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ENVIRONMENTAL ASSESSMENT OF SURFACE SHORTWALL MINING

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UNITED STATES BUREAU OF MINES
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16. Abstract (Limit: 200 words)

The purpose of this investigation was to assess the environmental impact of the surface mining methods currently used in the steep-sloped areas of central Appalachia--southern West Virginia, eastern Kentucky, southwestern Virginia, and northeastern Tennessee. Comparisons are made between mountaintop-cross ridge mining, contour strip, augering, and an innovative method--surface shortwall mining that was attempted at Julian, W. Va. Included in the report are a discussion and analysis of current Appalachian production, reserves, and the extent of land affected on a county-by-county basis. Additionally, the seams within the steep-sloped region were assessed according to minimal standards of thickness, surrounding lithology, and areal extent to determine their amenability to surface shortwall mining. The seams were tabulated with their ash, sulfur, and British thermal unit content. Only minimal statements are made concerning quantity because of the narrow set of conditions required by the shortwall method. Other sections deal with the possible technical failings of an operational surface shortwall system based on field studies, discussions with people experienced with shortwalls, and research into ground control problems at sites where shortwall and longwall operations have been monitored.

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FOREWORD

This report was prepared by Skelly and Loy, Engineers and Consultants, 2601 North Front Street, Harrisburg, Pennsylvania under USBM Contract Number J0285033. The contract was initiated under the U.S. Bureau of Mines Mining Environmental Research Program. It was administered under the Technical direction of the Twin Cities Research Center with Mr. Bruce Nelson acting as the Technical Project Officer. Mr. Larry Rock was the contract administrator for the Bureau of Mines.

This report is a summary of the work recently completed as part of this contract during the period September 13, 1978 to June 17, 1979. This report was submitted by the authors on December 21, 1979.

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EXECUTIVE SUMMARY

INTRODUCTION

The project's purpose was to investigate the conditions, both operational and environmental which existed in the course of an experiment financed under an Environmental Protection Agency contract and conducted by the West Virginia Surface Mining and Reclamation Association. Further project purposes were to combine that information with other data from field trips and the results of past monitoring investigations to arrive at a relative assessment of the surface shortwall in terms of both its relative environmental impacts and its technical feasibility in steep slope areas of Appalachia. These comparative assessments were made against other well established mountaintop removal and contour mining techniques.

CONCLUSIONS AND RECOMMENDATIONS

The basic conclusions arrived at were that the surface shortwall technique is technically feasible, given further government sponsorship and experimentation. There are several major maneuvers such as inside and outside curves which need further work. Since environmental monitoring was never completed on the EPA experiment, it would be well to reconduct a similar experiment and perform similar environmental monitoring. Conclusions drawn were that subsidence would occur equal to about 75% of seam height, acid drainage could result from updip mining and could be avoided by downdip mining. Other conditions were that aesthetic impacts would be much less than with conventional surface mining methods, both in terms of the reduced visual impact of the smaller highwall and the reduced number and sizes of fill storage sites and environmental mitigation measures.

Research suggestions focused on both the technical and the environmental aspects. Technical aspects involved an evaluation of underground equipment capabilities in above ground usage, a redesign and evaluation of armored face conveyors and shortwall support systems. Other health and safety related research suggested was further investigation of the rock mechanical stability of shallow overburden situations where the arching theory no longer applies.

MINING IN STEEP SLOPED APPALACHIA

The topography of steep sloped Appalachia reflects the presence of highly resistent Pottsville sandstones and conglomerates. These rock units have caused a highly dissected appearance to the topography requiring a special mining method such as cross-ridge mountaintop removal, and various contour methods. The planning and operational considerations for these methods, particularly the contour methods, is very similar to those of the surface shortwall. Shortwall requires use of different bench clearing techniques since no blasting can be done. At the Julian site, a 3 yd^3 dipper shovel was used with good results.

Operational considerations of surface shortwall mining include the deployment and extraction of the shortwall face. This was accomplished with some success a number of times during the experiment. Other potential problems deal with negotiating curves and with the possible alignment and geoengineering problems associated with each type of curve - inside or outside curves.

Augering has requirements similar to shortwall mining but a review of the operating characteristics and its failings places augering in an unfavorable position as compared to surface shortwall mining. Recovery rates are far poorer and the environmental effects of augering can be far worse.

A few of the seams amenable to shortwall mining were reviewed for quality by a set of criteria including a 3-4 foot minimum seam thickness and certain overburden characteristics such as presence of shales and sandstones of varying characteristics. Though quantity figures are attached to reserves (Appendix A), the figures are not to be interpreted too closely.

ENVIRONMENTAL IMPACT ANALYSES

The greatest potential adverse impacts from shortwall are subsidence and effluent from the broken highwall. As compared with augering, though subsidence can be a greater problem with shortwall, development prospects for most of the area are very minimal, so subsidence would affect few people. The effluent problem with shortwall stems from the broken rock. It will therefore be very difficult to control if it occurs. Whether or not it will occur is not determinable.

The impacts associated with individual unit operations should be much the same as for any contour type mining operation. However, because of a reduction in size of the operation as a whole and the individual unit operations, many environmental mitigation devices such as sediment ponds and gathering ditches can be made smaller. The overall impact would also be expected to be less due to reduced or no blasting, a consequent larger spoil size consist which reduces dust and far easier AOC reclamation of the smaller highwall. It is likely that special packing of the subsided area could preclude entry of water and thereby further reduce the impacts.

As a general observation and as a form of ranking, surface shortwall mining was given a higher ranking than contour mining for the previously cited reasons. Cross-ridge techniques were ranked slightly higher because of the complete coal extraction afforded. Augering was ranked as a fourth.

INTRODUCTION

From 1974 to 1977, the EPA and the West Virginia Surface Mining and Reclamation Association conducted a surface shortwall operation at Julian, West Virginia. Results of the operation were expected to show a reduction in total environmental disturbance per ton of coal mined, thus speeding the way for increased use of typical underground mining methods in surface mining situations. It was anticipated that the methodology could eventually be applied in area mining situations in the Midwest and West, though the concept might be in a somewhat varied form. While invoking international excitement, the results of the experiments drew mixed reactions from the parties involved.

More specifically, the purpose of this project was to look at the mining methods currently used in the steep slope areas of Appalachia and determine the environmental impacts of these methods as compared to an idealized situation with surface shortwall concepts. In performing this comparison, it was found that the single case of surface shortwall mining conducted to date was an inadequate statistical base for a direct comparison, particularly since an acceptable report on the Julian project has not yet been released. Thus, indirect comparisons of environmental and engineering/economic factors were necessary with an idealized surface shortwall scenario as the base case. Further comparisons of the methods were then reviewed on the base case example.

An attempt was made to quantify the range of conditions in which a surface shortwall would be operable, and to determine the range of production levels at which a surface shortwall would be economically feasible within these conditions. A literature search into the background of the Julian experiment was conducted to identify the conditions that were found at the site; and to compare these to the conditions, geologic and economic, determined necessary by industry experience for the efficient operation of shortwalls. Once identified, these conditions were applied to the seams found in the steep slope areas of Appalachia. Although there are extensive areas of steep slope conditions in other parts of Appalachia, such as Alabama, the area taken for prime consideration included eastern Kentucky, northeastern Tennessee, southwestern Virginia and southern West Virginia (Figure 1).

This, the final report, presents a review of the conventional mining methods applicable to moderate and steep slope areas with a discussion of the mining limitations imposed by either size or cost of equipment. In this way an introduction is made to the comparative, economic and geotechnical considerations important in planning a surface shortwall operation. While the surface shortwall requires a bench, requirements peculiar to the method do not allow the use of standard contour methods and the surface shortwall methods. Instead, the surface shortwall has its own requisite benching practices. All of these mining factors have been defined to show conditions which are amenable to surface shortwall mining.

Comparative environmental effects of the mining methods are discussed. A matrix shows the types and relative amounts of environmental degradation to be expected from the different methods and a set of tables

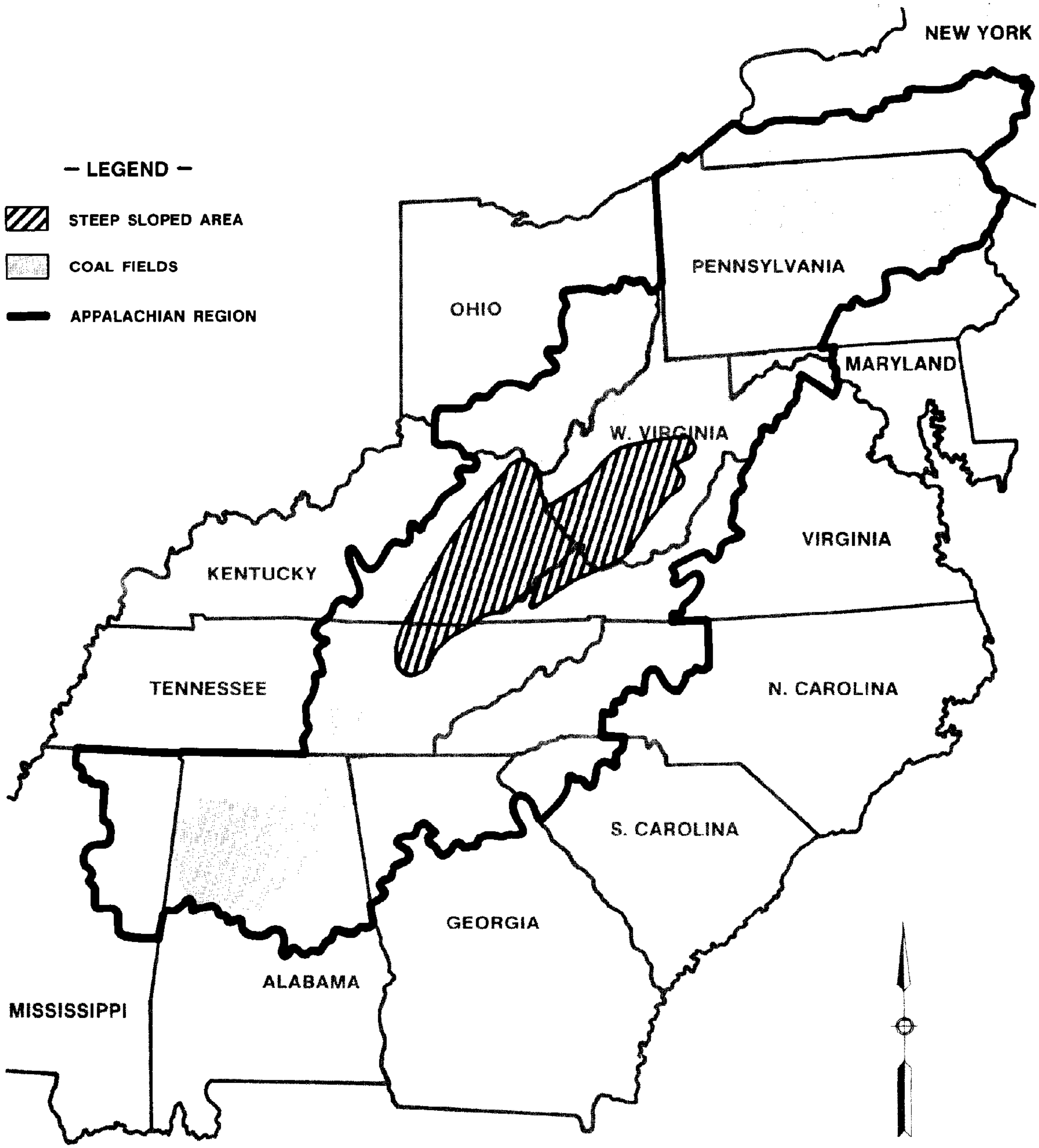


FIGURE 1. - Appalachian coal fields and steep sloped study area.

shows the areas under discussion with the areal extent of the seams which are amenable to the surface shortwall method. The large number of variables involved in the surface utilization of an underground method cause doubt as to the validity of the figures shown as a resource base available to shortwall mining. This is particularly true in light of the very limited experience gained at Julian. In view of this, a better estimation could probably be gained through further experimentation and a good testing program of the capabilities of a "wall" type system in the geologic, topographic and economic constraints as they are discussed herein.

Recommendations have been made for further research and attached to this report. Accompanying this is a discussion of alternative mining methods which could ease the problems with abutment pressures found at the Julian site.

CONCLUSIONS AND RECOMMENDATIONS

While the original experiment which provided the basis for this project was not well documented, alternative bases for concept development were found and, with evaluation, valid conclusions have been developed. There are several categories of conclusions to be drawn falling loosely along lines of:

- A comparison of the newly assessed environmental benefits with the older assumed benefits.
- An assessment of the actual technical capabilities of the system in light of the experiment and other related mining practices.
- The real level of use which a system of this productive caliber can expect in Appalachia.
- Alternative uses of this or similar systems elsewhere.
- The additional research and technology needed to further the use of surface shortwall techniques.

A review of the environmental benefits of the surface shortwall system shows that most of the claimed advantages would be verified if the system was put into a commercially operable mode. Other conclusions to be drawn can be summarized as:

- Subsidence would occur approximately equal to 75% to 90% of seam thickness. In some situations, this would pose difficulties in post-mining land use. In the steep slope areas, it would not because most of the hills are used for little residential or commercial development. This would result in a slight aesthetic impact and an undetermined impact on the root systems of trees and shrubs.
- Acid drainage could result from updip mining. This would complicate the mining process quite a bit in seams that undulated or rolled.

- Acid bearing rock layers immediately above the coal would be buried deep within the spoil. While this was cited as an assumed advantage, it could be a disadvantage from the standpoint of allowing infiltrating water to mix with these acid producing layers where there is a fireclay understrata.

- The aesthetic impacts would be greatly reduced from nearly any other surface mining method, since only a 40 foot highwall would need to be reclaimed against a highwall of 100 feet or more for other surface techniques. Concomitant with this is the reduction in ecological disturbance since clearing and grubbing would not be necessary over the shortwall mining.

- In a more general sense, much less rock would be disturbed requiring less designing and implementing of sediment control devices such as ponds, traps, and ditches. Most of these devices would still be needed but their size could usually be substantially reduced.

There is really no reason to believe that the method would not work on a full scale production basis. The problems which were encountered have in retrospect been seen as primarily site specific. If given the opportunity to fully develop the method, its productive capabilities could nearly match those of a similar contour operation while also requiring much less spoil movement, fewer valley fills and meanwhile extracting nearly 100% of the resource. The few potential problems which do exist lie in a lack of legislative definition of the system and a lack of experience in this type of equipment usage. Ideally, the face could be made as much as 250 feet long thereby further diminishing the role of the bench clearing process. As stated earlier, the entire operation must focus on the shortwalling process — this including the overburden removal and reclamation. Because of the relative lack of equipment, the overall pit dimension could be far smaller than many contour operations of the same productive level.

While a few attempts were made at maneuvering the equipment including deployment and retraction of the chock line, this is still a very little understood methodology, particularly as it applies to curves. Certainly, improved alignment techniques will be required for these maneuvers.

The question of the level of use to which this method would be put is a difficult one. There are a number of determinants which have not been adequately assessed. A far more detailed estimation of amenable coal reserves is required — an estimate which is not presently possible because of a lack of knowledge of the coal resources. Acceptability to the mining industry is another factor which may have been influenced by what was felt as a poor showing at Julian. To bolster confidence in the method will certainly require further, more positive experimentation.

The technique may also find use in other mining situations in different parts of the country. Seams in the midwest, for instance, may be amenable to trench and shortwall type mining. There, a much more valid estimate of reserves in place is possible, therefore giving a better assessment of its viability.

Clearly, additional research is needed both in this field and in other fields which would impact this method. This research is needed in both technology development for the mining system and in environmental impact mitigation practices. More specifically, needed technology development includes:

- A reevaluation of the capabilities of the typically underground equipment to work in the conditions found at the surface (temperature, etc.)

- New conveyor technology to make the armored face conveyor more easily extendible or retractable. This would aid in lengthening or shortening the face.

- New chock/shield support technology to make them more applicable to the particular abutment pressures found in a surface shortwall application.

- An assessment of the rock mechanics reactions in shallow overburden situations where the arch theory no longer applies.

- Better definition of the reactions of an exposed highwall to various types of undercutting. For instance, it might be better from a geotechnical standpoint if the miner cut its way out rather than cutting its way in.

- Furthering this, methodologies should be developed which use a braced cutting auger to slice out 15-20 feet of coal from beneath the highwall. This would require further development of highwall stabilizing practices.

Needed research related to environmental mitigation or research evaluation would include:

- Assessment of impact of blasting at the highwall on the hydrology of the hill. Several people stated that such fractures are propagated hundreds of feet along strong sandstone strata into the hill.

- Development of technology for sealing highwalls to preserve perched water tables or to prevent acid discharges from auger or shortwall operations.

- Further examination of midwest coal reserves for amenability to either trench/auger or trench/shortwall techniques. This would include an assessment of environmental impact in terms of both environmental disturbances and the economic impact on farmland values in the midwest.

MINING IN STEEP SLOPED APPALACHIA

INFLUENCE OF TOPOGRAPHY AND GEOLOGY

The topographic/geologic conditions in the steep slope areas under consideration are generally the major factor in determining the mining methods to be used. Although much of the rest of Appalachia might be classified as hilly or rolling, central Appalachia is generally thought of as mountainous, often with very steep slopes. Those areas which have been found suitable for mining have often been only of a moderate slope, usually less than 30°. Since topography directly reflects the geology of the area, geology must be considered in evaluating an area for mining.

The geology of the area (Figure 2) is generally characterized by a widespread uplift in the Allegheny Plateau which consequently brought a lower rock formation to the surface. This lower formation, the Pottsville, includes the Kanawha, New River and Pocahontas series, all of which have higher percentages of massive, erosion-resistant sandstones in them than the overlying Allegheny and Conemaugh formations which have eroded away in this area. These higher formations form the rolling topography which characterizes northern Appalachia. As a direct result of the cliff-forming tendencies of the highly resistant Pottsville sandstones, and the dissecting action of the local streams, the relief in these portions of Kentucky, Tennessee, Virginia, and West Virginia is much greater than that of the northern Appalachians.

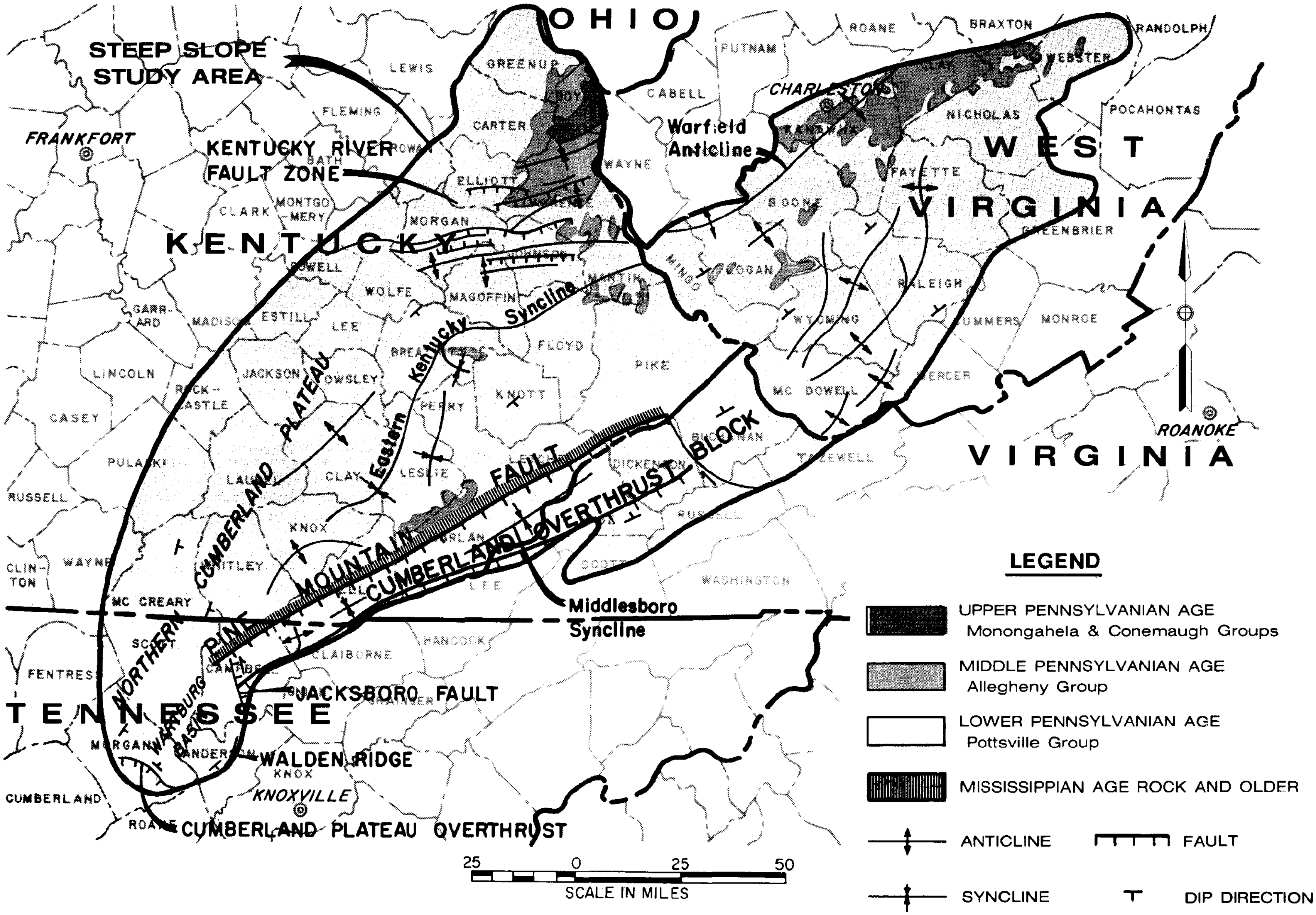


FIGURE 2. - Geologic map of steep sloped Appalachia.

This geologic/topographic (Figure 2 and Figure 3) combination besets mining ventures in the area with environmental problems not encountered elsewhere in Appalachia. Increased erosion and stream sediment loads, acid drainage, and assurance of adequate final reclamation are a few of the greatest difficulties. Other problem areas include wildlife access across highwalls, windblown erosion and maintenance of the hydrologic balance in places where a phreatic surface may have previously existed. Even where mining occurs above the water table, as is usually the case in these steep slope areas, there are often local water tables perched on impervious layers which may be disturbed by mining. The legacy of past mining practices, particularly those that left highwalls intact and utilized outslope deposition of overburden, is not one to be proud of: approximately 20,000 miles of highwalls and 1,700 miles of massive outslope landslides, as well as thousands of acres of orphaned lands and severely degraded streams and lakes (Doyle, 1976).

As mandated by the recently passed Surface Mining Act, there are only four broad categories of surface mining techniques which are allowable in steep slope areas: 1) mountaintop removal or cross-ridge mining techniques with their ancillary overburden storage method — the head-of-hollow fill; 2) contour mining with accompanying on-bench backstacking; 3) auger mining; and 4) innovative techniques. While not specifically addressed by the regulations, surface shortwall/longwall methods would fall in the latter category. The importance of surface mining in Appalachia is illustrated by Figures 4 and 5 which show the production and reserves of the steep slope areas as well as the rest of Appalachia.

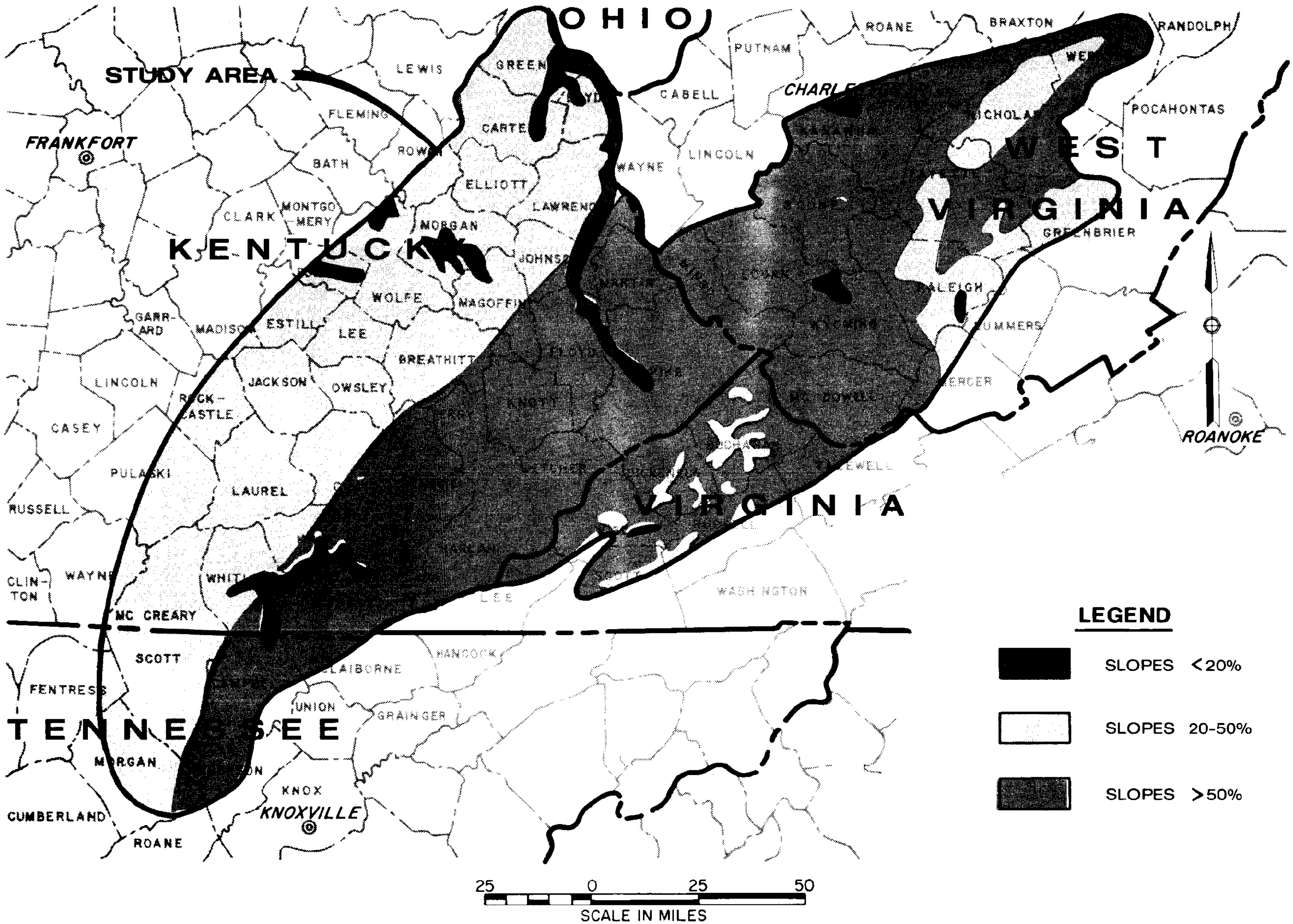


FIGURE 3. - Summary of slopes within study area.

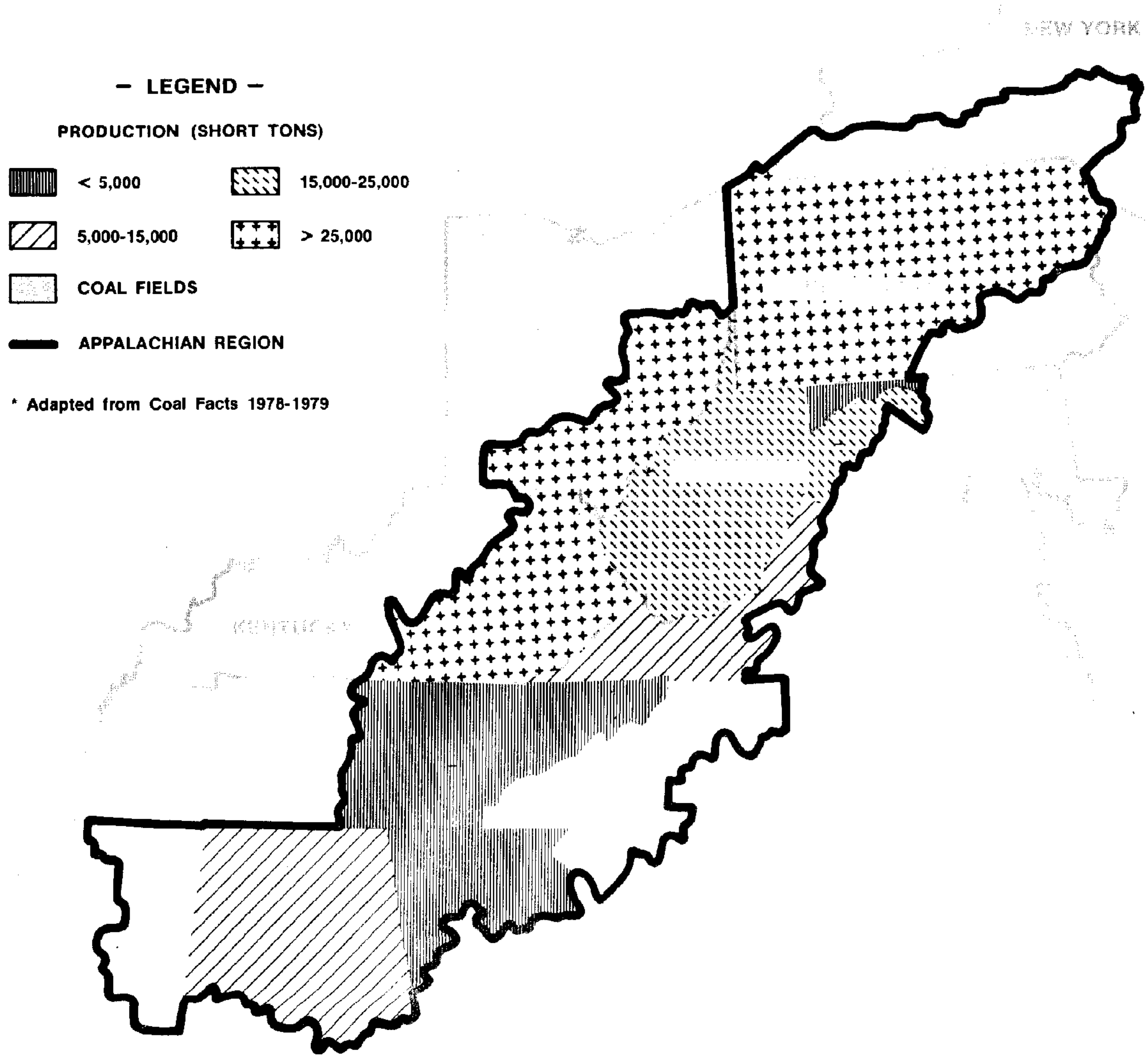


FIGURE 4. - Surface coal production during 1977 in Appalachia.*

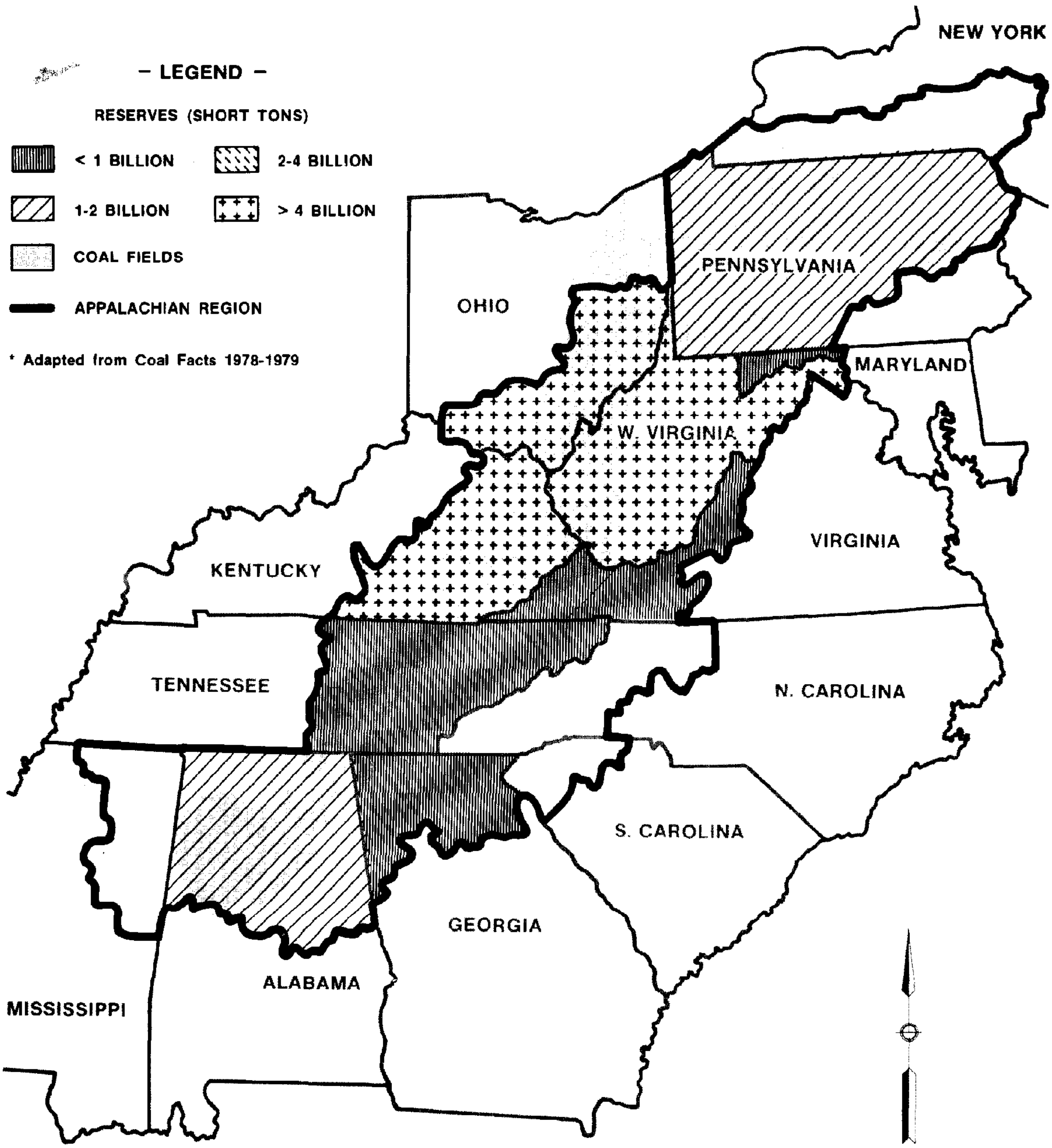


FIGURE 5. - Strippable coal reserve tonnage in Appalachia, 1976.*

The problem now becomes one of determining the mining method which is most efficient and practical in the conditions that prevail — both topographic/geologic and economic. Table 1 represents the distribution of 248 selected surface mining permits in the steep sloped central Appalachian area in 1973, before enactment of the Surface Mining Act. According to this survey, contour methods were predominant by a 2:1 margin over mountaintop operations. This may be due to the fact that the efficiency of contour methods is a function only of topography, while mountaintop or cross-ridge operation efficiency is a function of topography, seam thickness(es) and the level of the seam(s) with respect to the top of the mountain.

Many of the conclusions which could be drawn from that data are now invalid due to the changes in what was a third major determinative— legislative requirements. State laws have certainly existed for many years but their impact on choice of mining methodology was always clouded by the extent of enforcement provided. Implications of this are that while the regional topographic conditions may have been constant, state lines could have great effects on the methodology of mining. Because of what will be a blanket enforcement plan on a regional basis under OSM, it is expected that usage of specific mining methodologies will become more uniform throughout the region even as individual states gain primacy.

The mining industry is, then, in a period of transition in the steep slope areas. As such, it is difficult to determine how this major factor will impact the choice of mining method until final regulations have been established and the industry has stabilized. It is expected that the

TABLE 1. - Distribution of selected surface mines by method and slope in the central Appalachian study area.*

SLOPE (Degrees)	CONTOUR	MOUNTAINTOP REMOVAL	AUGER
0–5	1	0	0
6–10	3	0	0
11–15	9	3	0
16–20	25	19	2
21–25	59	17	2
26–30	48	22	4
31–35	20	9	3
> 35	1	1	0
Total (Percent)	166 (67%)	71 (29%)	11 (4%)
SUMMARY (Percentages)			
Rolling Terrain (0°–20°)	63%	37%	0%
Steep Slope (> 21°)	68%	26%	6%

Sample Size = 248 Mines

*SOURCE: ICF, Inc., Energy and Economic Impacts of HR-13-950 Surface Mining Control and Reclamation Act of 1976, CEQ/EPA #EQ6AC016, September 1977.

percentage by number of mountaintop removal operations, specifically cross-ridge, will increase because of cash flow benefits and because in many cases this is the only method capable of working in steep slopes in compliance with the regulations. However, bonding requirements can be more stringent for mountaintop removal operations.

PLANNING CONSIDERATIONS COMMON TO ALL METHODS

In any surface mining operation, utmost importance must be accorded mine planning to alleviate complications in development or in reclamation, since a lack of planning can cause more environmental and aesthetic harm than would otherwise result. To this end, planning for mining generally should follow a fairly strict regimen incorporating the following phases:

- site feasibility
- mining
- reclamation

The necessity for the feasibility planning becomes more apparent as the physical complexity of the situation increases (multiple seams, overburden geometry, pollution potential, market conditions, and distance to cleaning plants).

Feasibility is generally based on one or more of the following physical and economic realities:

1. The overall stripping ratio will be the greatest determinant in assessing the property, particularly in conjunction with the slope of the area. This combination will dictate feasible bench width which in turn dictates the methodology and equipment used.

2. Stripping ratios may also become too high or may change due to pinching of the seam. Though use of certain techniques can sometimes eliminate this problem, depending on seam geometry it can become acute. The real impact would be in terms of mine planning for actual conditions expected two or three months ahead.

3. A suitable valley fill site needs to be found nearby into which the first cut of overburden can be placed. The amount of overburden strongly depends on the geometry and swell factor of the material, as well as the material handling method. The valley fill is of particular importance since it is the only method of spoil disposal allowed other than backstacking on the bench. Because the valley fill must have long-term stability, a valley or hollow must be chosen with drainage grades, etc., which are amenable to its use as a fill site.

4. Often, for any particular operator, the methods used in the past or the equipment on hand dictate applicability and, therefore, feasibility. However, there may be a need for additional or different equipment at the new site.

5. Alleviation or mitigation of environmental degradation may be prohibitively expensive. For instance, the site specific conditions may disallow alternatives other than a very extensive drainage system for sediment control, including ponds, flow check devices and drainage ditches.

6. Steep slope surface mining operations are often far removed from market over frequently treacherous roads. This will lead to a diminished market potential for the coal since transportation costs will be high.

An assessment of feasibility can generally be accomplished by standard exploration techniques such as core borings, a review of geological records and a careful examination of any previous mining records. These generally give a good idea of geologic conditions and eliminate siting a mine where the coal is of questionable market value because of location or grade.

Inherent in a feasibility study is the need to assess the economic viability of the venture by balancing the anticipated market against projected maximum production costs and desired profits through the life of the mine. These economic considerations can become very complex when viewed from the standpoint of the previously cited factors.

The efficacy of the mining method used is predicated on the equipment combinations which are workable considering the topographic conditions and the stripping ratio at the site. Figure 6 shows that the slope is crucial as a determinant of bench width. The implications of this in the mining process are not great until backfilling is nearly complete and the equipment has to function in an increasingly smaller area. Also, the reclamation becomes exceedingly difficult if attempted on an outslope surface which is angled at nearly the angle of repose. For a seam of coal 4 feet thick, a 100 foot highwall would result in an average 11:1 stripping ratio which is marginally profitable. But for a 30° slope with that highwall, the bench would be 170 feet wide at the base and 85 feet wide when half backfilled. This could pose problems in light of specific limitations of the equipment generally used in surface operations. For instance, Table 2 indicates the turning radii for most of the equipment types used in Appalachia. It is obvious that in the table example, this limitation could have significant impact on the choice of mining method.

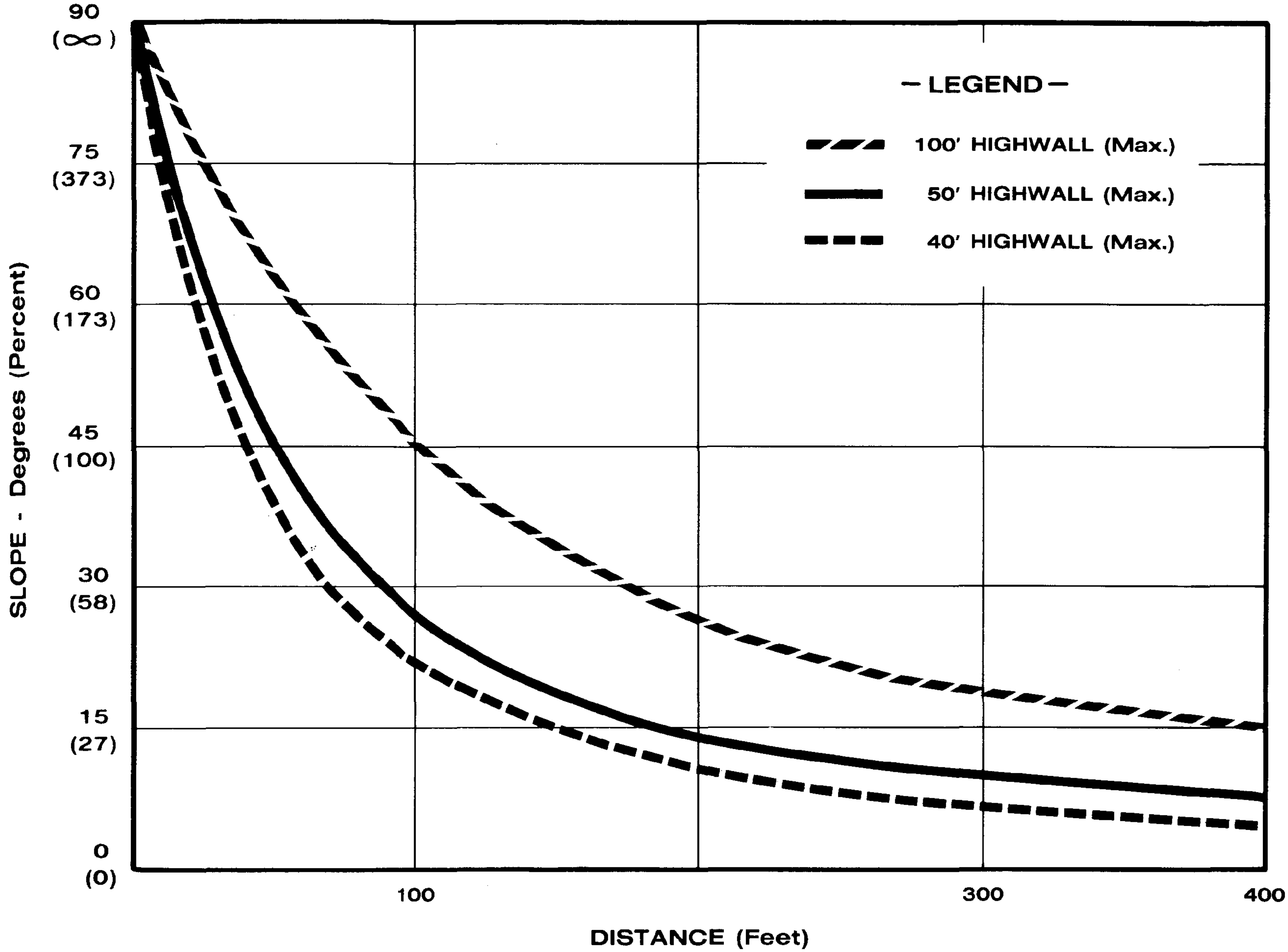


FIGURE 6. - Bench widths for various slope angles and highwall heights.

TABLE 2. - Ranges of turning radii for mining equipment.

EQUIPMENT	SIZE	TURNING RADIUS
Front End Loader	6–9 $yd.^3$	11 yards
	9–12 $yd.^3$	14 yards
Scraper	6–10 $yd.^3$	11 yards
	10–15 $yd.^3$	14 yards
Trucks	8–12 $yd.^3$	10 yards
	12–18 $yd.^3$	14 yards
Dozers		Turn in own length

Prior to initiating the actual mining, environmental safeguards need to be established. The problems associated with surface mining are many and varied; however, one aim of pre-planning should be to arrive at a satisfactory method of site drainage. The intent here should be twofold: 1) to divert all drainage from areas unaffected by mining into natural stream channels, and 2) to divert all drainage from affected areas to sediment control structures. Though specific design is a matter of company preference, drainage structures are generally of several types: diversion ditches, culverts, filters, and sediment ponds. Filters are not meant to be alternatives to actual sediment ponds and do not necessarily reduce the required pond size, but are meant to reduce sediment loads reaching the ponds. Sediment structures may be of several types:

- Gabion - rock-filled wire baskets
- Crib - rock-filled concrete cribs
- Rock dams
- Excavated pond - overflow discharge
- Excavated/Embankment - with spillway
- Embankment - with a riser and emergency spillway

OPERATIONAL CONSIDERATIONS COMMON TO ALL METHODS

Following placement of environmental safeguards, the actual mining process can begin. The first area to be affected is scalped of all organic materials (cleared and grubbed). Timber can be sold commercially or certain portions of it can be used in sediment control by constructing flow velocity checks. Next, soil is removed, segregated and seeded in a storage pile. In the steep slope regions, topsoil is minimal (0-6 inches) and often spotty at best, precluding removal by large excavating equipment. Instead, the best suited layer or layers ($\geq$6") of overburden material must be segregated for later use as the reclamation top cover. Typically, a bench is then cleared and drilling and blasting initiated. The material from this initial cut is then taken to a valley fill area where it, and all other excess overburden, is stored. On removing the initial cut, an outcrop barrier is left to act as a natural seal or filter for acid drainage and to act as an abutment for the toe of the backstacked overburden. This barrier must be left along the entire outcrop. If the mining is actually reaffecting older mined areas, the barrier may not be present, which only slightly affects the economic or technical aspects of the mining. Size of the initial cut will vary depending on:

- size of equipment to be used in full-scale mining
- anticipated swell of overburden
- geologic and topographic contours
- availability and proximity of a suitable valley fill site
- area bonded for mining

Beyond the initial cut, excavation methods may vary a great deal depending on:

- number and spacing of seams
- presence of toxic overburden
- spoil haulage distance
- equipment type
- equipment size
- quantity of equipment
- geological formation and lithology
- final land topography

The drilling and blasting techniques for all surface mining methods (except shortwall mining) are similar and will therefore be treated here. The major considerations are:

- drill depth (30', 40', etc.)
- drill hole spacing (10' x 12', 12' x 12', etc.)
- drill hole size (6 3/4" to 10 5/8')
- type of explosive (ANFO or other)
- type of detonating device (Primacord, caps, or other)
- detonation pattern (including delays used - simultaneous row or modified chevron)
- explosive load and its placement (100-150 lbs. per hole)

Physical features of the mine site which influence the choice of drilling and blasting alternatives include:

- lithology of overburden
- thickness of overburden
- fracture spacing or desired material size
- noise and vibration limitation
- moisture content of overburden
- distance of overburden displacement
- distance to nearest dwelling which affects the
- maximum amount of explosive detonated (OSM)

Once mining has progressed into full production, reclamation must be undertaken within the guidelines of the approved plan. In addition to post-mining land use (if any), other items must be considered as part of reclamation:

- regrading - provides the final landform
- slope stability for both the backstacked material and any contiguous or nearby valley fills
- seedbed preparation and appropriate amendments
- revegetaion - provides habitat, controls erosion, and improves aesthetics

Because much of this land may be used at some time in the future for development, it is of utmost importance that it be reclaimed properly. For spoil stability, a minimum factor of safety of 1.5 is presently specified in mining regulations for all final fill grades and, in many instances, the length of uninterrupted slope is limited. Also, segregation and burial of toxic substances is required to reduce the chance for acid leaching or discharge into what may later be a recharge zone for local wells.

Revegetation must be done according to the performance standards set in the Surface Mining Act. Typically this calls for seeding in accordance with the provisions of the post mining plan using indigenous species where possible. Introduced species may be used but only under approval of the permitting agency. For application of the mixture of seed, fertilizer, mulch and water, hydroseeders are popular primarily because of the slopes involved. For the mulch, generally the brush can be chipped and spread as a wood fiber. The actual degree of revegetation is governed according to strict minimal reclamation standards (see Appendix C).

The following discussions highlight a few of the mining methods used in central Appalachia. The intent is to give a cursory view of how various equipment combinations might function within the limitations just discussed. Those methods presently used in central Appalachia can generally be divided into three distinct categories: overburden removal, such as mountaintop removal or contour haulback; pillared, such as augering; and non-pillared or complete extraction, which would include the surface shortwall/longwall concepts. Of the total surface production in Central Appalachia, 95% comes from overburden removal techniques, and 5% originates through augering. There is, at this time, no operation in the region using a shortwall concept for surface mining.

