AN ASSESSMENT OF COAL RESOURCES AVAILABLE FOR DEVELOPMENT

CENTRAL APPALACHIAN REGION

- FIRST YEAR SUMMARY -

by
M. Devereux Carter
and
Nancy K. Gardner

U. S. Geological Survey
in Cooperation with
Kentucky Geological Survey, James C. Cobb, Head, Coal Section
Virginia Division of Mineral Resources, Elizabeth V. M. Campbell, Applied Geology Section
West Virginia Geological and Economic Survey, Nick Fedorko, Head, Coal Section

U.S. GEOLOGICAL SURVEY
Open-File Report 89-362
Reston, Virginia
1989

DEPARTMENT OF THE INTERIOR
Manuel Lujan, Jr., Secretary
U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

For additional information
write to:

Branch of Coal Geology
U.S. Geological Survey
956 National Center
Reston, Virginia 22092

Copies of this report can be
purchased from:

U.S. Geological Survey
Books and Open-File Reports Section
Box 25425
Federal Center, Bldg. 810
Denver, Colorado 80225

EXECUTIVE SUMMARY

Current Federal estimates of the Nation's coal resources, for example Averitt (1975), do not account for many factors that could inhibit the availability of coal for development, and, consequently, may be mistakenly optimistic for long-term policy planning purposes. A cooperative program between the U.S. Geological Survey (USGS) and the State geological agencies of Kentucky, Virginia, and West Virginia was initiated in 1987 and continued in 1988 to identify the major current constraints to coal mining that could inhibit availability of the coal resources within the Central Appalachian Region and to estimate the amount of coal resources actually available for development in that region. A methodology was developed and tested in four 7.5-minute quadrangle areas to determine if the identified constraints to mining in the region would materially affect the availability of coal for development. The results from these four study areas suggest that constraints to mining would have significant impact because it is estimated that only about 60 percent of the original coal resources of these study areas will be available or accessible for mining, and that is before recovery factors are applied. The amount of coal that may actually be recoverable may only be about 30 to 40 percent of the original resources.

The four 7.5-minute quadrangle areas covered by this report were selected to be representative of their general localities so that the results obtained from these four might be extrapolated to other areas in the surrounding region. A pilot study to test the feasibility and proposed methodologies was completed early in 1988. The first three quadrangle studies to be formally funded under the cooperative program were completed in September, 1988. Findings of all four study areas are summarized herein.

Restrictions to mining were identified by consultation with local coal-industry engineers, geologists, and mine operators, as well as State and Federal regulatory personnel. Land-use restrictions applicable to the four study areas were power lines, pipelines, cemeteries, oil and gas wells, towns, major streams, public roads, railroads, and one large forest preserve. Technologic restrictions included coal beds considered too thin or too deep to mine, buffer zones around active or abandoned mines, mined and minable coal beds too close above or below one another, oil and gas wells penetrating underground-minable coal beds, and such geological factors as washouts (erosional events that removed coal precursors and sometimes coal) and organic constituents that prevent complete and rapid burning of the coal. Graphic and resource calculation programs of the USGS *National Coal Resources Data System* (NCRDS) were applied to combine and manipulate all coal bed thickness and depth-of-burial data with the

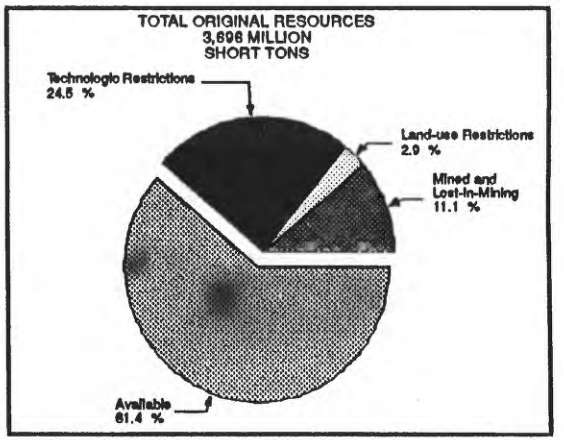
constraints to mining, and then to calculate original, remaining, and available coal resource tonnages.

Although there is a wide variation among the individual resource categories, the overall results are remarkably consistent for the four study areas. Approximately 61 percent (ranging from 58 to 64 percent) of the original resource is estimated to be available for mining. Coal mined and lost-in-mining accounts for 11 percent of the reduction of the original resource, while land-use restrictions comprise 3 percent, and technologic restrictions 25 percent. Of all restrictions, land-use totals about 11 percent and technologic about 89 percent. Together, these restrictions reduce the remaining resource by about one-third. Approximately one billion tons of coal are estimated to be rendered unavailable for mining by land-use and technologic restrictions within the four areas of study.

Noncompliance to new-source performance sulfur dioxide (SO_2) emission standards is not considered a restriction to mining; however, it can be a factor in the marketability of a coal, making it less attractive than a nearby competitive compliance coal. Chemical data are sparse in the four areas studied However, statistical analyses of those beds with available sulfur data indicate that approximately one-half of the available coal resources in these areas could be expected to meet current new-source performance standards of 1.2 pounds SO_2 per million Btu input.

Economic considerations (e.g., mining costs, available transportation, and proximity to markets) and the application of recovery factors were beyond the scope of this study. If applied, these factors would certainly further reduce the amount of coal currently estimated to be available. In any case, it seems evident that less than one-half of the coal resources remaining in these study areas will ever be mined.

As expected, results of the first four studies are inconclusive in terms of delineating regional trends. Studies in about 20 strategically placed 7.5-minute quadrangle areas may be necessary to adequately represent the entire Central Appalachian Region. A total of nine 7.5-minute quadrangle area studies will have been completed by September, 1989; the four summarized in this report and five more in preparation. It is estimated that about 15 studies will be needed before extrapolation of results into the surrounding region could begin, but this will be monitored on a continuing basis.



Contents

List of Figures

List of Tables

CONVERSION FACTORS

To convert from	To	Multiply by
Inches (in.)	Centimeters	2.54
Foot, feet (ft)	Meters	0.3048
Miles (mi)	Kilometers	1.609344
Tons, short (2000 lbs)	Tons, metric (2,204.6 lbs)	0.90718474

Chapter 1

INTRODUCTION

Assessments of the coal resources of the United States generally report the tonnage estimates only in terms of the location, bed thickness, overburden depth, and an estimate of the reliability of the measurements used. While this provides an important basic foundation, current Federal estimates of the Nation's coal resources may not account for many factors that could inhibit development of the coal, and, consequently, may be mistakenly optimistic for long-term policy planning purposes.

This report summarizes the results of studies in the first four 7.5-minute quadrangle areas of a continuing, cooperative assessment of the coal resources actually available for development in the coal fields of the Central Appalachian Region States of Kentucky, Tennessee, Virginia, and West Virginia (fig. 1). The subject studies will be referred to hereinafter as *coal-availability studies*, or *program*, and the overall study area as the Central Appalachian Region.

The coal-availability program was started in 1987 with a pilot study in the Matewan 7.5-minute quadrangle, Pike County, Kentucky (fig.1), and was subsequently expanded in fiscal years (FY) 1988 and 1989 to include eight additional 7.5-minute quadrangle areas in Kentucky, Virginia, and West Virginia. A summary report on the second group of five studies will be completed soon after the end of FY 1989. All nine studies will have been conducted in cooperation with the geological surveys of Kentucky, Virginia, and West Virginia; areas in Tennessee will be included in future studies.

The coal-availability program was developed to improve upon the quality and usefulness of previous coal-resource assessments (for example, Averitt, 1975) by estimating the location and amount of the remaining resource that might actually be available for development under current regulatory and general economic and technologic conditions. Development at this time means, for all practical purposes, surface (strip, auger) or underground (deep) mining; however, if other technologies for recovering coal or coal energy are adopted in the near future, the results and methodology described herein will be applicable to them as well.

Coal-availability assessments require a large amount of detailed work at reasonably large map scales in order to pro-

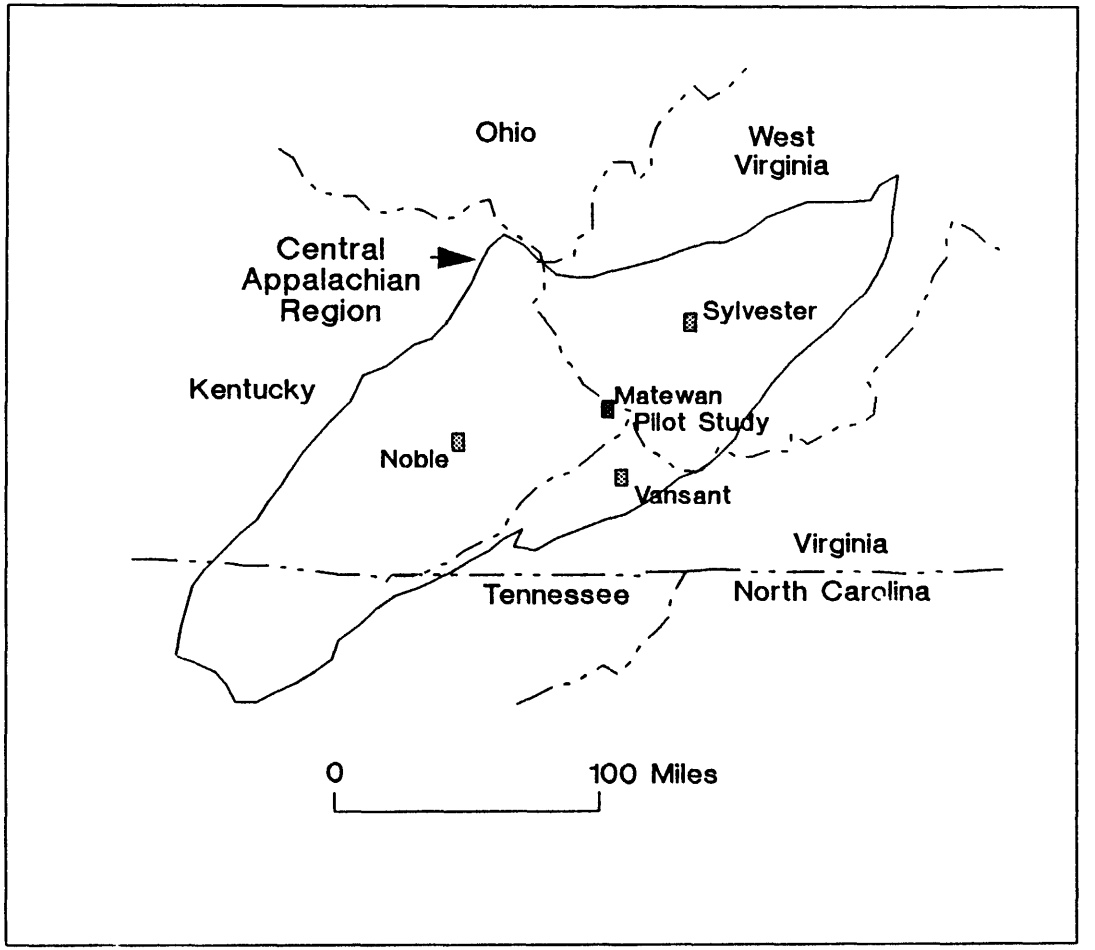


Figure 1. — Index map of the Central Appalachian Region showing the location of the first four 7.5-minute quadrangle study areas of the **Coal Resources Available for Development** assessment.

duce meaningful results. The 7.5-minute quadrangle map (1:24,000 scale) area was selected for a variety of reasons that are discussed in detail in the Methods section. In the Central Appalachian Region, each 7.5-minute quadrangle covers an area of about 59 square miles. The coal-availability assessment process is carried out by application of a geographic information system (GIS) of the USGS's *National Coal Resources Data System* (NCRDS) to each of the 7.5-minute quadrangle study areas. Coal-availability assessments are produced by subtracting actual areas of coal beds that have been mined (and lost-in-mining) and areas affected by specified categories of regulatory and technologic restrictions to mining from estimated amounts and areas underlain by original in-place coal resources, on a bed-by-bed basis. The result provides the location as well as the amount of the estimated available coal resources in each study area insofar as regulatory prohibitions and technologic restrictions to mining are, or can be, reflected in: 1) specific local laws and practices; 2) coal-bed thickness, continuity, depth, and coal quality; 3) proximity of one coal bed to another; and 4) reliability of original resource estimates.

As described, the coal-availability program would appear to require very large resources of time and funds in order to achieve the detail necessary to reliably predict coal availability for any given region. However, because of the methodology and procedures developed by the USGS in cooperation with the aforementioned State geological surveys (Eggleston and others, in preparation), only modest resources per study area are currently required for this work.

The current approach to the problem of the development of adequate detail in a cost-effective manner is to study a representative sample of 7.5-minute quadrangle areas within each major coal-bearing region in the conterminous United States. The Central Appalachian Region was chosen as the first region for a test of the program because it contains the largest resources of low-sulfur coal in the eastern United States, the geology of the region is reasonably well known, and the Central Appalachian Region States of Kentucky, Virginia, and West Virginia have a history of productive cooperation with the NCRDS. Through careful selection, it is currently estimated that only about 20, out of about 450, 7.5-minute quadrangle areas will have to be studied in the Central Appalachian Region in order to predict the availability of coal for development throughout the entire region. The problem of the extrapolation of individual study-area results is the subject of continuing research, however, and the current plan will be reevaluated after the first 15, or so, study areas have been completed.

The methodology and practices described do not identify "coal reserves" (i.e., recoverable coal) in the strict sense. The coal availability program does not yet take into account the details of land and resource ownership, minimum mine sizes, mining methods, coal recoverability, or markets that would be required to identify "reserves". However, research is being conducted at the U.S. Bureau of Mines (USBoM) in cooperation with the USGS, to develop a methodology to incorporate some or all of these "reserve identifying" factors into the coal-availability program at some future time. One major benefit of the GIS approach to this program is that it enables any study to be revised and/or updated as new data become available.

1.1 ACKNOWLEDGEMENTS

This report is the result of a multi-agency project that has included significant contributions by a number of persons in addition to those cited in the text and in the References Cited section.

Many of the NCRDS staff provided invaluable data entry, editing, and programming assistance. Noreen H. Rega, Paula M. Washington, and Sara L. Banks entered the stratigraphic data. Andre D. Bush processed the digitized boundary files. Kathleen K. Krohn managed the data base aspects of the project. Margaret F. Johnson and Meng-Cherng Sun each made significant modifications to the NCRDS graphics programs that greatly enhanced the proficiency of the system. William G. Miller, manager of NCRDS, orchestrated the vital hardware, software, and telecommunications changes that allowed completion of this initial phase of the project within the required time frame and typeset the final text of this report.

Gerry Lebing and Sharon A. Harris of the USGS Information Systems Division provided frequent assistance in generating the graphic illustrations for this report.

Following the Matewan quadrangle pilot study (fig. 1), the ensuing three study areas (fig. 1) were accomplished through USGS-State cooperative agreements. Duleep I. Pandite and Robert D. Ashworth of the USGS Administrative Division are commended for so ably emplacing the cooperative agreements in an unusually short amount of time essential in getting the 1988 area studies underway.

Under the USGS-State cooperative agreements, the Principal Investigators of the State geologic agencies, James C. Cobb of the Kentucky Geological Survey, Stanley S. Johnson of the Virginia Division of Mineral Resources, and Thomas R. Jake of the West Virginia Geological and Economic Survey provided the essential link between the USGS and State project geologists. Under their leadership, the cooperative projects ran smoothly and the three new studies were completed on schedule. The highly competent and enthusiastic professionals of these agencies ensured the success of this project.

Special thanks go to Harold J. Gluskoter and Stanley P. Schweinfurth, USGS Branch of Coal Geology, for support throughout the project.

Chapter 2

METHODS

To assess the available coal resources of the entire Central Appalachian Region by studying the region in the detail necessary to produce meaningful results would be a monumental task. To do this in a timely and cost-effective manner requires that areas of manageable size and significance be identified to serve as models to ultimately allow extrapolation of results into the areas between models and to the regions beyond. The 7.5-minute quadrangle was selected as the ideal study scale for several important reasons: 1) a 1:24,000-scale map has proven optimal for general purpose geologic and resource mapping in the United States; 2) because of its widespread utility, base maps, geologic maps, and digital elevation models (DEM's) commonly are available at this scale; 3) focusing on a selected group of these relatively small areas, 50 to 65 square miles, allows consideration of the effects of a large number of restrictions that would be difficult and prohibitively expensive to accomplish on an entire coal region or even a coal field basis.

