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A Methodology for the Environmental Assessment of Advanced Coal Extraction Systems

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ABSTRACT

This document describes the methodology which was developed to identify and assess potential environmental impacts of advanced mining technology as it moves from a generic concept to a more precise systems definition. Two levels of assessment are defined in terms of the design stage of the technology being evaluated. The first level of analysis is appropriate to a conceptual design. At this level it is assumed that each mining process has known and potential environmental impacts that are generic to each mining activity. By using this assumption, potential environmental impacts can be identified for new mining systems. When two or more systems have been assessed, they can be evaluated by comparing potential environmental impacts. At the preliminary stage of design, a systems performance can be assessed again with more precision. At this level of systems definition, potential environmental impacts can be analyzed and their significance determined in a manner to facilitate comparisons between systems.

An important output of each level of analysis is suggestions calculated to help the designer mitigate potentially harmful impacts.

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SECTION I

INTRODUCTION

The Jet Propulsion Laboratory, through an interagency agreement between NASA and the United States Department of Energy, has been assigned the task of defining and developing advance systems for the mining of deep coal. Advanced systems are understood to be those which promise (1) a substantial performance advantage over current technology, or (2) the economic extraction of coal from reserves not presently minable. In addition, new systems should incorporate the maximum number of mining activities that create the least environmental damage or that have the potential for total mitigation of an impact. Thus, to develop new systems that have the potential for fewer environmental consequences than present-day mining systems, an environmental assessment methodology must be developed that will identify and evaluate not only the potential impacts of underground mining, but also those impacts that are associated with the surface support of deep coal extraction.

In developing a methodology to evaluate new mining concepts, consideration must be given to the environmental impacts that may result when a system is implemented in a specific environmental setting. However, the evaluation of new technology is very complex; both technology and the environment are continually evolving. This evolution creates a difficult problem since environmental assessments typically require specific data on a system's performance requirements and characteristics of the environmental setting. Thus, when concepts exist as only partially developed ideas, there is little specific engineering data or siting characteristics available for an assessment. As a system becomes more well defined, however, more specific information becomes available. As a consequence, systems are first assessed when they exist as partially developed concepts so that major potential environmental problems are flagged in the early stages of systems development. Systems are assessed again when they become better defined so that environmental problems may be identified at the level of detail which permits exploration of specific mitigation strategies. By using such an approach to identify and evaluate potential environmental impacts during each level of systems development, systems may be redesigned to mitigate potential impacts, or if the effects cannot be mitigated, the concepts may be restructured in a more fundamental fashion.

This document provides a two-stage methodology for assessing and evaluating the major potential environmental impacts of new mining systems as they move from a broadly defined concept to a more precise systems definition. The first stage of assessment, the conceptual methodology, occurs when the system is defined at the conceptual design stage. The conceptual design stage is defined when the basic architecture of the system is known and the subsystems have been identified. Engineering data may be missing or in the early phase of confidence.

A. CONCEPTUAL METHODOLOGY

Because specific engineering data and environmental siting characteristics are virtually absent at the conceptual design stage, a general or generic assessment is a necessity. In pursuit of a general approach to environmental assessment, the conceptual methodology is constructed with the objective of flagging the major aspects of system performance--both positive and negative--that are critical to the continued development of a mining concept. To obtain this objective, the conceptual methodology is based on the following assumptions:

(1) All mining systems can, at the conceptual stage, be defined in terms of their component generic processes. For coal mining systems, these generic processes are identified as follows (for definitions, see appropriate heading in Section II):

(a) Construction of Access and Haul Roads.

(b) Removal of Overburden.

(c) Development of Systems Access.

(d) Coal Cutting.

(e) Coal Hauling.

(f) Coal Processing.

(2) Each identified mining process has known and potential environmental impacts that are generic to each mining process.

(3) Characteristics of the environmental setting need only be known on a regional scale (e.g., eastern, interior, or western coal provinces.)

Using the assumptions above, the conceptual methodology is constructed into two basic units: (1) Characterization of Generic Environmental Impacts, and (2) Completion of the Environmental Identification Checklist.

1. Generic Environmental Impacts

This section provides a review and discussion of known and potential environmental impacts that are generic to each mining process (e.g., construction of access and haul roads, removal of overburden, development of systems access, coal cutting, coal hauling, and coal processing). Each mining process is described in terms of specific subsystems and/or technologies (e.g., haulage: truck, conveyor, rail and pipeline) and the known or potential impacts are identified for each technology. By identifying impacts with a

particular subsystem, the user can associate known or potential impacts of a conventional technology with a similar subsystem of an advanced mining concept. For example:

MINING PROCESS: Systems Access

SUBSYSTEM: Vertical Access Holes

IMPACTS CONVENTIONAL TECHNOLOGY (Oil and Gas Wells)	IMPACTS ADVANCED TECHNOLOGY (Borehole Miner)
1. Aquifer Contamination 2. Alteration of Groundwater	Assume same impacts as Conventional Technology

Potential Impacts

The objective of associating impacts with subsystems is to gain the ability to identify potential environmental impacts with a subsystem instead of the complete system. As a consequence, systems may be more easily redesigned to mitigate potential environmental impacts associated with a specific subsystem. However, the use of this format introduces a certain amount of redundancy in these cases where different mining processes have similar potential impacts. For example, the disruption or removal of soil and vegetation have similar impacts whether it occurs from the construction of access and haul roads or removal of overburden.

2. Environmental Identification Checklist

The environmental identification checklist consists of forty-five general questions which address land, water, air, biologic and energy impacts. Answers to these questions will identify most of the anticipated negative impacts. Each question has been constructed to indicate possible impacts based upon the available information the user has on the basic engineering components of the mining system and the regional characteristics where the system may be implemented.

The level of information required for filling out the environmental checklist has been purposely restricted to regional characteristics (e.g., general geologic column, regional water availability, general landforms, etc.). Because site-specific details are irrelevant at this level of analysis, they have been omitted. As a result, specific environmental issues that are site specific have not been addressed (e.g., geochemical differences in coal and overburden, locally steep slope, soil salinity, etc.). Site-specific analysis, however, becomes important when a system reaches a design stage that requires a field demonstration.

When the user has read the Generic Environmental Impact section and has collected the regional site characteristics outlined in the conceptual methodology, the Environmental Evaluation Checklist can be filled out. By filling out the checklist at the level of detail indicated, the user will have an assessment that indicates areas of critical environmental concern which may be the result of underground, quasi-underground (e.g., contour and auger mining), or surface mining processes. Thus, if a system embodies a specific set of mining processes, the methodology will provide a means to identify the expected environmental impacts associated with each subsystem. As a consequence, mining systems at the conceptual design stage can be evaluated to determine their suitability for continued development or the feasibility of redesigning subsystems that may be potentially harmful to the environment.

Those systems that have been evaluated using the conceptual methodology and have been developed to the preliminary design stage, can be assessed again using the preliminary methodology. A system is defined at the preliminary design stage when the overall performance of the system is known, the subsystems and their interfaces have been defined, and the capital and operating costs have been estimated. (For a detailed definition see Appendix E.)

B. PRELIMINARY METHODOLOGY

The major advantage of having additional or more detailed engineering data of a system is the ability to quantitatively estimate the amount of natural resources (e.g., land, water, and energy) that will be required by that system to operate in a given environment. By having engineering data at the preliminary design stage together with representative site characteristics, potential impacts on a region's natural resources can be quantified. Thus, it is the objective of the preliminary methodology to quantify the potential impacts of a mining system on a region's natural resources (e.g., total area distributed by a mining system, water requirements versus water resource availability, sediment yield, etc.).

When potential impacts have been identified with the conceptual methodology and selected impacts on a region's natural resources have been quantified using the preliminary methodology, the user can rank all impacts according to their relative significance. Because of variations in regional characteristics (e.g., topography, climate, land use, etc.), the relative significance of impacts for any particular system may vary from one region to another. Consequently, the preliminary methodology provides the user with a procedure for determining the significance of impacts for any region.

With the potential impacts of a mining system identified, quantified, and arranged in order of their significance, the system may be compared by the user to any other system that has been similarly assessed. Thus, the resulting comparison will provide a subjective indication as to the degree of advantage or disadvantage

one system may offer over another. This process, once again, allows the user to decide if a system is worth further development or if additional modification of the system is feasible to mitigate potential impacts.

C. SUMMARY

The environmental methodology presented in this document is constructed to evaluate the potential environmental impacts from the deep mining of coal. Two separate levels of evaluation, based upon the available engineering data of a system, are provided. These levels are: (1) the conceptual environmental methodology, which corresponds to the conceptual design stage and (2) the preliminary environmental methodology, which corresponds to the preliminary design stage. Each methodology provides the following:

(1) Conceptual Methodology--When a mining system is defined at the conceptual design stage, the conceptual methodology can be used to flag the major environmental impacts that may be associated with a system.

(2) Preliminary Methodology--As a system moves from the conceptual to preliminary design stage it can be assessed again with the preliminary methodology. The preliminary methodology is used to quantify potential impacts of a mining system on a region's natural resources.

Each level of evaluation provides a different output. The conceptual methodology is entirely subjective while the preliminary methodology allows the quantification of selected impacts. Regardless of these differences, their objectives are the same: At each level of system definition, provide an evaluation methodology to help the user determine if a mining system should undergo continued development or if further modification of the system is required to mitigate potential environmental problems.

