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Coal Reserves of the Boltsfork Quadrangle, Kentucky

A Coal Recoverability Study

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

BCY bank cubic yard

M million

Btu British thermal unit

st short ton (all tons in this report
are short tons)

ft foot

% percent

in inch

lb pound

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A COAL RECOVERABILITY STUDY

By Timothy J. Rohrbacher,¹ Dale D. Teeters,² Gerald L. Sullivan,² and Lee M. Osmonson²

ABSTRACT

This report presents a U.S. Bureau of Mines study that incorporates coal mining factors, coal recovery factors, and economic factors into the definition of an economically recoverable coal resource. The relationship between these factors to the Energy Information Administration's estimate of U.S. coal resources—the "Demonstrated Reserve Base"—is discussed. The Boltsfork 7 ½-minute quadrangle in eastern Kentucky was selected as the study area. Results indicate that of the original 280.2 M tons of resource in the quadrangle, only 99.8 M tons (35.6%) is recoverable at a mining cost of \$25 per ton or less.

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INTRODUCTION

The availability and amount of coal resources in the United States have been debated for years. Past estimates were based on gross estimates of coal in the ground and did not address the amount that might realistically be available for production after environmental and technological restraints were considered. Many technological, economic, and social changes have taken place that have impacted the coal industry since the last U.S. Bureau of Mines (USBM) comprehensive coal resource base was published in 1975 (1).³ The Clean Air Act Amendments of 1990 require reductions in sulfur dioxide and nitrous oxide emissions from coal-fired powerplants. The mining and marketing of coal will be changed significantly by this legislation. Regulations on mine reclamation and new safety and health standards and associated taxes have increased the costs and complexity of mining operations. Advancements in mining technology in underground and surface operations have changed the economic competitiveness of certain coalfields (2-9).

Concerns about securing environmentally acceptable and reliable energy sources have continually surfaced during the past 15 years and have resulted in many revised estimates of the coal reserves in the United States (1, 10-14). The Energy Information Administration (EIA) regularly updates the reserve base (established by the USBM in 1974) with new information from the State geological surveys, the U.S. Geological Survey (USGS), and coal industry production information. At the present time, the Demonstrated Reserve Base (DRB) of coal for the United States is estimated to be about 475 billion short tons (14). Even at consumption rates of 1.0 billion tons per year and a previously accepted recovery rate of 50%, there appear to be ample available coal resources for several centuries (all tons mentioned in this report are "short tons"). However, if the effects of mined-out prime reserves and environmental, industrial, economic, and social considerations are assessed and the technical aspects of the minability and washability of the individual seams are considered, the amount of coal that would be available and economically recoverable would be far less than that stated in the literature (1-3, 14).

In 1986, the USGS and the Kentucky Geological Survey (KGS) began a coal availability study (15-16) of an area within the central Appalachian coal region—the Matewan 7 ½-minute quadrangle—in order to determine the resources available for mining after environmental and technological restrictions were considered. The success of the Matewan pilot study in determining available resources gave the USGS motivation for an expanded program. Coal availability studies were undertaken in West Virginia,

Virginia, and Kentucky in cooperation with the USGS and the respective State geological surveys. Preliminary results from these geological survey studies indicate only about 50% of the original resources is available for mining. The question of how much of the available resources were economically recoverable was not addressed in this coal availability study.

The USBM expertise in coal mining technology and economics, together with the data collected for the coal availability studies, combined with experience gained in completing more than 70 detailed coal mine technical and economic assessments, and its active research role in the coal industry, could answer this important question. Therefore, the USBM devised a program to determine the recoverable resources and associated mining costs for quadrangles where the available resources had already been determined. The Matewan quadrangle, on the Kentucky-West Virginia border (fig. 1), was the prototype area. The Boltsfork quadrangle is also in Kentucky and its study was undertaken by the USBM after completion of the Matewan study. Two coal seams with minable resources (fig. 2) were identified by the KGS (17). Appendixes B and C contain a discussion of the basic assumptions and methodologies used during the analysis.

KGS-USGS COAL AVAILABILITY CONCEPT

Three pertinent steps were defined in the KGS-USGS Coal Availability study (16):

1. Study area selection,
2. Data collection and assimilation, and
3. Resource estimation.

Coal available for mining was defined by the KGS-USGS Coal Availability study as follows (15):

$$\begin{array}{r}
 \text{ORIGINAL COAL RESOURCES} \\
 \text{minus} \\
 \text{COAL MINED AND COAL ABANDONED} \\
 \text{DURING MINING} \\
 \text{equals} \\
 \text{REMAINING COAL RESOURCES} \\
 \text{minus} \\
 \text{COAL RESTRICTED BY LAND-USE} \\
 \text{CONSIDERATIONS} \\
 \text{minus} \\
 \text{COAL RESTRICTED BY TECHNOLOGICAL} \\
 \text{CONSIDERATIONS} \\
 \text{equals} \\
 \text{COAL AVAILABLE FOR MINING.}
 \end{array}$$

³Italic numbers in parentheses refer to items in the list of references preceding the appendixes at the end of this report.

U.S. BUREAU OF MINES COAL RECOVERABILITY CONCEPT

Following review meetings in Denver, CO, and Reston, VA, and preparation of a project outline, the authors conducted a preliminary recoverability and costing study of three Upper Elkhorn coal seams in the Matewan quadrangle. That preliminary evaluation showed excellent correlation with the USGS computer model for minable resources (98% agreement). Perhaps more importantly, however, the preliminary evaluation resulted in the establishment of an outline for the USBM's program methodology, as well as the development of recovery and costing models. The USBM's study incorporated the KGS-USGS methodology, reviewed the restrictions and modified the resources accordingly, addressed mining and

recovery losses, and finally applied the mine operating economics. This resulted in a uniform, consistent methodology to be applied throughout the USBM study:

COAL AVAILABLE FOR MINING
 minus
 MINING LOSSES
 minus
 WASHING LOSSES
 equals
 RECOVERABLE RESOURCES
 restricted by
 MINE OPERATING COSTS
 equals
 ECONOMICALLY RECOVERABLE RESOURCES
 (RESERVES).

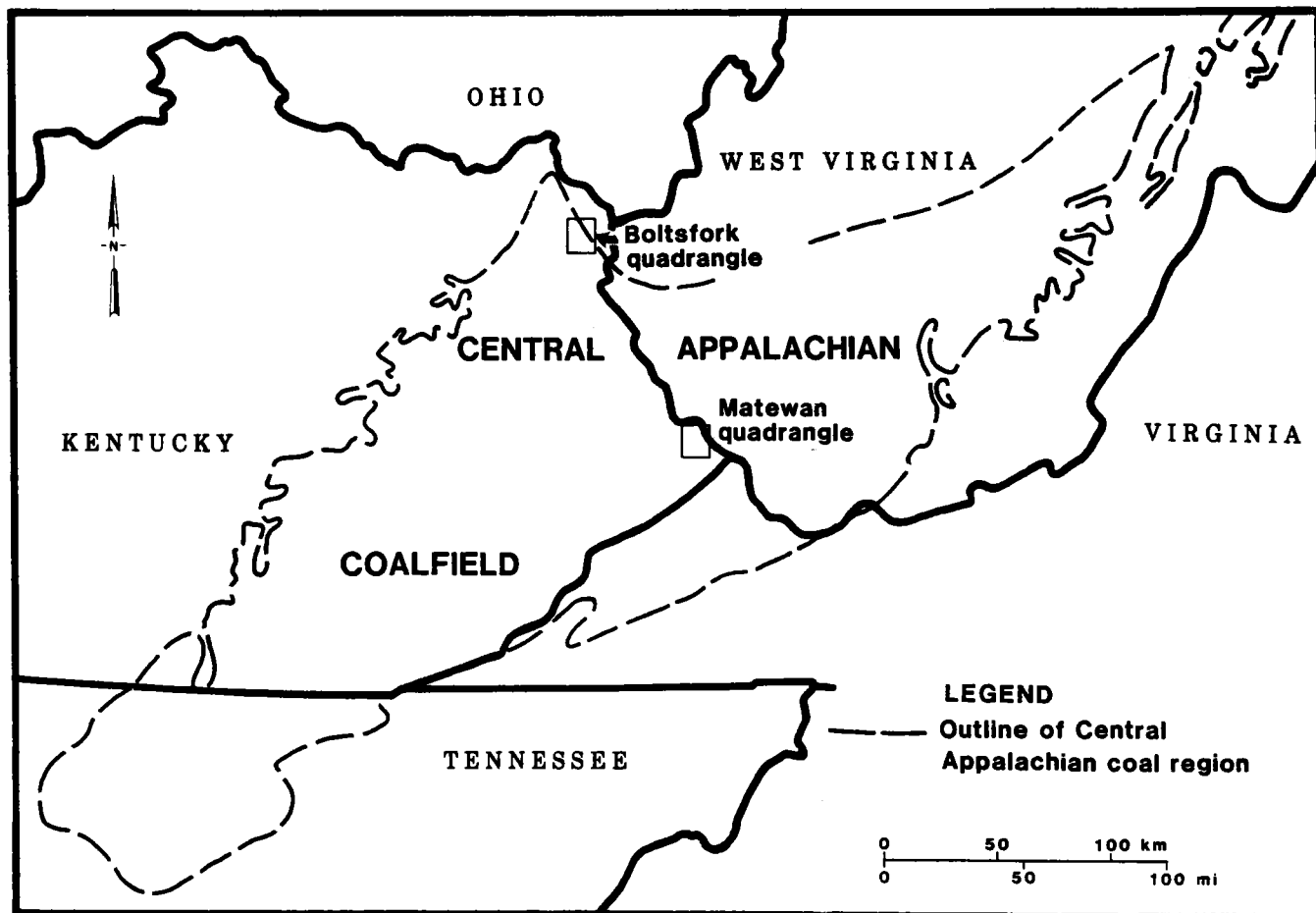


Figure 1.—Study area location.

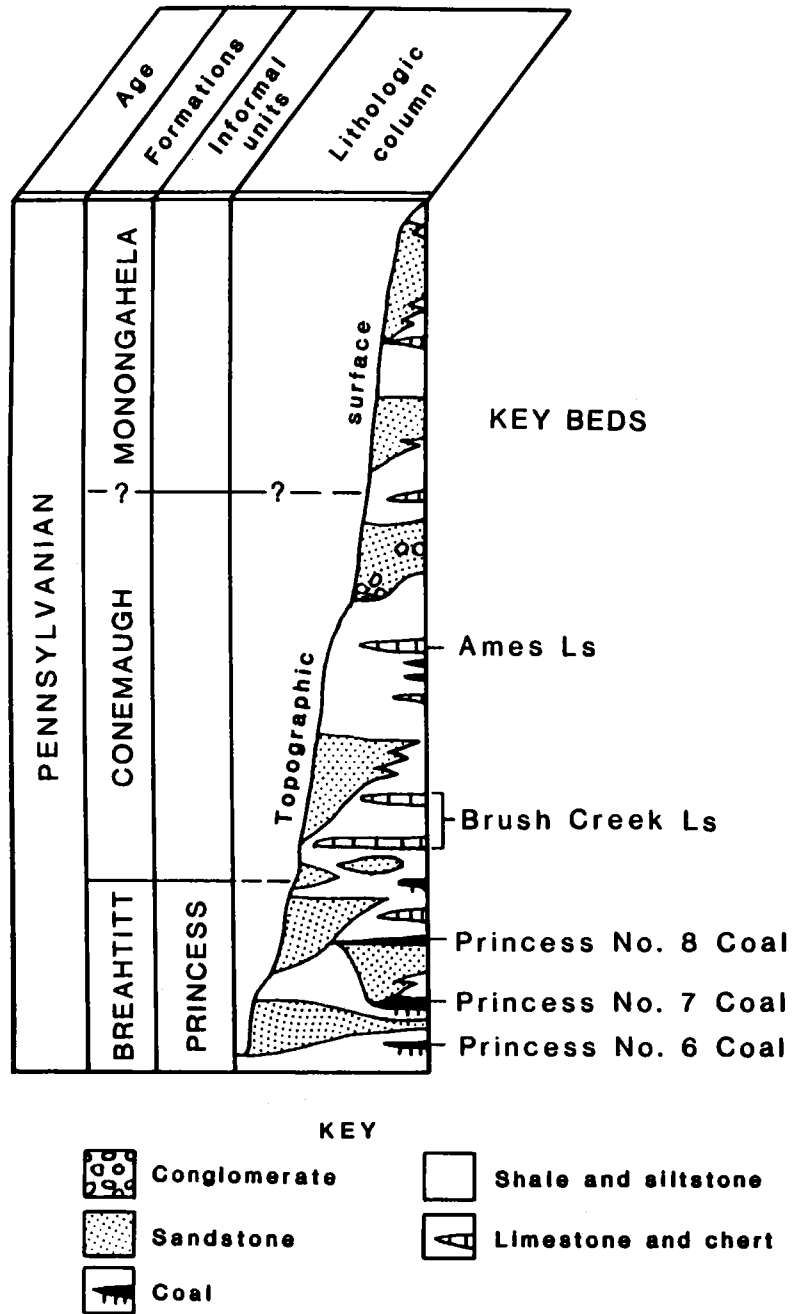


Figure 2.—Boltsfork quadrangle coal stratigraphy.

OBJECTIVES

Realistic coal resource assessments are important for the consideration of legislation and regulations affecting coal production and for the direction and implementation of research aimed at maximizing recovery and ensuring environmental protection. Major national concerns that prompted the KGS-USGS Coal Availability program and the USBM's Coal Recoverability program are:

1. Potential production disturbances in the world petroleum supply,
2. The requirement for low-sulfur (compliance) coal as a result of the Clean Air Act Amendments of 1990,
3. The social and economic disruptions that may occur in the United States as coal mining shifts from areas of high-sulfur coals to areas of low-sulfur coals,
4. Growing recognition of the need to mitigate the environmental consequences of past, present, and future coal mining,
5. The need for accurate coal resource, recovery, and cost estimates that will contribute to relevant Government policy decisions, and

6. The need to determine mineral value and development potential of coal resources on public lands controlled by the Bureau of Land Management and the Forest Service.

