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A STUDY OF COAL AVAILABILITY IN THE HACKETT 7.5-MINUTE QUADRANGLE, WASHINGTON COUNTY, PENNSYLVANIA

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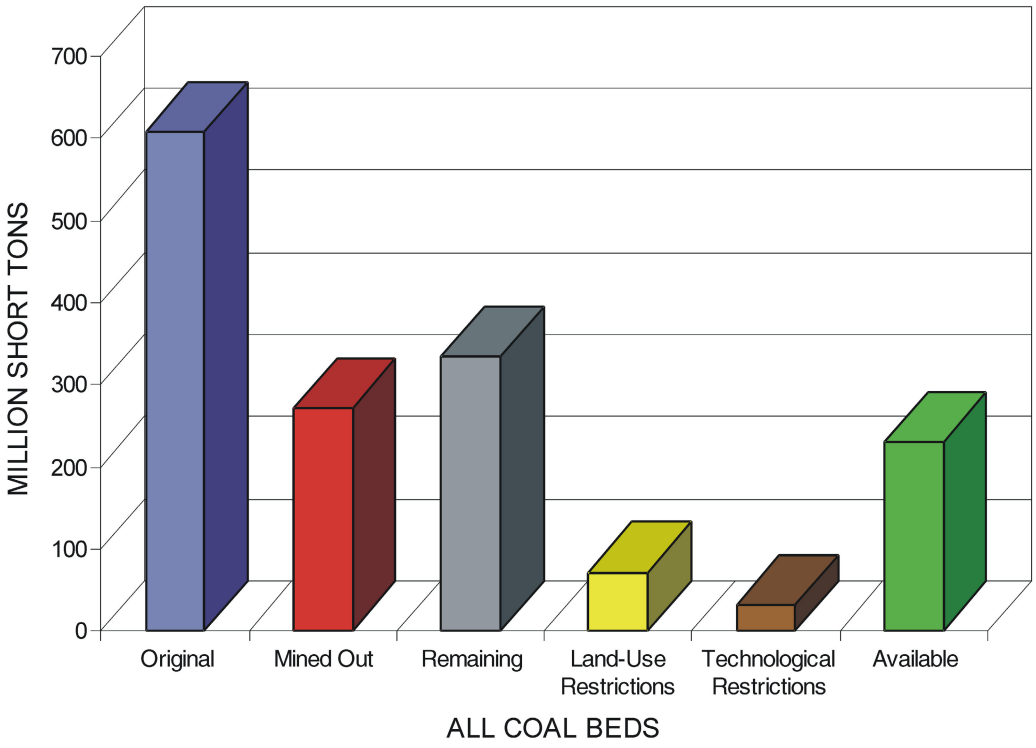

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A STUDY OF COAL AVAILABILITY IN THE HACKETT 7.5-MINUTE QUADRANGLE, WASHINGTON COUNTY, PENNSYLVANIA

by Leonard J. Lentz
John C. Neubaum
Pennsylvania Geological Survey

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A STUDY OF COAL AVAILABILITY IN THE HACKETT 7.5-MINUTE QUADRANGLE, WASHINGTON COUNTY, PENNSYLVANIA

by
Leonard J. Lentz and John C. Neubaum

ABSTRACT

The Hackett 7.5-minute quadrangle in southwestern Pennsylvania is underlain by upper Carboniferous and lower Permian rocks, which contain the Pittsburgh, Redstone, Waynesburg, and Waynesburg A coal beds. Extensive mining of these coals, particularly the Pittsburgh, during the last half century has removed nearly half of the original coal.

The Hackett quadrangle is one of four initial quadrangles in the bituminous coal fields of Pennsylvania selected in 1993 to demonstrate how much coal on average remains available for extraction within a mature mining district. Results from this first study indicate that of the approximately 607 million short tons of bituminous coal originally in the Hackett quadrangle, 272 million short tons, or 45 percent, has been mined out. An additional 83 million short tons, or 14 percent, of coal can be excluded due to resource restrictions, such as land-use and technological factors, leaving only about 252 million short tons, or 42 percent, of the original amount of coal available for mining.

INTRODUCTION

The Coal Resources Branch of the U.S. Geological Survey (U.S.G.S.) in cooperation with the Kentucky Geological Survey initiated a pilot study in 1987 to quantify coal resources available for mining in the Matewan 7.5-minute quadrangle, located in eastern Kentucky, by looking at the additional effect of land-use and technological restrictions to mining. Formally termed a Coal Availability Study, this pilot study provided the guidelines used in subsequent quadrangle studies in Virginia and West Virginia, and eventually Pennsylvania.

The U.S. Geological Survey in 1992 decided to expand the scope of the Coal Availability Study program from the central Appalachian Basin into the northern Appalachian Basin. The Pennsylvania Bureau of Topographic and Geologic Survey (Pennsylvania Geological Survey) responded with a proposal for four 7.5-minute quadrangle Coal Availability Studies for the Pennsylvania portion of the northern Appalachian basin over the next 4 years, followed by two more in a fifth-year proposal. This proposal was accepted by the U.S. Geological Survey and funding was initiated for the cooperative agreement in late 1993 under grant #1434-92-A-0987. The Hackett quadrangle, located in Washington County (Figure 1), was chosen as the first quadrangle for study of that initial group of four quadrangles submitted to the U.S. Geological Survey.

Data collected for the study include restriction categories based upon the regulations of the Commonwealth of Pennsylvania, coal drill-holes, outcrop and strip-mine highwall descriptions, and maps delineating mined-out areas that were collected in the fall of 1994. The drill hole data were incorporated into a computer database of stratigraphic data called the National Coal Resources Data System (NCRDS) maintained by the U.S. Geological Survey in Reston, Virginia. This database was searched and data were retrieved for inclusion into the geographic analysis program called GRASS (Geographical Resources Analysis Support System) to calculate available coal based upon various coal and overburden thickness categories. These various elements are further explained in the methods portion of this paper found in Appendix D.

This initial quadrangle was chosen for study because the authors felt it typified the past mining history of southwestern Pennsylvania—a mature mining region where only one seam is predominantly mined (i.e., Pittsburgh coal). Because of the vast amount of mining that has occurred, a lot of development drill holes have been driven by a number of companies active in the area. A lot of this drill hole data had been collected prior to 1993 by Survey staff geologists and therefore were available to the authors for this study. The plethora of data provided much needed stratigraphic control when creating structure and coal thickness maps for the study area, especially for the Pittsburgh coal bed. However in an unexpected way, this density of regularly spaced drill holes, while useful for defining the coal bed, eliminated the need to calculate hypothetical coal—a component in resource studies—within the study area. Without the presence of an explicit hypothetical coal component, the resultant coal tonnage figures for the quadrangle fall more appropriately into the category of reserves. This was not the intended

purpose, but rather an outcome of this resource study. The term resources will be used throughout this report for the sake of consistency. A further discussion as to what constitutes a resource study and a reserve study can be found in Wood and others (1983).

The study area incorporates coal stratigraphic data from nine quadrangles—the Hackett quadrangle, and approximately 3 miles into the eight surrounding/adjacent quadrangles—in an effort to minimize quadrangle "edge effects" when isopaching coal-bed thickness and deriving coal-bed structure maps. Resources are calculated, however, only from that line and point data (i.e., data points, mined-out areas, coal crop lines, restrictions to mining, etc.) that occur within the Hackett quadrangle.

Overall goals of the Coal Availability grant for Pennsylvania include the following:

1. Develop an operational Internet connection at the Pennsylvania Geological Survey that would link to the federally maintained National Coal Resources Data System located in Reston, VA.
2. Choose quadrangles for study that are representative of the bituminous coal measures of Pennsylvania and for which data exist.
3. Determine the original, mined-out, and remaining coal for 7.5-minute-quadrangle-sized study areas.
4. Determine the amount of coal available for mining in these study areas by also considering the effect that land-use and technological restrictions have on that remaining resource base.
5. Establish a methodology and a means of comparison of future 7.5-minute-quadrangle studies in other parts of the bituminous coal field in Pennsylvania.

This report presents the results of the Hackett study, providing estimates of the original, mined-out, remaining, restricted, and available resources.

LOCATION

The Hackett quadrangle is located in eastern Washington County, in southwestern Pennsylvania, approximately 11 miles southwest of the city of Pittsburgh and about 6 miles west of the Monongahela River (Figure 1). Drainage via Mingo Creek, Peters Creek, and the various

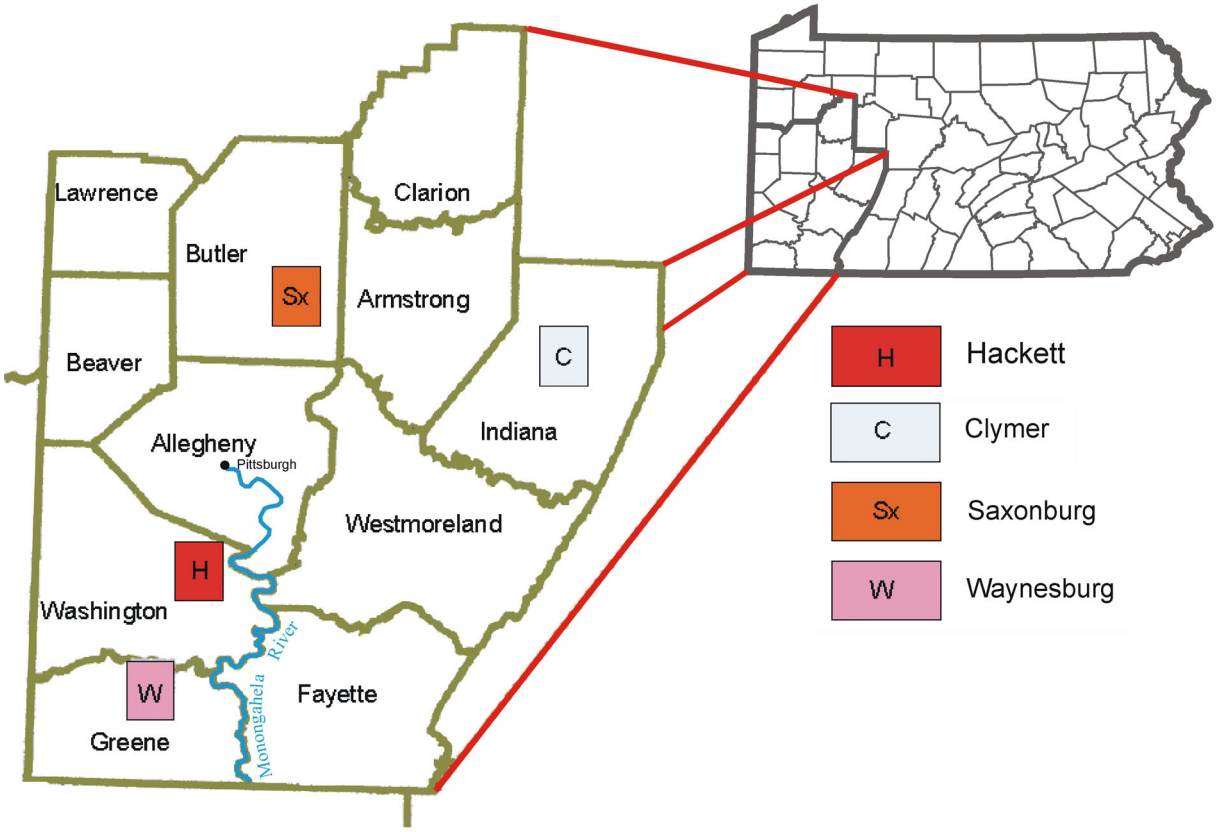

Figure 1. Location of the Hackett 7.5-minute quadrangle in relation to the other anticipated study locations for Pennsylvania.

branches of Pigeon Creek is towards the east into the Monongahela River (Figure 2). A small drainage divide in the extreme western part of the quadrangle directs tributaries a short distance westward into the northward-flowing Little Chartiers Creek. The village of Hackett is located on Peters Creek in the northeastern corner of the quadrangle, and the Borough of Bentleyville is located on Pigeon Creek in the extreme southeastern corner. These communities are the largest settlements in the quadrangle. State Route 136 and U.S. Interstate Highway 70 run east-west across the lower half of the study area. State Routes 917 and 88 run north-south across the quadrangle's eastern edge from Bentleyville to just east of Hackett (see Figure 2). An additional large number of county and township roads transect the study area as well.

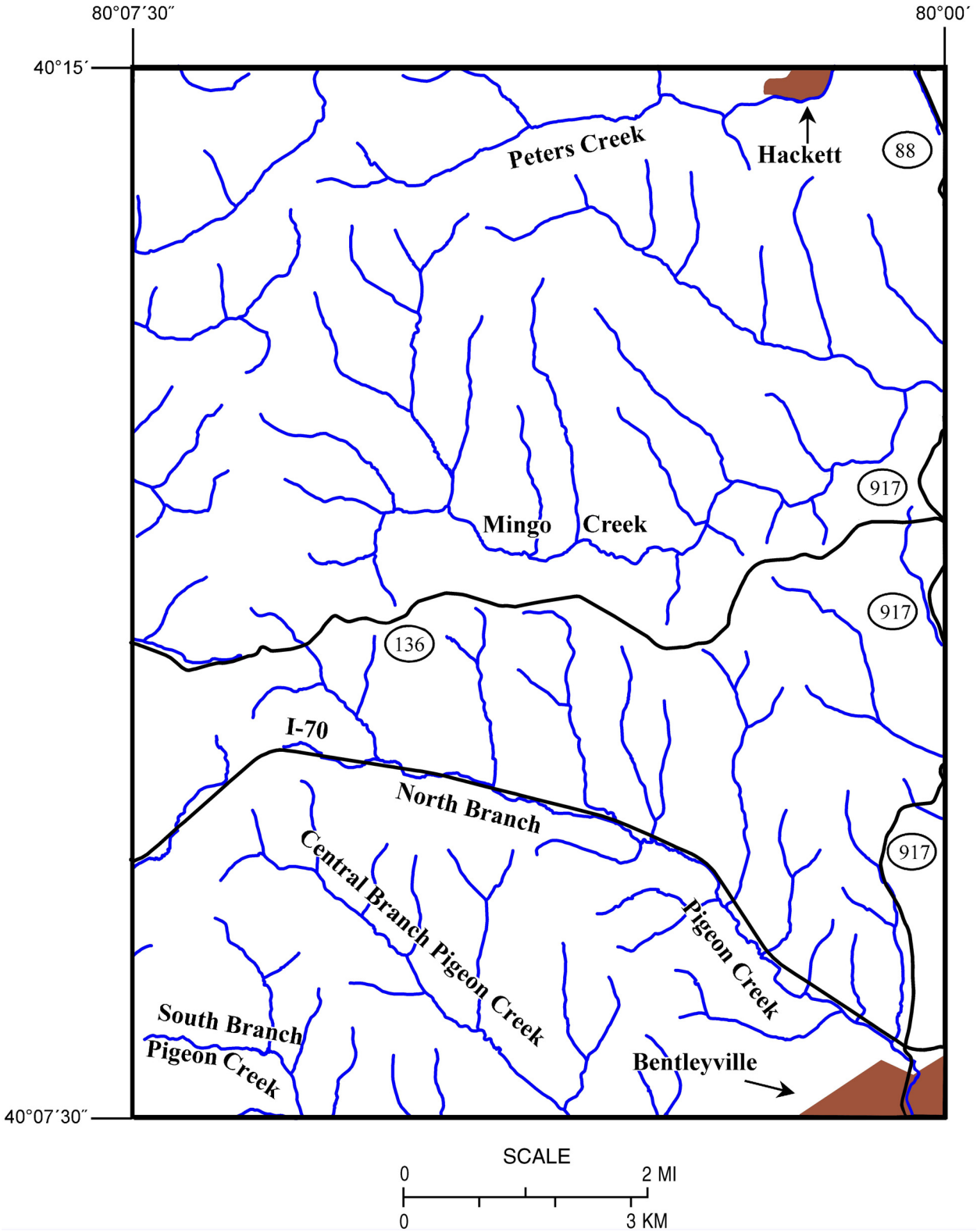

Figure 2. Locations of selected roads, streams, and towns in the Hackett quadrangle.

GEOLOGY

PHYSIOGRAPHY

The Hackett quadrangle lies within the Appalachian Plateaus physiographic province, Pittsburgh Low Plateau section. This province is moderately dissected with relatively low rolling hills and narrow valleys. Greatest relief occurs within the major drainages associated with the Monongahela River, which flows northward several miles east of the study area. Maximum topographic relief within the study quadrangle is about 600 feet, with an average relief of about 200-300 feet.

STRUCTURE

Although the strata in the Pittsburgh Low Plateau are typically flat-lying, the Plateau can be found to have a number of asymmetrical, gently folded rock layers formed into anticlines and synclines. Two such folds, the southwestwardly plunging, northeast-southwest trending Nineveh syncline and Amity anticline (Figure 3), pass through the Hackett quadrangle (Kent, 1967). The dip of the beds in these structures is steepest on the limb between the Nineveh syncline and Amity anticline in the western half of the quadrangle, where the rate of dip approaches 100 feet per mile. These structural features apparently had an influence on drainage patterns in the study area; a small drainage divide developed just west of the Nineveh syncline (see Figure 3). Similarly, parent streams, as portrayed by the black color-coded, linear-shaped Quaternary alluvium deposits, delineate a moderately dense, modified trellis to dentritic drainage pattern. These streams show a propensity for more of their tributaries to flow into them from the north than from the south, a reflection of regional dip, which is to the south-southwest (see fold plunges in Figure 3).

DEPOSITIONAL SETTING

The study area includes rocks of the Permian Dunkard and the Pennsylvanian Monongahela Groups (Figure 4). They are comprised typically of shale and limestone with subordinate amounts of sandstone and coal. The Pittsburgh coal bed, which denotes the base of the Monongahela Group, is the most widespread and thickest of all the coals in the study interval. There do not appear to be any viable coals above the Washington coal bed in the study

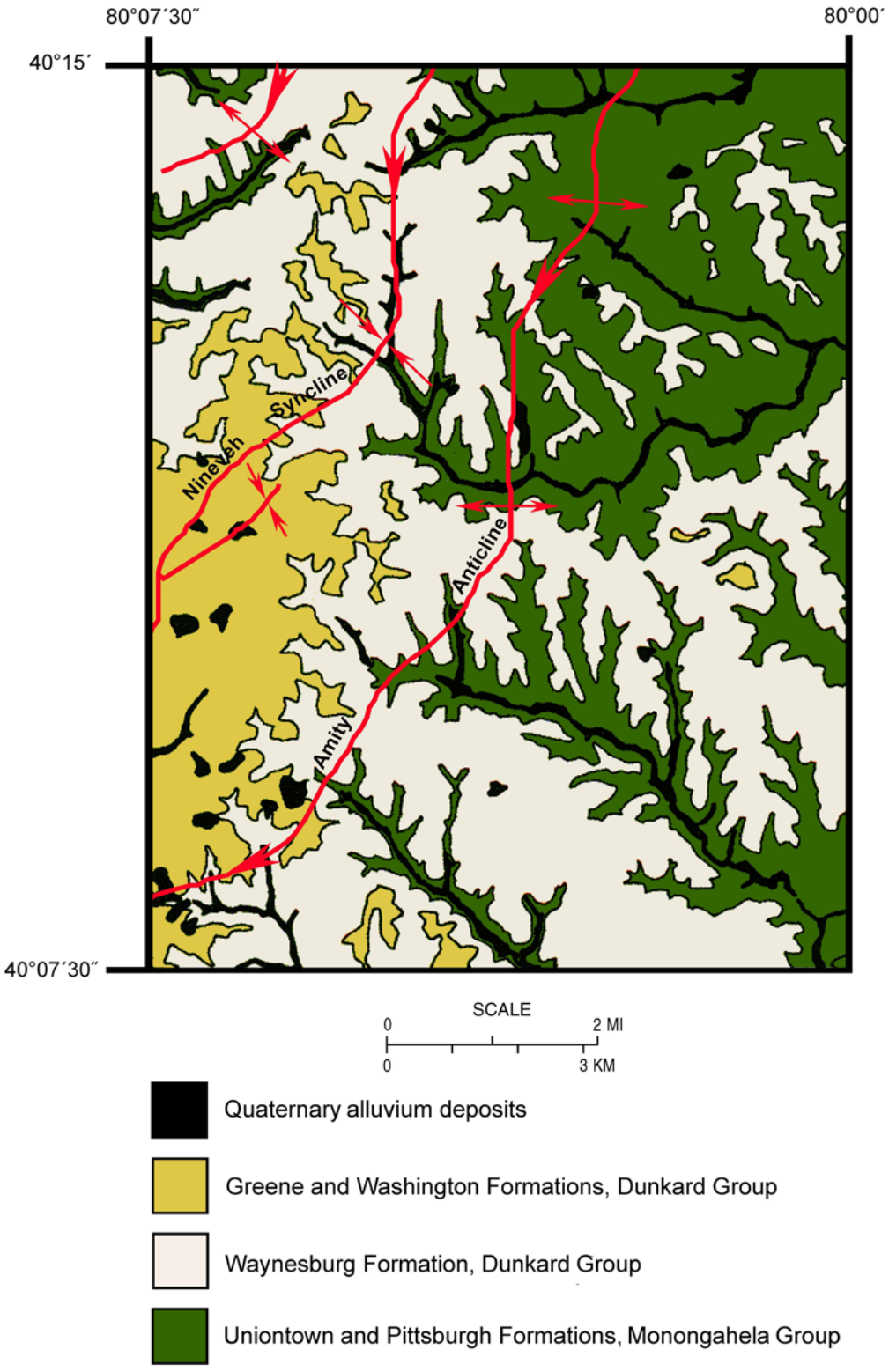

Figure 3. Simplified geologic map of the Hackett quadrangle (after Kent, 1967).

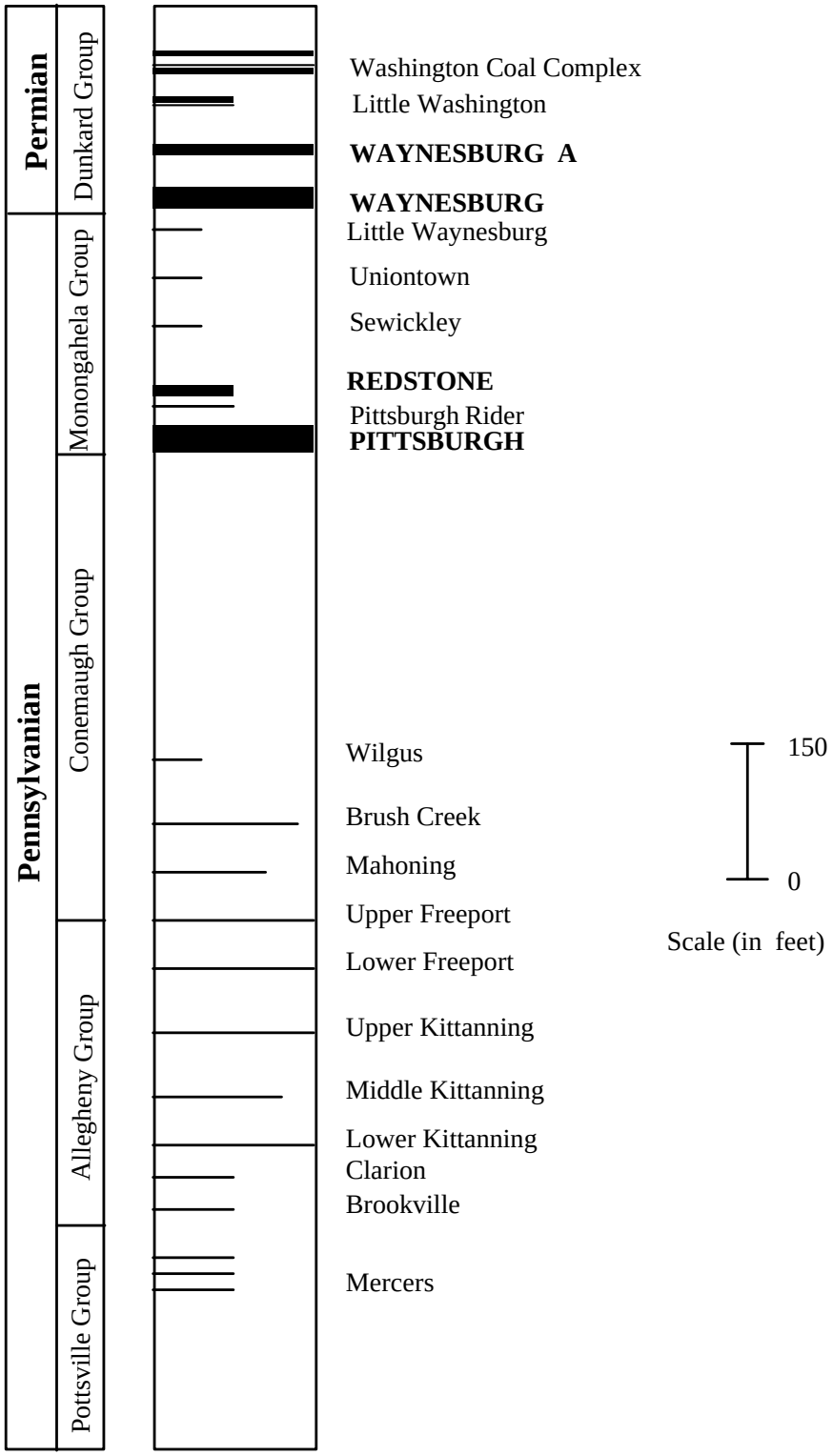

Figure 4. Generalized columnar section showing study coals (uppercase) and other minor coals in the Hackett quadrangle.

area. The geometry and vast areal extent of the coal beds in this part of the geologic section suggests that coal-forming peat probably collected within a lake-dominated, alluvial plain environment. In such a depositional setting one would expect a moderate-to-high ash and moderate-to-high sulfur coal-forming peat swamp. The coals typically reflect that expectation.

COAL BEDS

The coal seams mined in the study area, shown in uppercase on Figure 4, represent only a fraction of all the potentially minable coals known to occur in the Pennsylvanian and Permian rocks of western Pennsylvania. The Pittsburgh, Redstone, Waynesburg, and Waynesburg A coal beds were only worthy of consideration in this study because they met the objectives of a set of predefined criteria which have been discussed elsewhere in this study, and for which original coal can be computed (i.e., greater than 14 inches thick). These criteria excluded from the study marginal coals like the Pittsburgh Rider, Sewickley, Uniontown, and Washington because they are thin (usually less than 14 inches thick) and very highly localized geographically. In the study area, potentially economically important, but stratigraphically lower coals of the Allegheny and Pottsville Groups are overlain by greater than 1000 feet of overburden and are assumed to be too deep to be mined under current economic conditions. Additionally, data did not exist at the time of data collection (in 1994) for these deeper coal beds for this quadrangle study, as these lower coals appear not to have yet been targeted by coal companies for exploration. Therefore for the latter two reasons, coals deeper than the Pittsburgh coal bed were not considered in the resource calculations for this project.

