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Donald C. Haney, State Geologist and Director
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AVAILABLE COAL RESOURCES OF THE HANDSHOE 7.5–MINUTE QUADRANGLE, KNOTT COUNTY, KENTUCKY

Gerald A. Weisenfluh, Robert E. Andrews,
John K. Hiett, and Richard E. Sergeant

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Cover Illustration

Three-dimensional topography of the Handshoe Quadrangle viewed from the southeast.

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SUMMARY

Coal resources available for mining have been estimated for the Handshoe Quadrangle within the Hazard Coal Reserve District of the Eastern Kentucky Coal Field. Twelve coal beds within the quadrangle are potentially mineable and comprise the basis of these resource estimates. Seven of these beds have been commercially developed, but only four have produced more than 1 million tons: the Tiptop, Hazard No. 8, Hazard No. 4, and Upper Elkhorn No. 3. A computerized Geographic Information System was used to calculate estimates of original, mined–out, and remaining resources, restrictions to mining, and available resources.

Original Coal Resources

The total original coal resources for the Handshoe Quadrangle were **644.7** million short tons. Three beds, the Hazard No. 4, Upper Elkhorn No. 3, and Upper Elkhorn No. 1 comprise 63 percent of this amount. Approximately **63 percent** of the total original resources are in the greater–than–28–inch thickness category. Given a maximum overburden height of 100 feet for surface mining, **85 percent** of the resources lie in the deep–mineable category. The average reliability of the estimates based on the density of data points is **31 percent measured, 55 percent indicated, and 14 percent inferred.**

Mined–Out and Remaining Coal Resources

Total mined–out and lost–in–mining tonnages are **11.6** million tons. Surface mining accounts for **57 percent** of this amount. The remaining resources are **633.1** million tons or **98 percent** of the original. These resources are distributed similarly to the original resources with respect to overburden and thickness categories.

Restrictions and Available Coal Resources

The total restricted coal for the area is **230** million tons or **36 percent** of the remaining resources. Coal too thin to mine by underground methods (technological restriction) accounts for **92 percent** of this amount. The available coal resources are estimated as **403** million tons, which is **62.5 percent** of original and **64 percent** of remaining resources. Deep–mineable coal represents **81 percent** of the available resources. The Hazard No. 4, Upper Elkhorn No. 3, and Upper Elkhorn No. 1 coal beds comprise **75 percent** of available resources.

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INTRODUCTION

One of the primary functions of the Federal and state geological surveys is to estimate the amount and character of the Nation's mineral resources. Understanding these estimates and their inherent levels of uncertainty is crucial for policy makers involved with long-term economic planning. In Kentucky, one of the most important energy resources is coal, which occurs in two regions of the State: the Eastern and Western Kentucky Coal Fields.

About 6.6 billion tons of coal have been mined in these two regions since the beginning of the nineteenth century. The amount of coal remaining in Kentucky is estimated to be about 90 billion tons (Brant and others, 1983; annual production figures). Given present production levels of about 160 million tons per year, there is an apparently endless supply of coal in the Commonwealth. There may, however, be significant portions of this resource that are not available for mining, due both to regulatory statutes and adverse engineering or geological conditions (Eggleston and others, 1990). Quantification of the degree to which these factors restrict the resource is important for making projections of the amounts of coal resources available for future mining.

The objective of this program is to measure, for selected areas, the magnitude of past mining and potential restrictions to future mining. Mined-out tonnages are discriminated on the basis of surface or underground mining. Restrictions fall under two categories: land-use and technological. Land-use restrictions are those that are specified by local, State, or Federal regulations and generally apply to surface mining. Examples are streams, roads, cemeteries, powerlines, municipalities, and the applicable buffer zones of each. Technological factors that restrict the development of coal, such as deep mine buffers and adverse geological conditions, generally apply to underground mining.

Each analysis for this program is performed for one 7.5-minute quadrangle, a map area of about 55 square miles or 38,000 acres. Estimates are presented for original, mined-out, remaining, restricted, and available resources. This report describes the results for the eighth project area, the Handshoe Quadrangle, in Knott, Floyd, Breathitt, and Magoffin Counties, eastern Kentucky.

LOCATION, GEOLOGY, AND MINING HISTORY

The Handshoe Quadrangle is located between the towns of Hazard and Prestonsburg in eastern Kentucky. Most of the quadrangle lies in Knott County, with small areas in Breathitt, Floyd, and Magoffin Counties. No major municipalities are within the area and the only major access road is Kentucky Highway 80.

The Handshoe Quadrangle lies along the eastern flank of the Eastern Kentucky Syncline (MacFarlan, 1943), and is largely within the Hazard Coal Reserve District (Fig. 1). Regional structural dip in the area is to the northwest at a rate of about 30 feet per mile. No major drainages are within the quadrangle, and maximum topographic relief is about 1,000 feet.

The principal coal beds of the area, as shown by Danilchik (1977), range stratigraphically upward from the Upper Elkhorn No. 1 to the Tiptop (mistakenly identified as Skyline by Danilchik). The thickness of this interval is about 1,000 feet (Fig. 2). The major coal beds occur in three coal groups, which are separated by thick marine sequences. The lower group contains the Upper Elkhorn coal beds and is overlain by the Elkins Fork and Kendrick Shales. The Amburgy coal zone lies between these two marine intervals, but there are no mineable Amburgy coal beds in the Handshoe Quadrangle. The middle coal group contains the Whitesburg coals, the Hazard No. 4 coal zone, and the Hamlin/Copland coal zone. These coals are overlain by the Magoffin marine shale. The upper coal group contains five coal beds between and including the Hazard and Tiptop coals.

Historically, the coal beds of greatest economic importance have been the Upper Elkhorn No. 3 and the Hazard No. 4, which have been developed by underground methods, the Tiptop, and, to a lesser degree, the Hazard No. 8, which have been developed by surface-mining methods. However, the level of production has been relatively minor compared to surrounding quadrangles, such as the Noble Quadrangle, summarized later in this report.

METHODS

Approach

In order to estimate the tonnage of coal present within a given area, its volume must be known. The two factors necessary for calculating volume are area, which is defined by the outcrop of the coal bed, and thickness, which is estimated from point measurements along the outcrop and in subsurface boreholes. The various resource categories, mined-out areas, and restrictions described below make up some part of the whole area of each coal bed. Because the primary task is one of determining and measuring map areas, a computerized Geographic Information System (GIS) approach was selected to perform the analysis. This type of system allows for the storage of digital map information and automated comparisons and calculations on one or more maps. The primary effort is preparing analog point-

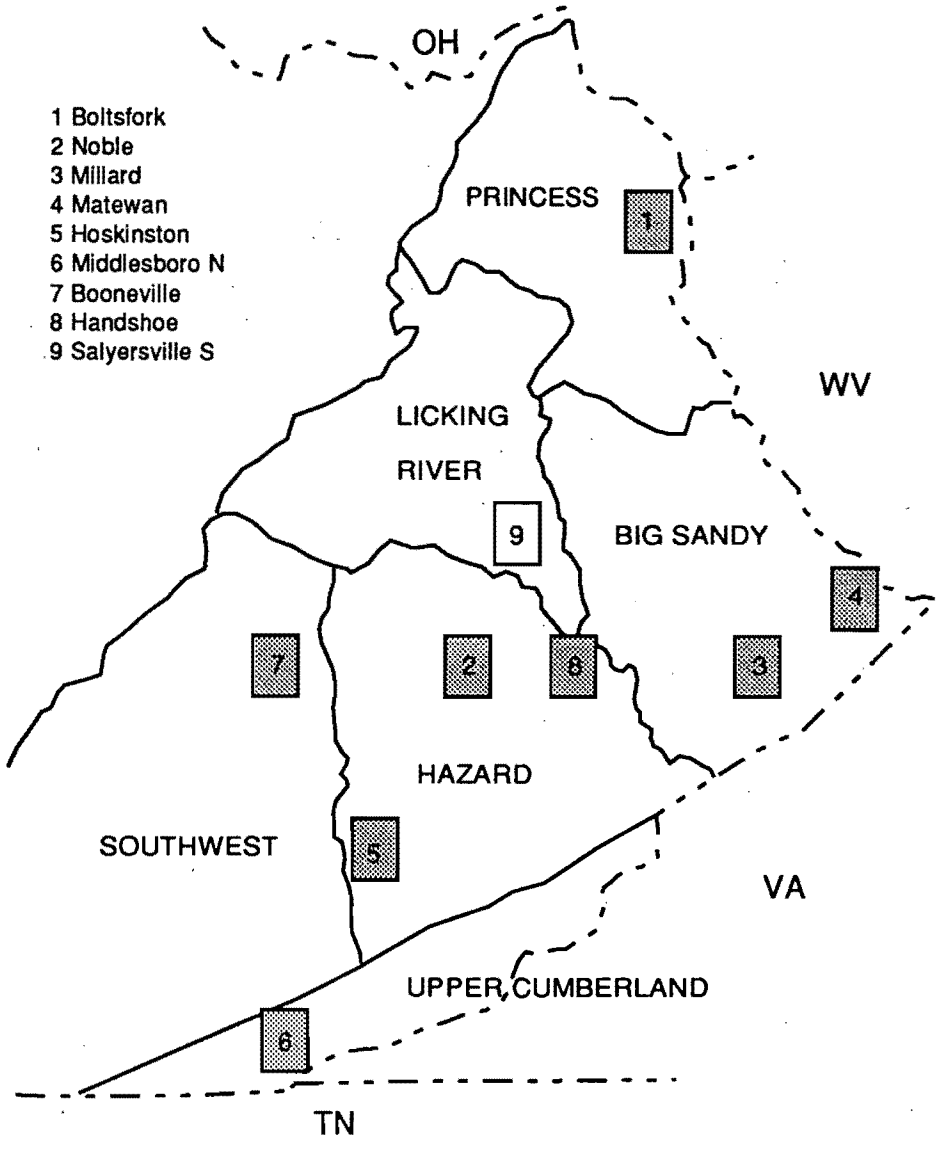

Figure 1. Location of the Handshoe Quadrangle within the Eastern Kentucky Coal Field. Completed (stippled) and proposed Coal Availability Quadrangles shown relative to the six coal reserve districts.

source data and map information and rendering them in digital form.

Data Preparation

Point Data

Most of the data relevant to the thickness of coal beds within the Handshoe Quadrangle were derived from measurements made by geologists and engineers from exploration core holes. These measurements include a coal bed's thickness, rock partings if present, elevation (calculated from surveyed collar elevations), and the stratigraphic position of the coal. These data were processed and extracted using the CMASTER system, a borehole data-base software product. Additional information about the thickness and elevation of coal beds was obtained from surface-mine permits from the Kentucky Natural Resources and Environmental Protection Cabinet. All data were re-examined in order to verify correlations and accuracy in measurement. The locations and measurements were then extracted into data files in which coordinates were expressed in the Universal Transverse Mercator System, thicknesses in whole inches, and elevations in feet above sea level.

Map Data

The various types of map information were digitized from stable map media (mylar tracings or photo repro-

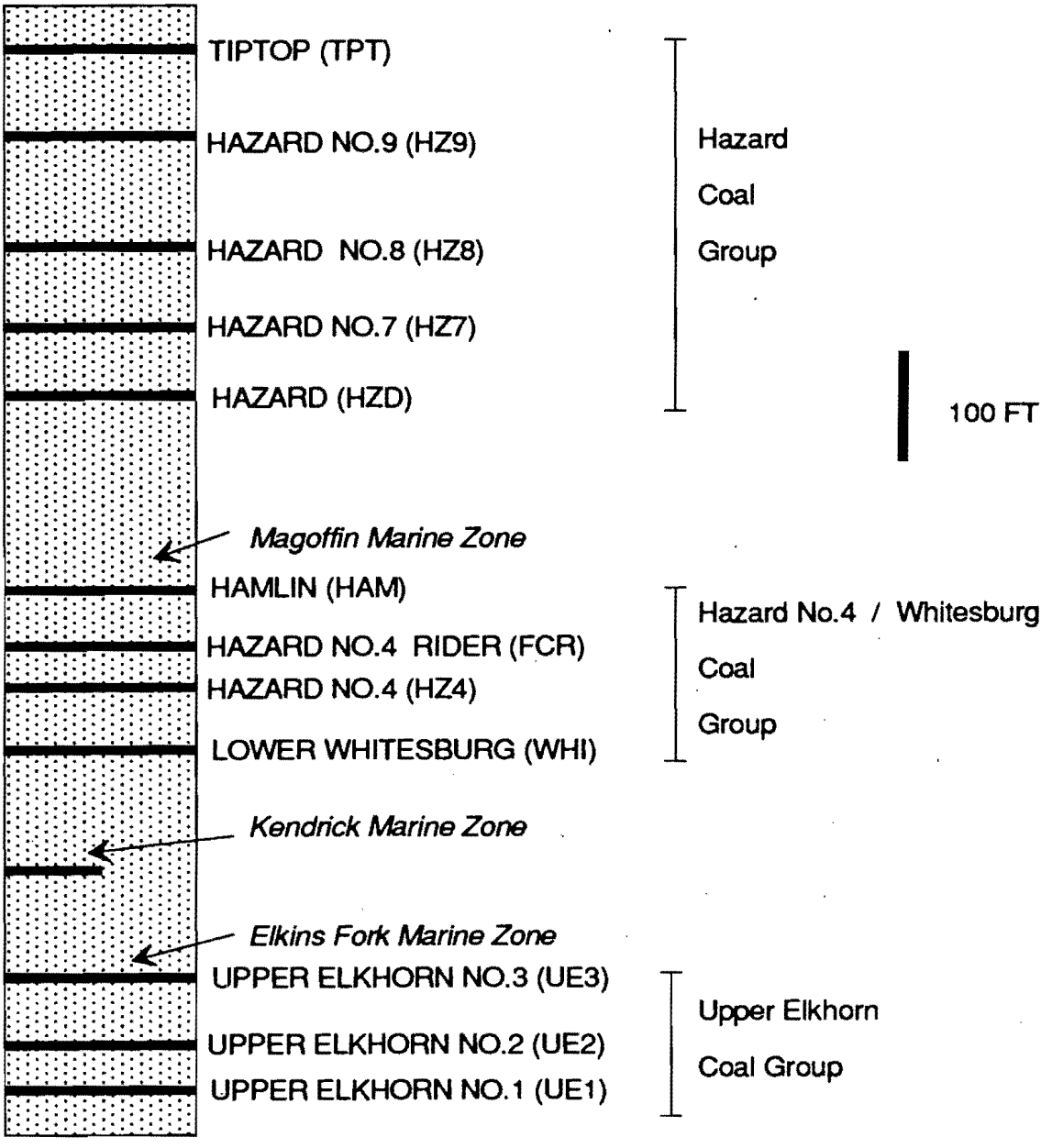

Figure 2. Stratigraphic section of the principal coal-producing portion of the Handshoe Quadrangle. Bed names and three-letter abbreviations given only for those coal beds for which resource estimates were prepared. Bed abbreviations are those used in subsequent figures in text. Coal groups are informal designations used only for the purpose of summarizing the coal resources of this quadrangle.

ductions) using the program GSMAP version 7.2. Coalbed outcrops were determined from the Handshoe 7.5-minute geologic quadrangle map (Danilchik, 1977) and from surface and underground mine maps obtained from the Kentucky Division of Permits and the Kentucky Department of Mines and Minerals. Land-use restrictions were digitized from U.S. Geological Survey 7.5-minute topographic base maps. The locations of oil and gas wells were obtained from the Kentucky Geological Survey's Oil and Gas Well Repository. The digital elevation model (D.E.M.) was obtained from the U.S. Geological Survey and consists of a rectilinear grid of surface elevations at 30 meter intervals within the map area. Restrictions and mined-out areas were field checked for accuracy.

Restrictions to Mining

Most land-use restrictions are outlined under Kentucky Natural Resources and Environmental Protection Cabinet Document 405 KAR (Kentucky Administrative

Register) 24:040, "Permit Application Review." This document relates to KRS (Kentucky Revised Statutes) 350.465 and 350.610, which defines the regulatory program for surface mining in Kentucky. These restrictions and their applicable buffers (areas where mining is not permitted) are given in Table 1. Seven of the restriction categories apply to the Handshoe Quadrangle. Except for Federally funded highways, nationally protected lands, and cemeteries, variances are granted for many of the listed restrictions.

Technological restrictions, also listed in Table 1, include barriers around existing underground mines, mining or potential mining within 40 vertical feet of a seam, oil and gas wells, and coal too thin (less than 28 inches) for underground mining methods.

Data Analysis

The Geographic Information System software utilized for this phase of the project was GRASS, a U.S. Government software package developed primarily by the U.S. Army Corps of Engineers, the Soil Conservation Service, and the U.S. Geological Survey. GRASS is a raster-based GIS, which means that map data are rendered as matrices of equal-sized grid cells. Maps stored in a GRASS data base must be oriented to a particular coordinate system. The Universal Transverse Mercator System, based on the Clark 1866 spheroid, was chosen for this study. The size of grid cells for each map must be specified, but can vary between maps (*see* Table 2). In order to utilize map information for calculations, the original vector data (points, lines, or areas) must be converted to raster (gridded) data files.

Table 1.—Potential Restrictions with Applicable Buffer Zones and Categories to Which They Apply. Restrictions Found in Handshoe Quadrangle Indicated by Asterisk.

Restrictions	*Buffer*	*Land-Use*	*Technological*	*Surface*	*Deep*
Airports	area + 100'	X		X	X
Bridges	area + 100'	X		X	
Cemeteries*	area + 100'	X		X	
Faults	area + 100'	X	X	X	X
Public Lands	area	X		X	X
Pipelines	area + 100'	X		X	
Powerlines*	area + 100'	X		X	
Railroads	area + 100'	X		X	
Roads*	area + 100'	X		X	
Streams*	area + 100'	X		X	X
Parks, National	area	X		X	
Parks, State	area	X		X	
Towns*	area + 300'	X		X	X
Oil & Gas Wells*	200'	X	X	X	X
Coal Too Deep	area		X		X
Mine Buffers*	50'		X		X
Interburden < 40'*	area		X		X
Mining Within 40'*	area		X		X
Coal Too Thin*	area		X		X

Table 2.—List of Map Types Used for GRASS Data Analysis. Data Source, Method of Generation, GRASS Cell Resolution, and Other Pertinent Information Given.

