OFS 1997-10

Availability of Coal Resources for Mining in Illinois

Augusta, Kewanee North, Mascoutah, Pinckneyville, and Roodhouse East Quadrangles, Adams, Brown, Greene, Henry, Perry, Schuyler, and St. Clair Counties

Colin G. Treworgy, Cheri A. Chenoweth, Jamie L. McBeth, and Christopher P. Korose

Open File Series 1997- 10

Department of Natural Resources
ILLINOIS STATE GEOLOGICAL SURVEY
William W. Shilts, Chief

Natural Resources Building
615 East Peabody Drive
Champaign, Illinois 61820-6964
(217) 333-4747

CONTENTS

EXECUTIVE SUMMARY

This report is one of a series examining the availability of coal resources for mining in Illinois. It describes mapping of coal resources and related geologic features in five quadrangles (Kewanee North, Augusta, Roodhouse East, Mascoutah, and Pinckneyville) along the western margin of the Illinois Basin Coal Field. Coal company and State government experts were interviewed to determine how regulatory restrictions, cultural features, mining technology, and geologic, economic, and environmental conditions affect resource availability in the five quadrangles. Conditions in the Augusta, Kewanee North, and Roodhouse East Quadrangles are representative of mining conditions associated with the Colchester Coal in western Illinois. Conditions in the Kewanee North Quadrangle are also representative of some of the conditions associated with the Herrin and Danville Coals. Many of the conditions typical of mining in the southwestern part of the coal field are present in the Mascoutah and Pinckneyville Quadrangles.

The tonnage of the original coal resources and the percentage available for mining in each quadrangle are shown in table 1. Technical factors such as stripping ratio, thickness of unconsolidated and bedrock overburden, floodplains, and block size restrict the availability of 19% to 64% of the resources in each quadrangle. Land-use features (towns, roads, railroads, cemeteries, abandoned mines) restrict another 10% to 29%. Less than 1% to 18% of the original resources has been mined out. On a per seam basis, the Herrin Coal has the highest percentage available for mining: 49%. The availability of Danville, Springfield, Colchester, and Murphysboro Coals ranges from 15% to 28% of original resources. If surface-mined in combination with the Herrin Coal, the availability of the Danville and Springfield resources rises to more than 43%. The higher percentage of available Herrin Coal resources reflects the greater thickness and excellent mining conditions of this seam.

Table 1 Summary of the original resources and their availability for mining in the Augusta, Kewanee North, Mascoutah, Pinckneyville, and Roodhouse East Quadrangles; millions of tons and (percent of original resources).

Quadrangle	Original	Mined out	Available	Technical	Land use
Augusta	76	2 (2)	18 (24)	48 (64)	7 (10)
Kewanee North	129	8 (6)	52 (40)	32 (25)	37 (29)
Mascoutah	462	60 (13)	182 (39)	177 (38)	43 (9)
Pinckneyville	723	131 (18)	369 (51)	129 (18)	95 (13)
Roodhouse East	90	<1 (<1)	30 (34)	47 (53)	12 (13)

The assessment of the Augusta, Kewanee North, and Roodhouse East Quadrangles suggests that less than 25% of the Colchester Coal in western Illinois may be available for mining. Land use probably restricts mining of about 10% of these resources, and technical factors such as high stripping ratio and thick unconsolidated overburden restrict more than 70%.

The assessments of the Mascoutah and Pinckneyville Quadrangles together with an earlier assessment of the Collinsville Quadrangle indicate excellent conditions for underground mining of the substantial Herrin Coal resource in southwestern Illinois, but that this extraction method will result in lost opportunities for mining Danville and Springfield Coals . The presence of relatively thick limestone beds in the overburden of the Herrin Coal permits underground mining of these resources at much shallower depths than is possible in other parts of the state: as little as 35 feet of bedrock cover is needed. Based on the experience of several companies mining in this region, it appears that underground mining will be the preferred method for mining much of the remaining shallow (<150 ft deep) resources of Herrin Coal that has been traditionally classified as surface minable. Danville and Springfield Coals that are not by themselves available for mining because of such factors as block size or stripping ratio but would be if surface-mined in combination with the Herrin Coal, are thus unavailable. Although conditions associated with underground mining of the Herrin Coal are generally excellent, significant resources are restricted from mining where thick unconsolidated sediment overlies relatively thin bedrock, particularly in the floodplain of the Kaskaskia River and associated tributaries. Expansion of communities adjacent to the St. Louis metropolitan area is also becoming a significant limitation on mining in that area.

INTRODUCTION

Accurate estimates of the amount of coal resources available for mining are needed for planning by federal and state agencies, local communities, utilities, mining companies, companies supplying goods and services to the mining industry, and other energy consumers and producers. Current inventories of coal resources in Illinois provide relatively accurate estimates of the total amount of coal in the ground (e.g. Treworgy et al. 1997), but the actual percentage that is minable is unknown. Environmental and regulatory restrictions, the presence of towns and other cultural features, current mining technology, geologic conditions, and other factors significantly reduce the amount of coal available for mining.

Recognizing the difference between the reported tonnage and the tonnage of actually minable coal, the United States Geological Survey (USGS) initiated a program in the late 1980s to assess the amount of available coal in the United States (Eggleston 1990). As part of this ongoing, cooperative effort, the Illinois State Geological Survey (ISGS) is assessing the availability of coal resources for future mining in Illinois. This report assesses the availability of coal resources in five quadrangles: Augusta, Kewanee North, Mascoutah, Pinckneyville, and Roodhouse East (fig. 1). It also discusses the implications of these findings to the availability of coal for mining in larger regions of the state. The background of this program and a detailed description of the framework for the investigations in Illinois are provided in previous reports (e.g. Treworgy et al. 1994).

Selection of Quadrangles

Treworgy et al. (1994) divided Illinois into seven regions, each representing a distinct combination of geologic and physiographic characteristics (fig. 1), and selected two to four quadrangles representative of the mining conditions in each region. Quadrangle selection and resource assessment both focus on resources that have the highest potential for development (e.g. thick or lower sulfur content seams). This approach ensures that the most economically important deposits receive sufficient study and that little time is spent on coal that is unlikely to ever become available for mining.

Maps at 1:24,000-scale of the major coal seams, related geology, mines, and land use in each quadrangle were compiled based on previous regional investigations of mining conditions, resources, and geology. These maps provided the basis for detailed discussions with experts from mining companies, consulting firms, and government agencies active in the Illinois mining industry to identify the factors that affect the availability of coal in each quadrangle. Each quadrangle was discussed with three or more experts to develop a set of criteria defining available coal. These rules were then applied to each quadrangle to calculate the available resources and identify the factors that restrict significant quantities of resources from being minable.

The quadrangles studied for this report are distributed along the western edge of the Illinois Basin Coal Field and provide a broad cross section of the geologic and physiographic characteristics associated with mining of the major coals in this area. The Augusta and Roodhouse East Quadrangles represent mining conditions associated with the Colchester Coal at the western margin of the basin. The Kewanee North Quadrangle is the second of three quadrangles selected as representative of conditions along the crop of the Danville and Herrin Coals in the northwestern part of the basin. The first of these quadrangles, Princeville, was studied earlier (Treworgy et al. 1996a) and the third, Peoria West, will be completed in the next study. The Mascoutah and Pinckneyville Quadrangles represent conditions associated with surface and shallow underground mining of the Herrin Coal in southwestern Illinois. The Pinckneyville Quadrangle also includes assessments of the Danville, Springfield, and Murphysboro Coals in this area.

Coal Resource Classification System

The ISGS follows the terms and definitions of the USGS coal resource classification system (Wood et al. 1983). With minor modifications to suit local conditions, these definitions provide a standardized basis for compilations and comparisons of nationwide coal resources and reserves.

The term “original resources” refers to the amount of coal resources originally in the ground prior to any mining. The ISGS has traditionally defined resources as all coal in the ground that is 18 or more inches in thickness and less than 150 feet deep, or all coal 28 or more inches. This definition was modified for

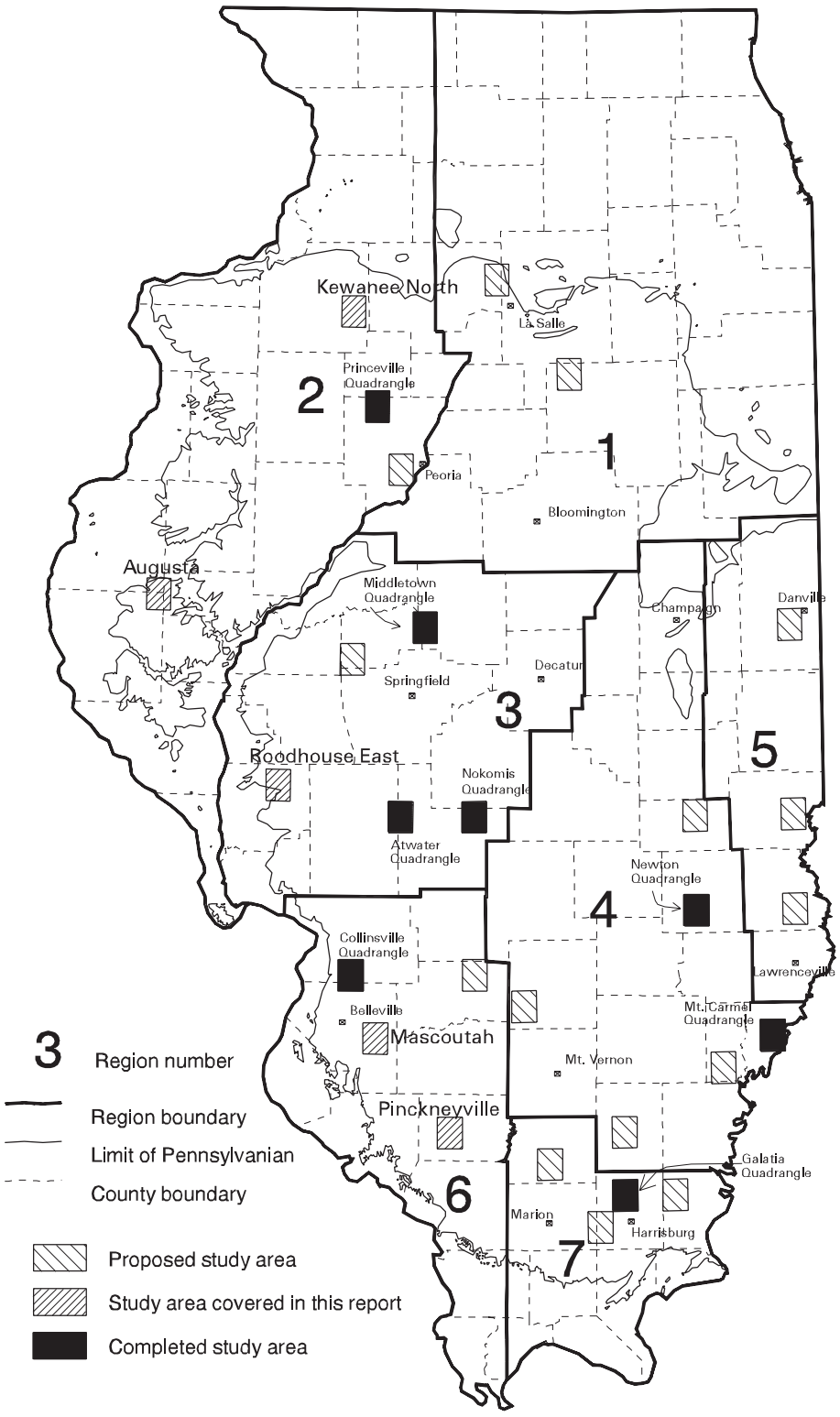

Figure 1 Coal resource regions and quadrangle study areas.

this report to include coal less than 200 feet deep and at least 12 inches thick. Also, in the case of Danville Coal in the Pinckneyville Quadrangle, coal as thin as 6 inches that was mined out or available for surface mining was included in the tabulation of original resources. These modifications were made to provide consistency with our estimates of original and available resources in the quadrangles previously studied.

The term “available coal” is not a formal part of the USGS system, although it is commonly used by the USGS and many State Geological Surveys. Available coal, as used in this report, does not imply that particular coal deposits can be mined economically at the present time. Rather, the term designates deposits that have no significant characteristics likely to make them technically, legally, or economically unminable for the foreseeable future. Determining the actual cost and profitability of these deposits will require further engineering and marketing assessments.

Sources of Data

Geologic data for this study were compiled from drill logs and records of mines. Mine boundaries were compiled from the best available mine map for each mine. In cases where no map was available, the location of the mine was marked with a point symbol and, if possible, the general area of mining was delineated. Surface elevations were acquired from USGS 7.5-minute topographic maps. Information on land cover features such as cemeteries, roads, railroads, and towns were compiled from topographic maps or extracted from USGS Digital Line Graph files. All major surface features were verified by field reconnaissance.

Previous Investigations

The ISGS has evaluated the availability of coal resources in eight other quadrangles located in the northwestern, central, and southern parts of the state (Treworgy et al. 1994, Treworgy et al. 1995, Jacobson et al. 1996, and Treworgy et al. 1996a, 1996b). Sixteen coal seams have been assessed in these studies. The coal available for mining in each quadrangle, has ranged from 18 to 79% of the original resources.

Each quadrangle represents a different geologic and geographic setting in Illinois and each quadrangle study identifies and defines factors that influence the availability of resources in that setting. Some factors, such as roof conditions, are different for each seam while other factors, such as minimum seam thickness, are applicable to all seams. Some factors, such as cemeteries, have the same effect on mining throughout the state while the effects of other factors, such as roads, are dependent on the region of the state and value of the underlying coal.

FACTORS AFFECTING THE AVAILABILITY OF COAL

Most factors that restrict mining are based on economic and social considerations and are not absolute restrictions on mining. Companies can choose to mine in areas of severe roof or floor conditions if they are willing to bear the higher operating costs, interruptions and delays in production, and lower employee morale that result from operating in these conditions. It is possible to surface mine through most roads and undermine small towns if a company is willing to invest the time and expense necessary to gain approval from the appropriate governing units and individual landowners, and to mitigate damages. Previous economic and social conditions have at times enabled companies to mine in areas where some factors are now restrictive. The current highly competitive price environment in the coal industry, which makes coal that is more expensive to mine uneconomic, is expected to prevail in the Illinois Basin indefinitely. Therefore, the criteria used to determine available coal for this report are likely to cover mining conditions for the foreseeable future.

The following factors defining available coal in the five quadrangles are a composite set of rules based on our interviews with mining companies (table 2).

Depth of Seam

All other factors being equal, shallower coals are less expensive to mine. However, for the depth range of the coals in these five quadrangles (all less than 300 feet deep), depth alone does not limit the availability of the coal. Depending on their thickness, coals less than 175 to 200 feet deep can be

Table 2 Criteria used to define available coal in the Augusta, Kewanee North, Mascoutah, Pinckneyville, and Roodhouse East Quadrangles.

Surface Mining

- Minimum seam thickness
  - Main seam: 1 ft
    - Overlying seams: 0.5 ft
  - Underlying seams: 1 ft
- Maximum depth: 200 ft
- Maximum glacial and alluvial overburden: see table 3
- Stripping ratio (cubic yards of overburden/ton of coal)
  - Maximum: 25:1
  - Maximum average: 20:1
- Minimum size of mine reserve (salable tons)
  - Cumulative tonnage needed to support a mine and preparation plant: 10 million tons
  - Individual block size:
    - Less than 40 ft of overburden: 150 thousand tons
    - More than 40 ft of overburden: 500 thousand tons
- Land use restrictions
  - 100 ft buffer:
    - Cemeteries
    - Railroads
    - State highways
    - Other paved roads (Augusta, Kewanee North, Roodhouse East only)
    - State parks
  - 200 ft buffer: Large underground mines
  - 500 ft buffer: Subdivisions
  - 2,640 ft buffer: Towns

Underground Mining

- Minimum seam thickness: 3.5 ft
- Minimum bedrock cover:
  - Mascoutah and Pinckneyville: 35 ft
  - Kewanee North: 40 ft
- Minimum size of mining block (clean coal): 20 million tons
- Land use restrictions
  - 200 ft buffer: Abandoned mines
  - 100 ft buffer or 45 degree angle of draw:
    - Towns
    - Churches and schools
    - Cemeteries
    - Dams
    - Parks
    - Railroads (special case on Pinckneyville Quadrangle only)
    - Roads (selected cases)
  - Limited extraction under floodplains

mined by either surface methods or underground methods (provided there is sufficient bedrock cover). The choice of surface or underground methods will depend on the comparative cost of extraction and the overall character of a company's reserves at a specific site. For example, if a company's reserve block is primarily deeper than 150 feet, it may elect to mine all of the coal by underground methods. Coals may be unavailable for surface mining due to their stripping ratio, a function of depth and thickness. This parameter is discussed separately below.

Thickness of Seam

For this study, 3.5 feet is the minimum thickness of available coal for underground mining. Mining thinner seams is unfeasible because larger reserve blocks are required, movement of miners and equipment is more difficult, the yield of clean coal per ton of material mined is lower, and the tonnage produced per mining cycle is reduced. These factors make it difficult to extract coal at a rate necessary to recover the capital investment in facilities for a modern underground mine.

The minimum thickness of coal for surface mining is 1 foot for the lowermost seam in an interval to be mined and 0.5 feet for overlying seams within the interval. Thinner seams are impractical to recover because the amount of out-of-seam dilution becomes too great a percentage of the material handled.

Stripping Ratio

The stripping ratio is the ratio of cubic yards of overburden that must be removed to recover one ton of coal. Whereas the thickness and depth of coal that can be economically mined are controlled in part by technical factors such as mining equipment, the maximum stripping ratio is strictly an economic limit. Coals with high stripping ratios may be more economical to mine by underground methods or may remain unmined until the market price for coal rises relative to production costs.

Companies calculate stripping ratios on the basis of the anticipated tonnage of clean coal that will be produced. This calculation requires assumptions about the type and performance of mining and washing equipment to be used, as well as tests of the washability of the coal. For this study, the stripping ratios are based on the tonnage of in-place coal excluding partings and are probably 5 to 15 percent higher than the actual tonnage of clean coal because mining and cleaning losses are not accounted for in the model.

Some companies use a "swell factor" to account for the increase in volume of overburden after it is blasted. Swell factors for lithologies typically encountered in Illinois mines range from 1 (no swell) for sand to 1.7 for shale (Allsman and Yopes 1973). Although this is a large range, this swell factor requires such site-specific knowledge of the quantities of different lithologies in the overburden (e.g. shale, limestone, sand, clay), we could not use it in our calculations. Cubic yards of overburden were calculated simply from the total thickness of consolidated and unconsolidated material overlying the coal.

For this study, the maximum stripping ratio adopted for available coal was 25 cubic yards of overburden per ton of in-place coal (25:1). The maximum average stripping ratio for any mining block was 20:1. Because we have not used clean coal tonnages or swell factors, these ratios are higher than the limits currently used by most companies.

Thickness of Bedrock and Unconsolidated Overburden

Underground Mining Underground mining requires adequate bedrock overburden to support the mine roof and seal the mine from water seeping down from the surface. If the bedrock cover is too thin (or significantly weathered), the mine roof may not be strong enough to support the overburden. Weak underclay, which can block mine entries and make the roof unstable by squeezing out from under pillars, is associated with thin bedrock conditions. Unconsolidated overburden material (glacial drift and alluvium) is not self-supporting and can add considerable pressure to the mine roof and pillars.

In addition to the dangers and expense of roof failures and floor squeezes, fractures resulting from mine roof failure may extend to the bedrock surface and allow water to enter the mine. At best, water seepage makes the movement of equipment more difficult and creates additional expenses for pumping and disposing of the water. In the worst case, the influx of water is rapid and equipment may be damaged

and the lives of miners threatened. In 1883, 69 miners drowned in the Diamond Mine near Braidwood. Other, less serious, cases of mine flooding have occurred over the years.

A conservative rule used by some companies and likely to guarantee good mining conditions is that the thickness of bedrock overburden should exceed the thickness of unconsolidated overburden. However, the amount of bedrock required can vary, depending on local geologic conditions such as the depth of the seam, composition of the bedrock overburden, and thickness of the glacial overburden.

Based on our interviews, the minimum thickness of bedrock for underground mining in the Mascoutah and Pinckneyville study areas is 35 feet. This is considerably thinner than the minimum of 75 feet we reported for our earlier study of the Middletown Quadrangle. In southwestern Illinois, one or more limestone members—the Brereton, Conant, Bankston Fork, and Piasa Limestones—commonly overlie the Herrin Coal. Total thickness of limestone over the coal is generally in excess of 15 feet. Because limestone has greater strength than shale, for example, a greater proportion of limestone in the bedrock means less bedrock is needed than might otherwise be the case. Mines have operated over small areas with less than 35 feet of bedrock, but roof and floor problems and even partial flooding of one mine are known to have occurred under these conditions.

The overburden of the Herrin Coal in the Kewanee North Quadrangle has less limestone than in the Mascoutah and Pinckneyville Quadrangles. However, a sandstone unit is present in the overburden in much of the quadrangle and the overlying unconsolidated material is generally less than 60 feet thick. For these reasons a minimum bedrock thickness of 40 feet was used. This minimum is slightly above that of the more competent bedrock of the Mascoutah and Pinckneyville Quadrangles, but well below the 75 foot minimum used in the Middletown Quadrangle, where the roof and floor strata are known to be weak and the unconsolidated deposits are 100 to more than 200 feet thick. No minimum bedrock thickness was considered in the Augusta and Roodhouse East Quadrangles, because the thinner coal seams in these quadrangles are available by surface mining methods only.

Surface Mining. Thick deposits of glacial drift or alluvial sediment can restrict surface mining because of their tendency to slump into the pit, fail under the weight of large draglines, and provide a path for groundwater movement into the pit. A minimum amount of bedrock overburden is needed to ensure that the coal is not weathered, and to provide stable material to hold the toe of the spoil pile. The maximum thickness of unconsolidated material that can be handled is dependent on the lithologic composition of the overburden, its physical properties (e.g. load bearing capacity, permeability), and the presence or absence of groundwater. The minimum bedrock and maximum glacial drift thicknesses that were handled by the companies we interviewed also depended on the mining plan and the type of equipment they were using to remove overburden.

We did not compile sufficient information to assess the lithology and physical properties of the unconsolidated sediment in the quadrangles studied. The experience of the companies suggests that for overburden of 50 feet or less a minimum of 10 feet of bedrock cover is needed. For overburden of more than 50 to 100 feet, one-third to one-half the material should be bedrock (table 3). The maximum thickness of unconsolidated overburden that can be handled over a large mining area is approximately 50 feet. Small areas of thicker unconsolidated overburden can be mined, but large areas of thick unconsolidated overburden will be avoided.

Table 3 Minimum thickness of bedrock and maximum thickness of unconsolidated deposits surface-minable for specified thicknesses of overburden (feet).

Overburden	Minimum bedrock	Maximum unconsolidated
10	10	0
20	10	10
30	10	20
40	10	30
50	10	40
60	20	40
70	23	47
80	30	50
90	40	50
>100	50	50

Floodplains

There are no laws specifically prohibiting underground or surface mining in floodplains. As with mining in any area, companies must ensure that their mining activities do not cause environmental damage or safety hazards. Both surface and underground mines have operated safely within the floodplains of streams and major rivers such as the Illinois and Wabash. The ability to mine under floodplains depends in part on the depth of the coal and the nature of the strata overlying the coal.

It is likely that the floodplains of Silver Creek and the Kaskaskia River in the Mascoutah Quadrangle and Little Galum Creek in the Pinckneyville Quadrangle will limit extraction of coal. The sediments in the Kaskaskia River floodplain, and probably the Silver Creek floodplain, are capable of yielding moderate to large supplies of groundwater (Bergstrom 1975). Although mining can take place within these floodplains if the minimum thickness of bedrock is present, high extraction mining methods will cause subsidence and cracking of the bedrock strata and will open fractures leading to the overlying unconsolidated sediments. In our assessment we assumed that companies will limit extraction to 50% of the coal to avoid the risks and expense of subsiding the surface within the floodplains in these quadrangles. Assuming that high-extraction methods would have recovered 70% of the coal in place, limiting extraction reduces the available coal in the floodplains to 50%.

Size and Configuration of Mining Block

A mine reserve must contain sufficient tonnage to allow companies to recover the costs of developing a mine (e.g. drilling, land acquisition, construction of surface facilities, initial box cuts and shafts, and purchase of equipment). Because of lower development costs, greater equipment mobility, and flexibility in operating plans, surface mines can be developed with smaller reserves and mining blocks than underground mines. Surface mines can be developed using trucks and earthmoving equipment that can be readily transported to the site.

Although there are exceptions, most Illinois coals are cleaned to some degree before final shipment. The coal can be trucked from the mine pit over the existing road network to a central preparation plant. The minimum reserve for a surface mine is 10 million saleable tons. This is equivalent to about 12.5 million tons of raw coal in place. The reserve may be distributed among a number of adjacent blocks. Each mining block should contain at least 150 thousand tons of saleable coal if the coal is less than 40 feet deep or 500 thousand tons if the coal is greater than 40 feet deep.

Because of the shallow depth of coal in these quadrangles, underground mines can be opened from a highwall, boxcut, or shallow slope and exploratory drilling will be relatively inexpensive. The minimum reserve block for an underground mine in these quadrangles is 20 million clean tons (equivalent to approximately 40 million tons in place). This is considerably smaller then the reserve size needed in quadrangles where the coal is deeper. In other quadrangle studies we have used a minimum reserve size of 80 to 100 million tons in place.

