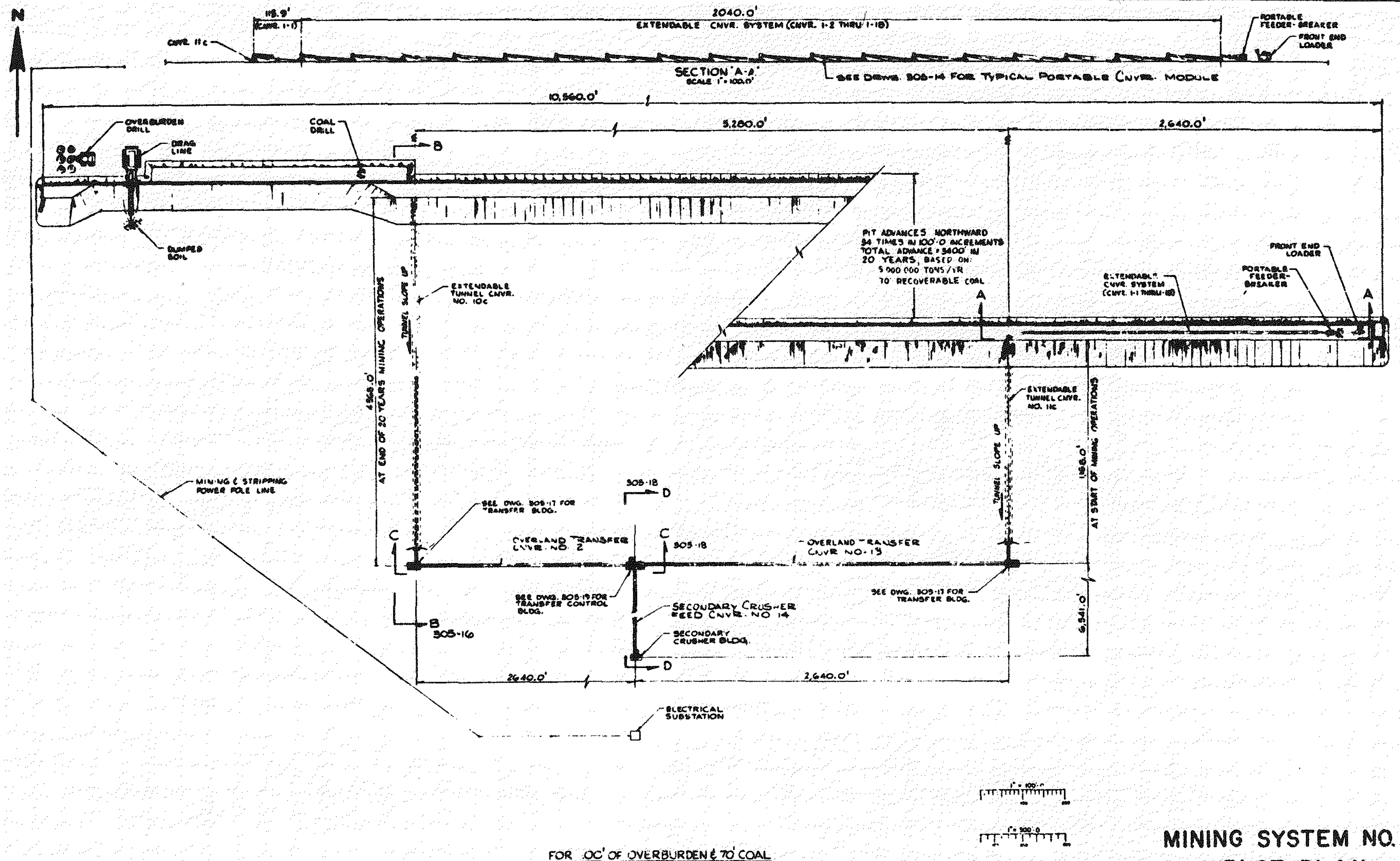
**MINING SYSTEM NO. 2
FLOW SHEET &
SCHEMATIC DIAGRAM**

Figure 15



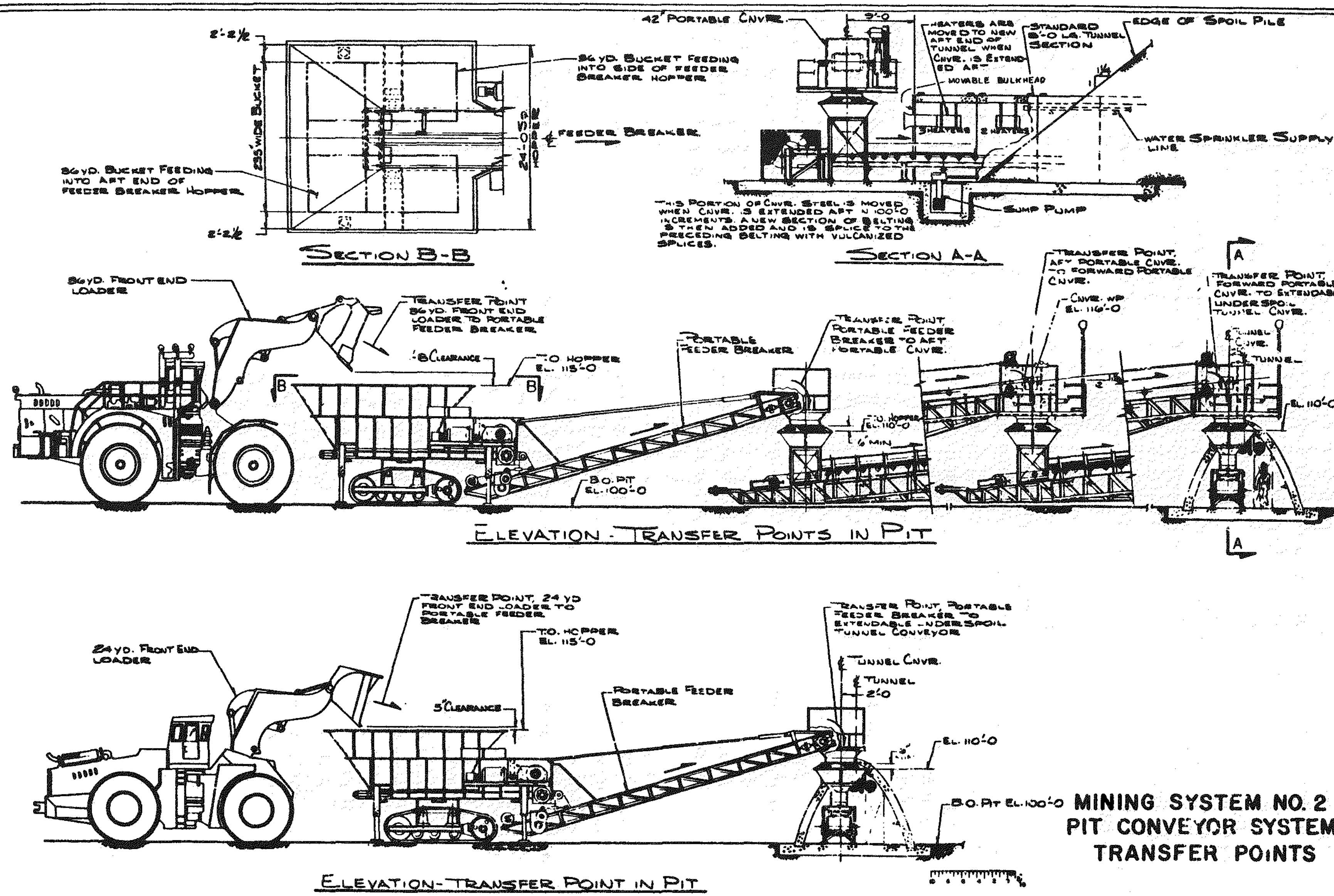
MINING SYSTEM NO. 2
PORTABLE
CONVEYOR MODULES

Figure 16



MINING SYSTEM NO. 2
PLOT PLAN

Figure 17



MINING SYSTEM NO. 2
PIT CONVEYOR SYSTEM
TRANSFER POINTS

Figure 18

Advantages of System No. 2 over other underspoil systems:

1. Flexibility. The portable pit conveyors are adaptable to curved pits and rolling floors. Moving to meet blending or lease holding requirements is easier than with shiftable conveyors.

2. Reliability. The interchangeable flights permit replacement with a spare unit, eliminating delays for repair.

3. No Interference with Dragline Casting. As the conveyor line advances behind the coal face, there is no requirement for space between the highwall and the spoils. Dragline operation is not effected.

4. Compatible with Pit Equipment. Portable conveyor units can be moved by any available equipment, whereas shiftable conveyors require special attachments.

5. Short Pit Conveyors. Portability permits one-half mile of conveyor to serve the full two-mile pit.

Some disadvantages of System No. 2 compared with truck haulage:

1. Limited Flexibility. Portable conveyors fall between trucks and shiftable conveyors in this regard.

2. Loading Inefficiency. The feeder-breaker is less maneuverable than trucks and thereby reduces loader productivity. The system is not well suited to shovel loading for this reason.

Comparisons of System No. 2 with other underspoil systems indicate the following:

1. Higher Power Requirements. Lifting and dropping with each flight requires more power than does a continuous conveyor belt.

2. Lower Availability. Separate flight motors and drives mean more exposure to breakdown. (This is partially offset by interchangeability of units).

3. Loading Inefficiency. Compared with the shiftable conveyor location, which is described for System No. 3, portable conveyors restrict loader movement and require more turning to dump.

Capital and operating costs for a complete mining operation under six combinations of overburden depth and coal thickness are summarized in Table 3. Initial capital costs for System No. 2 increase rapidly with deeper overburden, reflecting larger volumes of development stripping as well as more and heavier stripping equipment. Capital costs decrease slightly with thicker coal as the lower stripping ratio reduces initial investment in overburden excavators.

TABLE 3

CAPITAL AND OPERATING COSTS
System No. 2

Coal Thickness		30 Feet			70 Feet	
Overburden Depth	50 Feet	100 Feet	200 Feet	50 Feet	100 Feet	200 Feet
Total Initial Capital Cost	27,134,859	41,115,447	76,558,050	25,296,135	39,041,987	63,885,224
Operating Cost Per Ton of Coal						
1. Topsoil Removal	0.123	0.123	0.122	0.059	0.059	0.059
2. O.B. Drill & Blast	0.125	0.317	0.668	0.062	0.166	0.312
3. Overburden Removal	0.445	0.817	2.336	0.263	0.503	1.252
4. Coal Drill & Blast	0.097	0.102	0.101	0.099	0.097	0.101
5. Coal Loading	0.164	0.164	0.164	0.227	0.227	0.227
6. Coal Haulage	0.418	0.457	0.539	0.339	0.366	0.444
7. Misc. Pit & Oper.	0.033	0.033	0.033	0.033	0.033	0.033
8. Reclamation	0.143	0.143	0.085	0.059	0.062	0.050
9. General	0.034	0.034	0.034	0.034	0.034	0.034
10. Supervisory	0.213	0.213	0.213	0.213	0.213	0.213
Depreciation and I.T.I. on Capital Costs	0.151	0.273	0.495	0.188	0.348	0.589
Administration	0.195	0.267	0.479	0.158	0.211	0.331
TOTAL DIRECT COST	2.141	2.943	5.269	1.734	2.319	3.645

Several trends are noteworthy in the operating costs per ton of coal:

1. Overburden removal costs are the same as for System No. 1 except with 200-foot depth where truck haulage is included. The unit cost in this case is somewhat lower for System No. 2 as underspoil coal haulage eliminates the ramps which interfere with overburden haulage.

2. Coal loading costs by front-end loaders remain essentially the same for all systems. Unit costs are higher for 70-foot seams than for 30-foot seams because dozers are included for pushing the upper coal down.

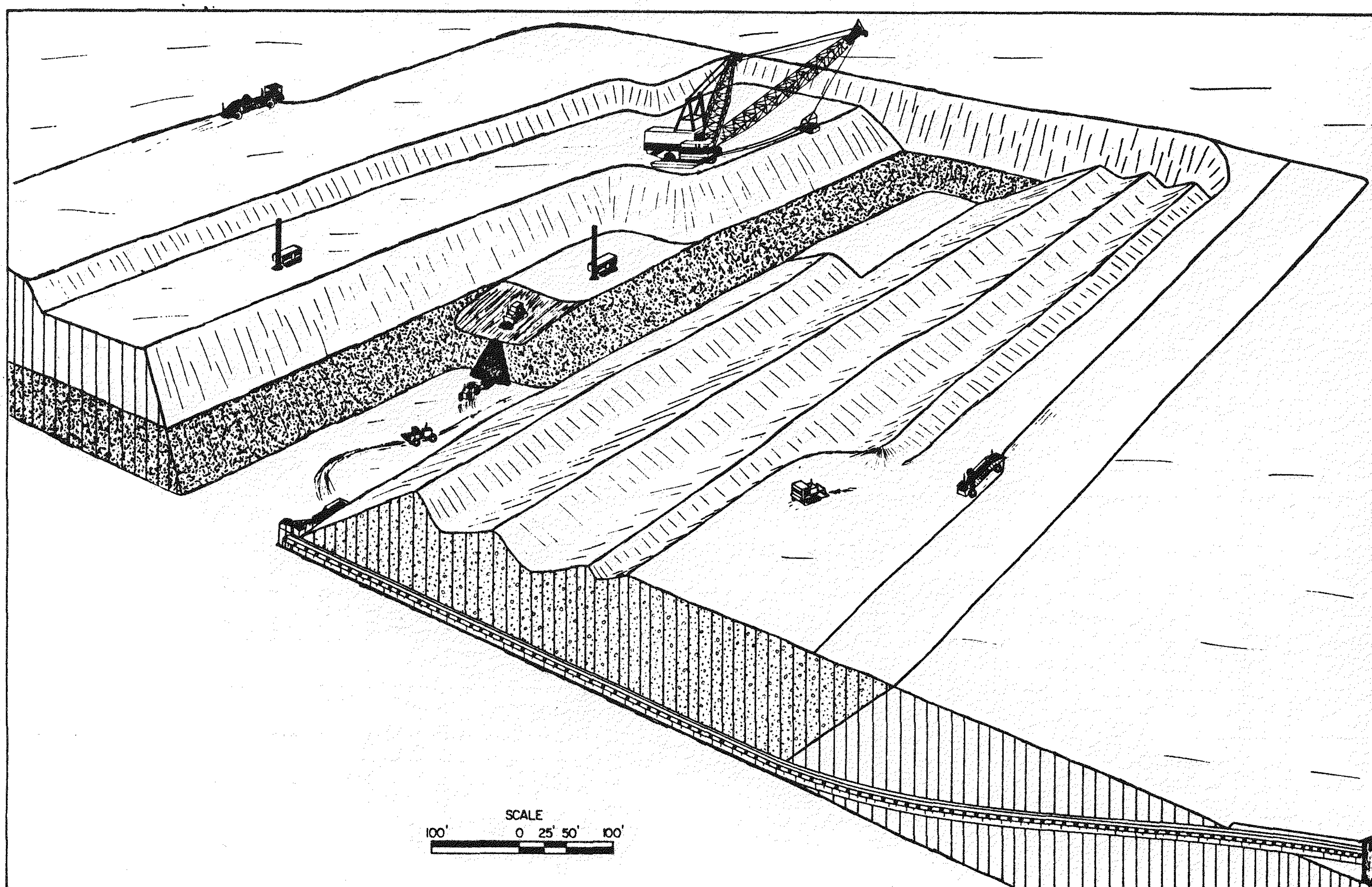
3. Coal haulage costs increase with pit depth but the rate of increase for conveyors is less than for trucks. As a result conveyor and truck haulage costs are approximately equal for 50-foot overburden whereas conveyor haulage becomes progressively less than truck haulage for 100 and 200-foot overburden. Conveyor coal haulage costs are lower for System No. 2 than for any other conveyor system, except No. 2A, for which in-pit haulage by tramming is included in coal loading costs (Appendix 3.1.4).

3.1.4.4 System No. 2A

System No. 2A is the simplest of the underspoil systems studied, as no pit conveyors are used. The layout is shown in Figure 7. Coal is trammed by front-end loaders from the face to the feeder breaker located at the underspoil tunnel portal with the underspoil and surface conveyor systems remaining unchanged. Two load-tram methods were evaluated in an effort to minimize pit costs and congestion. As neither proved feasible, only the concept and conclusions are described here in. The detailed study is included in the Appendix 3.1.4 under System No. 2A.

Short-face and long-face loading methods were investigated. Short-face involves loading from the conventional 100-foot face normal to the pit as shown in Figure 19. This method is common to all the systems studied. As the tram distance increases up to one-half mile, the required number of loaders increases to maintain constant production. Assuming congestion problems could be overcome, this number would range from two to nine 24 cubic yard loaders. This impractical situation suggested the alternative by which loaders would work a one-half mile long-face parallel to the pit. By relating face length and haul distance, each loader could be assigned an area so that the number of loaders would remain constant. The number of units is thereby reduced to six.

The only feasible application of this concept would appear to be replacement of the front-end loaders with scrapers or load-haul-dump units which would discharge into a feeder-breaker and conveyor system located below pit level. Such an operation could be compatible with the trench and tunnel



UNDERSPOIL HAULAGE SYSTEM NO. 2A

Figure 19

alternatives discussed in Section 3.1.5. Under those conditions the advantages of a simplified conveyor system, the flexibility of truck haulage, and the elimination of baul ramps could be combined.

Capital and operating costs for a complete mining operation under six combinations of overburden depth and coal thickness are summarized in Table 4. Initial capital costs for System No. 2A increase rapidly with deeper overburden, reflecting larger volumes of development stripping as well as more and heavier stripping equipment. Capital costs decrease slightly with thicker coal as the lower stripping ratio reduces initial investment in overburden excavators (Appendix 3.1.4).

Several trends are noteworthy in the operating costs per ton of coal:

1. Overburden removal costs are identical to System No. 2.

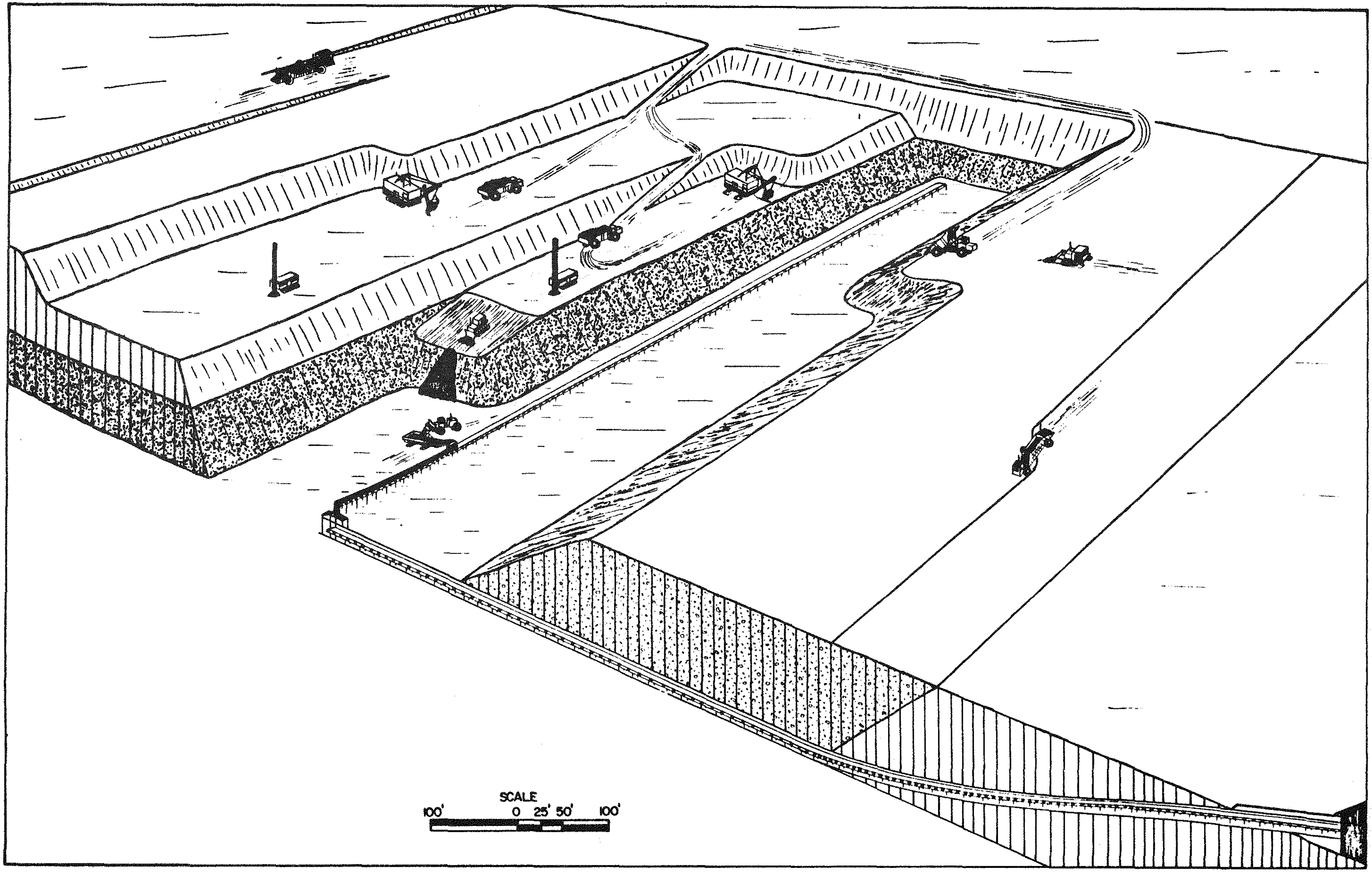
2. Coal loading costs are excessively high due to including the tramming costs from the coal face to the underspoil conveyor.

3. Coal haulage costs are relatively low as they do not include in-pit haulage.

3.1.4.5 System No. 3

System No. 3 combines underspoil haulage with shiftable pit conveyors. Four one-half mile long belt conveyors extend the full length of the pit as shown on Figure 20. Loading is similar to that in System No. 2 except that the feeder-breaker discharges into a travelling hopper mounted over the shiftable conveyor. As this conveyor occupies space between the highwall and the spoil toe, casting of overburden by a dragline or stripping shovel would be limited to the volume which could be cast clear of the conveyor land. A minimum 60-foot width is considered necessary to allow room for shifting and to avoid damage to the conveyor from blasting or slides. To investigate the cost trade-off between relatively inefficient casting with resultant limited conveyor space versus hauling overburden, this system is based upon all overburden being shovel loaded and truck hauled. With overburden casting out of consideration there is no cost premium for extra conveyor space other than the additional spoil disposal from a wider initial box cut.

Shiftable conveyors are proving adaptable to a variety of mining conditions, materials, and tonnages. For this application, each of the four individual conveyors is shifted laterally after mining the adjacent coal. Overburden is then dumped to advance the spoil over the area previously occupied by the conveyor. Shifting is accomplished in a series of steps, each 4 to 6 feet laterally, or total of 16 to 25 steps in a 100-foot wide cut. A rail and tie system supports the conveyor. Shifting is performed by a tractor mounting a roller head which engages the conveyor rail. This mechanism lists the conveyor to reduce ground friction while the tractor moves parallel to the "conveyor", snaking it over, one step at a pass.



UNDERSPOIL HAULAGE SYSTEM NO. 3

Figure 20

TABLE 4

CAPITAL AND OPERATING COSTS
System No. 2A

Coal Thickness		30 Feet			70 Feet	
Overburden Depth	50 Feet	100 Feet	200 Feet	50 Feet	100 Feet	200 Feet
Total Initial Capital Cost	28,932,936	41,263,898	77,634,705	25,969,394	36,972,781	67,887,426
Operating Cost Per Ton						
1. Topsoil Removal	0.123	0.123	0.122	0.059	0.059	0.059
2. O.B. Drill & Blast	0.125	0.317	0.668	0.062	0.166	0.312
3. Overburden Removal	0.445	0.817	2.336	0.263	0.503	1.252
4. Coal Drill & Blast	0.097	0.102	0.101	0.099	0.097	0.101
5. Coal Loading	0.478	0.478	0.510	0.538	0.537	0.537
6. Coal Haulage	0.389	0.428	0.509	0.309	0.336	0.414
7. Misc. Pit & Oper.	0.033	0.033	0.033	0.033	0.033	0.033
8. Reclamation	0.143	0.143	0.085	0.059	0.062	0.050
9. General	0.034	0.034	0.034	0.034	0.034	0.034
10. Supervisory	0.213	0.213	0.213	0.213	0.213	0.213
Depreciation and I.T.I. on Capital Costs	0.148	0.233	0.473	0.161	0.266	0.634
Administration	0.223	0.292	0.508	0.183	0.231	0.364
TOTAL DIRECT COST	2.451	3.213	5.592	2.013	2.537	4.003

Head and tail pulley sections are usually pontoon-mounted and are moved laterally by separate equipment, concurrently with the shifting operation. Shifting of a one-half mile section under favorable conditions would probably require two shifts with an additional shift at each end for preparation and reconnection to the underspoil system.

An important operational feature of the full length shiftable conveyor system is that, when not actually being shifted, it provides haulage from any part of the pit. The two interior conveyors are reversible which permits bypassing the nearest underspoil system if it should be inoperative.

The advantages over truck haulage are the same as those listed for System No. 2. By comparison with other underspoil systems, the following apply:

1. No Interference with Coal Loading. The conveyor location simplifies loading and reduces congestion at the face as compared with System No. 2. Shifting is accomplished in an area separate from coal loading.

2. Safety. By eliminating overburden casting, ample space can be provided for pit traffic. Protection of the conveyor against overhead casting or spoil slides is unnecessary. This advantage must be balanced against stripping costs which may increase with elimination of the dragline.

3. Redundancy. By reversing interior pit conveyors, coal haulage can bypass an inoperational tunnel.

The disadvantages compared to truck haulage are the same as those listed for System No. 2. By comparison with other underspoil systems, the following apply:

1. Long Pit Conveyors. Conveyors must extend throughout the pit as they are designed to shift laterally but not longitudinally. Note: Recently developed cable-supported conveyors can be shifted by dragging longitudinally in an "S" pattern. When proven, this system could be advantageous in strip coal mines.

2. Exposure to Damage. The shiftable conveyors extending the full length of the pit increase the possibility of damage due to blasting, slides, and other hazards. (Rolling rocks from the spoil face can be controlled by the "buck wall" normally placed at the spoil toe).

3. Special Shifting Equipment. The tractor with shifting head attachment is required whereas portable conveyors can be moved by standard dozers or loaders.

4. Limited Pit Layout. The pit must be straight with the possible exception of bends at the intersection of conveyor sections.

5. Smooth Floor Requirements. The pit floor must be relatively level and smooth to permit shifting.

Capital and operating costs for a complete mining operation under six combinations of overburden depth and coal thickness are summarized in Table 5. Initial capital costs for System No. 3 increase with deeper overburden, reflecting larger volumes of development stripping as well as more and heavier stripping equipment. Capital costs decrease slightly with thicker coal as the lower stripping ratio reduces initial investment in overburden excavators (Appendix 3.1.4).

Several trends are noteworthy in the operating costs per ton of coal:

1. Overburden removal costs are based on truck-shovel operations and are higher than corresponding dragline stripping costs. For example the unit cost of $0.58 per ton of coal ($0.38 per cubic yard of overburden) compares with $0.45 ($0.29) by dragline.

2. Coal haulage costs are considerably higher than by truck for 50-foot overburden but are approximately equal for 200-foot overburden. In general all coal haulage costs drop with increasing coal thickness due to shorter average haul distance with thicker coal.

3.1.4.6 System No. 3A

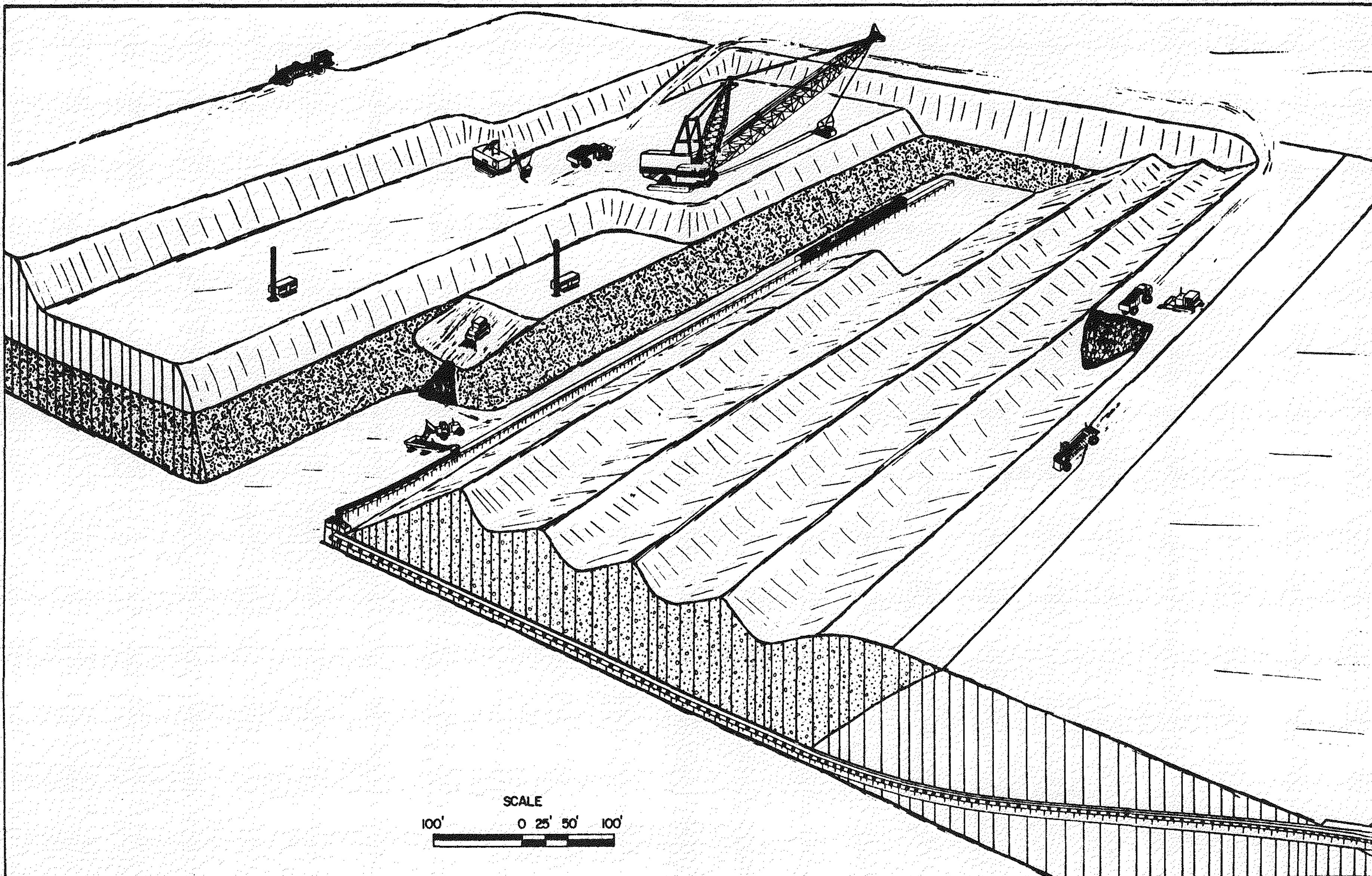
System No. 3A is a modification of System No. 3 which retains dragline stripping of overburden. The layout is shown in Figure 21. A 60-foot wide lane along the highwall toe is left clear for the shiftable conveyor. As the dragline casts directly over the conveyor, a protective cover is necessary to prevent damage from spillage. Considering the probability of an occasional large rock falling 100 feet or more from the dragline bucket, and extremely heavy structure is required for positive protection. Assuming precast concrete arch sections are used for underspoil tunnel support, they would probably be the most easily available and satisfactory means of protection. The cost estimates for this system include 10 eight-foot arch sections which rest on the pit floor, straddling the pit conveyor. They form a movable shed which can be leapfrogged forward by the dragline as stripping progresses. The embedded lifting eyes in each arch section permit quick handling. The elevated end sections of the pit conveyors are protected by structural steel canopies as tunnel sections do not provide adequate vertical clearance.

The layout and operation of the shiftable pit conveyors are identical to those for System No. 3. However, the restrictions on pit floor width to permit effective dragline operation may make this system impractical. The spoil at a specific site will largely determine the feasibility of combining dragline stripping with full-length shiftable conveyors.

TABLE 5

CAPITAL AND OPERATING COSTS
System No. 3

Coal Thickness		30 Feet			70 Feet	
Overburden Depth	50 Feet	100 Feet	200 Feet	50 Feet	100 Feet	200 Feet
Total Initial Capital Cost	29,891,719	43,582,144	75,979,443	28,412,955	42,289,016	57,225,689
Operating Cost Per Ton of Coal						
1. Topsoil Removal	0.122	0.122	0.122	0.056	0.059	0.058
2. O.B. Drill & Blast	0.124	0.318	0.669	0.064	0.167	0.312
3. Overburden Removal	0.579	1.213	2.617	0.341	0.673	1.217
4. Coal Drill & Blast	0.097	0.102	0.102	0.099	0.097	0.101
5. Coal Loading	0.164	0.164	0.164	0.230	0.230	0.227
6. Coal Haulage	0.510	0.549	0.631	0.428	0.459	0.526
7. Misc. Pit & Oper.	0.045	0.045	0.045	0.045	0.045	0.045
8. Reclamation	0.067	0.085	0.085	0.044	0.044	0.050
9. General	0.034	0.034	0.034	0.034	0.034	0.034
10. Supervisory	0.213	0.213	0.213	0.213	0.213	0.213
Depreciation and I.T.I. on Capital Costs	0.170	0.286	0.601	0.204	0.353	0.651
Administration	0.213	0.313	0.508	0.176	0.237	0.343
TOTAL DIRECT COST	2.338	3.444	5.811	1.934	2.611	3.777



UNDERSPOIL HAULAGE SYSTEM NO. 3A

Figure 21

The advantages over truck haulage are the same as those for Systems No. 2 and 3. By comparison with other underspoil systems, the following apply:

1. Utilizes Dragline Stripping. This advantage is limited to relatively shallow overburden as casting over the pit conveyors is inefficient and the volume which can be excavated without rehandling is restricted by the conveyors.

2. Redundancy. By reversing interior pit conveyors, coal haulage can bypass an inoperational tunnel.

The disadvantages compared to truck haulage are the same as those listed for System No. 2. By comparison with other underspoil systems, the following apply:

1. Long Pit Conveyors. Conveyors must extend throughout the pit as they shift laterally.

2. Exposure to Damage. This disadvantage is more pronounced than in System No. 3 because the conveyors are crowded between the highwall and the spoil to permit dragline casting.

Capital and operating costs for a complete mining operation under six combinations of overburden depth and coal thickness are summarized in Table 6. Initial capital costs for System No. 3A increase rapidly with deeper overburden, reflecting larger volumes of development stripping as well as more and heavier stripping equipment. Capital costs decrease slightly with thicker coal as the lower stripping ratio reduces initial investment in overburden excavators (Appendix 3.1.4).

Several trends are noteworthy in the operating costs per ton of coal:

1. Overburden removal by dragline casting is lower in cost than shovel/truck excavation (System No. 3) for 50-foot overburden. However, at 100 and 200-foot depths dragline excavation loses its advantage because of the interference caused by the pit conveyors.

2. Coal loading costs by front-end loaders remain essentially the same for all systems and all overburden depths.

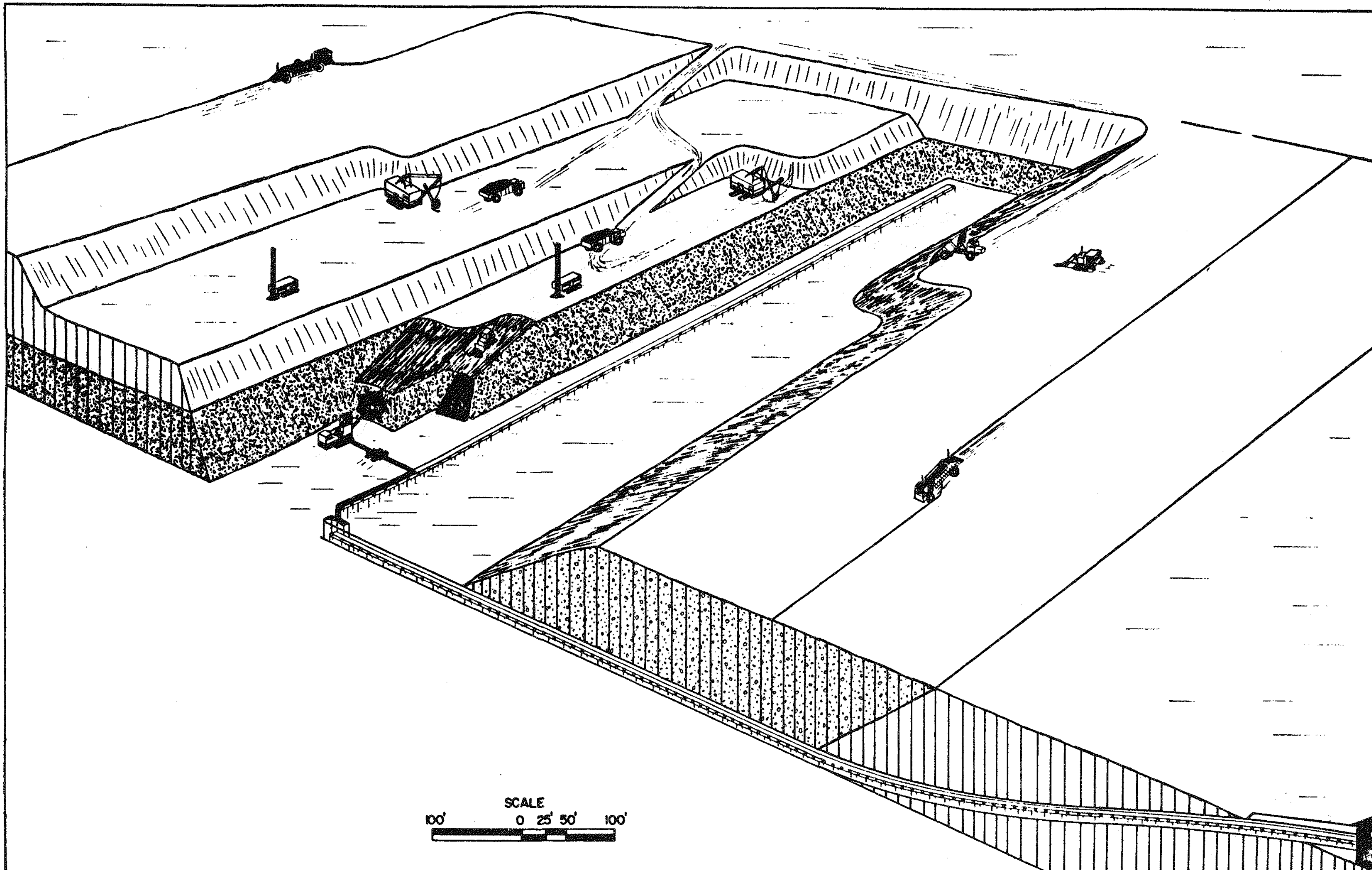
3.1.4.7 System No. 4

System No. 4 incorporates underspoil haulage with continuous loading by bucket wheel excavator. The layout is shown in Figure 22. Note that the feeder-breaker is eliminated because of heavier blasting of the coal, and the conveyor system and method of overburden excavation are identical to those for System No. 3. As all overburden is moved by scraper or truck rather than by dragline, ample space is available for the shiftable conveyors.

TABLE 6

CAPITAL OPERATING COSTS
System No. 3A

Coal Thickness		30 Feet			70 Feet	
Overburden Depth	50 Feet	100 Feet	200 Feet	50 Feet	100 Feet	200 Feet
Total Initial Capital Cost	32,608,590	56,193,201	88,254,171	33,128,815	47,579,446	64,288,983
Operating Cost Per Ton of Coal						
1. Topsoil Removal	0.124	0.124	0.122	0.057	0.058	0.058
2. O.B. Drill & Blast	0.125	0.318	0.669	0.063	0.166	0.312
3. Overburden Removal	0.500	1.322	2.631	0.402	0.843	1.906
4. Coal Drill & Blast	0.097	0.102	0.102	0.099	0.096	0.101
5. Coal Loading	0.164	0.164	0.164	0.227	0.227	0.227
6. Coal Haulage	0.514	0.553	0.633	0.434	0.460	0.528
7. Misc. Pit & Oper.	0.045	0.045	0.045	0.045	0.045	0.045
8. Reclamation	0.143	0.143	0.085	0.091	0.050	0.050
9. General	0.034	0.034	0.034	0.034	0.034	0.034
10. Supervisory	0.213	0.213	0.213	0.213	0.213	0.213
Depreciation and I.T.I. on Capital Costs	0.170	0.294	0.636	0.223	0.405	0.688
Administration	0.213	0.331	0.533	0.189	0.260	0.335
TOTAL DIRECT COST	2.342	3.643	5.867	2.077	2.857	3.687



UNDERSPOIL HAULAGE SYSTEM NO. 4

Figure 22

Bucket wheel excavators are relatively unproven in the U. S.; however, their potential for efficient coal loading combined with a conveyor haulage system appears promising. The relatively thick, level coal seams which predominate in the western coal fields offer ideal conditions for this combination. In comparing bucket wheel excavator systems with more conventional loading systems, a conservative availability of 40% was used. This factor allows for both the complex mechanical nature of the machine and its relative "newness" in the U. S. coal industry. The excavator was sized to compensate for this low availability, resulting in a theoretical loading capacity which considerably exceeds that of the conveyor system. To avoid the cost of a higher capacity conveyor system and increased storage facilities, a back-up front-end loader was included in the cost estimates. It is assumed that the heavier blasting required for BWE loading will provide beltable coal on a temporary basis, if some sorting is done by the front-end loader.

The net effect of these assumptions may place an unreasonable cost burden on System No. 4 and 4A. However, a more definitive comparison with proven loading systems would necessitate reliable productivity and cost data not now available.

The advantages over truck haulage are the same as those listed for System No. 2. Two possible loading advantages are that bucket wheel excavators are physically smaller and have a lower instantaneous power demand than shovels of the same capacity. By comparison with other underspoil systems, the following apply:

1. Feeder-Breaker Eliminated. The bucket wheel excavator breaks and feeds satisfactorily for belt conveyor haulage.

2. Continuous Feed. By eliminating surges a slightly higher belt loading may be realized.

3. Safety. Pit congestion is reduced by replacing two front-end loaders and a feeder-breaker with a single machine.

The disadvantages compared to truck haulage are the same as those listed for System No. 2. By comparison with other underspoil systems, the following apply:

1. Low Availability. Current U. S. experience indicates considerable lost time due to mechanical failure (possibly operator or maintenance related).

2. System Incompatibility. Oversizing the BWE to compensate for downtime necessitates larger conveyor system capacity. Back-up loaders to fill in during down time present a coal sizing problem if a feeder-breaker is not available.

3. Heavier Blasting. Better breakage is considered necessary for loading by bucket wheel excavator than by shovel or front-end loader, increasing drill and blast costs.

4. Less Flexibility. Mobility is low by comparison with front-end loaders. (Mobility of all loaders may be limited by the pit conveyor system).

The above disadvantages apply equally to comparisons with other underspoil systems. The short-comings of shiftable conveyors relative to extendible conveyors were described under System No. 3.

Capital and operating costs for a complete mining operation under six combinations of overburden depth and coal thickness are summarized in Table 7. Initial capital costs for System No. 4 increase rapidly with deeper overburden, reflecting larger volumes of development stripping as well as more and heavier stripping equipment. Capital costs decrease slightly with thicker coal as the lower stripping ratio reduces initial investment in overburden excavators (see Appendix 3.1.4).

Several trends are noteworthy in the operating costs per ton of coal:

1. Coal drill and bast costs are slightly higher, reflecting a higher powder factor for bucket wheel excavation.

2. Coal loading costs are approximately the same as those by front-end loaders with feeder breaker. For both methods, unit costs increase for the 70-foot coal thickness due to tractor work pushing down the upper coal.

3.1.4.8 System No. 4A

System No. 4A is a modification of System No. 4 which combines bucket wheel excavators, underspoil haulage, and dragline stripping of overburden. The layout is shown in Figure 23. As in System No. 3A, the shiftable pit conveyors are located at the base of the highwall and are protected from dragline spillage by moveable arch sections. The layout and operation of the pit conveyors are identical to those for System No. 4.

The advantages over truck haulage are the same as those for other underspoil haulage systems. By comparison with other underspoil systems, the following apply:

1. Utilizes Dragline Stripping. This advantage is limited to relatively shallow overburden, as casting over the pit conveyors is inefficient and the volume which can be excavated without rehandling is restricted by the conveyors.

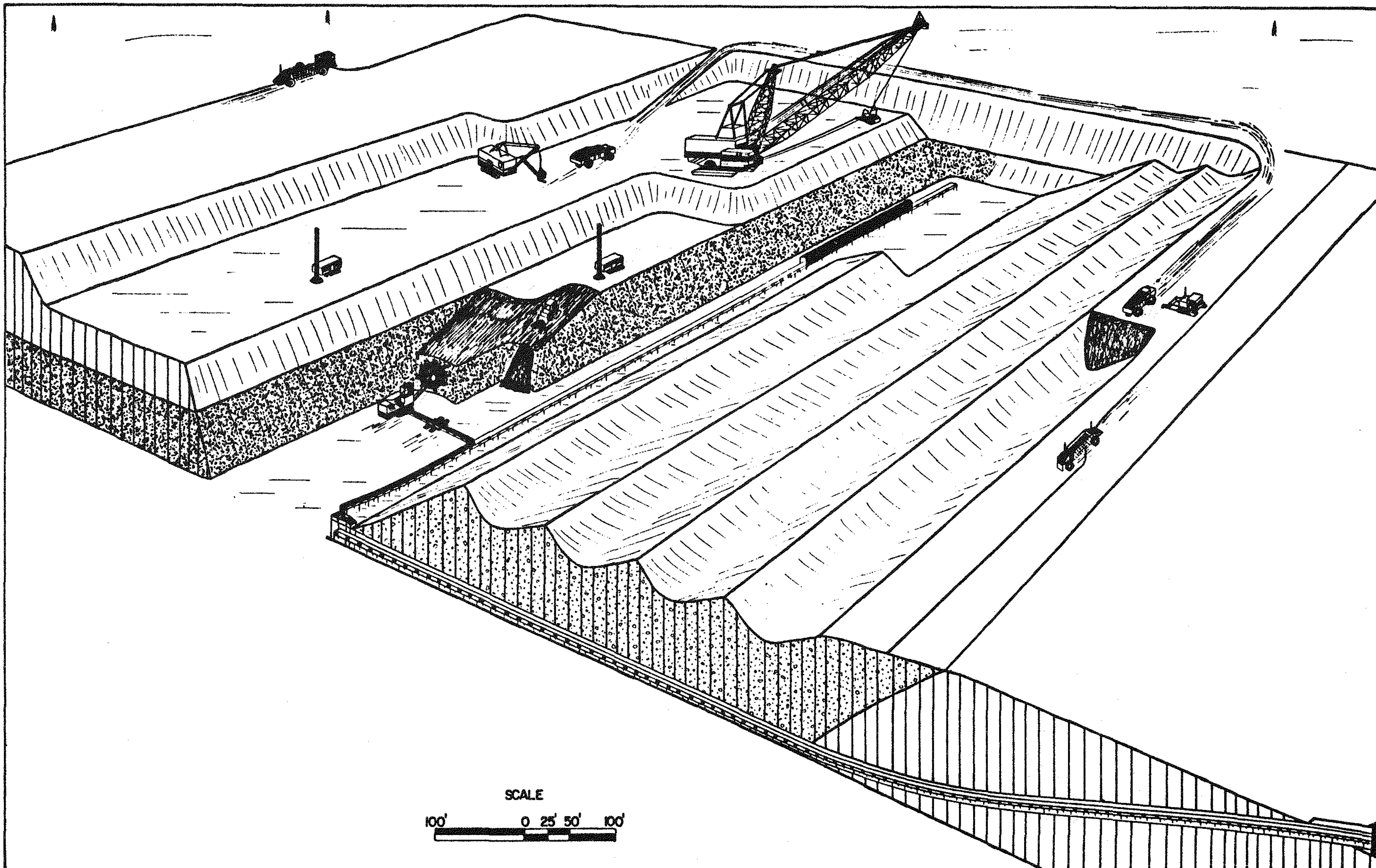
2. Redundancy. By reversing interior pit conveyors, coal haulage can bypass an inoperative tunnel.

The disadvantages compared to truck haulage are the same as those listed for System No. 2. By comparions with other underspoil systems, the following apply:

TABLE 7

CAPITAL AND OPERATING COSTS
System No. 4

Coal Thickness	30 Feet			70 Feet		
Overburden Depth	50 Feet	100 Feet	200 Feet	50 Feet	100 Feet	200 Feet
Total Initial Capital Cost	31,384,552	45,078,097	77,421,646	31,232,672	43,692,352	65,043,854
Operating Cost Per Ton of Coal						
1. Topsoil Removal	0.122	0.123	0.123	0.059	0.059	0.059
2. O.B. Drill & Blast	0.125	0.317	0.668	0.063	0.167	0.312
3. Overburden Removal	0.580	1.214	2.618	0.344	0.676	1.218
4. Coal Drill & Blast	0.111	0.116	0.116	0.109	0.106	0.111
5. Coal Loading	0.156	0.156	0.156	0.214	0.214	0.214
6. Coal Haulage	0.499	0.537	0.619	0.419	0.447	0.513
7. Misc. Pit & Oper.	0.048	0.048	0.048	0.048	0.048	0.048
8. Reclamation	0.067	0.085	0.085	0.050	0.050	0.050
9. General	0.034	0.034	0.034	0.034	0.034	0.034
10. Supervisory	0.213	0.213	0.213	0.213	0.213	0.213
Depreciation and I.T.I. on Capital Costs	0.171	0.287	0.603	0.208	0.353	0.658
Administration	0.213	0.313	0.528	0.176	0.237	0.343
TOTAL DIRECT COST	2.339	3.443	5.811	1.937	2.604	3.773



UNDERSPOIL HAULAGE SYSTEM NO. 4A

Figure 23

1. Long Pit Conveyors. Conveyors must extend throughout the pit as they shift laterally.

2. Exposure to Damage. This disadvantage is more pronounced than in Systems No. 3 and 4 because the conveyors are crowded between the highwall and the spoil to permit dragline casting.

Capital and operating costs for a complete mining operation under six combinations of overburden depth, and coal thickness are summarized in Table 8. Initial capital costs for System No. 4A increases rapidly with deeper overburden reflecting larger volumes of development stripping as well as more and heavier stripping equipment. Capital costs decrease slightly with thicker coal as the lower stripping ratio reduces initial investment in overburden excavators.

Operating costs per ton of coal for Systems No. 4 and 4A bear the same general relationship as those for Systems 3 and 3A (Appendix 3.1.4).

3.1.4.9 System No. 5

System No. 5 is an addendum to the earlier studies and the seven systems described above. It was observed that the application of the underspoil haulage concept could be broadened to include truck and shovel haul-around open pitting. Some of the criteria and results do not exactly parallel the other systems but conceptual comparisons can be made. A full description of System No. 5 is contained in Section 3.2.3 and an economic comparison is included in Section 3.1.6.

Truck and shovel haul-around open pit mines are designed to be shorter in pit length than are dragline strip mines. The reason for this is to make cause the truck haul distance as short as possible. With this short pit length it is often necessary to divide the property into two or more pit wide advances. Rather than mining one panel then returning to the starting boundary for the second advance, system five proposes to turn the direction of advance around 180° at the property boundary and mine the adjacent panel on the return, Figure 24.

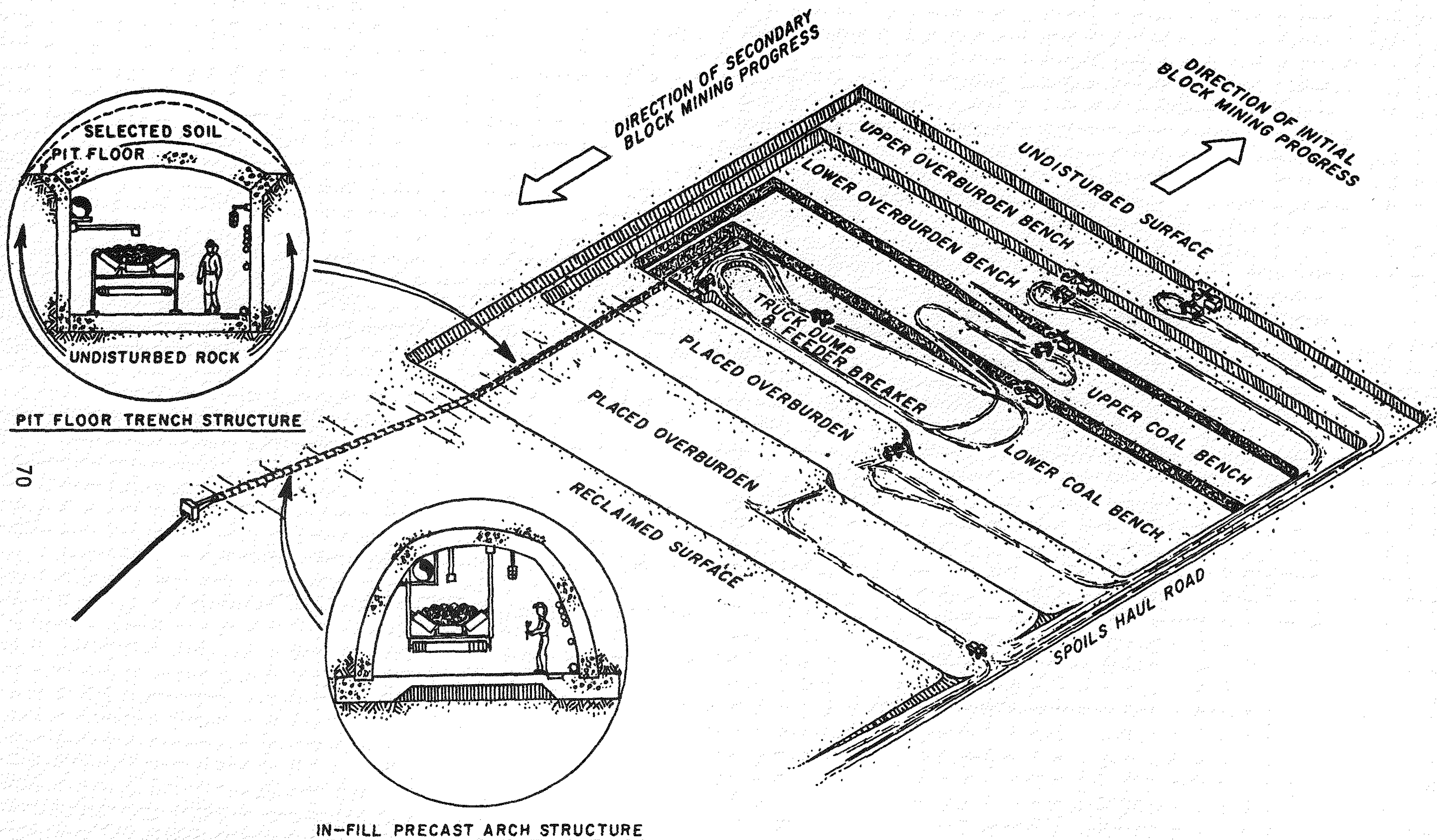
The conceptual application envisioned in Figure 24 has two overburden benches being stripped, while spoiling and reclamation advance at the same rate as coal mining. Because of the shorter pit length and wide pit floor, a single belt is proposed to be installed in an underspoil tunnel maintained near the end highwall. This location will allow re-excavation of the tunnel for access on the return mining of the adjacent panel.

Two different tunnel structures are illustrated in this section on Figure 24 to serve under different conditions. The in-fill inclined portion uses a precast concrete arch set on a poured in-place concrete invert. For the pit floor segment, it is proposed that a trench installation be used, not

TABLE 8

CAPITAL OPERATING COSTS
System No. 4A

Coal Thickness	30 Feet			70 Feet		
Overburden Depth	50 Feet	100 Feet	200 Feet	50 Feet	100 Feet	200 Feet
Total Initial Capital Cost	33,930,030	57,535,091	89,749,368	34,372,416	48,983,955	65,672,436
Operating Cost Per Ton of Coal						
1. Topsoil Removal	0.123	0.123	0.123	0.059	0.059	0.059
2. O.B. Drill & Blast	0.125	0.317	0.668	0.063	0.167	0.312
3. Overburden Removal	0.500	1.323	2.632	0.402	0.843	1.096
4. Coal Drill & Blast	0.111	0.116	0.116	0.109	0.111	0.111
5. Coal Loading	0.156	0.156	0.156	0.214	0.214	0.214
6. Coal Haulage	0.500	0.539	0.621	0.420	0.448	0.516
7. Misc. Pit & Oper.	0.048	0.048	0.048	0.048	0.048	0.048
8. Reclamation	0.143	0.143	0.085	0.091	0.050	0.050
9. General	0.034	0.034	0.034	0.034	0.034	0.034
10. Supervisory	0.213	0.213	0.213	0.213	0.213	0.213
Depreciation and I.T.I. on Capital Costs	0.171	0.295	0.637	0.221	0.407	0.690
Administration	0.212	0.331	0.533	0.187	0.259	0.334
TOTAL DIRECT COST	2.336	3.638	5.866	2.061	2.853	3.677



SYSTEM 5 – TRUCK AND SHOVEL HAUL-AROUND AND UNDERSPOIL HAULAGE

Figure 24

only to facilitate re-excavation but to also take advantage of the in-place rock strength in supporting the structure.

Coal is hauled from the two benches to the underspoil conveyor loading point by end-dump trucks. In-pit conveyors, however, would probably serve this function much more efficiently.

Some advantages of System No. 5 over truck haulage are:

1. Transport efficiency is greater as only coal is being elevated by a conveyor system, whereas both coal and truck weight is being elevated by truck haulage.

2. Manpower requirements will be less.

3. Capital costs prorated over large tonnages will be less.

4. Environmental impacts will be smaller and reclamation activitiess will be able to progress at a more uniform rate.

5. Safety to personnel and equipment will be greater.

Advantages of System No. 5 over other conveyor systems are:

1. Adaptable to a variety of pit designs and conditions.

2. Capital expenditure will be less as larger tonnages can be handled through a single tunnel.

Disadvantages of System No. 5 might be:

1. Higher initial capital cost.

2. Less flexibility when compared with truck haulage.

3. The single conveyor will not have the redundancy of the two conveyor systems.

4. A long term commitment to mine plans must be made to optimize efficiency.

Capital and operating costs were estimated for System No. 5 using an overburden thickness of 100 feet and a coal thickness of 70 feet. Table 9 lists these costs based on a production rate of 25,000,000 tons per year for a life of 14 years.

TABLE 9

ESTIMATED OPERATING COST OF UNDERSPOIL HAULAGE SYSTEM
System No. 5

Power (operating at full length)	$ 96.00 per hour
Labor	75.00
Materials and Supplies	10.00
Total	$181.00 per hour
Operating Cost Per Ton of Coal (6,000 ton/hour)	0.030 per ton
Annual Maintenance (10% of capital cost)	887,374
Maintenance Cost Per Ton (25,000,000 ton/year)	0.035 per ton
Replacement Feeder Breakers	700,000
Replacement Cost Per Ton	0.004 per ton

SUMMARY OF COST ON PER TON BASIS

Operating	$ 0.030 per ton
Maintenance	$ 0.035
Replacement (7th year)	$ 0.004
Ownership (14 years)	$ 0.048
Total	$ 0.117 per ton

3.1.5 Secondary Studies

3.1.5.1 General

The following secondary studies related to underspoil haulage are included in this report:

1. An evaluation of culvert/conveyor systems for application to multiple coal seams and to thin coal seams.

2. A cost trade-off analysis of underspoil tunnels and covered trenches excavated in rock below the pit floor in lieu of culvert-type installations on the pit floor.

3.1.5.2 Multiple and Thin Seam Applications

The basic disadvantage of conventional belt conveyor systems as compared with truck haulage is lack of flexibility. This disadvantage, in terms of horizontal movement to keep up with mine advance, has been largely overcome with the development of shiftable and extendible conveyors. The vertical flexibility to accommodate multiple coal seams is not so easily achieved.

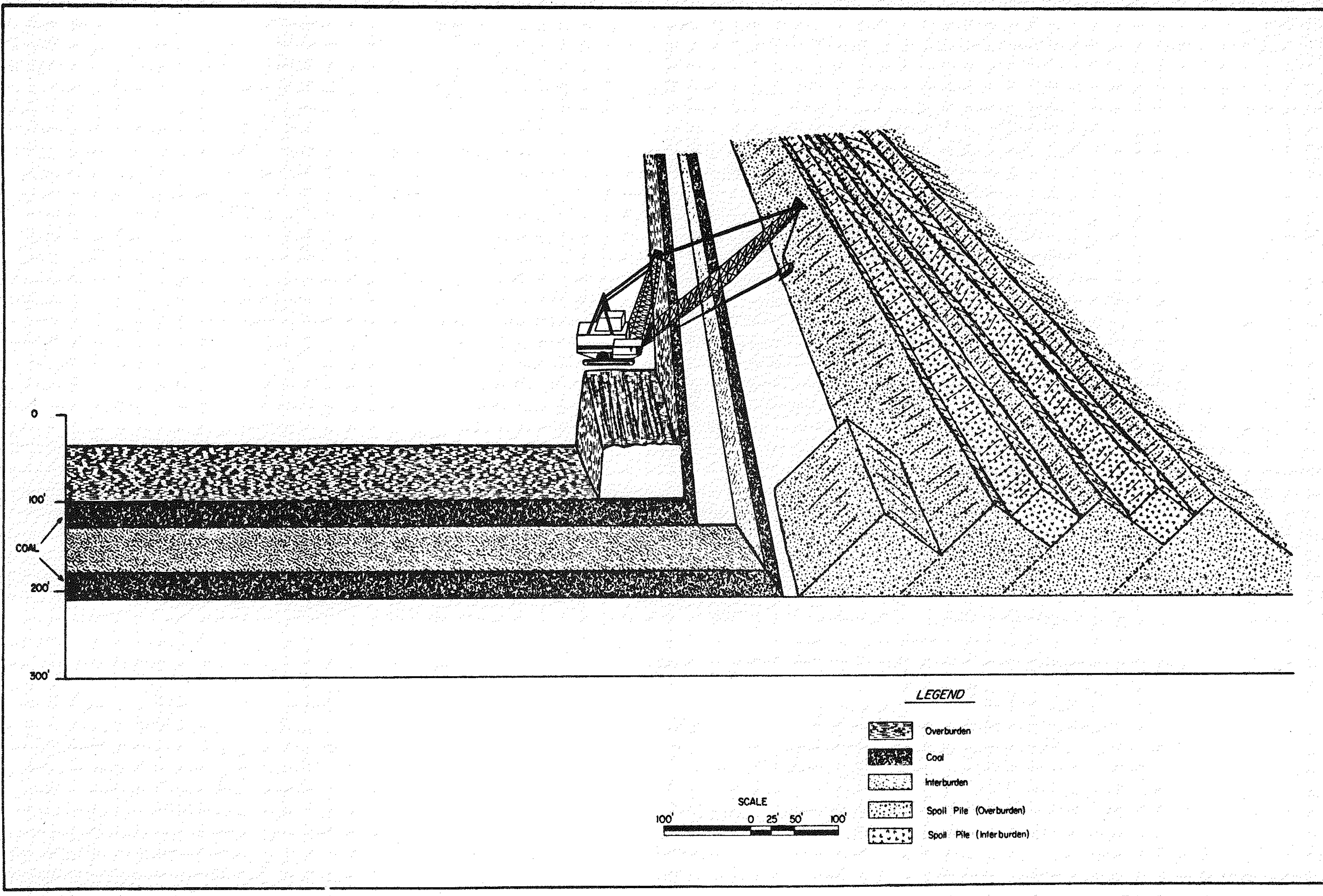
Recent inspection of multiple seam coal mining operations indicates that separate underspoil haulage conveyors at each seam level are not technically or economically feasible. Figures 25 and 26 show initial stripping and subsequent turnover cuts involved in a typical two-seam area strip mine. Even if the upper seam were sufficiently thick to justify the cost of a separate conveyor system at that level, there would be great difficulty in constructing and operating it. A culvert-type installation located at mid-height in the spoils would be subjected to extreme shear stresses due to differential settlement and possible sliding of the dumped material. Compaction of the spoils to reduce this effect is not feasible. An additional problem is the economic transportation of the upper seam coal across the pit to the underspoil conveyor.

One alternative is a single underspoil system located at or below the final pit bottom. This layout could prove feasible provided an economical method is developed for dropping the upper coal down the highwall to the pit bottom and moving it laterally to the underspoil system. However, the problems of installing and maintaining a shiftable pit conveyor at the base of the highwall appear considerably more severe with two coal seams than with one. Extendable conveyors following the coal face at each level are also a possibility but movement of the portable sections to avoid interference with blasting and dragline excavation would require constant coordination.

Should both the above alternatives be ruled out by site conditions, the underspoil system installed in a tunnel below the pit level, as described in Section 3.1.5.4 could provide the best method of moving coal from two seams to a common level. Assuming a raise was bored upward from the tunnel to the upper coal seam for each cut, coal could be dropped from both seams to a feeder in the tunnel. The raise could be left filled with coal after mining the upper seam so that removal of the parting would not plug the lower portion or cause damage to the underspoil conveyor.