Map Type	*Data Source*	*Method*	*Resolution*	*Comments*
Map Boundary	corner points		5 meters	used as data mask
Outcrops	1:24,000 USGS GQ	digitized	5 meters	used for original resource maps
Mines	Dept. of Mines & Minerals	digitized	5 meters	used for remaining resource calculations
Land–Use Restrictions	1:24,000 topographic map	digitized	5 meters	used for available resource calculations
Oil & Gas Wells	KGS data base	s. poly output	5 meters	restriction
Reliability Arcs	KGS coal data base	s. poly output	5 meters	reliability categories
DEM	1:24,000 USGS digital file		30 meters	used for creating overburden maps
Structure contour	KGS data base	s.surf.pln	30 meters	used for overburden maps
Overburden isopach	derived	r.mapcalc	30 meters	
Thickness isopach	KGS data base	s.surf.pln or s.surf.idw	30 meters	used for thickness maps

In the case of thickness and elevation point data, a gridding algorithm was used to interpolate cell nodes between data points. Two algorithms were utilized. The first,"s.surf.pln," accepts unequally spaced data and applies a first-order trend surface fit to the nearest neighbors found by the specified search. This program works best on structural data, which have a large first-order component. It also works adequately on thickness data that are relatively closely spaced. Interpolation problems occur in areas of sparse data and in the vicinity of closely spaced points that differ substantially in thickness. The second algorithm, "s.surf.idw," uses a simple inverse-distance weighting function. This program is efficient at honoring data points, but is inaccurate farther away from the points. It was implemented for seams where few data were available and the area of outcrop was limited (uppermost seams). A summary of data associated with each coal bed is given in Table 3.

Table 3.—Summary of Data Associated with Each Coal Bed Used in Resource Calculations.

Coal Bed	*Area (acres)*	*% > 14"*	*Data Points*	*Surface-Mine Acreage*	*Deep-Mine Acreage*
Tiptop	531	97	52	363	—
Hazard No. 9	4,699	43	89	138	—
Hazard No. 8	10,168	99	105	168	1.1
Hazard No. 7	14,703	58	97	13	0.5
Hazard	19,835	28	93	—	—
Hamlin	31,963	14	109	—	—
Hazard No. 4 Rider	33,000	13	122	—	—
Hazard No. 4	33,331	70	189	124	307
Lower Whitesburg	34,532	50	151	—	—
Upper Elkhorn No. 3	37,366	99	159	—	704
Upper Elkhorn No. 2	37,500	46	107	—	—
Upper Elkhorn No. 1	37,805	61	104	—	0.7

Once all maps were prepared, the USGS program "resources" used GRASS commands to calculate areas (in square meters) for all resource categories and for those portions of the original resource that were mined out or restricted. These data were then converted to acres, and tons were calculated using an average specific gravity figure for bituminous coal in the following equations:

1 acre=4,047 square meters

1 acre/foot of coal=1,800 short tons

Resource Categories

Tonnage estimates for each bed are reported by categories of coal thickness, overburden thickness, and reliability of the estimate. Standard U.S. Geological Survey procedures (Wood and others, 1983) stipulate thickness categories in multiples of 14 inches up to 42 inches, and multiples of 42 inches up to 168 inches. Categories above 168 inches are aggregated. For the Coal Availability studies, only two categories are used: 14 to 28 inches and greater than 28 inches. This division is based on the constraint that coal less than 28 inches in thickness is generally not mineable by underground methods.

Overburden categories are also based on the potential effect on mining method. Three categories are defined: surface mineable, deep mineable, and too deep to mine with current technology. The footages for these categories can vary depending on topographic relief and seam and interburden thicknesses, but are generally 100 or 200 feet for maximum surface-mine depths, and 1,000 feet for maximum underground overburden. Coal at depths greater than 1,000 feet is generally considered unmineable. For this study, 100 feet is used for surface mining and no overburden thicknesses were found that exceeded the limit for underground mining. It is common in eastern Kentucky underground mines for overburden to locally exceed 1,000 feet under the crests of ridges. Because these areas are generally small, this condition is generally not considered a restriction to underground mining. In practice, maximum overburden height for surface mining is generally determined by a ratio of overburden to coal thickness. The fixed footage used in these studies only provides an estimate of surface-mineable area.

Reliability categories are derived from areas determined by distances from coal-thickness measurements. "Measured" resources lie within $^1/_4$ mile (1,320 feet or 402 meters) of a data point, "indicated" resources between $^1/_4$ and $^3/_4$ miles (3,960 feet or 1,207 meters), "inferred" resources between $^3/_4$ and 3 miles (15,840 feet or 4,828 meters), and "hypothetical" resources beyond 3 miles. It is generally accepted that the rate of thickness variation differs for most coal beds; hence, "reliability" can only be interpreted in this context. The reliability categories do provide an indication of data spacing.

RESULTS

Overview

Original, mined-out, remaining, restricted, and available coal resources were calculated for 12 coal beds in the Handshoe Quadrangle. In ascending stratigraphic order, they are the Upper Elkhorn Nos. 1, 2, and 3, Lower Whitesburg, Hazard No. 4 (Fireclay), Hazard No. 4 Rider (Fireclay Rider), Hamlin, Hazard (Hazard No. 5A), Hazard Nos. 7, 8, and 9, and Tiptop (Fig. 2). All of the beds outcrop within the quadrangle and are accessible by surface and underground mining methods. Resource estimates, mining, and restrictions are reported for each bed by categories of coal thickness (14–28 inches or greater than 28 inches), overburden (surface mineable=0–100 feet, deep mineable=greater than 100 feet), and reliability (measured=$^1/_4$ mile, indicated=$^3/_4$ mile, inferred=3 miles), and are detailed completely in Appendix A.

The aggregated results of the Coal Availability investigation for each coal bed in the Handshoe Quadrangle are shown as proportions in Figures 3 and 4. Tonnages are summarized in Table 4, which lists the original, remaining, and available resources for each bed and totals for mined-out and restricted coal. Results of this study indicate that 403 million tons (62.5 percent) of the original resources (644.7 million tons) are available for future economic development. A total of 11.6 million tons (2 percent) of the original resources have been mined out, equally by surface and underground methods. A total of 230 million tons (36 percent) of the remaining resources are restricted from mining. Technological restrictions (mainly coal too thin to mine by underground methods) account for 96 percent of the total restrictions.

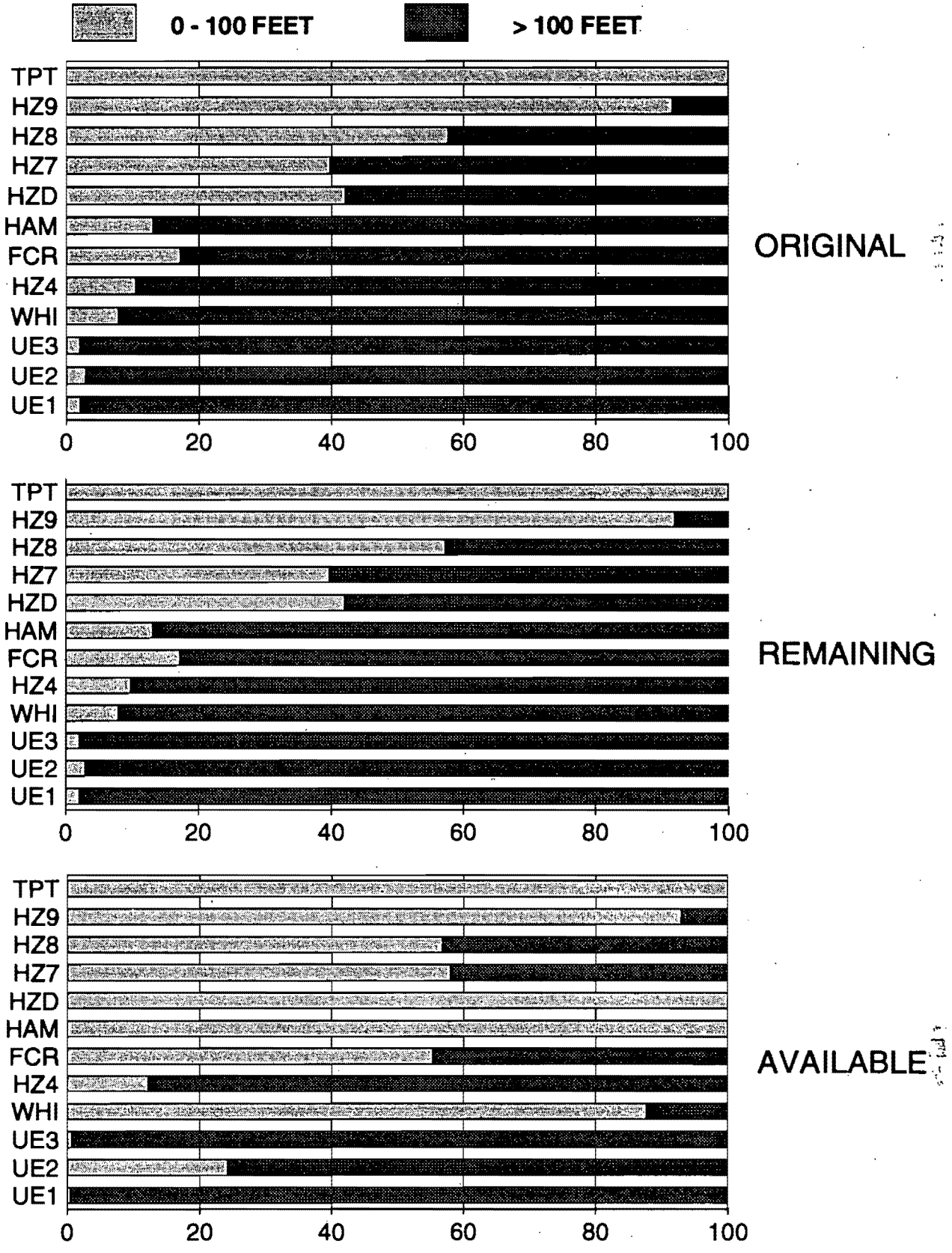

Figure 3. Proportional tonnages of original, remaining, and available coal resources by overburden categories.

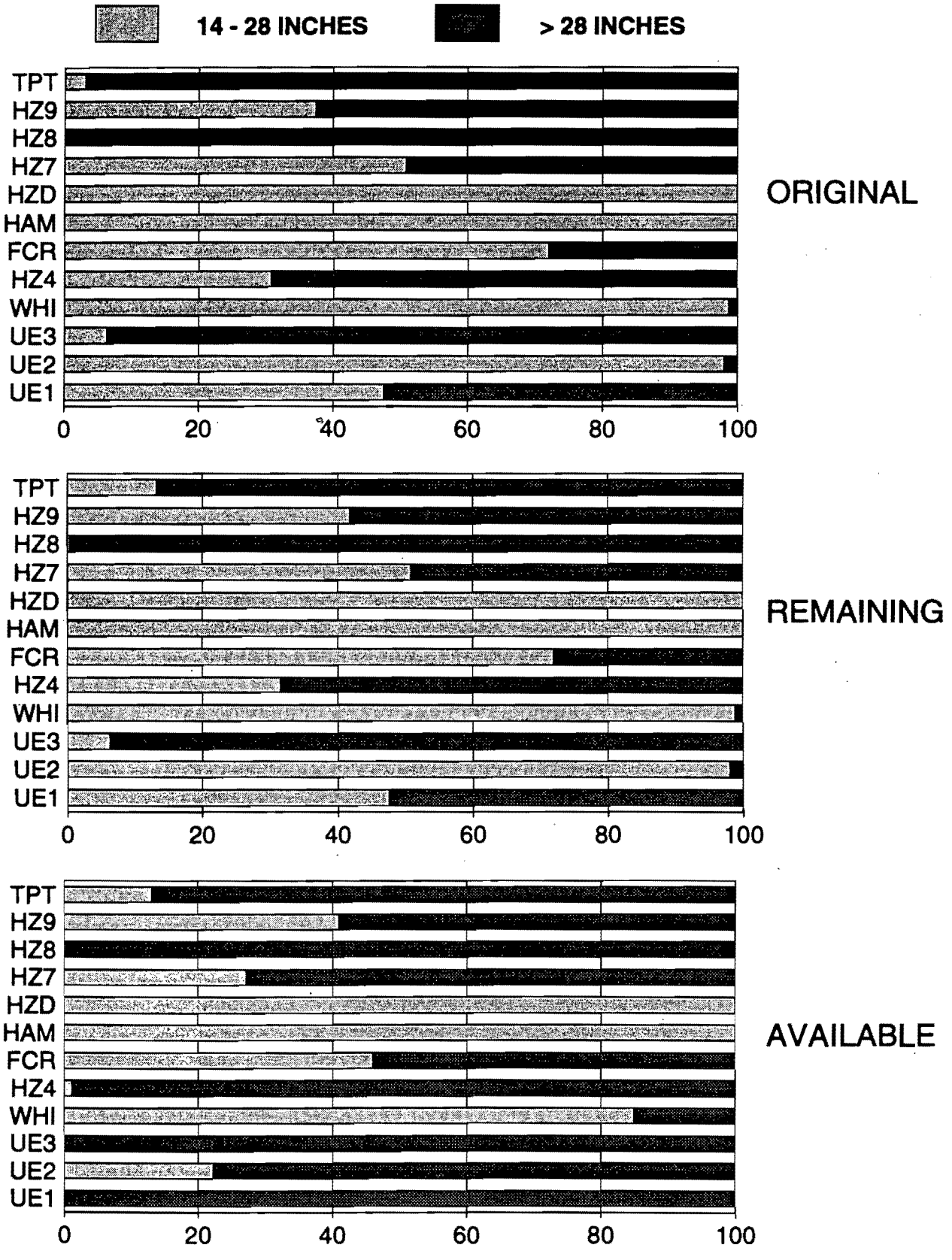

Figure 4. Proportional tonnages of original, remaining, and available coal resources by thickness categories.

Table 4.—Summary of Total Tonnage Estimates for Original, Mined-Out, Remaining, Restricted, and Available Coal Resources (Millions of Short Tons).

	Original	*Mined-Out*	*Remaining*	*Land-Use Restricted*	*Technical Restricted*	*Available*
Tiptop	4.8	3.7	1.1	0.0	0.0	1.1
Hazard No. 9	8.9	0.9	8.0	0.3	0.1	7.7
Hazard No. 8	59.9	1.0	58.9	0.9	0.3	57.7
Hazard No. 7	33.5	0.0	33.5	0.3	10.8	22.3
Hazard	13.9	0.0	13.9	0.2	8.0	5.7
Hamlin	12.2	0.0	12.2	0.5	10.6	1.1
Hazard No. 4 Rider	13.9	0.0	13.9	0.4	9.9	3.6
Hazard No. 4	105.6	2.6	103.0	1.6	31.8	69.6
Lower Whitesburg	44.5	0.0	44.5	0.5	40.5	3.5
Upper Elkhorn No. 3	205.6	3.3	202.3	2.8	15.9	183.6
Upper Elkhorn No. 2	50.0	0.0	50.0	1.3	47.8	1.0
Upper Elkhorn No. 1	92.0	0.0	92.0	1.7	44.0	46.3
TOTAL	644.7	11.6	633.1	10.3	219.8	403.0

Restrictions to mining that are not included in this study include surface and mineral ownership divisions not conducive to mineral development, economic considerations, recoverability, and undocumented geologic problems such as channel cutouts, seam splitting, or poor coal quality. Although these types of restrictions are beyond the scope of the present study, some are currently being investigated by the U.S. Bureau of Mines.

Original Resources

Original coal resources represent estimates of the total amount of coal greater than 14 inches in thickness prior to any mining. The 14-inch limit is arbitrary, but very little coal less than this thickness has been mined. The total original resources for all beds in this study are estimated as 644.7 million tons. The distribution of original coal resources aggregated by thickness and overburden categories is given in Table 5 and illustrated on Figures 5 through 8. The previous estimate for the same beds (Brant and others, 1983) was 498.2 million tons, a difference of 23 percent. However, on a bed-by-bed basis the differences were on the order of 30 to 140 percent. Compared to the present study, the Upper Elkhorn Nos. 1 and 3 coal beds were underestimated by Brant and others and the Hazard No. 4 coal bed was overestimated, each by more than 50 percent. These differences in resource estimates occurred because different thickness data sets were used. Brant and others also estimated an additional 48 million tons for other beds in the quadrangle. However, these estimates were based on few data or data located outside the map area. The present data set did not confirm the presence of mineable coal for these other beds. Consequently, they were not included in this study.

Distribution of Original Resources

STRATIGRAPHIC

The relative stratigraphic position of each coal bed and the occurrence of the coals in three distinct coal groups are shown on Figure 5. This figure also shows the total outcrop area of each bed and the proportion of outcrop areas containing coal greater than 14 inches. The total tonnages, given in Table 5, indicate that the resources are not distributed uniformly with respect to stratigraphic position. The lower coal group (Upper Elkhorn No. 1 to No. 3 beds) contains 54 percent of original resources, the middle group (Lower Whitesburg to Hamlin beds) 27 percent, and the upper group (Hazard to Tiptop beds) 19 percent. This upward decrease in resources is a function of the diminished area of outcrop for the topographically higher seams. However, Figure 5 shows that the rate of decrease in outcrop area is relatively small in the lower two coal groups and substantially greater for the upper coal group. This relationship, which has a significant impact on total resources, is the inverse of that found in the previous study (Booneville Quadrangle). Moreover, the upper seams, which have the greatest rate of area decrease and hence the more gentle surface slopes, are associated with resistant, sandstone-rich interburdens. This association suggests that factors other than the character of the interburden control the surface slopes. This hypothesis will be a subject for future analysis.