MOUNTAINTOP REMOVAL AND CROSS-RIDGE MINING

As used in central Appalachia, mountaintop removal was first demonstrated on a large scale in 1967. Popularity of the concept has increased rapidly since then because of the excellent return on investment that can be attained. Much of this benefit is achieved through use of more and/or larger equipment in severely steep sloped areas possibly combined with multiple seam conditions. As an alternative to contour mining, further benefits accrue in reduced environmental degradation, improved reclamation and heightened land value.

An increase in post-mining land use potential also often results. In confronting the problem of post-mining land use, plans must be submitted, bonded, and approved with the mining permits. To be effective, this planning must occur on a regional scale to eliminate the leveling of whole ranges of mountains, which occurs during mountaintop removal, ostensibly for future development. However, in the relatively inaccessible areas being discussed, very little actual development potential exists.

In accordance with this, the chief advantage for mountaintop removal should be the ability to replace spoil materials and conform landscaping to an environmentally useful and aesthetically pleasing use. Since most minerals will have been extracted during mining, a higher level of permanence can be associated with any planned development, unless other deep minable seams occur below the level surface mined. Newer regulations require that the proposed higher or better use of the land be bonded and the plans reviewed.

The economics of the mining process can be affected by the method of mining. Older methods attempted removal through encircling, in which all of a mountaintop site's low strip ratio outcrop coal — the "cheap coal" — was stripped before the more costly coal beneath the central portion of the mountaintop could be mined. This caused problems by isolating resources in remaining "applecores" when coal markets went sour and operators could no longer afford to economically recover the central, higher strip ratio coal.

An improved technique called cross-ridge mining, Figure 7, has evolved which eliminates many of the problems associated with mountaintop mining's multiple contour cut methods. With this approach, the greatest amount of overburden is taken at the same time as the least — the middle of the ridge is mined concurrently with the edges. Besides reducing chances of becoming spoil-bond, caused by moving successively deeper into a hill and subsequently moving more spoil into the same size backfill area, the technique provides for a much better cash flow situation.

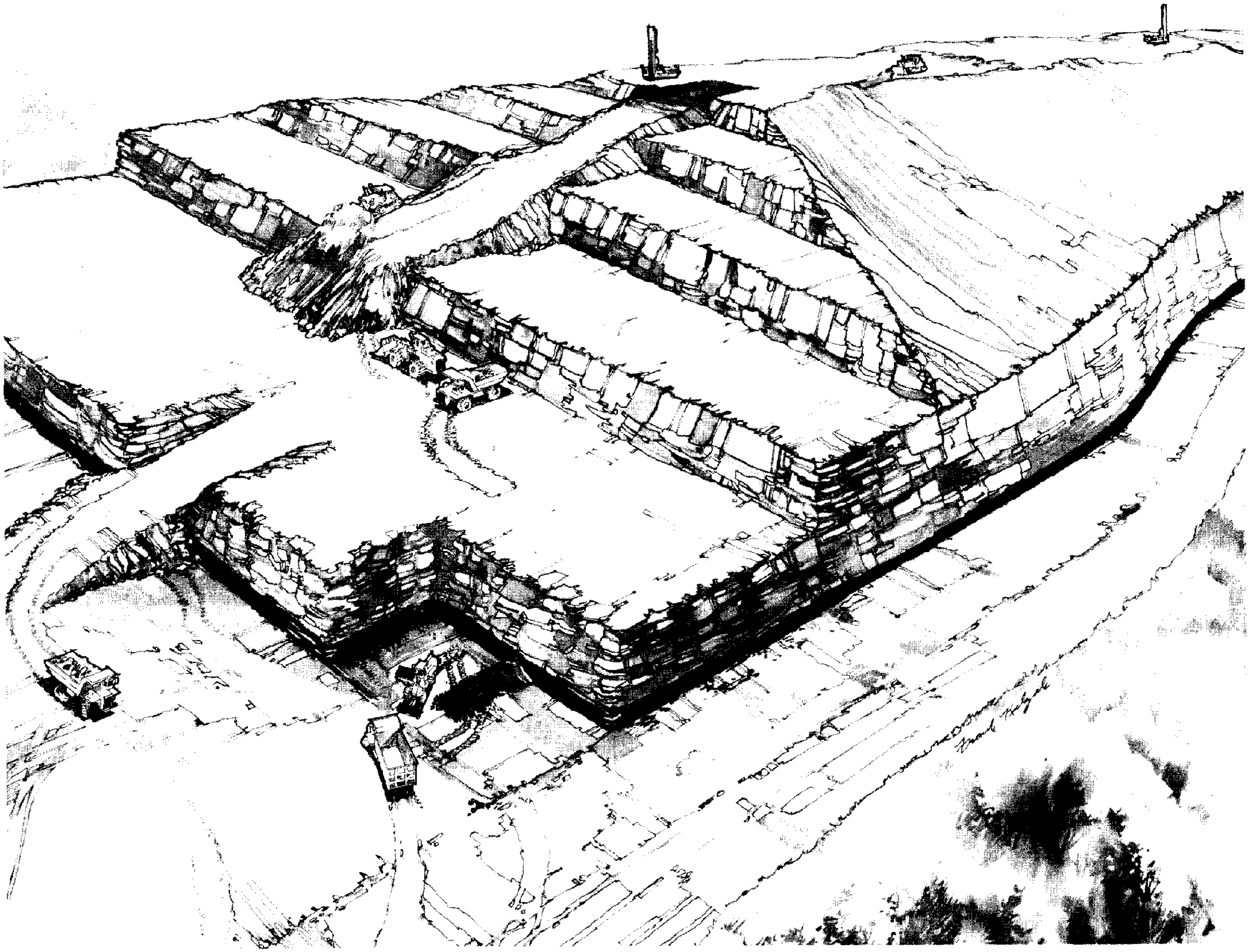


FIGURE 7. - Mountaintop removal by cross-ridge mining.

The bonding requirements have been promulgated in such a way that, if closure of a normal mountaintop operation is called for by unfavorable economics, the entire exposed highwall must be reclaimed. In using a cross-ridge technique, a shorter highwall is exposed in the mining process, which means that this reclamation process is much easier. Environmental benefits of cross-ridge over normal mountaintop removal mining are also manifest in the decreased exposure of the area to erosion, the resultant reduced amounts of airborne dusts, stream sediment loads, and other dispersed or non-point source pollutants, and fewer valley fills are required due to backstacking on the mined out ridge.

With the advent of mountaintop removal has come larger earthmoving equipment, such as 100 ton rock trucks, 14-18 cubic yard front-end loaders, large dozers, and dipper shovels. Equipment types which had never been seen in the steeper Appalachian hills are capable of use in a mountaintop removal operation because of the greater maneuvering space afforded. Often, though, in spite of space, multiple seams or other overburden geometry considerations may hamper use of certain equipment types. Stripping ratios of 14:1 or less are economically acceptable whether coal lies in one large seam or several smaller ones.

Operations usually begin with an initial cut being excavated to the lowermost seam to be mined at one end of the ridge. This cut is deposited in a nearby valley fill. Mining then proceeds along the spine of the ridge. Equipment concentrations would be in the center of the operation where the greatest amounts of overburden exist. Haulback can be by truck or dozers could push the overburden into the backfill area. Particularly if the highwall was broken up into terraces, a combination of trucks and dozers could be used. More innovative concepts involve the possible use of segmented conveyors for spoil haulback.

The reclamation plan for a mountaintop site is based on the ultimate land use, which in turn is based on a combination of the OSM regulations which apply and an areawide plan. An extremely adverse impact that could result from unplanned mountaintop removal is destruction of the aesthetic environment. In an unplanned situation, much more starkly level land may be produced which is practically unusable, due to inaccessibility, lack of services (water, sewage, electricity), or economic depression in the area. The cumulative effects of many such operations could change the beauty of the mountaintops into visually monotonous chains of mesa-like stumps.

CONTOUR MINING

Contour mining, though strikingly dissimilar to any other surface mining method, can itself be divided into any number of variations. The actual use of any one contour mining method, or variation thereof, is primarily dependent on the following ranked parameters:

- Topography of the area
- Equipment possessed
- Influences of legislation
- Previous mining history at the site

The topography of the area, as previously discussed, will have the greatest impact in keeping many operators from attempting to mine, either because of a lack of proper equipment for maneuverability or because of mandates to conform to certain performance standards. Once it has been established that mining is feasible, the mining history at the site will play a large role in determining methodology. If, for instance, an older unreclaimed bench exists, a scheme may be used that will allow reclamation of both the old and the new strip area while facilitating mining.

Legislative impacts have been, by and large, slow to evolve. Since 1938, when West Virginia passed the first surface mine legislation in the country, little other significant legislation was passed until the mid 70's, when the New Source Performance Standards (NSPS) for water discharges were promulgated by the Environmental Protection Agency (EPA). The greatest impact on methodology was prompted in the mining industry by the Surface Mining Act of 1977 (the Act), which set far-reaching performance standards for the industry. While the Act will not be discussed in its entirety here, its major impacts are the requirements for: 1) sediment ponds as already discussed; and 2) backfilling to approximate original contour. The backfilling requirement was the most stringent peculiar to contour mining, since little recourse was given for planned development, as was the case in mountaintop removal. A more indirect, but perhaps cumulatively the greatest, impact was the additional planning and engineering required.

The block cut contour mining concepts were devised to counter some of these legislative requirements as imposed by individual states prior to the OSM regulations. They are useful not only in material flow, but also in projecting future requirements and cash flows. In devising mining approaches, it is beneficial to look at the reserves incrementally and determine the net profitability of moving the overburden and loading the coal for each block. Reclamation costs may be easier to calculate, as are other environmental safeguards such as amortizing a sediment pond over ten or fifteen blocks of coal.

Though discussed later, the point should be made that the surface shortwall concepts require construction of an outcrop bench by the same lateral movement concepts. While the techniques required will incorporate many of those to be discussed here, dissimilarities will become apparent in the blasting methods required and the scale of the operation. Whereas most contour operations generate a bench 100 to 200 feet wide, the requirements and limitations imposed by shortwall mining will only allow a bench from 50 to 100 feet wide.

These lateral movement mining methods can be divided into the following major categories, though, in fact, these categories have many variations:

- Perpendicular block cutting with shovels
- Modified block cut
- Modified dozer-loader block cut
- Truck haulback

In terms of mine planning and the sequence of unit operations involved, all of these contour mining methods should be planned, developed, and executed as was previously suggested.

Since enactment of the Surface Mining Act, surface mining, and in particular contour mining, has become a singularly linear method of mining coal; so much so that in certain instances, it can be thought of as one dimensional in nature. Nearly any typical contour mining operation can be characterized by the seven following unit operations:

- Clearing and grubbing
- Topsoil removal
- Overburden removal
- Coal removal
- Overburden emplacement
- Regrading, topsoil emplacement and reseeding
- Revegetation – long-term

One of the primary effects of the 1977 Surface Mining Reclamation and Control Act was to limit the length of contour opening (that could be included as part of the first six items) to 1500 feet, and to provide bonding requirements which would assure minimum amounts of revegetation for the seventh. To most effectively meet the performance standards promulgated under the Act, operators have had to devise better uses for their equipment. Though it is difficult to define these methodologies, Table 3 shows an approximate breakdown of equipment usage.

TABLE 3. - Summary of equipment utilization by mining method.

MINING METHOD	OUT SLOPE ANGLE (Degrees)	CLEARING AND GRUBBING	TOPSOIL REMOVAL	OVERBURDEN REMOVAL	COAL REMOVAL	OVERBURDEN EMPLACEMENT	TOPSOIL EMPLACEMENT
Perpendicular Block Cutting with Shovels	10°–20°	Dozer	Scrapers and Dozers or FEL and Trucks	Shovels Trucks	FEL Trucks	Trucks Dozers	Dozer Hydroseeder
Scraper Haulback	15°–25°	Dozer	Scraper with Dozer assist	Scraper with Dozer assist	FEL Trucks	Scrapers	Dozer Hydroseeder
Truck and Scraper Haulback	20°–25°	Dozer	Scraper with Dozer assist	Trucks with FEL	FEL Trucks	Scraper Trucks Dozers	Dozer Hydroseeder
Modified Dozer/Loader Block Cut	20°–30°	Dozer	Dozer/ Loader	Dozer	FEL Trucks	Dozer	Dozer Hydroseeder
Truck Haulback	20°–35°	Dozer	FEL Trucks	FEL Trucks	FEL Trucks	Trucks Dozers	Dozer Hydroseeder

Perpendicular Block Cutting With Shovels

As illustrated in Figure 8, perpendicular block cutting with shovels is often used where slopes may not be overly steep and where a shovel may be used on blocks outlined by other equipment. In multi-seam operations, the upper seam is often used as the upper limit for shovel extraction. Due to a restriction on blasting to be noted later, small shovels, hydraulic excavators and other equipment types with high breakout capabilities will be needed in conjunction with dozer/rippers for bench preparation as part of any surface shortwall operation. In other circumstances of contour mining, the shovel's casting capabilities, the swell of the material, and the outslope angle are the limiting factors in its usage. Shovels are not used currently in steep slope areas.

Advantages

- High to very high production potential at moderate unit production costs
- Reduced blasting requirements due to the shovel's breakout force

Disadvantages

- Introduction of equipment not common to steep slope contour mining areas (shovels)
- Limited in maximum depth of shovel cut
- Limited to areas where the shovel cut is deep enough to be economical
- Results in a narrow shovel pit that is relatively isolated from other operations
- Precludes augering of coal in the shovel pit
- Coal must be removed from the shovel pit and stockpiled as the shovel advances
- Places other excavation equipment in an ancillary role thereby reducing flexibility

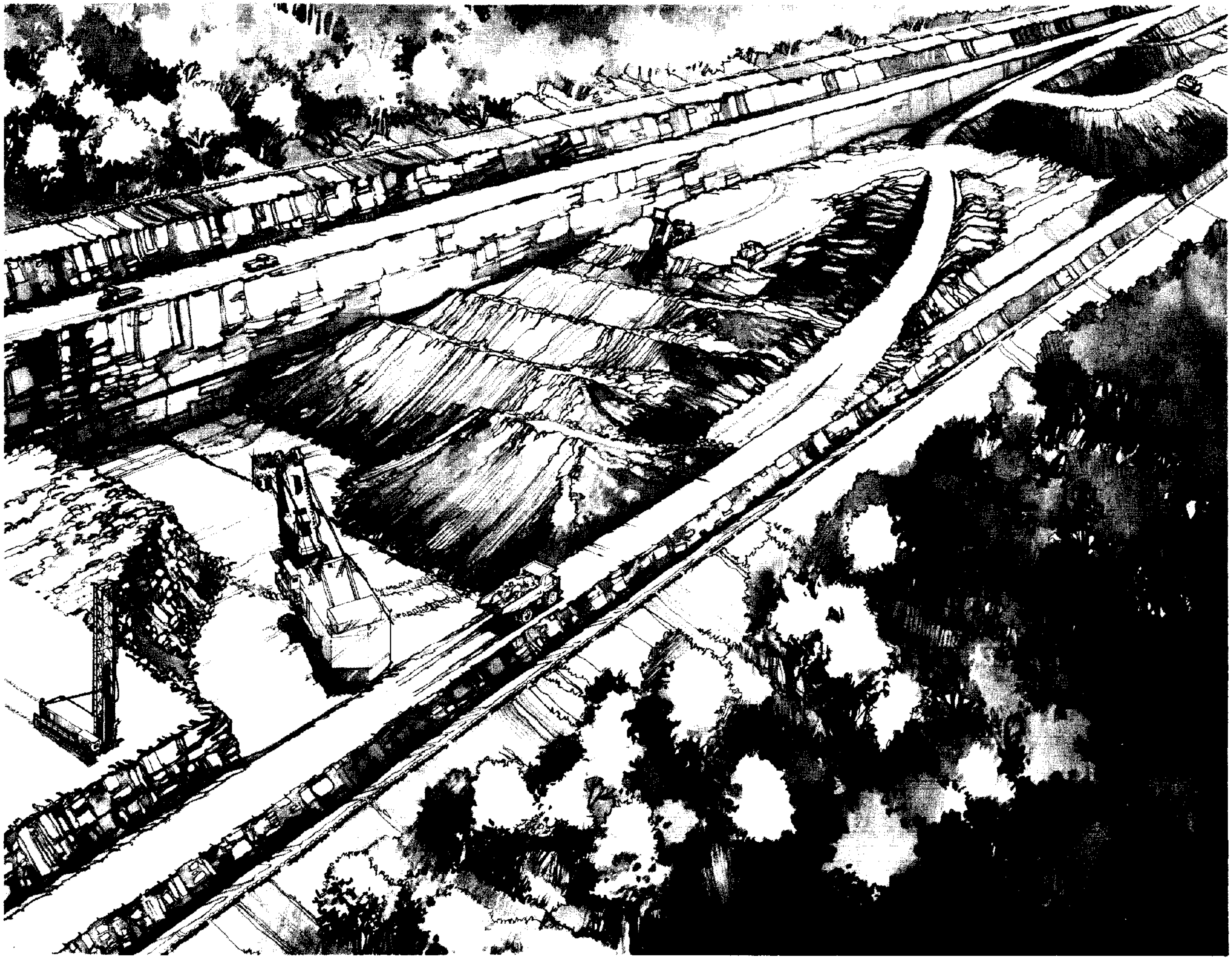


FIGURE 8. - Perpendicular block cut with shovels.

Modified Block Cut

Modified block cut mining (Figure 9), generally refers to small operations where large stripping equipment is not used. These larger equipment types (shovels, draglines) are precluded basically because too much production time is wasted traveling between pits and spoil storage space is limited in steeper slope areas. Because of the use of smaller equipment, this method is generally applicable to steep slope mining conditions. It should be understood that the modified block cut is more of a pit configuration than an actual method of equipment usage.

The basic premise behind use of the modified block cut is that there is a certain amount of time taken up with loading coal, blasting, clearing and grubbing and other ancillary operations. Mining is therefore done in a systematic, though complex, fashion by maintaining two open pits at once. Ideally, the method involves excavating a large initial cut and either storing the material in a seeded condition if the slope is moderate (as shown) or constructing a valley fill with it, if the slope is steeper than 20° (OSM mandate). Alternating cuts are then taken on either side of the initial cut by moving the spoil in a stepwise fashion from the right into the center, cleared area and from the left towards the center. As one block is cleared of overburden, a loader stays to load while the overburden removal fleet goes to the other end of the mine to again excavate overburden.

Though adaptable to trucks, the method was developed primarily for dozers and loaders because of the small block size which could be maintained and the therefore short push distances which were required. Because

FIGURE 9. - Modified block cut.

of the equipment mobility, a savings can be made on downtime which would otherwise result while the coal was loaded. In this scenario, while excavation takes place in one pit, drilling and blasting as well as coal loading can be taking place in the other. Unfortunately, because of the dozer requirements of a clear path for pushing overburden, augering or use of a surface shortwall are difficult to schedule into the operation without downtime.

There is a pit size limit in lost time, however, when, as the two pits progress ever further apart, the time for deadheading equipment becomes prohibitive. At this point, the operation is either stopped or a second set of production equipment can be instituted. Because of this limitation, the method is generally used in fairly confined areas so the distance between pits is usually no more than half a mile. Though the inter-pit traveling requires a temporary road, reclamation can be quite effective and, because of the small size of each pit, can be kept fairly close behind the excavation work.

Advantages

- Eliminates double handling of spoil
- Low capital investment (2 machines can mine)
- Retards acid formation with immediate burial of toxic materials
- Fast reclamation grading and replanting is accomplished
- Minimizes erosion
- Multi-seam mining is practical
- Extremely flexible system using very mobile equipment
- Small disturbed area with very small actual pit area
- Provides an initiation for a larger two unit mine

Disadvantages

- Limited overall size possible
- Small total coal production per year, but high tons/person-hour
- Good location for initial spoil placement is required
- Equipment not necessarily used to best advantage

Dozer/Loader Block Cut

Though dissimilar in many ways, the dozer/loader block cut (Figure 10) is a variation of the modified block cut methods, and is used in multi-seam operations for overburden handling in a single direction. Multiple seam conditions often prevail in the steep sloped areas with rider seams or split seams. Under two seam conditions, a block cut is made in the interburden between the lower and the upper seam along the outcrop of the lower seam extending back to the outcrop of the upper seam. Once the lower seam coal has been loaded out, the overburden from above the upper seam is pushed laterally into the area just cleared. This leaves the upper area cleared so it can be loaded out. Next the lower seam is uncovered and removed.

Peculiar to this method is its inherent flexibility in equipment utilization. The first cut and the entire interburden can be very effectively moved with other equipment such as trucks and loaders while dozers and loaders are used to move the burden above the upper seam. This procedure is effective in eliminating congestion in the upper pit. Again, this method also eliminates the chance for use of an auger in the upper pit due to the requirements of the dozers.

FIGURE 10. - Dozer/loader block cut.

The particular advantage for this method is generally seen in situations in which an older unreclaimed bench lies below the existing upper cropline being worked. With these conditions, overburden handling is much easier and past mining scars can be reclaimed along with current mining. Other advantages and disadvantages are:

Advantages

- Utilization of conventional surface mining equipment
- Low capital, high production potential
- Selective spoil placement
- Great deal of versatility and mobility of system and equipment
- Does not require particularly close scheduling

Disadvantages

- May require a large open cut length
- Requires spoil rehandle
- May cause increased airborne dust concentrations
- Precludes augering
- Labor intensive

Contour Strip/Truck Haulback

Truck haulback (Figure 11) may be used in nearly any mining configuration to some degree. This is due in large part to a truck's natural versatility and its precision in spoil placement. Trucks have achieved a widespread acceptance due to their fairly high reliability and their maneuvering capabilities. Because they constitute a method of batch haulage, the operation is not susceptible to the breakdown of a single piece of haulage equipment as is the case with extended overland belts. However, recent developments in segmenting these belts has totally eliminated what was an advantage

FIGURE 11. - Contour strip-truck haulback.

of batch haulage. Truck haulback systems are especially productive in steep sloped contour haulback situations and are used extensively in steep sloped Appalachia because of these inherent flexibilities. In many cases, the trucks may be constantly employed with little interruption for blasting or coal loading.

Several disadvantages do arise: 1) pit congestion, which is evident when three or more trucks are used; 2) bottlenecks from poor haul road design; or 3) loading slow downs due to difficult digging. Other unforeseen problems such as loading equipment downtime may occur, revealing the high labor intensive costs of such an operation. Planning a truck haulback mine involves matching loader and truck capacities as well as cycle times.

Profitability is affected by matching a 12 yd^3 loader with 30 yd^3 trucks. The loader is then left with the option of loading 24 yd^3 or 36 yd^3 into the truck. A half bucket could be loaded but the time involved in loading a partial bucket of overburden into the truck is the same as for a full bucket. This type of arrangement constitutes a loss in any of three ways:

1. A third, half-full, trip for the loader, or
2. A less than loaded truck, or
3. An overloaded truck that may break down

In steep slope areas, trucks are generally used with front-end loaders, since shovels or draglines are usually far too awkward to maneuver in the close conditions present. The operations then generally consist of a dozer clearing and grubbing the area. The soil is loaded into trucks and carried to the reclamation site. Next, benches are made and the overburden is blasted. Loaders and trucks are again used to carry this material to a proper deposition site. Once a block of coal is uncovered, it is loaded into road-legal 20 ton trucks and hauled away.

Though this is perhaps the most common contour mining method in steep slope areas, its use is predicated on the existence of a predetermined set of conditions. Since these conditions are rarely found, there is frequently some modification to the equipment usage. In some cases, scrapers might be amenable to move unconsolidated material. Often in spite of conditions, pieces of equipment such as small shovels which do not belong in steep slope areas, will be employed (possession dictates usage).

Advantages

- Loader - truck combination offers the ultimate in select placement; specific loads can be dumped at specific points.

- With good mining conditions, production can easily be increased with addition of another truck or loader to the cycle.

- Little concern is necessary for the texture of the material being transported since trucks can haul nearly anything.

- Reduced blasting is required (as compared to scraper or belt haulage).

Disadvantages

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

- A change in equipment numbers can ruin a delicate loader-truck balance.

- Mismatched loader-truck combinations do not allow for maximum production, as loaders may wait for trucks or vice versa.

- Spoil deposition is not smooth as with a scraper and needs regrading and recompacting, involving more equipment.
- A lot of time is wasted in truck turning and backing for dumping and loading.
- Method can become labor intensive.

Variations in Methods

Actual mining practices may differ quite extensively from what has been described based on application of the operators' equipment to existing conditions. For instance, providing conditions are right, scrapers may be used to haul much of the overburden, but only if it has been extensively ripped or is well blasted. In heavier or blockier material a dozer is usually required to push-load the scrapers.

Although often thought of as a flexible means of batch haulage with its inherent advantages, scraper flexibility is impaired in the close confines of a contour pit by the higher slope angles. Their use is generally contingent on having a fairly level surface and thus work best in fairly precise one-step segregation and transportation of topsoil to reclamation sites. Because of these limitations, use of scrapers is generally best done in conjunction with, or complementary to, truck haulback.

Draglines may on occasion be used in steeper sloped areas, but again, as with shovels or other large equipment types, a lack of mobility is a severe detriment. More recently, introduction of hydraulic excavators which can work in either a front-loader or backhoe mode has introduced a new style of flexibility into an older type of equipment piece. Excavators have the advantages of quick cycle times and fairly large bucket sizes in combination with a very large breakout force and a somewhat lower level of required maintenance.

Development of new contour mining methodologies has historically been based on the conditions present and, to a limited extent, on legislative mandates. Further development will be focused primarily on regulations but there will also be an interplay as new equipment is designed for use in various methods and as improved methodology develops to take best advantage of the capabilities of improved equipment. By example, recent developments of portable segmented conveyors offer the advantage of continuous haulage of overburden with a fairly high equipment availability. Through the well planned use of such equipment in methods such as those discussed, their relative efficiency can be heightened tremendously.

AUGER MINING

In the United States, augering for coal began in the mid 1940's in the bituminous coalfields of West Virginia from which it later spread to other central Appalachian states. Production began to grow when, after a few years of experimentation, the coal recovery auger developed into an efficient mining tool which often found use on the many miles of abandoned contour mining bench throughout Appalachia. From the first recorded production of 205,000 tons of augered coal in 1951, production steadily increased to 20,027,000 tons in 1970.

Since 1970, however, production by augering has decreased markedly. In 1972 production was 15,554,000 tons from approximately 574 mines. Later figures from 1974 indicate a production of 15,670,000 tons primarily from eastern Kentucky, with some from Virginia, Ohio, Pennsylvania, West Virginia, Maryland, and Tennessee.

Auger machine sales have also decreased in recent years, with only 26 sold since 1974. The sales breakdown by years is:

1974 - 5
1975 - 16
1976 - 1
1977 - 4
1978 - 0 (1st quarter report)

It is not known if all these augers are coal augers, since new single head machines are sold to the construction industry for driving drainage culverts under highways, etc. With many old augers operating in the early 70's now scrapped, the total population of operable augers is estimated at less than 100. Other evidence of a declining market is the slowdown of auger advertising and the absence of auger equipment being displayed at recent mining equipment shows.

The recent cutbacks in augering can be seen as the result of an entirely different climate of opinion towards augering on the part of the resource lessors and on the part of governmental bodies. These changes in attitude have resulted primarily from the exceptionally poor recoveries obtainable by conventional auger technology and by the environmental impacts of acid drainage from the auger holes. In review of the major shortcomings of augers, it is necessary to also review the factors involved in deciding to auger or follow another line of resource recovery. This decision does in fact come down to evaluation of three separate options: 1) Do no further mining, backfill the bench and leave the reserves untouched, 2) auger the reserves in view of its advantages or drawbacks, 3) punch mine the reserves either following contour mining or following augering.

Augering in central Appalachia is done principally in conjunction with a contour mining operation (Figure 12) or, in particularly steep sloped areas, it has been done independently by excavating auger benches where it was uneconomical to contour mine. Augering has typically been done by smaller operators who own one or two machines and who work them in conjunction with their own contour operations, or who are contracted by larger operators to temporarily supplement coal production during coal shortages or periods of high prices. For one report period, only 6 out of 140 augering companies were rated among the top 50 major coal producers. Production from these operations ranged from 218 to 335,300 tons for the year.

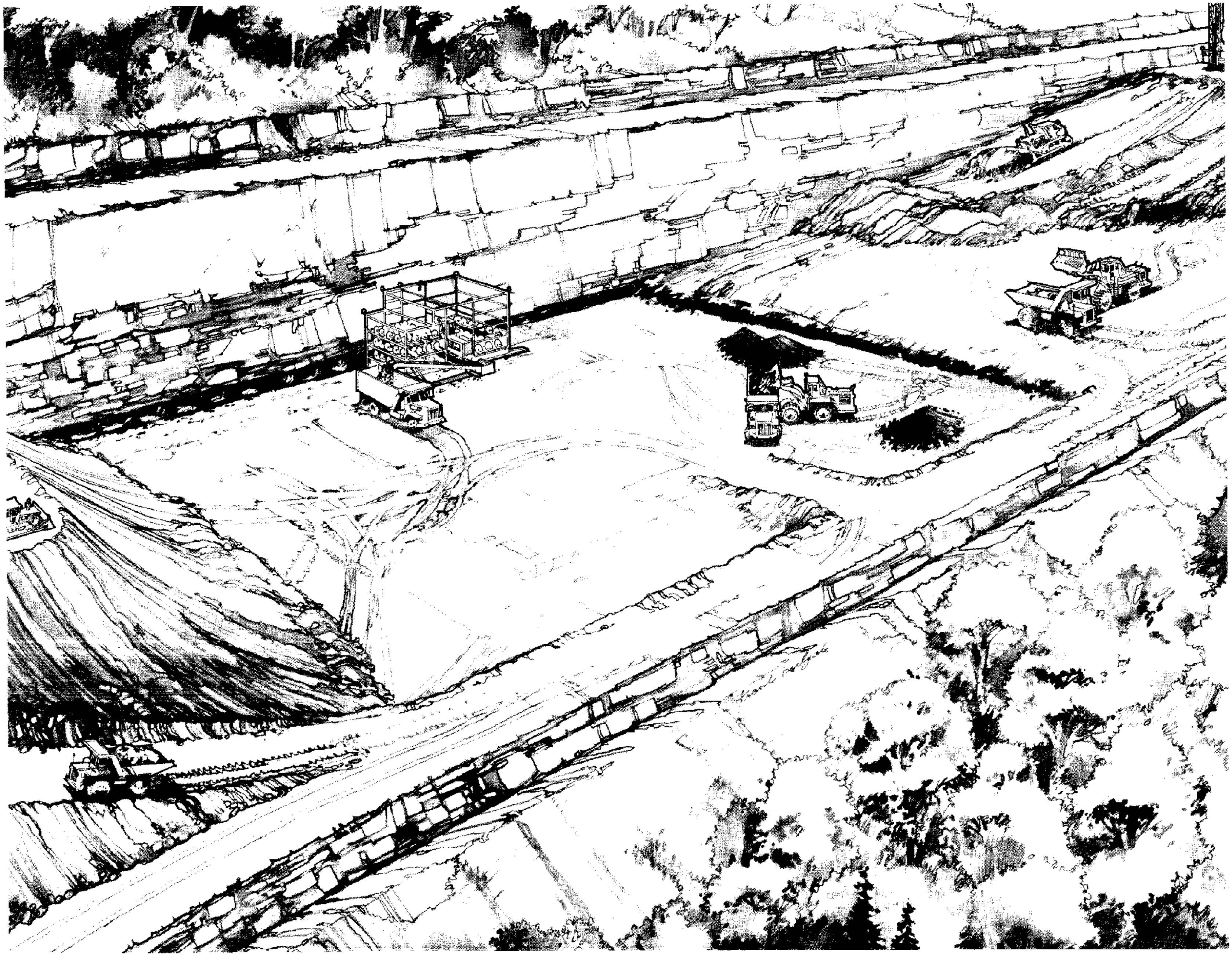


FIGURE 12. - Contour strip/auger mine.

Due to recent legislative enactments on both the state and federal level, the auger benching practices in the past are pretty much precluded due to the small recovery factors involved; thus augering has been relegated ancillary to a much larger contour mining operation. Also, since augering usually requires initial contour mining to create a bench, all surface mining regulations, including reclamation practices and water quality control, also apply to augering. Pennsylvania, West Virginia, Kentucky, Tennessee and Illinois have the most stringent augering regulation, primarily concerning plugging the holes with an impervious material, minimizing the highwall length, and time period for augering.

The federal law includes these requirements, with the addition of several new ones. In order to enable future recovery of deep coal under steep terrain, a 250 foot wide pillar must be left every 2,500 feet along the outcrop for future underground mine entrances. Also, a 500 foot barrier pillar must be maintained between the augering operation and any active or abandoned underground mine. In addition to requiring a watertight seal, the federal regulations also limit the time period in which sealing must be accomplished. Either the water must be treated or the hole plugged within 72 hours. If the water is treated, then plugging must be completed within 30 days.

Contacts with regulatory agencies in several states indicated that different regulations often carry more weight in one state than in another. For example, in Pennsylvania the requirement to maximize recovery is used by regulators to restrict augering. Few operations have been efficiently planned, making this regulatory approach effective. In West Virginia, surface mining water quality requirements are strictly enforced; and since surface mining regulations also apply to augering, the state strictly prohibits any updip augering of acid-producing coal seams. Depending upon the location of the outcrop with respect to structural geology, this could severely limit auger mining feasibility. Since the federal regulations have been so recently enacted and are still being revised and implemented, it is difficult to fully evaluate their potential impact. Plugging requirements are a good example. Taken literally, there really is no material which is totally watertight and impervious. Even clay, once saturated, will allow water to pass. Also, the cost of plugging each auger hole with clay could be prohibitive. Barrier pillar requirements, though restrictive, are probably not as significant as the plugging requirements.

Regulations requiring maximum coal recovery are important. They can either be used to discourage or encourage auger mining. Maximum recovery from augering would require an ability to control the auger direction precisely. Standard augers do not have this capability. Also, as noted, auger operations are generally not well planned and coal reserves are frequently wasted.

Maximum recovery regulations can encourage auger mining as follows. After reaching a limiting strip ratio during mining, the regulations require backfilling to return the slope to its original contour. In doing this, valuable coal reserves are made less accessible to further surface mining. Even if higher strip ratios become economical in the future, it may not be feasible to remove the fill material to reach the coal. If future exploitation potential is questionable, augering could provide a means of obtaining that extra coal which would otherwise become inaccessible after reclamation. Because of the backfill regulations, auger mining may be encouraged as a means of obtaining additional coal recovery before isolating the seam.

The backfilling requirement affects augering in other ways in that a maximum of 1,500 feet may be accorded the open pit from the cleared and grubbed area to the reclaimed area. This often leaves very little space for operation of an auger. Or, in those circumstances where the auger is not able to maintain a pace at least equal to that of the contour mining, it may fall behind, necessitating skipping large blocks of coal.

The economic feasibility of any mining method is dependent on several factors, such as the selling price of coal, operational expenses for labor, fuel, power, materials, supplies, administrative and other direct and indirect charges, production capacity, available equipment, and geologic conditions. Affecting the mining cost, these factors encourage the selection of one mining technique over another.

The character and quantity of overburden is an important geologic factor. The quantity of overburden which must be removed in surface mining to obtain a ton of coal is particularly important. Once an economically limiting strip ratio is achieved, the surface operation must cease and other options must be examined. The economics of underground mining is greatly influenced by geologic conditions such as the quality of the roof rock and consequent expenses for roof supports, shafts, ventilation, mine safety and development. If the roof material is fissile and soft, extra roof supports must be installed.

Auger mining is not as significantly affected by overburden conditions other than depth, and auger holes have good ground support characteristics because of the following: 1) There are no shatter cracks from use of explosives to decrease the effective area of pillars and cause points of excess stress concentration; 2) spacings between pillars are comparatively small; and 3) beam action of the roof is reduced because of the arching effect of a circular cut. Therefore, when overburden is too deep for efficient stripping, and roof rock is too weak for economic underground mining, augering provides a less costly alternative for coal recovery.

The quantity and quality of the coal reserves also influence economic feasibility of mining. Even a small underground mine requires a large coal reserve to justify the several million dollars in capital required to initiate operations. Historically, a punch mine has been fairly easy to open and only fairly small reserves were required to justify it. As evidence of this, there are numerous 1 to 5 man operations throughout the steep-slope area. In light of today's concern over environmental and health and safety issues, capital investment and operating costs have risen dramatically so that these mines are nearly impossible to start today on such a small scale. In these cases, an auger can be brought in and set up in a few weeks as opposed to the much longer period required for permitting and opening even a small punch mine. It is fairly well established that as a percentage of the total capital costs of the venture, engineering and permitting for a punch mine can be much more expensive than that for a larger mine.

Coal quality and quantity in seams of minable thickness is also a major factor since seams thinner than two feet are generally not considered minable by underground methods. In these cases, auger mining provides a means of extracting otherwise unobtainable coal. Shale partings can sometimes be selectively excluded during auger mining, while in surface and underground mining this is not usually the case. Because the overlying and underlying rock is rarely penetrated during augering, coal mined is generally lower in ash content and of higher quality than that removed by other mining techniques.

Based upon the many factors which influence mining cost, a general comparison can be made between augering, surface mining, and underground mining. The operating cost for a 36 inch diameter standard auger is approximately $9-10/ton FOB mine. Skelly and Loy's estimates for the World Bank for a typical surface mine indicated an average operating cost of $15-20/ton in the auger mining regions. Underground mining costs in the same regions average $20-25/ton. These cost figures provide a relative indication of mining costs, but vary greatly according to the many variables previously discussed.

If mining costs were the only factor in the determination of which mining technique to use, augering would be the obvious choice. However, with projected future energy demands, coal is expected to increase in value and importance. With this in mind, many coal property owners and mining operators are looking to increased recovery with minimal sterilization of potential future reserves.

Auger mining recovery is dependent on numerous factors. Among these are: web width required based on overburden thickness and coal compressive strength, coal thickness as it compares to the available auger diameters, the curve configuration of the highwall along the ridge, and the skill and planning of the operator. Although auger recoveries can exceed 50% of coal in-place, poor augering practices can reduce this figure to 10%. Average recovery for standard augers is 25-35% which is much lower than the expected 55-65% recovery in underground mining and the 90% recovery in surface mining.

Recovery is particularly important to owners of the coal rights, since they want to get the maximum from their reserves. However, operators who lease land for mining are less likely to be concerned about recovery, and are after maximum production and productivity. Because of the low recovery from auger mining, many lessors are now stipulating that auger mining is not to be allowed. Also, the new federal surface mining law calls for maximum recovery from augering, and in some cases regulators are using this requirement to minimize augering in their states.

In review of what has just been stated, the relationship of augering to the rest of the surface mining methods has gone from a simple, fairly direct, and many times independent operation to one of a very complex systems approach requiring detailed planning to alleviate previous handicaps. The main drawbacks are:

. With legislatively mandated spoil haulback in contour surface mines, there often is not enough bench room to allow for an augering operation.

- Time is a factor since many haulback operations are on a planned schedule and must achieve reclamation within a specified time frame. In a few cases, the augering operation could be slower than the contour haulback operation. These causal implications can be most directly applied to those states which previously had ineffective reclamation laws, since the augering could take place weeks or months later on an empty and unreclaimed strip bench.

- Scheduling is much more important now than previously for the above reasons (since augering must be concurrent with mining), often sharing the work area with coal removal operations and spoil placement.

- Since many coal lands are mined under lease, stipulations by the lessors are more often made which prohibit an auger from despoiling future coal resources.

- There is a limited capital flow, since an auger can only mine at a certain rate and a ceiling exists on the practical capabilities of augers to mine coal.

- The auger operator is dependent on the contour operation to leave a highwall from which augering can take place.

- Uncertainty reigns over what future technological advances will do to the economic mining limit. Even now, contour mining is taking place along highwalls which were at one time considered the economic limit of mining.

The decision whether or not to use an auger is judgmental, and must be made based on all of the above parameters.

An auger only has applicability when used in certain mining situations or in conjunction with certain contour methods. As previously noted, a dozer-loader pit would not allow the necessary room for augering. Certain types of operations, such as the modified block cut, would allow augering if done during the drilling phase of mining, but would require a great deal of equipment mobility. Generally, a case-by-case analysis would be required based on the situational aspects to determine acceptability.

There are three basic auger designs — single, dual, or triple head auger. Each of these has its relative advantages, but the dual head is the easiest to work with while offering a high recovery potential. Augers are fairly simple machines, but require that they be accurately leveled and aligned exactly. While usual hole depth may range from 120-150 feet, experience gives some operators the ability to run their augers down a dip in the coal and back up the other side. Though there are a number of indicators which would inform the operator as to whether the auger was still in coal or had drifted off into rock, it is generally conceded that a knowledge of the machine and its capabilities and practical knowledge of the seam is important to auger mining. Perhaps most important is a sensory perception which cannot be quantified but which often enables operators to mine to depths approaching 200 feet.

Projected advances in auger technology promise to allow augering depths to increase to 850 feet with telemetry guidance. An auger of this type would increase augerable reserves from 5 billion to 20 billion tons (Ford Bacon and Davis, 1975) throughout the country. Further, the use of augers in making square holes to minimize or remove pillars and webs is projected.

The following major section on surface shortwall mining will show how many of these deficiencies may be overcome. It will also serve to illustrate the interactions of the contour-type benching operations and the shortwall, and the increased complexity which would result in concurrent shortwall/contour mining.

SURFACE SHORTWALL MINING

FIELD VISITS

Field visits were scheduled as part of project efforts to various shortwall/longwall operations around the country to derive information relevant to a surface shortwall operation. It had been initially proposed that visits to operations with shallow overburden would provide good comparative information. In the course of setting up the trips, though, it was found that: 1) depth of overburden at such shallow levels was not in itself a determinant factor as to the technical feasibility of the method; 2) mines which had been mining under shallow cover no longer were; 3) problems were encountered in gaining visitation access to these mines.

Further attempts were made to schedule these trips to operations that had ongoing long-term geophysical or ground control monitoring projects underway. Unfortunately, in all cases monitoring which had been conducted as part of various private and governmental projects was complete. There was, then, no chance to view the monitoring nor speak with the investigators while monitoring was progressing. Many of these investigators were contacted and reports, if available, reviewed for their input. These projects and reports will be discussed in a later section.

The history of shortwall mining has not been an encouraging one. Use of the method was predicated on the "transition" it afforded between continuous miner sections and longwall operations. This transition was defined both in terms of the reduction in initial capital outlays and as a way to train crew members for longwall equipment operation and ventilation. Use of the method reached a climax at eleven units nationwide several years ago.

TABLE 4. - Summary of shortwall statistical information.

COMPANY — MINE	SEAM — HEIGHT X OVERBURDEN	PANEL WIDTH X LENGTH X PITCH	PILLAR SHAPE SIZE AND NUMBER OF ENTRIES HEAD/TAIL	MINER — HAULAGE —	SUPPORTS TONS/LEG AUXILIARY SUPPORTS	STATUS/ COMMENTS
Helen Mining Co. Blacklick Mine	L. Freeport 48 in. x 750 ft.	180 ft. x 3000 ft. x 2^{o} head to tail	diamond or rectangular size unknown 3/3	Jeffrey 120-L remote-Heli- miner (2) Joy 21SC	Westfalia chocks 42-700/4 Cribs and posts	Ongoing-plan- ning on second unit
Bethlehem Mines Corp. Hendrix #22	Elkhorn #3 42-48 in. x 300-700 ft.	150 ft. x 2000 ft. x $0-1^{o}$	rectangular 55 ft. x 30 ft. 3/3	Joy 11CM (2) Joy 18SC	Gullick-Dobson Chocks 42-500/4 Cribs and posts	Idle
Jewell Ridge Coal Corp. Jewell #12	Jawbone 48 in. x 650-300 ft.	210 ft. x 3700 ft. x 1^{o}	rectangular/ diamond 50 ft. x 30 ft. 4/3	Joy 14CM Joy 14BU (2) Joy 21SC	Gullick-Dobson Chocks 42-650/4 Posts	Ongoing
Jewell Ridge Coal Corp. Big Creek Tiller Mine	Tiller 42-48 in. x 500-700 ft.	150 ft. x 3000 ft. x 7^{o} head to tail 1^{o} to ft. of panel	rectangular - staggered 50'x50' & 50'x70' 4/4	LN265 CM (2) Joy 21SC	Westfalia chocks 700/4 Cribs	Ongoing
Eastern Associated Federal #1	Pittsburgh 78 in. x 700 ft.	180 ft. x 2200 ft. x 1^{o}	———	Jeffrey 120CM (2) NMS 48SC	Gullick-Dobson Chocks 800/4 Auxiliary Sup- port unknown	Ongoing
EPA - WVSMRA Julian Surface Shortwall	No. 5 Block lower split 48 in. x 40-80 ft.	89-109 ft. x 400 ft. pitch unknown	one pillar 75 ft. long no chain pillars	LN285 H Eichhoff face conveyor	Hemscheidt 42-650/4 Chocks Cribs	Project stop- ped Dec. 1976 No plans for renewal

However true the premises might have been, this has since been reduced to approximately five units in operation today. This reduction in use was based primarily on problems with the roof when so large a web was cut with the pass of the continuous miner and on logistical problems in the use of shuttle cars.

Out of these five shortwalls currently in operation in this country, three were visited. Visits would have been scheduled to the other two except for problems of one mine being temporarily shut down and the other's equipment being moved. Neither of these two sites were visited because it was not felt that trips would be worthwhile without the advantage of seeing the equipment in operation and viewing any operational failings. Also, often in the course of visits, talks with equipment operators offered insights into roof control problems which could later be followed up in talks with management.

The mines visited included two shortwalls in Virginia, one shortwall in Pennsylvania and a single longwall in Utah. The visit to the mine in Utah was made to see some subsidence resulting from mining near the outcrop. A fifth place visited was the Julian site of the EPA surface shortwall experiment to gain some ideas as to the geology and geomorphology of the area.

The types of information gathered included summary statistical information and other operational information which has been tabulated into Table 4. The latter types do not lend themselves easily to presentation in a tabular format because most of it is either peculiar to the mine itself or often remarks made in direct reference to various aspects of the Julian experiment. The format to be used will involve tabulation of most operational information and a simple descriptive narration of other relevant information in two classifications — that pertaining to their own operation and that pertaining to the Julian experiment. Later sections will discuss the results of ground monitoring studies done on shortwall operations.

MINE SITE — VaA

Mine VaA is a shortwall operation working in the vicinity of the Cumberland Overthrust Block Fault in southwestern Virginia. This fault trends northeast from northeastern Tennessee through southwestern Virginia and defines the border between the Cumberland Plateau and the Ridge and Valley Province. In this regard, it also defines the edge of the coal measures which lie in the Cumberland Plateau. While being deeply dissected and therefore quite "mountainous", the strata in the Plateau region are known as essentially horizontal throughout the lateral extent of the Plateau. This area includes most of the eastern Kentucky coalfields.

The near presence of the fault structure to the mine is evidenced by a number of drag characteristics, chief of which is the rather steep inclination ($\approx$10%) of the principal haulageway which runs perpendicular to the fault in the vicinity of the portal. This steepness of dip is perceptibly reduced the further one goes into the mine away from the fault. This drag characteristic may also have some effect on roof characteristics as explained later.

The shortwall face operations are oriented such that the length of the panel is at a 30° angle to the dip line of the seam. Figure 13 illustrates the relative orientation of these features. Actual dips were found to be 10 ft. along the face and 150 ft. along a typical 3000 ft. panel.