Mine blocks must have dimensions that are suitable for layout of a mine. Narrow blocks of coal with convoluted shapes (such as between abandoned mines or other barriers) cannot be safely and economically mined by underground mining methods.

Quality of Coal

The quality of the coal has a great influence on its marketability, but generally not on its technical minability. For example, coals with low sulfur and chlorine content and high heat content are more marketable than coals with high sulfur and chlorine content and lower heat content. In some cases, a premium quality coal may command a high enough price to allow companies to absorb the higher cost of mining under unfavorable geologic conditions. The coals in the quadrangles studied for this report are, with the exception of the Murphysboro Coal, similar in quality to the majority of coal resources found in the state. The Murphysboro Coal is believed to have a sulfur content of perhaps as low as 1%. Although the market demand for lower sulfur coals is currently higher than for high sulfur coals, the price paid for lower sulfur coals is not appreciably higher. Therefore, quality variations between individual coals were not considered in evaluating the availability of coals in these quadrangles.

Surface Features

Although any surface feature can be undermined or mined through if a company obtains permission from the owner and agrees to repair damages, companies generally find it impractical to mine under or through certain features because of the expense of restoring the feature or the social and political hurdles required to obtain the necessary permission. Limited extraction may take place under small towns such as Conant on the Pinckneyville Quadrangle. However, unless such an area is crucial to development of the mine layout, it will generally be avoided. This study considers all coal under towns, schools, churches, levees, dams, public parks, and cemeteries as unavailable for mining, and coal under rural subdivisions and railroads as unavailable for surface mining.

A number of companies that we interviewed do not mine under railroads. However, in recent years, at least two longwall mines in Illinois, the Monterey No. 1 Mine and the Orient No. 6 Mine, have extracted coal underlying railroads. This study thus considers coal underlying railroads to be available for underground mining. One exception is the Herrin Coal resources underlying the Missouri Pacific track running east-west across the middle of the Pinckneyville Quadrangle, where the active mine in the vicinity has been laid out with its production panels just south of and parallel to the track. Given this mine configuration it is unlikely that future mines in this area will be designed to cross under the tracks.

Roads are treated in different ways depending on their classification, location and the value of coal beneath them. Interstate highways are the only significant road restriction for underground mining. For other types of roads, companies can either arrange to subside them and repair the damage or leave pillars of sufficient size to prevent subsidence. Roads can be a significant barrier to surface mining. Because of local opposition to mining and the relatively low value of coal beneath roads (because of seam thickness), most roads in the western and northwestern parts of the state (e.g. Augusta, Kewanee North, and Roodhouse East Quadrangles), are considered a restriction to surface mining. In southern Illinois, the general acceptance of surface mining by the local population and the higher tonnage of coal per acre make it feasible for companies to surface mine through lightly used roads. We considered only state highways to be a restriction to surface mining in the Mascoutah and Pinckneyville Quadrangles.

A buffer of unmined coal must be left around any property or surface feature that cannot be disturbed. The size of the buffer depends on the depth and thickness of the coal, the composition of the overburden, and the angle of draw used to calculate the area that could be affected by subsidence from underground mining. For both surface and underground mining we used a 100 foot buffer for churches and schools. For underground mining, we used a 200-foot buffer for towns and cemeteries. In practice, the required buffer might be slightly smaller where the coal is shallow and larger where the coal is deeper. Surface mining requires a larger buffer around towns because of the potential disturbance by dust, vibrations from blasting, and disruption of water wells. We used a buffer of 500 feet around rural subdivisions and a half mile around towns.

Abandoned Mine Workings

Illinois law requires that companies leave an unmined barrier of coal 200 feet wide around abandoned underground mine workings. Exceptions can be made for surface mining of areas previously mined by underground methods. Surface mines have in many instances mined through all or portions of small abandoned underground mines. This may be done because the extent of the underground workings is not known or the area of the underground workings is so small that it is not worth the expense of diverting the surface operation around it. For example, the Augusta Quadrangle contains a number of small, unmapped underground mines within blocks that are otherwise suited for surface mining. It is likely that surface mining would proceed in these areas with the expectation that the tonnage recovered will be reduced by the amount of coal removed by the previous mining.

Companies generally avoid large abandoned underground mines when surface mining because the amount of recoverable coal is significantly reduced and there is a potential for large quantities of water to be present in the abandoned mine.

AVAILABLE RESOURCES

Availability of Colchester Coal in the Augusta and Roodhouse East Quadrangles, Western Illinois

The Augusta and Roodhouse East Quadrangles are representative of mining conditions associated with the Colchester (No. 2) Coal in western Illinois (regions 2 and 3; fig. 1). The Colchester Coal is present throughout large areas of these regions, but more than 90% of the seam is 3 feet or less in thickness. The coal was mined in underground mines in western Illinois from the early 19th century to the 1950s, but large-scale extraction occurred only when surface mining came to the area in the 1920s. For the past 20 years, total annual production from surface mines in the Colchester Coal in these regions has been on the order of 1 million tons. Total resources of Colchester Coal remaining in regions 2 and 3 are about 9 billion tons, of which 6 billion tons are surface minable (less than 150 feet deep).

The Colchester Coal was mined underground at several locations south of the town of Augusta and east of the town of Roodhouse. These mines likely operated only for local trade, excavated only a small area, and had been abandoned by the early 1940s. Surface mining began in the Augusta Quadrangle in the 1920s and continued until 1969. Several hundred acres of land were surface-mined just south of the town of Augusta and further south along Cedar Creek. In recent years the Black Beauty Coal Company has mined the Colchester Coal adjacent to the Augusta Quadrangle. The only surface mine in the Roodhouse East Quadrangle was operated by the Birch Creek Coal Company from 1950 to 1967.

Land Cover The land cover in the Augusta and Roodhouse East Quadrangles is largely rural, as is typical of the area underlain by the Colchester Coal in regions 2 and 3 (figs. 2 and 3). Upland areas are broad, flat-lying, and are used mainly for row crop farming and pasture. Steep-sided valleys and narrow wooded zones are common along streams and rivers. The glacial drift is less than 50 feet thick over wide areas, but more than 100 feet thick in buried bedrock valleys. The Augusta Quadrangle contains the towns of Augusta (population ~600) and La Prairie. Most of the town of Augusta lies outside of the outcrop of the Colchester Coal. The Roodhouse East Quadrangle contains the towns of Roodhouse (population ~2,100) and Wrights. The road network, although well developed, consists of light duty, 2-lane paved and unpaved roads. A single rail line crosses a portion of both quadrangles. The Weinborg-King State Park occupies the northeast corner of the Augusta Quadrangle.

Geology and Coal Resources The youngest bedrock strata in the Augusta Quadrangle are in the lower part of the Carbondale Formation (fig. 4). The entire Carbondale Formation may be present in the Roodhouse East Quadrangle (fig. 5). The Colchester Coal is the only mapped resource in both quadrangles and is commonly 1.5 to 2.5 feet thick (figs. 6 and 7). Locally the coal thickens to slightly more than 3 feet. Where present in the Roodhouse East Quadrangle, the Colchester is at least 1.5 feet thick, but in the Augusta Quadrangle the coal thins to as little as a few inches or is missing. Some of the reported areas of thin coal may be clay dikes or erosion of the coal by channels contemporaneous with or slightly later than the peat deposition. The coal is partially or completely eroded and replaced by Pennsylvanian sandstone in a large area in the northeast quarter of the Augusta Quadrangle. Drill holes have encountered multiple benches of coal inter-layered with sandstone. This suggests that the channel was contemporaneous with peat deposition. However, in one mine just to the east, the coal is known to be eroded by a younger Pennsylvanian channel.

The tonnage of coal resources is reduced by half in areas known or suspected to have been mined by small underground operations. Because of the relatively small size and imprecisely defined extent of these workings, and the location of the workings within the block of remaining resources, it is assumed that it would be more expedient for a surface mine to excavate the abandoned underground mines and recover the pillars rather than attempt to circumvent the mined areas.

The Colchester Coal is less than 125 feet deep in the Augusta Quadrangle and less than 150 feet deep in the Roodhouse East Quadrangle (figs. 8 and 9). Stripping ratios of less than 10:1 are found only in narrow bands along stream valleys (figs. 10 and 11). Less than half the coal on the quadrangles has a stripping ratio of less than 30:1. Pre-glacial erosion of the bedrock is largely responsible for the areas where the coal is now missing. The pre-glacial topography has been concealed by tens of feet of

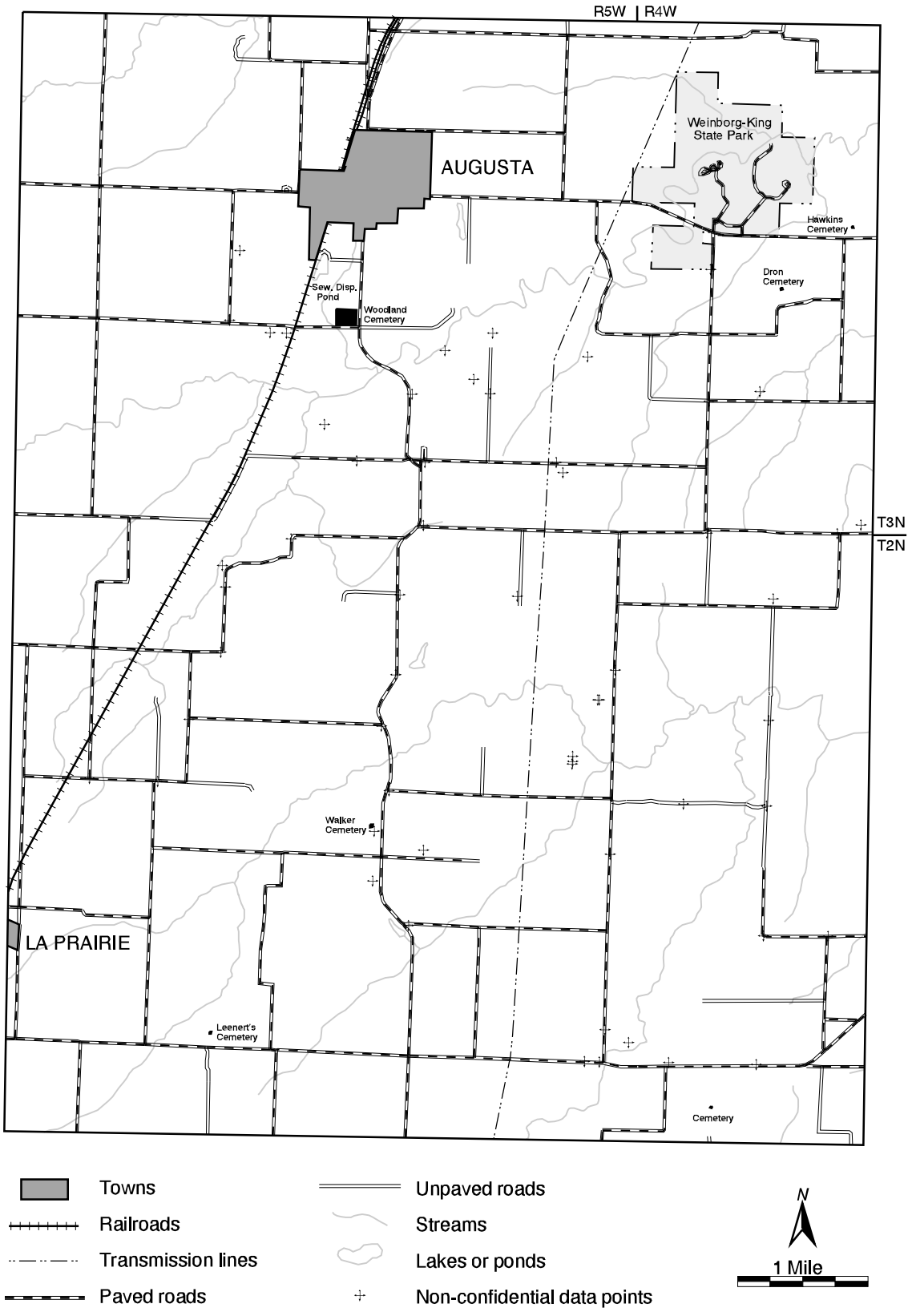

Figure 2 Surface features, Augusta Quadrangle.

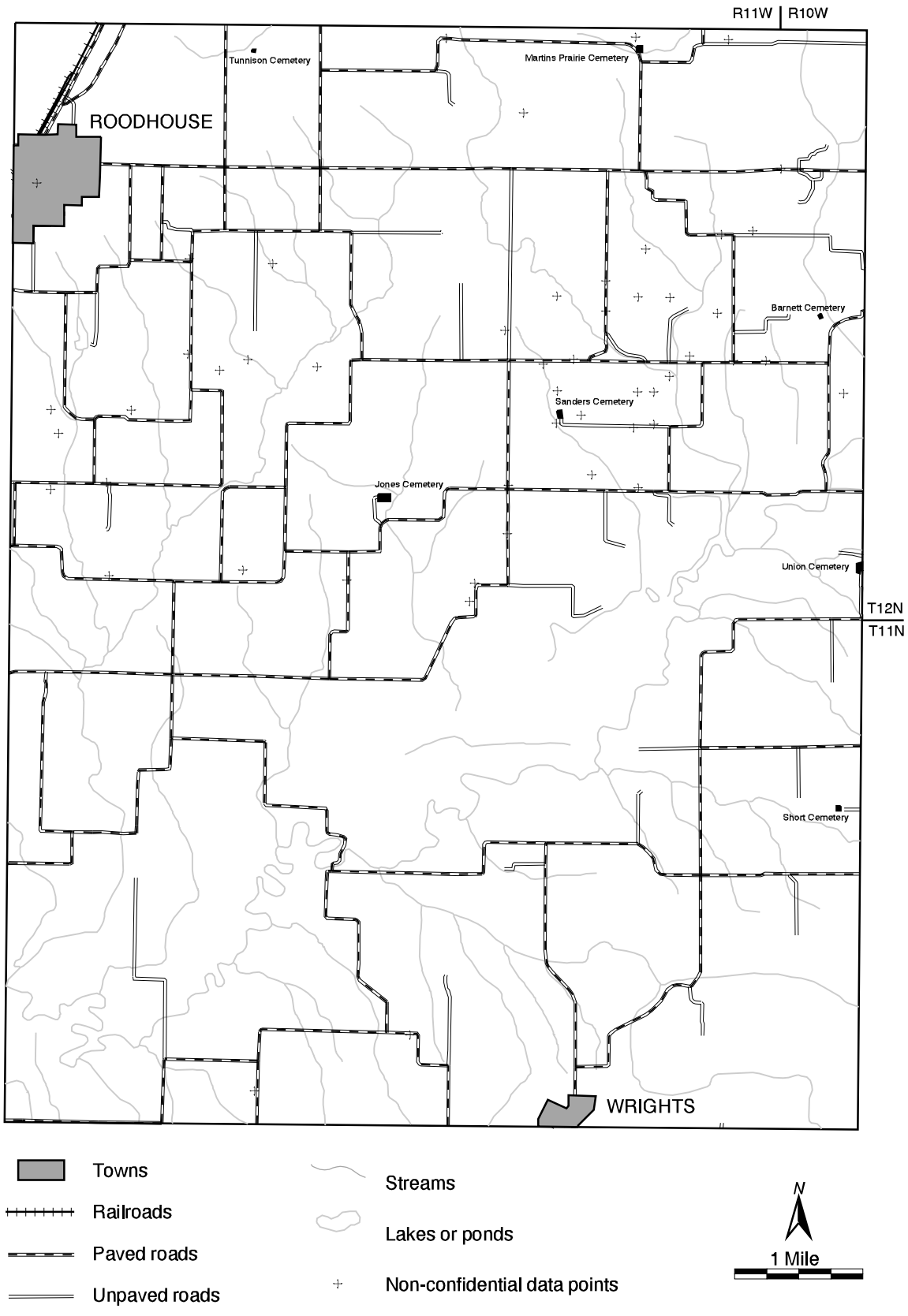

Figure 3 Surface features, Roodhouse East Quadrangle.

glacial drift and alluvium, and outcrops of the coal are only visible in areas where recent stream erosion has cut down through the recent sediments. In most areas the exact position of the crop can only be determined by closely spaced drilling.

A coal known as the Roodhouse Coal was mined in a small area east of the town of Roodhouse. Although the coal was reported to be as much as 9 feet thick, it has not been identified away from the mine area and is thought to be a local deposit. The Herrin Coal, 2 to 4 feet thick, is present just to the north and southeast of the Roodhouse East Quadrangle. The coal may be locally present in the quadrangle. No resources of these coals have been mapped.

Availability of Coal Colchester Coal resources in the Augusta and Roodhouse East Quadrangles are too thin to be available for underground mining as it is now practiced in Illinois. Surface mining is the only method likely to be used for mining these resources for the foreseeable future. Available surface-minable coal amounts to 24% of the original resources in the Augusta Quadrangle and 34% of the original resources in the Roodhouse East Quadrangle (table 4, figs. 12 and 13). The available coal is found in linear deposits that parallel the outcrops (figs. 14 and 15). Unfavorable stripping ratio is the major restriction on the availability of resources, affecting more than 50% of the resources in both quadrangles. Land use was the only other major restriction, affecting 10 to 13 percent of the resources. About 16% of the resources in the Augusta Quadrangle are unavailable due to the thickness of the glacial and alluvial overburden. Although areas of thick glacial sediment are present in the Roodhouse East Quadrangle, they are either in areas that are small enough to be mined or within the area restricted by the town of Roodhouse. About 1 to 2% of the resources in both quadrangles are in blocks that are too small or irregularly shaped for mining.

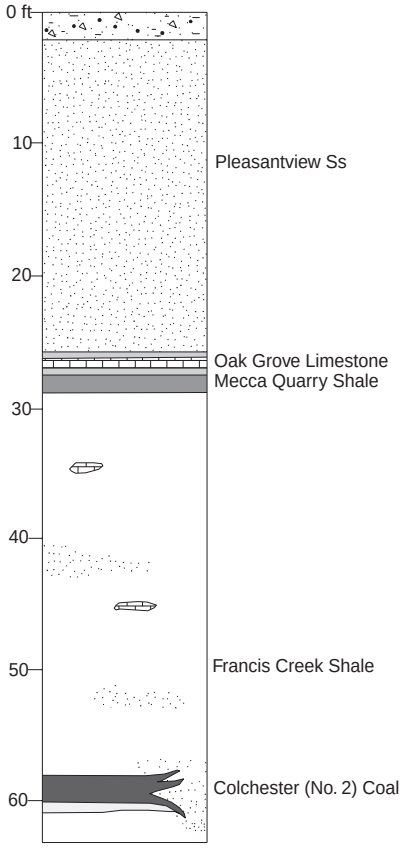

Figure 4 Generalized stratigraphic column, Augusta Quadrangle.

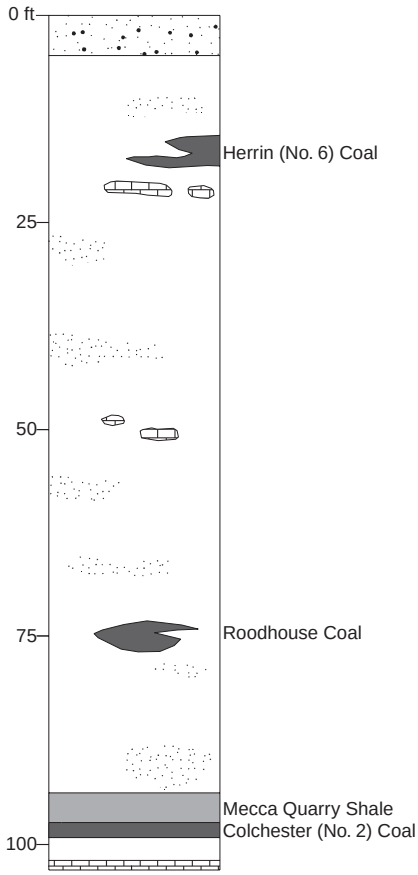

Figure 5 Generalized stratigraphic column, Roodhouse East Quadrangle.

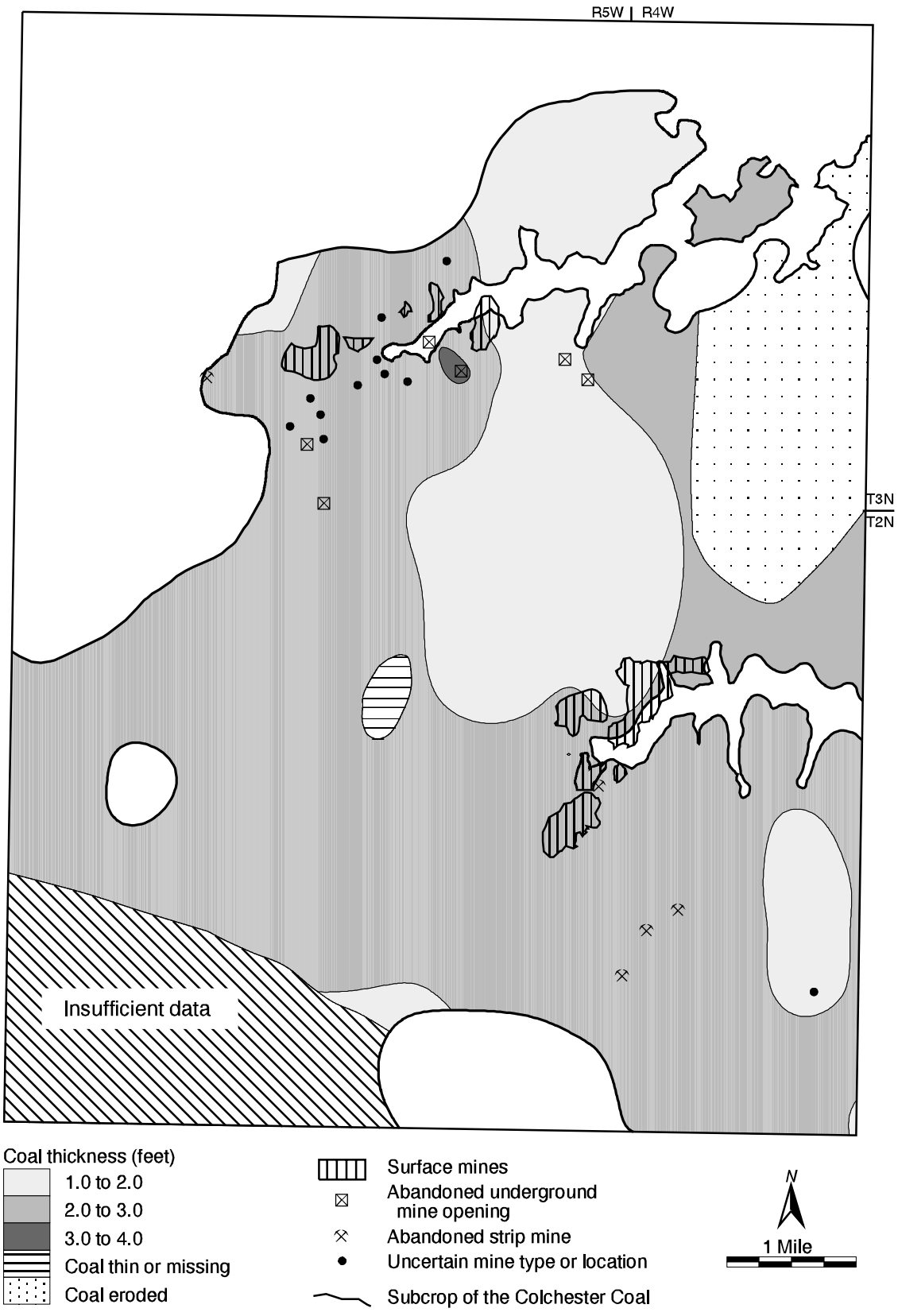

Figure 6 Thickness of the Colchester Coal, Augusta Quadrangle.

Figure 7 Thickness of the Colchester Coal, Roodhouse East Quadrangle.