Pittsburgh Coal Bed

The Pittsburgh coal bed, used in the metallurgical and electricity-generating industries, underlies nearly the entire quadrangle (Figure 5). It is absent in the northeastern corner of the quadrangle (represented by outcrop of the coal bed), where post-depositional erosion has removed it. The Pittsburgh coal bed averages around 96 inches thick, though it may obtain a thickness of up to 120-144 inches in the study area. Typically, the Pittsburgh coal bed comprises two major benches: roof coal(s) and a main coal, which are separated by a hard, often slickensided shale or fireclay called “draw slate.” The main mined bed averages 68 inches thick and contains several thin shale “finger” partings (quarter inch or less thick) throughout. These

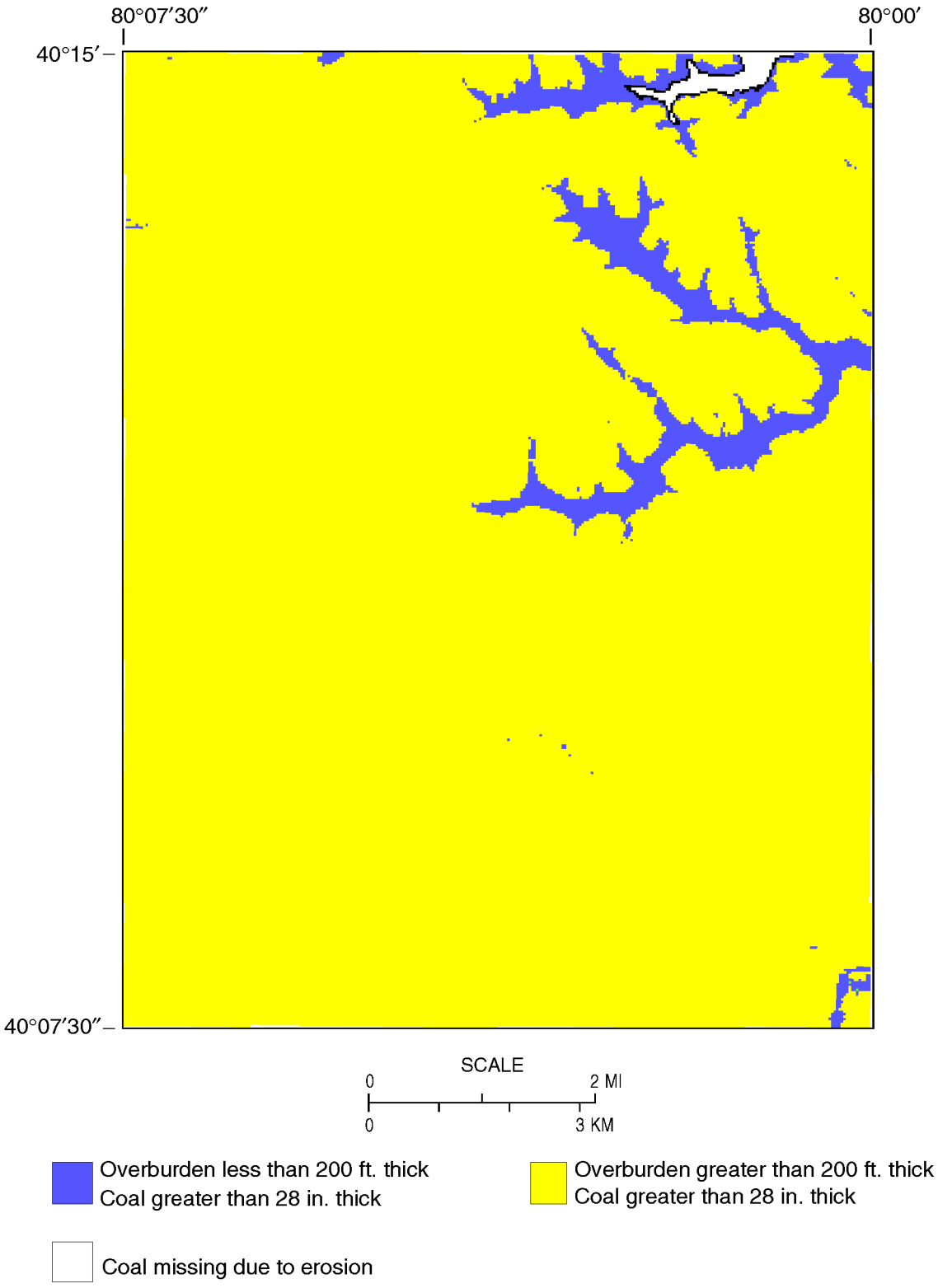

Figure 5. Outcrop extent, amount of overburden, and coal thickness for the Pittsburgh coal bed.

thin partings are taken along with mining because they represent such a small proportion of the total coal taken, and they are easily washed out of the coal at the preparation plant. The roof coal bed is often ignored during mining for it is usually thin (less than 12 inches) and of poor quality. However, there are rare instances when the roof coal can become thick enough to mine (up to 24 inches), and be of decent quality (i.e., not too shaly) to warrant being taken along with mining of the main bench. However, this potential resource has not been included in the Hackett report, because it is a random occurrence and those locations where it is taken have not been well documented by the mining companies. Depth of cover for the Pittsburgh coal bed varies from 0 feet (at outcrop) in the northeastern corner of the quadrangle to over 800 feet in the southwestern part of the quadrangle.

Redstone Coal Bed

The Redstone coal bed, occurring 30-50 feet above the Pittsburgh coal bed, is of limited areal extent in the quadrangle (Figure 6) and probably represents the southwestern edge of a larger, more laterally extensive pod of coal located just to the northeast of the study area. Its thickness ranges from less than 14 inches to more than 33 inches over a very short distance in the northeastern corner of the quadrangle. This coal bed is often miscorrelated with the Pittsburgh Rider coal bed, a relatively insignificant coal occurring about 30 feet above the Pittsburgh coal bed. The Redstone coal may contain several shale partings within it. If the partings are too numerous or too thick in the thinner part of the coal bed, the coal is likely not to be mined. In those thicker portions of the coal bed, the coal is mined and those partings are separated from the coal at the preparation plant. Depth of cover ranges from 0 feet (at outcrop) to about 250 feet southwestward to its southern limit of occurrence.

Waynesburg Coal Bed

The Waynesburg coal bed outcrops in the deeper valleys throughout much of the southern and southwestern part of the quadrangle and gradually rises with the regional dip towards the northeastern corner of the study area, outcropping only on the hilltops there (Figure 7). The Waynesburg coal bed ranges in thickness from 96 inches at some localities to 3 or 4 inches in a few other isolated spots, with thinning attributed to channel sandstone scouring.

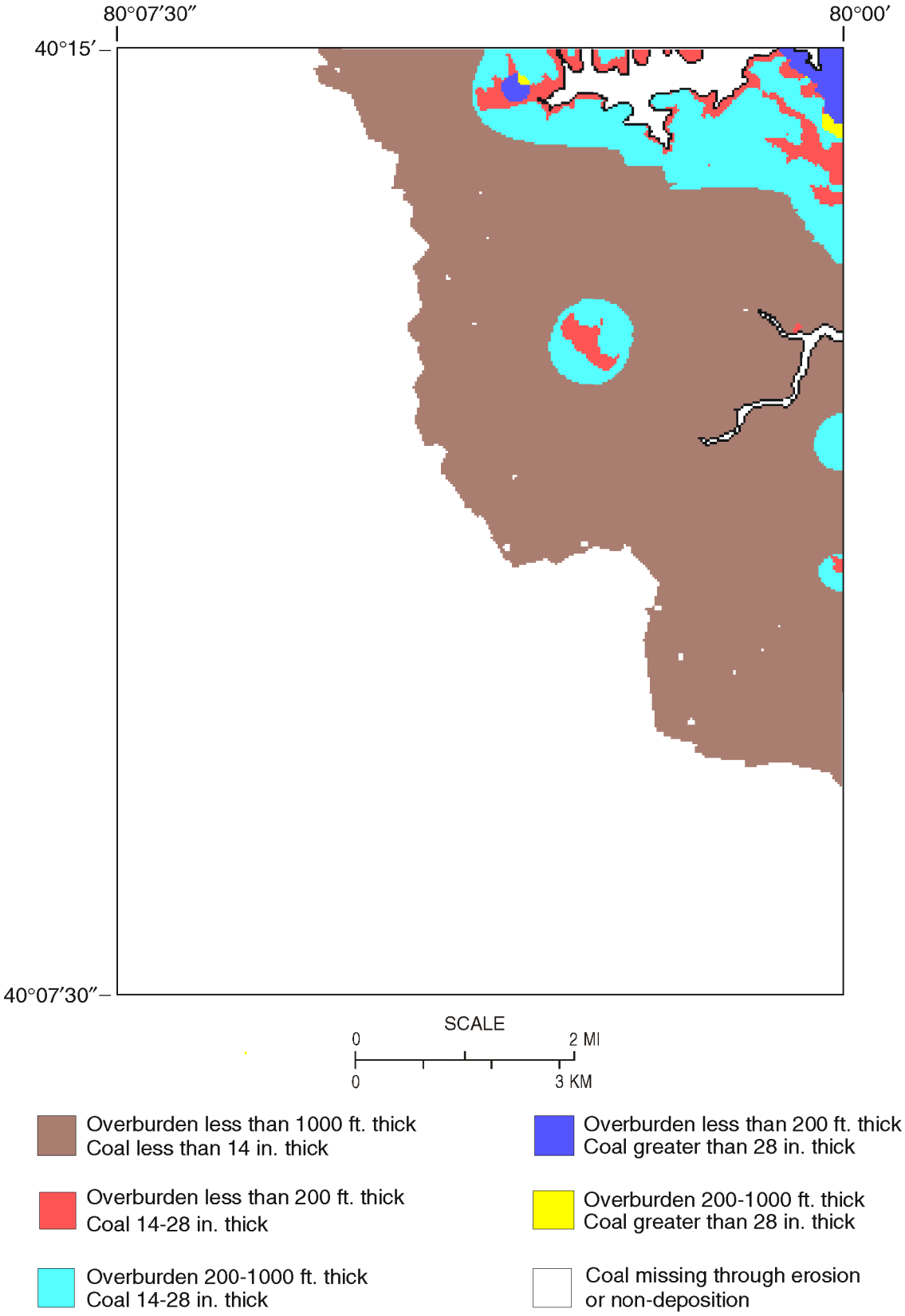

Figure 6. Outcrop extent, amount of overburden, and coal thickness for the Redstone coal bed.

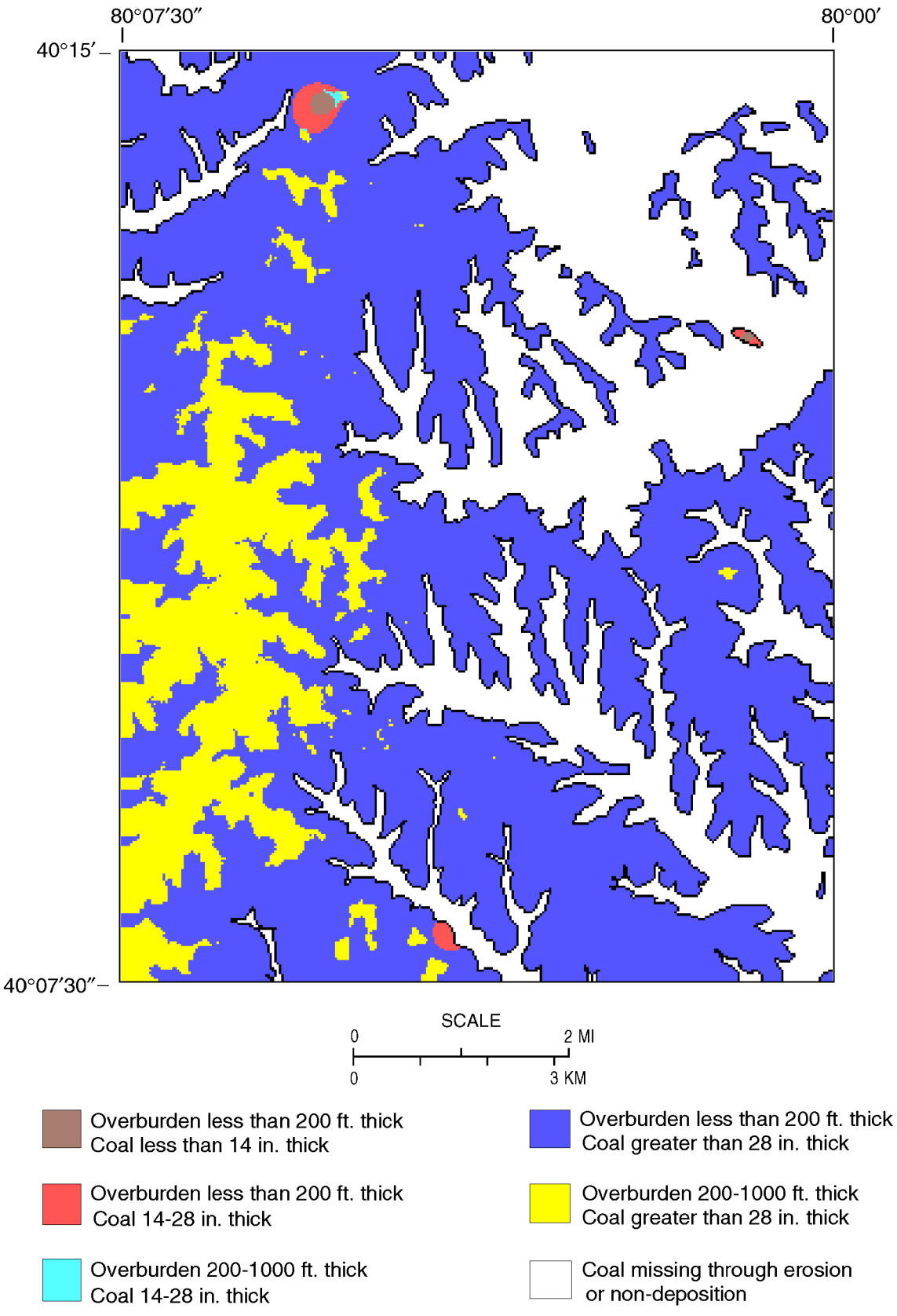

Figure 7. Outcrop extent, amount of overburden, and coal thickness for the Waynesburg coal bed.

Over the majority of the quadrangle it averages about 58 inches thick with two good benches of coal typically separated by a 12-inch-thick claystone parting. Each bench exhibits numerous thin shale, fusain, and pyrite partings that are removed during washing at the preparation plant. The two benches are usually taken separately during strip mining to avoid taking that thick claystone parting that separates them. Depth of cover ranges from 0 feet (at outcrop) to about 460 feet in the southwestern part of the quadrangle.

Waynesburg A Coal Bed

The Waynesburg A coal bed, occurring on average 50 feet above the Waynesburg coal bed, ranges in thickness from 0 inches (i.e., missing in a few isolated places) to as much as 40 inches in the southwestern part of the quadrangle (Figure 8). Its thickness can vary greatly over short lateral distances, perhaps due to sandstone channel scour or to increasing water depth, which restricted peat development in the swamp. It outcrops in the higher elevation areas of the southern and southwestern portion of the quadrangle. The Waynesburg A coal bed rises with the regional dip to the northeast and is missing altogether in the northeastern part of the quadrangle because of removal by post-Alleghanian erosion. This coal bed usually has a number of thin shale partings throughout that are usually taken with the coal during mining. Depth of cover ranges from 0 feet (at outcrop) to about 435 feet in the southwestern part of the quadrangle.

MINING HISTORY

Mining probably has occurred in the study area since the early 1900s, based upon old maps and reports from that era, with more extensive mining occurring after the 1950s. Early Pittsburgh coal-bed mining appears to have started initially as small surface-mining operations, removing coal in those areas where it outcrops along Peters Creek in the northeastern corner of the quadrangle in the vicinity of the village of Hackett (see Figure 5). Later, underground-mining techniques were employed and drift mines were driven from those surface mines to the south and west, as well as from other surface mines along the Monongahela River about 1 mile to the east. Elsewhere in the quadrangle, shafts (e.g., Ginger Hill) were driven to further develop underground mining, and to shorten coal haulage routes out ahead of the southwestward expansion of the underground mines. At some locations in the quadrangle, this meant

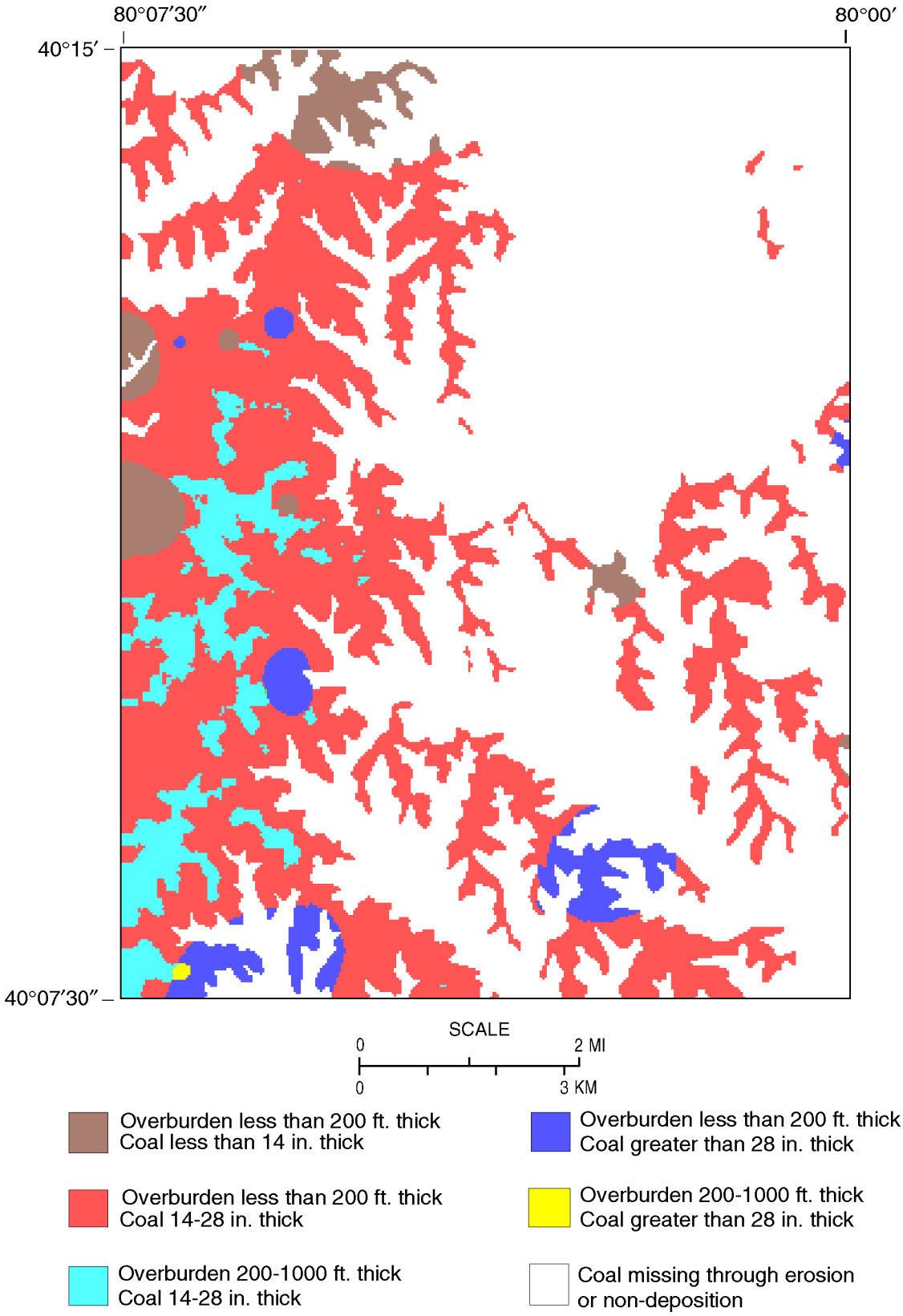

Figure 8. Outcrop extent, amount of overburden, and coal thickness for the Waynesburg A coal bed.

underground mining occurred in close proximity to the surface (i.e., less than 200 feet of cover). Today, such shallow coals might have been candidates for surface mining, instead. Two kinds of mining technology have been used to mine the Pittsburgh. Up until about the early 1980s, it was predominately mined by room-and-pillar mining methods. Since then, it has been principally mined using longwall mining techniques. This coal bed has been extensively mined in the study area (Figure 9).

The three remaining coals, the Redstone, Waynesburg, and Waynesburg A, are exclusively surface mined in this area. The Redstone coal was mined by contour mining methods along its outcrop belt on both sides of Peters Creek in the northern part of the quadrangle near the village of Hackett. At certain places along crop, it appears that this coal may have been surface mined in conjunction with the surface mining of the Pittsburgh coal bed. A visual inspection of a few old surface-mine pits along Peters Creek, just west of the village of Hackett, found orphaned highwalls that were of sufficient vertical height to indicate that indeed both coals were mined at the same time. Elsewhere along Peters Creek, the Redstone coal bed's highly variable thickness made it extremely difficult to follow along crop. Mining efforts were probably limited to those places where it was much thicker (up to 33 inches). Figure 10 depicts where that mining occurred. Although there has not been any recent mining of the Redstone coal bed, a minable portion of the resource still remains. The Waynesburg and overlying Waynesburg A coal beds are currently being surface mined using either contour or hilltop removal methods; the extent of that mining is shown in Figures 11 and 12, respectively. Most surface mines are small box-cuts off coal crop, excavated into the hillsides to the point of reaching either state-regulated highwall heights or an uneconomical overburden to coal ratio. Where the Waynesburg and overlying Waynesburg A coal beds occur in close stratigraphic position (e.g., 40 feet or less) to one another on those hilltops and hillsides in the study area, they are mined concurrently. The Waynesburg coal bed is the more desirable coal of the two for mining due to its greater overall thickness. Commonly in the study area, the Waynesburg coal bed and also possibly the Waynesburg A coal bed are surface mined to provide a product that can then be blended with local supplies of the lower ash and lower sulfur Pittsburgh coal.

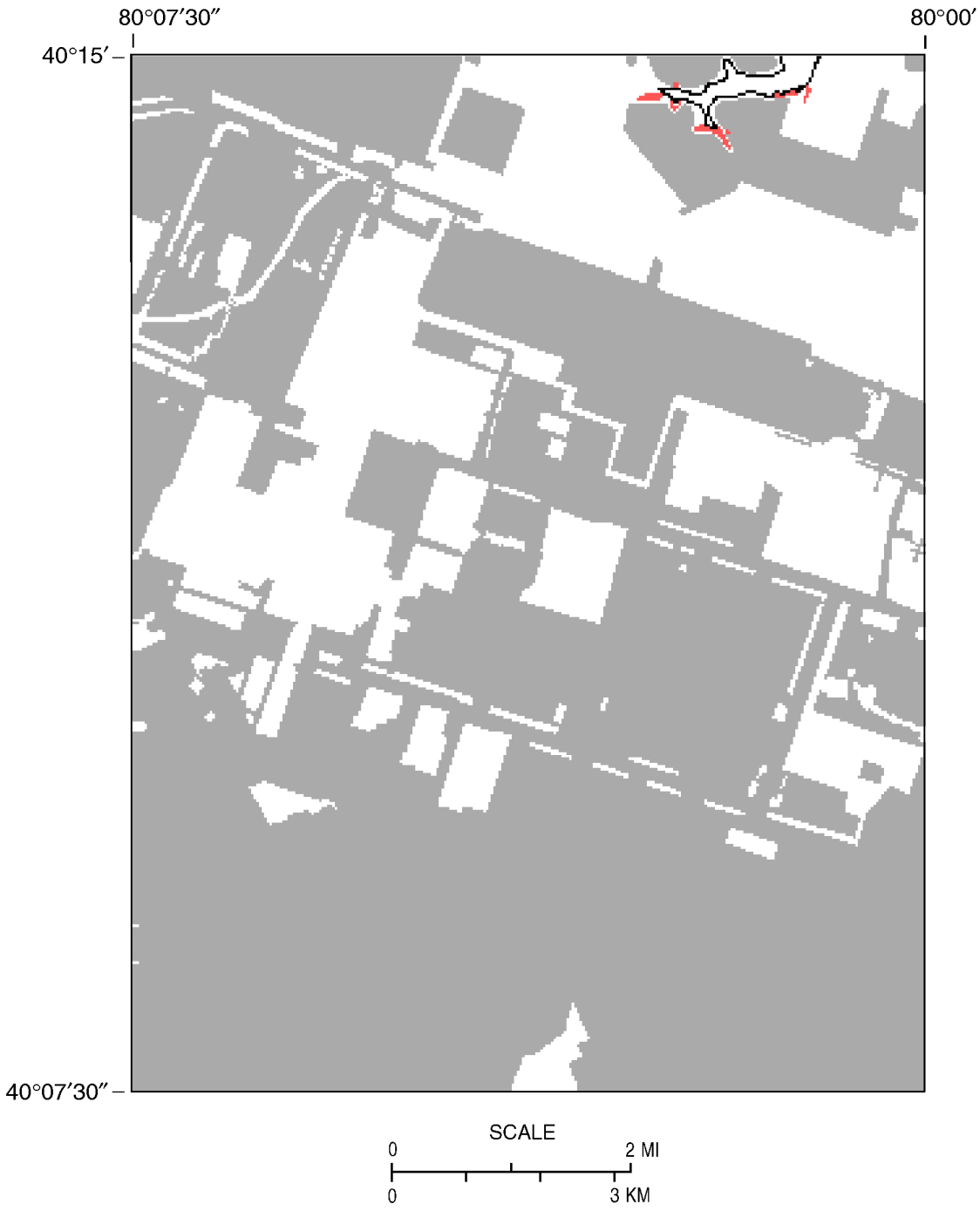

Figure 9. Pittsburgh coal outcrop (black) with surface-mined-out (red) and underground-mined-out (gray) areas.

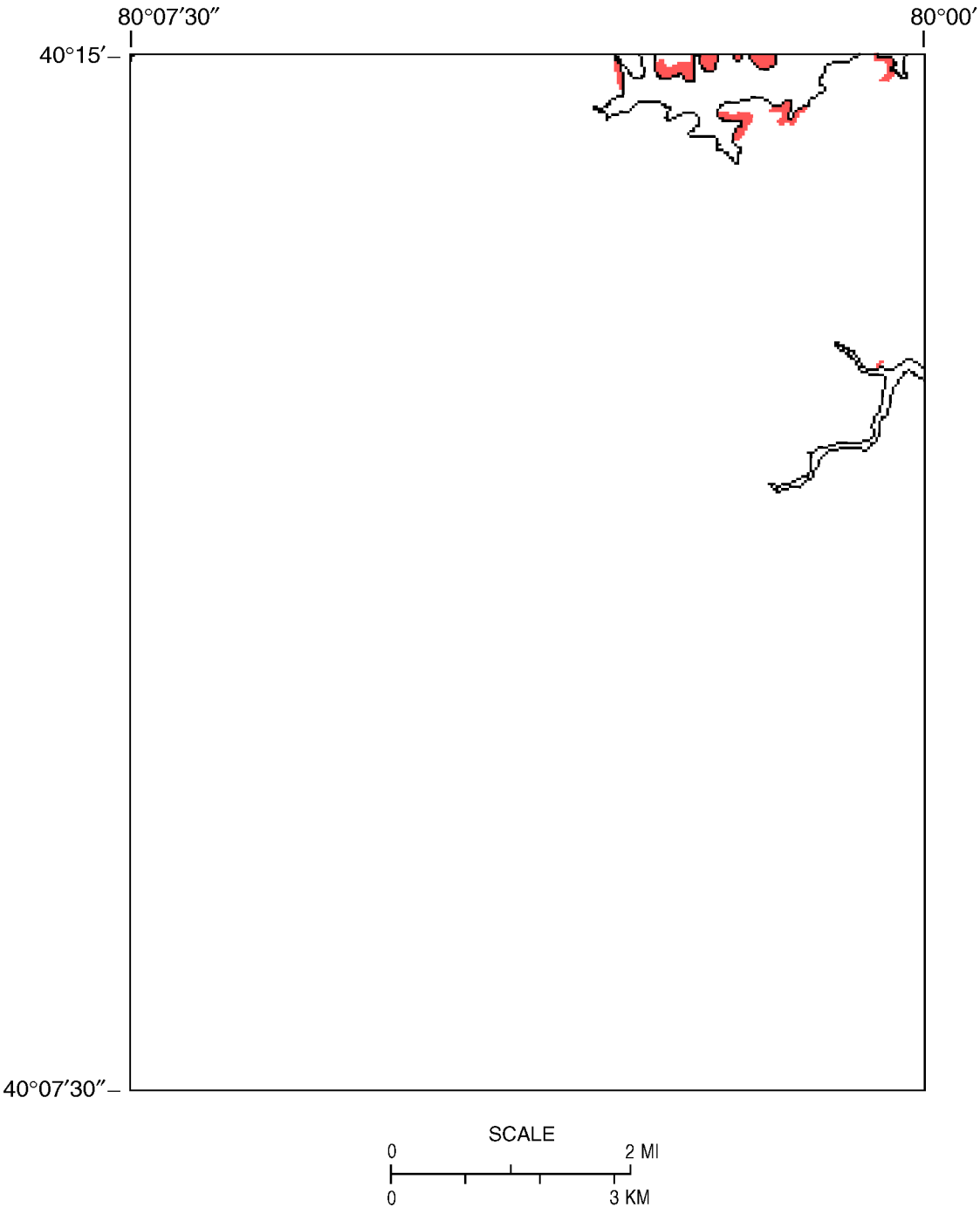

Figure 10. Redstone coal outcrop (black) with surface-mined-out areas (red).