Finally, it should be emphasized that the level of detail and the objectives of this document are not those of an environmental impact report and, therefore, should not be construed as its equivalent.

SECTION II

CONCEPTUAL ENVIRONMENTAL ASSESSMENT METHODOLOGY

The conceptual environmental assessment methodology, as discussed previously, is used to identify potential environmental impacts of mining systems at the conceptual stage of design in conjunction with regional characteristics. Potential environmental impacts are identified by using a checklist and are then summarized in a way that facilitates comparisons of mining systems. Accordingly, the conceptual methodology is organized into three sections:

Conceptual Methodology Instructions: In order to identify the potential impacts of a mining system, the regional environmental setting appropriate to the target coal resource must be characterized. This section identifies the regional characteristics necessary to perform a conceptual assessment. In addition, the section details how to fill out the checklist and summary sheet.

Generic Environmental Impacts: This section provides a tutorial description of the environmental impacts that are associated with present-day mining systems, as well as possible impacts that may occur from new technologies. Procedures for mitigating these impacts and the major laws which regulate the coal mining industry today are briefly reviewed. This descriptive material is meant to serve as a reference while performing an assessment.

Environmental Identification Checklist and Checklist Summary: With the aid of the information in the generic impact section, the checklist is constructed to identify potential environmental impacts. With the completion of the checklist, the potential impacts may be summarized on the Checklist Summary Sheet, devised to highlight the salient differences between mining systems, thus facilitating judgments as to the degree of advantage one system might offer over another.

A. CONCEPTUAL METHODOLOGY INSTRUCTIONS

1. Background of Analyst

The analyst completing the checklist is assumed to have a general knowledge of both coal mining operations and potential environmental impacts of existing technology. Additional background on potential impacts may be obtained from the following section on the generic impacts of coal mining.

2. Auxiliary Data

The regional data required to complete the checklists consists of the following categories (for a detailed list of data sources and selection of a mining region, see the preliminary methodology, Section III-A):

(1) Geography

(a) Climate - annual precipitation and temperature patterns.

(b) Landforms - predominant landforms (e.g., plains, plateaus, mountains, hills, valleys, etc.) and soils.

(c) Land Use - predominant land uses.

(2) Geology

(a) Depth of Overburden - average depth of overburden for the coal bed or beds of interest.

(b) Number of coal beds - single or multiple.

(c) Structure (e.g., flat-lying, folded).

(3) Hydrology

(a) Groundwater - average aquifer yield.

(b) Surface Water - minimum and maximum surface flows (discharge).

(c) Water Use - primary regional use of existing water resources.

The amount of information collected for an assessment should be summarized in a general fashion. For example (hypothetical region):

(1) Geography

(a) Climate: The maximum temperatures of 90°F or higher occur in July, the warmest month of the year, with temperatures falling below zero degrees in January. Maximum precipitation generally is in spring and early summer. The average rainfall in winter is less than 3 in. per month, and the average in spring is more than 4 in. per month.

(b) Landform: The region consists of numerous ridges (slopes greater than 20%) that are broad at the summit with gently sloping alluvial valley floors. In most localities the depth of the valley floor is generally 1000 to 1500 ft below the ridge tops. Soils on the ridges are usually 10- to 15-in. thick with a shallow A horizon. Alluvial soils are thick, well-drained, and suited to agriculture.

(c) Land Use: Ridges are predominately forested while the valley bottoms are urbanized with some agriculture.

(2) Geology

(a) Depth of Overburden: From the ridge tops to the first coal bed greater than 24 in. the range is from 400 to 700 ft.

(b) Number of Coal Beds: From the upper coal bed to the valley floor there are 7 coal beds (greater than 24 in.) with a total thickness greater than 250 in.

(c) Structure: All beds are flat (dip less than 2 degrees) with some minor folding where the beds exceed 10 degrees.

(3) Hydrology

(a) Groundwater: Aquifer yields in the ridges range from 50 to 100 gpm. In the valley floors groundwater yields can exceed 500 gpm.

(b) Surface Water: Surface water discharge from most river basins is greatest during the spring when 2.7×10^4 to 1.0×10^2 gpm can be expected.

(c) Water Use: 15-10% of all water resources are used by urban and industrial consumers.

3. How to Fill Out the Environmental Identification Checklist

The mining system being assessed must be described at a level of detail which permits a ready comprehension of the basic mining activities, including equipment characteristics and the manner in which it will be operated. (For an example, see the mining system summary of Appendix A.) In addition to the mining system summary, all auxiliary data used for the assessment must be included along with the summary. Given the auxiliary data and the completed mining system summary, the Environmental Identification Checklist (Section II-C) can be filled out.

The checklist consists of forty-five questions which address the most general air, water, biologic, land, and energy impacts. These questions help the user identify most of the negative impacts. The questions have been constructed to indicate possible impacts based upon the available information the user has on the basic engineering components of the mining system and the regional characteristics.

The development of these questions was influenced by the impacts discussed in the works of Doyle (1976a; 1976b), and Down and Stocks (1977). Like other checklists, this one is necessarily confined to typical problems and is intended to serve as a guide rather than a handbook. None of the checklist questions are tied to legal reclamation standards or site-specific issues.

When filling out the checklist the user should try to answer all questions with a definite "yes" or "no" answer. In order to complete an assessment no more than 25% of the questions should be answered with a "maybe". If the user answers more than 25% of the questions with a "maybe", then the user does not have sufficient engineering data or regional characteristics for an assessment. Under these circumstances, the user has the following options: (1) collect more information on the regional characteristics of the target coal region (see Section III-A), (2) obtain further information on the engineering characteristics of the mining system or make the necessary engineering assumptions to understand the systems operation (note: all assumptions should be clearly stated and included with the mining system summary), or (3) defer the assessment until the necessary data are available.

For each question checked "yes" or "maybe" on the environmental identification checklist, an impact identification sheet (Figure 2-1) should be filled out. (For an example see Appendix A.)

If the user cannot fill out the checklist answer sheet fully, then the section or sections indicated with each question on the checklist should be read. If the information in these sections is not adequate, the references cited in each section should be consulted.

4. How to Fill Out the Checklist Summary

For each question, find the number corresponding to the question on the summary sheet (Figure 2-2). Darken the positive or negative side based upon the correspondence between the given answer and the labeled "yes" and "no" in the appropriately numbered line of the summary sheet (see Figure 2-2). All "maybe" answers should be left blank.

B. GENERIC ENVIRONMENTAL IMPACTS

This section provides a review and discussion of known and potential environmental impacts that are generic to specific coal mining processes. A mining process can be divided into subsystems and/or technologies (e.g., Haulage can be divided into truck, conveyor, rail, or pipeline) and the known or potential environmental impacts can be identified for each subsystem and/or technology. In this document, the following mining processes have been defined:

(1) Construction of access and haul roads.

(2) Removal of overburden.

(3) Development of systems access.

(4) Coal cutting.

(5) Coal hauling.

(6) Coal processing.

1.a.

(1) Nature of Activity _____

_____

_____

_____

_____

_____

(2) Probable Impacts _____

_____

_____

_____

_____

_____

(3) How Impact Could be Mitigated _____

_____

_____

_____

_____

_____

1.b. etc.

Note: This sheet or its equivalent is recommended as a guide to identifying and characterizing impacts at an early stage of design.

Figure 2-1. Illustration of an Impact Identification Sheet

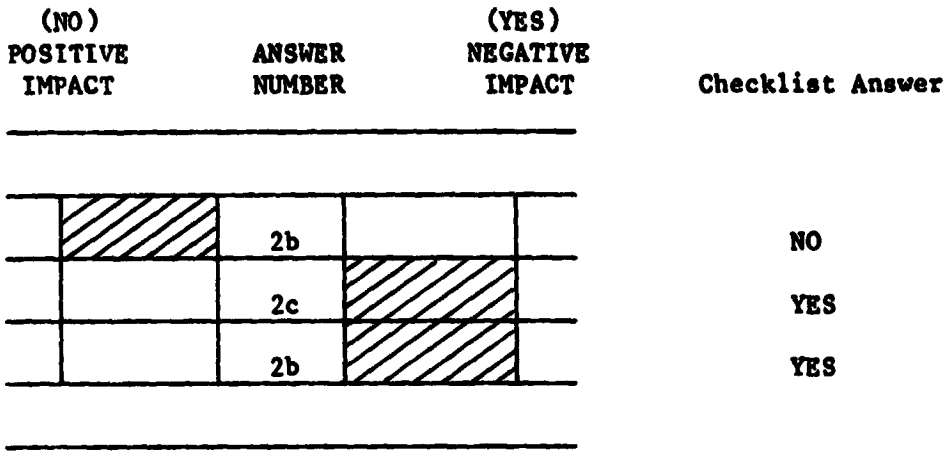

Figure 2-2. An Example of How to Fill Out the Summary Sheet

For each process, along with its components, there are subdivisions which describe environmental impacts of present-day mining systems, their estimated magnitude, pertinent mining regulations, and suggested mitigating procedures. Also included is a summary of anticipated major environmental impacts.