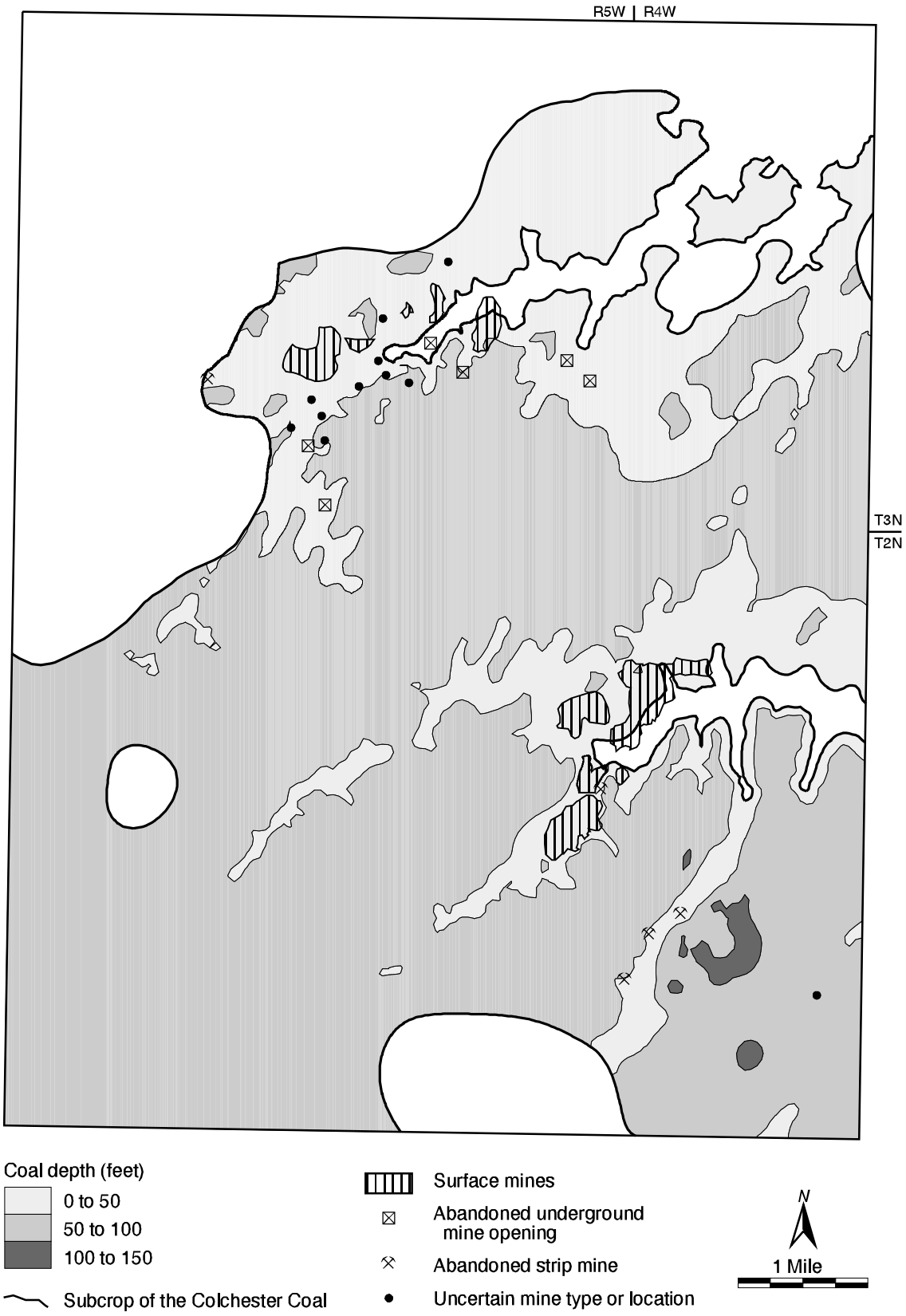

Figure 8 Depth of the Colchester Coal, Augusta Quadrangle.

Figure 9 Depth of the Colchester Coal, Roodhouse East Quadrangle.

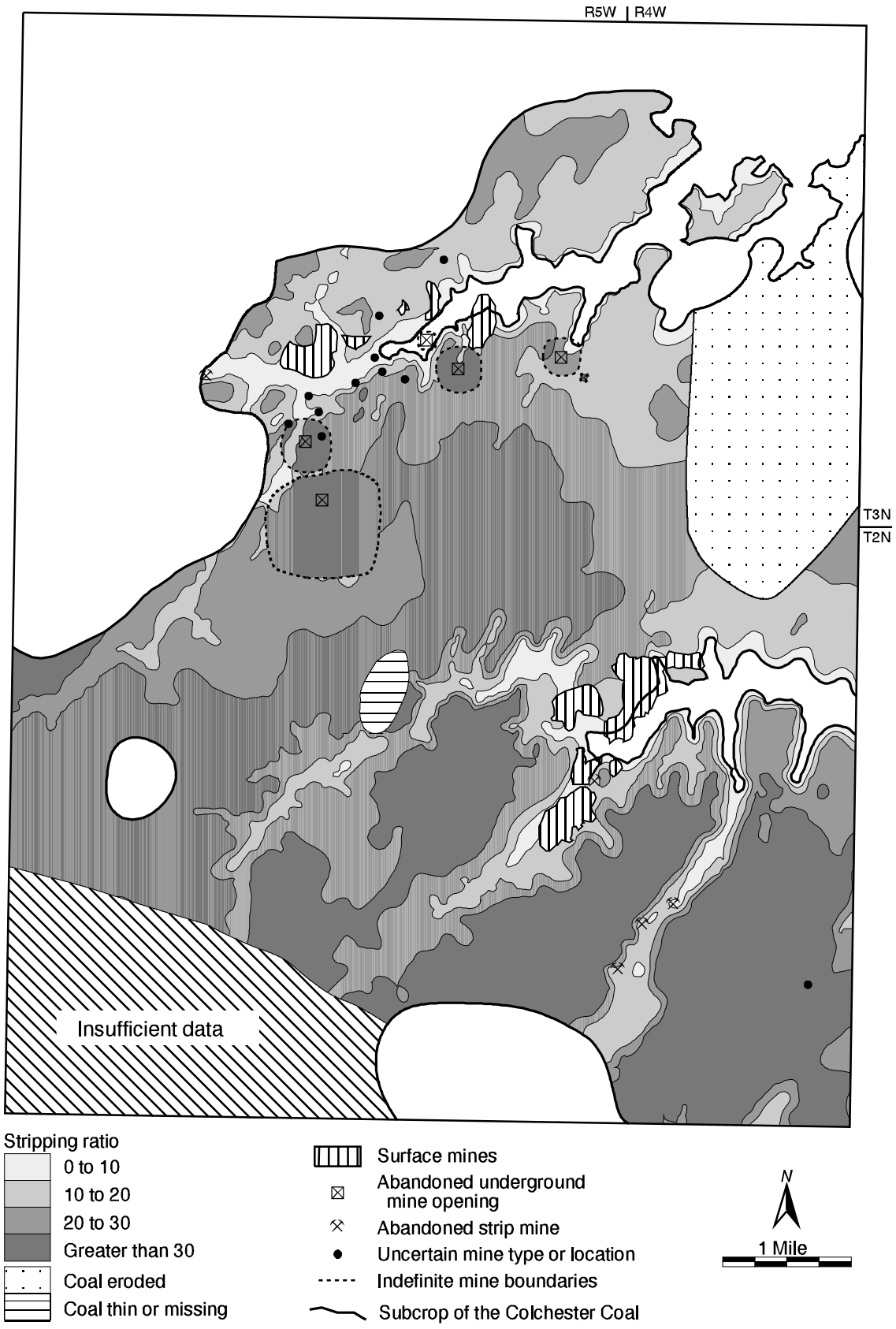

Figure 10 Stripping ratio of the Colchester Coal, Augusta Quadrangle.

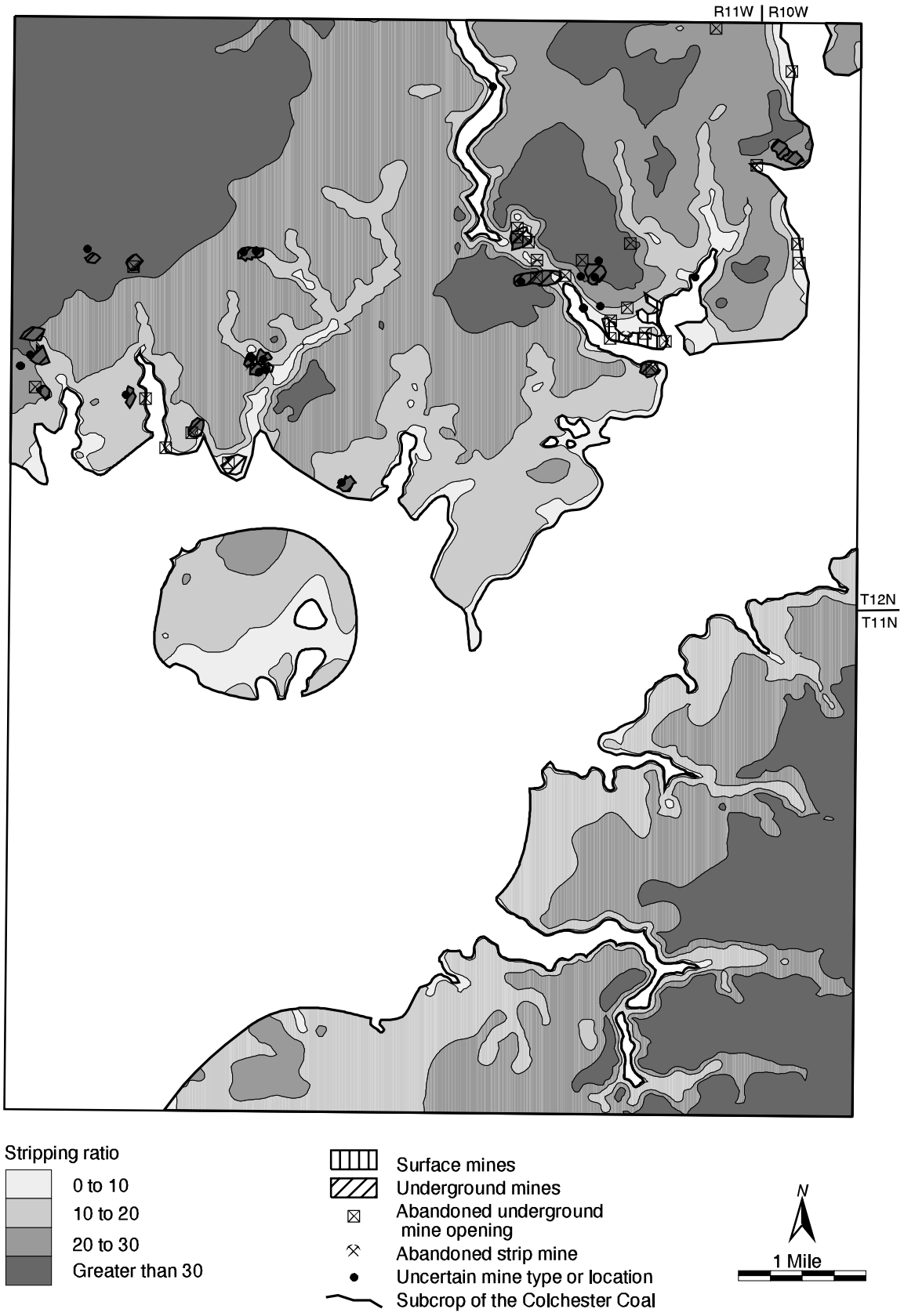

Figure 11 Stripping ratio of the Colchester Coal, Roodhouse East Quadrangle.

Table 4 Availability of the Colchester Coal for surface mining in the Augusta and Roodhouse East Quadrangles; thousands of tons and (percent of original resources).

	Augusta		Roodhouse East	
Original	75,765	(100)	89,526	(100)
Available	18,474	(24)	30,236	(34)
Mined out	1,557	(2)	223	(<1)
Land use restrictions				
Towns	1,653	(2)	6,279	(7)
Railroads	386	(<1)	138	(<1)
Cemeteries	87	(<1)	94	(<1)
Roads	4,011	(5)	5,496	(6)
Parks	1,211	(2)	-	-
Total	7,348	(10)	12,007	(13)
Technical restrictions				
Stripping ratio	35,380	(47)	45,293	(51)
Unconsolidated overburden	12,015	(16)	-	-
Block size	991	(1)	1,767	(2)
Total	48,387	(64)	47,060	(53)

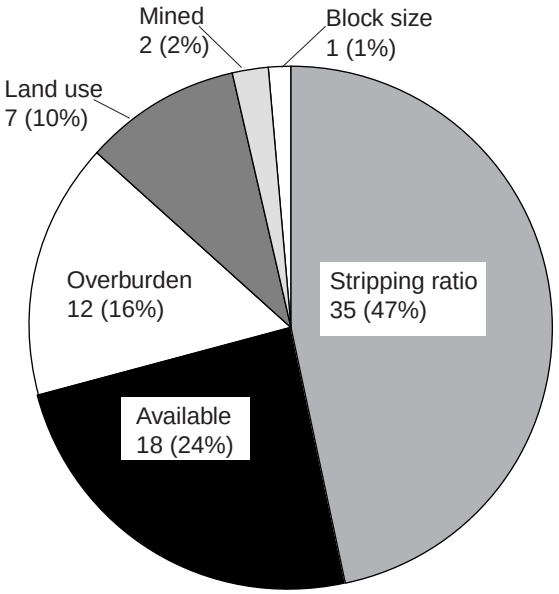

Figure 12 Availability of the Colchester Coal for surface mining, Augusta Quadrangle; millions of tons and (percent of original resources).

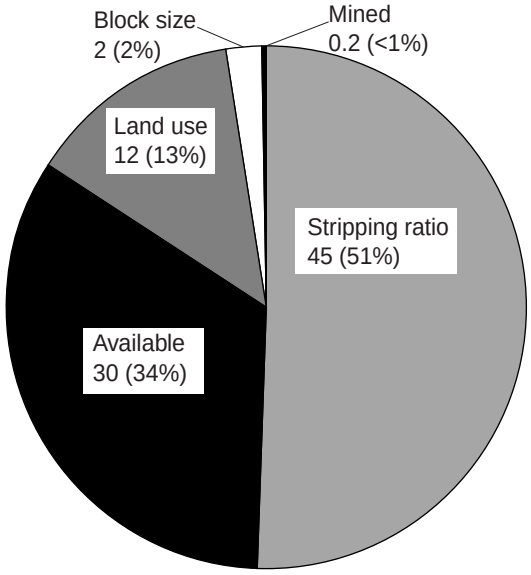

Figure 13 Availability of the Colchester Coal for surface mining, Roodhouse East Quadrangle; millions of tons and (percent of original resources).

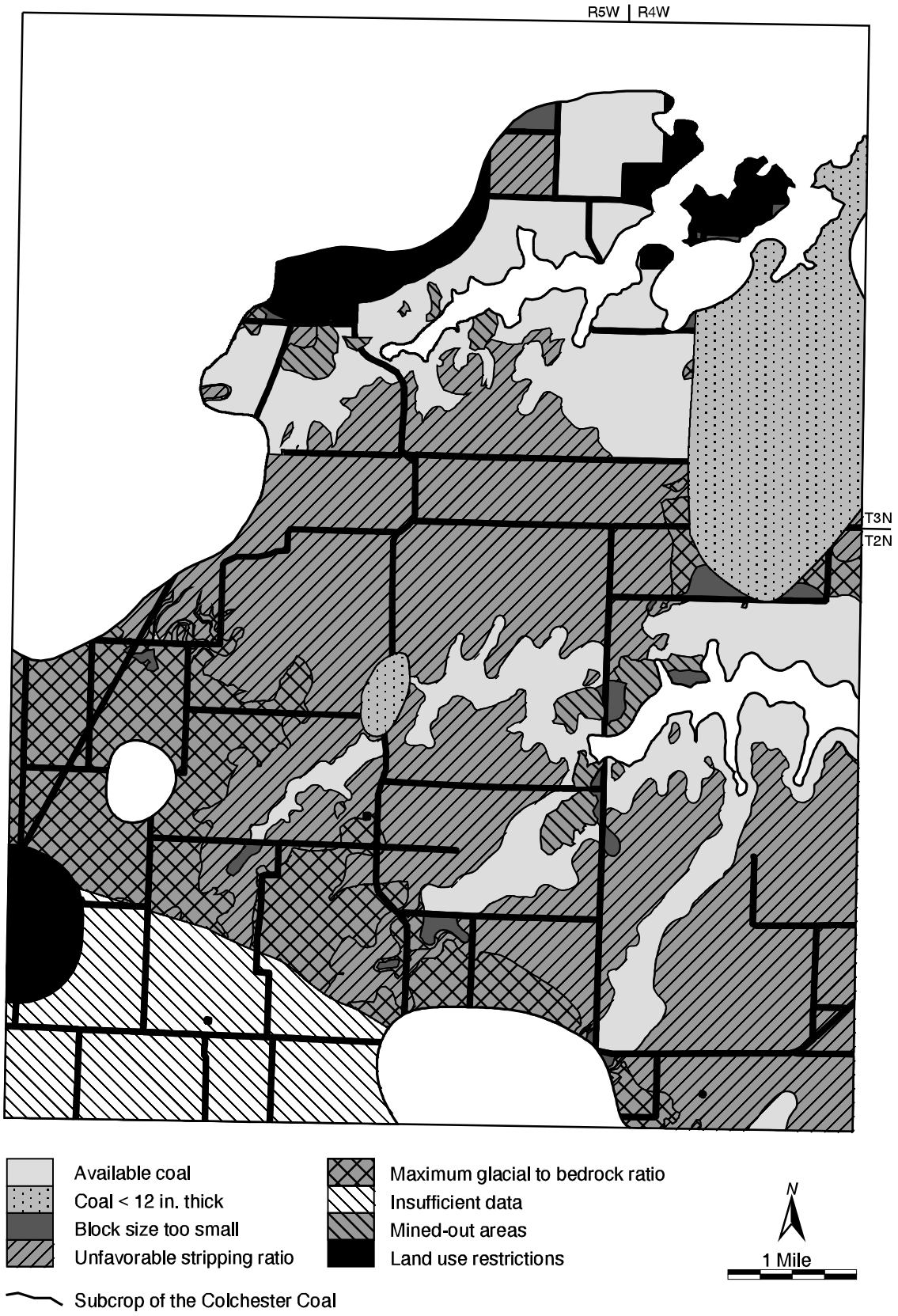

Figure 14 Resources of Colchester Coal available for surface mining, Augusta Quadrangle.

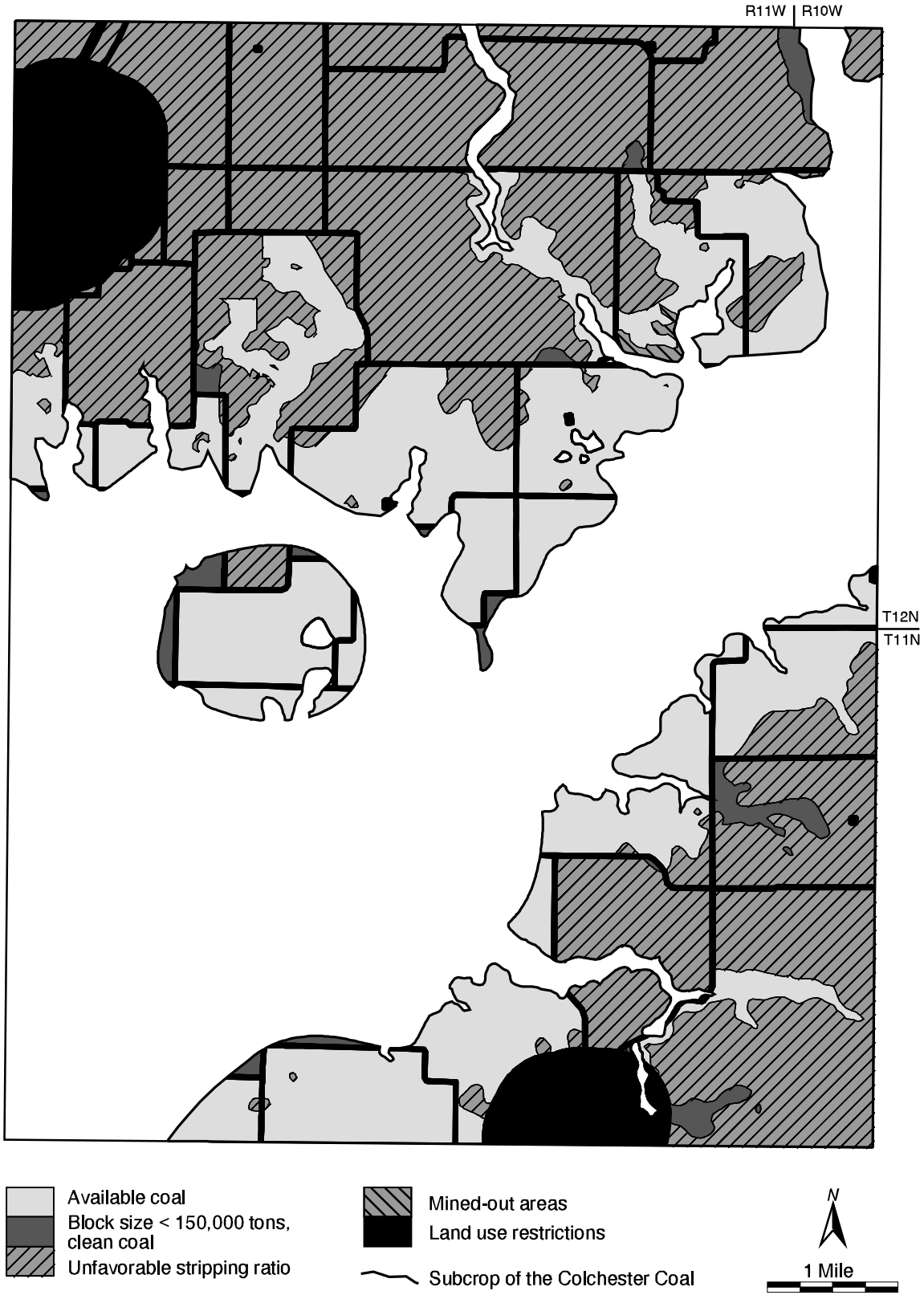

Figure 15 Resources of Colchester Coal available for surface mining, Roodhouse East Quadrangle.

Availability of Coal in the Kewanee North Quadrangle, Northwestern Illinois

The Kewanee North Quadrangle is representative of some of the mining conditions in the eastern half of region 2. In this part of the region, the Colchester Coal is one hundred to several hundred feet deep and younger coals (e.g. Springfield, Herrin, Danville) are mined. The Herrin Coal was mined in the Kewanee North Quadrangle, as it was in much of region 2, in small underground mines from before 1865 to 1944. With the development of large equipment to efficiently remove overburden, underground mines in this region closed and production shifted to surface mines. From 1929 to 1968, many large surface mines operated within a 20 mile radius of Kewanee, but the resources in the Kewanee North Quadrangle were never developed. In 1996, the last surface mine in the region that produced from the Herrin Coal closed. Depletion of the most attractive resources, the high cost of meeting current reclamation laws, and intense market competition from low-sulfur western coals are reasons for the decline of the local industry. In the early 1990s, a mining company obtained a permit to open a test pit in the Kewanee North Quadrangle. For unknown reasons, possibly related to local opposition to mining, the company withdrew its permit without opening the pit.

Land Cover Most of the Kewanee North Quadrangle is used for pasture and cropland. The town of Kewanee (population ~13,000) is located at the southern edge of the quadrangle and Johnson Sauk Trail State Park is in the east-central part of the quadrangle (fig. 16). The park, consisting of a small man-made lake and reforested farmland, is bordered on all sides by highways, homes, and cleared farmland. The road network consists of 2-lane state highways and light-duty county roads. Most public roads in the quadrangle are paved. A railroad crosses the southeast corner of the quadrangle and an electric transmission line crosses the northern portion of the quadrangle, outside of the area of mapped resources. There are no major rivers or streams.

Geology and Coal Resources The Kewanee North Quadrangle lies on the edge of two major physiographic areas, an upland area called the Galesburg Plain and a lower area containing deep, buried bedrock valleys known as the Green River Lowland (Larson et al. 1995). The pre-glacial bedrock surface had well developed drainage with more than 50 feet of relief found locally in long, narrow stream valleys. Coal resources are present in three seams: the Danville, Herrin, and Colchester Coals, which crop out beneath the drift along the edge of the Galesburg Plain (fig. 17).

The coal resources in the Kewanee area were mapped as part of regional studies by Cady (1952) and Smith and Berggren (1963). No additional coal test holes in the quadrangle have become available since 1963, but additional data are available for areas adjacent to the quadrangle. The resource map of the Colchester Coal used in this study is a combination of the information mapped by these two previous studies. The maps of the Danville and Herrin Coals were modified: a few correlations were changed, the subcrop was modified based on additional data from water wells, and the coal thickness was contoured in half-foot increments.

Mapping of the crops of the coals is difficult. Although there are several hundred drill holes in the quadrangle, the bedrock surface is irregular and buried by tens of feet of glacial and alluvial sediments. Much more closely spaced drilling would be necessary to accurately delineate the subcrop of the Danville and Herrin Coals.

Danville Coal The Danville Coal ranges in thickness from about 1.5 to 4.5 feet and ranges in depth from less than 30 feet to more than 100 feet (figs. 18 and 19). The Danville Coal has not been mined in this area.

Herrin Coal The Herrin Coal, which lies 35 to 55 feet below the Danville, ranges in thickness from 2 to 5.5 feet (fig. 20). In the Kewanee North Quadrangle, the depth of the Herrin ranges from less than 30 feet along its subcrop to about 175 feet (fig. 21). Because of the relatively thin interval between the Herrin and Danville Coals, any surface mining is likely to be a dual-seam operation. Stripping ratios for the combined coals are less than 30:1 throughout most of the quadrangle (fig. 22).