The objective of the USBM Coal Recoverability program is to address these concerns by:

1. Developing a methodology to calculate recoverable coal resources and their associated mine operating costs,
2. Using that methodology to improve estimates of the National Coal Reserve Base,
3. Determining the probable effects that clean air legislation and other environmental restrictions may have on coal production,
4. Developing baseline information to help with policy and legislative decisions affecting the competitiveness of coal mining in the United States and the State economies dependent on coal production, and
5. Assisting Federal land managing agencies in the evaluation of coal resources on public lands.

ACKNOWLEDGMENTS

This report is the culmination of efforts by several State and Federal agencies working toward the common goal of determining the economically recoverable resources within a specific area of the central Appalachian coal region. Anne Allen, mining engineer, (USBM, AFOC, Anchorage, AK), provided assistance with the calculation of coal reserves. Matt Plis, physical scientist (USBM, IFOC, Denver, CO) developed the COALVAL program used extensively during the study to facilitate the interactive data sheets, and assisted with the determination of coal reserves. The KGS and USGS provided the geological modeling and data files from which resources were calculated.

James C. Cobb, Assistant State Geologist (KGS), and his staff provided detailed geological information, a tour of the Boltsfork quadrangle area, and a review of the final report manuscript. M. Devereux Carter (USGS, Reston, VA) contributed resource calculations, computer guidance, and assistance in coordinating the USGS Coal Availability program with the USBM Coal Recoverability program. Carol L. Molnia and Vicky L. Clark (USGS, Denver, CO) provided computer assistance; and Chuck Oddenino, Project Manager (USBM, Branch of Minerals Availability), Washington, DC, provided technical guidance.

PROGRAM DESIGN

After examination of the KGS and USGS Coal Availability project in early 1989, a preliminary recoverability methodology was developed along with map needs and formats, preliminary work schedules, and mining restriction criteria. Geological and geographic information was provided by the KGS, Lexington, KY. This information included: coal correlations, coal croplines, coal thickness and parting data, coal quality data, digitized restrictions to mining, mined-out areas, oil and gas wells, cemeteries, etc.

The Boltsfork quadrangle area was toured so that the locations of wash plants, railroads, highways, haulage roads, streams, and rivers could be verified, and other pertinent mining infrastructure could be noted, such as trends in the terrain and haulage routes. The tour verified that no active mining was currently taking place in the quadrangle area proper. Also verified was that no preparation plants were in the quadrangle area or in adjacent quadrangle areas. Several mines in and around the Boltsfork quadrangle were evaluated for operational details.

All coal is and/or was shipped raw to the river (Big Sandy or Ohio), or to one of several powerplants along the riverways. Recovery rates from practical mine design and mine surveys were investigated in other localities with similar mining configurations. Normal planning variables, such as seam thickness, floor and roof quality, seam hardness, seam quality, parting and coal content within a seam, and depth of seams, were collected. Industry and Government sources were used for equipment costs and cost indexes, productivity, transportation costs, coal quality versus coal sales price, taxation, etc.

The available coal resources as determined by the USGS and cooperating State geological surveys are the original resources minus the mined-out resources, resources restricted from mining by environmental factors, and resources restricted from mining by technological factors. Only coals 14 in or more in thickness are considered for surface mining. All coal croplines and restrictions are digitized for area and volume/tonnage calculations. Environmental restrictions include towns, highways, streams, cemeteries, and major gas and electrical lines. Technological restrictions include coal less than 28 in thick for underground mining, barrier pillars between mines, oil and gas well buffers penetrating mines, and coal quality.

These coal availability estimates give the resource in coal-only thickness, reliability, and depth (surface minable or underground minable) classes. The restrictions to mining are estimated individually so that the magnitude of resources made unavailable because of cemeteries, oil and gas wells, protected lands and streams, and other factors is known.

The USGS and State availability program defines coal resources in terms of coal-only tonnages, (any parting greater than 3/8 in is deleted from the seam thickness). A major difference between the KGS-USGS Coal Availability program and the USBM Coal Recoverability program is the USBM use of total coal seam thickness, including partings, in determining mining methods, resource recovery, and applicable mining costs. The Bureau's assumptions and methodology reflect recovery of some coal in the mining of full seams that would have been excluded in a coal-only scenario (i.e., seam parting of up to 50% of the total seam thickness is included in the minable resource number). Also, the Bureau did not limit the mining of the coal if the coal had high sulfur or high ash content; instead, operating costs became the limiting factor for the reserve. Thus, high sulfur coal is limited in reserve by its lower sales price. Ash content, denoting

inseam parting and out-of-seam dilution, is accounted for by (1) the additional cost of washing the run-of-mine (ROM) product, and (2) the percentage of ROM product washed out during cleaning, thereby effectively lowering the clean or salable tonnage recovered and raising the cost per ton to produce the coal. The USBM recoverability program defines coal resources in terms of total seam (coal plus partings) tonnages. Table 1 compares the two programs with respect to this and other significant differences in the definitions used.

Table 1.—Coal resource definition differences—KGS-USGS coal availability program and USBM coal recoverability program

Criterion	KGS-USGS	USBM
Tonnage inclusion	Coal-only	Coal plus partings (total seam).
Minimum mining thickness:		
Surface minable	14 in (coal-only)	12 in (coal + partings).
Underground minable	28 in (coal-only)	24 in (coal + partings).
Minimum mining cover	NAp	100 ft.
(UG)		
Maximum mining cover	1,000 ft	NAp.
(UG)		
Maximum mining highwall ..	200 ft	20:1 ratio.
NAp	Not applicable.	
(UG)	Underground.	
Ratio 20-ft highwall to 1-ft coal thickness.		

As a result of the redefinition of coal resource availability, the USBM estimation of the total original, in-place, resource for the Boltsfork quadrangle is 15% more than the KGS-USGS estimate; however, due to significant differences in estimated resource losses determined for previously mined resources and restrictions to future mining, the USBM estimate of the remaining minable resource is less than the KGS-USGS estimate by 7%. The reasons for these differences are explained above in the discussion of definitions and are the result of differences in the approaches taken. The USBM approach allows more tons to be added to the original resource by using the total seam thickness, but then removes more tons by accounting for mining losses. In any event, this revised minable tonnage, derived from USGS and KGS coal availability data, formed the foundation for the USBM recoverability program. Table 2 shows the different resource tonnage estimates of the KGS-USGS and the USBM.

Table 2.—Comparison of KGS-USGS and USBM coal resource estimates for the Boltsfork quadrangle

(Thousand short tons)

Resource categories	KGS-USGS	USBM
Total original, in-place resource	243,400	280,200
Previously mined resource (includes mining losses)	11,600	12,600
Remaining original, in-place resource	231,800	267,600
Resource lost due to restrictions (technical, environmental, and social)	62,100	110,100
Remaining minable, in-place resource	169,800	157,500

The Bureau's recoverability methodology removes the resources lost during mining and washing, resulting in recoverable resources. Mining economics are applied to the recoverable resources to determine the amount of coal that can potentially be mined at a profit.

To determine the resource recovery, mining assumptions are made and preliminary mine plans are developed for each seam. The resulting resource data are entered into COALVAL's coal mining models, and thereby the quantity of in-place resources that can ultimately be recovered is determined (appendix B). These recoverable resource data are then incorporated into COALVAL's cost models, which calculate associated mining costs (appendix C).

Because a market analysis is beyond the scope of the USBM Coal Recoverability program, coal is defined in this study to be economically recoverable if the operating costs associated with mining it are less than \$25/ton.

Many elements influence the cost of mining a ton of coal. Major factors to be considered are (1) geology of the resource to be mined, (2) Federal, State, and local taxes, (3) royalties, (4) payroll, (5) productivity, (6) transportation, and (7) preparation costs.

The geology of the resource includes engineering properties of the roof and floor of the seam (which directly affect the mine recovery possible from a resource and may

add external dilution to the seam), thickness and continuity of the seam, thickness and continuity of in-seam noncoal partings, and coal quality. These factors often dictate the mining methods to be used and directly affect the wash plant recovery which, in turn, affects the cost per ton of clean or salable coal.

Federal, State, and local taxes generally have little correlation with efficiency or productivity but can be a large cost consideration. Royalties commonly are a very large part of the total cost because they frequently do not vary with the price of coal, and usually have minimum payments required. Therefore, as the coal price or productivity decreases, the royalties become a larger percentage of the overall costs. Payroll and associated labor costs are usually the single largest contributors to coal mine costs. Productivity (tons of clean coal per employee shift) is sometimes the deciding factor between profit and loss. Transportation of the coal from the mine to the preparation facility and/or the train or barge loadout facility may account for 10% to 20% of the total operating cost.

Preparation costs also have a significant impact on the cost per ton of clean coal produced. The Princess 7 and 8 coals in the Boltsfork quadrangle provide a clear example of the effects of preparation costs. The practice in and around the Boltsfork quadrangle has been to ship all coal raw (ROM), to final delivery points. As a result of this practice there are no preparation plants in the area. Because of the quality of the coal in this area (table 3), coal washing is necessary to produce a salable product. To do so however, will require considerable capital and investment to the infrastructure. To demonstrate the effect of ROM versus washed coal on the reserves of this quadrangle, a comparison is provided in table 4. (The comparison does not take into account increased capital cost or transportation changes because of changes in shipping destinations.) The assumption has been made for the Boltsfork quadrangle that all coal is shipped raw (the current and past practice), and the preparation portion of the COALVAL cost models reflects no preparation costs.

Table 3.—Coal quality: Boltsfork quadrangle

(Quantitative analysis—As-received basis)

Coal seam	Sulfur % average	Ash % average	Btu/lb average	Potential SO ₂ lb/MBtu average	Coal seam	Volatility rank ¹	Sulfur/ compliance categories ²	Sales price ³	Recoverable tons <\$25/st
Princess 7 ..	2.83	11.38	11,775	4.83	Princess 7 ..	Bituminous High-vol B	Medium-sulfur noncompliance	\$23.26	77,101,617
Princess 8 ..	3.26	30.01	8,731	7.57	Princess 8 ..	Bituminous High-vol A	High-sulfur noncompliance	\$15.27	22,659,334

¹ According to the USGS Coal Resource Classification System.

² Low-sulfur coal contains 1% or less total sulfur, on an as-received basis, medium-sulfur coal contains >1% and <3% total sulfur, on an as-received basis, and high-sulfur coal contains 3% or more total sulfur, on an as-received basis (USGS Circ. 891). Compliance coal meets the current EPA standard for potential emissions (no more than 1.2 lb of SO₂ per MBtu of heat input, from utilities burning the coal, when no sulfur reduction processes are used). Source: Kentucky Geol. Surv. Info. Circ. 9, ser. XI, 1982.

³ Average pricing May 1990.

Table 4.—Comparison of operating cost of ROM coal versus operating cost of washed coal

Coal seam	Recoverable tons at mining cost (Millions)				
	Raw	Washed			Total
	<\$25/st	<\$25/st	>\$25 <\$30/st	>\$30 <\$40/st	
Princess 7 ..	77.1	7.4	24.0	32.0	63.4
Princess 8 ..	22.7	15.1	4.2	2.0	21.3
Total	99.8	22.5	28.2	34.0	84.7

The quality of the coal being mined does not necessarily have a direct effect on the cost to mine or wash that coal; however, the quality does affect the price that can be received for the salable product. The 1990 Clean Air Act Amendments effectively broaden the range of the definitions of compliance coal to include coals over a wide range of sulfur content. This amendment established a strategy for controlling acid rain by limiting the amount of sulfur dioxide that powerplants can legally emit. The national target for sulfur dioxide emissions reduction is 10 million tons annually. The primary target of this legislation is

coal-burning powerplants. This SO₂ reduction is to take effect in two phases. Phase 1 begins in 1995 and phase 2 begins in the year 2000. A major provision of the acid rain bill is the creation of a system of "emissions allowances" that will allow powerplants to buy or sell emissions credits, depending on their particular situations. Powerplants can choose to burn compliance coal, use scrubbers or other sulfur-reduction devices to reduce sulfur emissions, or buy allowances from other companies who have exceeded their reduction requirements (18). This provision sets up a seemingly unlimited set of opportunities for coal use of any quality, depending upon the individual utility's circumstances. Because phase 1 does not start until 1995, the effect of the amendments on coal usage is not yet known. The ultimate phase 2 targets include among other possibilities, an emission level of 1.2 lb of SO₂ per MBtu. This report, therefore, will use the existing definition of compliance coal that meets the EPA standard for potential emissions from coal-burning utilities, when no sulfur dioxide (SO₂) reduction processes are used (19). The current standard is dependent upon the minimum allowable total emissions within an affected area and is no more than 1.2 lb of SO₂ per MBtu of heat content.

COAL QUALITY

Information concerning the quality of the coals within the Boltsfork quadrangle ranges from extensive to extremely limited. The most productive coal seams have the greatest available amount of coal quality information, whereas the nonproductive seams have little or no coal quality information specific to the quadrangle. Coal seam quality data for the seams of the Boltsfork quadrangle are given in table 3. Seams of high production have more statistically supportable averages than seams of lower production.

Due to the variability of coal characteristics throughout central Appalachia, an attempt was made to use coal quality analyses specifically from the Boltsfork quadrangle to compile the table's information. In this regard, two data sources (20-21) were indispensable as sources of coal quality data, because they include individual coal sample information from, adjacent to, or near the Boltsfork quadrangle for both coal seams.