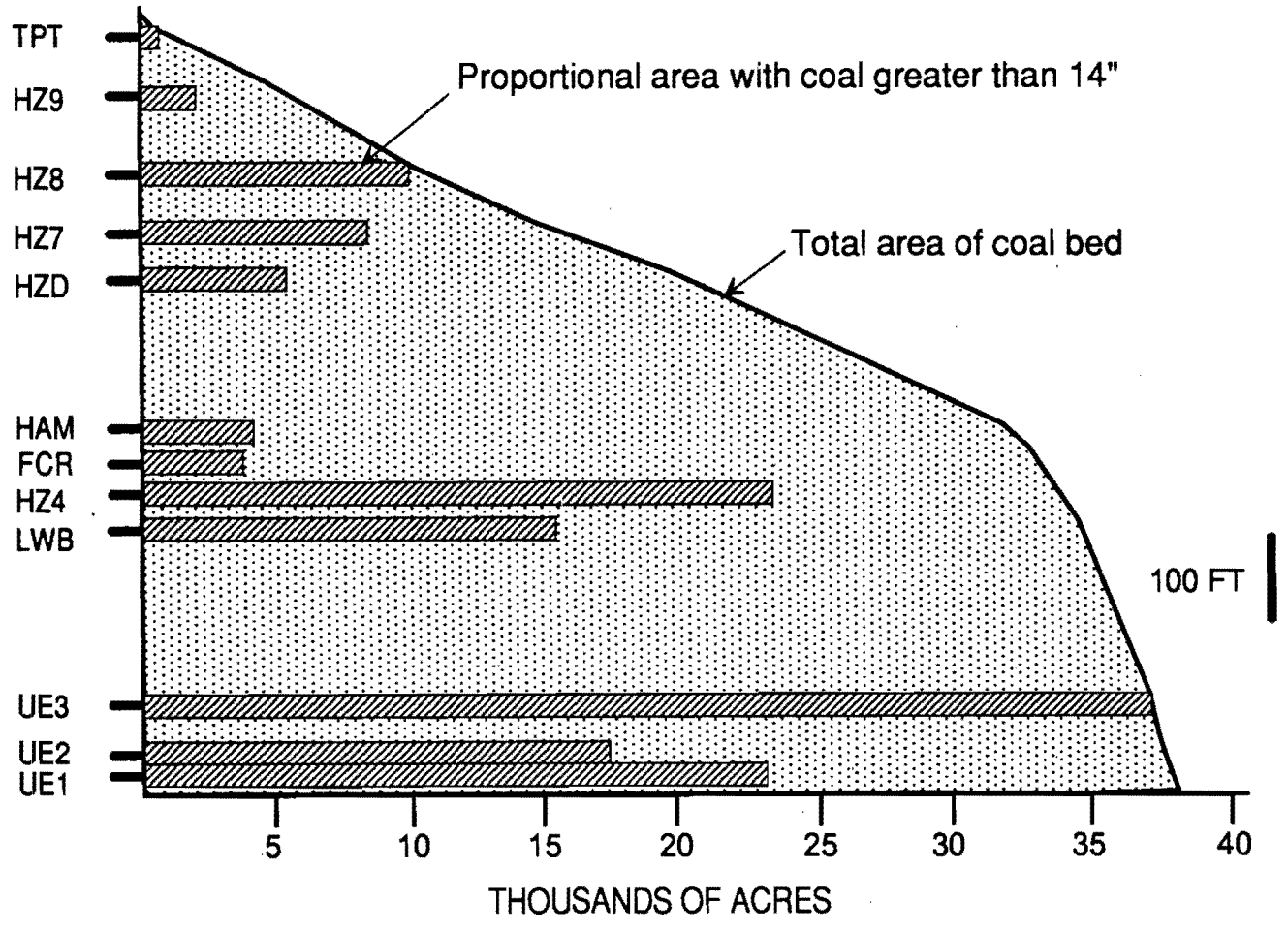

Figure 5. Outcrop area of each coal bed and the proportional amount of area that contains measurable resources (greater than 14 inches). Total area shaded and area with original resources shown as horizontal bars.

Table 5.—Original Coal Resources Reported by Overburden and Thickness Categories (Thousands of Short Tons).[1]

Coal Bed	*Surface (0–100')*			*Deep (> 100')*			*Thickness Totals*		*TOTALS*
	14–28"	*>28"*	*Total*	*14–28"*	*>28"*	*Total*	*14–28"*	*>28"*	
Tiptop	156	4,625	4,780	0	0	0	156	4,625	4,780
Hazard No. 9	3,248	4,943	8,191	107	646	753	3,355	5,589	8,944
Hazard No. 8	220	34,345	34,565	36	25,311	25,347	256	59,656	59,912
Hazard No. 7	6,306	7,040	13,347	10,778	9,401	20,179	17,085	16,441	33,526
Hazard	5,829	0	5,829	8,023	0	8,023	13,851	0	13,851
Hamlin	1,594	0	1,594	10,560	0	10,560	12,154	0	12,154
Hazard No. 4 Rider	1,943	447	2,390	8,079	3,432	11,511	10,023	3,879	13,901
Hazard No. 4	1,756	9,379	11,136	30,803	63,661	94,464	32,560	73,040	105,600
Lower Whitesburg	3,426	98	3,524	40,524	430	40,954	43,950	528	44,478
Upper Elkhorn No. 3	699	3,690	4,389	12,448	188,756	201,204	13,147	192,446	205,593
Upper Elkhorn No. 2	1,369	127	1,495	47,655	838	48,493	49,023	965	49,988
Upper Elkhorn No. 1	851	1,094	1,945	42,966	47,098	90,064	43,817	48,192	92,009
TOTAL	27,397	65,788	93,185	211,979	339,573	551,552	239,377	405,361	644,736

[1] Totals may not equal sum of components because of independent rounding.

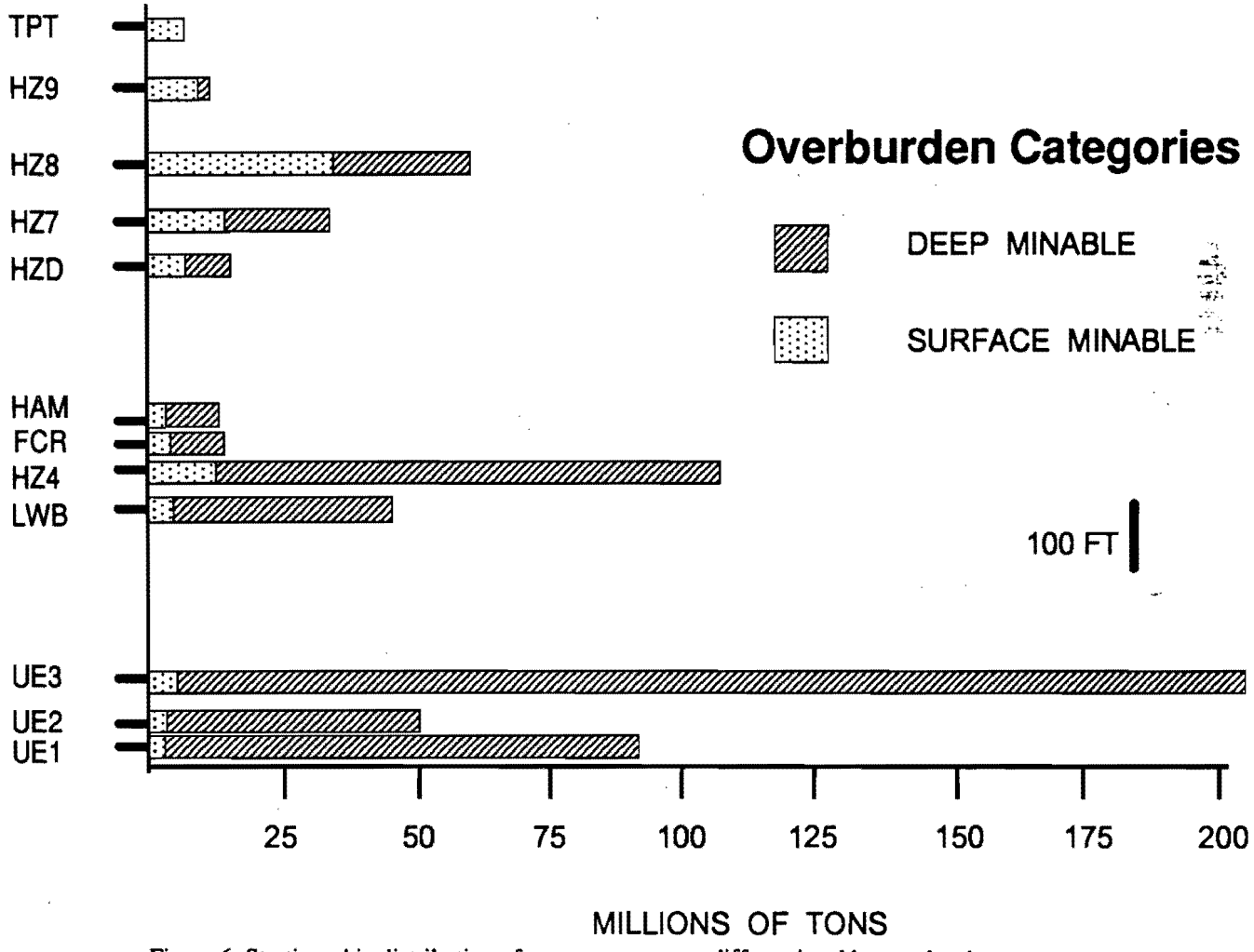

Figure 6. Stratigraphic distribution of resource tonnages differentiated by overburden category.

OVERBURDEN

The distribution of coal resources on the basis of overburden categories is illustrated on Figures 3 and 6 and tabulated in Table 5. The greater-than-100-feet category (deep-mineable) comprises 85 percent of the total estimate. The proportion of deep-mineable coal to surface-mineable coal for individual seams increases, as expected, from the topographically higher to lower seams (Fig. 3). Figure 7 represents the stripping potential or outcrop access for each bed as measured by the total length of the outcrop perimeter. In eastern Kentucky, mining potential is, in part, a function of outcrop access, because few shaft or slope mines have been developed. Figure 7 shows that the coal beds within the upper coal group have the greatest potential outcrop access. The lower two coal groups have limited outcrop access, and are therefore dominantly deep-mineable resources. However, the only underground development that has taken place for beds in these coal groups is near the outcrop (Appendix A). Large areas of the lower coal beds remain undeveloped, mainly because of limited outcrop access.

THICKNESS

The distribution of coal resources on the basis of thickness categories is given in Table 5 and Figures 4 and 8. In addition, Appendix A contains maps showing the areal distribution of thickness categories accompanied by frequency distributions and summary statistics for coal-thickness data. Figure 8 shows that the coals fall into three distinct groups: (1) beds containing dominantly greater-than-28-inch coal, (2) beds containing dominantly less-than-28-inch coal, and (3) beds with roughly equal proportions of each. These groups are composed of the following coal beds:

Greater than 28":
Tiptop
Hazard No. 8
Upper Elkhorn No. 3

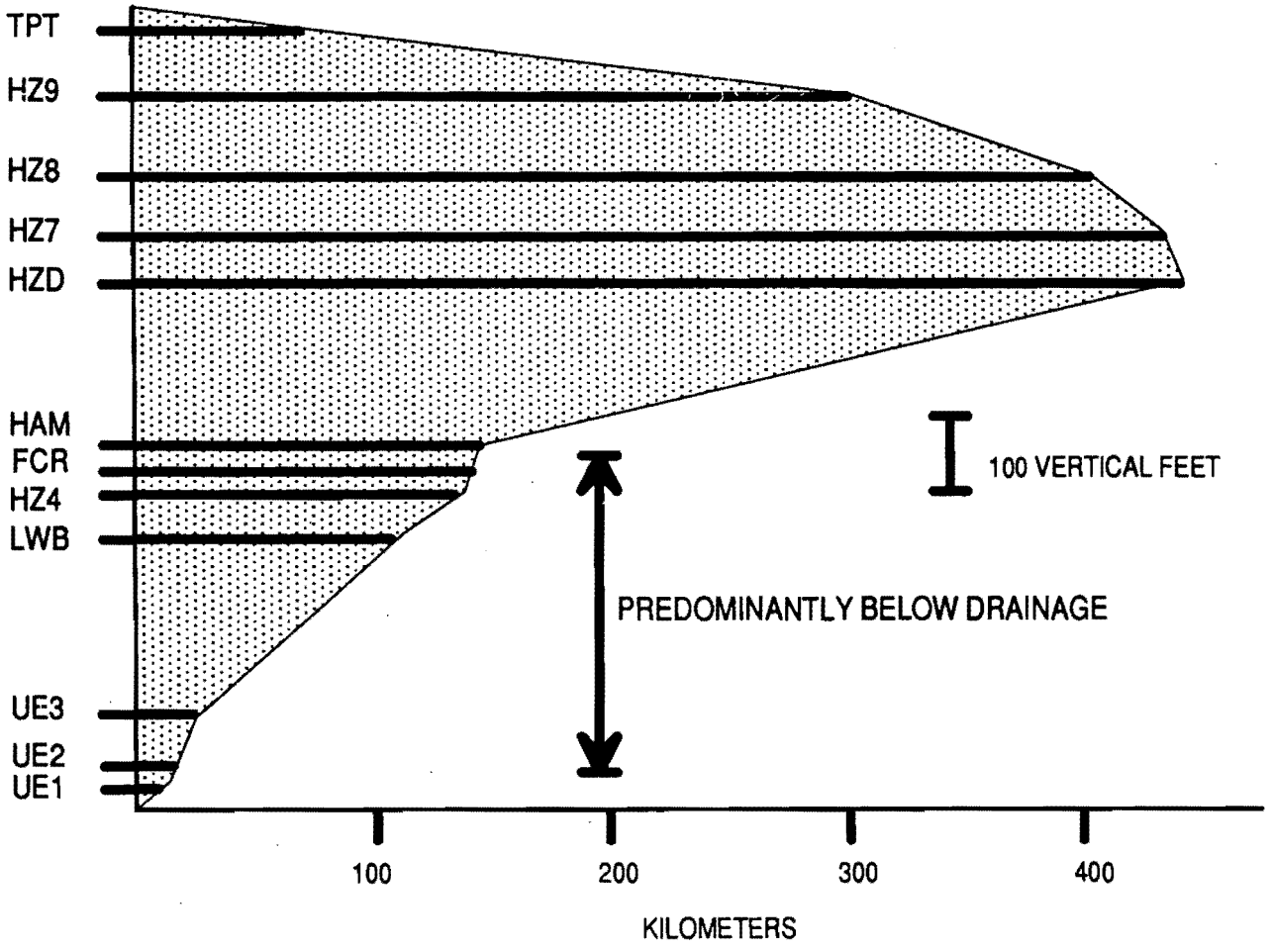

Figure 7. Total linear distance of outcrop for coal beds in the Handshoe Quadrangle.

Mixed:
- Hazard No. 9
- Hazard No. 7
- Hazard No. 4
- Upper Elkhorn No. 1

Less than 28":
- Hazard
- Hamlin
- Hazard No. 4 Rider
- Lower Whitesburg
- Upper Elkhorn No. 2

Those coal beds with the most resources and the most historical production fall only within the first two groups. Coal beds within the last group (dominantly less than 28 inches) comprise 21 percent of the original resources, and it is unlikely that they will be developed to any significant extent in the future.

GEOGRAPHIC

The geographic arrangement of coal resources is illustrated by maps in Appendix A that show the thickness distribution and the outcrop area of each bed. Several relationships can be observed that affect coal-resource potential in the Handshoe Quadrangle. First, the outcrop access for the lower two coal groups is limited to the eastern part of the quadrangle. Also, surface access is relatively small for the Upper Elkhorn beds. Consequently, most of the development for these coals has been by underground methods. Conversely, outcrop areas for the upper coal group (Hazard coals) is limited to the western two-thirds of the map area, and mine access is entirely above drainage.

One of the factors that favors extensive surface mining in adjoining quadrangles is geographic coincidence of thick, stratigraphically sequent coal beds, particularly for the topographically highest beds. Areas of greatest thickness development for beds in each coal group are inconsistent within the Handshoe Quadrangle. Figure 9 shows those areas where one or more of the Hazard Nos. 7, 8, and 9 beds are greater than 28 inches in thickness. These coals are extensively mined in nearby quadrangles, largely by contour-strip and mountaintop-

removal mining methods. All three beds are thick only in the south-central part of the Handshoe Quadrangle, where the outcrop areas are relatively small (*see* Appendix A). In the northern portion of the quadrangle, only the Hazard No. 8 coal is thick, and for a substantial part of this area both the No. 7 and No. 9 are entirely missing. These relationships partially account for the lack of surface mining in the Handshoe Quadrangle.

Figure 10 shows a similar relationship for the Upper Elkhorn No. 1, Upper Elkhorn No. 3, and Hazard No. 4 coal beds, which comprise 63 percent of the original resources. The area where all three coals are thick is confined to the northeastern quarter of the quadrangle. Fortunately, this is also where there is outcrop access to the beds. Both the Upper Elkhorn No. 1 and Hazard No. 4 thin and split in a westerly and southerly direction as these beds dip into the subsurface. Only the Upper Elkhorn No. 3 is persistent in thickness over most of the quadrangle.

Reliability of the Estimates

The reliability of resource estimates is expressed by the categories of measured, indicated, and inferred, which are tabulated for each bed in Appendix A and illustrated in Figure 11. These designations are based on the density of thickness data points; data density is also quantified in Table 3, where the total acreage and number of points per bed are given. For all beds, approximately 31 percent of the resource is estimated as measured, 55 percent as indicated, and 14 percent as inferred.

Mined-Out and Remaining Resources

Estimates of mined-out tonnages and remaining resources are aggregated by thickness and overburden categories in Tables 6, 7, and 8 and by all categories in Appendix A. Mined-out areas for each bed are shown on maps in Appendix A. In this study, mined-out tonnages are estimated from mine acreages and extrapolated coal thicknesses interpolated from discrete thickness measurements. Production data are not used because they are difficult to associate with specific map areas and they do not account for coal lost in mining.

Table 6.—Mined-Out and Lost-in-Mining Tonnages from Surface Mines Reported by Overburden and Thickness Categories (Thousands of Short Tons).[1]

Coal Bed	*Surface (0–100')*			*Deep (> 100')*			*Thickness Totals*		*TOTALS*
	14–28"	*>28"*	*Total*	*14–28"*	*>28"*	*Total*	*14–28"*	*>28"*	
Tiptop	8	3,661	3,669	0	0	0	8	3,661	3,669
Hazard No. 9	0	826	826	0	108	108	0	934	934
Hazard No. 8	0	850	850	0	164	164	0	1,014	1,014
Hazard No. 7	20	31	51	4	1	4	24	32	55
Hazard No. 4	11	814	825	0	52	52	11	866	877
TOTAL	39	6,182	6,221	4	325	328	43	6,507	6,549

[1] Totals may not equal sum of components because of independent rounding.