Many of the mines around Kewanee were seasonal operations that produced coal only during the winter months and some mines flooded during the periods of inactivity. The shallow depth to the coal some-

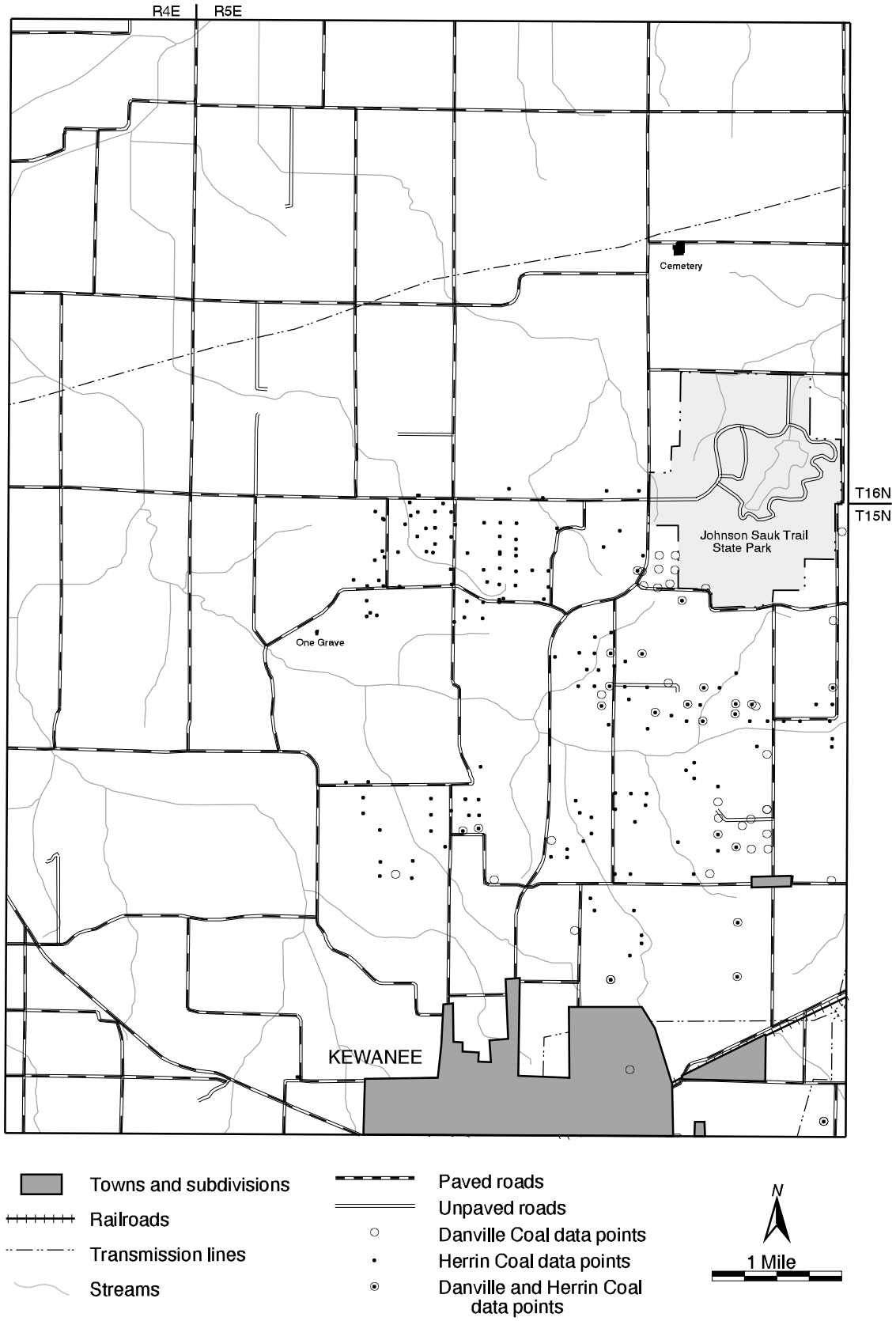

Figure 16 Surface features, Kewanee North Quadrangle.

times made it cheaper simply to start a new mine nearby rather than attempt to pump out and repair the old works. Because of this practice, the exact location and extent of many operations is not well known and extra exploratory drilling is necessary to fully assess the remaining resources in some areas. In our mapping of resources, we assumed that many of these general areas were mined out. Although in practice, additional coal may be extracted from these areas by surface mining, the amount of additional coal is not large enough to materially alter the results of our assessment.

Clastic dikes, also called clay dikes, horsebacks, and whitetop, were common in the mines in this area (unpublished ISGS mine notes; Damberger 1970). The relatively small size and irregular pattern of clastic dikes makes them impossible to avoid in mining operations. Their effect is to reduce the tonnage of coal recovered, increase cleaning costs, and (in underground operations) increase the cost of roof control. Although areas are not restricted from mining because of the presence of clastic dikes, their presence is undesirable and can lead companies to favor mining in other areas.

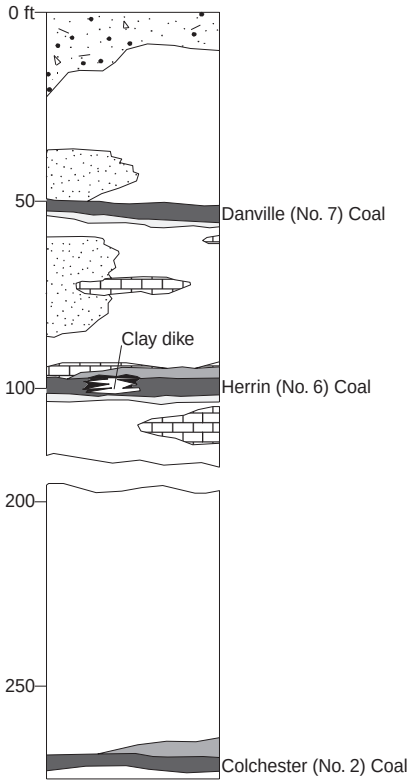

Figure 17 Generalized stratigraphic column, Kewanee North Quadrangle.

Colchester Coal The Colchester Coal averages 30 inches thick in the quadrangle. The coal crops out below more than 50 feet of unconsolidated sediment along the margins of a buried bedrock valley in the northern third of the quadrangle. The seam dips to the southeast and is on the order of 250 feet deep in the southeast corner of the quadrangle. The Colchester has been mined extensively in the vicinity of the town of Atkinson, about 5 miles north of the Kewanee North Quadrangle, but the coal was never mined in this quadrangle.

Available Coal Of the 129 million tons of resources originally in the Kewanee North Quadrangle, 52 million (40%) are available for mining (table 5 and fig. 23). Technical factors (high stripping ratio, thick unconsolidated material, size of mining block) restrict 32 million tons (25%) of the resources. Land uses (towns, roads, railroads, parks, cemeteries) restrict 37 million tons (29%). Almost 8 million tons (6%) of the resources have been mined or left as pillars in mines. Some of this pillar tonnage may be recovered if the old works are excavated by surface mining.

About 12 million tons (38%) of the 31 million tons of resources of Danville Coal are available for surface mining (table 5 and fig. 24). This classification assumes that the Danville Coal will be surface mined in combination with the underlying Herrin Coal. If for some reason, only the Danville Coal was surface mined, the resulting higher stripping ratios and smaller block sizes reduces the amount of available Danville Coal to approximately 9 million tons (29% of original resources).

Almost 47% (40 million tons) of the 76 million tons of original resources of Herrin Coal are available for mining (table 5). About 32 million tons are available only for surface mining, 3 million tons are available for surface or underground mining, and 4 million tons are available only for underground mining (figs. 25 and 26, table 5). Although the tonnage available for underground mining in the quadrangle is less than the minimum size for an underground mine, the resources extend into the adjacent quadrangle where additional tonnage is available.

A large portion of the area of Danville and Herrin resources coincides with the town of Kewanee; consequently, a significant percentage of resources is restricted by the town and highways. All of the Danville and Herrin resources are at depths shallow enough for surface mining. Areas are restricted from surface mining by thick unconsolidated overburden, high stripping ratios, or both. These technical

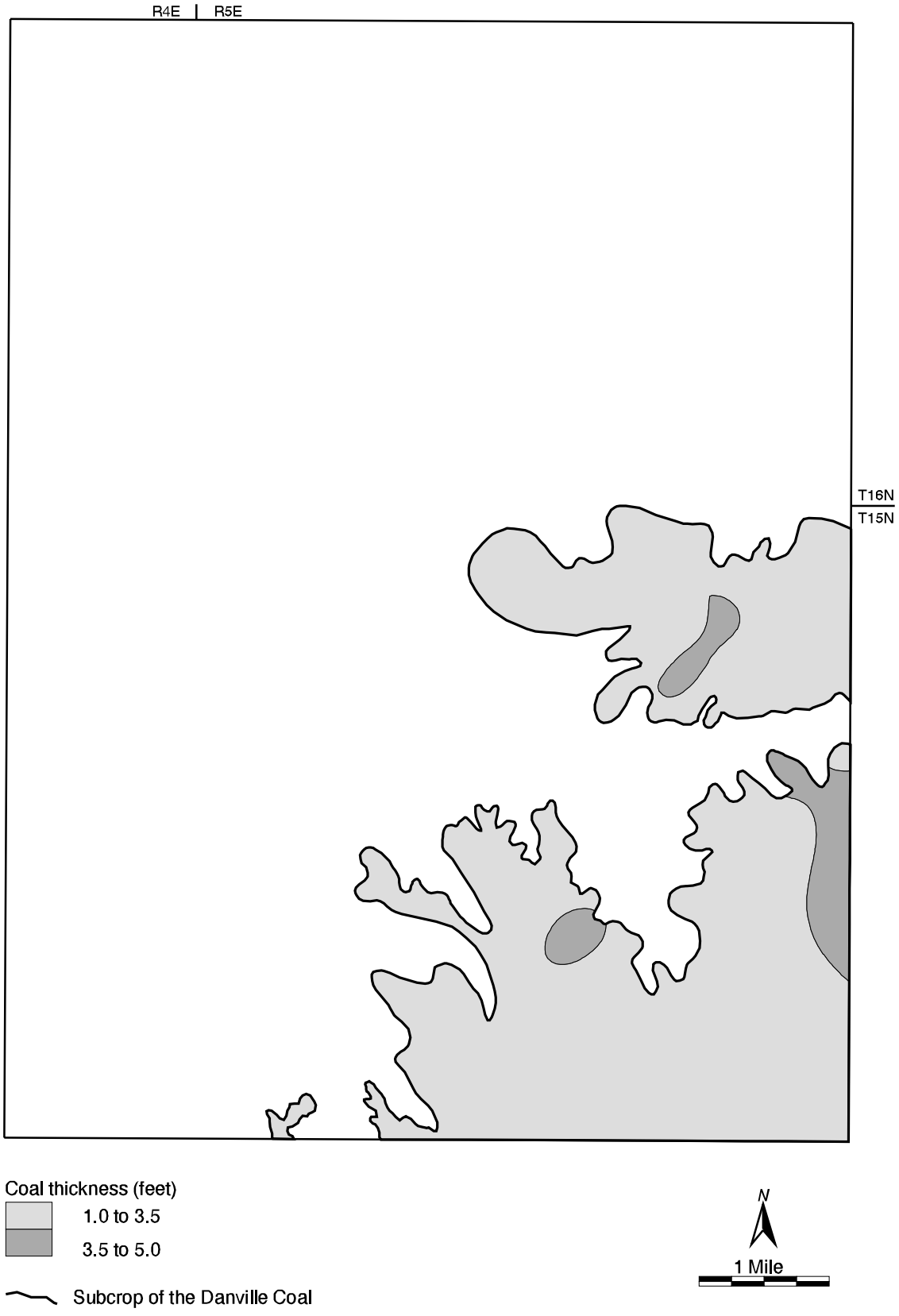

Figure 18 Thickness of the Danville Coal, Kewanee North Quadrangle.

Figure 19 Depth of the Danville Coal, Kewanee North Quadrangle.

Figure 20 Thickness of the Herrin Coal, Kewanee North Quadrangle.

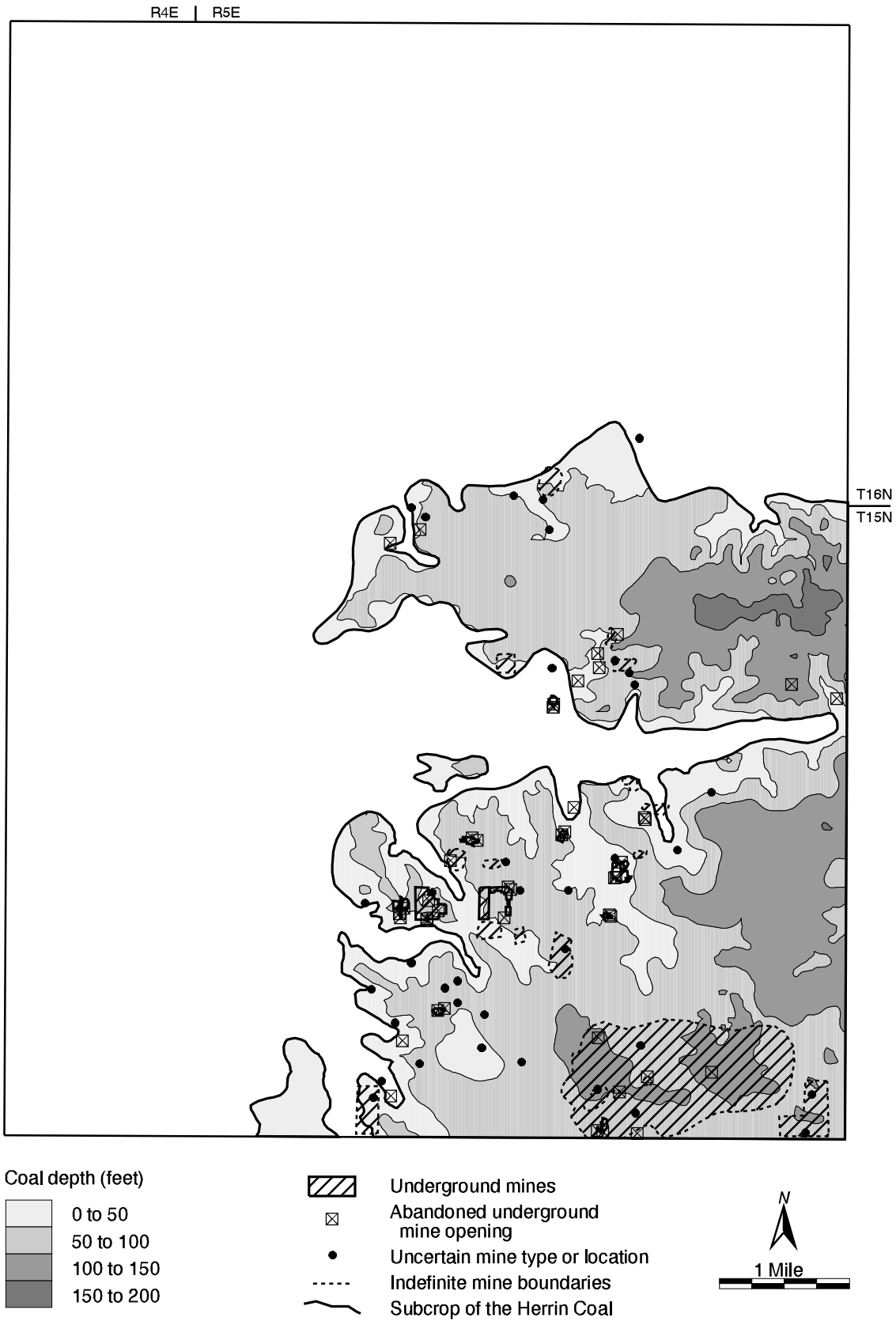

Figure 21 Depth of the Herrin Coal, Kewanee North Quadrangle.

Figure 22 Stripping ratio, Danville and Herrin Coals combined, Kewanee North Quadrangle.

Table 5 Availability of coal resources for mining in the Kewanee North Quadrangle; thousands of tons and (percent of original resources).

	Danville		Herrin		Colchester		Total	
Original	31,161	(100)	75,567	(100)	22,722	(100)	129,450	(100)
Available surface	9,475	(30)	35,386	(47)	-	-	44,860	(35)
Available if Herrin surface mined	2,692	(9)	-	-	-	-	2,692	(2)
Available underground	-	-	4,489*	(6)	-	-	4,489	(3)
Mined out	-	-	7,680	(10)	-	-	7,680	(6)
Land use restrictions								
Towns	8,613	(28)	14,726	(19)	-	-	23,339	(18)
Railroads	230	(<1)	86	(<1)	-	-	316	(<1)
Cemeteries	56	(<1)	72	(<1)	-	-	128	(<1)
Roads	2,414	(8)	4,849	(6)	1,259	(6)	8,522	(7)
Parks	1,692	(5)	3,308	(4)	-	-	5,000	(4)
Total	13,001	(42)	23,042	(30)	1,259	(6)	37,305	(29)
Technical Restrictions								
Stripping ratio	538	(2)	530	(<1)	19,403	85	20,471	(16)
Unconsolidated overburden	4,323	(14)	2,065	(3)	-	-	6,388	(5)
Block size	1,130	(4)	2,375	(3)	-	-	3,505	(3)
Coal <42"	-	-	-	-	2,060	(9)	2,060	(2)
Total	5,990	(19)	4,970	(7)	21,463	(94)	32,424	(25)

*An additional 3 million tons of available surface minable coal are available for underground mining.

restrictions, together with the numerous land use restrictions, divide the remaining resources into small areas, some of which are too small or irregular to mine. Technical restrictions on underground mining are thin bedrock cover, block size, and thin coal.

Except for the large concentration of mines in the southeast corner of the quadrangle, the presence of numerous small, abandoned underground mines does not have a significant effect on the availability of coal. If the mined areas are avoided, the adjacent areas have a size and geometry suitable for mining. However, assuming that about 50% of the coal still remains in these mined areas, the stripping ratio of most mined areas is favorable and an operator may choose to mine through many of the smaller abandoned mines.

None of the 23 million tons of resources of Colchester Coal is available for mining. The coal is too thin for underground mining and in areas where the coal is shallow enough for surface mining, the stripping ratio and thickness of unconsolidated material are high (fig. 27 and table 5).

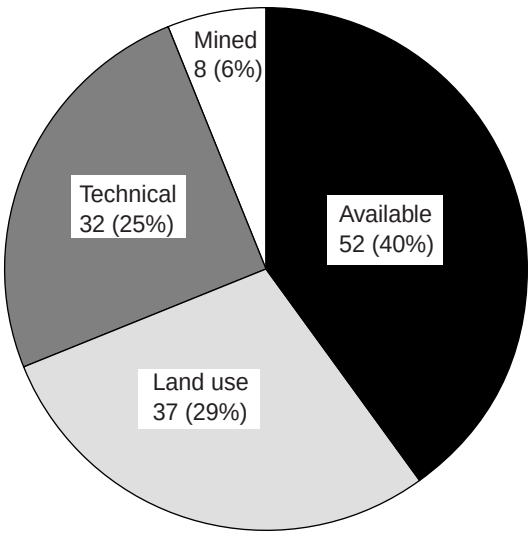

Figure 23 Availability of coal resources, Kewanee North Quadrangle; millions of tons and (percent of original resources).

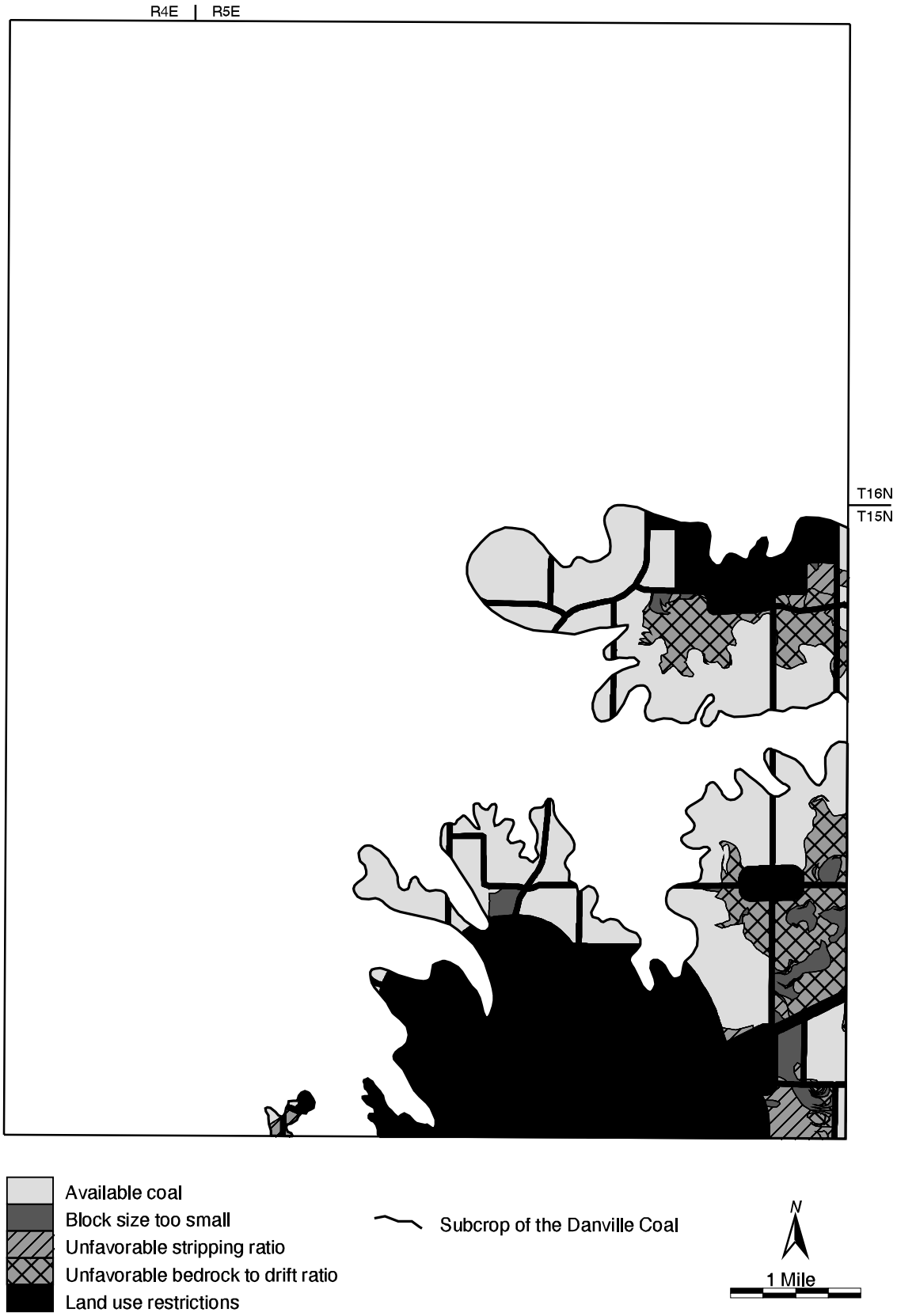

Figure 24 Resources of Danville Coal available for surface mining, Kewanee North Quadrangle.

Figure 25 Resources of Herrin Coal available for surface mining, Kewanee North Quadrangle.

Figure 26 Resources of Herrin Coal available for underground mining, Kewanee North Quadrangle.

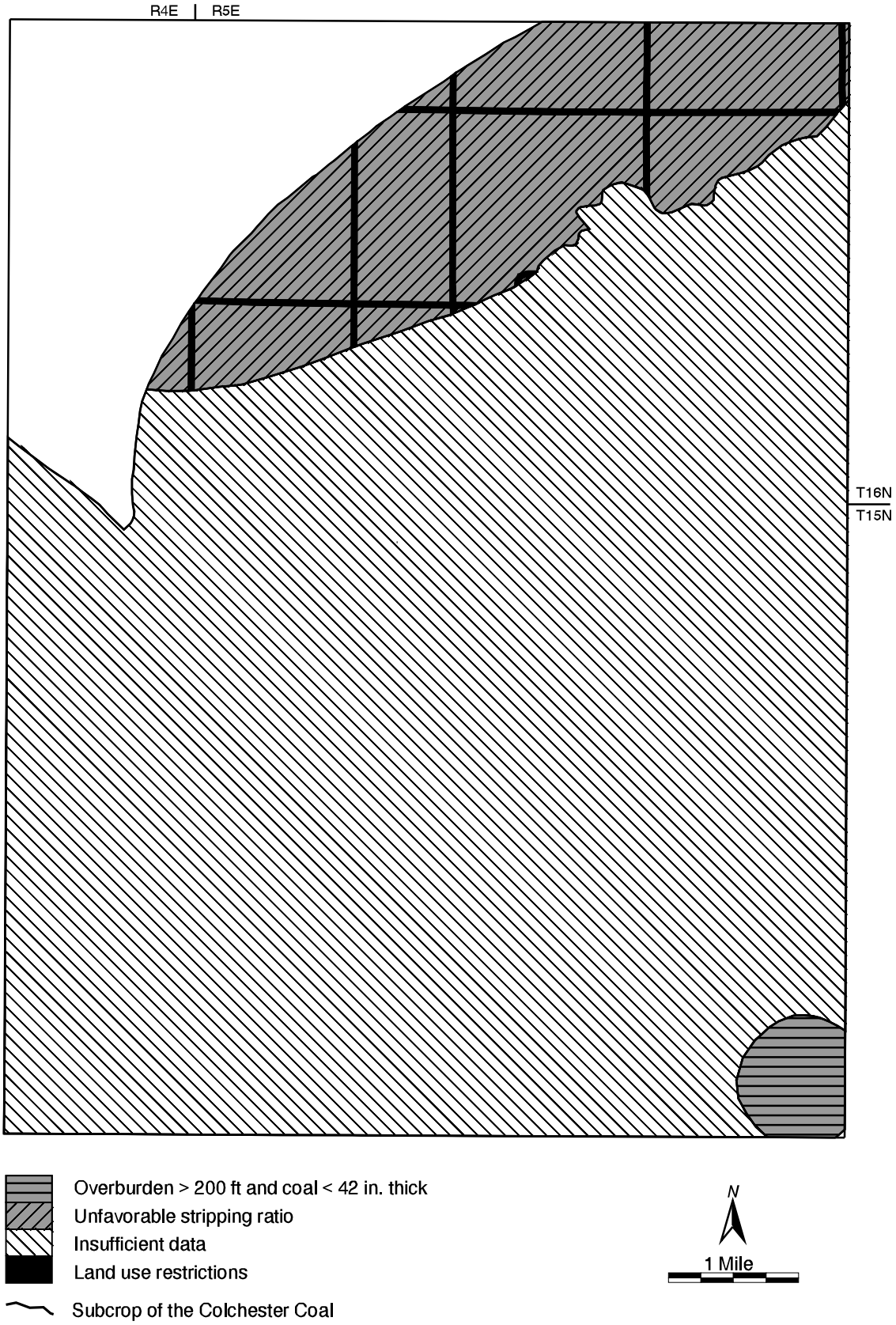

Figure 27 Resources of Colchester Coal available for surface and underground mining, Kewanee North Quadrangle.