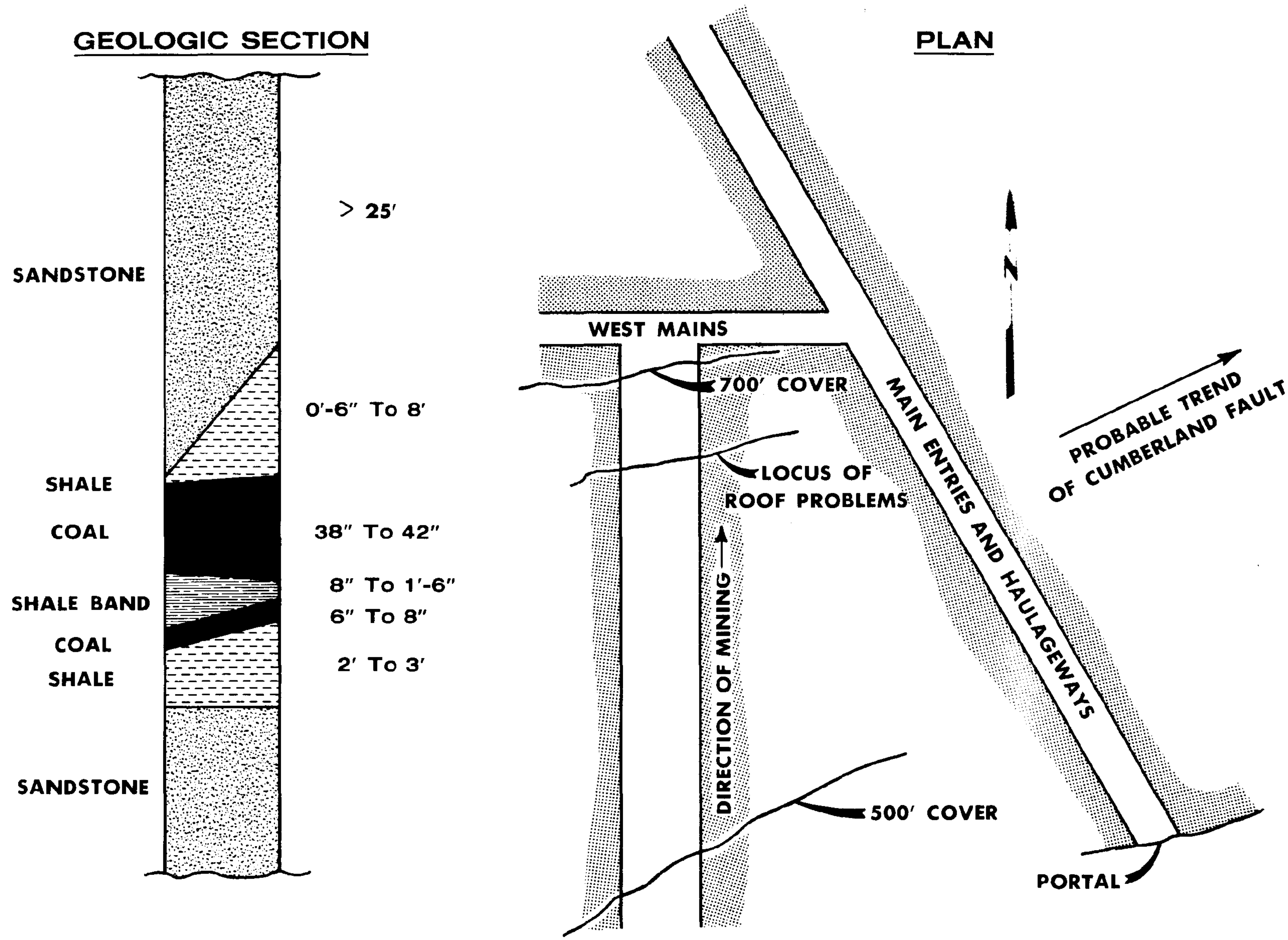


FIGURE 13. - Mine VaA - Geologic section and plan layout.
No Scale

Figure 13 also shows a typical geologic section for the mine. The diagram indicates a substrata of shale, 5 ft.-6 ft. of benched coal topped by shale and/or sandstone. The immediate roof was usually a massive sandstone which would not usually be thought of as a good roof for this type operation. It can be speculated that due to the intense bending pressures within the rock, there has been enough prefracturing to allow breakage. The shales were not evident as an immediate roof over much of the mine, but mine personnel commented that there seemed to be no correlation between the amount of shale and the difficulty with mining. There was no shale at the highwall face surrounding the portal, and on examination the sandstone did not appear highly fractured.

Roof Control

Figure 14 is fairly indicative of the management's philosophy in regards to roof control, which is to minimize it so as to allow a complete collapse of the roof. On those occasions when they have attempted a higher degree of support, they have usually run into troubles which might be characterized as due to an unbalanced or unequalized situation — weight may have shifted causing possible abutment pressure changes. One other problem would seem to be directly related to the fault structures previously mentioned. Figure 13 shows a locus of roof problems approximately 500 ft. from the end of the panels. In each of the panels mined thus far, roof control problems have been encountered, usually accompanied by large amounts of water. While the shale understrata remains continent in spite of the water, muddy and slickensided conditions usually force abandonment of the panel.

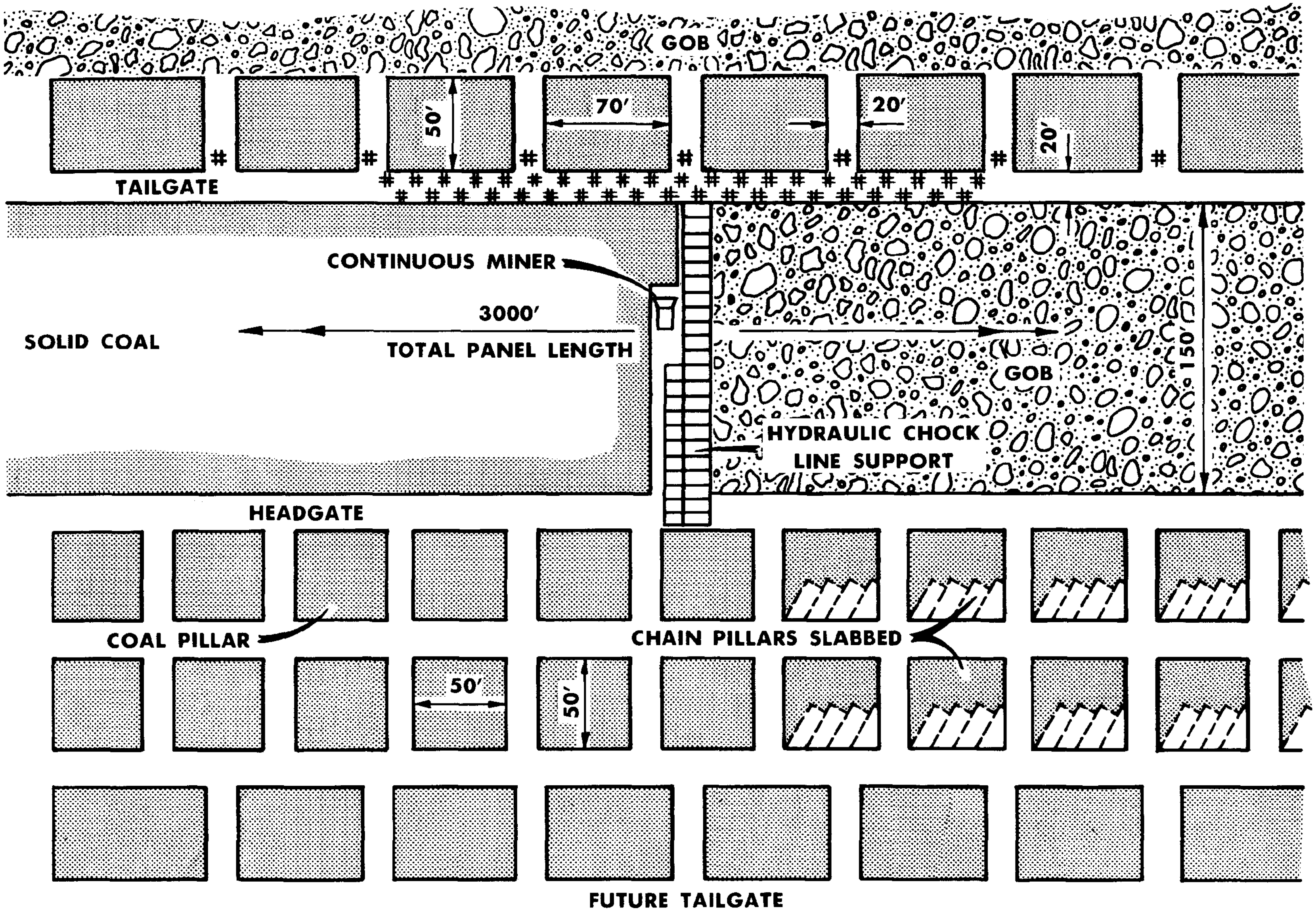


FIGURE 14. - Mine VaA - Plan layout of shortwall section.
No Scale

It is unknown where the water comes from. Speculation is that the water emanates from a seam 100-150 feet above, in which there may have been some old workings. The only explanation for the water coming in at that point is that it travels by way of a porous structure such as a large joint system. This joint system is easily seen as trending nearly parallel with the main fault system.

The particular problems as they occurred at Julian were similar to this problem in that there was slippage along a plane. The relative orientations of the face advance and the slippage plane are different. There the miner was continually driving into the plane whereas here the entire face was driven into the plane of weakness. In this case, the problems with the highly jointed zone and weakness of roof hit the entire face at once. This particular case indicates that groundwater disturbances due to a shortwall operation can be great. The most important difference to note is that surface shortwall operations would tend to have a greatly different impact on groundwater flow systems since they would conceivably encircle a mountain, thereby intercepting a number of springs, seeps, and other perched water sources.

There has been no subsidence monitoring done at this site chiefly because the land is entirely owned by the mining company, is not settled and is forested. Neither have any changes in vegetation been noted as a result of mining.

The type or amount of subsidence which would occur depends to a large extent on how the roof falls. In this situation with the sandstone immediate roof, initial break or fall has usually occurred about 150-200 ft. into the panel. It has been as much as 700 ft. before a good fall occurred. Once a pattern of breakage is established, falls occur along the chock line with no apparent overhang or hang-ups. Management feels that these falls occur in only one step up to about 30 feet because of the thickness of the sandstone. It is unknown how other falls occur. Management also feels that due to the systematic mining of the coal with shortwall or longwall techniques, the mountain may develop instabilities resulting in abutment pressure changes requiring augmented roof support.

MINE SITE — VaB

Mine VaB is also a shortwall operation in Virginia, but is located further back into the Plateau area away from the overthrust block fault mentioned earlier. The result of being further back is manifested in a seeming reduction in the characteristics associated with the fault. The dip of the seam is greatly reduced and any problems with the roof seem to stem more from anomalies in the depositional environment or later erosional hiatus.

Dip in the mine is approximately 24 ft. along a 3700 ft. panel length toward the face and slightly toward the headgate from the tailgate.

Figure 15 indicates the direction of mining relative to the main haulage routes and to the probable fault structure in the area. At this mine, the shortwall panels are parallel with the mains which are again nearly perpendicular to the fault structure.

Figure 15 also shows a typical geologic section for the mine. The diagram indicates a substrata of shale, 4 ft.-5 ft. of coal with a shale immediate roof and a primary roof of massive sandstone. As previously mentioned, the influence of the fault and joint structure don't play as important a role in

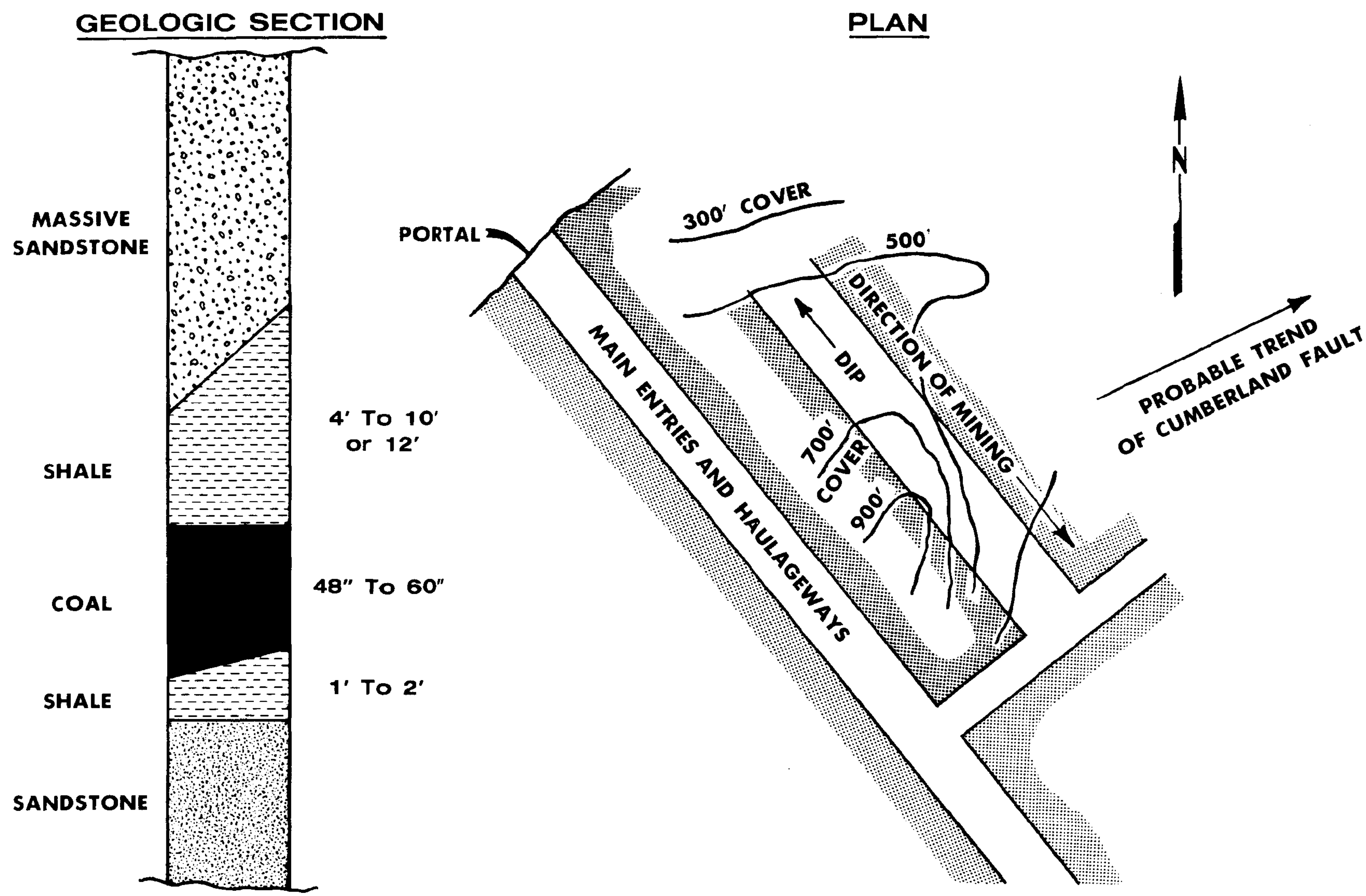


FIGURE 15. - Mine VaB - Geologic section and plan layout.
No Scale

roof control as was found in Mine VaA. Discussions with management people indicated that the 4 feet of shale indicated in Figure 15 was an operational minimum. The correlation of sandstone presence with roof control problems has been shown to a high degree. Thus, while the shale is an average of 6 ft. thick, those areas in which it goes to 10 ft. or 12 ft. thick usually have no roof problems of consequence. Company management has prepared overlays of the problem areas and has been able to develop correlations between the thickness of the shale, the roof control problems and channel sands which appeared during mining in the seam directly above. This establishes something of a correlative relationship between the channel sands, the shale thickness and the presence of slickensides, but a causal relationship must be developed based on more geologic evidence which management doesn't have. It is likely that there is an ancient fault running through the area.

The ground control problems manifest from this anomaly range from simple problems with occasional slickensides to massive support problems in the past which have caused withdrawal to another panel. In spite of this, a commendable attitude has developed toward roof control of allowing the roof to cave as quickly and methodically as possible. Average falls during mining are 10-20 ft. high or the thickness of the shale. However, about every two weeks, a fall of the primary sandstone roof occurs which probably goes at least to the top of the sandstone.

Again, no estimation has been made of the subsidence which has occurred due to the mining because of the lack of economic value of the land. Lush vegetation in the portal vicinity seemed to bear out the lack of concern because it showed no ill effects. Also, no disturbance of hydrologic balances has been detected even in mining into those areas with adverse roof conditions. The conditions at Mine VaA may have resulted in an aquifer above their locus of roof problems, but the same condition is not evident here.

Roof Control

Every effort has been made on the part of management through their engineering and design to get the roof to fall as quickly and completely as possible. Again, as in Mine VaA, at those times when they have oversupported, the operation has suffered for it. During the shortwall mining, there are no supports used in the headgate to supplement the roof bolting done during development except for the chock line which runs out into the head entry. The tail entry receives the same level of treatment in having posts set 4 feet apart in two rows down the tailgate 50 feet ahead of the operation. Additionally, no chocks are set under the last 10 feet of the face, thus enabling quicker falling of the roof (Figure 16).

In working under a shale roof like this, management has also found that crushing the shale can be very deleterious to roof stability, not only directly over the chock, but also in weakening the roof in the prefracture zone at the face itself. In the proximity of slickensides, this could cause them to fall easier than otherwise. An operational modification taken is to preload the chock tip, then bring the main body of the chock up snug with the roof.

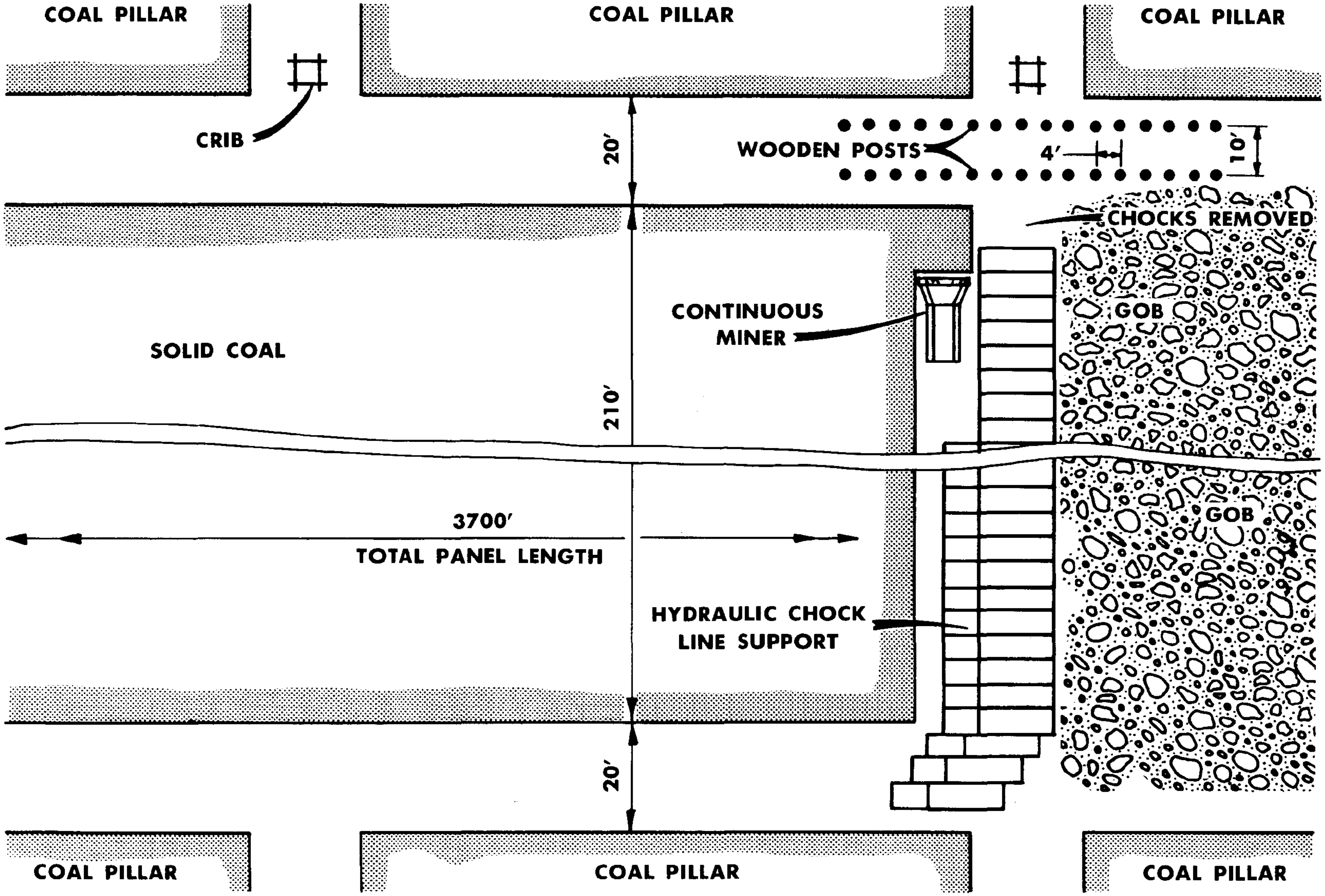


FIGURE 16. - Mine VaB - Plan layout of shortwall section.
No Scale

MINE SITE PaA

Mine PaA is a third shortwall operation in the Allegheny Plateau region of Pennsylvania. This area is mildly dissected into a rolling farm type topography. Mine PaA is a shaft mine instead of a drift mine as were the previous two, so that with the reduction in topographic relief evident between this mine and the previous ones, more constant abutment pressures may be assumed.

In researching the area no particularly important geologic structures were found which would cause adverse roof conditions and, in fact, few roof problems were found. Management has made some observations concerning the roof structure which largely bear out findings from the previous two mines. Though they have not had any convergence problems, there seems be a correlation between occurrence of sandstone close to the coal (Figure 17) and a slickensided roof. There were also indications of what the management felt were abutment pressure shifts. These were characterized by cracks which formed in the center roof of the No. 2 entry. The actual shift may be indicating a cantilever type reaction on the part of the Mahoning Sandstone member, which is extremely massive. The engineers felt that the Mahoning was breaking in about two week intervals, but interim rock mechanical reactions could cause the cracks. Conversely, they could also be locally caused by a simple sagging beam mechanism. Generally, roof conditions are quite stable since they have never had a problem so severe that a panel was abandoned.

Mine management does not subscribe to the concept of prefracture of the roof due to cantilever pressures at the face. They do feel as did the management

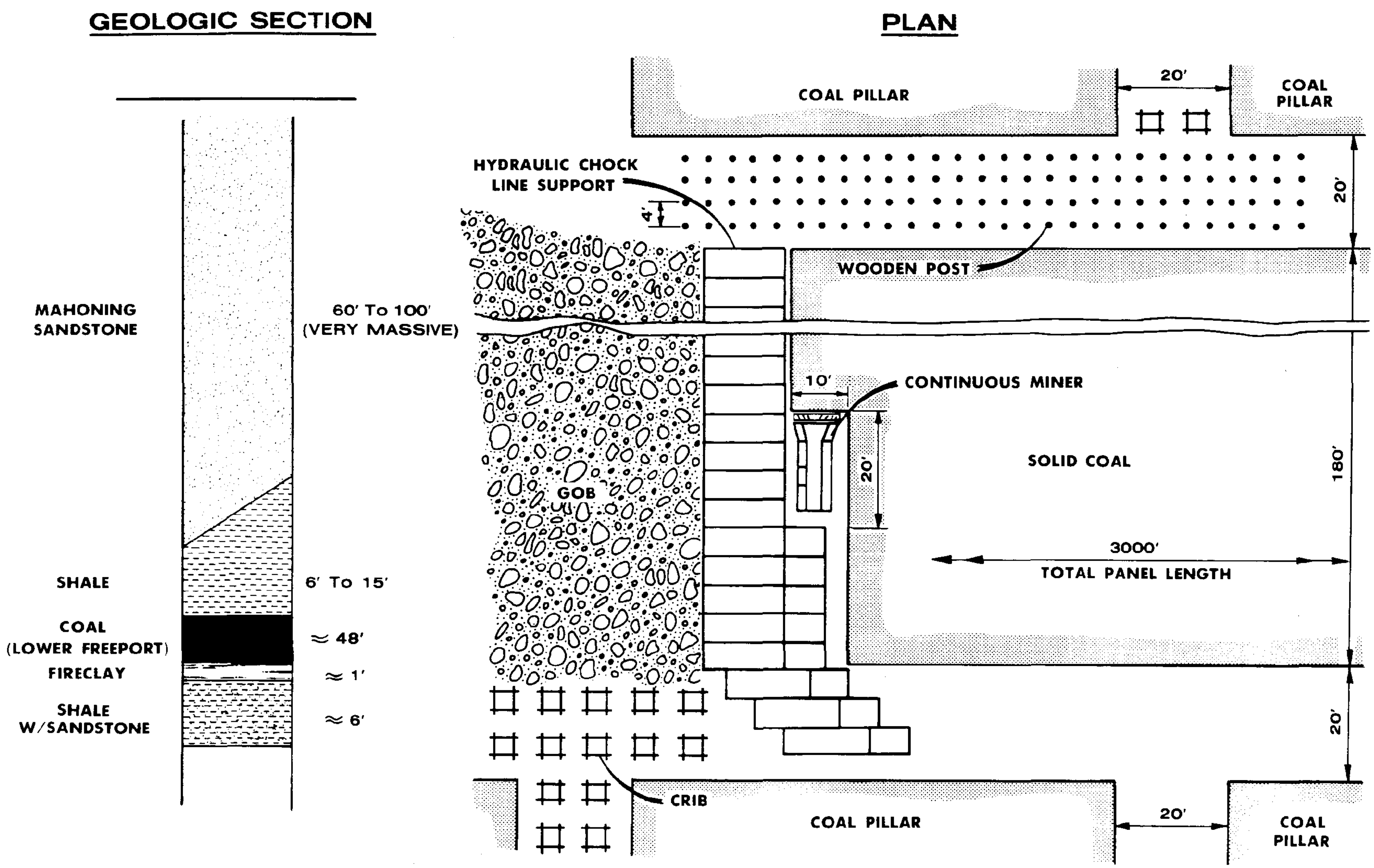


FIGURE 17. - Mine PaA - Geologic section and plan layout of shortwall.
No Scale

at Mine VaB that excessive loading pressures on the roof by the chocks can crush the shales and create problems. They maintain pressures in the system at 3000 psi rather than the recommended 4000 psi for the above reason and to save wear on the hydraulic pump. The chocks are also not preloaded.

Subsidence has been checked over the shortwall site. By setting up a grid and measuring land elevations with a level both before and after mining, an average of .02 inches of subsidence was detected. This amount is within what could be considered error. It is unknown how soon after mining the leveling was done. It may be that in view of its temporal dependency, subsidence had not had a chance to begin.

No study has been initiated of hydrologic disturbances. Management felt that there hadn't been any disturbances since there was no evidence of large amounts of water. Mining at the depths that they were (750 ft.), they felt they were below the water table. Absence of soil water or other disturbances of the local flora had not been detected and would have been difficult to isolate because the area was primarily farmland.

Roof Control

Figure 17 shows a diagram of the operation and indicates the types of roof supports used and their placement. The figure indicates a much higher support density for the operation and a more conservative approach in general to the mining process. Management would like to reduce the support density, but more stringent mining laws in Pennsylvania will not allow it. Some characteristics of the operation such as the wrap effect of the headgate chocks precludes use of the entry immediately across from the face. Operations at other shortwalls allowed use of the crosscut for one cut after the face had gone by thereby aiding immensely with haulage.

Development was done with a continuous haulage system which allowed use of diamond shaped pillars. This system is effective in reducing the incidence of "runners" by effectively interrupting faults with solid blocks of coal. In conventional practice, these "runners" can by chance lie in cross-cuts or along entries, causing long term roof control problems.

MINE SITE UtA

Mine UtA is a longwall operation in east central Utah — the only longwall operation visited. The visit was initially made to study subsidence effects at a place where mining had come nearly to the outcrop, but it turned out that there are a number of other parallels which can be drawn between the operation and possible surface shortwall configurations.

The area around the mine is one which is quite arid and therefore sparsely vegetated. This fact belies one of the chief considerations of mining in the area in that the hydrology of the area has had a severe impact at times on the operations. This is further evidenced by the 3,000,000 gallons of water which are pumped out of the mine daily. Partially at fault for causing this water is the location of the mine on the limb of a large fold. A combination of the seam's 10% dip and the topography of the area causes the seam to outcrop high in the hills on one side of the mine and then to extend down below the mine yard and under a mountain resulting in as much as 2500 ft. of overburden. This combination of dipping seams and a sharp variation in relief has resulted in interesting mining conditions. Thus, the area in the mountains near the outcrop acts as a superior recharge zone and the total change in elevation of the seam causes a fairly high head. In attempting to determine the point of hydrologic disturbance and the primary causal factors, the management has used dye tracing techniques with only limited results. Findings were inconclusive, but there was some gradual seepage which wouldn't have accounted for the quantities of water inflow which exist. Further work has not been done.

Longwall development at this mine involves use of single entry development in many cases which parallels to an extent the presence of a highwall. This will be discussed in a later section, but generally encompasses considerations of differences in abutment pressure reactions between the cases where there are confining pressures and cases where there aren't. In dealing with these variations in roof conditions, roof support practices should be examined for their application.

In other places at the mine, a two entry system was used. This offers both a point of comparison between roof control results and another parallel which might be drawn in illustration of a variation in surface shortwall technique — that of leaving a pillar along the highwall.

Orientation of the longwall face is along the dip line with the headgate at the downdip end. This not only aids in monitoring water flow and monitoring sumps for pumping, but aids the face chain haulage. The headgate has been developed as a single entry divided for ventilation and belt haulage by a steel partition.

The local stratigraphy (Figure 18) is such that the seam is split into an upper and a lower bench by a major parting which varies from 20 ft. in some parts of the mine down to zero in others. The effect of this is to require longwall type machinery in some portions of the mine capable of mining 11 ft. of coal or, as has been done in a few instances, to mine out the bottom bench of coal after the upper bench has been mined. Though the operation we visited wasn't mining in the latter fashion, indications by management made it apparent that it was done. During the surface shortwall experiment, there were conditions due to a slip plane near the highwall which paralleled this soft or loosely consolidated condition. The major difference is that here there was only a 2 ft. web taken against the 10 ft. web taken in the experiment. An alternative to the use of top and bottom slicing is to take the entire seam at once when a minimal parting thickness warrants. In future panels, an attempt will be made to change equipment midway through the panel so that a different range of chock heights may be employed (one support type will not handle the entire range of mining heights required). This versatility in equipment manipulation is useful in maneuvering a surface shortwall operation in and out of the outcrop as required by adverse seam or topographic conditions.

The only major roof control problems encountered involved lateral slickensides which on occasion caused the roof to fall before it could be supported by the face chocks. Other than this, no abnormal roof control problems have been encountered.

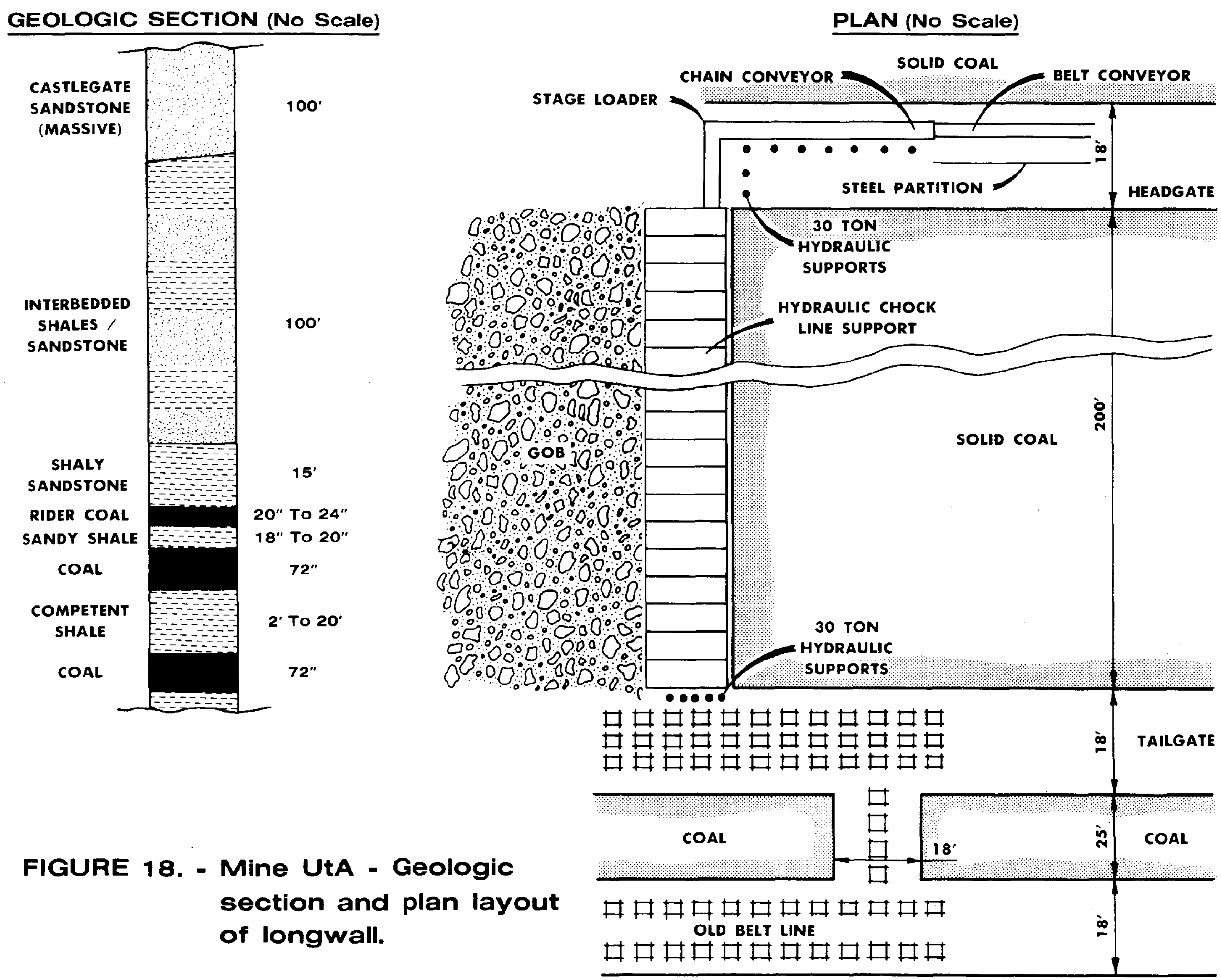


FIGURE 18. - Mine UtA - Geologic section and plan layout of longwall.

Roof Control

Figure 18 also shows the auxiliary roof control measures taken. Generally, a great deal more auxiliary support is needed at this operation than was required at previous ones. The necessity for this may be based on the single headgate entry development, the length of the panel, the high degree of topographic relief change, the dip of the coal beds or, of course, any combination of all these factors.

In the tailgate, a massive amount of timbering is done, generally in the form of cribs four feet wide made of 12" x 12" blocks. These were situated in a high density arrangement (Figure 18) in an effort to maintain a bleeder entry for the panel. In spite of these efforts, the cribs were not totally competent. This may also be the result of having the tailgate in a two entry development, both entries of which they have tried to maintain. The cribs have been placed such that two of these large cribs have been placed in the old head entry straddling the old belt line. Three more for a total of five have been placed in the tail entry as described for bleeder protection. These cribs are built 50 ft. in advance of mining. Supplemental to the cribs are five temporary 30-ton hydraulic jack supports that are advanced as the operation moves.

In the headgate, the steel partition dividing the entry is taken down 50-100 ft. in advance of the face and a simple brattice cloth is used to isolate the belt. Closer to the face 8 to 10 30 ton hydraulic supports are used along the stage loaders.

The character of the roof is such that initial falls are obtained approximately 60 ft. into a new panel. Thereafter, the first 20 ft. of roof — up to a fairly strong strata — falls almost immediately. The primary roof hangs up and falls only every week and in a pattern of thirds. The middle third first, followed by the two thirds on the sides. Generally, roof control is not a great problem.

One aspect of the operation which was not broached was their projected efforts for ventilation when mining the following panel. At that time, without a packwall down the single entry, establishment of an airflow and an escapeway could be difficult.

GENERAL COMMENTS

This section has been included to provide a backdrop of the feelings that the operators had for the surface shortwall as it occurred or for the concept of application of shortwall/longwall techniques to highwalls.

The single most widely discussed statement among people who are familiar with shortwall installations is that they are not a panacea for situations which might pose problems for other methods. In those instances in which the mechanics of the roof strata do not allow use of room and pillar mining, shortwall mining should also not be attempted. In spite of the assumed advantages alluded to earlier of training and familiarization with equipment acquisition, shortwall mining actually requires a very good understanding of particular roof conditions to appreciate how a shortwall system will work. The basic disadvantage of shortwall mining is the extraordinarily large web or cut which must be taken in any cut. Though it would then be desirable to use a smaller or narrower machine, other equipment limitations such as the width of the shuttle cars used for transportation or the requirements of space for personnel movement dictate otherwise. Most of these limitations can be met with use of a conveyor-type system. In so doing, one basic tenet of the use of shortwall has been compromised — a sophisticated equipment piece is brought in which is generally seen connected with longwall installations.

A few comments received concerned inflexibility of regulations, either at the state or federal level, to meet the specific requirements of the ground control problem at hand. Mine PaA in particular felt that by oversupporting the roof, they might be endangering the operation to some extent. Much of this problem may not only stem from an inadequately researched and prepared roof control plans, but also from regulatory inflexibility. This has particular import in its application to the surface shortwall. The technique, though it has been tried, is basically a new one and employs techniques which are generally not under current regulation. As such, it is subject to new regulatory controls which may be indiscriminately added and not geotechnically reasonable.

Often broached was the subject of large scale abutment pressure shifts, particularly in terrain with high relief. A few of the management people expressed some concern over how abutment pressures induced by large scale shortwall mining would change mining conditions. For instance, if mine planning called for mining out coal from under one side of a mountain, would shifting of the mountain's weight cause roof flexures such that problems with kettlebottoms, slickensides, and faults would be greater. Since shortwall mining is a relatively new method, none of the units have actually produced from more than a few panels — probably too few to make a valid assessment — in the average 2½ to 3½ years they've been in operation. The same thought might be projected to longwall operations except that more complete settling is able to occur, inducing strata breakage further up into the overburden and relief of arching pressures which otherwise seem to occur.

Operationally, because of tendencies of the roof to seek stabilization, management people felt that during strikes or any extended work stoppage, any present cut should be finished and the support line brought up to the face. Additionally, the supports should be posted to maintain a higher support level. In keeping with this, a major complaint of management was the necessity, and converse lack of ability, to maintain continuity of the operation due to shift changes. As a comparison, one operator pointed out that the "wall" methods may be looked at as incremental slicing of the coal. As such it would be ideally conducted as a uniform sweeping of the face, reducing so called increments to nearly zero. Unfortunately, present technology precludes this and in lieu of continuity there is incremental slicing, either with a plow (6"), a shearer (≈24"), or a continuous miner (≈10 ft.). As the steps toward a larger web are taken, the ground control complications get more difficult and the need for continuity of operation also increases.

Of particular importance to the surface shortwall methods was the comment by one operator that the overburden removed in preparing a bench should not be blasted. In his experience as a surface mine operator who also often worked as an underground punch miner, he found that blasts of the overburden, particularly massive sandstones, often propagated cracks a hundred or more feet into the highwall — much to the detriment of roof control in that area. In view of this opinion, overburden removal must be done by dozers with rippers, loaders and often shovels.

Other minor comments were also made concerning the ability to maintain adequate ventilation and an escape route. These, however, will be most adequately covered in the next section.

HISTORY OF SURFACE SHORTWALL MINING

The only known instance of the use of shortwall type equipment in a surface mining application occurred at a site near Julian, West Virginia during a period of a few months in 1976. As stated earlier, results of the experiment drew mixed reactions from the parties involved.

On one hand, because it had worked at all, it seemed to promise a possible reduction in environmental degradation through a blanket settling of all overburden and a resultant reduction in long term subsidence. It was perceived that acid mine drainage might also be reduced if this settling was to take place in such a way that perching shales and clays were not totally disrupted and entry of water was thereby precluded. Also, all acid rock from above the seam would automatically be buried in the deepest parts of the overburden. This contrasts sharply with the usual results from contour haulback in which, even in the best planned operations, acidic rocks are inadvertently scattered throughout the bottom layers of the backfilled material without regard for toxicity. In light of the anticipated environmental advantages of this new method, it is unfortunate that no long term post-mining environmental studies were initiated to verify the amounts of acid discharge or the extent of damage to flora from subsidence. Such studies were initiated but never completed or the data analyzed.

Other feelings concerning this new mining approach evolved around the lack of real production in spite of its productive capabilities. Actual mining only amounted to a few hundred feet during the several months of operation. The lowered production levels were caused in part by a strike through the summer and in part by a lack of haulage vehicles for the coal produced. This was compounded by a seeming lack of foresight in regards to the immediate geologic conditions.

Basically, the surface shortwall concept was initiated in an attempt to eliminate or improve on two other surface mining methods: augering and surface contour mining. Augering is usually seen as an ancillary operation when used in conjunction with contour mining. In that capacity, it is an operation that can be temporarily deployed or discontinued on a few hours or a day's notice. It does have the disadvantages of:

- Isolating reserves - it is, though, readily adaptable to OSM regulations which require that entrance points to the interior reserves be left every 2,500 feet;
- Having an extraction ratio of 35-45% which leaves a great deal of coal behind;
- Having an overall extraction ratio much less than the nominal figure above since whole blocks of coal are isolated as wedges which cannot be reached by the auger or any other means;
- Allowing environmental degradation by seepage of groundwater into the cavities left by the augering and subsequent leakage of this acid water around the mandatory plug at the exposed end.

Contour mining also has certain disadvantages which can be at least partially alleviated through use of the surface shortwall method by:

- Minimizing disruption of existing land forms. Where current practice might dictate a bench 200 feet wide, use of a surface shortwall would require 80 feet of bench with the remaining 120 feet being mined with the shortwall equipment;

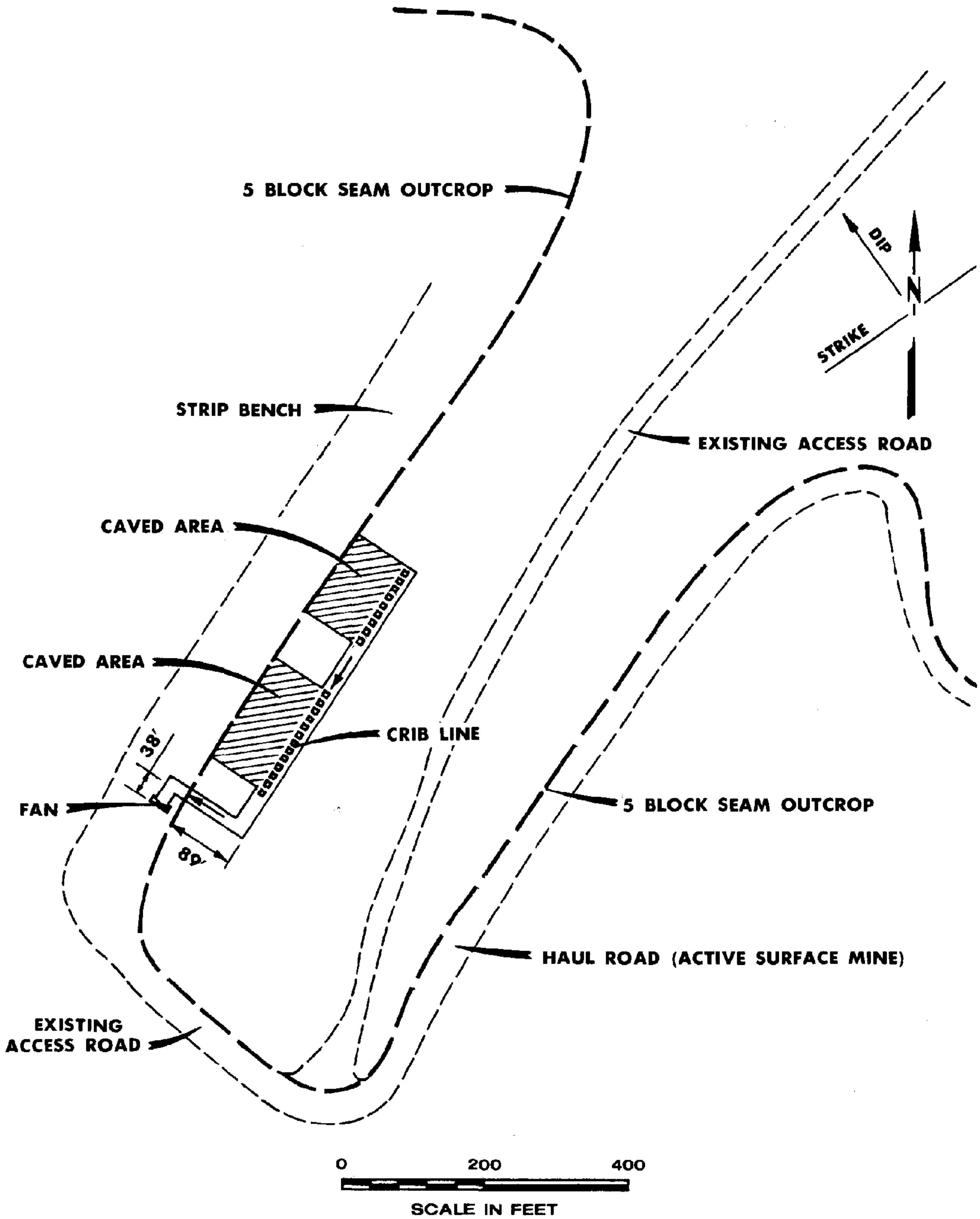


FIGURE 19. - Experimental surface shortwall site Julian, W. Va. - plan view.

- Reducing the amount of acid material scattered throughout the overburden;
- Minimizing the amount of area needing reclamation. This could pay major dividends in steep slope areas where reclamation is exceedingly difficult.

In improving on these two methods, it was hoped that the advantages of both could be combined while minimizing detracting characteristics. One major disadvantage of the concept found was that once started, it can be difficult or dangerous to stop, and certainly the system cannot be initiated where desired at will; a great deal of forethought and planning are required along with concomitant engineering to make the system work.

The major difference in planning for a surface shortwall operation is that the entire operation from clearing and grubbing to final reclamation will focus on the shortwall. All time elements are based on the production rates of the shortwall operation. This is manifested in the approach that must be taken — that the shortwall is not an ancillary operation or an unnecessary appendage to the mining process for the sake of winning more coal, but is rather the focal point of the entire operation.

Figure 19 illustrates the extent of mining as it occurred at Julian. The figure indicates that there were two separate periods of mining with total mining having been on the order of 400-500 feet. Mine development began with clearing of a bench along a fairly straight stretch 200 yards long. This was done in such a fashion that the highwall was nowhere more than 40 feet high while the bench varied from 30 to 85 feet in width. Highwall height was limited in this manner to minimize the danger of collapse. In keeping with good practice, the overburden was not blasted, but was instead ripped by bulldozers and loaded into trucks by a Bucyrus Erie 3 $yard^3$ shovel. As opposed to an ideally continuous operation with excavation and reclamation respectively preceding and following the shortwall operation, in this instance the bench was cleared nearly a year before the shortwall operation began. Spoil was stored off site, but the site has recently been reclaimed.

Development of the underground mine began by driving two entries on 60 foot centers into the hillside a total of 89 feet with a single crosscut at the end which was maintained for ventilation. The chocks were then positioned along one entry at 60 inch centers and in banks of three. Once the face conveyor had been positioned and necessary outside preparations made, mining could commence.

As planned, the operation was to use a portable fan to be situated at the highwall end of the face conveyor. Tubing $1\frac{1}{2}$ - 2 feet in diameter would then supply air to the face. This ventilation method was rejected by MESA (MSHA was not yet formed). There were other difficulties experienced in attempting to maintain compliance within the constraints imposed by the 1969 Coal Mine Health and Safety Act (CMHSA):

- Mode of fan operation, i.e., whether it should be blowing or exhausting;
- Maintenance of return escapeway, i.e., MESA required that there be at least two escape routes from any underground environs;
- Maintenance of a bleeder entry for bleeding noxious gases from the goaf or gob.

To meet MESA requirements four foot cribs were erected at the tail of the shortwall face so that a five foot passageway or escapeway was left. Thus, nine feet of roof was not allowed to fall.

The passageway also served as a return airway leading to a permanently installed fan situated at the face of No. 2 entry. This arrangement provided far better ventilation than would have been possible with the portable fan and tube arrangement originally proposed in the feasibility study. There were few problems associated with maintenance of the return escapeway as described, nor were there operational difficulties in erecting the cribs. Cribs were also erected under the highwall to control collapse until an initial fall occurred and the operation stabilized. This fall occurred after about four passes or forty feet. An engineer on the project indicated that there were no buttress chocks in use for stabilizing the highwall, though they had been considered at one point.

The mining equipment used were Hemscheidt chocks with a capacity of 175 tons per leg (550/4) and a Lee Norse CM-285-H continuous miner with a 10 foot head. The switch to use of a continuous miner over use of a shearer as proposed in the feasibility study was made due to the greater flexibility afforded by the continuous miner in modifying its cuts and in making new entries and crosscuts as required. Complementing the above was an Eichhoff 17 inch longwall type armored face conveyor for face haulage.

Figure 19 also indicates that there were two separate episodes of mining; fairly early in the mining process, difficulties were evidenced from a geologic peculiarity in the highwall. A "mud vein" was present which, when mining commenced on a new cut, acted much like a slickenside in allowing the highwall to slough off and onto the bench. At one point, several of the chocks were also knocked over. At this juncture, the total support line was pulled out and reinstituted a few feet down the highwall. The highwall was trimmed to 60° and a canopy was provided to protect men and equipment against rockfalls and to forestall highwall collapse. The basic problem was one of dealing with a mud filled vein running parallel to the highwall and a few feet in the hill (Figure 20). This vein or fault acted as a slip surface causing the highwall to prematurely collapse. No figures were available on the degree of its dip or its character underground, but it was a problem throughout the operation. It generally caused as much as a couple hours delay when initiating the cut until the miner finally cut through the slip and the highwall was supported. The fact that an experimental procedure was put ih a situation which embarassed its true capabilities was probably the result of poor planning, but the operation could not be moved for three reasons: 1) the fan would have to have been moved; 2) moving the mine and the fan would have constituted opening a new mine requiring new permits; 3) a new bench would have been required since this mining was being done from a previously cleared bench.