Computer techniques were a critical component in handling the multitude of parameters considered, overlain, combined, and calculated. The USGS provided the NCRDS with its stratigraphic and geochemical data bases, GIS capabilities, and programs to manipulate data and calculate available coal resources according to the classification system of the USGS (Wood and others, 1983). The computer also permitted relatively quick and easy updates as restrictions were added or modified and new estimates generated.

State geological agency personnel met with local coal industry engineers, geologists, and mine operators, as well as State and Federal regulatory personnel, who were familiar with local mining practices and with regulations as they applied to these practices, to determine the specific constraints applicable within their specific study areas. State personnel were responsible for all collection, evaluation, and correlation of coal data; encoding of stratigraphic data and digitizing of line data; and editing and validation of data in the system. State personnel also performed all computer manipulation (gridding, contouring, combining, resource calculation, and tabulation) in three of the four study areas. The USGS primarily developed the methodology and coordinated the pro-

gram to ensure the maintenance of standards and consistency. The USGS also provided data entry and storage, as well as interactive access to the data bases and software necessary to utilize the data and calculate available resources. The USGS further provided computer training and assistance to State personnel throughout the project. Research is continuing into the appropriate methodology for extrapolating the results obtained from each study area to the larger coal area it represents and ultimately to the entire region.

Buffer zones in which mining is not permitted were drawn around many of the surficial and underground features to be included as a part of the areas restricted from mining. Areas adjacent to surficial features that are restricted from mining, e.g., 100-ft buffer zones around power lines and pipelines, were digitized by the State agency personnel. Unminable buffer zones surrounding oil and gas wells and cemeteries were generated by NCRDS GIS graphics programs. NCRDS personnel accessed the USGS Information Systems Division's ARC/INFO GIS to delineate unminable buffer zones around active or abandoned underground mines, which were then returned to NCRDS programs for further GIS processing.

Prior to the initiation of the cooperative program, a pilot study (fig. 1) was performed to develop the methodology and to test the applicability of NCRDS software to the program requirements. In fact, the methodologies were modified and NCRDS subroutines were enhanced as the project progressed. For the pilot study, all data were provided by the Kentucky Geological Survey, and all computer data manipulation and resource calculation and tabulation were performed by the USGS. The methodology developed during the pilot study and the summary results of that study are documented in Eggleston and others (in preparation). The methodology established in the pilot study provided the framework for the additional three study areas described herein.

Chapter 3

STUDY AREAS

The four study areas (fig. 1) were selected to be representative of the topography, geology, culture, and mining practices of their respective localities. All have large coal resources and major active mining operations. The Matewan 7.5-minute quadrangle in Pike County, Kentucky, was the pilot-study area jointly studied by the Kentucky Geological Survey and the USGS; detailed results are presented in Carter and others (in preparation). Approximately 10 percent of the Matewan quadrangle lies in West Virginia, and that part was excluded in the Matewan study. The Noble quadrangle, Breathitt, Perry, and Knott Counties, Kentucky, was assessed by the Kentucky Geological Survey; detailed results are documented in Sergeant and others, 1988. The Sylvester quadrangle, Boone and Kanawha Counties, West Virginia, was assessed by the West Virginia Geological and Economic Survey; detailed results are reported in Blake and Fedorko, 1988. The Vansant quadrangle, Buchanan County, Virginia, was studied by the Virginia Division of Mineral Resources; detailed results are in Campbell and Sites, 1988.

All four quadrangles are rural areas with rugged, deeply dissected terrain characteristic of the Central Appalachian Region. Surface-mining practices in the region include contour, mountaintop removal, and augering. Deep-mining practices include room-and-pillar and long wall. All of the coal beds occur in rocks of Early and Middle Pennsylvanian age (fig. 2). The coal-bearing sections range from 800 to 2,600 feet in thickness and contain 10 to 21 potentially minable coal beds. Interburden thicknesses vary from 10 to 350 feet. Most coal beds occur higher than the valley bottoms so that surface and underground drift mines predominate, except in the Vansant quadrangle where most of the mining is from shaft mines in the subsurface Pocahontas No. 3 coal bed.

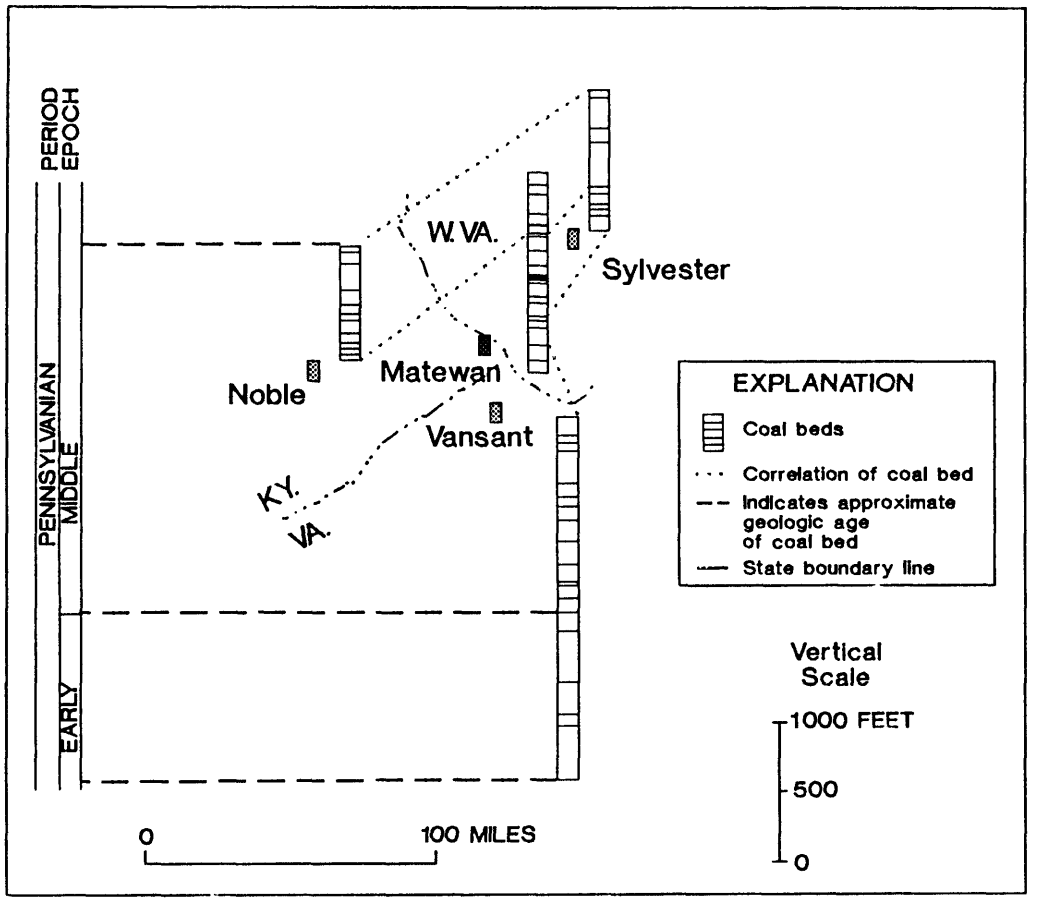


Figure 2. — Relative stratigraphic positions of the coal-bearing strata underlying the Matewan, Noble, Sylvester, and Vansant 7.5-minute quadrangles, Kentucky, West Virginia, and Virginia.

Chapter 4

RESTRICTIONS USED

For this summary report, the restrictions to mining were subdivided into two major categories — *land-use* and *technologic*.

Land-use restrictions are placed upon mining by societal policies to preserve those surface features or entities that could be adversely affected by mining. Land-use restrictions, therefore, may change if societal interests change. Land-use restrictions largely apply to surface mining, but may also affect underground mining. Technologic restrictions affect the economics or safety of mining and are determined by current levels of technology; these can only change with advances in science and engineering or changes in economic conditions. Technologic restrictions affect both surface and underground mining, but are generally more prohibitive to underground mining.

The restrictions to coal mining and the criteria applied in each of the four study areas are summarized in Table 1 and described briefly below. Detailed discussion of the restrictions and criteria are included in the study area reports cited in the Study Areas and References Cited sections. The major land-use restrictions to mining are delineated in the Surface Mining Control and Reclamation Act of 1977 (Office of Surface Mining Reclamation and Enforcement, 1988). These restrictions, or more stringent ones, must be applied within each State — unless waivers can be obtained. The individual study area reports present the authority for the specific restrictions and criteria applied within each quadrangle in terms of citable laws, regulations, or local practices.

4.1 Land-use Restrictions

4.1.1 Land-use Restrictions to Surface Mining

Power lines and pipelines.

Power lines and pipelines are present in all four study areas, but were not considered to be restrictive to surface mining in the Vansant quadrangle. In the other three study areas, a 100-ft buffer zone is commonly left on each side of the power line or pipeline. Therefore, a 100-ft buffer line was digitized around each power line and pipeline in these three

	Matewan, KY	Noble, KY	Sylvester, WV	Vansant, VA
LAND-USE RESTRICTIONS				
Surface Mining				
Power lines	100 ft buffer	100 ft buffer	100 ft buffer	NE
Pipelines	100 ft buffer	100 ft buffer	100 ft buffer	NE
Cemeteries	100 ft buffer *	100 ft buffer	100 ft buffer	100 ft buffer * *
Oil and gas wells	200 ft square	200 ft square	100 ft radius buffer	200 ft radius buffer
Major streams	100 ft buffer	100 ft buffer	Alluvial flood plain	100 ft buffer
Towns	300 ft buffer	300 ft buffer	Actual area	Actual area
Forest preserve	None	Actual area	None	None
Deep Mining				
Major streams	NE	NE	Alluvial flood plain	NE
Towns	NE	NE	Actual area	NE
Forest preserve	None	Actual area	None	None
TECHNOLOGIC RESTRICTIONS				
Surface Mining				
Too thin * * *	NE	NE	lt 28 in.	NE
Deep-mine barrier pillars	NE	50 ft buffer	100 ft buffer	NE
Thicker beds too close above/below	NE	NE	lt 25 ft * * * *	NE
Geologic factors	ND	ND	Actual area; ST	ND
Too deep	gt 200 ft	gt 200 ft	gt 200 ft	gt 200 ft
Deep Mining				
Too thin	lt 28 in.	lt 28 in.	lt 28 in.	lt 40 in. * * * * *
Too deep	gt 1,000 ft	None	NE	NE
Deep-mine barrier pillars	50 ft buffer	50 ft buffer	100 ft buffer	200 ft buffer
Deep mining too close above/below	lt 40 ft	lt 40 ft	None	lt 40 ft
Thicker beds too close above/below	lt 40 ft	lt 40 ft	lt 25 ft	lt 40 ft
Oil and gas wells	200 ft square	200 ft square	100 ft radius buffer	200 ft radius buffer
Geologic factors	ND	ND	Actual area; ST	ND

* applied 300 ft square around center point of cemetery.
* * applied 100 ft square around center point of cemetery.
* * * coal lt 14 in. not included in original resource estimate.
* * * * applied only to underground mining within 200 ft of the surface.
* * * * * applied only to coal beds lying totally in the subsurface and only accessible by shaft

NE = no effect, factor may be present but not considered to be restrictive due to local practices.
ND = no data or insufficient data.
ST = statistics were applicable where data were insufficient to map the factor.
None = none in quadrangle.
lt = less than gt = greater than

Table 1. — Restrictions to coal availability and applicable criteria as used in the Matewan, Noble, Sylvester, and Vansant 7.5-minute quadrangle areas, Kentucky, West Virginia, and Virginia (in millions of short tons).

quadrangles and entered into NCRDS as the areas restricted from surface mining by power lines and pipelines.

Cemeteries.

Surface mining is not permitted in, or near, cemeteries in most areas. In the Sylvester quadrangle, the actual area of each cemetery plus a surrounding 100-ft buffer zone was digitized. In the Matewan and Vansant quadrangles, where 100-ft buffer zones are also required, the cemeteries were too small to digitize from the 1:24,000-scale maps. Therefore, 300-ft and 100-ft squares, respectively, were drawn around the central point of each cemetery to represent the area of unminable coal.

Oil and gas wells.

Buffer zones are required and were created around the location point of each oil and gas well in all of the study areas: in Kentucky, 200-ft squares; in the Sylvester quadrangle, circles with 100-ft radii; and in the Vansant quadrangle, circles with 200-ft radii.

Major streams.

In Kentucky and Virginia, a 100-ft buffer zone is required, and was digitized, around streams and rivers with mean annual flow greater than 5 cubic feet per second. In West Virginia, the valley floors of the Coal River and its major tributaries constitute a restriction to both surface and shallow underground mining and were so digitized.

Towns.

In Kentucky, a 300-ft buffer is required and was digitized around residential and public buildings. In Virginia and West Virginia, where areas of population concentration are restricted from mining, the actual population concentration areas were digitized.

Forest preserve.

In the early 1900's, a 15,000-acre tract was deeded to the University of Kentucky with the provision that it never be mined. The portion of the forest preserve that lies within the Noble quadrangle was therefore considered as a restriction to mining and its boundaries were digitized.

Major roads and railroads.

These were determined to be restrictions to mining only in the Sylvester quadrangle, but, because they were all within the valley floor boundaries, they did not present an additional impact on available resources and consequently were not assessed.

4.1.2 Land-use Restrictions to Underground Mining

Major streams.

In the Sylvester quadrangle, the valley floors of the Coal River and its major tributaries were considered to be restrictive to underground mining of potentially minable coal beds at relatively shallow depths below. Major streams were not considered a restriction to underground mining in the two Kentucky

study areas because there were no known minable coal beds below major-stream drainage, and deep coal mining was not restricted below major streams in the Vansant quadrangle.

Towns.

In the Sylvester quadrangle, actual population concentrations were included as restrictions and were digitized. Towns were not considered restrictions to underground mining in the Kentucky and Virginia study areas.

Forest preserve.

That portion of the forest preserve in the Noble quadrangle described above as restricted for surface mining is also considered a restriction for underground mining and the same digitized boundaries were applied.

4.2 Technologic Restrictions

4.2.1 Technologic Restrictions to Surface Mining

Too thin.

According to the USGS classification system, beds with coal thickness less than 14 inches are not considered to be a resource (unless local practice is to mine the thinner coal beds) and, therefore, were not considered in these studies. In the Sylvester quadrangle, local surface mining practices preclude mining of beds with less than 28 inches of coal; thus, any beds with less than 28 inches of coal were considered as restrictive to surface mining throughout the entire quadrangle. This factor was not considered a constraint to surface mining in the other three study areas.

Deep-mine barrier pillars.

In the Matewan and Vansant quadrangles, underground mines in shallow coal beds were not considered restrictive to surface mining. However, in the Noble quadrangle, 50-ft buffer zones are customarily left around underground mines during surface mining operations, and, therefore, were digitized as restrictions to surface mining. In the Sylvester quadrangle, where a considerable amount of underground mining occurs within 200 feet of the surface, 100-ft buffer zones were digitized around the near-surface active and abandoned underground mines; these buffer zones were considered to be restrictive to underground mining but not to surface mining.

Thicker beds too close above or below a potentially minable coal bed.

This was only considered a restriction to underground mining in the shallow coal beds that were potentially surface minable in West Virginia where the beds were within 25 feet of one another.

Geologic factors.

In the Sylvester quadrangle, areas where coal beds had been eroded away before, or soon after, burial (washouts) were mapped and excluded from resource calculations. Also, inertinite (organic components) in coal that would prevent complete and rapid burning of coal in power-generation boilers designed to burn pulverized coal were detected in two coal

beds and included as restrictions to mining. There were insufficient data to include these or other geologic factors as restrictions in the other three quadrangle areas studied.

Too deep.

Although surface-mining depths vary with changes in thickness and character of coal beds and with changes in the lithology of the overburden, 200 feet was assumed to be the maximum possible depth for surface mining in each of the four study areas. A 200-ft overburden thickness line was derived by subtracting the elevations at the tops of the coal beds from the elevations at the ground surface that are stored in the USGS digital elevation models (DEM's) for each study area.