One potentially significant restriction on mining that was not evaluated in this study is the attitude of the local population toward mining. Based on recent events, it appears that a portion of the local population is opposed to surface mining in the vicinity of Kewanee. In 1992, the county board voted to deny an application for an exploratory pit a few miles north of town and a citizens' group petitioned the state to have the area declared unsuitable for mining. Opponents of mining included local property owners and agricultural leaders who were concerned that surface mining would permanently destroy valuable crop land and cause other environmental damage. The mining company eventually dropped its plans and the issue of whether the area should be mined was never resolved. It is not known what effect, if any, the opposition to surface mining had on the mining company's plans. Legal opposition to mining, even if not ultimately successful, can delay production and make it difficult for a company to make or fill contract obligations. The threat of opposition therefore can be a significant restriction on the availability of coal.

Availability of Coal in the Mascoutah Quadrangle, Southwestern Illinois

The Mascoutah Quadrangle is representative of mining conditions associated with shallow coal resources in the western part of region 6. Coals crop out along the western edges of this region and dip gently east and northeast toward the center of the basin. The Herrin Coal is the major resource in the region of the Mascoutah Quadrangle. The Colchester Coal has been mined locally in areas northeast of St. Louis, but in most of the northern part of this region, including the Mascoutah Quadrangle, the Herrin Coal is the only resource that is considered minable.

Underground mining of the Herrin Coal in the quadrangle began in 1870 or earlier. At least five and perhaps six underground mines operated in the quadrangle throughout the late 1800s or early 1900s, but all closed before the end of the Great Depression, except for one that remained active until 1956. In 1957 a new era of mining began with the opening of the River King surface mine. In 1969, there was a resurgence of underground mining in the quadrangle with the opening of the River King underground mine. As is the case with a number of underground mines in region 6, the River King underground mine produced from resources that were less than 150 feet deep and normally classified as surface minable. In this case local geologic conditions and patterns of land ownership favored the underground mining. The River King surface mine, having exhausted the resources in the quadrangle that could be mined cheaply, moved operations to reserve blocks further south, and finally closed in 1986. The River King underground mine closed in 1990.

Land Cover and Surficial Geology Although the Mascoutah Quadrangle is largely rural, it is expected to experience rapid development in the years ahead (fig. 28). Interstate 64 passes just north of the quadrangle and connects it with Belleville and the St. Louis metropolitan area to the west. A regional airport is under development north of town, just off the quadrangle. A significant portion of the Mascoutah Quadrangle is flat-lying land occupied by the floodplains of the Kaskaskia River and Silver Creek. The area west of Silver Creek is a bedrock upland area that stands topographically as much as 100 feet above much of the rest of the quadrangle. Elsewhere in the quadrangle, thick deposits of alluvium and glacial drift conceal the bedrock surface (fig. 29). Remnants of glacial moraines form knobs and linear ridges of sand, gravel, and till that stand more than 80 feet above the surrounding lowlands. The distribution of lithologies within the unconsolidated sediment is quite variable, but thick, water-bearing layers of sand and gravel are present (Ross Brower, personal communication; Bergstrom 1975).

Although the Danville, Springfield, and possibly some older coals are present in the quadrangle, the only mapped resources are in the Herrin Coal (fig. 30). The Herrin Coal is present throughout the quadrangle except in a small area in the southwest corner where the coal crops out and is eroded. The coal and associated geology were mapped using drilling records from more than 560 holes in and adjacent to the quadrangle. All but 215 of these records are proprietary and belong to coal companies that have explored for coal in the area. As is the case in much of the west-central and southern parts of the basin, the Herrin Coal is consistent in thickness over wide areas, ranging in the quadrangle from 5.25 to 9.5 feet thick (fig. 31). The coal is less than 50 feet deep in a small area of the quadrangle where it crops out beneath glacial and alluvial sediments, but burial depth ranges from 50 to just over

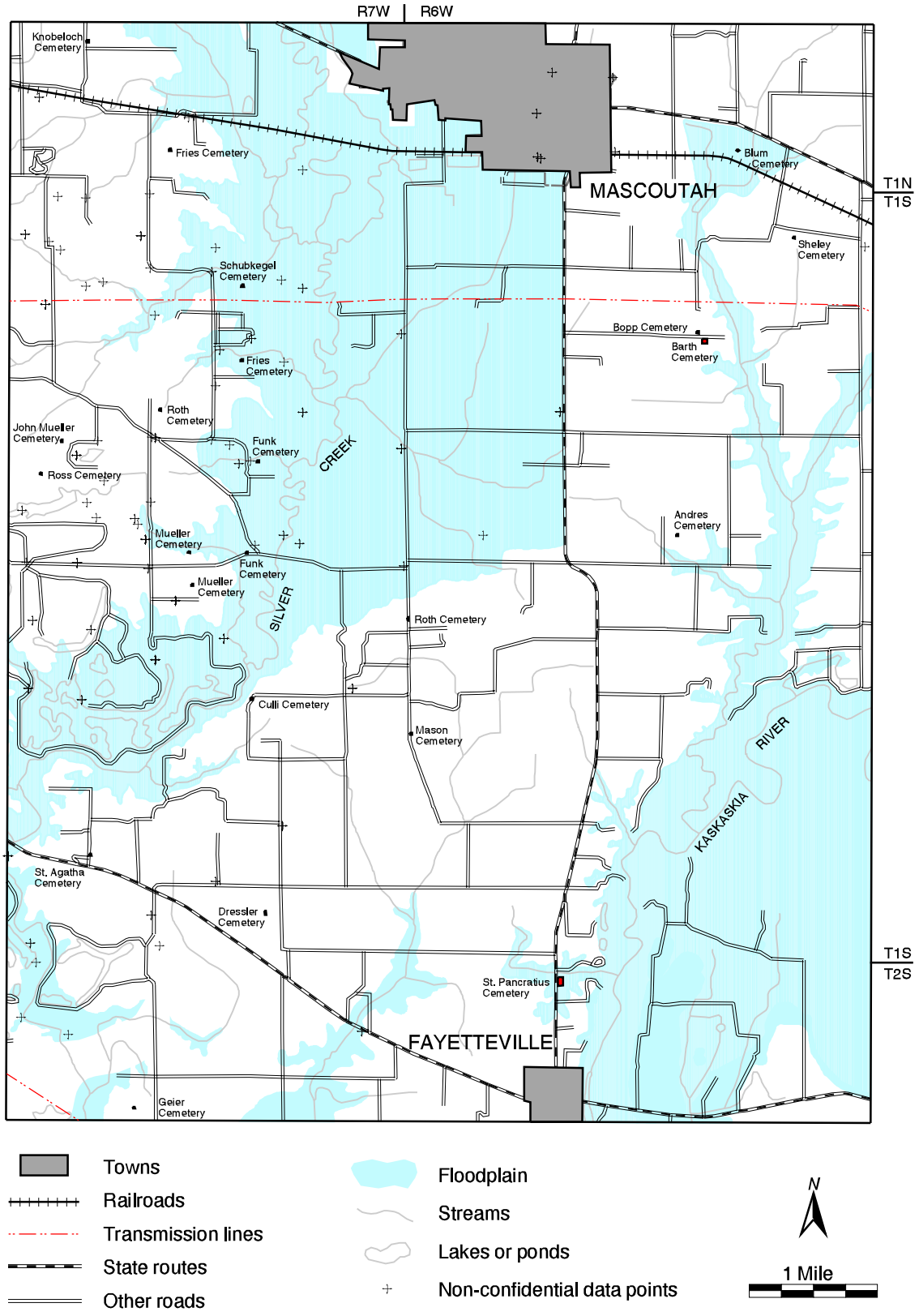

Figure 28 Surface features, Mascoutah Quadrangle.

Figure 29 Thickness of unconsolidated overburden, Mascoutah Quadrangle.

200 feet throughout most of the quadrangle (fig. 32). Much of the overburden is glacial drift and alluvium and all but a few scattered areas in the quadrangle have less than 70 feet of bedrock cover over the Herrin Coal (fig. 33). The relatively thick coal results in stripping ratios of less than 20:1 in more than half the quadrangle area (fig. 34), but the relatively thick unconsolidated sediments will present a challenge for surface mining (fig. 29).

The Danville Coal is locally present 25 to 35 feet above the Herrin Coal, but is commonly less than 2.5 feet thick. The Springfield Coal is present about 65 feet below the Herrin Coal and is believed to be commonly less than 3 feet thick. No resources have been mapped for seams other than the Herrin Coal.

Three or four limestone members, the Brereton, Conant, Bankston Fork, and Piasa, are commonly present in the 50 feet of strata immediately above the Herrin Coal (fig. 30). Mean cumulative thickness of these limestones in the Mascoutah area is about 14 feet. The presence of relatively thick, competent limestone in the overlying strata makes it possible to mine underground with less bedrock cover than is necessary for other coals or in other parts of the state.

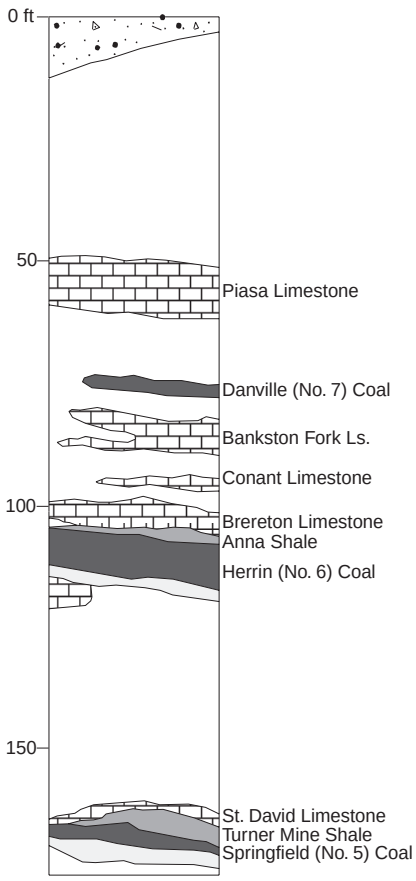

Figure 30 Generalized stratigraphic column, Mascoutah Quadrangle.

Availability of the Herrin Coal Overall, only 39% of the resources originally in the Mascoutah Quadrangle are available for mining (fig. 35 and table 6). About 13% of the resources have been mined. Technical restrictions (thin bedrock, thick unconsolidated sediments, size of mining block) restrict 38% of the resources. Land uses (towns, highways, railroads, cemeteries) restrict 10% of the resources. Most of the resources in the Mascoutah Quadrangle are at depths that can potentially be mined by either surface or underground methods (approximately 35 to 200 ft deep). The amount of resources available for mining differs sharply between the two methods.

Surface mining Of the original coal resources that were potentially surface-minable (resources with less than 200 feet of overburden), only 6% are available for mining (fig. 36 and table 6). The major restriction on surface mining is the thickness of the unconsolidated material. Most of the quadrangle is overlain by glacial and alluvial sediment more than 50 feet thick. Although this overburden could be removed if necessary, the significant costs involved and the availability of ample resources with more favorable mining characteristics elsewhere makes it unlikely that these resources will be surface mined in the foreseeable future. Less than 1% of the resources have too high a stripping ratio and 2% are in blocks that are too small or irregularly shaped. Land uses (towns, roads, railroads) restrict development of 12% of the resources. It is likely that the development that is taking place in the Mascoutah area has or will soon cause property values and local sentiment to be unfavorable for surface mining.

Underground mining About 47% of the original resources in the quadrangle are available for underground mining (fig. 37 and table 6). About 13% of the resources have been mined. Thin bedrock is the major restriction on underground mining. Large areas of resources have less than 35 feet of bedrock cover overlain by thick glacial or alluvial sediments. An additional 6% of the resources are restricted because of the likely need to reduce the amount of coal extracted where the resources are within a floodplain and the bedrock cover is relatively thin. Small size or irregular shape of the mining block restricts 3% of the resources. Land uses (towns, cemeteries) restrict 7% of the resources. Because of the development expected in the Mascoutah Quadrangle, it is likely that land uses will restrict considerably more resources in the near future.

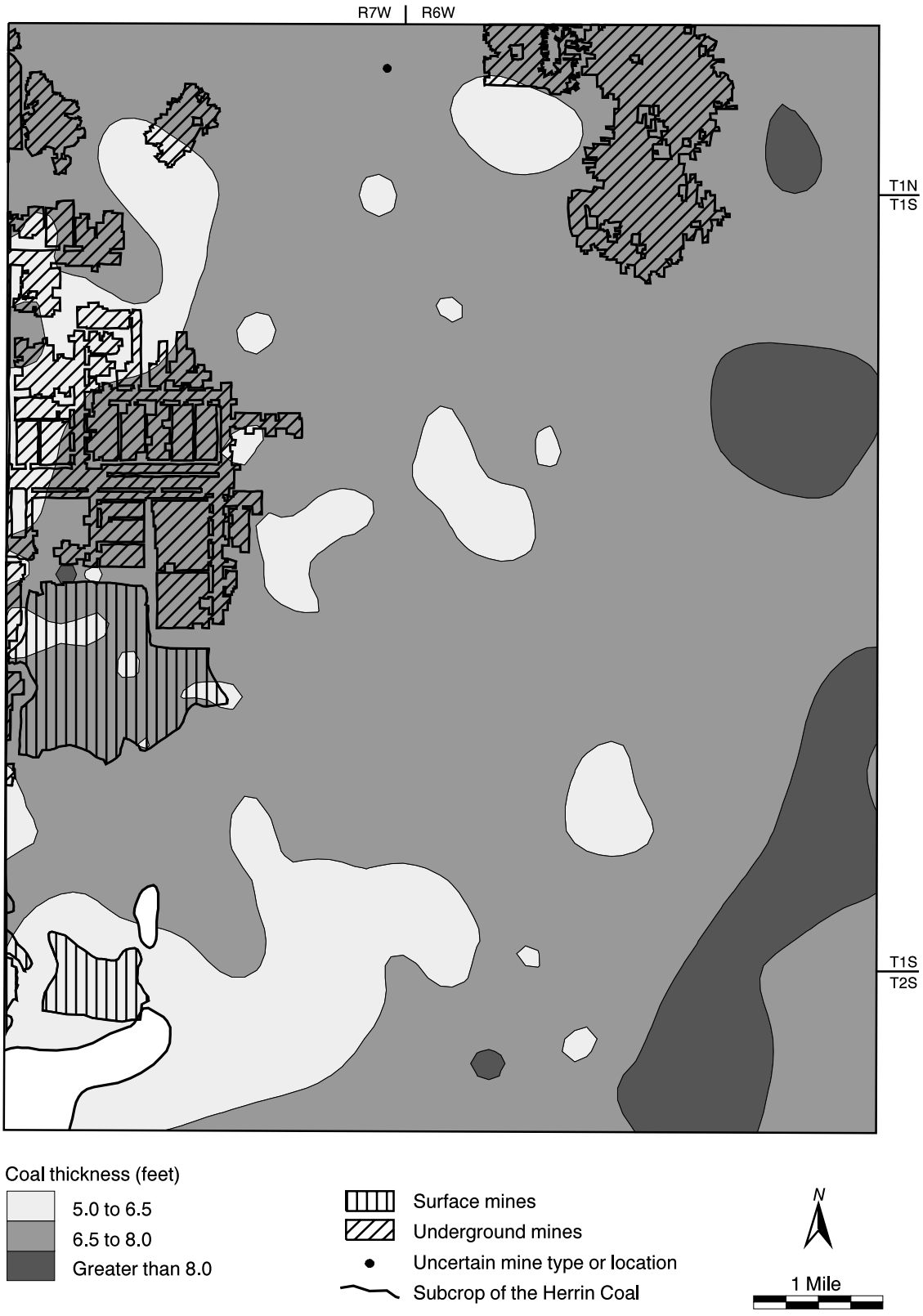

Figure 31 Thickness of the Herrin Coal, Mascoutah Quadrangle.

Figure 32 Depth of the Herrin Coal, Mascoutah Quadrangle.

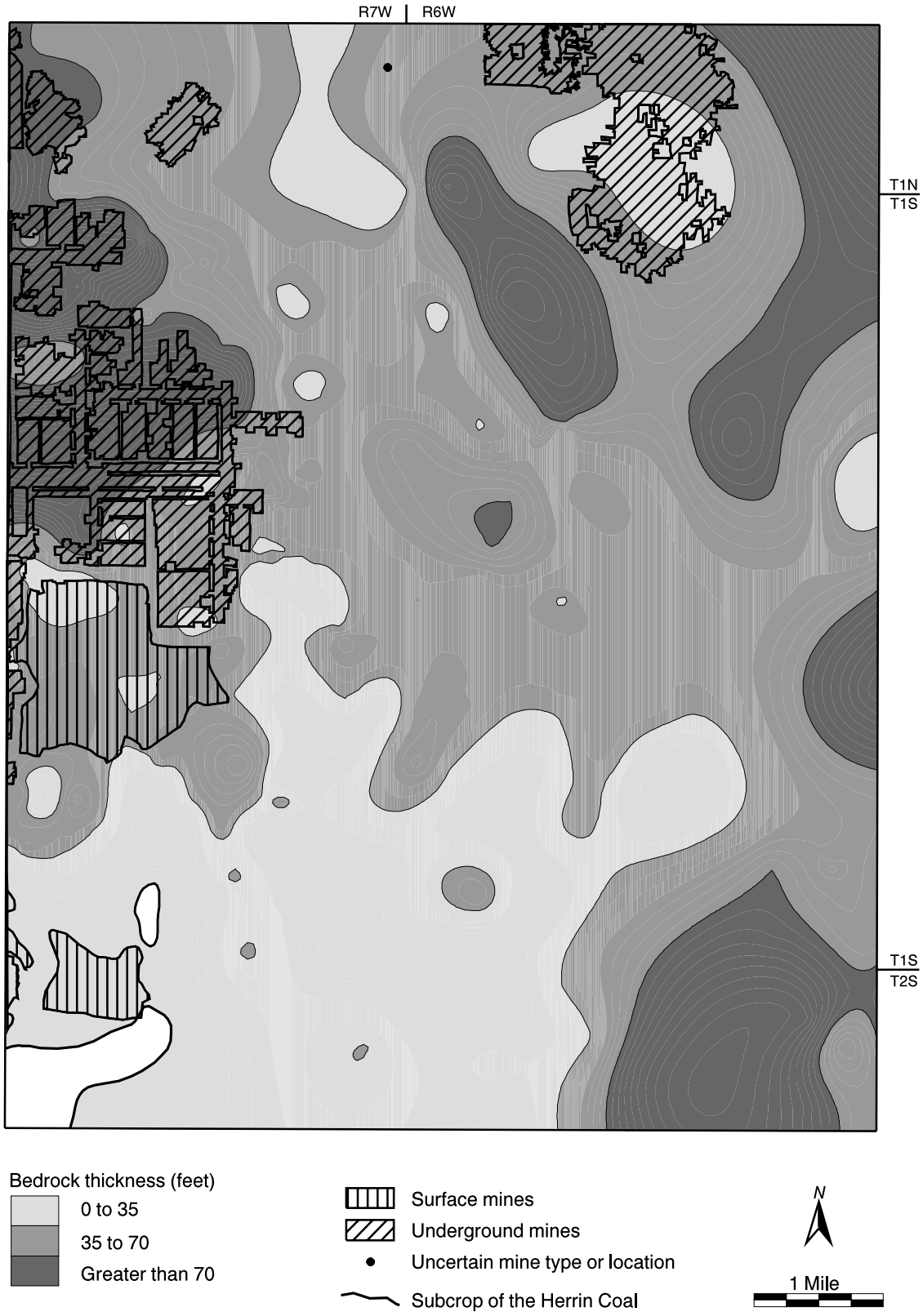

Figure 33 Thickness of the bedrock above the Herrin Coal, Mascoutah Quadrangle.

Figure 34 Stripping ratio of the Herrin Coal, Mascoutah Quadrangle.

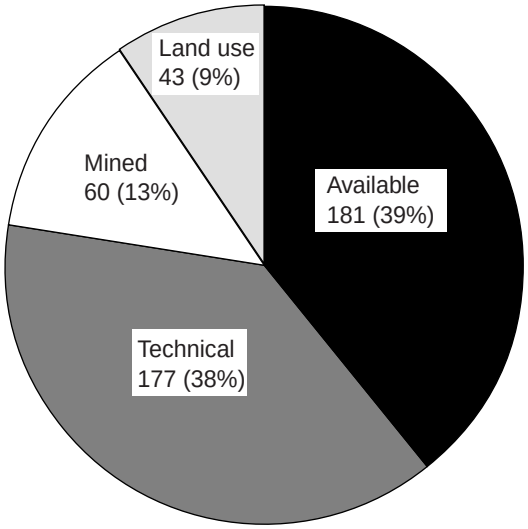

Figure 35 Availability of Herrin Coal resources, Mascoutah Quadrangle; millions of tons and (percent of original resources).

Table 6 Availability of the Herrin Coal for mining in the Mascoutah Quadrangle; thousands of tons and (percent of original resources).

Entire quadrangle, surface and underground mining		
Original	462,044	(100)
Available	181,689	(39)
Mined	60,220	(13)
Land use restrictions	43,063	(9)
Technical restrictions	177,073	(38)

Surface minable (0 to 200 ft deep)		
Original	443,434	(100)
Available	25,065	(6)
Mined out	60,221	(14)
Land use restrictions	52,259	(12)
Technical restrictions	305,889	(69)
Land use restrictions		
Towns	31,622	(7)
Cemeteries	678	(<1)
Roads	3,853	(<1)
Railroads	714	(<1)
Abandoned mines	15,393	(3)
Technical restrictions		
Stripping ratio	71	(<1)
Thick unconsolidated overburden	292,941	(66)
Block size	10,780	(2)

Underground minable (>35 ft deep)		
Original	462,030	(100)
Available	219,110	(47)
Mined out	60,257	(13)
Land use restrictions	30,879	(7)
Technical restrictions	151,783	(33)
Land use restrictions		
Towns	11,694	(3)
Cemeteries	1,080	(<1)
Abandoned mines	18,105	(4)
Technical restrictions		
Floodplain	28,632	(6)
Thin bedrock overburden	108,924	(24)
Block size	14,227	(3)

Figure 36 Resources of Herrin Coal available for surface mining, Mascoutah Quadrangle.

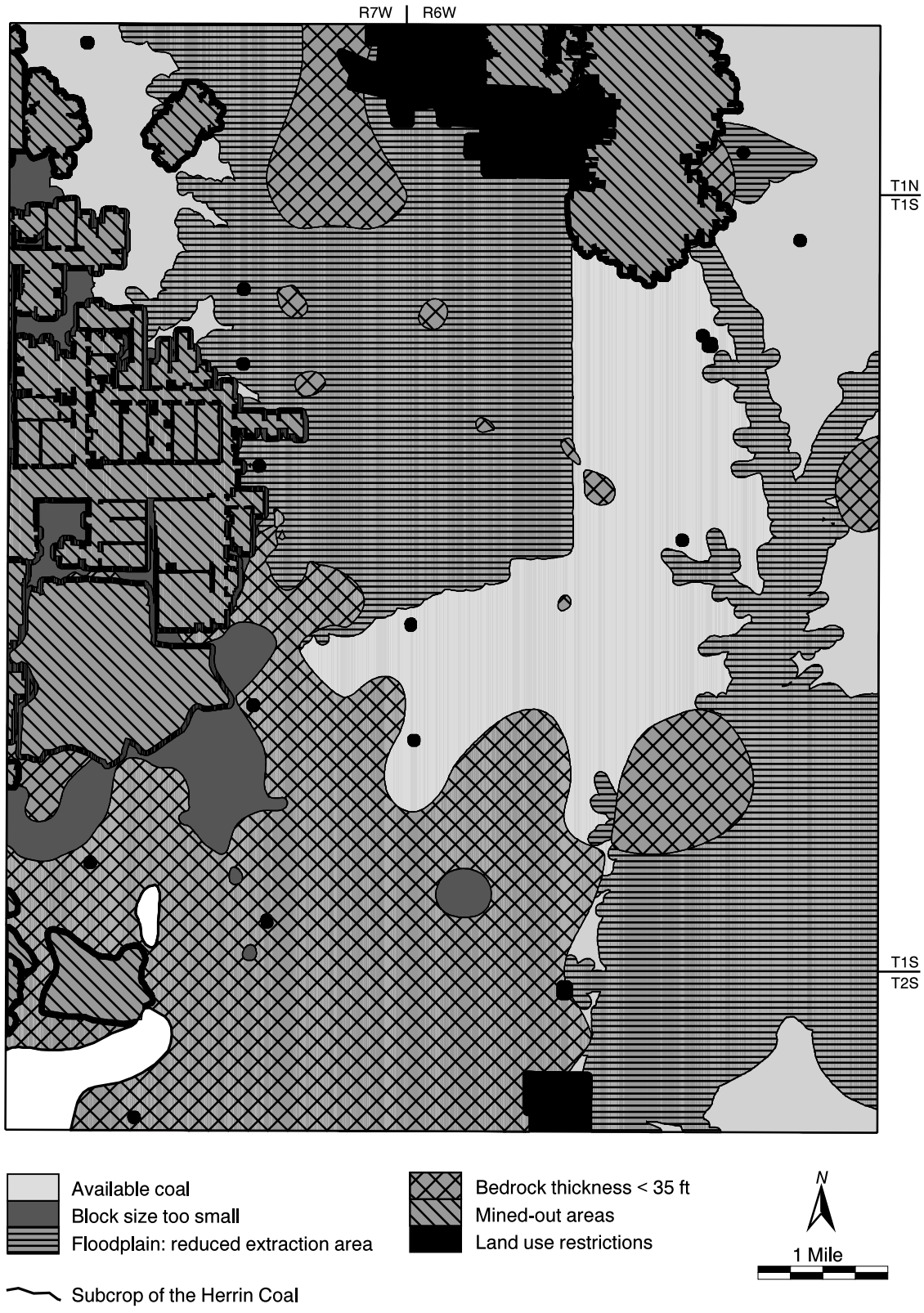

Figure 37 Resources of Herrin Coal available for underground mining, Mascoutah Quadrangle.