As can be seen in table 3, all the coals within the quadrangle are either high sulfur or medium-sulfur, high-volatile, bituminous varieties. If the standard of 1.2 lb of SO₂ per MBtu is considered, there are no compliance coals within the Boltsfork quadrangle. Because coal quality data are very limited, the table data represent only a very restricted characterization of the coal within the Boltsfork quadrangle. The quality of a coal is not considered a restriction to its minability; however, it can be a factor in its marketability. The Boltsfork quadrangle quality data are limited, but sulfur trends for the area can be constructed.

In addition to coal quality characteristics, the table also indicates the sales price for each seam's coal. The sales prices are based on sulfur and ash contents and Btu heating values of the coals for central Appalachian "District 8" coal prices (f.o.b. mine) for May 1990.

RESULTS

Table 5 shows that the total original, in-place, resource for all seams in the Boltsfork quadrangle is 280.2 M tons, of which 12.6 M tons have been mined out. Resource losses resulting from restrictions amount to another 110.1 M tons. Subtracting these, a minable resource of 157.5 M tons, or 56% of the original resource, remains

(fig. 3). When this resource available for mining was theoretically "mined out," 57.7 M tons was left in the ground as barrier pillars, in seams located too close to other seams, or otherwise considered unminable for a variety of reasons. When these values are subtracted from the "minable resource" number, the resultant 99.8 M tons

(35.6% of original in-place resource) remains as a "recoverable resource." The fact that so little of the in-place resource is potentially recoverable is noteworthy. Figure 4 illustrates the various resource losses and availabilities.

The "recoverable resource" was then evaluated with the costing models to determine the amount of economically recoverable resource remaining. The results further reduce the amount of recoverable coal, depending upon the economics assumed at the time of the study.

At \$25 per ton operating cost, only 35.6% (99.8 M tons) of the original resource was economically recoverable; however, all of the "recoverable resource" was minable at less than \$25 per ton when no washing was performed on the ROM coal.

Ultimately, no economically recoverable coal that met standards for SO₂ emissions (compliance coal) was found in the quadrangle.

Table 5.—Coal seam resources, restrictions and process losses

(Thousand short tons)

Seam name	Original resources	Mined-out resources	Restricted resources			Process losses		Recoverable resources
			Land-use restrictions	Technologic restrictions	Barrier restrictions	Mining losses	Washing losses	
Princess 7 ...	177,578	10,642	2,462	26,198	14,940	46,235	0	77,102
Princess 8 ...	102,653	1,990	5,625	57,161	3,744	11,473	0	22,659
Totals ...	280,231	12,632	8,087	83,359	18,684	57,708	0	99,761

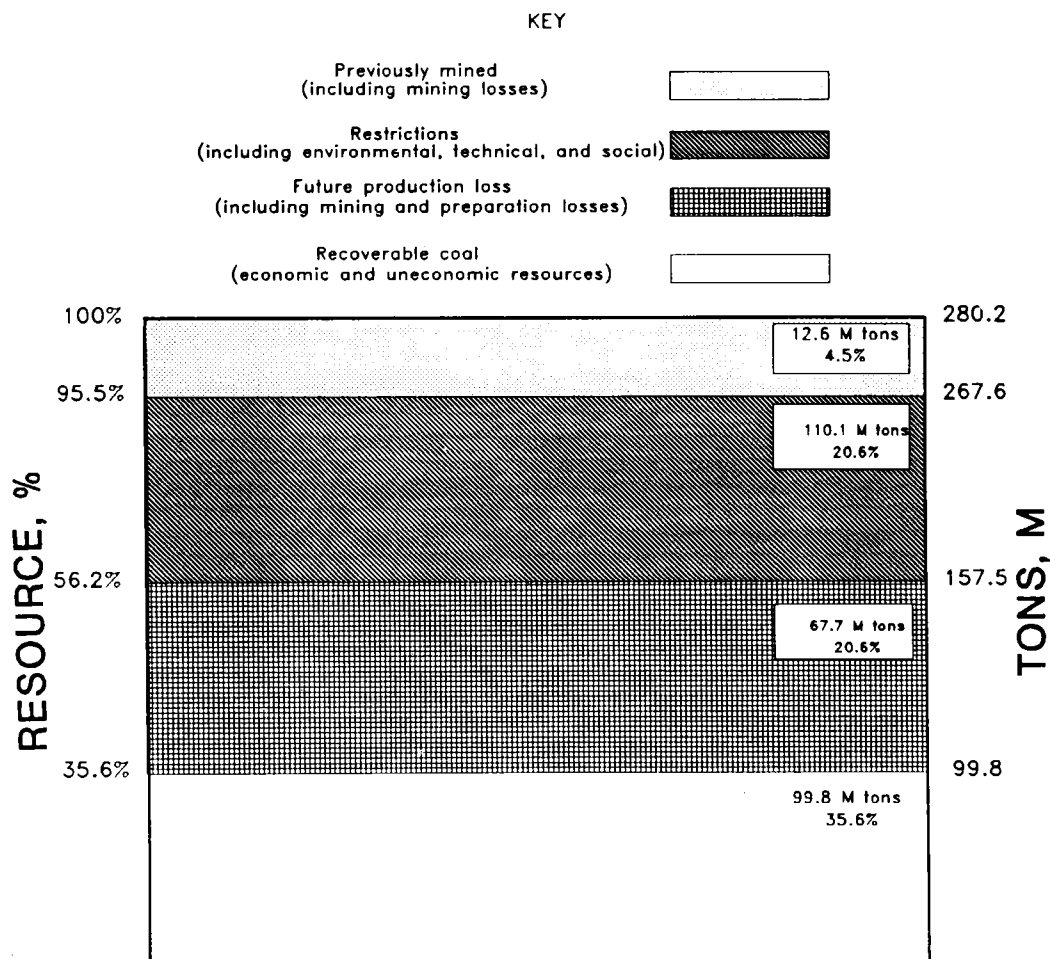
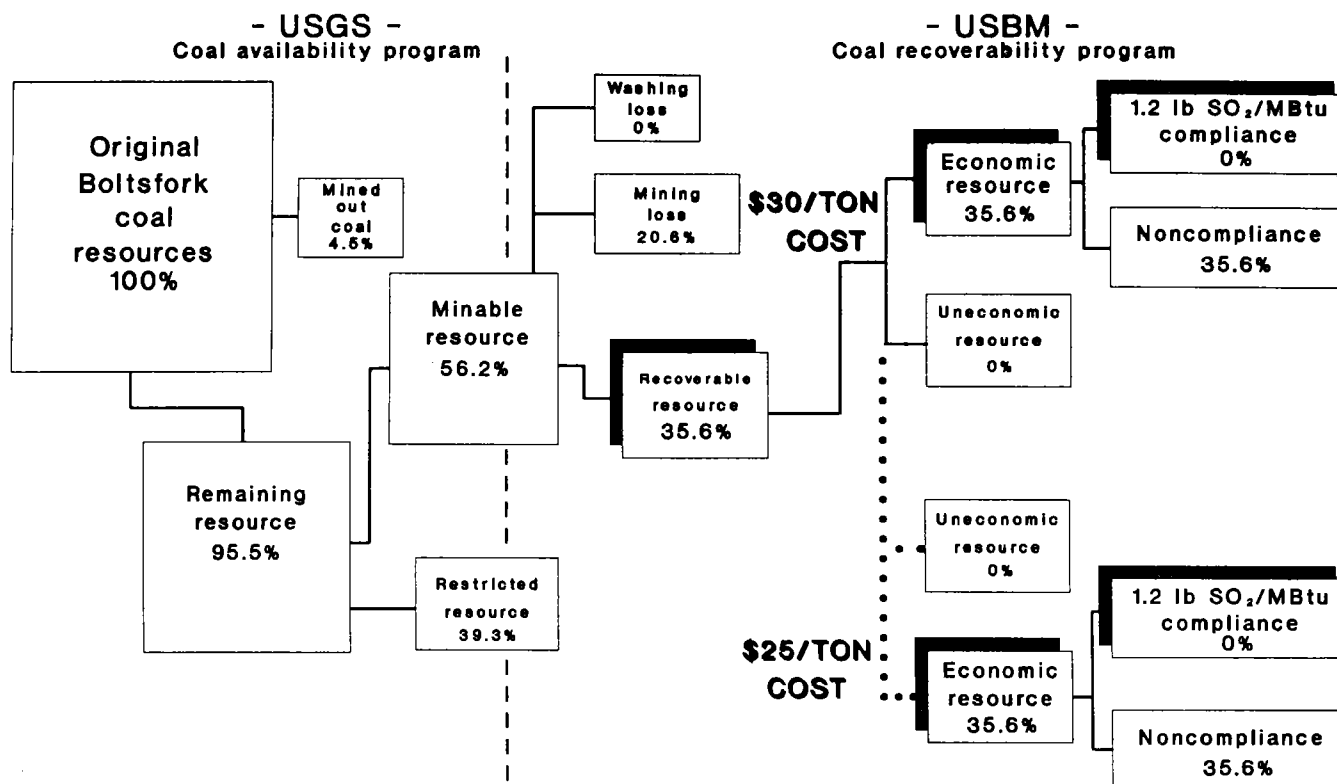


Figure 3.—Coal resource graphical summary.



All percentages based on original Boltsfork coal resource of 280.2 million tons.
Sales prices per ton are relative to May 1990 markets.

Figure 4.—USGS/USBM coal resource programs—Boltsfork quadrangle results chart.

CONCLUSIONS

Without detailed information and cost modeling of coal resources, it is not possible to make informed decisions regarding national, regional, or local energy policies. Traditional procedures and methodologies used to estimate the coal reserve base have used historical mining recovery factors and applied them throughout coal regions to obtain the estimated recoverable coal tonnage. Restrictions relative to the environment and social concerns, site-specific geology, mining and preparation technology, and economics have not been considered. However, as this study shows, these restrictions significantly impact the amount of coal that is ultimately recoverable.

Results of this study indicate that of the original 280 M tons of coal resources in the Kentucky portion of the Boltsfork 7 ½ minute quadrangle, only 99.8 M tons, or 35.6% of the original in-place resource is potentially recoverable. Consistent with previous Coal Recoverability program work (28-29), economically recoverable coal is defined to be coal costing less than \$25/ton to mine, therefore, all of the Boltsfork quadrangle's recoverable coal is also economically recoverable. However, because of the poor quality of this coal, its sales price (table 3) will

be significantly less than \$25/ton if it can be marketed at all. Much of this coal will eventually prove to be unprofitable to mine.

A market analysis is not within the scope of this report, but a brief discussion of table 4 and the comparison it represents may be in order. The mining costs developed in this report are operating costs and include all direct and indirect costs. Capital and associated infrastructure costs to construct new preparation facilities and their required support are not developed.

Table 4 assumes adequate preparation capacity is in place and considers only operating costs associated with the coal preparation. The results in table 4, should the coal be washed and a better product developed, indicate the amounts of coal available at various cost ranges. These tons are therefore available at a sales price equal to the top of each cost range. That is to say, of the 99.8 M raw tons available, only 22.5 M tons (22.5% of available coal resources) would be available at \$25/ton. This is 8% of the original resource. At a sales price of \$30/ton, 50.7 M tons (51% of available or 18% of original resource) become available. At a sales price of \$40/ton, 84.7 M tons

become available (85% of available or 30% of original resource).

The results of this study are for one quadrangle only but, coupled with results from the previous Matewan quadrangle study, they suggest that the DRB is seriously overstated and that the DRB should be used with caution until further data are available. It is difficult to predict at this point of the study whether or not the Matewan and Boltsfork results are representative of quadrangles throughout the central Appalachian region.

If similar results are found in subsequent investigations, a strong argument can be made that some traditional

coal-producing regions may soon be experiencing resource depletion problems far greater and much sooner than previously thought. This will affect not only the coal industry, but the entire social and economic infrastructure of the affected areas. As production shifts from one region to another, so will jobs, people, and businesses. Entire government base structures are being directly affected by the industry migration. This migration may be accelerated as the coal industry seeks additional reserves elsewhere, or develops lower production cost reserves that meet regulatory requirements and therefore are more marketable.

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APPENDIX A.—GLOSSARY

Available coal resources.—Coal resources, minable by either surface or underground methods, that are unencumbered by land-use, environmental, societal, regulatory, or technologic restrictions as applied within a specific State or region. In this study, available resources are derived by the following formula:

$$\begin{array}{r}
 \text{ORIGINAL COAL RESOURCES} \\
 \text{minus} \\
 \text{COAL MINED AND LOST-IN-MINING} \\
 \text{equals} \\
 \text{REMAINING COAL RESOURCES} \\
 \text{minus} \\
 \text{COAL RESTRICTED BY LAND-USE} \\
 \text{CONSIDERATIONS} \\
 \text{minus} \\
 \text{COAL RESTRICTED BY TECHNOLOGIC} \\
 \text{CONSIDERATIONS} \\
 \text{equals} \\
 \text{AVAILABLE COAL RESOURCES.}
 \end{array}$$

Buffer zone.—The area surrounding a restrictive feature (mine, town, cemetery, oil or gas well, stream, etc.) in which mining is not permitted.

Coal availability/minable resource.—Refer to Available coal resources.

Coal recoverability.—Refer to Recoverable coal.

Coal reserve.—Refer to Reserve.

Coal resources.—Deposits of coal in the Earth's crust in such amounts that physical extraction is currently or potentially feasible.

Coal seam.—A bed or stratum of coal.

Coal washing/preparation.—The process of cleaning (i.e., removing ash, etc.) or preparing run-of-mine coal to meet market specifications and to make it suitable for a particular use.