The actual operational details involved a sequence of chock and conveyor moves in concert with the operation of the miner. As the miner head passed each chock, the canopy was extended 51 inches (full extension), and the conveyor was advanced 30 inches. As the head passed the third

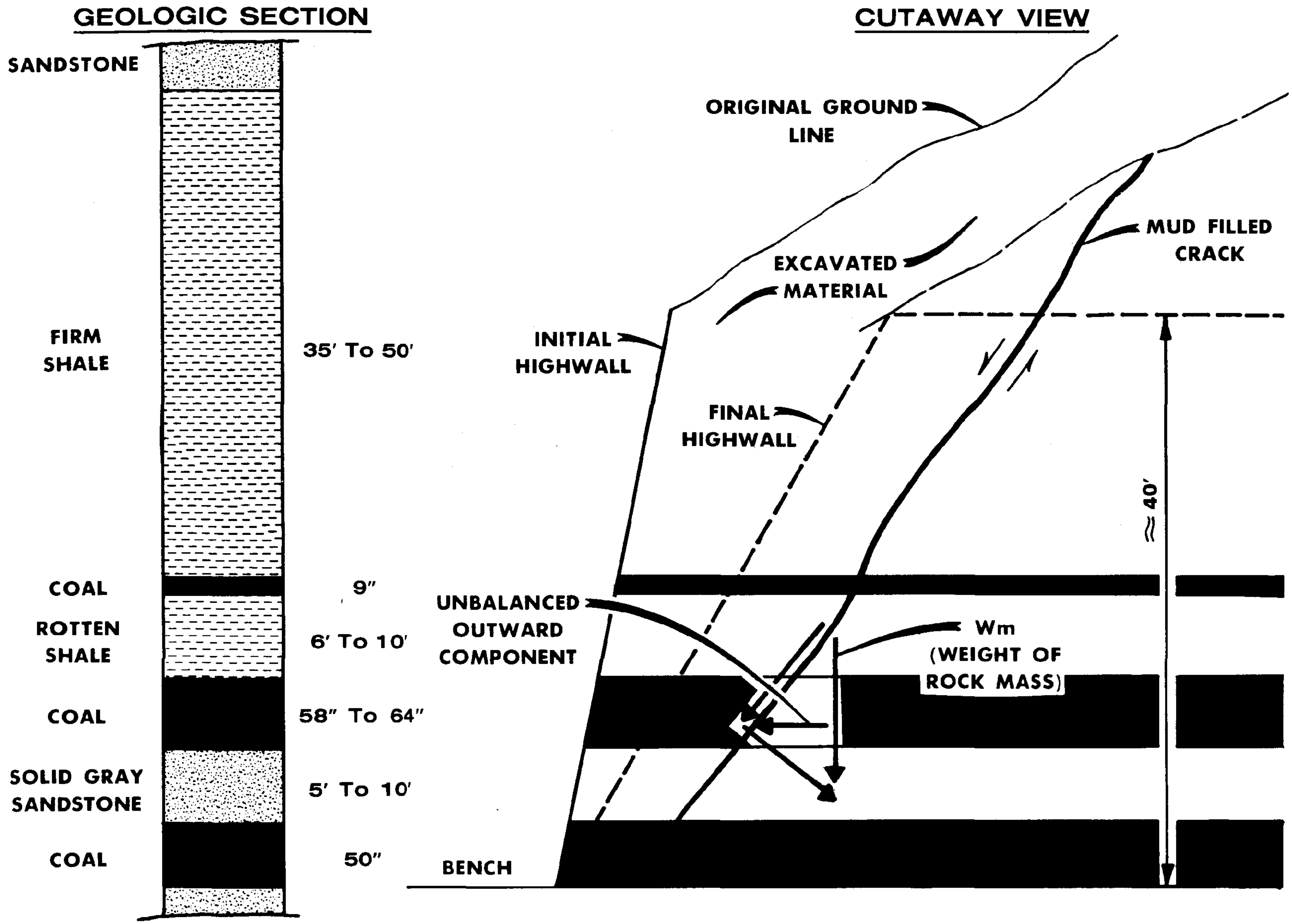


FIGURE 20. - Geologic section and cutaway view of Julian site.
No Scale

chock, a 30 inch chock move was made. Once completed, the conveyor was advanced 30 inches. When the head passed the sixth chock (30 feet), another 30 inch chock move was made. At completion of the cut, the miner was backed out and two 30 inch chock moves were made. The hydraulics of the chocks were arranged so that three chocks were essentially hooked together. In this way, any one of the three could be controlled from a single station. This not only heightened safety by reducing the traveling that chocksetters did, but also potentially resulted in quicker chock movements than would otherwise have occurred.

Despite the numerous setbacks due to labor stoppages, transportation shortages, and difficulties with compliance provisions (including the EPA which helped fund the experiment), the experiment did point out a number of specifics:

- The mining concept is feasible. This may not be readily apparent, possibly because planning was not on par with that required;
- The operation can be done within legislative constraints;
- With proper planning a pit size can be maintained which will drastically reduce the amount of land under bond and, therefore, the size and cost of pollution control devices;
- Resource recovery rates can be very high and approach 100% since, ideally, no wedges or blocks of coal are left sterilized.

The reduction in environmental degradation can be effected because the benching operation is kept small, and the actual shortwall mining operation takes up very little area.

The major disadvantage to surface shortwall mining is selectivity of seams which are usable. As will be apparent from following discussions, the list of criteria to be satisfied, while not to be interpreted too closely, does not allow much room for leeway. It is also obvious that most minable seams in the steep slope area tend to be fairly thin or only locally thick. Other disadvantages become apparent:

- Though coal resources are significant, they may be too scattered to allow wide use by a group of operators;
- Acceptance and use by a group of operators is needed to allow better technology transfer and exchange of ideas;
- The working environment to mine the coal is significantly poorer than if surface mining is used;
- Operational details have not been worked out nor was any attempt made during the experiment to negotiate a major curve — only long straight benches thus far;
- Interior reserves may be more gravely isolated than with augering since the equipment cannot be retracted and deployed easily at the 2,500 foot intervals.
- It is not clear how the concept will work in light of new regulations, i.e., Surface Mining Act and Federal Mine Health and Safety Act.

What is clear is that, though all the mining methods and equipment combinations thus far discussed have their respective advantages and disadvantages, no single concept has been devised which entirely eliminates all of the negative environmental aspects.

Figures 21 and 22 indicate the manner in which mining could progress given a systems approach to the technique. Once an initial fall is obtained,

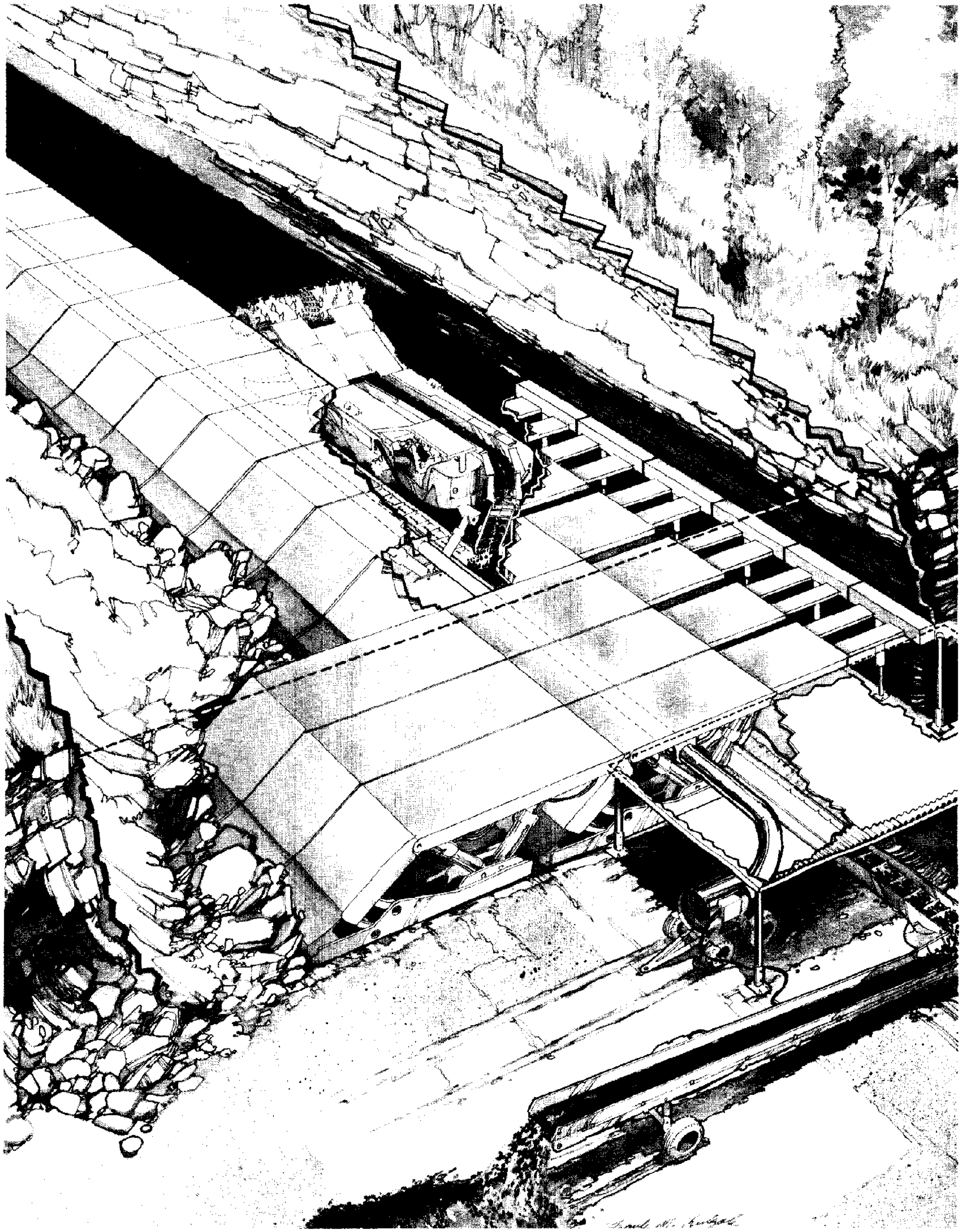


FIGURE 21. - Cutaway view of a surface shortwall mine.

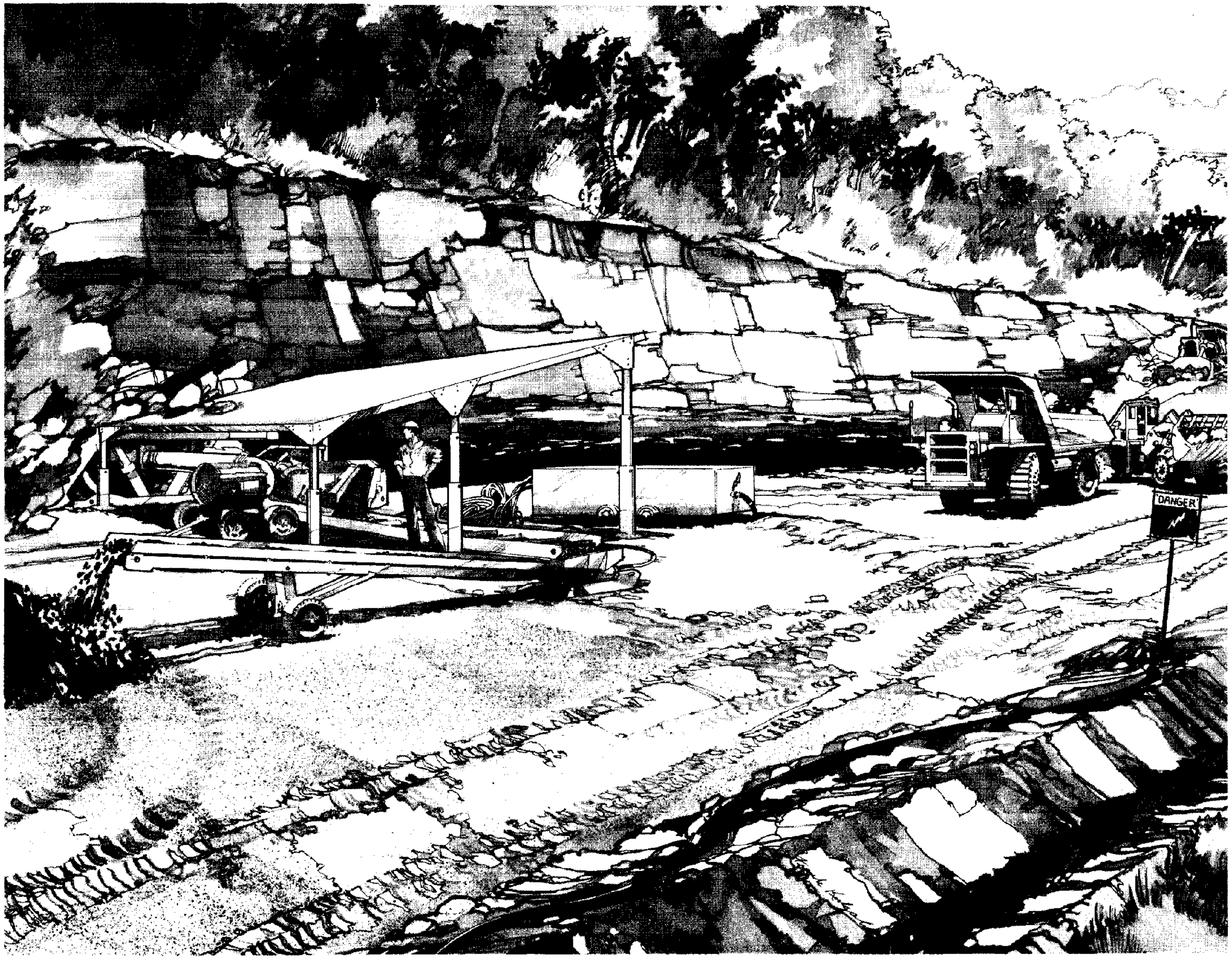


FIGURE 22. - Front view of a surface shortwall operation.

roof collapse would progress along with the mining. Figure 22 particularly points out the system's approach of the operation. A single medium sized dozer or loader in combination with a shovel and a 35 ton rock truck could maintain the bench an appropriate distance ahead of the shortwall operations. As mining progresses to the right, overburden is deposited and compacted to the left. Space is left for a coal haulage road. Reclamation of this road would need to be in accordance with the permitted mine plan. All other environmental safeguards such as sediment ponds and diversion ditches are required since a major landform disturbance is in progress.

Also to be noted in Figure 21 are the hydraulic jacks which support the end of the canopy. One manufacturer has developed chocks similar to these which offer superior support through use of a 30 ton hydraulic arm which can be dropped as shown.

TECHNICAL ASPECTS OF SURFACE SHORTWALL MINING

In reviewing the technical aspects of any mining method, it is well to have a broad base of experience on which to found conclusions or statements of speculation. The single aborted instance of shortwall use in a highwall offers an insignificant statistical base for realistic review, but when projections are made based on underground usage experience, it is possible to arrive at a synthesis which offers a good working model. This section will be an attempt to synthesize practical underground shortwall experience, the experience at Julian, West Virginia, and the results of ground monitoring research at other shortwalls in Appalachia — a few of which were visited — into a realistic projection.

Geotechnical and Ground Control

One of the primary considerations in analyzing performance of roof control systems is in realizing the relative impacts of the various abutment pressures and their interrelationships with arching or beam theory. The essence of arching theory is that there is an arch formed between two supporting elements requiring mechanical supporting devices only to hold up the material within the arch. Conversely, beam theory dictates use of supports either in supporting one or both ends of the beam or its midsection. As applied to "wall" mining processes, one or both of these theories have been brought into play. This has been done by describing an arch from the solid coal panel across to the gob area or alternatively, a beam of prefractured material requiring support extending again from the face into the gob area.

The shapes and thicknesses of these arches or beams are highly dependent on the type of strata in the immediate and primary roof. These beams and arches actually extend both across the panel from chain pillar to chain pillar and from the panel into the gob. The shapes and thicknesses of these beams and arches are highly dependent on the type of strata in the immediate and primary roof.

Another crucial dependence lies in the topography of the area — not only the amount of relief, but the degree of change in relief or the steepness of slope. Depending on how the topography changes, the side, face and rear abutment pressures will also change causing variations in these arches and beams.

In their original equipment proposal, Lee Norse compared the proposed experiment with a very shallow (80-120 ft.) shortwall in operation in Jennerstown, Pennsylvania. At this mine, subsidence and strata breakage occurred through to the surface. In making the comparison, the arch theory was discarded since in this, a parallel instance, once the rock breaks through to the surface, the arch has failed. On closer examination, the arch theory also fails in its other possible direction, across the side abutments since there is only one side support left. This leaves beam theory as the major consideration in its two forms — supported on both ends and cantilevered. Fortunately, abutment pressures in surface shortwall would always come from the same relative direction — the mountain over the tailgate.

An examination of the influence of the highwall on abutment pressures leads to some interesting observations. Depending on the steepness of the highwall, it may mathematically be regarded as a boundary value problem, particularly when the highwall is vertical. A cursory mathematical treatment of that might indicate a "spike" as a result of the changes in overburden pressures from the bench into the coal. On initial mining of a pass at the outcrop, a strictly vertical pressure changes into a cantilevered abutment pressure. During the course of the experiment and due primarily to the mud vein, the highwall was trimmed back from the original 75° to approximately 60°. In so doing, a great deal of the pressure was taken off the sliding wedge which constituted the material on the outside of the slip plane. Perhaps the best method to use would be reduction of highwall height to only 10 to 20 feet. However, this obviously leads to very narrow benches.

No information is available on the sequence of overburden breakage either vertically — immediate roof then primary roof — or laterally -- that next to the highwall followed by the inby material. Figure 20 indicates the possible changes in pressure on the strata in its cantilevered state by removing material that was slipping. Reducing the highwall angle obviously takes a great deal of pressure off the supporting strata enabling it to maintain itself longer. The amount of pressure that a strong sandstone or limestone strata will hold may be best illustrated by the findings of researchers working on the Beth-Elkhorn shortwall operation. In their main roof, they found a massive sandstone strata that never broke across a span of 730 feet in spite of 700 to 800 feet of overburden. Subsequent crushing of the gate pillars caused a general subsidence of from one to ten feet and a maximum equal to 44% of seam thickness. Significantly, the subsidence trough had a smooth flat floor and did not reflect the presence of the chain pillars. It must be presumed that the sandstone is now lying in a stable position on the crushed pillars and the broken immediate and primary roofs. It was concluded that conditions favorable for shortwall mining could be predicted by a prior rock mechanics study and that under more favorable conditions, a very large area could be subsided uniformly by shortwall mining (University of Kentucky, 1979).

Direct application of these results to a surface shortwall are impossible, again because of the lack of two sets of chain pillars. However, many of the cyclothems in Pennsylvania rocks do contain massive sandstones of the quality and thickness (≅50-100 feet) required. Mines VaA and VaB both had 30 foot sandstones within only a few feet of the seam. Application of a surface shortwall in these conditions could allow a very strong cantilever to occur. The effectiveness of this strategy would depend on the depth of cut. With the nominal 89-110 foot cut as used at Julian, and suitable highwall support and perhaps backfilling, the strata could remain continent for a long while allowing a controlled subsidence. With longer cuts of up to 250 feet, such practices would be totally impractical.

Reports from people involved with the experiment suggest that beyond the first few feet of each cut, mining and roof control were no real problem. There were a few qualitative operational adjustments suggested, however. Chief among these was a reevaluation of the chock setting procedures. The chocks used at Julian had setting capabilities of 416 tons at a nominal line pressure setting of 4,000 psi. The chocks were often lifting and breaking the burden, particularly at the outcrop, where it was only 30 to 40 feet thick. The reason for this is apparent when differences in the applications are understood. The chocks used were primarily for use under deep cover, where pressures might run 400 to 600 psi. In the conditions present under a highwall, pressures would approach 50 to 100 psi. Though a direct comparison cannot be made, it is still apparent that setting pressures in excess of those required will act as stress on overlying rocks, eventually straining them past their elastic limit, particularly where jointing or slickensided areas could act as fracture planes. It was suggested that valves be set such that the outer banks of chocks have their setting pressures at 750 psi, with inner banks receiving increased pressures in increments to 3,000 psi for the last bank. These findings may belie the need for a minimal highwall leaving only health and safety factors to be considered. These will be discussed later.

Operational Considerations

The Julian experiment did not last long enough to attempt more than cursory experimentation with operational techniques. In fact, it could be argued that the operation never reached the level of stabilization necessary for operational experimentation. As examples, neither the negotiation of inside and outside curves, nor extension and retraction of the system into and out of the coal were experimented with extensively. Further modifications will be covered under the section on shortwall variations.

The extension and retraction of the shortwall system into and out of the coal, while not necessary, can be an important method for improving cash flows, modifying equipment usage, or negotiating in difficult topography. Modifying cash flows is a rather obvious benefit since simply by extending the face, more coal can be produced and the development costs better defrayed. In times of poor markets and in the interest of maintaining continuity of operation, the face can be retracted until a breakeven point is reached. The equipment usage criterion is more difficult to assess but could involve retracting half of the string for a period of time for periodic overhaul, repairs or replacement. The final criterion of ease in negotiating in difficult topography will be discussed in paragraphs which follow.

One technique was practiced at Julian on a couple of occasions. Initial entry development was only 89 feet but the face was lengthened to 119 feet and conversely shortened somewhat by gradually turning the face equipment to drift in or out. An engineer on the project inferred that as it was practiced there, the practical limit of guidance was reached by their standard methods of estimation and that survey laser guidance might be needed for more complex maneuvers.

A typical operational sequence for insertion of more supports and a longer face length might involve extending the conveyor the required amount followed by hookup of one additional chock. Once this chock was gradually taken under cover, other chocks could be hooked up until either the end of the conveyor was reached or the desired face length attained. Retraction of the chock string would involve the opposite sequence.

An alternative technique for retraction would be to simply pull out a certain number of the supports. Insertion of equipment would then involve driving the cuts beyond the last support probably bolting the extra face length and setting up the extra chocks. This method has certain detracting features, chief among which are:

1) The fact that the kink produced will disturb ventilation flow. Though this happens very often in any underground mine, minimization of it is always desirable.

2) Introduction of complications in ground control. Adverse falling characteristics near the kink could cause blockage in the escapeway by toppling cribs.

3) It would be necessary to stop the operation for a few shifts to move up conveyors, chocks, etc. This could adversely affect ground control by disrupting system continuity.

Clearly, this aspect of surface shortwall operation is important, particularly in light of following discussions on negotiation of curves.

There are a number of problems associated with negotiating curves which, though very peculiar to this method and very difficult to overcome, are not total engineering obstacles. There are two types of curves to be addressed in their complexities — inside curves and outside curves. Due to outside curves being somewhat simpler, it will be dealt with first. The most prominent problems associated with it are: 1) alignment of the chocks during mining; and, 2) negotiation of the curve along a changing (increasing or decreasing) radius. Following paragraphs will address each of these points in turn.

Figure 23 illustrates an outside curve on an outcrop in southern West Virginia and a possible mode of operation to negotiate it. It is absolutely crucial that alignment of the chocks be maintained to as close a degree as possible. In underground usage, panels and faces are set up along

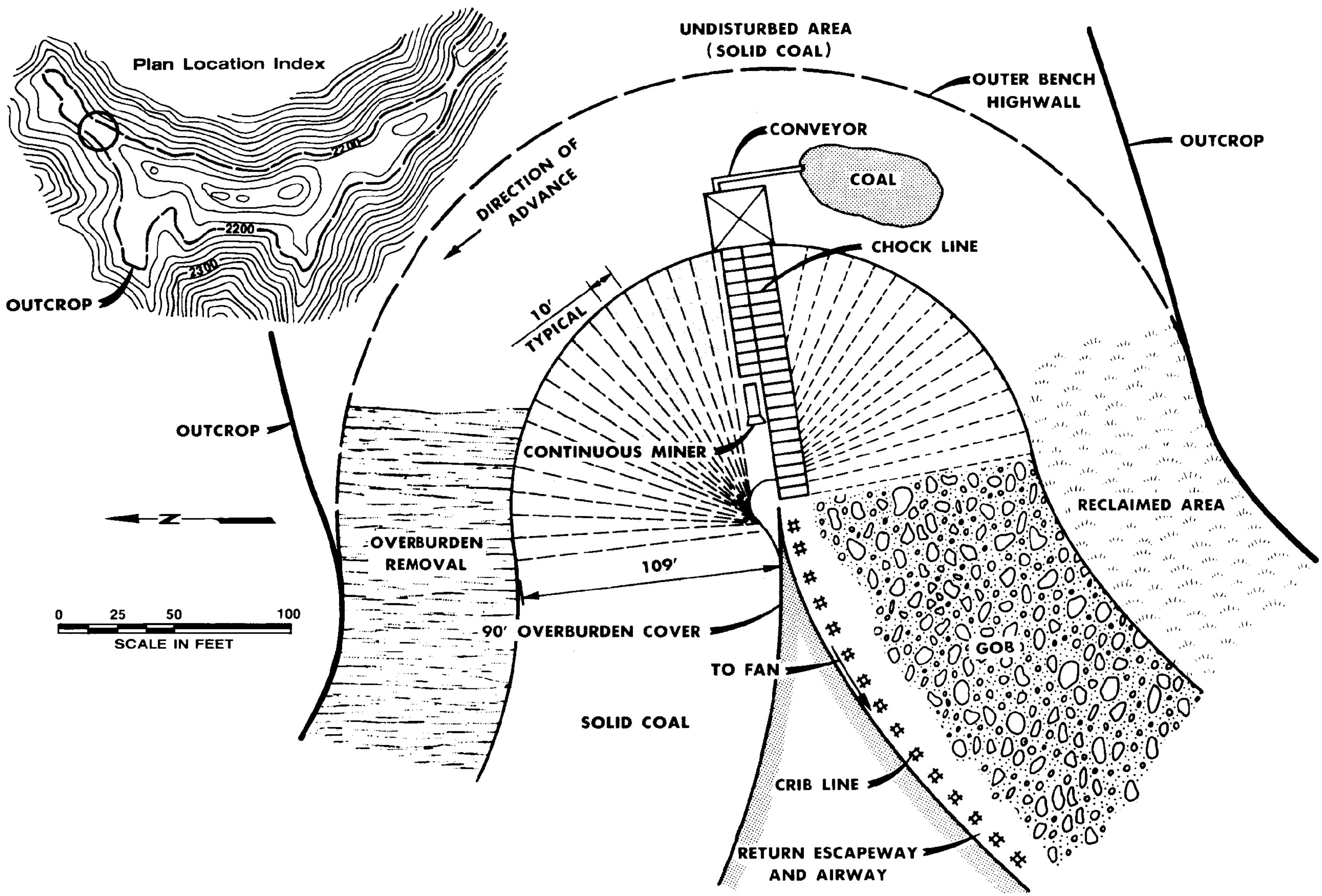


FIGURE 23. - Plan view of outside curve at a typical W. Va. site.

straight lines and there is usually little difficulty in maintaining alignment. However, in a surface application, there will be a number of factors coming into play all of which will be decisive in maintaining alignment: 1) it is most desirable to maintain the entire support string in the coal at all times; and 2) the radius of curvature will be changing, causing the center of curvature to change position. Since the support string always should be lined up on a radius line, the inside end of the string will have to move at different rates, often not moving at all. There are three cases possible in this regard with at least one plausible result of each:

- The radius of the curve is greater than the length of the face in which case both the inside and outside ends of the support line move. This is the simplest and most desirable case offering the fewest potential problems. The inby end of the chockline will simply be moved to maintain alignment between the outby end and the center of curvature.

- The radius of the curve is equal to the length of the face in which case the inby end of the chockline is situated directly on the center of curvature. The outby end will then be the only one which moves. Assuming the inby end actually does act as a pivot, roof control will become increasingly difficult. Since mining will be done in wedges, the outby end will move forward a full cut width and therefore support fresh roof. The inby roof will be gradually deteriorating over the time that it takes to negotiate the full curve. The length of time depends on the length of the support string and therefore the radius of curvature. For the 100 foot face shown, a 180° rotation would transcribe an arc 214 feet long. With a miner head 10 feet wide, 32 wedge cuts would be requied to negotiate the curve. At the nominal rate of two cuts per shift mined at Julian, this would require about 16 shifts or more likely two full weeks to negotiate. During this time, the roof over the pivot chock would become increasingly more highly fractured. This is the case shown in Figure 23.

- The radius of the curve is less than the length of the face in which case the center of curvature is situated outby the end of the chockline. In this case, the inby end of the chockline will again pivot about itself with the same problems resulting in roof control at the inby end. A further complication also develops in that the outby end of the support string extends progressively further out onto the bench, since the area that is being mined may be eccentric in shape. Several of the chocks may need to be removed and depending on bench width, the conveyor may need removing also. There is a positive aspect to this in that as the mining progresses around an eccentric curve, and the radius of curvature becomes shorter, the "arc" rate of mining increases so that the curve is negotiated progressively faster. This reduces the time element of pivoting for the inby end and, therefore, the ground control problems as well.

If the curve is at the end of a long narrow neck, either of the last two cases will cause the mining to progress back along the neck immediately adjacent to previous mining, thus using the escapeway and return airway twice.

Neither of the last two cases are very probable. Chiefly because topographically, curves of that type usually occur along necks of ridges. These necks usually represent areas with less than average overburden and are, therefore, easier to simply strip than surface shortwall. Given the right types of equipment, in the course of benching, a trench would be developed across the neck and benching progressed on the other side. Excavating of overburden on the neck could begin with the spoil cast back into the reclamation area of the shortwall operation. While the shortwall mines across the neck, the excavating equipment could mine the neck. With adequate equipment and equipment scheduling, this should pose little problem.

Figure 24 represents a situation requiring the shortwall to negotiate an inside curve and a possible procedure for effecting the turn. While this type turn is simpler in concept, it is potentially much more difficult to actually execute. As opposed to the three different cases caused by topographic influences on outside curves, a limiting factor on the topography of an inside curve causes the radius of curvature to always be longer than the chock line. While this simplifies some engineering considerations, it complicates others. Recommendations by a project engineer were that, due to greater complexities of inside curves, outside curves should be attempted first to gain the necessary experience in alignment and maintenance of ground stability.

As viewed in Figure 24, the problem results from the pivoting action which takes place under the highwall. While the inby end of the chock line moves 390 ft., the outby end, sitting under the highwall, moves only 170 ft. While being pivoted in this fashion, increasing instability of the highwall would pose a significant health and safety hazard to personnel and machinery both outside and immediately underground. To negotiate the curve shown, a total of about 40 cuts or passes of trapezoidal shape would be necessary. These 40 cuts at a nominal 2 cuts per shift or 4 cuts per two shift day would require 10 days to negotiate the curve.

The technical difficulties already posed in mining an inside curve are further compounded by other factors which affect bench development as well as mining:

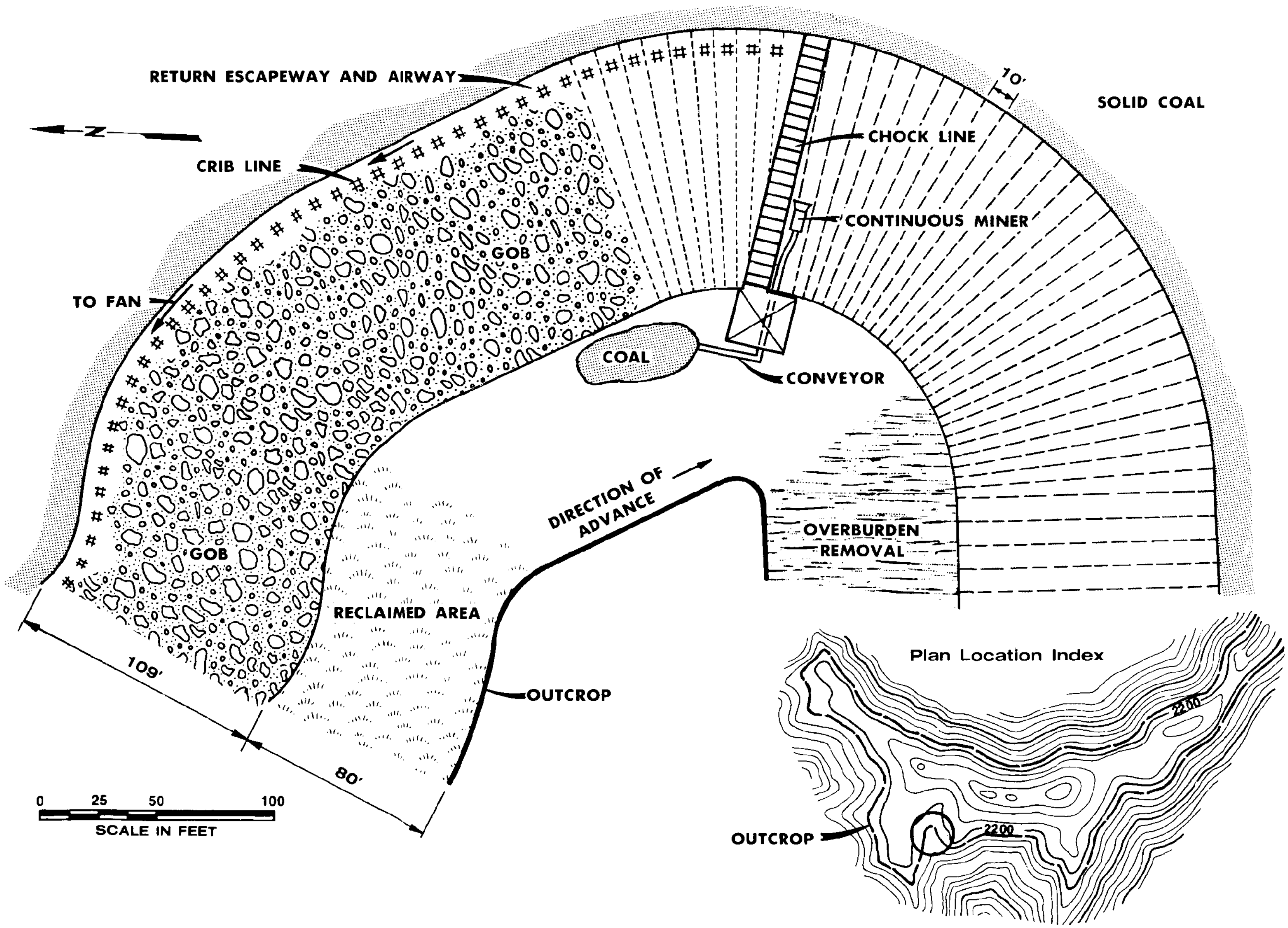


FIGURE 24. - Plan view of inside curve at a typical W. Va. site.

- Nearly always an inside curve generates a higher volume of overburden per unit of coal for a given bench width because of the steeper topography which usually prevails. In preparing for an inside curve, overburden is usually stacked higher or compacted more carefully for a certain period in advance.

- There are often streams or wet weather seeps on inside curves which can cause bad conditions during the bench development. These streams, according to the performance standards of the Surface Mining Act must also be protected by diversion away from the mine workings in protected channels.

- The presence of steeper slopes necessitates a higher highwall to maintain the minimum recommended bench width. This compounds the health and safety hazards of people working around the highwall.

- The presence of water in either springs or seeps on the outside usually is a good indicator of poor rock conditions. There is a very definite causality between the poor rock and the streams, which generally works in only one direction. The poor rock conditions cause springs to occur where they do, hence valleys to form and so inside curves to exist. The existence of water rarely of its own abilities forms widespread poor rock conditions. These conditions may actually be traces of large scale geologic structures such as faults or lineaments.

Clearly a great deal of engineering and planning are required in advance of either an inside or outside curve. In the particular case of the former, inside curves, the operation could run into poor mining conditions compounded by excessive overburden removal, stream flows requiring diversion ditches and hydrologic planning, higher than normal highwalls with greater instability and greater personnel danger, and extremely poor mining conditions from possibly fractured rock and wet seepage conditions.

Groundwater flow can have a significant impact on the viability of a mining venture in terms of: 1) its inflow and the consequent result on production and 2) outflows, both during and after mining, of an acid discharge which the buffering capacity of the receiving stream may not be able to assimilate. The relative position of the water table, the phreatic surface and any underlying impervious shale or claystone layers are the most important consideration here. Mine operators narrow these considerations down to being "above drainage" or "below drainage". Often deep mines are below the water table since there is at least one impervious layer between themselves and the water table. In the steep sloped areas of Central Appalachia, this will rarely be the case. Instead, mines are generally above the phreatic surface but may instead be subject to inflow from perched water tables which represent percolation water which has run into an impervious layer. This layer then directs the water down dip to the surface at an outcrop.

Though the quantities are not necessarily large, once the impermeable layer is broken, through subsidence, the inflow can affect production in several ways. If severe enough it can lower workers morale; and if mining is progressing down dip, it can collect at the face causing problems with softening of the clay floors usually present, thus compromising equipment mobility. This was demonstrated at Mine VaA. Environmental damage is especially apparent in the Central Appalachians because of the clastic, iron bearing nature of the rocks. In none of the regional lithologies is there any limestone present to neutralize acidity generated in the water.

Further north, the Kanawha formation is covered by the Monongahela formation which contains a higher percentage of limestones and does not represent quite as severe a problem.

Generally, groundwater inflow is not expected to be as large a problem at a surface shortwall operation as at a comparable underground operation. The surface application does not represent nearly as large an interception area nor is it as permanent an installation since it is able to move out of a large inflow area after several weeks. An underground application may have inflow problems for years.

Attempts to curb acid generation at surface mines generally focus on getting the water out of the mine before iron disulfide (FeS_2) forms. Legislative dictates call for isolating all inflow water in diversion ditches and safely getting it off the property. Any water which is directly impacted by the mining must be diverted to treatment facilities and sedimentation ponds.

Other operational difficulties center around equipment failings in which new equipment technology may be required. The surface shortwall experiment took underground mining equipment which had never been designed for extremes of environment other than dust and relegated it to an environment in which it had to perform its full functions in not only its design environment but also in the extremes of temperature which prevailed. One very acute example of the results of this was in the reaction of the hydraulic oil to these extremes. Since part of the mining took place during the winter months, temperatures at times dropped to 0° F.

Pure petroleum hydraulic oil was used since water would freeze and the standard fireproof mixture is 95% water and 5% miscible oil. Presumably any problems arose due to the rapid changes in viscosity of the oil as it warmed or cooled going through the mixing valves. These valves may not have been designed for the application and as a result hydraulic responses may have been very slow. Additionally, a great deal of leakage was reported throughout the hydraulic system, possibly due to thermal expansion differentials.

Though further experimentation can certainly be done with the equipment as it is, an intensive surface shortwall testing program would call for redesign of many of the major components of both the support and the mining systems.

A final group of factors which has had and will continue to have a profound effect on all types of surface mining is the various governmental agencies which have been involved in generating legislation aimed at controlling the environmental or health and safety impact of all varieties of mining. This particular type of operation, since it is hybridized, falls subject to more regulatory scrutiny then nearly any other technique. Being primarily an underground utilization of equipment, there are a number of MSHA permits required including roof control, ventilation, mine plans and projections as well as full compliance with all MSHA regulations. Since there is a surface expression of the mining in the bench operation, the operation also falls under the auspices of the Office of Surface Mining (OSM) and the regulations promulgated under the recent

Surface Mining Act (see Appendix C). These regulations are applicable not only from the standpoint of the contour benching operation, but also the possible surface expression of the underground mining such as subsidence, sedimentation and pollution emanating from the portal area as runoff or mine outflow.

A complete list of legislative impacts would be impossible, but the most recent major impacts would be attributable to the Surface Mining Act. One specific impact would be the requirement that in the event of augering, an entrance block be left into the interior reserves. These blocks must be at least 250 ft. wide separated by no more than 2,500 ft. of highwall. While this mandate is reserved and stated specifically for augers, there has been no real definition made of surface shortwall mining as a mining category. This lack of definition requires that there be an interpretation of existing laws for their application to surface shortwall mining. This could be an extremely arbitrary process. Evidence of this as a real possibility occurred at the Julian project. Permitting procedures were reported held up for lengthy period while officials decided how to classify the operation. As a single case, this again offers a poor statistical comparison to what would happen if the technique were used on a widespread basis.

There are other legislative difficulties though, such as restrictions on updip drift mining which could be interpreted as applicable or the requirement that auger holes be sealed with a clay plug. Acid drainage forms when the roof strata falls to the floor of the cavity left by mining.

Seepage or groundwater then interacts with this acid producing material. This acid water is then usually trapped above the underclays usually present on the floor and flows out. The acid producing potential of a surface shortwall may be about the same as that for auger holes. Whether the same plugging requirements will be applied to surface shortwall as are presently being applied to augers is not known, but methodologies should be investigated for sealing off the collapsed highwall, particularly when the mine is updip and is allowing drainage to exit.

There are numerous other technical aspects of surface shortwall mining which need to be addressed, but which will not be addressed here due to inadequate knowledge of the extent of experimentation and its results. There has never been an acceptable report of the project submitted which leaves little left but speculation as to justification for practices and procedures or the causal factors in any of the technique's failings. Another section will attempt to provide an estimation of how this might be alleviated through equipment research and development and a planned approach to the experimentation. The Bureau of Mines can be a valuable contribution in this process because of the obvious aesthetic and real environmental advantages gained through widespread use of this method.

COAL SEAMS AMENABLE TO SURFACE SHORTWALL SYSTEMS

Only a few of the many seams that are surface mined in Appalachia are amenable to mining by surface shortwall methods. In attempting to quantify those seams or portions of seams which are amenable to this method, due consideration must be given to specifying the range of conditions under which a shortwall system can operate. In evaluating the major seams of the steep slope area, the following criteria were devised as representing minimal requirements. The reasons for these many limitations become clearer with consideration of the capabilities of the equipment involved:

- Seam thickness from 4 to 8 feet to accommodate a continuous miner. The shields must be able to provide clearance for the miner, including the bit drum, in a fully extended position. Often the coal is not a full four (4) feet thick but an upper transition zone of shale and coal can be cut to provide clearance for the equipment. An upper limit must also be set to provide against instability of the shields or chocks. The importance ascribed this is evidenced by the tipping of chocks experienced at Julian, West Virginia due to lateral pressure from the material above the fault.

- Presence of a solid bottom or floor of strong impervious shale or sandstone. A solid floor is required to guard against the material becoming soft. Industry experience has shown numerous instances where short — or longwall panels have come near failure due to a fireclay floor which soaked up water and allowed the supports to tip forward. Under this criteria, fireclay bottoms should be no more than six (6) inches thick.

- Presence of a strong shale or weak sandstone immediate roof. The roof is perhaps the single most crucial parameter in the consideration of a seam. While the scope of this treatment does not include a detailed discussion of rock mechanics, a certain causal relationship should be established. The roof should be solid enough to maintain itself when the coal is mined out and the steel support is extended. Conversely it should be weak enough to fracture properly. Proper fracture is actually a pre-fracture in which tensional forces break the top part of this immediate roof just prior to the coal being mined. The measure of continence for the roof is the rate at which this fracturing occurs. In the limit where coal is being incrementally shaved off the face as with a plow, this can be seen more easily.

- Presence of massive sandstone or limestone approximately 8 to 10 feet thick forming the main roof just above the immediate roof. The quality of the main roof and overall overburden pressure have a great deal to do with the fracturing qualities just discussed. There is not a direct correlation between the actions of the roof at a depth of 600 feet in an underground situation and at 60 feet in a surface mining application. A very fine evaluation must be made discriminating the roof which is too strong and that which is not strong enough. Due in part to the root systems of trees and various geochemical processes, the rock near the surface will not be competent to the extent expected. Because of this, the arch theory which is extensively used to evaluate underground roof control practices does not find application in the surface scenario. Thus, while the supports will need to support the entire overburden load, a cantilevering effect needs to be induced to aid in pre-fracture while also not generating a squeeze on the equipment. In light of the small amount of application which this system has seen, this is not as critical as has been suggested. However, a careful evaluation of lithologic conditions is necessary.

- A seam that is flat or slightly upward pitching and updip into the hill. This condition is far from desirable from an environmental standpoint since it may cause dispersion of acidic or ferrous leachates into the gob area. It is beneficial from a health and safety and geotechnical standpoint since it limits pooling of water and subsequent softening of the underlying rock layers.

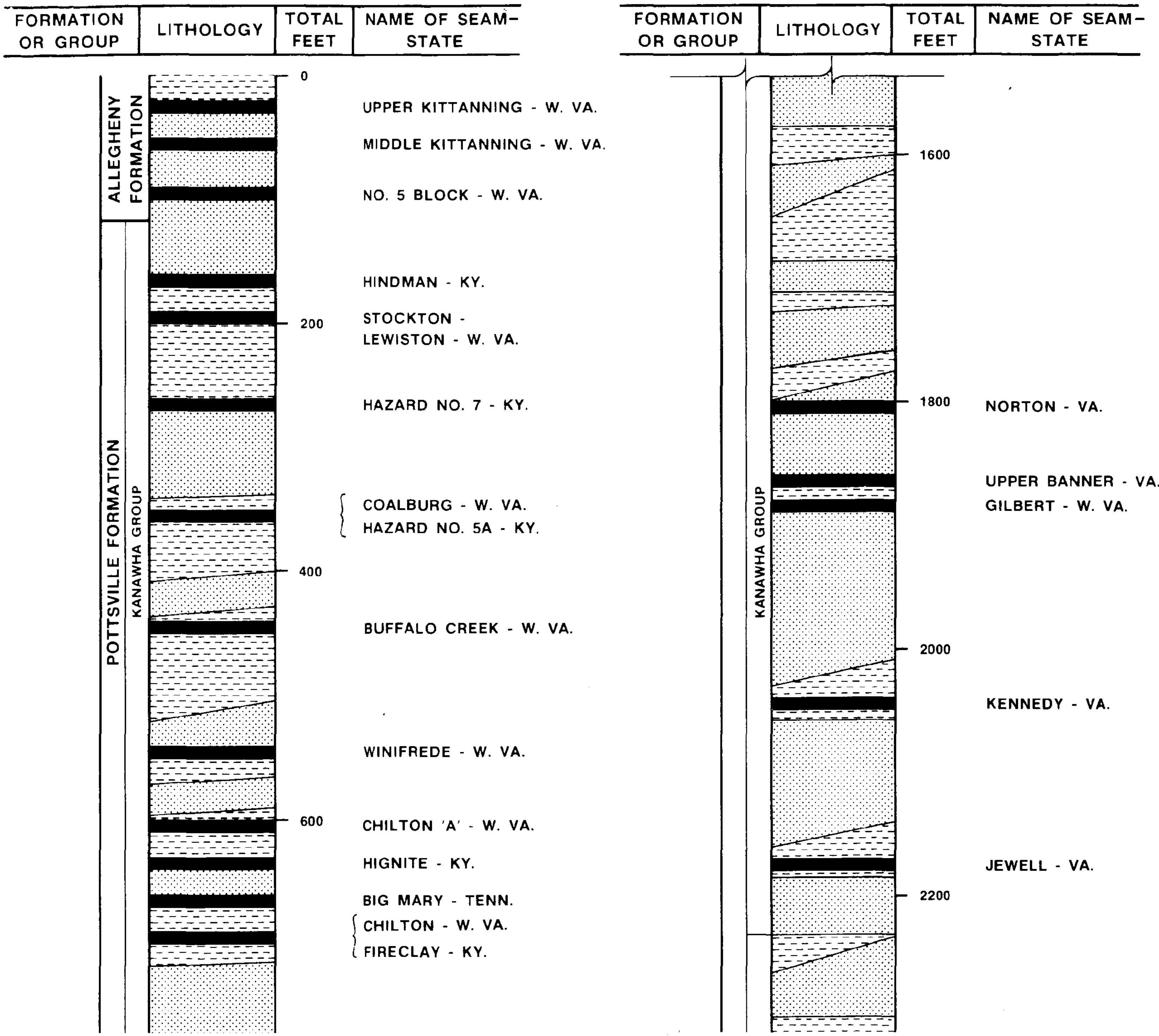
- The seam should be uniform without interruptions such as channel sands or other pinching phenomena. The range of application of a continuous miner and support combination is limited particularly in the short end. Though continuous miners are capable of cutting rock to a limited extent, a localized pinching is usually caused by a channel sandstone which is not easy to cut and, if extensive, could shut down the operation.