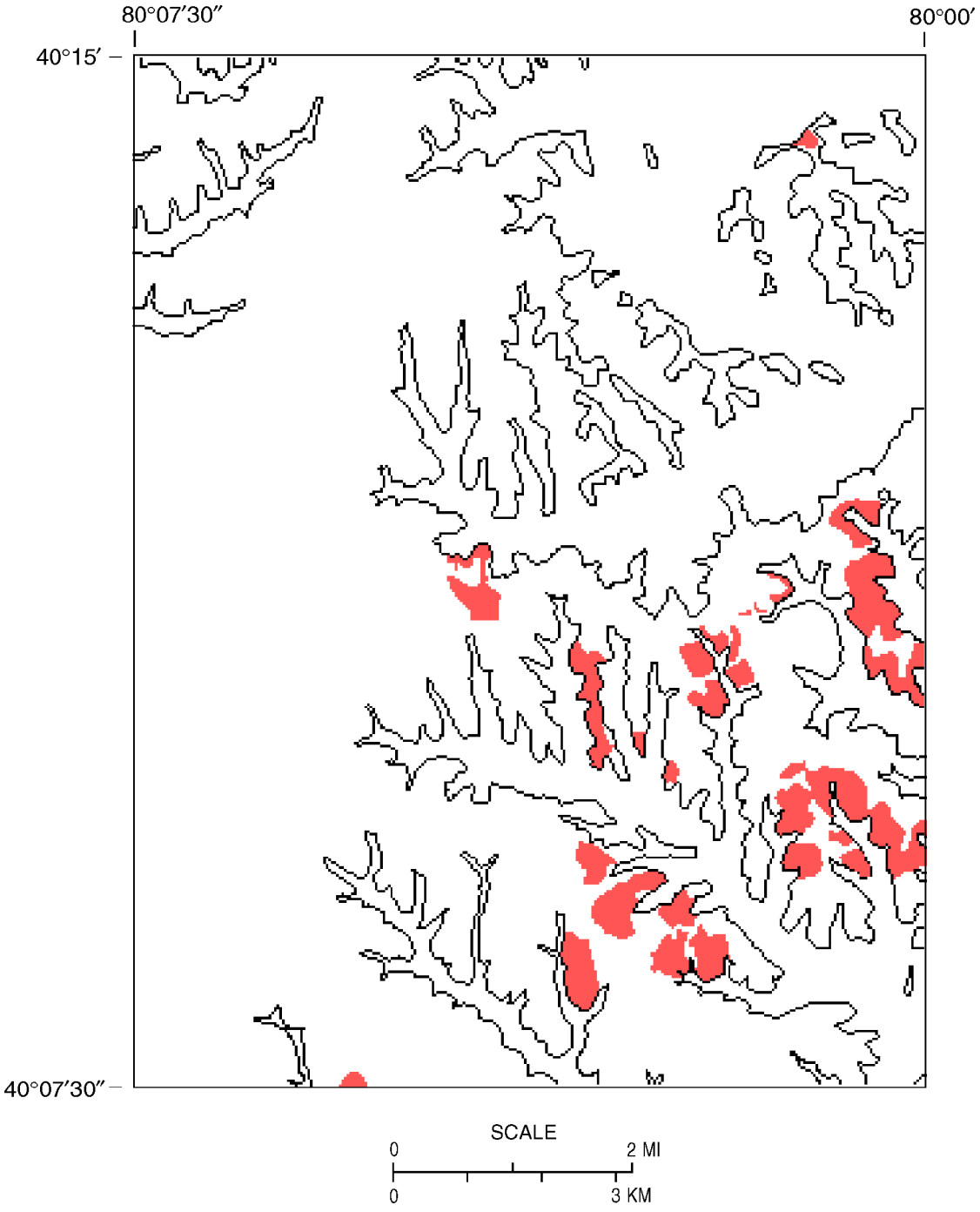

Figure 11. Waynesburg coal outcrop (black) with surface-mined-out areas (red).

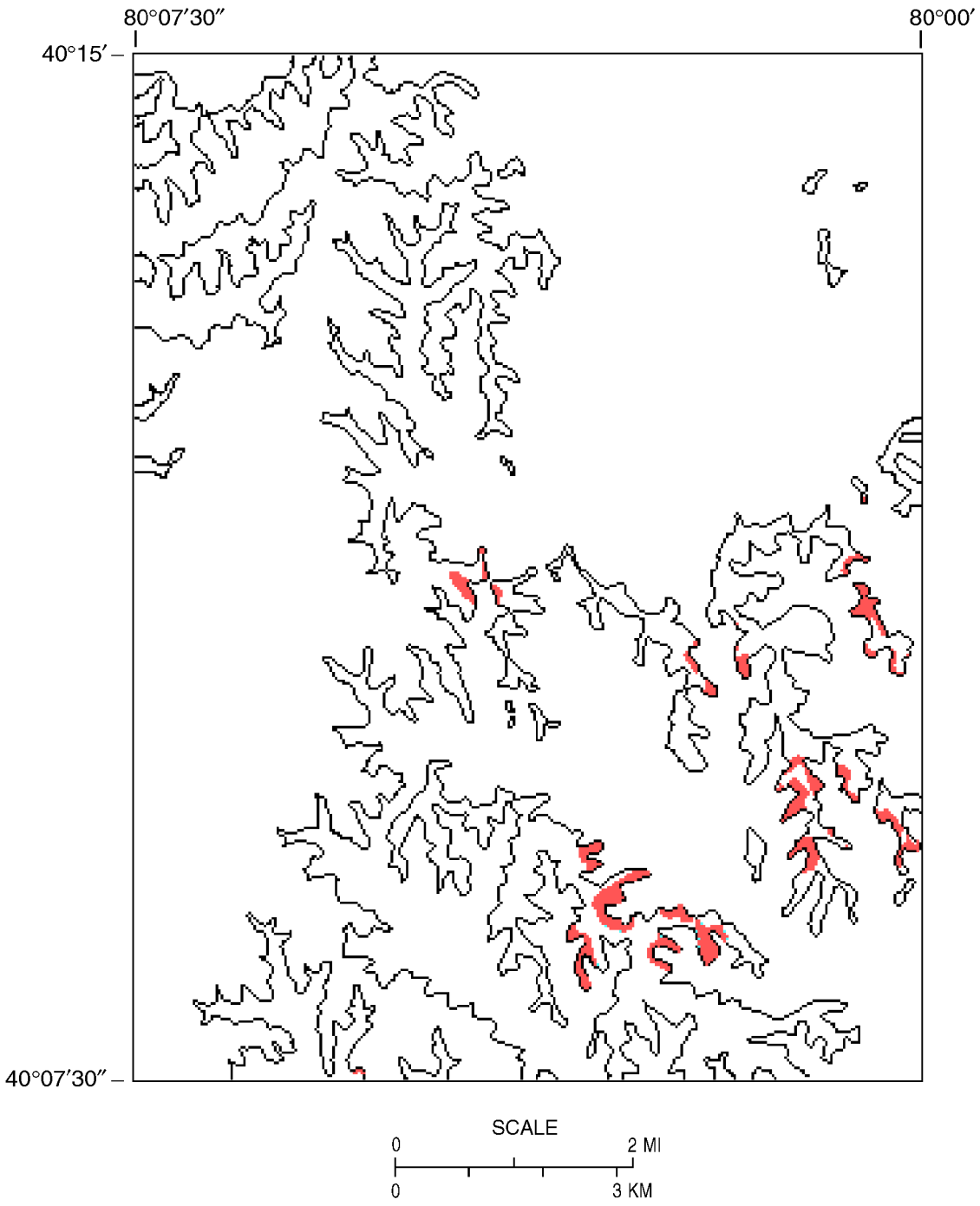

Figure 12. Waynesburg A coal outcrop (black) with surface-mined-out areas (red).

DATA COMPILATION

Data were nonexistent for coals stratigraphically lower than the Pittsburgh coal bed. These beds, namely the Upper and Lower Freeport, Upper, Middle, and Lower Kittanning, Brookville-Clarion complex, and Mercer coals (see Figure 4), may or may not be greater in thickness than the 14 inch minimum required to compute original resources. Previously described selection criteria also eliminated from study the Pittsburgh Rider, Sewickley, Uniontown, and Washington coals. This left four coal beds as acceptable for study for which data were sufficient to perform the coal availability analysis.

Mining information and coal crop lines were compiled from work maps created by Skema (1987). These work maps were further updated by collecting recent mining information for the Hackett quadrangle from mining permits stored at the Pennsylvania Department of Environmental Protection district mining offices in McMurray and Greensburg, Pa., and through the use of recent aerial photography (for strip mining) and some field reconnaissance. Land-use practices and technological restrictions to mining were determined from state and local regulations, and by conversation with company personnel at mine sites.

COAL RESOURCES OF THE HACKETT QUADRANGLE

Resources are calculated in short tons for the purpose of this study, using a basic conversion factor of one acre per foot of coal equals 1,800 short tons of coal. By convention short ton is the standard means to denote a 2,000 pound ton in tonnage estimates. Other terminology to describe tons (e.g., long ton, metric ton) is not usually used in resource studies, because values associated with other terminology are usually greater than 2,000 pounds (e.g., 2,200 pounds for long ton).

The relative volumes of the original coal resources for the four coal seams studied in the Hackett quadrangle, as determined by using the USGS-modified GRASS resources program, are depicted in Figure 13. The grand total coal tonnage for the four beds studied in the quadrangle is estimated to be 607 million short tons (Figure 14); 272 million short tons, or 45 percent of the original amount, has since been mined out or lost in mining, leaving remaining resources of approximately 335 million short tons, or 55 percent of the original (see Figure 14). About 291 million short tons, or 87 percent of that coal remaining, is greater than 28 inches thick.

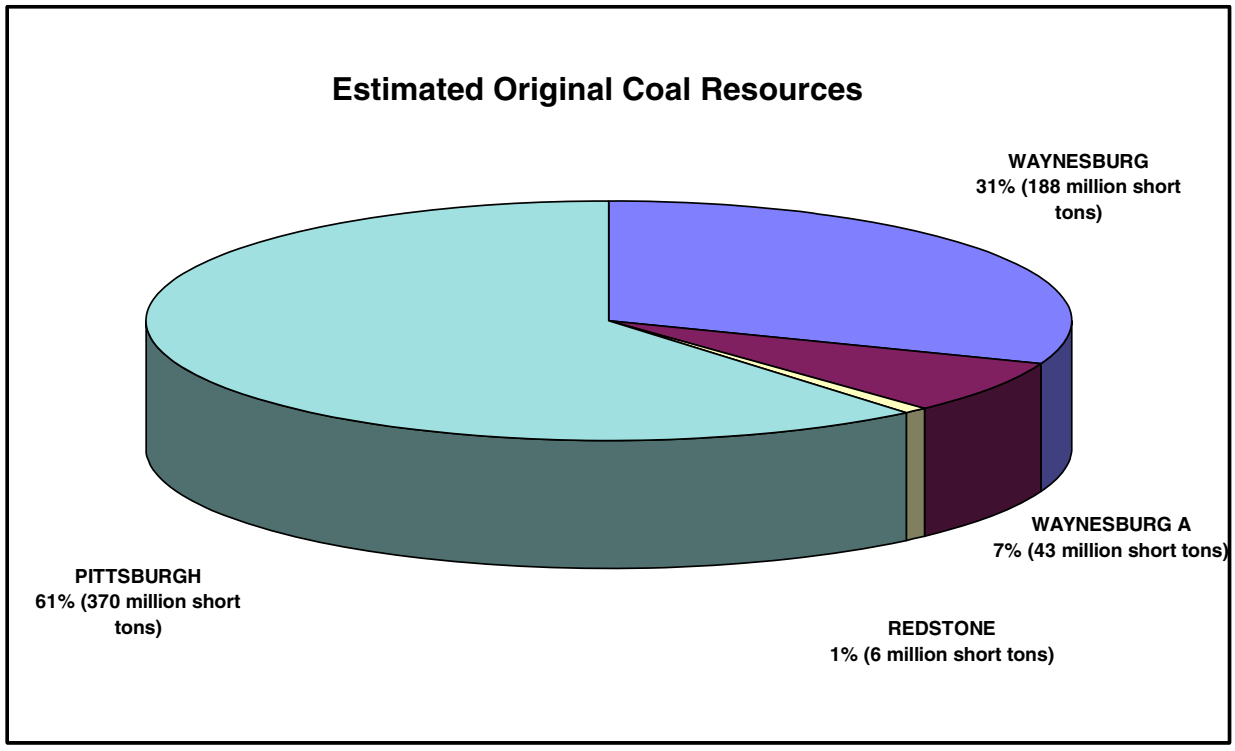

Figure 13. Summary of original coal resources in the Hackett quadrangle.

Additional resources probably exist in the Upper Freeport, Lower Freeport, Upper Kittanning, Middle Kittanning, Lower Kittanning, Clarion, Brookville, and Mercer coal beds, but their lateral extent and thickness are unknown in this area, making a resource estimate for these seams impossible.

Thirteen land-use and three technological restrictions to mining were identified for the Hackett quadrangle (see Appendix D). Figure 15 is a composite map illustrating the distribution of the 13 land-use restrictions in the quadrangle. Table 1 lists the gross amount of coal restricted to mining by coal bed for both land-use and technological restriction types. Land-use and technological restrictions, which impact upon both the surface and subsurface mining of coal, account for an additional resource likely lost to mining of about 83 million short tons (14 percent of total), thus leaving nearly 252 million short tons, or 75 percent, of the remaining amount available for future mining (see Figure 14). Approximately 42 percent of the original coal resource is available. Of this available coal, approximately 228 million short tons, or 90 percent of this amount, is greater than 28 inches thick. Original, mined-out, remaining, restricted, and

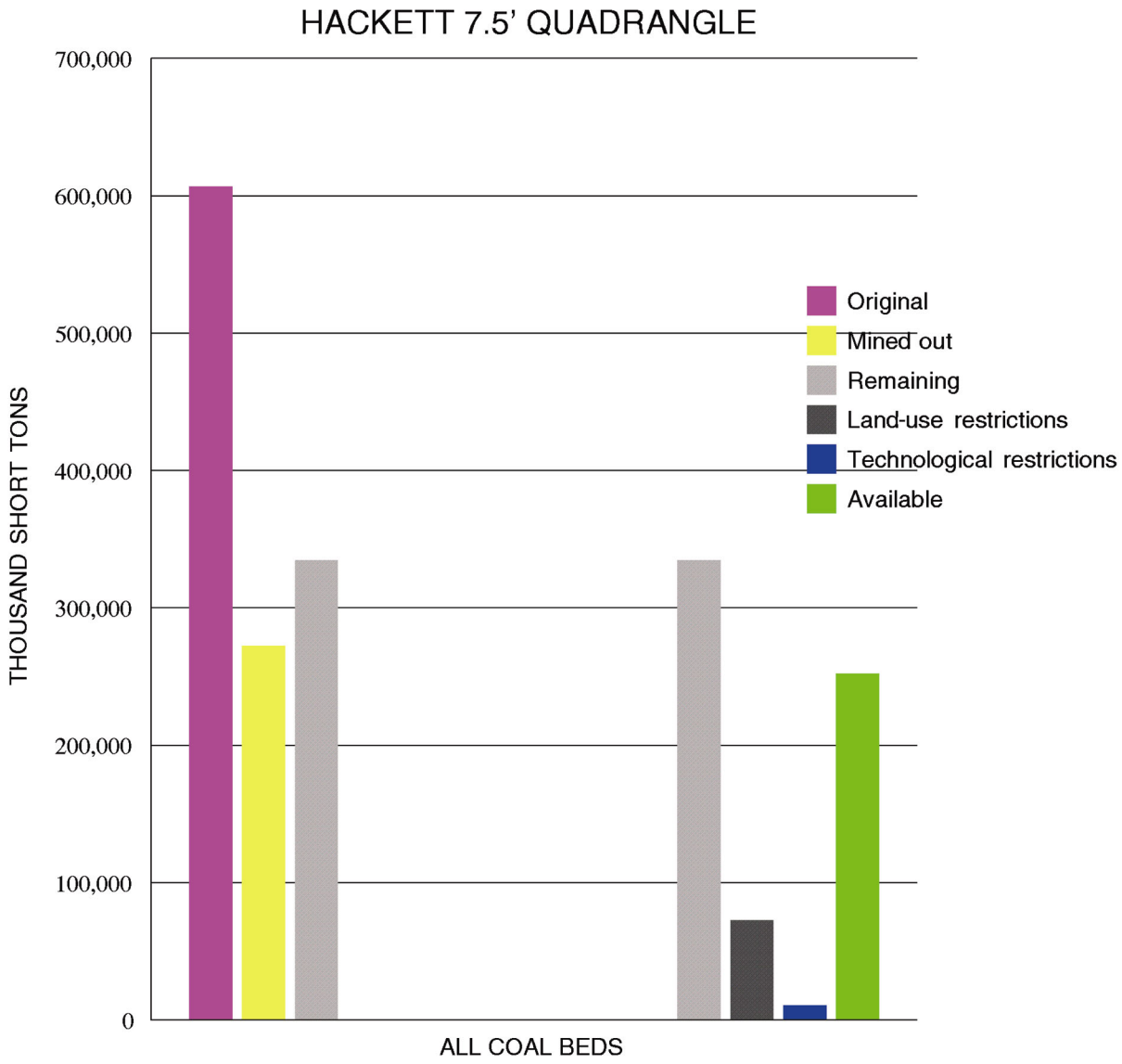

Figure 14. Cumulative tonnages for all coal beds in the Hackett quadrangle.

available tonnage totals for the individual coal beds have been summarized below, and in Appendix A, where they have been rendered into pie charts. Complete resource tabulations for each bed are given in Appendix B.

PITTSBURGH COAL BED SUMMARY

It is estimated that approximately 370 million short tons of Pittsburgh coal was present in the Hackett quadrangle, which represents 61 percent of all the coal initially present in the

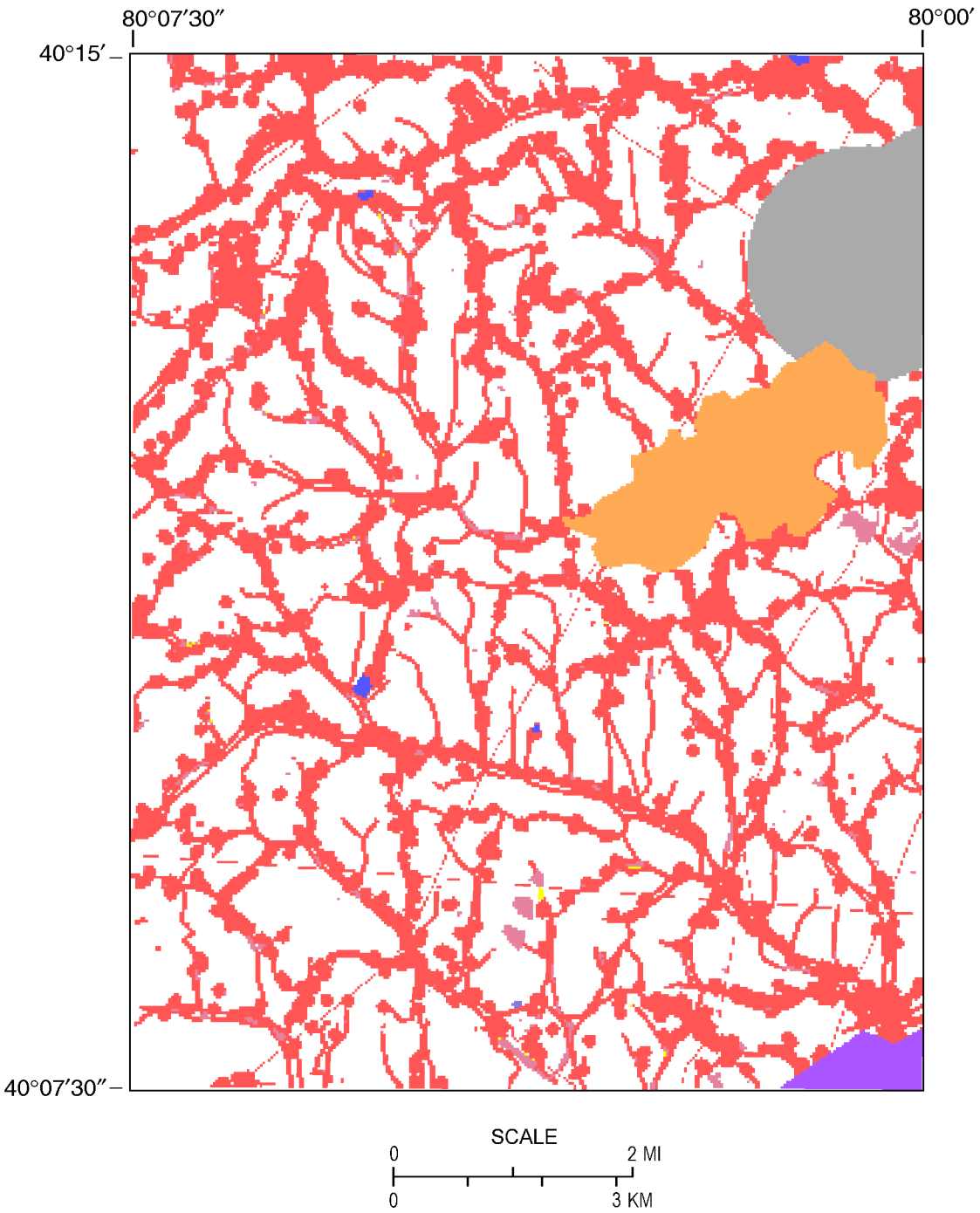

Figure 15. Spatial arrangement of land-use restrictions for the Hackett quadrangle. Some of the restrictions present are roads, streams, and houses, shown as red lines and small red clusters; town and cemeteries, shown as purple and small blue areas, respectively; and a township park and PNDI site, shown as the large orange and gray areas, respectively.

Table 1. Estimated Coal Resources Unavailable Due to Land-Use and Technological Restrictions in the Hackett Quadrangle (in short tons)[1]

	SURFACE (0 TO 200')													
Coal Bed	Cemeteries	Houses	Lakes	Railroads	Towns	PNDI Sites	Parks	O&G Wells	Streams	Wetlands	Pipelines	Powerlines	Roads	Total
WAYNESBURG A	50,380	8,667,767	26,918	6,534	93,934	111,431	53,758	116,338	1,238,211	178,310	135,745	63,770	3,875,073	**14,618,169**
WAYNESBURG	118,871	34,256,876	168,868	93,342	990,352	2,338,363	943,726	387,837	8,806,410	1,263,213	689,874	244,703	14,883,765	**65,186,200**
REDSTONE	0	1,015,466	0	16,176	0	372,279	0	0	299,567	13,838	5,727	16,500	378,746	**2,118,299**
PITTSBURGH	0	5,906,733	0	81,743	0	1,567,407	3,644,652	28,726	3,563,177	160,753	25,279	74,256	3,426,000	**18,478,726**
TOTAL	**169,251**	**49,846,842**	**195,786**	**197,795**	**1,084,286**	**4,389,480**	**4,642,136**	**532,901**	**13,907,365**	**1,616,114**	**856,625**	**399,229**	**22,563,584**	**100,401,394**

	DEEP (>200')				
Coal Bed	Coal Too Thin	O&G Wells	Mine Barriers	Total	Grand Total
WAYNESBURG A	4,610,810	15,215	0	**4,626,025**	**19,244,194**
WAYNESBURG	27,765	125,872	0	**153,637**	**65,339,837**
REDSTONE	3,364,463	0	0	**3,364,463**	**5,482,762**
PITTSBURGH	0	320,687	1,862,877	**2,183,564**	**20,662,290**
TOTAL	**8,003,038**	**461,774**	**1,862,877**	**10,327,689**	**110,729,083**

[1]Table composited from GRASS "tables" directory, v_*.tab files. Summation of these individual restrictions is greater than total shown on appendices tables.

quadrangle and minable by past and current technologies of coal extraction (see Figure 13). Of this amount, nearly 259 million short tons was removed by both surface- and underground-mining methods, leaving about 111 million short tons remaining. Most of the mining has been in the southern half of the quadrangle; several large blocks remain in the northern half (Figure 16).

Ten of a possible 13 land-use and two of the three technological restrictions identified in the quadrangle impact future surface and deep mining of the Pittsburgh coal bed and remove approximately an additional 12 million short tons from potential mining. The impact of these restrictions on the resource is portrayed by the graphs in Figures 17 and 18 and is tabulated as gross tonnages in Table 1.

This leaves nearly 99 million short tons of Pittsburgh coal available for future mining, mostly in the northern half of the quadrangle (Figure 19), representing less than 27 percent of the original tonnage for this bed (Appendix A). All of the available coal is greater than 28 inches thick in the quadrangle, which is ideal to deep mine, especially when using longwall methods of extraction. A small amount of the available resource, a little more than 2 million short tons, is left as strippable coal (i.e., less than 200 feet of overburden and no restrictions). There are other factors that should be considered when evaluating the available resource. Over half of the original, remaining, and available resources are classified as “measured” or “indicated,” suggesting that the data is fairly closely spaced with interpolation of coal thickness values only needed when distances between known points became up to 0.75 mile apart (see Appendix D, page 91, for a further explanation of these terms). Another factor that would lessen the amount of Pittsburgh coal available for mining is the sterilization of part of the reserve due to a mine fire a number of years ago. This mine fire closed a large underground mine located in the northern part of the quadrangle to further exploitation; it was still closed and in the hands of the original owner at the time these data were collected in 1994. If this mine can not be reopened, then a large block of Pittsburgh coal is lost in mining, and the available tonnage shown on the summary tables in Appendix B for the Pittsburgh would need to be decreased accordingly. At the current time, it is unknown whether Commonwealth regulators will allow further coal extraction from this mine. In the meantime, other mining companies have expressed their interest to the Commonwealth in opening the mine again. Therefore in light of the above, consider the 99 million short tons of available coal to be an optimistic value.