Table 7.—Mined-Out and Lost-in-Mining Tonnages from Underground Mines Reported by Overburden and Thickness Categories (Thousands of Short Tons).[1]

Coal Bed	*Surface (0–100')*			*Deep (> 100')*			*Thickness Totals*		*TOTALS*
	14–28"	*>28"*	*Total*	*14–28"*	*>28"*	*Total*	*14–28"*	*>28"*	
Hazard No. 8	0	6	6	0	0	0	0	6	6
Hazard No. 7	1	0	1	0	0	0	1	0	1
Hazard No. 4	20	170	190	19	1,541	1,560	39	1,711	1,749
Upper Elkhorn No. 3	29	94	123	147	3,034	3,180	176	3,128	3,304
Upper Elkhorn No. 1	0	3	3	0	0	0	0	3	3
TOTAL	50	273	323	166	4,575	4,740	216	4,848	5,063

[1] Totals may not equal sum of components because of independent rounding.

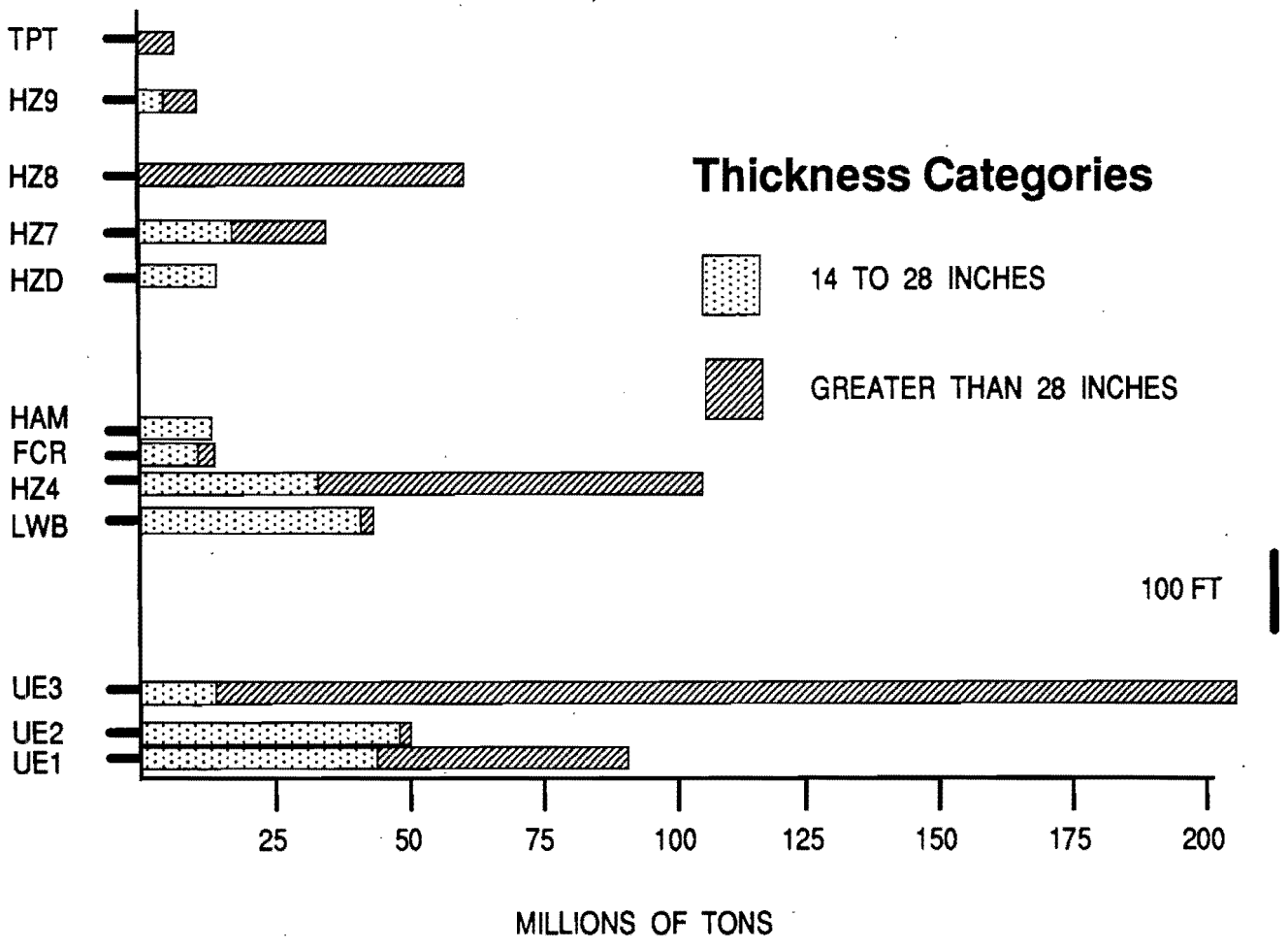

Figure 8. Stratigraphic distribution of resource tonnages differentiated by thickness category.

Table 8.—Remaining Coal Resources Reported by Overburden and Thickness Categories (Thousands of Short Tons).[1]

Coal Bed	*Surface (0–100')*			*Deep (> 100')*			*Thickness Totals*		*TOTALS*
	14–28"	*>28"*	*Total*	*14–28"*	*>28"*	*Total*	*14–28"*	*>28"*	
Tiptop	148	964	1,111	0	0	0	148	964	1,111
Hazard No. 9	3,248	4,117	7,364	107	538	645	3,355	4,655	8,010
Hazard No. 8	220	33,489	33,709	36	25,147	25,184	256	58,637	58,893
Hazard No. 7	6,285	7,010	13,294	10,775	9,400	20,175	17,059	16,410	33,469
Hazard	5,829	0	5,829	8,023	0	8,023	13,851	0	13,851
Hamlin	1,594	0	1,594	10,560	0	10,560	12,154	0	12,154
Hazard No. 4 Rider	1,943	447	2,390	8,079	3,432	11,511	10,023	3,879	13,901
Hazard No. 4	1,726	8,395	10,121	30,784	62,068	92,853	32,510	70,463	102,973
Lower Whitesburg	3,426	98	3,524	40,524	430	40,954	43,950	528	44,478
Upper Elkhorn No. 3	670	3,596	4,266	12,302	185,722	198,024	12,972	189,318	202,290
Upper Elkhorn No. 2	1,369	127	1,495	47,655	838	48,493	49,023	965	49,988
Upper Elkhorn No. 1	851	1,091	1,942	42,966	47,098	90,064	43,817	48,189	92,006
TOTAL	27,309	59,334	86,639	211,811	334,673	546,486	239,118	394,008	633,124

[1] Totals may not equal sum of components because of independent rounding.

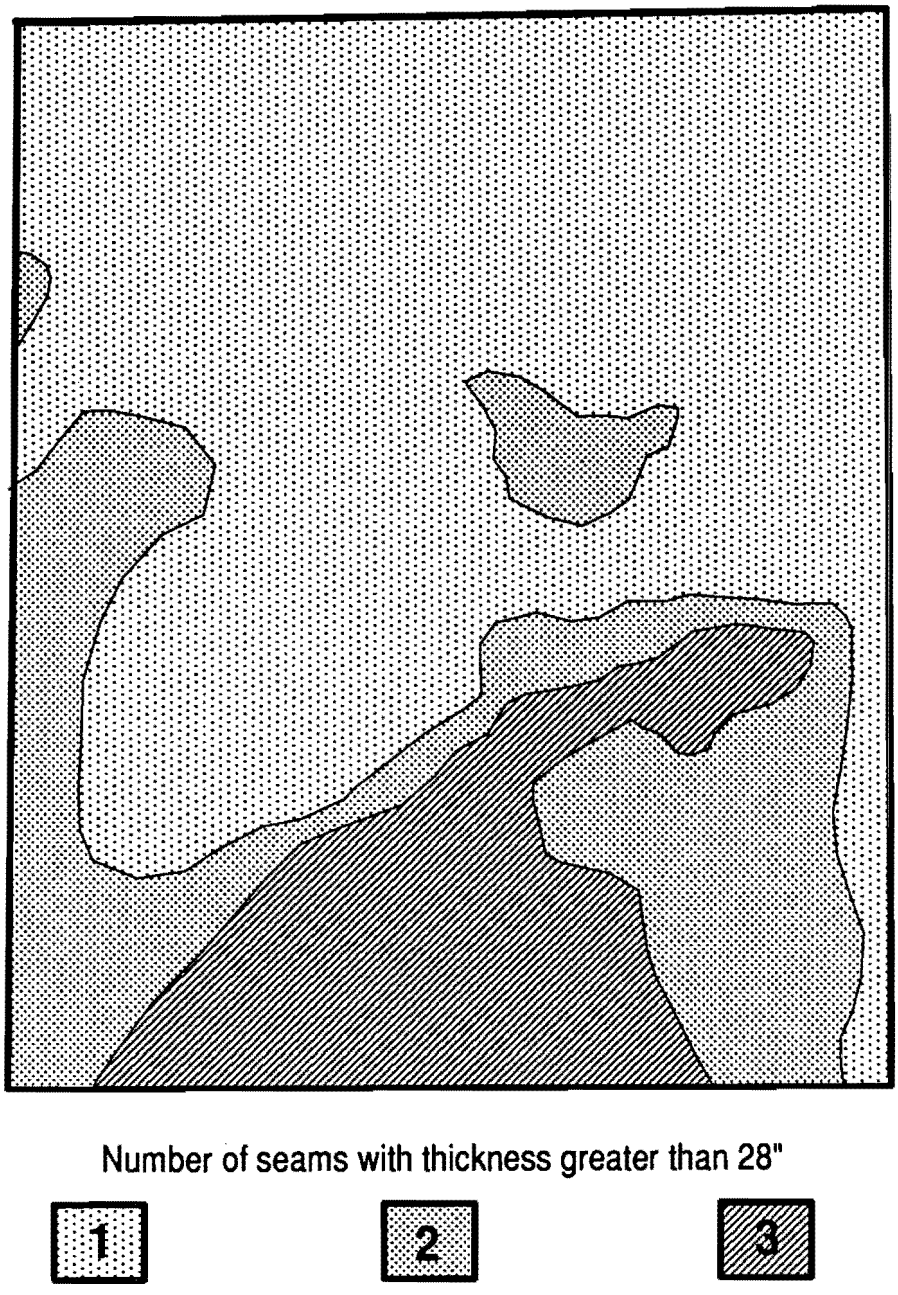

Figure 9. Areas where one or more of the Hazard Nos. 7, 8, and 9 coal beds are greater than 28 inches in thickness. 1. Hazard No.8 bed. 2. Hazard No.8 and 9 beds.

The total amount of mining in the Handshoe Quadrangle has been a modest 11.6 million tons, only 2 percent of the original resource. Slightly more than half of this amount has been by surface methods. Most of the surface tonnage has come from the Tiptop coal, which is largely mined out. Only 1 million tons have been mined from the Hazard No. 8 bed, possibly because of its high ash yield and sulfur content. Underground reserves totaling 5 million tons have been mined from the Hazard No. 4 and Upper Elkhorn No. 3 coal beds.

Figure 10. Areas where one or more of the Upper Elkhorn Nos. 1 and 3 and Hazard No. 4 coal beds are greater than 28 inches in thickness. 1. Upper Elkhorn No. 3 bed. 2. Upper Elkhorn No. 3 and Hazard No. 4 beds.

Total remaining resources are estimated as 633.1 million tons or 98 percent of the original. These resources are distributed similarly to the original estimates with respect to thickness and overburden categories (Figs. 3–4). About 62 percent are in the greater-than-28-inches thickness category and 86 percent are in the greater-than-100-feet overburden category. Three seams, the Hazard No. 4 and Upper Elkhorn Nos. 1 and 3, comprise 63 percent of the remaining resources, 95 percent of which is in the deep-mineable category.

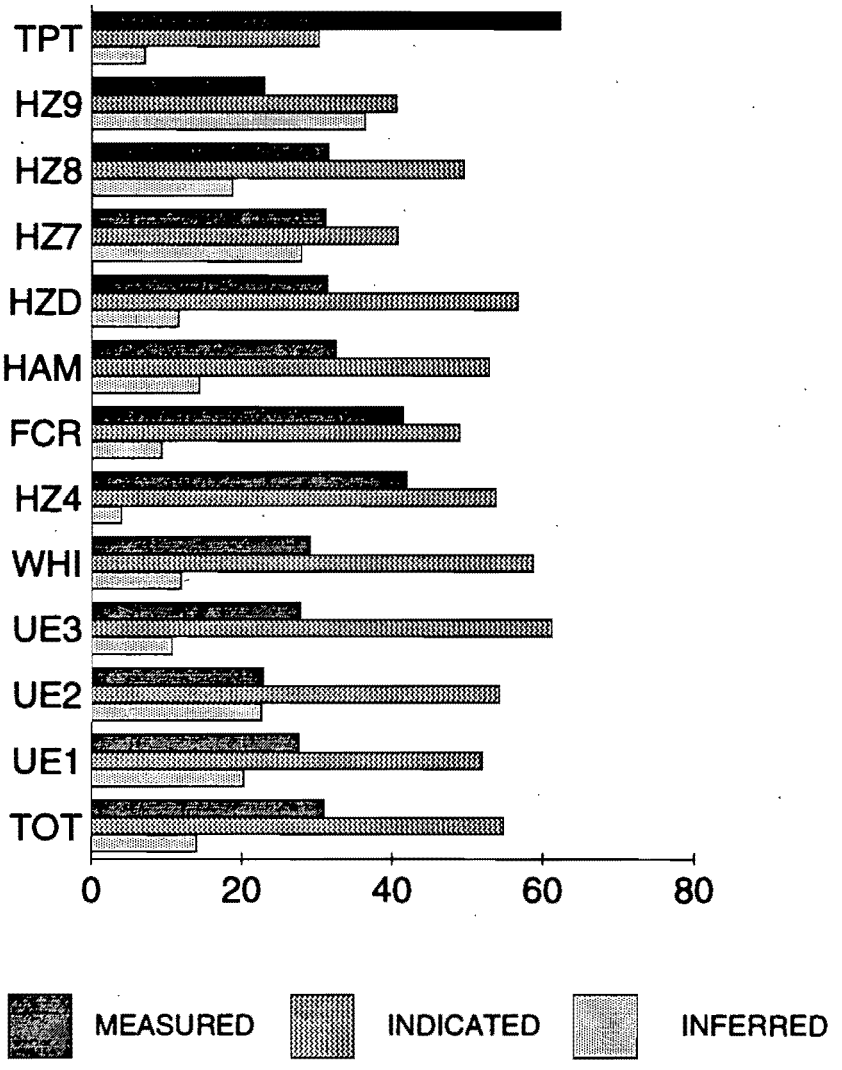

Figure 11. Proportional amount of original resources by reliability category for the Handshoe Quadrangle.

Restrictions and Available Resources

Tonnages for restricted coal are reported in two formats. In order to calculate the available resources, the unique area of each restriction is subtracted from remaining resources. This is necessary because of overlapping buffers for some restrictions. In many areas, for example, roads, streams, and municipal areas occupy the same general space in valley bottoms. These results (total restriction tonnages by resource category) are shown in Table 9. Table 10 and Appendix A give the total tonnages associated with each restriction and its buffer without accounting for overlap. In most cases the sum of these restriction tonnages will exceed the totals used for calculating available resources.

The total amount of restrictions for the Handshoe Quadrangle is 230 million tons or 36 percent of the remaining resource. Technological restrictions (largely coal too thin to mine by underground methods) account for 96 percent of this total. Only about 10 million tons are associated with land-use restrictions, and most of the restricted coal is a result of streams and municipal areas.

Table 9.—Total Restrictions Reported by Overburden and Thickness Categories (Thousands of Short Tons).[1]

Coal Bed	*Surface (0–100')*			*Deep (> 100')*			*Thickness Totals*		*TOTALS*
	14–28"	*>28"*	*Total*	*14–28"*	*>28"*	*Total*	*14–28"*	*>28"*	
Tiptop	0	0	0	0	0	0	0	0	0
Hazard No. 9	109	142	251	107	0	107	216	142	358
Hazard No. 8	1	913	914	36	281	317	3	1,19	1,232
Hazard No. 7	184	159	343	10,775	21	10,796	10,959	181	11,139
Hazard	147	0	147	8,023	0	8,023	8,170	0	8,170
Hamlin	465	0	465	10,560	0	10,560	11,025	0	11,025
Hazard No. 4 Rider	297	114	411	8,079	1,836	9,915	8,377	1,950	10,326
Hazard No. 4	779	776	1,555	30,784	1,023	31,807	31,563	1,799	33,362
Lower Whitesburg	447	*	447	40,524	0	40,524	40,971	*	40,971
Upper Elkhorn No. 3	347	2,485	2,832	12,302	3,596	15,898	12,649	6,081	18,730
Upper Elkhorn No. 2	1,156	109	1,265	47,655	119	47,774	48,811	228	49,039
Upper Elkhorn No. 1	779	910	1,689	42,966	1,080	44,046	43,744	1,990	45,735
TOTAL	4,711	5,608	10,319	211,811	7,956	219,767	216,522	13,565	230,087

[1] Totals may not equal sum of components because of independent rounding.

* Indicates measurements less than the reported precision.

Table 10.—Total Tonnages Associated with Individual Restriction Categories (Thousands of Short Tons). Does Not Account for Overlapping Areas.

Coal Bed	*Land Use*							*Technological*				
	Cemeteries	*Oil & Gas*	*Pipeline*	*Powerline*	*Roads*	*Streams*	*Towns*	*Barriers*	*Interburden < 40'*	*Mining Within 40'*	*Oil & Gas*	*Coal Too Thin*
Tiptop	0	0	0	0	0	0	0	0	0	0	0	0
Hazard No. 9	0	5	99	130	17	0	0	0	0	0	1	107
Hazard No. 8	0	248	101	453	112	5	0	*	0	0	281	36
Hazard No. 7	*	119	21	99	88	16	1	0	0	0	122	10,775
Hazard	0	49	0	38	2	50	10	0	0	0	76	8,023
Hamlin	0	75	0	23	0	414	0	0	0	0	141	10,560
Hazard No. 4 Rider	21	46	6	20	63	82	338	0	0	60	116	8,079
Hazard No. 4	19	223	8	86	184	706	721	261	0	0	1,237	30,784
Lower Whitesburg	9	102	0	45	61	139	161	0	0	0	686	40,524
Upper Elkhorn No. 3	120	181	21	60	437	929	2,269	312	0	0	3,530	12,302
Upper Elkhorn No. 2	32	69	38	12	274	471	1,148	0	119	0	923	47,655
Upper Elkhorn No. 1	59	117	17	53	355	682	1,370	0	0	0	1,924	42,966

* Indicates measurements less than the reported precision.