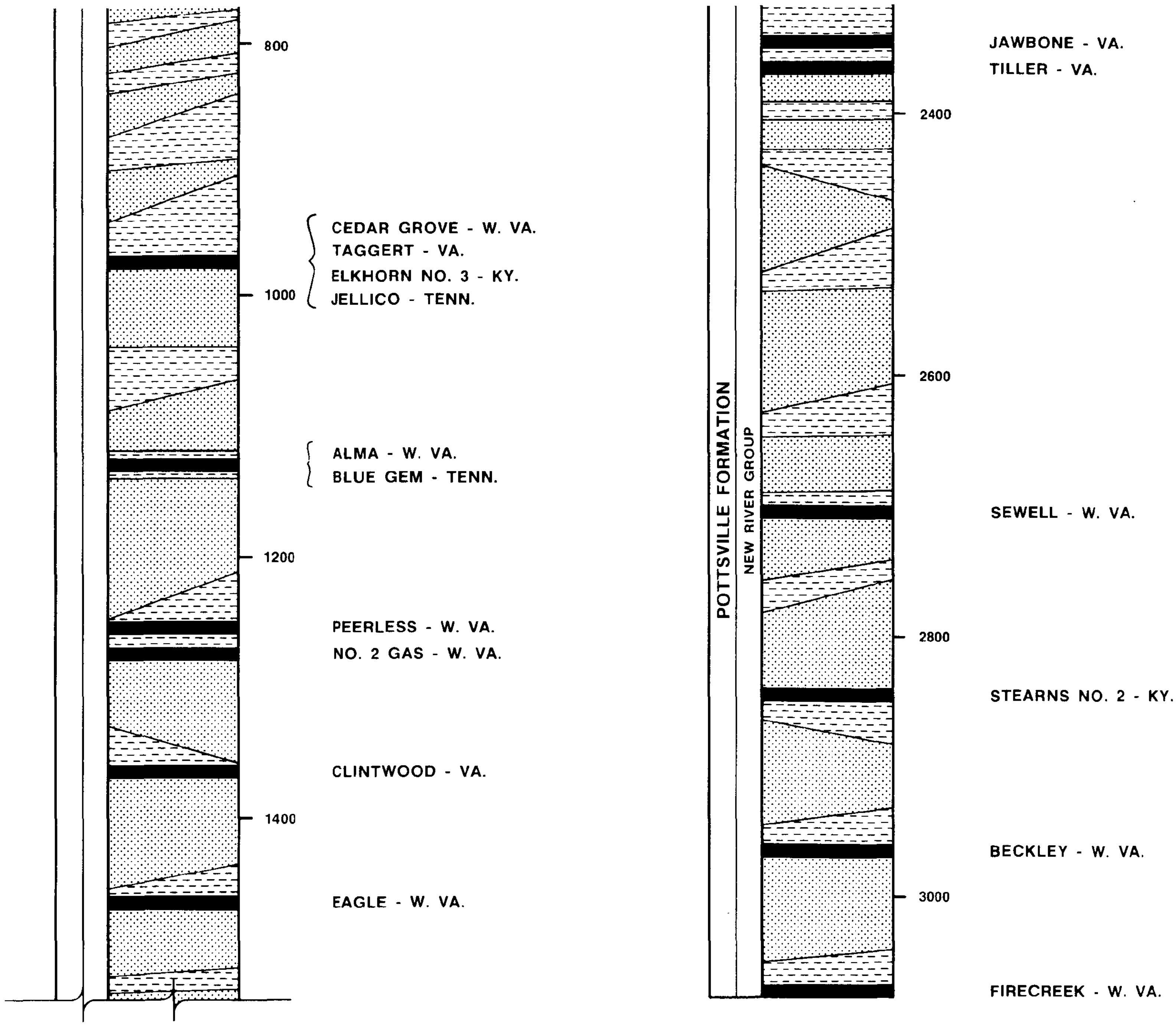
- There should be no mud or clay veins, slickensides, intense fracturing, heavy pyritic intrusions or other localized anomalies. Besides the environmental problems which would be caused by the pyrite, extensive operational difficulties arise due to the fracturing, clay veins, and slickensides. Slickensides pose an immediate safety threat in that they fall between the time that the coal is mined and the roof can be supported. Mud and clay veins pose different problems depending on their orientation. If parallel with the bench as they were at Julian, they can cause a continual problem over the term of the operation. This is evidenced by the tipping of chocks experienced at Julian due to lateral pressure from the mountain transmitted along a mud vein which acted as a plane of failure. If oriented transverse to the bench, clay veins may pose an immediate threat of failure for the operation by causing extensive falls along the line of supports. The only recourse in this situation is to extract all equipment and reinstitute the operation in new entries, a time consuming and expensive operation.

Though the foregoing discussions may seem to preclude use of surface shortwall in any seam, a thorough evaluation of central Appalachia revealed a number of seams which are amenable to surface shortwall mining in at least a portion of their lateral extent. The stratigraphic column (Figure 25) has been generalized from the region around Pike County, Kentucky, Mingo County, West Virginia and Buchanan County, Virginia. Inferences drawn from this column should be made based on the fact that though the specific lithology may change substantially over a short distance, the general stratigraphic succession as shown is maintained over a broad area. The actual intervals between specific lithologic beds will change somewhat since the Pottsville Formation (which makes up 90% of the column) is expanding to the south and west and becoming smaller to the north.

Table B-1 (Appendix) indicates the approximate areal extent of each of these seams within the constraint of a four (4) foot minimum thickness. Also indicated are the quality of the coal in terms of sulfur, ash and BTU content within the counties listed.

Though it was thought that specific quantity figures might be possible, this was abandoned because of the constraints of thickness and geologic anomalies, both of which may be disconcertingly site specific. Also, with West Virginia as the exception, there is an acute lack of detailed information on coal reserves in the three other states of the study area. The information presented in this table is not meant to exclude many other smaller seams which locally are within the defined constraints. Within the scope of the limiting conditions presented, if is felt that though Table A-1 does give an estimate of the reserve base, a detailed discussion of those reserves would be arbitrary in nature and potentially misleading. To give good reserve estimates would require a real knowledge of the technique's capabilities and topographic and geologic information on the region simply not available to the degree necessary.


FORMATION OR GROUP
LITHOLOGY
TOTAL FEET
NAME OF SEAM–STATE
ALLEGHENY FORMATION
POTTSVILLE FORMATION
KANAWHA GROUP
0
200
400
600
UPPER KITTANNING - W. VA.
MIDDLE KITTANNING - W. VA.
NO. 5 BLOCK - W. VA.
HINDMAN - KY.
STOCKTON -
LEWISTON - W. VA.
HAZARD NO. 7 - KY.
COALBURG - W. VA.
HAZARD NO. 5A - KY.
BUFFALO CREEK - W. VA.
WINIFREDE - W. VA.
CHILTON 'A' - W. VA.
HIGNITE - KY.
BIG MARY - TENN.
CHILTON - W. VA.
FIRECLAY - KY.
FORMATION OR GROUP
LITHOLOGY
TOTAL FEET
NAME OF SEAM–STATE
KANAWHA GROUP
1600
1800
2000
2200
NORTON - VA.
UPPER BANNER - VA.
GILBERT - W. VA.
KENNEDY - VA.
JEWELL - VA.



FIGURE·25. - Typical stratigraphic section for steep sloped Appalachia.

SURFACE SHORTWALL VARIATIONS

Many of the difficulties experienced at the Julian site could have been alleviated through use of certain modifications of the surface shortwall method. First among these would be a review of the original feasibility analysis which was done on the concept. (Moomau, 1974). The concept as originally stated was to utilize a longwall type shearer instead of the continuous miner. The logic is clear why the switch was made to the continuous miner (miner) since they were readily available at the time and have a flexibility which is not inherent in shearer systems. This is most aptly seen in the development work and the gradual lengthening and shortening of the shortwall face possible with the miner. The faults in the logic become most apparent in projecting these usage types into future surface applications of these "wall" concepts.

Developing future usage scenarios for these "wall" concepts requires that the limitations of the concepts be developed, and their full implications understood. The major implications with a shearer concept are:

- The shearer would cut a much smaller web ($\approx$ 2 feet) so would represent a more incremental type of mining.
- Depending on the power of the cutting motors, the shearer would cut the face much faster and could potentially equal the production rate for the miner.
- The result of the above premises would be to allow stronger support at the face since longwall type supports need not extend over such a large area. This would allow

better transfer of roof loads onto the supports which would consequently allow better fall characteristics behind the supports in the gob area.

- The shearer concept could be made as flexible in the operational mode as the miner concept since they both use armored face conveyors and would have the same difficulties in lengthening or shortening the face.

- Negotiation of curves would be much easier with a shearer concept because of enhanced ease of alignment and the much quicker face movement and cutting capabilities. Also because of the smaller web, the supports could be maintained much closer to the face. This would eliminate much of the crumbling the roof at the pivot point is subject to otherwise.

- It would be much more difficult to get supplies such as necessary cribbing and posts back to the tailgate to maintain an escapeway and return air route there.

In light of the experience obtained at Julian, and of the advantages listed, it might be well in another attempt to try the shearer concepts.

Other variations possible focus around use of a continuous miner since additional ongoing development is necessary. Many of the alternatives mentioned in interviews of people familiar with the project seemed to focus more on the particular problems with the highwall than with other possible concerns. This concentration may be misplaced since the difficulties were more a result of a peculiar geologic condition than the inherent instabilities of highwalls. Nevertheless, geologic peculiarities can be expected anywhere and as such call for concepts which can alleviate their impact.

The major modification proposed is illustrated in Figure 26 as the retention of pillars immediately beneath the highwall. The operational and equipment usage significance are tremendous since there is no longer direct access to the interior coal except at the ends of pillars.

General practice and state and federal laws restrict the pillar sizes to a maximum dimension of 100 ft. This dimension could presumably be the length of the pillar parallel with the highwall. Because of the lack of large overburden pressures, the pillars could be kept much smaller than this, perhaps as small as 15-20 ft. along the highwall and the same in the opposite direction into the coal. The cross cuts could then be kept to a minimum size of 12-16 ft. or just enough to allow maneuvering on the part of the continuous miner developing the entry.

The effect of having the pillar under the highwall at the time of roof collapse is not well understood, but it would presumably be similar to the tailgate types of roof collapse. The analogy is made that way because the roof over tailgates is already broken on one side and thus not subject to the degree of cantilever forces true of more continent headgate strata. The similarities end there since the overburden pressures are much less than exist in an underground application. It is possible with strong strata that the overburden over the pillars would be lifted up as the rest of the roof collapsed behind the check line.

There are several options open in terms of equipment usage: 1) use a single continuous miner; 2) use of two continuous miners; 3) use a shearer and a miner. Use of a single continuous miner would

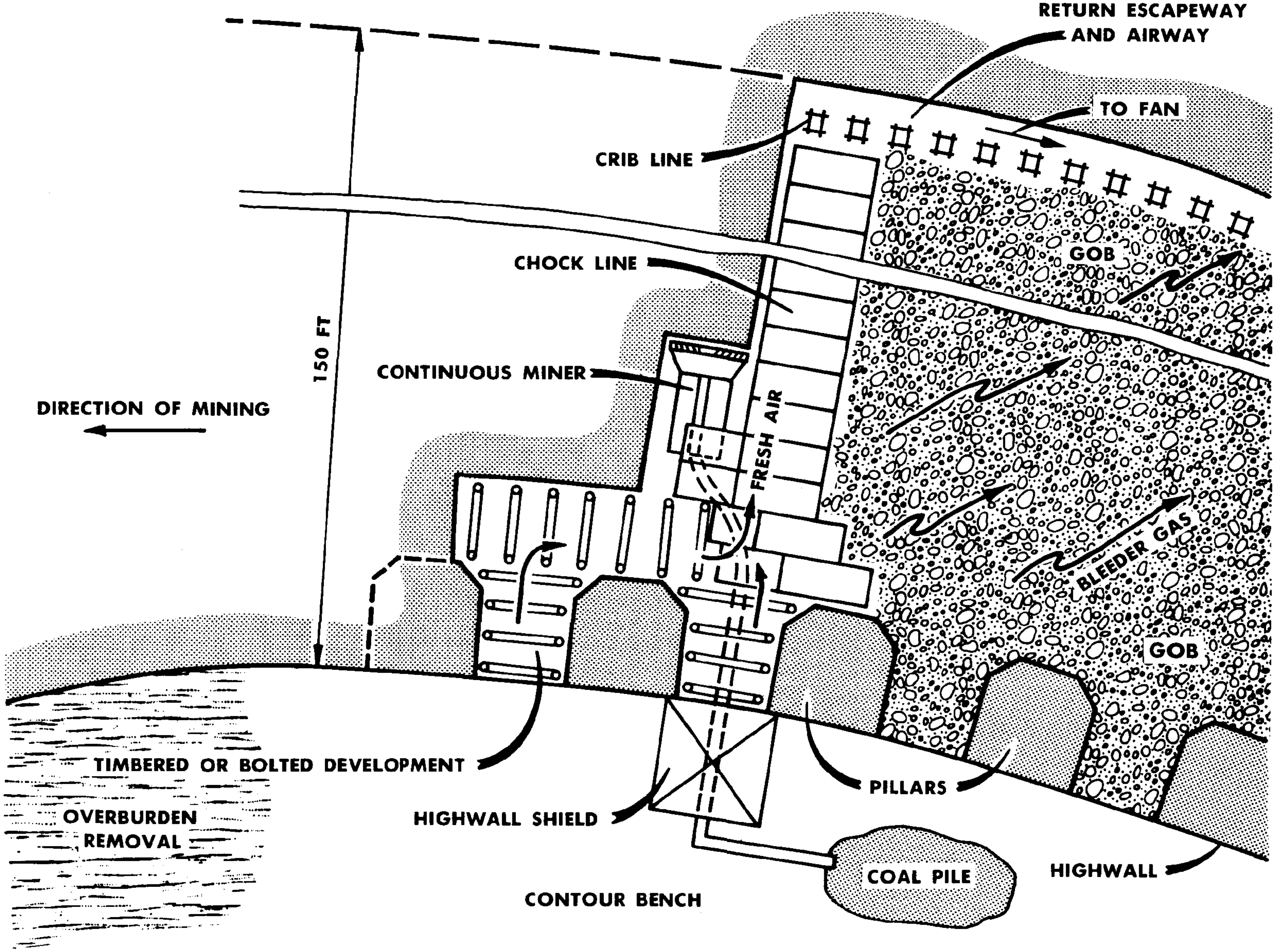


FIGURE 26. - Plan view of surface shortwall operation with highwall buttress pillars.

mean that it would be responsible both for the shortwall mining and for the development work. This necessarily means that the shortwall face would sit idle while the miner was working in its development mode. This, as previously discussed, would lead to instabilities in the roof, particularly when curves are negotiated. Because of the topography of the area, curves are prominent features in the roof and design must be done with these considerations in mind.

Actual operation sequences are more difficult to project, but development with a single miner would be kept far enough ahead to continually maintain two open crosscuts outside — one through which coal would be conveyed, the other to provide access by the miner and a necessary bolter. Coal from the development operation could be hauled either by scoop or by a mobile conveyor which are being used more frequently in continuous mining sections underground.

Use of a two miner system would not involve a great deal more consideration than the single miner system. The most obvious advantages would stem from greater continuity of both the shortwall and the development work, the most obvious deterrent would be the price of the extra miner, particularly since mining work could not keep pace with development. Presumably the second miner would act as a spare.

The third option represents the best use of both equipment types. The shearer is able to work to best advantage at the face with the only obvious detrimental aspect being inaccessibility to the tailgate. The miner can be used to best advantage meanwhile in the development work.

Extraction or deployment of more face equipment would be more difficult due to the presence of the pillars. At Julian, the chock line could be lengthened or shortened at will resulting in a great deal of flexibility in surmounting geologic or topographic anomalies. Use of highwall pillars would require logistical consideration of the face conveyor and the deployment and hookup of chocks whether singularly or in banks of three.

Other proposals were also made and reviewed, but in nearly all cases, either the technology required is far beyond modern capabilities or the concept would involve logistics, support services and start up capital beyond the worth of the venture. For instance, following development of a bench circumscribing a ridge at an outcrop, a chock line could be set up at one end and mining done by removing all of the coal in that seam along the entire ridge. While most of the technology has been developed, other problems with such items as the length of the chain conveyor and chain strengths have not. The concept would work well for ridges no more than 100 ft. wide, but in the deeply dissected areas of central Appalachia, ridges are often no more than points extending out from the original plateau. Also, attempts to cross the entire ridge would require capital outlays far beyond those currently thought of as economical. The most obvious positive attribute to this concept is the lack of a tailgate and its requisite maintenance.

Perhaps a better use to which this concept can be put is in area mining of shallow seams in relatively more flat lying terrain in the Midwest. This type of trench and mine operation would be of particular interest in farmland areas or alluvial valley floors since disturbance of the strata could be kept to a minimum and hydrologic functions could be better maintained.

In another section, recommendations have been made as to the directions in which further research should take both in the application of shortwall/longwall mining to steep sloped areas, but also to more level areas with shallow seams. As has been demonstrated, a single instance of shortwall application to surface mining on a very limited basis constitutes a poor statistical base for further analysis.

ENVIRONMENTAL IMPACT ANALYSES

The environmental impacts of the four mining methods - mountaintop removal, contour strip, augering, and shortwall - can be explored at four different levels. These levels include:

- general site impacts
- impacts associated with specific mining unit operations
- regional impacts
- environmental controls to mitigate environmental impacts

The magnitude of each level of impact is also dependent on the environmental setting of the mine site as well as regional setting. Each of these points are discussed below.

ENVIRONMENTAL AND DEMOGRAPHIC SETTING OF STUDY REGION

Topography

The steep slope coalfield of Appalachia is generally located within the physiographic province called the Appalachian Plateau. Elevations generally increase from west to east, averaging 1,000 feet in the west and 2,000 feet in the east. The study region terminates on the east with the Ridge and Valley physiographic province. Elevations are typically greatest at this boundary, reaching approximately 4,000 feet above sea level.

This region is severely dissected by dendritic water courses into a maze-like network of steep hills and narrow valleys. In places, ridges peak at generally the same elevation, suggesting an original plateau surface. Local relief ranges between 500 and 1,000 feet.

Slopes in the region vary from the nearly flat flood plains to mountain side-slopes, where 200 percent slopes are not uncommon.

Climatology

Listed below are the key regional climatological parameters:

Range of Annual Statistics

- Annual solar radiation - 350 to 400 langleys
- Mean annual sunshine - 2200 to 2500 hours
- Mean annual pan evaporation - 40 to 50 inches
- Mean annual precipitation - 40 to 50 inches
- Mean annual snowfall - 10 to 30 inches
- Mean annual frost-free period - 150 to 180 days
- Mean annual thunderstorm days - 50 days

Mean Seasonal Statistics

	January	April	July	October
· Precipitation	3-5 in.	3-5 in.	5-10 in.	2-4 in.
· Relative humidity	70-75%	60-70%	70-80%	70-75%
· Temperature	30-40°F	50-55°F	70-75°F	55-60°F

Regional topography greatly influences weather conditions. For example, storms generally track from west to east. As they move across the region, winds are subject to orographic lifting which causes the condensation and release of precipitation. This results in substantial increases in precipitation from west to east within the study region.

Local topography also influences weather conditions. A factor inhibiting direct sunlight hours is the fog often prevalent in the valleys. The circumstances contributing to the distribution of fog are diverse. Radiation type valley fogs occur when a high-pressure area is centered over the area, a common occurrence in late summer and fall. Low clouds and fog in the mountains are usually orographic in nature, caused by most winds moving upslope. Often, due to this phenomenon, there are great differences in these conditions on opposite sides of a ridge.

Thunderstorms are perhaps the most important weather event in the region. They occur approximately 50 days of the year and are often accompanied by violent local winds. These storms are more common in June and July and often cause flash flooding in the narrow valleys that cut through the plateau. Precipitation accumulations over a 24 hour period have exceeded 6 inches due to these storms. Large area storms are more common during the colder half-year. These are caused by exceptionally strong specimens of the ordinary lows that affect West Virginia quite frequently. Storms of this nature produce high winds and heavy rain or snow and, in some cases, lead to flooding of river towns.

Geology and Soils

The geologic divisions of the region are almost entirely of the Pennsylvania System, composed of interbedded sandstones, siltstones, shales, and coals. Variation in the region occurs when the ratio of these four constituents changes.

Older Mississippian formations are found in the valley floors, and the limestones characteristic of the Ordovician period contribute greatly to the fertility of the soils. However, these Ordovician period limestone deposits do not become a dominant feature until the Cumberland Plateau tapers off into the central portion of Kentucky known as the Bluegrass region, which lies adjacent to this study area.

The soils found in the valleys, the primary urban and agricultural areas, are generally flood plain soils such as Pope and Cuba while on the stream terraces and 1/2 and 2/3 of the way up the sides of the ridges, colluvial soils such as Allegheny and acidic Shelocta types are found. The upper ridge slopes are covered primarily with denser, acidic clay-shale soils, and are of a much more shallow depth than the alkaline alluvial valley soils.

On a regional level, most of the soils can be defined as Dystrochrepts (Sols Bruns Acides). These soils are warm, moist Inceptisols, which exhibit weakly differentiated horizons showing alteration of parent materials. These soils are low in bases and have no free carbonates in the subsurface horizons.

Hydrology

The study area can be divided into six major river basins:

- Tennessee River Basin
- Cumberland River Basin
- Kentucky River Basin
- Big Sandy River Basin
- Kanawha River Basin
- Guyandotte River Basin

All six rivers drain into the Ohio River.

Surface streams in the study area are arranged in a dendritic pattern. The drainage network is relatively dense, reflecting high runoff rates in this steep slope region. Steep slopes also influence flow rates which fluctuate widely with precipitation events.

Water quality in the area is influenced by land use practices, such as the widespread surface mining, logging, and farming in the area. High sediment loads tend to be a problem during and immediately after precipitation events when the capacities of sediment control structures are exceeded. Acid mine drainage is not generally a problem, but does occur locally when acid-producing seams are encountered in both surface and underground mining. Table 5 gives examples of typical water quality parameters in the region.

Ground water supplies vary widely depending on the type of aquifer available at a particular locale. Porous sandstones are the most productive aquifers, but siltstones, limestones and coal seams also provide groundwater. Well production varies from less than 80 gallons per minute to more than 6,000 gallons per minute. Most wells in the region do not exceed a depth of 200 feet since the possibility of encountering saline aquifers exists at greater depths. However, wells in the vicinity of Middlesboro, Kentucky, reach depths of 400 feet.

Land Use

Terrain limits the land use in the region. Most industrial, urban, and agricultural areas are contained within the stream and river valleys.

TABLE 5. - Regional water quality data.*

SAMPLE LOCATIONS	DATES	DISCHARGE (cfs)	pH	SUSPENDED SEDIMENT (mg/l)	TURBIDITY (JTU)
KANAWHA BASIN [1]					
Howard Creek	10/10/74	9	7.5	0	3
(Caldwell, WVA)	3/13/75	812	--	126	70
Kanawha River	3/20/75	152,000	7.8	1,820	65
(Winfield, WVA)	9/11/75	3,880	7.1	35	15
GUYANDOTTE BASIN [1]					
Mud River	6/16/75	46	7.2	--	2
(Palermo, WVA)	8/13/75	2.5	6.6	--	--
Mud River	12/04/74	812	7.4	51	40
(Milton, WVA)	8/14/75	8	7.5	38	9
KENTUCKY BASIN [2]					
Robinson Creek	5/12/72	1.06	4.4	--	3
(Shepardtown, KY)		0.004	4.0	--	0
Ten Mile Creek	2/11/72	0.35	5.9	--	2
(Ned, KY)	4/17/72	0.71	6.3	--	14
BIG SANDY BASIN [2]					
Ivy Creek	1/27/72	1.06	6.5	--	500
(Ivel, KY)	6/08/72	0.014	6.5	--	10
Robinson Creek	2/09/72	6.4	4.0	--	15
(Robinson Creek, KY)	5/12/72	3.5	4.8	--	3
Fords Branch	4/23/72	0.03	6.5	--	11
(Fords Branch, KY)	5/17/72	0.07	6.2	--	3

* SOURCE: 1. UNITED STATES GEOLOGICAL SURVEY
2. APPALACHIAN REGIONAL COMMISSION

Commercial coal mining (a major industry), and general farming operations utilize available slope and ridge areas. "Unused" land remains as forested areas, usually of second growth hickory and oak, some of which is utilized by a modest timbering industry. Natural gas and petroleum production in the Big Sandy gas fields are other important industries.

Important urban centers which border the study area are Charleston, Huntington, Knoxville, and Lexington. Within the region, county seats provide most of the urban services of this coal-dominated region. Notable among these towns are Hazard, Bluefield, Harlan, Welch, Beckley, and Logan.

Nearly all transportation routes linking urban areas follow stream valleys. The result of this pattern is intensive strip development in these stream valleys, which are highly susceptible to flood damage.

Summary statistics on development in the region have been generated by the Appalachian Regional Commission. Within central Appalachia, there are approximately 31,900 square miles with a population in 1975 of 1,886,000 people (approximately 59 people per square mile).

The rural nature of the region is shown in the statistics listed below:

Geographical Division	1970 Clustered Population*
U.S.	78%
Appalachia	55%
Central Appalachia	29%
Kentucky	28%
Tennessee	34%
Virginia	23%
West Virginia	32%

* Clustered population is defined as population living in communities of 1,000 or more inhabitants.

Not only is most of the population of central Appalachia dispersed, but also very few counties have any urban population greater than 15,000 or any single urban center with more than 10,000 people. This latter criteria defines a rural county according to the ARC. The distributing of population in rural counties according to various geographical divisions is shown below:

Geographical Division	Percent Living in Rural Counties
Appalachia	25%
Northern Appalachia	17%
Central Appalachia	72%
Southern Appalachia	23%

Most of the non-rural counties are located at the periphery of the study area near Charleston, Huntington, Knoxville, and Lexington.

With a relatively dispersed, rural population located in narrow flood plains, farms have tended to be small in size with significantly lower economic returns than the national average. The following statistics show how these trends were particularly true for central Appalachia in 1969.

Geographic Division	Percent Farm Land	Ave. Acreage/Farm and Ave. Value/Acre	
Eastern U.S.	46%	174	$324
Appalachia	34%	133	$227
Central Appalachia	41%	111	$199
Kentucky	46%	112	$196
Tennessee	47%	106	$212
Virginia	37%	103	$206
West Virginia	15%	148	$145

Central Appalachia experienced a 28 percent decline in the number of farms between 1959 and 1969, which corresponds generally to national trends.

Acreages devoted to specific land uses vary widely within central Appalachia. Forests comprise from 60 to 90 percent of the land area in most counties, farming accounts for 20 to 40 percent, and surface mining involves 2 to 20 percent. Urban areas normally require less than 5 percent of the land area.

The relatively small percentages of land areas devoted to mining do not accurately reflect the importance of coal mining to central Appalachia. Central Appalachia contributed nearly 27 percent of the nation's coal production in 1974. Significant amounts of this production were metallurgical grade.

Statistics of employment in mining, listed below, also indicate the importance of this industry:

Geographical Division	Percent Employed in Mining (1970)
United States	0.8%
Appalachia	2.2%
Central Appalachia	10.7%

Thus, coal mining is a major economic base activity of central Appalachia.

GENERAL SITE IMPACTS

In assessing the environmental impacts of surface mining, certain factors stand out as the most important contributors to environmental problems. These factors include:

- surface area disturbance by vegetation removal
- interruption or diversion of surface drainage
- interruption or diversion of groundwater flows

- the movement of heavy equipment involving both the generation of airborne particulates from the ground surface and chemical air pollution from the engine emissions
- noise and dust generation associated with drilling and blasting of overburden
- subsidence from augering or surface shortwall and blasting of overburden
- alteration of terrestrial community structures

Each of these factors contribute in varying degrees to the major types of environmental stress conditions: watershed erosion/siltation problems; chemical quality changes in streams, lakes and groundwater; changes in surface water and groundwater hydrology; air pollution; noise pollution, alteration of land use potential; and, the generation of visual and other aesthetic disamenities.

The relationship of the surface shortwall technique to the other three surface mining methods with regard to environmental impact is illustrated in Table 6. The major results of this table can be summarized in the following manner:

- Auger and Shortwall Mining

    1. Both methods require contour bench with consequent impacts.

    2. Shortwall has greater immediate subsidence potential but augering has some long-term subsidence potential

    3. Auger has greater potential groundwater flow pattern alteration and chemical contamination

- Contour and Mountaintop Mining

    1. Both methods disturb greater surface areas than shortwall or augering

    2. Mountaintop disturbs considerably more area than contour mining

TABLE 6. - General environmental impact matrix.

	DURING MINING				AFTER RECLAMATION			
	SURFACE		AUGER	SHORTWALL	SURFACE		AUGER	SHORTWALL
	CONTOUR	MT. TOP			CONTOUR	MT. TOP		
· Erosion/Siltation Problems	Medium	High	Low	Low	Low	Low	Low	Low
· Disturbed Surface Area	Medium	High	Low	Low	None	None	None	None
· Surface Water Network Disturbed	Low	High	Low	Low	Low	Low	Low	Low
· Chemical Water Pollution	Medium	High	Medium	Medium	Low	Low	Medium	Low
· Disturbed Surface Area	Medium	High	Low	Low	None	None	None	None
· Surface Water Network Disturbed	Low	High	Low	High	Low	Low	Low	Low
· Groundwater Network Disturbed	Medium	High	High	High	Low	Low	High	Medium
· Water Supply Problems	Medium	High	Medium	Medium	Low	Low	Medium	Medium
· Surface Water Network Disturbed	Low	High	Low	High	Low	Low	Low	Low
· Groundwater Network Disturbed	Medium	High	High	High	Low	Low	High	Medium
· Air Pollution	Medium	High	Low	Low	Low	Low	Low	Low
· Disturbed Surface Area	Medium	High	Low	Low	Low	Low	Low	Low
· Heavy, Equipment Movements	Medium	High	Low	Low	N/A	N/A	N/A	N/A
· Blasting Required	Medium	High	None	None	N/A	N/A	N/A	N/A
· Noise Pollution	Medium	High	Low	Low	N/A	N/A	N/A	N/A
· Heavy Equipment Movements	Medium	High	Low	Low	N/A	N/A	N/A	N/A
· Blasting Required	Medium	High	None	None	N/A	N/A	N/A	N/A
· Land Use Problems	N/A	N/A	N/A	N/A	Low	Low	High	Medium
· Subsidence (or Residual Compaction)	N/A	N/A	N/A	N/A	Low	Low	High	Medium
· Aesthetic Problems	Medium	High	Low	Low	Medium	Medium	Low	Low
· Disturbed Surface Area	Medium	High	Low	Low	None	None	None	None
· Heavy Equipment Movements	Medium	High	Low	Low	None	None	None	None
· Blasting Required	Medium	High	None	None	None	None	None	None
· Topographic Alteration	Medium	High	Low	Low	High	Medium	Low	Low

- Differences between auger/shortwall and mountaintop/ contour methods

    1. Mountaintop/contour operations involve considerably more potential for erosion/ siltation problems during mining, while auger/shortwall methods minimize these problems

    2. Post-mining problems with augering involve interception and pollution of groundwater flows, and with shortwall mining involve subsidence which reduces land use potential. Through the use of controlled placement, mountaintop and contour operations can design reclaimed areas to minimize post-mining environmental proglems.

    3. Mountaintop/contour operating produce the greatest aesthetic impact with shortwall having some impact and augering having no additional aesthetic impact.

IMPACTS ASSOCIATED WITH SPECIFIC MINING UNIT OPERATIONS

Many unit operations in surface mining are common to the four mining methods analyzed here. Significant differences among the mining meth-od with respect to their utilization of unit operations occur principally in coal removal and loading. Shortwall and augering minimize underground extraction using conventional earthmoving equipment and maximize underground extraction - with shortwall utilizing continuous miners and conveyors, and augering utilizing conventional augering equipment. Contour and mountaintop mining both rely on conventional earthmoving equipment. Thus, augering and shortwall involve coal removal operations more similar to underground mining than conventional surface mining. The following discussions analyze the environmental impacts of specific unit operations involved in the four mining methods.

Haul Road Construction

Environmental impacts due to haul roads can occur during the initial construction, during usage by haul trucks, and after cessation of mining operations, primarily in the form of erosion and sedimentation problems. Since haul roads constitute 10% or more of the area disturbed by the surface mining operation, this problem can become significant. Measures designed to mitigate these impacts include diversion ditches, sediment traps, and appropriate surfacing for the type of haulage use.

Fugitive dust from haul roads can become an air quality problem during dry spells, unless care is taken to keep the road surface watered down.

Haul road construction impacts are particularly severe in steep sloped terrain and on mountaintop removal operations, due to the topography and greater lengths of road necessary to transport the overburden and coal. Since the amount of spoil removed by augering and shortwall are normally less than a conventional contour operation, fewer equipment pieces and smaller equipment may be associated with them, consequently haul road impacts for these two operations should be less. It must be understood, though, that any mining operation requires a minimum amount of roads regardless of the size of the mine. In terms of methods of construction and road placement and drainage, the surface mining performance standards will act as an equalizer.

Clearing and Grubbing

Clearing and grubbing result in the loss of habitat for wildlife over the disturbed area. Because the vegetative cover is stripped, the wildlife inhabiting the area will be displaced. The loss of vegetative cover also exposes the disturbed area to erosion unless the subsequent phases of the surface mining operation follow close behind. Generally, the timber is harvested commercially prior to clearing of brush and grubbing of stumps and roots. As the mining operation advances along the coal seam; the brush and stumps are pushed downslope and stockpiled along the outer edge of the disturbed area. This material is later either placed in the worked-out pit and covered with overburden during the backfilling operation, or burned in some states. Stockpiling of brush and stumps on the lower slopes of the disturbed area has proven to be an effective filtering device to trap sediment eroded from the disturbed area. However, the practice of windrowing and burial will not be permitted under the new OSM regulations.

Impacts from clearing and grubbing are related to the amount of disturbed area exposed at any given time. Among the various methods, mountaintop removal involves the greatest amount of disturbed area and thus involves a greater magnitude of impacts. Contour operations clear and grub a greater area than augering or shortwall, but much less than a mountaintop removal mine. As it pertains to the surface mining operations, clearing and grubbing impacts are directly proportional to the amount of coal mined. In some ways, this establishes the basis for comparison of surface effects of the different mining methods — subsidence damage to flora from augering and shortwall and total eradication in the case of contour strip or mountaintop removal.

Drilling and Blasting

The physical impacts of blasting occur when a blast is detonated and the bulk of the energy is consumed in the process of fragmentation. Some permanent displacement of rock occurs close to the location of the drilled holes containing the explosive. This activity normally occurs within a few tens of feet of the blast hole with leftover energy being dissipated in the form of waves traveling outward from the blast, either through the ground or atmosphere. Ground waves produce oscillations in the soil or rock when they pass, with the intensity of these oscillations decreasing as distance from the blast increases.

In cases where structures are built on property adjacent to a surface mining operation, damage from blasting vibrations could occur. However, advances in blasting technology and a more knowledgeable blasting profession have minimized real structural damages. Vibration levels that are completely safe for permanent structures can still be annoying and unpleasant to the local residents. Though no actual damage occurs, air blast pressures may cause windows to rattle, and loud noise can result.

Weather conditions can increase airborne dust from both drilling and blasting. When hot, dry conditions typical of temperature inversions prevail, dust levels are much higher. This condition exists frequently in early dawn and after sundown, typically during late summer.

When blasting is done in congested areas or close to a structure, stream, highway, or other installation, fragments thrown by the blast may also be a health and safety problem. These impacts can be minimized when a trained blasting crew is involved.

Drilling and blasting impacts are directly related to the rate of overburden removal (which determines the number and frequency of blasts that occur). This indicates that contour mining and mountaintop removal would have roughly equivalent impacts on a per ton basis. Augering, if done in conjunction with contour mining, would have no blasting impacts. If done from its own bench, the impacts per ton would be roughly half those of the surface mining methods. Surface shortwall would have no impact from blasting since none is done.

A true measurement of blasting impact is difficult since little is known of the result of blasting fractures on the hydrology around the highwall. Further, trauma suffered by local fauna should probably also be included except that relatively few people or animals live in the very steep sloped areas.

Overburden Removal and Backfilling

In overburden removal, transportation and backfilling operations, the magnitude of environmental damage is directly proportional to the length of the open pit and duration of exposure for the pit. This is true because revegetation follows closely behind the stripping operation and the smaller the exposed area at any given time, the more rapidly mining, backfilling, and subsequent revegetation can be completed. This decreases the area susceptible to erosion and transport of sediment and to leaching and movement of toxic substances.

During this phase of the operation, the topographic features and characteristics are changed, and the original geologic overburden profiles are destroyed. Backfill material is generally a heterogeneous mixture of rock fragments, rock particles and soil-sized material derived from the overburden strata. If care is not taken to selectively place undesirable material, establishing vegetation in later phases may be difficult. Also, toxic materials are subject to being leached from the fill, if placed near the surface of the fill.

Care must be taken in stabilizing the fill and providing adequate drainage around it to minimize the sediment yield or prevent massive failures.

In general, more pit area is exposed for a longer duration in mountaintop removal operations. Contour operations generally expose a greater surface area and involve greater equipment movement than augering or shortwall, but not nearly to the extent associated with mountaintop operations. The overall effects of augering and shortwall may be equivalent in some categories to those effects derived from contour mining. Subsidence destroys overburden profiles and may cause problems in the hydrologic system in much the same way as contour mining.

Coal Removal

Coal removal and hauling could result in about the same environmental impacts as overburden removal. These impacts include exposing toxic materials that can be leached from the pit area, generation of dust, and disruption of wildlife from equipment noise and traffic on the access road.

Coal haulage also can seriously damage public roads. While a number of government policies currently attack this problem (e.g., fines for overweight trucks and reduced weight limitations), public road maintenance costs remain high. Adherence to weight limits for coal trucks minimizes this impact.

Coal removal by these four surface methods involves another potential impact. Often large amounts of groundwater are intercepted with extraction of a coal seam which may be an aquifer. This water must be conveyed to a detention area and treated before it can be released. To the extent that the treatment process successfully removes pollutants from the effluent, no environmental impacts are involved. However, by intercepting this amount of groundwater and conveying it to some surface stream, the hydrology of the mined area has been significantly altered. Impacts to the physical and biological elements of the ecosystem due to this alteration will depend on site specific conditions.

Problems associated with coal transport are common to all four methods, but are likely more severe in mountaintop operations where an entire hydrologic system including the recharge zone may be altered or destroyed.

In the steeper sloped areas, few of the seams actually act as major aquifers because of their height above the water table so interception of an aquifer may not be that much of a problem. However, both augering and shortwall involve major impacts in their coal removal processes not felt in either of the surface operations. These impacts are usually manifest by subsidence, accompanied potentially by acidification of water. However, incomplete compaction of the subsided material due to a lack of pressure can cause an extreme porosity in the material which can augment the hydrologic and acid formation problems.

Reclamation

Reclamation in a mining operation is the key to the post-mining environmental performance. The degree to which a mining method accommodates or precludes environmentally sound reclamation will determine the long term environmental impacts associated with that method.

Reclamation involves three interrelated steps:

- Final regrading and compaction
- Seedbed preparation — scarification, mulching, and fertilization
- Revegetation

Final regrading and compaction assures the stability of the surface by bringing the regraded spoil to final grade, assuring a relatively compact soil surface, and removing oversized rocks from the potential soil horizon.

After final regrading and compaction, seedbed preparation and revegetation should follow relatively soon. Prior to planting of trees and shrubs, the regraded surface must be adequately prepared to ensure success. This preparation should consist of working the soil, liming, mulching, and applying fertilizer.

Revegetation of the reclaimed area is one of the most important operations in surface coal mining to minimize the environmental impact. Experience has shown that natural revegetation is a very slow process. Native vegetation may not even be compatible with the environment in the mined area, because of the possibility of low nutrient levels or toxic spoils. Futhermore, the surrounding vegetation may not have pioneer or primary invader-type cover.

All of the mining methods analyzed in this report can adequately reclaim backfilled overburden. Only in the case of auger mining do surface problems arise. Because roof collapse is inherent in the shortwall method, the surface above the extracted coal seam is subject to relatively immediate subsidence. Long term instability and fracturing primarily from augering but also from shortwall mining not only create potential land use problems, but also can affect groundwater flows and thus the moisture content of the soil. Direct impacts on vegetation and indirect impacts on the remainder of the ecosystem could be substantial if soil moisture retention were impaired due to this subsidence.

REGIONAL IMPACTS

The segment of Appalachia of concern in this study is a steeply-dissected region with narrow floodplains, steep valley sides, and narrow, winding ridge tops. All of the mining methods analyzed in this report can be utilized to produce coal in this region. Choice of method in the past was strictly dependent on economic criteria and the operator's available equipment. Thus, site characteristics as they relate to environmental impacts were not considered in choosing a mining method.

With the advent of environmental laws and regulations, pollution abatement became an integral, and sometimes expensive part of surface mining. Thus, it became important to choose mine sites that maximized economic return with pollution abatement expenses included as part of mining costs. Sites which provide a minimum of environmental problems have a comparative advantage over other sites with environmental hazards, all other factors remaining equal.

Two interrelated site characteristics most often affect environmental performance of a surface mine - slope, and the relation of the volume of overburden to the area affected. With increased slope, there is generally more overburden above a given coal seam. Thus, as slope increases, overburden handling problems increase, i.e. there is more overburden to be backfilled in a given area.

Surface mining methods which combine a minimum of surface removal, and extend resource recovery with underground methods, include augering and shortwall. When compared to contour and mountaintop mining, augering and shortwall prove superior in steep slope regions in the sense that they minimize the ratio of overburden to coal. By reducing overburden handling requirements, the need for extensive excess spoil disposal areas (valley fills) can be avoided. These valley fills require expensive measures such as sediment ponds, extensive clearing and grubbing, long haul routes, and stringent compaction requirements.

The positive environmental impacts of augering and shortwall mining must be weighed against the negative long-term impacts described previously. These problems include the interception of groundwater flows, groundwater chemical pollution, and the reduction of land use potential.

Post-mining groundwater problems are most severe with augering, which leaves extensive mine voids in the coal seams. Groundwater can be drawn into these voids, affecting local groundwater levels (perched water tables), and can become polluted. Seepage from these pools, if polluted, can pose a regional water quality problem when augering is relied on extensively to extend resource recovery in a steep sloped region.

Post-mining land use problems can also be severe where shortwall mining has been utilized. With close to 100 percent recovery of a coal seam using underground extraction, roof collapse and subsidence are inevitable. Subsidence reduces land use potential for any type construction, and can make farming and grazing difficult ventures. By altering groundwater infiltration flows and soil moisture retention levels, existing vegetation can be significantly affected. These problems can be compounded by instability and fracturing of the soil profile, thus affecting root systems. On a regional level, changes in vegetation can significantly alter the entire ecosystem by altering the existing faunal communities. Thus, the widespread use of shortwall methods as compared to other surface methods could have significant long-term biological impacts on the regional ecosystem.

To summarize, steep slope topography may induce the choice of augering or shortwall to reduce both overburden handling costs and reclamation costs.

ENVIRONMENTAL CONTROLS

The purpose of this section is to provide a general comparison of the environmental control measures required to mitigate the adverse environmental impacts associated with the four surface mining systems — contour haulback, augering, surface shortwall, and cross-ridge mountaintop mining. This type comparison will provide an understanding of the relative magnitude of the environmental controls required for each mining method.

Environmental controls relating to each of the above mining methods can be divided into six categories:

- topsoil handling
- drainage controls
- excess spoil disposal
- sediment controls
- special reclamation practices
- regrading and revegetation

Each of the mining methods are evaluated below with respect to equipment and methods required to accomplish the above environmental operations.

Topsoil Handling

Topsoil must be segregated as part of clearing and grubbing in all surface mining methods. Only in the case of cross-ridge mining will this cause major problems. Because large surface areas must be disturbed by this mountaintop removal method, topsoil must be continually scraped by small FEL's and transported by haul trucks from above the working face to temporary disposal sites along the edge of the ridge — normally near the outcrop barrier. From these sites, when regrading is completed, the topsoil can be transported to backstack areas for final placement.

In the other mining methods, topsoil handling can be designed as a unitized operation. Soil from the contour cut can be continuously stockpiled on the bench being excavated as normal loading operations proceed then regraded onto the reclaimed slope for vegetating once mining has passed. Alternately, an amount of soil, equivalent to that required for reclaiming the pit area, can be stockpiled and continuous transfer of soil then initiated from the clear and grub area to a predetermined spot on the regraded backstack material. This involves extra equipment such as haulage trucks and also stockpiling the soil in a semipermanent seeded condition. While adaptable to both contour operations and mountaintop removal, the latter technique must usually be used for mountaintop mining because the continuous stockpile technique usually involves too much soil when dealing with an entire ridge top. Thus, due to the limited size of contour haulback, augering, and shortwall mining, topsoil handling poses no major problem relative to the requirements of a mountaintop removal system.

Drainage Controls

For the purposes of this discussion, drainage controls are meant to include all structures designed to divert water from undisturbed areas away from disturbed areas, and all structures designed to convey water from disturbed areas to sediment control structures. No simple technique for water quality control is particularly widespread in steep sloped Appalachia. In fact, because of the broad range of topographic conditions to be found, often few similarities can be found between one operation and another. Throughout the region, planning efforts are directed at using this repertoire of technique to minimize the cost of these environmental controls. Thus rather than use rather expensive sediment ponds, operators may have many smaller check dams which cumulatively accomplish the same objective. Diversion ditches play an important environmental role in all surface mining systems by minimizing the amount of water to be handled by the sediment control structures. Generally, this is done by constructing a collection ditch at the boundary between the disturbed and undisturbed areas; when overland flow is intercepted from an undisturbed area, the effluent from the ditch can be released directly into the environment; when overland flow is intercepted from a disturbed area, the effluent must be directed to any one of a variety of sediment control structures.

Drainage control structures in the contour haulback, augering, and shortwall methods are similar. Each of these three systems require a highwall diversion ditch and a low wall diversion ditch. Figure 27 displays these controls schematically. As shown in these schematic profiles, the position of the diversion ditches is the same for the contour haulback and augering systems. In the case of the shortwall system, however, the highwall diversion ditch must be positioned above the area subject to subsidence. Otherwise with the fracturing and irregular, downward movements associated with subsidence, the ditch would become unusable. Also, as previously pointed out, to preclude or reduce chances of acid generation, it is imperative that no water be allowed into the shortwalled area.

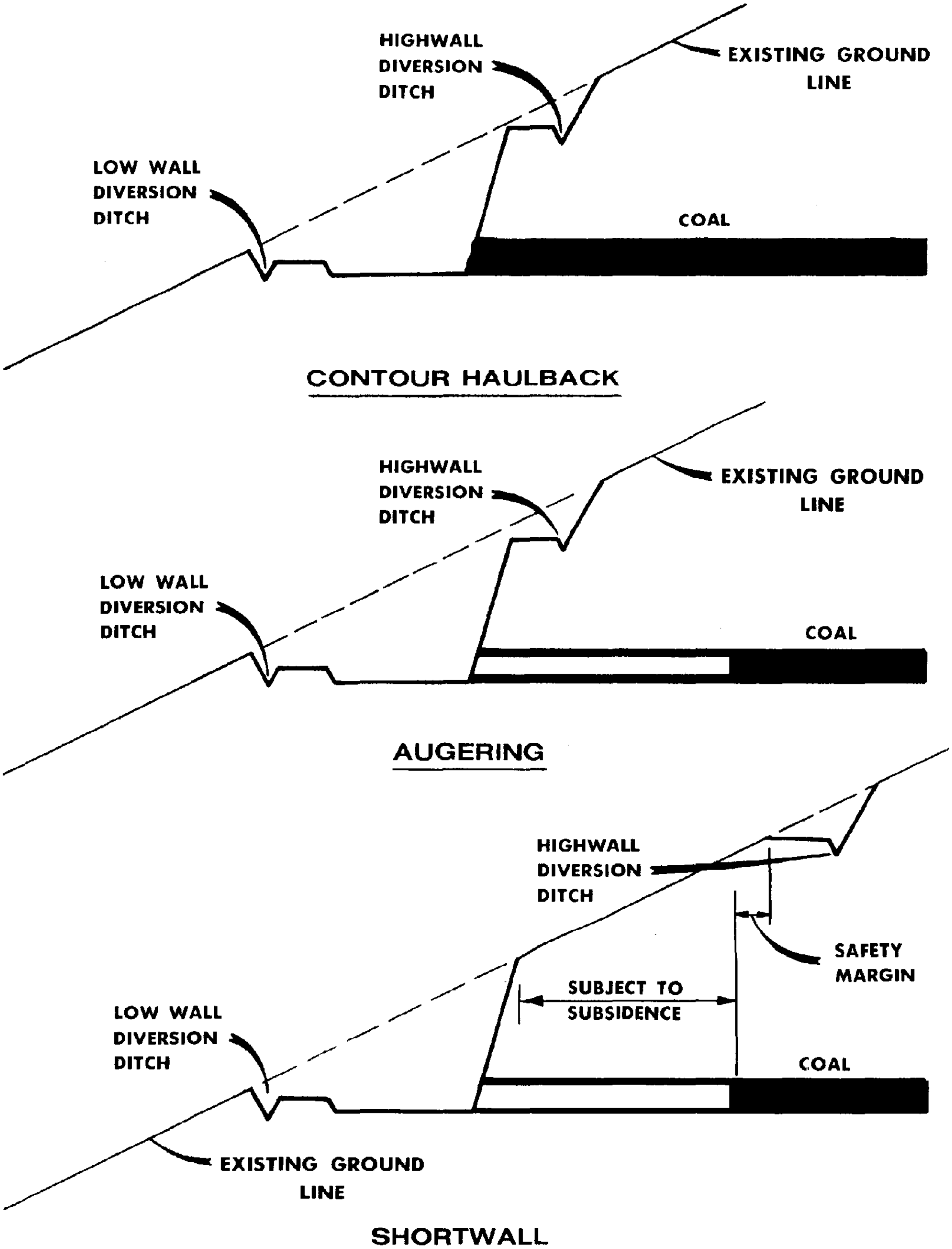
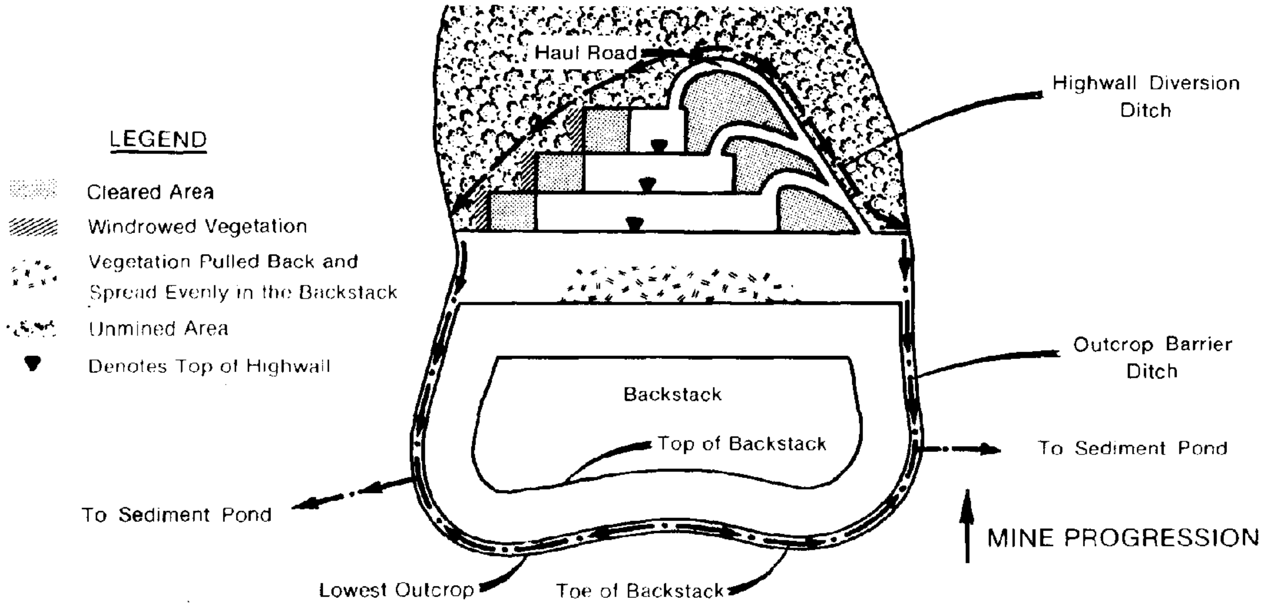


FIGURE 27. - Drainage ditches for contour, auger and shortwall mining.