Availability of Coal in the Pinckneyville Quadrangle, Southwestern Illinois

The Pinckneyville Quadrangle is representative of mining conditions in the southern part of region 6. Coals of the Carbondale Formation (Danville, Herrin, Springfield) crop out along the southern edge of the quadrangle and dip at low angles toward the northeast (fig. 38). The Murphysboro Coal, which crops out south of the quadrangle, also contributes some resources.

The first recorded mining in the state was about 20 miles south of the Pinckneyville Quadrangle in 1810. Since that time, underground mining has been going on continuously in or around the quadrangle. In the early 1900s the development of mechanical equipment suitable for removing overburden led to widespread surface mining in this region. The Pyramid surface mine produced from the Herrin Coal in the quadrangle from 1926 to 1960. The largest shovel in the world, the Captain, operated in the Pinckneyville Quadrangle until 1991, when it was damaged by a fire and scrapped. More coal (about 1.5 billion tons) has been produced from this region than any other in the state and much of that production has been from surface mines. In recent years, the number of surface mines and their production has dropped steadily due to the depletion of the shallowest resources. Arch Mineral's Horse Creek mine is the last active surface mine in this quadrangle. In 1991, Arch opened a drift mine, the Conant Mine. Mine plans filed with the state suggest that Arch plans to extract the majority of the resources remaining in the quadrangle by underground mining.

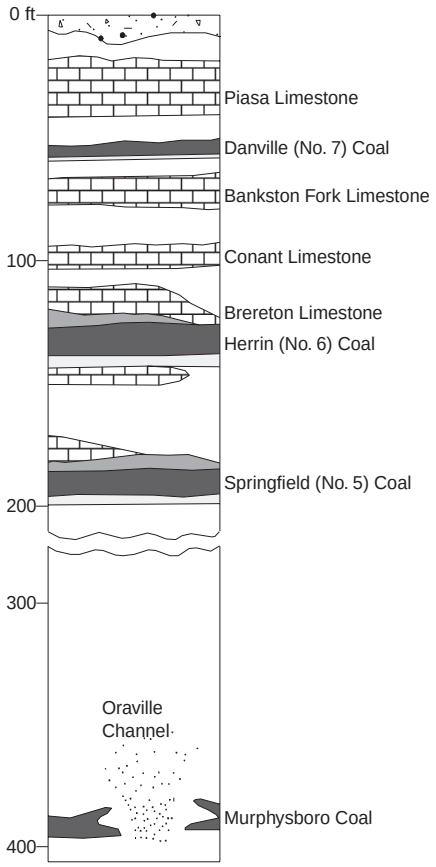

Figure 38 Generalized stratigraphic column, Pinckneyville Quadrangle.

Land Cover Except for the town of Pinckneyville, the quadrangle is a rural area consisting largely of row crop farmland and pasture (fig. 39). Pyramid State Park, an unreclaimed surface mine that was donated to the state, occupies several square miles in the southeast part of the quadrangle. Large areas of active or recently reclaimed surface mining are present in the southwest portion of the quadrangle. There are no interstate highways and, aside from the town, there are few restrictions to mining. The streams in the quadrangle are all relatively small and, except for the dam at the Pinckneyville reservoir, present no significant obstacles to mining.

Geology and Coal Resources Glacial and alluvial sediments are relatively thin in the Pinckneyville Quadrangle, as they are in much of the southern part of region 6. Throughout much of the quadrangle the bedrock is covered by less than 50 feet of unconsolidated sediment (fig. 40). Coal resources have been mapped in the Pinckneyville Quadrangle for the Danville, Herrin, Springfield, and Murphysboro Coals based on mine maps and drilling records from 943 holes. All but 786 of the holes are proprietary and belong to companies that have explored for coal in this area. Other coals are known to be present (e.g. DeKoven and Davis), but the limited information available on these indicates that they are thin and/or discontinuous.

The Danville Coal averages 1.9 feet thick, but is less than 0.5 feet thick in a few areas and was reported to be 4 feet thick in one area (fig. 41). The coal, which lies approximately 45 feet above the Herrin Coal, occurs at depths in the quadrangle of slightly more than 200 feet (fig. 42). Because of the thinness of the coal seam it is mined only in surface operations.

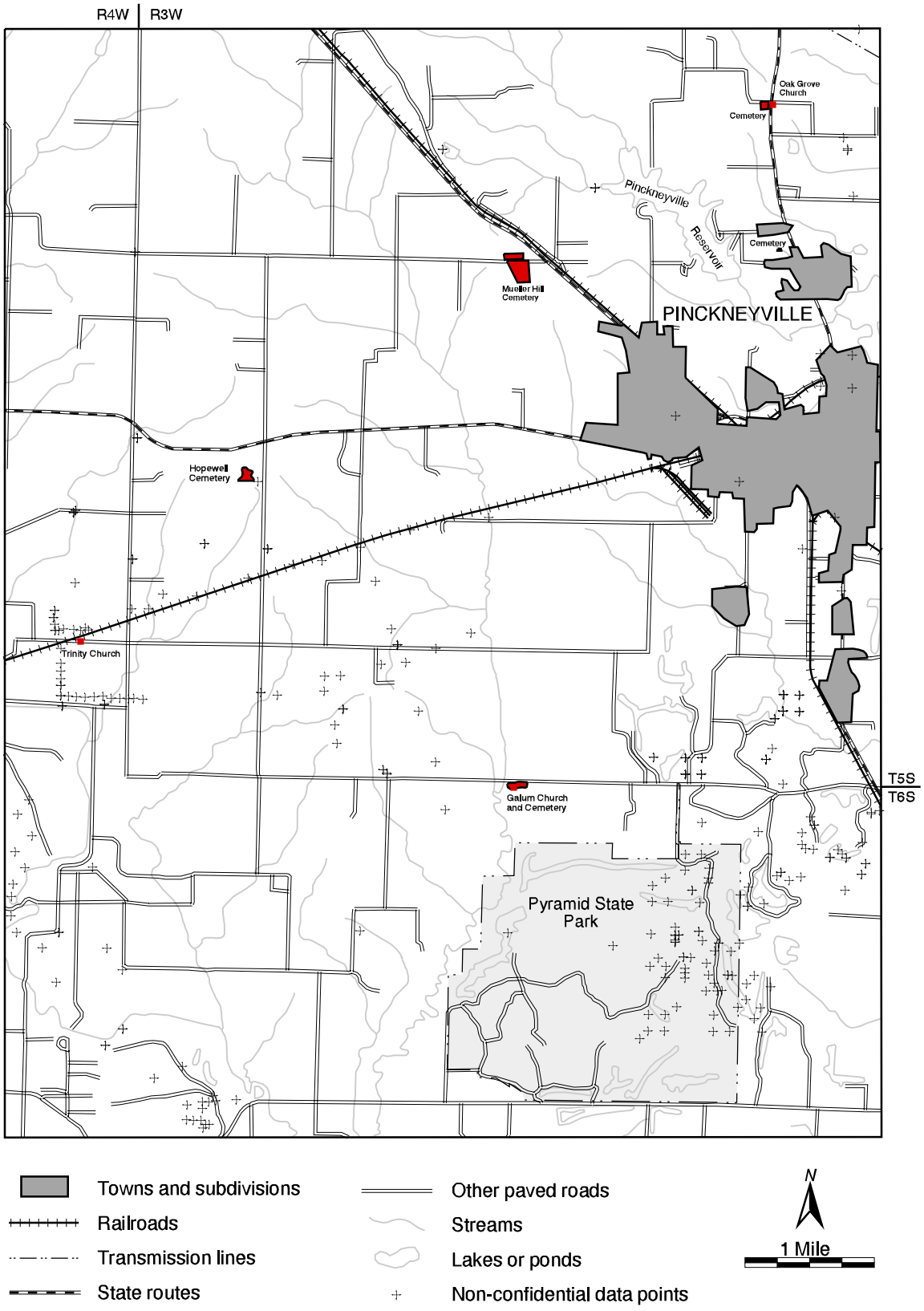

Figure 39 Surface features, Pinckneyville Quadrangle.

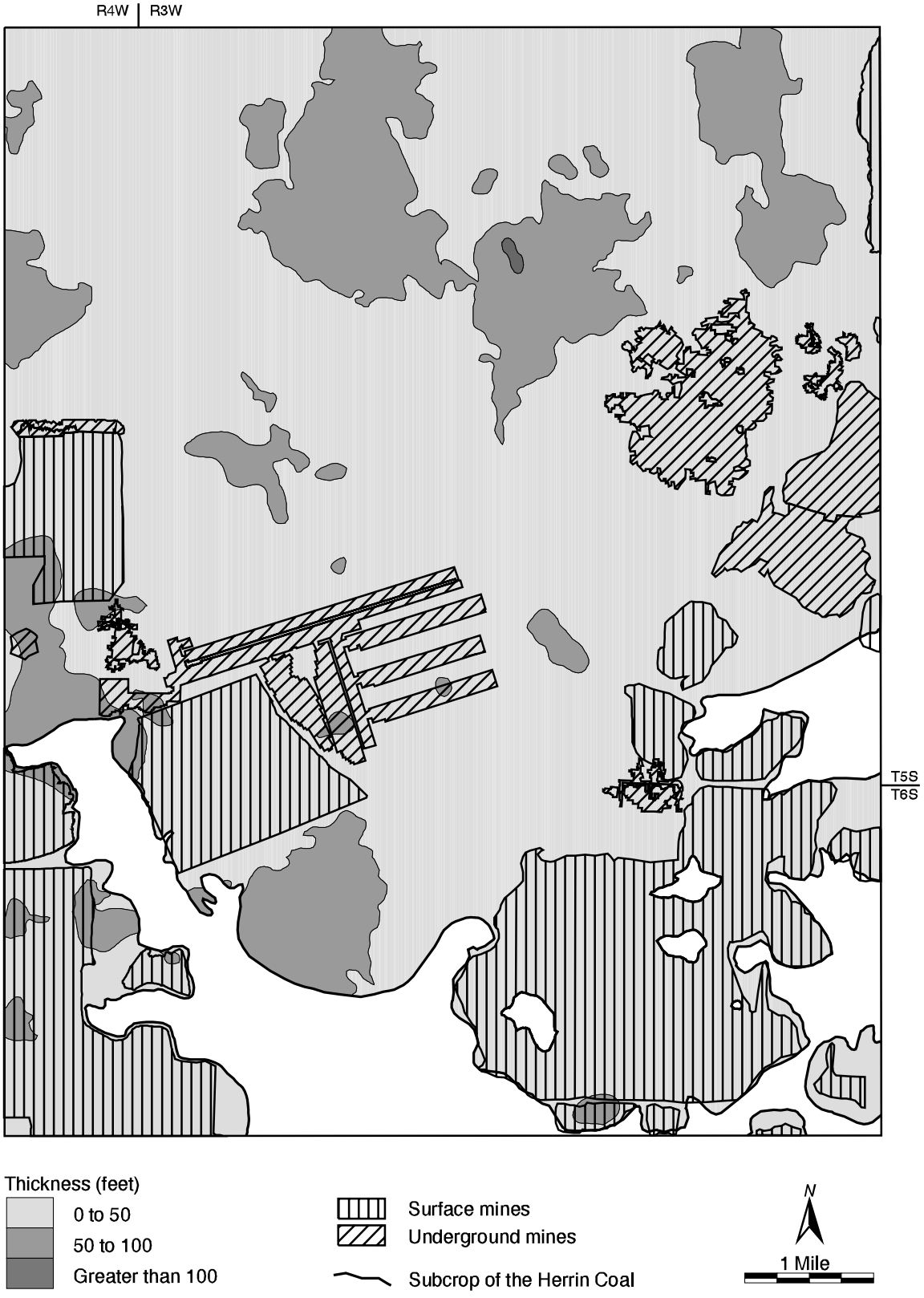

Figure 40 Thickness of unconsolidated overburden, Pinckneyville Quadrangle.

Figure 41 Thickness of the Danville Coal, Pinckneyville Quadrangle.

Figure 42 Depth of the Danville Coal, Pinckneyville Quadrangle.

The Herrin Coal has been the primary target for mines in this quadrangle. The seam ranges from 4.5 to 7.5 feet thick and averages just less than 6.5 feet (fig. 43). Much of the area where it is less than 100 feet deep has been mined (fig. 44). Along the northern edge of the quadrangle the coal lies at depths of more than 250 feet. Because of the relatively thin cover of unconsolidated sediment, most of the Herrin Coal in the quadrangle has sufficient bedrock cover (>35 ft) to be accessible by underground mining (fig. 45).

The Springfield Coal is present throughout most of the quadrangle. Resources of the Springfield Coal have only been mapped in the southern two-thirds of the quadrangle (fig. 46). Although the extent of the coal to the north is uncertain because of the limited exploration data available, it is probably thin north of the quadrangle. Where resources have been mapped, the coal ranges from 1 to 5.5 feet thick and averages about 3.3 feet. In this part of the state, the Springfield Coal lies approximately 25 feet below the Herrin Coal and is projected to lie at depths of nearly 300 feet along the northern edge of the quadrangle (fig. 47).

The stripping ratios of the Danville and Springfield Coals are relatively high throughout most of the quadrangle (figs. 48 and 49). However, the interval between the Danville, Herrin, and Springfield Coals is relatively thin and when considered together, the three seams have a much lower stripping ratio (fig. 50). In recent years, companies have commonly mined the Herrin and Springfield Coals in a single pit.

The Murphysboro Coal was mapped in Jackson and Perry Counties by Jacobson (1983). No additional data have become available since that time, so no additional resources were mapped for this study. In the vicinity of the Pinckneyville Quadrangle, the Murphysboro Coal lies stratigraphically about 250 feet below the Herrin Coal at depths of 200 to 350 feet. The Oraville Channel, a sandstone-filled channel that was once a river flowing through the Murphysboro swamp, passes through the Pinckneyville Quadrangle (fig. 51). The thickness of the coal varies considerably more than the upper coals and ranges from thin or missing to more than 5 feet. Little is known about the mining conditions associated with the Murphysboro Coal. The Herrin and Springfield Coals in similar geologic settings are known to have severe mining conditions, including unstable roof, thick partings, and abrupt changes in seam elevation, immediately adjacent to the channel (Nelson 1983, Treworgy et al. 1995).

Available Coal Of the 722 million tons of coal originally in the Pinckneyville Quadrangle, 367 million tons (51%) are available for mining, 131 million tons (18%) have been mined or left as pillars in mined areas, 89 million tons (12%) are restricted by land use, and 138 million tons (19%) have a technical restriction (table 7 and fig. 52). The relatively low percentage of resources restricted by technical factors reflects the excellent mining conditions associated with the Herrin Coal, the major resource in this quadrangle. The availability of the other coals was below the average for the quadrangle.

If considered alone, only 5 million tons (9%) of the 62 million tons of original resources of the Danville Coal are available for mining, all of it by surface methods (table 7 and fig. 53). If the underlying Herrin Coal were surface mined, an additional 22 million tons of Danville Coal could be recovered. However, this does not appear likely. Current mining trends in this area suggest that most of the remaining Herrin Coal will be mined by underground methods. Consequently, unfavorable stripping ratio is the primary restriction on mining the Danville Coal.

Almost 232 million tons (61%) of the original resources of the Herrin Coal are available for mining. Much of the coal can be mined by either underground or surface mining. A greater amount of the resources in the quadrangle (214 million tons) is available by underground mining than by surface mining (120 million tons) primarily because land use and depth are less of a restriction on underground mining (table 7 and figs. 54, 55). About 28% of the resources (107 million tons) has been mined or left as pillars. Land use restricts 7% of the resources, and technical factors (e.g. block size and thickness of bedrock and unconsolidated cover) restrict 4% of the resources. The percentage of resources restricted by technical factors is one of the smallest of any of the quadrangles studied to date and reflects the excellent mining conditions associated with the Herrin Coal.

About 36 million tons of the Springfield Coal (25% of the original resources of 138 million tons) are available for mining, all of it surface minable (fig. 56). If the coal is surface mined in conjunction with the overlying Herrin Coal, the improved stripping ratio makes an additional 33 million tons available. Land

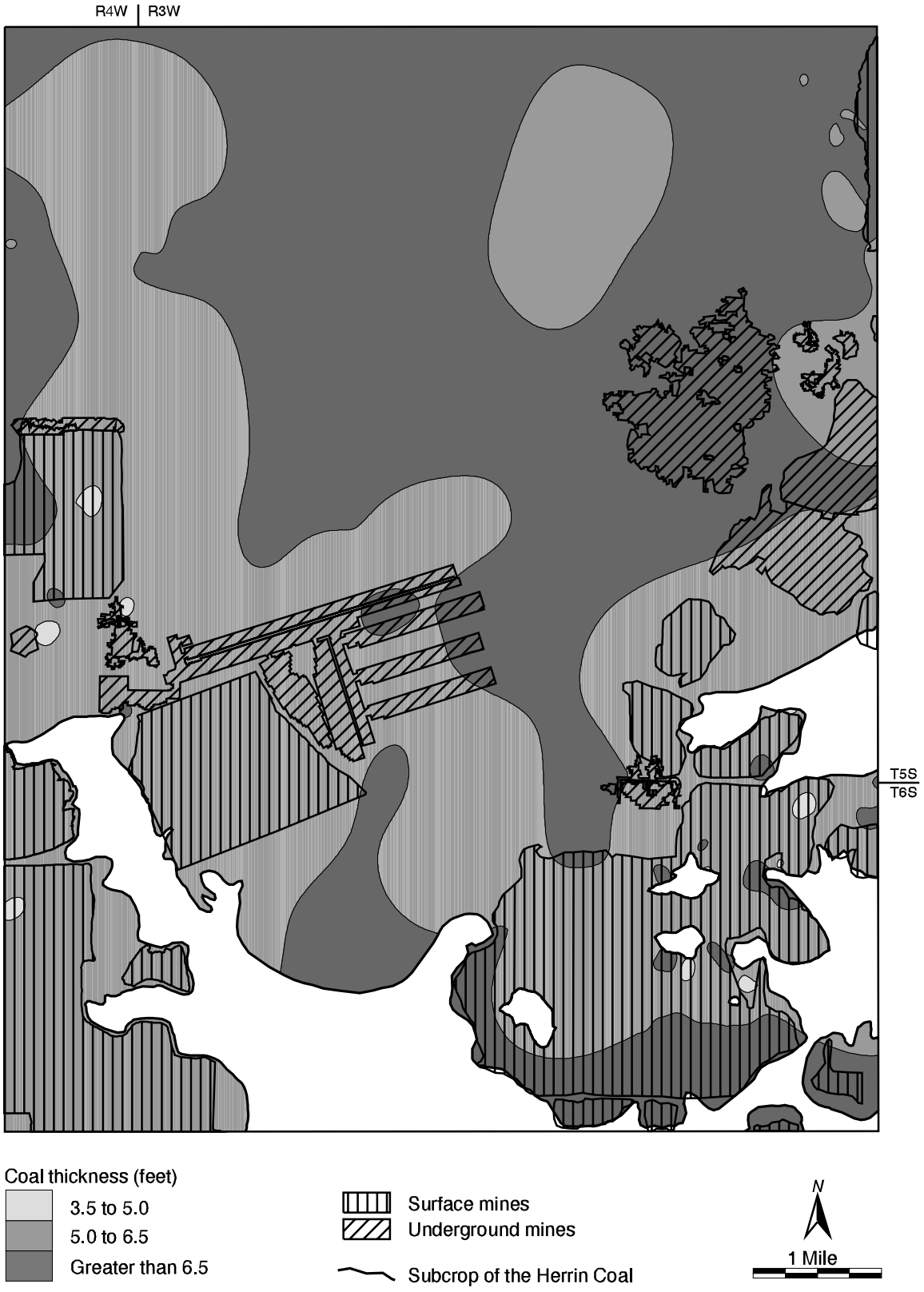

Figure 43 Thickness of the Herrin Coal, Pinckneyville Quadrangle.

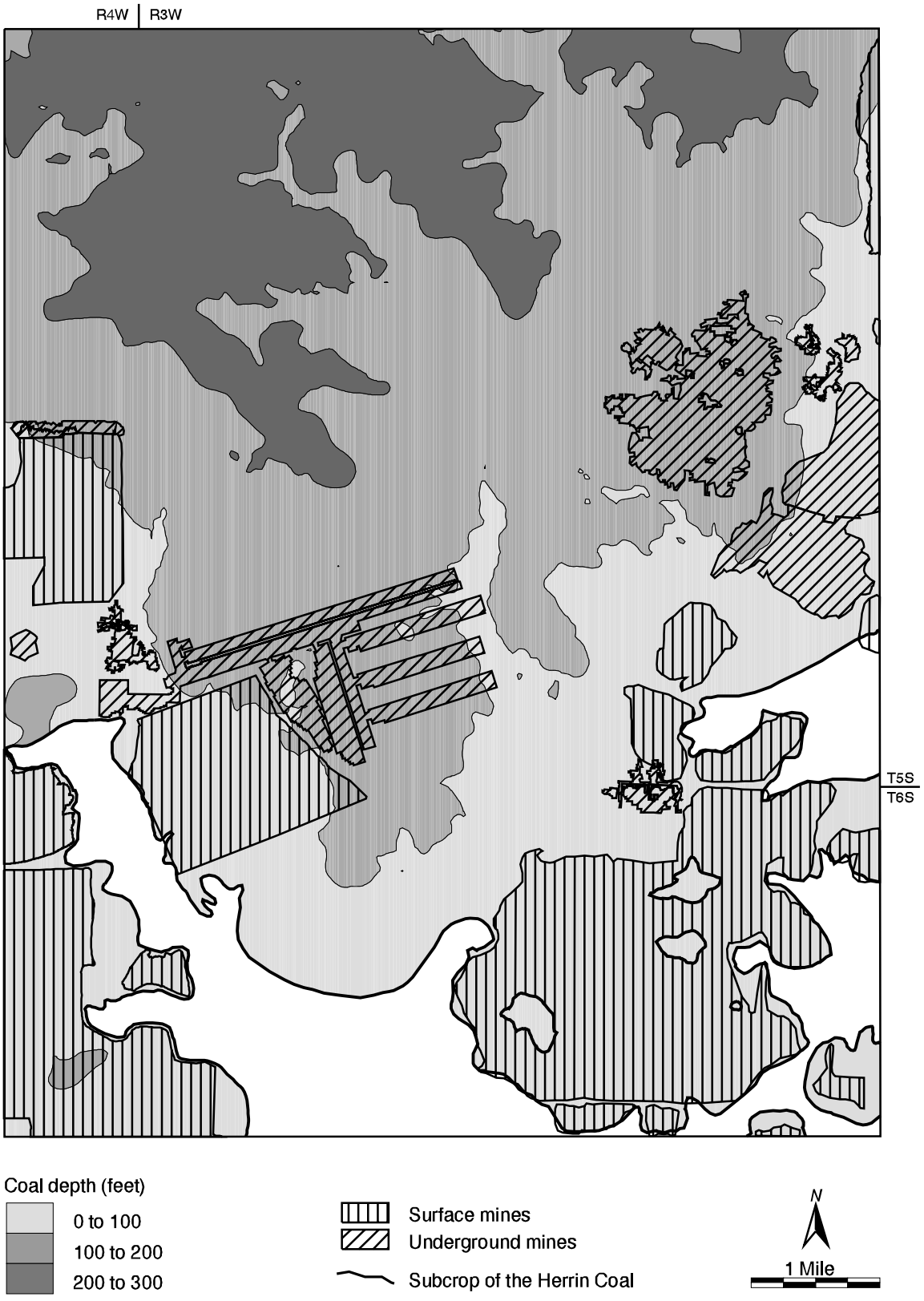

Figure 44 Depth of the Herrin Coal, Pinckneyville Quadrangle.