The amount of coal available for mining in the Handshoe Quadrangle is 403 million tons (Table 11). This amount represents 62.5 percent of original and 64 percent of remaining resources. An estimated 326.7 million tons (81 percent) of available coal resources are in the deep-mineable (greater than 100 feet) category and 380.4 million tons (94 percent) are in the greater-than-28-inches category. The Hazard Nos. 4 and 8 and the Upper Elkhorn Nos. 1 and 3 coals account for 89 percent of the available resources, and again, most of these resources are accessible by deep-mining methods only.

Table 11.—Available Coal Resources Reported by Overburden and Thickness Categories (Thousands of Short Tons).[1]

Coal Bed	*Surface (0–100')*			*Deep (> 100')*			*Thickness Totals*		*TOTALS*
	14–28"	*>28"*	*Total*	*14–28"*	*>28"*	*Total*	*14–28"*	*>28"*	
Tiptop	148	964	1,111	0	0	0	148	964	1,111
Hazard No. 9	3,139	3,975	7,114	0	538	538	3,139	4,513	7,652
Hazard No. 8	219	32,576	32,795	0	24,867	24,867	219	57,442	57,661
Hazard No. 7	6,101	6,851	12,951	0	9,378	9,378	6,101	16,229	22,330
Hazard	5,682	0	5,682	0	0	0	5,682	0	5,682
Hamlin	1,129	0	1,129	0	0	0	1,129	0	1,129
Hazard No. 4 Rider	1,646	334	1,979	0	1,596	1,596	1,646	1,929	3,575
Hazard No. 4	947	7,619	8,566	0	61,045	61,045	947	68,665	69,612
Lower Whitesburg	2,979	98	3,077	0	430	430	2,979	528	3,507
Upper Elkhorn No. 3	323	1,111	1,434	0	182,126	182,126	323	183,237	183,560
Upper Elkhorn No. 2	212	18	230	0	719	719	212	737	949
Upper Elkhorn No. 1	72	181	253	0	46,018	46,018	72	46,199	46,271
TOTAL	22,597	53,727	76,321	0	326,717	326,717	22,597	380,443	403,039

[1] Totals may not equal sum of components because of independent rounding.

COMPARISON TO PREVIOUS STUDIES

The Handshoe Quadrangle has a moderate amount of original resources compared to the seven quadrangles completed previously (Table 12). Of all quadrangles, Handshoe and Hoskinston have the least amount of prior mining. The range of the proportional amount of land-use versus technological restrictions is large for all quadrangles. This discrepancy is caused by the presence of large public lands in some of the quadrangles. Handshoe has relatively few land-use restrictions, primarily because most of the remaining coal resources are in the deep-mineable category. It has a moderate proportion of technological restrictions and, like the other quadrangles, this is due to one restriction, "coal too thin to be mined by underground methods." The proportion of available coal for Handshoe is somewhat greater than the average of 54 percent for all quadrangles.

Table 12.—Summary of Nine Eastern Kentucky Coal Availability Quadrangles Giving Total Tonnages (Millions of Short Tons) and Proportions.*

Quadrangle	*Original Resources*		*Remaining Resources*[2]		*Land-Use Restrictions*[3]		*Technological Restrictions*[3]		*Available Resources*[2]	
Appalachia[1]	1,349	100%	1,005	75%	26	3%	277	28%	703	52%
Boltsfork†	243	100%	231	95%	15	7%	43	19%	173	71%
Booneville	80	100%	70	88%	1	1%	29	41%	40	50%
Handshoe	645	100%	633	98%	10	2%	220	35%	403	63%
Hoskinston†	342	100%	332	98%	19	6%	171	52%	142	42%
Matewan	987	100%	858	87%	17	2%	226	26%	616	62%
Middlesboro North	339	100%	328	97%	36	11%	138	42%	155	46%
Millard†	843	100%	777	92%	30	4%	400	52%	347	41%
Noble†	460	100%	399	86%	58	15%	71	18%	270	59%

* All tonnages and percentages rounded to nearest whole number.

† Results updated in 1993.

[1] Data from Virginia Division of Mineral Resources.

[2] Percentage of original.

[3] Percentage of remaining.

Comparison with the Noble Quadrangle is illustrative as the two quadrangles are located near each other, lie in the same Coal Reserve District, and include the same stratigraphic interval. In many respects, though, the restriction and availability results for these two studies are markedly different. The original resources for the Noble Quadrangle are heavily weighted toward surface-mineable coal, whereas the Handshoe Quadrangle contains mostly deep-mineable coal. This discrepancy is probably because the lower coals (Hazard No. 4 and below) are poorly documented in the Noble Quadrangle. The thickness trends for adjoining areas of these seams are thinning toward the direction of Noble, so, despite the lack of data, there may not be significant resources for these seams in the Noble Quadrangle.

Noble also contains a large public land, Robinson Forest, and this, combined with the fact that much of the resources are surface mineable, resulted in a disproportionately large percentage of land-use restrictions.

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APPENDIX A:
Coal Availability Results, Area of Outcrop, and Total Coal Thickness

TIPTOP COAL BED

Coal Availability Results
(Thousands of Short Tons)[1]

	SURFACE (0-100')						*DEEP (> 100')*					
	14-28"			*> 28"*			*14-28"*			*>28"*		
	MEAS	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*
Original	70	85	*	2,918	1,365	342	0	0	0	0	0	0
Mined-Out Surface	0	8	0	2,364	1,108	189	0	0	0	0	0	0
Mined-Out Deep	0	0	0	0	0	0	0	0	0	0	0	0
Remaining	70	77	*	553	257	153	0	0	0	0	0	0
Total Restrictions	0	0	0	0	0	0	0	0	0	0	0	0
Total Available	70	77	*	553	257	153	0	0	0	0	0	0
Land-Use Restrictions[2]												
Cemeteries	0	0	0	0	0	0	0	0	0	0	0	0
Oil & Gas Wells	0	0	0	0	0	0	0	0	0	0	0	0
Pipelines	0	0	0	0	0	0	0	0	0	0	0	0
Powerlines	0	0	0	0	0	0	0	0	0	0	0	0
Roads	0	0	0	0	0	0	0	0	0	0	0	0
Streams	0	0	0	0	0	0	0	0	0	0	0	0
Towns	0	0	0	0	0	0	0	0	0	0	0	0
Technological Restrictions[2]												
Barriers	0	0	0	0	0	0	0	0	0	0	0	0
Interburden < 40'	0	0	0	0	0	0	0	0	0	0	0	0
Mining Within 40'	0	0	0	0	0	0	0	0	0	0	0	0
Oil & Gas Wells	0	0	0	0	0	0	0	0	0	0	0	0
Coal Too Thin	0	0	0	0	0	0	0	0	0	0	0	0

MEAS = Measured. IND = Indicated. INF = Inferred.

* Indicates measurements less than reported precision.

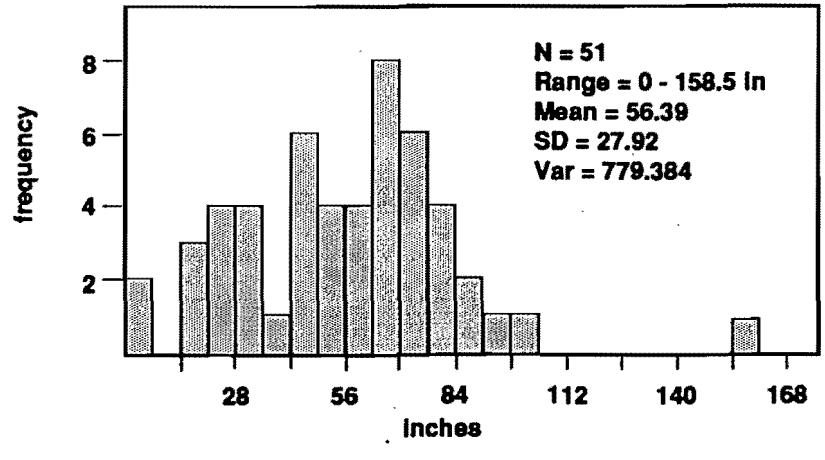
[1] Totals may not equal sum of components because of independent rounding.

[2] Total tonnage associated with each category. Sums of individual restrictions exceed the restriction total due to overlapping areas.

Tiptop Bed

Left: Extent of Tiptop bed within the Handshoe Quadrangle (stippled) and interpolated thickness isolines. Tick marks on isolines indicate decreased thickness. Data points shown by dots and mined-out areas by black areas.

Below: Histogram of total coal thickness with summary statistics. Includes data from the margins of adjoining quadrangles.



HAZARD NO. 9 COAL BED

Coal Availability Results

(Thousands of Short Tons)[1]

	SURFACE (0-100')						*DEEP (> 100')*					
	14-28"			*> 28"*			*14-28"*			*>28"*		
	MEAS	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*
Original	576	1,689	983	1,205	1,747	1,990	19	42	46	256	149	241
Mined-Out Surface	0	0	0	90	300	436	0	0	0	10	71	27
Mined-Out Deep	0	0	0	0	0	0	0	0	0	0	0	0
Remaining	576	1,689	983	1,115	1,448	1,554	19	42	46	246	77	214
Total Restrictions	26	63	19	15	39	88	19	42	46	0	0	0
Total Available	549	1,627	963	1,100	1,409	1,466	0	0	0	246	77	214
Land-Use Restrictions[2]												
Cemeteries	0	0	0	0	0	0	0	0	0	0	0	0
Oil & Gas Wells	5	0	0	0	0	0	0	0	0	0	0	0
Pipelines	0	0	0	0	0	0	0	0	0	0	0	0
Powerlines	8	59	19	15	29	0	0	0	0	0	0	0
Roads	13	4	0	0	0	0	0	0	0	0	0	0
Streams	0	0	0	0	0	0	0	0	0	0	0	0
Towns	0	0	0	0	0	0	0	0	0	0	0	0
Technological Restrictions[2]												
Barriers	0	0	0	0	0	0	0	0	0	0	0	0
Interburden < 40'	0	0	0	0	0	0	0	0	0	0	0	0
Mining Within 40'	0	0	0	0	0	0	0	0	0	0	0	0
Oil & Gas Wells	0	0	0	0	0	0	1	0	0	0	0	0
Coal Too Thin	0	0	0	0	0	0	19	42	46	0	0	0

MEAS = Measured. IND = Indicated. INF = Inferred.

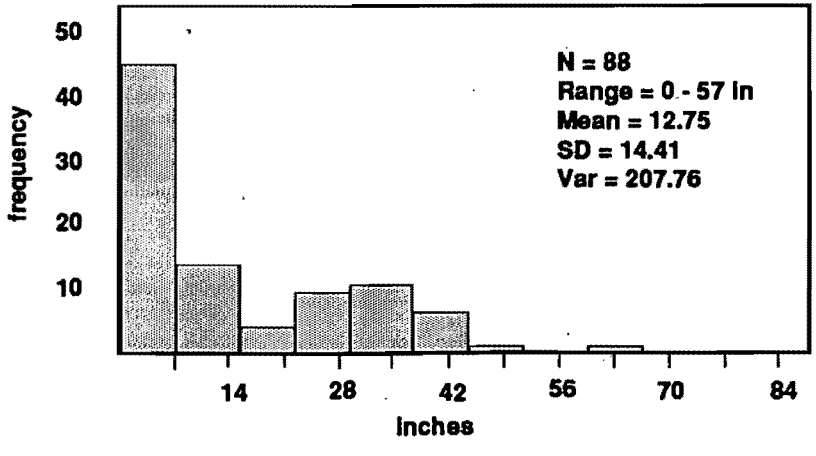
[1] Totals may not equal sum of components because of independent rounding.

[2] Total tonnage associated with each category. Sums of individual restrictions exceed the restriction total due to overlapping areas.

Hazard No. 9 Bed

Left: Extent of Hazard No. 9 bed within the Handshoe Quadrangle (stippled) and interpolated thickness isolines. Tick marks on isolines indicate decreased thickness. Data points shown by dots and mined-out areas by black areas.

Below: Histogram of total coal thickness with summary statistics. Includes data from the margins of adjoining quadrangles.



HAZARD NO. 8 COAL BED

Coal Availability Results

(Thousands of Short Tons)[1]

	SURFACE (0-100')						*DEEP (> 100')*					
	14-28"			*> 28"*			*14-28"*			*>28"*		
	MEAS	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*
Original	9	31	179	9,869	17,889	6,587	0	15	21	9,031	11,794	4,487
Mined-Out Surface	0	0	0	52	299	499	0	0	0	23	75	66
Mined-Out Deep	0	0	0	0	3	3	0	0	0	0	0	0
Remaining	9	31	179	9,817	17,588	6,085	0	15	21	9,008	11,719	4,421
Total Restrictions	1	0	0	315	511	87	0	15	21	65	191	25
Total Available	8	31	179	9,501	17,077	5,998	0	0	0	8,943	11,528	4,396
Land-Use Restrictions[2]												
Cemeteries	0	0	0	0	0	0	0	0	0	0	0	0
Oil & Gas Wells	0	0	0	90	122	36	0	0	0	0	0	0
Pipelines	0	0	0	0	0	0	0	0	0	0	0	0
Powerlines	1	0	0	145	275	32	0	0	0	0	0	0
Roads	0	0	0	61	50	0	0	0	0	0	0	0
Streams	0	0	0	1	5	0	0	0	0	0	0	0
Towns	0	0	0	0	0	0	0	0	0	0	0	0
Technological Restrictions[2]												
Barriers	0	0	0	0	0	0	0	0	0	0	*	0
Interburden < 40'	0	0	0	0	0	0	0	0	0	0	0	0
Mining Within 40'	0	0	0	0	0	0	0	0	0	0	0	0
Oil & Gas Wells	0	0	0	0	0	0	0	0	0	65	191	25
Coal Too Thin	0	0	0	0	0	0	0	15	21	0	0	0

MEAS = Measured. IND = Indicated. INF = Inferred.

* Indicates measurements less than reported precision.

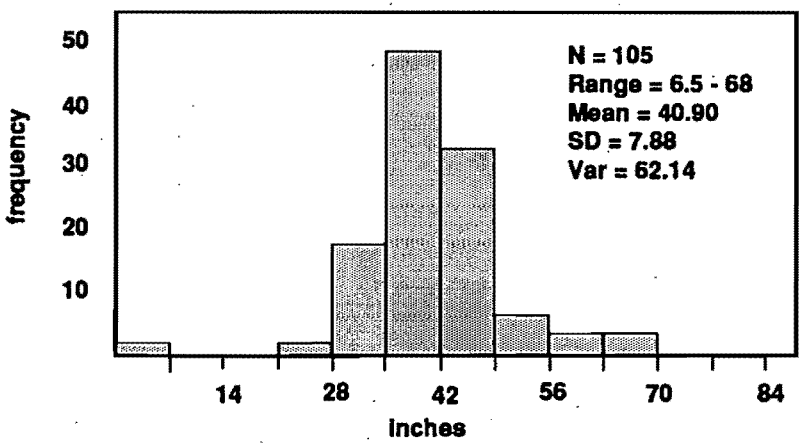
[1] Totals may not equal sum of components because of independent rounding.

[2] Total tonnage associated with each category. Sums of individual restrictions exceed the restriction total due to overlapping areas.

Hazard No. 8 Bed

Left: Extent of Hazard No. 8 bed within the Handshoe Quadrangle (stippled) and interpolated thickness isolines. Tick marks on isolines indicate decreased thickness. Data points shown by dots and mined-out areas by black areas.

Below: Histogram of total coal thickness with summary statistics. Includes data from the margins of adjoining quadrangles.



HAZARD NO. 7 COAL BED

Coal Availability Results
(Thousands of Short Tons)[1]

	SURFACE (0-100')						*DEEP (> 100')*					
	14-28"			*> 28"*			*14-28"*			*>28"*		
	MEAS	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*
Original	1,845	3,314	1,147	1,661	2,688	2,692	3,781	4,908	2,089	3,179	2,767	3,455
Mined-Out Surface	16	4	0	17	14	0	2	1	0	1	*	0
Mined-Out Deep	*	1	0	0	0	0	0	0	0	0	0	0
Remaining	1,830	3,308	1,147	1,644	2,674	2,692	3,779	4,907	2,089	3,178	2,766	3,455
Total Restrictions	64	114	6	30	88	41	3,779	4,907	2,089	4	5	12
Total Available	1,765	3,194	1,141	1,614	2,586	2,650	0	0	0	3,174	2,761	3,443
Land-Use Restrictions[2]												
Cemeteries	0	*	0	0	*	0	0	0	0	0	0	0
Oil & Gas Wells	19	18	3	11	41	27	0	0	0	0	0	0
Pipelines	0	0	0	0	0	0	0	0	0	0	0	0
Powerlines	14	42	3	19	14	6	0	0	0	0	0	0
Roads	23	33	0	0	32	0	0	0	0	0	0	0
Streams	8	7	0	0	*	0	0	0	0	0	0	0
Towns	0	1	0	0	0	0	0	0	0	0	0	0
Technological Restrictions[2]												
Barriers	0	0	0	0	0	0	0	0	0	0	0	0
Interburden < 40'	0	0	0	0	0	0	0	0	0	0	0	0
Mining Within 40'	0	0	0	0	0	0	0	0	0	0	0	0
Oil & Gas Wells	0	0	0	0	0	0	51	41	8	4	5	12
Coal Too Thin	0	0	0	0	0	0	3,779	4,907	2,089	0	0	0

MEAS = Measured. IND = Indicated. INF = Inferred.

* Indicates measurements less than reported precision.