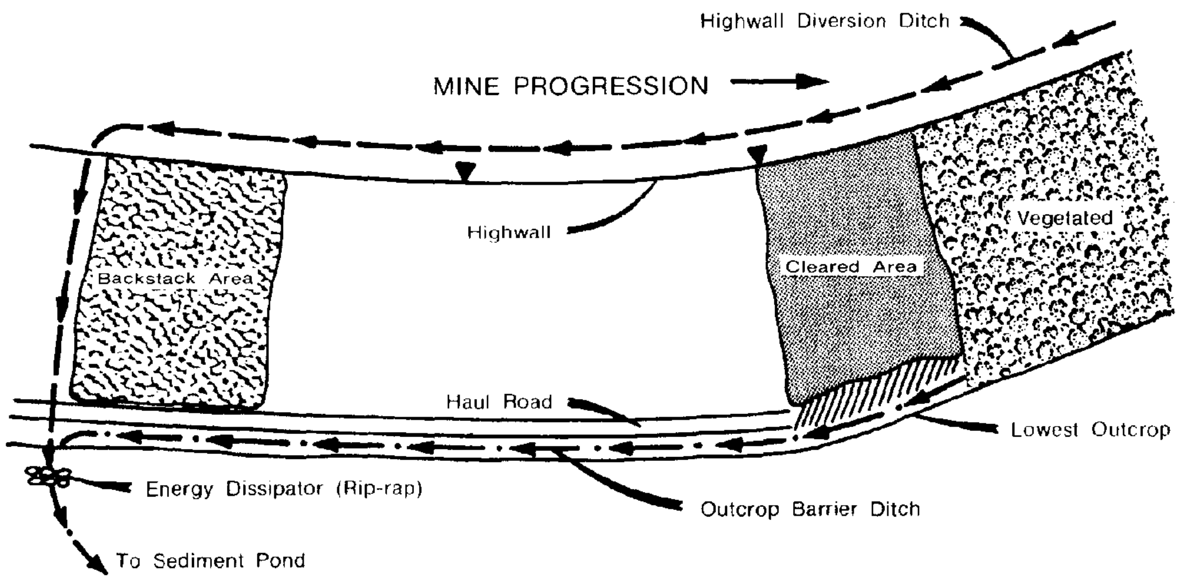
For the cross-ridge mining system, a much different type of drainage control system must be established, reflecting the much larger areas to be considered and the radically different configuration of the mining system itself. With the excavation face and all unit operations moving in the direction of the ridge, a diversion ditch for undisturbed water must be located in front of the clearing and grubbing operations. This ditch will divert any drainage from the undisturbed area in front of the working face and convey it below the lowest coal seam. This type ditch must be continuously reconstructed as mining progresses along the ridge since it is running parallel with the highwall or transverse to the ridge.

A second diversion network must be constructed along the outcrop barrier, enclosing the excavated area. This ditch will catch all drainage from the excavation/backstack area and convey it to a sediment control structure (normally a sediment pond). Figure 28 displays these drainage controls for a cross-ridge system in schematic form. The highwall diversion ditch in this system carries on the same function as the highwall diversion ditch in the other mining systems — to divert drainage away from the active mining area. The outcrop barrier ditch takes on the same function as the low wall diversion ditch in the other systems — to catch all drainage from the disturbed area and convey it to a sediment control structure.

In many cases mining will continue on for many miles following the contour along and sometimes across ridges into different drainage systems. Due to this and the presence of rolls and dips in the seam, the water can often not be drained along such an extensive system but must instead be



CROSS-RIDGE MINING



CONTOUR MINING

FIGURE 28. Application of drainage controls to cross-ridge and contour-type mining operation.

directed either to a new sediment pond or be redirected by a more direct route through pipes or a ditch to the original pond. While no pond can be abandoned, as the mining operation moves on the need for the pond will gradually be reduced until it can finally be "decommissioned" by approval of the bonding authority.

Additional drainage controls are necessary as permanent flow structures in reclaimed areas for all the mining systems. In the contour haulback, augering, and shortwall systems, lateral drains must be constructed to convey drainage from the highwall to the low wall diversion ditch and from there to energy dissipators (rather than a sediment control structure) since the need for treatment no longer exists. In the cross-ridge system, a series of drains must be constructed to handle the runoff on the backstack. These drains will lead directly to the outcrop barrier ditch.

Drain construction can be accomplished with bulldozers or backhoes, with bulldozers being the more versatile machine in steep slope conditions. Typically the drains will be excavated in original ground to be filled with durable rock. Drain dimensions must be sized according to fairly strict standards (Appendix C) to accomodate typical storm volumes from the specific drainage areas.

Excess Spoil Disposal

In general, all surface mining systems will generate excess spoil due to the swell of the overburden once it is disturbed. Typically swell will amount to 50% of original volume while the compactive effort of backstacking will reduce this by 10%. The more material that is excavated, the more excess spoil is generated. When comparing systems in this regard, it is important to relate the amount of excess spoil generated per ton of coal being produced. Utilizing this criterion, cross-ridge mining generates the greatest amount of excess spoil, followed by contour haulback, with augering and shortwall mining generating the least excess spoil.

In steep slope regions, disposal of excess spoil implies the construction of valley fills. A valley fill constitutes not only the fill itself, but also the ancillary drainage and sediment control structures inherent to a stable design. No differences in fill design will exist among the various systems — only the size and/or number of required fills will differ. With the large volumes of material to be excavated in a cross-ridge mountaintop removal system, a few large valley fills may have to be constructed near the initial cut area. In contour haulback mining, numerous smaller fills will likely be constructed as the contour stripping proceeds around the ridge. The same type of fill configuration is required for augering and shortwall, since they are simply extensions of contour mining; however, no extra overburden removal is required and there is thus no need for additional valley fill provisions.

The construction of valley fills usually occurs with truck haulage from the excavation pit to a predetermined spot in a valley for controlled placement of the spoil. Dozers will regrade the material to a specified lift thickness to meet compaction requirements. Drainage and sediment controls for the fill must be established prior to the initiation of fill construction.

Dozers and backhoes are appropriate for the construction of drains and excavated sediment ponds.

Sediment Controls

Sediment controls in the form of sediment ponds are typically found in surface mines below valley fills, but this need not be the case. "On-bench" sediment controls are commonly required in steep slope regions where sites for sediment ponds with sufficient surface area are difficult to find. For example, sediment traps (Figure 29) can be used in contour operations, rather than a low wall diversion ditch leading to a sediment pond. These sediment traps are possible in contour operations — i.e., haulback, augering, and shortwall — because disturbed areas are minimal. In cross-ridge mining, sediment traps would be less likely to be successful, because the volumes of water and sediment are so much larger.

Where traps or related structures are not possible, sediment ponds must be constructed. Ponds can be constructed by either excavating a depression or damming up a natural swale (Figure 30). The choice will depend on the nature of the soil and bedrock, and the grade of the valley side slopes. With a natural valley floor conducive to groundwater flow or one which is narrow with steep side slopes, excavated ponds become the only practical design. Thus, cross-ridge mining operations will most often utilize sediment ponds (the most appropriate sediment control structure for large scale surface mines), while the choice of design will depend on site specific conditions.

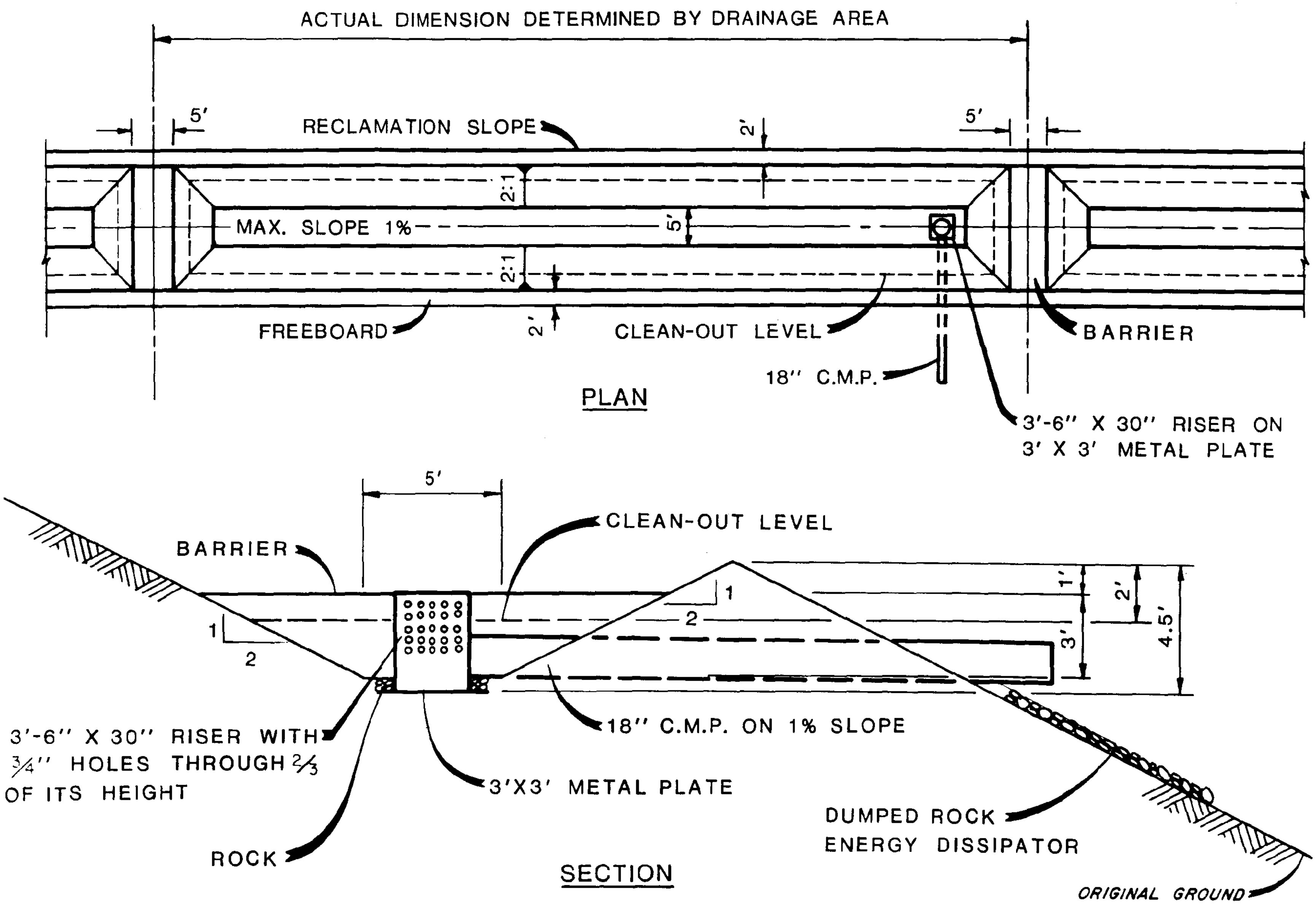


FIGURE 29. - Example: Sediment trap with riser.

FIGURE 30. - Embankment type sediment pond with riser.

Construction of sediment controls will require various types of equipment, with choice depending on site conditions and the size of the control structure. Generally, sediment traps can be dug out by backhoes working from the edge of an excavation bench. Embankment ponds can be formed by dozers regrading the appropriate materials brought in by haul trucks. Excavated ponds can require various levels of equipment requirements — from simply a dozer for the smaller ponds to a dozer-loader-truck excavation team with ancillary drilling and blasting.

Special Reclamation Practices

Of the four general mining methods being analyzed here, augering and shortwall mining require special reclamation practices to mitigate adverse environmental impacts unique to each method. The unique characteristics arise due to the underground extraction of the coal. With a void so created, alterations of groundwater flow occur in both the augering and shortwall mining systems. Additionally, the subsidence created by shortwall creates surface problems.

Mitigation of the problems associated with augering requires the utilization of seals to block discharges of large quantities of potentially polluted water into the backfill. Numerous types of seal technology are currently available and a particular method should be chosen to meet site specific conditions.

The environmental problems associated with the subsidence in shortwall mining cannot be handled as directly as in augering. With the rupturing of the rock strata, once subsidence is induced, groundwater flow alterations will occur. Sealing flows becomes virtually impossible since no discrete points of effluent can be determined. The most that can be hoped for are positive results from surface compaction efforts, which will minimize groundwater infiltration. Thus once subsidence has occurred, heavy equipment such as bulldozers should grade and track the affected surface areas to create a soil layer with a smooth surface and uniform density. Without this mitigation measure, percolation and groundwater flows would be greatly increased in the area mined by shortwall methods. This could have adverse affects on backfill stability. In any event, alterations of existing groundwater flows from fracturing and subsidence pressures cannot be fully mitigated, and, thus, is an adverse impact which could not be avoided with surface shortwall mining.

Regrading and Revegetation

With the destruction of natural vegetation associated with the various surface mining methods, regrading and revegetation will mitigate their most obvious adverse environmental impacts — the erosion and siltation of unvegetated areas. Under steep slope conditions, regrading and revegetation of disturbed surface areas may require the use of winches to accomodate various pieces of reclamation equipment on outslope areas. Typically, regrading involves the use of dozers to both regrade and scarify surfaces. Fertilization and initial seeding efforts are then accomplished by hydroseeders.

Utilization of equipment in this manner will occur in all the surface mining systems; only the extent of the disturbed area will differ. The cross-ridge system will require the most extensive regrading and revegetation effort due to the large areas affected by this mountaintop removal system. Short-wall will require slightly more regrading and revegetation than augering or contour haulback, due to marginal increase in affected area from subsidence effects.

Steep slope conditions will be present for all four mining systems. Typically 50 percent slopes will require regrading and revegetation. Winches attached to dozers can lower other dozers, trucks, or hydroseeders to pursue the reclamation effort. In some instances, helicopters have been used to revegetate.

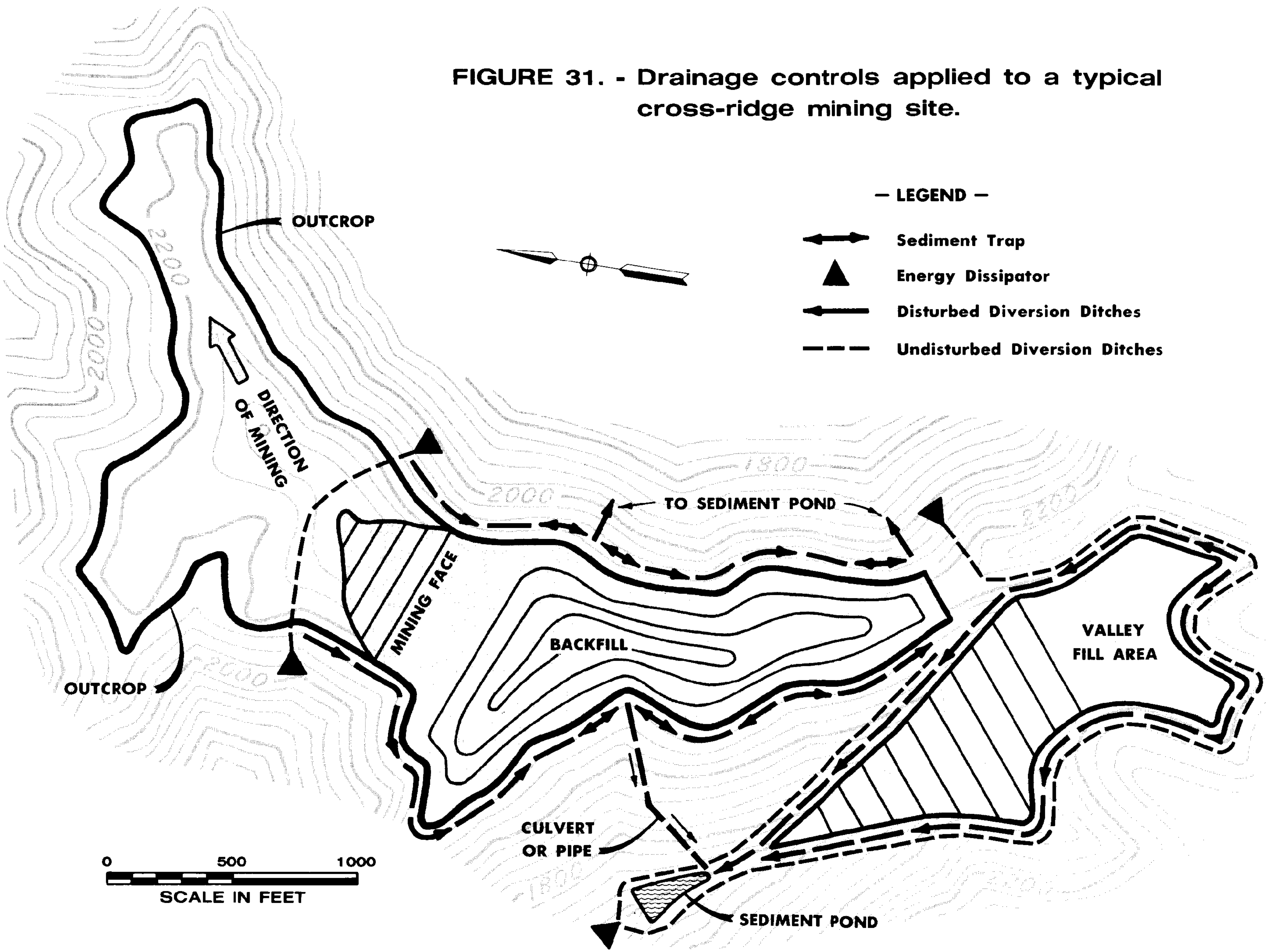
Summary

To summarize the discussion of environmental controls presented above, two plans (Figures 31 and 32) have been prepared showing typical configurations for these controls. Using the sample site presented in previous sections, the positions of the controls for a chosen "time slice" in the progression of the mines has been shown. Two mine progressions are shown — one for a cross-ridge mountaintop removal operation and another for the three types of contour operations (contour haulback, augering, and shortwall).

The types of impact mitigation measures include:

- topsoil storage areas
- diversion ditches
- excess spoil disposal areas — valley fills
- sediment ponds and sediment traps
- revegetated backstack areas

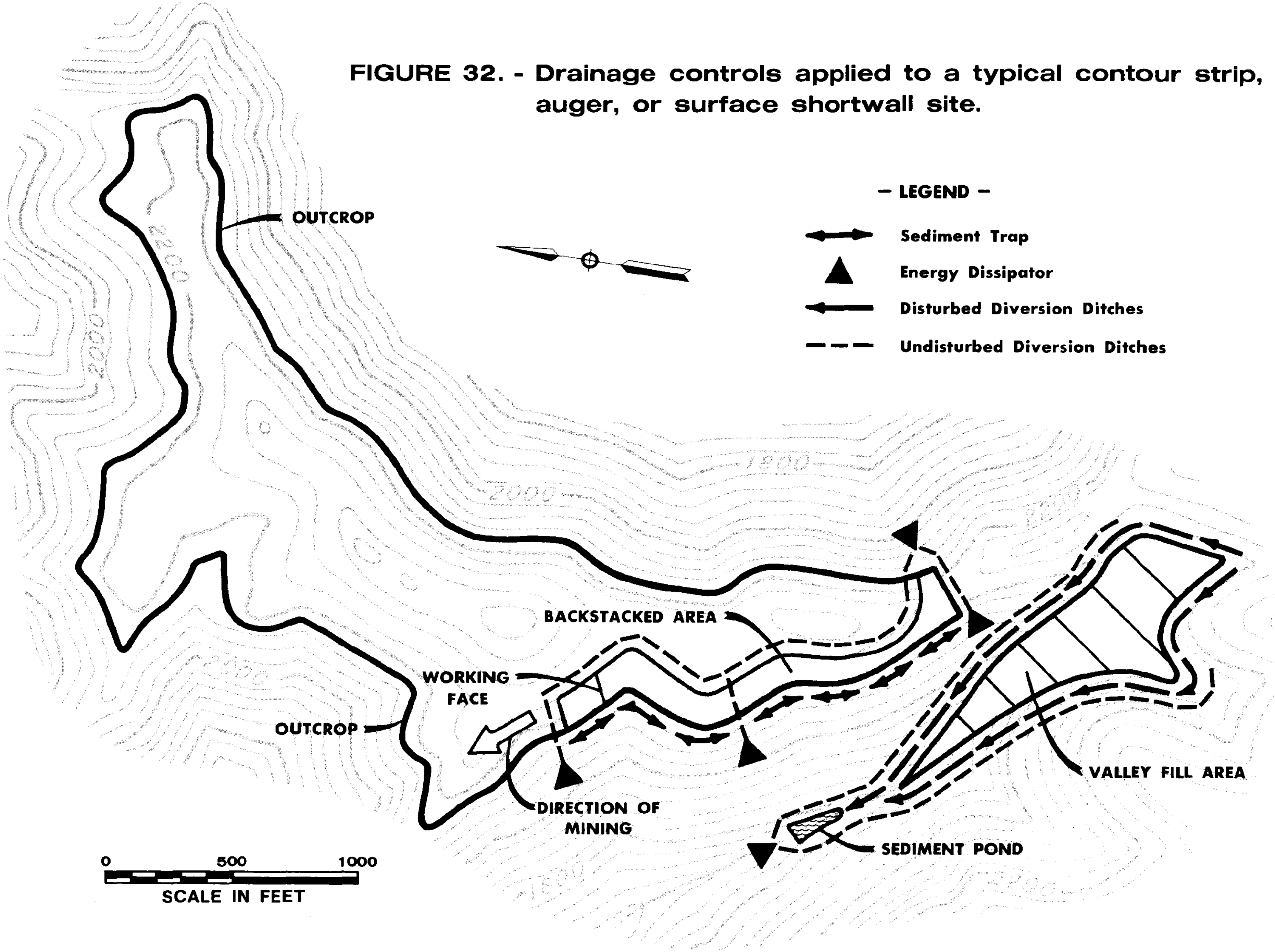
FIGURE 31. - Drainage controls applied to a typical cross-ridge mining site.



Not shown are special reclamation controls such as auger seals and the extra regrading and diversion ditches required by shortwall, which have been discussed previously.

A comparison of the two plans indicates the more extensive nature of the environmental measures for a cross-ridge mine relative to the contour operations. One should not forget, however, that long-term environmental stability is normally better with cross-ridge operations. Cross-ridge backstacks can be designed to stable specifications, while the contour backstacks must approximate original contour. In terms of an overall assessment, the relative impact should be measured in light of the amount of coal recovered and the "finality" of recovery. Under these criteria, though the aesthetic as well as real environmental impacts of mountaintop removal mining are the greatest, the coal is entirely mined negating the possibility of reaffecting the land and not sterilizing other reserves. Surface shortwall is perhaps second most desirable in that, though some coal may be sterilized against future mining, the coal which is mined achieves 100% extraction while a large part of the area affected is only subsided and thus receives no substantial aesthetic impact. Contour mining, having no ancillary operations has a fairly substantial impact; it requires a number of valley fills, sediment ponds and all other mitigation measures, but may achieve total recovery in only a very limited area and tends to isolate reserves to a large degree. Augering is least desirable from an environmental standpoint on nearly any basis. Percentage recoveries are very low compared to the total area affected. While the surface effects are negligible, there can be a great deal of acidic effluent from auger holes in spite of sealing. Further, augering isolates reserves not

FIGURE 32. - Drainage controls applied to a typical contour strip, auger, or surface shortwall site.



only in small "islands" left by circling, but also in the enormous amount of coal left in the pillars between holes.

Though many of these discussions would seem to be invalidated by a lack of conclusive data on surface shortwall mining, many of the projections made are based on as much substantial and qualitative information as is available. There is obviously further work to be done in the areas presented in the Conclusions and Recommendations section. Such work, as a continuation of this project awaits the initiation of an agency such as the Department of Energy or the Bureau of Mines.

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APPENDIX A - APPALACHIAN SURFACE MINING STATISTICS BY COUNTY

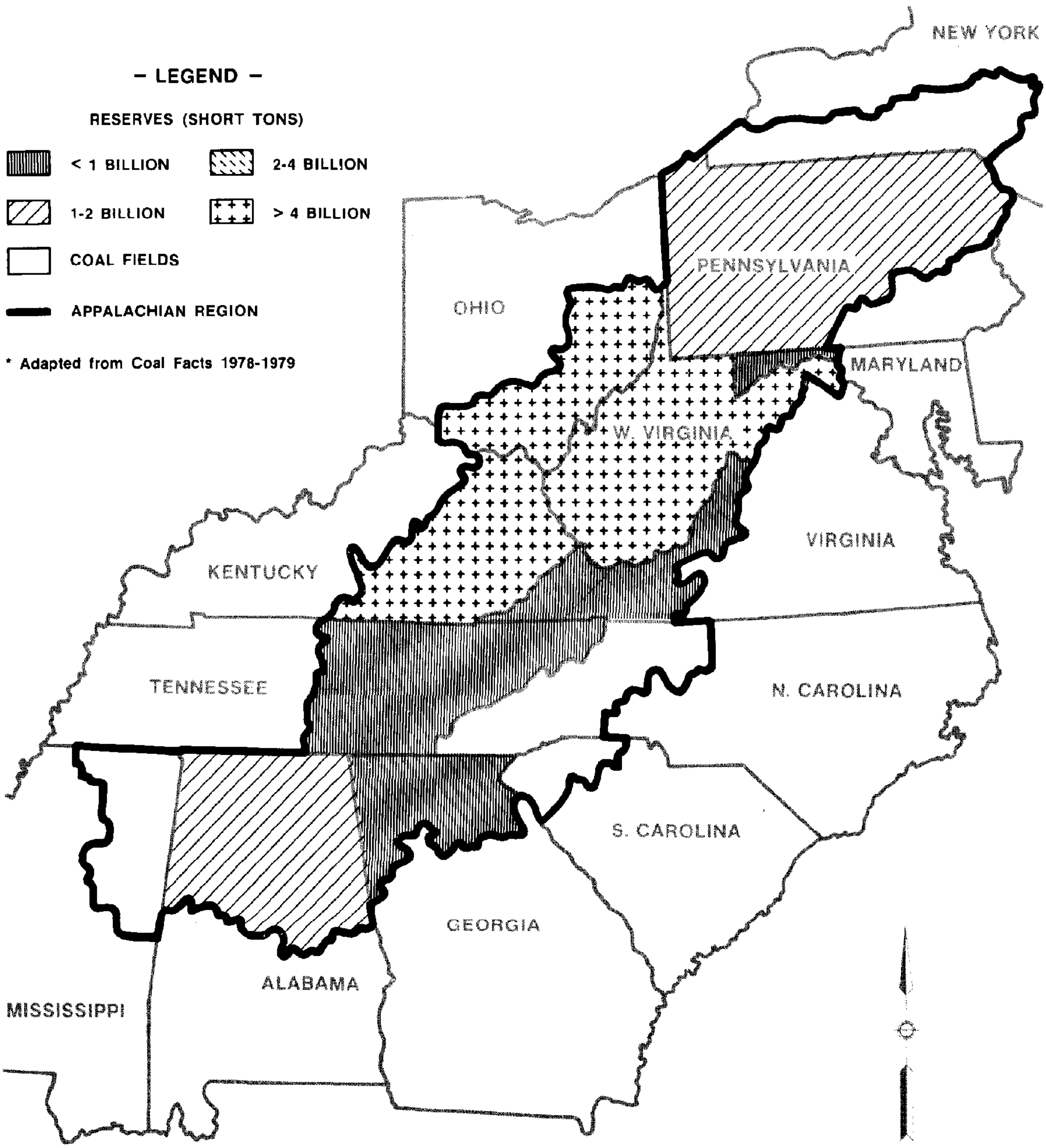

FIGURE A-1. - Strippable coal reserve tonnage in Appalachia, 1976. *

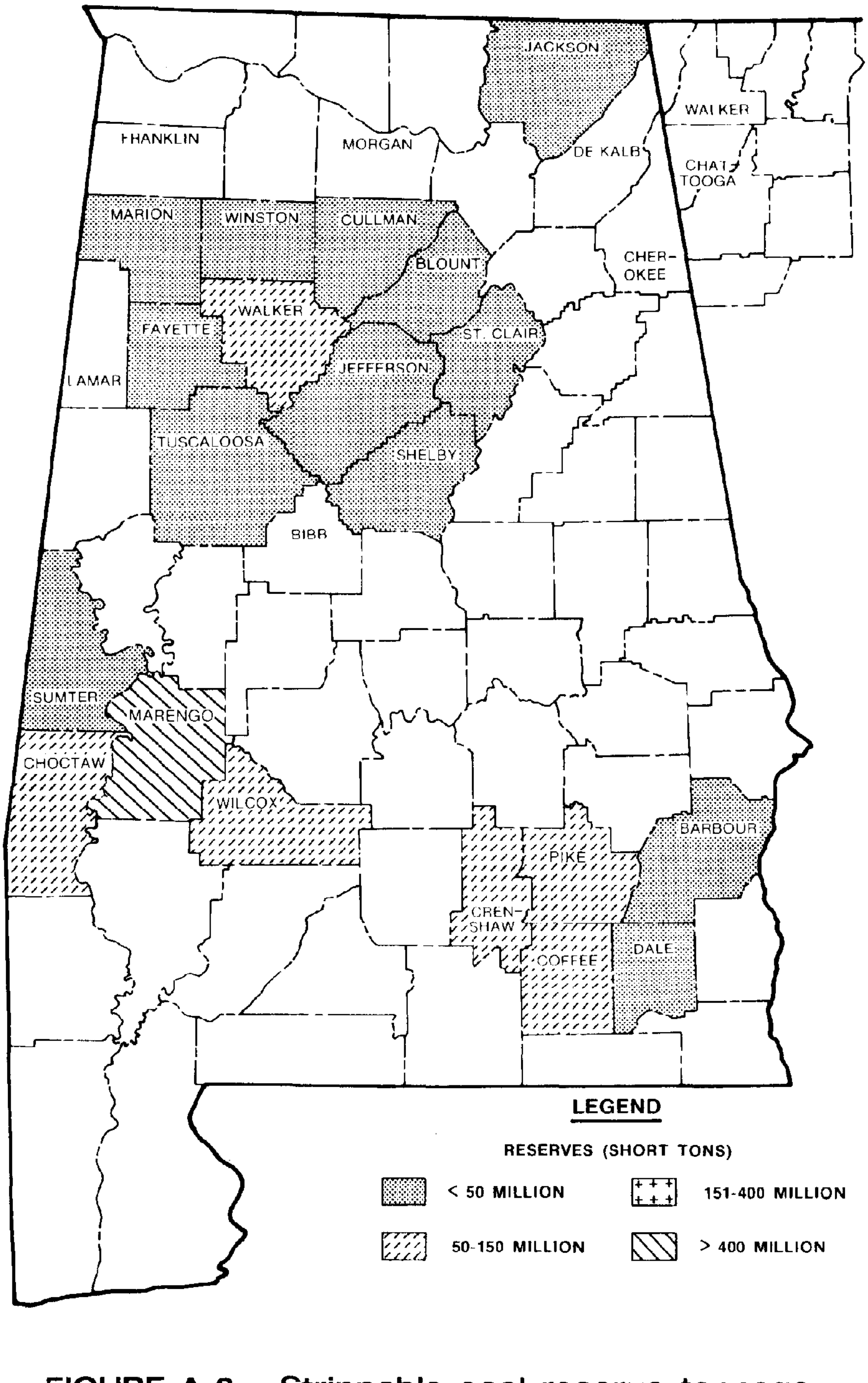

FIGURE A-2. - Strippable coal reserve tonnage in Alabama and Georgia.

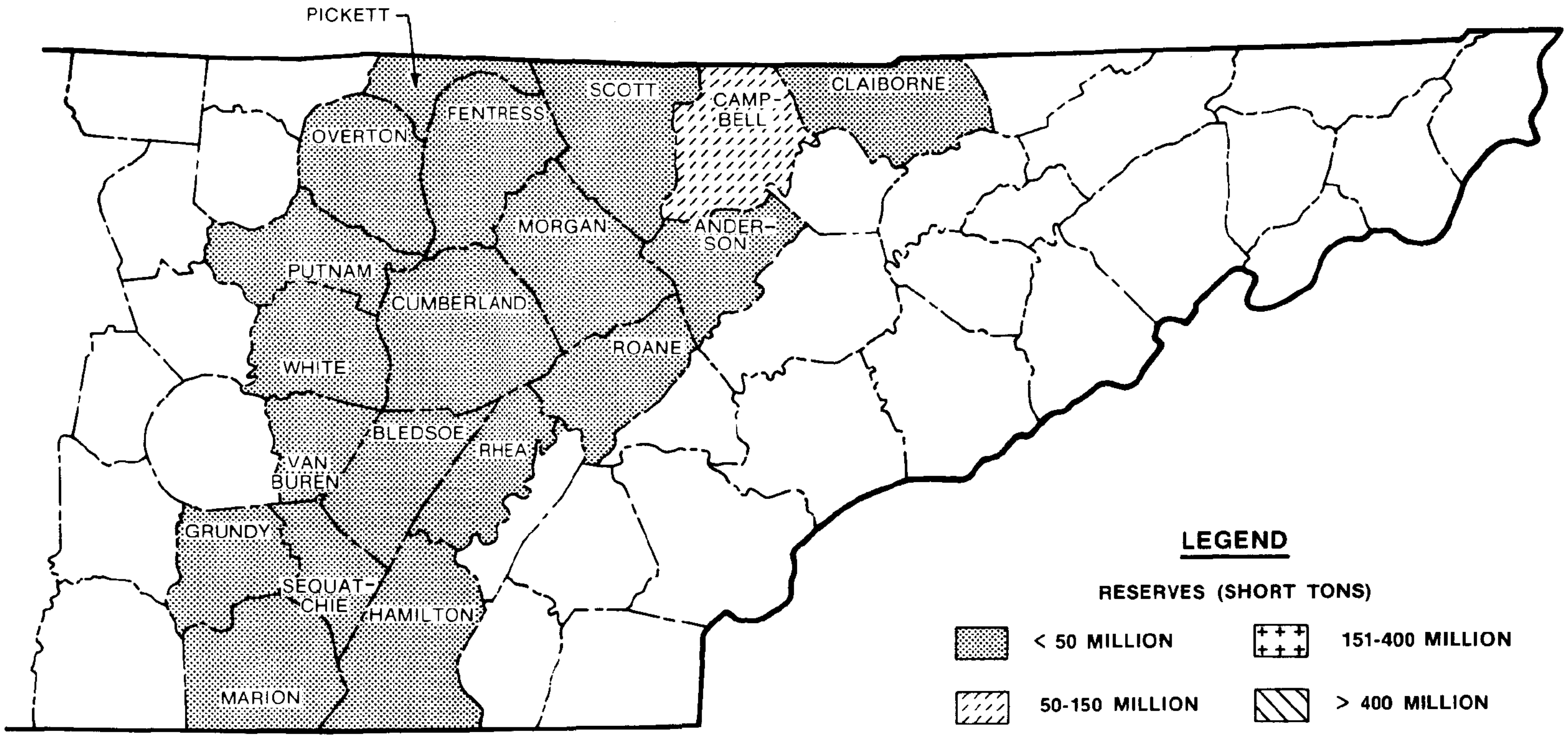

FIGURE A-3. - Strippable coal reserve tonnage in Tennessee.

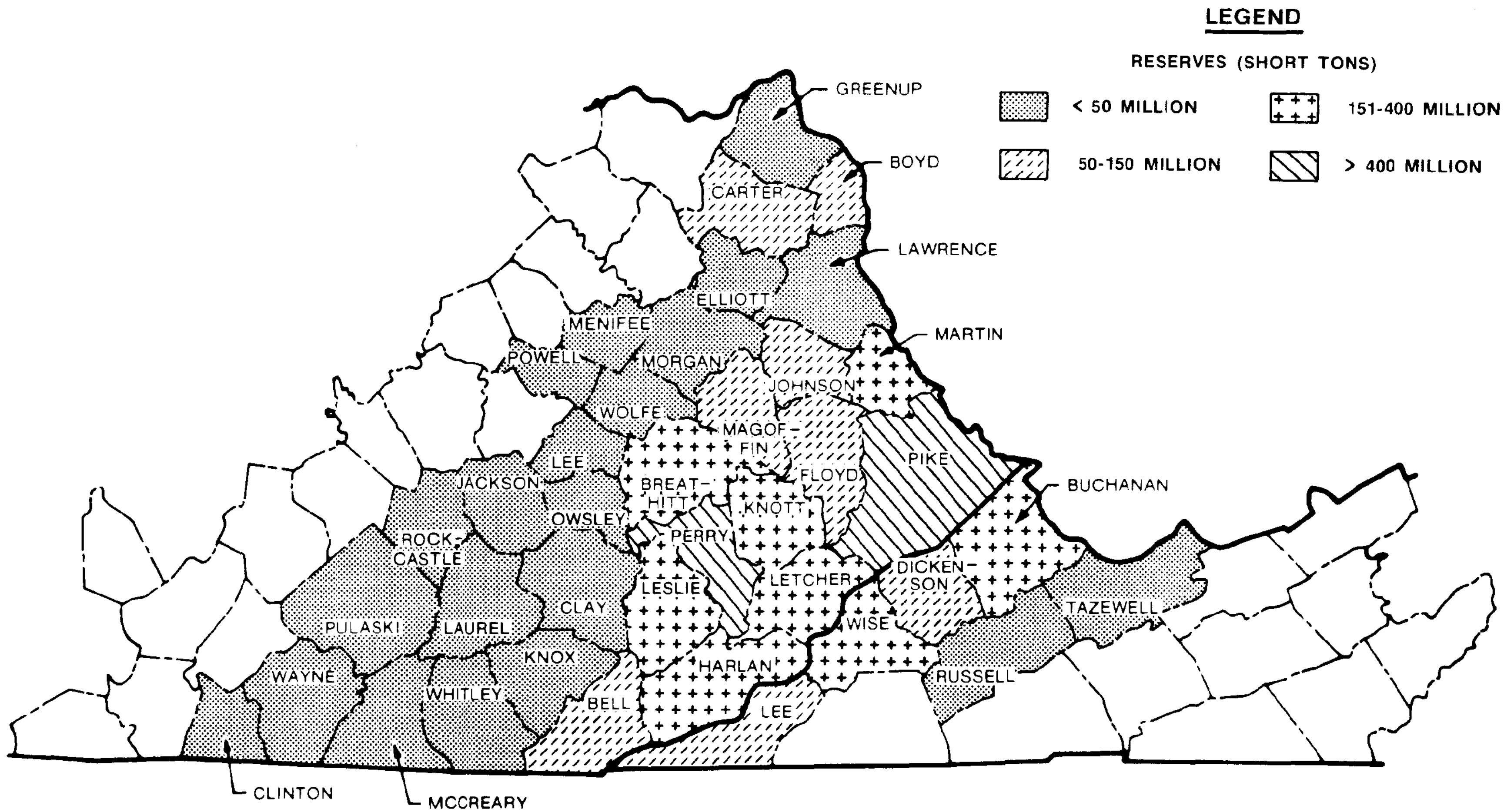

FIGURE A-4. - Strippable coal reserve tonnage in Kentucky and Virginia.

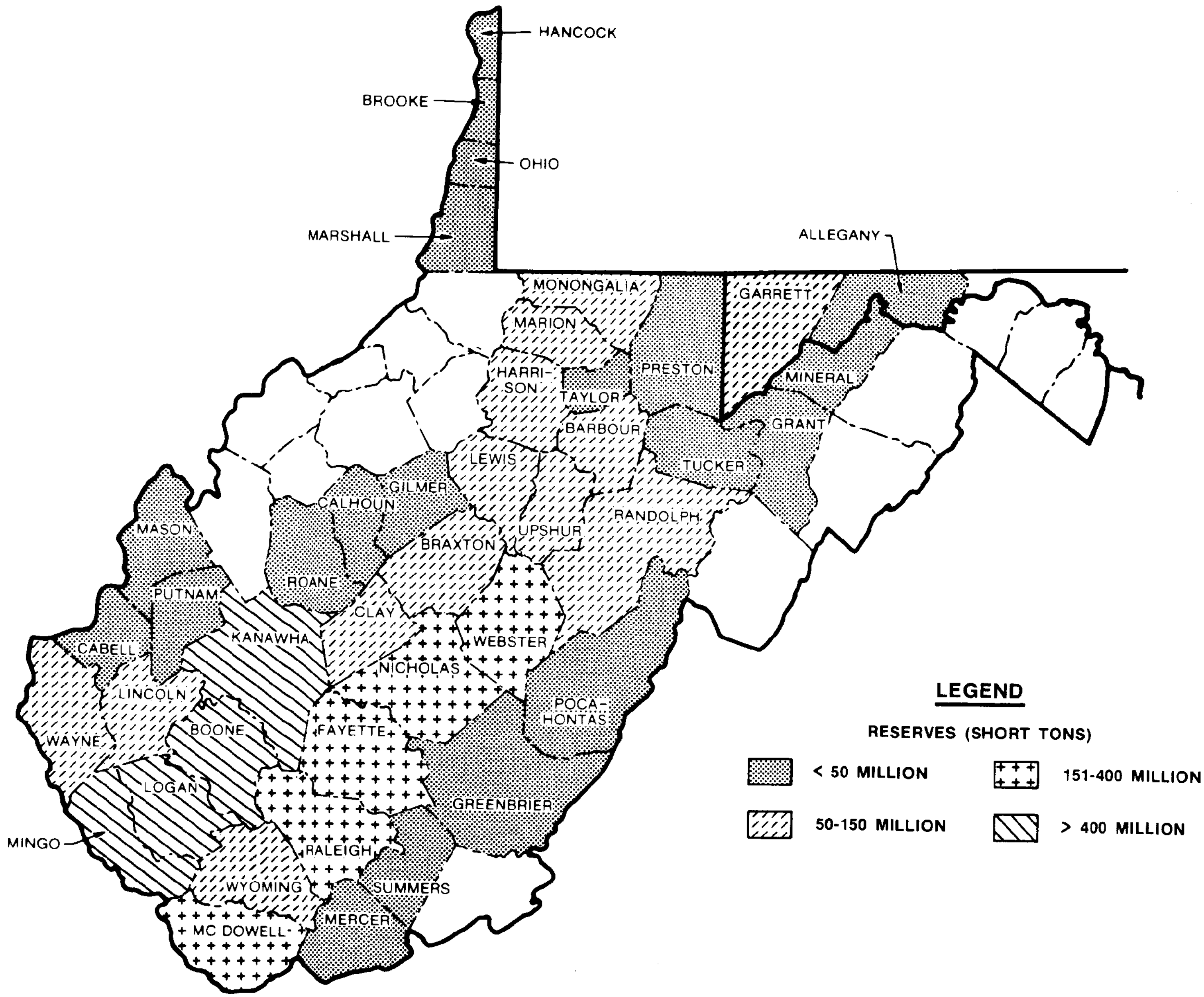

FIGURE A-5. - Strippable coal reserve tonnage in West Virginia and Maryland.

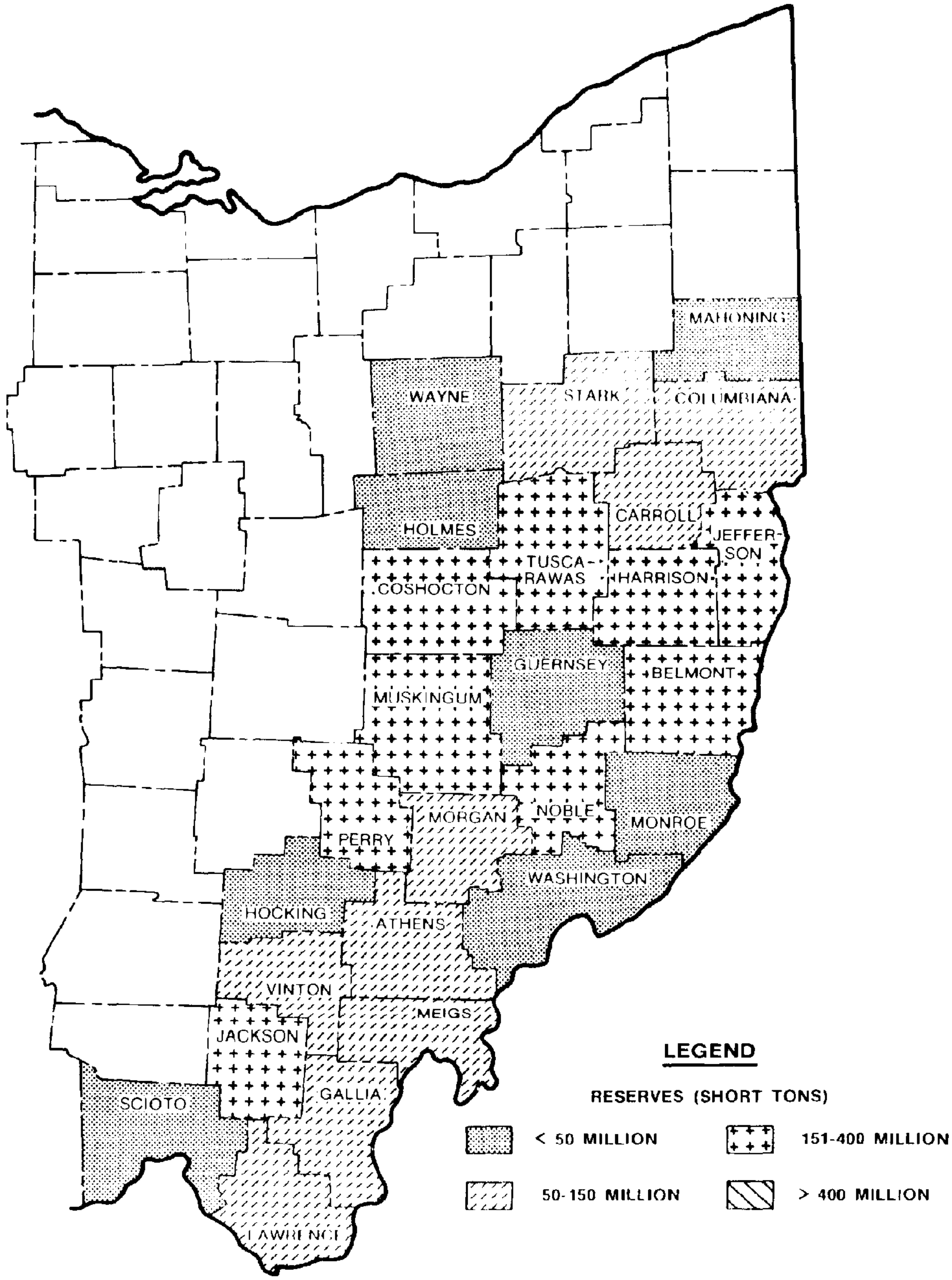

FIGURE A-6. - Strippable coal reserve tonnage in Ohio.