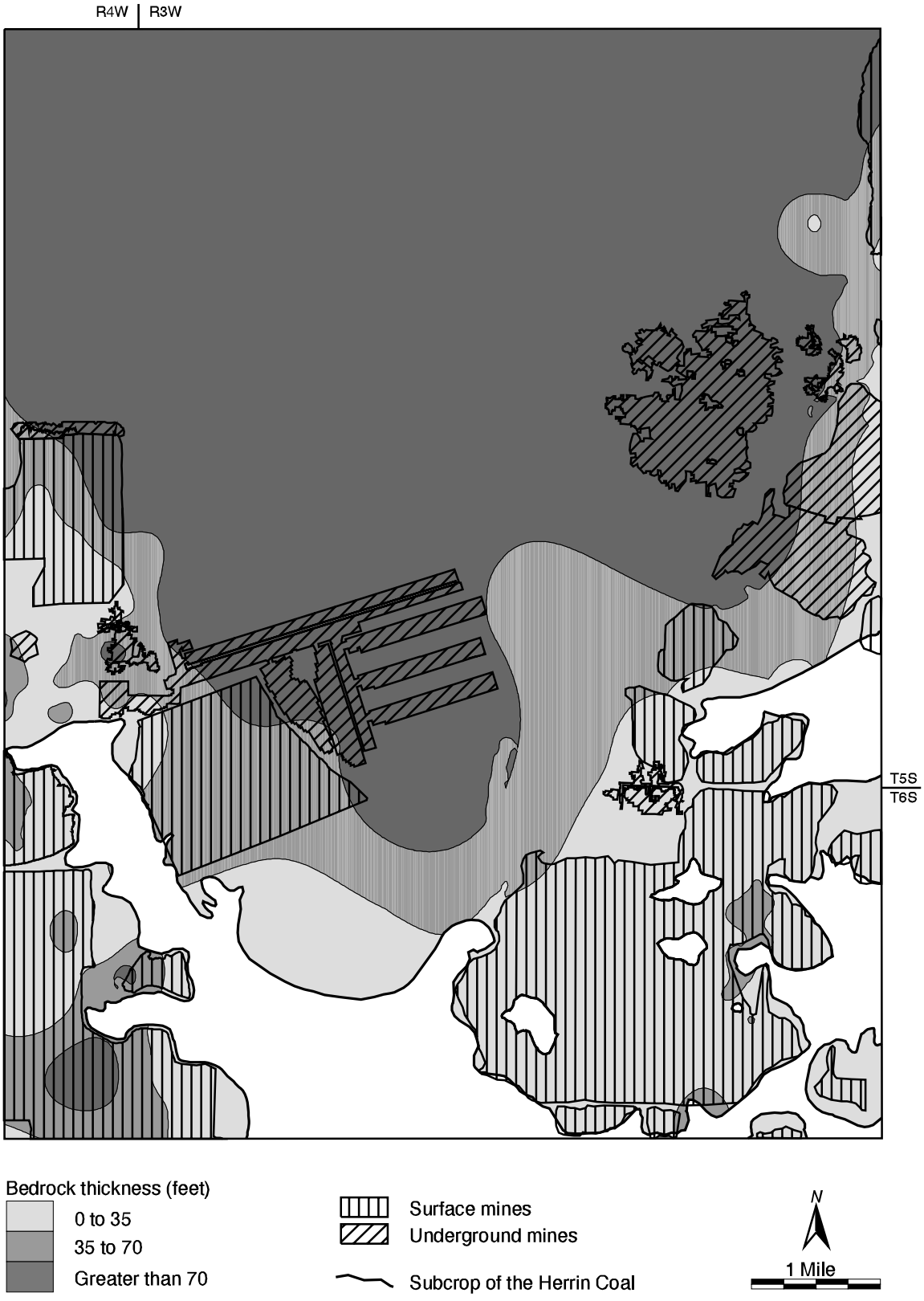

Figure 45 Thickness of the bedrock above the Herrin Coal, Pinckneyville Quadrangle.

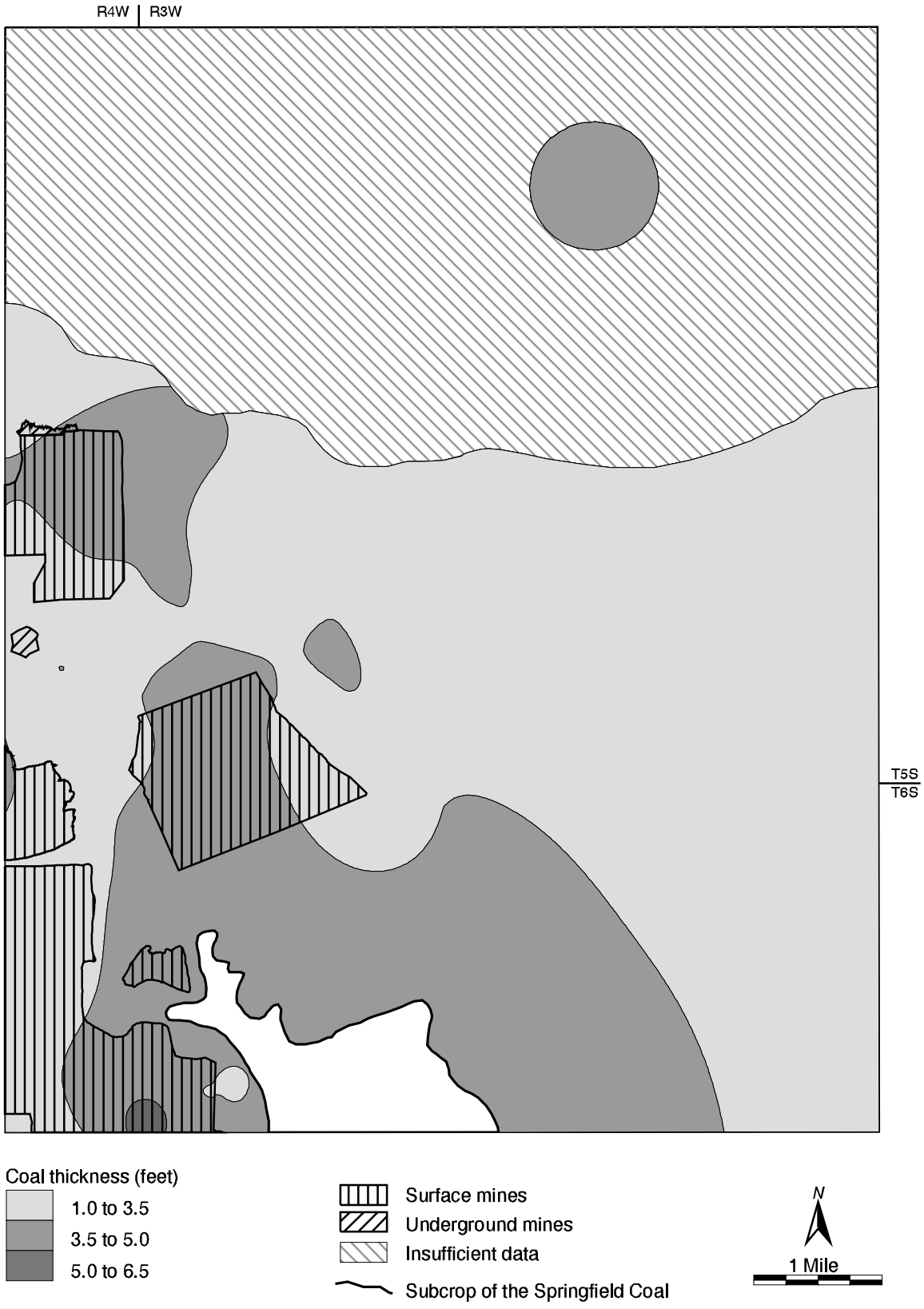

Figure 46 Thickness of the Springfield Coal, Pinckneyville Quadrangle.

Figure 47 Depth of the Springfield Coal, Pinckneyville Quadrangle.

Figure 48 Stripping ratio of the Danville Coal, Pinckneyville Quadrangle.

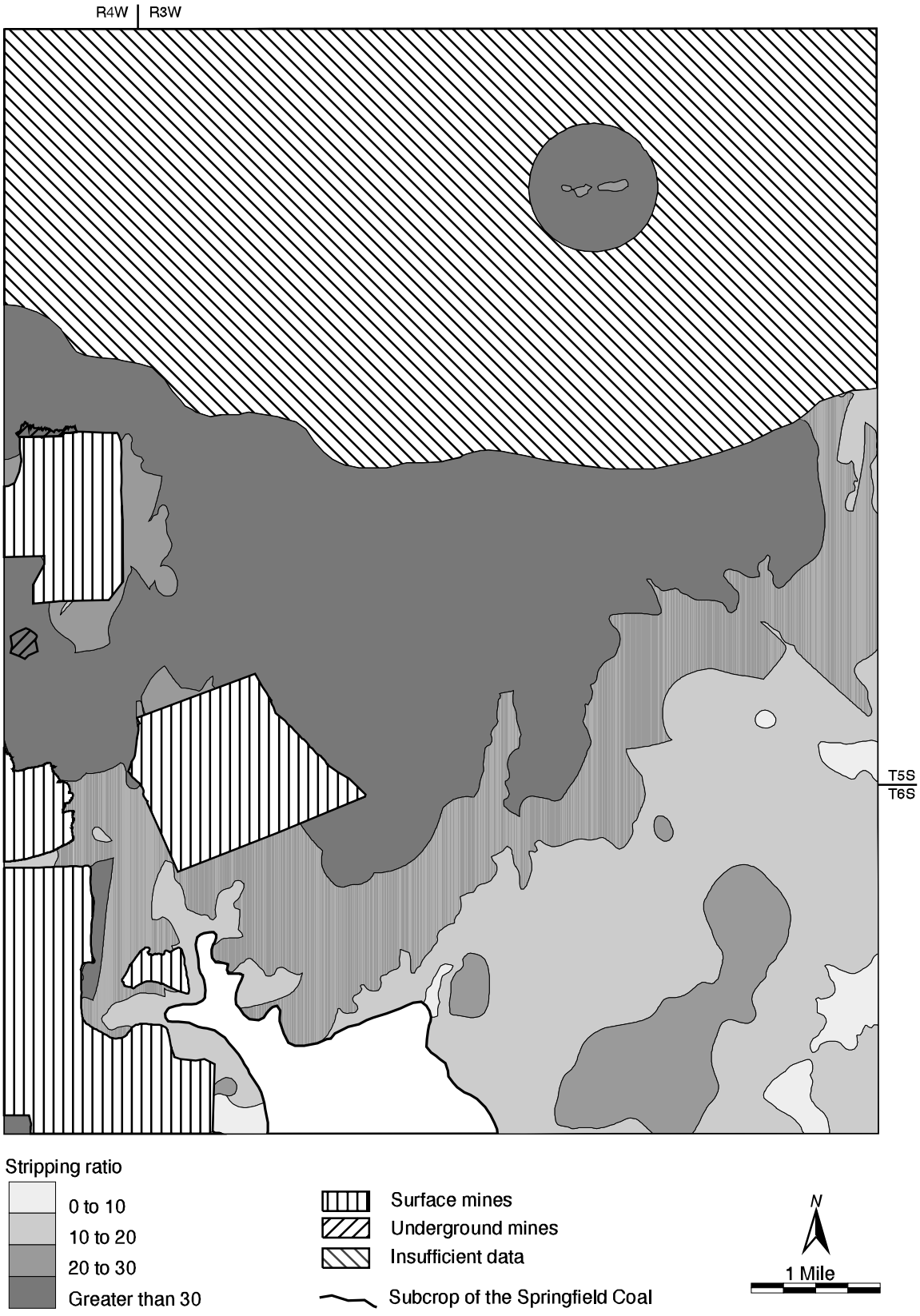

Figure 49 Stripping ratio of the Springfield Coal, Pinckneyville Quadrangle.

Figure 50 Stripping ratio of the combined Danville, Herrin, and Springfield Coals, Pinckneyville Quadrangle.

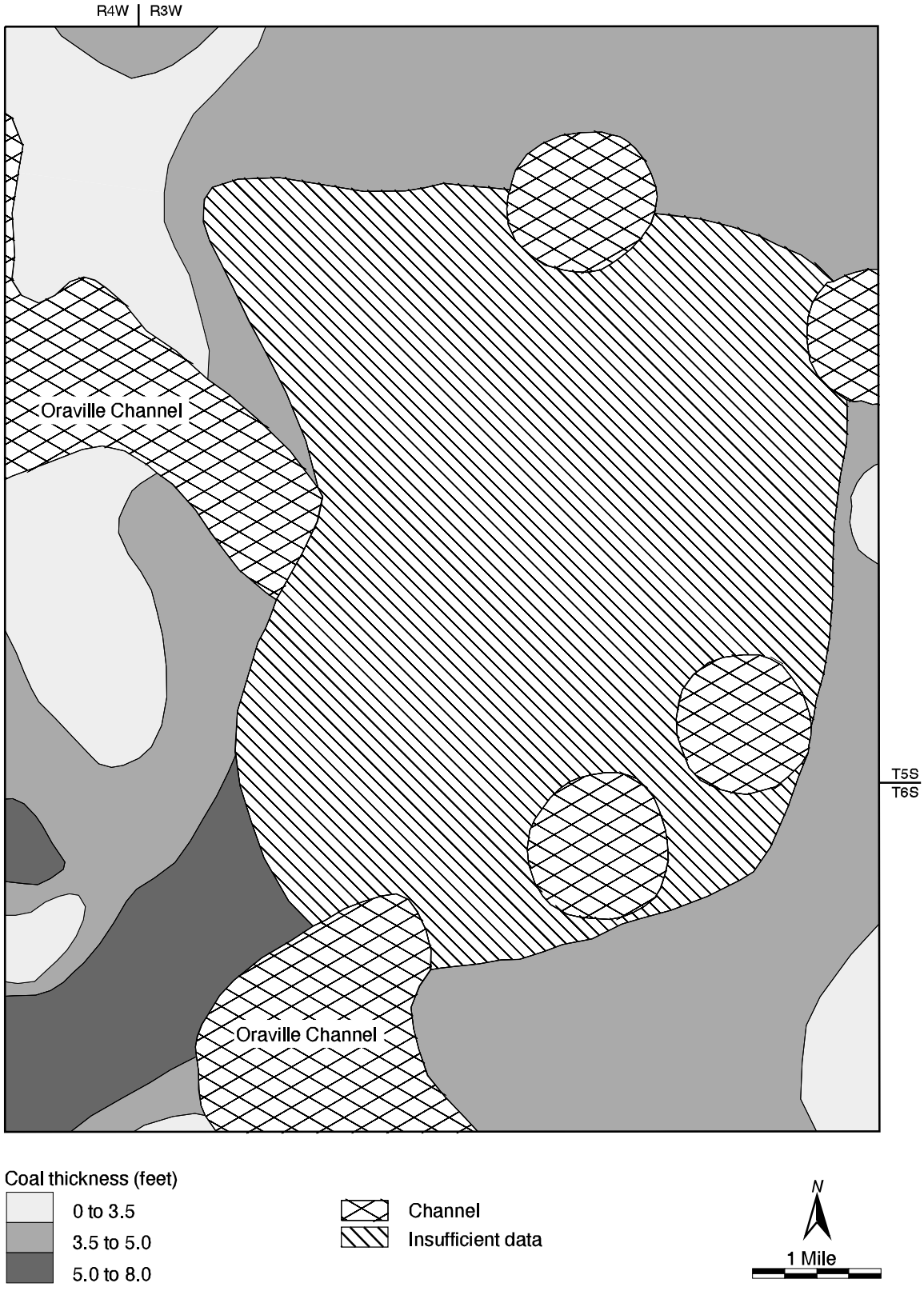

Figure 51 Thickness of the Murphysboro Coal, Pinckneyville Quadrangle.

Table 7 Availability of coal resources for mining in the Pinckneyville Quadrangle; thousands of tons and (percent of original resources).

	Danville		Herrin		Springfield		Murphysboro		Total	
Original	62,555	(100)	379,695	(100)	138,519	(100)	142,055	(100)	722,825	(100)
Available	5,417	(9)	233,235	(61)	22,119	(16)	39,700	(28)	300,471	(43)
Available with conditions	22,864	(37)	-	-	45,399	(33)	-	-	68,263	(9)
Mined out	1,803	(3)	107,185	(28)	21,454	(15)	-	-	130,441	(18)
Land use restriction	12,718	(20)	27,034	(7)	38,799	(28)	16,586	(12)	95,136	(13)
Technical restriction	19,754	(32)	12,241	(3)	10,747	(8)	85,770	(60)	128,512	(18)
Surface minable (0 to 200 ft deep)										
Original	62,555	(100)	312,337	(100)	135,092	(100)	-	-	509,985	(100)
Available	5,417	(9)	118,985	(38)	22,119	(16)	-	-	146,521	(29)
Possibly available	22,864	(37)	-	-	45,399	(34)	-	-	68,264	(13)
Mined out	1,803	(3)	107,182	(34)	21,454	(16)	-	-	130,438	(26)
Land use restriction	12,718	(20)	50,118	(16)	38,789	(29)	-	-	101,635	(20)
Technical restriction	19,754	(32)	36,052	(12)	7,320	(5)	-	-	63,127	(12)
Land use restrictions										
Towns	10,415	(17)	30,870	(10)	5,274	(4)	-	-	46,559	(9)
Cemeteries	232	(<1)	502	(<1)	118	(<1)	-	-	853	(<1)
Railroads	1,011	(2)	2,076	(<1)	878	(1)	-	-	3,965	(<1)
Roads	1,058	(2)	2,675	(1)	917	(1)	-	-	4,650	(1)
Church or school	2	(<1)	16	(<1)	8	(<1)	-	-	25	(<1)
Abandoned mine	-	-	11,505	(4)	14,274	(11)	-	-	25,779	(5)
Parks			2,475	(1)	17,329	(13)	-	-	19,803	(4)
Technical restrictions										
Stripping ratio	18,998	(30)	3,443	(1)	1,650	(4)	-	-	24,091	(5)
Block size	756	(1)	14,644	(5)	4,706	(5)	-	-	20,106	(4)
Unconsolidated overburden			17,966	(6)	964	(1)	-	-	18,960	(4)
Underground minable (>35 ft deep)										
Original	-	-	368,503	(100)	128,530	(100)	142,055	(100)	639,089	(100)
Available	-	-	213,756	(58)	-	-	39,700	(28)	253,456	(40)
Mined out	-	-	101,794	(28)	21,274	(17)	-	-	123,068	(19)
Land use restriction	-	-	29,157	(8)	26,016	(20)	16,586	(12)	71,759	(11)
Technical restriction	-	-	23,797	(6)	81,239	(63)	85,770	(60)	190,806	(30)
Land use restrictions										
Towns	-	-	8,044	(2)	5,520	(4)	3,452	(2)	17,015	(3)
Cemeteries	-	-	984	(<1)	180	(<1)	107	(<1)	1,271	(<1)
Parks	-	-	1,210	(<1)	17,388	(14)	12,985	(9)	31,582	(5)
Railroads	-	-	2,771	(<1)	49	(<1)	-	-	2,820	(<1)
Roads	-	-	460	(<1)	302	(<1)	-	-	762	(<1)
Churches and schools	-	-	97	(<1)	31	(<1)	41	(<1)	169	(<1)
Abandoned mines	-	-	15,442	(4)	2,547	(2)	-	-	17,989	(3)
Dam	-	-	150	(<1)	-	-	-	-	150	(<1)
Technical restrictions										
Thin bedrock	-	-	17,775	(5)	14,248	(11)	-	-	32,022	(5)
Floodplains	-	-	1,691	(<1)	448	(<1)	-	-	2,139	(<1)
Block size	-	-	4,331	(1)	25,225	(20)	65,078	(46)	94,635	(15)
Coal <42"	-	-	-	-	41,318	(32)	20,691	(15)	62,010	(10)

use restricts 22% of the resources (30 million tons), technical factors restricts 13% of the resources (18 million tons), and 16% of the resources (22 million tons) have been mined out. None of the Springfield resources are available for underground mining (fig. 57). Thin coal, small block size, thin bedrock, and land use are significant restrictions.

Of the 142 million tons of Murphysboro Coal, 40 million tons (28%) are available for mining (fig. 58 and table 7). Block size and seam thickness restrict 65 million and 20 million tons, respectively. Land use restricts mining of only 17 million tons (12% of the resources). The channel, variable thickness of the coal seam, and the land use pattern divide much of the remaining area of minable coal into blocks that were too small or irregularly shaped to be mined.

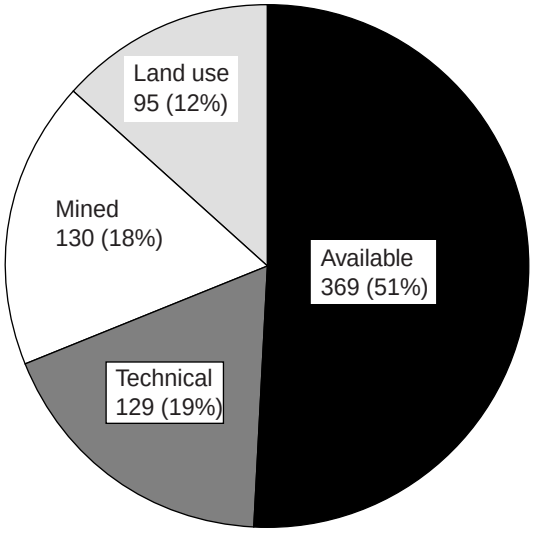

Figure 52 Availability of coal resources, Pinckneyville Quadrangle; millions of tons and (percent of original resources).

EXTRAPOLATION OF QUADRANGLE STUDIES TO MINING REGIONS

A full extrapolation of the findings from individual quadrangles to the mining regions that they represent cannot be accomplished until all the sample areas have been studied. At this point in the project, however, some seams in specific regional settings have been sampled to the extent planned and some initial conclusions can be drawn. The Augusta, Kewanee North, and Roodhouse East Quadrangles provide a reasonable sample of the mining conditions associated with the Colchester Coal in western Illinois. An additional quadrangle will be studied in this region before drawing conclusions about the Danville, Herrin, and Springfield Coals. The Mascoutah and Pinckneyville Quadrangles can be used to assess the availability of the Danville, Herrin, and Springfield Coals for surface mining and shallow underground mining in southwestern Illinois.

Availability of Colchester Coal for Mining in Western Illinois

The Augusta, Kewanee North, and Roodhouse East Quadrangles are representative of the general range of conditions associated with the Colchester Coal in western Illinois (regions 2 and 3). The assessments of these quadrangles can be used to draw conclusions about the availability of the Colchester Coal in these regions.

None of the resources are thick enough for underground mining. Underground mining of seams less than 42 inches thick ceased in these regions more than 50 years ago due to the overwhelming economic advantage of surface mining or underground mining of thicker seams. Although seams on the order of 24 inches thick have been mined underground in recent years in Appalachia, these seams have special quality characteristics that command a higher market price. The Colchester Coal is not known to have any quality characteristics that make it significantly more valuable than other resources. The availability of ample surface minable resources and underground minable resources in thicker seams makes the likelihood of underground mining of the Colchester Coal so remote that it is not considered an available resource.

The three quadrangles studied for this report indicate stripping ratio and land use are likely to be the major restrictions on the availability of Colchester Coal for surface mining in regions 2 and 3. Figure 59 shows that the percentage of resources of Colchester Coal with a stripping ratio greater than 25 to 1 in these regions is higher than is indicated by the three quadrangles studies: 79% vs. 54%. In part, this is because some of the resources with a high ratio in the quadrangles studied also had a land use restriction and were allocated to that restriction category. The other explanation is that the quadrangles studied were not random selections. As noted in the section on *Selection of Quadrangles*, The Augusta and Roodhouse East Quadrangles were selected because they were two of the more suitable areas for

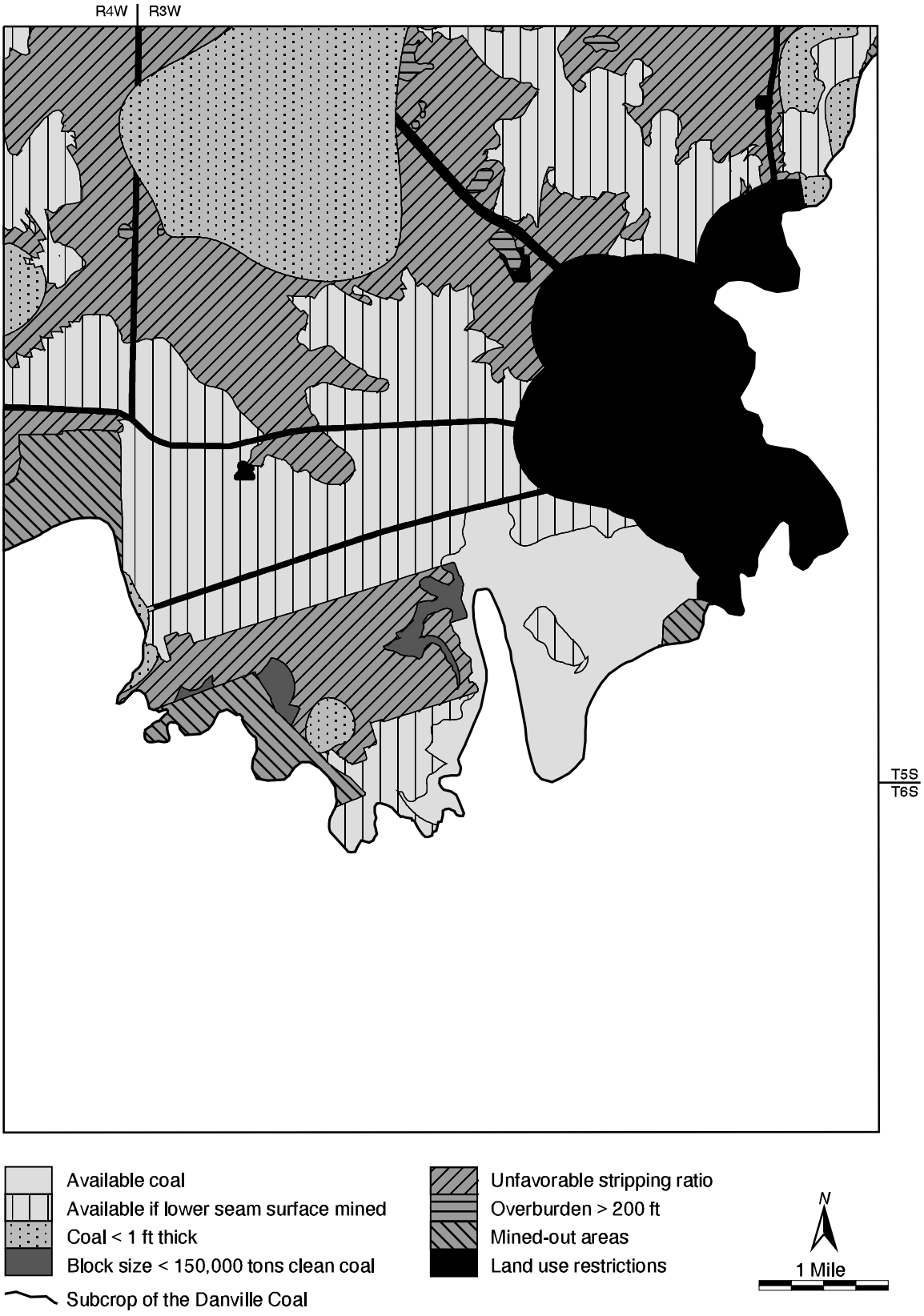

Figure 53 Resources of Danville Coal available for surface mining, Pinckneyville Quadrangle.