4.2.2 Technologic Restrictions to Underground Mining

Too thin.

In the Kentucky and West Virginia quadrangles, beds with less than 28 inches of coal were considered too thin for underground mining. In the Vansant quadrangle, only those coal beds that were both totally subsurface (requiring access by shaft) and less than 40 inches thick would not be expected to be mined and, therefore, were considered as restricted.

Too deep.

In eastern Kentucky, 1,000 feet is generally considered the maximum depth for underground mining. This was applied as a restriction to mining in the Matewan quadrangle. In the Noble quadrangle, none of the coal beds lie below 1,000 feet. In the Vansant and Sylvester quadrangles, depth has not been prohibitive to mining. In fact, nearly all of the extensively-mined Pocahontas No. 3 coal bed is beneath more than 1,000 feet of overburden.

Deep-mine barrier pillars.

Barrier pillars around underground mines are required for mine safety in all four study areas. In Kentucky, 50 feet is required; in West Virginia, 100 feet; and Virginia, 200 feet. Therefore, buffer zones of the appropriate width were generated around each active and abandoned underground mine.

Deep mining too close above or below a potentially minable coal bed.

Where deep mining has occurred either above or below another potentially minable bed, the other bed will not be mined if the beds are within a minimum distance above or below one another. This distance is generally 40 feet in the Kentucky and Virginia study areas. In West Virginia, local practice sets minimum acceptably safe interburden thickness at 25 feet, but there were no occurrences of underground mining either 25 feet above or below a potentially minable coal bed within the Sylvester quadrangle.

Thicker beds too close above or below a potentially minable coal bed.

When two potentially minable coal beds occur within a minimum distance from one another, one or the other will not be mined. According to local practice, this minimum vertical

distance is 40 feet in the Kentucky and Virginia quadrangles, and 25 feet in the Sylvester quadrangle. For these four study areas, where there are not sufficient quality data to indicate otherwise, the assumption was made that the thicker of the two coal beds would be selected for mining.

Oil and gas wells.

For safety, coal must remain unmined near oil and gas wells in underground mines. The same criteria are applied as for land–use restrictions to surface mining described above.

Geologic Factors.

The same geologic factors described above for surface mining apply also to deep mining.

Chapter 5

RESULTS

Results of the coal availability investigations for the four study areas are summarized in Table 2 and Figures 3–14. Individual coal bed statistics are depicted in the twelve tables of the Appendix. Much more detail is presented in the individual reports cited for each of the study areas.

Table 2 shows the calculated coal-resource tonnages by study area for original coal, coal mined and lost-in-mining, remaining coal, coal restricted due to land-use and technologic restrictions, and available coal resources. Figures 3 and 4 show the same information by percentages. A total of one billion tons of coal is estimated to be unavailable due to land-use and technologic restrictions in the four areas studied. Of the original resources in the four areas, only 61 percent are estimated to be available for mining under current conditions. The range in the amounts of available resources is surprisingly small — 58 percent in the Vansant quadrangle to 64 percent in the Sylvester quadrangle. Figures 3 and 4 show that the coal mined and lost-in-mining ranges from 6 percent in the Sylvester quadrangle to 14 percent in the Vansant quadrangle, an 11 percent average. The land-use restrictions exhibit the greatest variability — less than 1 percent in the Vansant quadrangle to 17 percent (largely a forest preserve) in the Noble quadrangle, a 3 percent average. Technologic restrictions range from a minimum of 11 percent in the Noble quadrangle to 28 percent in the Sylvester quadrangle, a 25 percent average. In the four quadrangles, land use accounts for only 11 percent of the restrictions, while technologic factors average 89 percent; however, in more populated areas of the Central Appalachian Region, this relationship could be altered in favor of land-use restrictions.

Figure 5 depicts summary statistics for both surface and deep minable coal in the four study areas combined. Of the original coal resources, 3 percent has been removed by surface methods and 8 percent has been mined and lost-in-mining by underground methods; land use restricts 2 percent of the surface and 1 percent of the deep coal; and technologic considerations restrict less than 2 percent of the surface coal but 23 percent of the deep coal. In the four study areas, the deep coal beds are more affected by restrictions than are the surface minable coal beds. The remaining surface resource

	Matewan, Kentucky	Noble, Kentucky	Sylvester, West Virginia	Vansant, Virginia
Original				
Surface	336	327	286	131
Deep	650	133	957	877
Total	986	460	1,242	1,008
Mined and Lost-in-Mining				
Strip and Auger	11	60	31	7
Underground*	118	1	49	135
Total	128	61	80	142
Remaining				
Surface	313	266	235	106
Deep	545	133	928	760
Total	858	399	1,162	866
Restrictions				
Land Use				
Surface	17	58	9	1
Deep	—	20	5	—
Total	17	77	13	1
Technologic				
Surface	—	**	64	—
Deep	228	51	286	277
Total	228	51	350	277
Total				
Surface	17	58	73	1
Deep	228	71	291	277
Total	245	129	364	278
Available				
Surface	296	208	162	104
Deep	317	62	637	483
Total	613	270	798	587
Percent of Original	62	59	64	58

* Includes underground mining within the surface resource category.

** Less than 0.5

Note: Totals may not equal sum of components because of independent rounding.

Table 2. — Summary of the estimated original, mined and lost-in-mining, remaining, restricted, and available coal resources in each of the Matewan, Noble, Sylvester, and Vansant 7.5-minute quadrangle areas, Kentucky, West Virginia, and Virginia (in millions of short tons).

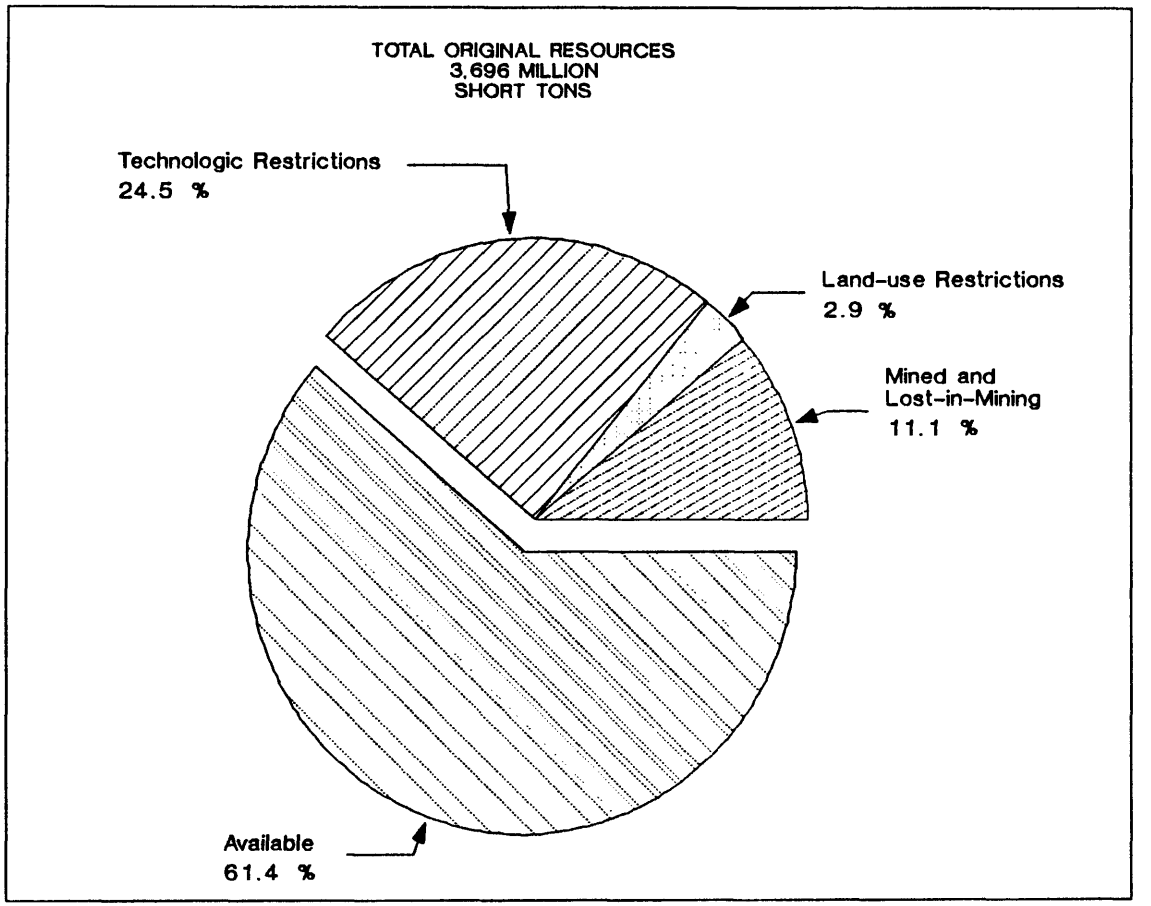


Figure 3. — Summary of the estimated original, mined and lost-in-mining, restricted, and available coal resources in the Matewan, Noble, Sylvester, and Vansant 7.5-minute quadrangle areas, Kentucky, West Virginia, and Virginia.

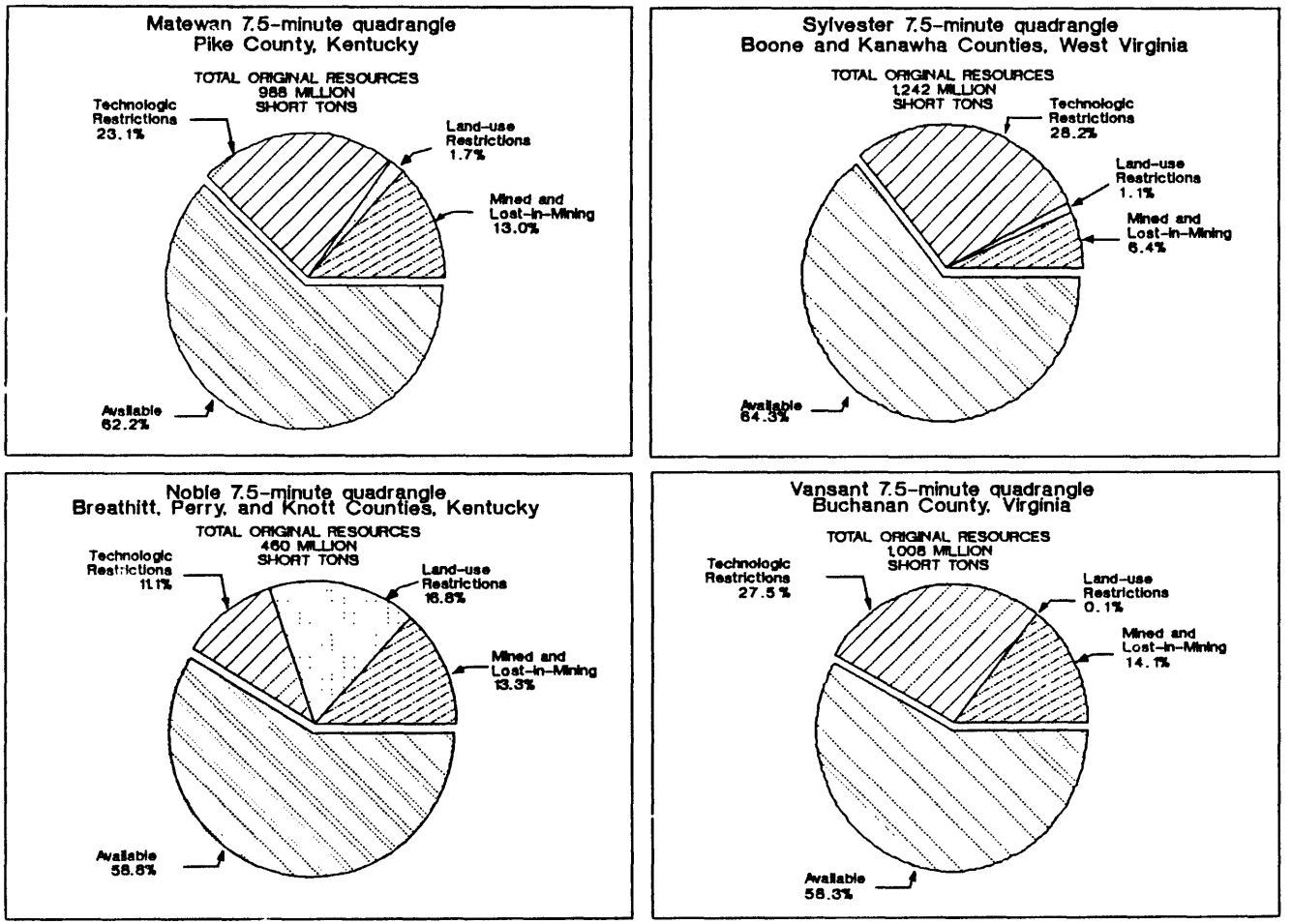


Figure 4. — Estimated original, mined and lost-in-mining, restricted, and available coal resources in each of the Matewan, Noble, Sylvester, and Vansant 7.5-minute quadrangle areas, Kentucky, West Virginia, and Virginia.

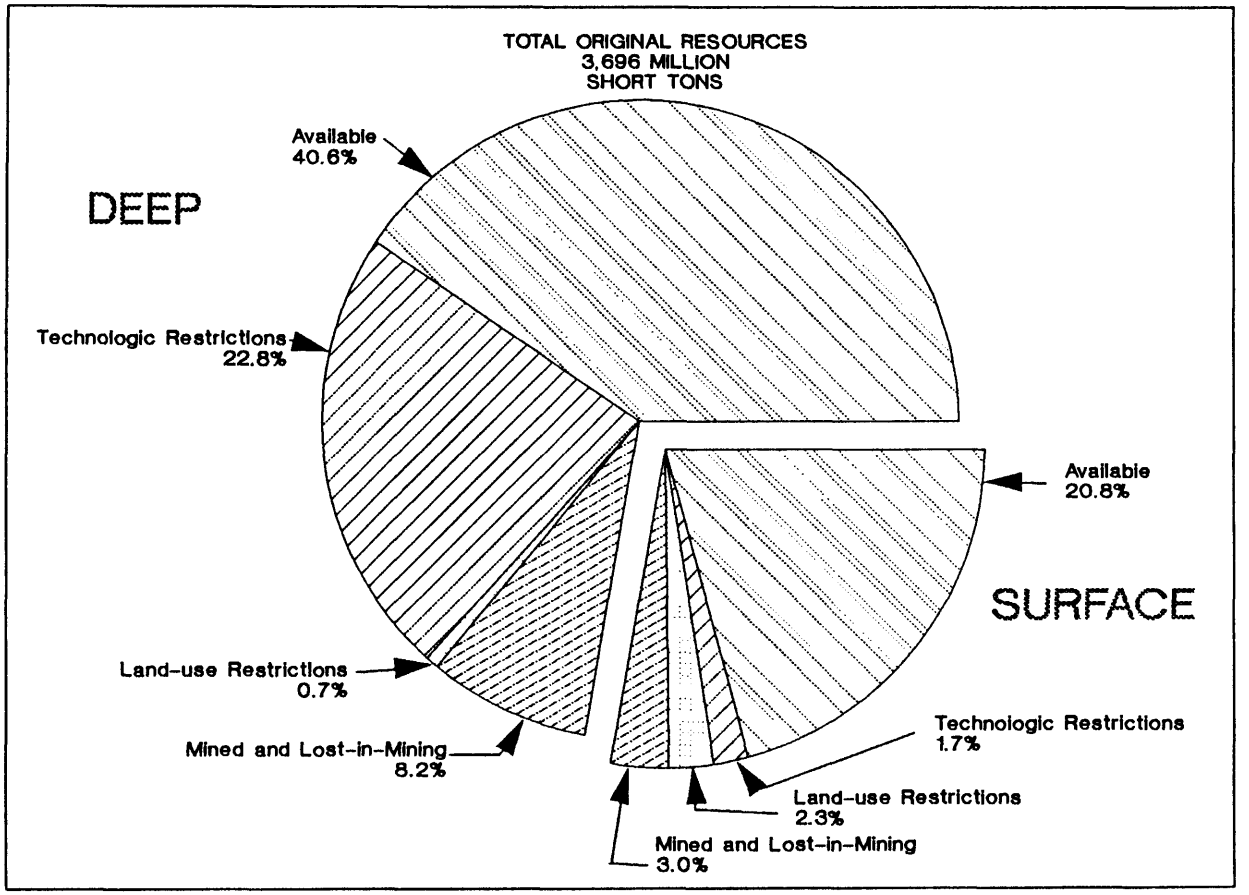


Figure 5. — Summary, by surface and deep resources, of the estimated original, mined and lost-in-mining, restricted, and available coal resources in the Matewan, Noble, Sylvester, and Vansant 7.5-minute quadrangle areas, Kentucky, West Virginia, and Virginia.

is reduced by 16 percent, while resources of the remaining deep minable coal beds are decreased by 27 percent. One-third of the available coal is minable by surface methods and two-thirds by underground methods.