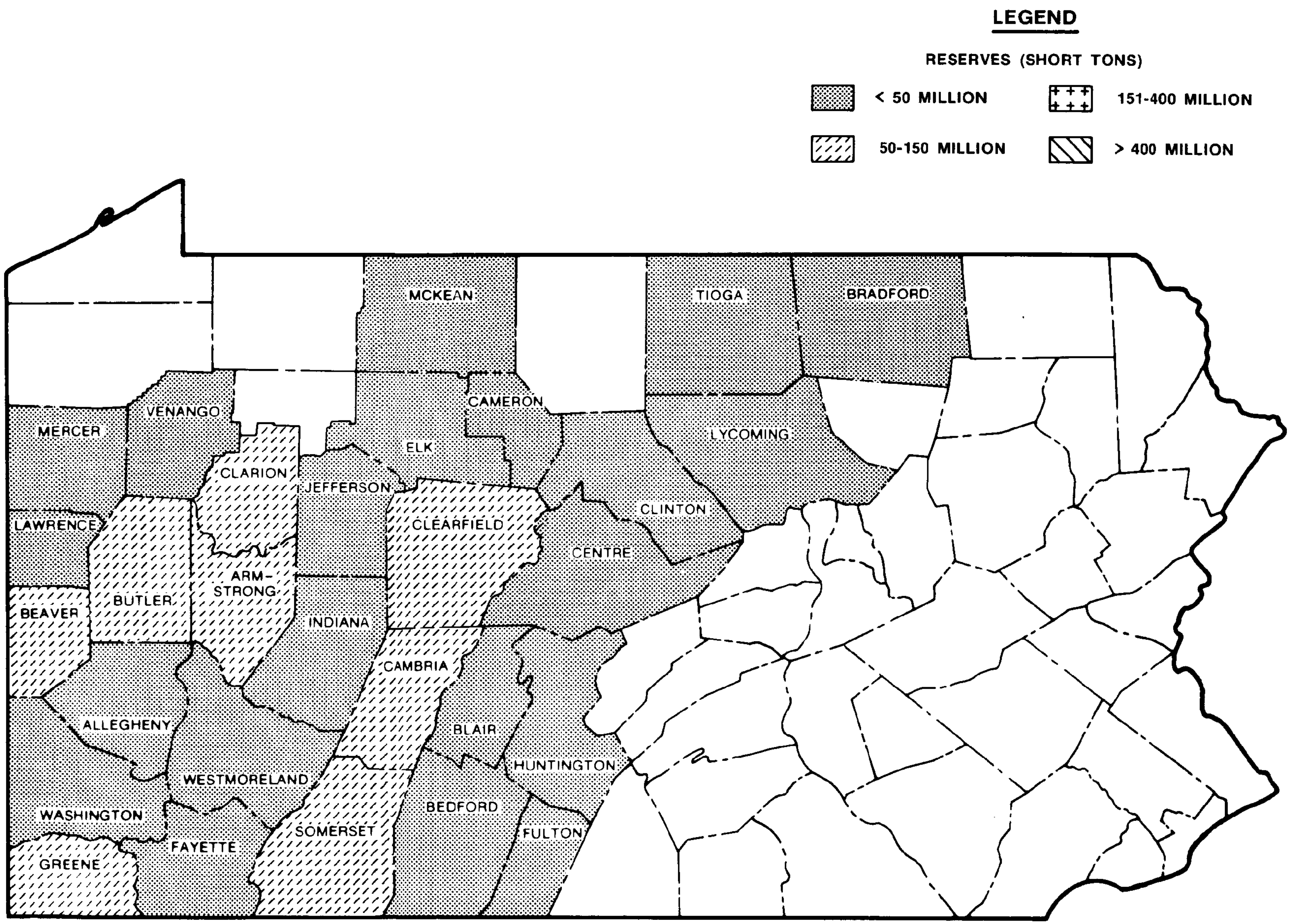

FIGURE A-7. - Strippable coal reserve tonnage in Pennsylvania.

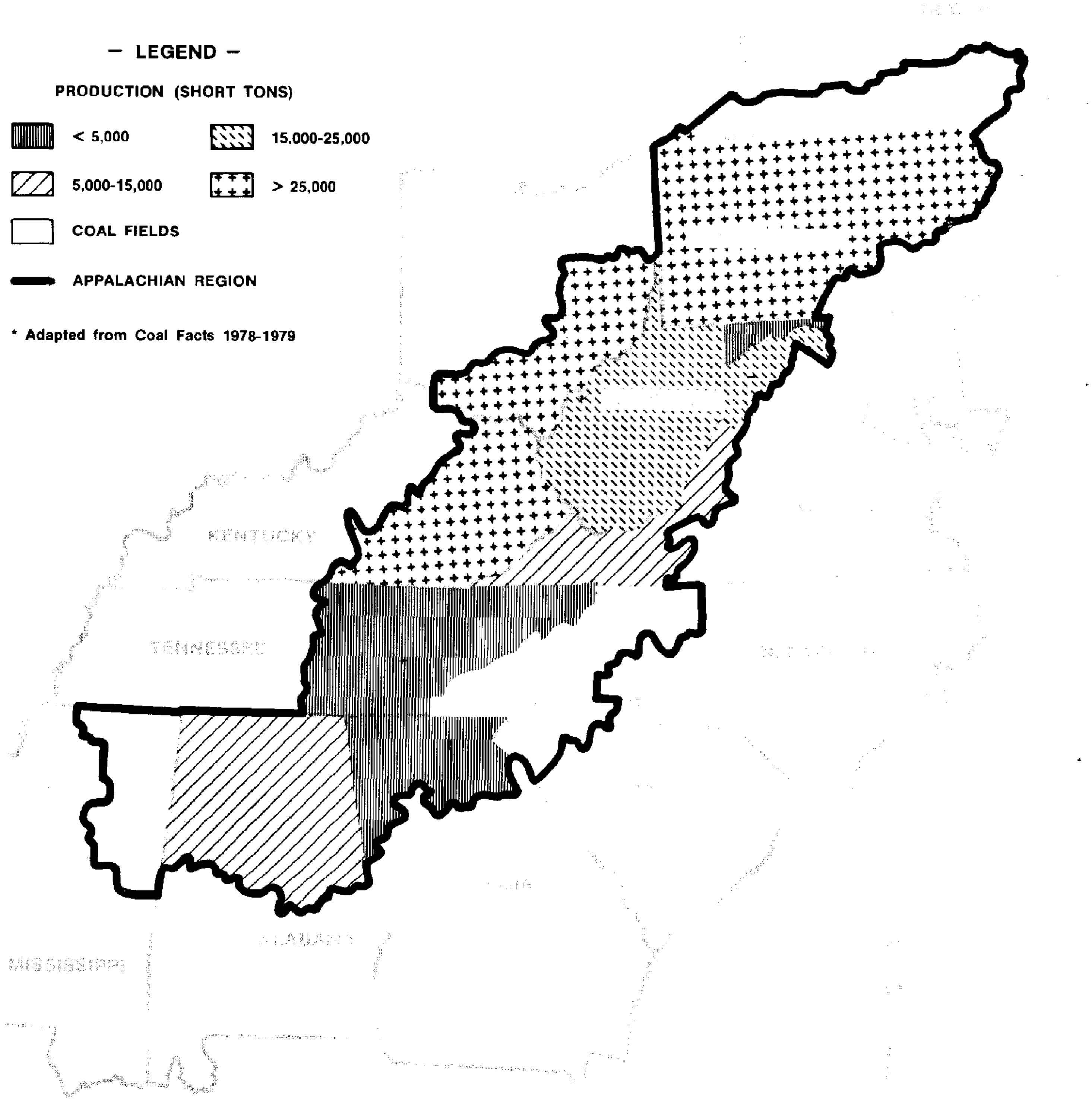

FIGURE A-8. - Surface coal production during 1977 in Appalachia. *

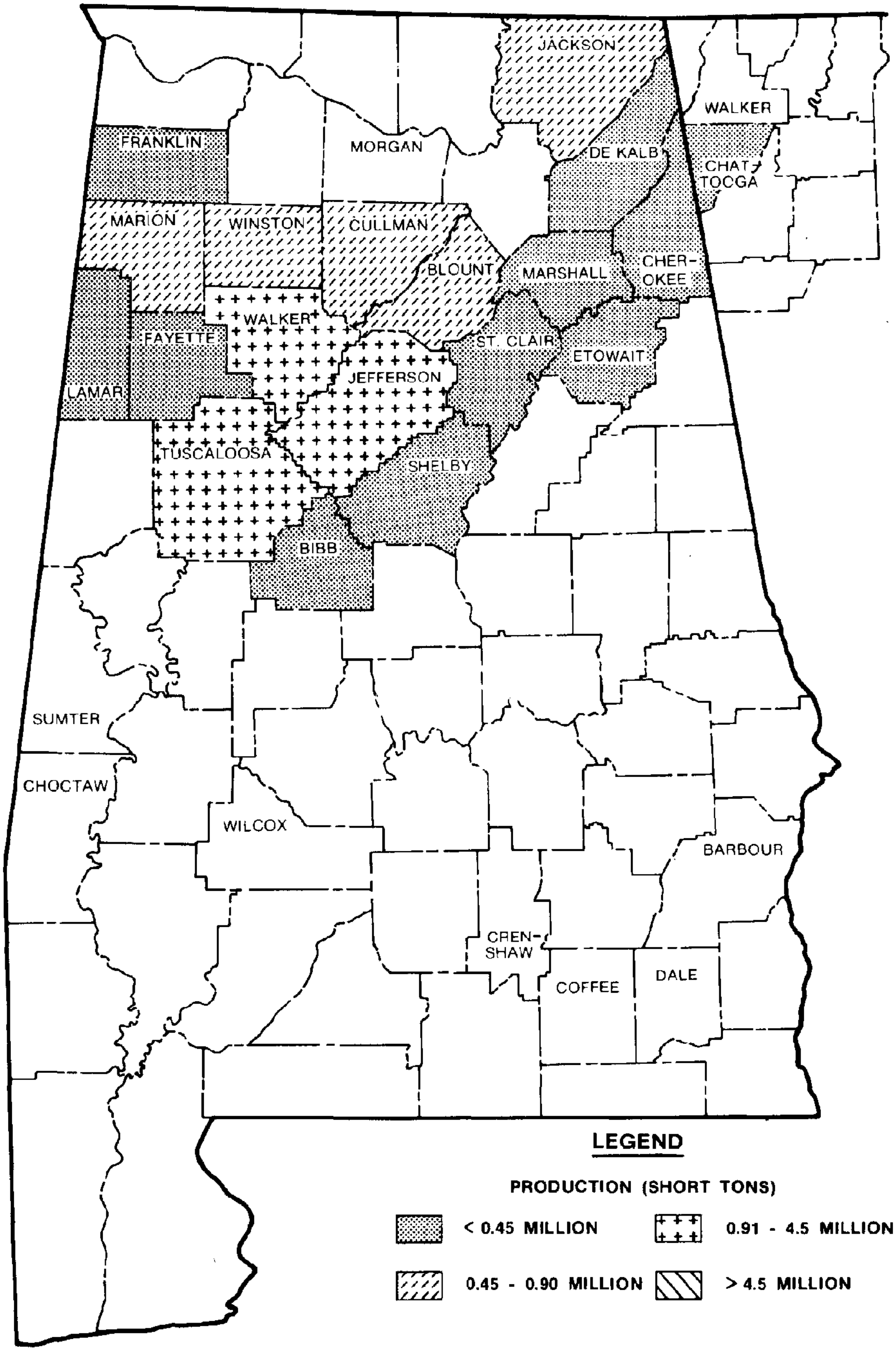

FIGURE A-9. - Surface coal production during 1976 in Alabama and Georgia.

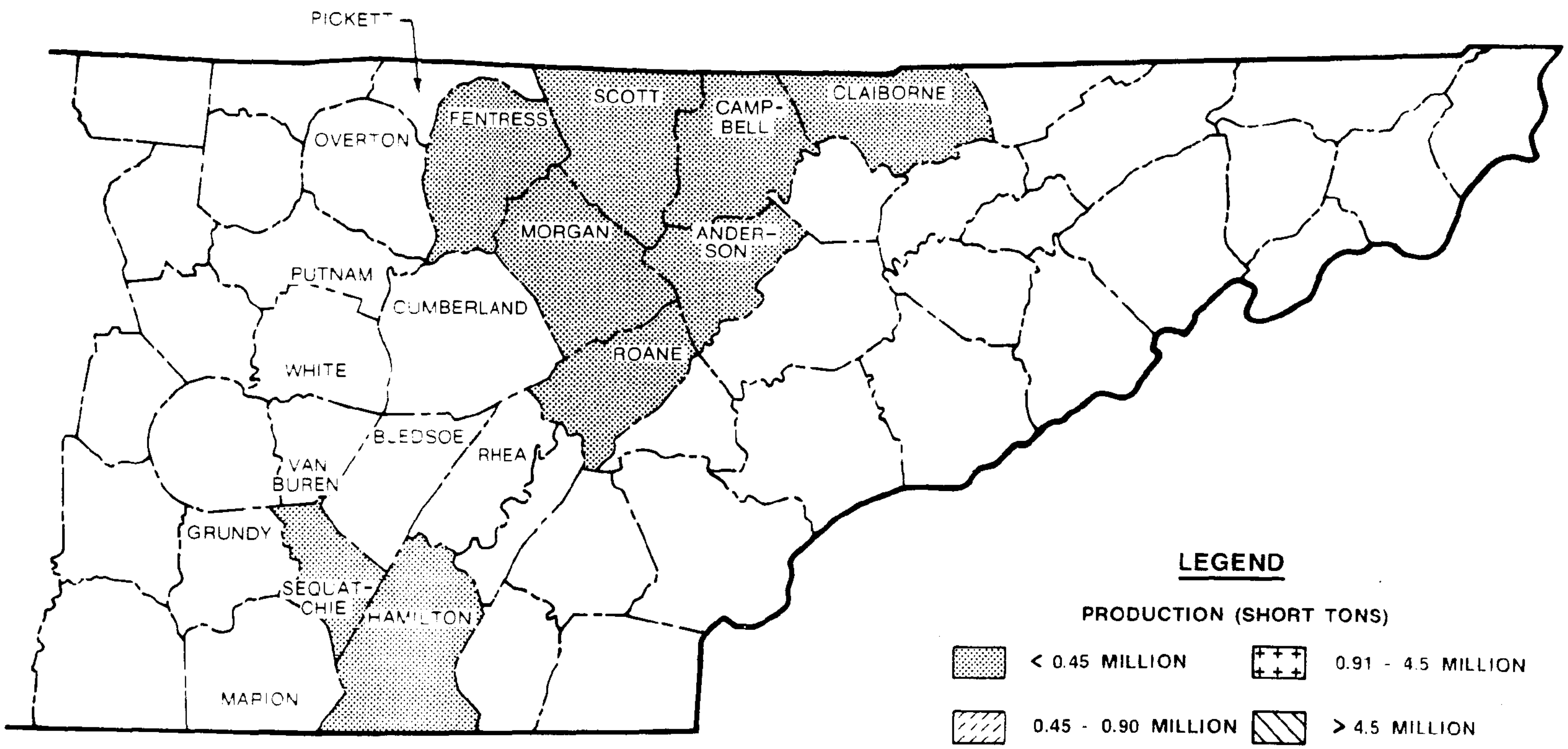

FIGURE A-10. - Surface coal production during 1976 in Tennessee.

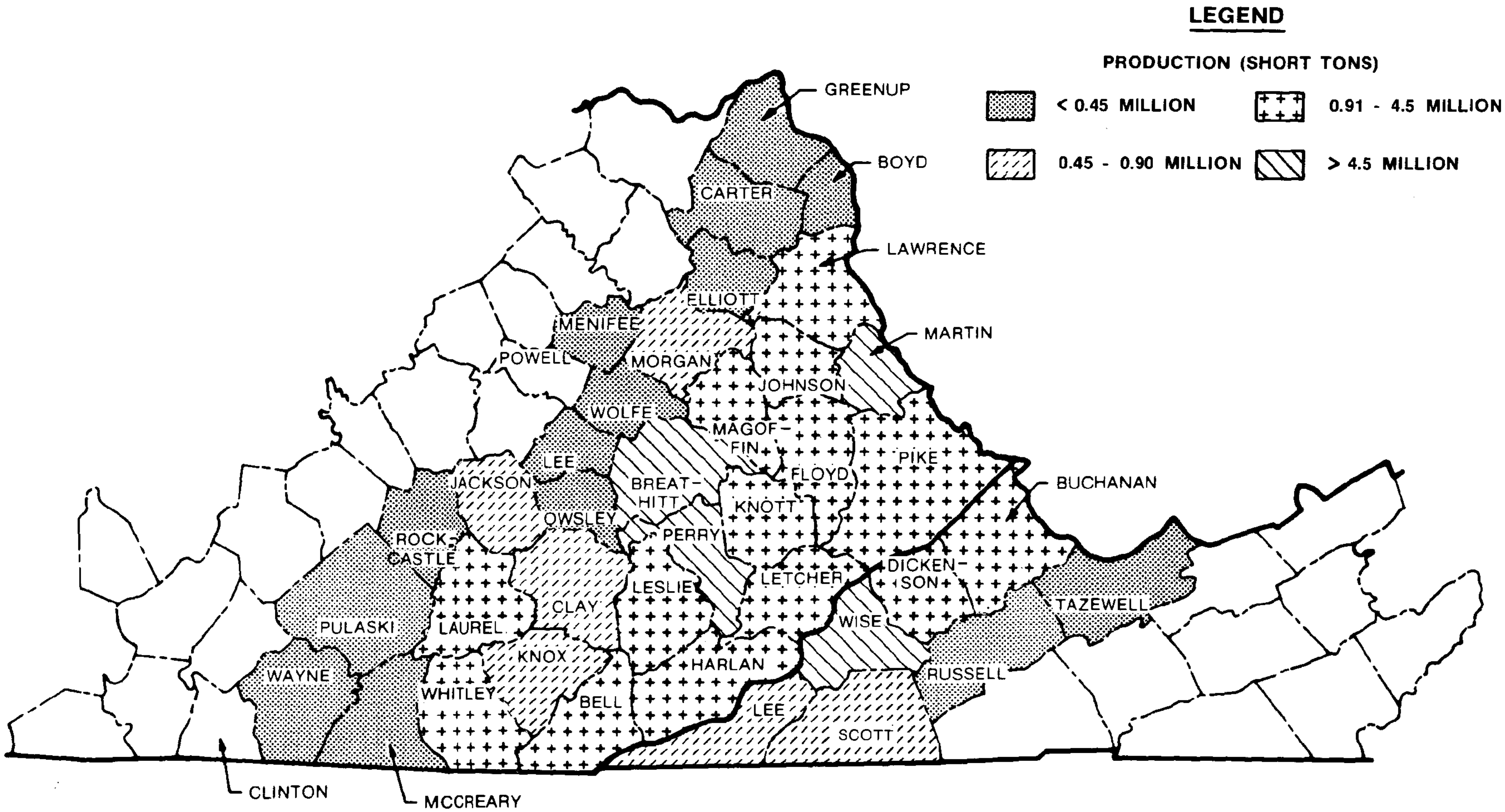

FIGURE A-11. - Surface coal production during 1976 in Kentucky and Virginia.

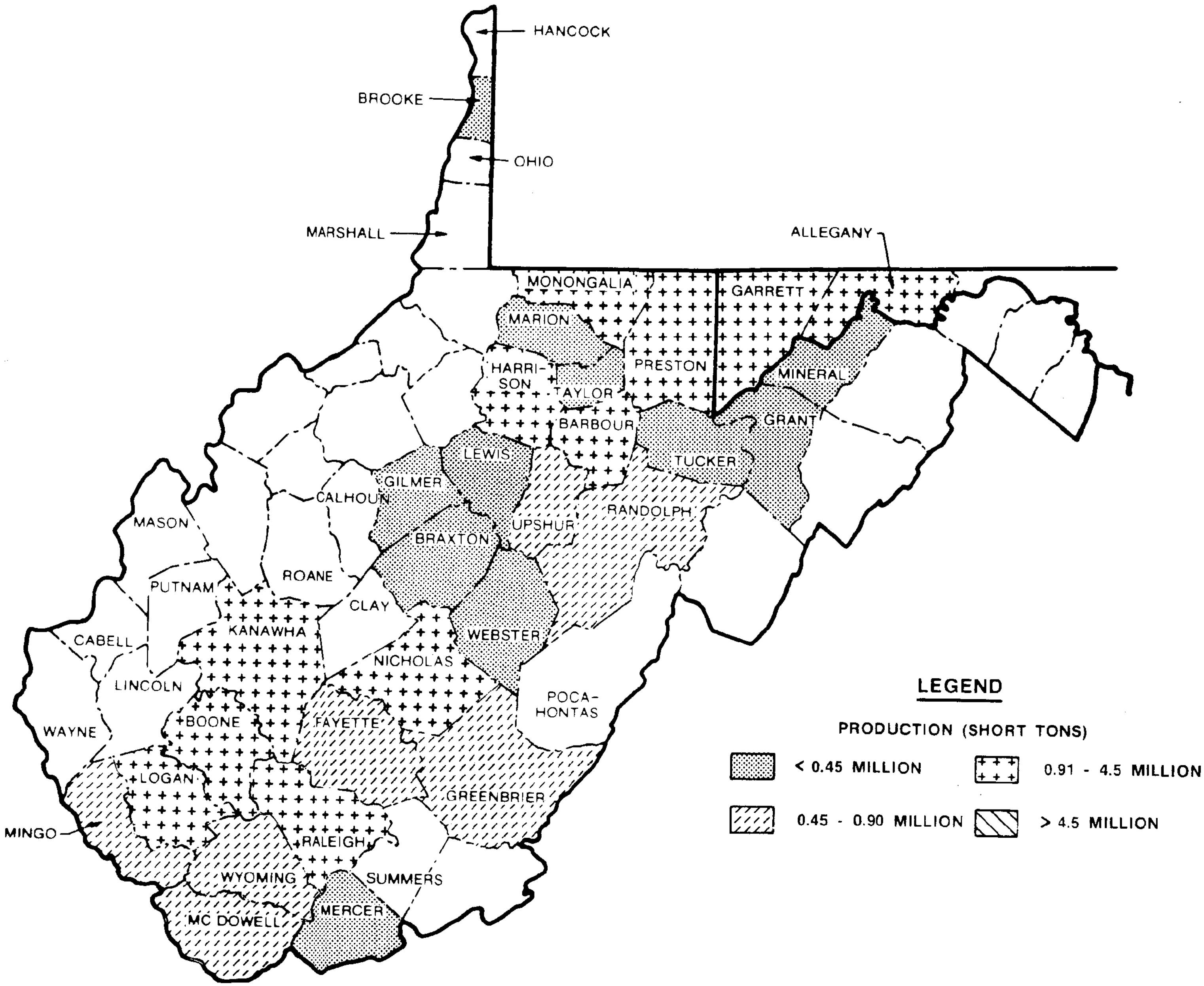

FIGURE A-12. - Surface coal production during 1976 in West Virginia and Maryland.

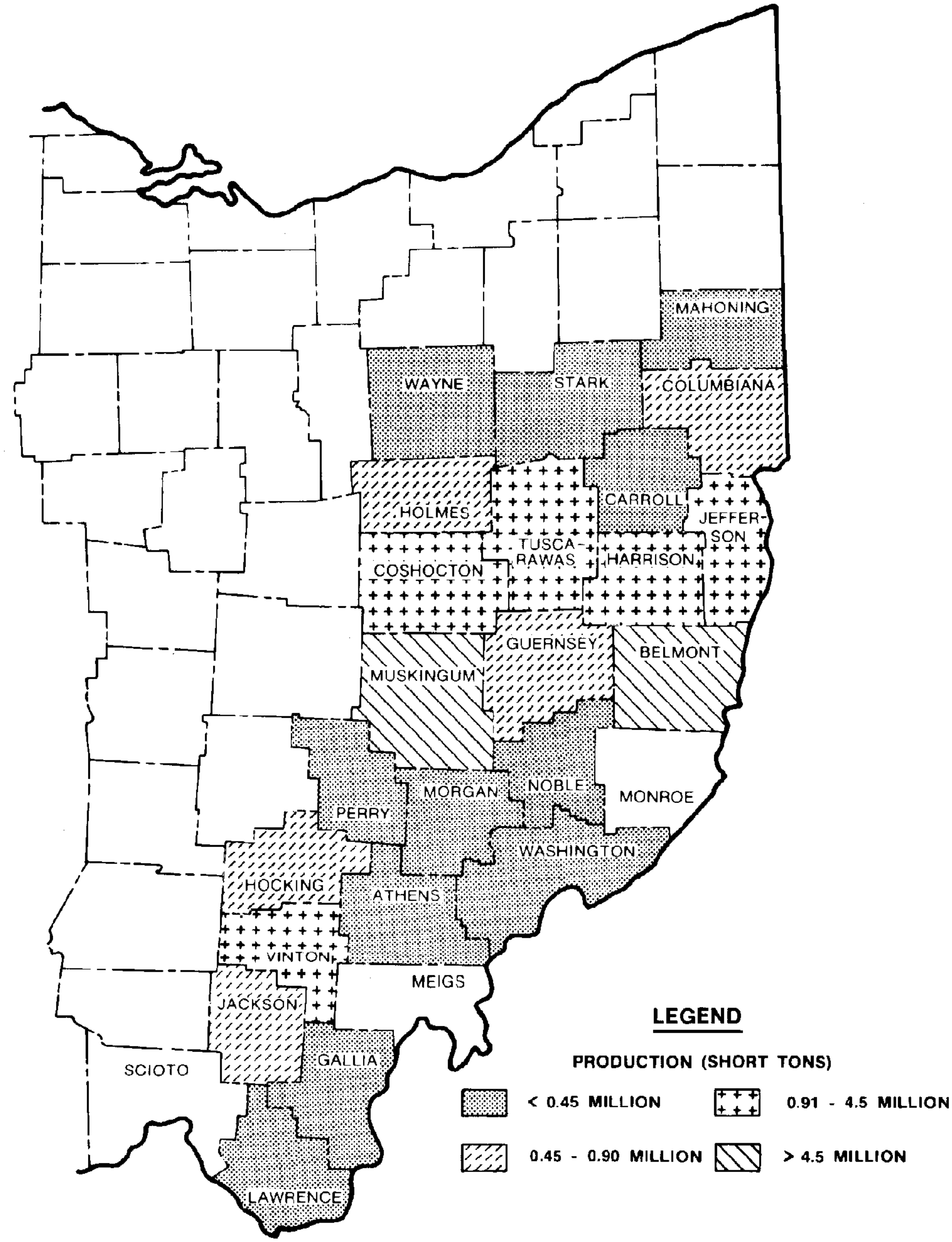

FIGURE A-13. - Surface coal production during 1976 in Ohio.

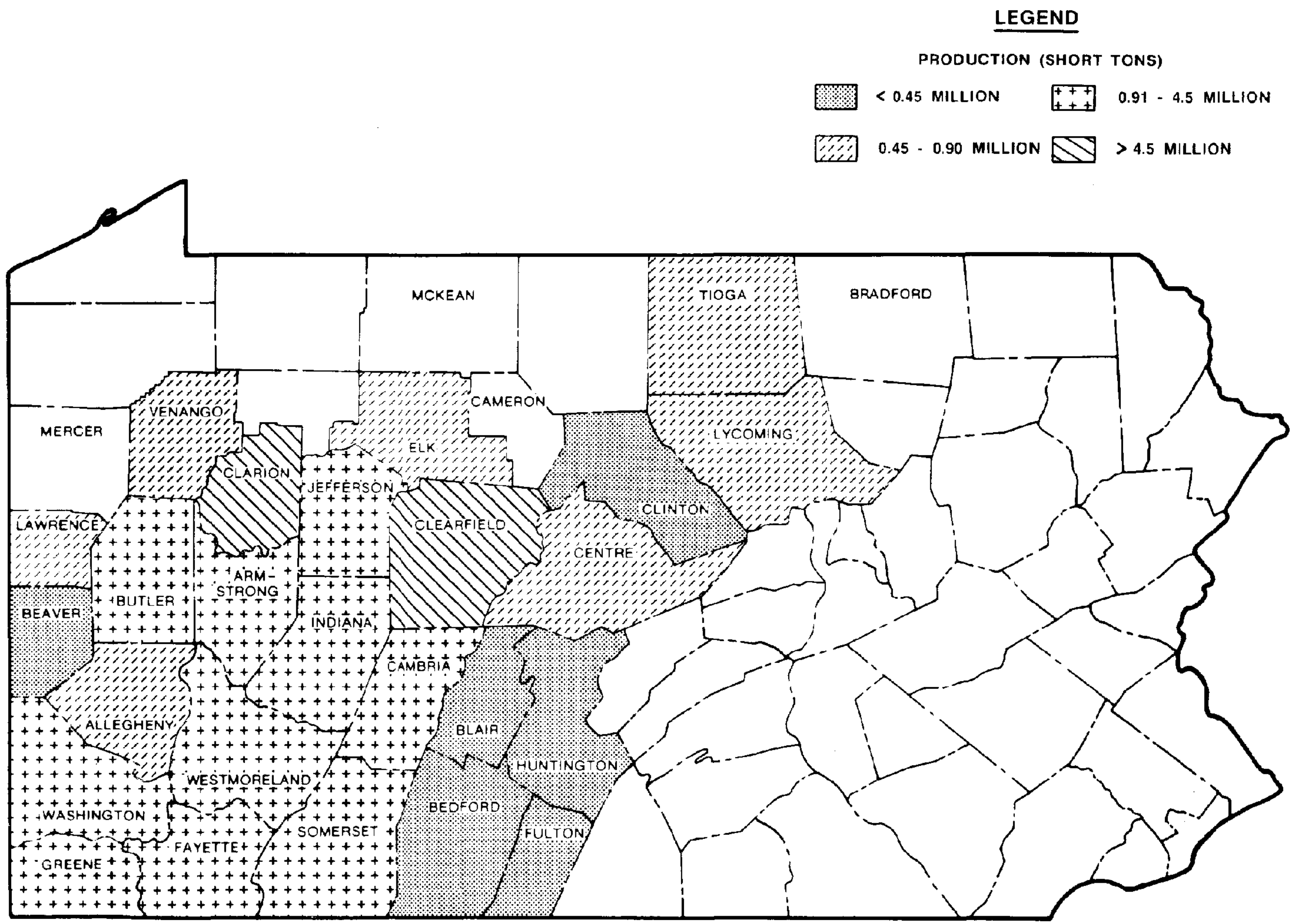

FIGURE A-14. - Surface coal production during 1976 in Pennsylvania.

TABLE A-1. - Summary coal statistics by slope, 1976.

AVERAGE SLOPE	STATE	COUNTY	TOTAL PRODUCTION*	STRIPPABLE RESERVES *	SHORTWALL RESERVES *
> 26°	WVA	Webster	0.303	285.24	163.84
		Kanawha	2.272	698.38	125.12
		Boone	2.205	935.06	427.17
		Logan	1.498	1,017.28	431.31
		Mingo	0.638	568.19	331.32
		Wyoming	0.471	130.44	61.82
		McDowell	0.946	422.56	63.34
	VA	Tazewell	0.297	118.19	10.32
		Buchanan	3.762	362.37	76.98
		Dickenson	1.411	75.19	49.58
		Russell	0.422	69.93	28.52
		Lee	0.563	127.64	38.72
		Wise	6.497	316.33	74.15
	KY	Martin	5.363	262.04	0
		Floyd	2.347	241.10	44.13
		Pike	4.782	1,251.49	164.37
		Knott	1.535	310.57	87.41
		Perry	5.107	746.77	332.18
		Letcher	1.259	390.36	0
		Leslie	2.525	323.71	0
		Harlan	1.938	848.61	8.06
		Knox	0.993	71.94	0
		Bell	3.264	175.59	9.90
	TN	Campbell	0.143	83.44	20.93
		Anderson	0.311	53.35	12.58
		TOTAL	50.8	9,884	2,561

*Million short tons

TABLE A-1. - Summary coal statistics by slope, 1976 - (Cont'd.)

AVERAGE SLOPE	STATE	COUNTY	TOTAL PRODUCTION*	STRIPPABLE RESERVES*	SHORTWALL RESERVES*
< 26°	WVA	Nicholas	1.266	386.08	202.20
		Fayette	0.927	316.77	85.84
		Raleigh	1.098	435.41	100.26
	KY	Greenup	0.102	38.43	0
		Carter	0.333	127.87	0
		Boyd	0.267	63.64	0
		Elliot	0.373	27.07	0
		Lawrence	1.166	36.44	0
		Morgan	0.604	25.61	0
		Johnson	2.719	161.06	0
		Magoffin	2.171	149.88	0
		Wolfe	0.345	11.05	0
		Breathitt	6.352	380.24	138.46
		Owsley	0.265	0.48	0
		Rockcastle	0.054	23.73	0
		Jackson	0.605	43.51	0
		Laurel	1.173	67.26	0
		Pulaski	0.322	0.62	0
		Clay	0.570	69.15	0
		McCreary	0.245	59.53	20.95
		Whitley	1.389	40.36	0
		Lee	0.277	6.87	0
	TN	Scott	0.222	24.63	0
		Morgan	0.379	26.22	0
		TOTAL	23.4	2,449	547

*Million short tons

APPENDIX B - COAL QUALITY FOR SEAMS MINABLE BY SURFACE SHORTWALL METHODS

TABLE B-1 - Coal quality for seams minable by surface shortwall method.

COAL SEAM	STATE	COUNTY	ASH (%)	SULFUR (%)	BTU
Upper Kittanning	West Virginia	Braxton	9.8	0.7	13,750
		Clay	7.6	1.7	13,830
		Nicholas	11.1	1.0	13,050
		Randolph	12.3	1.3	13,420
		Webster	8.6	0.9	—
Middle Kittanning	West Virginia	Braxton	6.4	0.7	14,670
		Clay	10.4	0.8	13,350
		Nicholas	11.2	1.5	13,520
		Randolph	14.3	2.0	12,830
		Webster	10.8	0.9	—
		Fayette	—	—	—
No. 5 Block	West Virginia	Boone	8.5	0.8	13,350
		Logan	7.8	0.6	13,750
		Wayne	9.0	1.1	13,410
		Lincoln	—	—	—
		Kanawha	10.4	0.8	13,380
		Webster	19.6	1.3	11,620
		Nicholas	6.0	0.7	14,140
		Braxton	5.3	1.0	14,010
		Randolph	11.7	1.4	13,410
		Roane	—	—	—
Hindman	Kentucky	Breathitt	6.3	0.8	13,750
		Magoffin	7.9	0.8	13,440
		Floyd	—	—	—
		Letcher	—	—	—
		Harlan	—	—	—
		Leslie	15.7	1.4	—
		Perry	7.7	2.2	13,660

TABLE B-1 - Coal quality for seams minable by surface shortwall method - (Cont'd.)

COAL SEAM	STATE	COUNTY	ASH (%)	SULFUR (%)	BTU
Stockton - Lewiston	West Virginia	Mingo	14.0	0.6	—
		Wayne	—	—	—
		Lincoln	12.0	2.1	12,820
		Kanawha	8.2	0.8	13,840
		Nicholas	10.5	2.5	13,410
		Webster	6.3	0.9	—
		Clay	—	—	—
		Braxton	—	—	—
Hazard No. 7	Kentucky	Harlan	5.1	0.6	14,080
		Letcher	7.6	0.7	13,500
		Perry	7.5	0.8	13,690
		Breathitt	10.0	0.8	13,220
		Knott	10.3	0.9	13,230
Coalburg	West Virginia	Mingo	7.6	0.7	13,780
		Logan	7.9	0.8	—
		Boone	10.2	0.7	13,590
		Kanawha	8.2	0.7	13,800
		Nichlos	8.4	1.0	13,940
		Webster	7.8	1.3	—
		Clay	9.4	0.8	13,610
		Wyoming	—	—	—
Hazard No. 5A	Kentucky	Perry	8.2	0.6	13,490
		Knott	5.6	1.4	14,100
		Breathitt	11.8	2.0	—
Buffalo Creek	West Virginia	Mingo	8.0	0.9	13,760
		Logan	—	—	—

TABLE B-1 - Coal quality for seams minable by surface shortwall method - (Cont'd.)

COAL SEAM	STATE	COUNTY	ASH (%)	SULFUR (%)	BTU
Winifrede	West Virginia	Mingo	7.9	0.7	13,830
		Lincoln	—	—	—
		Wyoming	15.2	0.7	12,840
		Boone	8.4	0.6	13,830
		Logan	10.1	1.4	13,430
		Fayette	—	—	—
		Clay	—	—	—
		Nicholas	8.8	0.8	13,680
		Webster	—	—	—
		Raleigh	7.1	0.8	14,300
Chilton - A	West Virginia	Logan	—	—	—
		Mingo	12.7	0.7	—
Hignite	Kentucky	Harlan	8.8	0.5	—
		Bell	6.3	0.7	13,990
		Knox	—	—	—
		Whitley	—	—	—
	Tennessee	Campbell	5.9	0.6	14,010
		Claiborne	6.4	0.7	13,770
Big Mary	Tennessee	Campbell	14.1	3.0	12,690
		Scott	13.7	3.5	12,770
		Morgan	10.0	2.7	13,470
		Anderson	9.9	3.1	13,450
Chilton	West Virginia	Mingo	7.7	1.0	—
		Wyoming	5.8	0.9	14,430
		Logan	8.5	0.6	13,860
		Boone	10.2	0.8	13,390
		Fayette	—	—	—
		Nicholas	—	—	—
		Webster	—	—	—

TABLE B-1 - Coal quality for seams minable by surface shortwall method - (Cont'd.)

COAL SEAM	STATE	COUNTY	ASH (%)	SULFUR (%)	BTU
Fireclay	Kentucky	Pike	7.4	1.1	13,810
		Floyd	—	—	—
		Perry	6.5	0.8	13,970
		Clay	6.3	1.0	14,010
		Knox	8.5	0.9	13,550
		Leslie	7.5	0.8	—
Cedar Grove	West Virginia	Webster	9.9	2.2	—
		Braxton	—	—	—
		Kanawha	5.0	0.7	14,440
		Boone	7.9	1.2	13,850
		Logan	7.9	1.2	13,970
		Mingo	8.1	1.2	13,910
		Fayette	—	—	—
		Raleigh	6.6	1.1	14,380
Taggart	Virginia	Lee	4.6	0.5	14,320
		Scott	—	—	—
		Wise	5.0	0.6	14,630
Elkhorn No. 3	Kentucky	Harlan	6.4	1.0	14,010
		Leslie	6.3	0.9	—
		Clay	—	—	—
		Laurel	8.7	2.2	13,610
		McCreary	11.7	1.1	13,120
		Bell	3.9	1.0	14,530
Jellico	Tennessee	Scott	10.4	2.9	13,330
		Claiborne	5.9	1.0	14,100
		Campbell	6.0	1.1	13,960
		Morgan	7.4	2.7	13,990
		Anderson	10.3	2.4	13,340

TABLE B-1 - Coal quality for seams minable by surface shortwall method - (Cont'd.)

COAL SEAM	STATE	COUNTY	ASH (%)	SULFUR (%)	BTU
Lower Elkhorn	Kentucky	Martin	7.6	1.9	13,780
		Pike	10.4	0.6	13,580
		Letcher	4.6	0.8	14,100
		Harlan	—	—	—
		Bell	—	—	—
		Lawrence	—	—	—
Imboden (Continuous with No. 2 Gas, W.Va.)	Virginia	Lee	5.9	1.1	14,090
		Scott	—	—	—
		Wise	11.0	0.7	13,510
		Dickenson	—	—	—
		Buchanan	—	—	—
Coal Creek	Tennessee	Anderson	6.8	1.4	14,130
		Campbell	6.9	0.9	14,010
		Claiborne	—	—	—
		Union	—	—	—
		Morgan	12.0	4.0	13,310
		Scott	5.5	0.9	14,380
Clintwood	Virginia	Dickenson	5.8	0.8	14,340
		Wise	9.7	1.2	13,590
		Buchanan	6.8	0.8	14,340
		Lee	2.2	1.7	14,520
Eagle	West Virginia	Mingo	5.8	1.2	14,540
		McDowell	5.8	1.2	14,540
		Wyoming	4.2	0.9	14,780
		Logan	7.1	0.8	14,050
		Boone	6.1	0.7	14,340
		Raleigh	5.3	0.8	14,490
		Fayette	7.0	0.7	14,360
		Kanawha	5.9	0.7	14,520

TABLE B-1 - Coal quality for seams minable by surface shortwall method - (Cont'd.)

COAL SEAM	STATE	COUNTY	ASH (%)	SULFUR (%)	BTU
Eagle	West Virginia	Nicholas	7.3	0.7	14,120
		Clay	—	—	—
		Braxton	12.8	3.6	13,150
		Webster	9.8	3.8	13,450
		Randolph	5.6	1.1	—
Norton	Virginia	Wise	8.5	1.2	13,970
Upper Banner	Virginia	Buchanan	5.8	0.5	14,540
		Dickenson	7.7	0.7	14,320
		Russell	6.5	0.5	14,420
		Wise	7.0	0.6	14,380
Gilbert	West Virginia	McDowell	—	—	—
		Mingo	—	—	—
		Wyoming	10.2	1.4	13,160
		Logan	—	—	—
		Raleigh	3.9	0.9	—
		Fayette	4.8	0.9	14,590
		Nicholas	5.3	1.5	14,670
		Webster	10.1	5.1	—
		Pocahontas	12.1	0.8	13,560
		Randolph	8.6	0.6	14,160
Kennedy	Virginia	Wise	10.7	0.8	13,720
		Scott	—	—	—
		Dickenson	8.1	0.8	14,270
		Buchanan	5.6	1.0	14,700
		Russell	9.6	1.2	13,510
		Tazewell	5.5	1.0	13,960
	West Virginia	McDowell	—	—	—

TABLE B-1 - Coal quality for seams minable by surface shortwall method - (Cont'd.)

COAL SEAM	STATE	COUNTY	ASH (%)	SULFUR (%)	BTU
Jewell	Virginia	Russell	6.3	0.7	14,590
		Wise	12.4	1.0	13,280
		Buchanan	5.4	0.6	14,850
		Dickenson	—	—	—
		Tazewell	5.9	0.7	14,780
Jawbone	Virginia	Wise	14.7	0.7	12,900
		Russell	16.0	0.9	12,680
		Dickenson	16.2	1.1	12,640
		Scott	—	—	—
		Buchanan	12.0	0.6	13,400
		Tazewell	14.0	0.5	13,290
		Smyth	—	—	—
Tiller	Virginia	Dickenson	7.6	0.5	14,520
		Wise	—	—	—
		Russell	7.8	0.4	14,190
Sewell	West Virginia	McDowell	6.2	0.6	14,700
		Wyoming	7.9	0.5	14,370
		Raleigh	4.8	0.9	14,880
		Fayette	6.5	0.6	14,460
		Greenbrier	5.8	1.0	14,550
		Nicholas	4.4	0.7	14,770
		Webster	6.4	0.5	14,480
		Pocahontas	6.7	0.7	14,430
		Randolph	6.8	0.6	14,390
		Tucker	11.6	0.9	13,610
	Virginia	Buchanan	—	—	—
		Tazewell	4.4	1.2	14,940

TABLE B-1 - Coal quality for seams minable by surface shortwall method - (Cont'd.)

COAL SEAM	STATE	COUNTY	ASH (%)	SULFUR (%)	BTU
Alma	West Virginia	Nicholas	7.6	1.9	—
		Clay	—	—	—
		Kanawha	—	—	—
		Fayette	10.6	0.7	13,840
		Raleigh	2.4	0.8	—
		Boone	6.9	1.9	14,110
		Logan	7.9	1.6	13,800
		Wyoming	5.4	0.8	14,190
		Mingo	5.5	0.6	14,390
		Lincoln	—	—	—
		Webster	—	—	—
Blue Gem	Tennessee	Campbell	2.6	1.0	14,430
		Claiborne	5.0	1.4	14,100
Peerless	West Virginia	Fayette	7.8	2.2	14,210
		Kanawha	6.0	1.8	14,390
		Nicholas	7.5	0.9	14,070
		Webster	4.0	0.9	14,550
		Randolph	5.0	0.7	14,420
No. 2 Gas	West Virginia	Nicholas	4.7	0.9	14,720
		Clay	—	—	—
		Fayette	6.1	0.8	14,450
		Kanawha	5.7	1.0	14,290
		Boone	6.6	1.4	14,070
		Lincoln	5.1	0.8	—
		Wayne	—	—	—
		Mingo	8.5	1.0	13,890
		Logan	6.1	0.6	14,380
		Wyoming	5.7	0.6	14,380
		Raleigh	6.7	1.0	14,360
		Upshur	11.8	0.9	—

TABLE B-1 - Coal quality for seams minable by surface shortwall method - (Cont'd.)

COAL SEAM	STATE	COUNTY	ASH (%)	SULFUR (%)	BTU
Stearns No. 2	Kentucky	McCreary	10.9	3.8	13,230
		Wayne	—	—	—
	Tennessee	Scott	—	—	—
Beckley	West Virginia	McDowell	9.6	0.7	14,110
		Wyoming	5.4	1.0	14,740
		Raleigh	6.1	0.7	14,660
		Fayette	—	—	—
		Greenbrier	9.0	1.3	14,060
Fire Creek	West Virginia	Pocahontas	—	—	—
		Webster	12.1	0.6	13,190
		Greenbrier	4.8	0.9	14,890
		Fayette	6.8	0.8	14,540
		Nicholas	9.6	0.7	14,040
		Raleigh	5.2	0.7	14,870
		Wyoming	4.5	1.0	14,930
		Mercer	4.5	0.5	15,070
		McDowell	7.1	0.8	14,510
		Randolph	12.1	0.6	13,110
	Virginia	Buchanan	—	—	—
		Tazewell	—	—	—

APPENDIX C - ABSTRACT OF THE SURFACE MINING CONTROL AND RECLAMATION ACT OF 1977 P.L. 95-87 PERMANENT PROGRAM PERFORMANCE STANDARDS

PART 816 - PERMANENT PROGRAM PERFORMANCE STANDARDS

SURFACE MINING ACTIVITIES

816.11 Signs and markers.
Signs and markers of durable material that can be easily seen and read must be posted and maintained during mining at the following locations:

a) all points of access from public roads or highways (retained until land release)
b) the perimeter of the permit area
c) the interior boundary of the buffer zone
d) blasting areas
    1) within 50' of private or 100' of public road
    2) in vicinity of charged holes
    3) at all entrances to permit area
e) topsoil stockpiles

816.13 Casing and sealing of drilled holes: General requirements.
Each exploration hole, bore holes, wells or other exposed underground openings must be sealed.

816.14 Casing and sealing of drilled holes: Temporary.
Temporary seals must be maintained and located on mine plan.

816.15 Casing and sealing of drilled holes: Permanent.
Must be sealed, filled or capped and cased when no longer essential, to keep out livestock, acid or other drainage.

816.21 Topsoil: General.

a) before disturbance of an area, topsoil and subsoils to be saved shall be separately removed and segregated from other material
b) after removal, topsoil shall be immediately redistributed or stockpiled pending redistribution

816.22 Topsoil: Removal.

a) topsoil removal must follow clearing of vegetation but preceed any surface disturbance
b) as a minimum, topsoil removal must include total A horizon or 6" of upper layer if A horizon is less than 6" or all unconsolidated material if total less than 6".
c) selected overburden materials may supplement topsoil if it results in an upgrading of the resulting soil medium
d) topsoil shall be removed in a separate layer from areas to be distributed, unless use of supplemental material is approved, all material to be redistributed shall be removed
e) the timing and amount of topsoil removal shall be done to minimize erosional loss

816.23 Topsoil: Storage.

a) topsoil stockpiling permitted only if prompt redistribution impractical
b) topsoil must be stored in a manner that does not lessen its capability to support vegetation

816.24 Topsoil: Redistribution.

Must be redistributed and stabilized so as to:

a) achieve uniform thickness
b) prevent excess compaction
c) protect from erosion

816.25 Topsoil: Nutrients and soil amendments.

Nutrients and amendments may be applied as determined by approved soil tests.