Compliance coal.—Coal that meets New-Source Performance Standards (NSPS), set forth by the EPA, for SO₂ emissions. This is coal that is in compliance without use of SO₂-reduction processes, such as scrubbers. The current maximum limit from new-source coal-fired powerplants is 1.2 lb of SO₂ per MBtu of heat input.

Deep coal resources.—Coal resources that would most probably be mined by underground mining methods.

Deep-mine barrier pillars.—Unmined coal left around the peripheries of active or abandoned underground mines

because of mine-safety requirements. Also referred to as deep-mine barriers.

Dilution.—The contamination of coal with barren rock from the roof and floor of an excavation.

Environmental restrictions.—Refer to Land-use restrictions. Examples of these restrictions are cemeteries, towns, and residences (social constraints), ground slopes <65%, major streams, and lakes (environmental constraints).

Floor rock.—The rock immediately underlying a coalbed. Where the coal section is overturned (inverted), the mining floor is actually above the coalbed, stratigraphically.

Interburden.—The rock between two coalbeds. When two potentially minable coalbeds occur within a minimum acceptable distance above or below one another, one (commonly the thinner of the two) will not be mined.

Land-use restrictions.—Constraints placed upon mining by societal policies to protect those surface features or entities that could be affected by mining. Since laws and regulations can be modified or repealed, the restrictions, including industrial and environmental restrictions, may change.

Lost-in-mining.—Unrecoverable coal remaining in the ground within a mine after all feasible extraction is completed. Includes coal that is (1) left to support mine roofs, (2) too thin or impure to mine, (3) unsafe for mining (e.g., bad roofs, faults, etc.), and (4) unmined around oil, gas, water, and disposal wells, shafts, conduits, haulageways, tunnels, and airways.

Mining methods.—The systems employed in the exploitation of coal seams and ore bodies. The method adopted depends on a large number of factors, the main ones being the quality, shape, size, and depth of the deposit; accessibility; and capital available.

National Coal Resources Data System (NCRDS).—The U.S. Geological Survey computer system for storage, retrieval, and manipulation of stratigraphic, geochemical, and coal resource-related data. The NCRDS stratigraphic data base contains information on more than 150,000 coal data points; the NCRDS geochemical data base includes analyses on nearly 13,000 coal samples. NCRDS graphics programs calculate and tabulate resources according to the specifications of the USGS coal-resources classification system. A national network of users and State co-operators is tied into NCRDS for interactive data retrieval, manipulation, and coal resource assessment.

Original coal resources.—Coal resources, containing 33% or less ash, that lie under less than 6,000 ft of overburden and are either 14 or more inches thick (for anthracite and bituminous coal) or 30 or more inches thick (for sub-bituminous coal and lignite); the coal must exist in such form and amount that physical extraction is currently or potentially feasible.

Operating costs.—The sum of mining, beneficiation, and administration costs.

Outcrop.—That part of a coalbed or rock stratum that appears at the surface (crops out).

Overburden.—Any material, consolidated or unconsolidated, that lies between a coal deposit and the surface.

Parting.—A small layer of rock in a coal seam.

Perennial stream.—A stream that flows continuously throughout the year.

Process losses.—Coal losses due to mining and washing.

Production.—The yield or output of a mine, metallurgical plant, or quarry.

Recoverable coal.—Coal that is, or can be, extracted from a coalbed during mining (see Reserve).

Recovery.—The proportion, or percentage, of coal (or ore) that is mined from the original deposit.

Recovery factor.—The percentage of total, estimated in-place coal that is potentially recoverable or, for a more precise determination, the percentage of total, estimated in-place coal that is actually mined. Recovery factors are generally about 50% for underground mining methods and from 80% to 90% for surface mining methods.

Reserve.—That part of a mineral deposit which could be economically and legally extracted or produced at the time of the reserve determination. When dealing with metalliferous minerals, reserves are customarily stated in terms of "ore;" however, when other materials (coal, oil shale, tar sands, limestone, etc.) are involved, a more appropriate term (such as "recoverable coal") may be substituted.

COAL AVAILABLE FOR MINING
 minus
 MINING LOSSES
 minus
 WASHING LOSSES
 equals
 RECOVERABLE RESOURCES
 restricted by
 MINE OPERATING COSTS
 equals
 ECONOMICALLY RECOVERABLE RESOURCES
 (RESERVES).

Restricted coal resources.—Coal resources that are determined to be unminable because of current land-use or technologic restrictions.

Roof rock.—In underground mining, the rock immediately overlying a coalbed. Often the upper part of a coal bed is left unmined to serve as a roof for the mining operations.

Strip ratio.—A numerical expression showing the proportional relationship of a unit amount of waste material to a similar unit amount of ore or mineral material; the waste material must be removed in order to gain access to the target material.

Surface coal resources.—Coal resources, usually within a few hundred feet of the surface, that would most probably be mined by surface mining methods.

Technologic restrictions.—Constraints, relating to economics and safety, placed upon mining by the state of technology or prescribed by law; the restrictions could change with advances in science or modifications in the law. In this report, geological factors are included as technologic restrictions.

Yield-Mine.—See Recovery.

Yield-Plant.—Ratio of salable product produced, including impurities, to the total input of the mine to the plant.

APPENDIX B.—ASSUMPTIONS

MINING METHODS

Local and practical mining methods were employed in the feasibility type mine planning. Four surface mining methods were examined: area stripping, mountain top removal, contour stripping, and auger mining. Contour stripping, auger mining, and mountain top removal were considered applicable, area stripping was not. Continuous miner and longwall operations were planned for deep mining, due to their high productivity. Conventional mining was not considered; however, it is recognized that conventional methods (drill, cut, and shoot) would have to be employed where geological conditions dictated. Recovery rates were determined for the applicable mining methods, and for the deep mining methods simple regression curves were fitted to the accumulated data for production rates; these were used to assign production rates for the deep mining methods by configuration and mining height. Surface transportation of coal, both washed and run-of-mine (ROM), was addressed by measuring haulage distances to known wash plant locations and rail loadouts.

Mine Recovery Factors

For many years a convenient rule of thumb of 50% has been used when estimating the amount of recoverable reserves in a loosely defined resource or mining area. This type of estimation does not consider either the minability of deposits, changes in technology, or changes in demand for coal. It is impossible to predict accurately the eventual recoverability of all coal deposits; however, a current average of recoverabilities depicting today's technology and economics will be useful for estimating deposits that are presently minable.

Lowrie (22)¹ makes a very good observation:

"The rationale, traditionally, for using the convenient figure of 50 percent as an acceptable approximation of average recovery is that it compensated for losses which were not ordinarily included at individual mines. This is an indefinite generalization which allows broad interpretation and perhaps erroneous exclusion of potentially recoverable deposits. Marginal deposits or those not ordinarily considered profitable or minable today, such as those behind prior workings, of poor quality, under adverse physical conditions, undermined, or underlying surface structures and so on, may be minable later rather than 'lost'. Subsequent reevaluation of deposits as a result of changes in technology and economics should be made from a category other than 'lost', which has a permanent connotation. Definitive evaluation of losses

attendant in mining such deposits should be deferred until the time of exploitation."

Each mining method considered for this project demonstrates a recovery unique to that particular method. For this reason, variations of each method were investigated. The investigation included creating several "typical" models and calculating the recoveries, analyzing published and unpublished recovery data from Government and industry sources, and drawing upon personal experience.

Recovery Considerations

The mining methods considered in this report are:

1. Contour strip (surface), with two coal thickness categories: 12 in to 36 in and greater than 36 in.
2. Auger (surface), with two coal-thickness categories: 12 in to 36 in and greater than 36 in.
3. Continuous miner, five-entry system (underground), using two different pillar sizes: 40 ft by 40 ft and 80 ft by 120 ft.

The following definitions that pertain to coal recovery, as used for this study, are derived from the USGS (23):

1. *Recoverable coal*.—The coal that is or can be extracted from a coalbed during mining. The term "recoverable" should be used in combination with "resources" and not with "reserves."
2. *Recovery percent*.—The percentage of coal extracted from a bed where the total tonnage originally in the bed is equal to 100%.
3. *Recovery factor*.—The estimated or actual percentage of coal, expressed as a decimal, that can be or was extracted from the coal originally in a bed or beds of an area, mine, district, field, basin, region, province, township, quadrangle, county, State, political province, nation, and (or) the world.

Six factors that are identified as significantly affecting recovery percentages in underground mines (22) are:

1. Pillaring system.
2. Top rock and conditions.
3. Bottom rock and conditions.
4. Marketability.
5. Coalbed thickness.
6. Productivity.

Thirteen factors that are identified as significantly affecting recovery percentages in strip mines (24) are:

1. Top coal removed with overburden.

¹Italic numbers in parentheses refer to items in the list of references preceding the appendix.

2. Bottom coal left in place.
3. Coal lost in ribs between cuts.
4. Losses due to partings.
5. Losses due to other factors, such as equipment limitations and spillage.
6. Outcrops (coal exposed to weather's degradation).
7. Utility, railway, and highway rights-of-way.
8. Streams.
9. Underground workings.
10. Oil and gas wells.
11. Property lines.
12. Buildings.
13. Other, such as landslide areas and cemeteries.

Five factors that are identified as significantly affecting recovery percentages in auger operations (24) are:

1. Auger diameter.
2. Auger spacing.
3. Average auger penetration.
4. Coalbed thickness.
5. Length of highwall available for augering.

Recovery Determination

A "typical" mine plan was drafted to scale with sufficient detail to incorporate the standard pillars, entries, and development works necessary to provide a representative scenario of the particular mining type under study. The mine plan was digitized, using the **GSMAP** computer program (25), to provide two-dimensional digital information of the mine plan. The digitized data were reproduced on paper by a pen plotter to verify the accuracy. The areas of all pillars were then calculated by the **GSMAP** program. The accuracy and methodology of digitizing using **GSMAP** were checked using multiple-pass planimetry. The mining and restriction areas were nearly identical between methods.

Standard, or "average," recovery factors were established for each of several conditions and mining methods. It is recognized these are not, and cannot be considered, definitive under all conditions, but reflect today's technology and economic conditions more accurately than the often used 50% factor.

The following mine recovery factors were used for this study:

1. For contour strip mines—78% where the coal *seam* is less than 36 in thick, and 93% where the coal *seam* is greater than 36 in thick.
2. For auger mines—30%.
3. For continuous miner mines—62% where the pillars are 40 ft by 40 ft, and 57% where the pillars are 80 ft by 120 ft. (80% maximum pillar extraction considered while leaving three bleeders around perimeter of mined area).

4. For longwall mines—84% where the pillars are 40 ft by 40 ft, and 78% where the pillars vary in size.

Recovery Model Dependencies

The resource recoverability calculations consist of the entire process of determining, from raw data, the amount and salability of coal from the area in question. The viability and accuracy of the calculations and associated modeling is dependent upon (1) the existence of a proven geologic model of the coalbed, (2) mining methods, (3) mining recovery, (4) mining sequence, (5) coal quality, and (6) dilution factors. Also influencing the model are coal washability parameters, wash plant recovery, mine size optimization, equipment configurations, land ownership, and all of the various environmental, social, and technical restrictions to mining. Equally important is the care with which the data are collected and used. Throughout the modeling process, utmost care was taken to assure that current, state-of-the-art methods were employed and that error was minimized.

Production Rates

The rate of production for surface and underground mining operations has long been discussed, studied, and computerized. Information on many of the factors influencing production within a specific coal seam, as shown in table B-1, were not available during the data collection. Rather than calculate idealized production rates from the influencing factors, actual ROM production rates from USBM evaluations and from industry and Government publications were used. Contour strip and auger mining production rates were determined from mine evaluations and heavy equipment production charts and were fairly constant. Production rates for deep mining methods employing continuous miners or longwalls varied over a wide range. Longwall productivity appeared to correlate with mining height, and linear regression analysis proved this assumption to be correct, with very little scatter of the data points from the mean. Continuous miner productivity was found to have fairly good correlation to mining height after other mining factors had been accounted for. These other factors (e.g., available spare or standby equipment, supersections, remote controlled equipment, extremely good mining conditions, and retreat pillar robbing) foster significantly higher production rates than normal. Development mining, development for longwalls, and some captive mines, have lower than normal production rates. When the mine circumstances were addressed, the continuous mining productivity could be broken out into high, normal, and low production rates, and linear regression analysis suggested good correlation between mining height and production rate. These regression analyses are shown in figures B-1A through B-1D.

Table B1.—Factors influencing mine productivity

Factors common to surface and underground mining	
Production needed.	Seam thickness.
Overburden/coal interface.	Dip of coal.
Ground water.	Partings.
Workforce experience.	Production layout.
Development.	Working time at face.
	Planned maintenance.
Factors common to deep mining conditions	
Roof and floor conditions.	Remote controlled equipment.
Methane liberation.	Continuous haulage.
Cutability.	Panel production.
Width of face.	Pillar extraction.
Depth of cut.	
Factors common to surface mining conditions	
Ground slopes/dip of coal.	Overburden stability.

Average production rates were determined for several ranges of mining heights and mining methods. Tables B-2 and B-3 show the production rates used in this study. These seam height configurations were used to specify production equipment sizing and capital costs for the mine costing models.

Table B2.—Surface production rates by mining method

Mining method	Production per seam thickness	
	> 12 in < 36 in	> 36 in
Contour stripping	5,200 BCY/shift	6,500 BCY/shift.
Area stripping	8,500 BCY/shift	8,500 BCY/shift.
Auger mining	175 tons/shift	250 tons/shift.

Table B3.—Deep mine production rates by mining method

Mining method	Production per seam thickness			
	(short tons/shift)			
	> 24 in < 42 in	> 42 in < 72 in	> 72 in < 96 in	> 96 in
Continuous miner ...	394	516	654	839
Longwall mining	NAP	1,609	2,451	3,575

NAP Not applicable.