Figures 6 through 9 depict the original, remaining, and available surface and deep resources by coal bed. The beds are arranged in stratigraphic sequence from left to right representing coal beds from top (youngest) to bottom (oldest). The surface minable coal dominates the upper part of the section while the largest underground resources are in the middle to lower parts of the section. Larger amounts of coal appear to be restricted in the middle and lower coal beds. In fact, in the Vansant quadrangle, four of the lower five coal beds appear to be totally eliminated from future mining due to technologic restrictions.

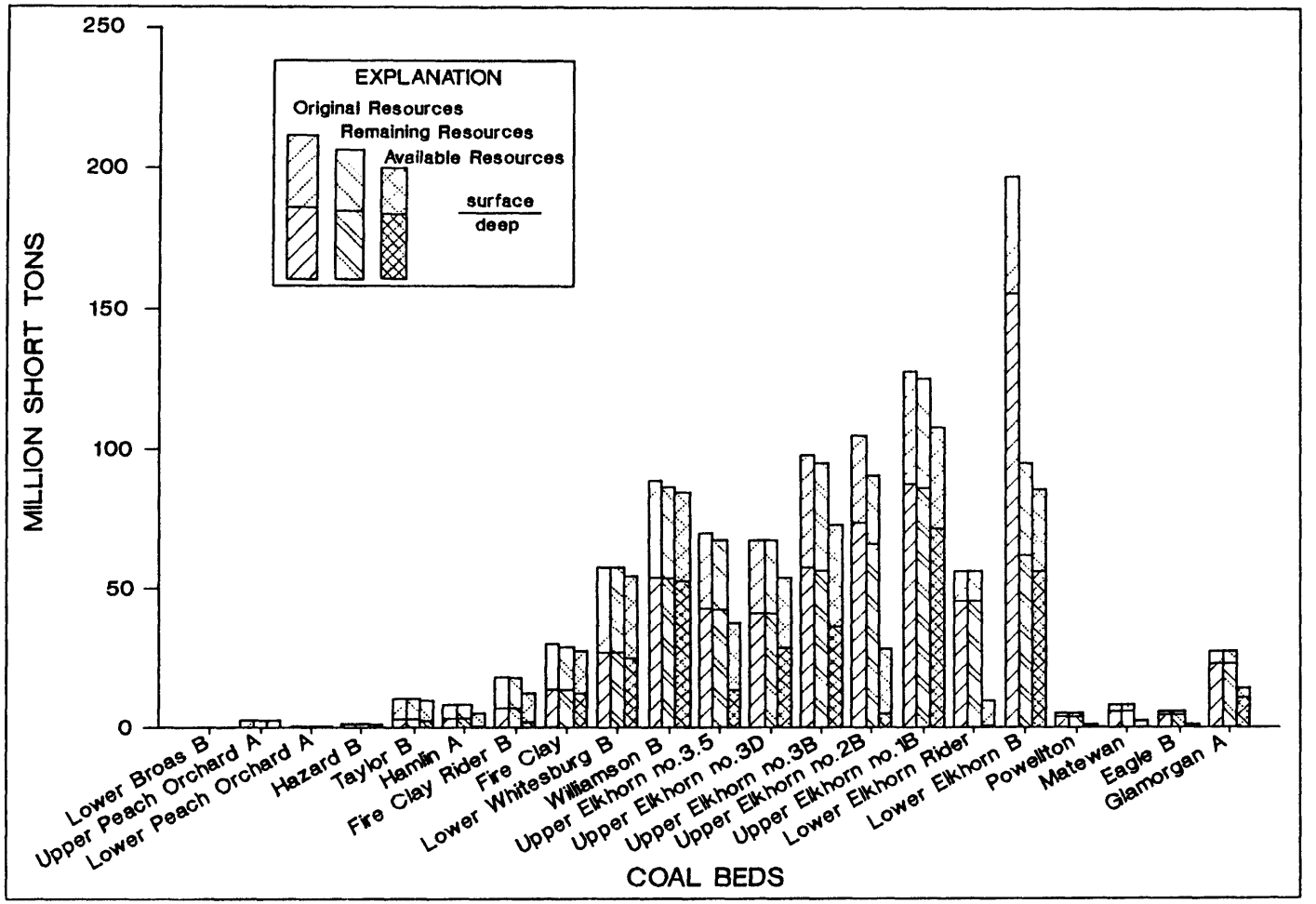


Figure 6. — Estimated original, remaining, and available coal resources, by coal bed, in the Matewan 7.5-minute quadrangle, Pike County, Kentucky. Coal beds are in stratigraphic sequence with the youngest (uppermost) at the far left and the oldest (deepest) at the far right.

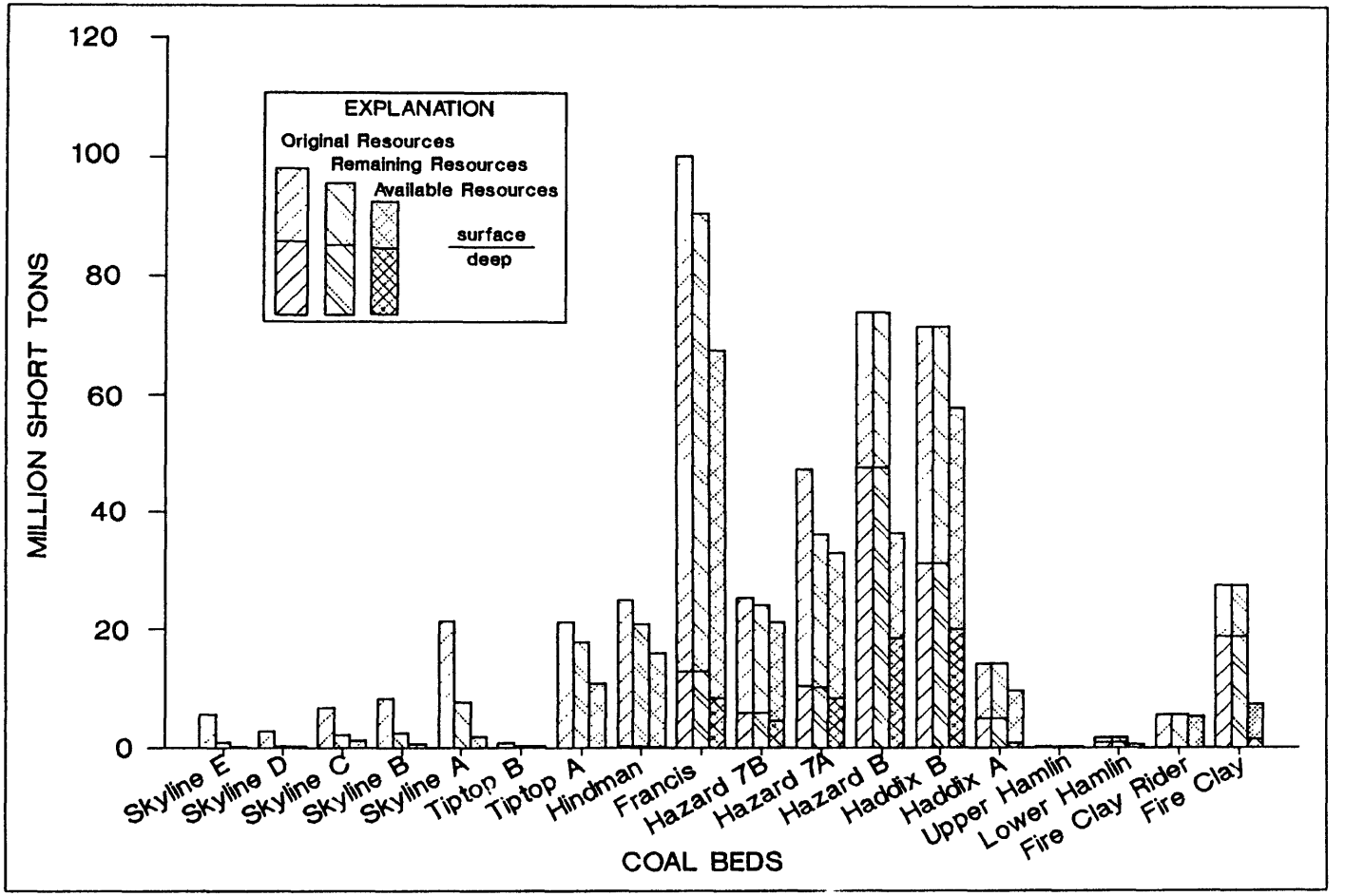


Figure 7. — Estimated original, remaining, and available coal resources, by coal bed, in the Noble 7.5-minute quadrangle, Breathitt, Perry, and Knott Counties, Kentucky. Coal beds are in stratigraphic sequence with the youngest (uppermost) at the far left and the oldest (deepest) at the far right.

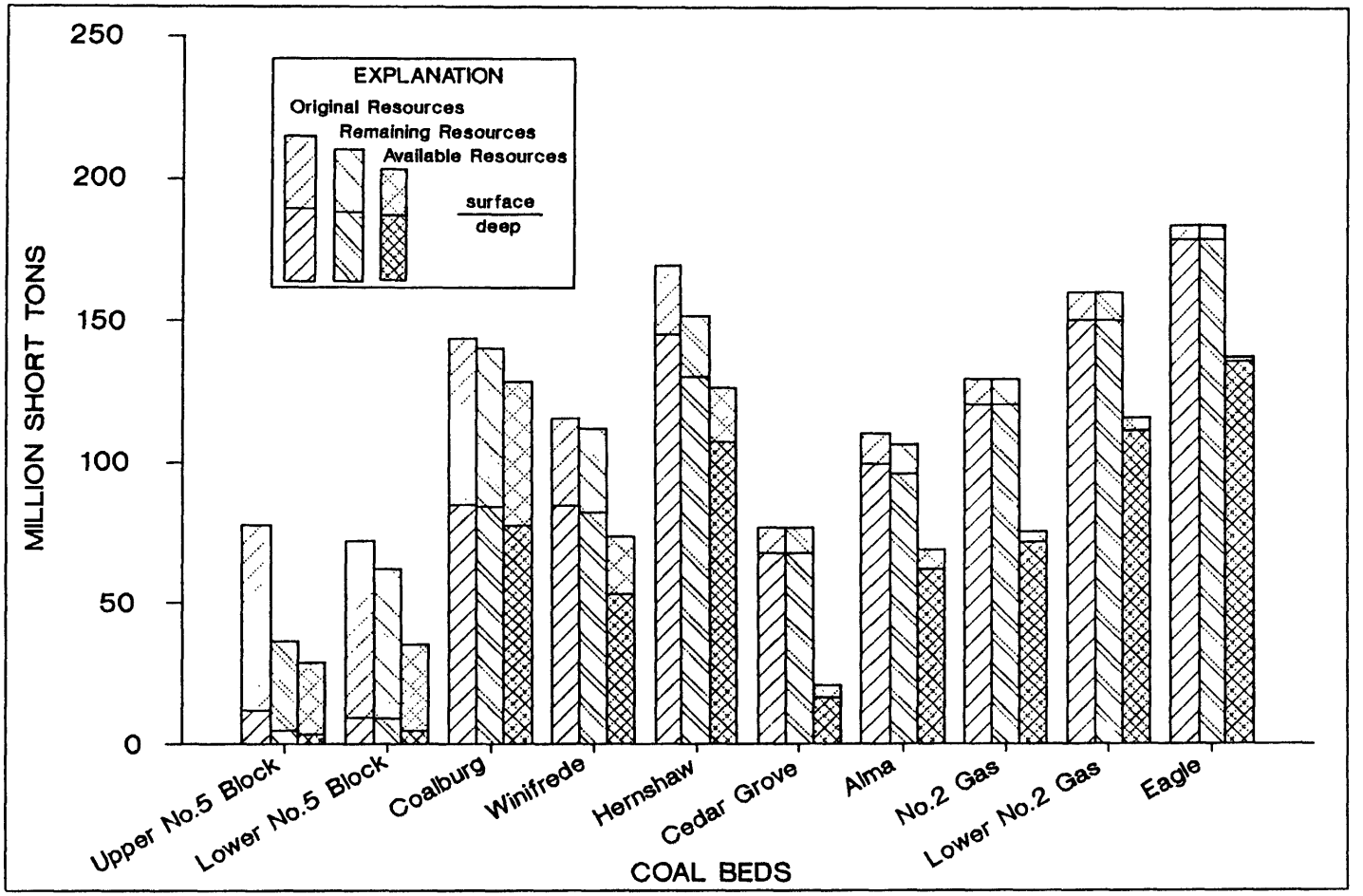


Figure 8. — Estimated original, remaining, and available coal resources, by coal bed, in the Sylvester 7.5-minute quadrangle, Boone and Kanawha Counties, West Virginia. Coal beds are in stratigraphic sequence with the youngest (uppermost) at the far left and the oldest (deepest) at the far right.

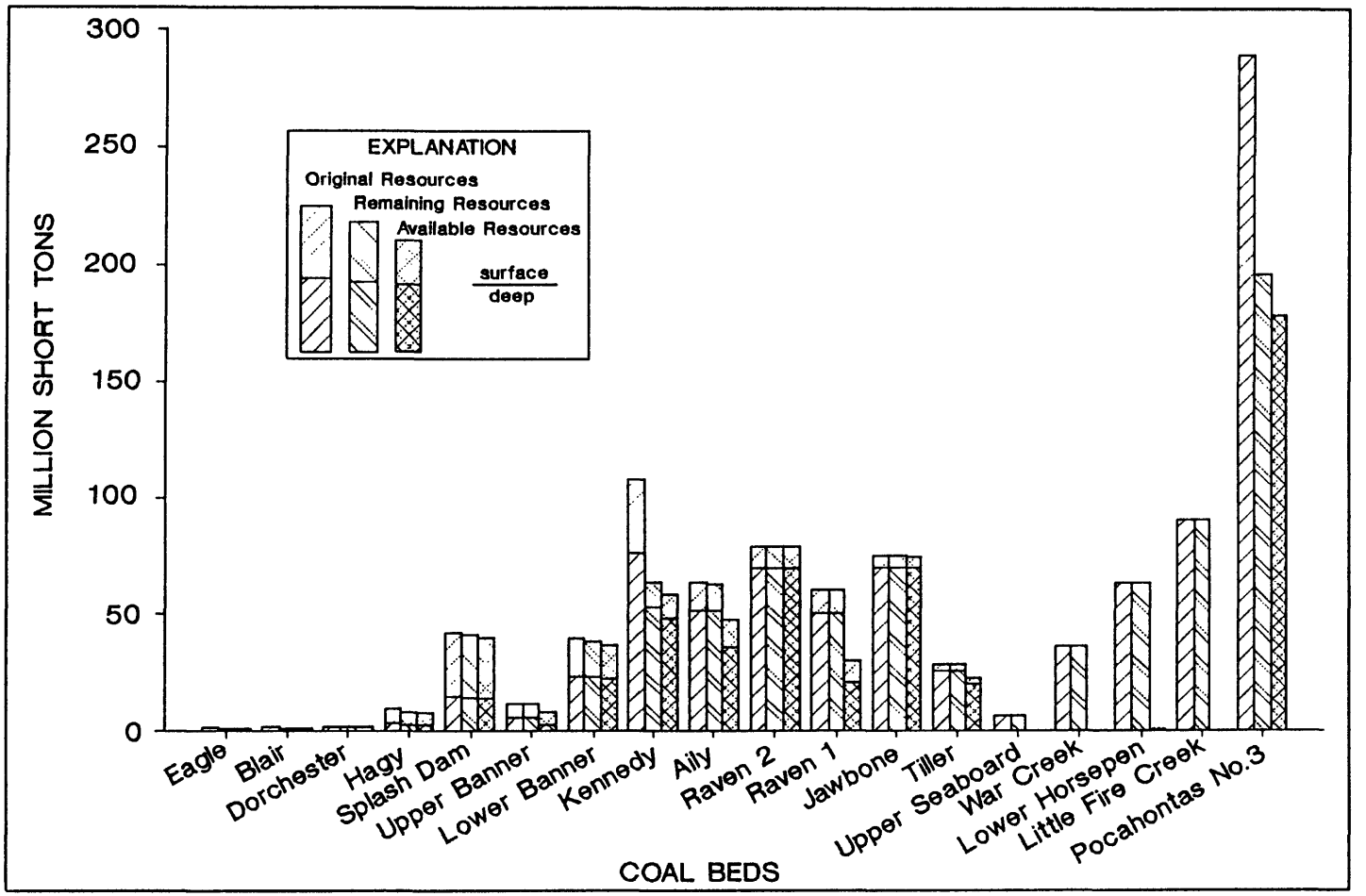


Figure 9. — Estimated original, remaining, and available coal resources, by coal bed, in the Vansant 7.5-minute quadrangle, Buchanan County, Virginia. Coal beds are in stratigraphic sequence with the youngest (uppermost) at the far left and the oldest (deepest) at the far right.