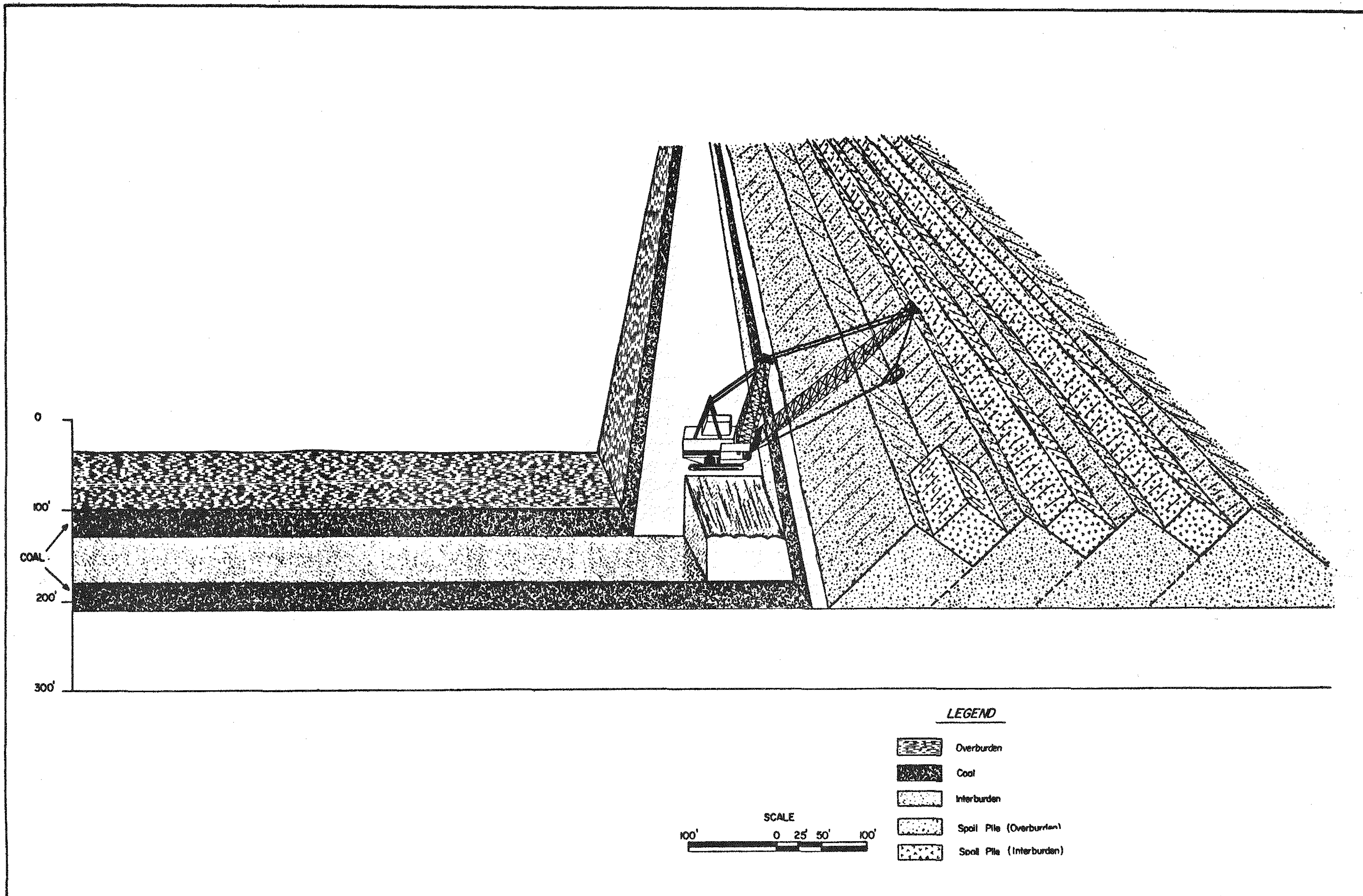
This brief analysis has concentrated on the problems involved in applying underspoil haulage methods to multiple coal seams. It should be noted that these same problems complicate conventional truck haulage. With additional study of a more site-specific nature, there is certainly a potential for feasible application of underspoil haulage to multiple seams. However, the economics related to total coal thickness as described in the following section, apply equally to single and multiple seam applications. By this study, multiple seams of 5 to 6-foot thickness do not appear suited to the present underspoil haulage concept.

The preliminary study concluded that underspoil coal haulage is feasible only for relatively thick coal seams. More detailed study generally confirms this conclusion, although the minimum coal thickness for which underspoil haulage is feasible varies considerably with overburden depth and other factors. These costs relationships are discussed in Section 3.1.6. The



OVERBURDEN EXCAVATION-TWO COAL SEAMS-1 of 2

Figure 25



OVERBURDEN EXCAVATION—TWO COAL SEAMS—2 of 2

Figure 26

most obvious fact is that tunnel and conveyor lengths must increase in length just as haul roads do to keep pace with mine advance. The costs of these haulage systems are therefore inversely related to coal thickness for a given tonnage. This effect is more pronounced with capital-intensive conveyor haulage than with the more labor-intensive truck haulage.

The effect of overburden depth on the cost of underspoil coal haulage is particularly important as coal thickness decreases. The weight of rigid culvert, such as a concrete arch section, is directly related to depth of spoil. However, with increasing overburden depth, installed costs increase at a lesser rate than spoil height because both fabrication and installation are less than directly proportional to concrete weight. The cost of flexible culvert such as structural plate increases with spoil height only to a certain point above which design loads and hence installed costs do not increase. Thus thinner overburden does not fully compensate for thinner coal seams in terms of underspoil culvert and conveyor costs. Assuming a constant stripping ratio, decreasing coal thickness directly increases both tunnel and conveyor length, whereas the decreasing overburden thickness effects only culvert costs and the decrease is less pronounced.

The effect of overburden depth on the cost of conventional coal haulage is well known. In addition to increased truck operation costs, deeper pits result in deeper and longer ramps. Assuming these ramps must be advanced annually, the volume of required fill is substantial as it is related to the pit depth squared. By comparison with underspoil systems, the decrease in truck coal haulage costs with shallower overburden should thus be more pronounced. Assuming a constant stripping ratio, this effect results in an increased cost advantage for truck haulage as coal seams become thinner.

In summary, if we assume constant annual coal tonnage and stripping ratio, then decreasing coal seam thickness results in:

1. Longer underspoil and haul road systems (costs inversely proportional to coal thickness)

2. Lighter weight underspoil culverts (costs less than directly proportional to coal thickness and consequential thinner overburden)

3. Smaller fill volumes to advance ramps (costs directly proportional to coal thickness and overburden thickness)

The net effect is an increasing advantage of truck haulage over underspoil haulage as coal seams become thinner. This trend is indicated in the range of coal and overburden thicknesses studied in detail, as described in Section 3.1.6. The underspoil haulage concepts presently under consideration are therefore not applicable to seams less than approximately 50 feet thick unless unusual conditions increase the cost of conventional haulage.

3.1.5.3 Thruspoil Alternatives

The potential advantage of a thruspoil coal conveyor system is the economy of belt conveyors without the expense of culverts or tunnels. To evaluate this possible advantage it was assumed that the underspoil culvert/conveyor system is replaced with a movable sloping conveyor extending over the spoil slope and an extendable conveyor on the spoil surface which connects with the overland conveyor. The pit conveyor system would remain unchanged. With each successive cut, the portable conveyor must be removed to permit spoil dumping and then replaced in its advanced position over the new slope (see Section 3.3.6). The two conveyor lines insure continuous coal haulage during the advances and retain redundancy against breakdown.

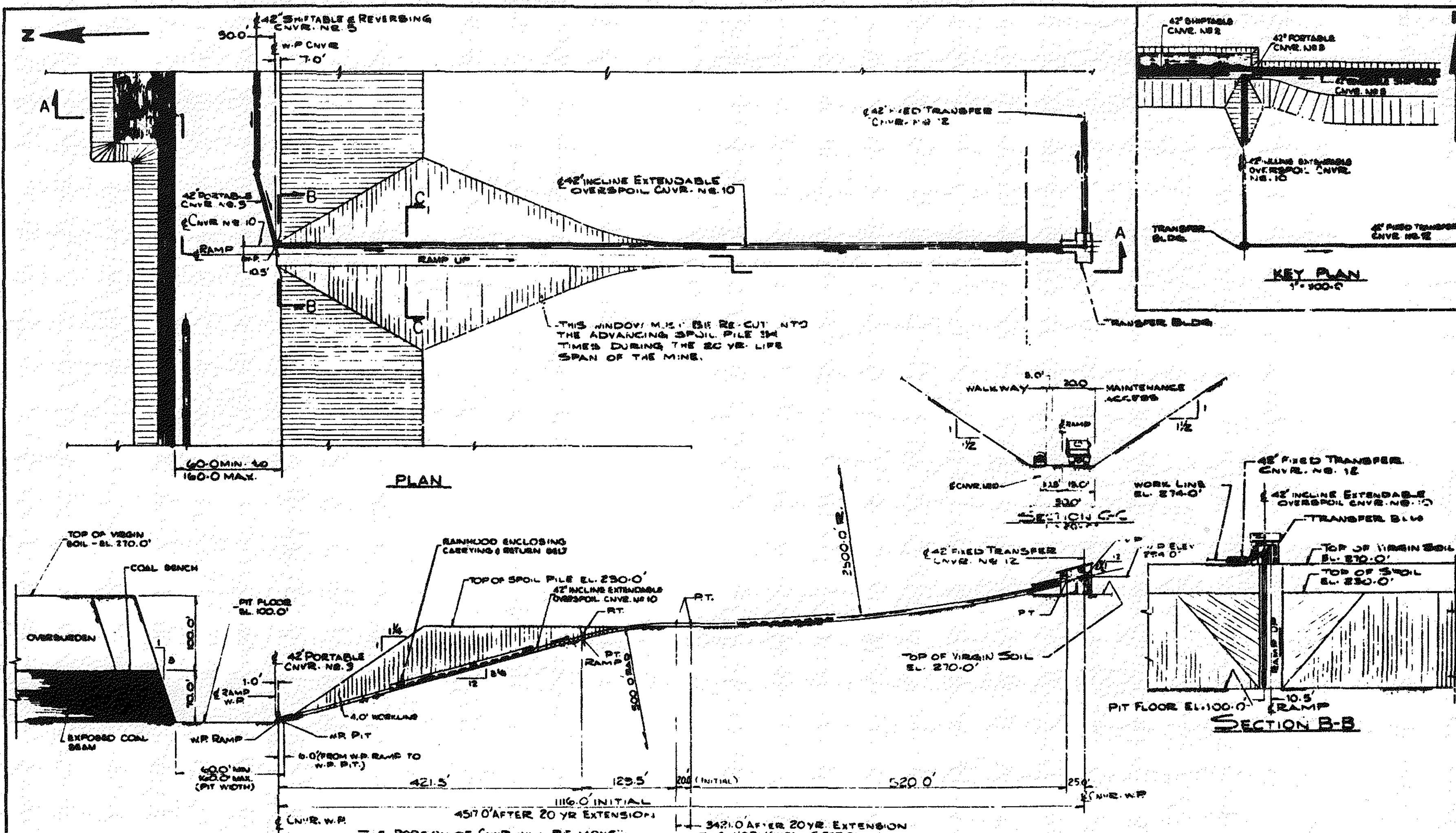
Each advance involves extending the parallel conveyors 100 feet. Assuming the collector conveyors are never moved, this concept results in the "fencing in" of the central half of the spoil area. Overpasses must be provided to maintain access to this area for topsoil and spoil haul units as well as for revegetation operations. Concrete arches and haul ramps constructed of spoil are located near the upper end of each portable conveyor. These overpasses are removed and advanced every five years to reduce overburden haul distances and facilitate reclamation in the same way that haul ramps are advanced annually.

This concept was evaluated by a cost comparison with conventional and underspoil haulage, assuming 100-foot deep overburden and 70-foot thick coal. The results are discussed in Section 3.1.6. Two types of belt conveyors and three slope layouts were investigated as described in the following paragraphs.

Layouts for conventional belt conveyors were investigated for window-type ramps perpendicular to the pit as shown in Figure 27 and open ramps as shown in Figure 28. Cost estimates were made for both and compared with other methods of haulage. The ramps have a 15° slope and 30-foot width to provide space for both the incline conveyor and for a pit access road (27%). The spoil slopes above and below these ramps are flattened from angle of repose to 1.5:1 to insure stability under all weather conditions.

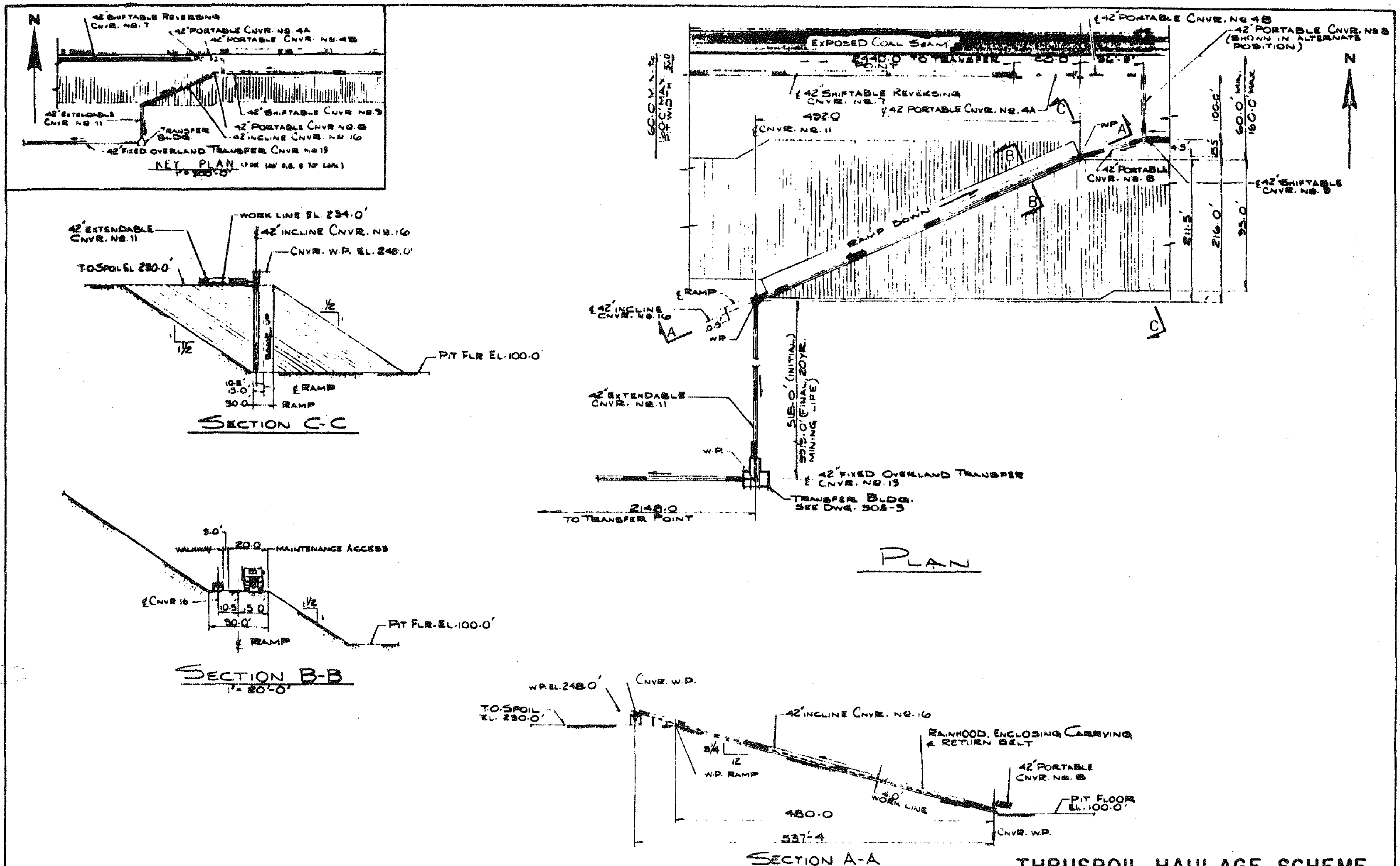
The earthwork necessary to construct and advance these ramps with each cut is substantial. The cost estimates allow for a track-mounted dragline-crane to rough out these ramps and to handle the incline conveyor during removal and replacement. A tractor-dozer is used to fill the abandoned ramps and finish grade the new ramps. This equipment alternates from one conveyor location to the other. When not shifting the extending conveyors it is used in constructing and shifting the extending conveyor overpasses. As this work does not fully occupy the equipment, the cost would be quite high for advancing the thruspoil conveyor unless other part-time uses for the equipment exist.

Ramp construction can be eliminated by the use of steep-slope elevating conveyors (Figure 29). For estimating purposes it was assumed that the spoil face is stabilized by dragline flattening and trimming to a uniform slope of 1.5:1 or 34°. As this is approximately twice the maximum slope



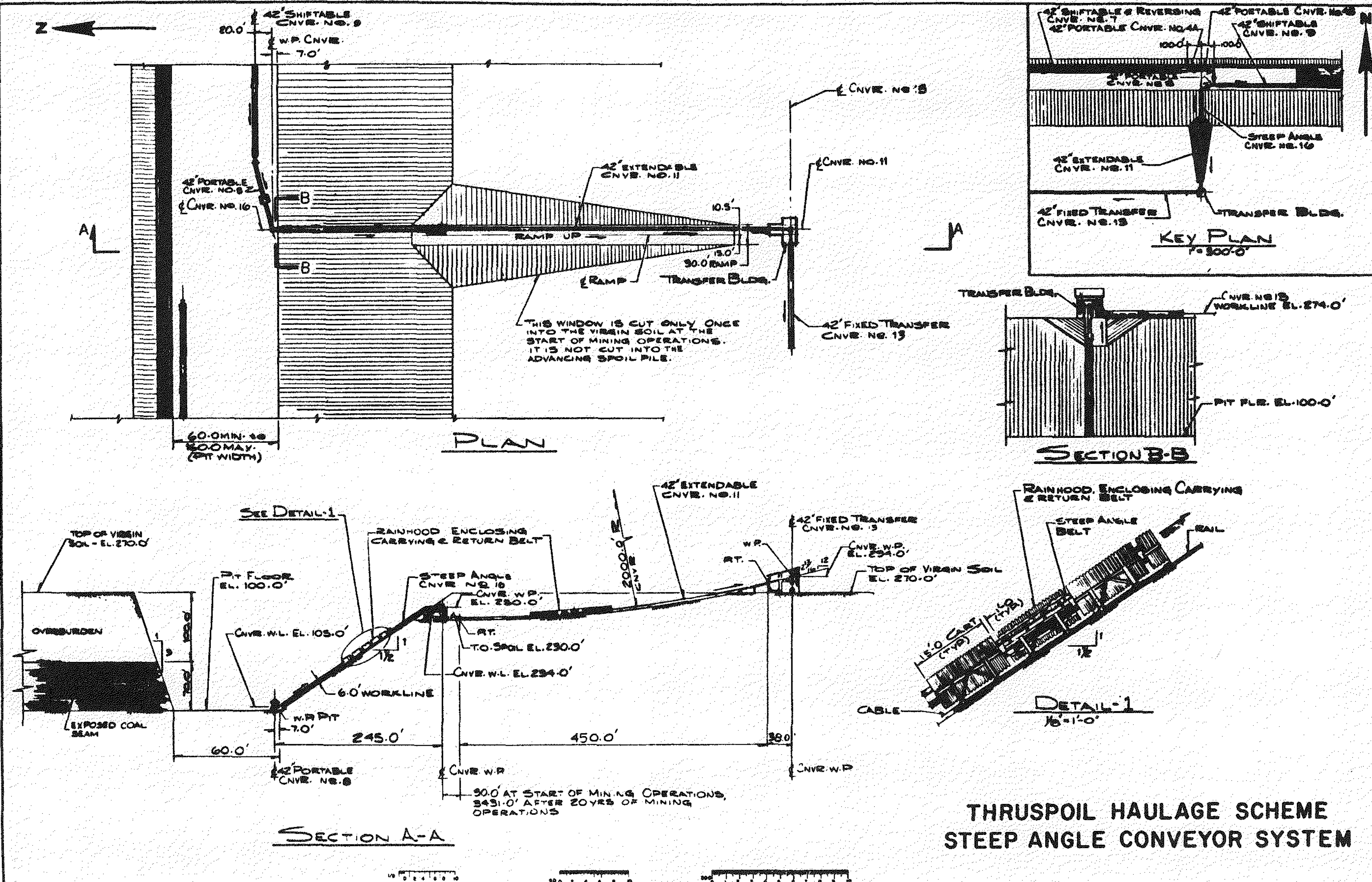
THRUSPOIL HAULAGE SCHEME
PERPENDICULAR CONVEYOR SYSTEM

Figure 27



THRUSPOIL HAULAGE SCHEME
PARALLEL CONVEYOR SYSTEM

Figure 28



THRUSPOIL HAULAGE SCHEME
STEEP ANGLE CONVEYOR SYSTEM

Figure 29

angle for conventional belt conveyors, a special design is required. Several types of steep angle conveyors have been used in such applications. Material is retained on the belt by either a second belt forming a sandwich system or by cleats or compartments. The estimate was made for the compartmentalized belt as it is available with steel cable reinforced belting comparable in quality to that of the conventional conveyor systems. In addition, it is capable of conveying a wide variety of materials and at capacities of several thousand tons per hour. Maximum required capacity for this application is approximately 1,800 tons of 6-inch minus coal per hour.

The work and equipment involved in advancing this thruspoil system is similar to that for conventional conveyors. The construction and shifting of overpasses is identical. The earthwork required for ramps is eliminated, however, so that dozer and dragline time is substantially reduced.

3.1.5.4 Underpit Conveyor Alternatives

The loading conditions imposed on rigid and flexible conduits by high dumped spoil are described in Section 3.1.2.4. While these loads can not be very accurately predicted because of varying interaction between the structure and the surrounding material, two basic principles are well established:

1. Flexible or yieldable structures tend to transfer static loads to the surrounding backfill or ground.

2. Static loads become progressively less as installation changes from projecting to trench to tunnel. The relative positions of each type of installation are shown in Figure 10.

Lacking specific data on spoil and rock characteristics, the following load criteria were established for the various installations studied. They are considered reasonably conservative for the conditions likely to be encountered in the Powder River Basin and similar coal fields. Vertical loads correspond to the weight of a column with height and material as listed:

Installation Method	Support Type				
	Concrete Arch	Structure Plate	Steel Arch	Tunnel Yieldable	Tunnel Rigid
Conduits on Pit Floor (Full Projecting)	2.00 Hs Spoil	Manufacturer Design Varies	-	-	-
Conduits in Rock Trench (Full Projecting)	1.0 Hs	Manufacturer Design Varies	-	-	-
Tunnel (Two Diameters of Cover)					
Moderately Heavy Ground	-	-	-	-	1.1 (B+H)
Heavy Squeezing Ground	-	-	-	2 D Rock	-

Hs = Total Height of Spoil B = Tunnel Width
D = Horizontal Tunnel Diameter H = Tunnel Height Appendix 3.1.5

These criteria result in design loads with 200 feet of overburden or 260 feet of spoil which range from 15.6 tons per square foot for projecting concrete arches to approximately 2.5 tons per square foot for steel tunnel arches. The potential for cost savings in reduced supports is necessarily limited by construction, operation and maintenance considerations, as well as by the degree of risk allowable. While the theoretical safety factors for the various alternatives are roughly comparable, the concrete arch is considered the most predictable as to behavior under actual loads. For this reason it has been used in all cost estimates in this study.

Construction details for underspoil conduits on the pit floor are covered in Section 3.1.3.3. This type installation is the least complicated of all the alternatives from the standpoint of specialized equipment. The concrete arches in the conceptual design are precast and installed on a reinforced concrete invert slab which maintains alignment and grade underspoil loads. Conveyor extensions can be assembled on the slab prior to setting the arches, allowing time for the slab to gain strength and reducing total extension time. Steel arch/liner plate sets can be installed on a similar slab using embedded anchor bolts to secure preassembled sections. Structural plate culvert can also be preassembled. This alternative requires careful bedding of the pipe in select granular material rather than an invert slab. The interior culvert invert is paved after installation to provide a flat floor (Figure 10 and, Figure 7).

Backfilling of concrete arches can be by dragline casting or truck dumping once a protective fill has been dozed into place immediately surrounding the structure. Fine spoil material should be selected but compaction is not essential.

Manufacturers of structural plate culvert and various tunnel support systems are understandably reluctant to provide firm design and cost information until installation and loading conditions are known. Quality of backfill material and methods of placing and compaction are critical to the performance of such flexible structures. For this reason a cost allowance was made for inspection and testing during backfill adjacent to the structure as shown in Figure 10. Once this backfill is completed, spoil can be dumped over the installation by dragline or trucks.

The principal advantages of concrete arches over the alternatives studied are structural reliability without special backfill, and long-term durability. The main disadvantages are weight and size for handling and installation. Placing concrete in the pit is a common disadvantage to all three systems although it may be possible to substitute a steel frame for the concrete invert in the steel arch alternative. Both arch alternatives have the advantage over circular culverts of easier conveyor installation.

The mobile equipment required for pit floor installations includes a ripper-dozer for foundation work, a crane and flat-bed truck or lowboy for handling and setting support sections, and transit mix trucks for invert concrete. Special backfill requires trucks, a small dozer and a towed vibratory compactor.

Trench installation involves a cost trade-off between lighter structural support and the trench excavation costs. The relative advantages of the three alternative types of support are essentially the same as when installed on the pit floor. For estimating purposes a special tunnel portal section similar to that shown in Figure 6 was assumed for each type of support. This section is relocated in the trench as it is for pit floor installation, with each extension. It includes the feed hopper and tunnel heaters.

Trench installation of concrete arches is the same as pit floor installation except that the invert slab is thinner and does not require forming. Assuming a 12-inch thick arch is the minimum practical for casting and handling, there is no cost advantage in trench installation for the 50-foot overburden case. The cost advantage in lighter support does show up for 100 to 200-foot overburden, however. Trench installation of flexible supports such as structural plate culvert and steel arches requires special backfill procedure as manual compaction is slow, expensive, and requires trench widening for work space. To avoid these disadvantages, soil-cement backfill can be placed directly from transit-mix trucks without compaction. A possible alternative would be granular backfill compacted by ponding and jetting. However, this method would probably risk flooding the conveyor. Although soil-cement is considerably more expensive than normal compacted backfill, the volume reduction associated with trench installation results in a net savings over pit floor installation. No reduction was made in the weight of steel support systems in trenches as the trench walls and soil cement is assumed to provide support equal to that of compacted backfill. This is a conservative assumption which should be investigated for possible further cost reductions by using lighter weight steel.

From an operational standpoint, trench installation involves specialized equipment and procedures not required for pit floor installations or for routine mining operations. The trench walls require line drilling and presplitting or the use of shale saw to prevent disturbance and overbreak. Cost allowances have been made for such specialized equipment as well as a backhoe for excavation. However, after backfilling the trench installation there is a decided advantage over projecting conduits as pit traffic can pass over the underspoil system at pit floor level. Another possible advantage of trench installation is the use of scrapers or surface type load-haul-dump units to move coal directly to the underspoil conveyor system through a pit-level dump hopper.

Pit floor trench installation of underspoil conveyors was considered and designed as part of the System Five study (Section 3.2.3). Instead of placing a conduit or arch in the trench with backfill; the System Five approach utilitzes the pit floor rock as part of the tunnel structure support. Reinforced concrete is poured in place to construct the floor, walls, and roof beam seat. The floor and walls bear little stress but retain the in-place rock and seal out water. An arched roof panel-beam supports the vertical load of the loose spoils and transfers this load to the rock through beveled seats. These panel-beams will be reinforced precast concrete.

The installation of underspoil conveyors in true tunnels driven in rock underlying the coal seam has several possible advantages over pit floor and trench installations. Construction cost under favorable rock conditions will be much less than culverts or arches in fill as the rock becomes the major structure for supporting the spoil pile. Secondly, the under-pit tunnel will be out of the way of mining and reclamation operations. A third advantage is in the possibility for mining multiple seams. Raises can be used for dropping the coal from several horizons to the underground tunnel.

The technical feasibility of the rock tunnel alternative would appear to depend upon:

1. Favorable ground and groundwater conditions.

2. Relatively flat-lying coal.

3. A long-term commitment to mine in a fixed direction and area.

4. Having a surface location where an incline might be driven to provide initial access to the tunnel.

The basic cost estimate for this study is predicated on the use of precast concrete arch sections installed on the pit floor. This combination is considered to be the most reliable and the least disruptive to mining operations of the alternatives which are not sensitive to site conditions.

Table 10 compares maximum and minimum total costs per ton for: conduits on the pit floor, conduits in rock trench, and rock tunnels. The basis for estimate is again the model mine discussed in Section 3.1.1.1. To maximize the total costs, 30 feet of coal under 200 feet of overburden was assumed. To minimize the cost, 70 feet of coal under 50 feet of overburden was assumed.

Conduits in rock trench appear to be the least expensive approach and rock tunnels the most expensive. Conditions of construction and operation will probably be more the according factors in choosing between approaches instead of strictly cost considerations.

TABLE 10

TUNNEL COST COMPARISON

Direct Cost Per Ton Coal - Two Tunnel

	Maximum Total Cost Coal 30' Overburden 200'	Minimum Total Cost Coal 70' Overburden 50'
Conduits on Pit Floor		
Concrete Arch	0.152	0.044
Structural Plate Culvert	0.118	0.042
Steel Arch/Liner Plate	0.122	0.056
Conduits in Rock Trench		
Concrete Arch	0.110	0.050
Structural Plate Culvert	0.106	0.038
Steel Arch/Liner Plate	0.108	0.048
Rock Tunnels		
Moderately Heavy Ground (Rigid Arches)	0.176	0.080
Heavy Squeezing Ground (Yieldable Arches)	0.214	0.098

Note: See Appendix 3.1.5, "Secondary Studies", for detailed cost analysis.

3.1.5.5 Underspoil Related Studies

Six small studies related to underspoil handling of coal were conducted within the framework fo this general program. Several of these studies were complementary to underspoil haulage systems while certain of the others were considered to be alternatives to underspoil for cases where underspoil would be rejected as a conveyor haulage system. The six major topics studied are:

1. Newly announced BLM Coal Leasing Program.

2. Comparisons of manpower requirements between converyor and truck haulage.

3. Comparison of energy consumption between conveyor and truck haulage.

4. In-Pit coal haulage systems improvements.

5. Dumping ramps for trucks.

6. Coal elevating concepts as alternatives to underspoil haulage.

The complete text for these studies are found in Section 3.3 of this report.

3.1.6 Cost Comparison of Systems

The economic evaluation of the various systems must be recognized as a hypothetical study based on assumed conditions which have been simplified for comparison purposes. As such it requires tempering with realistic judgement in order to select a "best" system for detailed design. The purpose of this section is to present the cost comparison as a measure of economics feasibility to be balanced against the technical advantages and disadvantages of each system as outlined in Section 3.1.4.

3.1.6.1 Cost Estimate

Tables 12, 13, and 14 (in Appendix 3.1.6) summarize the comparative capital and direct costs for each system based on 50, 100 and 200-foot deep overburden, respectively. The basic cost estimate includes all development and mining costs except the following:

1. Coal acquisition costs.

2. Exploration and testing.

3. Off-property roads, railroads, power and communication lines.

4. Water, sewage, and waste water treatment facilities.

5. Rail loop and loadout facilities.

6. Coal storage facilities.

7. Coal royalties.

8. Environmental Impact Studies and Permits.

9. Corporate overhead.

10. Profit on venture.

Capital costs are based on the assumption that excavation for mine development is performed by the operator and that all conveyor facilities are constructed by an outside contractor. Initial stripping and construction procedures are described in Section 3.1.2. Appendix 3.1.6.lists the criteria assumed for calculating the capital costs.

Operating costs are based on the mine labor and equipment rates described in Section 3.1.3 for mine development. All rates and unit costs were current in 1977. Operating cost criteria are listed in Appendix 3.1.6.

3.1.6.2 Economic Evaluation

Total direct mining costs per ton of coal for each of the systems including System Five and a thruspoil system are listed on Table 11. Tables 12, 13 and 14 in appendix 3.1.6 provide a detailed breakdown by unit operations.

Graphical illustration of the cost variations with respect to overburden thickness are expressed in Figures 30 and 31 for the 30 and 50-foot coal thicknesses. Figures 32, 33 and 34 illustrate the changes in total costs as they vary with coal thickness.

Figure 35 further illustrate the relative costs of seven underspoil systems and subsystems, one thruspoil system, and compare them with the truck haulage, system one, as a basis. The bars illustrate the cost percentage more or less than the system one cost.

Figure 35 shows that for an overburden depth of 50 feet no underspoil system is cost comparable with truck haulage for either the 30 or 70-foot coal thicknesses. Thruspoil, however, appears to be slightly less costly or equal to truck haulage for this shallow overburden.

System No. 2 is shown to be cost comparable with truck haulage in Figure 35 for 30-foot thick coal under 100 feet of overburden. The thruspoil

TABLE 11

1977 Costs

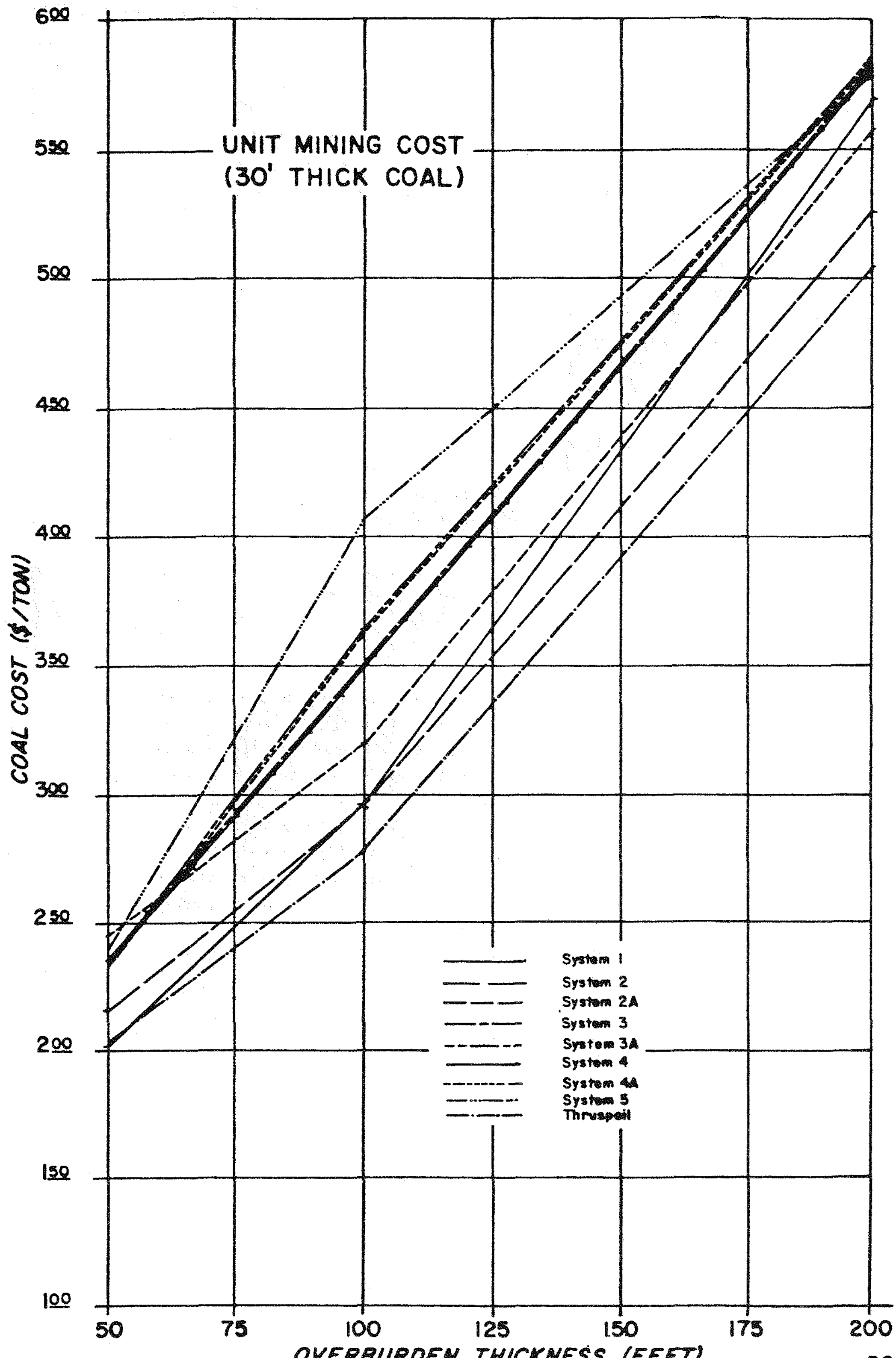
Total Direct Mining Cost Per Ton

System No.

1	2	2A	3	3A	4	4A	5*	Thruspoil**	
$2.092	$2.141	$2.451	$2.338	$2.342	$2.339	$2.336	$2.378	$2.012	50 ft. OB 30 ft. Coal
2.950	2.943	3.213	3.444	3.643	3.443	3.638	4.073	2.780	100 ft. OB 30 ft. Coal
5.715	5.269	5.592	5.811	5.867	5.811	5.866	5.767	5.035	200 ft. OB 30 ft. Coal
1.651	1.734	2.013	1.934	2.077	1.937	2.061	1.857	1.665	50 ft. OB 70 ft. Coal
2.225	2.319	2.537	2.611	2.857	2.604	2.853	3.040	2.231	100 ft. OB 70 ft. Coal
3.977	3.645	4.003	3.777	3.687	3.773	3.677	3.653	3.491	200 ft. OB 70 ft. Coal

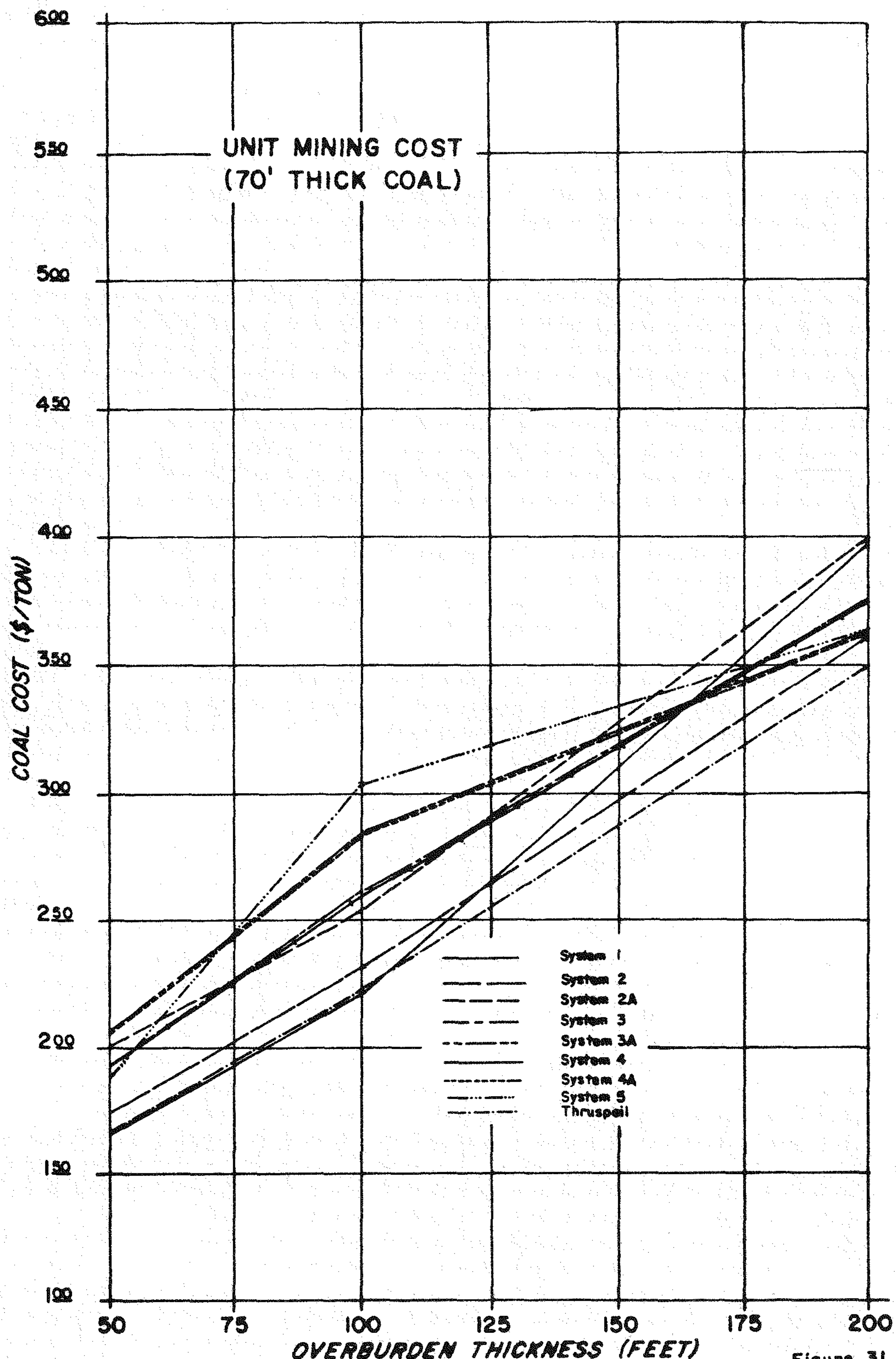
*Based on modified system three data
**Based on modified system two data

Note: See Appendix 3.1.6 for details



UNIT MINING COST
(30' THICK COAL)
COAL COST ($/TON)
OVERBURDEN THICKNESS (FEET)
6.00
5.50
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
50
75
100
125
150
175
200
System 1
System 2
System 2A
System 3
System 3A
System 4
System 4A
System 5
Thruspoil

Figure 30


UNIT MINING COST
(70' THICK COAL)
COAL COST ($/TON)
6.00
5.50
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
50
75
100
125
150
175
200
OVERBURDEN THICKNESS (FEET)
System 1
System 2
System 2A
System 3
System 3A
System 4
System 4A
System 5
Thruspoil
Figure 31

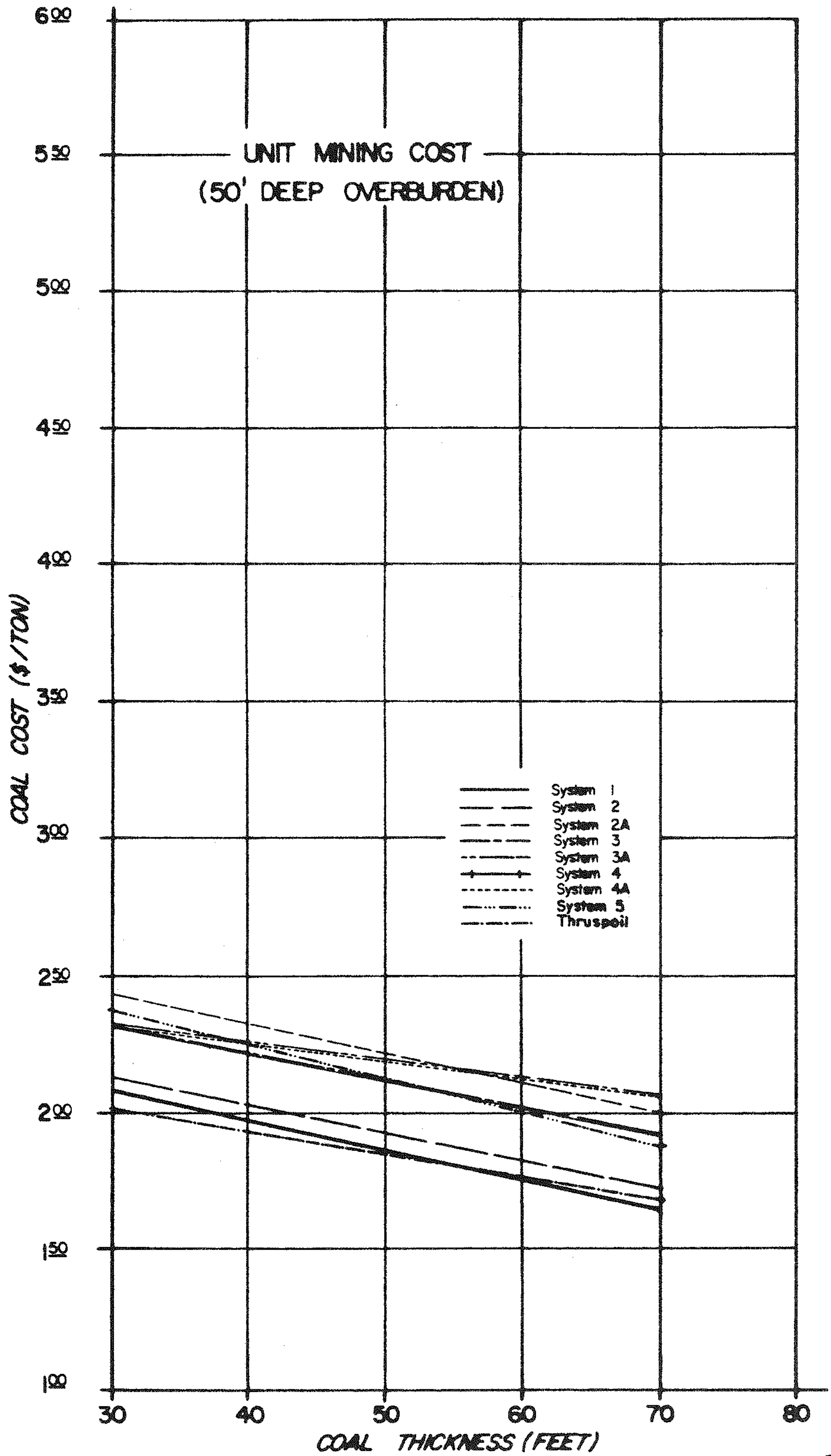
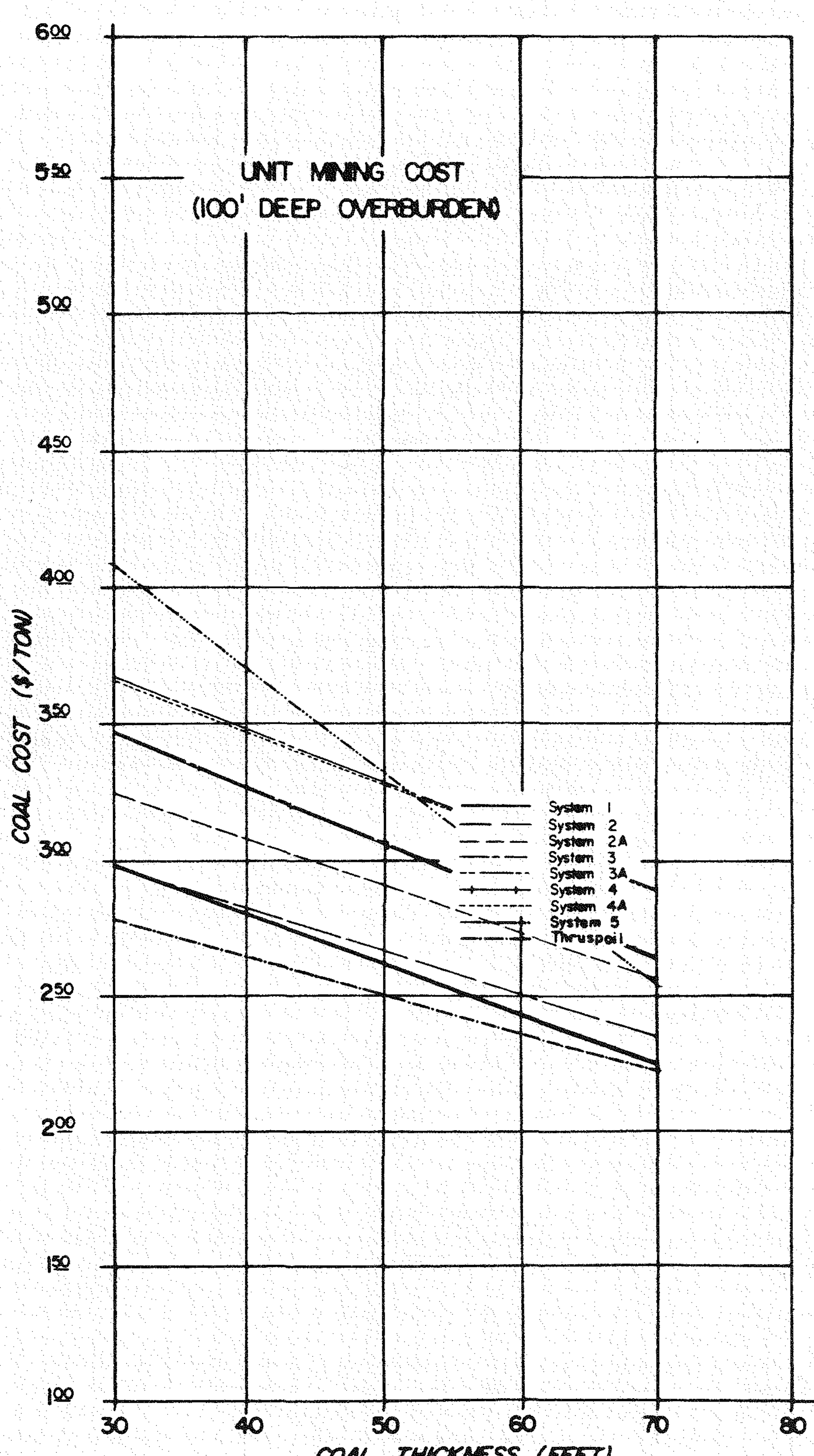

UNIT MINING COST
(50' DEEP OVERBURDEN)
COAL COST ($/TON)
COAL THICKNESS (FEET)
System 1
System 2
System 2A
System 3
System 3A
System 4
System 4A
System 5
Thruspoil

Figure 32



UNIT MINING COST
(100' DEEP OVERBURDEN)
6.00
5.50
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
COAL COST ($/TON)
30
40
50
60
70
80
COAL THICKNESS (FEET)
System 1
System 2
System 2A
System 3
System 3A
System 4
System 4A
System 5
Thruspoil

Figure 33

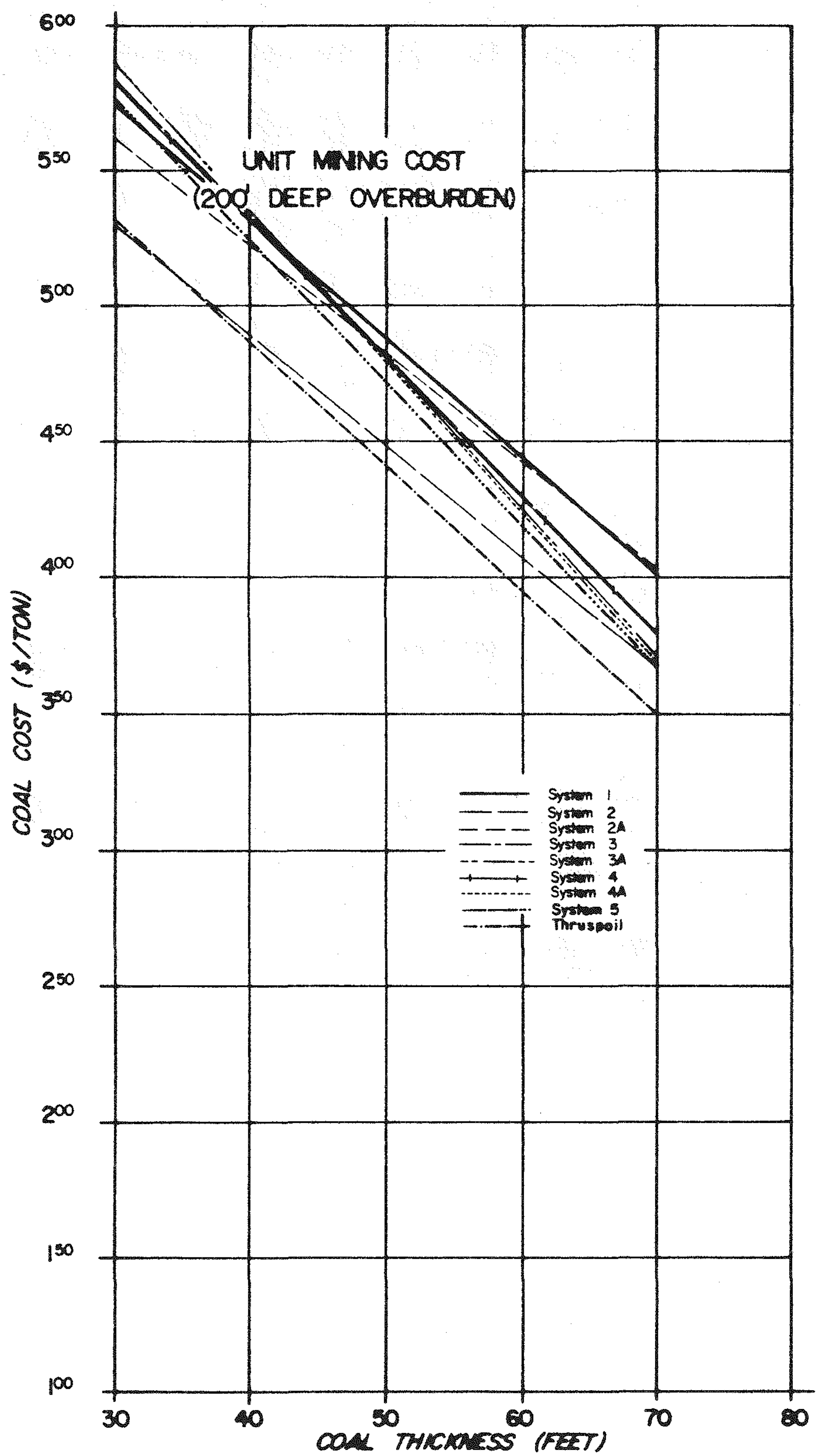

UNIT MINING COST
(200' DEEP OVERBURDEN)
COAL COST ($/TON)
COAL THICKNESS (FEET)
6.00
5.50
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
30
40
50
60
70
80
System 1
System 2
System 2A
System 3
System 3A
System 4
System 4A
System 5
Thruspoil

Figure 34

system is again slightly less expensive on a per ton basis than truck haulage. All other systems are more expensive to operate for both the 30 and 70-foot thicknesses with 100 feet of overburden.

The 200-foot thick overburden situation is shown in Figure 35. At this depth System No. 2 and the thruspoil system are clearly more economical for both coal thicknesses than is truck haulage. The other six systems are more economical for 70-foot thick coal but more costly for 30-foot coal.

These three comparison graphs demonstrate the point that underspoil haulage by conveyor and thruspoil conveyor haulage have economic advantages when their high capital expenditures can be offset by the low operating costs achievable in thick coal deeply buried under thick overburden. Higher annual productions will tend to magnify these economic advantages.

3.1.6.3 Possible Cost Reductions

Several areas of possible cost reductions have been evaluated on an order-of-magnitude basis. These apply to both the underspoil systems and to the thruspoil alternatives discussed in Section 3.1.5.3. They do not apply to the conventional system for which no cost-cutting modifications appear possible.

For underspoil haulage methods, trench installation of a structural plate culvert in lieu of the pit floor installation of precast concrete arches has potential cost savings features as noted in Section 3.1.5.4. The System No. Five study (Section 3.2.5) investigated this possibility with very positive cost savings.

Cable-supported conveyors in lieu of the standard steel stringer type offer capital cost reductions. Wider idler spacing and ties in lieu of concrete footings also reduce capital costs. For a 20-year life under favorable mine conditions, these changes should be considered, provided savings in first cost are not out weighed by extra maintenance cost.

Engineering, procurement, and installation of the conveyor systems by the mine operator in lieu of contracting to a design-construct firm is a third area of possible cost reduction.

Some duplication of field construction supervision and both field and home office administration costs could result from the separate contract arrangement. The use of permanent office, warehouse, and shop facilities by the mine operator-constructor could avoid separate temporary facilities by a contractor.

Three methods of utilizing conveyor haulage to move coal from the pit through the spoil slope are described in Section 3.1.5.3. Figures of each method are 27, 28, and 29. An order-of-magnitude cost comparison was made to determine economic feasibility. This comparison was based on replacement of

— UNDERSPOIL HAULAGE COST VARIATION ANALYSIS —

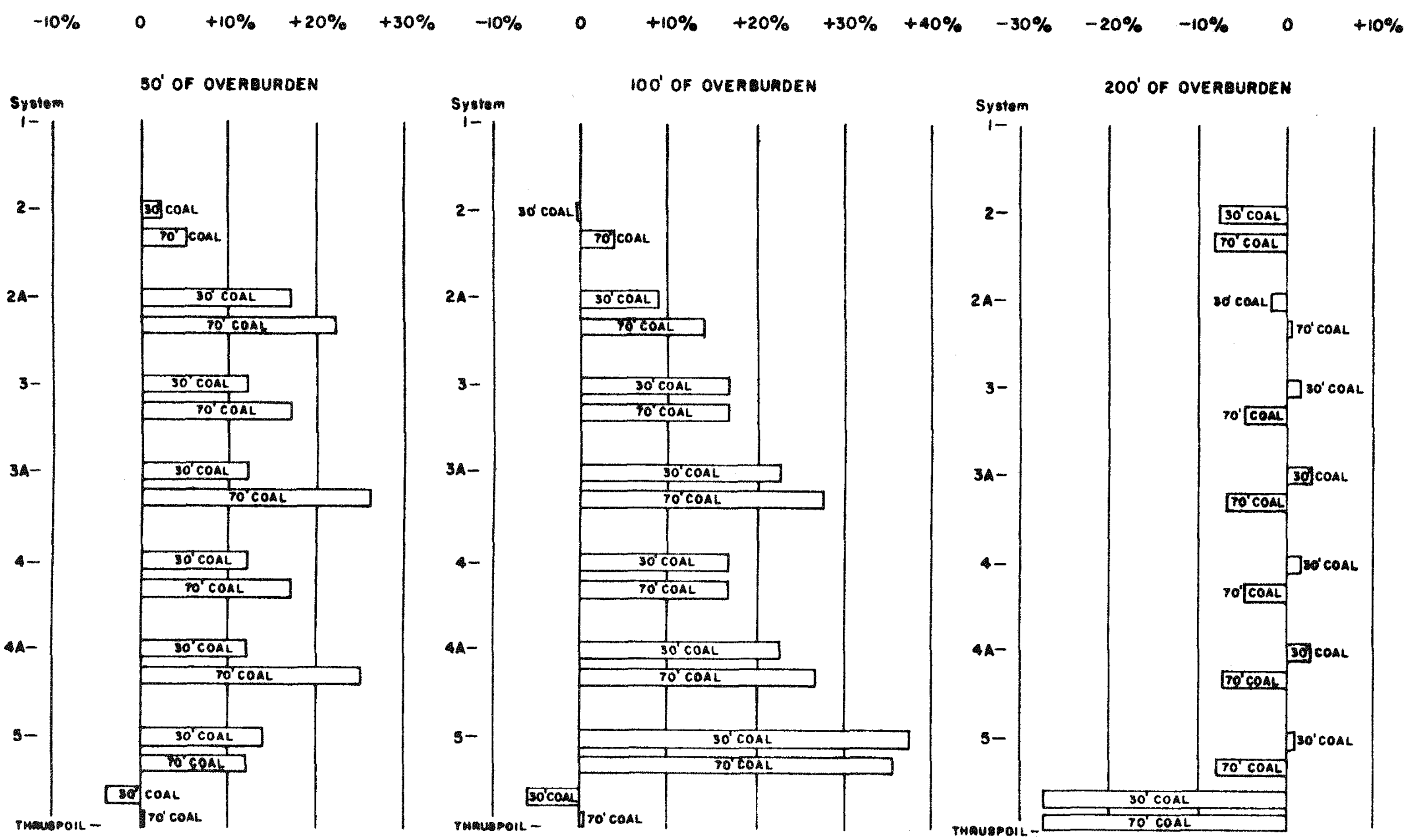


Figure 35

the underspoil portion of System No. 3A with each of the three thruspoil methods. The pit and surface conveyors remained unchanged. Pit conditions were 100-foot deep overburden and 70-foot thick coal. A cost reduction of approximately $0.07 per ton of coal was indicated by the comparison study.

Any cost reductions related to thruspoil haulage must be weighed against operational considerations which are not reflected in the costs. These include:

1. Use of Equipment. The crane-dragline and dozer required to advance the thruspoil system are only partially utilized. The cost estimate assumes productive use elsewhere in the mine when not required for extensions, a condition which may not be possible to achieve.

2. Spoil Settlement. Both the inclined conveyor and the two parallel extendable sections are located on newly dumped spoil. Settlement during the first year could be several feet and differential settlement between successive spoil rows could be severe. While conveyor installations under similar conditions have been observed to perform satisfactorily, the possibility of extra maintenance exists. No cost allowance has been made for this realigning and leveling work.

3. Wear and Tear. To avoid interference with dragline casting, the slope conveyors must be removed and replaced for each 100-foot cut. This represent up to 4 advances per year with 30-foot thick coal. Extra wear and tear on conveyor structures and belting due to continued handling has not been included in the cost estimate. However, it is an item which must be considered in comparing against underspoil systems which are extended but never relocated.

The possible cost advantages of less expensive conveyors and of operator-constructed facilities apply to thruspoil haulage systems also. (Under the Phase II portion of this study, three other thruspoil and surface conveying systems were conceived. See Section 3.3.6 for these details.)

Conceptual changes outside the basic guidelines of this study could weigh heavily in favor of conveyor haulage systems over conventional systems. The first is an increase in production rate. As noted in Section 2, provisions have been made for doubling annual tonnage from five to ten million tons per year by increasing belt width and speed. Incremental capital and operating costs for the higher capacity conveyors would be substantially less than proportional to tonnage so the unit coal costs should drop considerably. On the other hand, doubling annual tonnage under conventional haulage conditions would probably not reduce unit coal costs appreciably. This capability to expand economically is an advantage of conveyor systems which deserves further investigation. It should be noted that the Preliminary Study concluded that as production rates increased to ten million tons per year the advantage of conveyors over trucks in terms of coal haulage cost became greater.

The second area of cost reduction involves sacrificing the redundancy of two separate underspoil systems. While a single conveyor line from the pit may involve unacceptable risk, it would appear that a single centrally located underspoil system could be backed up by a thruspoil system for use only if needed. Again, further study is required to determine the engineering and economic feasibility of this change in concept.

Other conceptual changes are discussed in Phase II related studies. These are the System Five Study in Section 3.2.3 and the Underspoil Haulage Related Studies in Section 3.3.

3.2 Phase II - Demonstration Site Selection

As stated earlier this study as it was conceived and has progressed to this time consists of three phases. Phase I is the "Engineering and Economic Evaluation of Underspoil Haulage" as presented in Section 3.1 of this report. Phase II has taken several directions with the intent of producing an actual field demonstration. Phase III is contingent on successful location of a suitable site under Phase II. Should Phase III proceed, it will produce an in-mine demonstration of a prototype system in an area strip mine. However, Phase II did not succeed in finding a cooperative mine.

The actual Phase II work consisted of developing a "Field Demonstration Plan". Using this plan area strip coal mines were canvassed to discover interest in the in-mine prototype. One of the coal mining companies contacted, expressed interest in an installation should it be adaptable to its design and operation. Using plans and data from the interested mine, System Five was developed under criteria differing from the Phase I designs. The Master Plan for Phase III was approached in general terms as specific designs would be site-specific, and no mine was available.

3.2.1 Field Demonstration Plans

The original statement of work for the underspoil haulage demonstration included three separate parts. Phase I, Detailed Design and Demonstration Site Selection, comprised the work in the current contract which includes a field demonstration plan for the prototype system. Phase II, Component Fabrication and Testing, involved shop and in-mine testing of full-size culvert test sections. Phase III, In-Mine Demonstration of a Prototype System, consisted of the system demonstration in a strip coal mine to be approved by the Bureau of Mines.

3.2.1.1 General

The coal mine visits included in the Phase I work indicated several potential sites for prototype demonstration. However, none of these sites were both suitable and available for the Phase II testing for several reasons:

1. Coal mines stripping 200 feet of overburden (the upper limit of the study range) are unusual at present.

2. Coal mines dumping spoil at a rate high enough to provide valid load tests in a reasonable time period are also unusual.

3. Close follow-up of Phase II after Phase I may be impractical considering the time requirements and the uncertainties involved in locating a suitable coal mine and in reaching agreements for component testing where the culverts might have no future value to the mine.

To avoid this delay, the possibility of load testing culverts in a site other than a coal mine was considered. To investigate the feasibility of this alternative, an active copper mine in Arizona was studied. A testing plan including layout sketches, a schedule, and cost estimate are presented in Section 3.2.1.2 for this site. The study indicates that while culvert load testing at such a site is certainly possible, it is not economically attractive. Although the desired height and rate of spoil dumping are available, the accurate simulation of foundation reaction is also questionable as the coal mines floor must be approximated by compacted and/or stablizied soil at the test site.

Economically, the installation of culverts and the special handling of large volumes of overburden to backfill them is undesirable if the culverts are of no practical use after testing.

The obvious alternative, provided a delay in the culvert test program is acceptable, is a field demonstration plan permitting both culvert testing and demonstration of the prototype underspoil haulage system with a single installation. By integrating the original Phase II testing and the Phase II demonstration work, the test results, will be valid and the test structures usable. This concept has been developed in the field demonstration plan described in Section 3.2.1.3. A typical area strip mine in the Powder River Basin of Wyoming has been used as a basis for the plan.

It should be noted that no commitments have been made regarding either the Arizona copper mine nor the Wyoming coal mine used in this study. Representatives of these mines kindly agreed to furnish basic data and mine plans with the understanding that his information would be used only for study purposes at this time.

The field demonstration plans described herein are thus based upon existing mine sites and plans but upon assumed conditions of availability. As these mines are representative of their type, the general procedure and, to some extent, the estimated costs should be applicable to similar mines in the Rocky Mountain region.

The term "contractor" as used in this section refers to a company which would take full responsibility for design, construction management, and performance of the field demonstration program, under contract with the Bureau of Mines.