However, these sections do not have detailed information on the reclamation requirements and procedures for specific mining regions. This was a deliberate omission because reclamation techniques and procedures vary greatly between eastern and western coal regions. For example, in the western coal regions the annual amount of precipitation can be so low that it hinders successful revegetation. Soils in the West are also less fertile than those in the East, they are alkaline, and can have severe salinity problems. In contrast to the West, the eastern coal regions must deal with steep slope revegetation, shallow soils, and potentially severe acid mine drainage. In addition, it has been shown that there is a wide variation in the geochemistry between eastern and western coals (Dovorak, et al., 1978).

Not only do the procedures for reclamation vary, but the potential for successful reclamation also varies. For example, Knuth, et al. (1978) have modeled reclamation potential based on soil type, slope, pH of the overburden, geology of the overburden, mean annual precipitation, and average annual runoff for the eastern and interior coal regions. This model shows that different regions have more favorable conditions for reclamation success than others (e.g., Illinois has more favorable conditions than Eastern Kentucky). However, Knuth, et al. (1978) also indicate that even with poor reclamation conditions, the coal industries in some states (e.g., West Virginia) achieve environmentally sound reclamation, while operators in states with more favorable conditions (e.g., Arkansas) do not achieve proper reclamation. Although coal regions in the United

States do vary in their potential for reclamation, it has been demonstrated by the State of West Virginia (and others), that when mine operators and enforcement officials are environmentally educated, experienced, and motivated, reclamation is successful.

Before continuing with generic impact sections, it is important to note that impacts related to both surface and underground mining activities will be discussed. Because this document deals with both types of impacts, it is useful to make a clear distinction between the two. Figure 2-3 is a matrix which suggests the potential environmental impacts of a typical area surface mine that might occur in Indiana, Illinois, or Western Kentucky and a typical room and pillar underground operation that might occur in Eastern Kentucky, West Virginia, or Pennsylvania. This matrix is presented only to help the user distinguish between surface and underground-related impacts while proceeding through the generic impact sections. It is not meant to be completed as part of a site-specific evaluation of a particular system.

1. Construction of Access and Haul Roads

a. Introduction. Coal-haul and mine access roads are defined as "any road constructed, improved or used by the operator (except public roads) that ends at the pit or bench" (Grim and Hill, 1974). The activities of road construction or improvement can result in the clearing of vegetation, disruption of the soil horizons, and alteration of the natural topography which may result in numerous environmental impacts.

b. Environmental Impacts.

1) Disruption of the soil. With the compaction or removal of the soil surface during and after construction, soils will undergo chemical, physical, and biologic changes:

a) The use of construction and mining equipment in the preparation of mine sites and active mining operations is accompanied by applications of pressures to the soil. Pressures applied to the soil will result in the compaction of the soil surface. When the soil is compacted, the growth of plants decreases and erosion increases.

b) When soils are stripped, the topsoil and subsoil may be separated and stored until the land is reclaimed. However, the stripping, separation, and reapplication of the different soil horizons depends upon the type of land that is being mined (e.g., prime farmland, rangeland, etc.). During reclamation, the stored soils will be mechanically spread over the mine spoil. Such soil will not have sufficient tilth. This means that these soils will have reduced infiltration of rainfall and inadequate aeration. The net result will be less vegetative growth and increased erosion due to greater runoff. In addition to problems associated with less soil tilth, the storage of soil for long periods of time may cause a general reduction in soil productivity due to the possible destruction of microbiological components.

PROPOSED ACTIONS WHICH MAY CAUSE ENVIRONMENTAL IMPACT	PHYSICAL AND CHEMICAL CHARACTERISTICS															BIOLOGICAL COND.								CULTURAL FACTORS								
	EARTH				WATER				AIR	PROCESSES						FLORA			FAUNA					LAND USE					AESTHETICS AND HUMAN NATURE			
	MINERAL RESOURCE NOT EXTRACTED	SOILS	LANDFORMS	GEOLOGY	SURFACE	UNDERGROUND	QUALITY (pH, TSS)	RECHARGE	QUALITY (GASES, PARTICULATES)	FLOODS	EROSION	DEPOSITION	COMPACTION	STABILITY (SLIDES)	SUBSIDENCE	AREA DISTURBED	VEGETATION	AQUATIC PLANTS	MICROFLORA	BIRDS	AQUATIC ANIMALS	LAND ANIMALS	MICROFAUNA	BARRIERS	FORESTRY	RANGELAND	AGRICULTURE	URBAN	RECREATION	SCENIC VIEWS & VISTAS	WILDERNESS QUAL.	LANDSCAPE DESIGN	HISTORICAL & ARCHAEOLOGICAL RESOURCES
PREMINING																																
FACILITIES CONSTRUCTION		2D	2D		2S		2		2		2S	2D	2	2D		2D	2S					2D								2D	3	2S	3
ACCESS AND HAUL ROADS		3	3		3		3		3		3	2	3	2		3	3					3		3						3	3	3	3
SHAFT DEVELOPMENT				3		3		3																		3	3	3	3		3	3	3
MINING**																																
VEGETATION REMOVAL		3	3				2S			2D	2D	2D		2D			2D	2D	2D	2D	2D	2S	2S							2D	3	
SOIL REMOVAL & STORAGE		2D																	2S				2S		2D	2	2S			2D	2D	2D
OVERBURDEN REMOVAL		△	△	△	△	△	△	△	△	△	△	△		△		△								△	△	△	△	△	△	△	△	△	△
COAL EXTRACTION	1S			3		3	2	3							3										2	2	3	3	3		3		3
COAL HAULAGE								3					3									3		3						2	2	2	
COAL PREPARATION							3		2																								
RECLAMATION																																
BACKFILLING			3	3			3	3	3				2									3											
REFUSE DISPOSAL							3		3																					3			
REVEGETATION & AMENDMENTS							2D		2D																								
ABANDONMENT																																
MINE SEALING						3	3	3		3																							
LAND MANAGEMENT							2D		2D																								

*Adapted from Leopold, et al. (1971)

**Assumes no further road, facilities, or shaft development

DEFINITIONS (Primary Activity)

△ Impact of Surface Mine

○ Impact of Deep Mine

S D Impact of both Surface (S) and Deep (D) Mines

1--Minor (detectable) Impact

2--Moderate (apparent and somewhat significant) Impact

3--Major (significant) Impact

Figure 2-3. A Comparison Between the Potential Environmental Impacts of a Surface Mine and a Deep Mine*

The effects of soil compaction and soil tilth that result from mining activities (even with proper reclamation) can substantially limit the future use of the affected lands (e.g., prime farmland to pasture). For a general discussion of man's impacts on soil, see Albrecht (1971).

2) Erosion and Sedimentation. With the removal of vegetation, topographic alteration (e.g., cut and fill, highwalls, slope instability, alteration of surface drainage), and soil compaction (reduced permeability) the possibility for erosion and sedimentation will increase significantly (Thronson, 1971). If erosion (as the result of the above activities) is allowed to occur unabated, the following environmental effects could occur:

(1) By increasing a stream's sediment load, its ability to transport sediment in suspension or traction will be reduced (given normal flow). As a result of this reduced sediment carrying capacity, deposition of sediment may occur. This deposition of sediment could decrease reservoir storage, fill navigation channels, increase flood crests, degrade water-based recreation areas, promote eutrophication, and destroy the habitat for fish and other aquatic life.

(2) If sediments that contain a high percentage of soluble constituents are added to a body of water, the total dissolved solids (TDS) of the effected body of water will increase. High TDS levels are objectionable because of possible physiological effects, mineral taste, and economic consequences. For high concentrations of dissolved solids, there may be agricultural crop damage (if used for irrigation), corrosion damage to water systems, and a reduction of consumer acceptance of the water (EPA, 1972).

3) Habitat Alteration. The destruction of wildlife habitat by topographic alteration, sedimentation, or removal of native vegetation imposes a significant stress upon the existing community structure. The initial and gradual destruction of habitat will result in the displacement or destruction of various wildlife populations and an increase in road kills due to traffic. In addition, most reclaimed areas result in grassland habitats which may be beneficial for small mammals and birds, but adverse for big game, and may result in a decrease of species diversity (Bisselle, et. al., 1975). In several cases, however, there have been attempts to reestablish native trees.

It must be pointed out that the complex nature of a habitat and subsequent impacts on that habitat are very difficult to assess. For this reason, impacts on a habitat can be determined accurately only for specific sites. If more information about the impacts on the biologic environment and habitat alteration is desired, refer to Canter (1977) or Jain (1977).

4) Air Quality. Degradation of air quality caused by particulates from coal transport, wind erosion, road dust, and vehicular emissions will usually occur at local sites. It should be realized that impacts on air quality are a function of climate, changes in humidity and temperature, wind patterns, topography, and the acres disturbed. As a consequence, estimates of air-pollutant emissions should only be based on a proposed mining plan and the physical characteristics of a proposed mine site (e.g., climate, topography, attainment or nonattainment areas, etc.). It is most likely, however, that the major air quality impacts would occur along main traffic routes as the result of road and coal dust.

Particulate matter when deposited on leaves can plug stomates, lower photosynthetic activity, and cause leaf necrosis (Lerman and Darley, 1975; Bohne, 1969). It can also be inferred that long-term exposure to dust may cause changes in vegetation community structure.