5.1 Land-use Restrictions

Figure 10 depicts the combined land-use restrictions that were identified and applied to the remaining coal resources of each of the four quadrangles. The variation is quite striking, especially between the Noble quadrangle in Kentucky and the Vansant quadrangle in Virginia. The largest restricted areas in the Noble quadrangle are portions of a 15,000-acre forest preserve that was deeded to the University of Kentucky in the early part of the century with provision that the preserve never be mined. In the Vansant quadrangle, power lines, pipelines, and highways were considered locally not to cause serious enough constraints to surface or deep mining to be applied within this study area.

Figures 11 and 12 illustrate the individual land-use restrictions of the four study areas as a whole and by quadrangle. To keep the following percentages in perspective, note that land-use restrictions represent only 11 percent of all restrictions in the study areas. The largest single land-use restriction of the four areas is the forest preserve in the Noble quadrangle, accounting for just over two-thirds of the land-use restrictions (69 percent); while streams are 11 percent; towns, 9 percent; power lines and pipelines, each 4 percent; oil and gas wells, 2 percent; and cemeteries, 1 percent. Land-use restrictions are highly variable between the study areas: in the Noble quadrangle, the forest preserve accounts for almost 98 percent of the total; in the Vansant quadrangle, towns predominate with 88 percent; in the Sylvester quadrangle, towns and streams are nearly equal with 41 and 40 percent, respectively; in the Matewan quadrangle, the land-use restrictions are fairly evenly divided amongst streams at 38 percent, power lines 25 percent, and pipelines 20 percent. Oil and gas wells and cemeteries consistently comprise a small fraction of the land-use restrictions, ranging from 0 to 9 percent. Because of the steep slopes of the four study areas in the Central Appalachian Region, most population centers are concentrated in the valleys and, consequently, are below the outcrops of most of the major minable coal beds. The few coal beds affected by towns are those lower in the stratigraphic sequence.

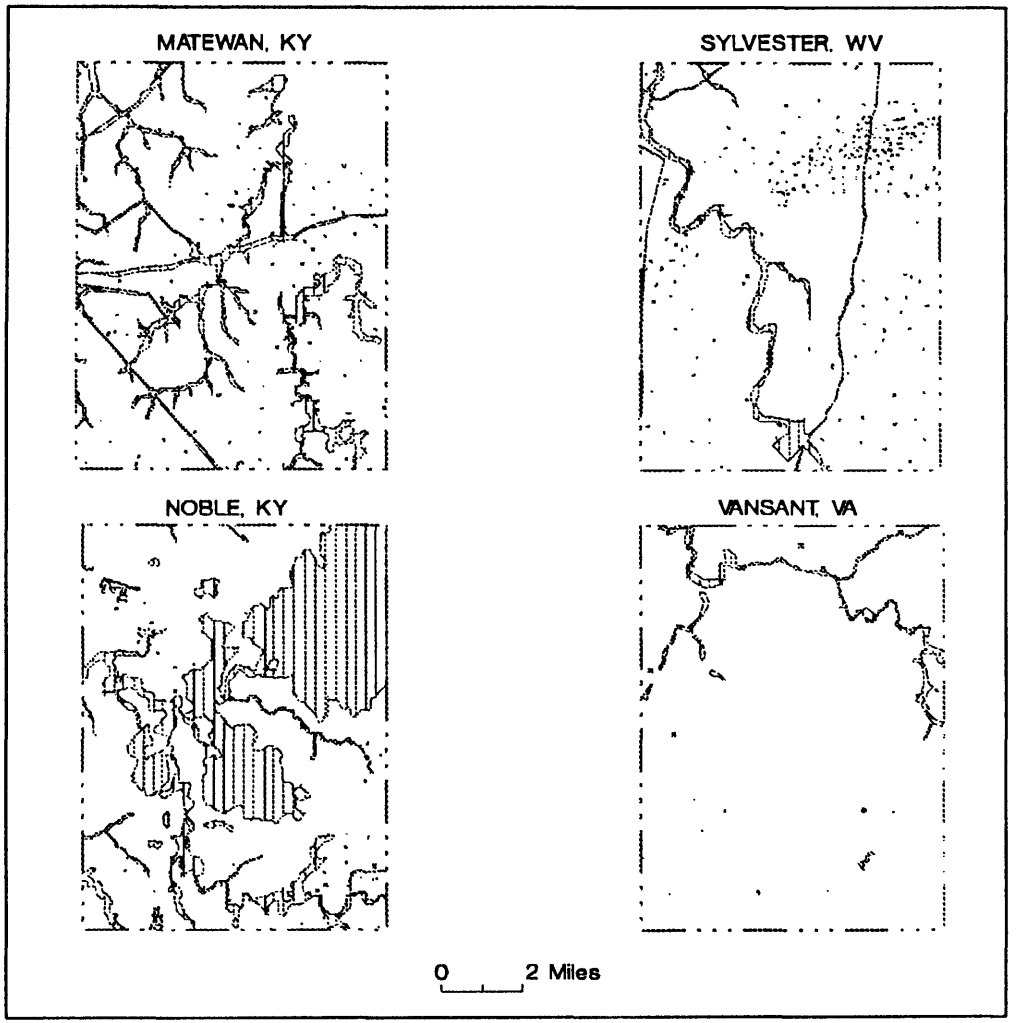


Figure 10. — Maps showing all applicable land-use restrictions combined in each of the four 7.5-minute quadrangle study areas.

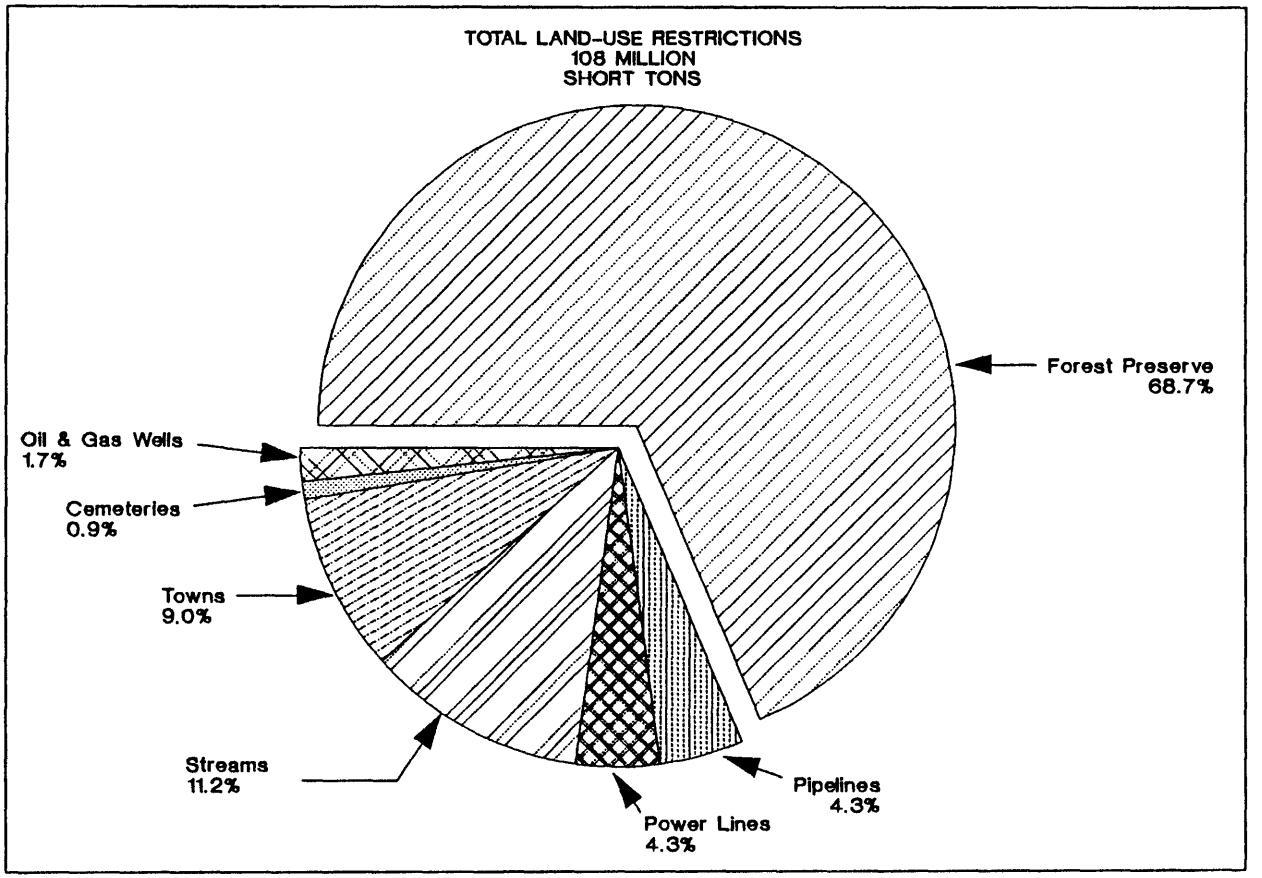


Figure 11. — Summary of the estimated portion of each of the land-use restriction categories in the Matewan, Noble, Sylvester, and Vansant 7.5-minute quadrangle areas, Kentucky, West Virginia, and Virginia.

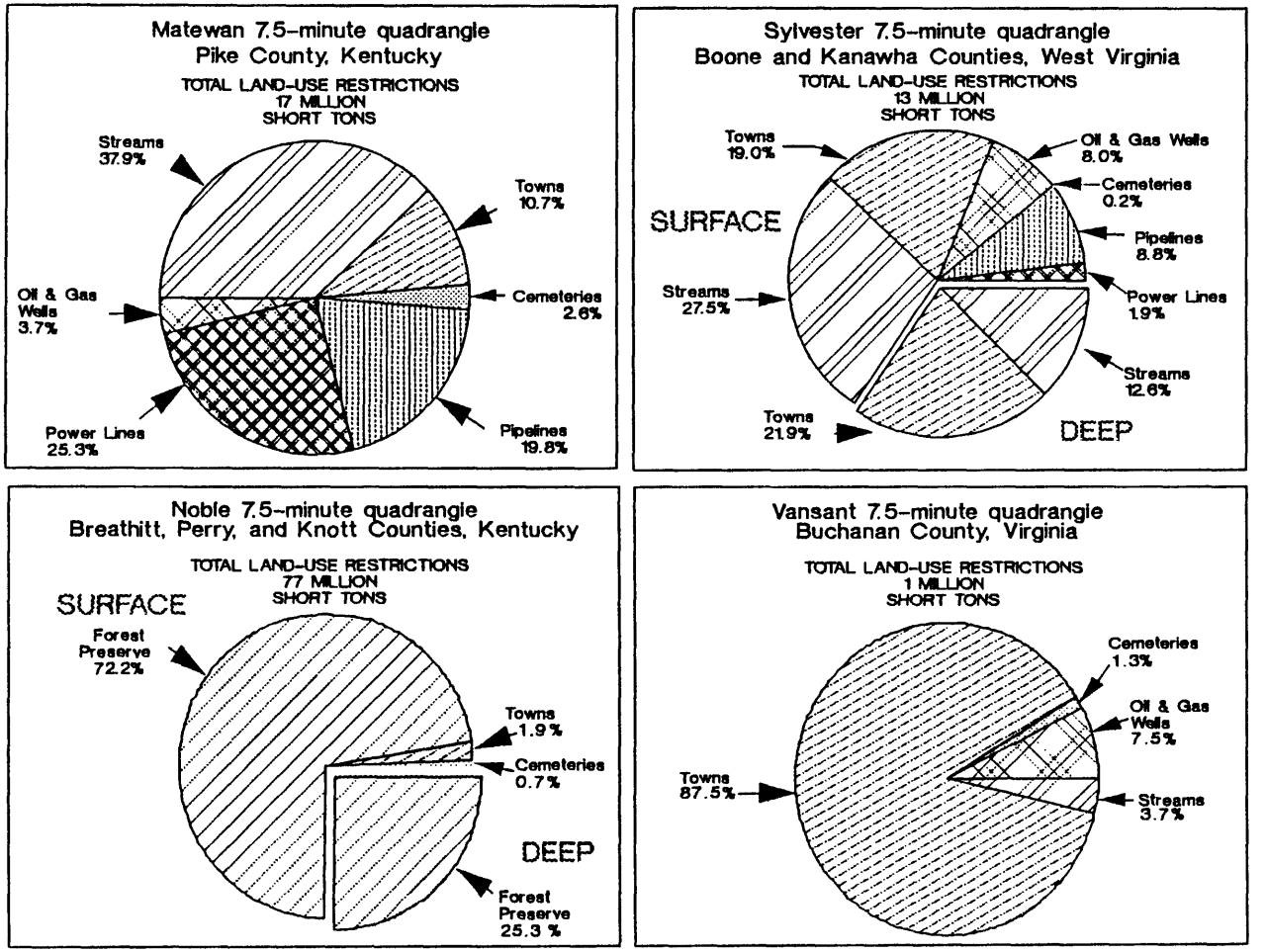


Figure 12. — Estimated portion of each of the land-use restriction categories in each of the the Matewan, Noble, Sylvester, and Vansant 7.5-minute quadrangle areas, Kentucky, West Virginia, and Virginia. Land-use factors restrict only surface coal beds in the Matewan and Vansant quadrangles. In the Noble and Sylvester quadrangles, land-use restrictions affect both surface and deep-minable coal beds, and are shown separately on the diagrams.

5.2 Technologic Restrictions

Figures 13 and 14 present the individual technologic restrictions of the four study areas combined and by quadrangle. By far the largest single technologic restriction, nearly 74 percent, is the minimum minable thickness of the coal. Coal beds occuring too close above or below one another is second at almost 19 percent. Deep-mine barrier pillars and previous deep mining in coal beds too close above or below one another each account for $2\frac{1}{2}$ percent of the restrictions. Geologic factors account for 2 percent of the technologic restrictions, while oil and gas wells and overburden together total less than 1 percent.

Coal considered too thin for mining is consistently the largest restrictive factor in each of the four quadrangles, ranging from 52 percent in the Matewan quadrangle to over 99 percent in the Noble quadrangle. The location of another thicker coal bed above or below within an unsafe distance may, or may not, be a significant factor in restricting the development of the remaining coal resource. This factor ranges from no reduction at all in the Noble quadrangle to 6 percent in the Sylvester quadrangle, 22 percent in the Vansant quadrangle, and 36 percent in the Matewan quadrangle. In the areas where appreciable underground mining has occurred, deep-mine barrier pillars and mines too close above or below potentially minable beds each restrict from 1 to 9 percent of the coal. Oil and gas wells are present in all four areas, but, as a constraint to mining, never exceed 1 percent.