3.2.1.2 Culvert Field Load Tests

The field load test program developed in this section contemplates independent performance of culvert tests prior to the in-mine prototype demonstration. As previously noted, a coal mine suited to testing culverts could not be located when this study was initiated. There were indications, however, that one or more existing waste dumps at copper mines in Arizona could be both available and suitable. Accordingly, one of these sites was utilized as the basis for the engineering study and cost estimate. Figure 36 shows the approximate layout of this dump. Details of a possible test installation are shown on Figures 37 and 38.

The value of test results from this program is probably not commensurate with the costs related to this site. To determine these costs, however, it was necessary to develop the detailed test plan which follows. These costs would be greatly reduced and the test results would be more meaninful if a suitable coal mine were available in which both culvert testing and prototype demonstration could be performed concurrently. Recommendations regarding arrangements for a coal mine suited to the combined program are made in this report.

While the separate site concept does not appear to be feasible, the test procedure developed in this section is directly applicable to culvert testing in a combined program. For this reason the complete test plan is included in the apendix.

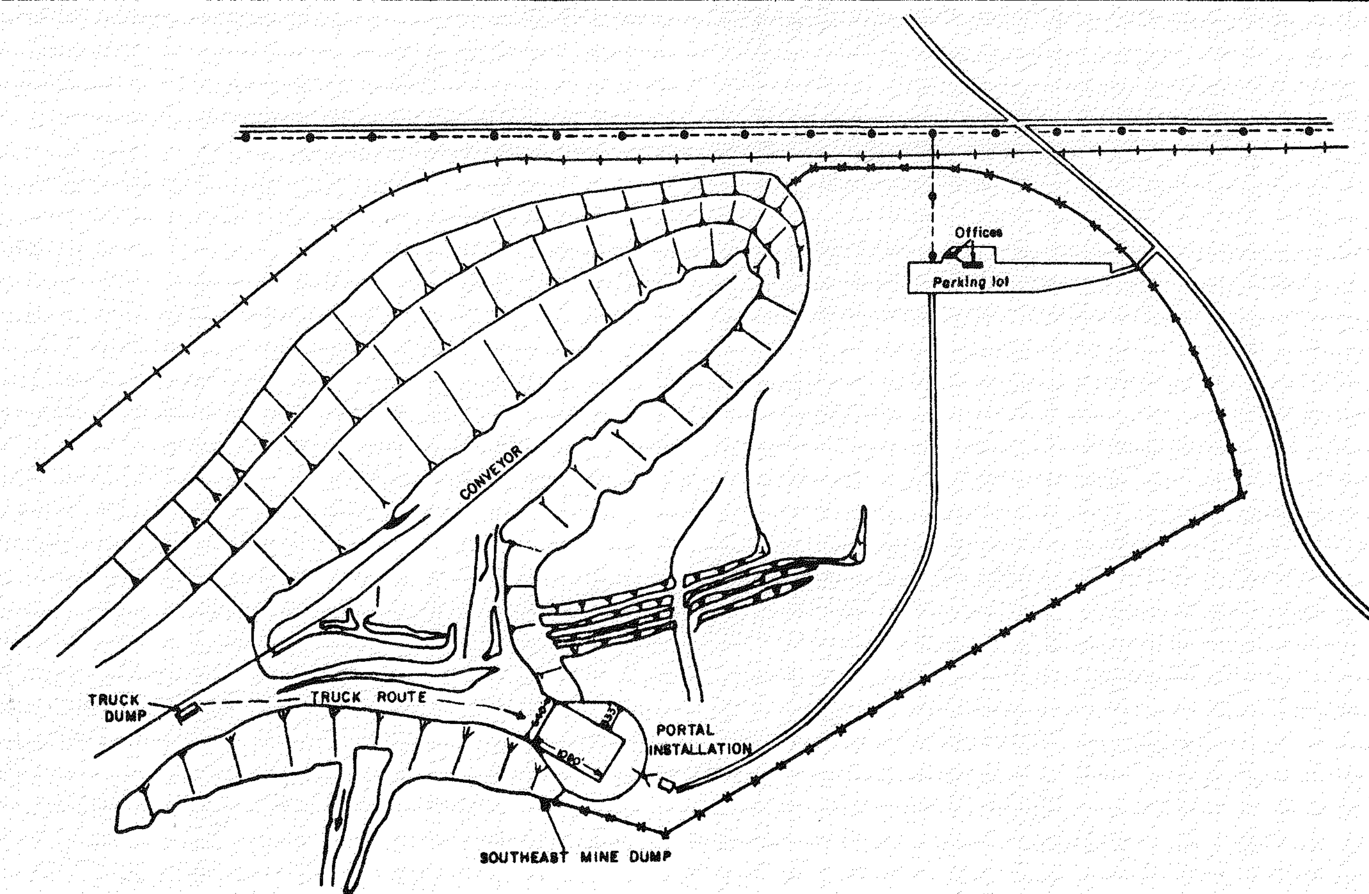
The cost estimate for the culvert test program at the Arizona site is summarized in Table 12. This estimate covers the cost of installation and performance of the load test program including hauling and placing of spoil to test three separate culvert designs. It should be noted that of the total $3,352,098 estimated cost, more than half ($1,795,245) is for hauling and dumping spoil to perform the load test. The cost of this program would be reduced if the test sections could be laid ahead of a routine spoil operation to avoid special handling. However, this opportunity did not exist at any of the sites investigated.

Details of the Culvert Field Load Tests at an Arizona coppr mine are contained in Appendix 3.2.1.

3.2.1.3 In-Mine Prototype Demonstration

A total of 15 surface coal mines were visited in the course of these studies. Table No. 13 lists these mines with details of location, ownership and operation. Seven of the mines are located in the Powder River Basin of Montana and Wyoming, the region which offers the best conditions for the current underspoil coal haulage concept. Two each were located in Colorado, New Mexico and Illinois.

All mines were active and producing in the general range of 1 to 10 MTY. Both single and multiple seam operations were involved. Seam thickness

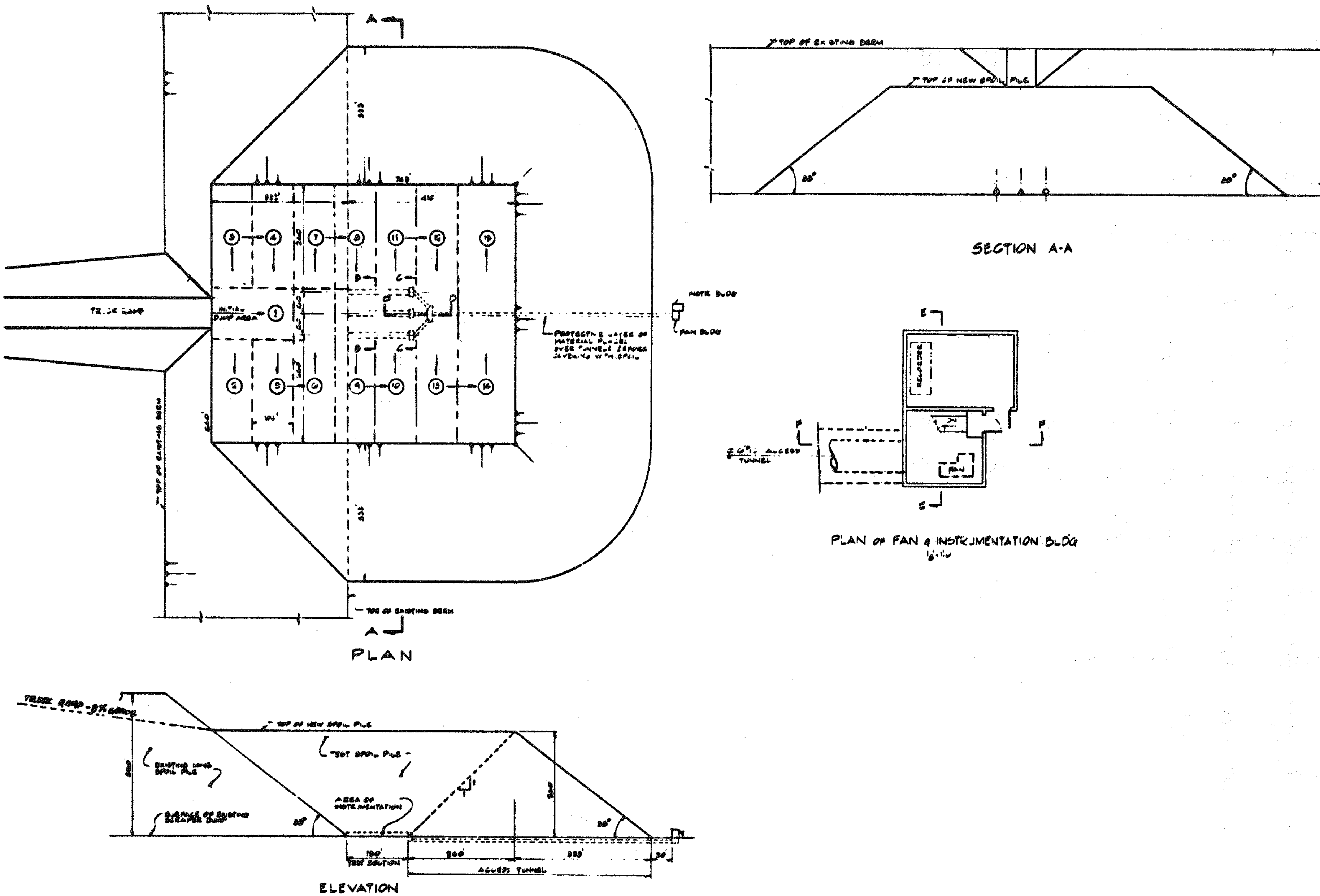


LEGEND

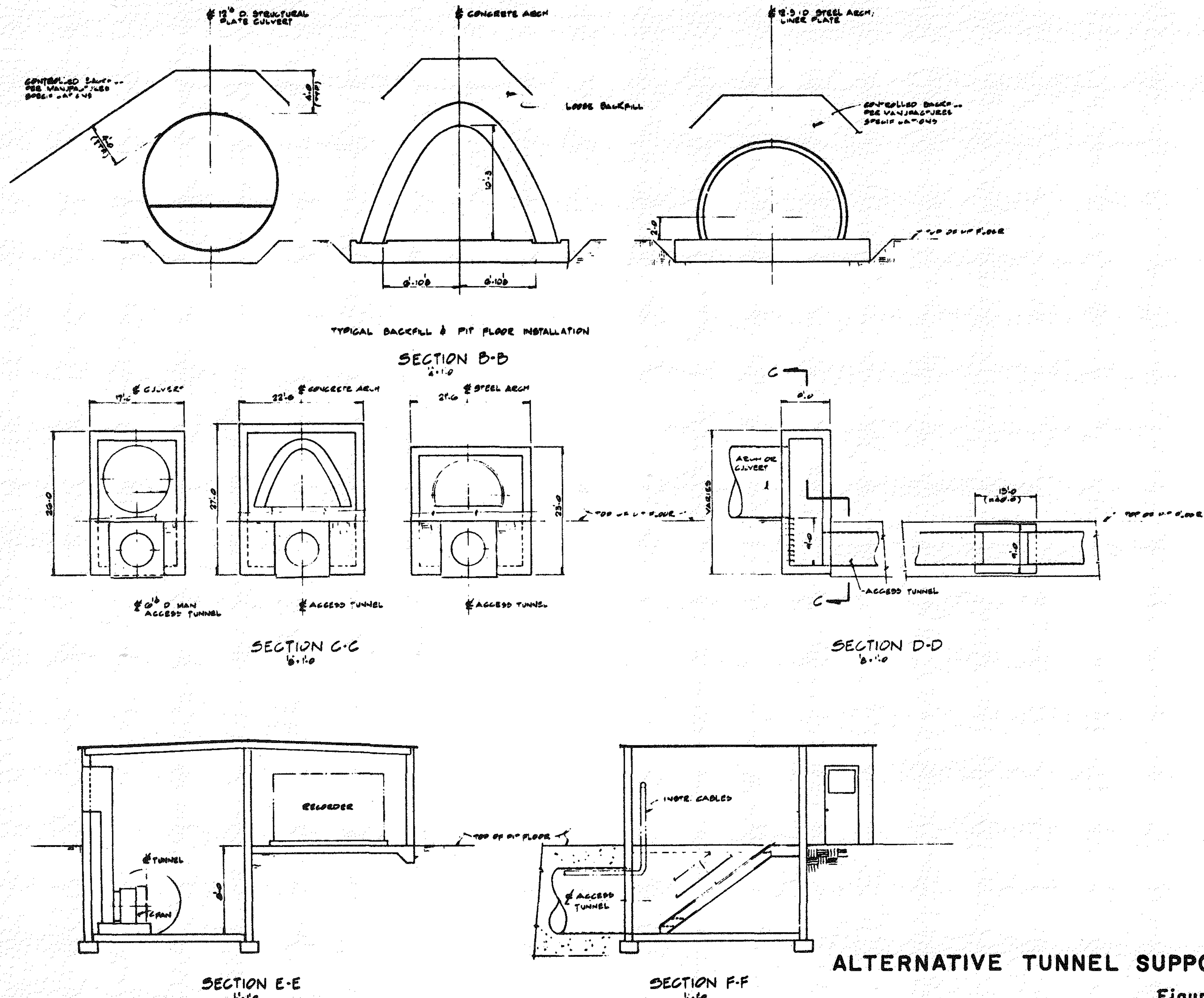
Road
Railroad
Power Line
Fence

CULVERT FIELD LOAD TEST AREA

Figure 36



FIELD DEMSTRATION PLAN—CULVERT FIELD TEST PLAN & SECTIONS Figure 37



ALTERNATIVE TUNNEL SUPPORTS

Figure 38

TABLE 12

COST ESTIMATE

PHASE II

	LABOR	MATERIAL	SUBCONTRACT	TOTAL
Mechanical	1,424	8,900		10,324
Civil	205,225	222,191		427,416
Haul and Dump Spoil			1,785,245	1,785,245
Instrumentation	94,464	75,446		169,910
Electrical	8,290	10,290		18,500
Start-up & Service Engineers	6,950		10,000	16,950
Sub-Total Direct Costs	316,353	316,827	1,795,245	2,428,425
Indirect Costs				194,314
Engineering, Home Office & Field Administration				375,078
Sales Tax				59,421
Builders Risk Insurance				13,146
Display Model				21,000
Consulting				78,290
Data Evaluation				46,645
Report				38,145
Fee				97,634
TOTAL				$3,352,098

TABLE 13

COAL MINE VISITS

MINE	OWNER	LOCATION	PRODUCTION MTY*
Colstrip	Western Energy	Colstrip, Montana	6
Decker	Peter Kiewit & Sons	Decker, Montana	10
Sarpy Creek (Absaloka)	Westmoreland Coal Co.	Hardin, Montana	4
Big Sky	Peabody	Colstrip, Montana	3
Belle Ayr	Amax Coal Co.	Gillette, Wyoming	3-10
Wyodak	Wyodak	Gillette, Wyoming	1
Dave Johnson	Pacific Power & Light	Glenrock, Wyoming	3
Cordero	Sunoco Energy Develop. Co.	Gillette, Wyoming	1
Seminoe #2	Arch Minerals Corp.	Hanna, Wyoming	4
Oak Creek	Energy Fuels Corp.	Steamboat Springs, Colorado	3
Edna	Pittsburg & Midway	Oak Creek, Colorado	1
Navajo	Arizona Public Service	Fruitland, New Mexico	7
San Juan	New Mexico Public Service Co.	Farmington, New Mexico	1
Captain	Southwestern Ill. Coal Corp.	Percy, Illinois	4
Fidelity No. 11	United Electric Coal Co.	Du Quoin, Illinois	1

*Approximate annual production rate when visited.

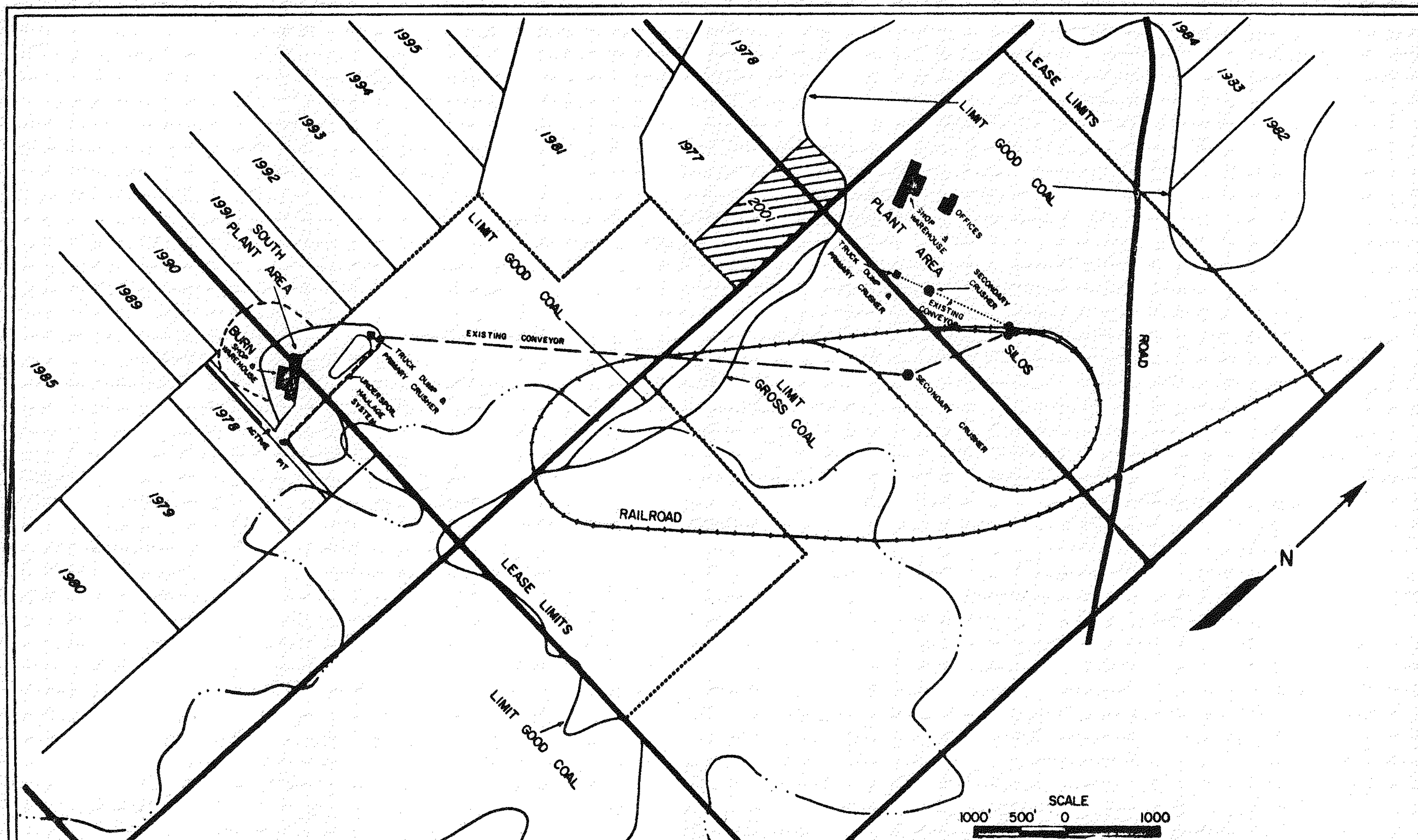
varied up to approximately 70 feet and overburden depth up to approximately 200 feet. Typical conditions for the Powder River Basin at the time of the inspection were 40-foot thick coal and 60-foot deep overburden, resulting in a stripping ratio of about 1.5 CY/ton. Future trends could reasonably be expected to reflect deeper overburden and possibly thicker coal, with a tendency toward higher stripping ratios. However, generalization such as this does not tell the true story as conditions vary widely. For example, one site involves multiple seams which are expected to merge with future mine advance to form a single 90-foot seam with overburden depths exceeding 200 feet. Other sites, where mining started along coal outcrops, involve relatively uniform coal thickness but overburden depths which will increase rapidly until only underground mining is feasible.

Discussions were held with representatives of the mines which appeared best suited to demonstration of underspoil coal haulage. Tentative mine plans and related information were obtained from several of these mines with the mutual understanding that no commitment related to a field demonstration was involved. From these plans, one was selected for development of the field demonstration plan. However, no meaningful recommendation as to a specific demonstration site can be made until the owner's mine plans and the conditions of the proposed demonstration can be better defined.

The field demonstration plan is based upon an existing mine in the Powder River Basin. The coal is typical sub-bituminous and occurs in a flat lying single seam. Current operations involve removal of approximately 55 feet of overburden and mining 45 feet of coal. However, overburden may increase substantially as mine operations expand. Coal is hauled by trucks from the face, up a ramp to a truck dump at the primary crusher. A surface conveyor then transports the coal to the secondary crusher and storage. The mine has not yet reached full production rates which are expected to be several million tons per year in the near future.

Figure 39 is a map of the mine area showing the location of surface facilities and the planned sequence of mining by year. Figure 40 is a hypothetical cross-section showing both truck and conveyor haulage systems installed in the mine. A plan view of the active pit area is shown in detail on Figure 41. The approximate location of the pit, the truck dump and primary crusher station, and the overland conveyor were taken from mine plans. Details of the layout for the haul ramp and underspoil conveyor locations were developed to permit simultaneous operation of the two haulage systems. These details do not necessarily reflect actual mine plans at this time. However, they illustrate a workable method of demonstrating the prototype underspoil haulage system in an active coal mine and the phasing in of this system to replace truck haulage when the demonstration has been successfully completed.

As the pit length is expected to be approximately 2,000 feet, a single underspoil tunnel is more than adequate to serve the entire pit. When the truck system is phased out, a decision would be necessary as to whether a back-up haulage system is required. With the exception of redundancy, the demonstration plan incorporates all underspoil haulage features described in the full-scale layout in Section 3.1.2.



FIELD DEMONSTRATION PLAN
PHASE II/III
Figure 39

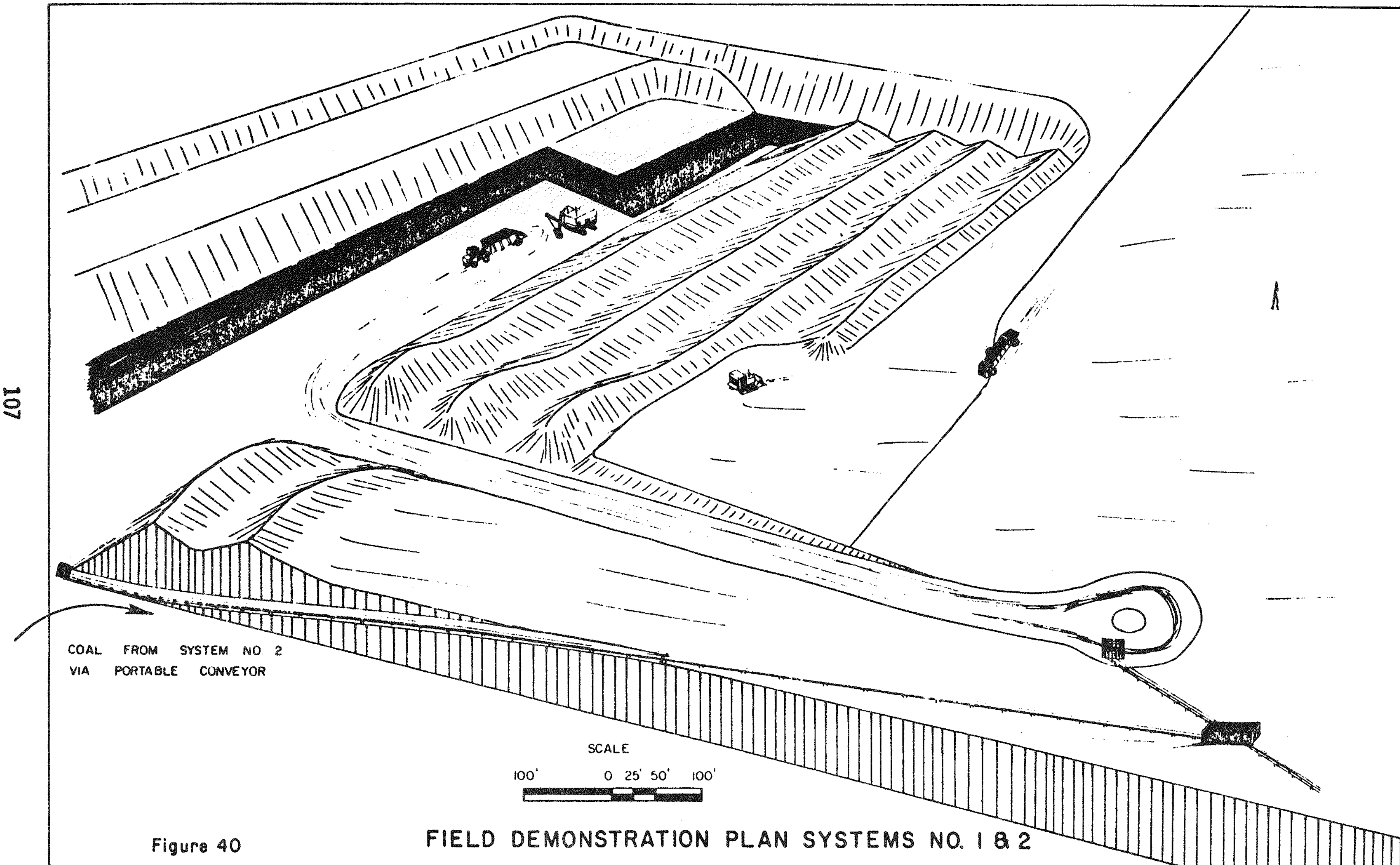
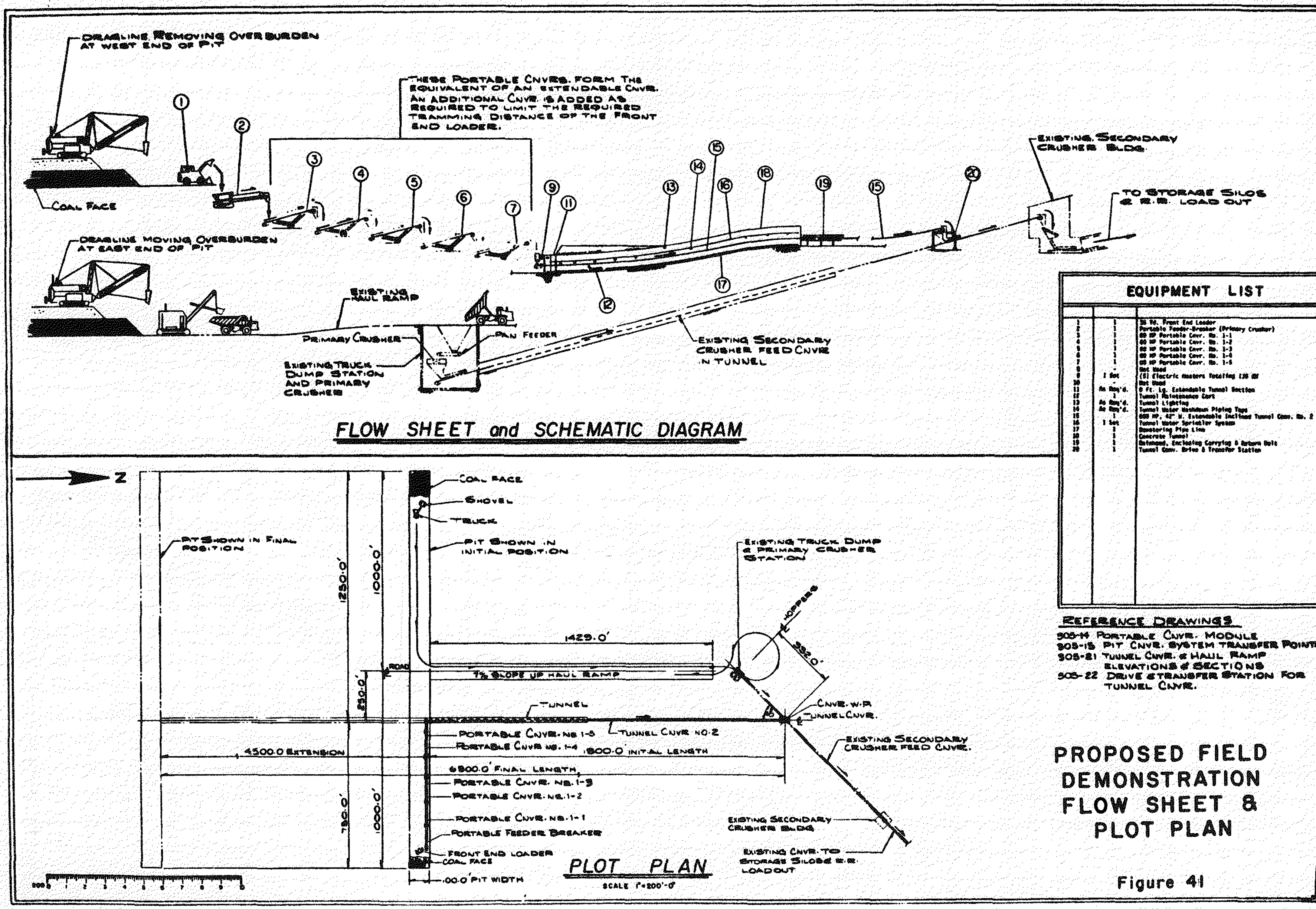


Figure 40 FIELD DEMONSTRATION PLAN SYSTEMS NO. 1 & 2



PROPOSED FIELD DEMONSTRATION FLOW SHEET & PLOT PLAN

Figure 41

1. Estimated Costs, Personnel and Equipment
2. Final Engineering
3. Component Design, Fabrication, and Delivery
4. System Installation
5. System Start-Up
6. System Modification and Maintenance
7. Data Collection and Evaluation
8. Report

3.2.2 Canvassing Effort for Test Site

Locating a suitable test site for a prototype underspoil haulage system was the major thrust of the Phase II effort. A list of 79 potential underspoil customers was prepared from various sources including the Phase I study field trips (Appendix 3.2.2). Using the criteria set forth in Phase II, priorities were set as below:

Priorities	Criteria
A	- 20 years reserve - +2 1/2 MM tons per year production - +100 ft. overburden - +20 ft. coal thickness
B	- Combination of 3 of above
C	- Combination of 2 of above
D	- One of above
E	- None of above but with plus 500,000 tons annual production

Using these priority ratings, 24 mines were selected for consideration and correspondence (Appendix 3.2.2).

Letters of introduction were mailed to all of these selected mines along with a pamphlet titled "Update on Underspoil Coal Haulage" (Appendix 3.2.2). The letters requested an appointment whereby Dravo engineers could present the proposed test to the coal mining companies.

During this period, two mine models based on the system No. 2 approach were fabricated by Dravo's model builders. One model illustrates, in plan and section, the basic concepts of the underspoil system. The other shows through movable segments of coal and overburden the pitwide stripping and mining methods and sequences. Equipment models and labeled and colored parts make visualization of the system easily understood. The object in constructing these models was to demonstrate the workability of the underspoil system. Color slides were made of the models showing through sequentual order several mining and stripping approaches.

The models were to be used for home office demonstrations or when transporting the model presented no problem, a presentation using the slides was used at other times. The mine models will be housed at the Carbondale Mining Technology Center. Reprints of earlier feasibility studies were also made available to interested mining companies.

Six coal mining companies responded to the mailing with interest in the underspoil haulage concept; however, only three companies requested a presentation of the proposed test idea.

AMAX Coal Company received the presentation with interest at their Indianapolis offices. They requested that Dravo engineers attempt to adapt the concept to their conditions and criteria present at the Belle Ayr Mine near Gillette, Wyoming. This situation required a single conveyor capable of transporting 6,000 tons per hour through a single end of the pit tunnel. They also desired that the tunnel be recoverable for a second usage in mining the adjacent block of coal. This adaptation study led to the development of System Five described in Section 3.2.3.

AMAX mining engineers prepared their own study of costs related to truck haulage from the pit to the loadout facilities as a comparison against the System Five underspoil proposal developed by Dravo. They found that underspoil haulage had certain operational and reclamation advantages along with economical savings; however, they rejected the underspoil site installation for the present because the economic savings were not sufficient to justify the high capital investment. Another fault they found was in the lesser flexibility of underspoil haulage when compared with truck haulage.

Utah International Company requested a presentation at their Navajo Mine near Farmington, New Mexico. Interest was expressed in the concept; but wheather it could be used at the Navajo Mine was questionable. Six and more thin coal seams are mined at several short lived pits simultaneously. The multiple seams present a technical problem for the underspoil system and the relatively short mine life for each pit makes the high capital cost per ton of coal economically unattractive.

ARCO Coal Company received the presentation with interest as they are in the process of designing their Coal Creek Mine, near Gillette, Wyoming. Their mining criteria geology and property situation are well suited for an underspoil haulage installation. The fact that the underspoil tunnel is similar to an underground coal mine slope and will require the same regulations as an underground mine caused them concern. Underspoil haulage being a new and unproven technique also opposed their instructions to use only proven technology. The ARCO engineers did, however, request that Dravo engineers study Coal Creek mine plans and attempt to develop alternative approaches to conveying the coal from the pit to surface using one or more of the coal elevating systems developed by Dravo in the "Underspoil Haulage Related Studies" (Section 3.3.6).

When it became increasingly apparent that canvassing was not producing a test site for the Phase III project; the Department of Energy personnel proposed that no more active canvassing be done by Dravo. In place of canvassing they proposed that Dravo expend their efforts on broadening the technology of continuous coal conveying from open-pit and strip coal mines. Section 3.3 titled "Underspoil Haulage Related Studies" is the result of these efforts.

3.2.3 System Five Study

As stated above in Secetion 3.2.2 AMAX Coal Company suggested that a logical extension of the underspoil haulage concept would be to adapt the idea to open-pit haul-around mining methods. System Five was developed to accommodate these criteria not only to fit the Belle Ayr Mine, but, to be applicable to many other truck and shovel haul-around pits.

3.2.3.1 Introduction

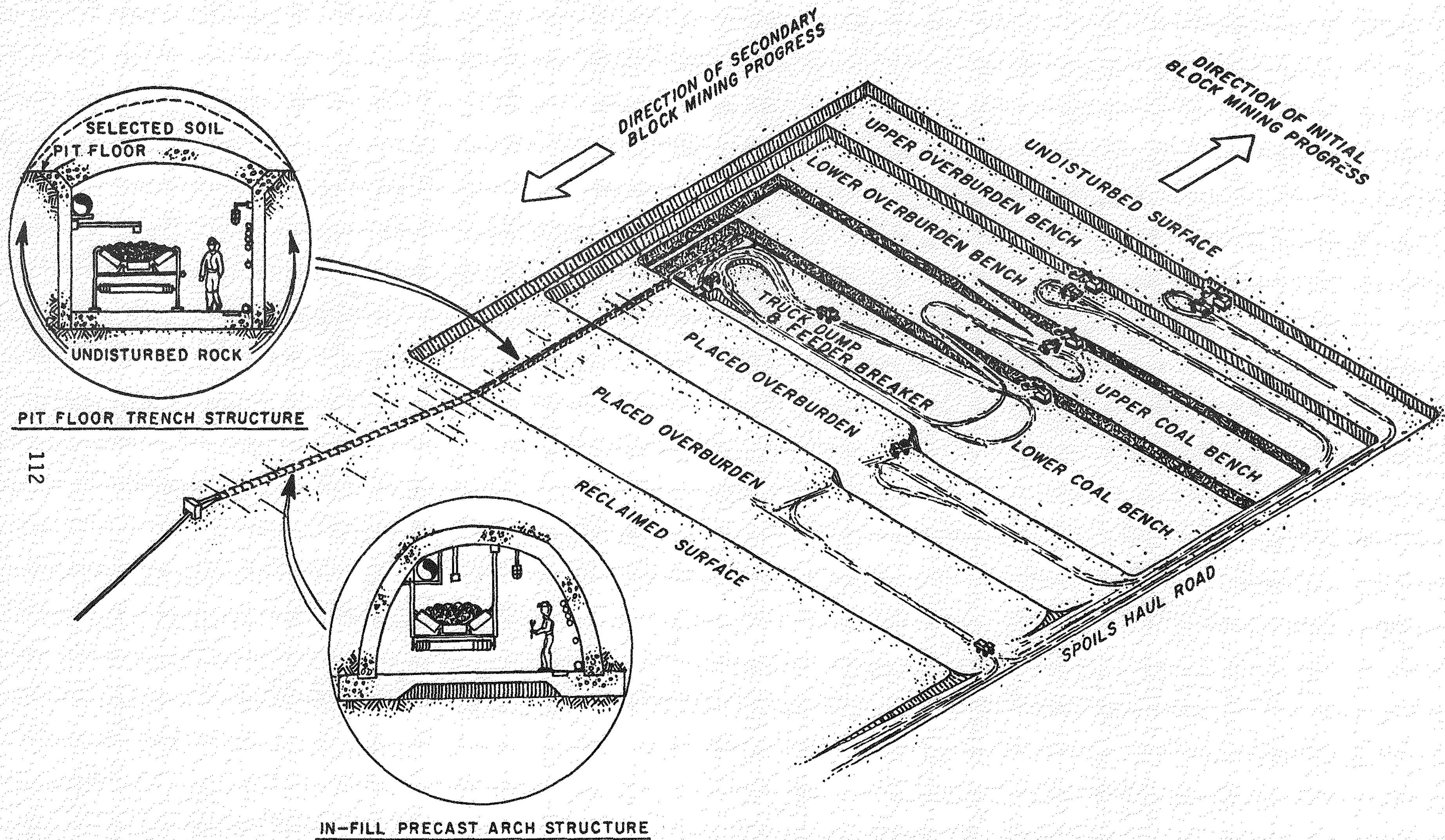
Dravo's past studies were aimed toward usage in long dragline operations. Two or more parallel tunnels were proposed for these pits to limit the in-pit haul distances.

System Five is an addendum to the earlier studies as it is proposed for a truck shovel haul-around spoilage pit. Because of the shorter pit length and wide pit floor, a single belt is proposed. System Five was designed to accommodate a turn-around direction of advance and re-excavation of the once buried tunnel structure for a second usage of the belt.

3.2.3.2 Conceptual Application

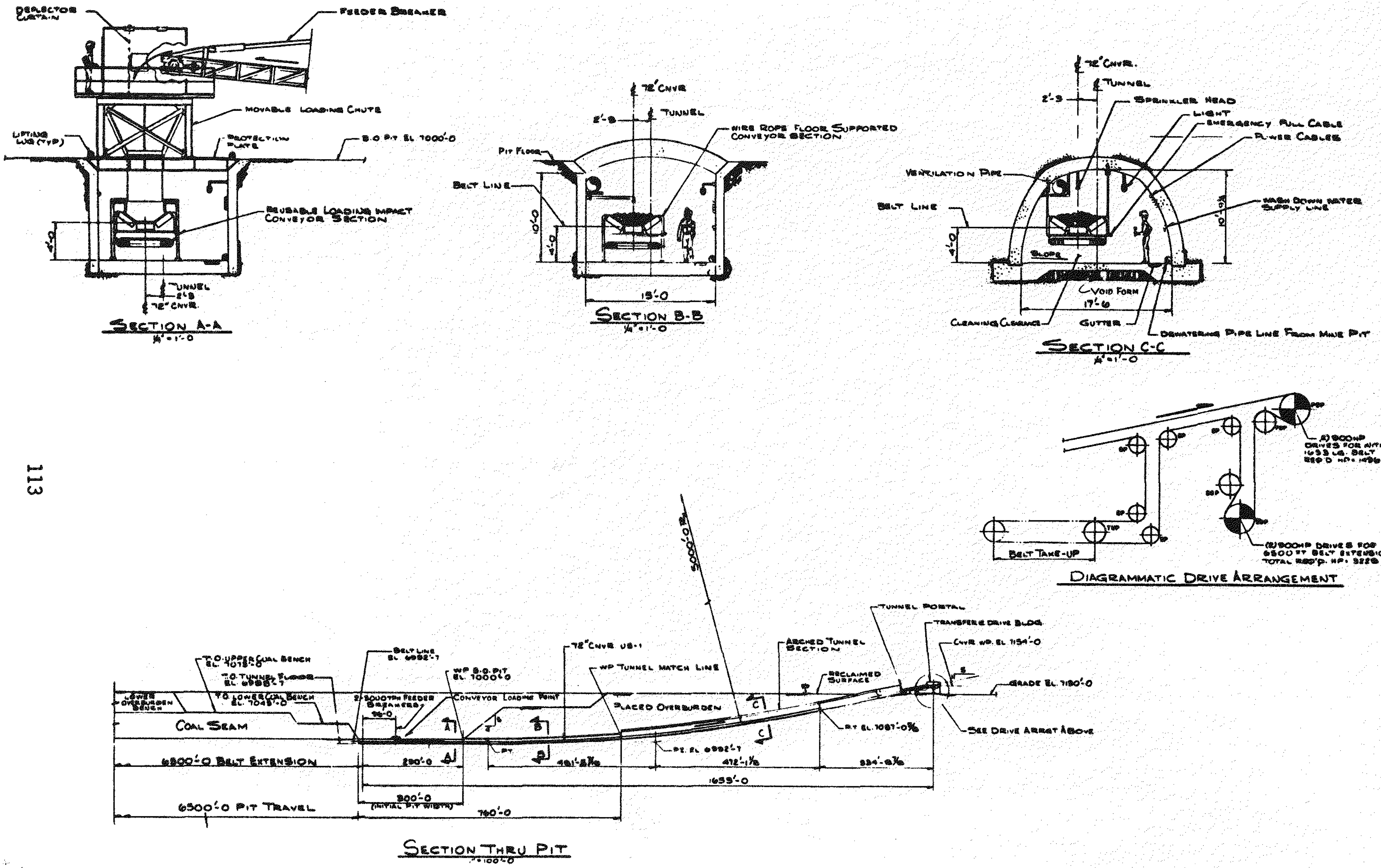
Application of Underspoil Haulage System No. Five to the haul-around mine plan is illustrated by Figure 42. Two benches of overburden are being stripped with trucks and shovels. Spoiling and reclamation advance at the same rate as stripping. Coal is mine in two benches and hauled to surge bins and feeder breakers at the underspoil conveyor loading point. This plan uses end-dump coal trucks. In-pit shiftable conveyors could also be considered for this purpose to produce an even greater coal haulage efficiency.

Figure 43 contains a longitudinal profile of underspoil tunnel and cross sections of the tunnel structure. Two different structures are illustrated to serve under the different conditions. One is the inclined in-fill portion and the other is the pit floor segment. An arched precast concrete structure is proposed for the inclined segment under the assumption that this portion would be in-fill and, therefore, subject to side and bottom stresses



SYSTEM 5 – TRUCK AND SHOVEL HAUL-AROUND AND UNDERSPOIL HAULAGE

Figure 42



SYSTEM 5—CONVEYOR PROFILE & SECTIONS Figure 43

as well as vertical loading. The pit floor segment is proposed to be constructed in a trench to provide for east re-excavation and to take advantage of the rock in supporting the structure (Figure 43). The requirement of 6000 tons per hour was placed on the conveyor belt. Figure 43 illustrates the belt conveyor system capable of producing this tonnage.

Based on the turn-around concept for re-excavating the underspoil tunnel two approaches were devised for mining the same rectangular lease block as suggested for the underspoil model. Referring to Figure 44, three figures are shown. The top figure illustrates the double tunnel underspoil system devised for systems one through four.

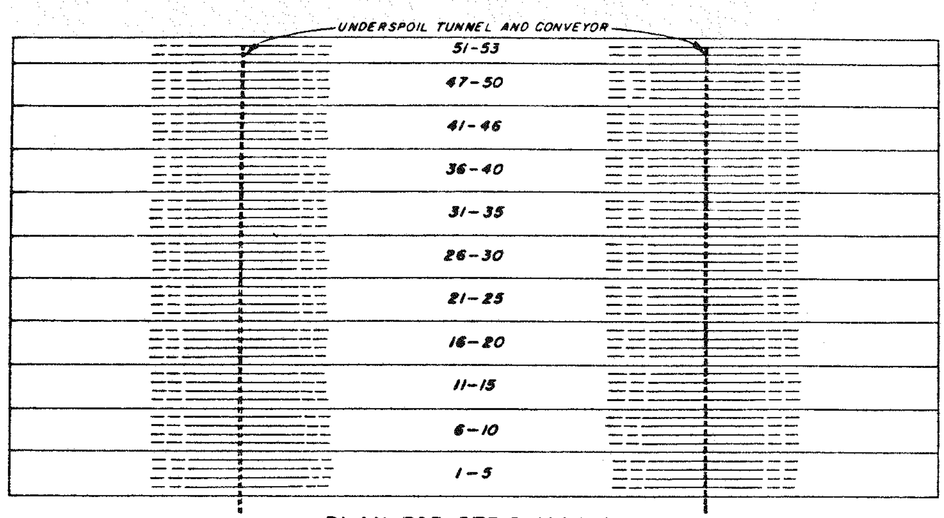
The lower two figures in Figure 4 illustrate System Five turn-around approaches. Two tunnel installations are proposed in the middle figure for positions similar to the previous installation; but sequential in construction instead of congruent. In this middle case, the right hand tunnel will be advanced to the boundary then through the turn-around procedure, be re-excavated in returning. The second tunnel will be constructed with the completion of the first and be continued in a similar manner to the first tunnel.

A single installation approach is illustrated in the bottom figure. The tunnel parallels the long dimension of the block with a single turn-aroung. A tunnel and conveyor nearly two miles long will result from this layout with the consequences of possibly requiring a mid-point transfer and a ventilation and access shaft to surface.

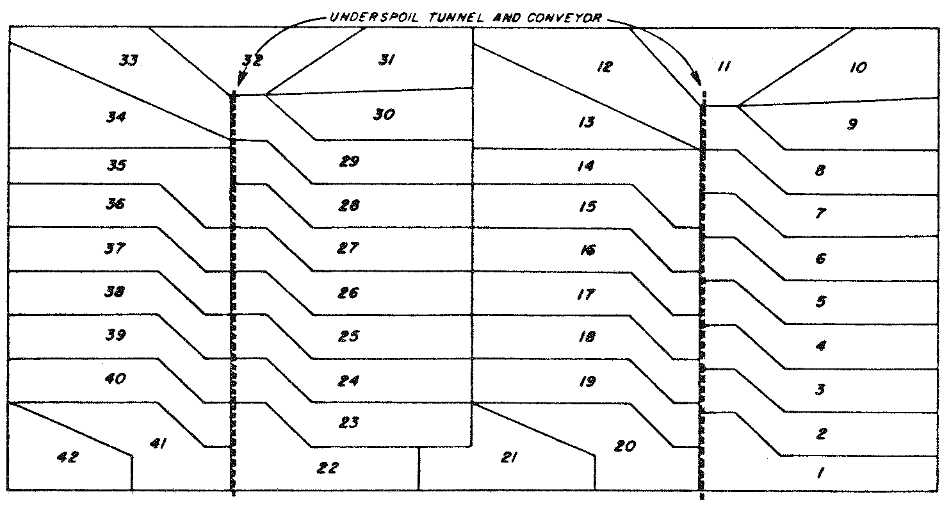
Twelve hundred and eighty acres of coal could be mined through the above described layouts, however, less or more could be served by the systems. Irregularly shaped coal deposits or lease holdings might require some modifications to tunnel alignments. Changes in tunnel direction can easily be made; however, the conveyors can not be bent without transfer points.

To handle the required 6000 tons per hour, two Stamler Model BF-23-12-10 feeder-breakers are proposed. The manufacturer states that these will handle 3000 tons per hour. These will discharge into a single short portable conveyor then into a loading point hopper as shown in Figure 43. The feeder breakers will be set up parallel to each other under two joined surge hoppers as shown on Figure 45. Figure 46 is an elevation view of the feeder-breakers with their surge or discharge hopper. The feeder-breakers are skid mounted but should sit on a concrete platform. The hoppers are designed to have a combined surge capacity of approximately 320 tons or 2.67, 120 ton truck loads. While these are mounted on concrete piers, they are considered to be portable in that they can be unbolted at the middle, lifted out of place with a crane or shovel, and transported individually in two trucks.

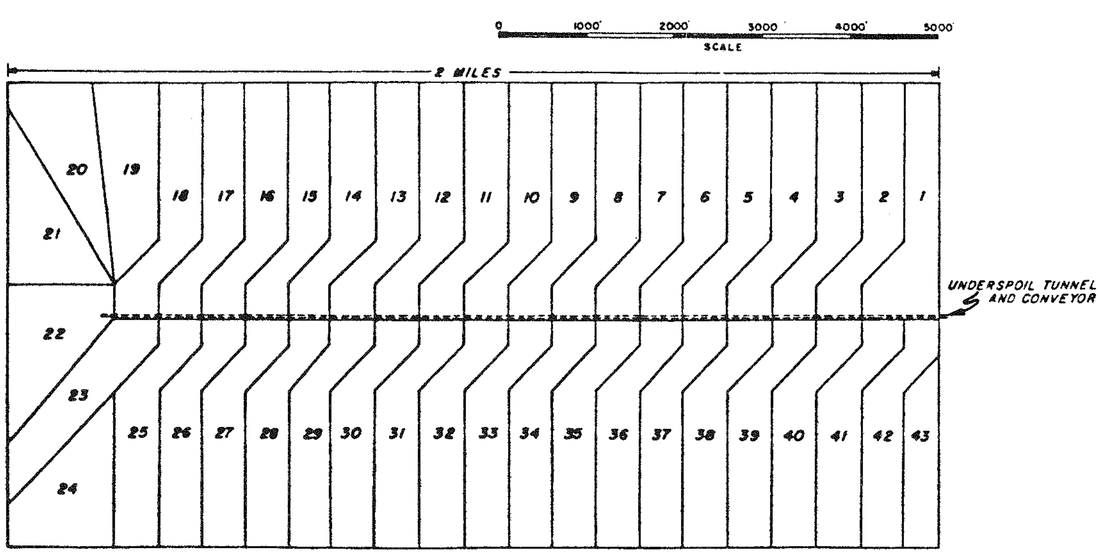
The combined height of feeder-breakers and hoppers is approximately 26 feet. To dump the end-dump coal haulers into this surge hopper a ramp must be constructed similar to the one illustrated in Figure 45. Approximately 550 to 600 feet of pit bottom width is necessary for this design.



PLAN FOR STRIP MINING

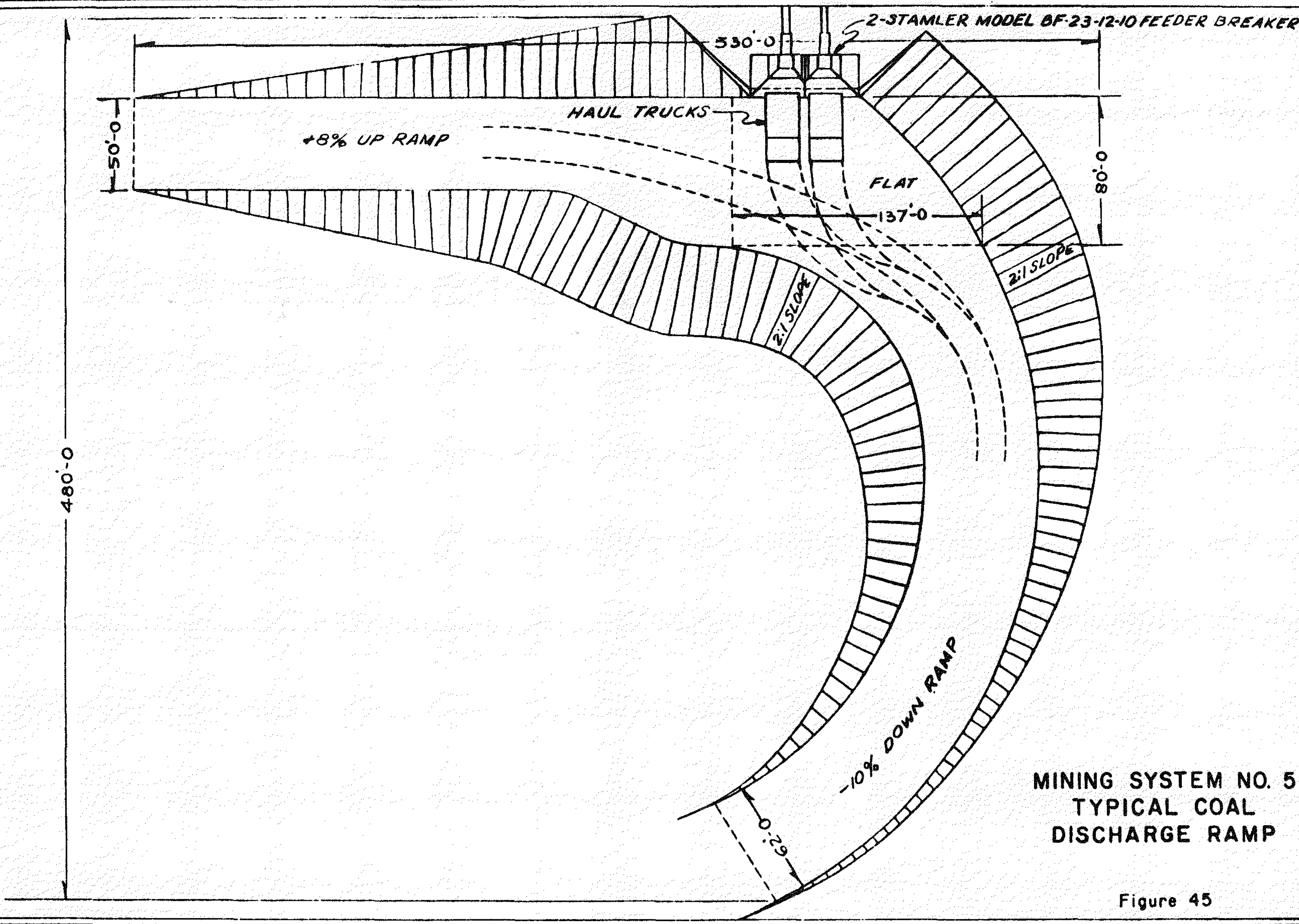


TRUCK AND SHOVEL HAUL-AROUND PIT — REPEATED INSTALLATION



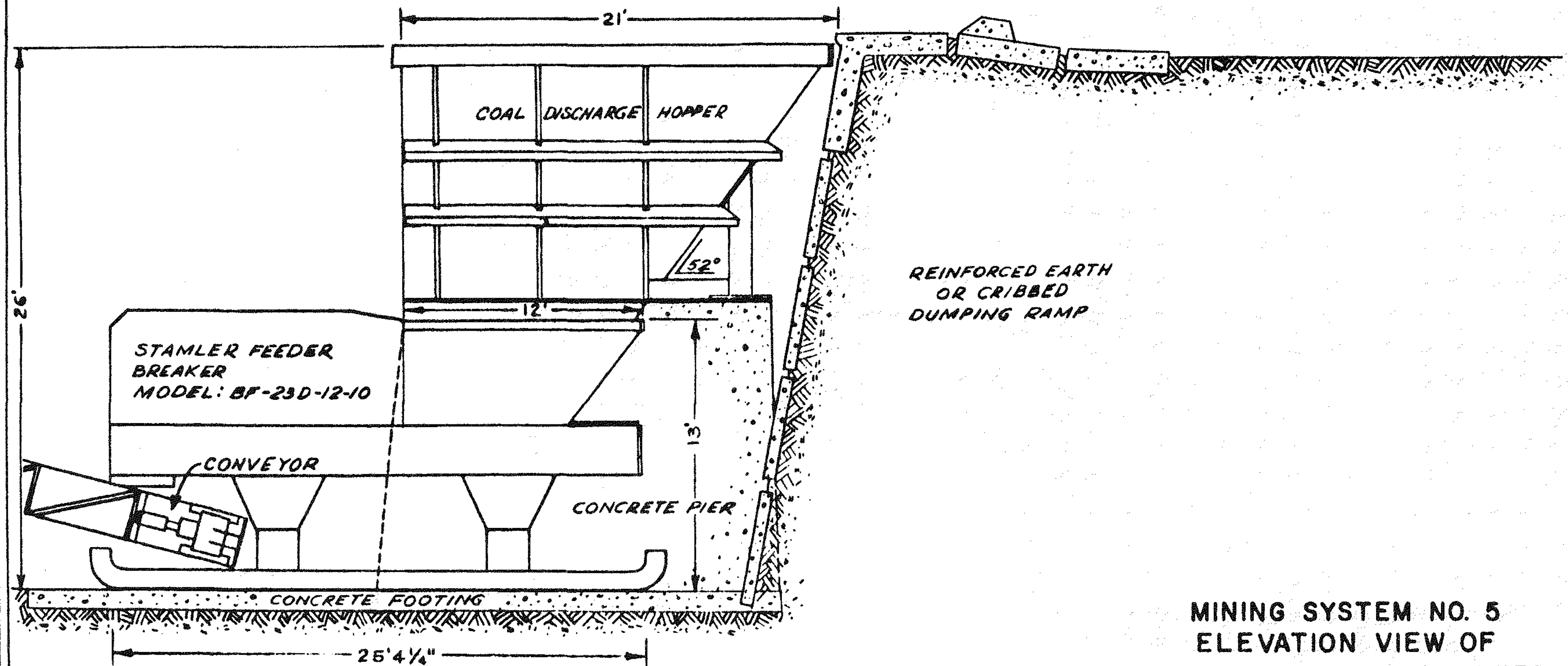
TRUCK AND SHOVEL HAUL-AROUND PIT - SINGLE INSTALLATION

Figure 44 — GENERAL LAYOUTS FOR MINE MODEL SYSTEMS



MINING SYSTEM NO. 5
TYPICAL COAL
DISCHARGE RAMP

Figure 45



MINING SYSTEM NO. 5
ELEVATION VIEW OF
COAL DISCHARGE FACILITIES

Figure 46

Figure 43 illustrates two conveyors. A cable support system is planned to take advantage of the rigid structure provided by the tunnel. Power requirements are for full length. Motors can actually be added as needed.

Tonnage	6,000 STPH
Belt Width	72 Inches
Belt Speed	963 FPM
Actual Belt HP	3,073 HP
Horsepower Required at Motor Shaft	3,228 HP
Motors Required	(4)900 HP @ 1750 RPM

Two different tunnel structures are proposed although others may be more suitable under different conditions. The tunnel segment that is inclined from the land surface to the pit floor was assumed to be maintained in back-filled spoils; consequently, a structure capable of resisting stress expected in this condition was designed. The pit floor tunnel was designed to be constructed in a trench below the pit floor, consequently, a different structure is proposed to take advantage of these conditions.

1. The inclined segment structure is illustred in Figure 43. It was designed by computer analysis to closely aproximate a semi-circle.
   - -base width 17'-6"
   - -width at conveyor height of 4 feet 15'-0"
   - -wall thickness 1'-6"
   - -load criteria
     - a. 130 feet of fill at 55 lb/ft^3
     - b. invert to rest on compacted fill
   - -invert width 27.5 feet with void space as shown
   - -arch is precast reinforced concrete
   - -segment length 5 feet
   - -invert is cast in place
   - -centerline height 10'-9 1/4"

   This structure is designed for 130 foot burial. Where burial is less, a lighter structure can replace this. It might be advantageous to design the reclamation to use a shallower fill over this structure. Steel culverts cold be used under a shallow fill. Should the inclined segment be cut in virgin rock instead of fill then the pit floor design can be used for a considerable savings in initial cost.

2. The pit floor segment structure is illustrated in Figure 43. This design takes advantage of the wall rock of the trench to support the major part of the loading stress. A curved roof panel beam spans the opening between cast in-place of walls.
   - -inside width 15'
   - -inside height 10'
   - -wall thickness 1'
   - -floor thickness 1'
   - -roof panel beam thickness 2'-0"
   - -roof panel beam length 10'
   - -weight of panel beam 25 ton

-roof panel beams are removable for second access
-water sealant used on all joints with bentonitic soil cover to reduce water seepage
-water collection ditch and sumps used for seepage collection

The low profile of this trench structure will allow re-excavation by shovels. Roof panel beams are intended to be removable to allow easy re-access to the conveyor on the second pass.

3.2.3.3 In-Pit Coal Loading Facilities

Using end-dump coal haulers to move mined coal from two shovels to the underspoils conveyor loading point involves unloading, surging, sizing, and feeding facilities. Coal must be placed on the conveyor belt at a continuous uniform rate with lump sizes not to exceed eight inches. To accomplish this the following are proposed:

1. Coal discharge ramp will be constructed of compacted spoils fill hauled from a stripping shovel by end-dump trucks and shaped with dozers to approximate the plan shown in Figure 45.

2. Coal discharge or surge hoppers are to be constructed of steel in two separate but joinable sections as shown in Figure 46. Combined capacity is 320 tons or 2.67 truck loads.

3. Two feeder-breakers operating in parallel will draw coal from the combined hoppers and place it on a short 72 inch portable belt operating at right angles to the feeder-breaker discharge belts. Details of the feeder-breaker are contained in Appendix 3.2.3. Selection of these machines was to demonstrate feasibility of off-shelf equipment and is not a recommendation over other available machines.

4. One feeder-breaker discharge collection belt would move the coal from the feeders to the underspoil belt. It would be located at approximate right angles to both the feeder-breakers and the underspoil haulage belt. This belt can be variable in length depending on the pit floor conditions, but will have the same capacity as the underspoil belt.

5. The underspoil conveyor loading hopper is illustrated on Figure 43.

6. A water retention dam is suggested to isolate the underspoil tunnel from the major part of the pit should there be a large in-flow of water. It can be low extensions of the discharge ramp. Other dams along the edges of the underspoil tunnel can be used to further reduce the water in-flows to the tunnel.

3.2.3.4 Other Considerations

For this conceptual study some other facilities were not detailed, yet need to be mentioned. Some of these are: tunnel ventilation, water collection and discharging, automation of conveyor system to reduce labor costs, and surface transfer conveyors and structures.

Estimated Costs 1979 Dollars

Inclined Tunnel Arches Precast Concrete and cast-in-place Concrete invert	$ 1,142.00 per lin. ft.
Pit Floor Trench Tunnel Precast Concrete panel beam and cast-in-place floor and walls Includes excavation	$ 677.00 per lin. ft.
Conveyor 72"	$ 237.60 per lin. ft.
Conveyor Installation	$ 16.00 per lin. ft.
Conveyor Total (including drive motors and initial equipment)	$ 253.60 per lin. ft.
Pit floor discharge ramp (one each move)	$ 42,000.00
Hopper and feeder-breaker mounting	$ 12,870.00
Portable Conveyor in-pit use	$ 95,000.00
Feeder-breakers	
Ea. (Stamler Brother)	$350,000.00
Two machines	$700,000.00
Discharge surge hoppers	
Ea. Unit fabricated	$ 18,000.00
Both sides	$ 36,000.00

Initial Costs to Surface Conveyor Only

Inclined tunnel segment	
850 feet @ $ 1,142.00/ft.	$970,770.00
Pit floor tunnel	
500 feet @ $677/ft.	$338,500.00
Conveyor (Surface)	
1350 feet @ $216.57/ft.	$292,370.00
Drive motors and initial equip.	$307,347.00
Total	$599,717.00
Pit floor discharge ramp + hopper F-B mountings	$ 54,870.00
Portable in-pit conveyor	$ 95,000.00
Feeder-breakers	$700,000.00
Discharge surge hoppers	$ 36,000.00
Total Initial Cost	$2,794.787.00

Cost for Each 500 Foot Advance

Pit floor tunnel segment	$338,500.00
Conveyor	$108,285.00
Pit floor discharge ramp	$ 54,870.00
Total incremental cost	$501,655.00
1,134 ft. 500 ft. = 2.27 each year	$1,138,757.00

Cost for Advancing Full Designed Length 8,153 Ft.

Initial cost (1350 ft surface)	$2,794.787.00
Cost to advance remaining 6,803 ft.	
Tunnel	$4,605,631.00
Conveyor	$1,473,326.00
Total	$6,078,957.00
Total cost complete installation	$8,873,744.00
Annual ownership based on 14 years*	$ 633,830.00
Ownership cost per ton (25,000,000 ton/yr)	$ 0.048*

* Ownership cost include only capital costs and interest at 10%.

Application of Underspoil Haulage System No. 5 to the haul-around mine plan is illustrated by Figure 42. Two benches of overburden are being stripped with trucks and shovels. Spoiling and reclamation advance at the same rate as stripping. Coal is mined in two benches and hauled to surge bins and feeder breakers at the underspoil conveyor loading point. This plan uses end-dump coal trucks. In-pit shiftable conveyors could also be considered for this purpose to produce an even greater coal haulage efficiency.

Figure 43 contains a longitudinal profile of underspoil tunnel and cross-sections of the tunnel structure. Two different structures are illustrated to serve under the different conditions. One is the inclined in-fill portion and the other is the pit floor segment. An arched precast concrete structure is proposed for the inclined segment under the assumption that this portion would be in-fill and, therefore, subject to side and bottom stresses as well as vertical loading. The pit floor segment is proposed to be constructed in a trench to provide for easy re-excavation and to take advantage of the rock in supporting the structure.

Underspoil Haulage System No. 5 is a viable application of the underspoil haulage concept to truck and shovel, haul-around, strip mining. The wide pit floors of the mining method allow easy extension of the tunnel structure and conveyor with minimal disruption of production. Because of this lack of disruption, a single conveyor and tunnel can be used. By locating the tunnel adjacent to one of the endline highwalls, an adjoining block of coal might be mined with re-excavation of the tunnel.

The pit floor tunnel structure can be located in a trench, thereby taking advantage of in-place rock for support. Another advantage of the trench installation is the low projection this structure makes above the floor elevation, aiding in re-excavation.

Initial capital costs of the system are very high; however, it is capable of transporting a very large amount of coal at a very low operating cost. By prorating the capital cost against a large coal tonnage, it becomes very low.

The conveyor itself is designed with proven technology and off the shelf components. The tunnel structures are conservatively designed to withstand the loading. Detailed engineering with the aid of soils and rock mechanics studies should produce less costly structures.