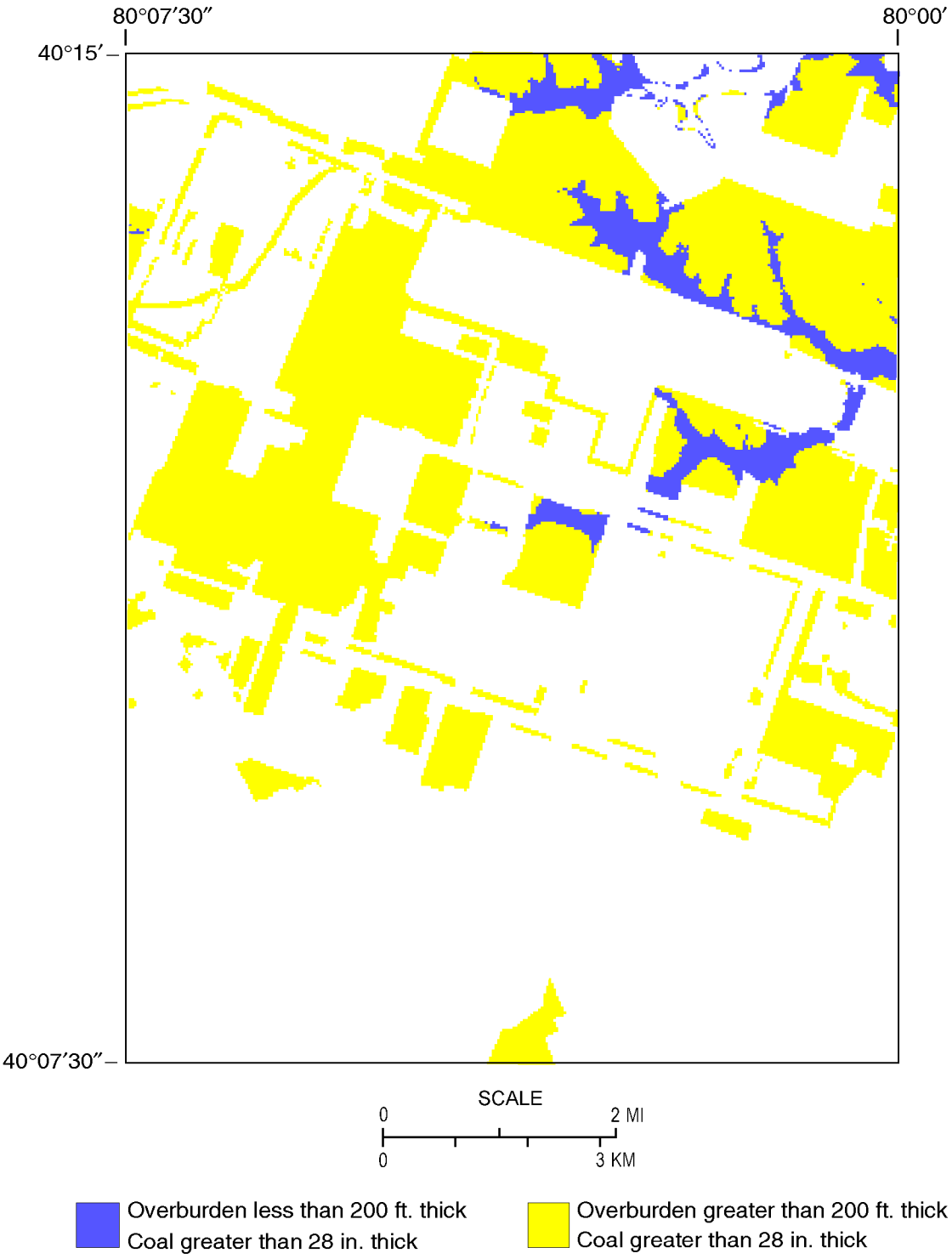

Figure 16. Remaining Pittsburgh coal by coal-bed and overburden thickness categories.

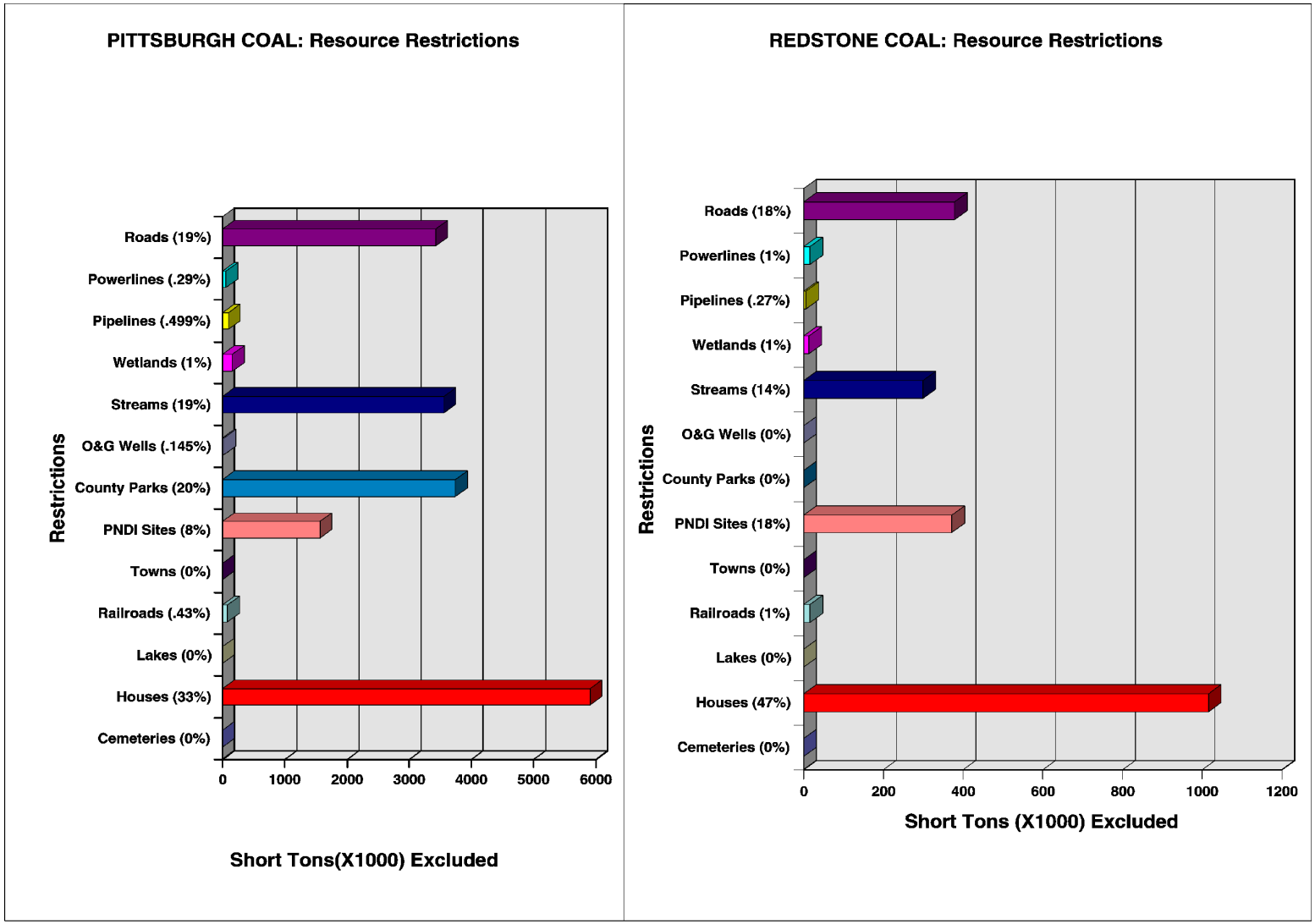

Figure 17. Impact of individual land-use restrictions on the Pittsburgh and Redstone coal beds.

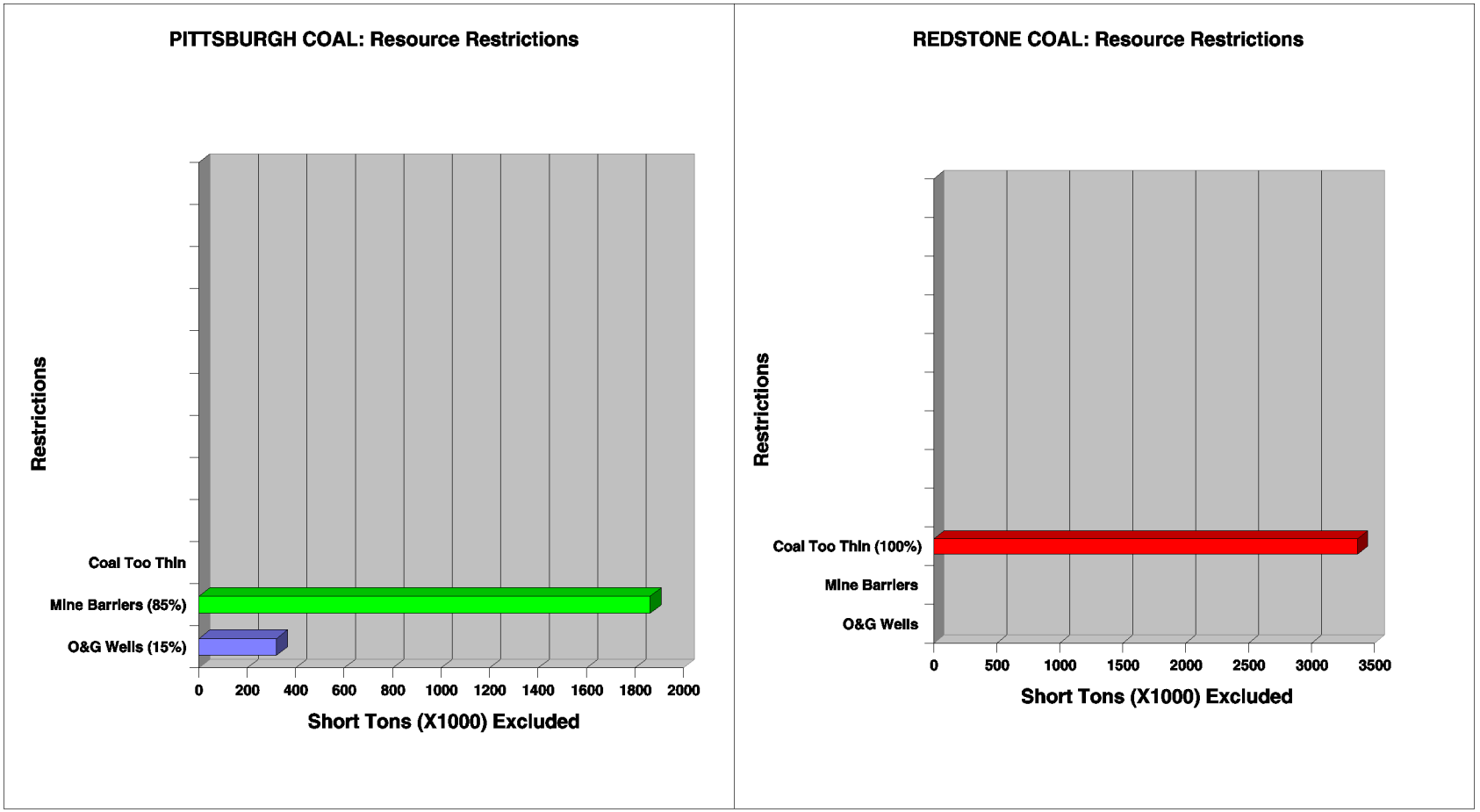

Figure 18. Impact of individual technological restrictions on the Pittsburgh and Redstone coal beds.

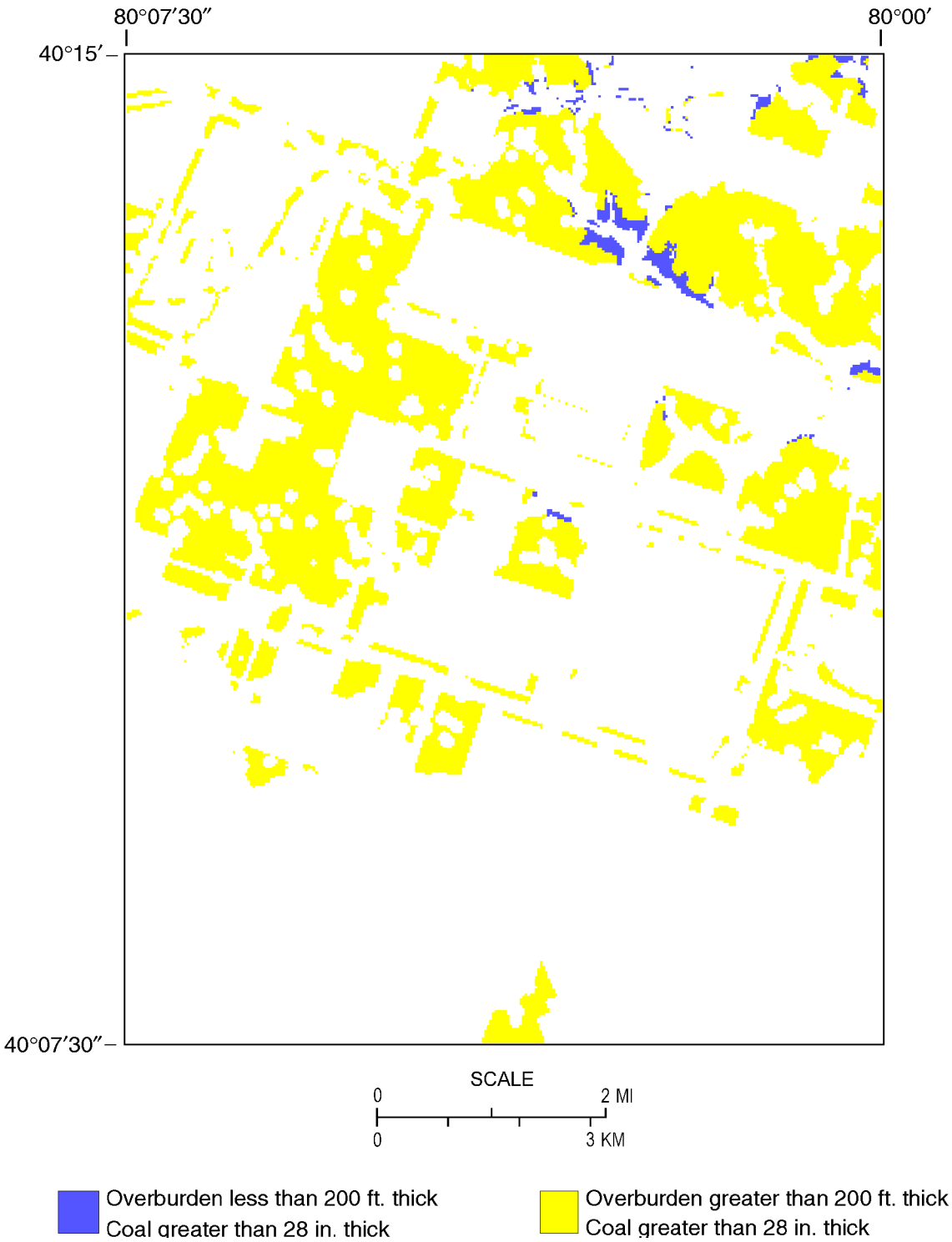

Figure 19. Available Pittsburgh coal by coal-bed and overburden thickness categories.

REDSTONE COAL BED SUMMARY

The Redstone coal bed held nearly 6 million short tons or 1 percent of the total original resources for the quadrangle (see Figure 13) prior to mining. Approximately 343,000 short tons has been mined out by surface-mining methods, leaving over 5 million short tons of coal remaining. It appears that this coal has never been extensively deep mined in the immediate study area. Figure 20 depicts the limit of the remaining Redstone coal-bed resources in the quadrangle.

Land-use and technological restrictions encountered remove roughly 4 million short tons of coal from consideration, leaving just under 1 million short tons or about 13 percent of the original coal resource available for mining (Appendix A). Because this coal bed is of limited areal extent, only eight of the 13 identified land-use restrictions and one of the three technological restrictions in the quadrangle actually intersect the coal bed. Figures 17 and 18 show how the individual land-use and technological restrictions affect the resource; the gross tonnages are shown in Table 1 (the five restrictions not encountered are represented as a zero value on the table). Figure 21 indicates which portion of the Redstone coal bed resource is still available after consideration of the impact of the restrictions on the resource.

The majority of this available resource (63.9 percent) is less than 28 inches thick within the Hackett quadrangle. Of the portion that is greater than 28 inches thick, only 10 percent is under more than 200 feet of cover. When those two factors are considered and then combined with the limited areal extent of the coal bed, it becomes unlikely that the Redstone coal would be deep mined using current mining practices. However, it could remain as a surface-mined resource. The area of thickest available coal occurs in the extreme northeast corner of the quadrangle and at its westernmost outcrop (see Figure 21). Most of the original, remaining, and available resources have been classified as “indicated “and “inferred” as shown in the summary tables in Appendix B. This result indicates that the data points were not as closely spaced as those of the Pittsburgh coal-bed dataset and that coal-bed tonnage calculations relied more on interpolation of coal-bed thickness in those areas where the distance between the known thickness values increased up to 3 miles apart. Therefore, the amount of available Redstone coal may be more or less than shown. Further exploratory drilling would be necessary to more accurately define this resource.

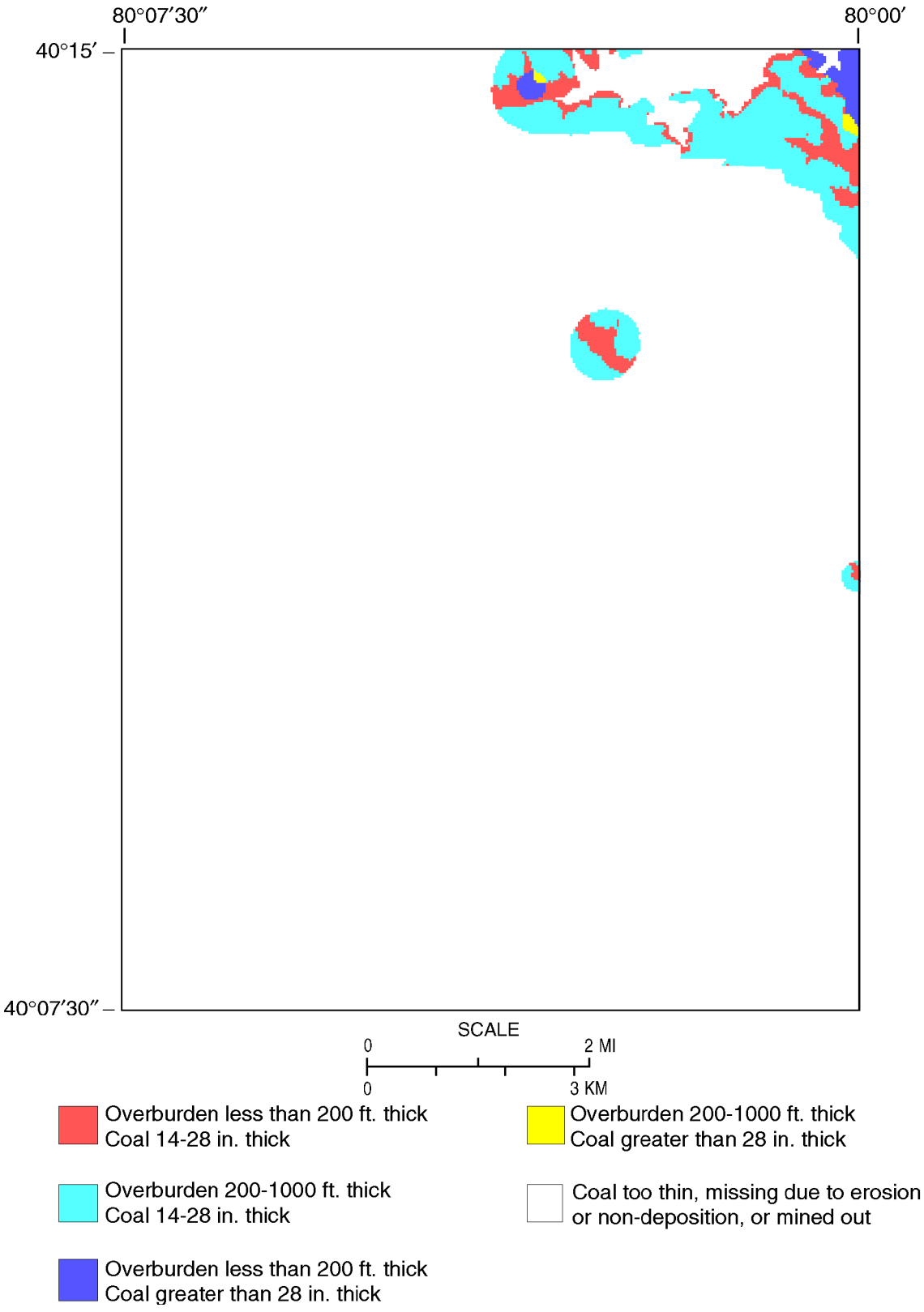

Figure 20. Remaining Redstone coal by coal-bed and overburden thickness categories.

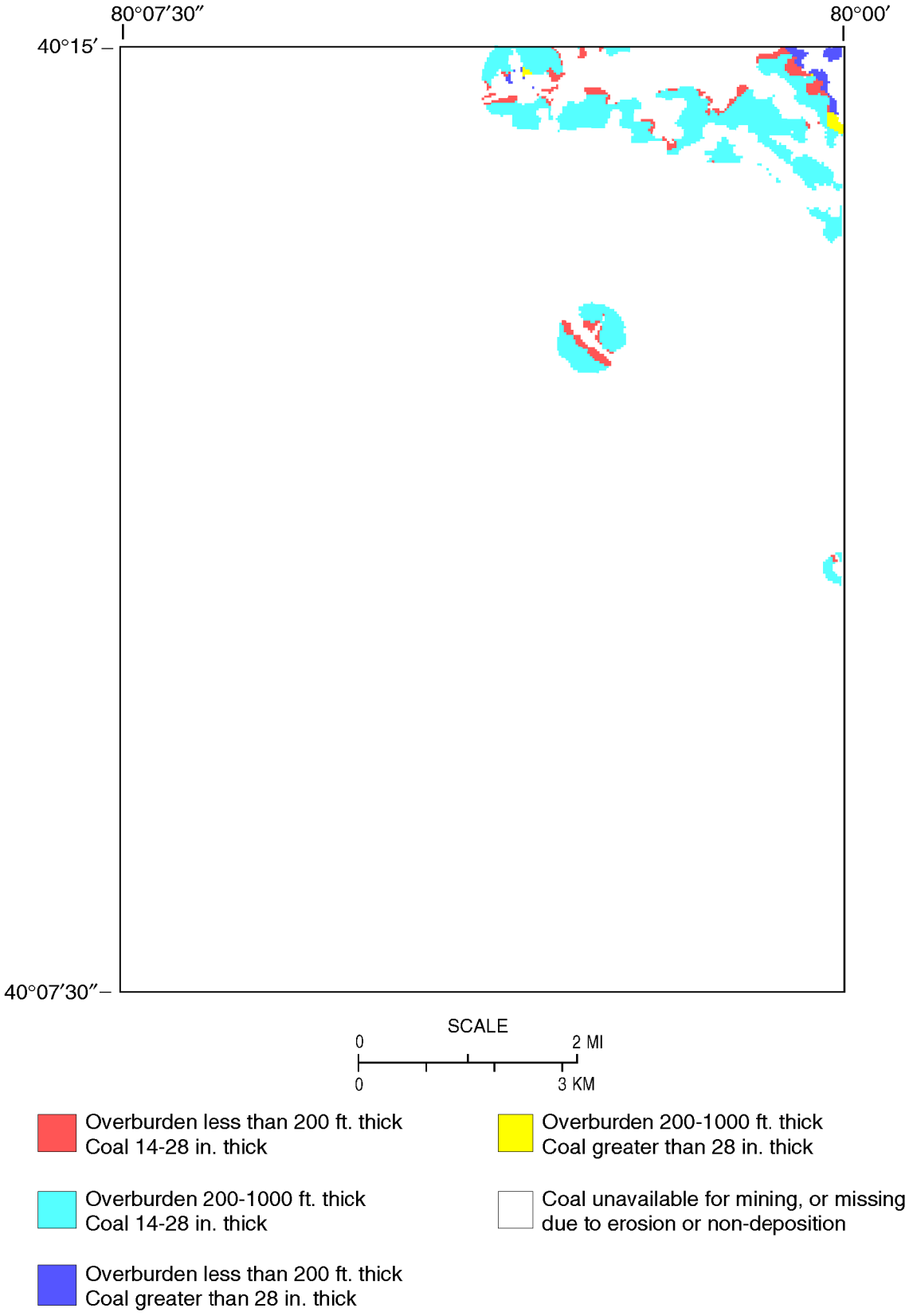

Figure 21. Available Redstone coal by coal-bed and overburden thickness categories.

WAYNESBURG COAL BED SUMMARY

In the Hackett quadrangle, the Waynesburg coal bed accounted for approximately 188 million short tons of coal or 31 percent of the original resources (see Figure 13). About 12 million short tons of coal has been mined out by surface-mining methods, leaving 176 million short tons remaining for development. Figure 22 shows the extent of that remaining resource. The Waynesburg coal bed has always been surface mined in this area; no evidence could be found to indicate that it was ever deep mined.

All 13 land-use and two of the three technological restrictions impact the Waynesburg coal bed. Their gross tonnages are given in Table 1. Figures 23 and 24 provide a graphical companion to this table, by pictorially illustrating the amount of coal excluded due to the individual land-use and technological restrictions. These land-use and technological restrictions remove about another 50 million short tons of coal from potential mining, leaving about 126 million short tons or 67 percent of the original coal resource available for surface or underground mining (Appendix A). Figure 25 indicates where that available resource occurs in the study quadrangle.

Nearly all of the available coal (99 percent) is greater than 28 inches thick and is covered with less than 200 feet of overburden. Consequently, current methods of coal extraction by surface mining are likely to continue in the future. Future deep-mine potential is considered to be low, due mainly to the limited area of coal with sufficient overburden thickness. The resultant small block size that would likely be required in order to successfully mine under those conditions would probably preclude the Waynesburg coal bed as an attractive target economically. Perhaps factors such as high sulfur content and existence of a thick parting in the coal bed will also be a hindrance to future underground mining of this seam. The greatest proportion of the resource falls into the “indicated” category, but the majority of the available resource falls in the “indicated” and “inferred” range, which indicates that some data points were more widely spaced (0.75 to 3 miles from nearest known value) than the optimum (less than 0.25 mile from a known value) in the Waynesburg dataset, and that an increased amount of interpolation was therefore needed to derive values for coal thickness, hence tonnages, for the entire quadrangle.

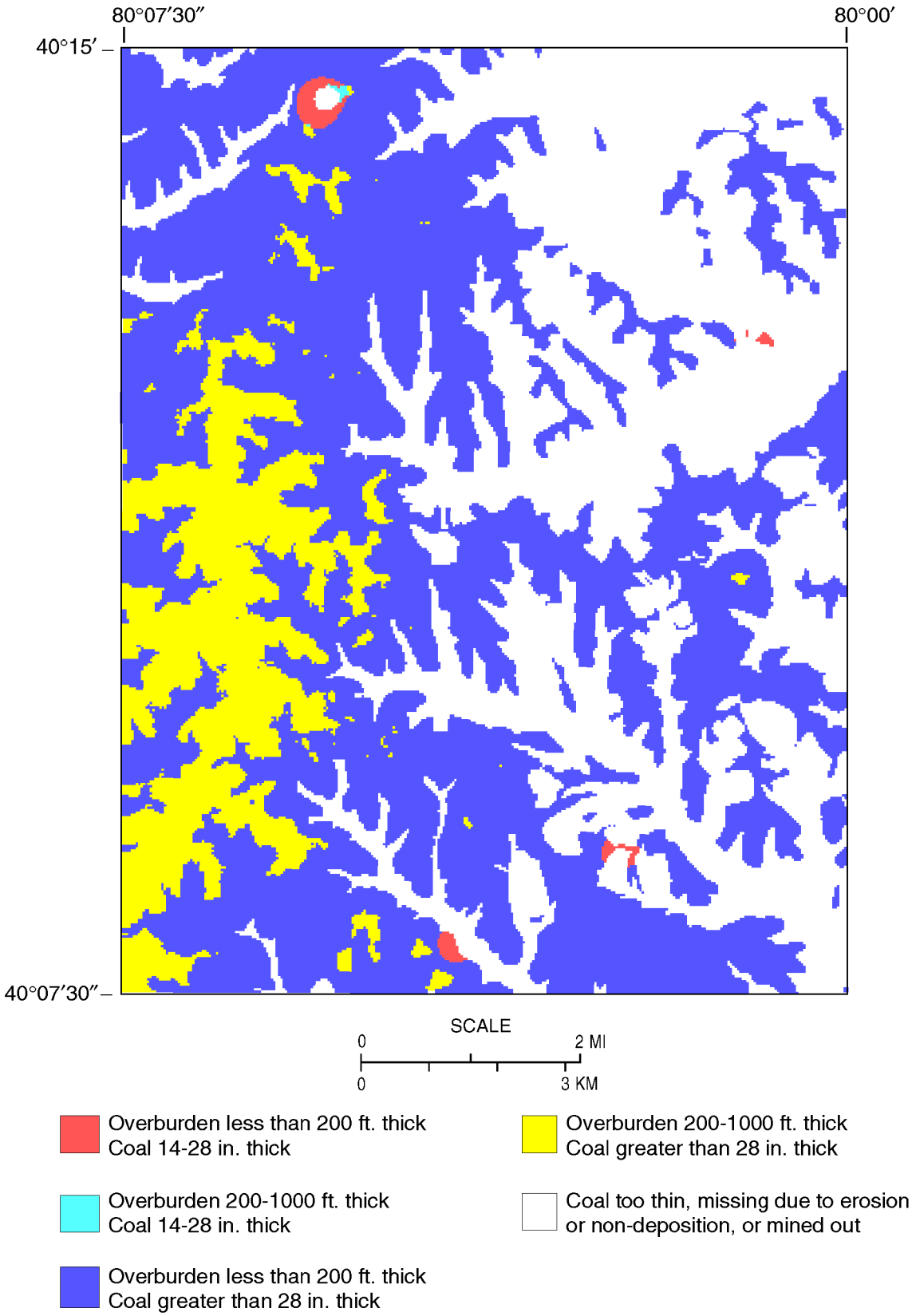

Figure 22. Remaining Waynesburg coal by coal-bed and overburden thickness categories.