Mine Design

The surface mining configuration was planned to operate with two separate fleets of equipment in two different locations at the same time. This procedure utilized support equipment, enhanced coal production and blending, and allowed sequencing of auger mining. The planning process assumed common ownership of surface and mineral rights and assumed that mining would be done in a logical, orderly manner for maximum recovery of the resource. Only contour stripping methods were applied in the Boltsfork quadrangle. Neither area mining

nor mountain top removal was planned. The production parameters in contour stripping were dependent upon seam thickness. Seams 36 in thick or greater were assumed to have stripping rates of 6,500 BCY per shift, whereas seams that ranged in thickness from 12 in to 36 in had stripping rates of 5,200 BCY per shift. Mine bench widths varied, but a minimum of 80-ft was used for all stripping. The 80-ft minimum width allowed endloaders to safely load trucks and provided the trucks with enough room to turn around on the bench. Since the average ground slope is about 26° (48.8%), the minimum bench width could be maintained with seam thicknesses of less than 24 in. These conditions, along with the thin interburden between many of the seams, would allow multiple seam stripping. For this reason, the 80-ft-minimum-width bench was used for all strip-minable resources with seam thicknesses of between 12 in and 24 in. During the surface planning, logical portal locations were noted for underground development. Surface mine production was evaluated using a work schedule of 8 hours per shift, 2 shifts per day, 5 days per week (240 days per year). It was assumed that the surface mining equipment would develop the "face-up" area for the deep mine portals, mine offices, and applicable stockpile areas. Reclamation plans would be developed which would leave enough bench area for production haul roads from the deep mine stockpiles.

Auger mining followed closely behind the stripping operations and used the coal production equipment and support equipment. It was assumed that the stripping operation left the highwall and bench in a condition that would require little maintenance by the auger operations. Twin-headed augers were the chief production equipment, with a complement of drill heads and auger steel matched to the coal seam thickness. Average recovery rates of 30% and average depth of holes of 60 ft were assumed. Highwall miners, although not specified, could be an option for the thicker seams.

Deep mine development was laid out with five mains, 18 ft to 20 ft wide, with normal offset barrier pillars and production panels employing room and pillar mining methods laid out at right angles to the mains. Submains were laid out beneath and parallel to the mountain ridges (spurs). Minimum panel widths were five entries and, as the panels approached the outcrop, the minimum advance was with two entries. Only mining with continuous miners was considered. It is recognized that some coal seams are best mined by conventional methods owing to particular geological conditions. That information was not available to the authors in the detail necessary for planning; therefore, conventional mining methods were not addressed in this study. The optimum size operation was assumed to be two continuous miner production units, for continuous mining methods, and two continuous miners and one longwall panel for a longwall operation. Minimum mining

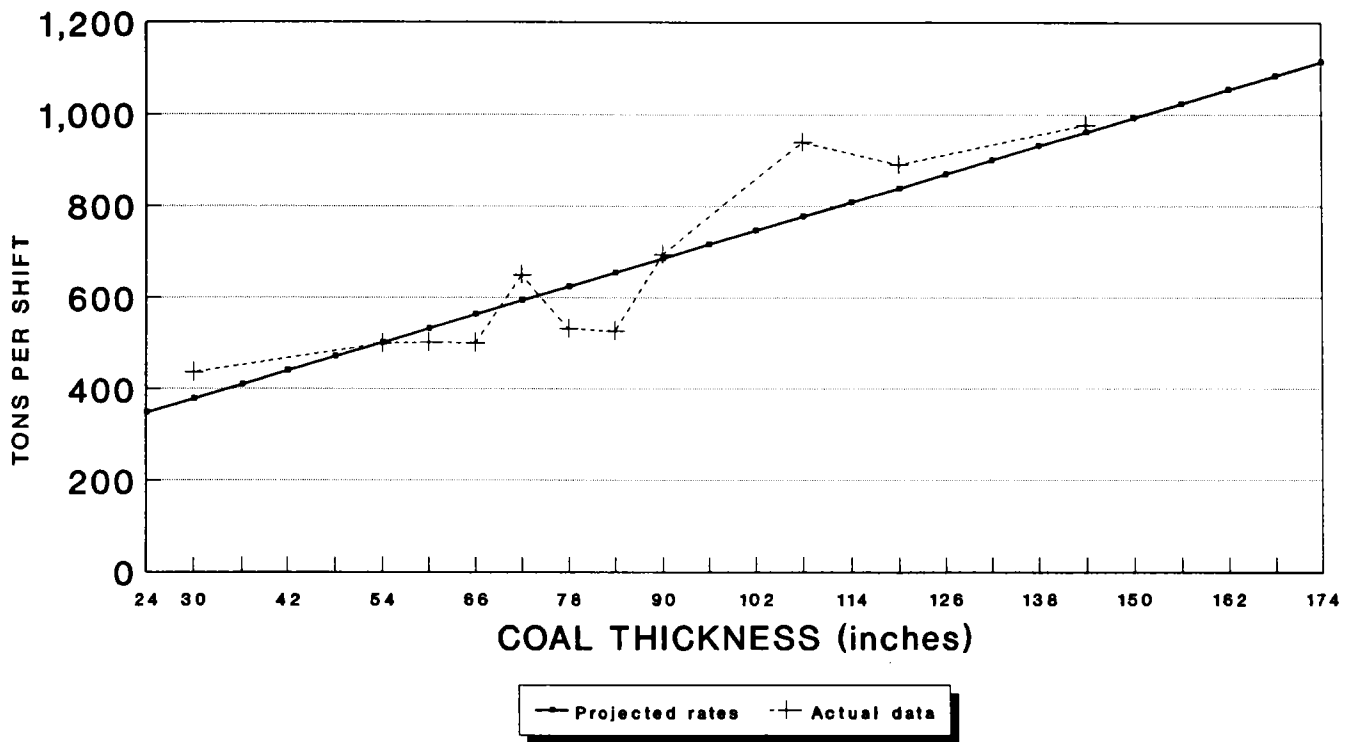


Figure B-1A.—Linear regression analysis: continuous miner-normal productivity.

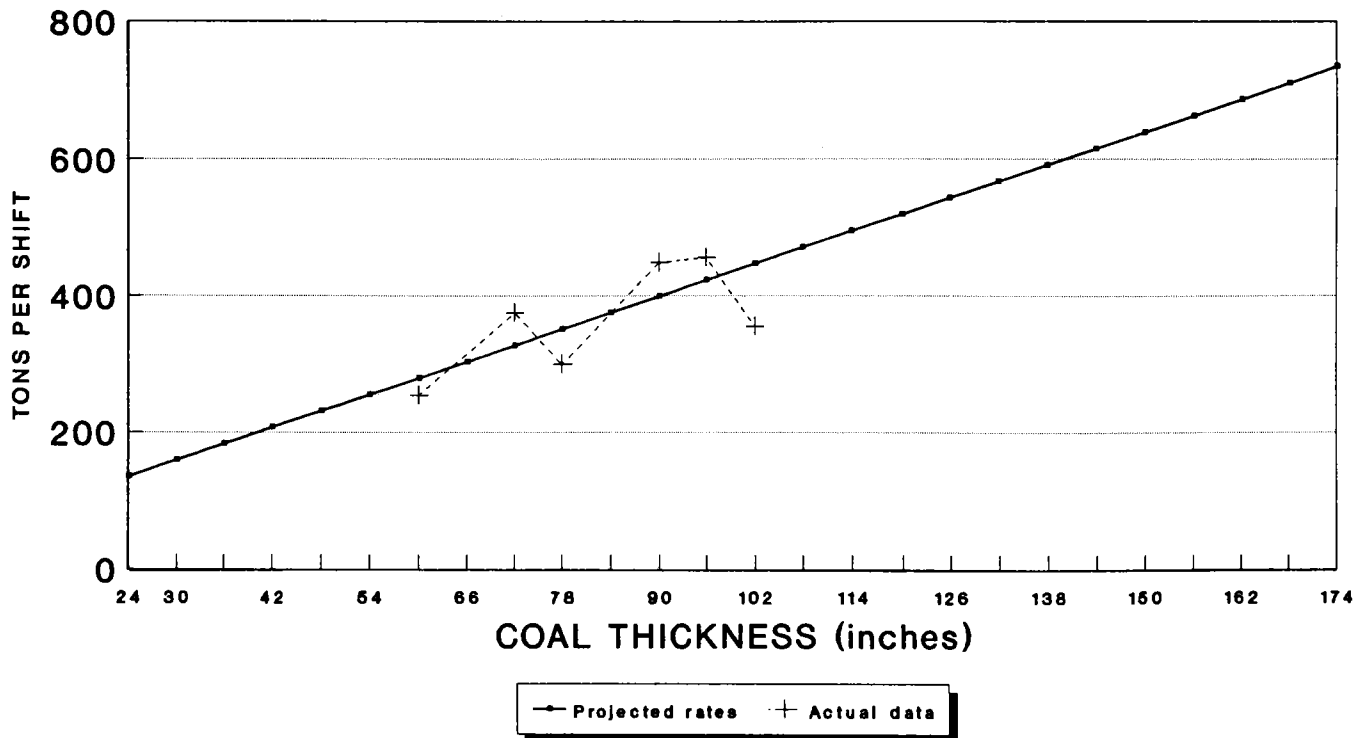


Figure B-1B.—Linear regression analysis: continuous miner-low productivity.

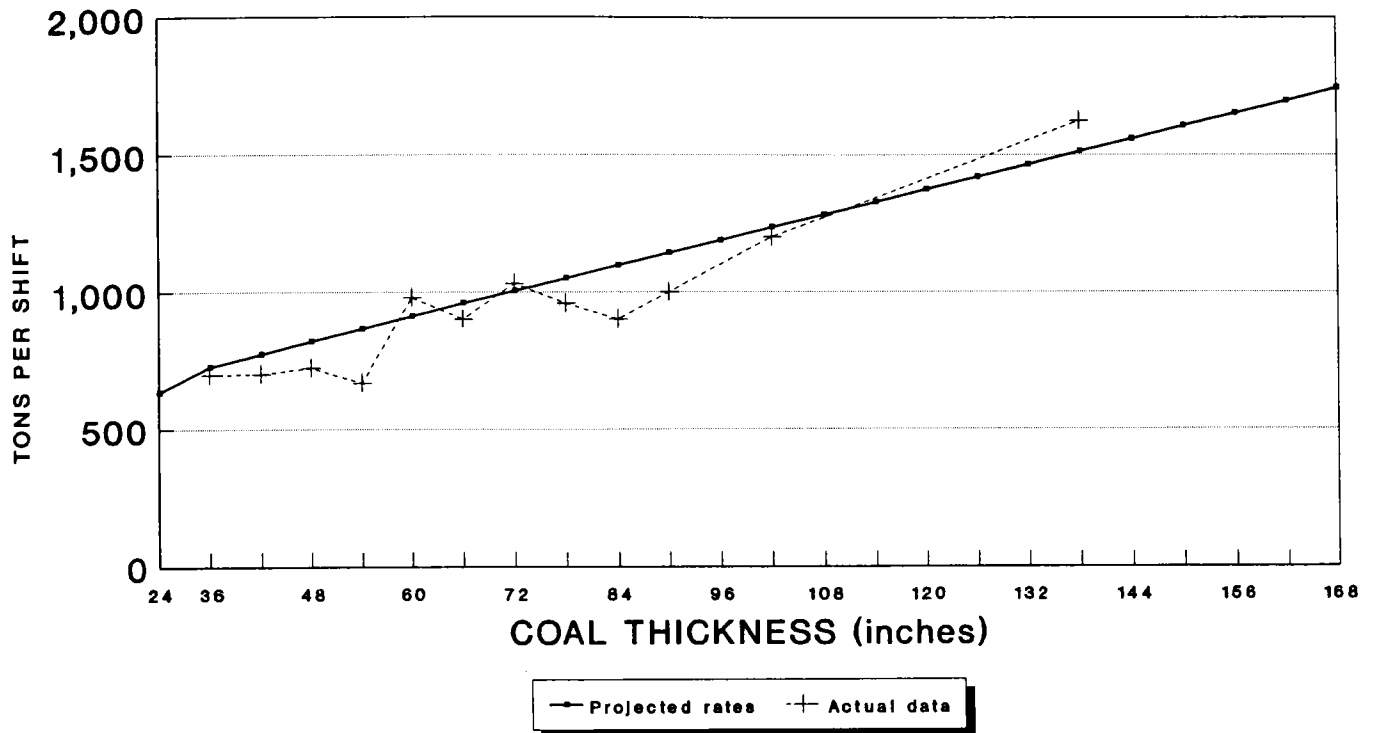


Figure B-1C.—Linear regression analysis: continuous miner-high productivity.