3.2.4 Masterplan For Phase III

The contract modification signed by Dravo and the Department of Energy outlined the requirements for the "Master Plan For Phase III" as follows:

1.4.3 Master Plan for Phase III

1.4.3.1 Predicated upon the successful location of the test/demonstration site as described above, a site-specific masterplan shall be developed detailing the implementation of Phase III. It shall detail construction schedules, layouts, labor and equipment requirements, expenditures schedules, and capital and operating cost estimates for the test/demonstration of underspoil haulage. Also, a means of evaluating the performance and success of the test/demonstration shall be described and tabulated to enable observers and researchers documentation of the success of the test/demonstration.

This masterplan study and report would carry the site-specific for a test facility from Phase II into Phase III with continuity. Phase III being the actual final engineering, construction, operation, testing, and evaluation of the prototype installation. The payback prorate agreement would also be negotiated between the mine operator and the Department of Energy.

Phase II effort did not located a test demonstration site and therefore no master plan was prepared. Effort originally planned for developing the master plan for Phae III was redirected to studies related to underspoil haulage as described in Section 3.3 below. It is hoped that at some time in the future the Phase III project can be re-instituted.

3.3 Underspoil Haulage Related Studies

As discussed in Section 3.2.2, when a demonstration test site was not located following a reasonable amount of canvassing effort, the Department of Energy engineers proposed that no more active canvassing be done by Dravo. They requested instead, that project emphasis be placed on broadening the technology of continuous coal conveying from open-pit and strip coal mines. Other subjects related to coal conveying were also proposed making a total of six "Underspoil Haulage Related Studies".

3.3.1 New BLM Coal Leasing Program

On June 4, 1979 Secretary Cecil D. Andrus announced the establishment of a new Federal Coal Management Program designed to lease approximately 1.5 billion tons of federally owned coal to mining companies. This program is intended to meet increasing energy production needs through 1987.

Competive coal leasing was suspended in 1971 by moratorium while an environmental impact statement was being prepared.

Leasing targets for three major coal regions of the west were designated for 1981 and 1982. These targeted regions are: The Green River - Hams Fork Region of Idaho, Wyoming, Utah, and Colorado (531 million tons in sales beginning in January 1981); the Uinta - Southwestern Utah Region of Utah and Colorado (109 million tons beginning in mid-1981); and the Powder River Region of Montana and Wyoming (776 million tons beginning in 1982) see Figure 1.

The purpose of this study is to make a general evaluation as to the possibilities for application of the underspoil haulage concept to mining coal in these regions. Without specific knowledge of the lease locations and geology it is not possible to make more than general comments.

3.3.1.1 Green River - Hams Fork Region

The Green River - Hams Fork Regions combine to form a long narrow bank of coal mineralization stretching from southeastern Idaho, through southwestern Wyoming, into Utah and northwestern Colorado (Drawing One). U.S.B.L.M. leasing plans are for 531 million tons beginning in 1981.

Multiple lenticular coal seams characterize the Green River Region. Dips are small except along the western margin where they are uplifted from 20° to 50°. Thicknesses average about 9 feet but may coalesce to form one seam 30 to 40 feet thick. Much of the Green River Region is overlain by younger rocks which conceal the coal beds.

The Hams Fork Region is in the uplifted band west of the Green River Region. It is characterized by multiple highly faulted and folded seams. Coals up to 100 feet thick are mined at steep dips.

Where strip mining is economically feasible in the flatter thick seams of the Green River Region, it appears that the underspoil haulage concept might be utilized. The steeply dipping multiple seams of the Hams Fork Region, however, will require some conceptual changes to become feasible for underspoil haulage application.

3.3.1.2 Uinta - Southwestern Utah Region

Leasing of coal for this region is planned for 109 million tons beginning in mid-1981. The Uinta Region is characterized by a multiplicity of relatively thin coal seams and structural disturbance. Strip minable coal is generally limited to uplifted and exposes areas.

The average thickness of the seams appears to be about 10.5 feet with very little coal occurring in thicknesses greater than 30 feet. The Book Cliffs field portion of the Uinta Region in Utah produces from beds averaging 5 to 6 feet in thickness. Various geologic activities have greatly disturbed the horizontality of these coals so that they rarely occur flat lying under strippable overburdens.

Coal beds in southwestern Utah are generally flat lying but thin and heavily covered by overburden.

In general it appears as if the Uinta - Southwestern Utah Regions are not suitable for the current concepts of underspoil haulage systems.

3.3.1.3 Powder River Region

The announced program schedules 776 million tons of new coal to be leased beginning in 1982 for the Powder River Basin of Montana and Wyoming. Strippable coal reserves have been estimted by the U. S. Bureau of Mines to be approximately 55 billion tons in this region. The new leasing will amount to only about 1.4% of the total strippable reserve.[1]

Forty-five seams have been named in Montana and Wyoming for Powder River Basin coal. Some of these may be shown to correlate in the future others may be added. These seams vary from five to over 200 feet in thickness with the major part of the volume occurring in coal thicknesses in the 30 to 70 foot range.[1]

The Powder River Basin forms a gently asymmetrical syncline between mountain ranges on the east and west. Dips are usually found to be less than 5° with overburdens from zero to several hundred feet. Most of the present stripping involves 100 to 200 feet of overburden.

Underspoil haulage of coal was generally envisioned to apply to the Powder River Basin type occurrences. It, therefore, is logical that much of this new coal leasing will be ideally suited to an underspoil haulage application.

3.3.1.4 Conclusions

New coal leases in the Green River and the Powder River Regions might be well suited to take advantage of the underspoil haulage concepts. The thick coal seams and relatively deep overburden will justify the high initial capital costs when compared with truck haulage. A quantitative estimate for the amount of this coal minable through an underspoil system can not be made without more information; nevertheless, from knowledge of present operations it can be estimated that a major volume of the coal can be planned for mining through underspoil conveyor systems.

The Hams Fork, the Uinta, and the Southwestern Utah leases will probably be unsuited for open pitting by underspoil haulage systems. Hams Fork coal seams are steeply dipping, therefore, outside the present concepts for the systems. Uinta and southwestern Utah coals occur in multiple but thin seams.

Much of it is best suited for underground extraction methods, and those areas that might be strip mined would have difficulty using the underspoil systems because of the many mining horizons and geologic disturbance.

[1] Keystone Coal Industry Manual 1974, McGraw-Hill N.Y., N.Y.

3.3.2 Comparison of Manpower Requirements

Manpower is the most sensitive factor in most activities whether business, social, or political. Where intelligence and creativity are needed, only people can do the job; but, where the need is for accomplishing a simple task, such as transporting coal, machinery can accomplish this best with a minimal labor force.

Available personnel are in critically short supply in many of the newer coal development areas. Bringing in a large labor force not only is expensive, but also creates environmental, social and economic problems for the areas. Manpower needs are consequently an area appropriate for special consideration and study.

3.3.2.1 Objective of Study

The overall objective of the underspoil haulage study is to develop conveyor coal haulage methods and knowledge as a superior alternative to truck transport. Direct comparison of manpower requirements between a totally truck haulage system and a totally conveyor system is made in this study.

3.3.2.2 Basis for Study

All manpower determinations and criteria were taken from the underspoil haulage study engineering back-up.

3.3.2.3 Criteria of Input

The general design criteria for the underspoil haulage mine model were the basis of input using Systems No. 1, 2, and 3A for the specific manpower data.

3.3.2.4 Procedure

Truck haulage manpower requirements were taken from System No. 1 for each overburden and coal thickness. Averages for these six cases were calculated to be 57 manshifts per week for the haul truck drivers and 23 manshifts per week for the road maintenance workers. The total of 80 manshifts per week for two shifts, five days per week then means that eight people were engaged in coal haulage at any time. Using the pay scales and tax and fringe rate of the 1977 report, the costs of labor for week, year, and ton were estimated.

Conveyor haulage manpower requirements were taken from Systems No. 2 and 3. System No. 2 utilizes piggyback portable conveyors and System No. 3 utilizes a shiftable conveyor in the pit. The same number of manshift weeks was found for both conveyor systems. It was also found that the work force did not vary for the varied coal and overburden thicknesses, but remained a total of 50 manshifts per week. This 50 manshifts per week was derived from using four operators and one maintenance person two shifts a day, five days per week. The cost of this labor per week, year, and ton were then estimated using the same pay scale and burdens as the 1977 report.

3.3.2.5 Analysis of Results

The following data illustrates the manpower requirement difference between all truck haulage and all conveyor haulage of coal from the pit floor to the mine railroad loadout point.

Haulage System	Manshifts Per Week***	Base Rate	Taxes & Fringes	Total Cost/Wk	Total Cost/Yr	Cost Per Ton **
Truck	80	$6.45*	$2.90	$5,984	$311,168	$0.062
Conveyor	50	6.45*	2.90	3,740	194,480	0.039

Savings in labor costs using conveyor transport as opposed to truck haulage = $0.023 per ton.

Percent Savings = 37%

* Late 1976 early 1977 rates.
** Annual Production rate is 5,000,000 tons
*** Includes maintenance and repair labor

Factors other than direct costs needing consideration in this comparison are:

- Fewer workers operating less hazardous equipment, as in the conveyor situation, will have a greater degree of personnel safety than will the truck drivers.

- The environmental impact of the creation of the coal mining operation will be less with fewer people.

- Overhead and support personnel costs will be less with a smaller work force than with a larger one.

- The conveyor operation will be less vulnerable to the skilled labor shortage because of its lower manpower requirements.

3.3.2.6 Conclusions

Direct operating costs pertaining to labor will be approximatley 37% less for the conveyor haulage system as opposed to the truck haulage of coal. Haulage lengths and gradients will affect truck haulage personnel requirements; whereas, conveyor haulage systems personnel will be affected very little by length and gradient changes.

Factors also related to manpower requirements that show conveyor haulage has advantages over truck haulage include: personnel safety, environmental impacts, overhead and support personnel costs, and labor shortage influences.

3.3.3 Comparison of Energy Consumption

Energy consumed in producing another energy source should be analyzed to maximize the end product efficiency. Diesel powered truck haulage is commonly used as the prime mover of coal from the face loading point to the railroad or power plant receiving point. The main thrust of the underspoils haulage study is, however, to urge utilization of the more efficient conveyor haulage systems. A comparison of energy consumptions between the two methods is, therefore, of vital interest, especially with the present day and future energy shortages.

3.3.3.1 Objective of Study

A direct comparison of energy consumptions, costs, and related factors is the objective of this study.

3.3.3.2 Basis for Study

A considerable amount of engineering and estimating study was accomplished in the several underspoils projects. This work along with other reference sources and estimates provided the basis for study.

3.3.3.3 Study Criteria

Comparisons can only be made under similar conditions and factors; consequently, a model situation was derived for evaluation based on Underspoil Haulage Phase II mine designs:

- 5 million tons per year of coal production.
- 250 operating days per year.
- 14 operating hours per day.
- 1/2 mile maximum in-pit haul.

- 1/4 mile average in-pit loaded haul.
- Average overburden depth, 116.67 feet.
- Average coal thickness, 50 feet.
- Total coal haul distance, 3 miles.

3.3.3.4 Procedure and Determinations

To determine the diesel fuel consumption and costs, a haul road profile analysis was made using the aforementioned criteria. From this information the number of truck operating hours was determined. Fuel consumption per hour was determined from other reports and fuel costs were obtained from a supplier. Total fuel consumption and costs were then determined. These costs were prorated over the hourly tonnage of 1430 tph to determine the cost per ton of coal moved. The cost per ton-mile was then determined by dividing the fuel cost per ton by the three miles as set in the model for a haul distance.

The electrical energy consumed by the composite conveyor system was estimated from the Underspoil Haulage Phase II back-up data. Horsepowers were estimated from the haul distances and material lists. These were applied to an 80% motor efficiency to give an estimated power consumption in kilowatt hours. The cost per kwh was then applied to these estimates to produce an energy cost per hour which was in turn prorated over the 1430 tph of coal production to give an energy cost per ton. A cost per ton-mile was determined by dividing the cost per ton by three miles.

Other energy related factors which could not be put into quantitative terms were discussed as cost is not the sole basis for best comparing the two systems.

Diesel fuel cost was obtained from a local supplier at 74.5 cents per gallon during July 1979. Electrical costs were estimated to be approximately 3.0 cents per kwh by experience in the area.

3.3.3.5 Analysis of Results

3.3.3.5.1 Truck Haulage

Seven and one-half 120 ton trucks will transport 1430 tph three miles consuming 17.5 gallons of fuel oil per hour/per truck for a total of 1838 gallons per day.

Fuel consumed in transporting one ton of coal will be 0.0919 gallons. At the fuel cost of 74.5 cents per gallon the average fuel cost per ton is $0.0685.

Prorating the $0.0685 per ton against the three mile average haul, a cost of 2.28 cents per ton mile is estimated.

3.3.3.5.2 Conveyor Haulage

In-pit segment energy requirements for transporting 1430 tph an average distance of 1/4 mile is 117.17 hp or 109 kwh at 80% motor efficiency using the shiftable conveyor.

The portable conveyor system will require more energy input to overcome the continual elevating for transfer of load than will the shiftable conveyor. Requirements for the portable system carrying the same load for the same distance are 339.23 hp or 316 kwh at 80% efficiency.

The underspoil, overspoil, or thruspoil segment of the conveyor system will require a maximum of 395.8 hp or 369 kwh at 80% efficiency.

The surface conveyors will require 777.0 hp or 724 kwh.

Total conveyor power requirements will then be: 1290 hp or 1202 kwh for the shiftable and 1512 hp or 1409 kwh for the portable system.

Costs per ton using 3.0 cents per kwh are $0.025 for the shiftable and $0.030 for the portable conveyors.

Prorating $0.030 per ton transportation costs against the three mile haul distance gives one cent per ton-mile for an estimated energy cost using conveyors only.

3.3.3.5.3 Other Energy Considerations

Crude petroleum, the basic source of diesel fuel, is in scarce and critical supply; where as, coal, the basic source of most electricity near mining areas, is in abundant supply and is being produced by the power consuming operation.

Manufacturing the haul trucks and tires consumes much more energy in one form or the other than does the manufacture of the simpler conveyor equipment.

Truck haulage of coal required a much larger labor force than does conveyor haulage, not only for operation but for supervision and maintenance. These people will consume more energy in getting to work and in other required services and facilities than smaller conveyor work force.

The major wasting of energy in truck haulage, as compared with conveyor belt haulage, is in the lifting of the mass of the truck out of the pit and in the frictional force due to the combined weights of the coal and truck

None of these forces can be recovered. Returning conveyor belt forces, however, can be recovered to help lift the up portion of the belt thereby reducing energy requirements.

3.3.3.6 Conclusions

Belt conveyor haulage of minerals and mineral products has long been used because of its inherent efficiency. A high degree of energy conversion to material transport and lifting is achieved by the high ratio of payload to carrier weight. Friction and motor inefficiency cause the significant energy losses. Truck haulage, on the other hand, has a relatively low payload to carrier ratio and very high frictional forces and engine efficiency causing high energy losses.

Because conveyors and trucks use different energy forms, the only direct comparison can be made in the monetary costs. This study concluded that as far as energy consumption solely is concerned, trucks cost two and one quarter to three times as much to operate as do conveyor systems.

Monetary costs, however, are not the only factors that need to be considered in comparing energy consumptions. Future demands for petroleum products will undoubtedly cause a greater cost difference in the two if in fact adequate supplies can be assured.

Using scarce energy resources to produce abundant energy forms when it is not necessary violates sound conservation phylosophy and may in the future cause problems in obtaining operating permits from environmental protection agencies. Many surface coal mines supply mine-mouth generating plants. These especially should take advantage of conveyor haulage.

Coal mining has the unique ability to supply its own energy needs through its product, whether the coal goes to a local electric power plant or a distant one feeding a power grid, the result is that there will be a net energy gain and the power cost will be tied to this same product value. A coal pit dependent on the petroleum industry may very well find its energy cost escalating while their produce value remains fixed. Diesel shortages may even cause mine closures compounding the overall energy shortage.

Energy consumption is a valid consideration when planning a mine, and conveyor coal haulage is by far the superior method of transporting from this standpoint.

3.3.4 In-Pit Coal Haulage Systems Improvement

The success or failure of any conveyor coal transportation system may be the result of the coal loading and haulage equipment and system practices employed. An optimum means of loading and haulage to the conveyor must be developed to minimize operating costs without jeopardizing the systems safety, operational flexibility or reliability. By analyzing the currently practiced techniques that are employed in loading and haulage, an optimized method of loading and haulage may be found to minimize the coal transportation costs.

3.3.4.1 Objective of Study

The objective of this study is to make a broad comparison of various loading and haulage methods and equipment that can be used to load and transport coal from the coal face to the conveyor loading point. Operating advantages and disadvantages as well as operating costs for each method are to be used in the analysis.

3.3.4.2 Basis For Study

Economic summaries based on cost information derived from equipment manufacturers and operating mines were used to determine the operating costs of each haulage system discussed. This operating and cost information as well as other reference sources will provide the basis for this study.

3.3.4.3 Criteria Of Input

3.3.4.3.1 Scope

This report deals with the determination of the operating and cost information for loading and hauling coal to a conveyor transport system. The typical mine to be evaluated would be similar to those mines in the Powder River Basin with production assumed at 5,000,000 tons of coal per year from a horizontal 70-foot coal seam. Topsoil and spoil removal methods are assumed to be the same in all cases. Operating costs that were derived in other parts of the underspoil conveyor study and additional cost information necessary in the haulage comparison were estimated in late 1976 dollars.

3.3.4.3.2 Accuracy

Cost information used in this study is considered to be within the ±30% criteria established for the Underspoil Haulage Study.

3.3.4.4 Procedure

In order to effectively evaluate which haulage system is the optimum system to deliver coal to the conveyor system, a common starting and ending point must be devised. Since some of the equipment to be evaluated loads as well as hauls the material, Dravo assumed that the starting point in the evaluation was assumed to be the point where the haulage unit dumps into the hopper which feeds either the feeder breaker or the conveyor belt.

Cost comparisons of three types of loading equipment and six types of haulage equipment were prepared. In addition new developments in loading and haulage equipment with insufficient cost information were also discussed.

3.3.4.4.1 Loading

A comparison of loading with shovels, loaders, and bucket wheel excavators was made for varying production rates. The loading equipment sizes used in this study were assumed to be the same as those used in earlier sections of the underspoil conveyor study. Loading equipment costs were based on costs developed in the underspoil conveyor study.

Economic life of each piece of loading equipment was based on the number of years each unit would operate regardless of the number of operating hours used per year. Operating costs per hour were assumed to be the same no matter how the annual production figure changed.

New advances in loading equipment such as:

1. Unit Rig's Unimatic
2. HMC's Easi-Miner
3. IR's Surface Miner
4. Rahco BWE
5. C.M.I. Corp. BWE
6. Barber-Green BWE

were not included in the loading cost comparison because insufficient operating cost information is available (Figure 47).

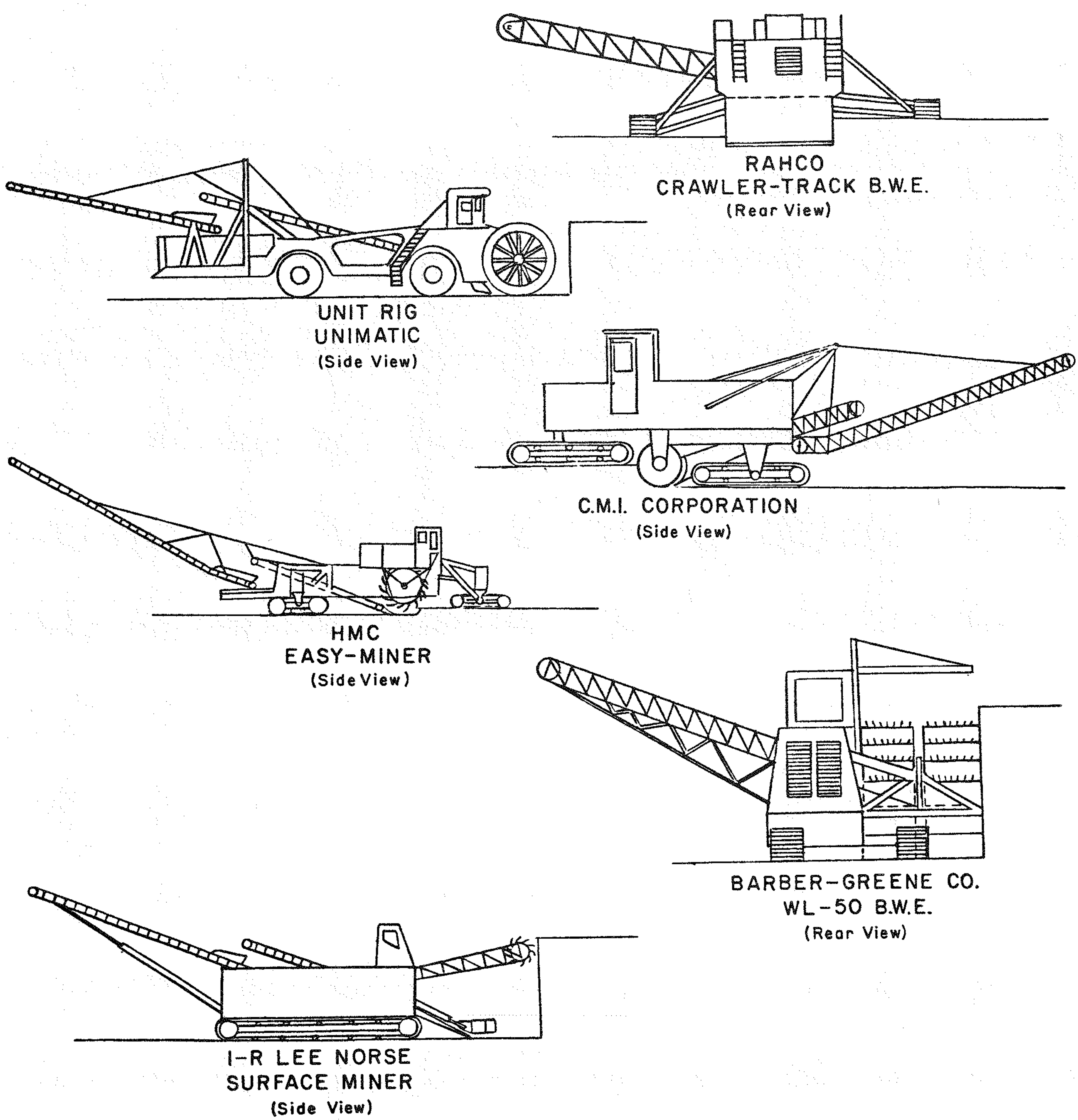
3.3.4.4.2 Haulage

The haulage cost comparison was based on varying the distance the haulage equipment traveled from the coal face to the hopper of the feeder breaker or conveyor belt. Haulage distance was varied from 100 feet to 2 miles. Six haulage systems were analyzed and are as follows:

1. Truck Haulage
2. Shiftable Conveyor Haulage
3. Portable Conveyor Haulage
4. Loader Haulage
5. Scraper Haulage
6. Trackless Train Haulage

3.3.4.4.2.1 Truck Haulage

Truck haulage in this study was comprised of loading trucks with electric shovels, hauling the coal to the feeder breaker bin and dumping the coal into the bin. Haulage costs were calculated for 120 ton and 170 ton rear



NEW CONTINUOUS EXCAVATORS Figure 47

dump haulage trucks. Operating costs per hour were derived from the underspoil conveyor report.

Loading equipment used in the estimate was the same as that used in System No. One of the underspoil report.

Haulage truck profiles were run to reflect changes in the truck productivity by varying the haulage length. All profiles were calculated for level hauls. The truck haulage time increased from 8 minutes per load to 21 minutes per load for distances of 100 feet and 2 miles, respectively.

3.3.4.4.2.2 Shiftable Conveyor Haulage

Conveyor haulage consisted of loading the shiftable conveyor with 24 cubic yard loaders at a 100-foot distance, and transporting the coal by conveyor to the underspoil conveyor (Figure 48). Additional costs were estimated for equipment required to move the conveyor.

Shiftable conveyor costs were based on capital cost of \$3.50 per inch of belt width per foot of belt length. Maintenance costs and material costs were assumed at 10% and 5% of the original capital costs. Depreciation was based on straight-line depreciation and a 10 year life. Power costs were based on the following formula:

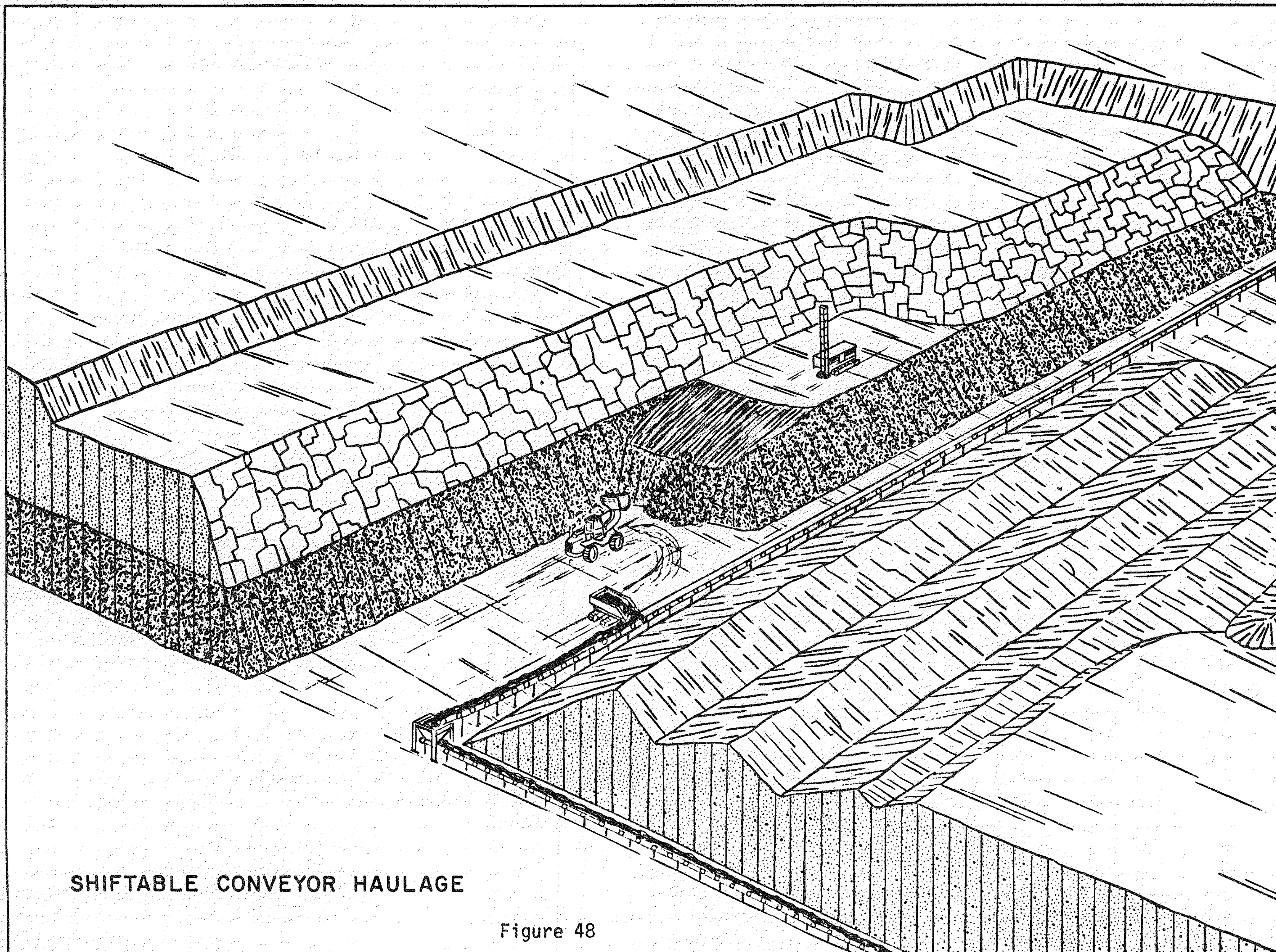
$$\text{Power costs} = \$.05/\text{KW} \left[\frac{\text{Hpd}}{\text{E\%}} + 0.10\ \text{Hpc}\right] \times \frac{\text{TPY}}{\text{TPH}} \times .7457\ \frac{\text{KW}}{\text{HP}}$$

where

Hpd = demand horsepower
Hpc = motor rated horsepower
E% = motor efficiency
TPY = tons of material conveyed per year
TPH = tons of material handled per hour
$0.7457\ \frac{\text{KW}}{\text{HP}}$ = conversion factor from horsepower to kilowatts
0.05/KW = selling price of electric power per kilowatt

Power requirements increased from 50HP to 600HP for 100 feet and two mile lengths of belt, respectively.

Since shiftable conveyors can be moved fairly easily perpendicular to flow of material, but very poorly laterally along the flow of material, two shiftable conveyors are required to prevent extended down-time required in moving from one lateral location to another. As the result a spare shiftable conveyor with 1,320 feet of length was included for each conveyor system over one quarter mile in length. Those systems below one quarter mile length had a totally redundant system equal to the length of the original conveyor.



SHIFTABLE CONVEYOR HAULAGE

Figure 48

3.3.4.4.2.3 Portable Conveyor Haulage

Portable conveyor haulage consisted of loading the coal with 24 cubic yard loaders at the coal face and transporting the coal a distance of 100 feet to the portable conveyor. The coal was subsequently transported by the portable conveyors to the underspoil conveyor (Figure 49). As the haulage length got longer, additional lengths of portable conveyors were added.

Portable conveyor costs were calculated for a capital cost of $5.50 per inch of belt width per foot of belt length. Other conveyor costs were calculated in the same manner as the shiftable conveyor.

Overall conveyor availability was assumed at a conservative 90%. Each length of portable conveyor was 120 feet.

3.3.4.4.2.4 Loader Haulage

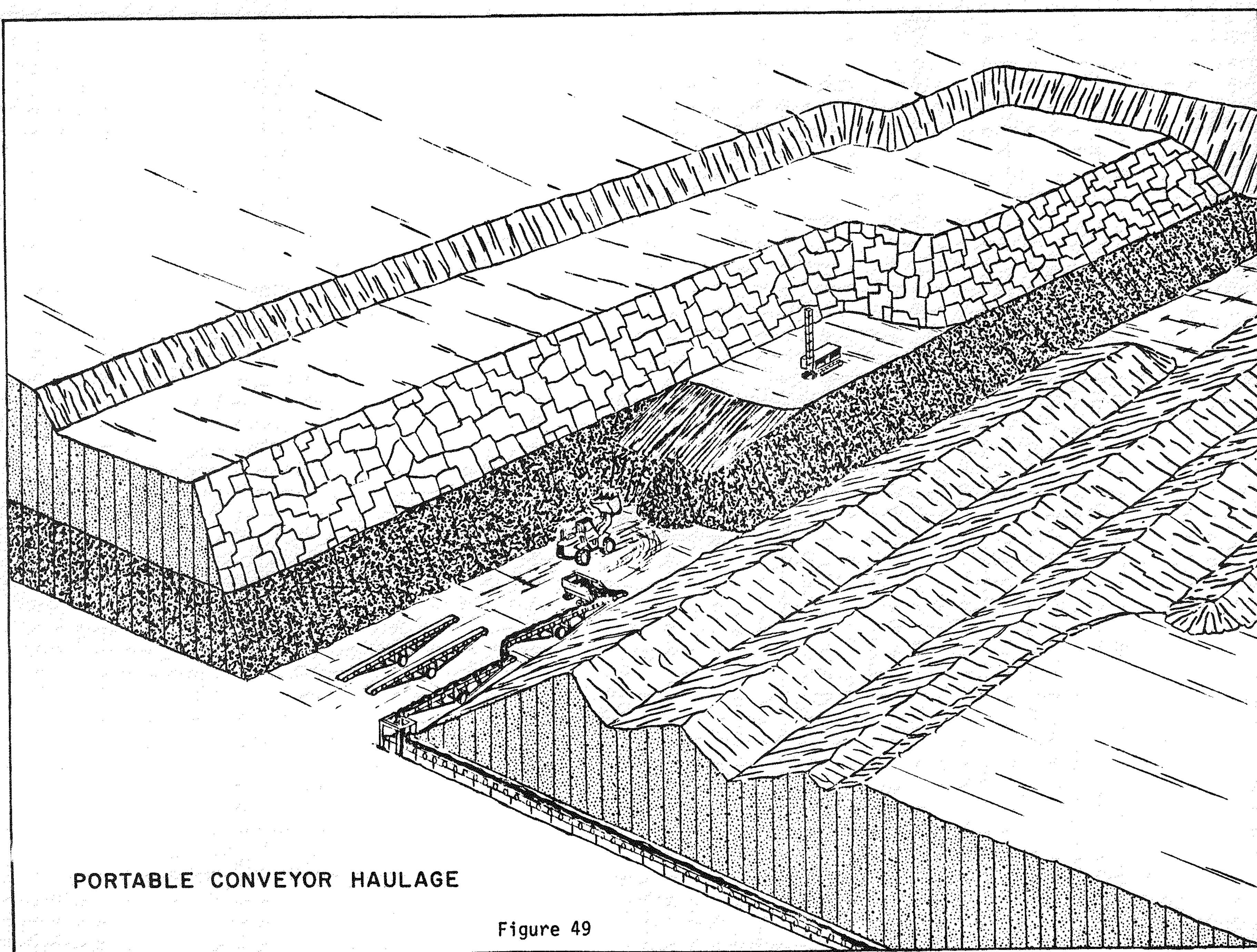
Haulage with loaders consisted of loading the coal with 24 and 36 cubic yard loaders, tramming the loaders to the underspoil conveyor and dumping coal into the feeder-breaker (Figures 50 and 18). Operating costs per hour for each loader fleet was obtained from another section of the underspoil report. Loader performance data was obtained by estimating average travel speed, load time, dump time, bucket raise and lower time and maneuvering time.

Loader operating cost per ton varied from a low of $.14 per ton for the 36 cubic yard loader operating at a distance of 100 feet from the under-spoil conveyor to $.72 per ton for the 24 cubic yard loader operating at a distance of 2640 feet from the underspoil conveyor. Operating cost per ton figures were not calculated for distances further than one half mile because of the rapid escalation in costs for the loader going from a 100-foot to 2650-foot tramming distance.

3.3.4.4.2.5 Scraper Haulage

Scraper haulage consisted of loading the coal with scrapers, transporting the coal to a underspoil conveyor and dumping it into a feeder-breaker. Since the scraper must pick up material it intends to load from the surface of the material, an additional haulage distance is required (Figure 51). The distance used was calculated based on an average coal thickness of 70 feet, average scraper operating height of 35 feet and average ramp grade of 8%. The resultant 500 feet additional distance is necessary to relate scraper haulage to the other haulage configurations. No additional costs were calculated for the feeder-breaker assembly necessary to support the scraper during the unloading process.

Cost estimates for scraper operation were based on operating cost per hour information derived elsewhere in the report and from operator manuals



PORTABLE CONVEYOR HAULAGE

Figure 49

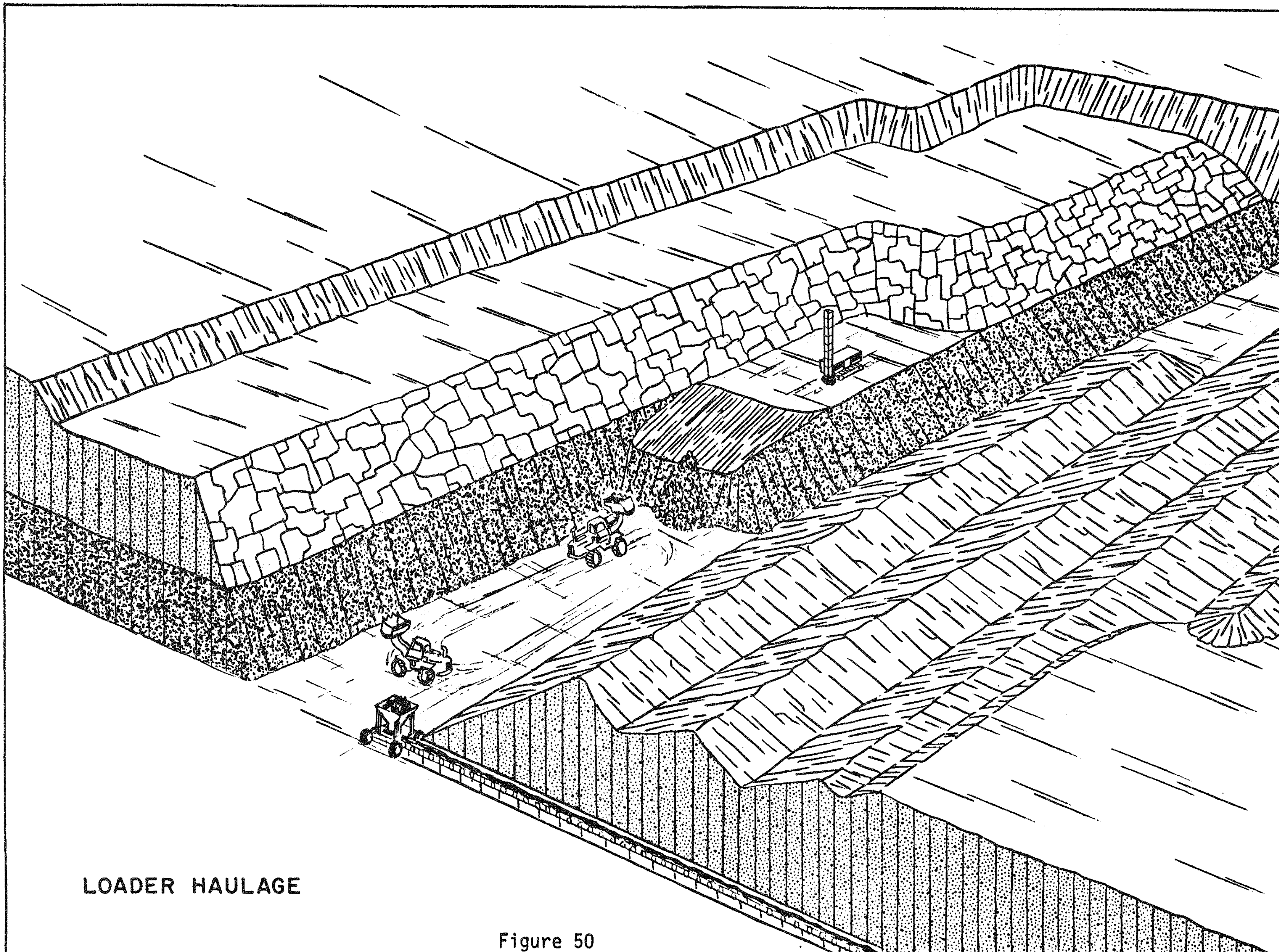
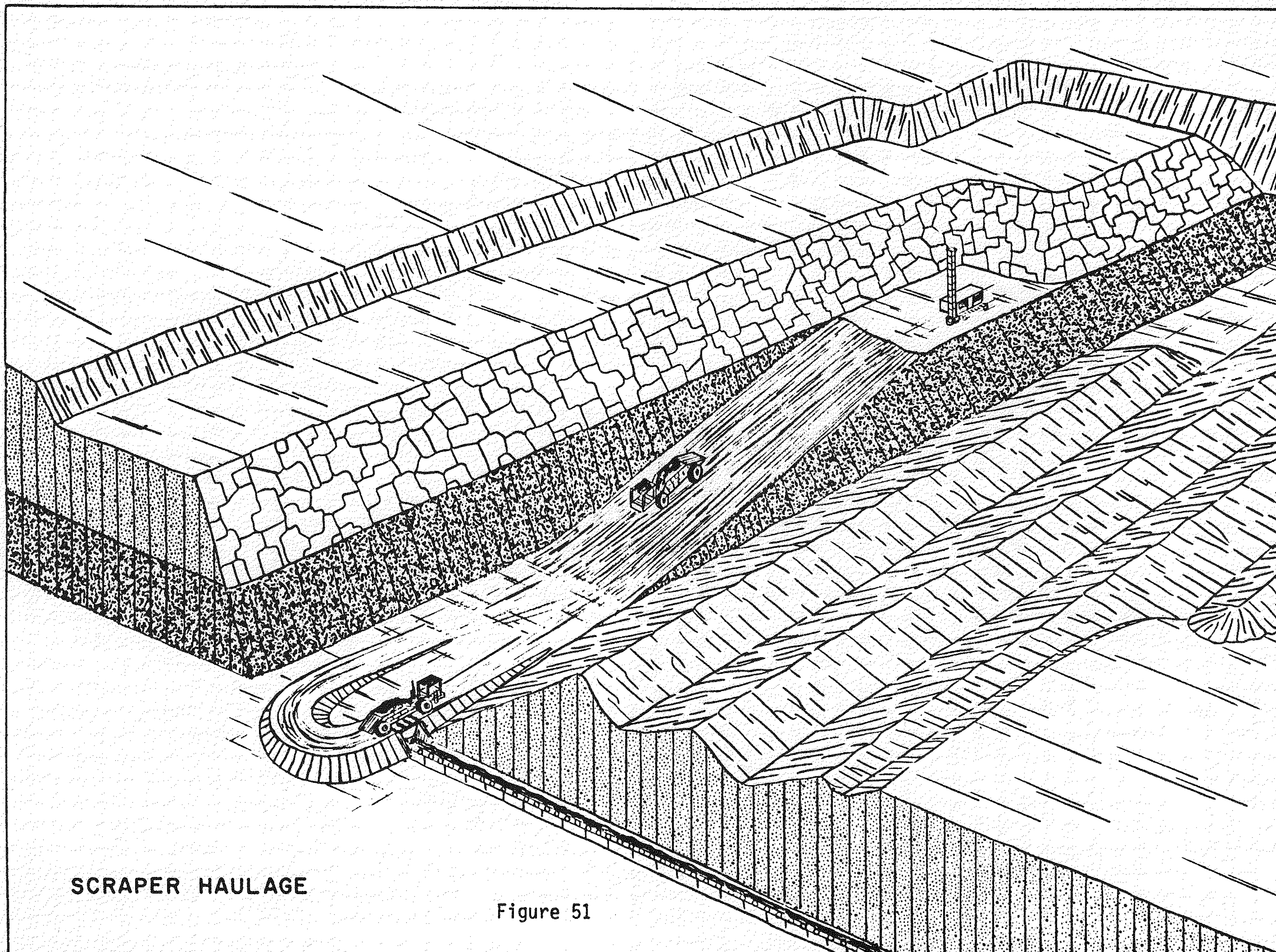


Figure 50



SCRAPER HAULAGE

Figure 51

"Cat Equipment Hand Book". Cost per ton estimates ranged from $.11 per ton for 100-foot hauls to $.91 per ton for two mile hauls.

3.3.4.4.2.6 Trackless Train

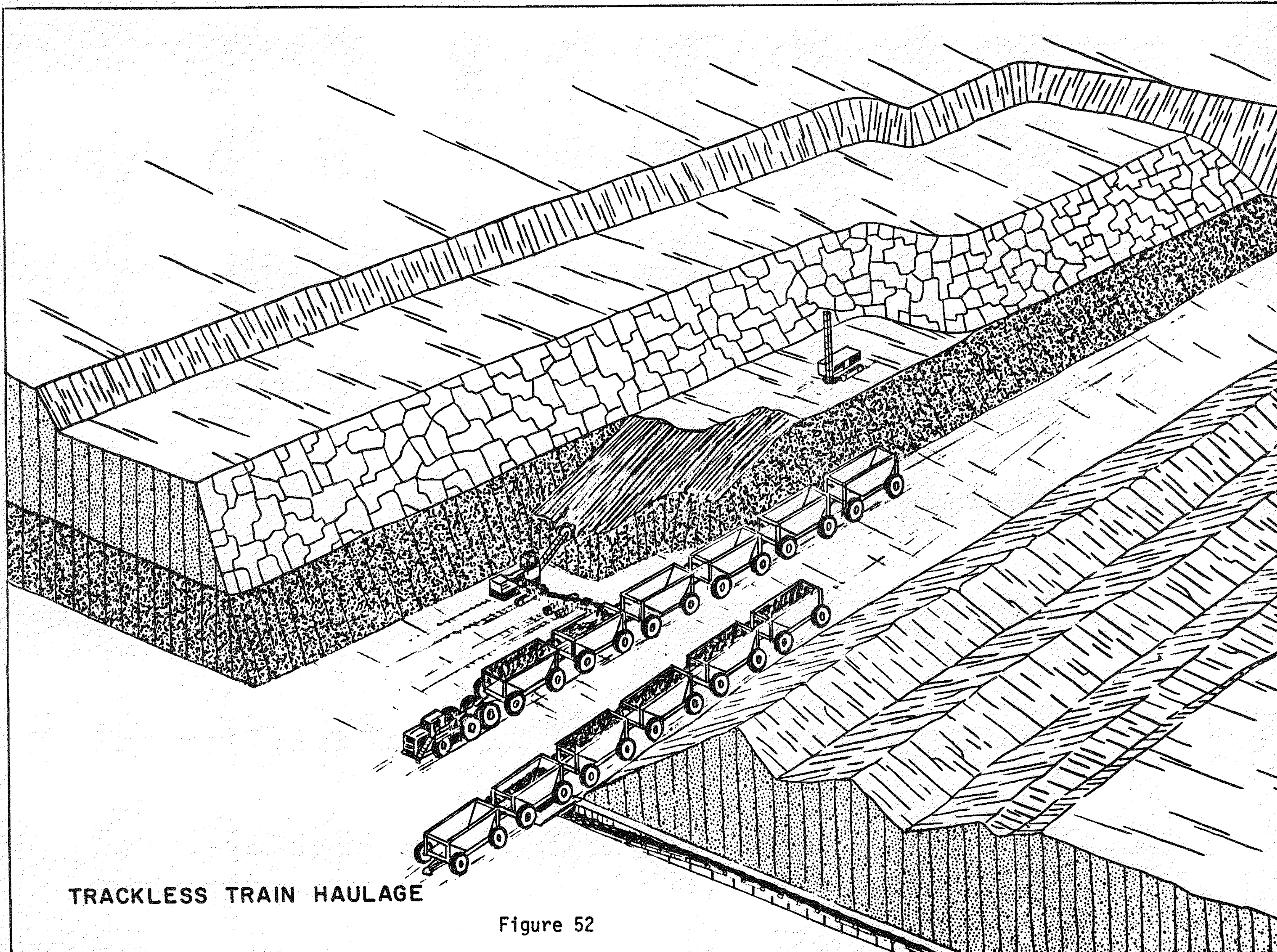
The trackless train concept that is presented is not a new one. Trackless trains have been in use for many years in the underground mining of metallic and nonmetallic minerals. It is included in this study as an alternative because of its low labor intensity, its suitability to undulating pit floors where conveyors might not be suitable, its relatively low cost of haulage, its compatibility with waste removal equipment such as a dragline and its low fuel requirement.

The trackless train as shown in Figure 52 consists of a bucket wheel excavator at the coal face loading 120-ton trailers. The trailers are coupled together into a train consisting of six cars. These trailers are moved by a double axled tractor capable of handling the trailers plus the 720 ton payload. The coal is hauled to an underspoil conveyor installation where it is unloaded from the belly dump trailers and dumped into the collection hopper of the conveyor. Each trailer would be equipped with an air brake system similar to these employed on on-highway trailers. Trailers would also be equipped with hitches on both ends to permit material haulage in either direction. Movement of the trailers around the dumping pocket for the conveyor could be accomplished by using either the tractor or a suitable winch system that would permit unloading these cars without additional equipment. Coal loading of these cars could be timed to coincide with the advance of the bucket wheel excavator which would eliminate the need for moving the cars during the loading process. Minimal interference with spoil disposal will result because only four trains per hour will travel under the swing of the dragline and the trains passage could be timed in such a way that the dragline's lost time could be minimized.

Haulage cost information that was derived for the trackless train was based on an operating rate of 5,000,000 tons of coal per year, the use of 120 ton coal haulage trailers, a rolling resistance of 3 percent, haulage surface of a net 0% grade, operating cost information for similar pieces of equipment and loaded haulage speeds calculated from equipment performance curves.

Operating parameters and cost information were derived for varying haulage distances. Operating costs and production rates for the bucket wheel excavator were based on information derived earlier in the underspoil study.

Two different tractor drive configurations were evaluated. The first unit consisted of a truck chassis with a single axle and dual wheels with a 1600 HP engine (very similar to the chassis for the 170 ton Haulpak truck). This tractor had electric drive wheel motors to generate the tractive force. The second unit consisted of a truck chassis with a 2500 HP locomotive engine with dual tandem axles and mechanical drive. The 1600 HP drive unit could



TRACKLESS TRAIN HAULAGE

Figure 52

haul the loaded train at a rate of 5 miles per hour while the 2500 HP tractor could haul the same train at 11 miles per hour. The 1600 HP unit with the electric drive will develop a substantial quantity of heat at the low haulage speed that would not be dissipated. Because of this heat build-up and the calculated lower production costs of the larger tractor, the 2500 HP unit was the only unit compared to the other haulage systems explored.

An application where the trackless train might produce an exceptional advantage is in the very narrow dragline pit described in Section 3.3.6.4.3 of this work. In this case a bucket elevator is proposed on one end highwall. Because of the dragline stripping it would be necessary to pass under the swing of the dragline boom with coal haulage. Trucks would need to pass too frequently and also have a difficult time turning around in the narrow bottom. Conveyors could not operate safely under the swinging dragline bucket. Trackless trains, however, would only need to hold-up the dragline infrequently and then only for a few minutes. Only the tow tractor would need to turn-around as it would uncouple from the coal cars and pick up a string of empty cars.

3.3.4.5 Analysis of Results

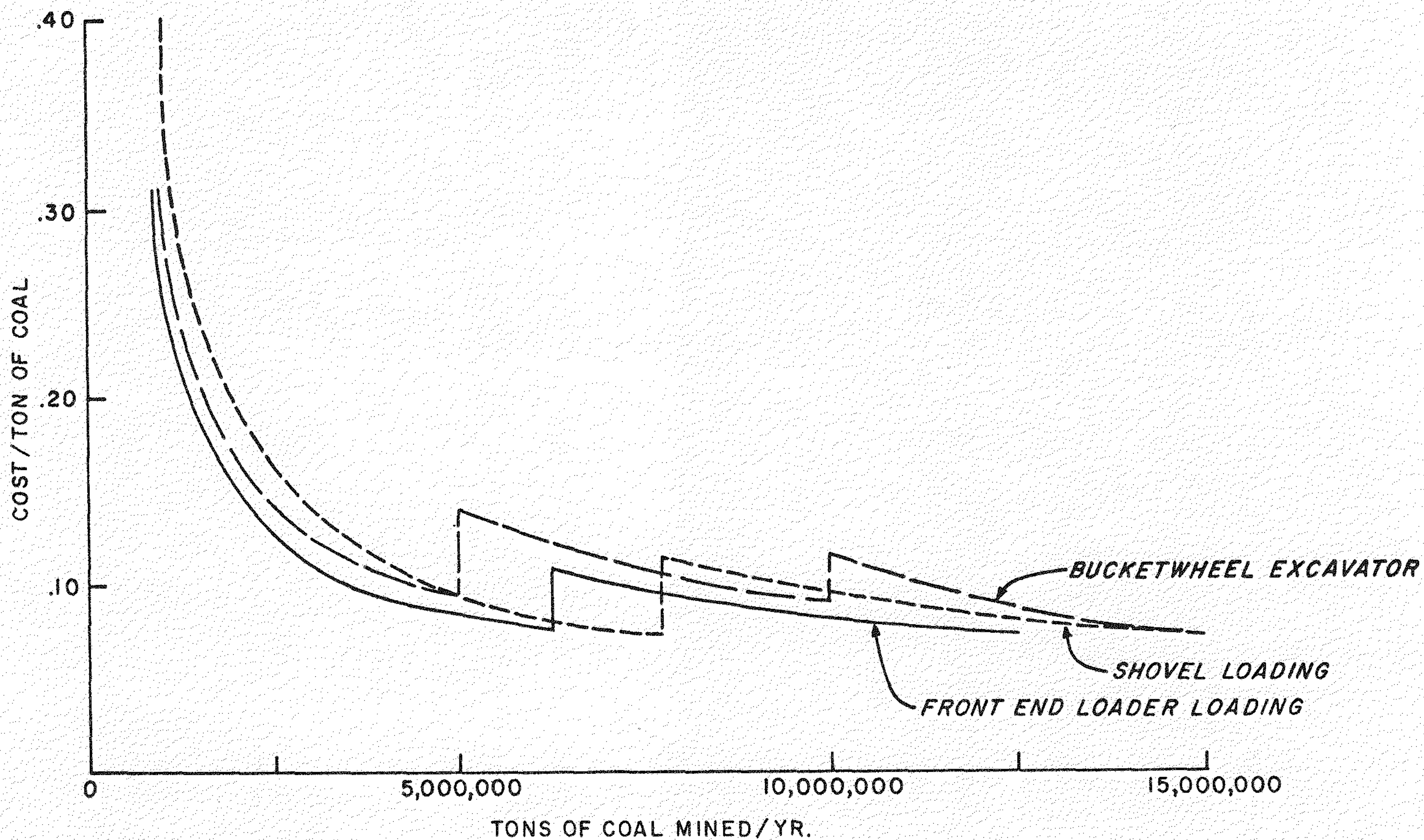
3.3.4.5.1 Loading

A comparison of coal loading costs for a shovel, loader and bucket wheel excavator at varying production rates was made. Figure 53 summarizes the results of this comparison. Details of the cost information that were used in the comparison are outlined in Appendix 3.3.4. The loading equipment cost comparison showed the cost changes of each type of loading equipment when an additional piece of equipment is required to meet the production schedule. The vertical lines in the cost curve for each type of equipment represented the point where an additional piece of equipment would be required. Generally all three types of equipment seemed to have comparable costs for coal loading at a rate of 5,000,000 tons per year. If the tonnage production figure is increased, the bucket wheel excavator, sized for 5,000,000 tons per year, would not be economically compatible with the other two systems.

The loading cost comparison did not include other continuous mining equipment such as those illustrated in Figure 47 because of the lack of sufficient operating and cost information. When and if sufficient information is available these novel approaches to continuous loading could prove economically attractive. These advances in continuous loading equipment are mentioned to remind the reader that loading techniques other than the three basic ones (shovels, loaders and bucket wheel excavators) are available and could prove advantageous to operate.

3.3.4.5.2 Haulage

To effectively analyze or compare the currently available means of hauling material, a common ground of evaluation must be obtained. Some units are designed for hauling alone while others have multiple functions such as



LOADING EQUIPMENT COST COMPARISON

Figure 53

and hauling. The common ground in an equitable comparison must include the means of loading the hauling unit since, in some cases, loading is an integral part of the units operation. The basis arrived at for this comparison includes the loading and haulage function. No consideration was given to the differences in transferring material to the underspoil conveyor. The results of this comparison is outlined in Appendix 3.3.4. A graphical representation is given in Figure 54. The results show that the front-end loader operating over short distances at a constant yearly tonnage figure is cheaper to operate than any other means of hauling the material. Above 300 feet the portable conveyor is the cheapest mode of operation. Between 1/3 and 1 1/2 miles, the shiftable conveyor becomes the cheapest unit. For distances greater than 1 1/2 miles the trackless train becomes the cheapest haulage system.

3.3.4.5.2.1 Truck Haulage

Truck haulage costs increased 60 to 70% due to the increase in haulage distance from 100 feet to 2 miles. Details of how the haulage costs varied are listed in Appendix 3.3.4 for both the 120 and 170 ton haulage units. The truck haulage system has the following advantages and disadvantages:

Advantages

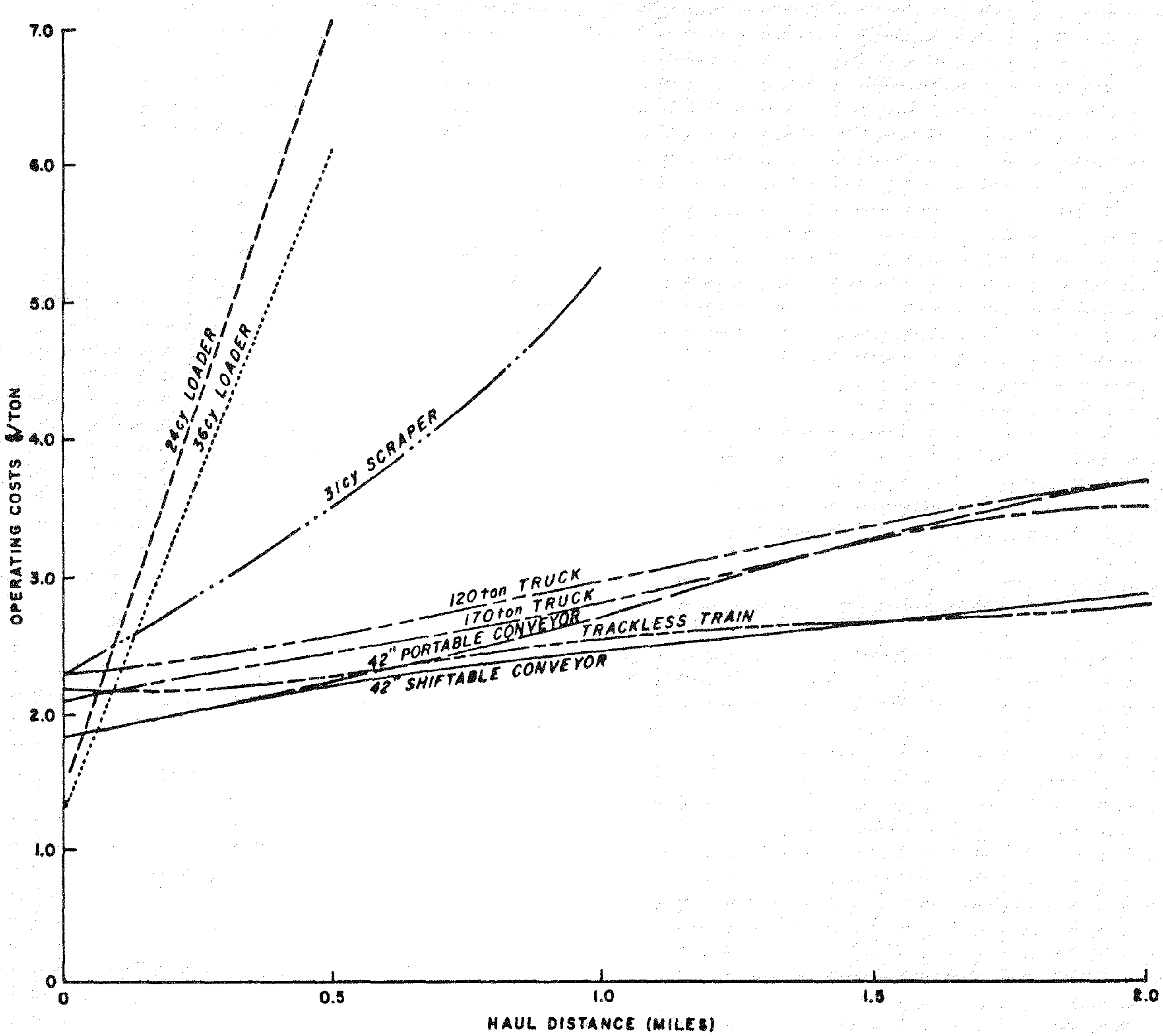
1. Flexibility-Can move coal from several separate areas simultaneously and can be shifted quickly from one area to another for ore blending purposes.

Disadvantages

1. Trucks have low availability as the result of meachancial and driver inefficiencies.
2. Interferes with stripping.
3. Interference with continual reclamation.
4. High fuel consumption.
5. Labor intensive.
6. Special preparation of feeder-breaker required to feed conveyor belt.
7. Large repair facility required.
8. Large road system required.
9. Less safe.

3.3.4.5.2.2 Shiftable Conveyors

Shiftable conveyors costs per ton increased 60% when the length changed from 100 to 10,560 feet one way. A cost breakdown is given in Appendix 3.3.4.



HAULAGE EQUIPMENT COST COMPARISON

Figure 54

Shiftable conveyors seem to be the lowest cost unit for distances between 1/2 and 1 1/2 miles. The advantages and disadvantages of the shiftable conveyor are as follows:

Advantages	Disadvantages
1. Moderate changes in gradient negotiable	1. High capital cost
2. High manpower productivity	2. Lump size limitation
3. Medium to Low operating cost if utilization is high	3. Inability to change directions rapidly
4. High reliability and availability	4. Loading and distribution point limitation
5. Environmental advantages, no air or noise pollution	5. Output inflexibility
6. Safety-fewer people and built-in mechanical and electrical safety devices	6. Maximum length of single flight limited
7. Low labor costs	7. Some spoil material removal constraints
8. Low power costs	8. Unsuitable for undulating pit floors
9. Low maintenance costs	
10. Smaller truck shop compared to truck operation required	

3.3.4.5.2.3 Portable Conveyors

Portable conveyor costs increased 106% when the conveyor length requirement changed from 100 feet to two miles. Portable conveyors are the cheapest operating unit between 300 feet and one third mile. Above a mile and one half portable conveyors would cost as much as a truck operation. Detailed costs are presented in Appendix 3.3.4. The advantages and disadvantages of a portable conveyor system are as follows:

Advantages

1. Flexibility -- portable conveyors are adaptable to curved pits and rolling floors.

2. Considerably less spare conveyor footage is required.

3. Several spare units available to keep availability high.

4. Advantage over extendable conveyor in that time required to add another conveyor is much less than that required to add piece of belting etc., to the extendable conveyor.

5. High coal productivity. Compared with trucks, belt conveyor systems have relatively high unit availability.

6. Fuel uncertainties. The future cost and availability of electrical power versus diesel fuel may favor conveyor haulage.

7. Low interference with stripping.

8. No interference with reclamation.

9. Low labor dependence.

10. High efficiency.

11. No interference with stripping pit equipment -- shovel-truck or drag-line waste equipment.

12. Cheaper to operate than trucks.

Disadvantages

1. Limited flexibility. Portable conveyors fall between trucks and shiftable conveyors in this regard.

2. Loading inefficiency.

3. Higher power requirements than shiftable conveyor.

4. Lower availability than single conveyor.

3.3.4.5.2.4 Loader Haulage

The practice of using rubber-tired loaders to load and/or haul material from the face to a discharge point have been well documented throughout the mining industry. Loader cost per ton figures increased approximately 3.5 times by going from 100 feet to one half mile haul distances. Loader haulage costs and production information are listed in Appendix 3.3.4. High rates of increase in relation to distance are the result of loader inability to haul as large a volume as the trucks, the low top end speed, and the relatively high operating costs. Other advantages and disadvantages are given below:

Advantages

1. Very mobile - can be used to load anywhere in the pit.

2. Flexibility.

Disadvantages

1. High unit cost.

2. Not made for tramming long distances.

3. Low top end speed.

4. Poor availability compared to conveyors.

5. High fuel consumption.

3.3.4.5.2.5 Scraper Haulage

The use of scrapers in hauling material is well documented. John Goris and Thomas Brady estimated that the effective haulage range is 500 to 4000 feet. Under the operating parameters and assumptions made in this study, the 31 cubic yard scraper was not economically competitive with the other haulage systems explored (see Appendix 3.3.4). The main reason for this was that the scraper operation must take place on top of the material it is to remove. That means that with a 75 foot coal seam and 8% road grades, the scraper will have to travel an additional 500 feet resulting in higher costs. The advantages and disadvantages of the scraper system are as follows:

Advantages

1. One unit loaders, hauls and dumps.

Disadvantages

1. Additional unloading facility required.

2. Cat to prepare road for scraper from top of coal to bottom.

3. Travel on shot coal may compact and require ripping.

4. Specially prepared feeder-breaker required for feeding conveyor.

3.3.4.5.2.6 Trackless Train Haulage

Trackless train haulage costs, including the bucket wheel excavator loading costs, increased 85% for the 1600 HP tractor and 28% for the 2500 HP tractor when the haulage distance increased from 100 to 10,560 feet. Trackless train operating costs were lower than any other system when the haulage distance increased above one and one-half miles. Detailed costs for both tractor types are listed in Appendix 3.3.4. The advantages and disadvantages of the trackless train over other systems are as follows:

Advantages

1. Extremely flexible.

2. Not labor intensive.

3. Flexibility advantages over conveyors for undulating pit bottoms.

4. Only one or two power units required to move trains around.

5. Increases box utilization because of higher availability.

6. Less HP requirements than with trucks.

7. Boxes designed to be pulled from both ends.

8. Bin size requirement for continual flow of material from boxes to underspoil conveyor would be minimized.

9. Minimum pit bottom width.

10. Little if any interference with dragline operation.

11. Increased safety because of less congestion.

Disadvantages

1. Would not be able to transport coal up ramps without reducing load.

2. System not as flexible as the truck system.

3.3.4.6 Conclusions

The optimum means of transporting the coal from the coal face to the underspoil conveyor was not one but three methods depending on the length of haul required. Loaders proved to be the lowest cost for distances between 0 and 300 feet. For distances between 300 and 1 1/2 miles, the portable or shiftable conveyor was the cheapest. And, for distances greater than 1 1/2 miles a new system utilizng a series of trailers with one drive unit seemed to be the most economical. Truck haulge although slightly higher in cost than the cheapest method, has the greatest flexibility of any of the methods explored. The flexibility consideration alone could result in the selection of the truck system over other systems. The study demonstrates the need to treat each mine separately. The optimum conditions for one mine may not be the same for another mine. This was demonstrated when comparing different haulage lengths to the underspoil conveyor.

3.3.5. Dumping Ramp for Trucks

In-pit transportation of coal by coal haulers or end-dump trucks require a dumping ramp or trench to gain sufficient height above the conveyor loading point to allow for dumping room and surge capacity. The optimization of this phase of the mining operation should reduce costs.

3.3.5.1 Objective of Study

Dravo was asked to develop several basic designs for unloading ramps or trenches that can serve end-dump trucks in conveyor belt loading.