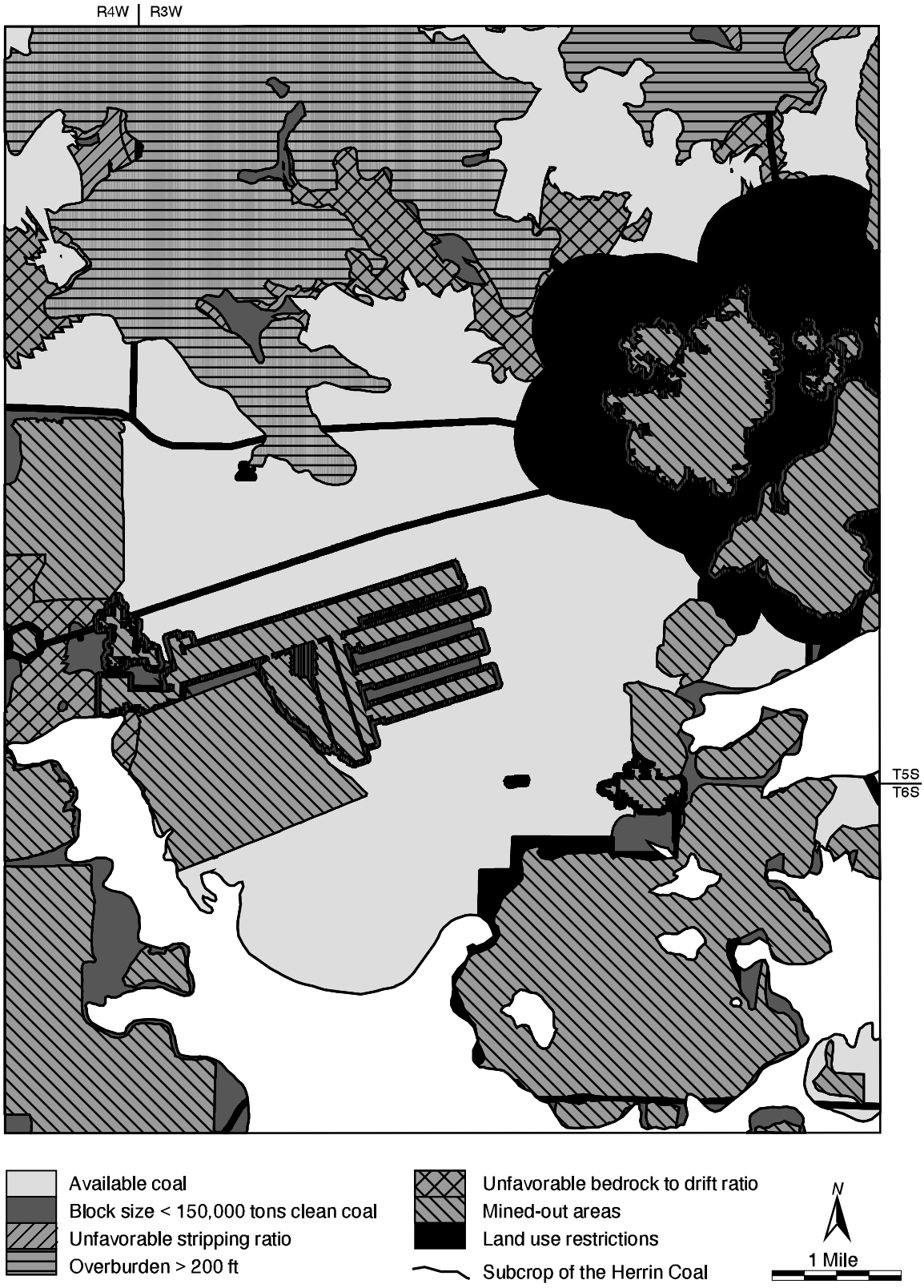

Figure 54 Resources of Herrin Coal available for surface mining, Pinckneyville Quadrangle.

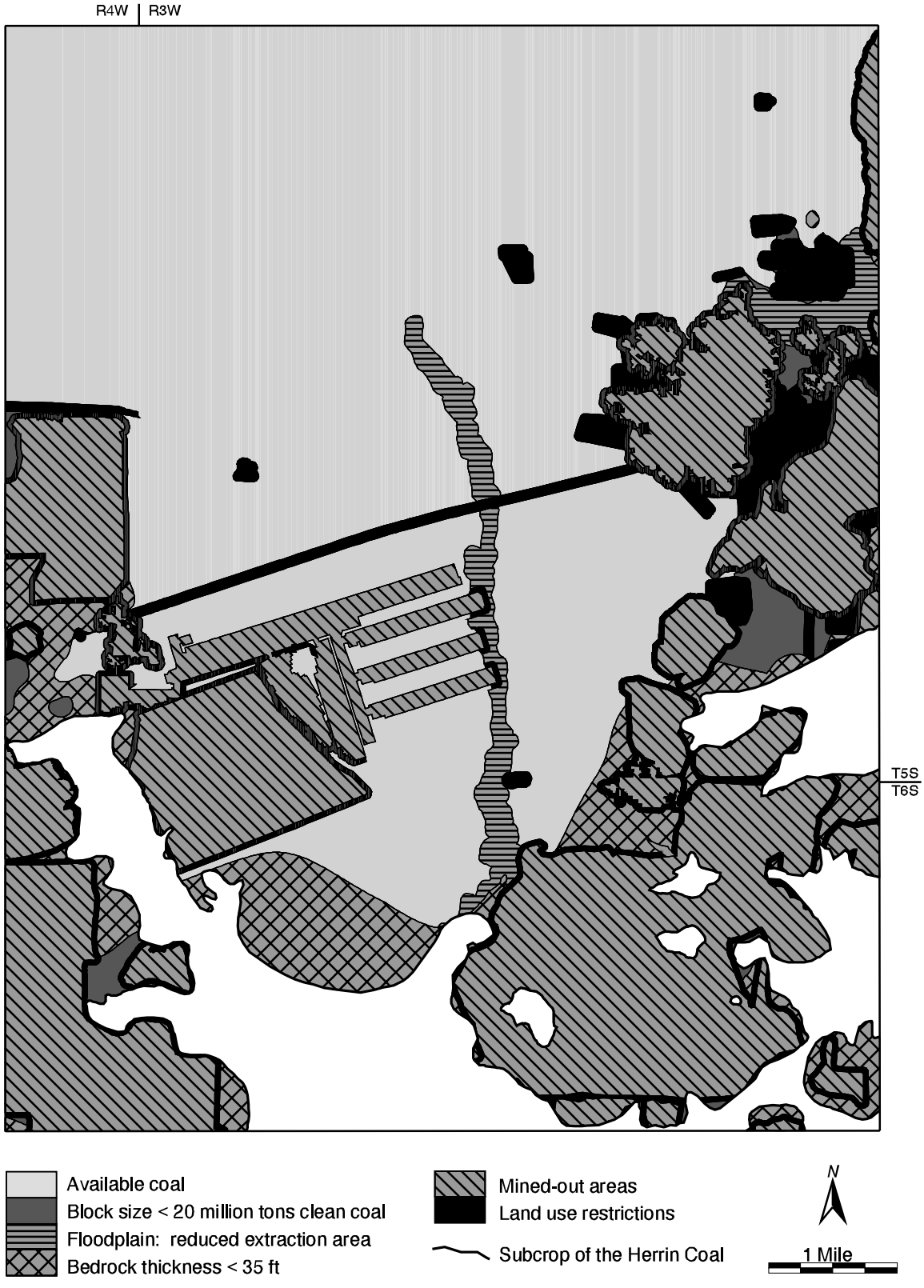

Figure 55 Resources of Herrin Coal available for underground mining, Pinckneyville Quadrangle.

Figure 56 Resources of Springfield Coal available for surface mining, Pinckneyville Quadrangle.

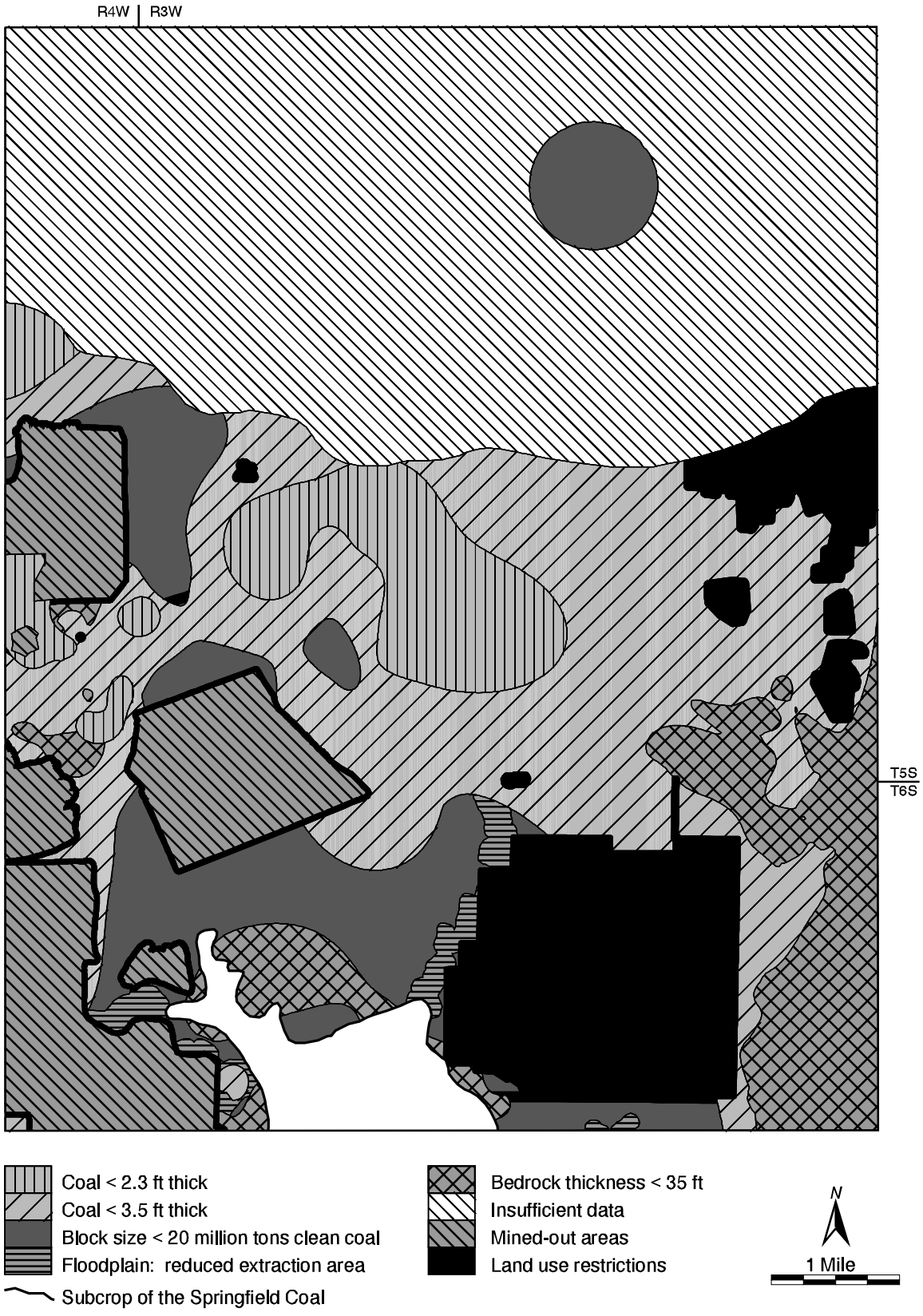

Figure 57 Resources of Springfield Coal available for underground mining, Pinckneyville Quadrangle.

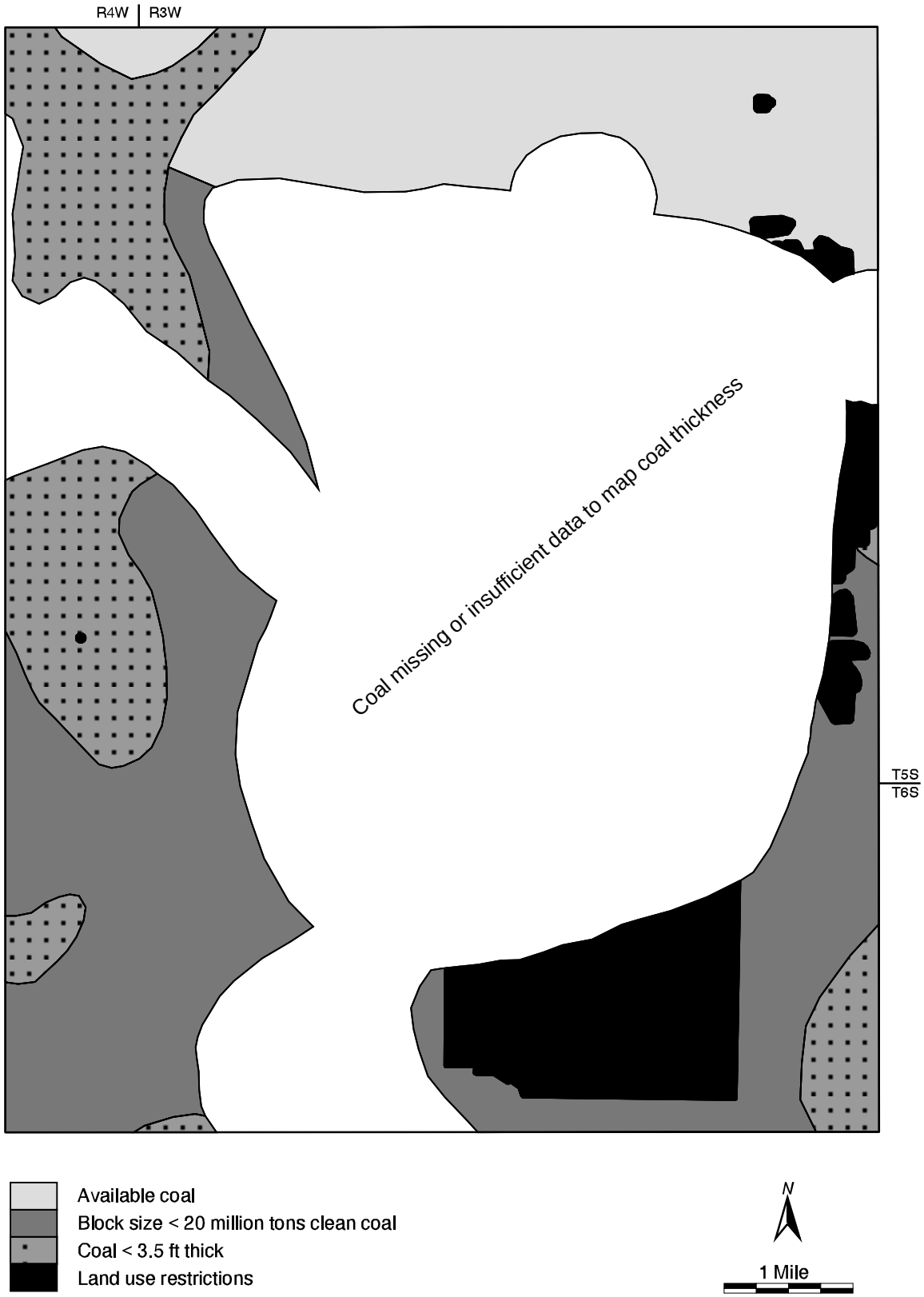

Figure 58 Resources of Murphysboro Coal available for underground mining, Pinckneyville Quadrangle.

surface mining of the Colchester Coal in their regions. In the Kewanee North Quadrangle, which was selected because of its suitability for surface mining of stratigraphically higher coals, all of the Colchester resources had too high a ratio to be minable.

The distribution of land use restrictions should be comparable throughout the region to that found in the Augusta and Roodhouse East Quadrangles. This restriction probably affects on the order of 10 to 15% of the resources. Block size probably restricts 1 to 2% of resources throughout the region; the same order of magnitude as it did in the Augusta and Roodhouse East Quadrangles.

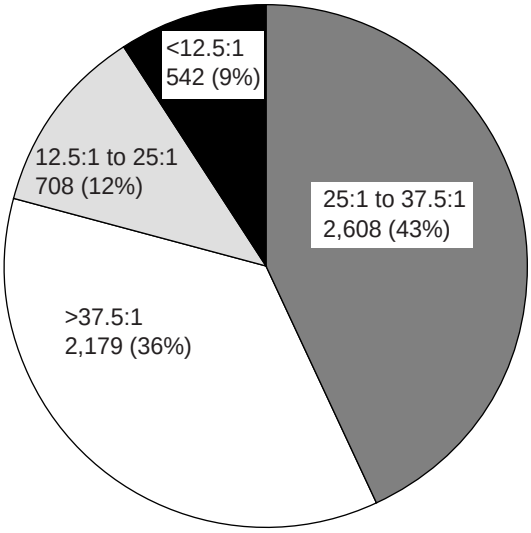

Figure 59 Resources of Colchester Coal in regions 2 and 3 by stripping ratio; millions of tons and (percent of remaining resources).

The amount of Colchester Coal resources restricted by the ratio of unconsolidated to bedrock overburden cannot be estimated at this time. Unconsolidated sediments are not especially thick in many of the upland areas in western Illinois where the Colchester Coal is at surface minable depths. However, areas adjacent to buried bedrock valleys, such as the Colchester Coal in the Kewanee North Quadrangle, will have thick unconsolidated overburden in addition to a high stripping ratio.

Availability of Shallow Coals for Surface and Underground Mining in Southwestern Illinois

The Mascoutah and Pinckneyville Quadrangles, and the Collinsville Quadrangle studied earlier (Treworgy et al. 1996), represent the range of geologic and land use conditions associated with shallow (<300 ft deep) coals in southwestern Illinois (region 6). The Herrin Coal is the major resource in this region. Mining conditions associated with the Herrin Coal are highly favorable in the southern part of this region. The strata immediately above the Herrin Coal in this region contain a relatively high proportion of limestone beds. Because of these competent strata, underground mining with as little as 35 feet of bedrock cover is common and a high percentage of the resources have been mined or are available for mining. Thick glacial and alluvial sediments in the northern part of the region probably limit both surface and underground mining of resources that lie at depths ranging from 50 to 200 feet, particularly where these areas coincide with floodplains of major streams. However, more information on the extent of thick unconsolidated sediments in this region is needed to fully evaluate the quantity of coal affected. Communities, rural subdivisions, and other facilities in the greater St. Louis metropolitan area are a rapidly growing restriction on mining that will eventually affect large tracts of resources. These geologic and land use conditions are a greater restriction to surface mining, suggesting that the majority of remaining resources will be recovered by underground mining.

The Danville and Springfield Coals, to the extent that they can be recovered, are mined primarily in conjunction with surface mining of the Herrin Coal. In the Pinckneyville Quadrangle, only 9% of the Danville resources are available if mined alone, but an additional 35% are available if the underlying Herrin Coal is also surface mined. Only 25% of the Springfield Coal's resources are minable on their own, but the available coal increases to 51% of the resources if the overlying Herrin Coal is also mined. Because these coals are rarely more than 3 or 4 feet thick, they are generally not available for underground mining. These facts, together with the likelihood that increasing land use restrictions will favor underground mining of the Herrin Coal, suggests that much of the Danville and Springfield resources will never be mined.

CONCLUSIONS

The Colchester Coal in western Illinois (regions 2 and 3) is available only for surface mining. More than half the resources are probably restricted by technical factors, primarily high stripping ratios and thick unconsolidated overburden. Land use, primarily towns and roads, probably restricts 10 to 15% of the resources.

The Herrin Coal is the major resource in southwestern Illinois. Because of the excellent mining conditions associated with this coal in the southern part of region 6, 80% or more of the more than 2 billion tons of remaining resources may be available for mining. Mining conditions are less favorable in the northern part of region 6. Urban development and thick successions of unconsolidated overburden restrict mining. These restrictions, together with roof conditions favorable for underground mining, suggest that most future mining will be underground. Resources of the Danville and Springfield Coals in southwestern Illinois are available only for surface mining and are mined primarily in conjunction with the Herrin Coal.

REFERENCES

Allsman, P.T. and P.F. Yopes, 1973, Open-Pit and Strip-Mining Systems and Equipment, *in* SME Mining Engineering Handbook, Society of Mining Engineers of The American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., New York, NY, v. 2, 180 p.

Bergstrom, R.E., 1975, Assigned Sections on Coal Resources, Topography, Geology, Ground-Water and Construction Conditions, and Earthquakes (Seismicity) for COALCON Report, Illinois State Geological Survey, unpublished manuscript, 53 p.

Cady, G.H., 1952, Minable Coal Reserves of Illinois: Illinois State Geological Survey Bulletin 78, 138 p.

Damberger, H.H., 1970, Clastic dikes and related impurities in Herrin (No. 6) and Springfield (No. 5) Coals of the Illinois Basin, *in* W.H. Smith, R.B. Nance, M.E. Hopkins, R.G. Johnson, and C.W. Shabica, Depositional Environments in Parts of the Carbondale Formation—Western and Northern Illinois: Illinois State Geological Survey Guidebook 8, p. 111–119.

Eggleston, J.R., M.D. Carter, and J.C. Cobb, 1990, Coal Resources Available for Development— A Methodology and Pilot Study: U. S. Geological Survey Circular 1055, 15 p.

Jacobson, R.J., C.G. Treworgy, and C. Chenoweth, 1996, Availability of Coal Resources for Mining in Illinois, Mt. Carmel Quadrangle, Southeastern Illinois: Illinois State Geological Survey Mineral Note, 39 p.

Larson, D.R., B L. Herzog, R.C. Vaiden, C.A. Chenoweth, Y. Xu, and R.C. Anderson, 1995, Hydrogeology of the Green River Lowland and Associated Bedrock Valleys in Northwestern Illinois, Illinois State Geological Survey, Environmental Geology 149, 20 p.

Nelson, W.J., 1983, Geologic Disturbances in Illinois Coal Seams: Illinois State Geological Survey Circular 530, 47 p.

Smith, W.H., and D.J. Berggren, 1963, Strippable Coal Reserves of Illinois, Part 5A—Fulton, Henry, Knox, Peoria, Stark, Tazewell, and Parts of Bureau, Marshall, Mercer, and Warren Counties: Illinois State Geological Survey Circular 348, 59 p.

Treworgy, C.G., G.K. Coats, and M.H. Bargh, 1994, Availability of Coal Resources for Mining in Illinois, Middletown Quadrangle, Central Illinois: Illinois State Geological Survey Circular 554, 48 p.

Treworgy, C.G., C.A. Chenoweth, and M.H. Bargh, 1995, Availability of Coal Resources for Mining in Illinois: Galatia Quadrangle, Saline and Hamilton Counties, Southern Illinois: Illinois State Geological Survey Illinois Minerals 113, 38 p.

Treworgy, C.G., C.A. Chenoweth, and R.J. Jacobson, 1996a, Availability of Coal Resources for Mining in Illinois, Newton and Princeville Quadrangles, Jasper, Peoria, and Stark Counties: Illinois State Geological Survey Open File Series 1996-3, 47 p.

Treworgy, C.G., C.A. Chenoweth, and M.A. Justice, 1996b, Availability of Coal Resources for Mining in Illinois, Atwater, Collinsville, and Nokomis Quadrangles, Christian, Macoupin, Madison, Montgomery, and St. Clair Counties: Illinois State Geological Survey Open File Series 1996-2, 33 p.

Treworgy, C.G., E.I. Prussen, M.A. Justice, C.A. Chenoweth, M.H. Bargh, R.J. Jacobson, and H.H. Damberger, 1997, Illinois Coal Reserve Assessment and Database Development: Final Report, Illinois State Geological Survey Open File Series 1997-4, 105 p.

Wood, G.W., Jr., T.M. Kehn, M.D. Carter, and W.C. Culbertson, 1983, Coal Resource Classification System of the U.S. Geological Survey, U.S. Geological Survey Circular 891, 65 p.

ACKNOWLEDGMENTS

This project was supported by the U.S. Geological Survey, Department of the Interior, under assistance award No. 1434-HQ96AG-01460. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government. Margaret Bargh, ISGS staff, compiled information on mines in the Pinckneyville and Mascoutah Quadrangles. We are especially appreciative of the information on criteria that limit the availability of coal given to us by mining experts. Interviews were conducted with Gregg Bierei and Philip Deaton, Arch of Illinois, Victor Daiber and Grady White, Peabody Coal Co., Philip Ames and Bruce Dausman, Black Beauty Coal Company, and Daniel Barkley, Office of Mines and Minerals, Illinois Department of Natural Resources.