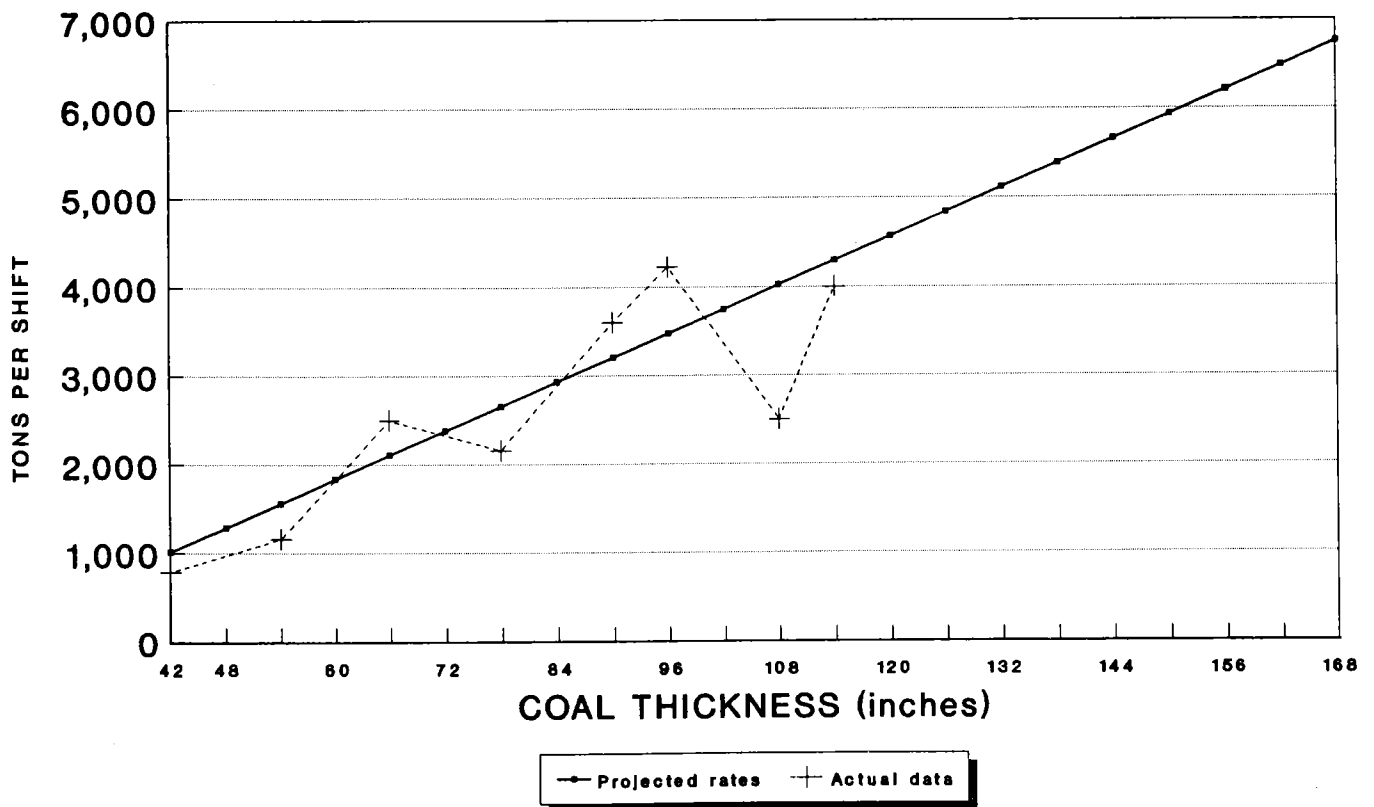


Figure B-1D.—Linear regression analysis: longwall productivity.

heights for continuous miners were set at 24 in of seam thickness and 5 in of out-of-seam dilution. The longwall minimum seam thickness was 42 in, with 3 in of out-of-seam dilution. Because of mining height restrictions on equipment, continuous miner operations had four separate height ranges: 24 to 42 in, 42 to 72 in, 72 to 96 in, and greater than 96 in. Also because of restrictions on equipment, longwall mining had three mining heights: 42 to 72 in, 72 to 96 in, and greater than 96 in. Equipment specifications, capitalization, production, etc. were all determined by these mining heights in the recovery and costing models. In addition to the minimum thickness of 42 in of seam height for longwalls, at present a machine size limitation (motor to horsepower limitations), panels were laid out with three entries on both sides of the panel, a minimum width of 550 ft, and a minimum length of 4,000 ft. Areas considered for longwall mining had to contain enough coal resource to depreciate the longwall equipment used in that seam. No area in the Boltsfork quadrangle met the necessary criteria for a longwall operation. All deep mine production was scheduled for 8 hours per day, 2 shifts per day, 5 days per week (240 days per year).

Development methodology for the basic mine plans is listed below:

1. Understanding of the coalbed to be planned and the superjacent and subjacent minable seams.
2. Identification of the effect of the land-use restrictions on the subject bed.
3. Ground slope determination, along the outcrop, to outline areas having an undisturbed slope greater than 32°—for technical restrictions and for determining the highwall stripping ratio cutoff.
4. Surface mine design using the maximum 20 ft of highwall to 1 ft of coal ratio to determine the bench widths and stripping areas. Where the highwall ratio could be greater than 20 to 1, a minimum bench width of 80 ft was used.
5. Auger mining planned to coordinate with the stripping. Production tonnages were calculated by bench length, seam thickness, depth of auger holes, and normal recovery rate.
6. Underground mine development planned using working site areas prepared during stripping. Mains and submains were planned to be driven parallel to and beneath the mountain ridges.
7. Integration of the coal-haulage zone map with the mine plans. Original resources, restrictions, and minable resources were calculated for each haulage zone.

Using the above guidelines, the first mine plan maps were constructed for the Princess 7 and Princess 8 seams.

SURFACE TRANSPORTATION

Topography in the Boltsfork quadrangle is moderate- to high-relief steep slopes and dissected terrain. Two major streams flow through the quadrangle. For the sake of efficiency, local practice was for all loaded trucks to haul coal downhill, by the most convenient route, to their destination. State, Federal, and county roads were located on the USGS 7 1/2-minute topographic map. After reviewing the geology and the potential for mining within the different watersheds, the quadrangle was divided into 16 haulage zones (fig. B-2). The geographical center of all minable coalbeds was located in each haulage zone and assumed to be the mine coal stockpiling area. Haulage distances were estimated from the "stockpile area" to the closest barge loadout or powerplant. In this haulage scenario, all coal was assumed hauled ROM to its final destination without washing.

All surface haulage of coal was done by contractor owned and operated trucks. Coal haulage contract costs for the eastern Kentucky, southern West Virginia, and southwestern Virginia areas were calculated as a fixed cost per truck plus a cost per ton-mile. These are included in the mine cost models as a basis for calculating the coal haulage costs. Escalating factors are used in the models to keep costs on a current level. Table B4 shows the one-way haulage distance and the cost assigned to each zone, for the Boltsfork quadrangle, as used in this study. Table B5 shows the results of the recovery calculations for one seam. The recoverable resources—by haulage zone, mining method, and seam thickness category—are then used in the mine costing models to generate the operating costs for these recoverable coal tonnages.

Table B4.—Haulage distances one way and assigned cost by zone

Zone	Distance (miles)	Cost (dollars)
1	4.00	1.10
2	2.60	.89
3	4.00	1.10
4	2.60	.89
5	2.60	.89
6	2.70	.91
7	2.70	.91
8	2.70	.91
9	2.70	.91
10	2.70	.91
11	2.70	.91
12	4.00	1.10
13	4.00	1.10
14	1.70	.76
15	1.70	.76
16	2.60	.89

Table B5--Recoverable resources--one seam summary

BOLTSFORK QUADRANGLE
PRINCESS 8 SEAM

***** RECOVERABLE RESOURCE CALCULATION *****

	COAL TONS	PARTING TONS	DILUTION TONS	TOTAL IN- PLACE TONS	% OF TOTAL	% MINE RECOVERY	R.O.M TONS RECOVERED	% WASH RECOVERY	TONS FINISHED PRODUCT
TOTAL IN-PLACE RESOURCES	91,780,209	0	10,872,963	102,653,172	100.00				
ACT/ABN UNDGRD. MINES	0	0	0	0	0.00				
ACT/ABN SURFACE MINES	1,918,660	0	71,741	1,990,401	1.94				
MINED OUT RESOURCES	1,918,660	0	71,741	1,990,401	1.94				
ENVIRON. RESTRICTIONS	5,422,577	0	202,756	5,625,333	5.48				
TECHNICAL RESTRICTIONS	49,494,489	0	7,666,979	57,161,468	55.68				
BARRIER RESTRICTIONS	3,241,685	0	502,155	3,743,840	3.65				
TOTAL RESTRICTIONS	58,158,750	0	8,371,891	66,530,641	64.81				
SURFACE MINABLE RESOURCES:									
AUGER	6,124,847	0	231,760	6,356,606	6.19	0.30	1,906,982	1.000	1,906,982
CONTOUR STRIP	15,015,992	0	561,464	15,577,456	15.17	0.85	13,189,550	1.000	13,189,550
MOUNTAIN TOPREMOVAL	0	0	0	0	0.00	0.00	0	0.000	0
UNDERGROUND MINABLE RESOURCES:									
CONTINUOUS MINER	10,561,960	0	1,636,108	12,198,068	11.88	0.62	7,562,802	1.000	7,562,802
LONGWALL	0	0	0	0	0.00	0.00	0	0.000	0
TOTAL MINABLE RESOURCES	31,702,799	0	2,429,332	34,132,131	33.25	0.66	22,659,334	1.000	22,659,334
AUGER RESOURCES		P	PERCENT						
MINABLE RESOURCES	6,356,606	100.00					12,198,068	100.00	
MINE LOSS RATE	0.70						0.38		
TONS LOST IN MINING	4,449,625	70.00					4,635,266	38.00	
WASH PLANT LOSS RATE	0.00						0.00		
TONS LOST DURING WASHING	0	0.00					0	0.00	
TOTAL TONS RECOVERED	1,906,982	30.00					7,562,802	62.00	
CONTOUR STRIP RESOURCES		PERCENT							
MINABLE RESOURCES	15,577,456	100.00					0	0.00	
MINE LOSS RATE	0.15						0.00		
TONS LOST IN MINING	2,387,906	15.33					0	0.00	
WASH PLANT LOSS RATE	0.00						0.00		
TONS LOST DURING WASHING	0	0.00					0	0.00	
TOTAL TONS RECOVERED	13,189,550	84.67					0	0.00	
MOUNTAIN TOP RESOURCES		PERCENT							
MINABLE RESOURCES	0	0.00					0	0.00	
MINE LOSS RATE	0.00						0.00		
TONS LOST IN MINING	0	0.00					0	0.00	
WASH PLANT LOSS RATE	0.00						0.00		
TONS LOST DURING WASHING	0	0.00					0	0.00	
TOTAL TONS RECOVERED	0	0.00					0	0.00	
RESTRICTED RESOURCES								PERCENT	
RESTRICTED							66,530,641	100.00	
TONS									
ENVIRONMENTAL RESTRICTS							5,625,333	8.46	
TECHNICAL RESTRICTIONS							57,161,468	85.92	
BARRIER RESTRICTIONS							3,743,840	5.63	
RECOVERABLE RESOURCES								PERCENT	
TOTAL							102,653,172	100.00	
RESOURCES									
RESOURCES PREV. MINED							1,990,401	1.94	
RESTRICTED RESOURCES							66,530,641	64.81	
MINING-LOSS RESOURCES							11,472,797	11.18	
WASH-LOSS RESOURCES							0	0.00	
RECOVERABLE RESOURCES							22,659,334	22.07	
RECOVERABLE TONS COST SUMMARY									
	AUGER	CONT. STRIP	MTN. TOP	CONT. MINER	LONGWALL	TOTAL	PERCENT		
TONS OF COAL IN <\$25 RANGE	1,906,982	13,189,550	0	7,562,802	0	22,659,334	100.00		
TONS OF COAL IN \$25-\$30 RANGE	0	0	0	0	0	0	0.00		
TONS OF COAL IN \$30-\$40 RANGE	0	0	0	0	0	0	0.00		
TONS OF COAL IN \$40-\$50 RANGE	0	0	0	0	0	0	0.00		
TONS OF COAL IN >\$50 RANGE	0	0	0	0	0	0	0.00		
TOTALS	1,906,982	13,189,550	0	7,562,802	0	22,659,334	100.00		
CHECK	1,906,982	13,189,550	0	7,562,802	0	22,659,334			

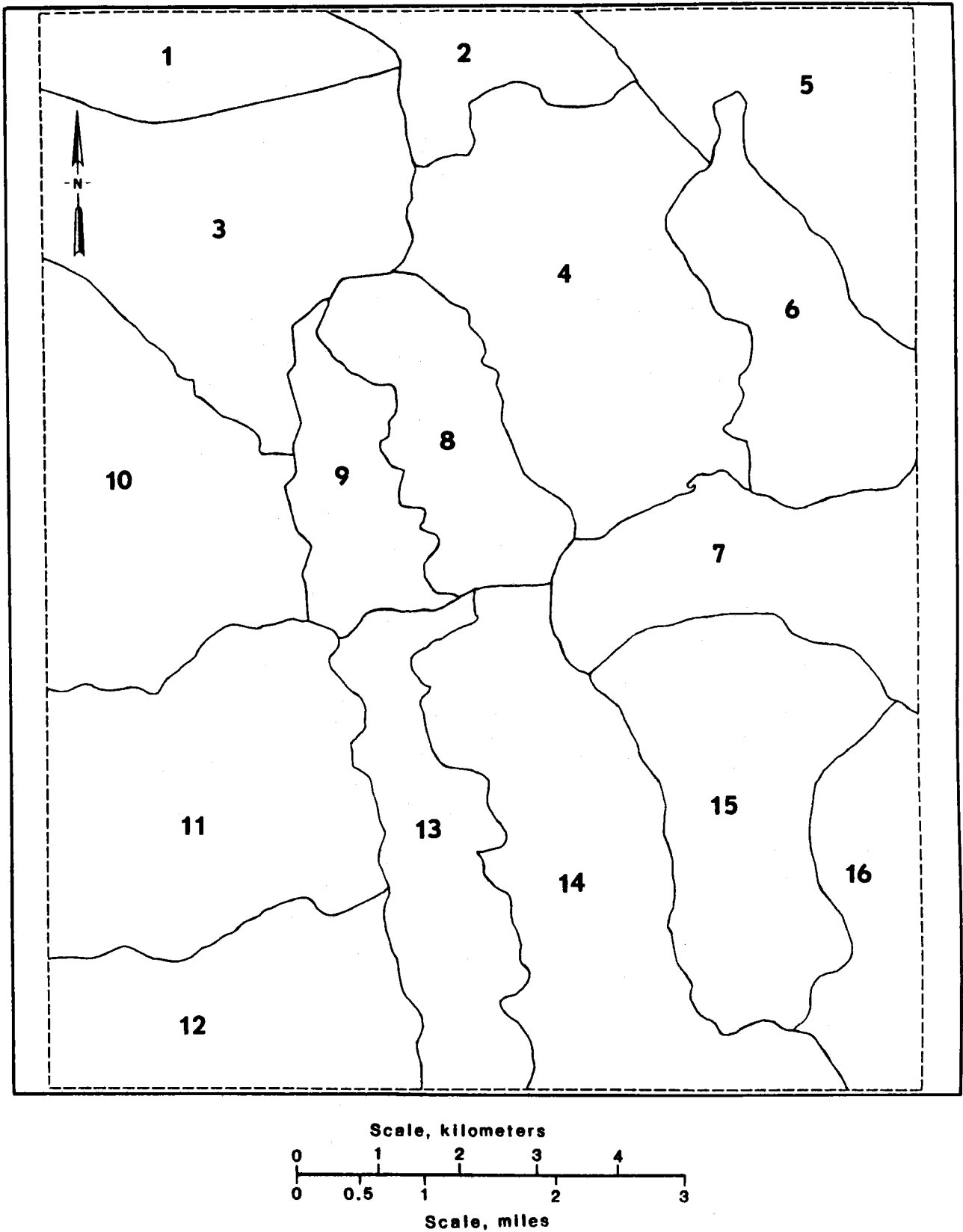


Figure B-2.—Boltsfork quadrangle haulage zones.