3.3.5.2. Basis for Study

Operating parameters derived from the underspoil studies, feeder-breaker design information, and truck characteristics were used as the basis of this study.

3.3.5.3 Criteria for Input

Operating equipment sizes, coal production rate, and conveyor operating data were derived from other portions of the underspoil haulage study. In order to simplify this portion of the study, the 120 ton haulage trucks were used to haul the 5,000,000 ton per year of coal from the coal face to the underspoil conveyor's feeder-breaker. From the feeder-breaker, the material travels over a portable conveyor to the underspoil conveyor.

3.3.5.4 Procedure

In Section 3.3.4 of this study an alternative was proposed that would allow truck and shovel operation at the coal face and an underspoil conveyor system to convey the coal out of the pit. The alternative presented started with loading the trucks with electric shovel transporting the coal to a feeder-breaker or portable crushing plant, breaking or crushing the coal, and discharging the coal to the underspoil conveyor. The problem faced in this report is to obtain alternatives for the design and construction of ramps to be used by the haulage equipment to dump into the crushing facility.

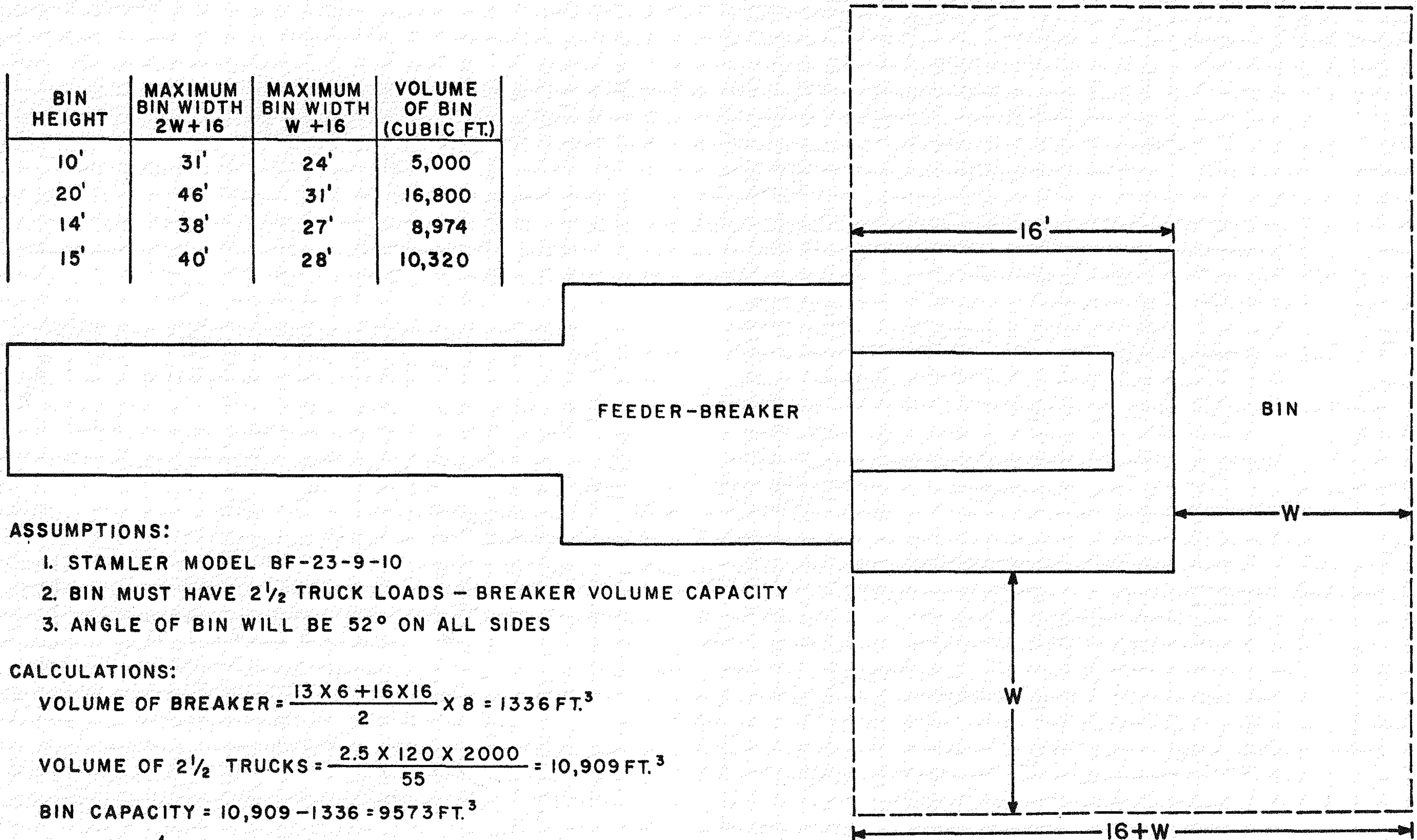
Several assumptions were made to effectively evaluate the ramp requirement and are as follows:

1. The coal hauler truck will carry a pay load of 120 tons. Only rear dump trucks will be evaluated, but belly dump trucks would have a similar dump configuration except that additional structural supports for the bin would be required.

2. A bin or storage facility would have a minimum capacity of 2 1/2 truck loads to handle coal flow fluctuations from the loading shovel to the conveyor.

3. Spoil material below the coal strata would have the same hardness as the spoil above the coal seam.

BIN HEIGHT	MAXIMUM BIN WIDTH 2W+16	MAXIMUM BIN WIDTH W +16	VOLUME OF BIN (CUBIC FT.)
10'	31'	24'	5,000
20'	46'	31'	16,800
14'	38'	27'	8,974
15'	40'	28'	10,320



ASSUMPTIONS:

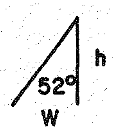
1. STAMLER MODEL BF-23-9-10
2. BIN MUST HAVE 2½ TRUCK LOADS – BREAKER VOLUME CAPACITY
3. ANGLE OF BIN WILL BE 52° ON ALL SIDES

CALCULATIONS:

VOLUME OF BREAKER $= \frac{13 \times 6 + 16 \times 16}{2} \times 8 = 1336 \text{ FT.}^3$

VOLUME OF 2½ TRUCKS $= \frac{2.5 \times 120 \times 2000}{55} = 10{,}909 \text{ FT.}^3$

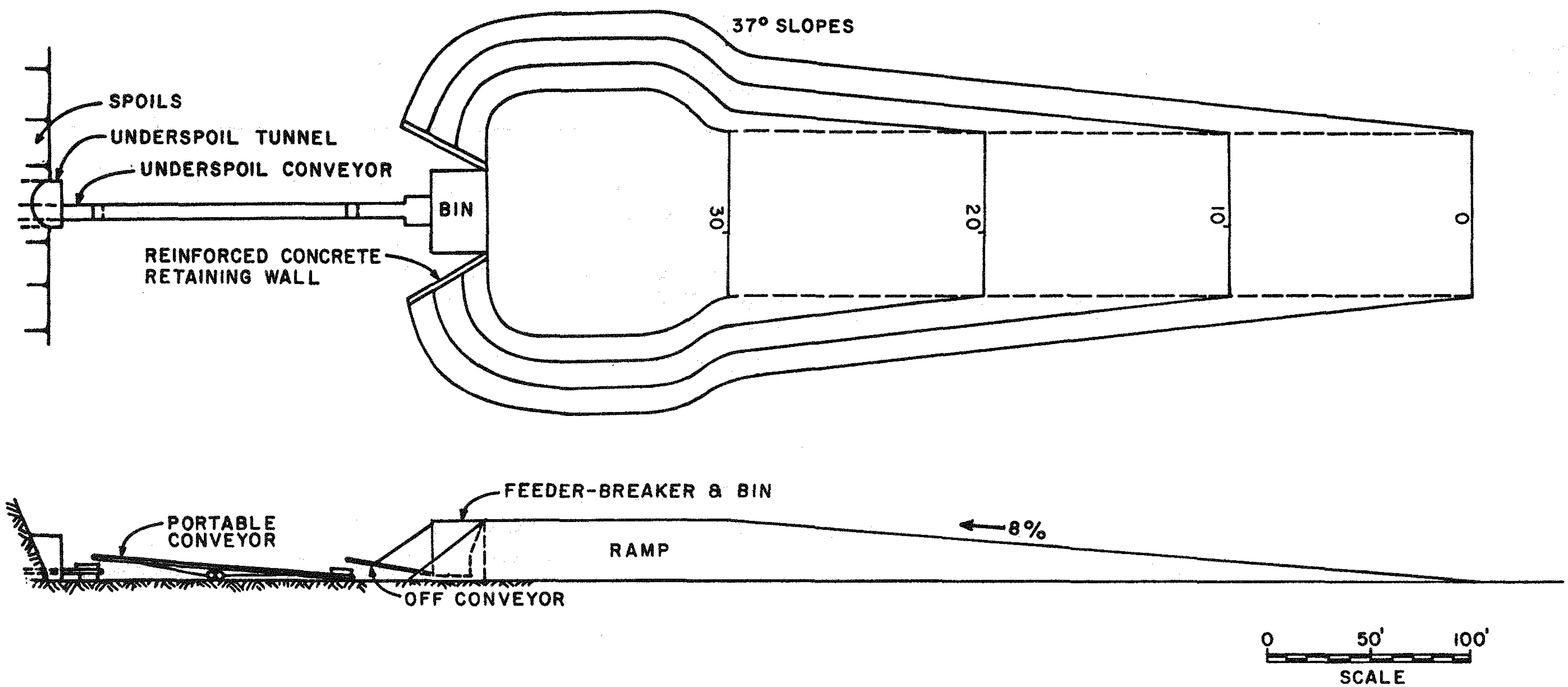
BIN CAPACITY $= 10{,}909 - 1336 = 9573 \text{ FT.}^3$



$W = \frac{h}{\tan 52°}$

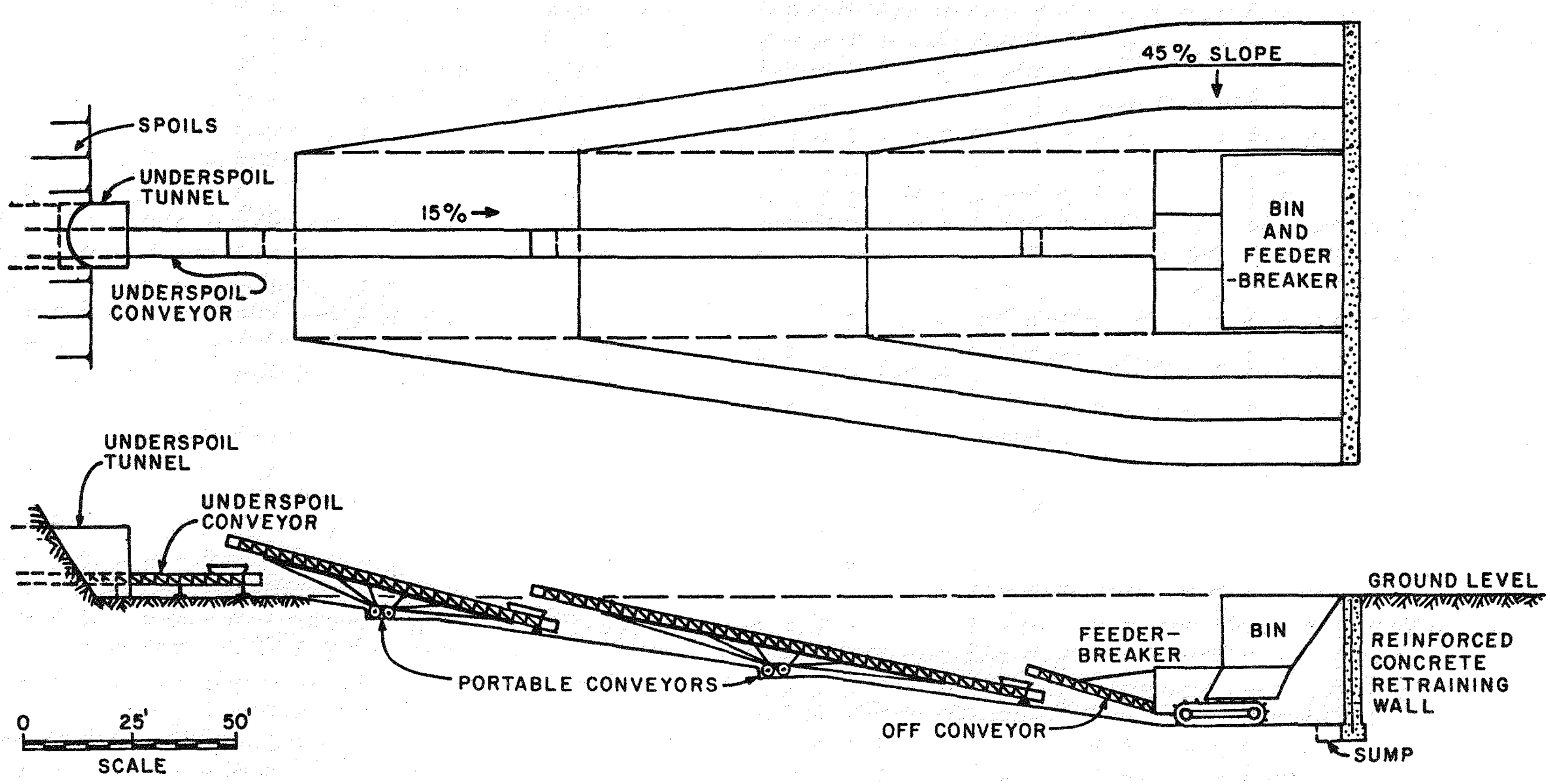
FEEDER-BREAKER AND BIN VOLUME DETERMINATION

Figure 55



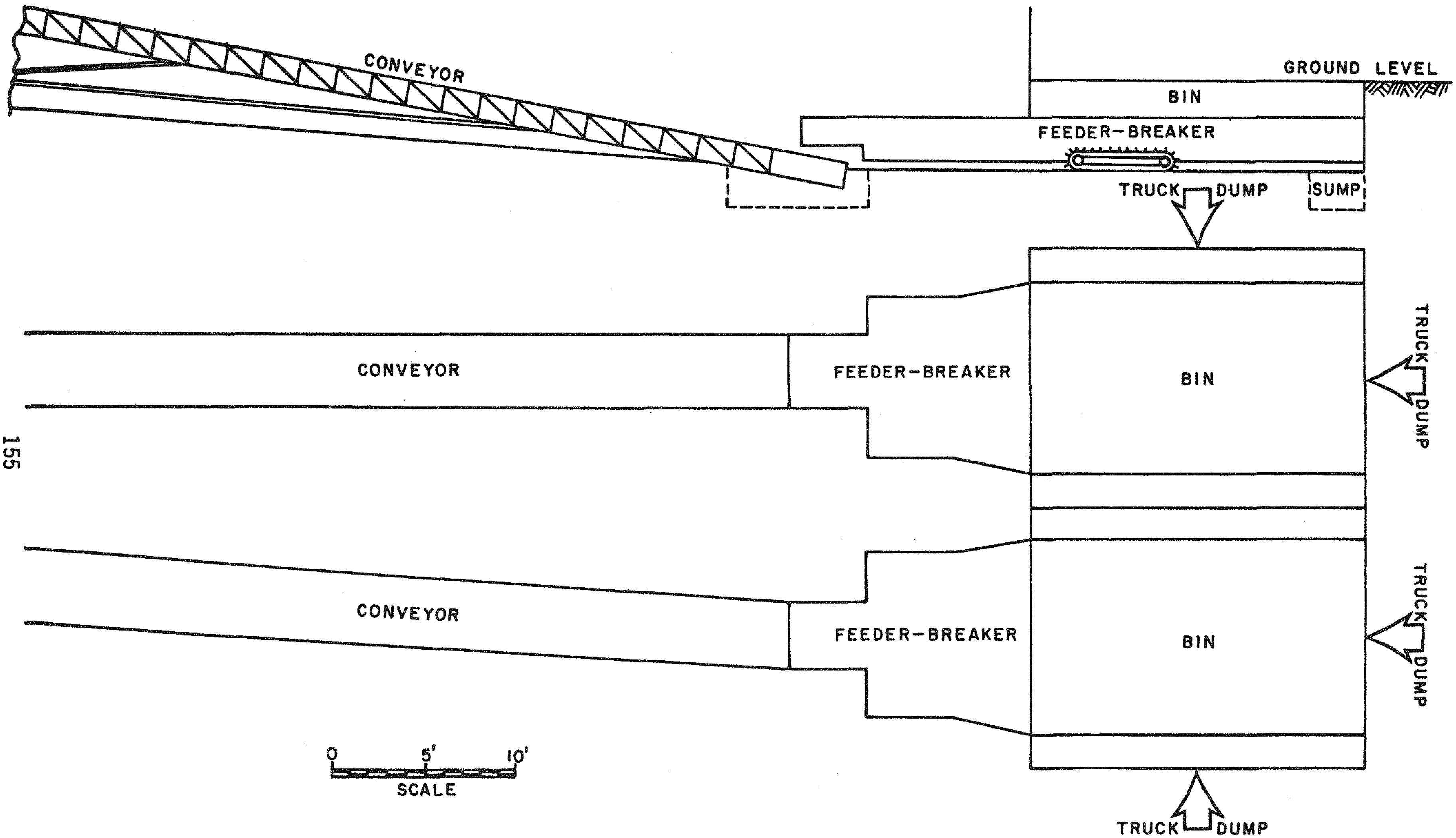
RAMP DESIGN FOR FEEDER-BREAKER WITH BIN ABOVE GROUND

Figure 56



RAMP DESIGN FOR FEEDER-BREAKER WITH BIN BELOW GROUND

Figure 57



LOW PROFILE FEEDER-BREAKER WITH DOUBLE DISCHARGE TO SINGLE UNDERSPOIL CONVEYOR

Figure 58

4. The maximum truck haulage grade will be 8%.

5. Maximum feeder-breaker grade will be 15%, unless ground clearance requirements require a lower slope.

6. Coal seam will be horizontal.

A search of the available crushing equipment disclosed that the feeder breaker probably has the lowest profile and is economically compatible with other pieces of equipment on the market today. Dravo decided that if a minimum height would produce a justification for modifying the ramp requirements, then the other crushing equipment, because of their increased height, would produce an even larger return. A Stamler Model BF-23-9-10 was used in the basic ramp design. Additional bin capacity was designed to meet the 300 ton storage capacity requirement. Figure 55 details the estimated volume of material required in the bin above the feeder-breaker.

Three basic ramp designs were estimated. The first design encompassed the building of a ramp 375' long and 80' wide to an elevated pad that is 120' square, to allow 120 ton haulage trucks to dump into a bin with a maximum elevation of 30' from the ground (Figure 56). A reinforced earth retaining wall was designed around the bin-feeder-breaker combination. An estimated 2600 square feet of retaining wall was required. Volume of fill material was determined to be 44,000 cubic yards. Slope of the ramp was 37 degrees.

The second design encompassed digging a cut for the feeder-breaker, thus permitting the haulage trucks to dump from the pit floor rather than a ramp (Figure 57). A cut 40 feet wide, 240 feet long and 30 feet maximum depth was required. A reinforced earth retaining wall containing an estimated 1200 square feet was required to protect the feeder breaker from rock fall. Slopes of the excavation were assumed at 45 degrees overall. Volume of material required to be excavated was 11,000 cubic yards. A small quantity of additional material would be required to be excavated to allow for the installation of a sump and pump for water drainage purposes. The ramp slope from the underspoil conveyor to the feeder-breaker was designed at 15%. A 200 foot conveyor or combination of portable conveyors was required to go from the feeder-breaker to the underspoil conveyor.

The third design included a low profile feeder-breaker, a minimum bin capacity and a spare feeder-breaker, bin and conveyor system (Figure 58). This design was based on the use of a low profile feeder-breaker similar to Stamler's BF-17B-6-10. Physical bin requirements were reduced to a minimum by utilizing storage capacity above the bin. The ramp was designed to permit two trucks dumping at one time. An additional piece of equipment such as a crawler dozer may be required to push up the coal above the low profile bin.

A comparison of the truck cycle times was made for the three designs. Truck cycle times were derived from 120 ton haulage truck performance information. In addition, Dravo assumed that the rolling resistance and the turn, back-up and dump times were the same for all designs. Increased truck haulage costs were based on the increased operating hours required for the ramp times and the cost per operating hour derived from another portion of the underspoil study.

Ramp development costs were based on $1.00 per cubic yard fill material costs and $1.50 per cubic yard cut material costs. Reinfored wall costs were based on $11.90 per square foot.

3.3.5.5 Analysis of Results

A summary of the three designed ramps is listed in Table 14. The low profile ramp required the least material to construct and the least quantity of retaining wall, but it also had the least coal storage capacity and could require an additional piece of equipment to push the coal to the storage bin. The advantages and disadvantages of each system are listed as follows:

Ramp Above Ground With Large Storage Bin

	Advantages		Disadvantages
1.	No flooding problems during wet weather.	1.	High volume of fill material required to be handled.
2.	Feeder-breaker is not confined and is maintained easily.	2.	Additional pit floor room required.
3.	Contains a minimum of 300 ton capacity.	3.	More reinforced wall required.
4.	Has reusable retaining wall and bin as well as bin supports.	4.	Coal haulage costs will be higher because of the vertical elevation gained by the truck.
5.	Material removed for ramp construction will be within the planned pit limits.	5.	Truck dumping from only one side.
		6.	No inplace spare feeder-breaker capacity.

Ramp Below Ground With Large Storage Bin

	Advantages		Disadvantages
1.	Reduced volume of material to be mined.	1.	Possible flooding of feeder-breaker during wet weather.
2.	Reduced truck haulage cost because of level haul.	2.	All material mined from the cut will be from ouside the mine plan.

TABLE 14

RAMP DESIGN PARAMETERS

	System 1 30' Ramp	System 2 30' Cut	System 3 Minimum Cut
Ramp (cut) slope	37°	(45°)	(45°)
Volume of material yd^3	43,853	(10,512)	(341)
Ramp Grade-Trucks	8%	0	0
Ramp Grade-Conveyors	0	15%	8%
Increased Haulage Time Hrs. per year	307	0	0
Reinforced wall $ft.^2$ required	2,600	1,200	370
No. of trucks dumping at one time	2	2	4
Bin Capacity (ft^3)	10,320	10,320	864
Total Storage Capacity (tons)	300	300	300*
Ramp Costs	$74,790	$30,050	$4,920

*Includes above storage bin capacity with Cat assistance

3. Addition of a sump, sump pump and piping required.

4. Dumping from only one side.

5. No spare capacity provisions.

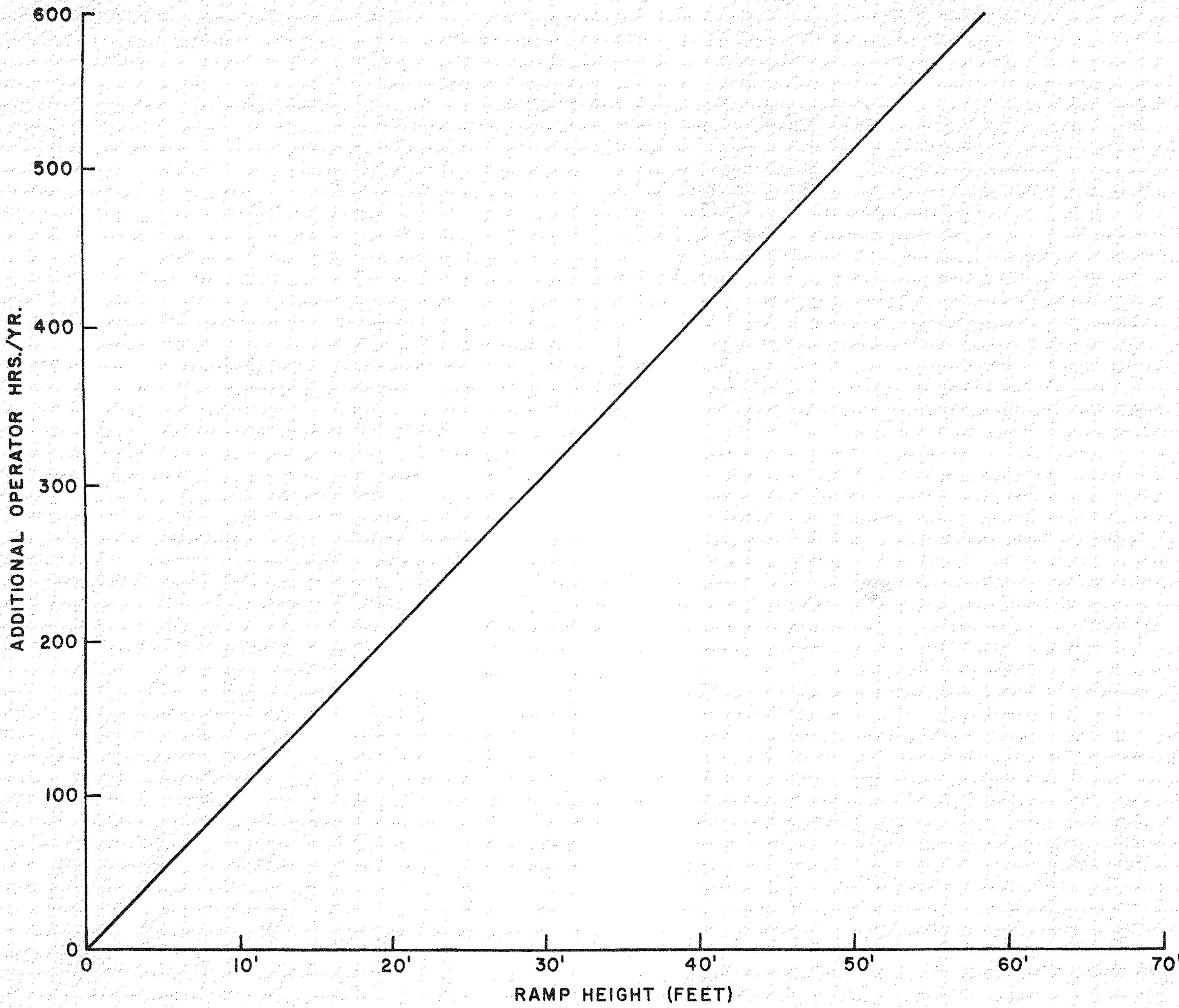
Ramp Below Ground With Minimal Storage Bin

Advantages	Disadvantages
1. Least amount of excavation required.	1. Possible flooding of feeder-breaker during wet weather.
2. Minimized truck haulage costs.	2. Maintenance of feeder-breaker restricted due to height and width of equipment repair area.
3. Capable of dumping from three sides.	3. Lowest coal storage capacity
4. Utilizes a spare feeder-breaker and conveyor.	4. May require an additional piece of equipment to push coal to the storage bin. Use of a second piece of equipment to feed the conveyor may result in discontinuous coal flow to the feeder-breaker.
5. Minimizes the reinforced wall requirements.	
6. Considerably lower ramp development cost.	

Truck haulage is affected by the change in height of the ramp that is constructed. The higher the ramp the more time it will take to unload the truck at a higher cost. A summary of the operating hour comparison of unloading trucks on ramps versus a level haul is given in Figure 59. For the 30 foot ramp design an estimated 307 additional hours of haulage time per year would be required or an increase of approximately $.01 per ton of coal produced. The installation cost of the 30 foot ramp is 15 times greater than that of the low profile feeder-breaker installation.

3.3.5.6 Conclusions

If truck-shovel haulage system is to be used to feed a conveyor system several additional steps must be outlined to get the coal from the truck to the underspoil conveyor. The run-of-mine coal would have to be dumped



ADDITIONAL OPERATOR . HOURS VS. RAMP HEIGHT

Figure 59

into a bin with a minimum capacity to handle equipment non-continuous deliveries. From the bin the material will flow to a crusher to size the material for conveyor feeding. From the crusher the material would flow onto a portable conveyor that would discharge onto the underspoil conveyor. The selection of the ramp configuration, the bin size, and the crusher selection will all influence the effectiveness of the haulage system.

Portable crushing units such as cone, hammer, impact and double roll crushers have fairly high vertical heights. This coupled with the bin requirements and unit costs resulted in the selection of the feeder-breaker as the design unit for this study. New portable crushers coming on the market at present may rival the feeder breaker as the lowest profile and cost efficient unit to use to size coal.

Ramp heights can vary widely. The operation and installation costs of the ramp are directly related to the height of the ramp. For this reason the shorter the vertical height the more economical will be the installation costs.

Bin configurations can also drastically effect the operational cost of the coal haulage system. A bin must be designed to allow the wet coal to flow to the feeder-breaker. Angles for the bin range from 50° to 90° depending on design. This study stayed with either 52° or 90° depending on the height requirement.

In conclusion, the ramp height or depth, the portable crusher type used, and the bin configuration will depend on the plant thru-put, the physical characteristics of the coal, the size of trucks used, the surge capacity of the bin required, the cost increase over a bare minimum that is acceptable to provide for some operating flexibility.

3.3.6 Coal Elevating Concepts

Bringing the coal from the pit floor mining operations and depositing it onto an overland conveyor is the thrust of this whole study. Installing the elevating conveyor under the advancing spoil pile received the major study; however, other approaches for elevating the coal out of the pit also found merit.

3.3.6.1 Objective of Study

Three concepts proposed in these underspoil related studies might prove to be more applicable and efficient under differing mine designs than is underspoil haulage. These are:

- Advancing Catenary Suspending Conveyor System

- Portable Modular Conveyors

- Bucket Elevator of Movable Structure

3.3.6.2 Basis for Study

The preceding underspoil studies were used where applicable; however, differing criteria were assumed to give breadth to the elevating method studies as there applications are more broadly diversified. Other studies and manufacturer's literature were also used as background for the idea development.

3.3.6.3 Criteria of Input

Criteria used for designing the system illustrating the Advancing Catenary Suspended Conveyor were taken from the plans of a yet to be started mine in the Powder River Basin of Wyoming. Other criteria was assumed for the remaining two concepts that generally reflects western coal situations.

3.3.6.4 Procedure

The three aforementioned coal elevating concepts are considered separately and in a manner illustrative of the idea.

3.3.6.4.1 Advancing Catenary Suspended Conveyor System

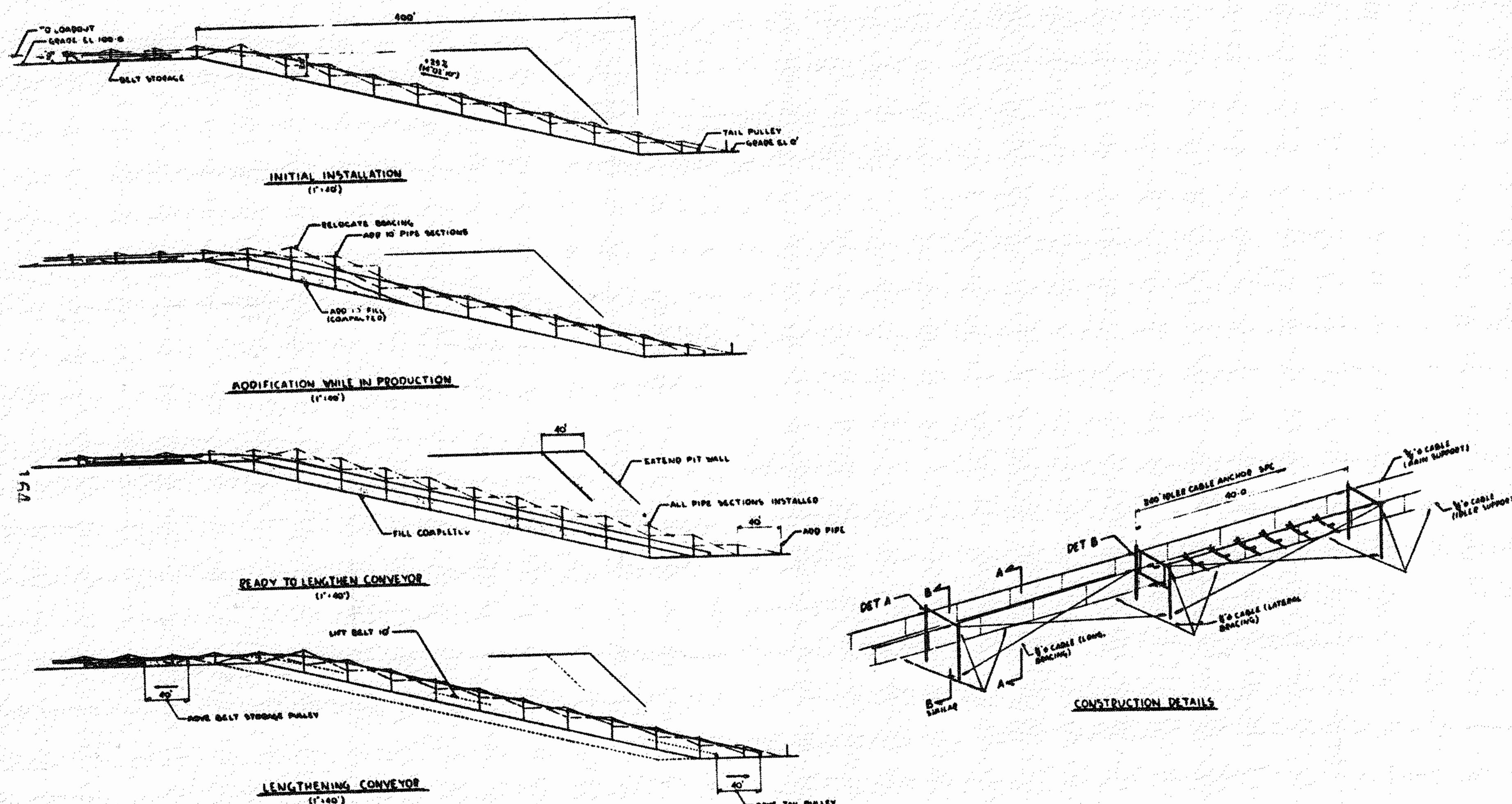
Thruspoil coal haulage was discussed in Sections 3.1.5.3 and 3.1.6 as a very favorable alternative to not only truck haulage but also underspoil haulage. The great advantage to thruspoil haulage is in the relatively low initial capital investment for equipment that is able to function at a low operating cost. The high cost of the underspoil tunnel structure is avoided by placing the conveyor in a steeply inclined ramp from the pit floor through the spoil piles to the surface conveyors. An operational problem is encountered in advancing the conventional surface conveyors in the ramp cut-by-cut without considerable mechanical and construction work. To advance the ramp segment only after a series of cuts will delay spoiling and reclamation activities in the conveyor area. Long interruptions in service would also be experienced through this advancing operation.

The "Advancing Cable Suspended Conveyor System" was conceived in an attempt to overcome the cut-by-cut advancing problem. Catenary cable supported conveyors have the feature of deriving its longitudinal support from the ground itself and its vertical support from posts or structures attached rigidly to the ground. Figure 60 illustrates the general construction of the system and the advancing capability and technique of this innovation. The initial installation involves constructing a ramp through a slot in the retreating highwall of the box cut at a slope of 25 percent or less. Steel pipe is cemented into holes bored in the undisturbed rock to become the support posts. These will be precisely set in both alignment and elevation then maintained in alignment by cable guys and braces. Drive for the conveyor will be at the head pulley where the coal is discharged onto the collector overland conveyor. The design model specified 40-foot spacing between support posts; however, this distance may be varied to fit mine designs. To allow for advancing of a 40-foot increment, 80 feet of belting is maintained in a belt storage loop between the drive and the top of the inclined segment.

Figure 61 illustrates the mechancial and construction details of the advancing catenary system. The unique feature with the proposed concept is in ability to extend each set of support posts in the series to allow for back-filling of spoils under the conveyor without dismantling the system. Ten-foot extensions were proposed as practical extension units. Raising the inclined segment by ten feet will allow 40 feet of extension on the pit floor at 25% gradient. A 120-foot wide cut will consequently require three 10-foot extensions to advance the conveyor 120 feet. As stated above, the initial posts will be solidly set into the pit floor or ramp cut rock. Extensions will be achieved by attaching 10-foot segments of steel pipe to the tops of these initial pipes and subsequent extensions using pipe couplings or welds. Cross members or frames will be clamped to these vertical posts to become the supporting members of the catenary system. The main catenary suspension cables will be attached to the upper cross members with turnbuckles for adjustment. These suspension cables will also be anchored to deadmen at the head and tail pulleys under tension. Wire rope will also be used for longitudinal bracing between pairs of support posts by angling between the tops of the posts and to points near the pipe couplings. These braces will be raised as the posts are extended. To maintain directional alignment and verticality, lateral bracing will be provided by light cables to deadmen at each support post as shown in Figure 60.

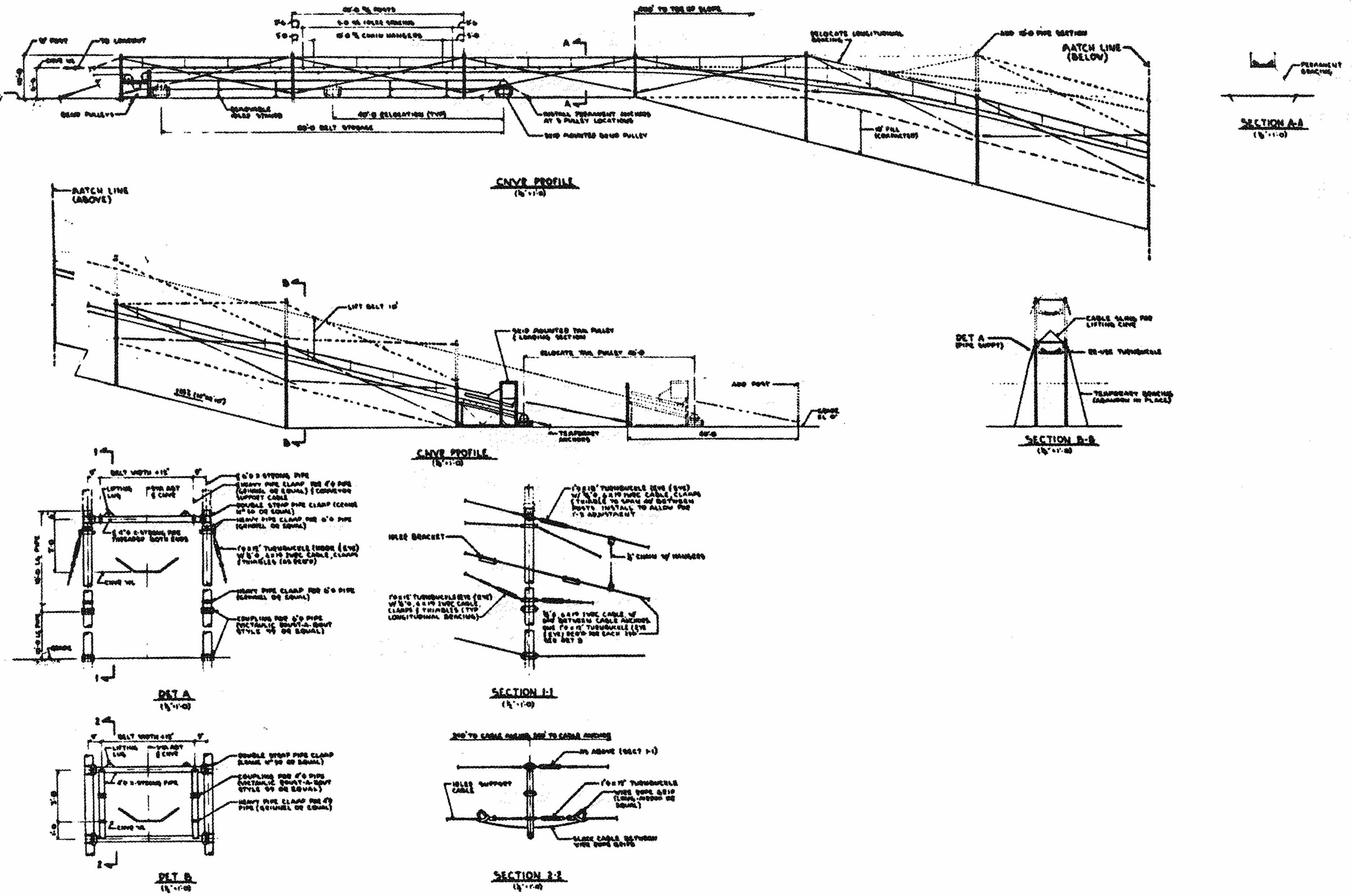
The main support cables form a catenary curve between support post pairs similar to the cables of a suspension bridge. Consequently, to avoid this wavy profile from being transmitted to the conveyor profile, a second pair of cables are suspended by adjustable chain hangers from the main suspension cables. The conveyor idlers are in turn attached to these lower cables. These idler support cables are anchored at the head pulley end and are gripped at the tail pulley end where reels are maintained for extending the system.

The conveyor advancing procedure is illustrated by again referring to Figure 60. For the initial installation, the posts are solidly cemented into the rock or in-place soils and 10-foot extensions are coupled to the tops of these pipes. After the coal has been mined from the area served by the conveyor, the advancing procedure can begin. The initial modifications to the inclined segment can actually be started while the belt is still being used if safety precautions are taken. Fill is placed under the conveyor and around



ADVANCING CABLE CONVEYOR SYSTEM

Figure 60



ADVANCING CABLE CONVEYOR SYSTEM CONSTRUCTION DETAILS Figure 61 the posts as closely as safety allows, then the post extensions are added with their cable braces. This structure extension is continued to the bottom of the pit and 40 feet beyond the existing posts. The filling is also completed in the ramp to complete preparations. The tail pulley is moved ahead 40 feet and the conveyors and cables are raised 10 feet at each support post pair. This process is then repeated until the pit cut or advancing distance is accomplished. With proper preparations this advancing process should proceed rapidly and might be done within a few days. A small hydraulic crane of the "Cherry Picker" type can work well for the conveyor raising. Filling around the conveyor can best be done by bulldozers pushing material from the side slopes of the slot instead of trying to dump material near the structure.

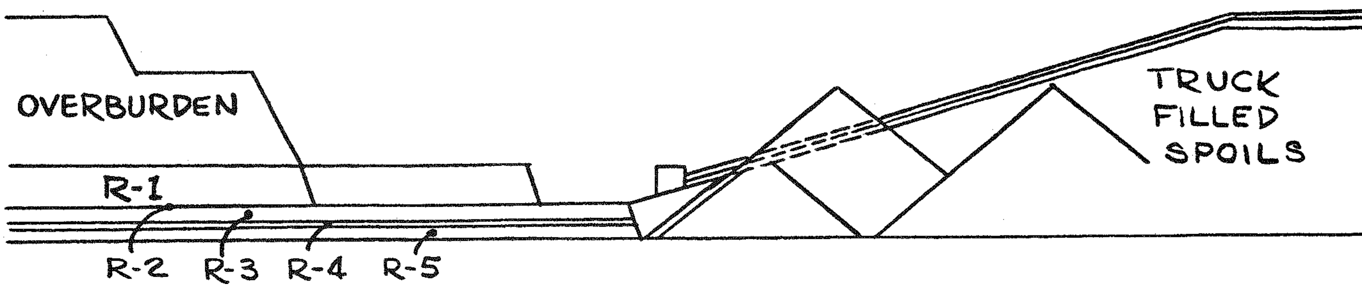
Catenary conveyors are very flexible in the vertical plane and can follow undulations in the surface topography within reasonable limits. This flexibility might be used in mining multiple, dipping, or rolling seams that would cause difficulties for rigid frame systems.

Mining of multiple seams or multiple benches is illustrated in Figures 62, 63, 64, 65 and 66. A Powder River Basin mine was used as a model for these various situations. The coal seams are designated as R-1, R-3, and R-5. Partings are designated as R-2 and R-4. In this case the conveyor loading point is left in the mouth of the spoil dump slot until after mining of the lowest seam has passed where upon it is advanced across the new cut until it is on the pit floor at the toe of in-place coal. When all coal is mined for that cut in the area of the conveyor, the belt is then raised to the elevation of the bottom of the upper most (R-1) coal seam. The conveyor is then on an elevated fill which will make it easy and safer for dragline spoiling during the next cut.

For the mine model, it is suggested that the spacing between conveyors be one-half mile instead of the one mile spacing described in the underspoil model. This closer spacing makes it possible to limit in-pit haul distances to approximately one quarter mile, and the using of in-pit portable conveyors to mine two or more seams through two or even three conveyors simultaneously. The lower capital cost for this thruspoil system helps justify the greater number of conveyors with the added economy of short in-pit haulage. Where three or more thruspoil conveyors are planned, the capacity of any one could be less than the total mine production output criteria for a further savings.

The main advantage of this advancing catenary thruspoil conveyor system over other systems is in the economy of conveyor haulage without the high capital expenditure of underspoil tunnel structures. Flexibility of design and operation is another major feature that rivals that of truck haulage. Safety, environmental protection, energy conservation, and mined surface reclamation are other factors that are favored by this system. Most component parts of the conveyor system are off-the-shelf and well proven and reliable. Some further mechanical design will be required for the support structures and some procedural studies should be made to insure optimum operating efficiency.

R-1 Coal Mining Situation



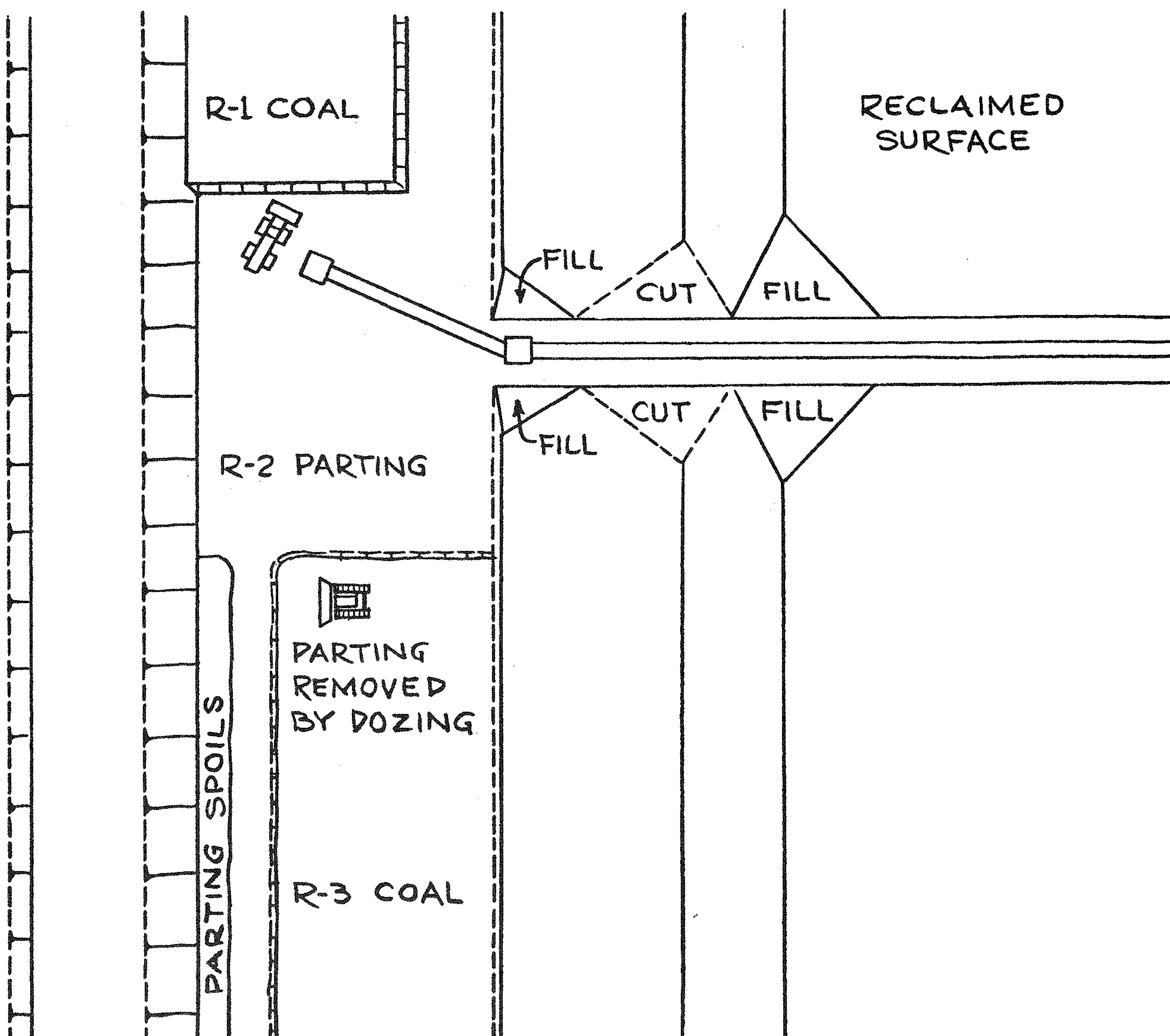


Figure 62

R-3 Coal Mining Situation

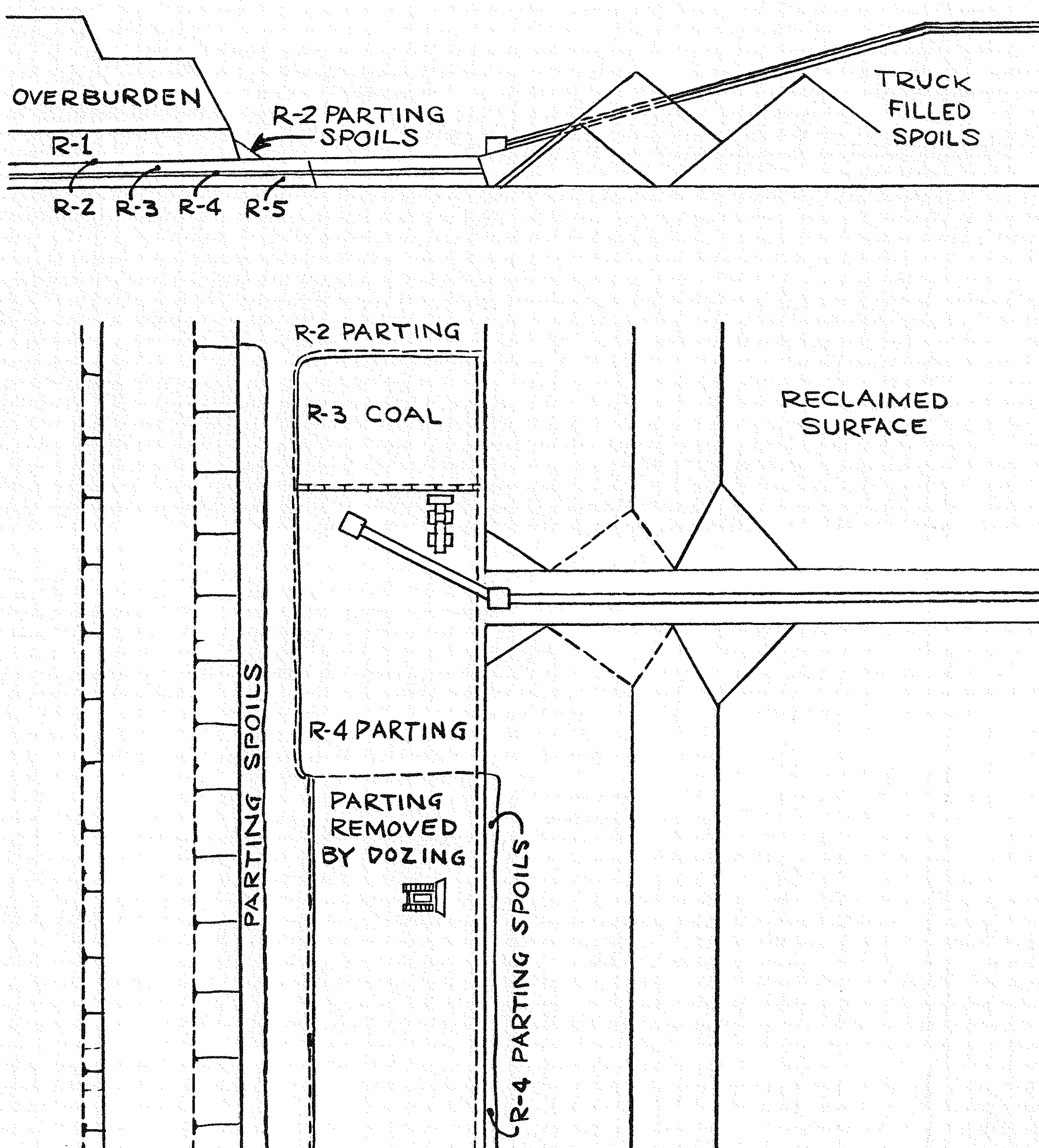


Figure 63

R-5 COAL MINING SITUATION (ADVANCING TOWARDS CONVEYOR)

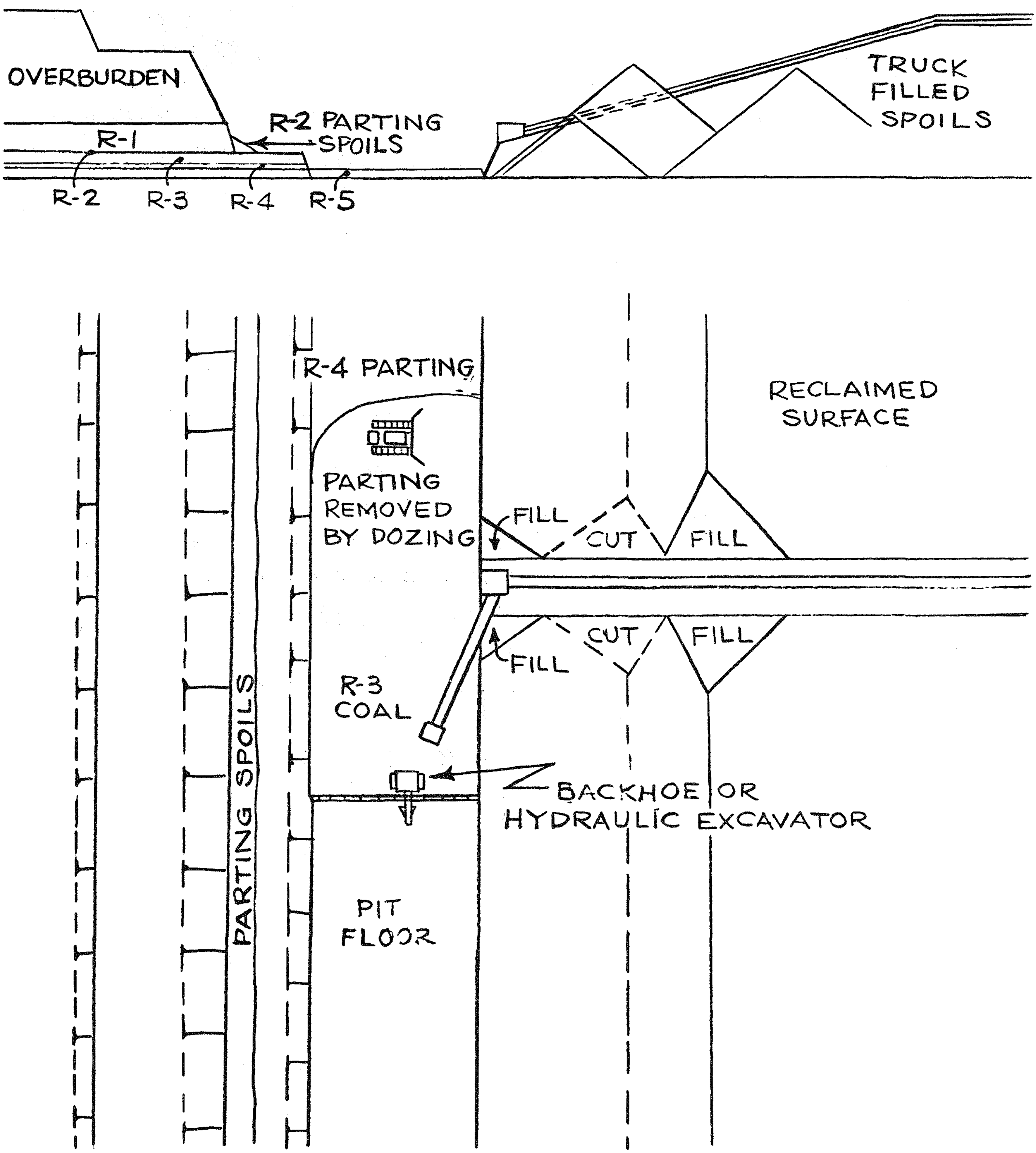


Figure 64

R-5 COAL MINING SITUATION
(RETREATING FROM CONVEYOR)
(CONVEYOR EXTENDED 125')

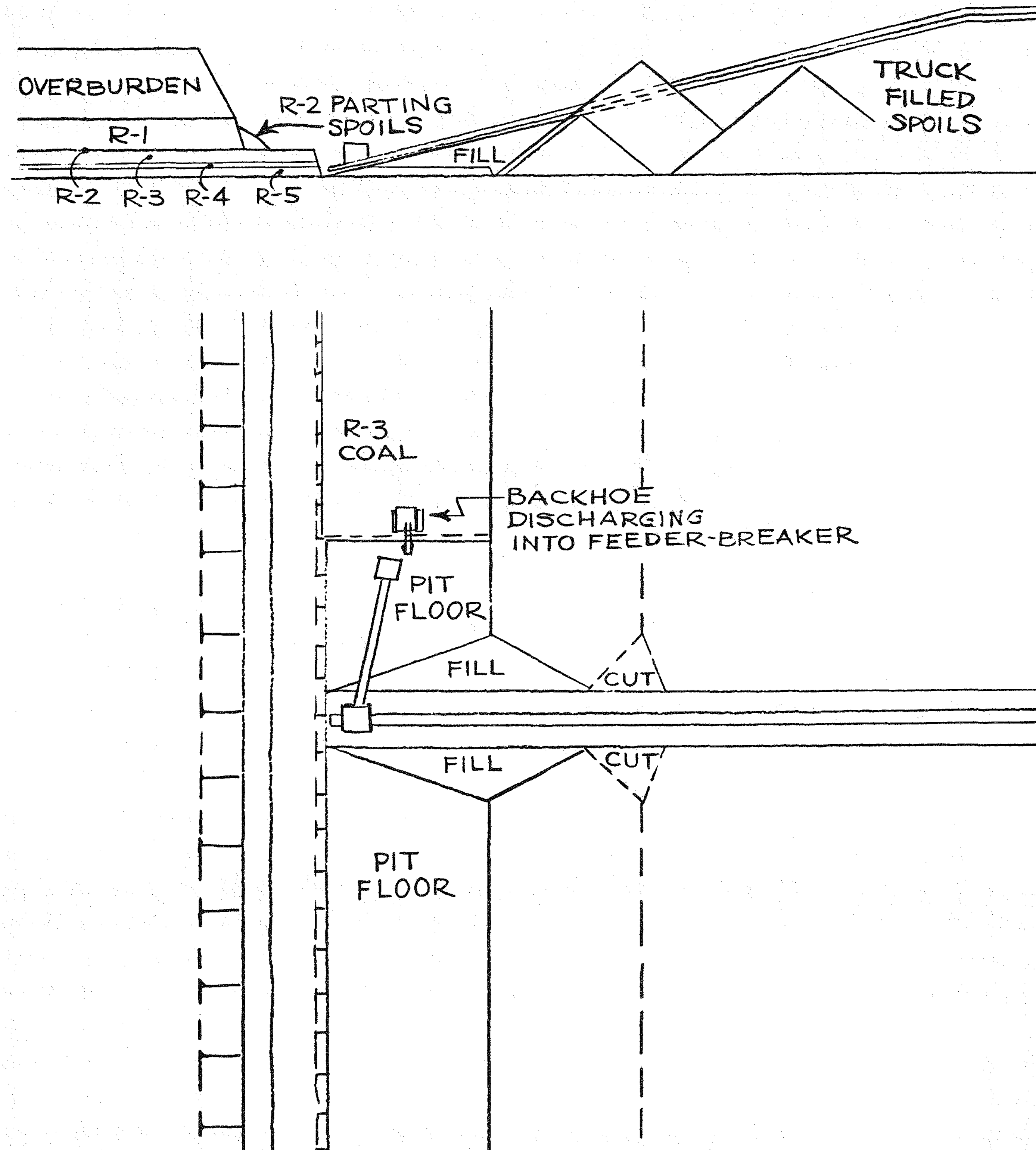
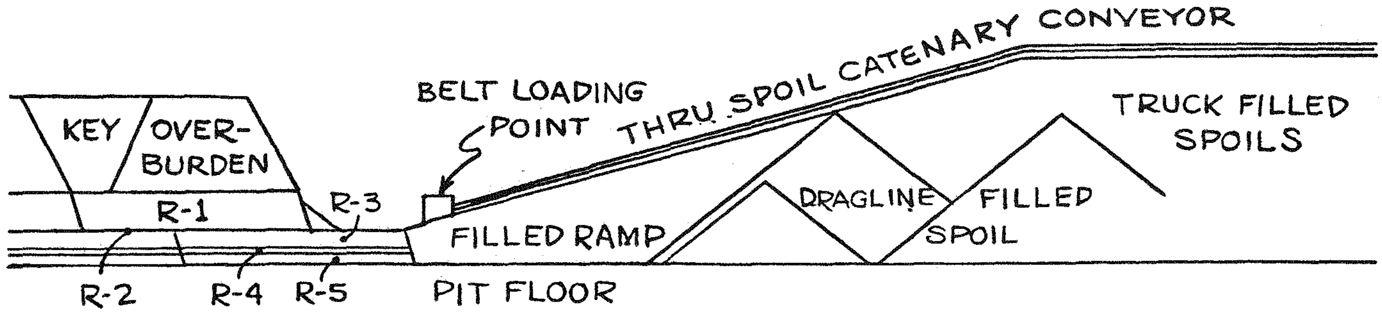


Figure 65

Situation Imminent To Dragline Striping Conveyor Re-elevation



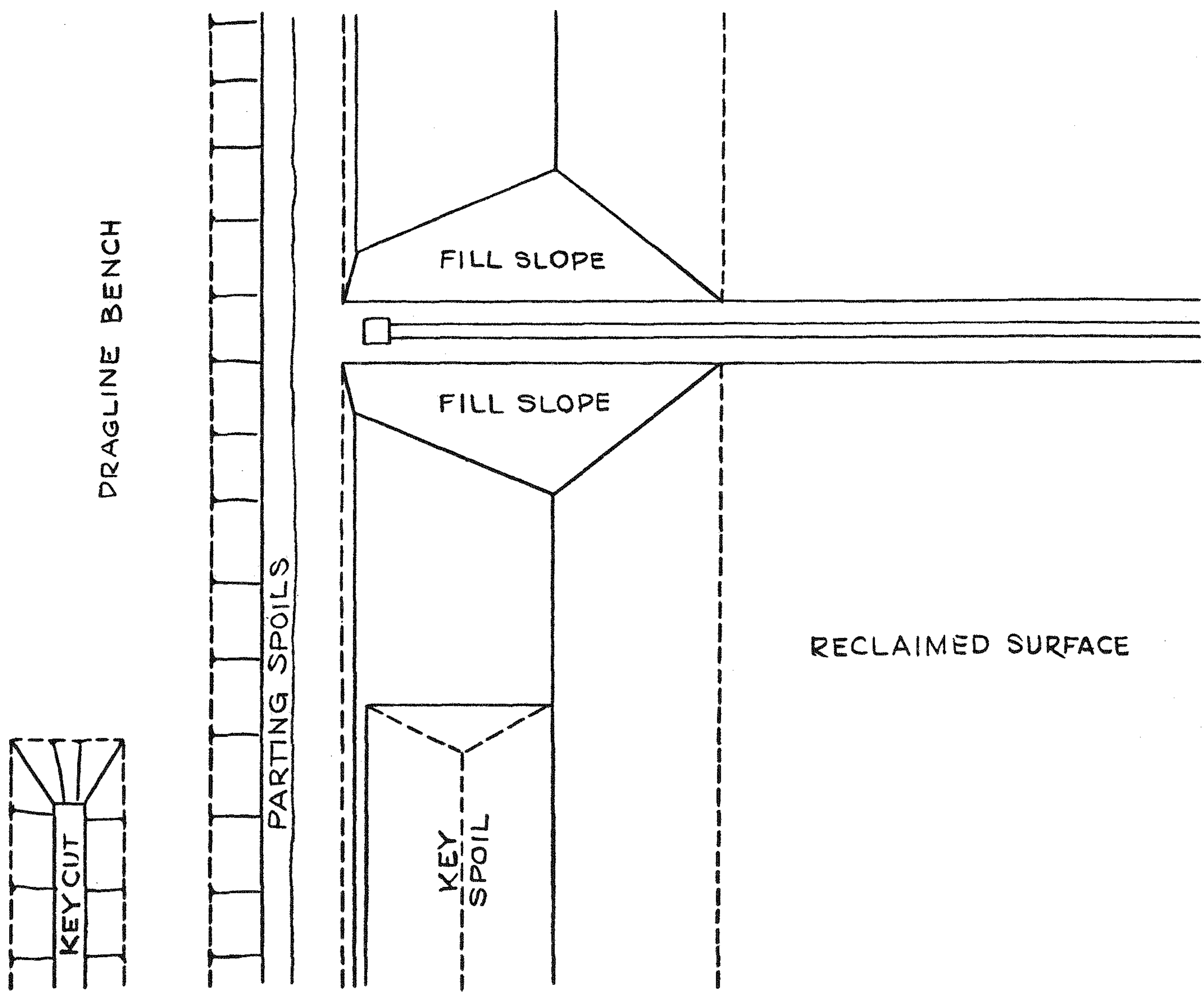


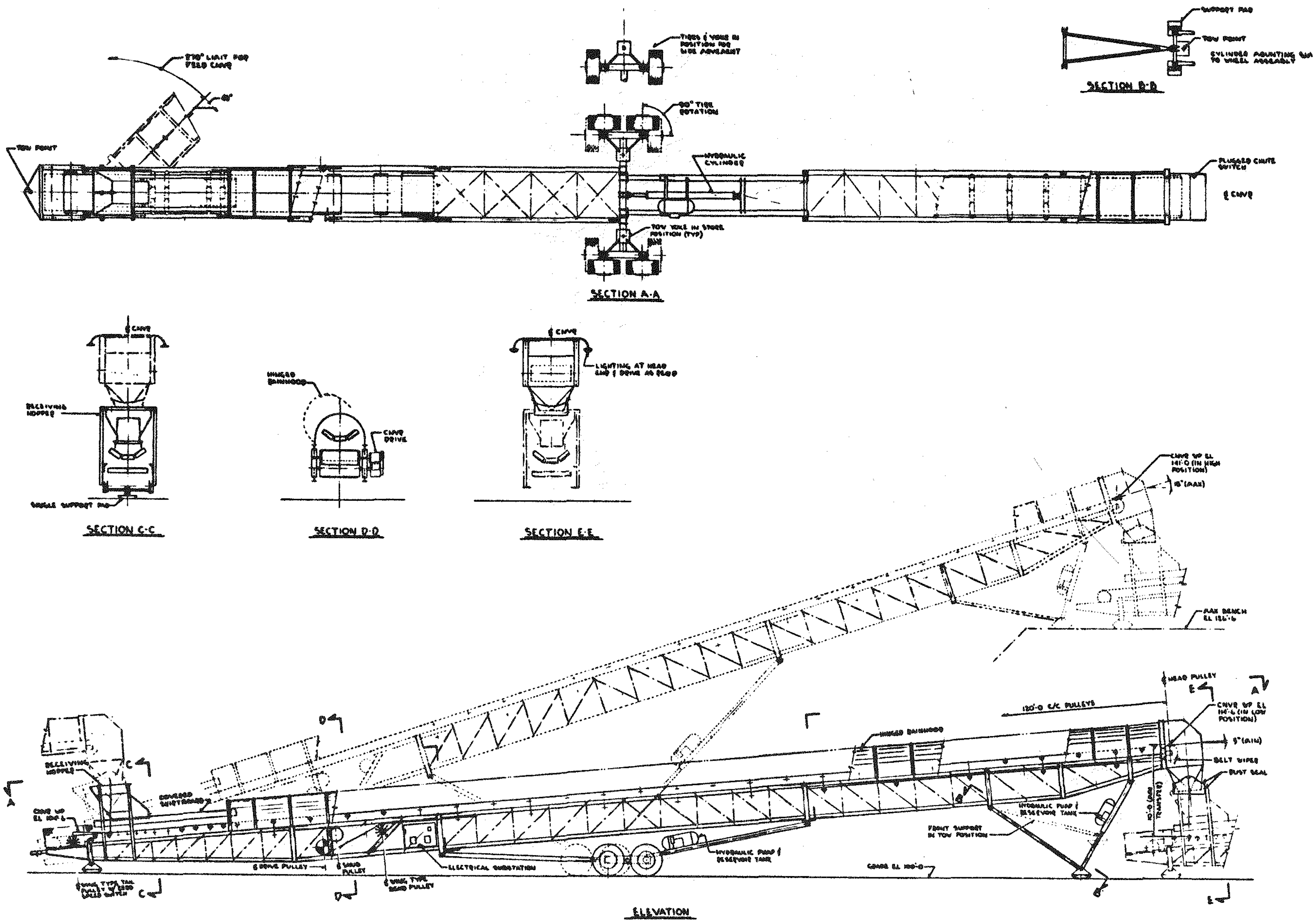
Figure 66

3.3.6.4.2 Portable Modular Conveyors Elevating Coal

Modular portable conveyor units were described and designed in Section 3.1.4.3 of this report. These earlier units were illustrated in Figure 16 and were intended to be used in transporting the coal from the face to the underspoil conveyor loading point. This basic design was modified for use in this elevating concept by adding hydraulic elevating ramps to make it possible to step up a 25-foot bench to another similar unit, Figure 67. A series of these units in "piggyback" fashion can then be used to elevate coal from an open pit operation, Figure 68. The units are 120 feet long and can step up a 25-foot bench without exceeding the critical angle of 18°. Another feature of this elevating unit is that the wheel trucks can be rotated 90° for side swing or traveling. Rainhoods and enclosed transfer points are also planned to avoid fugitive dust. Each unit will have its own electrical substation and hydraulic controls. Power will be carried through built-in cables and connectors so that units can be added to or removed from a series without rewiring. It is envisioned that a small special tractor capable of passing under the higher part of the unit would be used for moving the units about the pit. Some conveyor site preparation will be needed to insure proper location and operation of the units. Good field engineering will also avoid situations that would otherwise adversely affect location and movement of the conveyors.