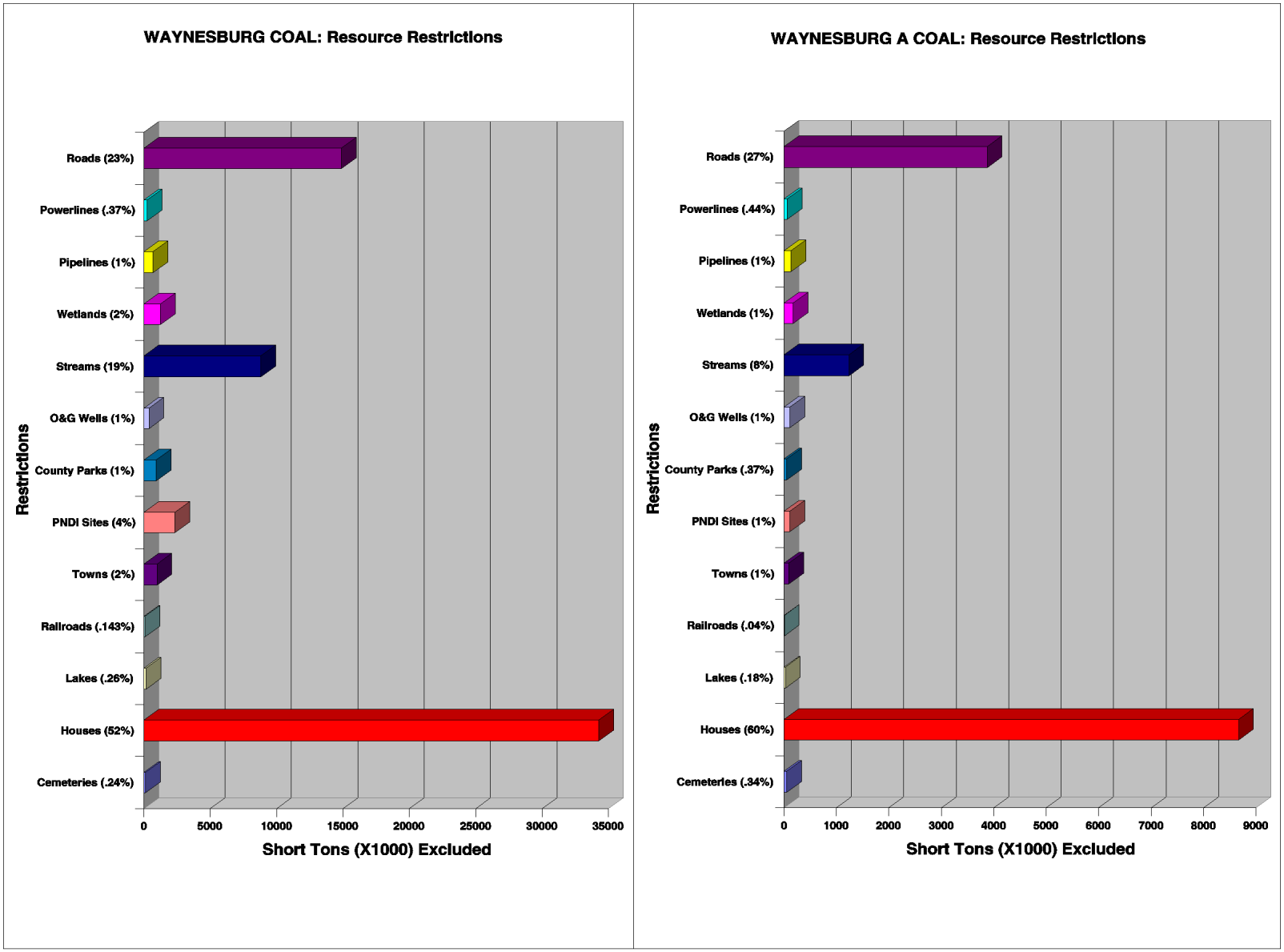

Figure 23. Impact of individual land-use restrictions on the Waynesburg and Waynesburg A coal beds.

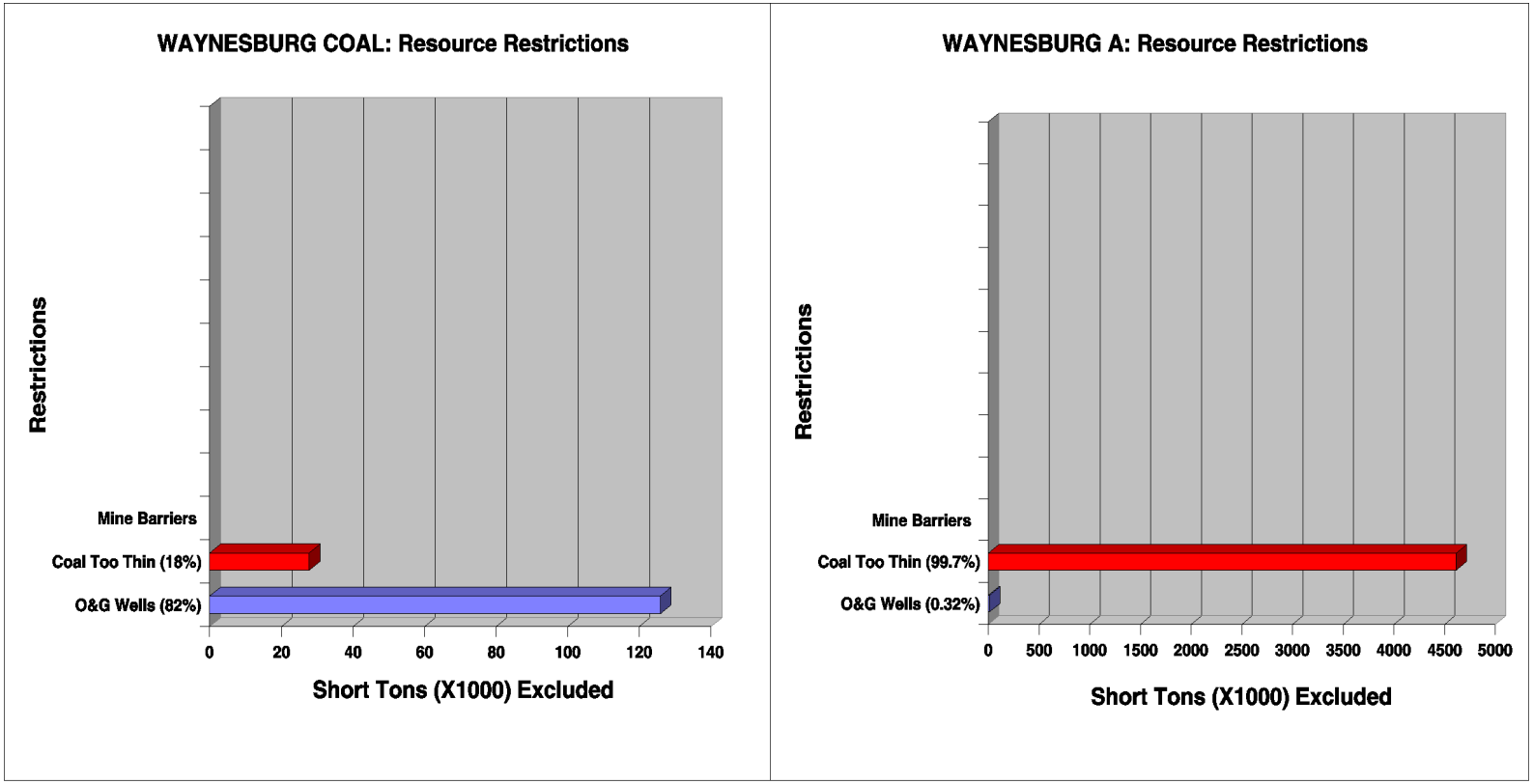

Figure 24. Impact of individual technological restrictions on the Waynesburg and Waynesburg A coal beds.

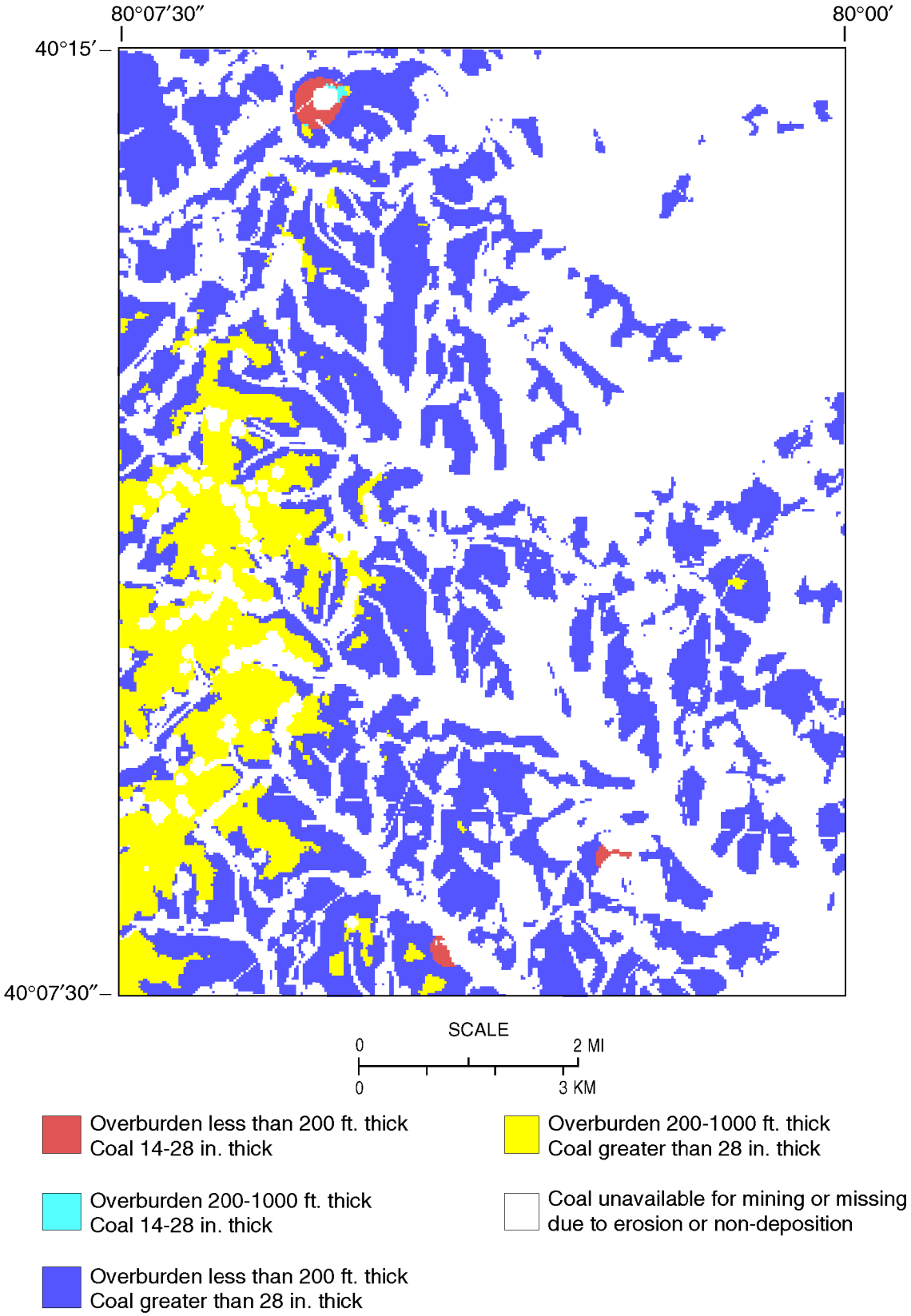

Figure 25. Available Waynesburg coal by coal-bed and overburden thickness categories.

WAYNESBURG A COAL BED SUMMARY

The Waynesburg A coal bed accounts for a little more than 43 million short tons of coal or about 7 percent of the total original resource in the study area (see Figure 13). Approximately 1.5 million short tons of coal has been mined, leaving less than 42 million short tons of coal remaining. It appears that this coal bed has always been surface mined, as no evidence was seen or records found to indicate that it was ever deep mined. Figure 26 displays the extent of the remaining Waynesburg A coal resource.

As with the Waynesburg coal bed, all 13 land-use and two of the three technological restrictions identified for the Hackett quadrangle intersect the Waynesburg A coal bed as well. Gross tonnages are calculated for these restrictions and have been placed in Table 1. See Figures 23 and 24 for companion graphs which summarize this table and pictorially portray how these individual land-use and technological restrictions impact the resource. Close to 16 million short tons of coal is excluded/lost to production due to these land-use and technological restrictions, leaving less than 26 million short tons of coal or 60 percent of the original resource available for mining. These relationships are shown on the pie chart of the Waynesburg A coal bed, found in Appendix A. In addition, Figure 27 indicates where that available resource is found in the quadrangle.

About 92 percent of the available portion of the resource is less than 28 inches thick, and therefore is considered unfavorable as an underground-mining target using current mining practices. However, it will continue to be a surface-mining target since overburden is mostly less than 200 feet thick, and it can often be extracted with the underlying and more widely mined Waynesburg coal bed. A majority of the coal was also calculated as “indicated” to “inferred,” indicative of a dataset with more widely spaced data points (up to 3 miles apart) than optimum (0.25 mile apart). Thus more interpolation of the data (i.e., coal thickness) between these points was required to provide a reasonable assurance of being representative of the coal’s true thickness in those areas.

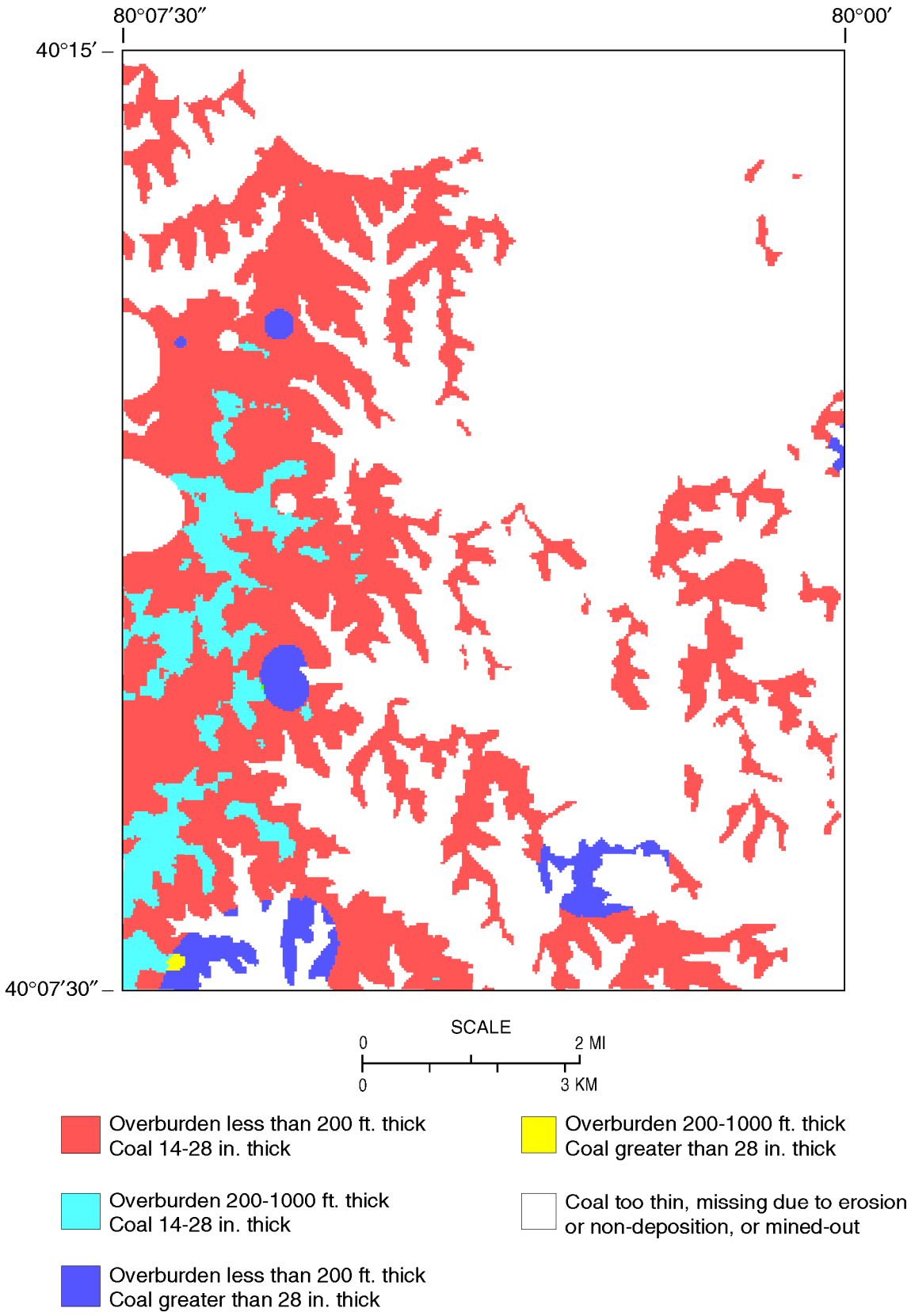

Figure 26. Remaining Waynesburg A coal by coal-bed and overburden thickness categories.

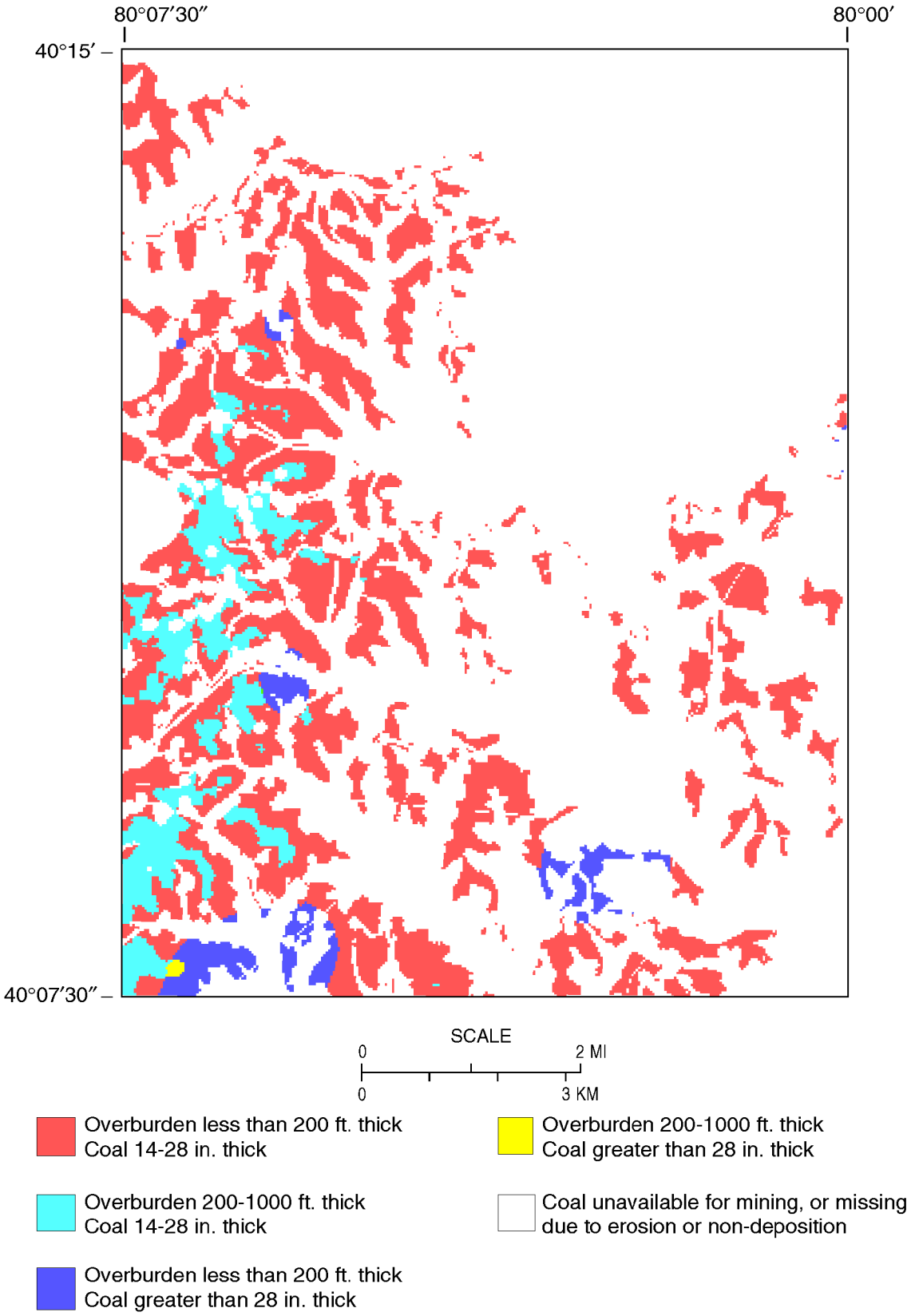

Figure 27. Available Waynesburg A coal by coal-bed and overburden thickness categories.

COAL QUALITY

All of the coal-quality data for the quadrangle came from in-house analyses of coal or from the literature. Three of the four study coal beds, Pittsburgh, Redstone and Waynesburg A, have poor sample coverage throughout the quadrangle. A discussion about what data exist follows.

When compared to the three other coals in the study, Pittsburgh coal quality is quite uniform, lacking the wide deviations in ash and sulfur content seen in the other coals. As presented in the Demonstrated Reserve Base (DRB) for Pennsylvania (U.S. Department of Energy, 1990), Pittsburgh coal-quality data for southwestern Pennsylvania indicate that the coal bed is typically of low to moderate sulfur content, averaging 2.0 percent, and of relatively low to moderate ash content, averaging 10 percent. Available coal-quality data for the Pittsburgh coal bed in the Hackett quadrangle are very sparse and are derived entirely from public domain records. Analyses for three coal samples were found in the literature (Clapp, 1907, Lord, 1913, and U.S. Department of Energy, 1990). These samples came from two strip-mine locations along crop in the northeastern corner of the quadrangle, and from one deep mine. Their analyses indicated sulfur and ash values less than the regional DRB average. Other Pittsburgh coal analyses taken from the literature for quadrangles adjacent to the Hackett quadrangle augment this general tendency for the coal to be at or near the regional average value. It may be reasonable, therefore, to assume that the Pittsburgh coal bed within the Hackett quadrangle has similar characteristics to those exhibited by these several analyses and the regional average. Additional coal-quality data from mining companies in the Hackett quadrangle, which might have helped validate this assumption, were not available to the authors.

Only the Waynesburg coal bed had a sufficient number of analyzed samples to provide statistically relevant coal-quality information. These proximate-ultimate analyses, based on as-received coal samples, have been summarized in Appendix C as a series of graphs. This as-received coal is non-compliant, high in ash (18.5 percent) and sulfur (2.7 percent) content. Washability tests for a number of the samples indicated the dominant form of sulfur was pyrite. Trace-element data also exist for several of the strip-mine samples that were collected. However, sample size was not large enough to determine any trends.

The Waynesburg A coal bed had only two analyzed samples and the Redstone coal bed had only one analyzed sample within the quadrangle. Analyses of these coals in the surrounding quadrangles indicate widely variable ash and sulfur contents, which suggests that values in the Hackett quadrangle may also be highly variable.

QUADRANGLE SUMMARY

Resources were calculated for four coal seams: the Pittsburgh, Redstone, Waynesburg, and Waynesburg A, which coincidentally are also the ones historically mined in the area. By aggregating two thickness categories (14-28 inches, and greater than 28 inches) with three overburden categories (less than 200 feet of cover, representing surface-minable resources; 200-1000 feet of cover; and greater than 1000 feet of cover, representing deep-minable resources) for each bed, tonnages for mined-out and remaining coal could be calculated. The overburden category "greater than 1000 feet" was ultimately excluded from the calculations based upon structure contour maps constructed for each coalbed in the quadrangle; none of the coal beds were found to have an overburden of greater than 1000 feet. All land-use and technological restrictions to mining and their appropriate buffers were compiled and subtracted from the remaining coal tonnages yielding coal available for mining. The reliability of the resource estimates is expressed by the categories measured, indicated, inferred, and hypothetical. Each category defines a decreasing degree of assurance in the extrapolated thickness value of a known data point for incrementally greater (predefined) distances away from that point. Fortuitously, enough closely spaced data points existed for the Hackett quadrangle, so it was only necessary to calculate tonnages for the measured, indicated and inferred categories.

Based on those criteria from above, the original, remaining, restricted and available resources for those four coal seams in the Hackett quadrangle were calculated and have been placed in the accompanying tables, charts, and figures of this report, and then summarized in Table 2. Of an estimated original resource of nearly 607 million short tons in the Hackett quadrangle, 272 million short tons, or 45 percent, has been mined out or lost in mining. An additional 83 million short tons, or 14 percent, was restricted due to modern-day regulatory

Table 2. Estimated Original, Mined, Remaining, Restricted, and Available Coal Resources in the Hackett Quadrangle (in short tons)[1]

	ORIGINAL			MINED			REMAINING		
COAL BED	**0-200'**	**>200'**	**TOTAL**	**0-200'**	**>200'**	**TOTAL**	**0-200'**	**>200'**	**TOTAL**
WAYNESBURG A	38,475,717	4,669,386	**43,145,103**	1,512,394	0	**1,512,394**	36,963,323	4,669,386	**41,632,709**
WAYNESBURG	155,798,716	31,909,350	**187,708,066**	11,531,144	0	**11,531,144**	144,267,572	31,909,350	**176,176,922**
REDSTONE	2,232,137	3,472,369	**5,704,506**	307,555	37,344	**344,899**	1,924,582	3,435,026	**5,359,608**
PITTSBURGH	18,412,511	351,593,089	**370,005,600**	5,745,987	252,965,989	**258,711,976**	12,666,524	98,627,099	**111,293,623**
TOTAL	**214,919,081**	**391,644,194**	**606,563,275**	**19,097,080**	**253,006,167**	**272,100,413**	**195,822,001**	**138,640,861**	**334,462,862**

	RESTRICTED			AVAILABLE		
COAL BED	**0-200'**	**>200'**	**TOTAL**	**0-200'**	**>200'**	**TOTAL**
WAYNESBURG A	11,207,103	4,609,000	**15,816,103**	25,756,219	58,000	**25,814,219**
WAYNESBURG	49,558,536	153,637	**49,712,173**	94,709,036	31,754,000	**126,463,036**
REDSTONE	1,268,015	3,364,463	**4,632,478**	656,565	70,000	**726,565**
PITTSBURGH	10,296,333	2,146,000	**12,442,333**	2,370,191	96,480,000	**98,850,191**
TOTAL	**72,329,987**	**10,273,100**	**82,603,087**	**123,492,011**	**128,362,000**	**251,854,011**

[1]Table composited from GRASS "tables" directory, v_*.tab files. Summation of these individual restrictions is greater than total shown on appendices tables.

statutes or technological impedances which impact surface and underground mining, leaving a resource of about 252 million short tons of coal, or about 42 percent, available for future development and extraction.

ACKNOWLEDGMENTS

The authors would like to thank M. Devereux Carter and Susan J. Tewalt of the U.S. Geological Survey for their help along the way as we assimilated the rudiments of the Coal Availability Study process. Also thanks to Donald Johnson of the U.S. Geological Survey for his assistance in helping us set up the Pennsylvania Geological Survey's NCRDS database link, and to Gayle H. McColloch, Jr. of the West Virginia Geological and Economic Survey for his comments and suggestions about GRASS software installation. We are very grateful to Allan Axon, formerly of the Ohio Department of Natural Resources, Division of Geological Survey for providing us his various enhancements to the GRASS resource scripts.