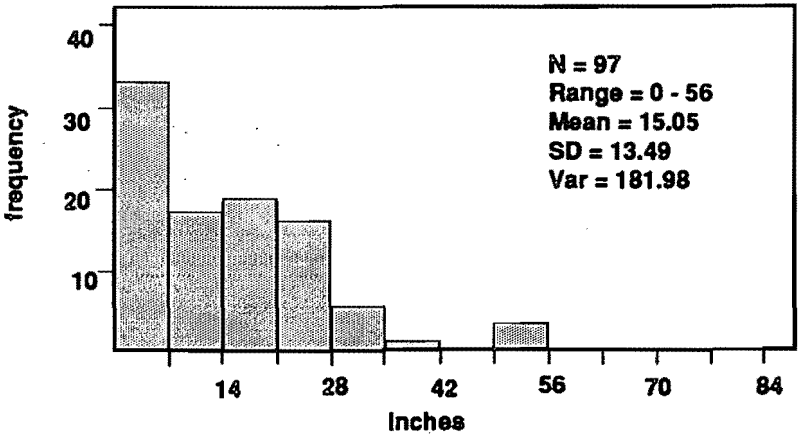
[1] Totals may not equal sum of components because of independent rounding.

[2] Total tonnage associated with each category. Sums of individual restrictions exceed the restriction total due to overlapping areas.

Hazard No. 7 Bed

Left: Extent of Hazard No. 7 bed within the Handshoe Quadrangle (stippled) and interpolated thickness isolines. Tick marks on isolines indicate decreased thickness. Data points shown by dots and mined-out areas by black areas.

Below: Histogram of total coal thickness with summary statistics. Includes data from the margins of adjoining quadrangles.



HAZARD COAL BED

Coal Availability Results
(Thousands of Short Tons)[1]

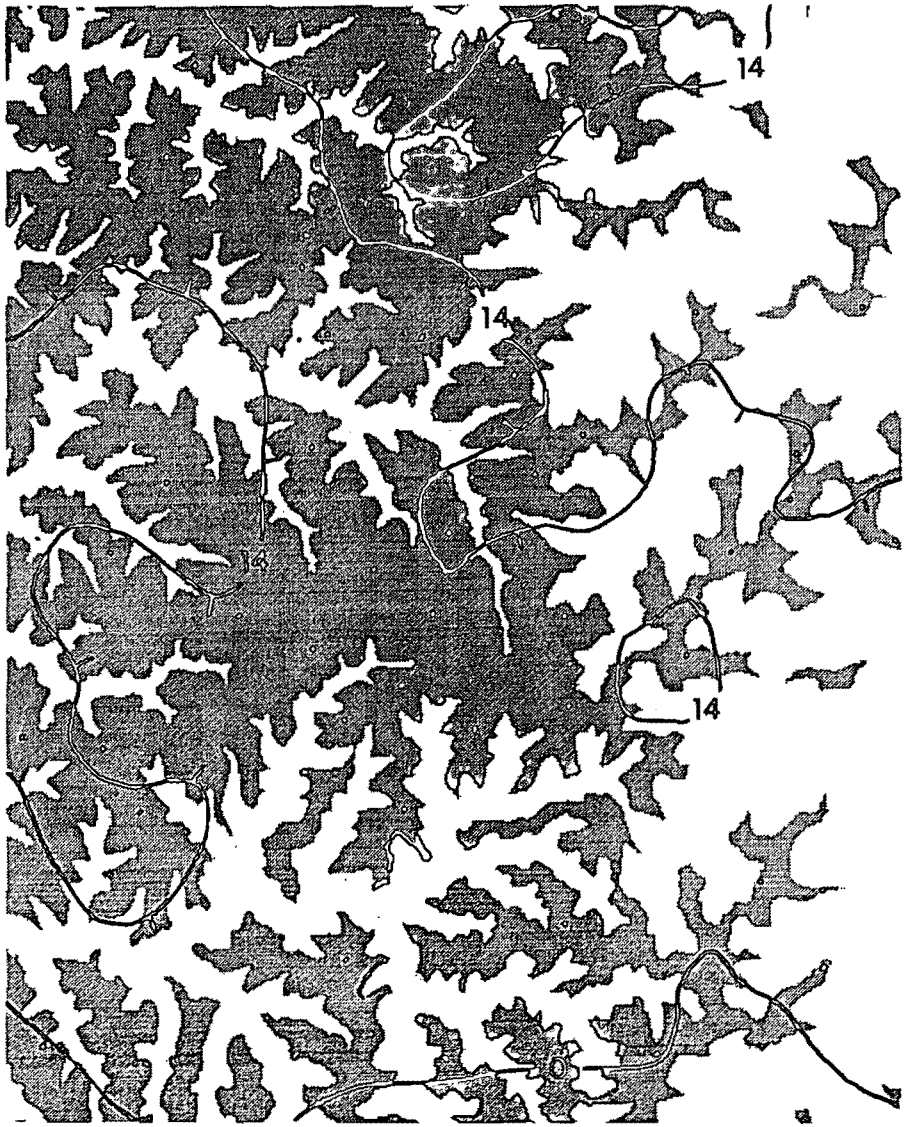
	SURFACE (0-100')						*DEEP (> 100')*					
	14-28"			*> 28"*			*14-28"*			*>28"*		
	MEAS	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*
Original	1,632	3,411	785	0	0	0	2,726	4,470	826	0	0	0
Mined-Out Surface	0	0	0	0	0	0	0	0	0	0	0	0
Mined-Out Deep	0	0	0	0	0	0	0	0	0	0	0	0
Remaining	1,632	3,411	785	0	0	0	2,726	4,470	826	0	0	0
Total Restrictions	30	92	25	0	0	0	2,726	4,470	826	0	0	0
Total Available	1,602	3,319	761	0	0	0	0	0	0	0	0	0
Land-Use Restrictions[2]												
Cemeteries	0	0	0	0	0	0	0	0	0	0	0	0
Oil & Gas Wells	8	34	7	0	0	0	0	0	0	0	0	0
Pipelines	0	0	0	0	0	0	0	0	0	0	0	0
Powerlines	1	25	12	0	0	0	0	0	0	0	0	0
Roads	*	1	0	0	0	0	0	0	0	0	0	0
Streams	21	28	*	0	0	0	0	0	0	0	0	0
Towns	0	5	5	0	0	0	0	0	0	0	0	0
Technological Restrictions[2]												
Barriers	0	0	0	0	0	0	0	0	0	0	0	0
Interburden < 40'	0	0	0	0	0	0	0	0	0	0	0	0
Mining Within 40'	0	0	0	0	0	0	0	0	0	0	0	0
Oil & Gas Wells	0	0	0	0	0	0	21	55	1	0	0	0
Coal Too Thin	0	0	0	0	0	0	2,726	4,470	826	0	0	0

MEAS = Measured. IND = Indicated. INF = Inferred.

* Indicates measurements less than reported precision.

[1] Totals may not equal sum of components because of independent rounding.

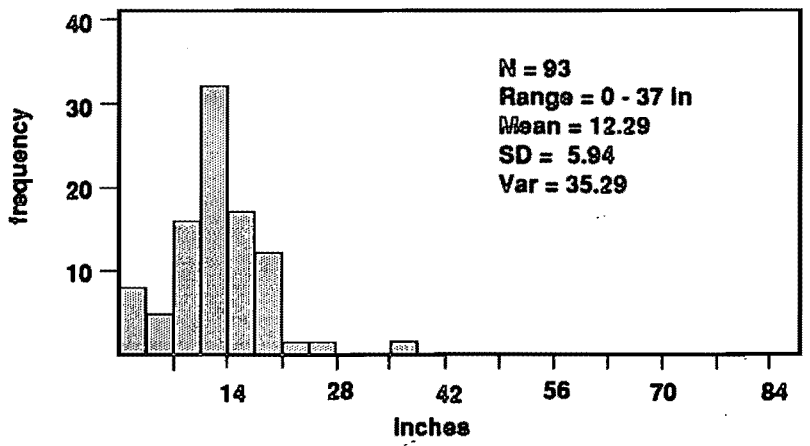
[2] Total tonnage associated with each category. Sums of individual restrictions exceed the restriction total due to overlapping areas.



Hazard Bed

Left: Extent of Hazard bed within the Handshoe Quadrangle (stippled) and interpolated thickness isolines. Tick marks on isolines indicate decreased thickness. Data points shown by dots and mined-out areas by black areas.

Below: Histogram of total coal thickness with summary statistics. Includes data from the margins of adjoining quadrangles.



HAMLIN COAL BED

Coal Availability Results

(Thousands of Short Tons)[1]

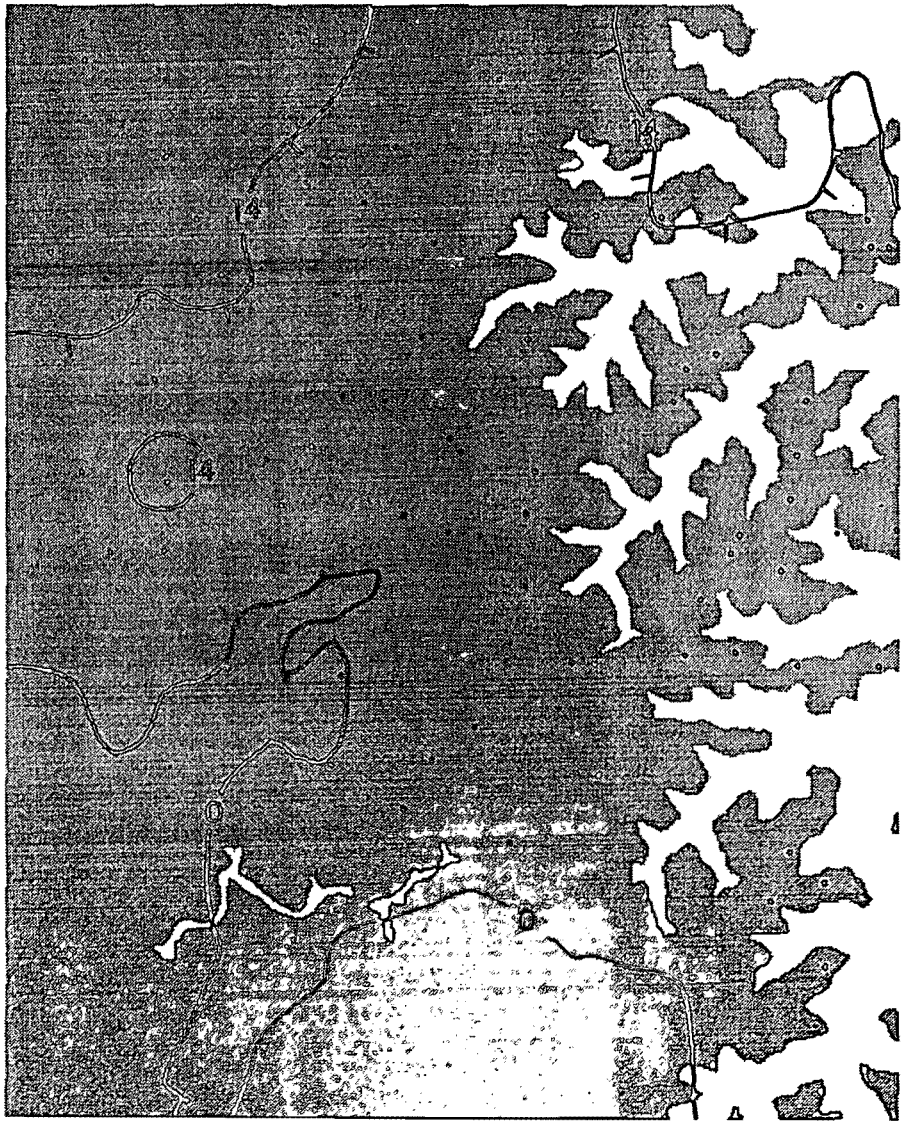
	SURFACE (0-100')						*DEEP (> 100')*					
	14-28"			*> 28"*			*14-28"*			*>28"*		
	MEAS	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*
Original	366	817	412	0	0	0	3,594	5,627	1,338	0	0	0
Mined-Out Surface	0	0	0	0	0	0	0	0	0	0	0	0
Mined-Out Deep	0	0	0	0	0	0	0	0	0	0	0	0
Remaining	366	817	412	0	0	0	3,594	5,627	1,338	0	0	0
Total Restrictions	108	281	76	0	0	0	3,594	5,627	1,338	0	0	0
Total Available	258	536	335	0	0	0	0	0	0	0	0	0
Land-Use Restrictions[2]												
Cemeteries	0	0	0	0	0	0	0	0	0	0	0	0
Oil & Gas Wells	7	44	25	0	0	0	0	0	0	0	0	0
Pipelines	0	0	0	0	0	0	0	0	0	0	0	0
Powerlines	0	14	9	0	0	0	0	0	0	0	0	0
Roads	0	0	0	0	0	0	0	0	0	0	0	0
Streams	102	250	62	0	0	0	0	0	0	0	0	0
Towns	0	0	0	0	0	0	0	0	0	0	0	0
Technological Restrictions[2]												
Barriers	0	0	0	0	0	0	0	0	0	0	0	0
Interburden < 40'	0	0	0	0	0	0	0	0	0	0	0	0
Mining Within 40'	0	0	0	0	0	0	0	0	0	0	0	0
Oil & Gas Wells	0	0	0	0	0	0	33	98	11	0	0	0
Coal Too Thin	0	0	0	0	0	0	3,594	5,627	1,338	0	0	0

MEAS = Measured. IND = Indicated. INF = Inferred.

[1] Totals may not equal sum of components because of independent rounding.

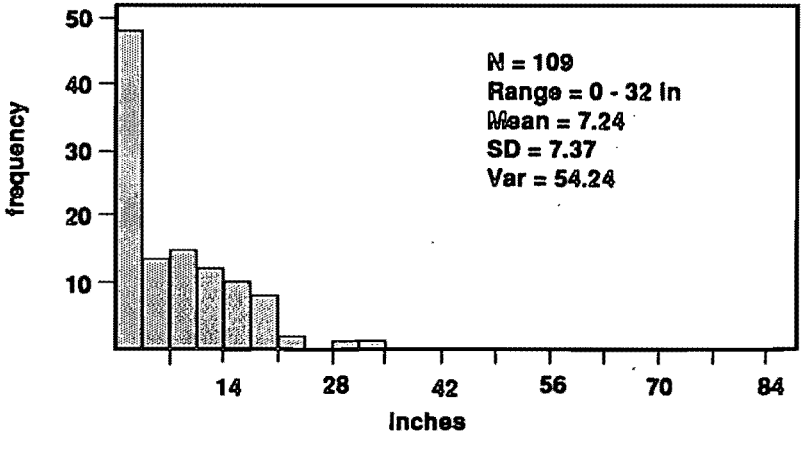
[2] Total tonnage associated with each category. Sums of individual restrictions exceed the restriction total due to overlapping areas.

Hamlin Bed



Left: Extent of Hamlin bed within the Handshoe Quadrangle (stippled) and interpolated thickness isolines. Tick marks on isolines indicate decreased thickness. Data points shown by dots and mined-out areas by black areas.

Below: Histogram of total coal thickness with summary statistics. Includes data from the margins of adjoining quadrangles.



HAZARD NO. 4 RIDER COAL BED

Coal Availability Results

(Thousands of Short Tons)[1]

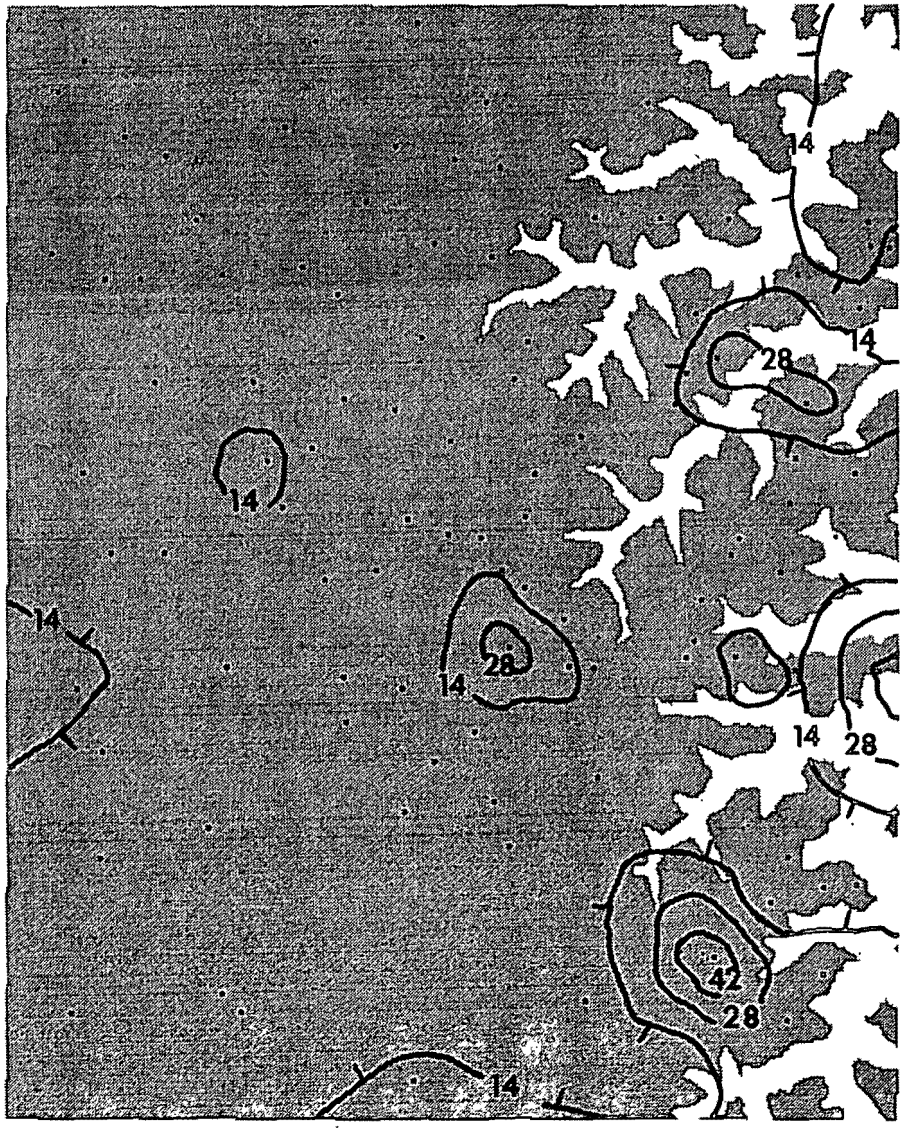
	SURFACE (0-100')						*DEEP (> 100')*					
	14-28"			*> 28"*			*14-28"*			*>28"*		
	MEAS	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*
Original	475	1,090	378	205	240	2	3,186	3,969	925	1,906	1,520	5
Mined-Out Surface	0	0	0	0	0	0	0	0	0	0	0	0
Mined-Out Deep	0	0	0	0	0	0	0	0	0	0	0	0
Remaining	475	1,090	378	205	240	2	3,186	3,969	925	1,906	1,520	5
Total Restrictions	112	130	55	9	105	0	3,186	3,969	925	1,320	516	0
Total Available	363	959	324	197	135	2	0	0	0	586	1,005	5
Land-Use Restrictions[2]												
Cemeteries	6	2	0	0	12	0	0	0	0	0	0	0
Oil & Gas Wells	22	12	7	1	4	0	0	0	0	0	0	0
Pipelines	0	0	0	0	0	0	0	0	0	0	0	0
Powerlines	7	0	0	8	6	0	0	0	0	0	0	0
Roads	25	24	1	0	13	0	0	0	0	0	0	0
Streams	30	30	1	0	21	0	0	0	0	0	0	0
Towns	82	108	49	0	99	0	0	0	0	0	0	0
Technological Restrictions[2]												
Barriers	0	0	0	0	0	0	0	0	0	0	0	0
Interburden < 40'	0	0	0	0	0	0	0	0	0	0	0	0
Mining Within 40'	0	0	0	0	0	0	0	0	0	6	54	0
Oil & Gas Wells	0	0	0	0	0	0	14	32	13	43	14	0
Coal Too Thin	0	0	0	0	0	0	3,186	3,969	925	0	0	0

MEAS = Measured. IND = Indicated. INF = Inferred.