A model mine situation was assumed similar to Powder River Basin pits and the other models discussed in this report. It was assumed that there would be 50 feet of coal thickness minable into two or more benches. Partings could be present without causing significant problems. Overburden was assumed to be 100 feet thick. The mine application model is illustrated in Figures 69, 70, 71 and 72 as a series of stages. Shovels will load overburden into end-dump trucks and haul it around the end of the pit for spoiling on two or more benches. Coal will be elevated and transported from the pit in the modular conveyor series shown in Figure 68 and in Figure 69-72 as it angles up the end highwall at an overall vertical angle of approximately 11 degrees. This end highwall will be cut by 25-foot benches instead of the 50-foot benches stipulated for the stripping benches accommodating the individual step-up conveyor units. To reduce the operating gradient of the conveyor series, it is set skew of the overall highwall slope at 1.4 to 1. The horizontal angle between a vertical plane passing through this conveyor string and the bench alignment will be approximately 19-1/2 degrees. A surface level overland conveyor will be constructed along the top of the uppermost stripping bench after topsoil has been removed and small irregularities in topography graded out. The elevating conveyor string will string coal from the top of the upper coal bench to this surface conveyor.

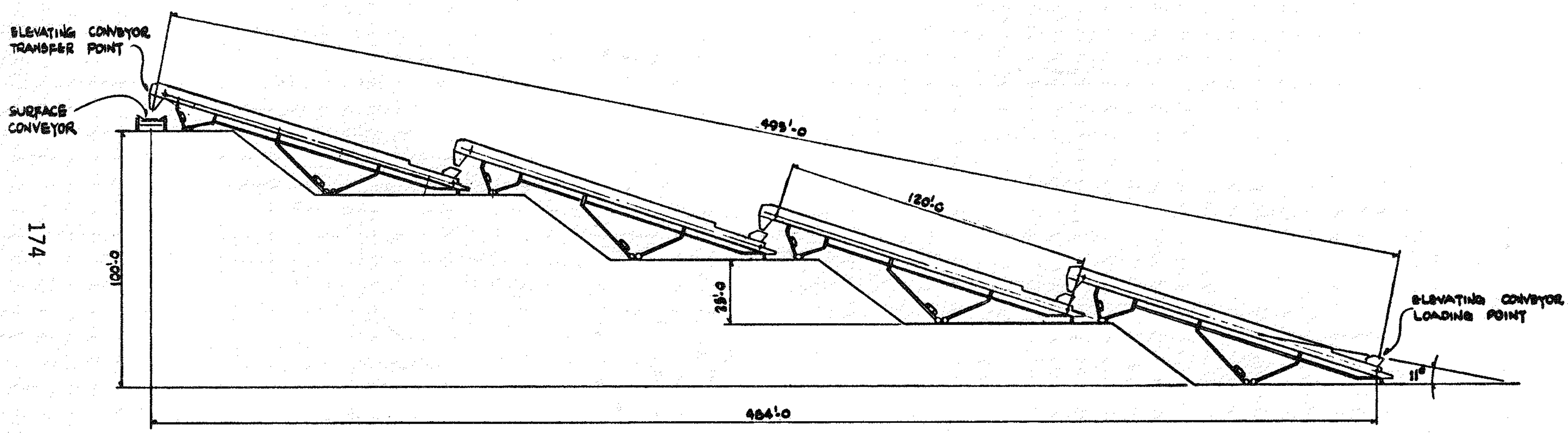
For this model, it was assumed that all in-pit haulage of coal would be by use of these same portable conveyor modules. Coal will be mined with front-end loaders discharging directly into feeder breaker units that will closely follow the loaders. Each bench will have its own unit discharging onto an elevating conveyor string that will step up to the top of the stripped coal seam, Figures 69-72. A series of modular units will collect the coal from these bench elevating conveyors and transport it to the end highwall elevating conveyor string and on out of the pit. The turnable wheels on the



CONCEPTUAL DRAWING—PORTABLE CONVEYOR MODULE

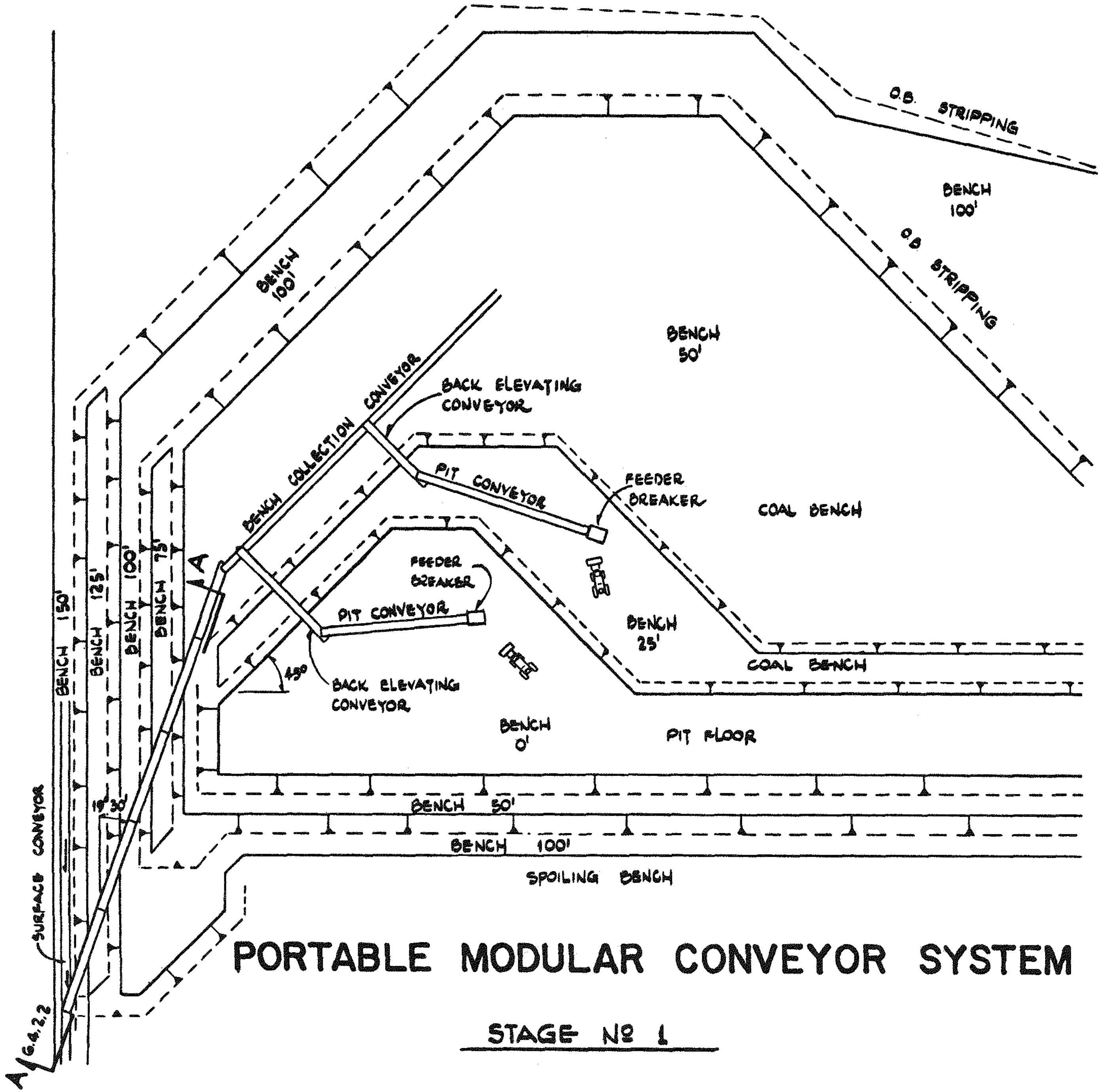
Figure 67

COAL ELEVATING CONVEYOR STRING



SECTION A-A

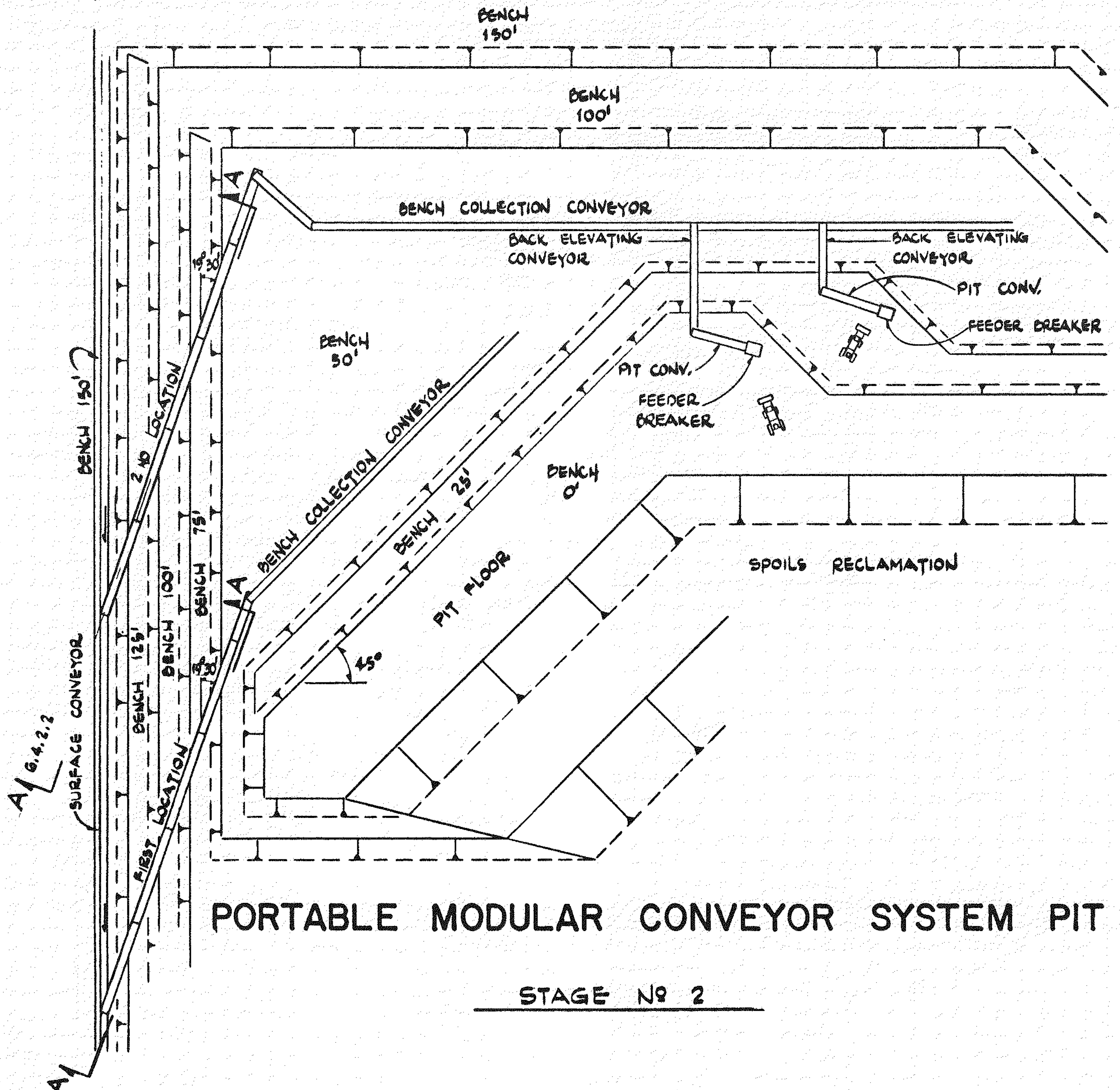
Figure 68



PORTABLE MODULAR CONVEYOR SYSTEM PIT PLAN

STAGE Nº 1

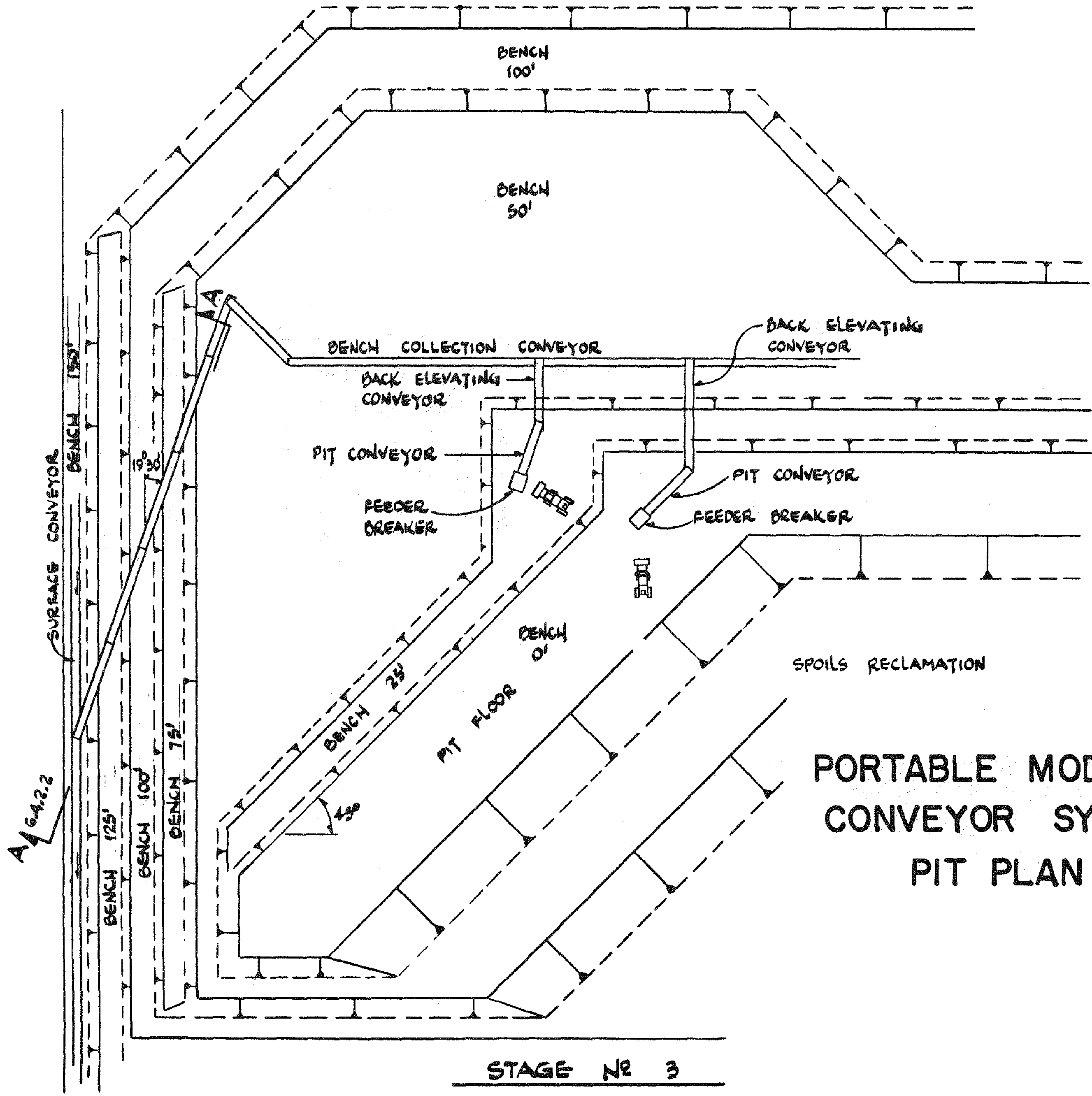
Figure 69



PORTABLE MODULAR CONVEYOR SYSTEM PIT PLAN

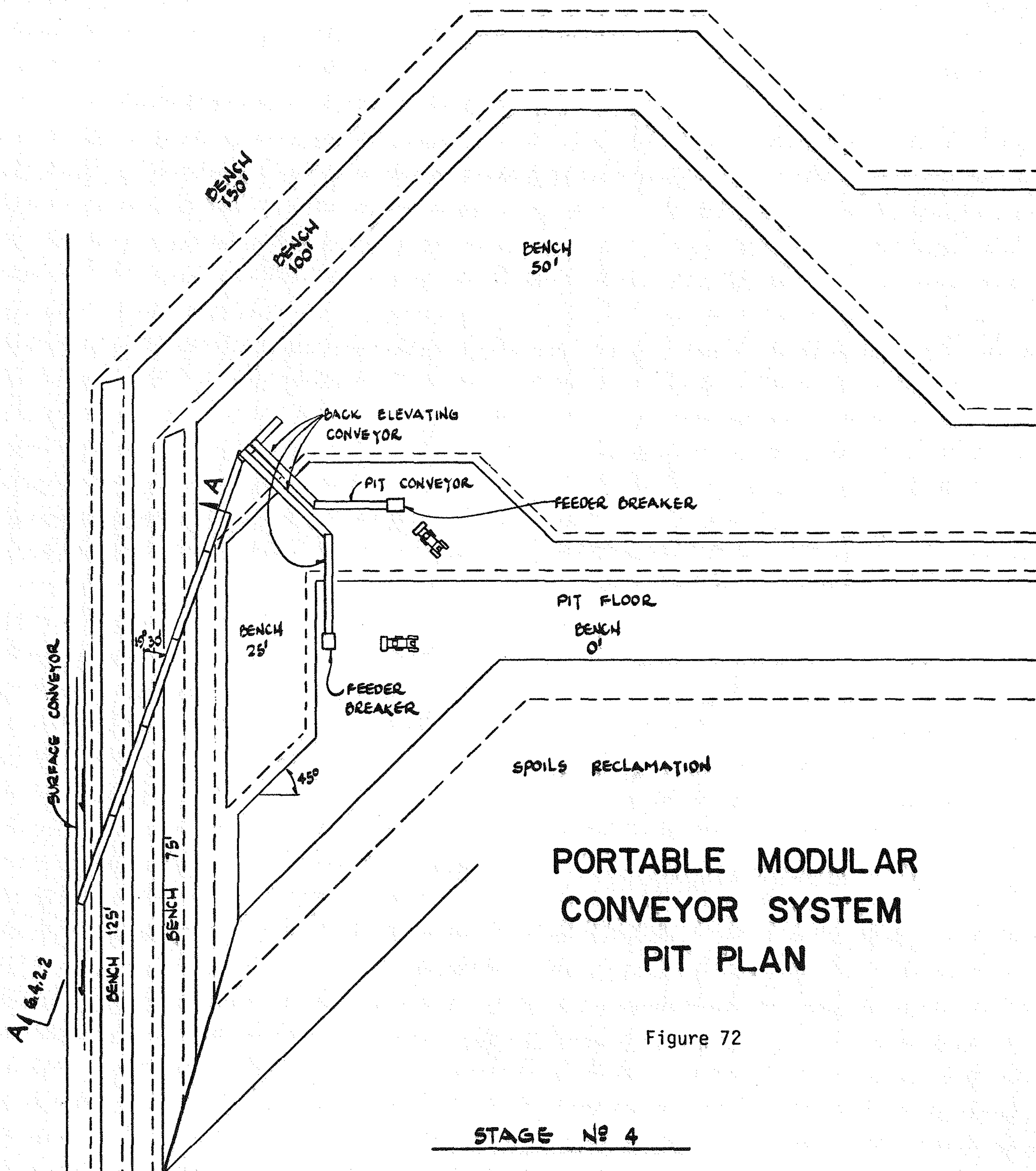
STAGE Nº 2

Figure 70



PORTABLE MODULAR CONVEYOR SYSTEM PIT PLAN

Figure 71



PORTABLE MODULAR CONVEYOR SYSTEM PIT PLAN

Figure 72

STAGE Nº 4

units will allow them to be moved along the benches to follow coal mining. Units will be added to or removed from the strings to allow placing of the feeder-breaker within an easy tramming distance of the loader.

The skewed angle of the pit elevating conveyor string mandates a wide pit at this end highwall be maintained. For the case of this model, approximately 800 feet of endwall will need to be developed at the surface. To avoid an overly large pit, a mining plan was devised using a four stage sequence as shown on Figure 69-72. The first stage involves stripping overburden and mining coal along faces angled 45 degrees to the direction of advance. Stage two begins when sufficient length along the end highwall has been exposed to allow the installation of an advanced string of pit elevating conveyors. The bench collector conveyor is then reoriented at this new location to parallel the long direction of the pit. Coal mining then is turned to advance faces also parallel to the pit length to the opposite endwall of the pit. Stage three requires the returning of the bench conveyors to the triangular shaped coal area developed in stage one. This coal will then be mined in a retreating direction toward this triangle removing sequence and again turning the mine development direction in the angled face direction leading back into the stage one situation.

All conveyor strings can be made up of the same portable modular units to allow easy shuffling of units. The advanced pit elevating string can be made up of excess units from the pit while the preceding string is still in operation. Units can be scheduled for maintenance or replacement as they become idle. This ability along with the replaceability of down units with spares will give the overall system high degree of availability.

Economy of operation for conveyor haulage systems is the greatest advantage of this system over truck haulage. Other advantages lie in safety, energy efficiency, environmental quality effects, and capital expenditure.

Portable modular conveyors have special advantages over other conveyor systems in their flexibility of application and operation. Shorter irregularly shaped pits may be planned. The direction of pit advance may be changed without serious consequence as in the underspoil concept. Advancing the elevating string of conveyors need only be done every 500 feet or so and then without any construction other than access roads. Dipping or irregular coal seams can be mined without significant affect. Variations in overburden thickness will only require adding or removing units to the elevating string.

Dragline stripping of overburden will not work as well with this modular conveyor elevating system as with truck and shovel or conveyor and shovel stripping, because of the wide pit necessary at the endwall. Long pits would also require long in-pit haulage of the coal to the end highwall conveyor.

Some transporting inefficiency will be produced in lost horsepower caused by repeatedly raising the load to transfer to the next unit. Reclamation will be delayed near the end highwall until the string is advanced.

While flexibility is a great advantage of portable modular conveyors, their efficient operation in a mine must be accomplished with sound planning and field engineering.

3.3.6.4.3 Bucket Elevator on Moveable Structure

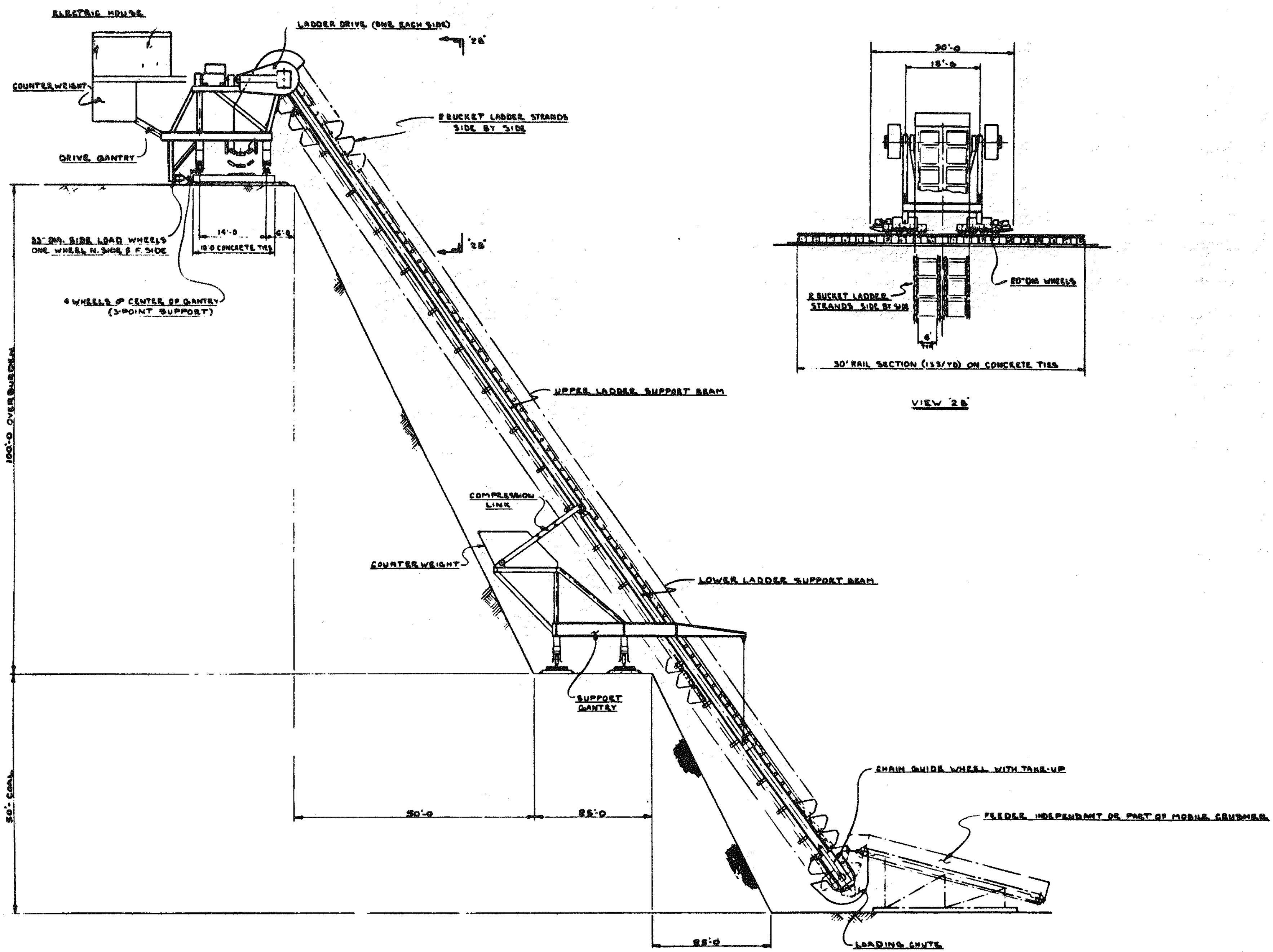
Bucket elevators have long been used for raising loose bulk material in mills, storage silos, and ship unloading facilties. They have the efficiency of continuous haulage along with the ability of being able to elevate loose materials vertically or nearly vertical. Applying these advantages to deep open pit coal mining appears to be a viable innovation.

Dravo's Engineering Works Division currently manufactures barge and ship unloaders for coal capable of elevating 3,000 tons per hour. This basic machine was therefore adopted as logical basis for designing a pit adaptation.

The conceptual idea is to elevate coal up an end highwall from the bottom of a coal pit and deposit it on an overland conveyor system using the bucket elevator. Figure 73 illustrates the idea in section based on a model similar to others described in this report. The coal mining thickness is 50 feet and the overburden 100 feet deep. Because the elevator will only occupy a narrow face of an end highwall, the mine plan and stripping method can take nearly any of the common forms. Coal loading can be either continuous as from a conveyor system or continuous miner, or can be somewhat cyclic as from trucks hauling to a surge bin or stockpile. The bucket elevator itself becomes a feeder of a continuous haulage system; however, it will still be necessary to prevent lumps larger than 16 inches from getting into the system or from high impact loads against the ladder as from trucks dumping directly onto the machine. This feeding can be accomplished by a feeder-breaker unit under the surge bin, by a front-end loader feeding from a stockpile on the pit floor through a grizzly, or through an in-pit continuous mining system. Advancing the elevator will be accomplished by moving it along two sets of rails constructed one on top of the overburden, and the other on top of the coal. This advancing can be done in long or short increments or even periodically during the day along a stockpile face.

Dravo's continuous barge unloader has a designed capacity of 3,000 tons per hour. Rather than redesign this machine to another thru-put it was decided to maintain this capacity for this study. This high capacity can be taken advantage of in handling in-pit stockpiles during train loadout times.

The machine has been designed to elevate coal on a wall profile, as shown on Figure 73, for approximately 150 feet. An intermediate bench 25 feet wide is located on top of the coal seam. It consists of two bucket ladder strands located side by side. Two strands were necessary because of the high forces developed in the supporting roller chains if only one ladder is used.



MOVEABLE BUCKET ELEVATOR SYSTEM

Figure 73

The structure is supported at two places, the first at the top of the overburden and the other at the 50-foot elevation on top of the coal seam. The support arrangement of the bucket ladder is designed to allow for vertical and horizontal dimensional deviations between the two support gantries by means of a system of links, hinges and rope suspension. Each of the two support structures is supported on 4-wheel truck assemblies to spread out the load. The wheels run on steel rails supported by ties. Rail and ties will be laid ahead of the moving gantries and removed after movement. The system is designed to be moved to keep up with the mine progression.

The upper support gantry is subject to a high sideload caused by the weight and location of the bucket ladder. This side force is transmitted into the ground through guide wheels running on a horizontal third rail. The two travel rails and the horizontal guide rail are mounted on common concrete ties. The lower support gantry requires a normal ballasted track. A soil mechanical analysis will be required to ensure stability of the overburden and coal banks under the high vertical and horizontal loads imposed on the rails.

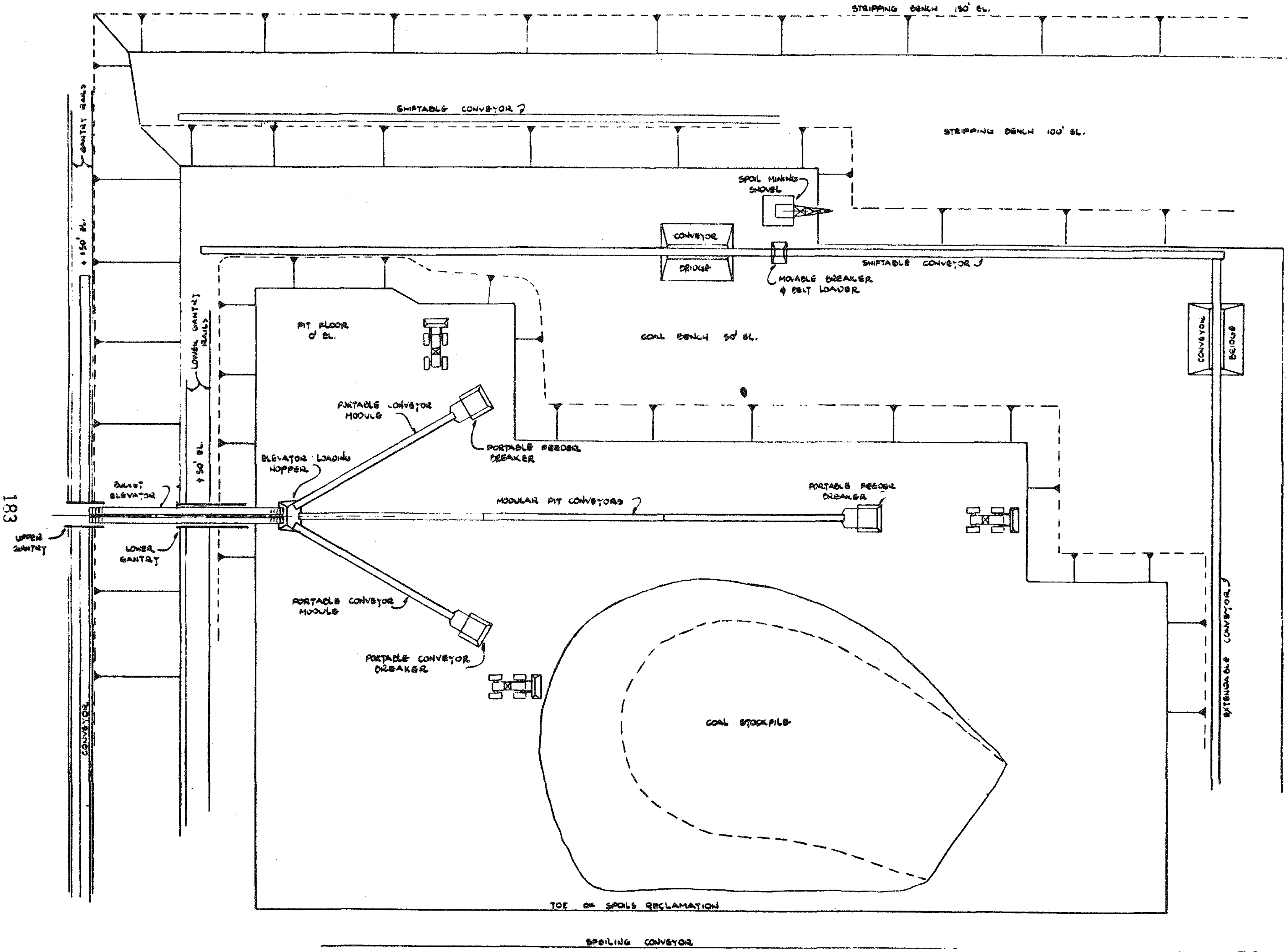
Two 300 HP motors are used to drive the ladders. The drives and the electrical house are located at the top of the machine for easier accessibility.

The coal is dumped into chute work at the top of the machine which directs the material directly on the main take-away belt. It is assumed that the take-away belt is positioned parallel to the direction of advance.

Most any pit configuration is possible with the bucket elevator. A very narrow dragline pit will be possible as well as a broad but short truck or conveyor haul-around (end-around) system.

The narrow dragline pit could work very effectively as little if any interference with the stripping will be produced by the coal hoisting. Transporting the coal on the pit floor efficiently the full length of the pit past the operating dragline will be essential to this narrow pit situation. In-pit conveyors could not be allowed to operate under the draglines swing. Trucks could not turn around in the narrow pit nor pass under the dragline. In section 3.3.4 of this report, a "Trackless Train" is proposed; which might be the answer to this in-pit coal haulage. The trains could pass below the dragline swing by only delaying the dragline occasionally for a few minutes. Only the short pull-tractor will need to turn around in the narrow pit bottom.

A broad floored but short open pit is proposed in Figure 74. It will have advantages in applying short haul-around distances to the overburden removal. In-pit modular conveyors can easily follow the mining units in more than one direction and even serve an in-pit coal stockpile. Mining efficiency can also be obtained with this coal elevating system where property boundaries or other restrictions mandate a small or irregularly shaped pit.



BUCKET ELEVATOR CONCEPT PIT PLAN

Figure 74

TABLE 15

ANALYSIS OF RESULTS

COAL ELEVATING SYSTEM	SYSTEM QUALITY								
	Dragline Stripping	Truck and Shovel Stripping	Wide Pit Floor	Narrow Pit Floor	Multiple Benches or Seams	Irregular Coal Bedding	High Initial Capital Cost	Low Operating Cost	High Energy Efficiency
1. Advancing Catenary Suspended Conveyor	X			X	X	X		X	X
2. Portable Modular Conveyors		X	X		X	X	X	X	
3. Bucket Elevator	X	X	X	X	X	X	X		X

4. OBSERVATIONS AND CONCLUSIONS

Underspoil haulage studies began as a concept for transporting coal from dragline strip mines without the need for haul ramp windows in the spoil piles. Improvements in reclamation ability along with some economic improvements were the main reasons for instigating these studies. Because cost saving is the most prominent incentive to make a change away from conventional systems, most of the effort in this study has been in investigating economic factors and producing comparisons. Variations of the basic concepts have been suggested but for the most part have not been subjected to the same amount of engineering as have the systems outlined in Section 3.1.4.

Underspoil coal haulage is technically feasible and economical under suitable conditions. Some of these conditions are:

1. Coal seam thickness greater than 40 feet.

2. Production rates in excess of five million tons per year.

3. Overburden deeper than 100 feet.

4. Consolidated lease holding.

5. Continuous coal occurrence.

The underspoil tunnels are costly on a linear footage basis, therefore, to make the system economically superior to truck haulage, a large amount of coal must be developed for each foot of advance. Coal thickness is consequently a most critical economic factor. It was shown by the study that 40 feet of coal thickness must be available for transport through the system to make underspoil haulage superior to trucks. Coal thickness greater than 40 feet will, of course, increase the economic advantages of underspoil haulage.

Similarly to coal thickness, coal production rate greatly affects the underspoil haulage economics. The systems are very capital intensive with the consequence that the time value of money has a significant affect on the overall economics. Five million tons per year was set as the model production rate. A lesser production rate would undoubtedly cause the economical advantages of underspoil haulage to become sub-marginal. On the other hand, significantly increasing the annual production rate will correspondingly improve the economics.

Increasing overburden depth improves the comparative economics of underspoil haulage as against truck haulage. The reason for this is that tunnel costs for installations deeper than 100 feet do not increase proportional to depth. On the other hand, truck haulage costs increase significantly with increasing haul ramp lengths. Cases of overburden depths greater than 200 feet were not investigated as such depths are presently unlikely for a strip mine, however, should such an installation be considered, a significant economic advantage will be found in underspoil haulage.

As stated before, underspoil haulage requires a large tonnage of coal to be handled through the system in order to recover the high capital cost and produce an economic advantage over conventional truck haulage. Large coal lease blocks are therefore necessary to provide this tonnage. Blocks of ground containing less than 100 million tons of coal will probably prove to be uneconomical as an underspoil haulage installation.

Discontinuous coal occurrences will also cause underspoil haulage to be more costly on a ton per linear foot of tunnel ratio is concerned. Should this discontinuity of coal seam be caused by faulting or rolling, then technical problems will be introduced along with the economics.

The alternative continuous haulage methods suggested as side studies in Phase II may achieve some of the same desired results as underspoil haulage and at the same time produce economic advantage superior to not only truck haulage but also underspoil. Thruspoil and endwall techniques probably will have the greatest economic advantage, while pit floor tunnels may prove to be the best installation for a specific installation.

Beyond direct costs, there are definite advantages to an underspoil system. Labor will be substantially less than truck haulage, not only for direct operating and maintenance labor, but also for indirect support labor. With the reduced labor goes the reduced dependence on the chronically labor short local sources. Safety of personnel will be a lesser problem as will support facilities. Energy involved in transporting the coal will be largely in the form of coal produced electricity instead of scarce diesel fuel. Costs and problems related to reclamation and environmental protection will be less for conveyor haulage than for truck.

All major coal producers are not only obligated to restore the lands they mine and protect the environment, but most are also interested in going beyond the federal and state regulations in doing the environmental job. Conveyor haulage and underspoil in particular is a very useful mining tool in allowing rapid and complete reclamation. Conveyor haulage produces much less fugitive dust than trucks rolling on dirt roads and the lesser work force has a smaller impact on nearby towns and their facilities.

The main advantages of underspoil haulage parallel those of well conceived belt conveying systems in general. Some of these are:

1. Economical transportation.

2. Low manpower requirements.

3. High degree of reliability.

4. Few adverse environmental impacts.

5. Low energy consumption.

6. Slight interference with reclamation.

7. Maintenance and support facilities are minimal.

8. Not very susceptible to weather conditions.

9. Safety of personnel and equipment is greater.

Using an underspoil tunnel as part of the coal conveying system has certain advantages over other conveyor methods:

1. Belt conveyors remain stationary in position with only periodic extension for advancement.

2. Conveyor is shielded from weather and other hazards by tunnel.

3. Belt loading point is at bottom of pit close to mining.

4. Reclamation can proceed over the underspoil tunnel.

5. Underspoil belt is continuous from surface to coal loading point through an engineered vertical curve.

6. Tunnel structure provides rigid support to conveyor.

Disadvantages of underspoil haulage systems are not operational in nature so much as they are engineering criteria that can be negated by well conceived plans and application. Some of these disadvantages that must be recognized are:

1. Capital cost of tunnel is high if proportioned over small tonnages.

2. System lacks flexibility of mine planning and daily changes when compared with truck haulage.

3. Coal must be broken and fed into belt at continuous rate.

4. Mining multiple coal seam with dragline stripping may not be possible.

5. The tunnel must be regarded as an underground mine passage thereby qualifying the governmental regulation as such.

It can be recommended that coal mining companies, anticipating a new mine plan, seriously consider using a mode of continuous coal haulage out of the pit. Underspoil nor any of the other systems can be made to apply to all mining situations. A thorough feasibility study made on the site-specific should reveal the optimum approach both from a technical and an economical viewpoint.

It can also be recommended that further studies be performed on coal haulage systems suggested in this report aside from underspoil haulage.

These systems are conceptual in development and will require some additional engineering before a site-specific installation can be considered. An effort might also be extended toward making the coal mining industry more aware of developments in coal haulage systems through more studies, seminars or articles in trade publications.

5. RECOMMENDATIONS FOR FUTURE STUDIES

The underspoil haulage studies have produced several ideas for future engineering studies. Some of these have been only conceived, others have been studied with some engineering. The underspoil system has probably been studied sufficiently until a site for installation becomes available, however, some of the side studies contain ideas and innovations that are worthy of feasibility studies.

5.1 Trackless Trains

Trackless trains operating to move coal in the bottom of a pit have certain advantages over both truck haulage and in-pit conveyors. They can approximate continuous haulage yet remain flexible for pit designs. Engineering studies should first address the concept then develop the equipment.

5.2 Advancing Catenary Conveyor

Thruspoil coal haulage was found to have very significant advantages over both truck haulage and underspoil haulage as discussed in Sections 3.1.5.3 and 3.1.6. The advancing catenary conveyor is a concept developed and designed by Dravo engineers to enable the conveyor to follow the advancing pit with little disruption of production. Engineering should be done on the conveyor equipmet and operating procedure. Pit designs will require little modifications.

5.3 Portable Modular Conveyors

Many different mining applications can be made with the portable modular conveyor units as described in Section 3.3.6.4.2. Engineering, designing and fabrication of one of these units is a project well worth consideration.

5.4 Bucket Elevator On Movable Stucture

The concept of operating a bucket elevator to raise coal of a steep highwall has attracted more interest than any other of the coal elevating concepts. Section 3.3.6.4.3 describes the system and equipment. Many differing mining schemes can use the equipment to advantage; therefore, the thrust of future work should be in detail designing and actual fabrication of a proto-type.

6. REFERENCES/BIBLIOGRAPHY

CIVIL ENGINEERING

ACI Standard 318-71 "Building Code Requirements for Reinforced Concrete" American Concrete Institute, 1970

American Institute of Steel Construction, Inc., "Manual of Steel Construction", Seventh Edition

American Iron and Steel Institute, "Hand of Steel Drainage and Highway Construction Products", R. R. Donnelley and Sons Co., 2nd Edition

Boden, B., West, G. and Harrad, C.J. "Tunnels in Mining and Civil Engineering"- Common Ground

Davis, R.E., "Structural Behavior of Concrete Arch Culvert" Journal of the Structural Division, Proceedings of the American Society of Civil Engineers, December, 1969

Davis, R.E. and Bacher, A.E. "Concrete Arch Culvert Behavior - Phase 2" Journal of the Structural Division, Proceedings of the American Society of Civil Engineers. November, 1972

Davis, R.E., Bacher, A.E. and Obermuller, J.C. "Concrete Pipe Culvert Behavior - Part 1", Journal of Structural Division. March, 1974.

Davis, R.E., Nix, H.D. and Bacher, A.E. "Arch Culvert Research - Phase 3" Journal of the Structural Division. April, 1979

Davis, R.E., Nix, H.D. and Bacher, A.E. "Arch Culvert Footing Movements" Journal of the Structural Division. April, 1979

Gaylord, E.H., Jr., and Gaylord, C.N., "Structural Engineering Handbook", McGraw-Hill Book Company

Proctor, R.V. and White, T.L., "Rock Tunneling with Steel Supports", Commercial Shearing and Stamping Co., 1946

Walkinshaw, J.L. "Reinforced Earth Construction" April 1975, Report No. FHWA-DP-18

ELECTRICAL ENGINEERING

"IPCEA Standards", Insulated Power Cable Engineers Association

"National Electric Code", National Fire Proctection Association, 1974

MECHANICAL ENGINEERING

Conveyor Equipment Manufacturers Association, "Belt Conveyors for Bulk Materials", Cahners Publishing Company Inc., First Edition 1966

Goodyear, "Handbook Conveyor and Elevator Belting" The Goodyear Tire and Rubber Company, 1975, Akron, Ohio

Krall, D. and Shurskis, K., "Conveyor Analysis and Modeling Program Users Manual", Dravo Corporation Minerals and Metals Division, Pittsburgh, Pennsylvania December, 1978

Marlatt, W. K. "High Capacity Belt Conveyors" Mining Congress Journal, Vol. 63 No. 1 January 1977, Pgs. 24-28

Stamler, W. R. "The Feeder-Breaker as a Continuing Contributor to Coal Mine Productivity" Presented at the Eastern Mining and Industrial Exposition Charleston, West Virginia, May 10, 1977

St. John, C.R. and Kronke, J.W., "Use of Belt Conveyors in Open-Pit Mining", Mining Congress Journal, April 1975 Pgs. 56-61

Tobey Yu, A., Dr., "Belt Modules: Answer to Renewed Demand for Coal" Skillings Mining Review Vol. 63 No. 7, February 16, 1974

MINING ENGINEERING

Caterpillar Tractor Company "Caterpillar Performance Handbook" Edition 7 Cat Publication 1976

Comparative Data Redbook - Compiled by National Research and Appraisal Company, Equipment Guide-Book Company, 1977

"Cost Reference Guide for Construction Equipment", Guide-Book Company, 1977

Cummins, A.B. and Given, I.A., "S.M.E. Mining Engineering Handbook, Vol. I and Vol. 2, Mudd Series", Society of Mining Engineers of AIME, Port City Press, 1973

Peele, R. and Church, J.A., Mining Engineers Handbook Vol. I and Vol. 2, Third Edition, John Wiley & Sons, Inc., 1959

Pfleider, E.P., "Surface Mining Mudd Series", The American Institute of Mining, Metallurgical and Petroleum Engineers, Inc., The Maple Press Company 1968

Johnson, G.A. "Underspoil Coal Haulage" Technical Paper Series 780468 Society of Automotive Engineers, Inc. 1978

Keystone Coal Industry Manual
Mining Information Services, Keystone Coal Industry Manual
McGraw-Hill Publication, 1976

Keystone Coal Industry Manual
Mining Information Services, Keystone Coal Industry Manual
McGraw-Hill Publication, 1978

COAL AGE

Donner, L.D. and Kruse, E. "Bureau Seeks New Surface Mining And Reclamation" Coal Age Vol. 80 No. 7 July, 1975

Martin, W.T. and Reese, H.B. "Innovative Surface Mining Equipment", Coal Age Vol. 80 No. 7 July, 1975

Jackson, D.: "Modern Equipment, Town, Reclamation Give Western Energy Bright Future" Coal Age Vol. 80 No. 8 August, 1975

"Decker Coal Combines Titanic Mining Effort With Effective Land Restoration" Coal Age Vol.80 No. 9 September, 1975

Jackson, D.: "Montana-Based Westmoreland Resources Mines Crow Indian-Owned Coal At Absaloka Mine", Coal Age Vol. 80 No. 12 December, 1975

"Improved Surface Mining Method" Coal Age Vol. 81 No. 2 February, 1976

Wilkinson, F.J.: "Good Management And A 52-Ft. Seam Made Decker Top Producer For 1975" Coal Age Vol. 81 No. 8 August, 1976

"New Equipment Concepts Abound As Surface Mining Technology Is Spurred By Increase Demand For Coal" Coal Age Vol. 81 No. 10 October, 1976

Wood, R. R., Jr.: "Dragline Boosts Chinook Output", Coal Age Vol. 81 No. 12 December, 1976

"High Vale Mine Expands Output To Feed A Fast-growing Power Plant" Coal Age Vol. 82 No. 2 February, 1977

Davis, H.: "Balanced Draglines Dig Deep Cover" Coal Age Vol. 82 No. 4 April, 1977

Jackson, D.: "Skull Point Mine Comes On Stream", Coal Age Vol. 82 No. 4 April, 1977

Jackson, D.: "Western Coal Is The Big Challenge To Reclamation Experts Today" Coal Age Vol. 82 No. 7 July, 1977

Jackson, D.: "Cordero On Stream In Powder River" Coal Age Vol. 82 No. 8 August, 1977

Paisley, E. and MacDonald, E. "Skids Speed Handling Cables", Coal Age Vo. 82 No. 8 August, 1977

Jackson, D.: "Jacobs Ranch Selects Open Pit Mining Plan", Coal Age Vol. 82 No. 11 November, 1977

Chironis, N.P.: "Safer And Speedier Haul Roads" Coal Age Vol. 82 No. 12 December, 1977

Chironis, N.P.: "How To Build Better Haul Roads" Coal Age Vol. 83 No. 1 January, 1978

Chironis, N.P.: "Midland Coal Digs Deep For Seams" Coal Age Vol. 83 No. 4 April, 1978

Jackson, D.: "McKinley Nears 5-Million TPY Goal" Coal Age Vol. 83 No. 4 April, 1978

Chironis, N.P.: "Scrapers Take On Dragline Job" Coal Age Vol. 83 No. 4 April, 1978

"Team of Scrapers Strip Overburden" Coal Age Vol. 83 No. 11 November, 1978

"Conveyors Aid Bucket Wheel Output" Coal Age Vol. 84 No. 1 January, 1979

Jackson, D.: "Miner Strips And Loads At 2800 TPH" Coal Age Vol. 84 No. 3 March, 1979

"Material Handling On The Move" Coal Age Vol. 84 No. 6 July, 1979

COAL MINING AND PROCESSING

Nolden, Carol: "Big Construction Signifies Growth At P & M's New Mexico Mine" Coal Mining & Processing Vol. 13 No. 6 June, 1976

"New Montana Mine Reaches For 5.5-Million TPY Mark" Coal Mining & Processing Vol. 13 No. 12 December, 1976

"Optimize Your Surface Mining & Reclamation Operations" Coal Mining & Processing Vol. 14 No. 6 June, 1977

Kanya, C.J.: "How To Cope With Blasting Problems In Strip Mining" Coal Mining & Processing Vol. 14 No. 9 September, 1977

"Surface Machines Of The 80's - What Will Be Different" Coal Mining & Processing, Vol. 15 No. 2 February, 1978

Sprouls, M.W.: "Black Thunder Aims At 20 Million Tons" Coal Mining & Processing Vol. 15 No. 7 July, 1978

Carter, R.A.: "Energy Fuels Corporation Leads Colorado Coal Production" Coal Mining & Processing Vol. 15 No. 12 December, 1978

ENGINEERING AND MINING JOURNAL

"Larger Tire Rims Can Cut Operating Cost" EMJ - Vol. 179 No. 7 July, 1978

"New Brake System Meets Tough Standards" EMJ - Vol. 179 No. 8 August, 1978

Taipale, J.: "What To Look For When Selecting Conveyor Belt Equipment" EMJ - Vol. 179 No. 8 August, 1978

MINING CONGRESS JOURNAL

Grandt, A.F.: "Reclamation Problems In Surface Mining" Mining Congress Journal Vol. 60 No. 8 August, 1974

Gold, R.J. and Gold, O.: "Wheel Excavators And Conveyors For Use In Surface Coal Mining" Mining Congress Journal Vol. 60 No. 11 November, 1974

"Open-Pit Mining" Mining Congress Journal Vol. 61 No. 2 February, 1975

Brawner, C.O., Pentz, D.L. and Campbell, D.B.: "Ground Stability In Surface Coal Mines" Mining Congress Journal Vol. 61 No. 6 June, 1975

Marston, D.O.: "Application Of Bucket Wheel Excavators To Thick Western Coal Seams" Mining Congress Journal Vol. 62 No. 6 June, 1976

Weiss, W.D. and Dunn, R.H.: "Modern Railroad Concepts For Transporting Western Coal" Mining Congress Journal Vol. 62 No. 11 October, 1976

Eadie, G.R.: "Surface Coal Mining - 1976" Mining Congress Journal Vo. 63 No. 2 February, 1977

Steidle, E.: "Evaluating The Role Of Draglines And Shovels In Mining" Mining Congress Journal Vol. 63 No. 4 April, 1977

Graham, R.J.: "Planning Of A New Surface Mine - Western Coal" Mining Congress Journal Vol. 63 No. 6 June, 1977

Thames, J.L. and Verma, T.R.: "Reclamation On The Black Mesa Of Arizona" Mining Congress Journal Vol. 63 No. 9 September, 1977

Ralston, D.S. and Wiram, V.P.: "The Need For Selective Placement Of Overburden And Equipment Considerations" Mining Congress Journal Vol. 64 No. 1 January, 1978

"Highlights Of Surface Mining In 1977" Mining Congress Journal Vol. 64 No. 2 February, 1978

Morey, P.G., and Lee, C.D.: "Optimization Of Dragline Operation" Mining Congress Journal Vol. 65 No. 6 June, 1979

MINING ENGINEERING

Bergmann, R.W.: "An Economic Evaluation Of Higher Voltages For Stripping Machines" Mining Engineering Vol. 24 No. 12 December, 1972

Griffin, T.A.: "New Uses For Bucket Wheel Excavators Mining Engineering Vol. 26 No. 10 October, 1974

Johnson, T.C.: "How Design Improvement Boost Walking Draglines' Productivity" Mining Engineering Vol. 26 No. 10 October, 1974

Waldbieser, W.C.: "Recent Development In Open Cut Mining And Machines" Mining Engineering Vol. 26 No. 11 October, 1974

MacDonald, D.B., and Eubanks, D.E.: "Western Coal Development: The Problems Of Economics, Engineering And Environment" Mining Engineering Vol. 28 No. 8 August 1976

Saperstein, L.W.: "Surface Mining" Mining Engineering Vol. 29 No. 3 March, 1977

Speake, C.J., Finch, T.E. and Haley, D.R.: "Calculating Dragline Reach Requirements For Western Surface Mines" Mining Engineering Vol. 29 No. 5 May, 1977

Wiebmer, J.D.: "Lignite And North Dakota A Cautious Response To Accelerated Mining Demands" Mining Engineering Vol. 29 No. 8 August, 1977

"Surface Mining" Mining Engineering Vol. 30 No. 5 May, 1978

"Expansion Begins At Cordero To Double Mine Production" Mining Engineering Vol. 31 No. 9 September, 1979

MINING MAGAZINE

"Steering Systems For Off-Highway Trucks" Mining Magazine Vol. 131 No. 1 July, 1974

"Tyres For The Mining Industry" Mining Magazine Vol. 134 No. 4 April, 1976

"Off-Highway Tyres Reconditioning For Economy" Mining Magazine Vol. 134 No. 6 June, 1976

WORLD COAL

"Vast Open-Pit Operation Creates Boom Town" World Coal Vol. 2 No. 12 December, 1976

Archibald, J.C., Jr.: "Horizontal Drilling Techniques Can Offer Substantial Cost Saving" World Coal Vol. 4 No. 3 March, 1978

Dorling, I.: "The Largest USA Coal Mine In The Pacific Northwest" World Coal Vol. 4 No. 8 August, 1978

Dorling, I.: "U.S.A.'s Black Thunder Mine - A Truck And Shovel Operation" World Coal Vol. 4 No. 10 October, 1978

WORLD MINING

Argall, G.O., Jr.: "Twin Buttes Pit Gets Bigger: 550,000 Tons Moved Out Of Pit Each Day" World Mining Vol. 29 No. 5 May, 1976

Kennedy, B.A., Clews, M.K. and Aimone, J.T.: "Open-Pit Equipment More Reliable; No Major New Handling Systems" World Mining Vol. 29 No. 7 June 1976

Kennedy, B.A. and Clews, M.A.: "Open-Pit Machines Easier To Maintain; New Mid-Size Trucks With Improved Tires" World Mining Vol. 30 No. 7 June, 1977

Kennedy, B.A.: "Open-Pit Equipment: Giant Dozers, Largest Crawler Mounted Electric Shovel" World Mining Vol. 31 No. 7 June, 1978

APPENDIX CONTENTS

APPENDIX

ALTERNATIVE SYSTEMS

Capital Cost Detail

Ref: 3.1.4

UNDERSPOIL HAULAGE -

CAPITAL COST DETAIL

50 Feet of Overburden System No. 1

1976 Dollars

Initial Capital Costs	Total Cost 30' Seam	Total Cost 70' Seam	Annual Owning Cost 30' Seam	Annual Owning Cost 70' Seam	Owning Cost/Ton 30' Seam	Owning Cost/Ton 70' Seam
Earthwork						
1st Box Cut	2,777,913	4,133,067				
Road Ramps	320,341	737,926				
Underspoil Tunnel	-	-				
Haul Road	312,200	312,200				
Subtotal & Deprec.	3,410,454	5,183,193	170,523	259,160	0.034	0.052
Interest			179,905	272,118	0.036	0.054
Miscellaneous						
Office Bldg. & Furniture	212,900	212,900				
Shop & Equipment	800,000	880,000				
Warehouse & Equipment	150,000	150,000				
Spare Parts Inventory	513,012	369,693				
Electrical Distribution	1,297,000	849,400				
Subtotal & Deprec.	2,972,912	2,461,993	148,646	1,230,997	0.030	0.025
Interest, Taxes, & Ins.			312,155	258,509	0.062	0.052
TOTAL INTEREST, TAXES & DEPREC. INSURANCE COST PER TON					0.162	0.183

UNDERSPOIL HAULAGE -

CAPITAL COST DETAIL

100 Feet of Overburden

System No. 1

1976 Dollars

Initial Capital Costs	Total Cost 30' Seam	Total Cost 70' Seam	Annual Owning Cost 30' Seam	Annual Owning Cost 70' Seam	Owning Cost/Ton 30' Seam	Owning Cost/Ton 70' Seam
Earthwork						
1st Box Cut	5,438,871	8,263,578				
Road Ramps	964,025	1,659,135				
Underspoil Tunnel	-	-				
Haul Road	312,200	312,200				
Subtotal & Deprec.	6,715,096	10,234,913	335,755	511,746	0.067	0.102
Interest			352,542	537,333	0.070	0.107
Miscellaneous						
Office Bldg. & Furniture	212,900	212,900				
Shop & Equipment	880,000	880,000				
Warehouse & Equipment	150,000	150,000				
Spare Parts Inventory	770,500	542,733				
Electrical Distribution	1,922,100	1,121,100				
Subtotal & Deprec.	3,935,500	2,906,733	196,775	145,336	0.039	0.029
Interest, Taxes, & Ins.			413,227	305,207	0.083	0.061
TOTAL INTEREST, TAXES & DEPREC. INSURANCE COST PER TON					0.259	0.299

UNDERSPOIL HAULAGE -

CAPITAL COST DETAIL

200 Feet of Overburden

System No. 1

1976 Dollars

Initial Capital Costs	Total Cost 30' Seam	Total Cost 70' Seam	Annual Owning Cost 30' Seam	Annual Owning Cost 70' Seam	Owning Cost/Ton 30' Seam	Owning Cost/Ton 70' Seam
Earthwork						
1st Box Cut	16,516,531	25,661,250				
Road Ramps	3,652,575	4,896,753				
Underspoil Tunnel	-	-				
Haul Road	312,200	312,200				
Subtotal & Deprec.	20,481,306	30,870,203	1,024,065	1,543,510	0.205	0.309
Interest			1,075,268	1,620,686	0.215	0.324
Miscellaneous						
Office Bldg. & Furniture	212,900	212,900				
Shop & Equipment	1,120,000	1,120,000				
Warehouse & Equipment	150,000	150,000				
Spare Parts Inventory	1,516,155	912,955				
Electrical Distribution	1,519,000	1,419,000				
Subtotal & Deprec.	4,518,055	3,814,855	255,903	190,743	0.045	0.038
Interest, Taxes, & Ins.			474,395	400,560	0.094	0.080
TOTAL INTEREST, TAXES & DEPREC. INSURANCE COST PER TON					0.559	0.751

UNDERSPOIL HAULAGE -

CAPITAL COST DETAIL

50 Feet of Overburden

System No. 2

1976 Dollars

Initial Capital Costs	Total Cost 30' Seam	Total Cost 70' Seam	Annual Owning Cost 30' Seam	Annual Owning Cost 70' Seam	Owning Cost/Ton 30' Seam	Owning Cost/Ton 70' Seam
Earthwork						
1st Box Cut	2,919,022	5,376,187				
Road Ramps	-	-				
Underspoil Tunnel	72,280	183,120				
Haul Road	-	-				
Subtotal & Deprec.	2,991,302	5,559,307	149,565	277,965	0.030	0.056
Interest			157,043	291,864	0.031	0.058
Miscellaneous						
Office Bldg. & Furniture	212,900	212,900				
Shop & Equipment	640,000	640,000				
Warehouse & Equipment	150,000	150,000				
Spare Parts Inventory	606,081	529,066				
Electrical Distribution	1,297,000	849,400				
Subtotal & Deprec.	2,905,981	2,381,366	145,299	119,068	0.029	0.024
Interest, Taxes, & Ins.			305,128	250,043	0.061	0.050
TOTAL INTEREST, TAXES & DEPREC. INSURANCE COST PER TON					0.151	0.188

UNDERSPOIL HAULAGE -

CAPITAL COST DETAIL

100 Feet of Overburden System No. 2

1976 Dollars

Initial Capital Costs	Total Cost 30' Seam	Total Cost 70' Seam	Annual Owning Cost 30' Seam	Annual Owning Cost 70' Seam	Owning Cost/Ton 30' Seam	Owning Cost/Ton 70' Seam
Earthwork						
1st Box Cut	6,950,334	12,224,150				
Road Ramps	-	-				
Underspoil Tunnel	183,329	435,269				
Haul Road	-	-				
Subtotal & Deprec.	7,133,663	12,679,419	356,683	633,971	0.071	0.127
Interest			374,517	665,669	0.075	0.133
Miscellaneous						
Office Bldg. & Furniture	212,900	212,900				
Shop & Equipment	640,000	640,000				
Warehouse & Equipment	150,000	150,000				
Spare Parts Inventory	1,147,415	710,555				
Electrical Distribution	1,922,100	1,121,100				
Subtotal & Deprec.	4,072,415	2,834,555	203,621	141,728	0.041	0.028
Interest, Taxes, & Ins.			427,604	297,628	0.086	0.060
TOTAL INTEREST, TAXES & DEPREC. INSURANCE COST PER TON					0.273	0.348