Additional thanks go to W. Henry Springer of the U.S. Steel Mining Company, Inc., to Jack Bergman (retired) and Jim Welsh of the Pennsylvania Department of Environmental Protection's Bureau of Mining and Reclamation, McMurray District Office, to Gary Kubieda of Twilight Industries for providing data, access to mine maps, and access to mines, respectively, to Fran Koch of the Commonwealth's Department of Environmental Protection, Bureau of Dams, Waterways, and Wetlands for providing information about wetland regulations and maps, and finally to Edward Dix and others within the Pennsylvania Department of Conservation and Natural Resources, Bureau of Forestry who provided us with assistance in accessing the PNDI database.

The work of Andrew Judd, Bradley Wolf, and Michael Cypcar, summer Scientific and Technical Interns for the Pennsylvania Geological Survey, was quite instrumental in shortening the compilation time required for the mine-out areas maps, the quadrangle restrictions map, and some of the illustrations used for this study. Their work is greatly appreciated.

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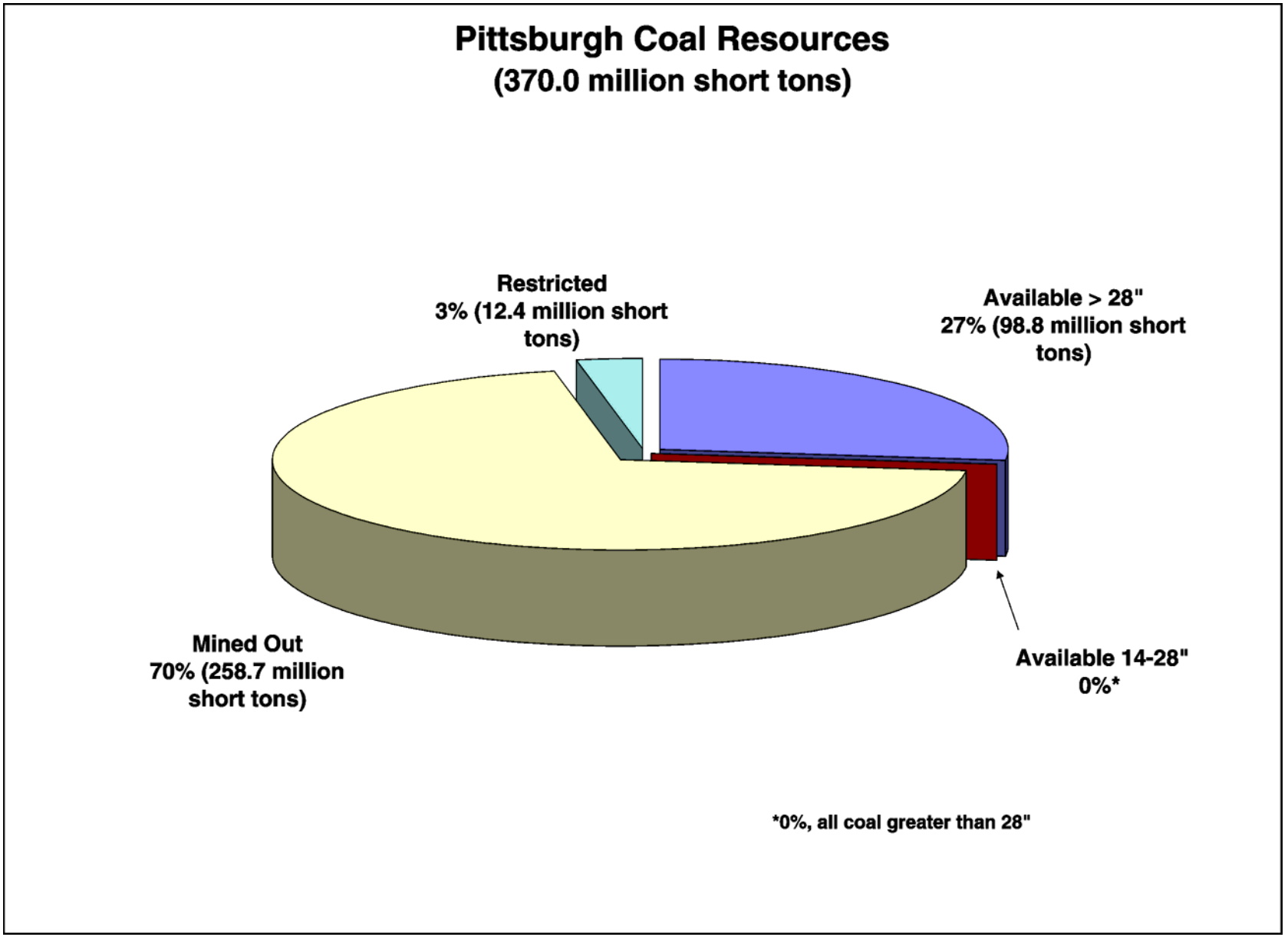
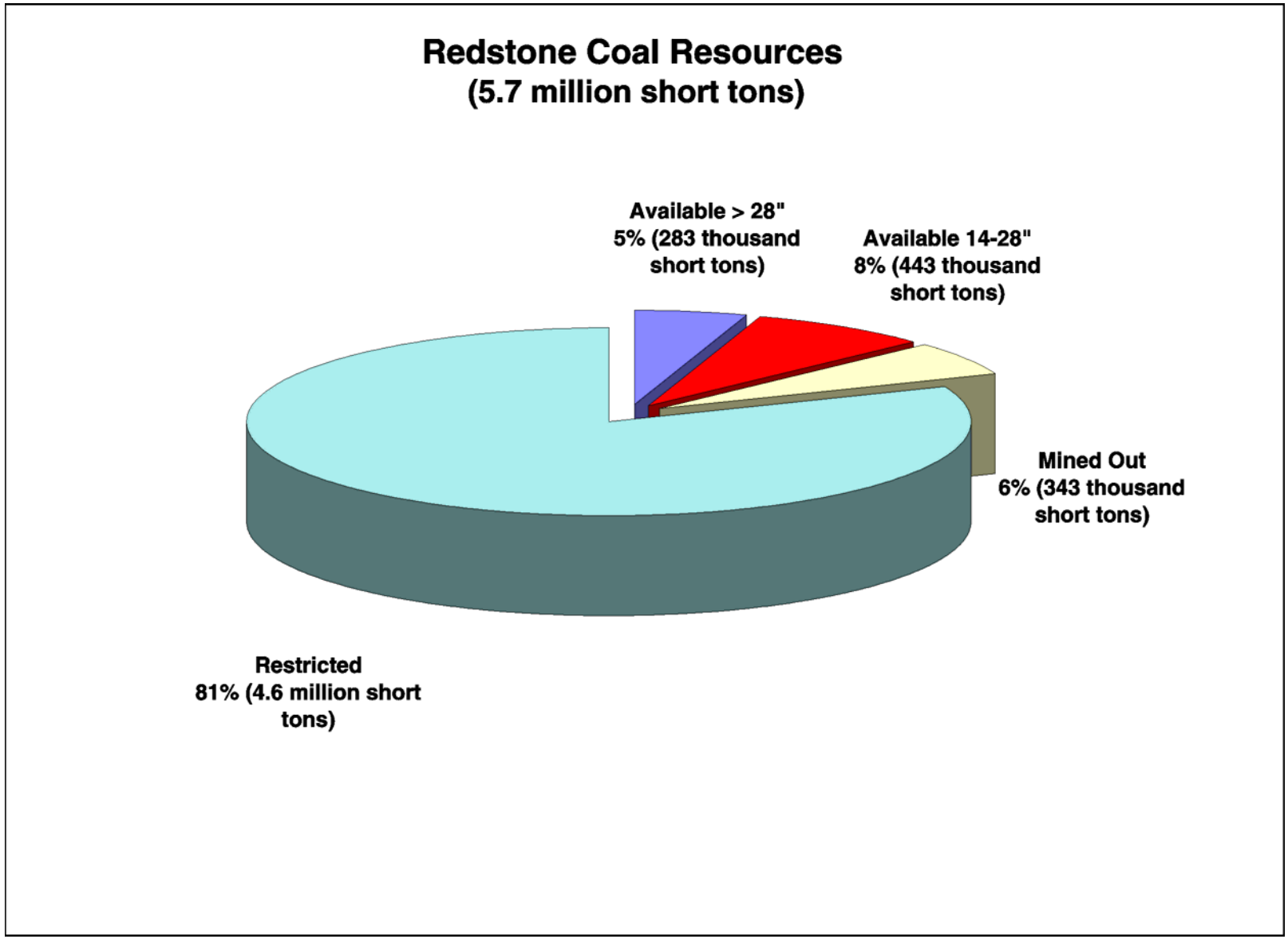
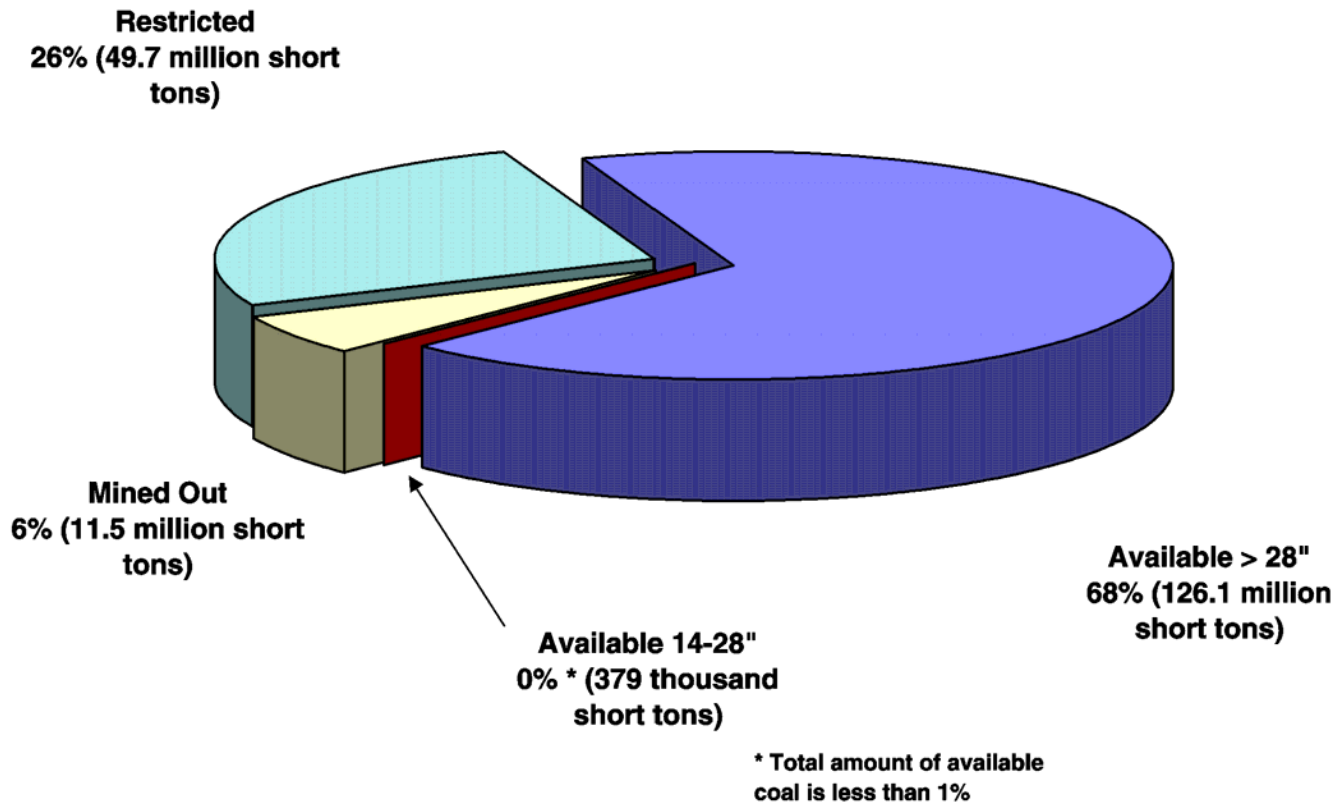
APPENDICES

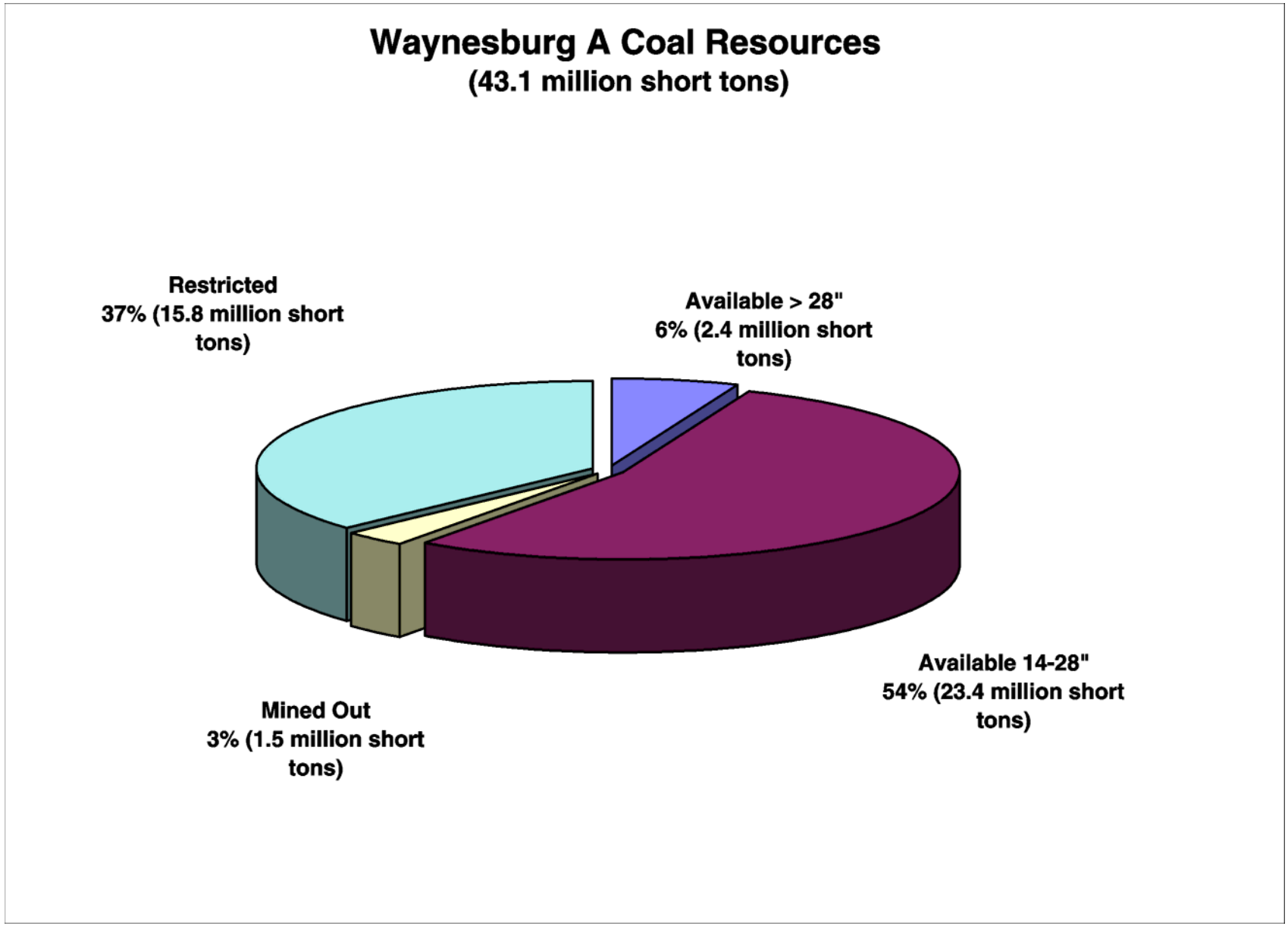
APPENDIX A. HACKETT COAL AVAILABILITY: PIE CHARTS OF THE PITTSBURGH, REDSTONE, WAYNESBURG, AND WAYNESBURG A RESOURCES DEPICTING MINED-OUT, RESTRICTED, AND AVAILABLE COAL


Pittsburgh Coal Resources
(370.0 million short tons)
Restricted
3% (12.4 million short tons)
Available > 28"
27% (98.8 million short tons)
Mined Out
70% (258.7 million short tons)
Available 14-28"
0%*
*0%, all coal greater than 28"


Redstone Coal Resources
(5.7 million short tons)
Available > 28"
5% (283 thousand short tons)
Available 14-28"
8% (443 thousand short tons)
Mined Out
6% (343 thousand short tons)
Restricted
81% (4.6 million short tons)

Waynesburg Coal Resources
(187.7 million short tons)




Waynesburg A Coal Resources
(43.1 million short tons)
Restricted
37% (15.8 million short tons)
Available > 28"
6% (2.4 million short tons)
Available 14-28"
54% (23.4 million short tons)
Mined Out
3% (1.5 million short tons)

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APPENDIX B. RESOURCE SUMMARY TABLES FOR THE PITTSBURGH, REDSTONE, WAYNESBURG, AND WAYNESBURG A COAL BEDS

Estimated coal resources of the Pittsburgh coal bed
in the Hackett 7.5-minute quadrangle, Washington County, Pa
(in thousands of short tons)

Resources are subdivided into categories of overburden thickness (0-200 ft, 200-1000 ft, and >1000 ft),
coal thickness (14-28 in and >28 in), and reliability of estimate (measured, indicated, inferred, and hypothetical).

		MEASURED			INDICATED			INFERRED			HYPOTHETICAL			TOTAL		
		14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL
ORIGINAL																
	0-200	0	4,402	4,402	0	9,070	9,070	0	4,940	4,940	0	0	0	0	18,412	18,412
	200-1000	0	65,673	65,673	0	206,776	206,776	0	79,143	79,143	0	0	0	0	351,592	351,592
	>1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	0	70,075	70,075	0	215,846	215,846	0	84,083	84,083	0	0	0	0	370,004	370,004
MINED OUT**																
SURFACE																
	0-200	0	0	0	0	37	37	0	316	316	0	0	0	0	353	353
	200-1000	0	0	0	0	0	0	0	11	11	0	0	0	0	11	11
	TOTAL	0	0	0	0	37	37	0	327	327	0	0	0	0	364	364
DEEP																
	0-200	0	1,112	1,112	0	2,891	2,891	0	1,415	1,415	0	0	0	0	5,418	5,418
	200-1000	0	40,191	40,191	0	148,584	148,584	0	64,180	64,180	0	0	0	0	252,955	252,955
	>1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	0	41,303	41,303	0	151,475	151,475	0	65,595	65,595	0	0	0	0	258,373	258,373
TOTAL																
	0-200	0	1,112	1,112	0	2,929	2,929	0	1,732	1,732	0	0	0	0	5,773	5,773
	200-1000	0	40,191	40,191	0	148,584	148,584	0	64,191	64,191	0	0	0	0	252,966	252,966
	>1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	0	41,303	41,303	0	151,513	151,513	0	65,923	65,923	0	0	0	0	258,739	258,739
REMAINING																
	0-200	0	3,290	3,290	0	6,141	6,141	0	3,235	3,235	0	0	0	0	12,666	12,666
	200-1000	0	25,482	25,482	0	58,191	58,191	0	14,953	14,953	0	0	0	0	98,626	98,626
	>1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	0	28,772	28,772	0	64,332	64,332	0	18,188	18,188	0	0	0	0	111,292	111,292
RESTRICTIONS																
LAND-USE																
	0-200	0	2,540	2,540	0	5,196	5,196	0	2,559	2,559	0	0	0	0	10,295	10,295
	200-1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	>1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	0	2,540	2,540	0	5,196	5,196	0	2,559	2,559	0	0	0	0	10,295	10,295
TECHNOLOGIC																
	0-200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	200-1000	0	275	275	0	1,388	1,388	0	483	483	0	0	0	0	2,146	2,146
	>1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	0	275	275	0	1,388	1,388	0	483	483	0	0	0	0	2,146	2,146
TOTAL																
	0-200	0	2,540	2,540	0	5,196	5,196	0	2,559	2,559	0	0	0	0	10,295	10,295
	200-1000	0	275	275	0	1,388	1,388	0	483	483	0	0	0	0	2,146	2,146
	>1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	0	2,815	2,815	0	6,584	6,584	0	3,042	3,042	0	0	0	0	12,441	12,441
AVAILABLE																
	0-200	0	749	749	0	944	944	0	676	676	0	0	0	0	2,369	2,369
	200-1000	0	25,207	25,207	0	56,803	56,803	0	14,470	14,470	0	0	0	0	96,480	96,480
	>1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	0	25,956	25,956	0	57,747	57,747	0	15,146	15,146	0	0	0	0	98,849	98,849

* Less than 1, not included in totals.
** Mined and lost-in-mining, by surface and deep mining methods.
Note: Totals may not equal sum of components because of independent rounding.

Estimated remaining coal resources of the Pittsburgh coal bed
unavailable due to LAND-USE restrictions in the Hackett 7.5-minute quadrangle, Washington County, Pa
(in thousands of short tons)

Resources are subdivided into categories of overburden thickness (0-200 ft, 200-1000 ft, and >1000 ft),
coal thickness (14-28 in and >28 in), and reliability of estimate (measured, indicated, inferred, and hypothetical).

	MEASURED			INDICATED			INFERRED			HYPOTHETICAL			TOTAL		
	14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL
0-200															
Houses	0	1,465	1,465	0	2,803	2,803	0	1,638	1,638	0	0	0	0	5,906	5,906
Oil and gas wells	0	10	10	0	17	17	0	0	0	0	0	0	0	27	27
County park	0	822	822	0	2,056	2,056	0	867	867	0	0	0	0	3,745	3,745
Pipelines	0	3	3	0	69	69	0	21	21	0	0	0	0	93	93
PNDI sites	0	417	417	0	851	851	0	298	298	0	0	0	0	1,566	1,566
Powerlines	0	26	26	0	17	17	0	12	12	0	0	0	0	55	55
Railroads	0	26	26	0	50	50	0	4	4	0	0	0	0	80	80
Roads	0	832	832	0	1,671	1,671	0	923	923	0	0	0	0	3,426	3,426
Streams	0	1,022	1,022	0	1,823	1,823	0	717	717	0	0	0	0	3,562	3,562
Wetlands	0	74	74	0	71	71	0	14	14	0	0	0	0	159	159
Total**	0	2,540	2,540	0	5,196	5,196	0	2,559	2,559	0	0	0	0	10,295	10,295
200-1000															
Houses	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oil and gas wells	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
County park	0	0	0	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	0	0	0
PNDI sites	0	0	0	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	0	0	0
Railroads	0	0	0	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	0	0	0
Streams	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wetlands	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>1000															
Houses	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oil and gas wells	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
County park	0	0	0	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	0	0	0
PNDI sites	0	0	0	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	0	0	0
Railroads	0	0	0	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	0	0	0
Streams	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wetlands	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL															
County park	0	822	822	0	2,056	2,056	0	867	867	0	0	0	0	3,745	3,745
Houses	0	1,465	1,465	0	2,803	2,803	0	1,638	1,638	0	0	0	0	5,906	5,906
Oil and gas wells	0	10	10	0	17	17	0	0	0	0	0	0	0	27	27
PNDI sites	0	417	417	0	851	851	0	298	298	0	0	0	0	1,566	1,566
Pipelines	0	3	3	0	69	69	0	21	21	0	0	0	0	93	93
Powerlines	0	26	26	0	17	17	0	12	12	0	0	0	0	55	55
Railroads	0	26	26	0	50	50	0	4	4	0	0	0	0	80	80
Roads	0	832	832	0	1,671	1,671	0	923	923	0	0	0	0	3,426	3,426
Streams	0	1,022	1,022	0	1,823	1,823	0	717	717	0	0	0	0	3,562	3,562
Wetlands	0	74	74	0	71	71	0	14	14	0	0	0	0	159	159
Total**	0	2,540	2,540	0	5,196	5,196	0	2,559	2,559	0	0	0	0	10,295	10,295

* Less than 1, not included in totals.
** Not necessarily sum. Calculated separately to avoid double counting of overlapping restrictions.
Note: Totals may not equal sum of components because of independent rounding.

Estimated remaining coal resources of the Pittsburgh coal bed
unavailable due to TECHNOLOGIC restrictions in the Hackett 7.5-minute quadrangle, Washington County, Pa
(in thousands of short tons)

Resources are subdivided into categories of overburden thickness (0-200 ft, 200-1000 ft, and >1000 ft),
coal thickness (14-28 in and >28 in), and reliability of estimate (measured, indicated, inferred, and hypothetical).

	MEASURED			INDICATED			INFERRED			HYPOTHETICAL			TOTAL		
	14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL
0-200															
Deep mine barriers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oil and gas wells	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
200-1000															
Deep mine barriers	0	218	218	0	1,210	1,210	0	434	434	0	0	0	0	1,862	1,862
Oil and gas wells	0	59	59	0	177	177	0	83	83	0	0	0	0	319	319
Total**	0	275	275	0	1,388	1,388	0	483	483	0	0	0	0	2,146	2,146
>1000															
Deep mine barriers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oil and gas wells	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL															
Deep mine barriers	0	218	218	0	1,210	1,210	0	434	434	0	0	0	0	1,862	1,862
Oil and gas wells	0	59	59	0	177	177	0	83	83	0	0	0	0	319	319
Total**	0	275	275	0	1,388	1,388	0	483	483	0	0	0	0	2,146	2,146

* Less than 1, not included in totals.
** Not necessarily sum. Calculated separately to avoid double counting of overlapping restrictions.
Note: Totals may not equal sum of components because of independent rounding.

Estimated coal resources of the Redstone coal bed
in the Hackett 7.5-minute quadrangle, Washington County, Pa
(in thousands of short tons)

Resources are subdivided into categories of overburden thickness (0-200 ft, 200-1000 ft, and >1000 ft),
coal thickness (14-28 in and >28 in), and reliability of estimate (measured, indicated, inferred, and hypothetical).

	MEASURED			INDICATED			INFERRED			HYPOTHETICAL			TOTAL		
	14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL
ORIGINAL															
0-200	452	136	588	363	0	363	830	449	1,279	0	0	0	1,645	585	2,230
200-1000	428	19	447	962	0	962	2,009	51	2,060	0	0	0	3,399	70	3,469
>1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	880	155	1,035	1,325	0	1,325	2,839	500	3,339	0	0	0	5,044	655	5,699
MINED OUT**															
SURFACE															
0-200	101	0	101	87	0	87	78	41	119	0	0	0	266	41	307
200-1000	8	0	8	18	0	18	10	0	10	0	0	0	36	0	36
TOTAL	109	0	109	105	0	105	88	41	129	0	0	0	302	41	343
DEEP															
200-1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL															
0-200	101	0	101	87	0	87	78	41	119	0	0	0	266	41	307
200-1000	8	0	8	18	0	18	10	0	10	0	0	0	36	0	36
>1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	109	0	109	105	0	105	88	41	129	0	0	0	302	41	343
REMAINING															
0-200	351	136	487	276	0	276	752	408	1,160	0	0	0	1,379	544	1,923
200-1000	420	19	439	944	0	944	1,999	51	2,050	0	0	0	3,363	70	3,433
>1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	771	155	926	1,220	0	1,220	2,751	459	3,210	0	0	0	4,742	614	5,356
RESTRICTIONS															
LAND-USE															
0-200	237	121	358	160	0	160	538	209	747	0	0	0	935	330	1,265
200-1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	237	121	358	160	0	160	538	209	747	0	0	0	935	330	1,265
TECHNOLOGIC															
0-200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
200-1000	420	*	420	944	0	944	1,999	*	1,999	0	0	0	3,363	0	3,363
>1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	420	0	420	944	0	944	1,999	0	1,999	0	0	0	3,363	0	3,363
TOTAL															
0-200	237	121	358	160	0	160	538	209	747	0	0	0	935	330	1,265
200-1000	420	*	420	944	0	944	1,999	*	1,999	0	0	0	3,363	0	3,363
>1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	657	121	778	1,104	0	1,104	2,537	209	2,746	0	0	0	4,298	330	4,628
AVAILABLE															
0-200	114	15	129	116	0	116	213	198	411	0	0	0	443	213	656
200-1000	0	19	19	0	0	0	0	51	51	0	0	0	0	70	70
>1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	114	34	148	116	0	116	213	249	462	0	0	0	443	283	726

* Less than 1, not included in totals.
** Mined and lost-in-mining, by surface and deep mining methods.
Note: Totals may not equal sum of components because of independent rounding.