The abatement of road dust is effectively controlled by intermittent spraying with water or treatments of calcium and sodium chlorides. If this procedure is not enforced, particulate pollutants may cause a considerable decrease in road visibility and human health hazard from their respiration (Down and Stocks, 1977; Penn. Dept. of Health, 1969).

5) Noise. Noise is normally defined as any unwanted, usually loud, objectionable sound. Excessive noise can have serious physiological and psychological impacts. It is well recognized that exposure to high noise levels can cause permanent impairment of hearing ability. Chronic noise may contribute to tension, irritability, and general psychological depression. Although noise effects on humans is well documented, it is not entirely clear that wildlife is similarly effected. Noise effects on wildlife in the immediate vicinity of mining activities, however, may cause animals to move away from the noise source (Down and Stocks, 1977).

c. Magnitude of Impacts. The major environmental impacts associated with road access are the consequence of erosion, sedimentation, and dust. If proper mitigating procedures are implemented for dust control, there will be little impact upon air quality. Proper reclamation and vegetation should limit erosion and sediment-related problems to the period of active mining only. Mismanagement or lack of proper reclamation, however, could result in long-term erosion and sedimentation.

In addition to the potential short- and long-term effects of erosion, the processes of erosion may be intensified in a physiographic region where any of the following conditions exist (Adapted from Brady, 1974):

(1) Steep slope.

(2) Long slope length.

(3) Low vegetative cover.

most important

(4) High rainfall intensity and frequency.

(5) Soil or rock which is easily eroded.

The prediction of erosion and sediment yield as the result of disturbing the earth's surface is a complex problem. There are numerous models which attempt to estimate erosion and sedimentation based on different combinations of the conditions listed above (for examples, see erosion and sedimentation in preliminary methodology, Section III-B-2).

Each model has specific applications depending upon the accuracy desired, cost, and physiographic characteristics. Model selection is based upon the nature of the question to be answered and site-specific constraints. Further, it must be appreciated that models produce approximations and there is no substitute for experience and real world data when considering a specific site (Haan and Barfield, 1978).

Finally, the amount of erosion and subsequent sediment yield in a given drainage basin will generally be proportional to the total area disturbed. Because access and haul roads do not usually occur in one localized area (e.g., area mining pit) but rather occur in either a high or low density over the landscape, they create a unique sediment control problem. Sediment control is a problem for several reasons: (1) in some geographic regions stream channels must be crossed or cut, and fills may be needed; (2) along the entire length of the road, drainage must be diverted, culverts constructed, and water collected; and (3) the road surface must be properly drained (e.g., dips, water bars) to prevent the accumulation of water. When drainage systems are properly engineered and are draining efficiently, sediment can be controlled. Eventually, however, there are usually failures due to improper engineering or lack of maintenance. For these reasons, mining systems should use as few access and haul roads as possible.

For a summary of anticipated major environmental impacts from access and haul roads, see Table 2-1.

d. Regulations. In 1977 the Surface Mining and Reclamation Act (SMRA) was enacted to control the environmental effects of surface mining and surface impacts from underground mining. The SMRA requires that each state which has mining activities conform to SMRA regulations, and as of 1978 the majority of states have issued laws in compliance. Because there is significant variation in each state's requirements (all states must adopt the minimum federal requirements), it is beyond the scope of this document to list them all. Only

Table 2-1. Summary of Anticipated Major Environmental Impacts from Access and Haul Roads

Resource	Premining	Mining Operation*	Mining Reclamation	Abandonment
Soils	MODERATE, LONG-TERM Topsoil removal will change physical, chemical, and biological properties	MODERATE, SHORT-TERM Loss of soil by wind and water erosion	MODERATE, SHORT-TERM Loss of soil during reclamation and management. Must add amendments as needed	MINOR, SHORT-TERM Land management may be required
Vegetation	MODERATE, SHORT-TERM Destruction of vegetation	NEGLIGIBLE	MODERATE, LONG-TERM Loss of both species diversity and vegetative stability	MODERATE, LONG-TERM Ongoing loss of species diversity and stability
Wildlife	MODERATE, LONG-TERM Destruction of habitat resulting in wildlife displacement and destruction	MINOR, SHORT-TERM Increased road kills due to traffic	MODERATE LONG-TERM Decrease in species diversity	MINOR, SHORT-TERM Ongoing loss of species diversity
Water	MODERATE, SHORT-TERM Drainage pattern alteration and topsoil stripping or topographic alteration will increase erosion and sedimentation	MODERATE, SHORT-TERM Ongoing erosion and sedimentation	MODERATE, LONG-TERM Differences between original and postmining conditions will increase erosion and sedimentation until a vegetative cover is established	MODERATE, LONG-TERM Permanent change in runoff characteristics may effect off site areas
Air	MODERATE, SHORT-TERM Windblown dust and vehicle emissions during construction	MODERATE, SHORT-TERM Degradation of air quality due to wind and vehicle erosion (assume no wetting of roads)	MINOR, SHORT-TERM Windblown dust and vehicle emissions during reclamation	NEGLIGIBLE

*Assumes no further road construction during active mining.
(Note: Format adapted from Draft Environmental Statement - Proposed Mining and Reclamation Plan Pronghorn Mine, Campbell County, Wyoming U.S.G.S. Survey).

DEFINITION: (Magnitude U.S.G.S. Survey)
Negligible--slightly detectable
Minor--detectable
Moderate--apparent and somewhat significant
Major--significant

Duration
Temporary--less than the life of project
Short-term--project life
Long-term--existing after project abandonment

selected portions of the Surface Mining and Reclamation Act which have the most significant impacts upon mining systems are listed in this document (see Appendix B). The list has been compiled as a basic reference to indicate areas of major control that should be considered when evaluating any mining system that impacts the surface. In addition to the SMRA there are numerous federal regulations (e.g., Clean Air Act, Federal Water Pollution Control Act, Marine Protection Research Sanctuaries Act, Noise Control Act, Coastal Zone Management Act, and the Endangered Species Act) that could affect the siting and operation of surface and underground mining. For the purpose of this document these regulations are not included here.

For access and haul roads, Section 515(17) of the Surface Mining and Reclamation Act requires that the amount of erosion and sedimentation directly related to access and haul roads must be controlled.

e. Mitigating Procedures. In response to SMRA requirements, the following mitigating measures are suggested only as examples of the types of procedures that might be required:

(1) Premining

(a) Design and plan the haul road system to minimize damage to other resources, such as streams and timber, and to minimize the amount of land utilized for roads, thus reducing the acreage disturbed.

(b) Insure proper grading of roads and construct drainage control structures (ditches, culverts, sediment basins) based on road design and hydrologic data for the area. For all-weather roads, a suitable subbase and base must be provided.

(c) Revegetate all road shoulders and overcast soils.

(2) Mine Operation

(a) To keep the road serviceable and erosion at a minimum, all ditches and culverts must be inspected, repaired, or cleaned to correct damage or obstructions.

(b) To minimize seasonal dust, road surfaces should be sprayed with water or appropriate chemicals.

(3) Mine Closing

(a) Maintain all roads, or

(b) Remove road surface (if present), backfill, compact, and regrade to the original contour and establish a diverse indigenous vegetative cover.

2. Removal of Overburden

a. Introduction. For the purpose of this document, overburden is defined as material of any nature, consolidated or unconsolidated, that overlies a deposit of coal. The removal of overburden is presented to give an indication of those general removal techniques that are currently being used in surface operations. For a general discussion of surface mining see Pfleider (1968). It is assumed that deep mining operations that may utilize removal techniques for their support, will be similar to those techniques discussed for conventional surface mining. The activities of overburden removal usually result in the clearing and covering of vegetation, removal and storage of soil horizons, storage of overburden, and alteration of the natural topography. Several complex environmental impacts result from these activities, each of which is discussed below.

b. Environmental Impacts.

1) Erosion and Sedimentation. Because the natural topography is modified by surface mining (e.g., benches, open pits, cut and fills), erosion and sedimentation may occur as the consequence of some of the following activities:

(1) Slope instability and subsequent slumping or earth slides, resulting from topographic alteration, may destroy large areas of natural vegetation and wildlife habitat. Debris from earth movements are also a readily available source of sediment which may fill reservoirs, clog stream channels, and cause flooding of adjacent lands.

(2) Diversion of surface drainage and the stripping of vegetation will change the discharge characteristics of a given watershed's hydrograph (volume of discharge as a function of time). As a result, flood magnitude, which is predicted by the discharge hydrograph, may exceed designed flood control measures and cause serious damage downstream (e.g., erosion damage, flooding, sedimentation).

(3) Large-scale earth moving also creates the problem of soil and spoil storage. In many cases, this results in the filling in of depressions, the construction of benches, and the steepening of existing slopes. The resulting land structures are usually highly susceptible to erosion, and consequently, contribute significant amounts of sediment to local bodies of water.

2) Groundwater Alteration. If overburden removal intersects the natural groundwater system, recharge areas, or springs, the natural groundwater flow may be irreversibly altered. An even more serious problem could result from the intersection of surface mining

activities with existing or abandoned underground mines. The consequence of such an intersection may result in pollution from uncontrolled mine drainage. It should also be noted that in areas where the natural groundwater system (unconfined) supports base flow of streams, overburden removal would be critical. If more detailed information is desired, see Lohman (1972), Eagleson (1970), Chow (1964).