[1] Totals may not equal sum of components because of independent rounding.

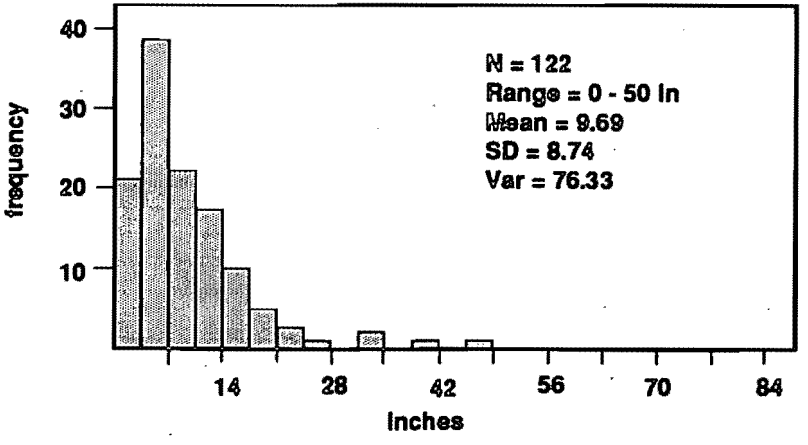
[2] Total tonnage associated with each category. Sums of individual restrictions exceed the restriction total due to overlapping areas.

Hazard No. 4 Rider Bed



Left: Extent of Hazard No. 4 rider bed within the Handshoe Quadrangle (stippled) and interpolated thickness isolines. Tick marks on isolines indicate decreased thickness. Data points shown by dots and mined-out areas by black areas.

Below: Histogram of total coal thickness with summary statistics. Includes data from the margins of adjoining quadrangles.



HAZARD NO. 4 COAL BED

Coal Availability Results

(Thousands of Short Tons)[1]

	SURFACE (0-100')						*DEEP (> 100')*					
	14-28"			*> 28"*			*14-28"*			*>28"*		
	MEAS	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*
Original	385	1,009	363	2,899	5,491	989	10,946	18,388	1,470	30,148	32,005	1,508
Mined-Out Surface	0	0	11	421	393	0	0	0	0	28	24	0
Mined-Out Deep	3	2	15	50	89	31	0	0	19	807	693	41
Remaining	382	1,006	337	2,428	5,009	958	10,946	18,388	1,451	29,314	31,288	1,466
Total Restrictions	190	506	82	336	433	7	10,946	18,388	1,451	557	451	14
Total Available	192	500	255	2,092	4,576	951	0	0	0	28,756	30,837	1,452
Land-Use Restrictions[2]												
Cemeteries	0	14	0	*	5	0	0	0	0	0	0	0
Oil & Gas Wells	15	21	10	78	97	2	0	0	0	0	0	0
Pipelines	0	0	0	0	0	0	0	0	0	0	0	0
Powerlines	0	0	0	21	65	0	0	0	0	0	0	0
Roads	18	100	5	0	60	0	0	0	0	0	0	0
Streams	130	289	8	145	134	0	0	0	0	0	0	0
Towns	68	342	70	134	102	5	0	0	0	0	0	0
Technological Restrictions[2]												
Barriers	0	0	0	0	0	0	*	0	6	162	78	14
Interburden < 40'	0	0	0	0	0	0	0	0	0	0	0	0
Mining Within 40'	0	0	0	0	0	0	0	0	0	0	0	0
Oil & Gas Wells	0	0	0	0	0	0	149	277	42	395	374	0
Coal Too Thin	0	0	0	0	0	0	10,946	18,388	1,451	0	0	0

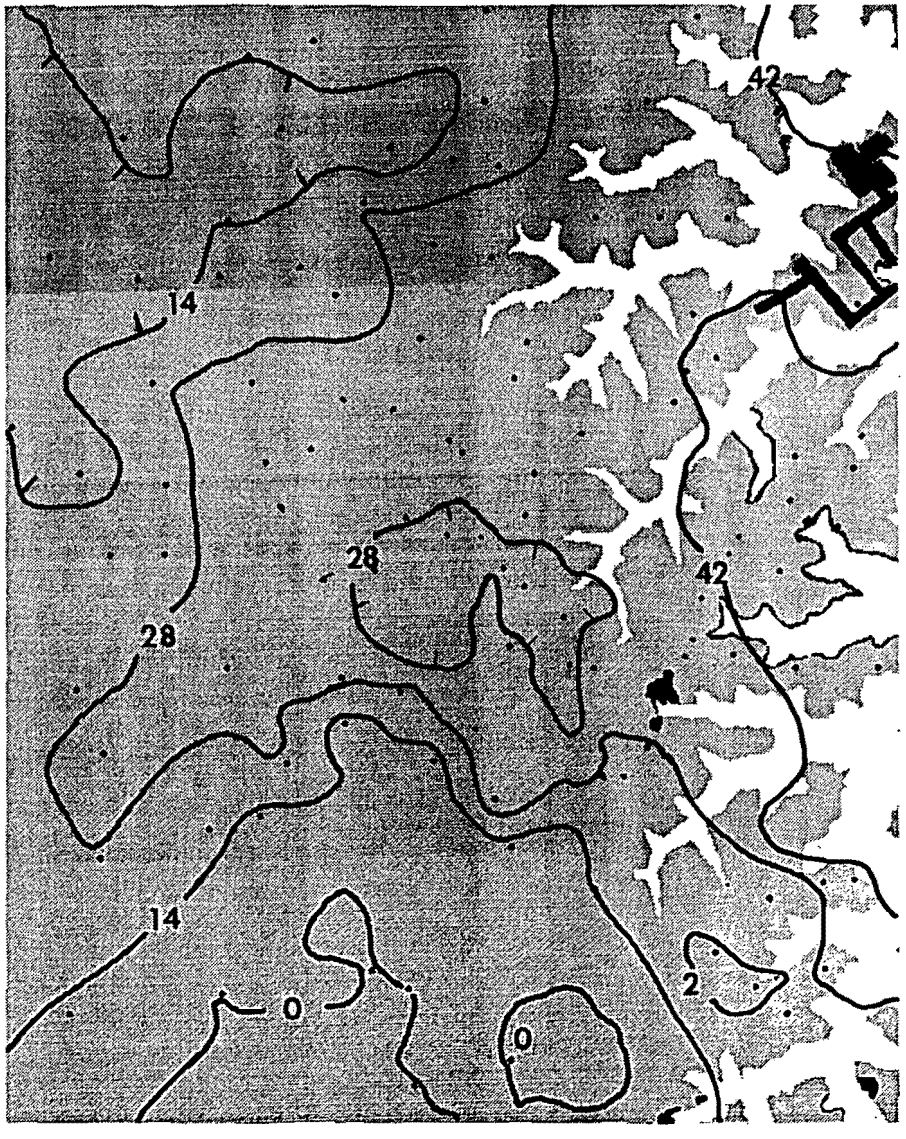
MEAS = Measured. IND = Indicated. INF = Inferred.

* Indicates measurements less than reported precision.

[1] Totals may not equal sum of components because of independent rounding.

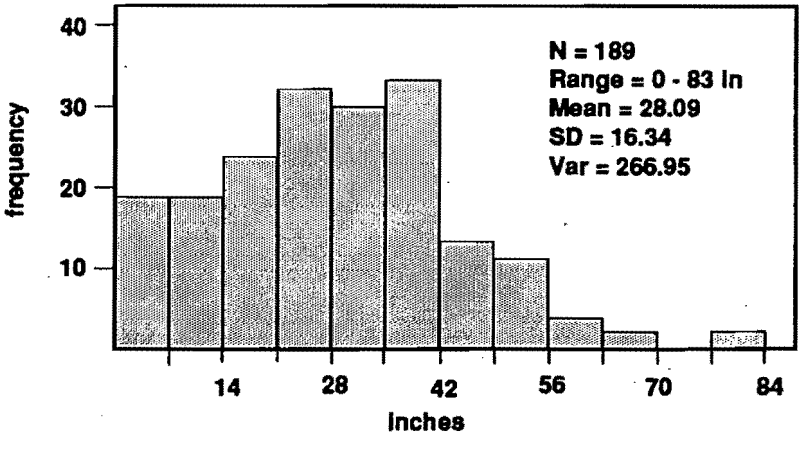
[2] Total tonnage associated with each category. Sums of individual restrictions exceed the restriction total due to overlapping areas.

Hazard No. 4 Bed



Left: Extent of Hazard No. 4 bed within the Handshoe Quadrangle (stippled) and interpolated thickness isolines. Tick marks on isolines indicate decreased thickness. Data points shown by dots and mined-out areas by black areas.

Below: Histogram of total coal thickness with summary statistics. Includes data from the margins of adjoining quadrangles.



LOWER WHITESBURG COAL BED

Coal Availability Results

(Thousands of Short Tons)[1]

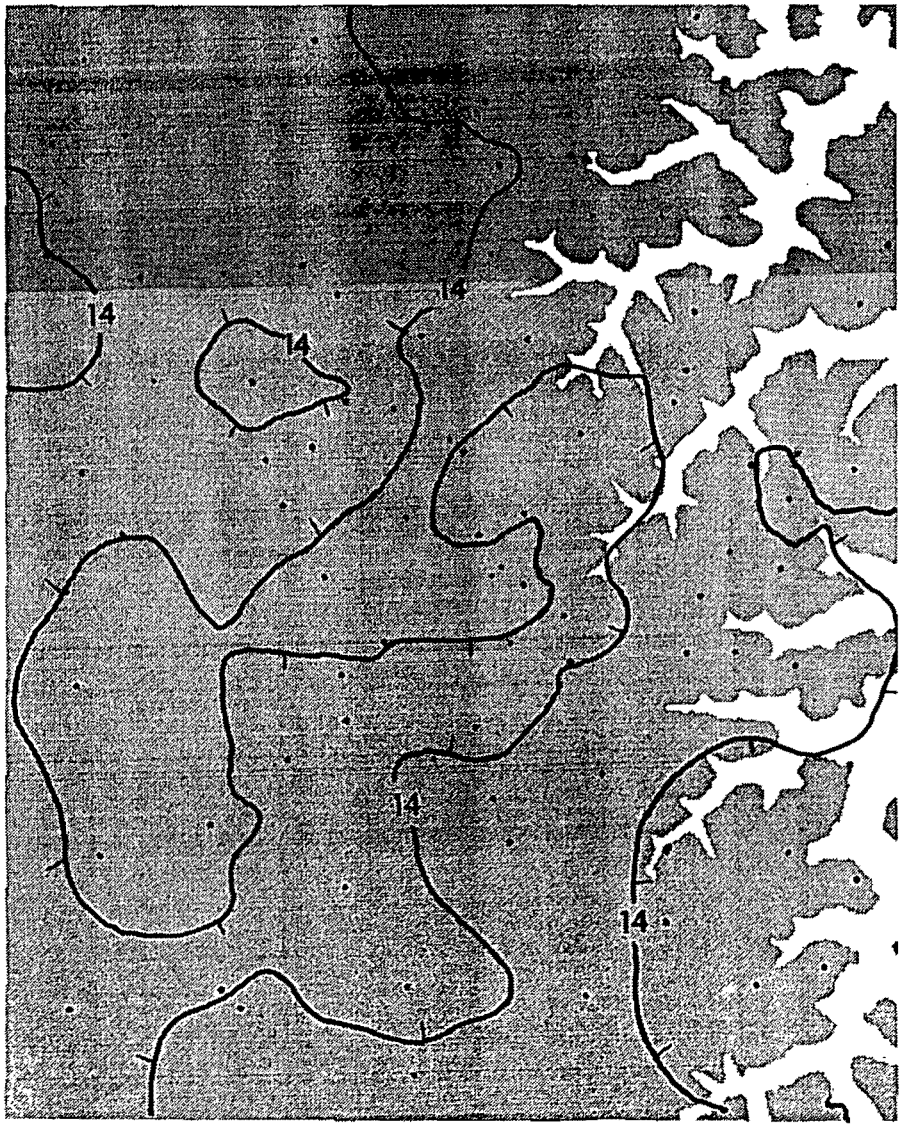
	SURFACE (0-100')						*DEEP (> 100')*					
	14-28"			*> 28"*			*14-28"*			*>28"*		
	MEAS	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*
Original	593	2,293	540	87	11	0	11,901	23,832	4,791	385	45	0
Mined-Out Surface	0	0	0	0	0	0	0	0	0	0	0	0
Mined-Out Deep	0	0	0	0	0	0	0	0	0	0	0	0
Remaining	593	2,293	540	87	11	0	11,901	23,832	4,791	385	45	0
Total Restrictions	79	319	48	*	0	0	11,901	23,832	4,791	0	0	0
Total Available	513	1,974	492	87	11	0	0	0	0	385	45	0
Land-Use Restrictions[2]												
Cemeteries	0	6	3	0	0	0	0	0	0	0	0	0
Oil & Gas Wells	27	60	15	*	0	0	0	0	0	0	0	0
Pipelines	0	0	0	0	0	0	0	0	0	0	0	0
Powerlines	2	43	0	0	0	0	0	0	0	0	0	0
Roads	0	55	6	0	0	0	0	0	0	0	0	0
Streams	22	114	3	0	0	0	0	0	0	0	0	0
Towns	28	103	30	0	0	0	0	0	0	0	0	0
Technological Restrictions[2]												
Barriers	0	0	0	0	0	0	0	0	0	0	0	0
Interburden < 40'	0	0	0	0	0	0	0	0	0	0	0	0
Mining Within 40'	0	0	0	0	0	0	0	0	0	0	0	0
Oil & Gas Wells	0	0	0	0	0	0	172	425	89	0	0	0
Coal Too Thin	0	0	0	0	0	0	11,901	23,832	4,791	0	0	0

MEAS = Measured. IND = Indicated. INF = Inferred.

* Indicates measurements less than reported precision.

[1] Totals may not equal sum of components because of independent rounding.

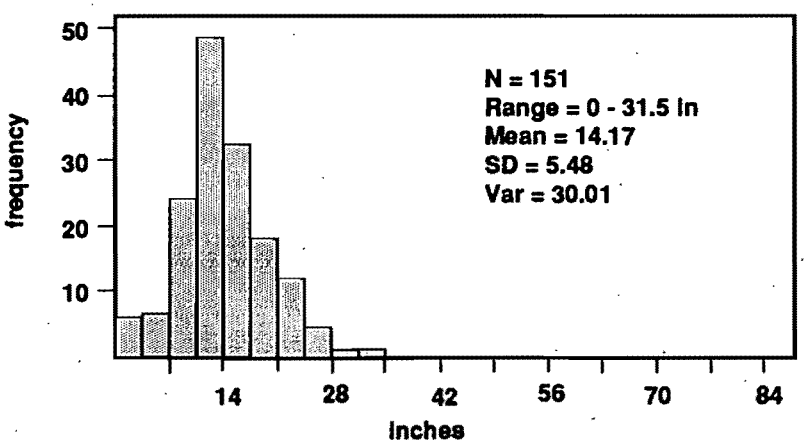
[2] Total tonnage associated with each category. Sums of individual restrictions exceed the restriction total due to overlapping areas.



Lower Whitesburg Bed

Left: Extent of Lower Whitesburg bed within the Handshoe Quadrangle (stippled) and interpolated thickness isolines. Tick marks on isolines indicate decreased thickness. Data points shown by dots and mined-out areas by black areas.

Below: Histogram of total coal thickness with summary statistics. Includes data from the margins of adjoining quadrangles.