Estimated remaining coal resources of the Redstone coal bed
unavailable due to LAND-USE restrictions in the Hackett 7.5-minute quadrangle, Washington County, Pa
(in thousands of short tons)

Resources are subdivided into categories of overburden thickness (0-200 ft, 200-1000 ft, and >1000 ft),
coal thickness (14-28 in and >28 in), and reliability of estimate (measured, indicated, inferred, and hypothetical).

		MEASURED			INDICATED			INFERRED			HYPOTHETICAL			TOTAL		
		14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL
0-200																
	Houses	182	116	298	123	0	123	400	192	592	0	0	0	705	308	1,013
	Pipelines	0	0	0	0	0	0	5	*	5	0	0	0	5	0	5
	PNDI sites	0	0	0	0	0	0	361	10	371	0	0	0	361	10	371
	Powerlines	3	8	11	4	0	4	0	0	0	0	0	0	7	8	15
	Railroads	7	4	11	4	0	4	0	0	0	0	0	0	11	4	15
	Roads	59	40	99	52	0	52	146	79	225	0	0	0	257	119	376
	Streams	108	50	158	26	0	26	66	47	113	0	0	0	200	97	297
	Wetlands	6	3	9	*	0	0	3	0	3	0	0	0	9	3	12
	Total**	237	121	358	160	0	160	538	209	747	0	0	0	935	330	1,265
200-1000																
	Houses	0	0	0	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	0	0	0
	PNDI sites	0	0	0	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	0	0	0
	Railroads	0	0	0	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	0	0	0
	Streams	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Wetlands	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>1000																
	Houses	0	0	0	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	0	0	0
	PNDI sites	0	0	0	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	0	0	0
	Railroads	0	0	0	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	0	0	0
	Streams	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Wetlands	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL																
	Houses	182	116	298	123	0	123	400	192	592	0	0	0	705	308	1,013
	PNDI sites	0	0	0	0	0	0	361	10	371	0	0	0	361	10	371
	Pipelines	0	0	0	0	0	0	5	0	5	0	0	0	5	0	5
	Powerlines	3	8	11	4	0	4	0	0	0	0	0	0	7	8	15
	Railroads	7	4	11	4	0	4	0	0	0	0	0	0	11	4	15
	Roads	59	40	99	52	0	52	146	79	225	0	0	0	257	119	376
	Streams	108	50	158	26	0	26	66	47	113	0	0	0	200	97	297
	Wetlands	6	3	9	0	0	0	3	0	3	0	0	0	9	3	12
	Total**	237	121	358	160	0	160	538	209	747	0	0	0	935	330	1,265

* Less than 1, not included in totals.
** Not necessarily sum. Calculated separately to avoid double counting of overlapping restrictions.
Note: Totals may not equal sum of components because of independent rounding.

Estimated remaining coal resources of the Redstone coal bed
unavailable due to TECHNOLOGIC restrictions in the Hackett 7.5-minute quadrangle, Washington County, Pa
(in thousands of short tons)

Resources are subdivided into categories of overburden thickness (0-200 ft, 200-1000 ft, and >1000 ft),
coal thickness (14-28 in and >28 in), and reliability of estimate (measured, indicated, inferred, and hypothetical).

		MEASURED			INDICATED			INFERRED			HYPOTHETICAL			TOTAL		
		14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL
0-200																
	Bed too thin	90	0	90	270	0	270	16	0	16	0	0	0	376	0	376
	Total**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
200-1000																
	Bed too thin	621	*	621	1,782	0	1,782	2,832	*	2,832	0	0	0	5,235	0	5,235
	Total**	420	0	420	944	0	944	1,999	0	1,999	0	0	0	3,363	0	3,363
>1000																
	Bed too thin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL																
	Bed too thin	711	0	711	2,052	0	2,052	2,848	0	2,848	0	0	0	5,611	0	5,611
	Total**	420	0	420	944	0	944	1,999	0	1,999	0	0	0	3,363	0	3,363

* Less than 1, not included in totals.
** Not necessarily sum. Calculated separately to avoid double counting of overlapping restrictions.
Note: Totals may not equal sum of components because of independent rounding.

Estimated coal resources of the Waynesburg coal bed
in the Hackett 7.5-minute quadrangle, Washington County, Pa
(in thousands of short tons)

Resources are subdivided into categories of overburden thickness (0-200 ft, 200-1000 ft, and >1000 ft),
coal thickness (14-28 in and >28 in), and reliability of estimate (measured, indicated, inferred, and hypothetical).

		MEASURED			INDICATED			INFERRED			HYPOTHETICAL			TOTAL		
		14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL
ORIGINAL																
	0-200	495	36,057	36,552	71	87,272	87,343	0	31,902	31,902	0	0	0	566	155,231	155,797
	200-1000	25	6,685	6,710	2	17,277	17,279	0	7,919	7,919	0	0	0	27	31,881	31,908
	>1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	520	42,742	43,262	73	104,549	104,622	0	39,821	39,821	0	0	0	593	187,112	187,705
MINED OUT**																
SURFACE																
	0-200	102	3,379	3,481	0	6,634	6,634	0	1,414	1,414	0	0	0	102	11,427	11,529
	200-1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	102	3,379	3,481	0	6,634	6,634	0	1,414	1,414	0	0	0	102	11,427	11,529
DEEP																
	0-200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	200-1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	>1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL																
	0-200	102	3,379	3,481	0	6,634	6,634	0	1,414	1,414	0	0	0	102	11,427	11,529
	200-1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	>1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	102	3,379	3,481	0	6,634	6,634	0	1,414	1,414	0	0	0	102	11,427	11,529
REMAINING																
	0-200	392	32,678	33,070	71	80,637	80,708	0	30,488	30,488	0	0	0	463	143,803	144,266
	200-1000	25	6,685	6,710	2	17,277	17,279	0	7,919	7,919	0	0	0	27	31,881	31,908
	>1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	417	39,363	39,780	73	97,914	97,987	0	38,407	38,407	0	0	0	490	175,684	176,174
RESTRICTIONS																
LAND-USE																
	0-200	79	13,049	13,128	4	26,599	26,603	0	9,825	9,825	0	0	0	83	49,473	49,556
	200-1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	>1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	79	13,049	13,128	4	26,599	26,603	0	9,825	9,825	0	0	0	83	49,473	49,556
TECHNOLOGIC																
	0-200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	200-1000	25	15	40	2	95	97	0	15	15	0	0	0	27	125	152
	>1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	25	15	40	2	95	97	0	15	15	0	0	0	27	125	152
TOTAL																
	0-200	79	13,049	13,128	4	26,599	26,603	0	9,825	9,825	0	0	0	83	49,473	49,556
	200-1000	25	15	40	2	95	97	0	15	15	0	0	0	27	125	152
	>1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	104	13,064	13,168	6	26,694	26,700	0	9,840	9,840	0	0	0	110	49,598	49,708
AVAILABLE																
	0-200	313	19,628	19,941	66	54,038	54,104	0	20,662	20,662	0	0	0	379	94,328	94,707
	200-1000	0	6,670	6,670	0	17,181	17,181	0	7,903	7,903	0	0	0	0	31,754	31,754
	>1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	313	26,298	26,611	66	71,219	71,285	0	28,565	28,565	0	0	0	379	126,082	126,461

* Less than 1, not included in totals.
** Mined and lost-in-mining, by surface and deep mining methods.
Note: Totals may not equal sum of components because of independent rounding.

Estimated remaining coal resources of the Waynesburg coal bed
unavailable due to LAND-USE restrictions in the Hackett 7.5-minute quadrangle, Washington County, Pa
(in thousands of short tons)

Resources are subdivided into categories of overburden thickness (0-200 ft, 200-1000 ft, and >1000 ft),
coal thickness (14-28 in and >28 in), and reliability of estimate (measured, indicated, inferred, and hypothetical).

	MEASURED			INDICATED			INFERRED			HYPOTHETICAL			TOTAL	
	14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL
0-200															
Cemeteries	0	12	12	0	79	79	0	27	27	0	0	0	0	118	118
Houses	14	8,904	8,918	0	18,739	18,739	0	6,597	6,597	0	0	0	14	34,240	34,254
Lakes	0	33	33	0	114	114	0	21	21	0	0	0	0	168	168
Oil and gas wells	0	95	95	0	255	255	0	37	37	0	0	0	0	387	387
County park	27	714	741	0	201	201	0	0	0	0	0	0	27	915	942
Pipelines	4	184	188	2	346	348	0	151	151	0	0	0	6	681	687
PNDI sites	23	0	23	0	309	309	0	2,005	2,005	0	0	0	23	2,314	2,337
Powerlines	0	13	13	0	75	75	0	155	155	0	0	0	0	243	243
Railroads	0	21	21	0	72	72	0	0	0	0	0	0	0	93	93
Roads	29	3,947	3,976	0	8,132	8,132	0	2,774	2,774	0	0	0	29	14,853	14,882
Streams	9	2,262	2,271	1	5,039	5,040	0	1,493	1,493	0	0	0	10	8,794	8,804
Towns	0	494	494	0	482	482	0	13	13	0	0	0	0	989	989
Wetlands	0	192	192	0	1,002	1,002	0	67	67	0	0	0	0	1,261	1,261
Total**	79	13,049	13,128	4	26,599	26,603	0	9,825	9,825	0	0	0	83	49,473	49,556
200-1000															
Cemeteries	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Houses	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lakes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oil and gas wells	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
County park	0	0	0	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	0	0	0
PNDI sites	0	0	0	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	0	0	0
Railroads	0	0	0	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	0	0	0
Streams	0	0	0	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	0	0	0
Wetlands	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>1000															
Cemeteries	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Houses	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lakes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oil and gas wells	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
County park	0	0	0	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	0	0	0
PNDI sites	0	0	0	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	0	0	0
Railroads	0	0	0	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	0	0	0
Streams	0	0	0	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	0	0	0
Wetlands	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL															
Cemeteries	0	12	12	0	79	79	0	27	27	0	0	0	0	118	118
County park	27	714	741	0	201	201	0	0	0	0	0	0	27	915	942
Houses	14	8,904	8,918	0	18,739	18,739	0	6,597	6,597	0	0	0	14	34,240	34,254
Lakes	0	33	33	0	114	114	0	21	21	0	0	0	0	168	168
Oil and gas wells	0	95	95	0	255	255	0	37	37	0	0	0	0	387	387
PNDI sites	23	0	23	0	309	309	0	2,005	2,005	0	0	0	23	2,314	2,337
Pipelines	4	184	188	2	346	348	0	151	151	0	0	0	6	681	687
Powerlines	0	13	13	0	75	75	0	155	155	0	0	0	0	243	243
Railroads	0	21	21	0	72	72	0	0	0	0	0	0	0	93	93
Roads	29	3,947	3,976	0	8,132	8,132	0	2,774	2,774	0	0	0	29	14,853	14,882
Streams	9	2,262	2,271	1	5,039	5,040	0	1,493	1,493	0	0	0	10	8,794	8,804
Towns	0	494	494	0	482	482	0	13	13	0	0	0	0	989	989
Wetlands	0	192	192	0	1,002	1,002	0	67	67	0	0	0	0	1,261	1,261
Total**	79	13,049	13,128	4	26,599	26,603	0	9,825	9,825	0	0	0	83	49,473	49,556

* Less than 1, not included in totals.
** Not necessarily sum. Calculated separately to avoid double counting of overlapping restrictions.
Note: Totals may not equal sum of components because of independent rounding.

Estimated remaining coal resources of the Waynesburg coal bed
unavailable due to TECHNOLOGIC restrictions in the Hackett 7.5-minute quadrangle, Washington County, Pa
(in thousands of short tons)

Resources are subdivided into categories of overburden thickness (0-200 ft, 200-1000 ft, and >1000 ft),
coal thickness (14-28 in and >28 in), and reliability of estimate (measured, indicated, inferred, and hypothetical).

	MEASURED			INDICATED			INFERRED			HYPOTHETICAL			TOTAL		
	14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL
0-200															
Oil and gas wells	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bed too thin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
200-1000															
Oil and gas wells	0	15	15	0	95	95	0	15	15	0	0	0	0	125	125
Bed too thin	25	0	25	2	*	2	0	0	0	0	0	0	27	0	27
Total**	25	15	40	2	95	97	0	15	15	0	0	0	27	125	152
>1000															
Oil and gas wells	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bed too thin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL															
Bed too thin	25	0	25	2	0	2	0	0	0	0	0	0	27	0	27
Oil and gas wells	0	15	15	0	95	95	0	15	15	0	0	0	0	125	125
Total**	25	15	40	2	95	97	0	15	15	0	0	0	27	125	152

* Less than 1, not included in totals.
** Not necessarily sum. Calculated separately to avoid double counting of overlapping restrictions.
Note: Totals may not equal sum of components because of independent rounding.

Estimated coal resources of the Waynesburg A coal bed
in the Hackett 7.5-minute quadrangle, Washington County, Pa
(in thousands of short tons)

Resources are subdivided into categories of overburden thickness (0-200 ft, 200-1000 ft, and >1000 ft),
coal thickness (14-28 in and >28 in), and reliability of estimate (measured, indicated, inferred, and hypothetical).

		MEASURED			INDICATED			INFERRED			HYPOTHETICAL			TOTAL		
		14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL
ORIGINAL																
	0-200	5,075	1,038	6,113	16,361	2,319	18,680	13,190	489	13,679	0	0	0	34,626	3,846	38,472
	200-1000	977	0	977	1,862	36	1,898	1,770	22	1,792	0	0	0	4,609	58	4,667
	>1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	6,052	1,038	7,090	18,223	2,355	20,578	14,960	511	15,471	0	0	0	39,235	3,904	43,139
MINED OUT**																
SURFACE																
	0-200	184	139	323	493	364	857	307	22	329	0	0	0	984	525	1,509
	200-1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	184	139	323	493	364	857	307	22	329	0	0	0	984	525	1,509
DEEP																
	0-200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	200-1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	>1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL																
	0-200	184	139	323	493	364	857	307	22	329	0	0	0	984	525	1,509
	200-1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	>1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	184	139	323	493	364	857	307	22	329	0	0	0	984	525	1,509
REMAINING																
	0-200	4,891	898	5,789	15,868	1,955	17,823	12,882	467	13,349	0	0	0	33,641	3,320	36,961
	200-1000	977	0	977	1,862	36	1,898	1,770	22	1,792	0	0	0	4,609	58	4,667
	>1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	5,868	898	6,766	17,730	1,991	19,721	14,652	489	15,141	0	0	0	38,250	3,378	41,628
RESTRICTIONS																
LAND-USE																
	0-200	2,040	390	2,430	4,981	444	5,425	3,240	110	3,350	0	0	0	10,261	944	11,205
	200-1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	>1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	2,040	390	2,430	4,981	444	5,425	3,240	110	3,350	0	0	0	10,261	944	11,205
TECHNOLOGIC																
	0-200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	200-1000	977	0	977	1,862	*	1,862	1,770	*	1,770	0	0	0	4,609	0	4,609
	>1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	977	0	977	1,862	0	1,862	1,770	0	1,770	0	0	0	4,609	0	4,609
TOTAL																
	0-200	2,040	390	2,430	4,981	444	5,425	3,240	110	3,350	0	0	0	10,261	944	11,205
	200-1000	977	0	977	1,862	*	1,862	1,770	*	1,770	0	0	0	4,609	0	4,609
	>1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	3,017	390	3,407	6,843	444	7,287	5,010	110	5,120	0	0	0	14,870	944	15,814
AVAILABLE																
	0-200	2,850	508	3,358	10,887	1,510	12,397	9,641	357	9,998	0	0	0	23,378	2,375	25,753
	200-1000	0	0	0	0	36	36	0	22	22	0	0	0	0	58	58
	>1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL	2,850	508	3,358	10,887	1,546	12,433	9,641	379	10,020	0	0	0	23,378	2,433	25,811

* Less than 1, not included in totals.
** Mined and lost-in-mining, by surface and deep mining methods.
Note: Totals may not equal sum of components because of independent rounding.

Estimated remaining coal resources of the Waynesburg A coal bed
unavailable due to LAND-USE restrictions in the Hackett 7.5-minute quadrangle, Washington County, Pa
(in thousands of short tons)

Resources are subdivided into categories of overburden thickness (0-200 ft, 200-1000 ft, and >1000 ft),
coal thickness (14-28 in and >28 in), and reliability of estimate (measured, indicated, inferred, and hypothetical).

	MEASURED			INDICATED			INFERRED			HYPOTHETICAL			TOTAL		
	14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL
0-200															
Cemeteries	0	0	0	40	0	40	9	0	9	0	0	0	49	0	49
Houses	1,540	337	1,877	3,920	295	4,215	2,488	85	2,573	0	0	0	7,948	717	8,665
Lakes	2	0	2	15	1	16	7	0	7	0	0	0	24	1	25
Oil and gas wells	23	0	23	67	7	74	17	0	17	0	0	0	107	7	114
County park	36	0	36	17	0	17	0	0	0	0	0	0	53	0	53
Pipelines	7	0	7	56	12	68	48	10	58	0	0	0	111	22	133
PNDI sites	0	0	0	0	0	0	111	0	111	0	0	0	111	0	111
Powerlines	0	0	0	4	0	4	59	0	59	0	0	0	63	0	63
Railroads	0	0	0	6	0	6	0	0	0	0	0	0	6	0	6
Roads	780	168	948	1,600	197	1,797	1,107	19	1,126	0	0	0	3,487	384	3,871
Streams	267	43	310	649	32	681	245	0	245	0	0	0	1,161	75	1,236
Towns	18	0	18	75	0	75	0	0	0	0	0	0	93	0	93
Wetlands	35	0	35	61	0	61	81	0	81	0	0	0	177	0	177
Total**	2,040	390	2,430	4,981	444	5,425	3,240	110	3,350	0	0	0	10,261	944	11,205
200-1000															
Cemeteries	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Houses	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lakes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oil and gas wells	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
County park	0	0	0	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	0	0	0
PNDI sites	0	0	0	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	0	0	0
Railroads	0	0	0	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	0	0	0
Streams	0	0	0	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	0	0	0
Wetlands	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>1000															
Cemeteries	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Houses	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lakes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oil and gas wells	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
County park	0	0	0	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	0	0	0
PNDI sites	0	0	0	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	0	0	0
Railroads	0	0	0	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	0	0	0
Streams	0	0	0	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	0	0	0
Wetlands	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL															
Cemeteries	0	0	0	40	0	40	9	0	9	0	0	0	49	0	49
County park	36	0	36	17	0	17	0	0	0	0	0	0	53	0	53
Houses	1,540	337	1,877	3,920	295	4,215	2,488	85	2,573	0	0	0	7,948	717	8,665
Lakes	2	0	2	15	1	16	7	0	7	0	0	0	24	1	25
Oil and gas wells	23	0	23	67	7	74	17	0	17	0	0	0	107	7	114
PNDI sites	0	0	0	0	0	0	111	0	111	0	0	0	111	0	111
Pipelines	7	0	7	56	12	68	48	10	58	0	0	0	111	22	133
Powerlines	0	0	0	4	0	4	59	0	59	0	0	0	63	0	63
Railroads	0	0	0	6	0	6	0	0	0	0	0	0	6	0	6
Roads	780	168	948	1,600	197	1,797	1,107	19	1,126	0	0	0	3,487	384	3,871
Streams	267	43	310	649	32	681	245	0	245	0	0	0	1,161	75	1,236
Towns	18	0	18	75	0	75	0	0	0	0	0	0	93	0	93
Wetlands	35	0	35	61	0	61	81	0	81	0	0	0	177	0	177
Total**	2,040	390	2,430	4,981	444	5,425	3,240	110	3,350	0	0	0	10,261	944	11,205

* Less than 1, not included in totals.
** Not necessarily sum. Calculated separately to avoid double counting of overlapping restrictions.
Note: Totals may not equal sum of components because of independent rounding.

Estimated remaining coal resources of the Waynesburg A coal bed
unavailable due to TECHNOLOGIC restrictions in the Hackett 7.5-minute quadrangle, Washington County, Pa
(in thousands of short tons)

Resources are subdivided into categories of overburden thickness (0-200 ft, 200-1000 ft, and >1000 ft),
coal thickness (14-28 in and >28 in), and reliability of estimate (measured, indicated, inferred, and hypothetical).

	MEASURED			INDICATED			INFERRED			HYPOTHETICAL			TOTAL		
	14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL	14-28	>28	TOTAL
0-200															
Oil and gas wells	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bed too thin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
200-1000															
Oil and gas wells	0	0	0	9	0	9	4	0	4	0	0	0	13	0	13
Bed too thin	977	0	977	1,862	*	1,862	1,770	*	1,770	0	0	0	4,609	0	4,609
Total**	977	0	977	1,862	0	1,862	1,770	0	1,770	0	0	0	4,609	0	4,609
>1000															
Oil and gas wells	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bed too thin	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL															
Bed too thin	977	0	977	1,862	0	1,862	1,770	0	1,770	0	0	0	4,609	0	4,609
Oil and gas wells	0	0	0	9	0	9	4	0	4	0	0	0	13	0	13
Total**	977	0	977	1,862	0	1,862	1,770	0	1,770	0	0	0	4,609	0	4,609

* Less than 1, not included in totals.
** Not necessarily sum. Calculated separately to avoid double counting of overlapping restrictions.
Note: Totals may not equal sum of components because of independent rounding.

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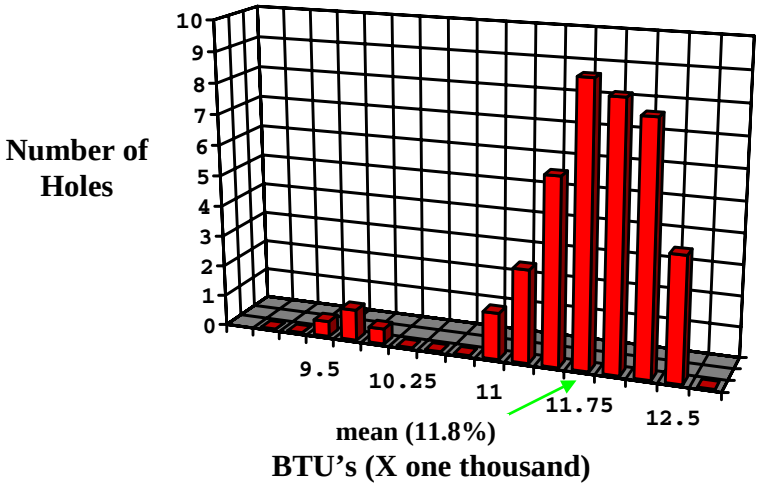
APPENDIX C. COAL QUALITY OF THE WAYNESBURG COAL BED

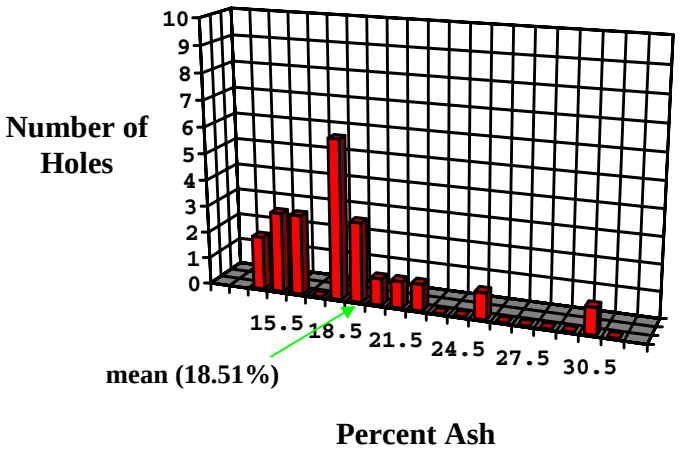
BTU CONTENT

Waynesburg Coal



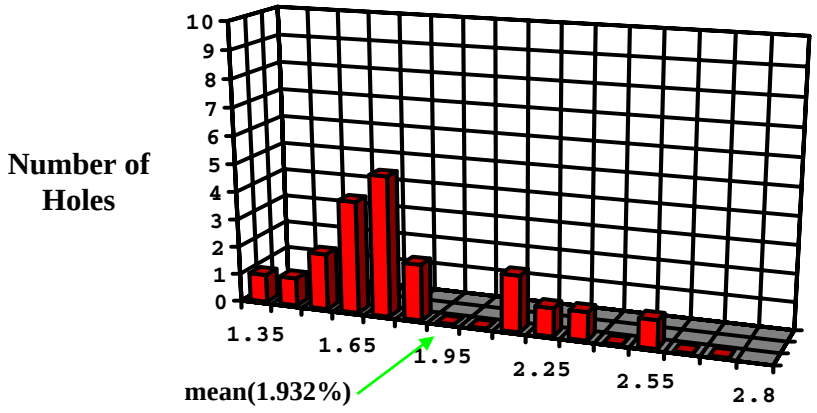
ASH CONTENT

Waynesburg Coal



MOISTURE CONTENT

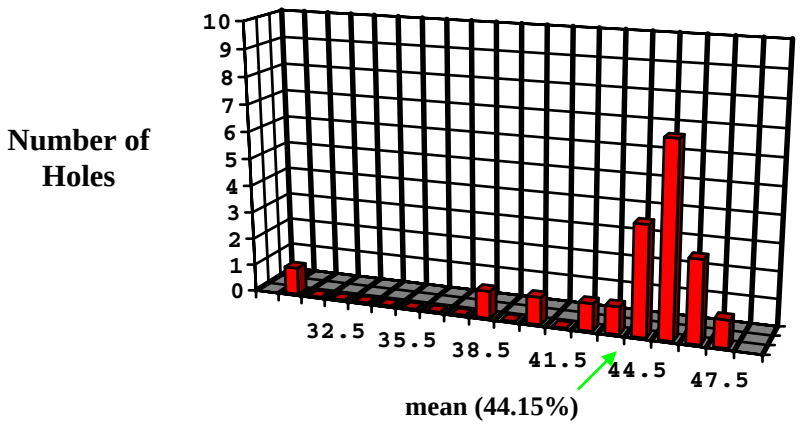
Waynesburg Coal



Percent Moisture Content

FIXED CARBON

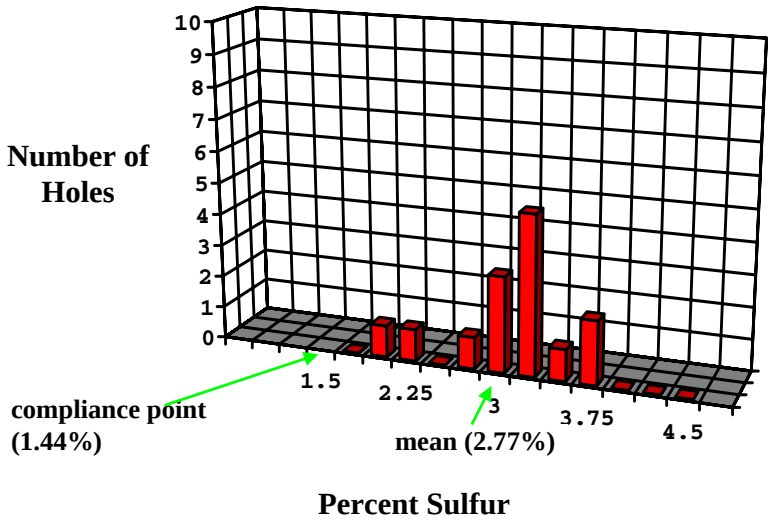
Waynesburg Coal



Percent Fixed Carbon

SULFUR CONTENT

Waynesburg Coal



APPENDIX D. HACKETT COAL AVAILABILITY STUDY METHODOLOGY

Introduction

Of all the tasks which Federal and State geological surveys do, the estimation of natural resources has always been of major importance. It is important not just to provide an estimate of how much of that resource remains, but also to provide a mechanism whereby planners and economists can determine potential employment displacements or employment opportunities within a geographical region by knowing the location of remaining resources. Coal is one of the resources in the United States currently being scrutinized by the U.S. Geological Survey as it looks to define those sources of energy to be used in the future. But how much coal remains and what is its quality? That is what the federally-funded Coal Availability Study program hopes to do, provide some idea of the remaining *available* coal resources on a basin by basin basis.