UNDERSPOIL HAULAGE - EP-8073

CAPITAL COST DETAIL

200 Feet of Overburden — System No. 2

1976 Dollars

Initial Capital Costs	Total Cost 30' Seam	Total Cost 70' Seam	Annual Owning Cost 30' Seam	Annual Owning Cost 70' Seam	Owning Cost/Ton 30' Seam	Owning Cost/Ton 70' Seam
Earthwork						
1st Box Cut	16,792,891	22,449,097				
Road Ramps	-	-				
Underspoil Tunnel	744,007	1,168,756				
Haul Road	-	-				
Subtotal & Deprec.	17,536,898	23,617,853	876,845	1,180,892	0.175	0.236
Interest			920,687	1,239,937	0.184	0.248
Miscellaneous						
Office Bldg. & Furniture	212,900	212,900				
Shop & Equipment	880,000	800,000				
Warehouse & Equipment	150,000	150,000				
Spare Parts Inventory	1,627,654	805,129				
Electrical Distribution	1,519,000	1,419,000				
Subtotal & Deprec.	4,389,554	3,387,029	219,478	169,351	0.044	0.034
Interest, Taxes, & Ins.			460,903	355,638	0.092	0.071
TOTAL INTEREST, TAXES & DEPREC. INSURANCE COST PER TON					0.495	0.589

UNDERSPOIL HAULAGE -

CAPITAL COST DETAIL

50 Feet of Overburden

System No. 2A

1976 Dollars

Initial Capital Costs	Total Cost 30' Seam	Total Cost 70' Seam	Annual Owning Cost 30' Seam	Annual Owning Cost 70' Seam	Owning Cost/Ton 30' Seam	Owning Cost/Ton 70' Seam
Earthwork						
1st Box Cut	2,750,473	4,135,587				
Road Ramps	-	-				
Underspoil Tunnel	72,280	182,295				
Haul Road	-	-				
Subtotal & Deprec.	2,822,753	4,317,882	141,138	215,894	0.028	0.043
Interest			148,195	226,689	0.030	0.045
Miscellaneous						
Office Bldg. & Furniture	212,900	212,900				
Shop & Equipment	640,000	640,000				
Warehouse & Equipment	150,000	150,000				
Spare Parts Inventory	628,009	499,052				
Electrical Distribution	1,297,000	849,400				
Subtotal & Deprec.	2,927,909	2,351,352	146,395	117,568	0.029	0.024
Interest, Taxes, & Ins.			307,430	246,892	0.061	0.049
TOTAL INTEREST, TAXES & DEPREC. INSURANCE COST PER TON					0.148	0.161

UNDERSPOIL HAULAGE -

CAPITAL COST DETAIL

100 Feet of Overburden System No. 2A

1976 Dollars

Initial Capital Costs	Total Cost 30' Seam	Total Cost 70' Seam	Annual Owning Cost 30' Seam	Annual Owning Cost 70' Seam	Owning Cost/Ton 30' Seam	Owning Cost/Ton 70' Seam
Earthwork						
1st Box Cut	5,409,063	8,250,602				
Road Ramps	-	-				
Underspoil Tunnel	183,336	434,802				
Haul Road	-	-				
Subtotal & Deprec.	5,592,399	8,685,404	279,620	434,270	0.056	0.087
Interest			293,601	455,984	0.059	0.092
Miscellaneous						
Office Bldg. & Furniture	212,900	212,900				
Shop & Equipment	640,000	640,000				
Warehouse & Equipment	150,000	150,000				
Spare Parts Inventory	892,532	690,166				
Electrical Distribution	1,922,000	1,121,000				
Subtotal & Deprec.	3,817,432	2,814,066	190,872	140,703	0.038	0.028
Interest, Taxes, & Ins.			400,830	295,477	0.080	0.059
TOTAL INTEREST, TAXES & DEPREC. INSURANCE COST PER TON					0.233	0.266

UNDERSPOIL HAULAGE -

CAPITAL COST DETAIL

200 Feet of Overburden — System No. 2A

1976 Dollars

Initial Capital Costs	Total Cost 30' Seam	Total Cost 70' Seam	Annual Owning Cost 30' Seam	Annual Owning Cost 70' Seam	Owning Cost/Ton 30' Seam	Owning Cost/Ton 70' Seam
Earthwork						
1st Box Cut	15,702,184	24,246,058				
Road Ramps	-	-				
Underspoil Tunnel	744,068	1,168,646				
Haul Road	-	-				
Subtotal & Deprec.	16,446,252	25,414,704	822,313	1,270,735	0.164	0.254
Interest			863,428	1,334,272	0.173	0.267
Miscellaneous						
Office Bldg. & Furniture	212,900	212,900				
Shop & Equipment	880,000	800,000				
Warehouse & Equipment	150,000	150,000				
Spare Parts Inventory	1,640,257	1,065,782				
Electrical Distribution	1,519,000	1,419,000				
Subtotal & Deprec.	4,402,157	3,647,682	220,108	182,384	0.044	0.036
Interest, Taxes, & Ins.			462,226	383,007	0.092	0.077
TOTAL INTEREST, TAXES & DEPREC. INSURANCE COST PER TON					0.473	0.634

UNDERSPOIL HAULAGE -

CAPITAL COST DETAIL

50 Feet of Overburden — System No. 3

1976 Dollars

Initial Capital Costs	Total Cost 30' Seam	Total Cost 70' Seam	Annual Owning Cost 30' Seam	Annual Owning Cost 70' Seam	Owning Cost/Ton 30' Seam	Owning Cost/Ton 70' Seam
Earthwork						
1st Box Cut	4,272,051	6,118,564				
Road Ramps	-	-				
Underspoil Tunnel	72,280	183,122				
Haul Road						
Subtotal & Deprec.	4,344,331	6,301,686	217,216	315,084	0.043	0.063
Interest			228,077	330,838	0.046	0.066
Miscellaneous						
Office Bldg. & Furniture	212,900	212,900				
Shop & Equipment	800,000	720,000				
Warehouse & Equipment	150,000	150,000				
Spare Parts Inventory	591,999	491,722				
Electrical Distribution	849,400	849,400				
Subtotal & Deprec.	2,604,299	2,424,022	130,215	121,201	0.026	0.024
Interest, Taxes, & Ins.			273,451	254,522	0.055	0.051
TOTAL INTEREST, TAXES & DEPREC. INSURANCE COST PER TON					0.170	0.204

UNDERSPOIL HAULAGE -

CAPITAL COST DETAIL

100 Feet of Overburden

System No. 3

1976 Dollars

Initial Capital Costs	Total Cost 30' Seam	Total Cost 70' Seam	Annual Owning Cost 30' Seam	Annual Owning Cost 70' Seam	Owning Cost/Ton 30' Seam	Owning Cost/Ton 70' Seam
Earthwork						
1st Box Cut	8,949,134	12,291,168				
Road Ramps	-	-				
Underspoil Tunnel	173,308	410,904				
Haul Road	-	-				
Subtotal & Deprec.	9,122,442	12,702,072	456,122	635,104	0.091	0.127
Interest			478,928	666,859	0.096	0.133
Miscellaneous						
Office Bldg. & Furniture	212,900	212,900				
Shop & Equipment	960,000	880,000				
Warehouse & Equipment	150,000	150,000				
Spare Parts Inventory	841,156	699,310				
Electrical Distribution	1,040,100	1,040,100				
Subtotal & Deprec.	3,204,156	2,982,310	160,208	149,116	0.032	0.030
Interest, Taxes, & Ins.			336,436	313,142	0.067	0.063
TOTAL INTEREST, TAXES & DEPREC. INSURANCE COST PER TON					0.286	0.353

UNDERSPOIL HAULAGE -

CAPITAL COST DETAIL

200 Feet of Overburden — System No. 3

1976 Dollars

Initial Capital Costs	Total Cost 30' Seam	Total Cost 70' Seam	Annual Owning Cost 30' Seam	Annual Owning Cost 70' Seam	Owning Cost/Ton 30' Seam	Owning Cost/Ton 70' Seam
Earthwork						
1st Box Cut	21,793,561	25,900,962				
Road Ramps	-	-				
Underspoil Tunnel	741,068	1,188,859				
Haul Road	-	-				
Subtotal & Deprec.	22,534,629	27,089,821	1,126,731	1,354,491	0.225	0.271
Interest			1,183,060	1,422,216	0.237	0.284
Miscellaneous						
Office Bldg. & Furniture	212,900	212,900				
Shop & Equipment	1,440,000	960,000				
Warehouse & Equipment	150,000	150,000				
Spare Parts Inventory	1,377,095	715,049				
Electrical Distribution	1,305,600	1,040,100				
Subtotal & Deprec.	4,485,595	3,078,049	224,280	153,902	0.045	0.031
Interest, Taxes, & Ins.			470,987	323,195	0.094	0.065
TOTAL INTEREST, TAXES & DEPREC. INSURANCE COST PER TON					0.601	0.651

UNDERSPOIL HAULAGE -

CAPITAL COST DETAIL

50 Feet of Overburden

System No. 3A

1976 Dollars

Initial Capital Costs	Total Cost 30' Seam	Total Cost 70' Seam	Annual Owning Cost 30' Seam	Annual Owning Cost 70' Seam	Owning Cost/Ton 30' Seam	Owning Cost/Ton 70' Seam
Earthwork						
1st Box Cut	3,781,648	6,663,495				
Road Ramps	-	-				
Underspoil Tunnel	72,255	181,627				
Haul Road	-	-				
Subtotal & Deprec.	3,853,903	6,845,122	192,695	342,256	0.039	0.068
Interest			202,330	359,368	0.040	0.072
Miscellaneous						
Office Bldg. & Furniture	212,900	212,900				
Shop & Equipment	640,000	640,000				
Warehouse & Equipment	150,000	150,000				
Spare Parts Inventory	683,329	611,789				
Electrical Distribution	1,255,000	1,037,800				
Subtotal & Deprec.	2,941,229	2,652,489	147,061	132,624	0.029	0.027
Interest, Taxes, & Ins.			308,829	278,511	0.062	0.056
TOTAL INTEREST, TAXES & DEPREC. INSURANCE COST PER TON					0.170	0.223

UNDERSPOIL HAULAGE -

CAPITAL COST DETAIL

100 Feet of Overburden System No. 3A

1976 Dollars

Initial Capital Costs	Total Cost 30' Seam	Total Cost 70' Seam	Annual Owning Cost 30' Seam	Annual Owning Cost 70' Seam	Owning Cost/Ton 30' Seam	Owning Cost/Ton 70' Seam
Earthwork						
1st Box Cut	8,734,196	14,414,241				
Road Ramps	-	-				
Underspoil Tunnel	183,333	410,915				
Haul Road	-	-				
Subtotal & Deprec.	8,917,529	14,825,156	445,876	741,258	0.089	0.148
Interest			468,170	778,321	0.094	0.156
Miscellaneous						
Office Bldg. & Furniture	212,900	212,900				
Shop & Equipment	640,000	800,000				
Warehouse & Equipment	150,000	150,000				
Spare Parts Inventory	1,218,890	789,638				
Electrical Distribution	1,335,700	1,307,700				
Subtotal & Deprec.	3,557,490	3,260,238	177,875	163,012	0.036	0.033
Interest, Taxes, & Ins.			373,536	342,325	0.075	0.068
TOTAL INTEREST, TAXES & DEPREC. INSURANCE COST PER TON					0.294	0.405

UNDERSPOIL HAULAGE -

CAPITAL COST DETAIL

200 Feet of Overburden

System No. 3A

1976 Dollars

Initial Capital Costs	Total Cost 30' Seam	Total Cost 70' Seam	Annual Owning Cost 30' Seam	Annual Owning Cost 70' Seam	Owning Cost/Ton 30' Seam	Owning Cost/Ton 70' Seam
Earthwork						
1st Box Cut	23,252,366	27,162,010				
Road Ramps	-	-				
Underspoil Tunnel	743,730	1,168,020				
Haul Road	-	-				
Subtotal & Deprec.	23,996,096	23,330,030	1,199,805	1,416,502	0.240	0.283
Interest			1,259,795	1,487,327	0.252	0.297
Miscellaneous						
Office Bldg. & Furniture	212,900	212,900				
Shop & Equipment	960,000	800,000				
Warehouse & Equipment	150,000	150,000				
Spare Parts Inventory	1,702,496	881,552				
Electrical Distribution	1,619,800	1,455,000				
Subtotal & Deprec.	4,645,196	3,499,452	232,260	174,973	0.046	0.035
Interest, Taxes, & Ins.			487,746	367,442	0.098	0.073
TOTAL INTEREST, TAXES & DEPREC. INSURANCE COST PER TON					0.636	0.688

UNDERSPOIL HAULAGE -

CAPITAL COST DETAIL

50 Feet of Overburden   System No. 4

1976 Dollars

Initial Capital Costs	Total Cost 30' Seam	Total Cost 70' Seam	Annual Owning Cost 30' Seam	Annual Owning Cost 70' Seam	Owning Cost/Ton 30' Seam	Owning Cost/Ton 70' Seam
Earthwork						
1st Box Cut	4,274,361	6,166,432				
Road Ramps	-	-				
Underspoil Tunnel	72,280	183,120				
Haul Road	-	-				
Subtotal & Deprec.	4,346,641	6,349,552	217,332	317,478	0.043	0.063
Interest			228,199	333,351	0.046	0.067
Miscellaneous						
Office Bldg. & Furniture	212,900	212,900				
Shop & Equipment	800,000	720,000				
Warehouse & Equipment	150,000	150,000				
Spare Parts Inventory	635,412	572,456				
Electrical Distribution	849,400	849,400				
Subtotal & Deprec.	2,647,712	2,504,756	132,385	125,238	0.026	0.025
Interest, Taxes, & Ins.			278,010	262,999	0.056	0.053
TOTAL INTEREST, TAXES & DEPREC. INSURANCE COST PER TON					0.171	0.208

UNDERSPOIL HAULAGE -

CAPITAL COST DETAIL

100 Feet of Overburden | System No. 4

1976 Dollars

Initial Capital Costs	Total Cost 30' Seam	Total Cost 70' Seam	Annual Owning Cost 30' Seam	Annual Owning Cost 70' Seam	Owning Cost/Ton 30' Seam	Owning Cost/Ton 70' Seam
Earthwork						
1st Box Cut	8,954,027	12,322,312				
Road Ramps	-	-				
Underspoil Tunnel	173,844	411,950				
Haul Road	-	-				
Subtotal & Deprec.	9,127,871	12,734,262	456,394	636,713	0.091	0.127
Interest			479,213	668,548	0.096	0.133
Miscellaneous						
Office Bldg. & Furniture	212,900	212,900				
Shop & Equipment	960,000	880,000				
Warehouse & Equipment	150,000	150,000				
Spare Parts Inventory	884,570	739,246				
Electrical Distribution	1,040,100	1,040,100				
Subtotal & Deprec.	3,247,570	3,022,246	162,378	151,112	0.032	0.030
Interest, Taxes, & Ins.			340,995	317,336	0.068	0.063
TOTAL INTEREST, TAXES & DEPREC. INSURANCE COST PER TON					0.287	0.353

UNDERSPOIL HAULAGE -

CAPITAL COST DETAIL

200 Feet of Overburden

System No. 4

1976 Dollars

Initial Capital Costs	Total Cost 30' Seam	Total Cost 70' Seam	Annual Owning Cost 30' Seam	Annual Owning Cost 70' Seam	Owning Cost/Ton 30' Seam	Owning Cost/Ton 70' Seam
Earthwork						
1st Box Cut	21,843,944	25,914,122				
Road Ramps	-	-				
Underspoil Tunnel	742,365	1,189,338				
Haul Road	-	-				
Subtotal & Deprec.	22,586,309	27,103,460	1,129,315	1,355,173	0.226	0.271
Interest			1,185,781	1,422,931	0.237	0.285
Miscellaneous						
Office Bldg. & Furniture	212,900	212,900				
Shop & Equipment	1,440,000	960,000				
Warehouse & Equipment	150,000	150,000				
Spare Parts Inventory	1,420,508	942,365				
Electrical Distribution	1,305,600	1,040,100				
Subtotal & Deprec.	4,529,008	3,305,365	226,450	165,268	0.045	0.033
Interest, Taxes, & Ins.			475,546	347,063	0.095	0.069
TOTAL INTEREST, TAXES & DEPREC. INSURANCE COST PER TON					0.603	0.658

UNDERSPOIL HAULAGE -

CAPITAL COST DETAIL

50 Feet of Overburden System No. 4A

1976 Dollars

Initial Capital Costs	Total Cost 30' Seam	Total Cost 70' Seam	Annual Owning Cost 30' Seam	Annual Owning Cost 70' Seam	Owning Cost/Ton 30' Seam	Owning Cost/Ton 70' Seam
Earthwork						
1st Box Cut	3,760,242	6,527,659				
Road Ramps	-	-				
Underspoil Tunnel	72,280	183,120				
Haul Road	-	-				
Subtotal & Deprec.	3,832,522	6,710,779	191,626	335,539	0.038	0.067
Interest			201,207	352,316	0.040	0.070
Miscellaneous						
Office Bldg. & Furniture	212,900	212,900				
Shop & Equipment	640,000	640,000				
Warehouse & Equipment	150,000	150,000				
Spare Parts Inventory	722,440	651,923				
Electrical Distribution	1,255,000	1,037,800				
Subtotal & Deprec.	2,980,340	2,692,623	149,017	1,346,312	0.030	0.027
Interest, Taxes, & Ins.			312,936	282,725	0.063	0.057
TOTAL INTEREST, TAXES & DEPREC. INSURANCE COST PER TON					0.171	0.221

UNDERSPOIL HAULAGE -

CAPITAL COST DETAIL

100 Feet of Overburden

System No. 4A

1976 Dollars

Initial Capital Costs	Total Cost 30' Seam	Total Cost 70' Seam	Annual Owning Cost 30' Seam	Annual Owning Cost 70' Seam	Owning Cost/Ton 30' Seam	Owning Cost/Ton 70' Seam
Earthwork						
1st Box Cut	8,733,478	14,423,621				
Road Ramps	-	-				
Underspoil Tunnel	183,329	435,269				
Haul Road	-	-				
Subtotal & Deprec.	8,916,807	14,858,890	445,840	742,945	0.089	0.149
Interest			468,132	780,092	0.094	0.156
Miscellaneous						
Office Bldg. & Furniture	212,900	212,900				
Shop & Equipment	640,000	800,000				
Warehouse & Equipment	150,000	150,000				
Spare Parts Inventory	1,258,002	829,563				
Electrical Distribution	1,335,700	1,307,700				
Subtotal & Deprec.	3,596,602	3,300,163	179,830	165,008	0.036	0.033
Interest, Taxes, & Ins.			377,643	346,517	0.076	0.069
TOTAL INTEREST, TAXES & DEPREC. INSURANCE COST PER TON					0.295	0.407

UNDERSPOIL HAULAGE -

CAPITAL COST DETAIL

200 Feet of Overburden System No. 4A

1976 Dollars

Initial Capital Costs	Total Cost 30' Seam	Total Cost 70' Seam	Annual Owning Cost 30' Seam	Annual Owning Cost 70' Seam	Owning Cost/Ton 30' Seam	Owning Cost/Ton 70' Seam
Earthwork						
1st Box Cut	23,256,763	27,173,581				
Road Ramps	-	-				
Underspoil Tunnel	744,007	1,168,756				
Haul Road	-	-				
Subtotal & Deprec.	24,000,770	28,342,337	1,200,039	1,417,117	0.240	0.283
Interest			1,260,040	1,487,973	0.252	0.298
Miscellaneous						
Office Bldg. & Furniture	212,900	212,900				
Shop & Equipment	960,000	800,000				
Warehouse & Equipment	150,000	150,000				
Spare Parts Inventory	1,745,909	921,488				
Electrical Distribution	1,619,800	1,455,000				
Subtotal & Deprec.	4,688,609	3,539,388	234,430	176,969	0.047	0.035
Interest, Taxes, & Ins.			492,304	371,636	0.098	0.074
TOTAL INTEREST, TAXES & DEPREC. INSURANCE COST PER TON					0.637	0.690

APPENDIX

SECONDARY STUDIES

Tunnel Cost Comparison

Total Annual Cost

Ref: 3.1.5

Appendix 3.1.5

TUNNEL COST COMPARISON

TOTAL ANNUAL COST - ONE TUNNEL

10% Interest 20 Year Life

Installation Method			100' Cuts /Year	Slope Length	Concrete Arch					Structural Plat Culvert					Steel Arch/Liner Plate				
					Cost/ Foot	Initial Installation	Annual Cost Initial Installation	Annual Installation	Total Annual Cost	Cost/ Foot	Initial Installation	Annual Cost Initial Installation	Annual Installation	Total Annual Cost	Cost/ Foot	Initial Installation	Annual Cost Initial Installation	Annual Installation	Total Annual Cost
Conduits on Pit Floor																			
Coal	OB	Spoil																	
30	50	65	3.95	400	488	195,200	20,008	192,760	212,763	460	184,000	18,860	181,700	200,560	598	239,200	24,518	236,210	260,728
30	100	130	3.95	650	562	365,300	37,443	221,990	259,443	570	370,500	37,976	225,150	263,126	598	388,700	39,841	236,210	276,051
30	200	260	3.95	1,150	737	847,550	86,873	291,115	377,988	570	655,500	67,188	225,150	292,338	598	687,700	70,489	236,210	306,699
70	50	65	1.69	600	498	292,800	30,012	82,472	112,484	460	276,000	28,290	77,740	106,030	598	358,800	36,771	101,062	137,833
70	100	130	1.69	850	562	477,700	48,964	94,978	143,942	570	484,500	49,661	96,330	145,991	598	508,300	52,100	101,062	153,162
70	200	260	1.69	1,350	737	994,950	101,982	124,553	226,535	570	769,500	78,873	96,330	175,208	598	807,300	82,748	101,062	183,810
Conduits in Rock Trench																			
Coal	OB	Spoil																	
30	50	65	3.95	470	529	248,856	25,508	209,145	234,653	398	187,060	19,173	157,210	176,383	522	245,340	25,147	206,190	231,337
30	100	130	3.95	720	529	381,225	39,076	209,145	248,221	508	365,760	37,490	200,660	238,150	522	375,840	38,522	206,190	244,712
30	200	260	3.95	1,220	529	645,966	66,212	209,145	275,357	508	619,760	63,525	200,660	264,185	522	636,840	65,276	206,190	271,466
70	50	65	1.69	670	529	254,751	36,362	89,482	125,844	398	266,660	27,332	67,262	94,594	522	349,740	35,848	88,218	124,066
70	100	130	1.69	920	529	487,121	49,930	89,482	139,412	508	467,360	47,904	85,852	133,756	522	480,240	49,224	88,218	137,442
70	200	260	1.69	1,420	529	751,862	77,066	89,482	166,548	508	721,360	73,939	85,852	159,791	522	741,240	75,977	88,218	164,195
					Yieldable Arches/Slope Exit					Standard Arches/Slope Exit									
Rock Tunnels Under Pit																			
Coal	OB	Spoil																	
30	50	65	3.95	625	562	4,785,992	490,564	-	490,564	463	3,942,908	404,148	-	404,148					
30	100	130	3.95	875	562	4,926,492	504,965	-	504,965	463	4,058,658	416,012	-	416,012					
30	200	260	3.95	1,375	562	5,207,492	533,767	-	533,767	463	4,290,158	439,741	-	439,741					
70	50	65	1.69	825	562	2,364,334	242,344	-	242,344	463	1,947,841	199,653	-	199,653					
70	100	130	1.69	1,075	562	2,504,834	256,745	-	256,745	463	2,063,591	211,518	-	211,518					
70	200	260	1.69	1,575	562	2,785,834	285,547	-	285,547	463	2,295,091	235,246	-	235,246					

APPENDIX

COMPARISON OF SYSTEMS

Capital Cost Criteria

Operating Cost Critera

Unit Cost Summary - All Summarys - 50' of Overburden

Unit Cost Summary - All Summarys - 100' of Overburden

Unit Cost Summary - All Summarys - 200' of Overburden

Ref: 3.1.6

Capital Cost Criteria

1. Mine Labor Rates. Current national UMWA + 35% payroll additives and 10% retirement.

2. Construction Labor Rates. Current construction scale for Wyoming.

3. Mining Equipment Rates. Ownership costs based on straight-line depreciation plus interest, taxes, and insurance. Operating costs based on experience records and manufacturers data.

4. Construction Equipment Rates. Prevailing rental rates in the Wyoming area.

5. Installed Equipment and Materials. Current prices plus subcontractor costs, overhead, and profit.

6. Engineering. Costs of preliminary site engineering and detail engineering are excluded, considering the scope of engineering involved in the current underspoil haulage project.

7. Contractor's Field Administration. Salaries and expenses for construction supervision.

8. Contractor's Home Office Administration. Expenses of project engineering, purchasing, expediting, scheduling, cost engineering, industrial relations, estimating, accounting, and general office expense.

9. Contractor's Contingency. A total of 10% of labor, materials, field administration, engineering, and home office administration, to cover items which would normally be accounted for in a definitive estimate.

10. Sales and Use Tax. Sales tax of 3% on all materials used by contractor.

11. Insurance. Builders risk floater cost.

12. Contractors Overhead and Profit. 5% and 10% of total cost.

Operating Cost Criteria

1. Type, size and capacity of each item of equipment was determined.

2. Purchase price of the equipment includes freight and erection costs.

3. Salvage value is assumed to be zero at the end of operating life.

4. Depreciation was calculated by the straight-line method based on hours of anticipated operating life. For rubber-tired equipment tire costs were deducted before depreciation rate was calculated.

5. All equipment ownership costs are estimated on an hourly basis and include depreciation, interest on capital, property taxes and insurance. A 10% interest rate and 10% to cover taxes and insurance costs were included.

6. Direct operating costs include power, fuel, tires, drill bits and steel, explosives, miscellaneous supplies and labor on an hourly basis.

7. Maintenance and repair labor and supplies are also hourly direct operating costs.

8. Necessary equipment and hours of utilization were assigned to the various unit mining operations and the operating and ownership costs for each unit were totaled to give an annual cost.

9. The annual cost was then divided by annual production to give the cost per ton which appears in Tables 12, 13 and 14.

10. Only the initial capital cost of equipment is shown on the tables. The operating costs include a depreciation allowance which provides for replacement.

11. The various unit operations consist of (1) overburden removal, (2) topsoil removal, (3) overburden drill and blast, (4) coal drill and blast, (5) coal loading, (6) coal haulage, (7) miscellaneous pit operations, (8) reclamation, (9) general expense including service trucks and crusher system, (10) supervisory salaries and transportation, (11) depreciation, interest, taxes and insurance on capital other than equipment. A local administration cost of 10% of total direct costs was added to cover administrative functions and coal sales.

UNDERSPOIL HAULAGE -

UNIT COST SUMMARY - ALL SYSTEMS 1976 Dollars/Ton

50 Feet of Burden

Item	System No. 1		System No. 2		System No. 2A		System No. 3		System No. 3A		System No. 4		System No. 4A	
Initial Capital Cost	30' Seam	70' Seam	30' Seam	70' Seam	30' Seam	70' Seam	30' Seam	70' Seam	30' Seam	70' Seam	30' Seam	70' Seam	30' Seam	70' Seam
Equipment	16,548,010	11,951,110	21,237,576	17,355,462	23,182,274	19,300,160	22,943,089	19,687,248	25,813,458	23,631,204	24,390,199	22,378,364	27,117,168	24,969,014
Earthwork	3,410,454	5,183,193	2,991,302	5,559,307	2,822,753	4,317,882	4,344,331	6,301,685	3,853,903	6,845,122	4,346,641	6,349,552	3,832,522	6,710,779
Miscellaneous	2,972,912	2,461,993	2,905,981	2,381,366	2,927,909	2,351,352	2,604,299	2,424,022	2,941,229	2,652,489	2,647,712	2,504,756	2,980,340	2,692,623
TOTAL CAPITAL COST	22,931,376	19,596,296	27,134,859	25,296,135	28,932,936	25,969,394	29,891,719	28,412,955	32,608,590	33,128,815	31,384,552	31,232,672	33,930,030	34,372,416
Direct Cost														
Topsoil Removal	0.151	0.056	0.123	0.059	0.123	0.059	0.122	0.056	0.124	0.057	0.122	0.059	0.123	0.059
Overburden Drill & Blast	0.125	0.063	0.125	0.062	0.125	0.062	0.124	0.064	0.125	0.063	0.125	0.063	0.125	0.063
Overburden Removal	0.445	0.263	0.445	0.263	0.445	0.263	0.579	0.341	0.500	0.402	0.580	0.344	0.500	0.402
Coal Drill & Blast	0.097	0.099	0.097	0.099	0.097	0.099	0.097	0.099	0.097	0.099	0.111	0.109	0.111	0.109
Coal Loading	0.132	0.132	0.164	0.227	0.478	0.538	0.164	0.230	0.164	0.227	0.156	0.214	0.156	0.214
Coal Haulage	0.356	0.358	0.418	0.339	0.389	0.309	0.510	0.428	0.514	0.434	0.499	0.419	0.500	0.420
Misc. Pit/Operation	0.035	0.035	0.033	0.033	0.033	0.033	0.045	0.045	0.045	0.045	0.048	0.048	0.048	0.048
Reclamation	0.143	0.056	0.143	0.059	0.143	0.059	0.067	0.044	0.143	0.091	0.067	0.050	0.143	0.091
General	0.043	0.043	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
Supervisory	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213
Depreciation, Interest, Taxes & Insurance on Capital Cost**	0.162	0.183	0.151	0.188	0.148	0.161	0.170	0.204	0.170	0.223	0.171	0.208	0.171	0.221
TOTAL DIRECT COST	1.902	1.501	1.946	1.576	2.228	1.830	2.125	1.758	2.129	1.888	2.126	1.761	2.124	1.874
Administration (10% of Direct Cost)	0.190	0.150	0.195	0.158	0.223	0.183	0.213	0.176	0.213	0.189	0.213	0.176	0.212	0.187
TOTAL COST PER TON	2.092	1.651	2.141	1.734	2.451	2.013	2.338	1.934	2.342	2.077	2.339	1.937	2.336	2.061

* On systems using feeder breaker, the costs are included in "coal loading".
** Depreciation, Interest, Taxes and Insurance on "Equipment-Initial Capital Cost", are included in direct costs above.

UNDERSPOIL HAULAGE -

UNIT COST SUMMARY - ALL SYSTEMS 1976 Dollars/Ton

100 Feet of Burden

Item	System No. 1		System No. 2		System No. 2A		System No. 3		System No. 3A		System No. 4		System No. 4A	
Initial Capital Cost	30' Seam	70' Seam	30' Seam	70' Seam	30' Seam	70' Seam	30' Seam	70' Seam	30' Seam	70' Seam	30' Seam	70' Seam	30' Seam	70' Seam
Equipment	24,893,110	17,598,910	29,909,369	23,528,013	31,854,067	25,473,311	31,225,546	26,604,634	43,717,972	29,494,052	32,702,656	27,935,844	45,021,682	30,824,902
Earthwork	6,715,096	10,234,913	7,133,663	12,679,419	5,592,399	8,685,404	9,122,442	12,702,072	8,917,529	14,825,156	9,127,871	12,734,262	8,916,807	14,858,890
Miscellaneous	3,935,500	2,906,733	4,072,415	2,834,555	3,817,432	2,814,066	3,204,156	2,982,310	3,557,700	3,260,238	3,247,570	3,022,246	3,596,602	3,300,163
TOTAL CAPITAL COST	35,543,706	30,740,556	41,115,447	39,041,987	41,263,898	36,972,781	43,582,144	42,289,016	56,193,201	47,579,446	45,078,097	43,692,352	57,535,091	48,983,955
Direct Cost														
Topsoil Removal	0.151	0.059	0.123	0.059	0.123	0.059	0.122	0.059	0.124	0.058	0.123	0.059	0.123	0.059
Overburden Drill & Blast	0.317	0.167	0.317	0.166	0.317	0.166	0.318	0.167	0.318	0.166	0.317	0.167	0.317	0.167
Overburden Removal	0.817	0.503	0.817	0.503	0.817	0.503	1.213	0.673	1.322	0.843	1.214	0.676	1.323	0.843
Coal Drill & Blast	0.102	0.097	0.102	0.097	0.102	0.097	0.102	0.097	0.102	0.096	0.116	0.106	0.116	0.111
Coal Loading *	0.132	0.132	0.164	0.227	0.478	0.537	0.164	0.230	0.164	0.227	0.156	0.214	0.156	0.214
Coal Haulage	0.470	0.419	0.457	0.336	0.428	0.336	0.549	0.459	0.553	0.460	0.537	0.447	0.539	0.448
Misc. Pit/Operation	0.035	0.035	0.033	0.033	0.033	0.033	0.045	0.045	0.045	0.045	0.048	0.048	0.048	0.048
Reclamation	0.143	0.056	0.143	0.062	0.143	0.062	0.085	0.044	0.143	0.050	0.085	0.050	0.143	0.050
General	0.043	0.043	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
Supervisory	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213
Depreciation, Interest, Taxes & Insurance on Capital Cost **	0.259	0.299	0.273	0.348	0.233	0.266	0.286	0.353	0.294	0.405	0.287	0.353	0.295	0.407
TOTAL DIRECT COST	2.682	2.023	2.676	2.108	2.921	2.306	3.131	2.374	3.312	2.597	3.130	2.367	3.307	2.594
Administration (10% of Direct Cost)	0.268	0.202	0.267	0.211	0.292	0.231	0.313	0.237	0.331	0.260	0.313	0.237	0.331	0.259
TOTAL COST PER TON	2.950	2.225	2.943	2.319	3.213	2.537	3.444	2.611	3.643	2.857	3.443	2.604	3.638	2.853

* On systems using feeder breaker, the costs are included in "coal loading".

** Depreciation, Interest, Taxes and Insurance on "Equipment-Initial Capital Cost", are included in direct costs above.

UNDERSPOIL HAULAGE -

UNIT COST SUMMARY - ALL SYSTEMS 1976 Dollars/Ton

200 Feet of Burden

Item	System No. 1		System No. 2		System No. 2A		System No. 3		System No. 3A		System No. 4		System No. 4A	
Initial Capital Cost	30' Seam	70' Seam	30' Seam	70' Seam	30' Seam	70' Seam	30' Seam	70' Seam	30' Seam	70' Seam	30' Seam	70' Seam	30' Seam	70' Seam
Equipment	49,816,610	29,802,730	54,631,598	36,880,342	56,786,296	38,825,040	48,959,219	27,057,819	59,612,879	32,459,501	50,306,329	34,635,029	61,059,989	33,790,771
Earthwork	20,481,306	30,870,203	17,536,898	23,617,853	16,446,252	25,414,704	22,534,629	27,089,821	23,996,096	28,330,030	22,586,309	27,103,460	24,000,770	28,342,337
Miscellaneous	4,518,055	3,814,855	4,389,554	3,387,029	4,402,157	3,647,682	4,485,595	3,078,049	4,645,196	3,499,452	4,529,008	3,305,365	4,688,609	3,539,388
TOTAL CAPITAL COST	74,815,971	64,487,788	76,558,050	63,885,224	77,634,705	67,887,426	75,979,443	57,225,689	88,254,171	64,228,983	77,421,646	65,043,854	89,749,368	65,672,436
Direct Cost														
Topsoil Removal	0.180	0.082	0.122	0.059	0.122	0.059	0.122	0.058	0.122	0.058	0.123	0.059	0.123	0.059
Overburden Drill & Blast	0.668	0.312	0.668	0.312	0.668	0.312	0.669	0.312	0.669	0.213	0.668	0.312	0.668	0.213
Overburden Removal	2.537	1.368	2.336	1.252	2.336	1.252	2.617	1.217	2.631	1.096	2.618	1.218	2.632	1.096
Coal Drill & Blast	0.102	0.101	0.101	0.101	0.101	0.101	0.102	0.101	0.102	0.101	0.116	0.111	0.116	0.111
Coal Loading *	0.132	0.132	0.164	0.227	0.510	0.537	0.164	0.227	0.164	0.227	0.156	0.214	0.156	0.214
Coal Haulage	0.641	0.518	0.539	0.444	0.509	0.414	0.631	0.526	0.633	0.528	0.619	0.513	0.621	0.516
Misc. Pit/Operation	0.035	0.035	0.033	0.033	0.033	0.033	0.045	0.045	0.045	0.045	0.048	0.048	0.048	0.048
Reclamation	0.085	0.060	0.085	0.050	0.085	0.050	0.085	0.050	0.085	0.050	0.085	0.050	0.085	0.050
General	0.043	0.043	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
Supervisory	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213	0.213
Depreciation, Interest, Taxes & Insurance on Capital Cost **	0.559	0.751	0.495	0.589	0.473	0.634	0.601	0.651	0.636	0.688	0.603	0.658	0.637	0.690
TOTAL DIRECT COST	5.195	3.615	4.790	3.304	5.084	3.629	5.283	3.434	5.344	3.352	5.283	3.430	5.333	3.343
Administration (10% of Direct Cost)	0.520	0.362	0.479	0.331	0.508	0.364	0.528	0.343	0.533	0.335	0.528	0.343	0.533	0.334
TOTAL COST PER TON	5.715	3.977	5.269	3.645	5.592	4.003	5.811	3.777	5.867	3.687	5.811	3.773	5.866	3.677

* On systems using feeder breaker, the costs are included in "coal loading".
** Depreciation, Interest, Taxes and Insurance on "Equipment-Initial Capital Cost", are included in direct costs above.

APPENDIX

FIELD DEMONSTRATION PLAN

Culvert Field Load Test-Arizona Copper Mine

Ref: 3.2.1

CULVERT FIELD LOAD TEST - ARIZONA COPPER MINE

Estimated Costs, Personnel, & Equipment

1. Cost Estimate

The estimated cost of the installed prototype underspoil haulage system is shown in Table 1. The estimate is based on the layout shown on Figures 1, 2, and 3, and is considered to represent accuracy of plus or minus 30% (20% accuracy with 10% contingency). The cost of equipment, materials, and labor represent rates and prices prevailing in the Wyoming area at the end of 1976.

The estimate is based on a battery limits concept with all utilities for construction and operating purposes brought to within battery limits by the mine owner unless otherwise specified in this report. Field labor costs are based on a 40 hour work week with no allowance for scheduled overtime or other incentives to attract qualified labor. Included in the costs are insurance, taxes, welfare, fringes, benefits, spot overtime, show-up time allowance and non-working supervisory allowance.

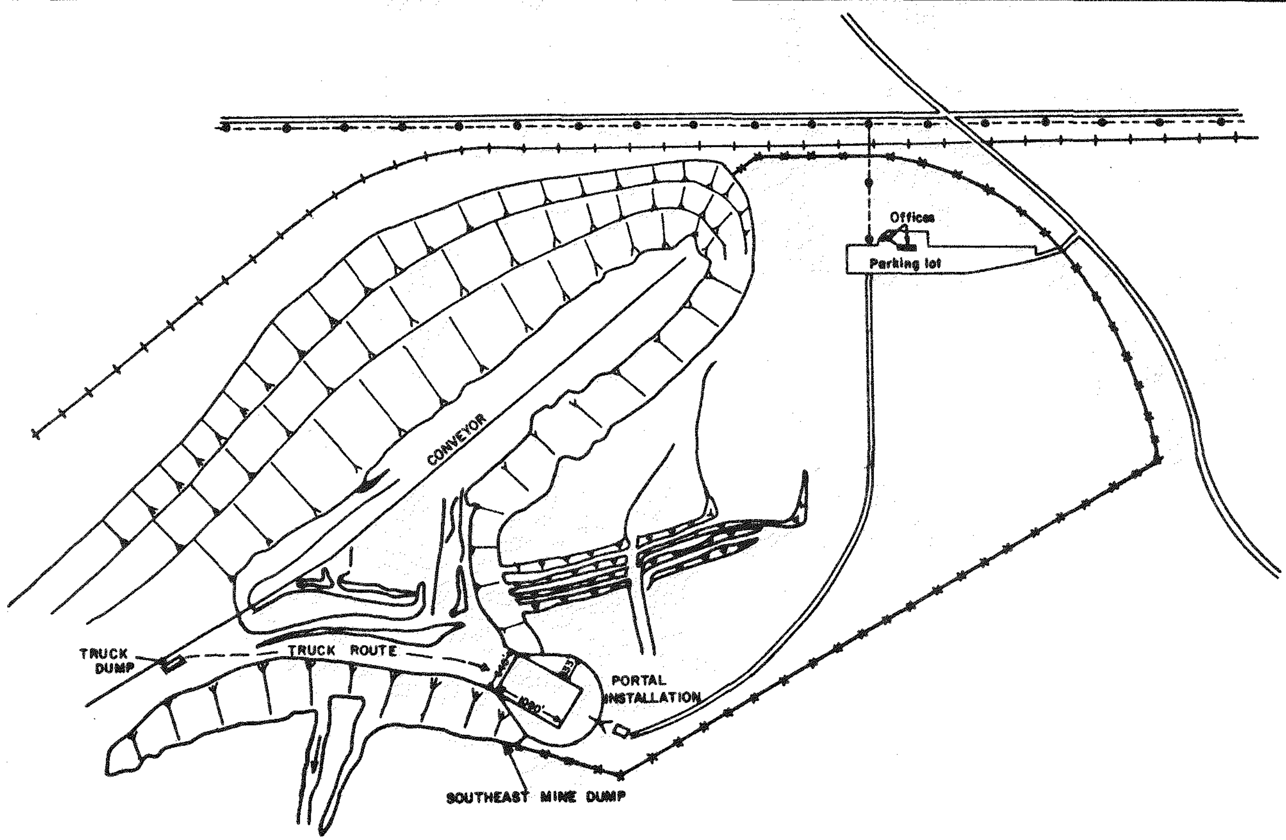
Excavation and backfill of the trench required for installation of the underspoil conveyor is included in the item for Civil construction.

In general all Civil, Electrical, Mechanical, and Piping items are based on detailed take-offs to establish required quantities. Costs are based upon quotes or recently developed unit costs for the Arizona area. All field installation costs include sub-contractor overhead and profit on all materials and labor.

Field indirect costs include rental, small tools, expendable supplies, office trailers, clean-up, temporary wiring and pipe required for construction. Field administration costs represent salaries and expenses for field personnel, including superintendent, engineers and administrative personnel. Also included are field office supplies and operating expenses.

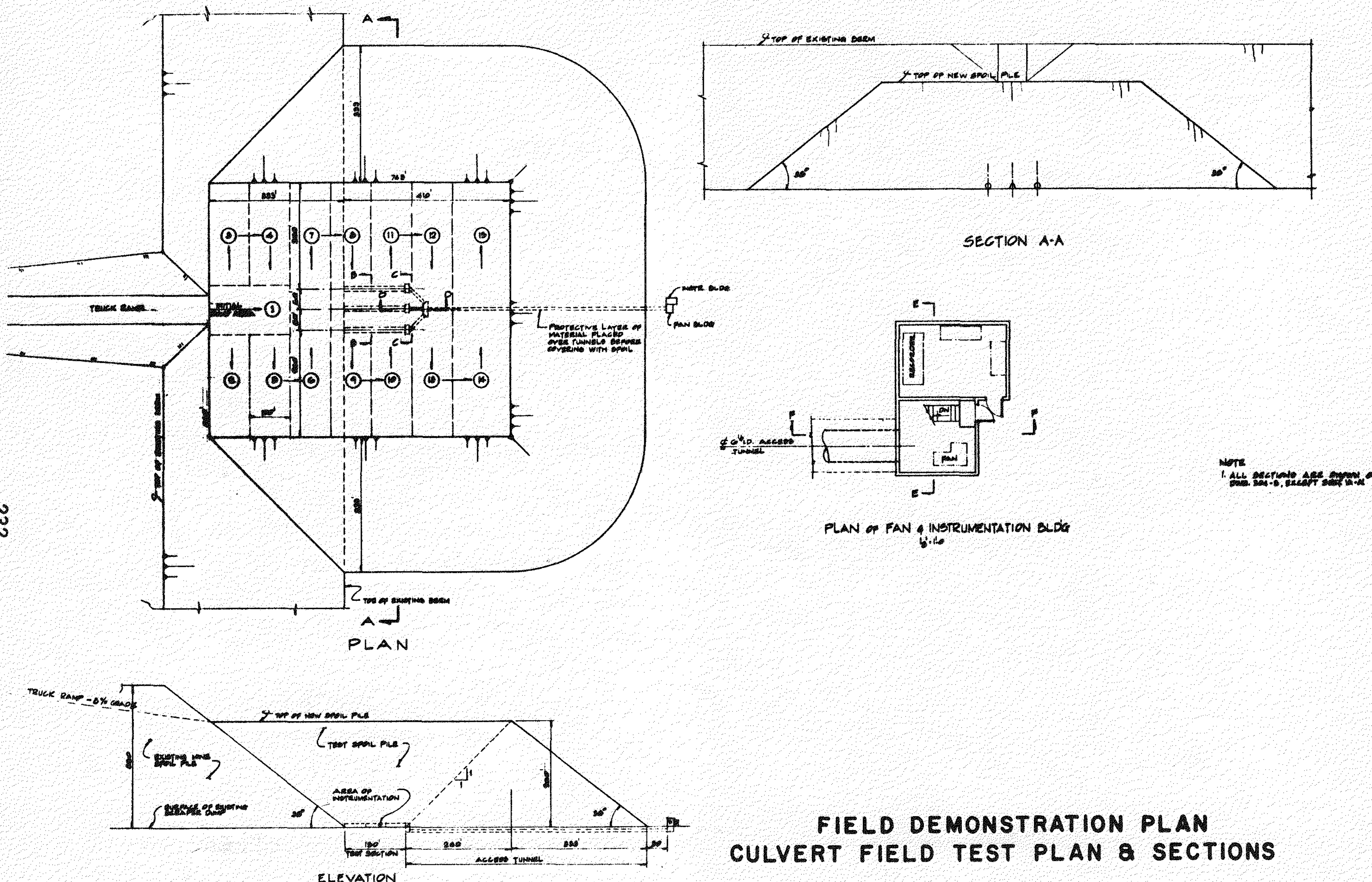
Design engineering costs are based on drawing requirements estimated for equipment procurement, construction, and operation of the system.

Home office administration includes salaries and expenses for such services as project engineering, purchasing, expediting, scheduling, cost engineering, construction supervision, industrail relations,



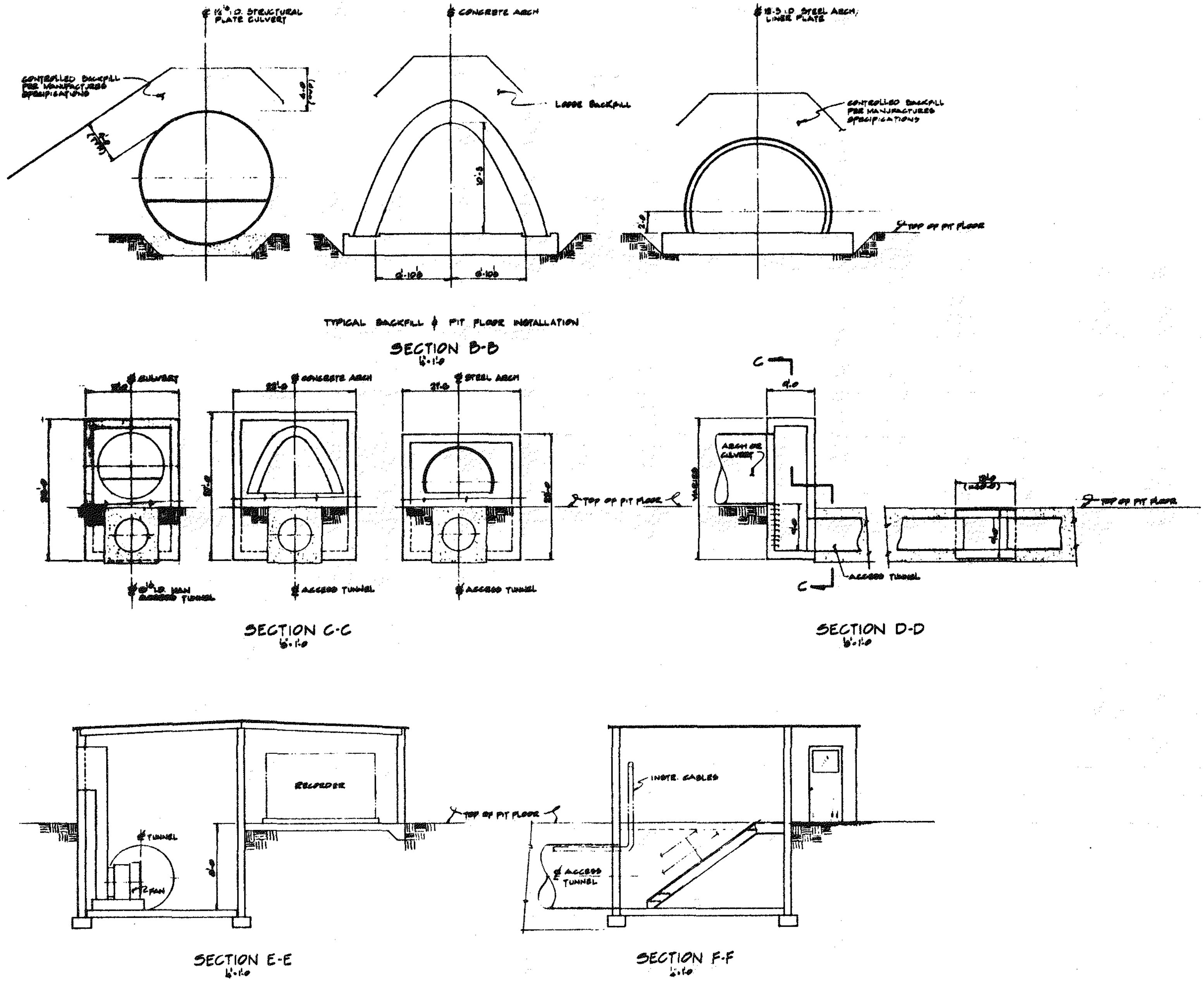
CULVERT FIELD LOAD TEST AREA

Figure 1



FIELD DEMONSTRATION PLAN
CULVERT FIELD TEST PLAN & SECTIONS

Figure 2



ALTERNATIVE TUNNEL SUPPORTS

Figure 3

TABLE 1

CAPITAL COST SUMMARY
CULVERT FIELD LOAD TEST - ARIZONA COPPER MINE

	LABOR	MATERIAL	SUBCONTRACT	TOTAL
Mechanical	227,953	1,197,405	3,600	1,428,958
Civil			447,865	447,865
Piping			263,000	263,000
Electrical		279,302	305,490	584,792
Service & Start-Up	16,100		15,000	31,100
Sub-Total Direct Cost	244,053	1,476,707	1,034,955	2,755,715
Indirect Costs				226,008
Engineering, Home Office & Field Administration				438,145
Sales Tax				94,683
Builders Risk Insurance				15,113
Fee				105,890
TOTAL				$ 3,635,554

estimating, development, accounting and miscellaneous secretarial and clerical personnel. Telephone, telex, printing and mailing expenses are also included.

Sales and use taxes include personal property tax on the rental equipment. A sales tax of 3% state and 1% local has been applied to all materials. The cost of builders risk insurance and a 3% fee are included.

It should be noted that the cost for the following were not included in this estimate.

1. Actual operating cost for production (the construction cost for extending the conveyor and tunnel have not been included).

2. Spare Parts Cost.

3. Maintenance Equipment Costs.

4. Land or Rights Cost.

5. Interest During Construction.

6. Escalation After December 31, 1976.

7. Utilities Outside Battery Limits.

8. Construction Utilities Cost.

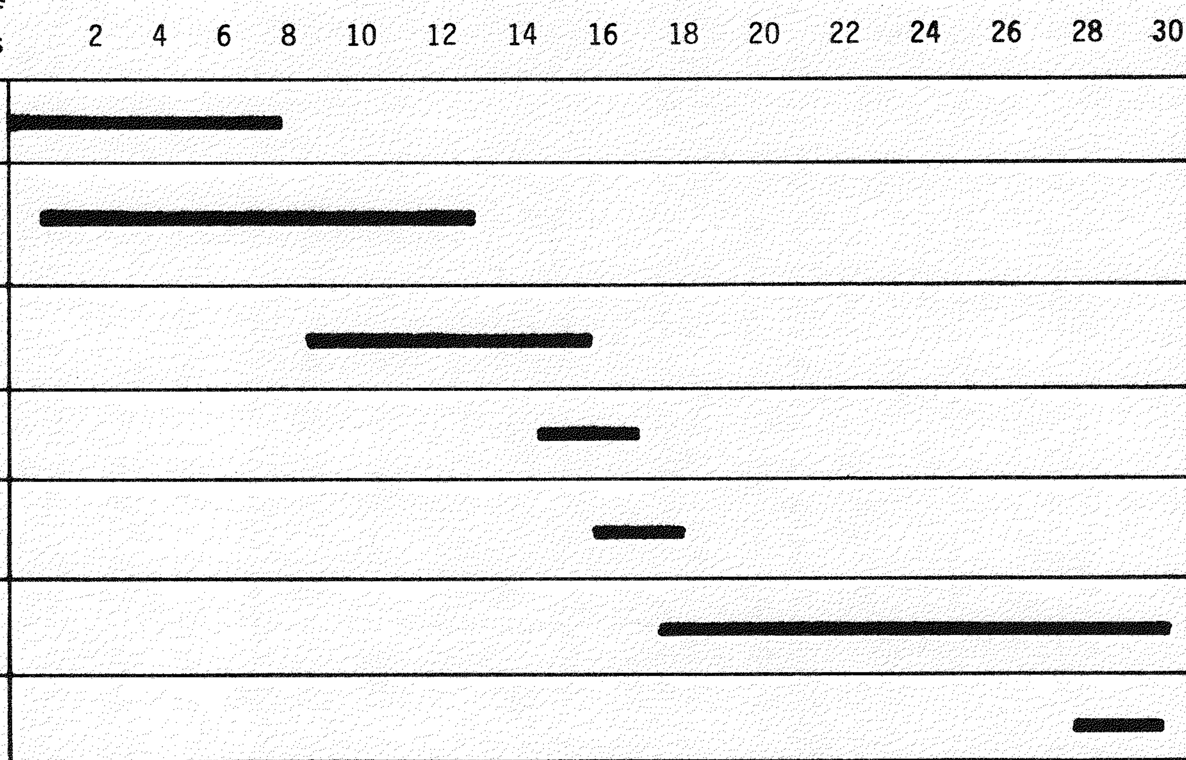
9. Permits or Licenses.

The schedule for performance of the field demonstration plan is shown in Table 2. Depending on the rate of advance, several alternative types of tunnel support could be included in the 12-month testing period.

TABLE 2

DEMONSTRATION SCHEDULE

	No. of Months
FINAL ENGINEERING	8
COMPONENT PURCHASE FABRICATION AND DELIVERY	12
SYSTEM INSTALLATION	7
START-UP	2
SYSTEM MODIFICATION	2
TESTING PERIOD	12
FINAL REPORT	2



2. <u>Personnel and Equipment Requirements</u>

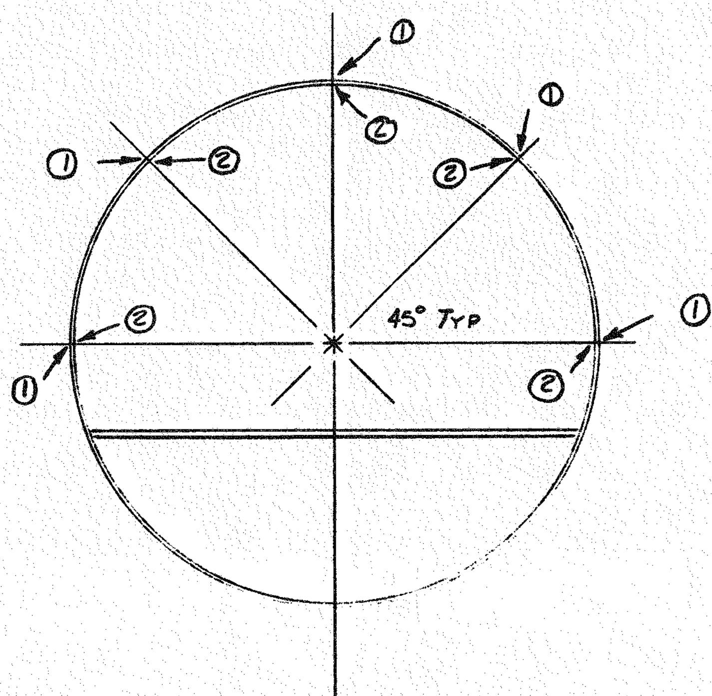
The set-up and conduct of the demonstration requires careful supervision throughout. It is assumed that excavation for the underspoil system will be performed by mine forces and that all other installation will be by outside subcontractor. The demonstration contractor will act as construction manager for the Bureau of Mines and will coordinate all phases of the demonstration to insure that the objectives are obtained with minimum interference to mine operation.

The contractor will provide a project manager with responsibility for supervising the detailed planning, design, installation, start-up and operation phases of the demonstration. He will coordinate with mine operations, with Dept. of Energy representatives at project level, and with the public (visitors). He will be represented on site by a construction superintendent during installation and by a project engineer during start-up and operation. This staff will provide continuity throughout all phases of the demonstration and insure that visitors have access to personnel who are well grounded in all aspects of the effort. During installation the staff will be supplemented by a 3-man survey crew. With installation completed, this staff will concentrate on start-up and implementing the data collection system for operations. Once the start-up phase is completed the actual demonstration will begin. The contractor's personnel during the operation phase will consist of the project engineer, one cost engineer, and a general foreman. A three-man operating crew consisting of an operator, an electrician, and a mechanic will be required for each operating shift. These crews would normally be on the mine payroll but supervised directly by the contractor's general foreman. Part-time labor from the mine bull-gang will also be required during the moving and positioning of portable conveyors.

All construction equipment will be furnished by the mine operator or the erection subcontractor. During start-up and demonstration it is assumed that the mine operator provides one front end loader and one tractor dozer for loading, cleanup, and moving the portable conveyors. The underspoil system includes the feeder/breaker and a maintenance cart for use in the tunnel. During the demonstration phase, normal support such as fuel and lube vehicles, shop repairs, and any required crane service is supplied by the mine operator. Emergency services such as ambulance and fire truck would also be available from the mine.

The demonstration contractor will provide a mechanic/parts truck for the service crew and a pickup for use by the project engineer and general foreman. Both vehicles will have radios which net with the mine radio system. During construction a survey vehicle will be required.

Dravo PITTSBURGH, PENNSYLVANIA	ENGINEERING COMPUTATIONS	EST NO. CONT NO. M7260 DIVISION E&C
COMPANY U.S. BUREAU OF MINES LOCATION UNDERSPOIL HAULAGE SYSTEM - PHASE II DESCRIPTION LOCATION OF SENSORS - STRUCT. PL. CULVERT		DATE 3-28-77 DR DEO CH REF



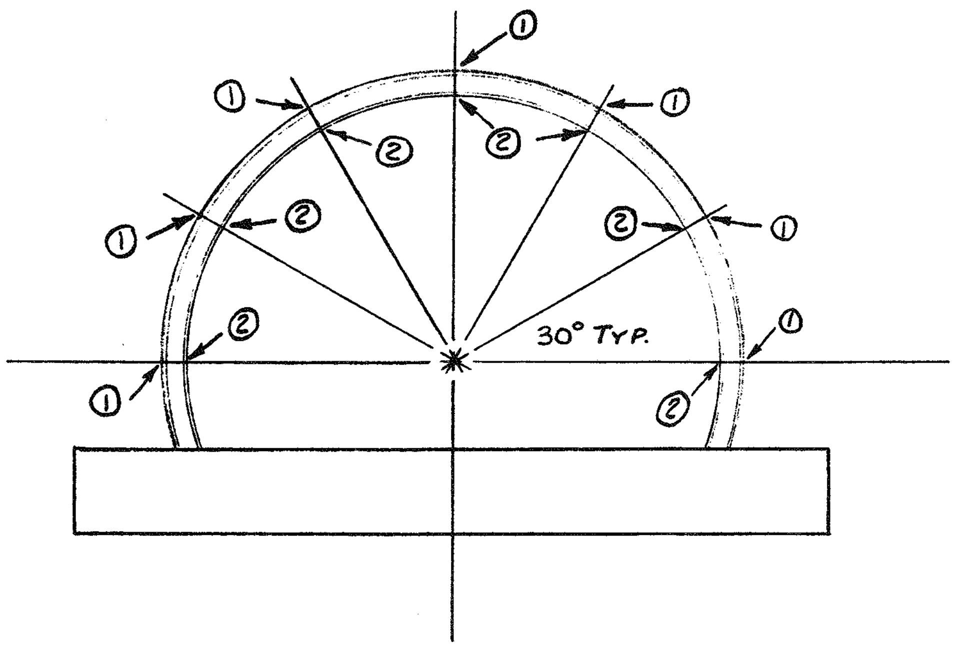
① LOCATIONS OF HYDRAULIC PRESSURE CELLS. EACH LOCATION IS MADE UP OF THREE SEPARATE CELLS SO AS TO MEASURE PRESSURE IN THREE MUTUALLY PERPENDICULAR PLANES.

② LOCATIONS OF STRAIN GAGES ATTACHED TO INNER STUCTURAL SURFACE. HERE ALSO, EACH LOCATION CONSISTS OF THREE INDIVIDUAL GAGES.

TEST LOCATIONS ARE IN ONE VERTICAL PLANE PERPENDICULAR TO TUNNEL AXIS AND THE PLANE IS LOCATED AT THE CENTER LINE BISECTING THE TUNNEL SECTION LENGTH.

SHEET NO. 1

Dravo — PITTSBURGH, PENNSYLVANIA	ENGINEERING COMPUTATIONS	EST NO. ______ CONT NO. ______ DIVISION M7260
COMPANY U.S. BUREAU OF MINES LOCATION UNDERSPOIL HAULAGE SYSTEM - PHASE II DESCRIPTION LOCATION OF SENSORS - STEEL ARCH / LINER PLATE		DATE 3-28-77 DR DEO CH ______ REF ______

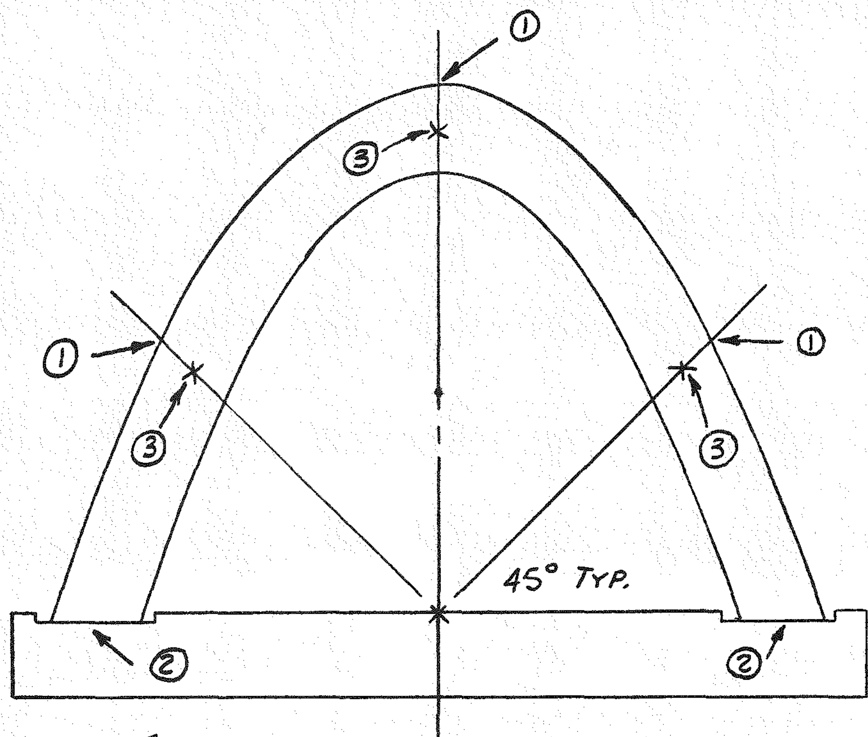


① LOCATION OF HYDRAULIC PRESSURE CELLS. EACH LOCATION IS MADE UP OF THREE SEPARATE CELLS SO AS TO MEASURE PRESSURE IN THREE MUTUALLY PERPENDICULAR PLANES.

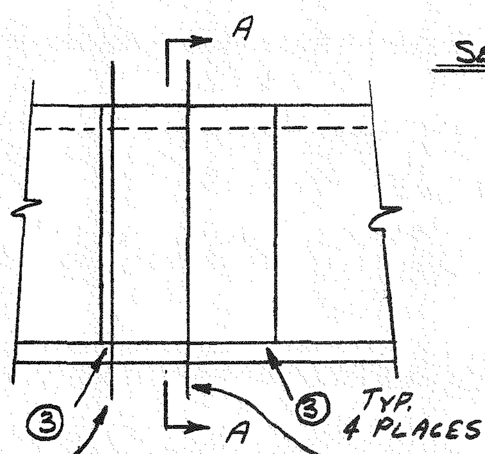
② LOCATION OF STRAIN GAGES ATTACHED TO INNER STRUCTURAL SURFACE. THREE GAGES AT EACH LOCATION.

TEST LOCATIONS ARE LOCATED IN A PLANE PERPENDICULAR TO THE TUNNEL AXIS AND THE PLANE BISECTS THE TUNNEL LENGTH.

Dravo PITTSBURGH, PENNSYLVANIA	**ENGINEERING COMPUTATIONS**	EST NO. ___ CONT NO. M 7280 DIVISION E&C
COMPANY U.S. BUREAU OF MINES LOCATION UNDERSPOIL HAULAGE SYSTEM - PHASE II DESCRIPTION LOCATION OF SENSORS - CONCRETE ARCH		DATE 3-29-77 DR DEO CH ___ REF ___



SECTION A-A



TUNNEL TEST SECTION ELEV.