APPENDIX C.—COST MODEL EXAMPLE

Once the mining type and the equipment to be used were finalized, the costs and depreciations associated with the equipment were developed. This procedure was done for each mining thickness category using that mining method in order to develop a total cost (f.o.b., rail car) for the coal for each haulage zone. In addition, these models were designed so that they can be updated by entering new information in the assumption list at the front of each model. Only the underground costing model is presented in table C1, but a costing model was developed for each mining thickness category using each mining method.

The number of calculations involved in evaluating up to 25 seams, with as many as 16 haulage zones per seam and 9 types of mining per seam, required that an interactive model be developed. COALVAL (29) accomplished this with Lotus 1-2-3 macros and linkage of spreadsheets.

Costing Models Layout

The productivity of a mine is usually directly related to the thickness of the coal seam being mined. This is true for both surface and underground mining operations. After deciding on the ranges of seam thickness that represented logical breaks in the productivity, the authors collected the mine equipment cost, production data for the equipment, and staffing information that was based on the seam thickness modeled. As much as possible, the model was fashioned after a corporate cost sheet. The major factors were divided into direct and indirect operating costs, overhead, and preparation. The layout of the costing model includes a front page of 32 assumptions used in the cost calculations and a second page summary of the cost involved in operating the particular type of mine. Following that is the heart of the cost model—the specific information and detailed calculations that are used to develop the summary on page 2 of the cost model. Because the same logic and assumptions are used in all models, only the values change from model to model. For each mining method, the model takes into account the:

1. Mining unit: The major equipment required to make up a mining unit, and the number of operating units and shifts worked by each piece of equipment are listed. Then the repair and maintenance (R&M) cost per hour, fuel and lubrication (F&L) cost per hour, and depreciation (DEPREC.) cost per hour are entered. These values are derived from industry data and manufacturers' specifications and pricing lists. The respective costs for R&M,

F&L, and DEPREC. are then calculated for the predefined shift and daily totals. This result is then used in the line item, "DEPRECIATION," on page 2 of the cost model. Costs for depreciation are on a straightline basis and equipment life is relative to industry standards.

2. Payroll: Labor costs consist of three general categories—production staff, auxiliary employees, and mine management and staff. The number of hourly and salaried employees needed to operate a mining unit is determined from USBM publications, in-house property evaluations, published articles, "Coal Mining Technology" (9), and industry experience. The number of divisional and corporate staff (listed in "OVERHEAD" on page 2) depends on the size and structure of the corporation. It has been assumed that one entity owns or manages the entire resource (for maximum recovery), therefore, this study assumes that some divisional and corporate staff is needed, but minimum numbers are used for minimum effect on the profit. For hourly costs, both non-union and union labor wages and burden must be considered. The range for this study uses information from the current labor contract and the norm for non-union mines that have been evaluated in each geographical area. For salary costs, a norm between the most recently published "Coalfield Salary Survey" (26) and salaries observed in USBM mine evaluations has been used. The additional fringe benefit burden rate used is from USBM mine evaluations.

3. Taxes: Tax rates are generally available from each State office of taxation.

4. Development costs: Development costs are the costs associated with developing a property and are amortized on an annual basis.

Other items on the page 2 summary for each model are developed from the original list of assumptions, set out on page 1, and include:

1. Explosives: Drilling and blasting costs applicable to underground mining are not considered due to the exclusive use of continuous miners and longwall mining methods in the study. Surface drilling and blasting costs are derived from industry and USBM publications.

2. Utilities: Utility costs, such as electricity and water, are public information available from the applicable rate control agency.

3. Auto expense: This cost is incurred for the use of vehicles by the supervisory personnel. Industry contacts and USBM mine evaluations are the sources for this information.

4. Insurance: Property insurance is based on a percent per \$100 property valuation. The sources for this expense are industry contacts and USBM mine evaluations.

5. Professional services: The costs include items such as engineering and environmental services, coal crushing and processing, accounting, project management, safety, and training. These costs were obtained from industry contacts.

6. Trucking: One of the highest costs in mine operations is the transportation from the mine to the wash plant/loadout facilities served by the railroad. Based on present preparation plant locations within and around the Boltsfork quadrangle, truck haulage routes and zones were

developed so that loaded trucks haul downhill. Although paved roads pass through some gaps, all travel is confined to the same watershed from which the coal is mined. Mileage calculations are made from the estimated geographic center of each zone and the cost-per-ton mile applied to haul distances. Haulage costs vary from \$0.71 per ton to more than \$1 per ton.

7. Other: Several generalized costs, including road maintenance, roof control material, coal transportation, supplies, licenses, and permits, are accounted for within various other cost categories. These costs were obtained from industry contacts and Bureau mine evaluations.

Table C1. — Standard costing model (example)

CONTINUOUS MINER/ROOM & PILLAR (WITH RETREAT CAVING) — MINE COSTS
(24–42" MINING HEIGHT)

ASSUMPTIONS

394	— RAW TONS PRODUCED/UNIT—SHIFT	
240	— DAYS WORKED/YEAR — PRODUCTION EMPLOYEES	
240	— DAYS WORKED/YEAR — AUXILIARY EMPLOYEES	
2	— NUMBER OF CONTINUOUS MINER UNITS	
2	— SHIFTS/DAY — PRODUCTION	
5	— DAYS/WEEK — PRODUCTION EMPLOYEES	
5	— DAYS/WEEK — AUXILIARY EMPLOYEES	
3	— SHIFTS/DAY — PRODUCTION PLUS MAINTENANCE	
35%	— BURDEN RATE — HOURLY AND SALARY	
110%	— BLACK LUNG TAX (SAME AS \$1.10/TON)	
\$548	— OP. SUPPLIES/UNIT/SHIFT (ROOF SUPPORT MATERIALS, PIPE, ETC.)	
\$0	— EQUIPMENT RENT/UNIT/YEAR	
\$15,508	— GENERAL UTILITIES/MONTH	
\$700	— AUTO EXPENSES/SALARIED EMPLOYEE (PER MONTH)	
\$0.30	— PROPERTY INSURANCE/\$100 OF CAPITAL VALUATION	
\$0.05	— \$/TON PROFESSIONAL SERVICES (PERMITTING, ENGINEERING, ETC.)	
\$362	— GENERAL EXPENSES/UNIT—SHIFT (CONTRACT SERVICES, MISC. EXPENSES)	
\$2.50	— \$/TON ROYALTY RATE	
\$0.15	— \$/TON RECLAMATION TAX (SMCRA)	
\$0.60	— \$/TON DEPLETION	
\$90,000	— OVERHEAD ALLOCATED/YEAR	
\$0.06	— RECLAMATION PROVISION (COST/CLEAN TON)	
\$1.00	— \$/TON RAIL LOADOUT COSTS	
\$2.85	— PREPARATION PLANT COST/RAW TON OF COAL	
\$0.65	— TRUCK HAULAGE COST (\$/RAW TON)	
60%	— % COAL RECOVERED FROM WASH PLANT	
0%	— % RAW MINED COAL DIRECTLY SALEABLE (WITHOUT WASHING)	
13%	— % FACTOR FOR HOURLY PAYROLL (FOR O.T. & PERS. DAYS @ <= FIVE DAYS/WEEK WORK SCHED.)	
18%	— % FACTOR FOR HOURLY PAYROLL (FOR O.T. & PERS. DAYS @ SIX DAYS/WEEK WORK SCHED.)	
18%	— % FACTOR FOR HOURLY PAYROLL (FOR O.T. & PERS. DAYS @ SEVEN DAYS/WEEK WORK SCHED.)	
\$27.00	— COAL SALES PRICE/CLEAN TON (BASED ON QUALITY)	
128,640	— TOTAL EMPLOYEE—HOURS/YEAR	
18.82	— CLEAN TON/EMPLOYEE—SHIFT	
23.52	— RAW TONS/EMPLOYEE—SHIFT	
\$29.24	— COST IN CAR	

ALSO:

- THE CM MINE IS SET UP WITH TWO COMPLETE PRODUCTION UNITS. EQUIPMENT IS SCHEDULED FOR TWO SHIFTS/DAY, FIVE DAYS/WEEK, WITH GENERAL AND PREVENTATIVE MAINTENANCE AND BELT MOVES SCHEDULED FOR THE THIRD SHIFT EACH DAY, FIVE DAYS/WEEK.
- REPAIR, SUPPLY, AND SUPPORT EQUIPMENT WILL BE SHARED BETWEEN PRODUCTION UNITS.
- ALL SURFACE SITE MAINTENANCE (SUCH AS SNOW REMOVAL AND ROAD MAINTENANCE) WILL BE DONE BY THE SURFACE MINING OPERATIONS.
- PRODUCTIVITY IS ASSUMED TO BE A FUNCTION OF MINING HEIGHT AND MINING HEIGHTS ARE ASSUMED TO BE SEAM THICKNESS.
- UNDERGROUND MINING CONFIGURATIONS LESS THAN 42" CONTRIBUTE 4" OF OUT-OF-SEAM DILUTION. CONFIGURATIONS GREATER THAN 42" CONTRIBUTE 2" OF DILUTION (UNDER IDEAL CONDITIONS).

Table C1.—Standard costing model (example)—Continued

TWO CONT. MINER UNITS (24 -42" MINING HEIGHT)		
RAW TONS PER YEAR	378,240	
CLEAN TONS	302,592	
		COST/TON
DIRECT COSTS		
PAYROLL	\$2,484,775	\$8.21
BURDEN	\$869,671	\$2.87
FUEL & LUBES	\$88,932	\$0.29
EXPLOSIVES	\$0	\$0.00
OTHER PRODUCTION SUPPLIES	\$526,132	\$1.74
REPAIR PARTS/MAINT.SUPL.	\$417,720	\$1.38
UTILITIES	\$186,094	\$0.62
EQUIPMENT RENTAL	\$0	\$0.00
AUTO EXPENSE	\$58,800	\$0.19
PROFESSIONAL SERVICES	\$15,130	\$0.05
RECLAMATION PROVISION	\$18,156	\$0.06
TRUCKING	\$245,856	\$0.81
GENERAL EXPENSES	\$347,603	\$1.15
TITLE COST	\$1,077,984	\$3.56
DEPRECIATION	\$446,769	\$1.48
TOTAL DIRECT COSTS	\$6,783,621	\$22.42
INDIRECT COSTS		
DEPLETION	\$181,555	\$0.60
MINE DEV. AMORTIZATION	\$185,243	\$0.61
OVERHEAD	\$90,000	\$0.30
INSURANCE	\$14,865	\$0.05
TOTAL INDIRECT COSTS	\$471,663	\$1.56
TAXES	\$836,458	\$2.76
ROYALTIES	\$756,480	\$2.50
COST IN CAR	\$8,848,222	\$29.24

Table C1.—Standard costing model (example)—Continued

PRODUCTION EQUIPMENT	EQUIPMENT OPERATING COST CALCULATIONS									
	# UNITS 1ST SHIFT	# UNITS 2ND SHIFT	# UNITS 3RD SHIFT	HRS WORKED PER SHIFT	TOTAL R&M PER DAY	TOTAL F&L PER DAY	TOTAL DEPR PER DAY	R&M PER HOUR	F&L PER HOUR	DEPR PER HOUR
CONTINUOUS MINERS	2	2	0	8	\$848.00	\$123.20	\$960.00	\$26.50	\$3.85	\$30.00
SHUTTLE CARS	4	4	0	8	\$416.00	\$112.00	\$420.16	\$6.50	\$1.75	\$6.57
ROOF BOLTERS	2	2	0	8	\$176.00	\$48.00	\$227.68	\$3.50	\$1.50	\$7.74
SCOOPS	2	2	0	8	\$136.00	\$32.00	\$98.88	\$4.25	\$1.00	\$3.09
SURF-4cy LOADER	1	0	0	4	\$20.00	\$17.44	\$20.60	\$5.00	\$4.36	\$5.15
GRADER	1	0	0	1	\$4.00	\$3.16	\$4.79	\$4.00	\$3.16	\$4.79
DAILY TOTAL	12	10	0		\$1,600.00	\$335.80	\$1,752.11			
ANNUAL TOTAL					\$384,000	\$80,592	\$420,505			
AUXILIARY EQUIPMENT	# UNITS 1ST SHIFT	# UNITS 2ND SHIFT	# UNITS 3RD SHIFT	HRS WORKED PER SHIFT	TOTAL R&M PER DAY	TOTAL F&L PER DAY	TOTAL DEPR PER DAY	R&M PER HOUR	F&L PER HOUR	DEPR PER HOUR
UTILITY SCOOP	1	1	1	8	\$96.00	\$24.00	\$74.16	\$4.00	\$1.00	\$3.09
PERSONNEL CARRIERS	3	3	1	1	\$17.50	\$3.50	\$8.05	\$2.50	\$0.50	\$1.15
ROCK DUSTER	1	0	0	1	\$1.00	\$0.25	\$0.96	\$1.00	\$0.25	\$0.96
SPARE SHUTTLE CARS	2	2	0	1	\$26.00	\$7.00	\$26.26	\$6.50	\$1.75	\$6.57
DAILY TOTAL	7	6	2		\$140.50	\$34.75	\$109.43			
ANNUAL TOTAL					\$33,720	\$8,340	\$26,264			
ANNUAL GRAND TOTAL					\$417,720	\$88,932	\$446,769			