3) Coal Mine Drainage Pollution.

a) Acid Mine Drainage (AMD). The removal and storage of overburden may expose iron sulfide (FeS_2) minerals to water under conditions of oxidation. Depending on the physical and chemical conditions, the reaction may proceed to form any of the following chemical species: ferric sulfate ($Fe_2(SO_4)_3$), ferric hydroxide ($Fe(OH_3)$), ferric iron (Fe_3+), sulfate ion (SO_42-), and hydrogen ion ($H+$). Mine drainage containing these constituents may also produce secondary reactions with minerals and organic matter to produce significant concentrations of aluminum ion ($Al3+$), calcium ion ($Ca2+$), manganese ion ($Mn2+$), and sodium ion ($Na+$).

Several laboratory studies (Gleason, et al., (1978); Smith, et al. (1974)) indicated that acid mine drainage is not only the result of a chemical reaction, but that bacterial mechanisms of acid formation are also common. The bacterial role in acid formation, however, is not well defined and requires additional research to determine its significance.

Mine drainage water of the type described above can have a very high acidity (pH = 2.0 - 4.5). Water with such a low pH will support only a limited aquatic flora and will not support fish life. Damage to aquatic life can also result from the precipitation of iron hydroxides and sulfates which blanket the bottom of stream beds. In addition, it will oxidize metal (culverts, bridges, pumps, etc.), chemically erode concrete, and render water unuseable for most industrial, urban, agricultural, and recreational uses (Doyle, 1976a).

The formation of acid mine drainage is a complex function of soil and rock properties, depth of the water table, aquifer characteristics, climatic conditions, and fluid properties. As a consequence, the quantitative prediction of acid mine drainage has not been successful (Gleason, et al., 1978). The point to be made, regardless of prediction, is that overburden and coal which contain acid-forming components without a source of alkalinity are a potential source of AMD. A regional map of the U.S. (Figure 2-4) shows the distribution of the total bituminous reserves that have been known to produce acid water. It is important to note that other coals (e.g., lignite, anthracite, subbituminous) also have the potential for producing AMD. A general discussion on AMD can be found in Barnes and Romberger (1968) and Boyer and Gleason (1974).

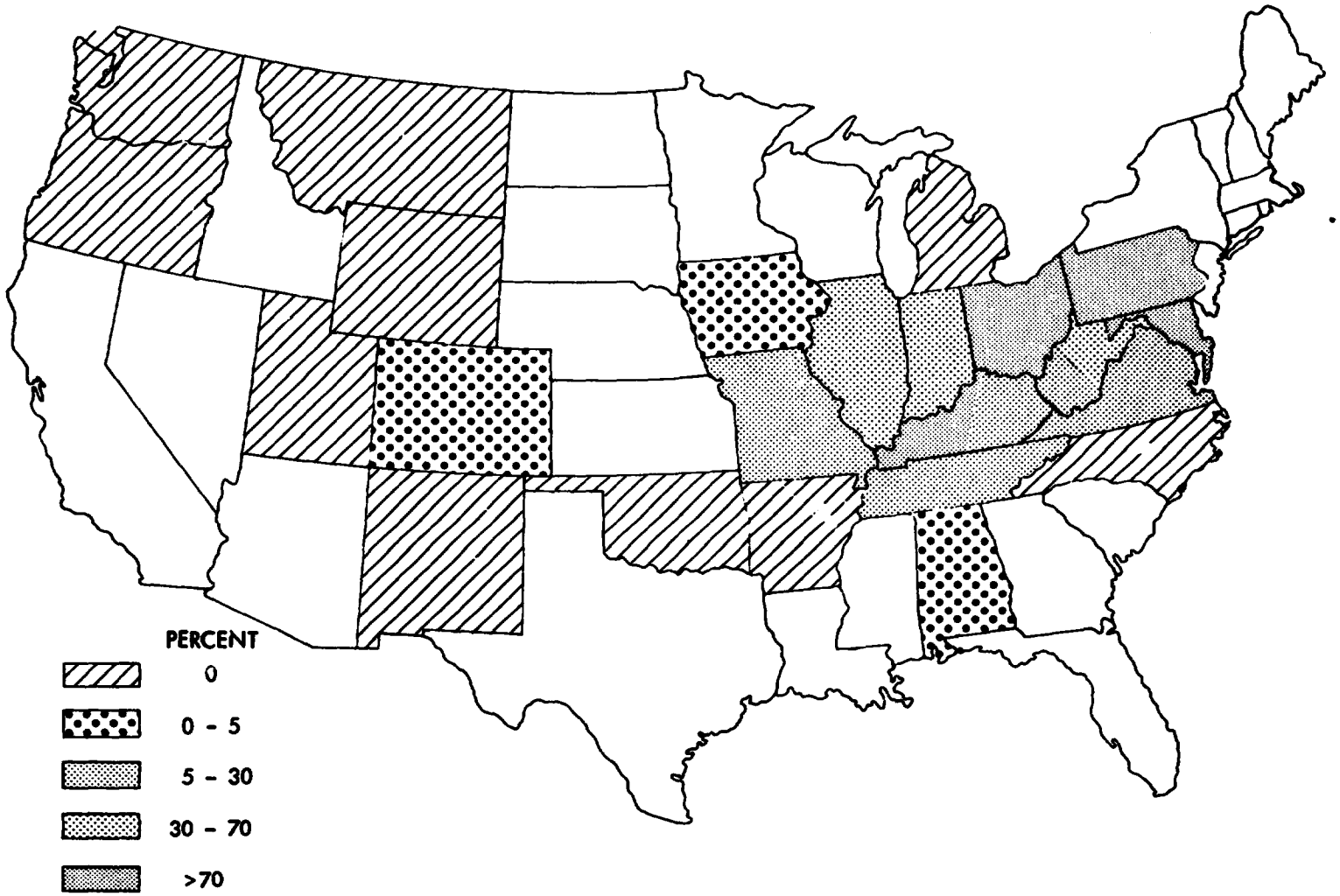

Figure 2-4. Percent of Total Bituminous Reserves Known to Produce Acid Water (Adapted from Gleason, 1978)

b) Toxic Chemical Species. Because coal is composed of a highly complex and heterogeneous mixture of sediments and organic material, it has a wide range of chemical constituents. One important group of chemical constituents is trace elements. Like acid producing materials, trace element concentrations vary widely with location, and even within the same seam. Table 2-2 illustrates the regional variability in the concentration of some trace elements that occurs in coal. For more specific information and the variation of coal properties with region, refer to Noyes (1978).

The concentration of trace elements released from a seam is dependent not only on the concentration of the trace elements in the coal, but in part, upon the solubility of the elements, the element's speciation (e.g., inorganic ions, ion pairs, organic complexes), intensity of chemical and physical weathering, and hydrologic conditions. Once trace elements are released into the terrestrial and aquatic ecosystems, they are subject to further transformations (e.g., absorption, precipitation), and are made available to plants and wildlife.

Trace elements can have a variety of effects on plants and wildlife including changes in physiology, productivity, species diversity and abundance. In addition, the effects of exposure to a single trace contaminant can be modified by the addition of one or more different trace elements causing antagonistic or synergistic effects. For a detailed treatment of possible toxicities in terrestrial and aquatic ecosystems see Dovarak, et al. (1978).

In addition to trace metal toxicities of coal and overburden, serious reclamation problems can result from the occurrence of soil salinity and the accumulation of trace metals (e.g., Se, Mo, B) in western soils. Plants may be adversely affected by either the development of high osmotic conditions in the plant substrate or by the presence of a phytotoxic constituent in the water (e.g., B, Na, Cl, Li). Because of the high salinity, reclamation in the western coal regions can be severely hindered. The occurrence of molybdenum and selenium in soils present no problems of toxicity to plants. However, plants and forage crops that have been grown in soils with relatively high amounts of molybdenum and selenium, can be toxic to animals (EPA, 1972). If further information is desired, refer to Study Committee on the Potential for Rehabilitating Lands Surfaced Mined for Coal in the Western United States, 1974, and Purves (1977).

c) Eutrophication. Exposed spoil may contain appreciable amounts of organic nitrogen (Reeder and Berg, 1976) which may be leached and transported to lakes, rivers, estuaries, or marine embayments. The addition of nutrients and overenrichment can result in eutrophication.

Table 2-2. Average Trace Element Concentrations (ppm) in Coal by Geographic Region (Adapted from Dvorak et al., 1978)

Element	Northern Appalachia	Southern Appalachia	Eastern Interior	Power River Region
Arsenic	12.5	9.5	7.0	3.5
Barium	73.5	102.0	41.3	275.0
Beryllium	1.0	0.9	1.5	2.0
Boron	17.5	21.5	78.7	48.0
Cadmium	-	-	2.9	0.3
Chromium	21.5	19.3	22.0	4.4
Cobalt	17.5	15.0	18.3	6.5
Copper	12.0	12.3	8.9	3.8
Lead	5.1	4.7	15.5	2.7
Mercury	0.2	-	0.1	0.1
Molybdenum	8.0	8.1	7.1	3.5
Nickel	19.0	17.8	24.7	3.7
Selenium	3.6	4.4	3.0	1.9
Vanadium	31.5	31.8	34.0	13.5
Zinc	19.5	20.8	87.0	39.5

Eutrophic bodies of water typically exhibit dense blue-green algal masses and aquatic weeds which reduce their recreational and aesthetic potential. In addition to compromising recreational uses, the accompanying water quality changes can cause undesirable shifts in the species composition of the aquatic community (EPA, 1972).