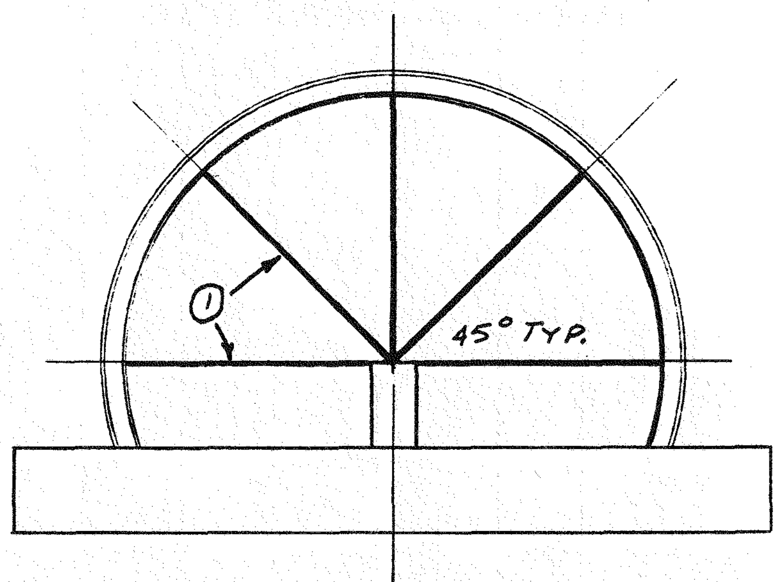
① LOCATION OF HYDRAULIC PRESSURE CELLS. THREE PER LOCATION

② LOCATION OF HYDRAULIC PRESSURE CELLS. ONE PER LOCATION; IN HORIZONTAL PLANE ONLY

③ LOCATION OF ELASTIC WIRE STRAIN METERS; THREE PER LOCATION.

SHEET NO. 3

Dravo PITTSBURGH, PENNSYLVANIA	ENGINEERING COMPUTATIONS	EST NO. ____ CONT NO. M7260 DIVISION E&C
COMPANY U.S. BUREAU OF MINES LOCATION UNDERSPOIL HAULAGE SYSTEM - PHASE II DESCRIPTION LOCATION OF EXTENSOMETERS		DATE 3-29-77 DR DEO CH ____ REF ____



(1) EXTENSOMETER LOCATIONS. TYPICAL FOR ALL TUNNEL SECTIONS. INSTALLATION IN THE STEEL TUNNELS WILL BE AT THE CENTER OF THE TEST SECTIONS. INSTALLATION IN THE CONCRETE ARCH WILL BE AT ONE END AS WELL AS AT THE CENTER OF THE TEST SECTION

APPENDIX

CANVASSING EFFORT FOR TEST SITE

Potential Underspoil Customers

Update on Underspoil Coal Haulage Pamphlet (October 1977)

Final Engineering

Data Collection and Evaluation

Ref: 3.2.2

Potential Underspoil Customers

STATE	MINE		1976 PRODUCTION	PRIORITY*
Alaska	1.	Usibelli	+ 700,000 (76)	C
Arizona	2.	Black Mesa	5,559,133 (76)	A
		Kayenta	4,667,034 (76)	B
Colorado	3.	Colowyo	600,000 (77E)	B
	4.	Energy Mine No. 1	1,478,922 (76)	D
	5.	Energy Mine No. 2	1,009,511 (76)	D
	6.	Energy Mine No. 3	518,881 (76)	D
	7.	Seneca Mine	1,525,294 (76)	D
	8.	Edna Mine	1,140,177 (76)	D
	9.	Seneca	710,313 (75)	D
	10.	Strip No. 2		
Illinois	11.	Sunspot	744,000 (76)	D
	12.	Leahy	2,663,000 (76)	C
	13.	Delta	731,000 (76)	D
	14.	Norris	876,365 (76)	D
	15.	Burning Star No. 2	1,283,896 (76)	D
	16.	Burning Star No. 3	955,074 (76)	D
	17.	Burning Star No. 4	2,803,199 (76)	C
	18.	Buckheart Mine 17	1,055,999 (76)	D
	19.	Fidelity Mine 11	1,091,773 (76)	D
	20.	Mecco Mine	1,534,449 (76)	D
	21.	Elm Mine	712,124 (76)	D
	22.	Eagle Strip	525,026 (76)	D
	23.	River King (Strip)	3,411,129 (76)	C
	24.	Will Scarlet	512,784 (76)	D
	25.	Eads Mine	614,228 (75)	D
	26.	Sahara Mine No. 6	830,308 (76)	D
	27.	Sahara Mine No. 20	506,114 (76)	D
	28.	Sahara Mine No. 21	519,637 (76)	D
	29.	Captain	3,537,959	C
	30.	Streamline	1,451,567	D
Indiana	31.	Chinook	1,058,000 (76)	D
	32.	Ayrcoe	876,000 (76)	D
	33.	Minnehaha	1,461,000 (76)	D
	34.	Ayrshire	2,712,000 (76)	C
	35.	Wright	1,268,000 (76)	D
	36.	Old Ben No. 1	2,527,295 (76)	C
	37.	Old Ben No. 2	1,718,539 (76)	D
	38.	Hawthorn	898,137 (76)	D
	39.	Latta	884,196 (76)	D
	40.	Dugger	703,807 (76)	D
	41.	Universal	2,678,945 (76)	C
	42.	Lynville	3,227,833 (76)	C
	43.	Squaw Creek	1,129,714 (76)	D

Montana	44.	Decker No. 1	10,207,648 (76)	A
		Big Sky Mine	2,397,348	B
	45.	Rosebud	9,264,700 (76)	A
	46.	Absaloka	4,083,894 (76)	A
New Mexico	47.	McKinley	842,339 (76)	C
	48.	Navajo	6,465,000 (76)	B
	49.	San Juan Mine	1,223,669 (76)	C
North Dakota	50.	Center Mine	1,664,486 (76)	C
	51.	Glenharold	3,706,718 (76)	B
	52.	Coteau	Under Development up to 7,100,000 tons by 1982	C
	53.	Falkirk	Under Development up to 5.6 million tons by 1980	C
	54.	Indian Head	1,122,980	D
	55.	Gascoyne	2,482,123 (76)	D
	56.	Buelah	1,325,262 (76)	D
Oklahoma	57.	Rogers County	1,616,040 (76)	D
	58.	Mine # 2		
Texas	59.	Fairfield	+3,000,000	C
	60.	Rockdale		
Wyoming	61.	Belle Ayr	7,355,000 (76)	A
	62.	Medicine Bow	2,774,440	C
	63.	Seminoe # 1	2,660,930	C
	64.	Seminoe # 11	2,660,930	C
	65.	Coal Creek	Under Development	A
	66.	Black Thunder	Under Development	A
	67.	Big Horn	751,634	D
	68.	Jim Bridger	3,429,065	A
	69.	Caballo	Under Development	A
	70.	Rawhide	Under Development	A
	71.	Elkol	1,844,846 (76)	B
	72.	Sorenson	2,276,799 (76)	B
	73.	Jacobs Ranch	Under Development	A
	74.	East Gillette # 16	Under Development	A
	75.	Dave Johnson	2,714,322 (76)	A
	76.	Hanna Basin	829,373 (76)	B
	77.	Rosebud Mine	2,182,946 (76)	B
	78.	Cordero	Development	A
	79.	Wyodak # 1	786,572 (75)	C

*Priorities

A-20 years reserve
-+2½ MM production/year
-+100' overburden
-+20' coal seam

B-Combination of 3 listed in A
C-Combination of 2 listed in A
D-One of listed in A
E-None of listed but with plus 500,000 tons annual production

List of Coal Mine Companies Contacted

PEABODY COAL COMPANY
Mr. Howard W. Williams
V.P. Western Surface Group
Belville, Illinois

COLOWYO COAL COMPANY
Mr. I. E. McKeever
President and General Manager
5731 State Highway 13
Meeker, Colorado 81641

DECKER COAL COMPANY
Mr. John Gable
Mine Manager
P. O. Box 12
Decker, Montana 68131

WESTERN ENERGY COMPANY
Mr. Paul Schmechel
Vice Presidetn & General Manager
40 East Broadway
Butte, Montana 59701

WESTMORLAND RESOURCES
Mr. Nick Tudor
Geologist
Box 449
Hardin, Montana 59034

UTAH INTERNATIONAL, INC.
Mr. C. K. McArthur
Sr. V.P./Mgr. Mng, Div.
550 California St.
San Francisco, California 94104

CONSOLIDATION COAL COMPANY
Mr. Larry Fuller
Manager of Mines
Wester Region
2 Inverness Dr. East Bldg.
Englwood, Colorado 80110

NORTH AMERICAN COAL CORPORATION
Mr. Robert E. Murray
President Western Operations
Kirkwood Office Tower
Bismarck, North Dakota 58501

INDUSTRIAL GENERATING COMPANY
1506 Commerce St.
Dallas, Texas 75201

AMAX COAL COMPANY
Mr. Charles W. Porterfield
V.P. Engineering
105 South Meridian Street
Indianapolis, Indiana 46225

AMAX COAL COMPANY
Mr. Jack Lautenschlager
V.P./Western Operations
P. O. Box 1880
Gillette, Wyoming 82716

ARCH MINERAL CORPORATION
Mr. G. H. Patrick
President
500 North Broadway
St. Louis, Missouri 63102

ATLANTIC RICHFIELD COMPANY
Mr. Authur E. Dall
Manager Mining Engineering Div.
Synthetic Crude and Minerals Div.
515 South Flower St
Los Angeles, California 90071

ATLANTIC RICHFIELD COMPANY
Mr. P. Boileau
Security Life Bldg.
Suite 1500
Denver, Colorado 80202

BRIDGER COAL COMPANY
Mr. Larry P. Tabaka
General Manager
P. O. Box 2068
Rock Springs, Wyoming 82901

THE CARTER MNG. COMPANY
Mr. S. Felde
Chief Engineer
P. O. Box 209
Gillette, Wyoming 82716

KEMMERER COAL COMPANY
Mr. Gerald P. Olsen
V.P. Operations
Frontier, Wyoming 83121

KERR McGEE COAL CORPORATION
Mr. aoy R. Smith
Div. Mngr./Western Operations
P. O. Box 1509
Gillette, Wyoming 82716

NORTHERN ENERGY RESOURCES COMPANY
Mr. David C. Nunenkamp
Manager, Technical Services
529 S.W. Third Avenue
Portland, Oregon 97204

PACIFIC POWER AND LIGHT
920 S.W. 6th Avenue
Portland, Oregon 97204

ROSEBUD COAL SALES COMPANY
Mr. Frank Shurter
Mine Supervisor
P. O. Box 98
Hanna, Wyoming 82327

SUN ENERGY DEVELOPMENT CO.
Mr. A. R. Allen
Mngr. Mine Development
12700 Park Central Pl.
Box 9
Dallas, Texas 75251

WYODAK RESOURCES DEVELOPMENT CORPORATION
Mr. Wilford J. Westre
V.P./General Manager
Garner Lake Rte.
Gillette, Wyoming 82716

GULF MINERAL RESOURCES COMPANY
Mr. O. A. Gallegos
1720 South Bellaire Street
Denver, Colorado 80222

Dravo

October, 1977

UPDATE ON UNDERSPOIL COAL HAULAGE

Underspoil haulage is a new application of conventional belt conveyor technology for the movement of coal in surface mines. Conveyors extend from the pit face to the surface through tunnels under the spoil. The potential advantages and limitations of this concept were outlined in a study completed in 1975 for the U. S. Bureau of Mines by the Denver Operations Office of Dravo Corporation.(1)

Since then Dravo has performed a more detailed feasibility study which indicates economic, safety, and environmental advantages over conventional truck haulage for surface mining conditions which prevail in many of the western coal fields.(2) The next objective of the on-going project is to locate an operating coal mine suited to prototype demonstration of a full-scale underspoil haulage system. When such a site is available, plans can be finalized for the demonstration, including testing of alternative tunnel support systems. Mine owners as well as manufacturers of conveyor and support systems indicate positive interest in participation.

Underspoil haulage is not the economic answer in every strip pit. The capital outlay involved in initial tunnel and conveyor installation can only be justified where long-term, high volume production is assured. Relatively thick coal and overburden are necessary to realize the full advantages of underspoil haulage. Fortunately these conditions prevail in many area strip mines in the West. And future uncertainties as to labor and diesel fuel, both cost and availability, tend to favor the new concept over conventional truck haulage which is labor intensive and fuel dependent. From a safety standpoint, elimination of truck traffic in the pit and on haul ramps, especially at night and in winter, is a plus for conveyors. The environmental advantages of underspoil haulage are less obvious but very important in any comparison with truck haulage. To better understand this comparison, we will take a brief look at both systems. Figure 1 is a simplified view of a conventional area strip mine working a single seam of flat-lying coal. Overburden is being cast across the pit by dragline, exposing the coal for removal by truck and shovel. Two haul ramps slope upward through the spoil dump and connect with surface roads leading to crushing and load-out facilities. Figure 2 shows the same mine with the ramps replaced by underspoil tunnel/conveyors. These conveyors are fed by mobile pit equipment consisting of front-end loaders, a travelling feeder/breaker and shiftable pit conveyors. At the surface, coal is transferred to a collection belt and then to an overland conveyor leading to the secondary crusher and loadout facilities.

DRAVO CORPORATION DRAVO BUILDING 1250 FOURTEENTH ST. DENVER, CO 80202 TELEPHONE: 303 893-4500

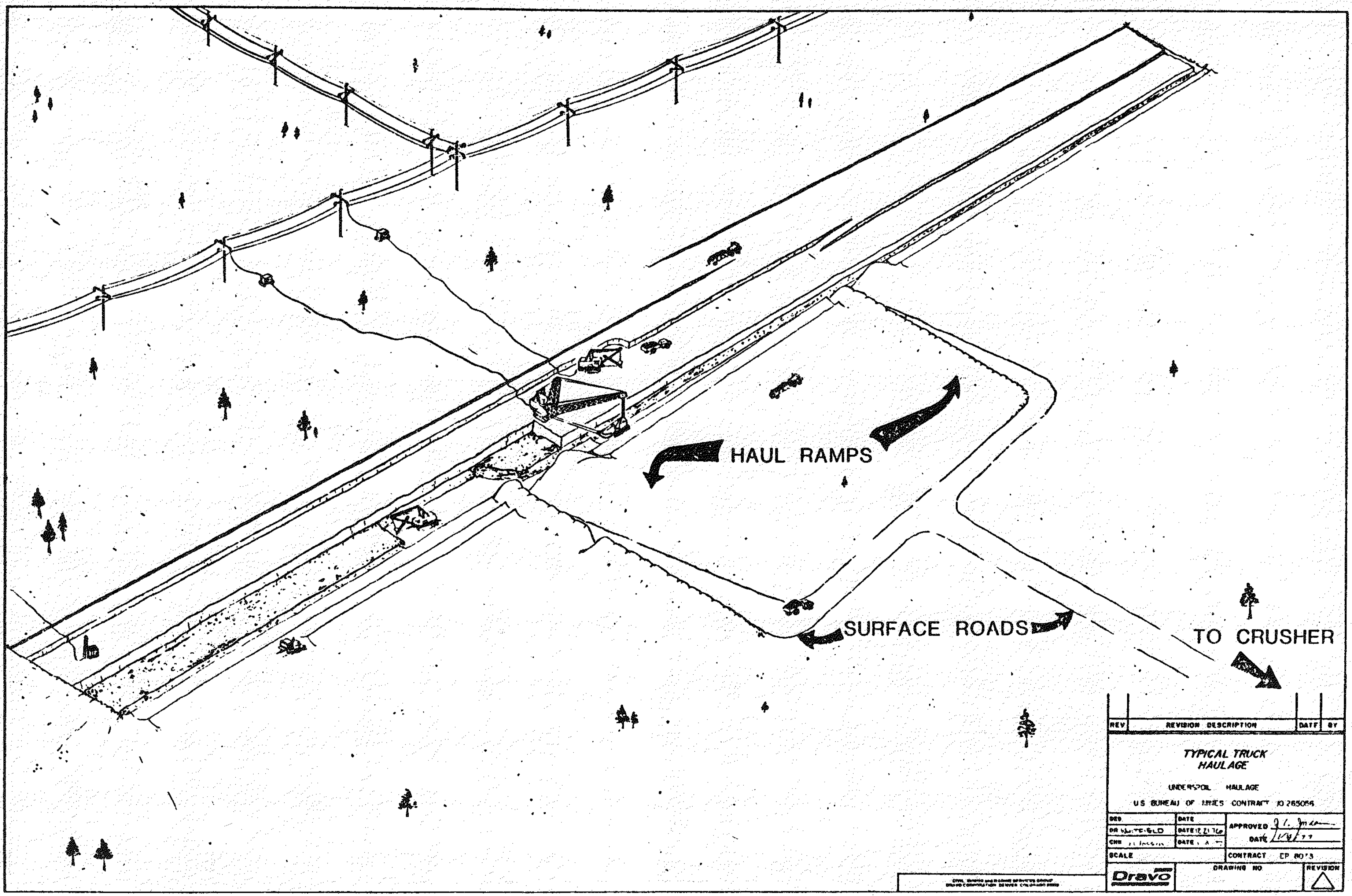

HAUL RAMPS
SURFACE ROADS
TO CRUSHER
REV
REVISION DESCRIPTION
DATE
BY
TYPICAL TRUCK HAULAGE
UNDERSPOIL HAULAGE
US BUREAU OF MINES CONTRACT JO 265056
DES
DATE
DR
DATE
CHK
DATE
APPROVED
DATE
SCALE
CONTRACT
DRAWING NO
REVISION
Dravo

Fig. 1

248

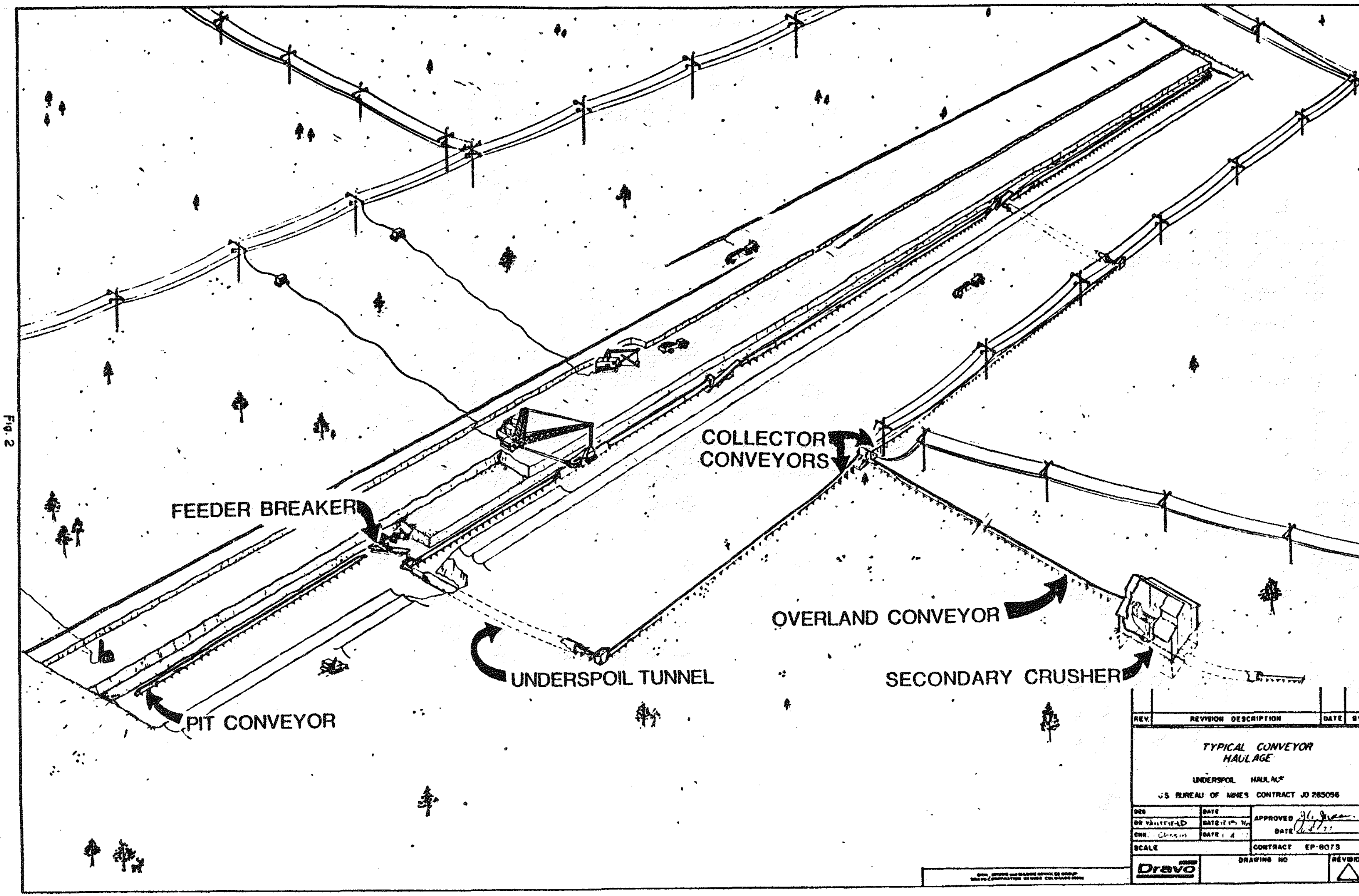

COLLECTOR CONVEYORS
FEEDER BREAKER
OVERLAND CONVEYOR
UNDERSPOIL TUNNEL
SECONDARY CRUSHER
PIT CONVEYOR
REV.
REVISION DESCRIPTION
DATE
BY
TYPICAL CONVEYOR HAULAGE
UNDERSPOIL HAULAGE
US BUREAU OF MINES CONTRACT JO 265056
APPROVED
DATE
SCALE
CONTRACT EP-8073
Dravo
DRAWING NO
REVISION

Fig. 2

Comparing the two mine plans, the elimination of truck ramps simplifies and expedites reclamation of the spoil. Even when ramps are advanced every year, they interfere with recontouring of the spoil ridges and with overburden and topsoil haulage. The figures show scrapers stripping topsoil, followed by truck and shovel benching, to reduce overburden depths to the capacity of the dragline on a single turnover pass. Both the scrapers and the trucks hauling overburden are obstructed by the ramps which, at 7% grades, would extend more than half a mile out from a 200-foot deep pit. From the viewpoint of the mine superintendent, who is primarily concerned with coal production, elimination of ramps gets away from dragline "gapping" and rehandling of spoil where ramps enter the pit. Considering that overburden handling is often the most costly part of mining and the dragline is the key unit of mining equipment, the "streamlining" of this operation is very important.

In developing the underspoil haulage concept, Dravo has tried to retain at least part of the flexibility of trucks. Both extendable conveyors and the shiftable type shown in Figure 2 were evaluated as a means of moving the coal from the face to the underspoil tunnels. While both concepts are feasible they lack the flexibility to fit today's pits which are generally not as straight and level as the figures indicate. A series of portable conveyor modules, on the other hand, is adaptable to such conditions and is economically feasible when combined with underspoil and surface conveyor systems. The system selected for demonstration involves the tandem positioning of multiple conveyor flights to form an extendable belt line along the pit as shown in Figure 3. Similar conveyor units are being used successfully under rather adverse conditions to convey overburden in copper mines and construction materials on large earthwork projects. For the proposed coal haulage application, the conveyor modules are wheel-mounted for towing by pit equipment and are fully interchangable for quick replacement of breakdowns. Thus flexibility and overall availability approach truck fleet conditions, but coal production is less dependent upon labor and fuel supplies which are particularly subject to shortages and rising costs.

The installation and periodic extension of underspoil tunnel/conveyors may be a new operation in surface mines but certainly not in underground mining or in materials handling in general. Figure 3 includes a cross-section of the proposed underspoil system. The sloping tunnel extending from the surface to the floor of the original box cut would be constructed and backfilled by conventional cut-and-cover methods. The horizontal section would be installed on the pit floor in increments corresponding to the pit width, normally about 100 feet. The uncompacted spoil which will be dumped, possibly several hundred feet deep over the tunnels, will create severe structural loading conditions. There is no precident for culverts of this diameter being subjected to uncontrolled backfill. At the same time there is no recognized method for accurately estimating such loads. For this reason a pre-cast reinforced concrete arch of very conservative design was used in preliminary studies. Flexible steel culverts, arch/liner plate supports, and ribbed or slotted steel plate supports offer possible economy and installation advantages once site conditions are established. A typical installation as shown in Figure 4 would be sized to permit replacement of idlers and to provide travel space for a small electric maintenance and cleanup cart. The tunnel contains a sprinkler system, washdown water line, dewatering pipe, and electrical power and control cables.

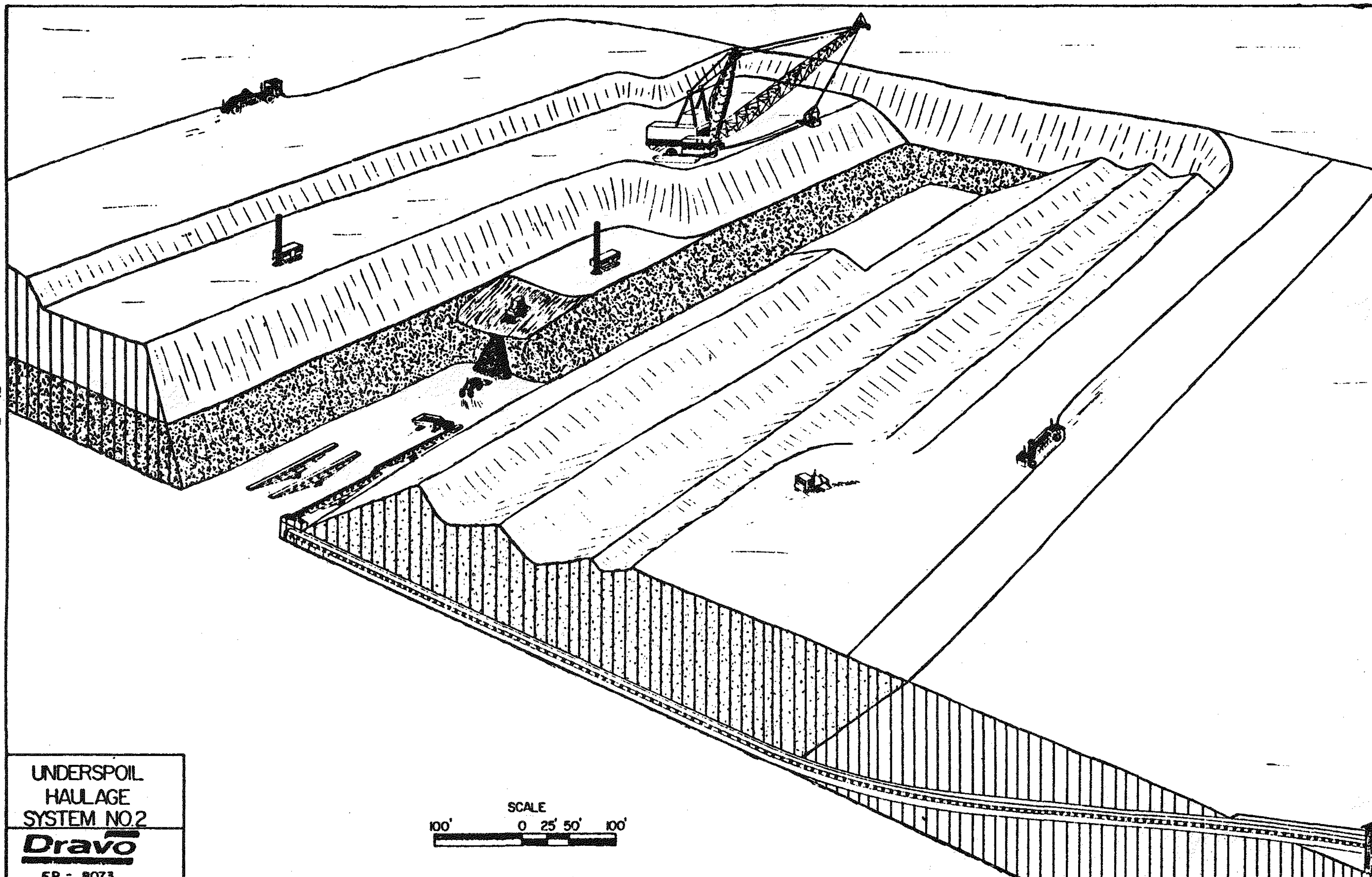

UNDERSPOIL
HAULAGE
SYSTEM NO.2
Dravo
EP - 8073
SCALE
100' 0 25' 50' 100'

Fig. 3

Assuming the concrete arch is used for both initial slope installation and subsequent extensions, a supply of precast sections would be maintained on site. A concrete invert slab would be placed ahead of the tunnel extension, providing a pad for erection of the conveyor prior to setting up the arch sections. Special backfill material and compaction would be unnecessary as the rigid arch does not rely upon lateral support for its strength. However, dozing of a cushion layer of finer sized spoil around the exposed tunnel sections is recommended to avoid damage or displacement from dragline casting. Flexible culverts and tunnel support systems do require controlled backfill and careful compaction to develop the ground arch which should permit use of a lighter section than the rigid type. The structural behavior and the economics of various alternatives can be evaluated as part of the full scale demonstration.

To minimize interference with dragline operations, the tunnels must be extended with each successive cut. Conceptual designs provide two tunnels so that one operates continuously while the other is being extended. The second tunnel is normally available as a backup haulage system, should the operating tunnel be down for maintenance. For short pits, the second tunnel would be unnecessary unless storage capacity were so limited that interruptions for extensions or repairs could not be tolerated. As the extension of a tunnel/conveyor could normally be done over a weekend and scheduled maintenance would be performed on the third shift, a single tunnel would probably be satisfactory and certainly more economical for short pits.

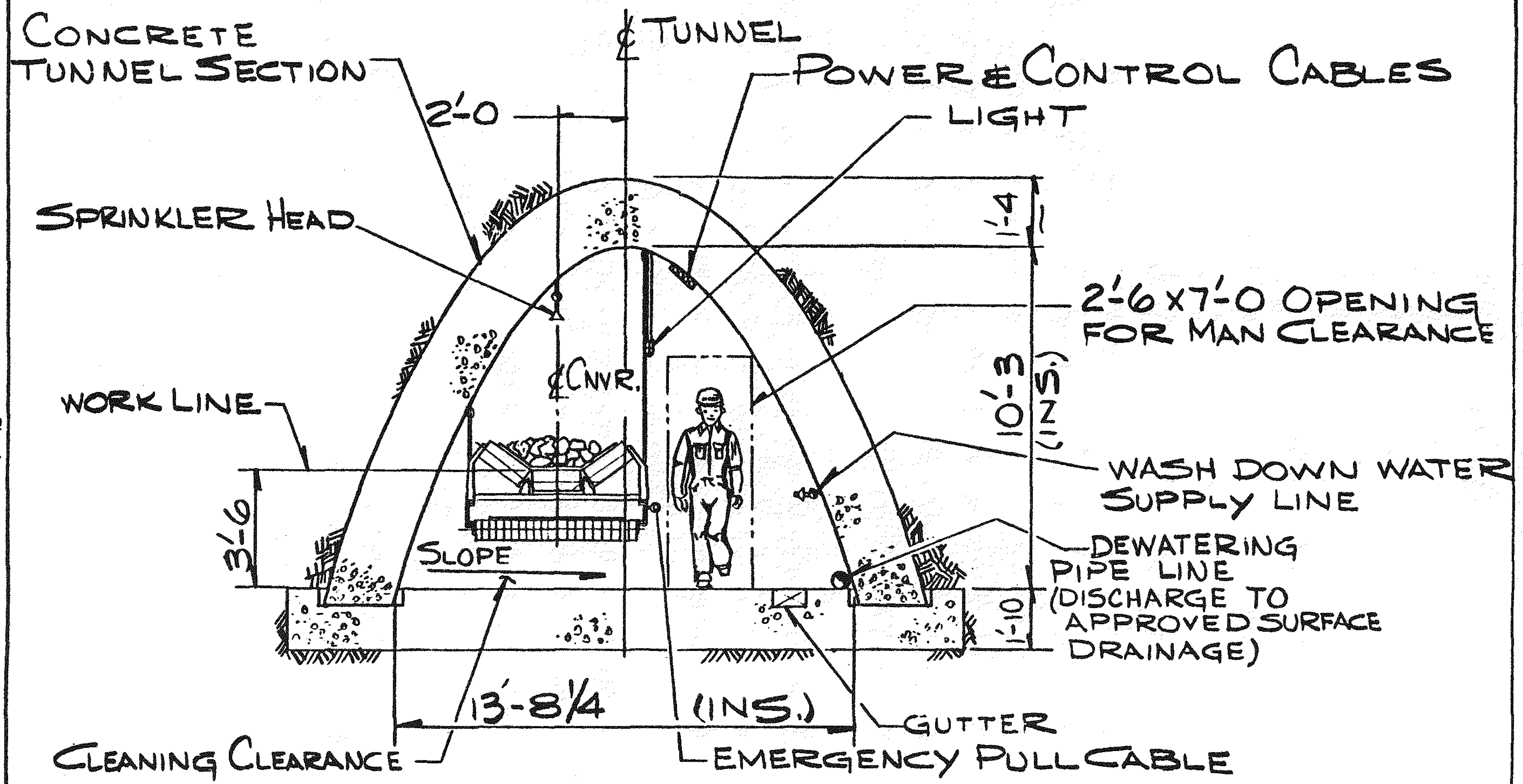
The underspoil conveyor selected for 5 MTY production is a 42-inch wide steel cable belt with vulcanized splices, operating at 810 feet per minute. The capacity can be doubled by replacement with a 54-inch belt running at 950 feet per minute. Thus a future increase in mine production to 10 MTY can be provided within the existing tunnels. Provisions are made to insure safe, comfortable working conditions within the tunnels and surface structures. Details of dewatering, ventilating, heating, and man-haul are developed to meet severe operating conditions. Monitoring and control devices are provided which permit operating of the entire conveyor system from a central control building but insure protection of personnel at any location along the belt lines.

In both the preliminary and the detailed feasibility studies, cost comparisons were made between conventional haulage and a number of underspoil alternatives, using common site conditions. The preliminary study evaluated coal haulage costs for three coal thicknesses (10, 30, and 70 feet) and three tonnages (2, 5, and 10 MTY). The detailed study was expanded to include all mining costs for coal thicknesses of 30 and 70 feet and overburden depths of 50, 100, and 200 feet. A summary of unit mining costs for each combination of these variables is shown on Figure 5 and 6. System 1 refers to conventional truck haulage, System 2 to underspoil haulage using portable conveyor modules in the pit. Conditions common to both systems are:

1. The coal lies near-horizontal in a single seam.

2. Coal is recoverable to the nominal seam thickness.

3. Production is 5 million tons per year.



SECTION 1-1
SCALE: 1/4"=1'-0"

Fig. 4

4. The pit is two miles long and is served by two haul ramps or alternatively two tunnel/conveyors.

5. The pit is 100 feet wide requiring a new cut and tunnel extensions every 7 months with 70-foot coal and every 3 months with 30-foot coal. For truck haulage, ramps are advanced once a year.

6. Reclamation requirements include recontouring within two to three spoil ridges of the pit, replacement of topsoil and subsoil totaling 5 feet, and revegetation to standards now being required in the Powder River Basin.

Figures 5 and 6 indicate neglegible cost advantage for underspoil haulage over truck haulage where overburden is less than 100 feet deep. At greater overburden depths, however, the advantage of conveyor haulage becomes increasingly pronounced. At 200-foot overburden, for example, savings of approximately 50¢ to $1 per ton are indicated where coal is 30 feet thick (Figure 5) and approximately 35¢ to 70¢ per ton where coal is 70 feet thick (Figure 6). The envelope representing a 10% variation in underspoil mining costs is based on the fact that operating costs for such new systems cannot be estimated with the accuracy possible for a conventional system. However, the increasing economic advantages of underspoil haulage with deeper overburden is quite apparent. The same effect was noted with increasing coal thickness and annual production in the preliminary feasibility study.

Both feasibility studies were reported in current dollars for conditions prevailing at the time. Several trends are noteworthy regarding probable future effects upon the economic picture for underspoil haulage:

1. Stripping depths are increasing. We have just reviewed the effect of this trend on the cost advantage for conveyors over trucks.

2. Labor and diesel fuel costs are rising faster then are those for manufactured equipment. This difference should be reflected in greater savings with conveyors over trucks.

3. Safety and environmental standards are becoming increasingly strict. This trend can be expected to favor conveyors in the overall mining cost comparison.

So much for the application of underspoil haulage to relatively thick, single coal seams. How about thin seams and multiple seams? These questions have been posed by both the Bureau and industry. Dravo's studies indicate that seams less than about 30 to 40 feet thick are not amenable to underspoil haulage. However, multiple seams exceeding 40 feet in combined thickness may be feasible since the economics are directly related to the tonnage conveyed through a given length of tunnel conveyor.

In developing single seam applications for underspoil haulage two alternatives to the pit floor installation of a culvert or arch section were investigated. These alternatives involve either a trench installation or a true tunnel driven under the coal seam from which raises are bored at intervals to provide feed points to the conveyor. Multiple coal seams could be mined

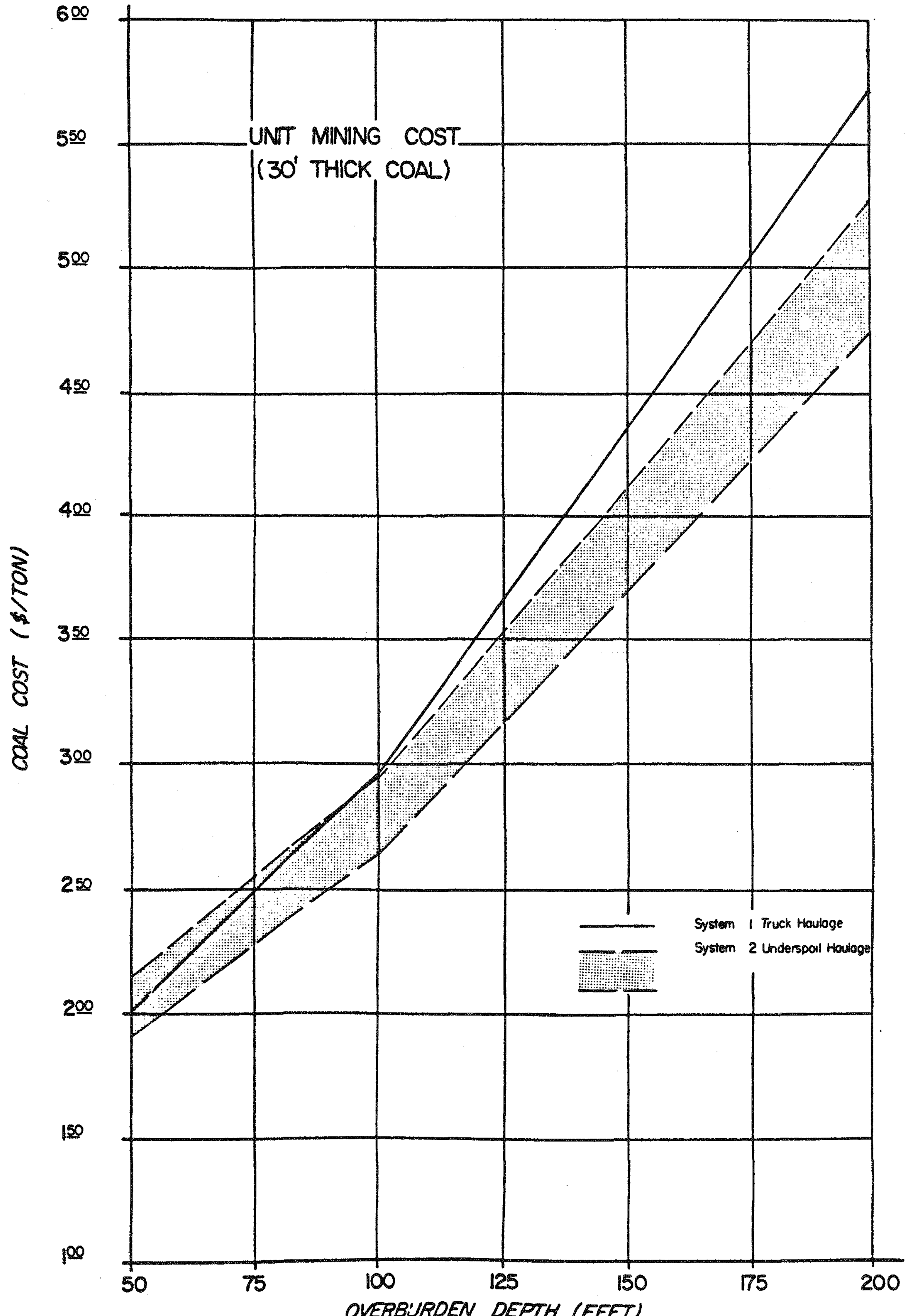

UNIT MINING COST
(30' THICK COAL)
COAL COST ($/TON)
6.00
5.50
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
50
75
100
125
150
175
200
OVERBURDEN DEPTH (FEET).
System 1 Truck Haulage
System 2 Underspoil Haulage

Fig. 5

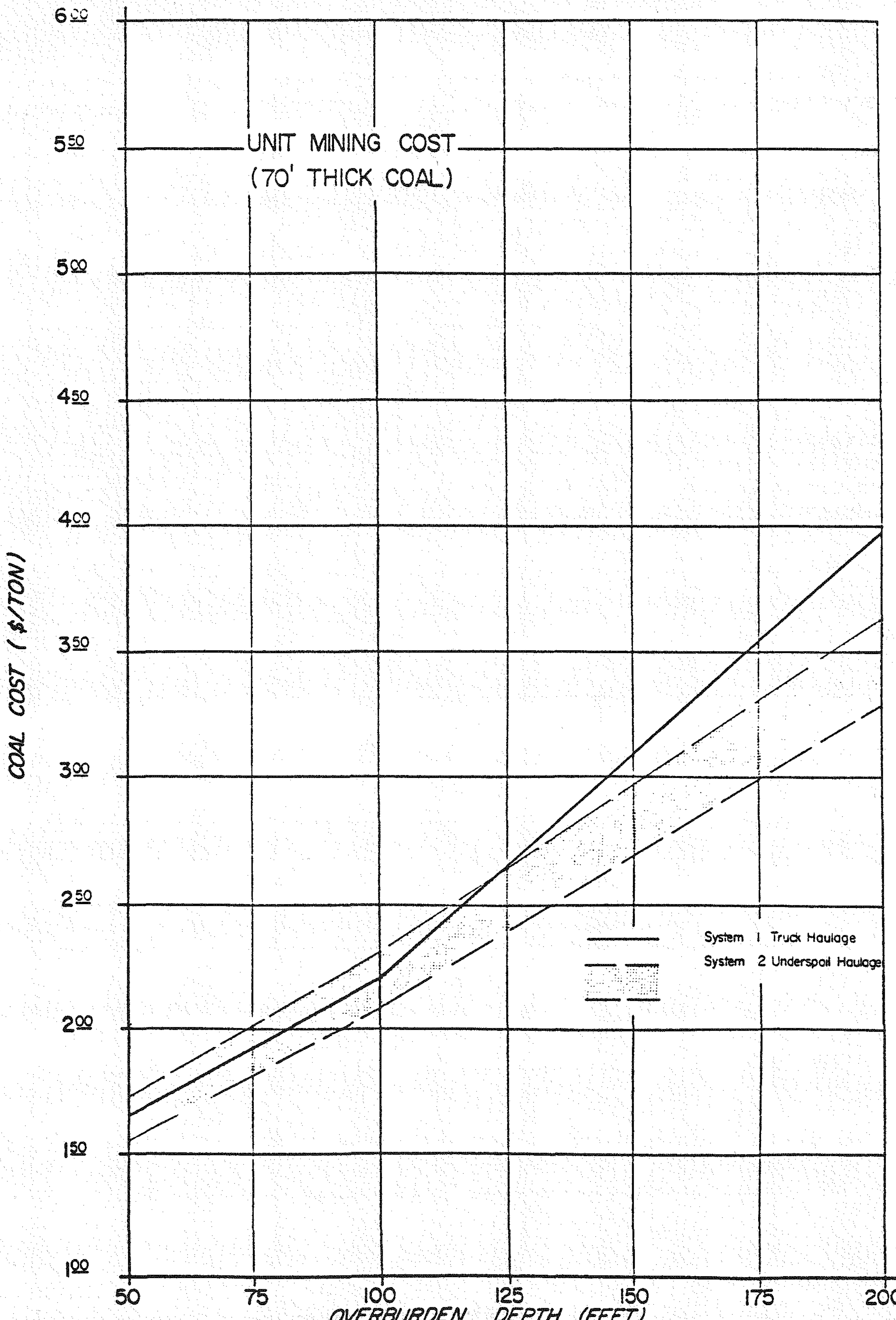

UNIT MINING COST
(70' THICK COAL)
COAL COST ($/TON)
6.00
5.50
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
50
75
100
125
150
175
200
OVERBURDEN DEPTH (FEET)
System 1 Truck Haulage
System 2 Underspoil Haulage

Fig. 6

and delivered through a feeder/breaker to this type of tunnel/conveyor system. The economics would be greatly enhanced if the interburden could be removed by the same method. With the two-tunnel concept this could be accomplished without interrupting coal production, provided a second feeder/breaker were available to crush the rock to beltable size. While this concept has not been fully explored it suggests interesting applications for underspoil coal haulage where tunneling conditions are favorable. The front end money involved in initial driving of the complete tunnels would necessarily be an adverse factor. The tradeoff between tunnel extensions and raise boring would also require careful evaluation.

Other variations of the underspoil haulage method will probably develop along with related technology. Hydraulic mining and slurry transportation of coal is compatible with underspoil installation of slurry pipelines in surface mines. Where water is available, coal can be moved directly from the face to surface facilities without the large tunnels required for belt conveyors. This concept would be particularly attractive where the slurried mine product could be fed directly into an overland coal slurry system, thus avoiding or reducing dewatering costs.

Looking beyond the coal industry, underspoil haulage may have application to other mining operations such as copper and uranium. The increased use of belt conveyors throughout the mining industry and the mounting pressure for methods which are safe and environmentally sound suggest an expanding future role for underspoil haulage.

NOTES:

(1) Available from National Technical Information Service, Springfield, Virginia 22151, by reference to Publication PB 254-575/AS, "Preliminary Engineering and Economic Evaluation of Underspoil Haulage in Area Strip Coal Mines, Part I".

(2) Available for technical review from U. S. Bureau of Mines or Dravo Corporation by reference to Interim Report, Contract No. J0265056, "Engineering and Economic Evaluation, Underspoil Haulage in Area Strip Coal Mines, Part II".

Final Engineering

1. <u>Civil</u>

The contractor will contact all interested culvert and tunnel support manufacturers to obtain their participation in the load tests. This participation might include cost sharing in the form of materials, installation, labor, and supervision at favorable rates. Technical advice regarding test procedure will be solicited with the provision that program control will remain under the contractor.

The work will begin with a soils analysis to define the physical characteristics of the spoil to be used in the backfill of the test sections and the bearing capacity of the test site foundation. A site survey will be performed to establish topography and existing spoil slopes. The test site will then be laid out including all access roads, construction staging area, haul roads, maintenance and personnel facilities, fencing and any other required facilities. With the results of the spoil tests, the design of the tunnel structures can be completed.

Drawings and specifications will be issued covering materials, fabrication and construction of the total test facility. The following requirements are estimated for a test program involving three different support systems.

<u>Drawing List</u>

1. Field Demonstration Plan Site Preparation
2. Field Support Facilities Site Plan
3. Rough and Final Contours
4. Plan and Elevations of Test Sections
5. Plan and Elevation of Access Tunnel
6. Sections and Details of Access Tunnel and Test Tunnel
7. Plan and Details of Fan and Instrument Building
8. Plan and Details of Office, Lunchroom, Restroom
9. Plan and Details of Maintenance Area and Fueling Point

<u>Specifications</u>

1. Soils Tests
2. Earthwork
3. Concrete
4. Reinforcing Steel
5. Grout
6. Precast Concrete

2. Electrical/Instrumentation

A consultant specializing in the measurement of stresses and strains in underground structures will be retained for Phase II. The consultant will recommend the procedures for obtaining the required technical information during the actual testing of the tunnel sections. He will select the test equipment required, recommend the test equipment installation procedures, assist in the conduct of the tests and in the evaluation of the test results.

The contractor will provide the detailed design for the physical installation of the test devices and any other required electrical or instrumentation needs.

3. Mechanical

Ventilation for the test tunnels and the access tunnel will be provided by a forced draft fan located in the fan building at the entrance of the access tunnel. This will be designed to meet MESA standards and other applicable codes. The duct system will be designed to provide fresh air to the far end of the test tunnel. Exhaust will be through the tunnel and out a louver in the fan building. Engineering design will include a specification for the selection of the ventilation equipment including air flow charts and sizing of the fan and ducting.

Component Design, Fabrication, and Delivery

1. Civil

The contractor will engage a precast concrete supplier for fabrication of the concrete arch tunnel sections as designed and specified by the contractor. An inspection of the precast facility will be made to ensure the proper performance as called out in the precast concrete specification.

The contractor will evaluate and approve the structural design of the steel tunnel sections. This structural design will be submitted to the contractor by the supplier whose product will be tested. If the design is deemed feasible by the contractor, he will then coordinate the fabrication and delivery of the certified test sections to the test site for installation and testing.

The laboratory testing of full scale components of the steel tunnel sections to determine the structural behavior of the tunnel material under various simulated load conditions is considered to be impractical. These full scale load tests would indicate possible failure modes of the tunnel sections but no positive correlation with the loads resulting from the dumped spoil could be made with certainty.

2. Electrical/Instrumentation

The contractor will engage an electrical and instrumentation supplier for the manufacture, delivery and installation of all components. The contractor will evaluate and approve the required equipment and will coordinate the delivery and installation of all electrical and instrumentation equipment.

3. <u>Mechanical</u>

The contractor will evaluate and approve the mechanical ventilation equipment and coordinate the delivery and installation.

Culvert Installation and Spoil Backfilling

1. <u>Civil Construction</u>

The contractor will construct the test facility per the drawings and specifications as described in the previous Section - Final Engineering.

The test site foundation will be prepared to simulate the shale floor of a typical coal pit. A soils consultant will be engaged and tests will be performed on representative coal pit floors. The insitu density, deformation characteristics, load bearing capacity and rock classification will be determined for typical floors. The analysis of the test site spoil will indicate its optimum moisture content, maximum dry density, gradation, angle of repose, settlement characteristics and its soil and rock classification. As a result of these tests, a procedure for preparing the test site foundation will be developed, using fine-grained spoil to simulate the pit floor. If only compaction of the spoil is required, this may be accomplished by hauling in material by scraper and placing it in 12 inch lifts. Water will be added by truck to bring the moisture content to optimum and disked to provide uniformity. A vibratory compactor will be used immediately following the water application to achieve the desired compaction. This process is repeated until the proper depth of compacted material is placed over the entire area of the test floor.

If greater strength is required than can be achieved with normal compaction, soil stabilization may be required.

Portland Cement will be mixed into the loose spoil by repeated disking, water added, and the spoil compacted. Lifts would be continued until proper depth of stabilized material had been placed over the entire floor of the test site. After curing, this soil-cement base would simulate the shale floor of the coal mine.

After the site preparation is complete, trenches will be excavated and the access tunnel constructed as shown on Drawing 304-2 and Drawing 304-3. The access tunnel consists of a 6 foot diameter corrugated metal pipe encased in reinforced concrete. The access tunnel will be designed to take the full load of the 260' deep spoil with a safety factor suitable for personnel access to the test sections. At the ends and junction of this access tunnel, reinforced concrete boxes will be cast-in-place to allow safe access into the test tunnel sections. A fan building and instrument building will be constructed at the entrance to the access tunnel. These buildings will have a partition separation to shield the ventilation fan noise from the instrument building. The concrete structures will be backfilled with native soil to the density of the surrounding foundation.

The three test tunnel sections will be installed, following standard construction practices except where the culvert manufacturer's recommendations involve special procedure.

The precast concrete arch will be placed in 8' long sections on a reinforced cast-in-place concrete slab. These 30-ton arch sections will be placed end to end for the full 150' length.

The steel arch and liner plate will also be assembled on a reinforced cast-in-place concrete slab.

The structural plate culvert will be erected on a specially prep-pared base per the manufacturer's recommendations.

Pressure sensors, extensometers and strain gauges will be placed on the tunnel sections and on the surface of the adjacent test area floor. Backfill will be placed to a level 4 feet above the culvert crowns. For the concrete arch, this will be loose dumped spoil. The backfill surrounding the steel sections will be graded, placed and compacted according to manufacturer's recommendations. This fill will protect the instruments during placement of the spoil in the test area.

The ventilation system will be installed using flexible ducting to supply air from the fan building to the test sections. Exhaust will be returned through the access tunnel and the louvers in the fan building. When the contractor has completed installation of all systems he will supervise the controlled spoil backfilling.

The following major construction equipment will be required to assemble, install and backfill each test pipe:

One 30 ton mobile crane to handle and install the concrete arch sections and the flexible culvert sections.

One 300 CFM air compressor to supply air for power tampers and hand tools.

One 10,000 gallon water truck to provide water for maintaining optimum moisture content during the preparation of the foundation for the tunnel sections and for dust control during construction.

One backhoe for the trenching of the access tunnel.

One welding machine for required field welding of miscellaneous steel.

One winch truck for handling concrete formwork and mechanical equipment.

Premix concrete trucks will be required to deliver cast-in-place concrete.

The installation work will require a superintendent and a general foreman. One survey crew will be required to establish and maintain grades and alignment of the foundations and the installed test pipe.

The backfill of the test sections will extend for a period of approximately three months. A volume of approximately 7 million cubic yards will be required to load the three test tunnel sections under 260' deep spoil. If additional tunnel sections are required to be tested, approximately 430,000 cubic yards of spoil will be needed for each 150 foot section of culvert added.

2. Electrical Installation

In order to supply power for the tunnel test facilities, a medium voltage power line, approximately one half mile long, will be required. The power line will supply a 100 KVA transformer at the test site.

The 100 KVA transformer will step the distribution voltage down to 480 volts. 480 volt power will be supplied to another step-down transformer furnishing 120 volt power for lighting and test instrumentation.

480 volt power will also be supplied to a tunnel ventilation fan. Control devices are included for a ventilation fan of 50 HP maximum.

Additional power will be available, at the required voltage, for building heating and ventilation. Minimum grounding will be supplied.

3. Instrumentation Installation

All instrumentation on Phase II work is provided for test data acquisition from tunnel sections undergoing tests in an actual spoil pile.

There will be a total of 76 pressure cells installed on the outer surfaces of the tunnel sections, under the concrete tunnel and in the space between tunnels. The pressure cell units measure the pressure applied perpendicular to the plane of the cell. Three cells are used at most test locations to record soil pressure in three different planes. The locations of these cells for each type of tunnel are shown in Figures 8, 9 and 10.

Eighteen pressure cells will be installed at six locations (a set of three locations between the concrete tunnel and each adjacent steel tunnel). These cells will measure spoil pressure in three directions.

Four cells, one at each corner, will be installed under the concrete tunnel section to measure total vertical pressure.

Eighteen elastic wire strain meters will be embedded in the walls of the concrete tunnel section. The meters will measure the strain, in three directions in the tunnel wall as the spoil builds up on the tunnel section.

Each tunnel will have an arrangement of five extensometers placed so as to measure the deformation of the tunnel cross-section perpendicular to the tunnel axis as the spoil load increases. A typical arrangement is shown on Figure 11.

The concrete tunnel will have two sets of extensometers and pressure cells. One set will be in a plane perpendicular to the axis and near the end of a precast unit. The second set of sensors will be in a plane, perpendicular to the axis, at the center of the precast unit. There will be a total of 20 extensometers.

The metal tunnel sections which are to be evaluated will have strain gauges attached to the inside structural members. The strain gauges will be installed so as to measure the deformation, in three directions, of steel tunnel structural members. There will be a total of 36 strain gauges. The pressure cells and strain gauges for the metal tunnel sections will be located in one vertical plane, perpendicular to the tunnel axis, located at the center of each tunnel.

The pressure cells are activated by a hydraulic system. Flexible hose pipe will be installed between each pressure cell and the automatic measuring system. Data from all other sensors will be gathered by multiconductor #18 SWG Type SJO cable connected between sensors and an automatic scanner-recorder. Hose pipe and cable will be installed on the tunnel walls and routed to the building housing the recording equipment

4. <u>Mechanical Installation</u>

The various tunnel test sections will be fully instrumented, and the data will be transmitted by wire cables in the access tunnel to the instrument building located beyond the edge of the spoil pile. Most of the time there will be no need for any person to be inside the tunnel test section so that continuous ventilation will not be required. However, the recording devices measuring tunnel deflections must register beyond their capability, and must be manually re-set periodically during the test. Also, repairs to the gauges and wiring may be required; and personal observations and photographs may be needed. Therefore, a capability of providing fresh air for each of the tunnel test sections is deemed necessary.

The proposed ventilation system is typical for tunnels. A forced draft fan located adjacent to the instrumentation building blows air through a duct located inside the access tunnel. This air duct connects to any of the tunnel test sections and continues to the farthest point of each tunnel test section. At this point the duct discharges into the tunnel and the fresh air returns to the outside atmosphere by first passing along the entire length of the tunnel test section and then the entire length of the access tunnel. Thus, there will be fresh air available at any point where a workman might be.

Only one tunnel test section will be ventilated at a time, that tunnel being the one which is to be entered. At the junction of the access tunnel and the three (3) tunnel test sections, there will be a piece of flexible connecting duct at the end of the supply duct. The person entering a particular tunnel test section will connect the flexible duct to the appropriate duct feeding the desired test section.

The flexible duct will be plastic fan line, typical of that used underground. The ductwork and fan will be sized to provide 9,000 ACFM minimum. This gives an air velocity in any test tunnel of at least 60 Ft./Min.

5. Spoil Placement

Spoil to be placed over the test tunnels will be obtained at a truck dump and hauled an average of 3,770 feet to the point where it will be dumped at the top of the bank. The existing spoil dump is approximately 100 feet higher than required for the test program. Scrapers will be used to cut a ramp in the top of this dump so that trucks can dump at the required level. A bulldozer will be used to distribute the spoil from the top of the bank. The spoil distribution will be controlled to simulate dumping from a dragline. Rate of dumping of spoil is anticipated to be 5,000 tons or 3,700 cubic yards per hour. The only auxilliary equipment anticipated is a motor grader and a water truck for haul road maintenance.

Design Changes

If major design changes are necessary to comply with the goal of the contract, the contractor will make all necessary changes and schedule a second test. The work would include new detail engineering, fabrication and delivery schedules and reinstallation of culverts.

Data Collection and Evaluation

1. <u>Data Collection</u>
   A Civil engineer and a technician will be assigned to the site for the duration of the project. A senior engineer will be at the site during initial layout and through the start of the test period. Data will be collected by the engineering team and transmitted to the main office. The senior engineer will visit the site when deemed necessary by the contractor during the test period.

2. <u>Data Evaluation</u>
   Data from two areas of the test program will be evaluated. First, the pressures recorded will determine the load characteristics of the spoil pile on the culverts. The analysis of these pressures, as continuously recorded during the backfilling operation, will indicate the behavior of a spoil pile and will give a history of the stress changes with time as the spoil dumping is proceeding.

   Since the behavior of spoil piles during dumping has not been studied, these results may be used not only to determine load characteristics, but to develop new criteria for spoil pile stability and better techniques of spoil pile construction.

   The second area of data will determine the tunnel response to the pressures exerted by the dumping of the spoil. The recorded deformations of the tunnel sections will act as a check on the pressure readings and provide documented test data for the development of culvert design criteria for use under deep loosely placed spoil piles.

   During the load test period, a status chart will be maintained for each test section. These charts will be available for inspection by visitors to the test site. Provisions will be made to brief all visitors and to conduct tours through the test sections.

Report

The contractor will submit to the USBM a report covering all phases of Culvert Field Load Test, including all data obtained, conclusions, and recommendations.

APPENDIX

IN-PIT COAL HAULAGE SYSTEMS

Coal Loading Costs

Truck Haulage Costs

Shiftable Conveyor Operating Costs

Portable Conveyor Operating Costs

Loader Haulage Costs

Scraper Haulage Costs

Trackless Train Haulage Costs

Ref: 3.3.4

COAL LOADING COSTS

Coal Tons Per Year	Bucket Wheel* Excavator		Shovel		Loaders	
	Total Cost $/Hr.	Cost Per Ton ($/Ton)	Total Cost $/Hr.	Cost Per Ton ($/Ton)	Total Cost $/Hr.	Cost Per Ton ($/Ton)
1,000,000	876.54	.614	1,041.87	.471	764.58	.428
2,500,000	354.00	.248	480.54	.217	390.36	.219
5,000,000	223.30	.157	293.43	.133	265.62	.149
7,500,000	266.90	.187	231.06	.104	307.20	.172
10,000,000	223.29	.157	293.43	.133	265.62	.149

* Costs Include Mobile Transfer Conveyor

TRUCK HAULAGE COSTS

	Operating Costs Ownership Cost $/Hr.	Operating Cost $/Hr.	Total Cost $/Hr.	Opr. Hrs. Hr.	Cost/Ton $/Ton	Total Truck Haulage $/Ton
Loading 120 Ton Trucks						
35 CY Shovel	149.70	61.55	211.25	2,260		
12 CY Loader	37.41	44.77	82.18	2,260		
Ave.	93.56	53.16	146.72	4,520	$0.13/Ton	
Haulage Distance 120 Ton Trucks						
100 Ft.	39.20	43.79	82.99	5,785	0.10	0.23
2,640 Ft.	39.20	43.79	82.99	7,917	0.13	0.26
5,280 Ft.	39.20	43.79	82.99	10,208	0.17	0.30
10,560 Ft.	39.20	43.79	82.99	14,653	0.24	0.37
Loading 170 Ton Trucks						
35 CY Shovel	149.70	61.55	211.25	2,260		
36 CY Loader	79.10	70.17	149.27	753		
Ave.	132.06	63.70	195.76	3,013	$0.12/Ton	
Haulage Distance 170 Ton Trucks						
100 Ft.	43.42	72.49	115.91	4,069	0.09	0.21
2,640 Ft.	43.42	72.49	115.91	5,588	0.13	0.25
5,280 Ft.	43.42	72.49	115.91	7,157	0.17	0.29
10,560 Ft.	43.42	72.49	115.91	10,294	0.24	0.36

SHIFTABLE CONVEYOR OPERATING COSTS

Shiftable Conveyor Length	Labor $/Hr.	Mat'l. $/Hr.	Power $/Hr.	M&R $/Hr.	Depr. $/Hr.	Additional Equipment	Total $/Hr.
100 Ft.	19	2	2	4	4	0	31
2,640 Ft.	19	8	6	17	17	18	85
5,280 Ft.	19	14	12	28	28	18	119
10,360 Ft.	19	25	24	50	50	18	186

SHIFTABLE CONVEYOR HAULAGE COST/TON

Shiftable Conveyor Length	Loader $/Ton	Shiftable Conveyor $/Ton	Total Conveyor Haulage
100 Ft.	.16	.02	.18
2,640 Ft.	.16	.06	.22
5,280 Ft.	.16	.09	.25
10,360 Ft.	.16	.13	.29

PORTABLE CONVEYOR OPERATING COSTS

Conveyor Length	Labor $/Hr.	Mat'l. $/Hr.	Power $/Hr.	M&R $/Hr.	Depr. $/Hr.	Additional Equip. $/Hr.	Total $/Hr.
100 Ft.	19	2	2	4	4	-	31
2,640 Ft.	19	10	23	19	19	-	90
5,280 Ft.	19	43	19	39	39	-	159
10,360 Ft.	19	39	87	78	78	-	301

PORTABLE CONVEYOR HAULAGE COST/TON

Conveyor Length	Loader $/Ton	Conveyor $/Ton	Total Conveyor Haulage $/Ton
100 Ft.	.16	.02	.18
2,640 Ft.	.16	.06	.22
5,280 Ft.	.16	.11	.27
10,360 Ft.	.16	.21	.37

LOADER HAULAGE COSTS

	Ownership Cost $/Hr.	Operating Cost $/Hr.	Total Cost $/Hr.	Opr. Hrs. Hr.	Cost/Ton $/Ton
24 CY Loader					
Haulage Length					
100 Ft.	45.64	70.71	116.35	7,014	0.16
2,640 Ft.	45.64	70.71	116.35	30,864	0.72
36 CY Loader					
Haulage Length					
100 Ft.	79.10	70.17	149.27	4,676	0.14
2,640 Ft.	79.10	70.17	149.27	20,576	0.61

SCRAPER HAULAGE COSTS

	Ownership Cost $/Hr.	Operating Cost $/Hr.	Total Cost $/Hr.	Opr. Hrs. Hr.	Cost/Ton $/Ton
31 CY Scraper Haulage Length					
100 Ft.	54.22	59.55	113.77	8,327	0.19
2,640 Ft.	54.22	59.55	113.77	15,568	0.35
5,280 Ft.	54.22	59.55	113.77	23,171	0.53
10,560 Ft.	54.22	59.55	113.77	39,825	0.91

OWNERSHIP AND OPERATING COSTS
FOR TRACKLESS TRAIN HAULAGE

	170 Ton Tractor			3200 Ton Tractor		
Distance	Loading Cost/Ton $/Ton	Haulage Cost/Ton $/Ton	Total $/Ton	Loading Cost/Ton $/Ton	Haulage Cost/Ton $/Ton	Total $/Ton
100	.0916	.111	.203	.0916	.127	.219
2,640	.0916	.150	.242	.0916	.144	.236
5,280	.0916	.183	.275	.0916	.162	.254
10,560	.0916	.283	.375	.0916	.189	.281

☆U.S. GOVERNMENT PRINTING OFFICE: 1980-740-145/1101