Table C1.—Standard costing model (example)—Continued

PAYROLL	# OF EMPS 1ST SHIFT	# OF EMPS 2ND SHIFT	# OF EMPS 3RD SHIFT	HR/SHIFT	PAYROLL RATE/DAY	GRADE	BASE RATE	RATE/HR 1st SHIFT	RATE/HR 2nd SHIFT +0.30/hr	RATE/HR 3rd SHIFT +0.40/hr
PRODUCTION EMPLOYEES										
CONT. MINER OPER.	2	2	2	0	\$561.40	5	\$16.615	\$17.39	\$17.69	\$17.79
CONT. MINER HELPER	2	2	2	0	\$547.84	4	\$16.210	\$16.97	\$17.27	\$17.37
SHUTTLE CAR OPER.	4	4	4	0	\$1,071.08	3	\$15.843	\$16.59	\$16.89	\$16.99
ROOF BOLTER OPER.	4	4	4	0	\$1,122.81	5	\$16.615	\$17.39	\$17.69	\$17.79
SCOOP OPERATOR	2	2	2	0	\$555.54	3	\$15.843	\$16.59	\$16.89	\$16.99
Table continues to right and down										
TOTAL - 1ST. SHIFT	14	14	14		\$1,902.53					
TOTAL - 2ND. SHIFT				0	\$1,936.13					
TOTAL - 3RD. SHIFT				0	\$0.00					
TOTAL PRODUCTION PAYROLL	28				\$3,838.66					
OVERTIME FACTOR					0.13					
TOTAL WITH O.T. PAY					\$4,337.69					
AUXILIARY EMPLOYEES										
SCOOP OPERATOR	1	1	1	0	\$267.77	3	\$15.843	\$16.59	\$16.89	\$16.99
POCKETMEN	2	2	2	0	\$535.54	3	\$15.843	\$16.59	\$16.89	\$16.99
SUPPLY MEN	1	1	1	0	\$262.83	1	\$15.548	\$16.28	\$16.58	\$16.68
LAMPMAN/WAREHSE	1	1	1	0	\$262.83	1	\$15.548	\$16.28	\$16.58	\$16.68
BELT MAINT/CLEANUP	2	2	2	2	\$792.49	1	\$15.548	\$16.28	\$16.58	\$16.68
MECHANICS	2	2	2	4	\$1,130.81	5	\$16.615	\$17.39	\$17.69	\$17.79
ELECTRICIANS	1	1	1	1	\$423.05	5	\$16.615	\$17.39	\$17.69	\$17.79
SURF. UTILITY OPER.	1	0	0	0	\$132.69	3	\$15.843	\$16.59	\$16.89	\$16.99
TOTAL - 1ST. SHIFT	11	10	10		\$1,469.05					
TOTAL - 2ND. SHIFT				7	\$1,360.37					
TOTAL - 3RD. SHIFT					\$978.58					
TOTAL AUXILIARY PAYROLL	28				\$3,808.00					
OVERTIME FACTOR					0.13					
TOTAL WITH O.T. PAY					\$4,303.04					
TOTAL HRLY EMPLS PER SHIFT	25	24	24	7						
TOTAL HOURLY EMPLOYEES	56									
TOTAL ANNUAL HOURLY PAYROLL					\$2,073,775					

Table C.1.—Standard costing model (example)—Continued

MINE MANAGEMENT AND STAFF	# EMPL			# EMPL 2ND SHIFT	# EMPL 3RD SHIFT	BASE SALARY		TOT SALARY PER YEAR
	1ST SHIFT					PER YEAR	PER YEAR	
GENERAL MANAGER	1					\$7,000	\$7,000	\$7,000
PRODUCTION FOREMEN	2			2		\$42,000	\$42,000	\$168,000
MAINT. FOREMEN	1				1	\$40,000	\$40,000	\$80,000
MINE ACCT/PUR. AGENT	1					\$40,000	\$40,000	\$40,000
MINE CLERK	1					\$18,000	\$18,000	\$18,000
TECHS/SURVEYORS	2					\$24,000	\$24,000	\$48,000
TOTAL ANNUAL SALARY								\$411,000
NUMBER OF EMPLOYEES WITH COMPANY AUTOS				7				
TOTAL SALARIED EMPLOYEES				11				
TOTAL RAW TONS PROD. COAL PER YEAR					378,240			
% RAW SALABLE					0%			
RAW TONS SALABLE					378,240			
RAW TONS COAL TO WASHER					378,240			
% REC					80%			
CLEAN TONS WASHED COAL					302,592			
TOTAL TONS COAL SOLD					302,592			
TIPPLE COST						COST/ YEAR		
RAIL LOADOUT (RAW COAL)		\$1.00		0	\$0			
PREP PLANT (WASHED COAL)		\$2.85		378,240	\$1,077,984			
TOTAL TIPPLE COST					\$1,077,984			
TAXES	TAX RATE	TAXED PRODUCT	COST/ YEAR	COST PER TON				
SALES	5.00%	\$1,652,146	\$82,607	\$0.27				
SEVERANCE	4.50%	302,592	\$336,586	\$1.18				
REAL PROPERTY	\$1.09	\$185,243	\$604	\$0.00				
TANGIBLE PROPERTY	\$1.13	\$4,984,900	\$16,855	\$0.06				
RECLAMATION (SMCRA)	\$0.15	302,592	\$45,389	\$0.15				
STATE MINL TAX (UNMINED)	\$0.21	302,592	\$1,566	\$0.01				
BLACK LUNG TAX	\$1.10	302,592	\$332,851	\$1.10				
TOTAL TAX/ YEAR			\$836,458	\$2.76				

TAX DEFINITION: 1) Sales taxes are based on the total capital cost 8 yr. ave. life + annual taxable items.
 2) Severance taxes are based on the sold tons times their realization, minus the cost of road transportation.
 3) Real property taxes are based on 30% of the assessed valuation times the amortization (property + buildings + improvements) times the tax rate.
 4) Tangible property tax is based on the total capital cost times the property assessment rate times the tax rate.
 5) Federal reclamation taxes are based on the sold tons times the tax rate.
 6) State mineral taxes on unmined reserves (annual planned production) is based on the sold tons times the coal value (usually the royalty rate) times the tax rate.
 7) Black lung taxes are based on sold tons times tax rate.

TAX RATES: PER \$100 OF ASSESSED VALUATION

STATE	COUNTY	STATE	COUNTY	STATE MINL
REAL PROP	REAL PROP	TANG PROP	TANG PROP	TAX
0.45	0.6365	0.45	0.6839	\$0.21

CONSTANTS:

COAL	PROP	BLACK LUNG
VALUE/T	ASSESS	TAX
\$2.50	30.00%	\$1.10
SEVERANCE	SALES	
TAX	TAX	
4.50%	5.00%	

Table C1.—Standard costing model (example)——Continued

CAPITAL EQUIPMENT SELECTION									
UNDERGROUND CONTINUOUS MINER — 2 PRODUCTION UNITS									
	NO.	(24–42" MINING HEIGHT)				ANNUAL		TOTAL	ANNUAL
	UNITS	TOTAL HRS	UNIT COST	DEPR TERM	HOURLY	STR. LINE	EQUIPMENT	EQUIPMENT	DEVELOPMENT
		PER DAY		(IN HRS)	DEPREC	DEPREC	COSTS	AMORTIZATION	
PRODUCTION EQUIPMENT									
CONTINUOUS MINERS	2	32	\$600,000	20,000	\$30.00	\$230,400	\$1,200,000	—	—
SHUTTLE CARS	4	64	\$131,300	20,000	\$6.57	\$100,838	\$525,200	—	—
ROOF BOLTERS	2	32	\$154,800	20,000	\$7.74	\$59,443	\$309,600	—	—
SCOOPS	2	32	\$61,800	20,000	\$3.09	\$23,731	\$123,600	—	—
SURF—4cy LOADER	1	4	\$206,000	40,000	\$5.15	\$4,944	\$206,000	—	—
GRADER	1	1	\$134,000	28,000	\$4.79	\$1,149	\$134,000	—	—
AUXILIARY EQUIPMENT									
UTILITY SCOOP	1	24	\$61,800	20,000	\$3.09	\$17,798	\$61,800	—	—
PERSONNEL CARRIERS	3	7	\$46,000	40,000	\$1.15	\$1,932	\$138,000	—	—
ROCK DUSTER	1	1	\$38,500	40,000	\$0.96	\$231	\$38,500	—	—
SPARE SHUTTLE CARS	2	4	\$131,300	20,000	\$6.57	\$6,302	\$262,600	—	—
FEEDER/BREAKERS	2	48	\$109,800	20,000	\$5.49	—	\$219,600	\$63,245	—
VENTILATION SYSTEM	1	24	\$96,000	87,600	\$1.10	—	\$96,000	\$6,312	—
BELT SYSTEM	1	24	\$873,000	87,600	\$9.97	—	\$873,000	\$77,403	—
POWER CENTERS	2	48	\$43,200	87,600	\$0.49	—	\$86,400	\$5,681	—
SURFACE SUPPORT AND FACILITIES									
SHOP/WAREHOUSE FACILITIES	1	24	\$40,000	87,600	\$0.46	—	\$40,000	\$2,630	—
OFFICE/CHANGE FACILITIES	1	24	\$36,000	87,600	\$0.41	—	\$36,000	\$2,367	—
ACCESS/HAUL ROADS	1	24	\$250,000	87,600	\$2.85	—	\$250,000	\$16,438	—
SITE—SURFACE DEVELOPMENT	1	24	\$18,000	87,600	\$0.21	—	\$18,000	\$1,210	—
UG COMPRESSORS & LINES	2	48	\$50,000	40,000	\$1.25	—	\$100,000	\$14,400	—
WATER/SEWAGE TREAT. FAC.	1	24	\$60,000	87,600	\$0.68	—	\$60,000	\$3,945	—
SURF POWER SUB/TRANS LINES	1	24	\$96,600	87,600	\$1.10	—	\$96,600	\$6,352	—
SURFACE EQUIPMENT									
120' STACKER CONVEYORS	1	24	\$80,000	87,600	\$0.91	—	\$80,000	\$5,260	—
LEASED COAL TRUCK HAULAGE	—	—	—	—	—	—	—	—	—
ANNUAL DEPRECIATION/AMORTIZATION COSTS						\$446,769		\$185,243	
TOTAL CAPITAL EQUIPMENT COSTS							\$4,954,900		

Table C.1.—Standard costing model (example)—Continued

UMWA WAGES – 1988 CONTRACT, UNDERGROUND MINING		02/01/90	
EFFECTIVE DATE			
GRADE 5 – BASE HOURLY RATE		\$16,615	
GRADE 4 – BASE HOURLY RATE		\$16,210	
GRADE 3 – BASE HOURLY RATE		\$15,843	
GRADE 2 – BASE HOURLY RATE		\$15,620	
GRADE 1 – BASE HOURLY RATE		\$15,548	
TRAINING RATES		\$14,974	
UNION WORK CLASSIFICATIONS – UNDERGROUND MINING			

A. CONTINUOUS MINING MACHINE OPERATOR	GRADE 5	E. LONGWALL MACHINE OPERATOR	
B. ELECTRICIAN		F. WELDER, FIRST CLASS	
C. MECHANIC		G. ROOF BOLTER	
D. FIREBOSS			
A. CUTTING MACHINE OPERATOR	GRADE 4	F. ROCK DRILLER	
B. DISPATCHER		G. CONTINUOUS MINER HELPER – TRAINEE	
C. LOADING MACHINE OPERATOR		H. ROOF BOLTER HELPER – TRAINEE	
D. MACHINE OPERATOR HELPER		I. MAINTENANCE TRAINEE (MAX. 12 MOS.)	
E. GENERAL INSIDE REPAIRMAN AND WELDER		J. ELECTRICIAN TRAINEE (MAX. 12 MOS.)	
A. DRILLER – COAL	GRADE 3	D. FACEMAN	
B. SHOOTER		E. DUMPER	
C. PRECISION MASON (CONSTRUCTION)		F. SHUTTLE CAR OPERATOR	
A. MOTORMAN	GRADE 2	D. ELECTRICIAN HELPER	
B. MAINTENANCE TRAINEE (MAX. 6 MOS.)		E. MECHANIC HELPER	
C. ELECTRICIAN TRAINEE (MAX. 6 MOS.)			
A. BELTMAN	GRADE 1	G. PUMPER	
B. BONDER		H. TIMBERMAN	
C. BRAKEMAN		I. TRACKMAN	
D. BRATTICEMAN		J. WIREMAN	
E. GENERAL INSIDE LABOR		K. LABOR – UNSKILLED	
F. MASON			