816.41 Hydrologic balance: General requirements.

a) mining shall be planned and conducted so as to protect hydrologic balances and prevent long-term adverse change on-site and off-site
b) changes in drainage flow shall be preferred to water treatment plants

816.42 Hydrologic balance: Water quality standards and effluent limitations.

a) all surface drainage from the disturbed area shall be passed through sedimentation ponds except from a storm greater than the 10 year, 24 hour event
b) sediment ponds shall be maintained until reclamation is complete
c) treatment not required if resulting from a 10 year, 24 hour precipitation event
d) sediment pond effluent limitations:

Characteristic	Maximum Allowable	30-Day Average
Iron, total	7.0 mg/l	3.5 mg/l
Manganese, total[1]	4.0 mg/l	2.0 mg/l
Total Suspended Solids[2]	70 mg/l	35 mg/l
pH	6.0-9.0	----

[1] does not apply to alkaline discharges
[2] 45 mg/l and 30 mg/l for Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming

816.43 Hydrologic balance: Diversion and conveyance of overland flow and shallow groundwater flow.

Overland flow diversion design criteria:

a) temporary diversions - 2 year storm
b) permanent diversions - 10 year storm

816.44 Hydrologic balance: Stream channel diversions.

a) flow from perennial and intermittent streams may be diverted subject to other limitations

b) the diversion shall be constructed to pass:

   1) temporary channel, bank and flood plain configurations - 24 hour, 10 year storm

   2) permanent channel, bank and flood plain configurations - 24 hour, 100 year storm

816.45 Hydrologic balance: Sediment control measures.

Construct, and maintain sediment control measures using the best technology currently available to:

a) prevent additional sediment either to stream flow or to runoff outside permit area

b) comply with the more stringent state or federal effluent limitations

c) minimize erosion by utilizing the proper mining and reclamation methods and sediment control practices including:

   1) disturbing smallest practicable area at any one time during mining operation and prompt revegetation as required in Section 816.111

   2) reduction in the rate and volume of runoff, in accordance with Section 816.101

   3) retaining sediment and diverting runoff within disturbed area

4) 4) use of protected channels or pipes to divert runoff so as not to cause additional erosion

   5) reduce overland flow using straw dikes, riprap, check dams, mulches and other measures

   6) treating with chemicals

816.46 Hydrologic balance: Sedimentation ponds.

Sedimentation ponds shall be built prior to any disturbance and shall be built to the following design criteria.

a) located near the disturbance but out of perennial streams

b) ponds must provide sediment storage capacity for 3 years accumulated sediment or 0.1 but no less than .035 acre-feet for each disturbed acre

c) provide storage for a 10 year, 24 hour design storm event

d) provide 24 hour detention time for runoff, which can be reduced to 10 hours if performance standards are met or $<$10 hours if performance standards are met, agency approval is given

e) sediment shall be removed from the pond upon reaching 60% total storage volume

f) emergency spillways capable of handling the 25 year, 24 hour event shall be provided

g) minimum of 1' of freeboard required

h) height of dam must include 5% for settlement

i) top width of dam $\geq \frac{(H+35)}{5}$

j) side slopes criteria: 1v:5h combined or 1:2 for either

k) the embankment foundation shall be cleared of organics and sloped to 1v:1h
l) fill material shall be clean and placed starting at the lowest point first and compacted. On completion it must be riprapped on the upstream face and vegetated on the downstream
m) when the embankment is more than 20' high or has a capacity >20 acre-feet, spillways must be sufficient to discharge the 100 year event, the static safety factor must equal 1.5 and appropriate barrier to control seepage along conduits shall be provided
n) all ponds shall be inspected for structural integrity
o) retention time will be 1 hour

816.47 Hydrologic balance: Discharge structures.
Controlled discharge structures such as riprap channels and energy dissipators must be used.

816.48 Hydrologic balance: Acid-forming and toxic-forming spoil.
Drainage into acid and toxic materials shall be avoided by:
a) identifying, burying, and treating if necessary
b) burying within 30 days
c) preventing contact with surface water

816.49 Hydrologic balance: Permanent and temporary impoundments.
Permanent impoundments may only be built if they have a stable water level, do not degrade.
a) the quality of the receiving waters downstream, have access provided for users, preserve downstream water uses, are of an adequate size for the approved post-mining land use
b) temporary impoundments shall meet the requirements of 30 CFR 816.46 (e)-(u) - sedimentation ponds
c) all impoundments shall:
    1) have stable, protected perimeter slopes of 2h:1v
    2) be seeded, mulched, graded and maintained throughout their existence
    3) be inspected and approved by a professional engineer

816.50 Hydrologic balance: Groundwater protection.
a) placement of backfill material to minimize contamination of groundwater with toxic, acid or harmful mine drainage
b) control effects of mine drainage cuts, pits, mine excavation or disturbance to prevent adverse impacts on groundwater systems or an approved post-mining land uses

816.51 Hydrologic balance: Protectional groundwater recharge capacity.
Mining shall be conducted so that the recharge capacity is restored to a condition which:
a) supports the approved post-mining land use
b) minimizes disturbances to the hydrologic regime in the mine and adjacent areas
c) provides a recharge rate approximating pre-mining levels

816.52 Hydrologic balance: Surface and groundwater monitoring.

a) groundwater
   1) groundwater levels, infiltration rates and subsurface flow and storage characteristics shall be monitored to determine the effects of surface mining activities on recharge capacity of reclaimed lands
   2) when mining activities effect aquifers, periodic monitoring of groundwater levels and quality shall be done
b) surface water
   1) surface water monitoring shall be adequate to measure discharge quantities and qualities
   2) Noncompliant results shall be forwarded to the regulatory authority along with quarterly water quality reports
   3) equipment shall be maintained during mining and reclamation; after reclamation is complete surface and groundwater quality shall be monitored to the approval of the regulatory agency

816.53 Hydrologic balance: Transfer of wells.

Use of monitoring or exploration wells by others may be transferred upon request and approval. This is subject to assumption by the transferee of all responsibilities for the well.

816.54 Hydrologic balance: Water rights and replacement.

Persons who conduct surface mining activities shall replace the water supply which has been affected by contamination, diminution or interruption proximately resulting from the surface mining activity.

816.55 Hydrologic balance: Discharge of water into an underground mine.

Surface and groundwaters may not be discharged or diverted into underground mines without regulatory agency approval.

816.56 Hydrologic balance: Post-mining rehabilitation of sedimentation ponds, diversions, impoundments, and treatment facilities.

Before abandoning a permit area, all sediment ponds and other diversions and impoundments shall be removed according to the criteria of their respective construction plans.

816.57 Hydrologic balance: Stream buffer zones.

a) subject to approval otherwise, a buffer zone of 100 feet must be maintained between intermittent or perennial streams or streams with a biological community and area disturbed by surface mining.
b) a stream with a biological community is determined by the existence of an assemblage of two or more species of arthropoda or mollusca.

816.59 Coal recovery.

Surface mining shall be conducted to maximize the utilization and conservation of coal while maintaining environmental integrity and minimizing required reaffecting of the land.

816.61 Use of explosives: General requirements.

a) blasting with more than 5 pounds of TNT shall be scheduled
b) blasting shall be conducted by trained, qualified and certified personnel who have knowledge of the hazards involved.

816.62 Use of explosives: Pre-blasting survey.

A pre-blasting survey will be made at the request of residents or owners of structures within one-half mile of blasting operations and a report made of the pre-blast condition of the structure.

816.64 Use of explosives: Public notice of blasting schedule.

a) from 10 to 20 days before any blasting, a specific blasting schedule shall be published in a local newspaper with copies to local governments, utilities and residences within one-half mile of the blasting area. This notice shall be republished each year.
b) This schedule will accurately identify the blast location and the dates and time periods (not to exceed an aggregate of 4 hours) of blasting, the signals and the access controls

816.65 Use of explosives: Surface blasting requirements.

a) all blasting between sunrise and sunset except in cases of health and safety and where other restrictions of notice are met.
b) blasting shall be done according to the published blasting schedule
c) warning signals shall be given
d) access to the area shall be controlled
e) any one of the airblast limits below shall not be exceeded at any public or private structure within the blast area

Lower frequency limit of measuring system, H_z (±3 dB)	Maximum level in dB
0.1 H_z or lower - flat response	135 peak
2 H_z or lower - flat response	132 peak
6 H_z or lower - flat response	130 peak
c-weighted, slow response	109 c

f) blasting shall be done so as not to damage any buildings but shall not be done within 1000 ft. of public or private structures or 500 ft. of utility or petroleum facilities and with maximum peak particle velocity <1 in./sec. near structures
g) the maximum weight detonated within any 8 ms interval $< w = D^2/60$

816.67 Use of explosives: Seismograph measurements

Where a seismograph is used and velocities are less than 1 in./sec., more exlopsive may be used on approval.

816.68 Use of explosives: Records of blasting operations.

Detailed records of blasting operations shall be retained for three years.

816.71 Disposal of excess spoil: General requirements.

a) excess spoil must be placed in designated and approved areas in a stable configuration
b) topsoil and organic material must be removed
c) all slopes shall be stabilized against erosion
d) all spoil will be compacted in horizontal lifts
e) where slopes $>$ 36% exist, keyways or rock toe buttresses shall be installed
f) inspections shall be made during critical construction periods or at least quarterly during construction by a professional engineer or specialist approved by the agency
g) drains must be provided for any natural flowage which occurs
h) disposal of spoil in other than valley or head-of-hollow fills must be in agreement with the regulatory agency

816.72 Disposal of excess spoil: Valley fills.

a) factor of safety of 1.5
b) durable rock underdrains from toe to head of fill along natural drainage channels
c) no rock $>$25% of drain size - $<$10% of rock $<$12 in.
d) main underdrain size:

Size	Rock Type	Drain Size	(Min.)
$<$1,000,000 yd^3	Sandstone	10	4
$<$1,000,000 yd^3	Shale	16	8
$>$1,000,000 yd^3	Sandstone	16	8
$>$1,000,000 yd^3	Shale	16	16

e) runoff from above fill must be diverted into channels to pass 100 year, 24 hour storm
f) terraces every 50 feet vertically and no less than 20' wide
g) slopes of the top and terraces of the fill shall be no steeper than 5%
h) drainage from the top of the fill shall be directed away from the fill in an approved manner
i) the outslope may be no $>$50%

816.73 Disposal of excess spoil: Head-of-hollow fills.

a) spoil placement not lower than approximate ridgeline
b) rock core drain 16 ft. wide projected up from main stream channel with lateral subdrains for tributary channels
c) surface drainage toward rock core - 3% max. slope
d) terraces graded 3%-5% toward fill and 1% toward center drain

816.74 Disposal of excess spoil: Durable rock fills

a) rock fills may be used on a site specific basis, if spoil is at least 80% non-slaking as approved
b) a factor of safety of 1.5 will be acheived at construction or 1.1 during earthquakes
c) drainage will be similar to provisions for other fills

816.79 Protection of underground mining.

- a) no surface mine may be operated within 500 ft. of active or abandoned underground mine workings except as approved by regulating agencies, and which result in improved recovery, abated pollution or elimination of public hazards
- b) future mining activities must not be jeopardized

816.81 Coal processing waste: General requirements.

- a) must be hauled to approved sites and designed:
  - 1) to standards of 816.71, 816.72, 816.79, 816.82-816.88
  - 2) to prevent combustion
- b) as approved, waste from outside the permit area may be disposed of

816.82 Coal processing waste banks: Site inspection.

- a) inspections occur at least quarterly, beginning 7 days after preparation of disposal area
- b) copies of findings must be maintained at the mine site
- c) the regulatory agency must be informed of any hazard

816.83 Coal processing waste banks: Water control measures.

- a) subsurface drainage system must be provided which intercepts all groundwater sources, is protected by a filter and is covered to preclude surface water or leachate
- b) surface drainage must be diverted away from bank in accordance with Section 816.72
- c) slopes must be protected by riprap or vegetation
- d) all surface water must be diverted
- e) all water discharges shall comply with 816.41, 816.42, 816.45-816.46, 816.52 and 816.55

816.85 Coal processing waste banks: Construction requirements.
Construction standards:

- a) must be constructed in accordance with 816.71, 816.72
- b) must have minimum safety factor of 1.5
- c) compaction must be in 2 foot lifts
- d) minimum acceptable dry density must be 90% of maximum dry density to prevent combustion and attain proper strength
- e) completed banks must be graded to conform to surrounding area
- f) minimum final cover thickness 4 feet of best available material
- g) variations for -28 sieve size material

816.86 Coal processing waste: Burning.
Coal processing waste fires shall be extinguished by only those persons, authorized by the operator, who have an understanding of the procedures to be used.

816.87 Coal processing waste: Burned waste utilization.
A plan for removal of burned coal processing wastes must be prepared and approved before removal.

816.88 Coal processing waste: Return to underground workings.
Return of coal processing wastes to underground workings must be approved and in accordance with 780.35.

816.89 Disposal of non-coal wastes.

a) non-coal wastes and residuals (grease, etc.) will be disposed of in a portion of permit area so as to allow no leachate or runoff to enter hydrologic system
b) area constructed with water barriers, compacted and covered with 2 ft. of soil but not within 8 ft. of a coal outcrop or storage area

816.91 Coal processing waste: Dams and embankments: General requirements.

a) dams and embankments may be constructed of coal processing wastes in accordance with 816.91-816.93, if approved and if environmental integrity may be maintained
b) waste used in construction must be analyzed for stability and approved

816.92 Coal processing waste: Dams and embankments: Site preparation.

a) site must be cleared and grubbed and all combustibles removed and stockpiled
b) surface drainage must be diverted in accordance with 816.43, 816.47
c) diversions must be designed for 100 year, 24 hour event

816.93 Coal processing waste: Dams and embankments: Design and Construction.

a) design must comply with 816.49 a) 5), e), f), g), h), i) except that:
    1) at least 3 ft. of freeboard
    2) factor of safety of 1.5 with seismic factor of 1.2
    3) foundation and abutments must be shown stable by lab testing
b) adequate spillways and outlets will be designed
c) at least 90 percent of water stored during max. precipitation event shall be removed in a 10-day period

816.95 Air resources protection.

a) air resources control
    fugitive dust control measures shall be implemented as an integral part of all mining operations. These measures can take the form of watering, paving, vegetating, traffic control, the minimization of exposed areas and other appropriate measures
b) monitoring equipment shall be installed and monitoring shall be conducted in accordance with Section 780.15 and approved by a regulatory authority

816.97 Protection of fish, wildlife, and related environmental values.

a) use the best technology currently available to minimize disturbances and adverse impacts on fish and wildlife and seek the enhancement of environmental values where possible.

b) report any rare species to the regulatory authority in the permit area
c) construct overhead transmission lines to have negligible detrimental effect
d) provide suitable cover, forage, and take any practical measures to promote flora and fauna on the reclaimed land

816.99 Slides and other damage.

a) a natural barrier must be provided at the elevation of the lowest coal seam to be mined, and extending from the outslope for an approved distance
b) on the occurrence of a slide which may affect public property, health safety or the environment, the operator shall notify the regulatory authority and comply with their remedial measures

816.100 Contemporaneous reclamation.

Reclamation efforts of all land that is disturbed by surface mining activities shall occur as contemporaneously as practicable with the mining operation.

816.101 Backfilling and grading: General requirements.

a) time schedule for reclamation
    1) contour mines - 60 days or 1,500 linear feet
    2) open pit with thin overburden - as approved by the regulatory agency
    3) area strip mines - 180 days or 4 spoil ridges behind pit being worked
b) all disturbed areas shall be returned to approximate original contour or post-mining use

816.102 Backfilling and grading: General grading requirements.

a) the post-mining grading shall not have slopes greater than those of pre-mining contour or of those specified by the regulatory agency
b) where grading affects previously mined but unreclaimed land and sufficient spoil is not available to return the slopes to original grade:
    1) overburden and spoil must be retained on solid portions of benches and
    2) highwalls must be eliminated with the least grade possible but always less than the angle of repose and with a factor of safety of of at least 1.3
c) cut and fill terraces may be constructed if compatible with post-mining land use
    1) terrace width shall be no more than 20'
    2) vertical distance as specified by the agency
    3) terrace outslope must be less than 50% unless factor of safety of 1.3 is achieved
    4) terrace culverts and rock drains must be approved by the regulatory agency
d) mining on slopes $>20^{o}$ shall meet the requirements of §Section 826
e) all final grading shall be done along the contour to minimize erosion unless posing a safety hazard

816.103 Backfilling and grading: Covering coal and acid- and toxic-forming materials.

a) must be covered with a minimum of 4 ft. or more of non-toxic material
b) acid-forming material shall not be buried or stored proximate to drainage
c) approved methods will be used to haul and compact material to prevent leaching and promote stability

816.104 Backfilling and grading: Thin overburden.

a) applicable where overburden x swell $<$.80 x (overburden + coal)
b) where operations have been conducted for more than 1 year and available spoil or waste material is shown to be insufficient to return to original contour, the operator shall:
   1) use all available suitable spoil or waste to minimize the final slope and maintain a 1.3 factor of safety
   2) eliminate highwalls with a slope no greater than 50%
   3) regrade for post-mining land use

816.105 Backfilling and grading: Thick overburden.

a) applicable where overburden x swell $>$1.2 x (overburden + coal)
b) where overburden and spoil is in excess, the operator shall:
   1) maintain the lowest practical grade and maintain a 1.3 factor of safety
   2) keep excess material within the permit area
   3) maintain hydrologic balance and long-term stability
   4) maintain compatability with the prevailing land use
   5) eliminate all highwalls and depressions
   6) meet the revegetation requirements of 816.111-816.117

816.106 Regrading or stabilizing rills and gullies.

Rills or gullies greater than 9" deep which form in areas that have been regraded and topsoiled shall be regraded or stabilized and reseeded to the approval of the regulatory agency. Other lesser rills may also be stabilized.

816.111 Revegetation: General requirements.

a) permanent vegetative cover on all affected lands of the same seasonal variety native to the area or species that supports the approved post-mining land use shall be established
b) vegetation shall be in compliance with the plans under 780.19 (e), 780.23 and carried out promptly and effectively
c) vegetation shall be in compliance with approved post-mining land use

816.112 Revegetation: Use of introduced species.

Introduced species may be substituted for native if field tested, necessary for erosion control under 780.19 (e) and 780.23, compatible with indigenous species and meet Federal or state standards on introduced, poisonous, or noxious species.

816.113 Revegetation: Timing.
Seeding shall take place during the first normal period following preparation. This shall be period locally accepted for planting that species. Seeding shall be as contemporaneous as possible with other mining operations.

816.114 Revegetation: Mulching and other soil stabilizing practices.
Mulch and other stabilizing practices shall be used unless other methods are approved and shown to meet 816.116. They shall be mechanically or chemically anchored if required and may consist of annual grasses if shown that they will be replaced by suitable and approved perennials.

816.115 Revegetation: Grazing.
When approved post-mining land use is range or pasture, the grazing capacity shall be approved by the regulatory authority at a level approximating that for non-mined land for at least the last 2 years of liability under 816.116 (b).

816.116 Revegetation: Standards for success.

a) success measured by approved techniques including reference areas
b) success shall be equal to that of reference area or approved standard
    1) areas > 26 in. precipitation, responsibility continues for 5 years, with productivity equal to standard for last 2 years
    2) areas < 26 in. precipitation, responsibility continues for 10 years, with productivity equal to standard for last 2 years
    3) precipitation based on 10 year records or other sources
c) productivity considered equal if at least 90% with 90% statistical confidence or 80% statistical confidence for shrub lands except:
    1) croplands - 90% production with 90% confidence during last 2 years of 5/10 year period
    2) f + w management - forest land - 70% production with 90% confidence or adequate to control erosion
d) for areas 40 acres or less with < 26 in. precipitation
    1) herbaceous species - 70% for 5 full years
    2) herbaceous/woody - 70% for 5 full years; 400 woody plants
       steep slopes - 600 woody plants

816.117 Revegetation: Tree and shrub stocking for forest land.

a) to be counted, a sprout must be 1 ft. high, in place for 2 years, healthy, and have 1/3 of height in crown
b) 450 sprouts per acre with 75% of commercial species
c) for wildlife habitat, etc, a pre-mining inventory will be made - restocking will use 90% of species mix
d) once sprout points counts have been attained the 5/10 year period begins

816.131 Cessation of operations: Temporary.

a) temporary abandonment of mining operation shall not relieve persons of obligation to comply with permit
b) notice of intention to cease or abandon operation, if temporary cessation will extend beyond 30 days, must be submitted to regulatory authority. The notice will identify the extent of impact, reclamation and the monitoring activities which will continue.

816.132 Cessation of operations: Permanent.

a) all affected areas must be reclaimed when permanent cessation of operation occurs
b) unless required for post-mining monitoring all facilities shall be removed and the affected land reclaimed

816.133 Post-mining land use.

a) all effected areas shall be restored in a timely manner to a level of potential use equal to pre-mining levels or to higher or better uses
b) the potential use comparison shall be made with the pre-mining use of the land or adjacent well-managed areas
c) prior to bond release the land must be restored to a land use compatible with adjacent land use unless:
    1) post-mining land use shall be compatible with adjacent use and at least of the quality of use prior to mining
    2) a master plan must be designed and approved
    3) provision of any necessary public facilities must be ensured as evidenced by letters of commitment from outside parties
    4) financing attainment and maintenance must be ensured, before surface mining may begin
    5) post-mining land use plans must have been prepared under the general supervision of a registered professional engineer
    6) the proposed use will not threaten public health or safety or water quality

816.150 Road: Class I: General.

a) Class I roads used for mining purposes must be designed, constructed, maintained and reclaimed to control or prevent damage to streams, erosion and siltation, water pollution, damage to fish and wildlife, damage to property, and flooding problems
b) variances may be made on the permanent maintenance of a Class I road

816.151 Roads: Class I: Location.

a) all roads insofar as possible must be located on ridges or the available flatter and more stable slopes
b) stream fords or active stream channels for haul roads are prohibited
c) stream fords for temporary access across streams may be permitted if they will not adversely affect sedimentation; all other stream crossings must use bridges, culverts or other structures

816.152 Roads: Class I: Design and construction.

a) overall grade must not exceed 10%
b) maximum pitch grade must not exceed 15%
c) maximum length of grade exceeding 10% is 300' per 1,000' of road
d) horizontal alignment must be compatible with topography
e) maximum roadway cut slope 1:1.5 in unconsolidated or 1:0.25 in rock or factor of safety of 1.5
f) cut slopes must be reclaimed if 1:1.5 or flatter
g) foundation areas for embankments must be cleared and grubbed and no vegetative matter may be placed in the embankment
h) embankments on slopes >20% shall be keyed in with the key being 10 feet wide and 2 feet below the toe of the fill
i) 12 inch compacted layers for rock <25% >6 in. diameter
36 inch compacted layers for rock >12 inches
all rock must be bladed into place - all layers shall be compacted and smoothed
j) embankment slopes must be less than 50%. If 85% rock, then 1:1.35 with a factor of safety of 1.25
k) roads shall slope to ditch or be crowned at least ¼"/ft.
l) all embankment slopes <1:1.5 will be vegetated

816.153 Roads: Class I: Drainage.

a) design criteria for Class I road drainage is to pass a 10 year, 24 hour precipitation event
b) trash racks must be installed as needed
c) a ditch must be provided on both sides of a through-cut and on the inside shoulder of a cut-fill section with cross drains
d) end area <35 ft.^{2} - pass 10 year, 24 hour storm
end area >35 ft.^{2} and bridges <30 ft. span - pass 20 year, 24 hour storm; bridges >30 ft. span - pass 100 year, 24 hour storm
e) all culverts covered by 1 ft. minimum of material
f) culvert spacing:

Road Grade	Minimum Spacing
0- 3%	1000 ft.
3- 6%	800 ft.
6-10%	500 ft.
>10%	300 ft.

g) minimum culvert downgrade angle - 30°
h) culvert inlets must be protected by headwall
i) culvert outlets must be at toe of slope with an apron of riprap

816.154 Roads: Class I: Surfacing.

a) roads shall be surfaced with rock or asphalt or sufficiently durable material for the anticipated traffic and vehicles
b) acid- or toxic-forming substances shall not be used in road surfacing

816.155 Roads: Class I: Maintenance.

a) roads and all necessary appurtenances shall be maintained throughout their life
b) road maintenance shall include repairs to: road surface, blading, filling of potholes, replacement of gravel or asphalt, revegetating, brush removal, watering for dust control, minor reconstruction
c) when damaged by catastrophic events, roads shall not be used until reconstructed

816.156 Roads: Class I: Restoration.

a) no longer needed for operations, reclamation or monitoring:
   1) the road shall be closed and natural drainage patterns restored
   2) drainage structures will be removed, and the entire road bed reclaimed

816.160 Roads: Class II: General.
Same as 816.150 except: post-mining reclamation of roads must be done according to 816.161-816.166.

816.161 Roads: Class II: Location.
Same as 816.151 eacept: culvert and crossing construction must be done according to 816.163.

816.162 Roads: Class II: Design and construction.
Same as 816.152 except:

a) maximum length of grade exceeding 15% is 300' per 1000'
b) horizontal alignment must be in accordance with 816.160-816.166
c) embankments on slopes >33% require 10' wide key - <33% require scarification
d) compaction shall be done by equipment without benefits of foundation analyses
e) embankment slopes must be <1:1.5; if 85% rock, then 1:1.35 with a factor of safety of 1.25
f) road surface shall be sloped to prevent ponding

816.163 Roads: Class II: Drainage.
Same as 816.153 except: ditches required only where needed - insloped or outsloped drainage shall be directly onto natural ground or embankment unless a culvert is required. Culverts and dips shall be speced as follows:

Road Grade	Minimum Spacing
0- 3%	1000 ft.
3- 6%	600 ft.
6-10%	400 ft.
>10%	200 ft.

816.164 Roads: Class II: Surfacing.
Same as 816.154.

816.165 Roads: Class II: Maintenance.
Same as 816.155 except: maintenance is relegated as as custodial care such as erosion control, structure and drainage system repair, rock and debris removal, surface replacement and road prism restoration.

816.166 Roads: Class II: Restoration.
Same as 816.156.

816.170 Roads: Class III: General.
Same as 816.160 except: post-mining reclamation of roads must be done according to 816.171-816.176. Also there are no provisions for retention of a Class III road beyond its immediately useful life.

816.171 Roads: Class III: Location.
Same as 816.161 except: all stream crossing structures are entirely temporary in nature. All road locations must be indicated at the submission of a permit application by flags, etc. A Class III road may be located where a higher class road will be. Construction of said higher class road must begin in 6 months or less.

816.172 Roads: Class III: Design and construction.
Same as 816.162 except:

a) overall grade $\leq 10\%$; pitch grade $\leq 15\%$; no more than 1000' $> 10\%$
b) meanders may be made to avoid natural obstructions
c) sidecast construction may be used in road cuts
d) embankment compaction only to maintain road and limit erosion

816.173 Roads: Class III: Drainage.

a) temporary culverts in streams and wet areas
b) culverts and bridges must pass 1 year, 6 hour storm
c) natural drainage shall not be altered

816.174 Roads: Class III: Surfacing.
Road surfaces shall be adequate, non-acidic and non-toxic, no more vegetation than required shall be cleared.

816.175 Roads: Class III: Maintenance.
Maintenance and use of the road shall be such that erosion is minimized and water quality does not suffer.

816.176 Roads: Class III: Restoration.
Same as 816.166 except: road is closed immediately after use.

816.180 Other transportation facilities.

Railroad loops, spurs, sidings, surface conveyor systems chutes, aerial tramways shall be designed and maintained, and the area restored using the best technology available to prevent:

a) damage to fish, wildlife, and related environmental values
b) addition of suspended solids to stream flow or runoff outside permit area in excess of state or federal regulations
c) degradation of water quantity and quality, erosion, siltation, and air pollution
d) damage to public or private property

816.181 Support facilities and utility installations.

Shall be designed, maintained, and used in a manner which prevents, using the best technology available:

a) damage to fish, wildlife, and related environmental values
b) suspended solids contribution in excess of state or federal regulations
c) damage of services provided by oil, gas, and water wells: oil, gas, coal-slurry pipelines; railroads; electric and telephone lines which pass over, under, or through permit area, unless approved by facility owner or regulatory agency

PART 817 - PERMANENT PERFORMANCE STANDARDS

UNDERGROUND MINING ACTIVITIES

817.11 Signs and markers.
Same as 816.11

817.13 Casing and sealing of underground openings: General requirements.
Same as 816.13 except:
more specific reference is made to adits, shafts and other underground openings

817.14 Casing and sealing of underground openings: Temporary.
Same as 816.14

817.15 Casing and sealing of underground openings: Permanent.
Permanent seals must prevent access and flow of water at any openings underground and must be designed to prevent access by people, wildlife and toxic drainage.

817.21 Topsoil: General requirements.
Same as 816.21

817.22 Topsoil: Removal.
Same as 816.22

817.23 Topsoil: Storage.
Same as 816.23

817.24 Topsoil: Redistribution.
Same as 816.24

817.25 Topsoil: Nutrients and soil amendments.
Same as 816.25

817.41 Hydrologic balance: General requirements.
Same as 816.41 except:
- a) reference is made to underground mining activities instead of surface mining
- b) design mines to prevent gravity drainage of acid waters
- c) seal and control subsidence to minimize pollution.

817.42 Hydrologic balance: Water quality standards and effluent limitations.

Same as 816.42 except:

Treatment facilities may be required instead of sediment ponds for surface and underground discharges. These shall be maintained until the land is restored and the effluent meets performance standards.

817.43 Hydrologic balance: Diversions and conveyance of overland flow and shallow ground water flow.

Same as 816.43

817.44 Hydrologic balance: Stream channel diversions.

Same as 816.44

817.45 Hydrologic balance: Sediment control measures.

Same as 816.45 except:

Water treatment practices may include underground sumps.

817.46 Hydrologic balance: Sedimentation ponds.

Same as 816.46 except:

a) ponds must be constructed before drainage from underground operations
b) pond volume shall equal the sediment volume from other sources plus the expected sediment from 1 year's worth of underground drainage.

817.47 Hydrologic balance: Discharge structures.

Same as 816.47

817.48 Hydrologic balance: Acid-forming and toxic-forming materials.

Same as 816.48 except:

Underground waste and spoil is included as toxic materials.

817.49 Hydrologic balance: Permanent and temporary impoundments.

Same as 816.49

817.50 Hydrologic balance: Ground water protection.

Same as 816.50 except:

a) surface entries and accesses to underground workings shall be located and designed to prevent or control gravity discharge of water from mine
b) discharges from underground mine other than drift may be allowed if:
    1) satisfies the water effluent limitations of CFR 30 817.42
    2) changes to hydrologic balance are minimal and approved post mining uses are not adversely affected

3) discharges are conveyed to a treatment facility, discharges from that facility meet effluent limitations and consistent maintenance is performed throughout the anticipated period of gravity discharge.

817.52 Hydrologic balance: Surface and groundwater monitoring.
Same as 816.52 except:

a) persons conducting underground mining activities shall conduct hydrologic, infiltration and aquifer tests
b) where test results indicate noncompliance, the authority shall be notified
c) surface flow and quality shall be monitored after cessation of underground workings and surface reclamation

817.53 Hydrologic balance: Transfer of wells.
Same as 816.53

817.54 Hydrologic balance: Water rights and replacement.
Same as 816.54 except:
Persons who conduct underground mining activities shall replace any water supply which has been affected by contamination, diminution, or interruption proximately caused by the mining.

817.55 Hydrologic balance: Discharge of water into an underground mine.
Same as 816.55 except:
Water from underground or surface mining shall not be returned to an underground working except under the criteria listed.

817.56 Hydrologic balance: Post-mining rehabilitation of sedimentation ponds, diversions, impoundments and treatment facilities.
Same as 816.56

817.57 Hydrologic balance: Stream buffer zones.
Same as 816.57 except:
The regulatory authorities may find that underground mining can proceed close to or through a stream within certain restrictions.

817.59 Coal recovery.
Same as 816.59 except:
Responsibilities are dictated to underground operators.

817.61 Use of explosives: General requirements.
Same as 816.61

817.62 Use of explosives: Preblasting survey.
Same as 816.62 except:
Responsibilities are dictated for underground operators.

817.65 Use of explosives: Surface blasting requirements.
Same as 816.65 except:
a) responsibilities are dictated for underground operators
b) notice to residents within ½ mile shall be made 24 hours prior to any blast.

817.67 Use of explosives: Seismograph measurements.
Same as 816.67

817.68 Use of explosives: Records of blasting operations.
Same as 816.68

817.71 Disposal of underground development waste and excess spoil: General requirements.
Same as 816.71 except:
Reference made to underground generated waste and spoil.

817.72 Disposal of underground development waste and excess spoil: Valley fills.
Same as 816.72 except:
a) regulations devised for underground generated waste and spoil
b) specific site consist requirements for drain materials are not set.

817.73 Disposal of underground development waste and excess spoil: Head-of-hollow fills.
Same as 816.73 except:
Reference is made to underground generated waste and spoil.

817.81 Coal processing waste banks: General requirements.
Same as 816.81 except:
Regulations devised for underground operators.

817.82 Coal processing waste banks: Inspection.
Same as 816.82 except:
Responsibility delegated to underground operators.

817.83 Coal processing waste banks: Water control measures.
Same as 816.83

817.85 Coal processing waste banks: Construction requirements.
Same as 816.85

817.86 Coal processing waste: Burning.
Same as 816.86 except:
Responsibility delegated to underground operators.

817.87 Coal processing waste: Burned waste utilization.
Same as 816.87

817.88 Coal processing waste: Return to underground workings.
Same as 816.88

817.89 Disposal of non-coal wastes.
Same as 816.89 except:
Specific responsibility delegated to underground operators.

817.91 Coal processing waste: Dams and embankments: General requirements.
Same as 816.91

817.92 Coal processing waste: Dams and embankments: Site preparation.
Same as 816.92

817.93 Coal processing waste: Dams and embankments: Design and construction.
Same as 816.93

817.95 Air resources protection.
Same as 816.95 except:
Specific responsibility delegated to underground operators.

817.97 Protection of fish, wildlife and related environmental values.
Same as 816.97 except:
Specific responsibility delegated to underground operators.

817.99 Slides and other damage.
Same as 816.99 except:
Practice of leaving an outcrop barrier is not specifically required.

817.100 Contemporaneous reclamation.
Same as 816.100

817.101 Backfilling and grading: General requirements.
a) backfilling and grading of disturbed surface areas in accordance with time schedule approved by regulatory authority as condition of permit
b) all areas affected be returned to approximate original contour
c) backfill material placed to minimize adverse affect on groundwater

d) post mining grade slope need not be uniform
e) cut and fill terraces may be used only if identified in Section 817.102.

817.102 Backfilling and grading: General grading requirements.
Same as 816.102 except:
All underground mining activities on slopes >20° shall meet the provisions of 30 CFR part 826.

817.103 Backfilling and grading: Covering coal and acid- and toxic-forming materials.
Same as 816.103

817.106 Regrading or stabilizing hills and gullies.
Same as 816.106

817.111 Revegetation: General requirements.
Same as 816.111 except:
Requirements for some seasonal variety on indigenous species not specified.

817.112 Revegetation: Use of introduced species.
Same as 816.112

817.113 Revegetation: Timing.
Same as 816.113

817.114 Revegetation: Mulching and other soil stabilizing practices.
Same as 816.114

817.115 Revegetation: Grazing
Same as 816.115

817.116 Revegetation: Standards for success.
Same as 816.116 except:
Revegetation requirements for permit areas of 40 acres or less in areas with 26" of rain are dropped.

817.117 Revegetation: Tree stocking for forest land.
Same as 816.117

817.120 Subsidence control: General requirements.
a) underground mining activities shall be planned and conducted to prevent subsidence damage to the surface and to maintain the value and foreseeable use of the land
b) operators must comply with the subsidence control plan pursuent to 30 CFR 784.19.

817.122 Subsidence control: Public notice.

a) a mining schedule shall be mailed to all surface owners affected at least 6 months prior to that mining
b) contents
    1) identification of mining areas
    2) dates where mining activities could cause subsidence of specific structures
    3) measures to prevent adverse surface effects.

817.124 Subsidence control: Surface owner protection.

Underground operators will
a) take all efforts to prevent subsidence
b) restore, rehabilitate or remove all damages which are due to subsidence
c) purchase the structure at presubsidence market value (no right of eminent domain implied), or
d) reimburse the owner for any diminution in market value.

817.126 Subsidence control: Buffer zones.

a) underground coal mining operations shall not be conducted beneath or adjacent to any perennial stream or impoundment having a volume of 20 acre-feet unless approved
b) underground coal mining beneath any aquifer that is sole source for a municipal water supply shall be conducted to avoid disruption of the aquifer
c) underground coal mining beneath public buildings shall not be permitted unless approved
d) mining shall be suspended under urbanized areas, major impoundments or streams if found to be a public hazard.

817.131 Cessation of operations: Temporary.

Same as 816.131 except:
Responsibility delegated to underground operators for notification and closure of all underground openings is expressly required.

817.132 Cessation of operations: Permanent.

Same as 816.132

817.133 Post mining land use.

Same as 816.133

817.150 Roads and associated structures: General requirements.

Same as 816.150

817.151 Road construction: Location.

Same as 816.151

817.152 Road construction: Erosion control.
Same as 816.152

817.153 Road construction: Drainage.
Same as 816.153

817.154 Road construction: Surfacing.
Same as 816.154

817.155 Maintenance of roads.
Same as 816.155

817.156 Restoration of roads.
Same as 816.156

817.180 Other transportation facilities.
Same as 816.180

817.181 Support facilities and utility installations.
Same as 816.181

PART 818
SPECIAL PERMANENT PROGRAM PERFORMANCE STANDARDS

CONCURRENT SURFACE AND UNDERGROUND MINING

818.2 Objective.
Insure maximum coal recovery and avoid multiple disturbances of surface lands or waters.

818.11 Applicability.
Applies only to those areas within the permit area that has been shown to be necessary for implementing proposed concurrent operations. Variance only effective for the time necessary to facilitate the underground mining activities.

818.13 Compliance with variance terms.
a) Any operations shall comply with requirements of a variance under this subchapter except to the extent that:
   1) a delay is specifically authorized.
   2) a delay is necessary to achieve the purposes of the variance.
b) Operators must comply with each requirement of the variance.

818.15 Additional performance standards.
In addition to 30 CFR 816 and 817, the following shall be complied with:
a) 500 ft. barrier pillar between surface and underground mining. A lesser distance may be approved if resulting in:
   1) improved resource recovery.
   2) abatement of pollution.
   3) elimination of public health and safety hazards.
b) the vertical distance between surface and underground mining activities working separate seams shall be sufficient to preclude surface water in the mine and provide for health and safety of miners.
c) no combined activities shall reduce the protection provided public health and safety below that required if conducted without a variance.

PART 819
SPECIAL PERMANENT PROGRAM PERFORMANCE STANDARDS

AUGER MINING

819.2 Objectives.
Objectives are to:
a) prevent adverse environmental effects from augering.
b) prevent unnecessary loss of coal reserves.

819.11 Auger mining: Additional performance standards.
a) augering shall be conducted to maximize coal recoverability of reserves remaining when mining completed. Access shall be left to recover interior reserves unless the authority feels that they are of insufficient extent or quality. Undisturbed sections shall be left which:
    1) are 250 ft. wide to the full depth of the auger holes.
    2) are no more than 2500 ft. apart.
    3) for multiple seam mining, are at least 250 ft. wide plus 50 ft. for each subjacent seam. The centers shall be aligned vertically.
b) no auger holes closer than 500 ft. horizontally to any abandoned or active underground workings.
c) each hole shall be plugged to prevent access of air or discharge of water.
    1) holes discharging toxic or acid material must be plugged within 72 hours by backfilling noncombustible and impervious material or the water shall be treated beginning within 72 hours.
    2) other holes shall be sealed within 30 days.
d) plugging not required if:
    1) water impoundment hazardous to environment or public health.
    2) drainage non-polluting.
e) auger mining prohibited if:
    1) water quality impacts cannot be prevented.
    2) recoverability of resources is impaired.
    3) subsidence affects surface facilities.

PART 820
SPECIAL PERMANENT PROGRAM PERFORMANCE STANDARDS

ANTHRACITE MINES IN PENNSYLVANIA

820.11 Performance standards: Anthracite mines in Pennsylvania.

a) anthracite coal mining and reclamation shall comply with all Pennsylvania provisions in effect on August 3, 1977.
b) amendments to the Pennsylvania program shall cause further regulations to meet the purposes of this Act.

PART 822
SPECIAL PERMANENT PROGRAM PERFORMANCE STANDARDS

OPERATIONS IN ALLUVIAL VALLEY FLOORS

822.11 Alluvial valley floors: Essential hydrologic functions.
- a) maintain geologic, hydrologic and biologic characteristics outside permit area to support hydrologic functions.
- b) reconstruct geologic, hydrologic and biologic characteristics within permit area to support hydrologic functions.
- c) characteristics are in 30 CFR 785.19 (d) (3) and other identified in premining investigations.

822.12 Alluvial valley floors: Protection of farming and water supplies.
- a) mining shall not interrupt, discontinue or preclude farming on alluvial valley floors.
- b) if so, the operation shall cease until remedial measures are taken.
- c) there shall be no damage to groundwater quantity or quality.

822.13 Alluvial valley floors: Protection of agricultural uses mining must be conducted to ensure agricultural utility of the land.

822.14 Alluvial valley floors: Monitoring.
- a) environmental monitoring shall be conducted until all bonds are released.
- b) monitoring shall be conducted at adequate frequencies to indicate long term trends and during mining.

PART 823
SPECIAL PERMANENT PROGRAM PERFORMANCE STANDARDS

OPERATIONS ON PRIME FARMLAND

823.11 Prime farmland: Special requirements.
- a) must obtain permit.
- b) topsoil must be removed before any mining activity and must not be mixed with undesirable material.
- c) revegetation success based on actual production compared to a pre-determined target production level.

823.12 Prime farmland: Soil removal.
- a) soil removal.
  - 1) entire A horizon or other materials.
  - 2) separately remove the B horizon or B and C horizons or other materials.
  - 3) separately remove C horizon or other strata to replace B horizon.
- b) minimum soil and soil material removed shall be sufficient to equal requirements of 823.14 (a).

823.13 Prime farmland: Soil stockpiling.
If not used immediately soil may be stored. If over 30 days, must be stored according to 30 CFR 816.23.

823.14 Prime farmland: Soil replacement.
- a) at least 48" of reconstructed soils unless natural subsurface inhibitor was present.
- b) replace soil on land that has been contoured and scarified.
- c) replace soil in a manner that avoids compaction and in an arrangement and order that satisfies 823.12.

823.15 Revegetation.
Within 10 years the area must be planted in commonly grown crops. As a minimum, 1) average crop production shall be measured based on 3 years data, 2) revegetation considered successful if 3 years average production equals predetermined target levels.

PART 824
SPECIAL PERMANENT PROGRAM PERFORMANCE STANDARDS

MOUNTAINTOP REMOVAL

824.11 Mountaintop removal: Performance standards.

a) variances granted from AOC for the following conditions:
   1) when regulatory authority grants an exemption under 30 CFR 785.14.
   2) when the entire coal seam is removed leaving a gently rolling contour without highwalls.
   3) when an approved proposed land use (agricultural, commercial, residential) is proposed.
   4) when all applicable requirements of 816.133 are met.
   5) requirements of this subchapter other than return to AOC are met.
   6) on outcrop barrier of sufficient width containing the toe of the lowest seam and its overburden is retained unless:
      1) site mined prior to May 3, 1978.
      2) a coal barrier next to a head-of-hollow fill may be removed.
   7) final graded slopes < lv:5h and the final graded outslopes < 1v:2h or a factor of safety of 1.5 is maintained.
   8) the rolling plateau is graded to drain inward except at constructed drains.
   9) natural water courses below the coal are not damaged.
   10) all toxic or acid materials including subjacent strata are buried below inert material.
   11) spoil placement conforms with a(3) or a(4) of this section as 30 CFR 816.52 and 816.71-816.74.

PART 825
SPECIAL PERMANENT PROGRAM PERFORMANCE STANDARDS

SPECIAL BITUMINOUS COAL MINES IN WYOMING

825.11 Requirements for certain special bituminous coal mines operating prior to January 1, 1972.

a) this section contains special performance standards for those portions of a special bituminous coal mine which:
   1) were approved prior to January 1, 1972, including expansion according to state law.
   2) have actually been producing coal since January 1, 1972.
   3) because of past duration of mining are committed to some of the provisions of this subchapter.
   4) involve mining multiple seams and mining has been initiated on the deepest coal seam.

b) special requirements for backfilling and grading are:
   1) highwalls and benches will be allowed to remain if found to be stable.
   2) exposed pit floors will be sloped and graded to provide access to the area, and topsoil and seed shall be applied according to 30 CFR 816.24, 816.102 and 816.111-816.117, of this subchapter; where water impoundments are included as part of the mine plan, riprap may be used if necessary to prevent erosion.
   3) spoil piles will be graded and contoured with no more than the overall slope of 17^{o} allowed and terraced may be used to break the slope when it can be shown that terraces will accomplish the required reclamation; for post-mining land use, steeper slopes may be permitted upon approval of the regulatory authority, provided it can be demonstrated that such a method will provide the required results.

825.12 Mines developed after August 3, 1977.

a) for mines developed immediately adjacent to portions of mines subject to Section 825.11.

b) these operations will comply with all requirements of Wyoming law.

c) maximum inclination of the reclaimed slopes shall not be $>$the average natural slopes in the immediate area; however, steeper slopes may be approved if it reduces the total affected area.

d) post-mining land uses without permanent water impoundments.
   1) backfill and grading shall be contoured according to 816.133.
   2) reclamation shall preserve original drainage system or provide an approved substitute.
   3) terraces or benches may be used only if contouring methods will not be adequate; detailed plans of dimensions of terraces or benches, check dams, and erosion control techniques.
   4) no depressions that accumulate water are allowed.

e) post-mining land uses with permanent water impoundments.
   1) the exposed mine pit are shall be reclaimed to blend with surrounding topography and be accessible; riprap shall be used where necessary to prevent erosion.
   2) it may be permissible to leave ½ the proposed shoreline composed of stabilized pit wall; the remaining shoreline shall be reclaimed to blend with the surrounding topography.

PART 826
SPECIAL PERMANENT PROGRAM PERFORMANCE STANDARDS

OPERATIONS ON STEEP SLOPES

826.1 Scope.
Applicability is to operations exclusively confined to steep slopes $> 20^o$ as defined in 701.5.

826.12 Steep slopes: Performance standards.

a) no spoil, waste materials or debris (abandoned equipment) shall be placed or allowed to remain on the downslope.
b) no exposed highwalls; must be covered and compacted and constructed with a safety factor of 1.3 to AOC.
c) no land above the highwall will be disturbed.
d) excess material will be disposed in accordance with 816.71-816.74 or 817.71-817.73.
e) woody materials not to be buried; may be chipped for mulch.
f) unlined drainage channels shall not be constructed.

826.15 Steep slopes: Limited variances.
AOC variances may be allowed if the following standards are met:

a) the highwall shall be completely backfilled and has a static factor of safety of at least 1.3.
b) the watershed control area within the mining area shall be improved or remain the same.
c) if approved, the land above the highwall may be distributed to an approved distance to control runoff, blend the highwall, or provide access.
d) the landowner shall request variance in writing.
e) all spoil will be retained on the mine bench, except for that amount required to ensure bench stability or to accomplish post-mining land use.

826.16 Steep slopes: Multiple seam.
In previously affected areas, spoil may be placed on a pre-existing bench if approved and:

a) all excess spoil is hauled, placed and retained on the solid bench.
b) the spoil must be graded to the minimum slope required for eliminating previous highwall.
c) must comply with 30 CFR 816.71 or 817.23.
d) the bench on which the spoil is to be placed must have been created and abandoned prior to August 3, 1977.

PART 827
SPECIAL PERMANENT PROGRAM PERFORMANCE STANDARDS

COAL PROCESSING PLANTS AND SUPPORT FACILITIES NOT LOCATED AT OR NEAR THE MINE SITE OR NOT WITHIN THE PERMIT AREA FOR A MINE

827.12 Coal processing plants: Performance standards.

a) signs and markers shall comply with 30 CFR 816.11.
b) roads, transport and associated structures shall comply with 30 CFR 816.150-816.181.
c) stream or channel realignment shall comply with 30 CFR 816.44.
d) sediment control structures shall comply with 30 CFR 816.45 and 816.46 all discharges shall meet requirements of 30 CFR 816.91-816.93.
e) permanent impoundment shall meet requirements of 816.49 and coal processing waste impoundments shall comply with 816.91-816.93.
f) water wells shall comply with 816.53 and water rights shall be protected in accordance with 816.54.
g) disposal of processing wastes, solid wastes and any excavated material shall comply with 816.81-816.88 and 816.71-816.73.
h) sediment control and discharge structures shall comply with 816.47.
i) air pollution control shall comply with 816.95.
j) fish, wildlife and related environmental values shall be protected in accordance with 816.97.
k) slide and surface areas shall comply with 816.99.
l) adverse affects from underground mining activities shall comply with 816.55 and 816.79.
m) reclamation shall comply with 816.56, 816.100-816.106, 816.111-816.117 and 816.131-816.133.
n) any related coal processing structure shall comply with 816.
o) structures located on prime farmland shall comply with 823.

PART 828

SPECIAL PERMANENT PROGRAM PERFORMANCE STANDARDS

IN-SITU-PROCESSING

828.11 In-situ-processing: Performance standards.

a) in-situ-processing activities shall comply with 817.
b) planned and conducted to minimize disturbance to hydrologic balance.
c) submit approval of permit under 785.22 to ensure health, safety or environmental hazards are treated, confined or disposed of.
d) shall prevent flow of process recovery fluid vertically into overlying or underlying aquifers; and horizontally beyond the affected area identified in permit.
e) shall restore quality of affected groundwater.

828.12 In-situ-processing: Monitoring.

a) monitor quality and quantity of surface and groundwater and sub-surface flow in accordance with 817.52.
b) air and water quality monitoring shall comply to appropriate Federal and state air and water quality standards.