UPPER ELKHORN NO. 3 COAL BED

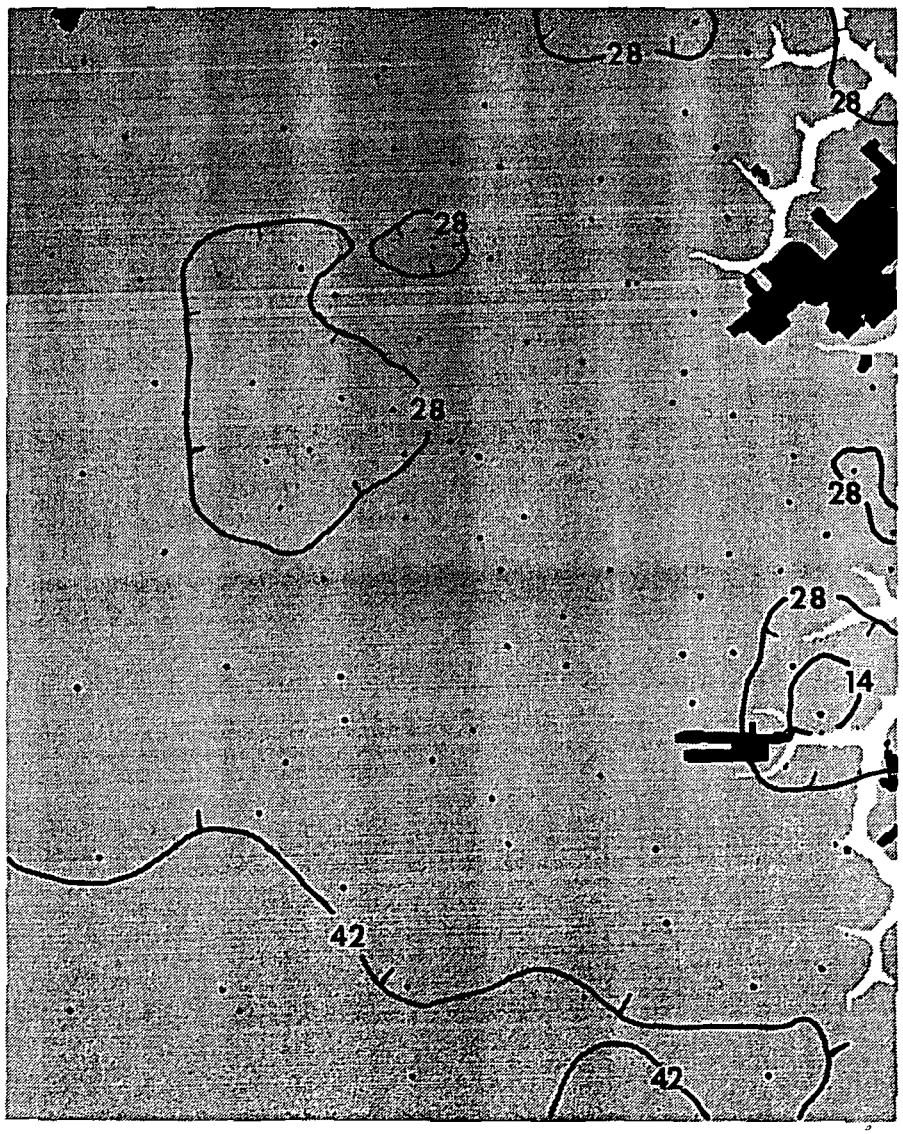
Coal Availability Results
(Thousands of Short Tons)[1]

	SURFACE (0-100')						*DEEP (> 100')*					
	14-28"			*> 28"*			*14-28"*			*>28"*		
	MEAS	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*
Original	61	363	275	771	2,302	618	4,795	6,977	676	51,684	116,552	20,520
Mined-Out Surface	0	0	0	0	0	0	0	0	0	0	0	0
Mined-Out Deep	0	5	24	22	44	29	0	111	36	1,685	1,222	127
Remaining	61	358	251	749	2,258	588	4,795	6,866	640	49,999	115,330	20,393
Total Restrictions	21	155	171	492	1,697	295	4,795	6,866	640	1,049	2,165	383
Total Available	40	202	81	258	561	293	0	0	0	48,950	113,165	20,010
Land-Use Restrictions[2]												
Cemeteries	4	15	6	21	66	8	0	0	0	0	0	0
Oil & Gas Wells	0	9	12	55	88	18	0	0	0	0	0	0
Pipelines	0	0	0	0	0	0	0	0	0	0	0	0
Powerlines	0	0	8	0	51	0	0	0	0	0	0	0
Roads	0	8	20	109	289	11	0	0	0	0	0	0
Streams	10	43	11	259	581	25	0	0	0	0	0	0
Towns	11	127	157	298	1,394	282	0	0	0	0	0	0
Technological Restrictions[2]												
Barriers	0	0	0	0	0	0	0	14	9	98	159	32
Interburden < 40'	0	0	0	0	0	0	0	0	0	0	0	0
Mining Within 40'	0	0	0	0	0	0	0	0	0	0	0	0
Oil & Gas Wells	0	0	0	0	0	0	67	138	15	953	2,007	350
Coal Too Thin	0	0	0	0	0	0	4,795	6,866	640	0	0	0

MEAS = Measured. IND = Indicated. INF = Inferred.

[1] Totals may not equal sum of components because of independent rounding.

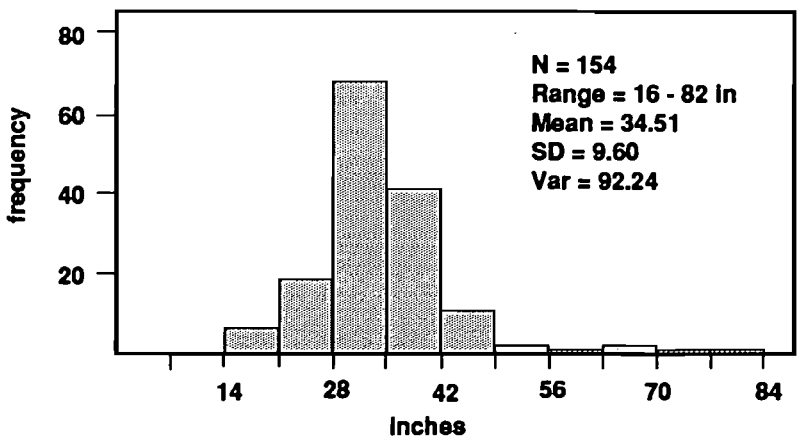
[2] Total tonnage associated with each category. Sums of individual restrictions exceed the restriction total due to overlapping areas.



Upper Elkhorn No. 3 Bed

Left: Extent of Upper Elkhorn No. 3 bed within the Handshoe Quadrangle (stippled) and interpolated thickness isolines. Tick marks on isolines indicate decreased thickness. Data points shown by dots and mined-out areas by black areas.

Below: Histogram of total coal thickness with summary statistics. Includes data from the margins of adjoining quadrangles.



UPPER ELKHORN NO. 2 COAL BED

Coal Availability Results
(Thousands of Short Tons)[1]

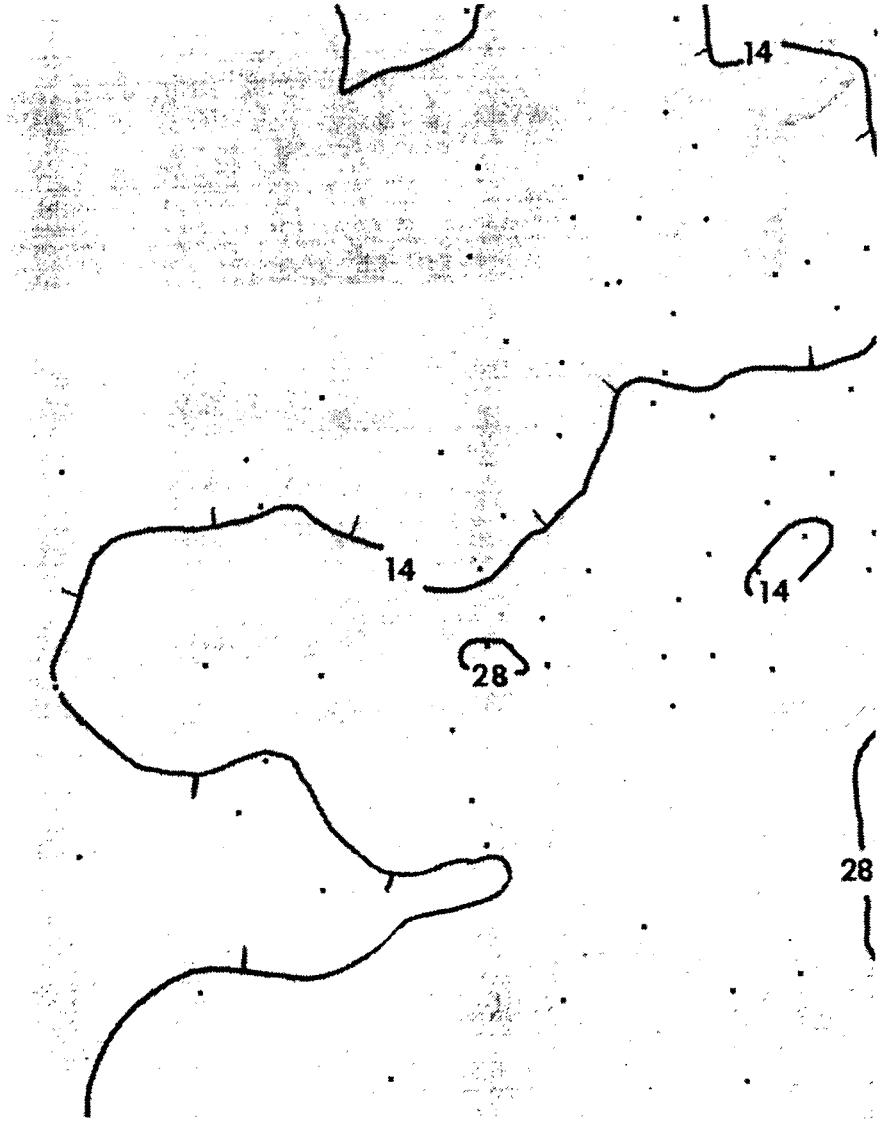
	SURFACE (0-100')						*DEEP (> 100')*					
	14-28"			*> 28"*			*14-28"*			*>28"*		
	MEAS	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*
Original	82	767	519	0	*	127	10,891	26,374	10,390	469	52	317
Mined-Out Surface	0	0	0	0	0	0	0	0	0	0	0	0
Mined-Out Deep	0	0	0	0	0	0	0	0	0	0	0	0
Remaining	82	767	519	0	*	127	10,891	26,374	10,390	469	52	317
Total Restrictions	40	663	453	0	*	108	10,891	26,374	10,390	0	*	119
Total Available	42	104	66	0	*	18	0	0	0	469	51	199
Land-Use Restrictions[2]												
Cemeteries	2	17	12	0	0	1	0	0	0	0	0	0
Oil & Gas Wells	*	44	24	0	0	*	0	0	0	0	0	0
Pipelines	0	0	0	0	0	0	0	0	0	0	0	0
Powerlines	0	0	12	0	0	0	0	0	0	0	0	0
Roads	*	177	65	0	0	32	0	0	0	0	0	0
Streams	30	331	92	0	*	18	0	0	0	0	0	0
Towns	10	586	447	0	*	104	0	0	0	0	0	0
Technological Restrictions[2]												
Barriers	0	0	0	0	0	0	0	0	0	0	0	0
Interburden < 40'	0	0	0	0	0	0	0	0	0	0	*	119
Mining Within 40'	0	0	0	0	0	0	0	0	0	0	0	0
Oil & Gas Wells	0	0	0	0	0	0	233	480	210	0	0	0
Coal Too Thin	0	0	0	0	0	0	10,891	26,374	10,390	0	0	0

MEAS = Measured. IND = Indicated. INF = Inferred.

* Indicates measurements less than reported precision.

[1] Totals may not equal sum of components because of independent rounding.

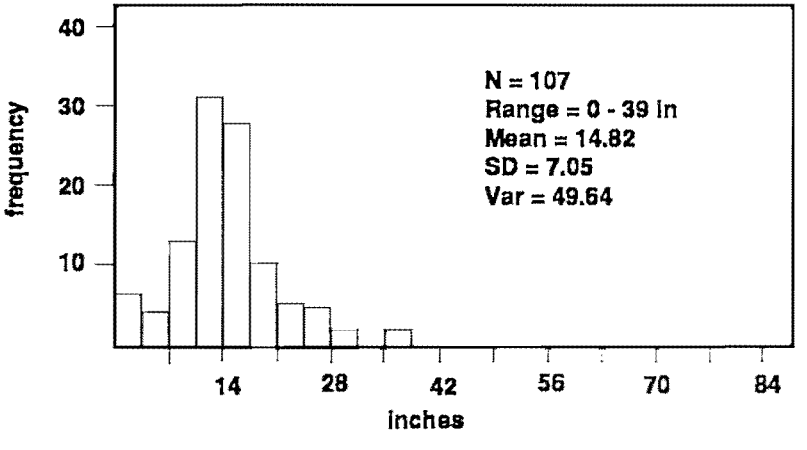
[2] Total tonnage associated with each category. Sums of individual restrictions exceed the restriction total due to overlapping areas.



Upper Elkhorn No. 2 Bed

Left: Extent of Upper Elkhorn No. 2 bed within the Handshoe Quadrangle (stippled) and interpolated thickness isolines. Tick marks on isolines indicate decreased thickness. Data points shown by dots and mined-out areas by black areas.

Below: Histogram of total coal thickness with summary statistics. Includes data from the margins of adjoining quadrangles.



UPPER ELKHORN NO. 1 COAL BED

Coal Availability Results

(Thousands of Short Tons)[1]

	SURFACE (0-100')						*DEEP (> 100')*					
	14-28"			*> 28"*			*14-28"*			*>28"*		
	MEAS	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*	*MEAS*	*IND*	*INF*
Original	5	418	429	206	590	297	6,816	21,020	15,130	18,388	25,882	2,828
Mined-Out Surface	0	0	0	0	0	0	0	0	0	0	0	0
Mined-Out Deep	0	0	0	0	0	3	0	0	0	0	0	0
Remaining	5	418	429	206	590	294	6,816	21,020	15,130	18,388	25,882	2,828
Total Restrictions	2	406	371	167	468	276	6,816	21,020	15,130	376	621	82
Total Available	3	12	58	40	122	19	0	0	0	18,012	25,261	2,746
Land-Use Restrictions[2]												
Cemeteries	*	31	16	0	11	1	0	0	0	0	0	0
Oil & Gas Wells	0	10	23	5	58	21	0	0	0	0	0	0
Pipelines	0	0	0	0	0	0	0	0	0	0	0	0
Powerlines	0	20	0	0	21	13	0	0	0	0	0	0
Roads	*	118	91	34	101	11	0	0	0	0	0	0
Streams	2	164	89	87	278	62	0	0	0	0	0	0
Towns	0	360	341	125	272	272	0	0	0	0	0	0
Technological Restrictions[2]												
Barriers	0	0	0	0	0	0	0	0	0	0	0	0
Interburden < 40'	0	0	0	0	0	0	0	0	0	0	0	0
Mining Within 40'	0	0	0	0	0	0	0	0	0	0	0	0
Oil & Gas Wells	0	0	0	0	0	0	111	343	390	376	621	82
Coal Too Thin	0	0	0	0	0	0	6,816	21,020	15,130	0	0	0

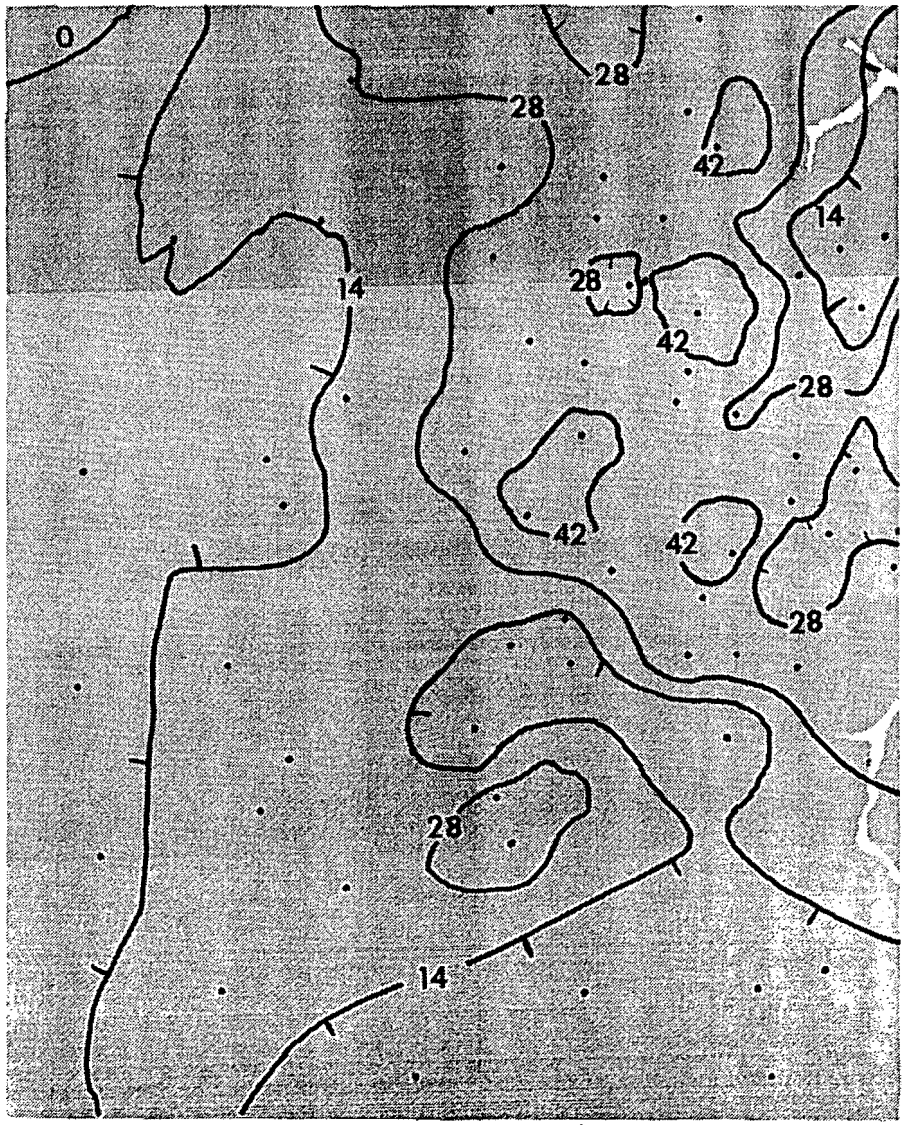
MEAS = Measured. IND = Indicated. INF = Inferred.

* Indicates measurements less than reported precision.

[1] Totals may not equal sum of components because of independent rounding.

[2] Total tonnage associated with each category. Sums of individual restrictions exceed the restriction total due to overlapping areas.

Upper Elkhorn No. 1 Bed



Left: Extent of Upper Elkhorn No. 1 bed within the Handshoe Quadrangle (stippled) and interpolated thickness isolines. Tick marks on isolines indicate decreased thickness. Data points shown by dots and mined-out areas by black areas.

Below: Histogram of total coal thickness with summary statistics. Includes data from the margins of adjoining quadrangles.