4) Habitat Alteration. The environmental effects of overburden removal on wildlife, for the purpose of this document, are assumed to be similar to those identified for access and haul roads (see Section II-B-1). Loss of habitat may also occur due to the contamination of aquatic ecosystems by acid mine drainage (Smith and Frey, 1971).

5) Aesthetics. The aesthetic aspect of coal mining and the environment is difficult to assess in view of the many subjective factors involved. Because aesthetic tastes vary as the result of physiographic and sociological factors, each site presents its own unique problems (EPA 1973).

Almost every coal mine will create undesirable visual impacts as the result of surface excavation, waste disposal, fixed or mobile plant machinery, or water pollution (color, odor, taste). If coal mines are located within public view, aesthetic issues may be of significant importance. This may necessitate landscape planning, relocation of mining activities, or even modification of an objectionable mining method.

6) Noise. See Access and Haul Roads, Section III-B-1.

c. Magnitude of Impacts. Environmental impacts generated by overburden removal and storage are a complex function of the geochemical character of the overburden, regional geology and hydrology, topography, climate, and the type of mining system. For this reason, it is difficult to identify a specific element or combination of elements responsible for causing the greatest degree of environmental impact. However, the identification of the most significant impacts generated by a mining system can be suggested.

Of the three most important impacts -- erosion and sedimentation, mine drainage, and aesthetics -- only mine drainage is not a direct function of the mining system. Because mine drainage pollution is a function of the geochemical composition of the overburden and coal, the mining sy tem has little effect upon potential toxic drainage. In other words, if there are no acid producing materials, the mining system cannot create AMD. However, it is possible to have acid producing materials present in the composition of the coal and overburden and have no acid mine drainage because of the climatic character of the area (e.g., very low rainfall). In this case the introduction of a hydraulic mining system could lead to environmental impacts that would not normally be encountered.

As pointed out previously, aesthetic impacts may or may not be important in different regions of the United States. This issue aside, the severity of impact can be assumed to increase as the impacted area becomes increasingly divergent from the existing topography. For example, a few small spoil piles on a plain may not be aesthetically displeasing, but as the spoil piles become larger and more numerous, their aesthetic impact increases. A similar relationship would also exist for activities that create depressions in plains and scars or flat areas in rugged topography (adapted from Stocks, 1977). Given this relationship, it is assumed that if a small surface area is disturbed, there would be less impact than from a similar region where a larger surface area has been disturbed.

This same general relationship, in terms of surface area disturbed, exists for erosion and sedimentation as well. Thus, it is assumed that the magnitude of environmental impacts associated with aesthetics, erosion, and sedimentation, will increase as a function of the amount of overburden removed and stored. Accordingly, the following levels of overburden removal are defined:

(1) Leveling -- the process of grading and removing of shallow overburden that does not result in the formation of a highwall nor extend around hillsides or over drainage divides.

(2) Bench cutting -- the process of deep cutting and removal of overburden (contour mining) which creates a shelf or bench on the side of a hill with the inside bordered by a highwall.

(3) Area stripping -- in regions of predominantly low relief, overburden is removed in narrow bands, one cut at a time, forming a deep open cut filled with spoil.

(4) Mountaintop removal -- overburden is removed from the tops of mountains, ridges, knobs, or knolls. The excess overburden not returned to the original surface is placed on ridges, in natural depressions, or used to form benches.

With the above definitions as a framework, it is possible to discuss the magnitude of environmental impact as the result of overburden removal.

1) Leveling. Because the process of leveling would remove only a shallow portion of the overburden, it would seem that this process would result in the least surface area disturbed and least amount of spoil storage required when compared with the other methods. However, there are a few additional considerations:

(1) If leveling takes place on steep slopes (for example, many coal regions in Appalachia have slopes greater than 25°) there will be increased hazards due to potential soil erosion and less effective reclamation. In addition, overburden storage on steep slopes, which are usually tenuously supported, may be easily disturbed (Note: this practice is now illegal). The result would be earthslides and long-term sedimentation problems, as discussed above.

(2) It has also been assumed that leveling would occur in single isolated areas. This is an advantage, because sediment control would be relatively easy. If a large number of sites were leveled over a wide geographic area, however, sediment control would be much more difficult.

If a new mining system utilizes a leveling process, it must be realized that the process itself may not cause significant environmental damage. However, if used in a system that would require a large number of sites, an access network for transportation, or operations in steep terrain, there may be substantial environmental damage that would be difficult to mitigate.

2) Bench Cutting. The process of cutting a bench (contour mining) has traditionally caused many environmental problems. Serious erosion, sedimentation, and aesthetic impacts generated by bench cutting can occur as the result of the following conditions:

(1) The conventional method of contour strip mining creates a shelf or bench on the side of a hill. The inside of the bench is bordered by a highwall (10- to 100-ft high), and on the outer side the pit is bordered by a high mound of spoil on the downslope. Both the downslope spoil and highwall are subject to severe erosion and slope instability (Note: mound of spoil on downslope is now illegal).

(2) Another problem inherent in bench cutting is potential toxic drainage from the stored overburden on the downslope. If toxic materials at the surface of overburden are exposed to weathering, drainage from overburden may pose a mine drainage pollution problem similar to that discussed above. With high erosion rates, prolonged exposure of fresh overburden to weathering may result in long-term mine drainage pollution. Because contour mining naturally occurs in steep, highly dissected terrain, erosion and sediment transport is extensive. In addition, natural drainage channels are crosscut by mining activities, adding to erosion and sediment control problems.

(3) If the coal or overburden has potential toxic materials (e.g., acid producing minerals), water which may accumulate on a bench can become polluted from the toxic components. If polluted water should be released as the result of a storm or the breakthrough of a barrier, the release of substantial amounts of mine drainage could destroy aquatic life in effected areas.

(4) Contour strip mines disturb an area of the earth's surface much greater than the area covered by that portion of the coal seam that is extracted. Benches meander from ridge to ridge effecting large geographic areas. As a result, the removal, placement, and control of overburden is of critical environmental concern. Sedimentation and AMD management, by the inherent nature of both the topography and the mining process, are difficult to initiate in an effective manner. As a result, natural habitats are not only altered by the bench itself but can also affect large areas downslope.

(5) Benches, highwalls, and spoil piles are extremely conspicuous in rugged and heavily forested regions. The aesthetic impact may not be as severe as a removed mountaintop, but the visual impact of contrasting ribbons of brown earth with green forest or snow is aesthetically disturbing.

Conventional contour mining has many environmental problems. Some new methods (slope reduction, box cut, head-of-hollow fill; see Grim and Hill, 1974 and Onsite Control of Sedimentation Utilizing the Modified Block-cut Method of Surface Mining, EPA, 1977) can minimize many adverse effects on the environment. In fact, if mining operations effectively implement all the required federal and state reclamation regulations, environmental impacts associated with overburden removal can be substantially mitigated. On a positive note, the resulting flat land generated by bench cutting, if reclaimed for a specific application (e.g., agriculture, grazing), can improve upon the previous land use.

Any new mining system that can operate in topography having slopes greater than 25° reduce the amount of overburden removal and minimize topographic alteration would offer a significant benefit. In addition, any significant improvement of overburden haulback (e.g., not using trucks) would also be a benefit.

3) Area Stripping. Area stripping can affect thousands of acres by modifying the natural topography, removal and storage of overburden, and habitat alteration. However, the magnitude of impact would seem to be much less, when compared to contour strip mining. There are several reasons which may suggest a reduced magnitude of impact:

(1) In the United States, area stripping characteristically occurs in relatively flat lying topography. For this reason, erosion is less, subsequent sediment control is easier, and there is adequate space for the construction of treatment and control facilities.

(2) Area stripping removes an area of the earth's surface which is approximately equal to the area covered by the coal bed that is extracted. In addition, the stripping process occurs in one isolated geographic region. As a result, natural drainage channels can be efficiently diverted and sediment control basins can be established at key points to control drainage effectively. After mining is completed, it is also easier to reestablish the previous drainage.

(3) Because area stripping usually confines spoil and soil storage to the mine site, mine drainage from the site can be controlled to a greater extent. Consequently, mine drainage can be effectively contained and treated, thereby reducing the occurrence of mine drainage discharge off the mine site.

(4) Area stripping can alter habitat significantly. However, when compared to conventional contour mining, area mining usually disturbs habitat only to the perimeter of the mine site and may not affect the areas somewhat removed from the mine site.

(5) Because of its localized nature, the overall aesthetic impact of area mining can be less than contour or mountaintop removal. Moreover, the ability to mitigate aesthetic impact by reclamation procedures is more effective for area mining. In comparison with the requirements for reclaiming the steep slopes of a contour mine, it is much easier to regrade the area mine to approximate original contour and reestablish a vegetative cover. As a result, the reclaimed slopes of contour mines still retain an unsightly remnant of the highwall.