Thickness of overburden is barely a factor in restricting coal development in the four quadrangles. In the Noble quadrangle, none of the coal beds are deeper than 1,000 feet below the surface. Forty-three percent of the coal beds in the Vansant quadrangle are deeper than 1,000 feet, but this is not considered a constraint to mining in this area. In fact, over two-thirds of the coal mined in the Vansant quadrangle has come from depths greater than 1,000 feet below the surface, all from the Pocahontas No. 3 coal bed. In the steep terrain of the Sylvester quadrangle, where about 6 percent of the coal is at depths greater than 1,000 feet, underground mining by drifting in from the outcrop reaches great depths in relatively short distances which is not restrictive to mining, just more expensive. In the Matewan quadrangle, there is a small amount of coal deeper than 1,000 feet; however, coal considered unlikely to be mined for reasons of depth totals less than 1 percent of the technologic restrictions within the quadrangle.

Geologic factors such as poor roof and floor conditions, washouts, displacement faults, colluvium, and inferior coal quality probably represent a significant constraint to mining. Unfortunately, there is too little information available in the four study areas to confirm this supposition. Only in the Sylvester quadrangle is there enough information to allow 1) the mapping of several areas where coal has been washed out (eroded away before or soon after burial), and 2) some statistical analysis of possible restrictions on two coal beds because of organic constituents (inertinite) that would inhibit complete and rapid burning in power-generation boilers. From only those few data points, it was determined that these two adverse geologic factors represent about 5 percent of the technologic restrictions in the Sylvester study area.

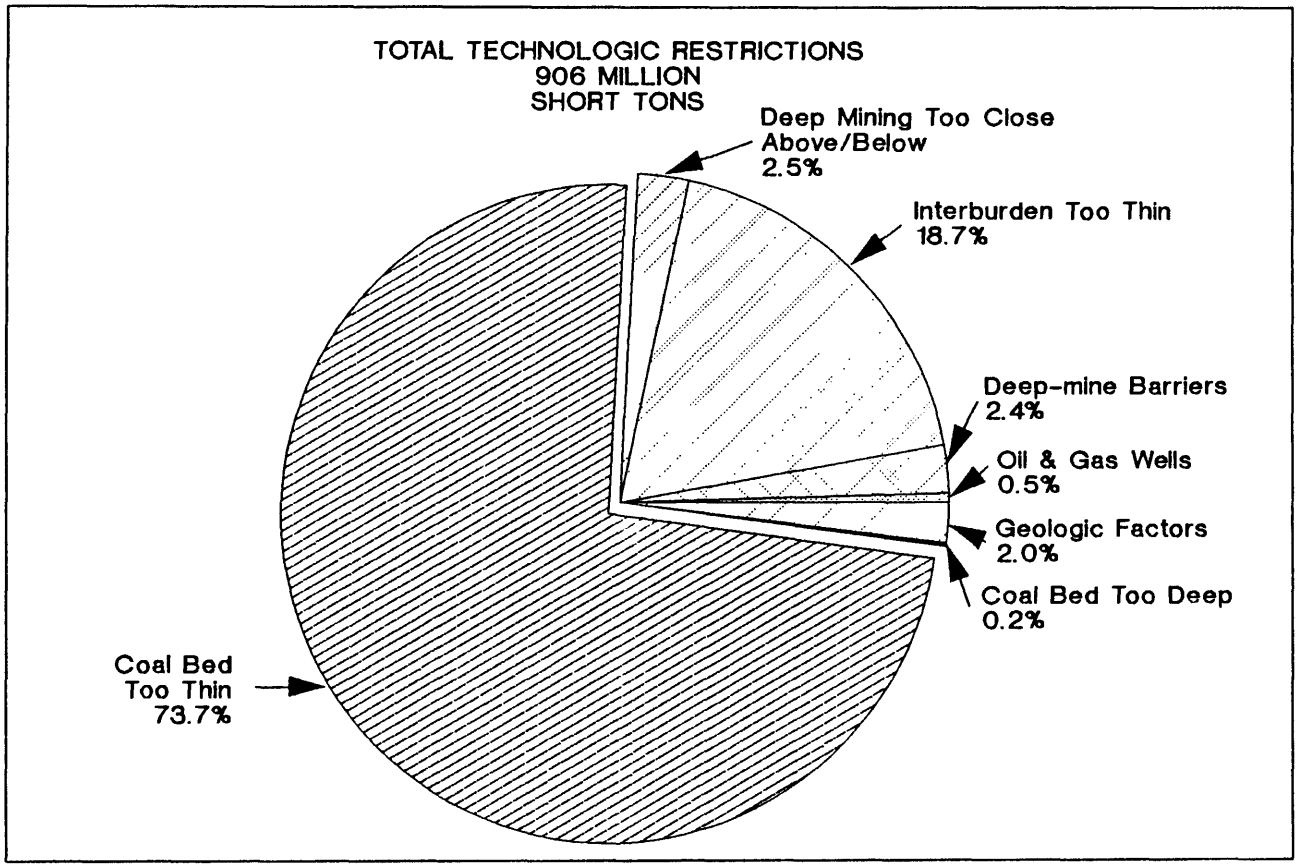


Figure 13. — Summary of the estimated portion of each of the technologic restriction categories in the Matewan, Noble, Sylvester, and Vansant 7.5-minute quadrangle areas, Kentucky, West Virginia, and Virginia.

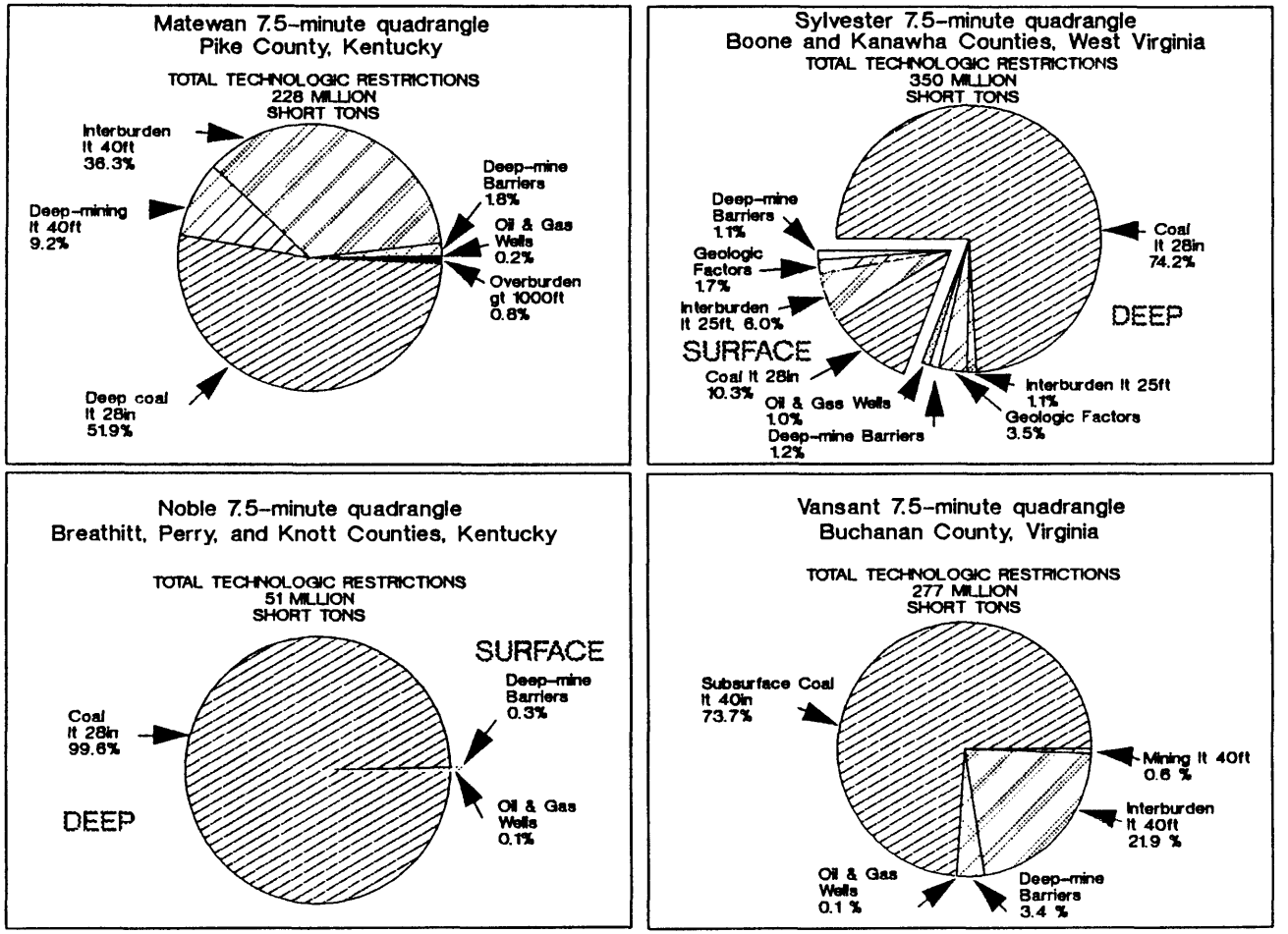


Figure 14. — Estimated portion of each of the technologic restriction categories in each of the the Matewan, Noble, Sylvester, and Vansant 7.5-minute quadrangle areas, Kentucky, West Virginia, and Virginia. Technologic factors restrict only deep coal beds in the Matewan and Vansant quadrangles. In the Noble and Sylvester quadrangles, technologic restrictions affect both surface- and deep-minable coal beds, and are shown separately on the diagrams. (lt = less than, gt = greater than)

5.3 Other Restrictions

Other major land-use restrictions looked for but not found in the four study areas were National and State forests, parks, and monuments, as well as protected species habitats. Major potential technologic restrictions that do not occur in the four study areas are coal beds that dip too steeply or are highly faulted.

There are a number of other potential restrictions to mining that were not applied in these four studies. These include such economic considerations as the cost of mining, availability of transportation, proximity to markets, subdivision of surface and mineral ownership, and size of a logical mining unit. In addition, recovery factors were not applied. The impact of such restrictions was beyond the scope of these studies, but they would certainly further reduce the amount of coal available for development.

5.4 Compliance Coal

Noncompliance with new source performance standards (NSPS) for sulfur dioxide emission, currently not to exceed 1.2 pounds of SO_2 per million btu input (Office of the Federal Register, 1988), is not a restriction to mining. However, compliance is certainly a factor in determining the marketability of coal and, consequently, the availability of compliance coal was evaluated in all four study areas. Matewan is the only quadrangle with enough control points to map the sulfur content in terms of SO_2 generation. In this study area, for the 90 percent of the coal beds with available data, only 44 percent of the resource in these beds meets NSPS SO_2 compliance levels. A statistical analysis of potential SO_2 generation was performed on coal beds with sufficient data in the other three quadrangles. In the Sylvester quadrangle, the results, while quite variable, indicate that the majority of the remaining resources could be expected to meet current compliance standards. In the Vansant quadrangle, with analyses on only seven coal beds, 43 percent of those resources could be considered compliance. For the Noble quadrangle, there are not enough data points to indicate more than that the coals vary in quality and that both compliance and noncompliance coal exist in the area. However, a report by Cobb and others in 1982 revealed that in eastern Kentucky approximately 43 percent of the coal beds meet compliance standards. Although the data are insufficient, one could generalize that approximately one-half of the available coal in the four study areas could be expected to meet current new-source SO_2 performance standards.

Chapter 6

SUMMARY

The first four study areas have been completed for the coal availability program conducted cooperatively between the U.S. Geological Survey and the State geological agencies of Kentucky, Virginia, and West Virginia to develop methodologies and models for prediction of the availability of coal resources for development in the Central Appalachian Region.

Major land-use and technologic constraints to the development of coal were identified and applied to the coal resources in the study areas. From these initial studies it is apparent that in the rural, rugged terrain of the Central Appalachian Region only a small percentage of the coal is restricted from development by land-use considerations (3 percent in the four areas) whereas quite a large amount (25 percent) is restricted by technologic factors. In these areas, an average of 61 percent of the original resources are estimated to be actually available for the development of mining under current conditions. Many economic considerations such as cost of mining, availability of transportation, proximity to markets, ownership of the surface and coal rights, and size of logical mining units were beyond the scope of the study, as was the application of recovery factors. Even so, it appears evident that only a fraction of the remaining coal resources of these study areas in the Central Appalachian Region will ever be mined, and only one-half of that fraction may meet current NSPS sulfur dioxide emission limits.

As expected, results from the first four study areas are inconclusive in terms of delineating regional trends. It is estimated that it will be necessary to study approximately 20 strategically-placed 7.5-minute quadrangle areas of the 450 in the region in order to adequately represent the Central Appalachian Region. Four areas are reported herein; two more have been completed recently and will be reported soon; and three additional studies will have been finished by September, 1989, bringing the total to nine. Perhaps after completion of about 15 studies, extrapolation of results into surrounding areas can begin. Additional research is ongoing for this phase of the overall study.

Chapter 7

REFERENCES CITED

Averitt, Paul , 1975, Coal resources of the United States, January 1, 1974: U.S. Geological Survey Bulletin 1412, 131 pages.

Blake, B. M., Jr., and Fedorko, Nick, 1988, The coal availability study in West Virginia — Sylvester 7.5-minute quadrangle: West Virginia Geological and Economic Survey, Final Report to the U.S. Geological Survey for Cooperative Agreement Number 14–08–0001–A0553, 67 pages.

Campbell, E. V. M., and Sites, R. S., 1988, Synopsis of the available coal resources study of Vansant 7.5-minute quadrangle, Buchanan County, Virginia: Virginia Division of Mineral Resources, Final Report to the U.S. Geological Survey for Cooperative Agreement Number 14–08–0001–A0100, 60 pages, appendix.

Carter, M. D., Cobb, J. C., Gardner, N. K., Sergeant, R. E., Tewalt, S. J., Chesnut, D. R., Jr., Davidson, O. B., and Hiett, J.K., Coal resources available for development in the Matewan 7.5-minute quadrangle, Pike County, Kentucky: U.S. Geological Survey Bulletin, in preparation.

Cobb, J. C., Currens, J. C., and Enoch, H. G., 1982, Compliance coal resources in Kentucky: Kentucky Geological Survey Information Circular 9, 52 pages.

Eggleston, J. R., Carter, M. D., and Cobb, J. C., Coal available for development — A methodology and pilot study: U.S. Geological Survey Circular, in preparation.

Office of the Federal Register, 1988, Protection of Environment *in* Code of Federal Regulations: National Archives and Records Administration, volume 40, parts 53–60, pages 195–293.

Office of Surface Mining Reclamation and Enforcement, 1988, Public Law 95–87, Surface Mining Control and Reclamation Act of 1977 (SMCRA): U.S. Department of Interior, 175 pages.

Sergeant, R. E., Cobb, J. C., Davidson, O. B., Anderson, W. H., Stickney, J. F., Chesnut, D. R., Jr., Smath, R. A., Hiett, J. K., Perry, D. B., and Gauthier, M. A., 1988, Final report of the Noble quadrangle coal availability study [Kentucky]: Kentucky Geological Survey, Final Report to U.S. Geological Survey for Cooperative Agreement Number 14–08–0001–A0564, 43 pages.

Wood, G. H., Jr., Kehn, T. M., Carter, M. D., and Culbertson, W. C., 1983, Coal resource classification system of the U.S. Geological Survey: U.S. Geological Survey Circular 891, 65 pages.

Chapter 8

GLOSSARY

Available coal resources:

Remaining coal resources that are thick and shallow enough to be mined by either surface or underground methods and that are unencumbered by land-use, environmental, societal, regulatory, or technologic restrictions as they may apply in a given State or region. In this study, available resources are derived by the following formula:

ORIGINAL COAL RESOURCES
-minus-
COAL MINED AND LOST-IN-MINING
-equals-
REMAINING COAL RESOURCES
-minus-
COAL RESTRICTED BY LAND-USE CONSIDERATIONS
-minus-
COAL RESTRICTED BY TECHNOLOGIC CONSIDERATIONS
-equals-
COAL RESOURCES AVAILABLE FOR DEVELOPMENT

Locally applicable averages for mining recovery factors may be applied after available coal resources are calculated, but are not applied in this study.

Buffer zone:

Area surrounding a restrictive feature (mine, town, cemetery, oil or gas well) in which mining is not permitted, i.e., barrier pillar around an active or abandoned underground mine.

Coal resources:

Naturally occurring concentrations or deposits of coal in the earth's crust in such forms and amounts that economic extraction is currently or potentially feasible.