One of the most important natural resources in Pennsylvania is coal. Its value as an energy source was acknowledged early on and it has maintained the economic health of the Commonwealth for nearly two centuries. Yet, how much remains? The Coal Availability Studies for Pennsylvania will provide a hint of the answer to that question.

Past resource estimates of coal in Pennsylvania have relied upon geologic understanding and interpretation of data gathered from surface mines and underground mines. Often these sites were few and far between. Coal resources were calculated by the geologist or engineer using one of several different methods, with each subsequent author tending to use some variation of the previous worker's method (e.g., Ashley, 1944), each yielding different results. Today, after decades of drilling for coal by coal companies, a more complete understanding of the geology and occurrence of coal is possible. Basic resource analysis methodologies have improved and have become standardized through time, too, like those developed in U.S. Geological Survey Circular 891 (Wood and others, 1983). However, there has yet to be a detailed study of the coal resources in Pennsylvania based upon this increase in data and improved methodology since the last full Demonstrated Reserve Base was completed by the U.S. Department of Energy in 1979.

The first Pennsylvania Geological Survey was formed in 1836 by act of the State Legislature for the expressed purpose of gathering and disseminating geologic information about coal and other natural resources within its borders, powering the Commonwealth into the industrial age. Today, in its fourth incarnation, the Pennsylvania Geological Survey (presently

known as the Bureau of Topographic and Geologic Survey) continues to provide information about the nature of the coal resources remaining in the Commonwealth.

The last coal resource estimate completed by the Pennsylvania Geological Survey reported that about 14 billion short tons of coal has been mined (underground and surface mines) in the bituminous region of Pennsylvania since the early 1800s and that the amount of bituminous coal remaining in the Commonwealth was estimated at 65 billion short tons. Of that amount, 10 billion short tons are estimated to be recoverable (Edmunds, 1972).

It would seem that there are ample reserves of coal left looking at those numbers. Yet additional factors, such as regulatory statutes and adverse geologic or engineering-related conditions (Eggleston and others, 1990) could exist which might impact on that total and further limit the amount of coal available for mining and therefore should be factored into any resource evaluation.

Also, it should be pointed out that for this study, in order to quantify available coal, only total coal is considered. Partings have intentionally been left out because their impact on the resource is beyond the scope of this study. However, personnel from the former U.S. Bureau of Mines in a follow-up study to this one, called Coal Recoverability, will consider the economic implications of partings in coal, as well as look at other economic indicators (e.g., coal chemistry), and their impact on coal minability. Towards that end, two data sets are provided to the U.S. Geological Survey upon completion of the study: coal without partings, and coal with partings.

Historical Background of Study

The U.S. Geological Survey (USGS) by the late 1970s was developing an in-house, electronic version of the file cabinet to hold coal information from a number of states that they called the National Coal Resources Data System (NCRDS). It was built upon the Multics, and later, the PRIME computer operating system. In addition the USGS developed two software programs to augment the database application. They were known as the Program to Analyze Coal Energy Resources (PACER) and Graphics Analysis of Resources using Numerical Evaluation Techniques (GARNET), and could be used to determine coal resources. This computer technology worked well for a number of years, but in 1987 the U.S. Geological Survey decided to expand and update this simple coal resource program and to replace PACER and

GARNET with a more robust system of computers and software based on the UNIX operating system. Their objective was to put together a database manager and analysis software comparable in function to the old system, plus add those elements found in the newly evolving geographic-information-system (GIS) technology which might provide for further refinement of the coal resource, for example, the addition of data layers that represent the various restrictions to mining arising out of new environmental regulations. PACER and GARNET were supplanted by the public domain GIS software called GRASS (Geographical Resources Analysis Support System). A USGS Coal Branch modified version of the GRASS software was put into use specifically for Coal Availability.

The Kentucky Geological Survey, in cooperation with the U.S. Geological Survey in 1987-88, initiated a pilot study of the 7.5-minute Matewan quadrangle, whose purpose was to refine this new GRASS-based coal analysis program and document procedures. The guidelines and procedures developed from the study are documented in USGS Circular 1055 (Eggleston and others, 1990) and are the routines used in the Coal Availability Studies that followed in Kentucky, Virginia, and West Virginia.

The Pennsylvania Geological Survey in 1978 became involved in the NCRDS program, providing the USGS with additional coal data from Pennsylvania. This coal stratigraphic and geochemical information was gleaned from county coal mapping studies, which were initiated in conjunction with this cooperative program. This cooperative effort in subsequent years has lead to the development of a very large computer database of coal data for Pennsylvania, which is electronically accessible by Pennsylvania Geological Survey geologists. With this information now in a digital format suitable for extraction and manipulation, it was anticipated that new reserve estimates for Pennsylvania might be readily calculated. Coal Availability seemed to be the next logical step. The Pennsylvania Geological Survey in 1992 proposed to the U.S. Geological Survey several quadrangles for study. The first quadrangle would be the Hackett quadrangle, Washington County, Pennsylvania. Basic concepts and the methodology applied to this study are contained in this chapter (i.e., Appendix D), whereas data generated for this study are found in Appendix B.

Restrictions

General

The Coal Availability Study program, for the purpose of determining available resources, identifies potential restrictions to mining, which are cataloged into two broad categories: land-use and technological. Land-use restrictions represent those cultural features that may restrict surface- and underground-mining operations by requiring protection from obliteration or damage, and are defined by the various regulations promulgated during 1966 and described in Title 25, chapter 86 of the Pennsylvania Code, becoming further revised with the passage of Act 54 in 1994. Examples of these are streams, roads, cemeteries, and wetlands. Each restriction usually has its own associated "buffer zone of exclusion" as dictated by those regulations. Technological restrictions represent those factors that can impinge upon both surface and underground mining. Typically, they are adverse geological conditions such as bad roof conditions, interburden between coals too thin, coal too thin to mine, and/or physical constraints like oil and gas wells, gas storage reservoirs, and deep-mine barriers. Their buffers are based either on existing mining practices or by regulations developed in 1966 (further modified in 1994). Many more physical constraints, other than these few examples, existed prior to the new legislation passed in 1994 (Act 54).

Resource restrictions were identified for this quadrangle based upon review of Commonwealth and local regulations, current mining practices, and the past experiences of mining company personnel. A map of the various land-use restrictions is displayed in Figure 15 in the main part of the text. These restrictions can hinder the production of the remaining coal resource and are, therefore, important in defining how much coal is actually available for mining. The following restrictions were defined for this study: power lines, gas pipelines, oil and gas wells, improved roads (but is contingent upon township rules), railroads, most streams, lakes, wetlands, buildings (including homes), cemeteries, Pennsylvania Natural Diversity sites (PNDI), urbanized areas (a town), parks (county/township park), bed too thin to mine, and mine barriers between underground mines. These restrictions are divided into two groups; those that affect surface mining, and those that affect underground mining. Some of these restrictions were found to be common to both groups (e.g., oil and gas wells). The software program was designed to define the cut-off point between surface- and underground-minable coals at less than 200 feet, or

greater than or equal to 200 feet of overburden, respectively. Depending on the reliability of data about mining practices, this cut-off number could be changed up or down to reflect mining practices for individual study quadrangles. It also may be expressed as an overburden ratio if necessary through additional programming.

Surface-Mining Restrictions

Local mining practices may vary, but based on the overall past surface-mining practices in this quadrangle where surface mining had occurred in areas of high cover, a 200 feet thick threshold to distinguish between surface and underground mining seemed reasonable to use. Land-use restrictions typically affect surface-mined coal. Technological restrictions, such as coal too thin to mine, may also impact upon this surface-minable resource. For this report, 14 inches of coal is the minimum thickness at which a coal bed is considered a surface-minable resource. Some of the restrictions are strictly adhered to, while others seem to be resolved on a case-by-case basis (e.g., oil and gas wells). Table 1 lists those restrictions that are regulated and are found for all coal beds that occur in the quadrangle. Location information for most of the restrictions was taken from the U.S. Geological Survey Hackett 7.5-minute topographic quadrangle map (1953, photorevised 1979), and was field checked for accuracy. Wetland areas were compiled and digitized from the U.S. Department of Interior's Fish and Wildlife Service National Wetlands Inventory Map prepared by the Office of Biological Services for the Hackett quadrangle in 1977. A search of a computer database maintained by the Commonwealth's Bureau of Forestry, an agency through which all mining permit applications must pass, provided all the known Pennsylvania Natural Diversity Inventory (PNDI) sites for Hackett and the surrounding quadrangles. It is a dynamic database, one that changes through time as additional rare animals or plants are identified. These sites are subsequently verified by a check of a topographic map file the Bureau of Forestry maintains, which shows location and type of restriction present. The county park restriction was compiled and later digitized from a copy of a map held at the Washington County Government Offices building in Washington, Pennsylvania. Additional oil and gas wells and homes were added to the Hackett base map based upon findings from field reconnaissance, deep-mine maps, and the Pennsylvania state oil and gas location map of the area.

A buffer for each restriction of an appropriate size required by Commonwealth regulations was automatically created around the digitized line and point data using GRASS (see Table 3). Oil and gas wells are protected by law and use various sized buffers per circumstance. Coal companies are allowed to mine within a 125-foot radius of an active well. By law, this radius can be made smaller if the coal mine operator can assure the integrity of the well, the oil or gas well operator files no objection to the change, and the Commonwealth's Department of Environmental Protection approves. For this study, a 100-foot radius buffer was chosen for each well based mostly upon local practices by the coal companies. Exceptions to the regulations are railroads, pipelines and power lines. Although protection is not required, pipelines, power lines and railroads often are protected anyway. Field experience suggests that coal companies tend to maintain a buffer of about 100 feet from the utility's right of way. And if a coal company can show that they can maintain the integrity of the power line, pipeline or railroad tracks during mining, then the company is allowed to mine closer. Yet due to the cost of moving such obstacles or trying not to disturb them, mining operators tend to avoid them. This 100-foot buffer is what was used in the resource tabulations. The buffer for a PNDI site represents an area of statutory inclusion, whose size is based upon the type of rare or endangered plant or animal species encountered. This zone of inclusion is digitized as another data layer for importation into GRASS. Regulations provide an additional buffer to protect perennial and intermittent streams (see Table 3), which may be waived through application for a variance. Wetlands and lakes are given by inference a similarly sized buffer, although no specific buffer is required. Towns or population clusters are not buffered, but rather the area polygon representative of the town jurisdictional area or population cluster is defined and digitized as a restriction. Parks are required to have, according to regulation, a 300-foot buffer to protect them from mining. However, since Mingo Park, located in the east-central part of the quadrangle, was developed after mining in the area ceased to exist, an additional 300-foot buffer was deemed unnecessary to protect it. Developers of the park included enough land within the park boundaries to buffer against the sights and sounds that any future mining might invoke within its vicinity, which enables the park to maintain the pleasant surroundings expected by its patrons.

Table 3. Buffer Zones Associated With the Various Identified Resource Restrictions in the Hackett Quadrangle

Land Use Restrictions	**Buffer Zone (in feet)[1]**
Cemeteries	boundary+ 100
Houses, public buildings, schools, churches, community or institutional buildings	structure + 300
Lakes	shoreline + 100
Railroads*	right-of-way + 100
Towns	corporate boundary
PNDI sites	site + one mile radius
Public parks	boundary + 300
Oil and gas wells	100 foot radius
Streams	bank + 100
Wetlands	area + 100
Pipelines*	right-of-way + 100
Power lines*	right-of-way + 100
Roads	right-of-way + 100
Technological Restrictions	**Buffer Zone (in feet)[1]**
Deep-mine barriers	200 foot diameter
Oil and gas wells	100 foot radius
Public buildings (see above)[2]	structure + 300

*Interpretive; no specific law; based on field practices.

[1]Compiled from the Pennsylvania Code, Title 25, Chapter 86, *Surface and Underground Coal Mining: General*, and other sources.
[2]Amended 1994 - Legislative Act 54; surface structures (houses, etc.) no longer constitute a restriction to underground mining; instead public buildings replace houses as a restriction.

Underground-Mining Restrictions

For the purposes of this report, underground/deep mining is defined for that coal occurring with greater than or equal to 200 feet of overburden. This is complicated by past deep-mining practices in some areas of the quadrangle that have had deep mining in under less than 100 feet of overburden. In those instances, the coal taken by underground extraction may show up in the surface-mined coal tally. For those situations it is better to consider the total coal removed by mining, rather than if it was a surface- or underground-mining method that extracted it.

Factors that physically hinder or impact the underground mining of coal are grouped together as technological restrictions. Examples of these type of restrictions are bad roof conditions, bed too thin, bed too deep, deep-mine barriers, interburden less than 40 feet thick, and oil and gas wells. Only oil and gas wells (as objects) remain currently regulated; prior to 1994, cultural structures (e.g., houses) also fell under regulatory purview. Subsequently, those pre-1994 restrictions (i.e., houses) have been removed from the list for consideration as a mining restriction. Instead were added to the list of protected structures in 1994 the category public buildings. Public buildings include churches, schools, and other large structures occupied by the public. Also regulated is the practice of mining near existing mines. Regulations stipulate that a 200-foot distance remain between mines, as one mine approaches the other; hence the practice of leaving a barrier pillar in the mine to separate it from the neighboring mine.

Perhaps a little background should be given about why this procedure changed, as the authors understand it. Legislation enacted in 1966 had as its goal the mitigation of structural damage to homes and buildings caused by mine subsidence, as well as aquifer loss prevention, and was proactive toward protecting the property of the owner. So prior to 1994, such features as oil and gas wells, roadways, streams and lakes, buildings, railroads, and utilities might have been an impedance to underground mining, because existing regulations at that time mandated that these objects be protected from the effects of mine subsidence. Room-and-pillar mines, and to some extent longwall mines often were designed in such a way to avoid concentrations of these excluded surface structures. This practice tended to result in a loss of coal from production. With passage by the Pennsylvania Legislature of Act 54 in 1994, protection of structures, except for oil and gas wells, and public buildings, is no longer necessary and mine permits can now be obtained that allow mining beneath them. Prevention is no longer the goal. The protection of property has moved into the realm of the reactive. The owner now must ask the coal company for compensation if damage does occur, and the coal company is obligated to compensate the owner for irreparable structural damage or loss of water supplies once damage is proven. Ultimately, the Pennsylvania Department of Environmental Protection will have the final say about which structures can be undermined.

Deep-mining regulations are now favorable to longwall mining interests and until legal confusion ensuing from passage of Act 54 about what can or cannot be protected is cleared up, underground-mining interests will continue to mine under everything and, therefore, see more

coal extracted out of the ground than ever before. Lost-in-mining ratios should fall, too. This report has been modified to reflect the new rules.

Several of the technological restrictions occur within the Hackett quadrangle. They are oil and gas wells, deep-mine barrier pillars, and bed too thin to be mined. Ordinarily, oil or gas wells require two different radii of exclusion, dependent upon whether the well is an abandoned or an active well. In most circumstances, the coal companies are allowed to mine through an abandoned oil or gas well that has been properly plugged. But it also requires permission to do so from the oil or gas company first. Active wells on the other hand must not be disturbed and coal companies usually leave a block of coal behind of a predetermined size to support the well. Commonwealth regulations allow underground mining within 500 feet of a well without a permit from the Commonwealth Department of Environmental Protection. Acquiring such a permit will grant mining within 150 feet of a well. If there are no objections from the well owner and there are no extenuating circumstances related to the site, the Department of Environmental Protection may grant permission to the coal mine operator for a smaller radius of less than 150 feet, or whatever is needed to support the well. Coal mining companies in the Hackett quadrangle most often used a radius around a well of 100-150 feet. In order to provide consistency with surface-mining practices, a minimum radius of 100 feet was used in GRASS as the buffer size. Another type of restriction common to underground mining is the barrier pillar. These mine barriers physically separate adjacent mines from one another and are not usually extracted. According to the regulations, in order to provide a degree of safety in the mines, a buffer 200 feet in diameter must be left between mines. However, historically, that particular diameter was not used in this quadrangle. Perhaps that regulation was not in force at the time the majority of the mining occurred, or common practice was to use a smaller diameter thickness. Whatever the reason, due to the uneven application of this practice in the Hackett quadrangle, not all deep-mine barriers are of that size, or they are not fully intact. Consequently, only the remaining barriers were individually digitized, and given a 200-foot buffer in GRASS, and then placed in the restriction category “deepmine barriers.” By using a 200-foot buffer for all barriers, some consistency could be maintained, and all coal potentially lost in mining due to all barriers averaged out. In subsequent study quadrangles, this 200-foot buffer was uniformly applied to all underground mines regardless if a pillar existed or not. Public buildings, although a restriction, were usually found incorporated by other restrictions such as towns. The last technological restriction to

mining used in this report is coal too thin to mine. In this report, 28 inches was chosen as the practical threshold at which a coal bed can be divided between being deep minable or not deep minable. All coal less than 28 inches thick was, therefore, excluded from the remaining coal resource.

As a historical reminder, although they are not excluded today, structures (buildings) required protection from subsidence prior to 1994. Therefore, a mining company using room-and-pillar or longwall methods to mine would have had to leave an appropriately sized block of coal behind for support, depending on depth of the coal seam from the surface. For this quadrangle, that size would be about 300 feet. Within these "protection areas," an operator could still have extracted up to 50 percent of the coal (as allowed by law) as long as individual support of structures with a pillar of coal was met. For a mining company using longwall mining methods, that block might be incorporated into one of the entryways; otherwise, the longwall panel would have to be oriented away from the area to be supported, leaving a large block of coal behind. That effectively removes the coal from (restricts) the resource, decreasing the amount of coal available for mining. Post 1994, because of the changes in the law, if one were to recalculate resources for the same area, one might expect an increase in the amount of coal available for mining. Thus, the authors felt it was important to reevaluate the resource based on the new regulations rather than the old ones when providing a resource estimate for this quadrangle.

Data Issues

Types of Data

Data basically fell into two types: point data and line data. The point data included core logs, measured sections, and coal chemistry analysis values. They typically contain information about their location, elevation, a physical description of the core or measured section, and a coal sample number for those coals collected for analysis. The line data included the outline of surface- and underground-mined-out areas, identified land-use and technological restrictions to mining, and coal crop lines. Line data of the mined-out areas and some restrictions, such as streams, lakes and wetlands, were converted into polygons prior to their inclusion in GRASS.

Data Criteria

A set of general criteria was established to determine which coals would be used in the study. They are enumerated below:

1. Coal has been historically mined in the study area and is potentially minable today; or
2. The coals are thick enough and are of good enough quality to warrant mining; or
3. A sufficient number of data control points existed, providing definition of the resource.

Original resources, as defined by the Coal Availability software program, is any in situ coal greater than or equal to 14 inches thick. Remaining and available resources were calculated for the Hackett quadrangle by combining three overburden categories, 0-200 feet, 200-1000 feet and greater than 1000 feet, with two coal thickness categories, namely 14-28 inches, and greater than 28 inches. At each control point per coal-bed name, only those lithologies called "coal" were summed for the seam. This eliminated partings and extraneous rock material from consideration in the available coal tonnage calculations. A follow-up study to this one, called Coal Recoverability, by employees of the former U.S. Bureau of Mines reintroduces these partings to the total seam thickness, and along with other factors, determines how much coal is actually recoverable (i.e., economic reserve).

Past mining practices considered coal found deeper than 1000 feet below the surface as too prohibitive to mine, because it was either technologically more difficult to mine or it was uneconomical to mine at that depth. Such a deep coal bed would be considered a restriction to mining. However, in this study area, depth of overburden as a restriction is not a problem, since overburden for the deepest mined coal bed (Pittsburgh) is less than 1000 feet within the quadrangle area.

Procedures for Data Manipulation

Four coal beds were chosen for study based on the criteria above. Then the NCRDS database was searched for all relevant records about each of the four coal beds centered on the Hackett quadrangle and extending for a distance in latitude and longitude equal to 3 miles into the adjacent eight surrounding quadrangles. This extra 3-mile search radius was chosen because it added points outside the study quadrangle which then could be used to smooth out any "edge effects" at the study quadrangle borders. Any unusual edge effects can become an important deleterious factor when gridding and contouring coal thickness and coal elevation values for

each coal, resulting in erroneous resource calculations. The data records (point data) found by the search had to be initially proofed and any gross errors corrected by the authors using a computer printout of those records. The corrected printouts were sent back to the U.S. Geological Survey Coal Branch personnel in Reston, VA, who then made corrections to the NCRDS database. Later, in order to fine-tune the data, a further editing and verification step was completed on-line by Pennsylvania Geological Survey staff using the NCRDS Ingres database manager software.

The USGS provided to the Bureau a copy of GRASS 4.1 (Geographical Resources Analysis Support System), one that it had further modified for use in Coal Availability. This version of GRASS was loaded on to the Bureau's Sun Microsystems Sparc2 Workstation. The newly corrected point data were searched by bed name using the NCRDS interface and prepared for use in GRASS by creating raster sites files (a formatted table) of coal-bed thickness and elevation, which could then be gridded. The gridded elevation file (data layer) created for the top of each coal was subtracted from the Digital Elevation Model (DEM) 30 meter spaced grid of surface elevations for the Hackett quadrangle, which was acquired from personnel in the Eastern Energy Resources Team of the USGS. The result was an overburden raster map data layer for the quadrangle. The grid of coal lithology thickness raster of each named coal bed was contoured. This was accomplished by using one of the several algorithms available in GRASS. In order to take advantage of the rather evenly spaced nature of the data in the Hackett quadrangle, the GRASS algorithm s.surf.idw was chosen to contour the data. The result from the GRASS algorithm s.surf.idw when combined with another GRASS subroutine, r.mapcalc, provided the two broad categories needed in the resource calculations (i.e., coal thickness ranges and overburden thickness categories).

Correlation of each coal seam was accomplished through manual (analog) methods using data from driller's logs, geologist's logs, and measured sections. A persistent coal bed, or if available, a marine zone was used to provide stratigraphic control throughout the quadrangle.

Mining information and coal crop lines were compiled from work maps created by Skema (1987). These work maps were further updated by collecting recent mining information for the Hackett quadrangle from mining permits stored at the Pennsylvania Department of Environmental Protection district mining offices in McMurray, and Greensburg, Pa., and through the use of recent aerial photography (for surface mining) and some field reconnaissance. Land-

use practices and technological restrictions to mining were determined from state and local regulations, and by conversation with company personnel at mine sites.

The mining and crop line data associated with each of these four coal beds were digitized using the U.S. Geological Survey software program GSMAP version 8 residing on a NEC 486-DX 33 Personal Computer at the Bureau. Once digitized, the data were converted in GSMAP into a GRASS-format file using the GSMAP utility GSMGRASS (GSMAP to GRASS). The digital data were then imported into GRASS and edited and processed to create the data layers used in the resources module. The GSMAP-digitized restriction data, after conversion by GSMGRASS, were imported as individual data layers into GRASS, which were proofed, buffered as necessary (using subroutines s.poly for oil and gas wells, r.buffer for roads, streams, etc.), and labeled for use in various GRASS tables. This vector data then had to be rasterized before it could be used in the various GRASS and Perl (a programming language) modules that were required to compute resources. Once completed, the tonnage calculated from the mined-out areas raster was subtracted from the original resource raster, and the various restriction rasters were totaled and subtracted from the remaining resource total raster, leaving a raster of the amount available for mining.

The GRASS program script, resources.init, allows for the creation of a series of input and output tables, in which are assigned names to the various restrictions, thickness categories, etc. The values in this table must match names given elsewhere in the program data files for the restrictions, thickness categories, etc., so that tonnages are correctly placed with the corresponding nametag. The GRASS-created raster files, when manipulated by the Perl resource scripts, result in the calculation of tonnages for the following parameters: original, mined-out, remaining, the various restrictions, and available coal. All coal resource calculations were executed on the Bureau's Sun Workstation.

Equipment Used in Data Manipulation

Pennsylvania Geological Survey geologists and summer interns digitized line data used in this Coal Availability Study by using a GTCO Corporation Digi-pad 5A® 24 by 36 inch digitizing table and the U.S. Geological Survey geologic map preparation software, GSMAP-version 8 (Selner and Taylor, 1992).

Access to Pennsylvania's point data in the NCRDS, which is stored on a U.S. Geological Survey Sun Microsystems fileserver, was through a Sun SPARCstation 2® workstation computer with an Internet connection located at the Bureau's midtown Harrisburg office (moved in 2001 to Middletown, Pa.). The Pennsylvania Geological Survey's Sun workstation is locally connected to a high-speed local area/wide area network (LAN/WAN) with access to the Internet provided via a Department of Environmental Protection (formerly Department of Environmental Resources) server located in downtown Harrisburg, which connects to a node provided by Verizon/Bell Atlantic-PA. A noncommercial service provider called PREPnet (recently acquired by Veriocity) provides the Internet service beyond that node.

Calculations of Original, Mined, Remaining, and Available Resources

Concept

The original coal resource for the Hackett quadrangle was calculated using the U.S. Geological Survey's modified GRASS resource script, which is modeled after criteria developed by Wood and others (1983) and published in U.S. Geological Survey Information Circular 891. The objective of Circular 891 is to provide a method of characterizing the certainty of a resource in a consistent manner. Several levels of confidence are possible, with a lesser degree of certainty occurring with progressively farther distance away from a data point of known value. For Coal Availability this measurement of confidence in the resource is classified as *measured* for a distance of 0.25 mile from a data point, *indicated* for a distance of 0.25-0.75 mile from a data point, *inferred* for a distance of 0.75-3.0 miles from a data point, and *hypothetical* for a distance of greater than 3.0 miles from a data point. Therefore, when reading the data tables in this report, expect the most confidence in a value determined for any "measured" or "indicated" tonnages and much less confidence in the tonnages calculated for an "inferred" or "hypothetical" value.

Coal-bed resources include all coal found within the measured, indicated, inferred, and hypothetical categories without any regard to economic considerations.

As defined by the USGS in Circular 891, original resources represent coal greater than 14 inches thick. GRASS automatically factors this requirement into its calculation of original resources of a coal bed.

Remaining resources can be calculated once original resources are known. Tonnages of surface-mined and deep-mined coal are calculated by totaling individual (digitized) mined-out areas (raster files). These extracted coal tonnages reflect the total of coal mined out and coal lost in mining for the quadrangle. Remaining coal resources (raster) for each coal bed can be easily calculated in GRASS by subtracting the mined-out areas (raster) total from the original resource (raster) total.

Each of the digitized data layers, which represents a type of restriction, was rasterized and individually subtracted from the remaining resource raster files in GRASS and totaled using Perl scripts for each coal bed. First, this was done for the surface-mining category, i.e., overburden less than 200 feet, and then it was done for the deep-mining category, i.e., overburden greater than 200 feet. The resultant individual restriction tonnages and their summation are shown on Table 1 in the main body of this report. Because they are individual totals, these tonnages depict a greater amount of coal excluded when compared to the restriction tonnages given in the tables in the appendices. However, because restrictions can overlap, the restricted resource total on a coal bed is not necessarily equal to the sum of the individual restrictions. Fortunately, GRASS adequately accounts for the effect of these overlapping restrictions, usually by taking the largest overlapping restriction total and placing it in the tables while ignoring the smaller overlaps. A more accurate restriction value is the result. The actual land-use and technological restriction totals in GRASS-generated v_*.tab output files, which are also used to create the tables found in the appendices, are based upon that factoring in of any overlapping restrictions and may have a different value from that of the tables in Appendix B. This “corrected” total is subtracted from the remaining resource by the Perl scripts for each coal bed and category in the final tally to arrive at an available resource.

Application

Available resource tonnages are summarized in Table 2 and are illustrated as a series of pie charts in Appendix A. Note in Table 2 that the categories 0-200 feet and >200 feet are provided as a convenient way to segregate tonnage values for surface-mined and deep-mined coals. See the individual coal-bed summary tables in Appendix B for a more thorough break-down of coal-bed resource tonnages using the measured, indicated, inferred, and hypothetical categories of resource classification for original, mined-out, remaining, and available coal.