4) Mountaintop Removal. In rolling to steep terrain, mining by mountaintop removal offers some significant improvements when compared with contour mining methods. However, there are some disadvantages which are unique to mountaintop removal.

There are several advantages in using mountaintop removal (adapted from Doyle, 1976a):

(1) As all the coal is removed, the reclaimed site will not be disturbed again by future mining.

(2) Because mining is restricted to one or several topographic highs, the drainage system is easier to control.

(3) Spoil is eliminated on the downslope, thus, erosion and landslides are considerably reduced.

(4) After mining and reclamation, the resulting flat land may afford land use of higher value to the region.

In addition to the benefits offered by mountaintop removal, there are at least three major disadvantages:

(1) The disruption and removal of overburden creates approximately a 30% increase in overburden volume. One common method for storing this extra overburden is the construction of a valley fill (also used for contour mining). Valley fill procedures utilize a controlled earth and rock fill across or through the head of a valley or hollow to form a stable, permanent storage space for mine spoil. This procedure destroys wildlife habitat, and if not construced and reclaimed properly, the fill will be a long-term source of sediment.

(2) A flat region does not blend well into a naturally rugged topography and, as a consequence, it creates a severe contrast that is aesthetically objectionable to many people.

(3) The total removal of the overburden may destroy existing ground water resources (e.g., perched aquifer or a coal

bed that is an aquifer) and may alter adjacent ground water systems. If this should occur, special reclamation may be required to reestablish hydraulic continuity within the former water zone.

The environmental impacts associated with overburden removal can be mitigated to a high degree with proper reclamation procedures and with environmentally educated mine owners and operators. However, the successful mitigation of impacts associated with overburden removal is dependent upon the factors discussed above. If impacts are to be reduced, a mining system should: minimize the amount of overburden disturbed (Note: overburden removal and subsequent backfilling results in the single most significant reclamation cost); stabilize and store topsoil and spoil in a manner that will limit erosion; maintain a compact mining site (this makes it easier to control possible air and water pollution); and schedule mining activities to insure immediate reclamation of disturbed areas.

For a summary of anticipated major environmental impacts from the removal of overburden, see Table 2-3.

d. Regulations. The following regulations of the SMRA are presented to highlight areas of major control that must be considered by any mining system which impacts the surface by the removal of overburden:

1) Air. Section 515(4) of the SMRA required that all spoil piles and affected areas be stablized to control air pollution. In addition, emissions from mining equipment will be regulated by regional air pollution control regulations.

2) Water. Section 515(4) of the SMRA requires that all toxic or acid-forming materials be managed to prevent contamination of ground and surface waters. This may be accomplished by: (1) preventing water from contacting the toxic materials, (2) burying and revegetation, or (3) treating the drainage before discharge.

Surface operations must also be conducted in such a manner as to prevent additional contributions of suspended solids to stream flow or runoff outside the permit area (Section 516(9), SMRA).

3) Land. Section 515 (2 to 6) of the SMRA requires that in all disturbed areas, operators remove and stabilize top soil, backfill and regrade to approximate original contour, establish a permanent vegetative cover on regraded areas, and restore the land to a condition capable of supporting the uses for which it was suited to mining.

Table 2-3. Summary of Anticipated Major Environmental Impacts from the Removal of Overburden

Resource	Premining	Mining Operation	Mining Reclamation	Abandonment
Soils	MODERATE, LONG-TERM Topsoil removal will change physical, chemical, and biological properties	MODERATE, LONG-TERM Ongoing stripping and removal could cause loss of soil productivity	MODERATE, LONG-TERM Loss of soil during reclamation. There may not be a suitable soil to place on spoil and must add amendments as needed	MINOR, SHORT-TERM Land management may be required
Land	MODERATE, SHORT-TERM Possible grading and topographic alteration	MAJOR, LONG-TERM Mining will permanently change the natural contour of the land and decrease its aesthetic value	MAJOR, LONG-TERM Topography that is restored will be similar but modified. There is also possible surface alternation from compacting spoil	NEGLIGIBLE
	MODERATE, SHORT-TERM Loss of original land use	MODERATE, SHORT-TERM Ongoing loss of land use	NEGLIGIBLE	MAJOR, LONG-TERM May change original land use
Vegetation	MODERATE, SHORT-TERM Destruction of habitat resulting in wildlife displacement and death	MODERATE, LONG-TERM Ongoing destruction of habitat resulting in wildlife displacement and death	MODERATE, LONG-TERM Decrease in species diversity	MINOR, SHORT-TERM Ongoing decrease in species diversity
Water	MODERATE, SHORT-TERM Drainage pattern alteration topsoil stripping or topographic alteration will increase erosion and sedimentation	MAJOR, LONG-TERM Destruction of overburden can destroy aquifers, create the possibility of AMD, and possible trace elements and organic to water bodies. Overburden serves as a source of sediment to water bodies	MODERATE, SHORT-TERM Overburden and spoil will serve as a continuing source of sediment until a stable vegetative cover is established. Shallow original aquifers may not be restored	MODERATE, LONG-TERM Buried spoil (if it has acid producing materials) may act as a long-term source of AMD. Ground water, on and off site may be permanently changed. Restored surface drainage may remain an increased area of erosion and sedimentation
Air	MINOR, TEMPORARY Windblown dust and vehicle emissions during construction	MAJOR, SHORT-TERM Dergradation of air quality due to overburden handling and wind erosion	MINOR, SHORT-TERM Windblown dust during reclamation	NEGLIGIBLE

For definitions of magnitude and duration, see the Summary of Access and Haul Roads, Section II-B-1.

e. Mitigating Procedures. In response to the requirements of the SMRA, the following mitigating measures are suggested only as examples of the types of abatement procedures that might be required.

(1) Premining

(a) Design and plan overburden removal so as to minimize area affected.

(b) Construct drainage control structures (ditches, sediment ponds, diversions of channels) based on hydrologic data from site.

(c) Construct water treatment facilities for toxic drainage (if potentially toxic overburden or coal are present) and suspended solids.

(2) Mine Operation

(a) Remove topsoil, store, and stabilize.

(b) Stabilize all spoil.

(c) Grade and revegetate spoil (if applicable).

(d) Maintain sediment control structures.

(e) Collect and treat all discharged water both for AMD (if present) and suspended solids.

(3) Mine Closing

(a) Bury all spoil which may produce AMD or toxic materials.

(b) Backfill, compact, regrade to the approximate original contour, revegetate, and restore all areas affected by overburden removal.

3. Development of Systems Access

a. Introduction. Systems access is defined as any entry (slope, shaft, drift, or borehole) made from the earth's surface to one or more coal seams. The process of making an entry can result in the fracturing and breaking of the overburden that is being penetrated. Excavation of an entry or several entries will result in the removal of some overburden. This activity can result in several environmental impacts.

b. Environmental Impacts.

1) Groundwater Alteration. Permeability of earth materials is usually variable. For this reason, water will tend to take preferred paths, flowing readily through permeable zones (alluvial sands, sandstones, limestone, and coal) and shunning, or flowing with difficulty through relatively impermeable (clay, shale, granite) materials. Generally, zones of greater permeability tend to parallel or coincide with formational boundaries, and changes of permeability in the horizontal field are usually gradual as compared to sharp vertical changes (Chorley, 1969).

Groundwater flow is not only a function of hydraulic gradient (difference in hydrostatic pressure between two points) and geologic characteristics (intergranual openings, jointing and fractures, and solution cavities) but is also influenced by man. In most cases where holes were drilled in quest of oil, coal, or other economic minerals, interaquifer movement of water has occurred (Pettyjohn 1972). Figure 2-5 illustrates flow through open holes created by improper drilling practices. As the result of creating hydraulically-connected aquifers, there may be several consequences.

a) Aquifer Contamination. The number and variety of potential contaminants that can enter groundwater resources are limitless. Any number of contaminants may enter an aquifer by flow through open channels, by percolation through the zone of aeration, or by migration in the zone of saturation. However, a more serious problem results when an isolated, contaminated aquifer is allowed free flow through open holes into a fresh aquifer. Once an aquifer has been contaminated, it is exceedingly difficult, if not economically infeasible, to reclaim it.

b) Alteration of Groundwater Flow. Each aquifer reaches an ultimate steady state as a function of water recharge and discharge. If hydraulically-connected aquifers upset the steady state, regional flow patterns may be altered. The net effect of these two factors may be in the loss of groundwater resources for existing urban, agricultural, or industrial users.

2) Mine Drainage Pollution. According to Doyle (1976b) most underground mines will affect the existing groundwater at the location where the mines are developed. If an unconfined or confined aquifer is intersected, groundwater will have to be pumped to allow mining activities. Dewatering of underground workings will lower the water table and may in turn affect base flow of streams, especially in humid regions.