Colluvium:

Loose deposits of rock debris usually at the foot of a slope or cliff brought there chiefly by gravity (mostly on a slope).

Compliance coal:

Coal that meets new-source performance standards (NSPS) of EPA for sulfur dioxide (SO_2) emission without

use of SO_2-reduction processes such as scrubbers. Current maximum limit on sulfur dioxide emissions from new-source coal-fired power plants is 1.2 pounds of SO_2 per million btu of heat input.

Deep coal resources:

Those coal resources that would most probably be mined by underground mining methods.

Deep-mine barrier pillars:

Coal left unmined around the peripheries of active or abandoned underground mines required for mine safety. Also referred to as deep-mine barriers in this report.

Digital elevation model (DEM):

Arrays of topographic elevations at regularly spaced 30-meter (approximately 100 feet) intervals that correspond in coverage to standard 1:24,000-scale 7.5-minute quadrangles; produced by the U.S. Geological Survey and distributed in tape format.

Displacement fault:

A fracture in the earth wherein the rocks have moved vertically and/or horizontally relative to one another. The displacement may range from several inches to many miles, and may be disruptive or prohibitive to the mining of coal in the immediate vicinity of the fault.

Floor rock:

Stratigraphically, the rock immediately underlying a coal bed.

Inertinite:

An organic component of coal that is inert, or partially inert, during coking processes. Inertinite could prevent complete and rapid burning of the coal in power-generation boilers unless the plant was specially designed to handle that particular coal.

Interburden:

The rock between two coal beds. When two potentially minable coal beds occur within a minimum acceptable distance above or below one another, one will not be mined — often the thinner of the two.

Land-use restrictions:

Constraints placed upon mining by societal policies to protect those surface features or entities that could be affected by mining. Laws and regulations can be modified or repealed; therefore, the restrictions may change.

Lost-in-mining:

The 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, i.e., bad roofs, faults, or

4) unmined around oil, gas, water, and disposal wells, shafts, conduits, haulageways, tunnels, and airways.

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 geochemical data base includes analyses on nearly 13,000 coal samples. The NCRDS graphics programs calculate and tabulate resources according to the specifications of the USGS coal-resources classification system (Wood and others, 1983). A national network of users and State cooperators is tied into NCRDS for interactive data retrieval, manipulation, and coal resource assessment.

Original coal resources:

The amount of coal, containing 33 percent or less ash, in the ground prior to production under less than 6,000 feet of overburden that is either 14 or more inches thick for anthracite or bituminous coal or 30 or more inches thick for subbituminous coal and lignite in such form and amount that economic extraction is currently or potentially feasible.

Outcrop:

That part of a coal bed or rock strata that appears at the surface (crops out).

Overburden:

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

Pennsylvanian:

A time period in geologic history between 270 million and 300 million years ago. The term also applies to a sequence of rocks deposited during the Pennsylvanian period.

Recoverable coal:

The coal that is or can be extracted from a coal bed during mining.

Recovery factor:

The percentage of total tons of coal estimated to be recoverable from a given area in relation to the total tonnage estimated to be in the ground prior to mining. The estimated recovery factors generally are 50 percent for underground mining methods and 80 to 90 percent for surface mining methods. More precise recovery factors can be calculated by determining the total coal in place before mining occurred and the total coal mined in any given area.

Remaining coal resources:

The coal resources in the ground after coal mined and lost-in-mining have been subtracted from the original resources.

Restricted coal resources:

Those remaining coal resources that are determined to be unminable because of current land-use or technologic restrictions.

Roof rock:

Stratigraphically, in underground mining, the rock immediately overlying a coal bed. Often the upper part of a coal bed is left unmined to serve as a roof to the mining operations.

Subsurface coal bed:

A coal bed that is completely below drainage and does not crop out at the surface nearby, so that for all underground mining of that coal bed, the coal could only be reached by shaft. Costs associated with shaft mining are higher than any other conventional method.

Surface coal resources:

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

Surface mine:

A coal-producing mine that extends no deeper than a few hundred feet down from the surface. Material above the coal (overburden) is removed to expose the coal bed, which is then mined by surface methods, such as area, contour, mountaintop removal, strip, open-pit, or auger.

Technologic restriction:

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. Geological factors are included as technologic restrictions in this report.

Underground mine:

A mine where coal is produced by first tunnelling into the earth to the coal bed and then extracting the coal by underground mining methods, such as room and pillar, longwall, and shortwall, or through in situ gasification. Underground mines are classified according to the type of opening used to reach the coal, i.e., drift (level tunnel), slope (inclined tunnel), or shaft (vertical tunnel). Deep mine is synonymous with underground mine.

Washout:

Area where a coal bed, or its precursor, has been eroded away, or washed out. This may occur before or after burial.

Appendix A

APPENDIX

Tables depicting the original, mined and lost–in–mining, land–use restricted, technologic restricted, and available coal resources, by coal bed and by quadrangle, for each of the four 7.5-minute quadrangle study areas, Central Appalachian Region, Kentucky, Virginia, and West Virginia.

Table A-1. — Estimated coal resources in the Matewan 7.5-minute quadrangle, Pike County, Kentucky

(in thousands of short tons)

Coal bed	Unrestricted									Restricted							Available		
	Original			Mined and Lost-in-Mining			Remaining			Land Use			Technologic						
	Surface	Deep	Total	Surface	Deep†	Total	Surface	Deep	Total	Surface	Deep	Total	Surface	Deep	Total	Total	Surface	Deep	Total
Lower Broas B	48	—	48	—	—	—	48	—	48	—	—	—	—	—	—	—	48	—	48
Upper Peach Orchard A	2,732	61	2,793	—	—	—	2,732	61	2,793	58	—	58	—	—	—	58	2,674	61	2,735
Lower Peach Orchard A	391	20	411	—	—	—	391	20	411	3	—	3	—	20	20	23	388	—	388
Hazard B	855	234	1,089	—	—	—	855	234	1,089	18	—	18	—	234	234	252	837	—	837
Taylor B	7,673	2,885	10,558	8	—	8	7,656	2,893	10,549	165	—	165	—	751	751	916	7,491	2,142	9,633
Hamlin A	5,007	3,242	8,249	—	—	—	5,007	3,242	8,249	175	—	175	—	2,890	2,890	3,065	4,832	351	5,183
Fire Clay Rider B	11,235	6,728	17,963	100	—	100	11,135	6,728	17,863	461	—	461	—	4,850	4,850	5,311	10,674	1,878	12,552
Fire Clay	15,936	13,936	29,872	364	619	983	15,465	13,423	28,888	505	—	505	—	1,006	1,006	1,511	14,960	12,417	27,377
Lower Whitesburg B	30,631	26,828	57,459	—	—	—	30,631	26,828	57,459	850	—	850	—	2,255	2,255	3,106	29,781	24,573	54,354
Williamson B	34,905	53,997	88,902	1,535	542	2,077	33,153	53,673	86,826	1,073	—	1,073	—	978	978	2,051	32,080	52,694	84,774
Upper Elkhorn No. 3.5	27,099	42,808	69,907	2,227	567	2,794	24,558	42,555	67,113	534	—	534	—	28,951	28,951	29,485	24,024	13,604	37,628
Upper Elkhorn No. 3D	26,248	41,018	67,266	—	—	—	26,248	41,018	67,266	996	—	996	—	12,326	12,326	13,322	25,252	28,692	53,944
Upper Elkhorn No. 3B	40,639	57,620	98,259	1,622	1,410	3,032	38,459	56,768	95,227	1,642	—	1,642	—	20,847	20,847	22,489	36,816	35,922	72,738
Upper Elkhorn No. 2B	31,375	73,982	105,357	3,440	11,066	14,506	24,906	65,945	90,851	1,654	—	1,654	—	60,876	60,876	62,529	23,252	5,070	28,322
Upper Elkhorn No. 1B	40,073	88,059	128,132	—	2,376	2,376	39,361	86,395	125,756	2,370	—	2,370	—	14,979	14,979	17,349	36,991	71,416	108,407
Lower Elkhorn Rider	10,484	45,747	56,231	—	—	—	10,484	45,747	56,231	1,574	—	1,574	—	44,991	44,991	46,565	8,910	756	9,666
Lower Elkhorn B	41,743	155,940	197,683	1,408	101,017	102,425	33,171	62,087	95,258	3,370	—	3,370	—	5,819	5,819	9,190	29,801	56,267	86,068
Powellton	1,314	3,860	5,174	—	—	—	1,314	3,860	5,174	302	—	302	—	3,860	3,860	4,163	1,012	—	1,012
Matewan	2,308	5,658	7,966	—	—	—	2,308	5,658	7,966	58	—	58	—	5,553	5,553	5,610	2,250	106	2,356
Eagle B	1,106	4,576	5,682	—	5	5	1,106	4,571	5,677	190	—	190	—	4,571	4,571	4,761	915	—	915
Glamorgan A	4,471	23,026	27,497	—	—	—	4,471	23,026	27,497	1,058	—	1,058	—	12,184	12,184	13,242	3,414	10,842	14,256
Total	336,271	650,227	986,498	10,704	117,603	128,307	313,456	544,735	858,191	17,056	—	17,056	—	227,942	227,942	244,998	296,400	316,792	613,192

†Includes underground mining within the surface resource category.

Note: Totals may not equal sum of components because of independent rounding.

Table A-2. — Estimated coal resources unavailable due to *LAND-USE RESTRICTIONS* in the Matewan 7.5-minute quadrangle, Pike County, Kentucky

(all less than 200-ft overburden — in thousands of short tons)

Coal bed	Oil and Gas Wells	Power Lines	Pipelines	Cemeteries	Towns	Streams	Total†
Lower Broas B	—	—	—	—	—	—	—
Upper Peach Orchard A	1	57	—	—	—	—	58
Lower Peach Orchard A	3	—	—	—	—	—	3
Hazard B	8	11	—	—	—	—	18
Taylor B	*	106	59	—	—	—	165
Hamlin A	1	104	70	—	—	—	175
Fire Clay Rider B	3	204	255	—	—	—	461
Fire Clay	13	253	240	—	—	—	505
Lower Whitesburg B	16	323	508	—	—	3	850
Williamson B	29	689	261	5	—	97	1,073
Upper Elkhorn No. 3.5	46	28	147	5	—	52	534
Upper Elkhorn No. 3D	57	321	365	16	—	250	996
Upper Elkhorn No. 3B	74	483	424	31	4	659	1,642
Upper Elkhorn No. 2B	73	449	259	74	13	824	1,654
Upper Elkhorn No. 1B	82	569	499	87	23	1,160	2,370
Lower Elkhorn Rider	33	386	37	69	132	994	1,574
Lower Elkhorn B	161	384	328	130	539	2,066	3,370
Powellton	9	52	—	8	85	191	302
Matewan	9	—	—	1	42	5	58
Eagle B	8	—	—	—	181	18	190
Glamorgan A	29	—	4	26	841	307	1,058
Total	655	4,420	3,454	452	1,861	6,626	17,056

* Less than 0.5

†Not necessarily sum. Calculated separately to avoid double counting of overlapping restrictions.

Note:

1. Totals may not equal sum of components because of independent rounding.
2. The figures above are all surface coal resources. No land-use restrictions were applicable to deep coal resource in the Matewan quadrangle.

Table A-3. — Estimated coal resources unavailable due to *TECHNOLOGIC RESTRICTIONS* in the Matewan 7.5-minute quadrangle, Pike County, Kentucky

(all greater than 200 ft overburden — in thousands of short tons)

Coal bed	Oil and Gas Wells	Deep-mine Barriers	Interburden lt 40 ft	Deep mining lt 40 ft	Coal lt 28 in.	Overburden gt 1000 ft	Total †
Lower Broas B	—	—	—	—	—	—	—
Upper Peach Orchard A	—	—	—	—	—	—	—
Lower Peach Orchard A	—	—	—	—	20	—	20
Hazard B	—	—	—	—	234	—	234
Taylor B	—	—	—	—	782	—	751
Hamlin A	—	—	974	—	2,102	—	2,890
Fire Clay Rider B	—	—	1,491	—	3,324	—	4,850
Fire Clay	17	91	—	—	930	—	1,006
Lower Whitesburg B	3	—	—	—	2,265	—	2,255
Williamson B	38	95	—	266	1,727	—	978
Upper Elkhorn No. 3.5	24	36	16,738	176	12,543	—	28,951
Upper Elkhorn No. 3D	9	—	4,145	1	8,178	—	12,326
Upper Elkhorn No. 3B	31	162	—	4,634	16,014	83	20,847
Upper Elkhorn No. 2B	69	804	51,267	1,062	8,128	322	60,876
Upper Elkhorn No. 1B	97	347	—	6,185	8,132	375	14,979
Lower Elkhorn Rider	13	—	11,569	9,501	32,840	573	44,991
Lower Elkhorn B	131	2,331	—	—	430	395	5,819
Powellton	—	—	—	—	3,849	11	3,860
Matewan	—	—	—	—	5,281	—	5,553
Eagle B	—	—	—	—	4,569	—	4,571
Glamorgan A	28	—	—	—	12,057	92	12,184
Total	459	3,866	86,184	21,825	123,406	1,851	227,942

†Not necessarily sum. Calculated separately to avoid double counting of overlapping restrictions.

Note:

1. Totals may not equal sum of components because of independent rounding.
2. The figures above are all deep coal resources. No technologic restrictions were applicable to surface coal resources in the Matewan quadrangle.

Table A-4. — Estimated coal resources in the Noble 7.5-minute quadrangle, Breathitt, Perry, and Knott Counties, Kentucky

(in thousands of short tons)

Coal bed	Unrestricted									Restricted							Available		
	Original			Mined and Lost-in-Mining			Remaining			Land Use			Technologic						
	Surface	Deep	Total	Surface	Deep†	Total	Surface	Deep	Total	Surface	Deep	Total	Surface	Deep	Total	Total	Surface	Deep	Total
Skyline E	5,677	—	5,677	4,741	—	4,741	936	—	936	782	—	782	—	—	—	782	155	—	155
Skyline D	2,785	—	2,785	2,397	—	2,397	388	—	388	186	—	186	—	—	—	186	201	—	201
Skyline C	6,664	—	6,664	4,582	—	4,582	2,083	—	2,083	930	—	930	—	—	—	930	1,153	—	1,153
Skyline B	8,227	—	8,227	5,687	—	5,687	2,540	—	2,540	1,957	—	1,957	—	—	—	1,957	583	—	583
Skyline A	21,438	—	21,438	13,817	—	13,817	7,621	—	7,621	5,728	—	5,728	—	—	—	5,728	1,894	—	1,894
Tiptop B	709	—	709	359	—	359	350	—	350	—	—	—	—	—	—	—	350	—	350
Tiptop A	21,347	—	21,347	3,566	—	3,566	17,782	—	17,782	6,979	—	6,979	—	—	—	6,979	10,802	—	10,802
Hindman	24,666	270	24,936	3,885	—	3,885	20,781	270	21,050	4,897	61	4,958	—	60	60	5,018	15,883	149	16,033
Francis	87,444	12,913	100,357	9,317	326	9,643	77,842	12,872	90,714	18,633	3,331	21,964	97	1,065	1,162	23,125	59,113	8,476	67,589
Hazard 7B	19,402	5,921	25,322	1,139	—	1,139	18,262	5,921	24,183	1,331	581	1,912	—	886	886	2,798	16,931	4,454	21,385
Hazard 7A	37,057	10,342	47,399	10,820	280	11,100	26,094	10,204	36,299	1,312	796	2,108	66	1,137	1,204	3,311	24,717	8,271	32,987
Hazard B	26,560	47,522	74,082	—	—	—	26,560	47,522	74,082	8,710	5,104	13,814	—	23,784	23,784	37,598	17,850	18,634	36,484
Haddix B	40,349	31,342	71,691	—	—	—	40,349	31,342	71,691	2,723	3,392	6,115	—	7,628	7,628	13,744	37,625	20,322	57,947
Haddix A	9,245	4,979	14,225	—	—	—	9,245	4,979	14,225	335	152	487	—	4,173	4,173	4,660	8,910	655	9,564
Upper Hamlin	85	75	160	—	—	—	85	75	160	—	—	—	—	75	75	75	85	—	85
Lower Hamlin	750	875	1,624	—	—	—	750	875	1,624	192	211	404	—	664	664	1,067	557	—	557
Fire Clay Rider	5,635	—	5,635	—	—	—	5,635	—	5,635	304	—	304	—	—	—	304	5,331	—	5,331
Fire Clay	8,845	18,802	27,647	35	—	35	8,811	18,802	27,613	2,835	5,914	8,749	—	11,558	11,558	20,307	5,975	1,331	7,306
Total	328,885	133,040	459,924	60,344	606	60,950	266,113	132,861	398,975	57,835	19,542	77,376	163	51,028	51,191	128,568	208,116	62,291	270,407

†Includes underground mining within the surface resource category.

Note: Totals may not equal sum of components because of independent rounding.

Table A-5. — Estimated coal resources unavailable due to *LAND-USE RESTRICTIONS* in the Noble 7.5-minute quadrangle, Breathitt, Perry, and Knott Counties, Kentucky

(in thousands of short tons)

	Surface					Deep		
Coal bed	Cemeteries	Towns	Streams	Forest Preserve	Total	Forest Preserve	Total	Total
Skyline E	59	—	—	723	782	—	—	782
Skyline D	67	—	—	119	186	—	—	186
Skyline C	90	—	—	840	930	—	—	930
Skyline B	69	—	—	1,888	1,957	—	—	1,957
Skyline A	204	—	—	5,523	5,728	—	—	5,728
Tiptop B	—	—	—	—	—	—	—	—
Tiptop A	13	—	—	6,966	6,979	—	—	6,979
Hindman	—	—	—	4,897	4,897	61	61	4,958
Francis	3	—	—	18,630	18,633	3,331	3,331	21,964
Hazard 7B	—	—	—	1,331	1,331	581	581	1,912
Hazard 7A	—	—	—	1,312	1,312	796	796	2,108
Hazard B	—	—	—	8,710	8,710	5,104	5,104	13,814
Haddix B	1	—	—	2,723	2,723	3,392	3,392	6,115
Haddix A	—	—	—	335	335	152	152	487
Upper Hamlin	—	—	—	—	—	—	—	—
Lower Hamlin	—	106	—	86	192	211	211	404
Fire Clay Rider	—	266	38	—	304	—	—	304
Fire Clay	2	1,067	—	1,767	2,835	5,914	5,914	8,749
Total	508	1,439	38	55,850	57,834	19,542	19,542	77,377

Note: Totals may not equal sum of components because of independent rounding.

Table A-6. — Estimated coal resources unavailable due to *TECHNOLOGIC RESTRICTIONS* in the Noble 7.5-minute quadrangle, Breathitt, Perry, and Knott Counties, Kentucky

(in thousands of short tons)

	Surface		Deep			
Coal bed	Deep-mine Barriers	Total	Coal lt. 28 in. †	Oil and Gas Wells	Total	Total
Skyline E	—	—	—	—	—	—
Skyline D	—	—	—	—	—	—
Skyline C	—	—	—	—	—	—
Skyline B	—	—	—	—	—	—
Skyline A	—	—	—	—	—	—
Tiptop B	—	—	—	—	—	—
Tiptop A	—	—	—	—	—	—
Hindman	—	—	60	—	60	60
Francis	97	97	1,058	6	1,065	1,162
Hazard 7B	—	—	886	—	886	886
Hazard 7A	66	66	1,127	11	1,137	1,204
Hazard B	—	—	23,770	13	23,784	23,784
Haddix B	—	—	7,612	16	7,628	7,628
Haddix A	—	—	4,171	1	4,173	4,173
Upper Hamlin	—	—	75	—	75	75
Lower Hamlin	—	—	664	—	664	664
Fire Clay Rider	—	—	—	—	—	—
Fire Clay	—	—	11,538	20	11,558	11,558
Total	163	163	50,961	67	51,028	51,191

†Includes deep-mine barriers.

Note: Totals may not equal sum of components because of independent rounding.

Table A-7. — Estimated coal resources in the Sylvester 7.5-minute quadrangle, Boone and Kanawha Counties, West Virginia

(in thousands of short tons)

Coal bed	Unrestricted									Restricted							Available		
	Original			Mined and Lost-in-Mining			Remaining			Land Use			Technologic						
	Surface	Deep	Total	Surface	Deep†	Total	Surface	Deep	Total	Surface	Deep	Total	Surface	Deep	Total	Total	Surface	Deep	Total
Upper No. 5 Block	65,451	12,181	77,632	22,874	18,833	41,708	31,269	4,656	35,924	481	—	481	5,342	1,223	6,565	7,045	25,446	3,433	28,879
Lower No. 5 Block	62,958	9,250	72,208	4,330	5,677	10,007	52,984	9,217	62,201	938	—	938	21,589	4,677	26,266	27,203	30,457	4,540	34,997
Coalburg	59,045	84,955	144,000	2,715	881	3,596	56,231	84,173	140,404	620	—	620	8,235	12,353	20,588	21,208	47,377	71,820	119,196
Winifrede	31,190	84,423	115,612	564	2,724	3,288	29,820	82,505	112,325	261	68	329	10,381	33,138	43,519	43,848	19,178	49,298	68,477
Hernshaw	24,464	145,424	169,888	744	16,870	17,614	21,839	130,435	152,274	605	345	950	2,193	22,259	24,451	25,402	19,041	107,831	126,872
Cedar Grove	9,074	68,087	77,161	—	3,781	3,781	9,074	68,087	77,161	26	—	26	5,145	51,534	56,679	56,705	3,903	16,552	20,456
Alma	10,460	100,042	110,503	12	—	12	10,315	96,394	106,709	361	576	937	3,278	33,185	36,463	37,400	6,876	62,633	69,309
No. 2 Gas	8,900	121,215	130,114	25	53	78	8,874	121,215	130,089	560	669	1,230	4,822	48,445	53,267	54,497	3,492	72,100	75,592
Lower No. 2 Gas	9,359	151,436	160,795	—	—	—	9,359	151,383	160,742	1,730	506	2,236	2,953	39,057	42,010	44,246	4,675	111,821	116,496
Eagle	4,816	179,595	184,411	—	—	—	4,816	179,595	184,411	2,937	2,614	5,551	519	40,128	40,646	46,198	1,361	138,853	138,213
Total	285,717	956,607	1,242,323	31,265	48,819	80,084	234,581	927,658	1,162,239	8,517	4,779	13,296	64,456	285,999	350,455	363,752	161,607	636,880	798,487

†Includes underground mining within the surface resource category.

Note: Totals may not equal sum of components because of independent rounding.

Table A-8. — Estimated coal resources unavailable due to *LAND-USE RESTRICTIONS* in the Sylvester 7.5-minute quadrangle, Boone and Kanawha Counties, West Virginia

(in thousands of short tons)

	Surface							Deep			
Coal bed	Power Lines	Pipelines	Cemeteries	Oil and Gas Wells	Towns	Streams	Total†	Towns	Streams	Total †	Total
Upper No. 5 Block	9	343	*	129	—	—	481	—	—	—	481
Lower No. 5 Block	48	376	*	514	—	—	938	—	—	—	938
Coalburg	54	183	—	248	135	—	620	—	—	—	620
Winifrede	67	14	—	51	129	—	261	68	—	68	329
Hernshaw	69	55	—	66	414	—	605	345	—	345	950
Cedar Grove	9	2	—	14	—	—	26	—	—	—	26
Alma	—	93	—	18	236	15	361	576	—	576	937
No. 2 Gas	4	69	—	17	343	131	560	669	—	669	1,230
Lower No. 2 Gas	—	48	21	31	437	1,225	1,730	505	1	506	2,236
Eagle	—	40	11	30	953	2,461	2,937	880	1,754	2,614	5,551
Total	261	1,222	32	1,118	2,647	3,832	8,517	3,044	1,755	4,779	13,296

* Less than 0.5

†Not necessarily sum. Calculated separately to avoid double counting of overlapping restrictions.

Note: Totals may not equal sum of components because of independent rounding.

Table A-9. — Estimated coal resources unavailable due to *TECHNOLOGIC RESTRICTIONS* in the Sylvester 7.5-minute quadrangle, Boone and Kanawha Counties, West Virginia

(in thousands of short tons)

Coal bed	Surface					Deep						
	Deep-mine Barriers	Geologic Factors	Interburden lt 25 ft	Coal lt 28 in.	Total †	Oil and Gas Wells	Deep-mine Barriers	Geologic Factors	Interburden lt 25 ft	Coal lt 28 in.	Total †	Total
Upper No. 5 Block	1,964	296	1,932	1,357	5,342	42	754	287	44	114	1,223	6,565
Lower No. 5 Block	1,223	97	19,443	3,622	21,589	90	94	—	3,913	630	4,677	26,266
Coalburg	47	3,841	—	4,351	8,235	919	205	5,823	—	5,406	12,353	20,588
Winifrede	67	1,555	—	8,759	10,381	350	197	3,997	—	28,595	33,138	43,519
Hernshaw	610	250	—	1,585	2,193	397	1,936	2,103	—	17,832	22,259	24,451
Cedar Grove	—	—	—	5,145	5,145	10	—	—	—	51,525	51,534	56,679
Alma	95	—	—	3,183	3,278	91	929	—	—	32,165	33,185	36,463
No. 2 Gas	—	—	—	4,822	4,822	163	—	—	—	48,282	48,445	53,267
Lower No. 2 Gas	—	—	—	2,953	2,953	513	32	—	—	38,512	39,057	42,010
Eagle	—	—	—	519	519	841	—	—	—	39,287	40,128	40,646
Total	4,006	6,040	21,375	36,295	64,456	3,416	4,147	12,211	3,957	262,347	285,999	350,455

†Not necessarily sum. Calculated separately to avoid double counting of overlapping restrictions.
Note: Totals may not equal sum of components because of independent rounding.

Table A-10. — Estimated coal resources in the Vansant 7.5-minute quadrangle, Buchanan County, Virginia

(in thousands of short tons)

Coal bed	Unrestricted									Restricted							Available		
	Original			Mined and Lost-in-Mining			Remaining			Land Use			Technologic						
	Surface	Deep	Total	Surface	Deep†	Total	Surface	Deep	Total	Surface	Deep	Total	Surface	Deep	Total	Total	Surface	Deep	Total
Eagle	831	—	831	300	—	300	531	—	531	—	—	—	—	—	—	—	531	—	531
Blair	1,216	—	1,216	535	—	535	682	—	682	—	—	—	—	—	—	—	682	—	682
Dorchester	1,359	91	1,450	16	—	16	1,343	91	1,434	—	—	—	—	—	—	—	1,343	91	1,434
Hagy	6,505	3,186	9,691	433	1,775	2,208	5,268	2,215	7,483	2	—	2	—	245	245	246	5,266	1,970	7,237
Splash Dam	27,362	14,393	41,754	439	486	926	26,603	14,225	40,828	10	—	10	—	883	883	893	26,593	13,342	39,936
Upper Banner	5,937	5,913	11,850	291	—	291	5,645	5,913	11,558	8	—	8	—	3,649	3,649	3,657	5,637	2,264	7,901
Lower Banner	15,719	23,561	39,280	952	254	1,206	14,723	23,351	38,073	1	—	1	—	1,184	1,184	1,185	14,722	22,166	36,888
Kennedy	31,749	76,188	107,937	3,882	40,137	44,019	10,646	53,272	63,918	20	—	20	—	5,095	5,095	5,116	10,626	48,176	58,802
Aily	12,105	51,288	63,393	133	—	133	11,971	51,288	63,259	70	—	70	—	15,431	15,431	15,501	11,901	35,857	47,758
Raven 2	10,006	69,415	79,421	173	—	173	9,833	69,415	79,249	54	—	54	—	22	22	76	9,779	69,393	79,172
Raven 1	9,978	50,401	60,379	86	87	173	9,873	50,333	60,206	138	—	138	—	29,829	29,829	29,967	9,735	20,504	30,239
Jawbone	5,436	70,211	75,647	46	—	46	5,390	70,211	75,601	579	—	579	—	36	36	615	4,811	70,175	74,986
Tiller	2,724	25,778	28,502	9	—	9	2,714	25,778	28,492	155	—	155	—	5,794	5,794	5,948	2,560	19,984	22,544
Upper Seaboard	—	6,651	6,651	—	—	—	—	6,651	6,651	—	—	—	—	6,651	6,651	6,651	—	—	—
War Creek	—	36,429	36,429	—	—	—	—	36,429	36,429	—	—	—	—	36,429	36,429	36,429	—	—	—
Lower Horsepen	—	63,687	63,687	—	—	—	—	63,687	63,687	—	—	—	—	63,280	63,280	63,280	—	407	407
Little Fire Creek	—	91,010	91,010	—	—	—	—	91,010	91,010	—	—	—	—	91,010	91,010	91,010	—	—	—
Pocahontas No. 3	—	289,014	289,014	—	92,397	92,397	—	196,617	196,617	—	—	—	—	17,804	17,804	17,804	—	178,814	178,814
Total	130,926	877,214	1,008,140	7,296	135,136	142,432	105,523	760,485	865,708	1,036	—	1,036	—	277,341	277,341	278,378	104,186	483,144	587,330

†Includes underground mining within the surface resource category.

Note: Totals may not equal sum of components because of independent rounding.

Table A-11. — Estimated coal resources unavailable due to *LAND-USE RESTRICTIONS* in the Vansant 7.5-minute quadrangle, Buchanan County, Virginia

(all less than 200 ft overburden — in thousands of short tons)

Coal bed	Oil and Gas Wells	Cemeteries	Towns	Streams	Total†
Eagle	—	—	—	—	—
Blair	—	—	—	—	—
Dorchester	—	—	—	—	—
Hagy	2	—	—	—	2
Splash Dam	8	2	—	—	10
Upper Banner	8	—	—	—	8
Lower Banner	*	*	—	—	1
Kennedy	19	2	—	—	20
Aily	4	2	64	—	70
Raven 2	1	1	51	*	54
Raven 1	3	2	133	—	138
Jawbone	26	2	517	34	579
Tiller	8	1	142	4	155
Upper Seaboard	—	—	—	—	—
War Creek	—	—	—	—	—
Lower Horsepen	—	—	—	—	—
Little Fire Creek	—	—	—	—	—
Pocahontas No. 3	—	—	—	—	—
Total	78	13	907	38	1,036

* Less than 0.5

†Not necessarily sum. Calculated separately to avoid double counting of overlapping restrictions.

Note:

1. Totals may not equal sum of components because of independent rounding.
2. The figures above are all surface coal resources. No land-use restrictions were applicable to deep coal resources in the Vansant quadrangle.

Table A-12. — Estimated coal resources unavailable due to *TECHNOLOGIC RESTRICTIONS* in the Vansant 7.5-minute quadrangle, Buchanan County, Virginia

(all greater than 200 ft overburden — in thousands of short tons)

Coal bed	Oil and Gas Wells	Deep-mine Barriers	Interburden lt 40 ft	Deep mining lt 40 ft	Subsurface coal lt 28 in.	Total †
Eagle	—	—	—	—	—	—
Blair	—	—	—	—	—	—
Dorchester	—	—	—	—	—	—
Hagy	—	245	—	—	—	245
Splash Dam	—	34	849	368	—	883
Upper Banner	2	—	3,534	114	—	3,649
Lower Banner	—	49	1,135	349	—	1,184
Kennedy	14	5,103	—	—	—	5,095
Aily	13	—	15,418	924	—	15,431
Raven 2	22	—	—	—	—	22
Raven 1	30	43	29,776	—	—	29,829
Jawbone	36	—	—	—	—	36
Tiller	18	—	5,776	—	—	5,794
Upper Seaboard	—	—	—	—	6,651	6,651
War Creek	22	—	474	—	36,429	36,429
Lower Horsepen	52	—	5,504	—	63,280	63,280
Little Fire Creek	50	—	—	—	91,010	91,010
Pocahontas No. 3	89	4,242	—	—	13,747	17,804
Total	347	9,715	62,466	1,755	211,117	277,341

†Not necessarily sum. Calculated separately to avoid double counting of overlapping restrictions.

Note:

1. Totals may not equal sum of components because of independent rounding.
2. The figures above are all deep coal resources. No technologic restrictions were applicable to surface coal resources in the Vansant quadrangle.