If overburden and coal contain potentially toxic materials (see Removal of Overburden, Section II-B-2) the lowering of the water table could result in oxidation of pyrite and the formation of AMD. As a consequence, acid waters could infiltrate from the mine workings into

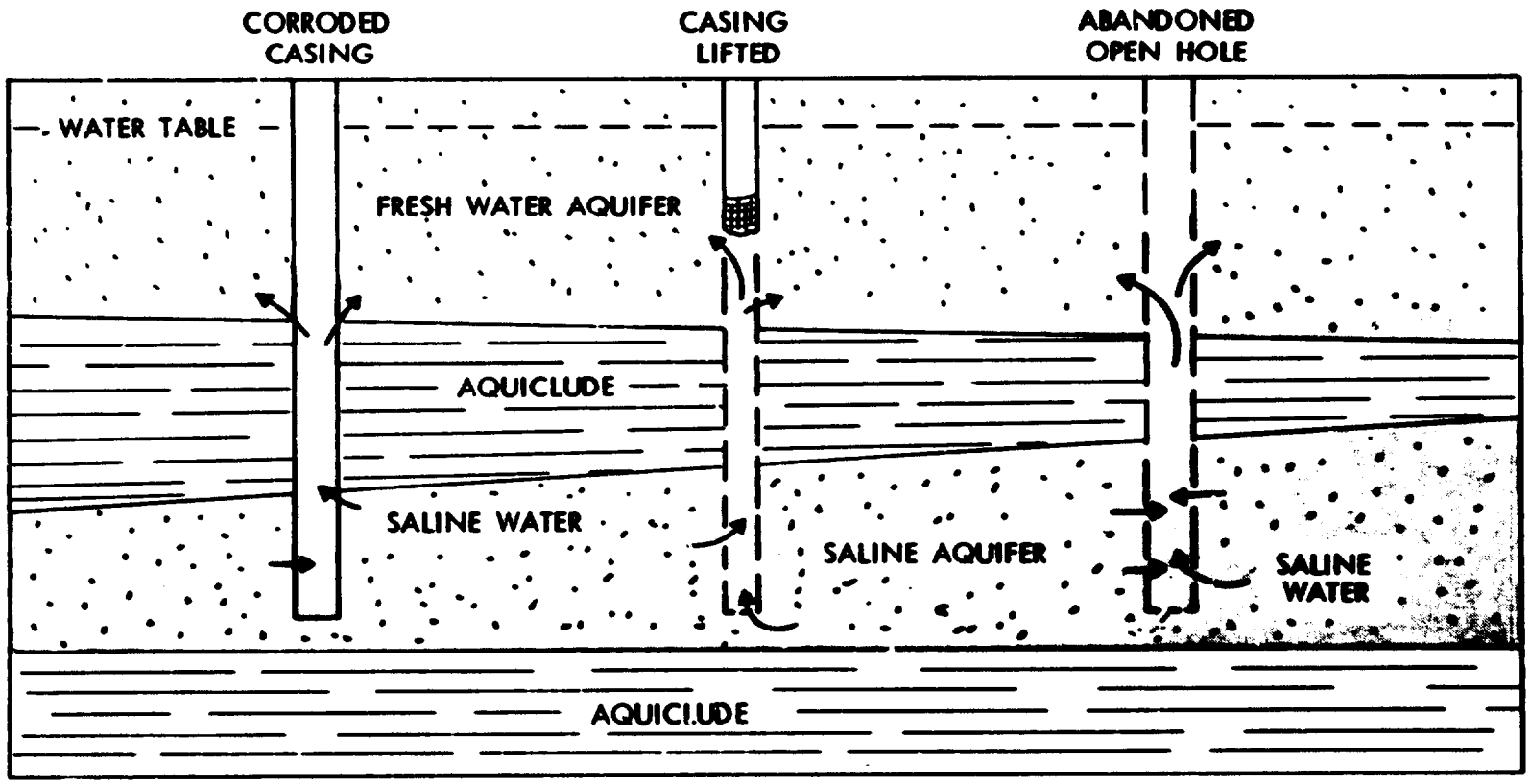

Figure 2-5. Samples of Hydraulically-Connected Aquifers from Improper Drilling Practices

the groundwater. In addition, polluted water that is pumped from the mine, unless treated, may eventually enter the groundwater by infiltration, either within or outside the producing aquifer system.

3) Erosion and Sedimentation. The storage of spoil taken from systems access activities may result in the filling of depressions, creation of small hills, and steepening of existing slopes. Landforms of this nature may be subject to erosion (see Access and Haul Roads, impacts, Section II-B-1).

c. Magnitude of Impacts. The magnitude of environmental impacts associated with systems access activities is a complex function of geologic and hydrologic characteristics of a region and the mining system. For this reason, magnitude of impact will be discussed in terms of the number of excavations, the ability to seal excavations, and the method of making that excavation or hole.

1) Number and Density of Access Holes or Excavations. The degree of impact generated by the placement of a hole regardless of size in geologic materials is based on the following assumption: if one hole has a potentially adverse environmental impact, then several holes have a correspondingly larger adverse environmental impact. This assumption is based on the fact that if interformational flow and potential toxic drainage are to be mitigated by casing and sealing, the probability of having a casing or sealing failure and subsequent aquifer contamination will increase with each hole.

Not only are the number of holes important, the density of holes can also be significant. A few holes spaced far apart would have a minimum impact upon the competence of the surrounding rock. A few holes spaced closely together would have a much greater potential for fracturing between holes. As a result, interformational communication could occur regardless of mitigating procedures.

Because a drift access does not penetrate overlying geologic materials, there should be a lower probability of altering natural groundwater flow. For this reason, drift access may be more desirable than vertical or slope access. However, if a coal seam is a major aquifer, groundwater alteration will inevitably occur.

The placement of access holes through geologic materials, regardless of mitigating activities, unavoidably and irreversibly alters the natural geologic formations. As a consequence, long-term environmental impacts associated with mine drainage pollution, contamination, and altered groundwater flows can be expected to occur at some future date.

2) Mine Sealing. Mine sealing is generally used to promote inundation of underground workings, with the intent of limiting the oxidation of pyritic minerals (Pucek and Emel, 1977). This process usually involves the construction of a physical barrier in a mine opening to prevent the passage of water out of the workings. Such a barrier must be designed to withstand water pressure that will be exerted against it.

Successful mine sealing can be accomplished using proper engineering techniques (e.g., gunite seals and grout curtains, or double and single bulkhead seals). Should a mine seal fail, the sudden release of large quantities of water (generally acidic) can cause downstream flooding, property damage, and far reaching fish kills (Doyle, 1976b).

As more and more mine shafts or boreholes are sealed, it can be assumed that there will be an increasing probability of seal failure. In addition, sealed mines will usually leak after some indefinite time period (Doyle, 1976b). As a result, sealed mines can be a long-term source of AMD. In order to combat this problem, a mine seal monitoring and maintenance program should be established.

3) Method of Excavation. Above and beyond the impacts generated by the mere presence of a hole are impacts associated with the way in which the hole is made. These methods can be grouped into five basic schemes.

a) Mechanical. Drills which mechanically break rock without the aid of water or explosives as a primary drilling agent would seem to offer the least amount of impact of all the mechanisms. Drills of this nature do not add excessive water to the surrounding geologic materials, other than from drilling mud. A drill which uses explosives will always run the risk of indirectly fracturing large areas of surrounding rock, and, as a result, may cause the interconnection of aquifers.

b) Water. The use of water as a drilling agent is undesirable for the following reasons:

(1) The addition of water to geologic materials which are normally dry will create AMD problems if pyritic materials are present. This will necessitate treatment of drilling water (neutralization) to raise the pH prior to release. Regardless of treatment, it will be impossible to stop the seepage of some acidic waters away from the mine workings. If groundwater is located in the same region, irreversible adverse effects may occur.

(2) When water is used as an erosive agent, it will naturally suspend sediment. Drilling water which has been so used

will require treatment to remove the prescribed amount of sediment before discharge (for EPA effluent guidelines, see Appendix B).

(3) If the region in which a water drilling method is used lacks sufficient quantities of water for drilling, then water may have to be imported. Imported water would require a transport system and a means of storage. Both of these processes will ultimately disturb more land.

(4) If the water needs treatment before discharge (a likely assumption), flat land for treatment facilities may be required. In areas of steep slopes, leveling may be necessary to create sufficient flat land to accommodate treatment facilities.

(5) If surface and groundwater are available and used in large quantities, water may be diverted from other competitive uses for existing water supply (e.g., urban, agricultural, or industrial).

c) Solvents. The use of water in combination with a chemical solvent or the use of a chemical solvent by itself may result in adverse environmental impacts.

(1) Given the variability of geologic materials, it would be difficult to predict possible adverse chemical reactions between a solvent and rock. There would also be some degree of variation in adsorption of a specific chemical solvent by different materials. It is also reasonable to assume that a solvent may be retained for long periods of time by some of the geologic materials it encounters.

(2) Infiltration of a large amount of any chemical solvent may seriously degrade water quality and have possible adverse effects upon public health as well as aquatic and terrestrial ecosystems.

d) Thermal. Any drilling device which melts, vaporizes, or thermally spalls rock materials must be cooled in some fashion. Because water would normally be used for this purpose, impacts could occur from the discharge of heated waste water.

(1) When heated wastes are discharged into water environments, the water temperature will cause a net decrease in dissolved oxygen. If critical levels of dissolved oxygen are reached, there may be pronounced effects on aquatic life. In addition, when water becomes heated or chilled too suddenly, it can also kill aquatic life (Jain, 1977).

(2) If a receiving body of water is not able to dissipate the waste heat efficiently (because of small volume or low flow) it should be cooled. This procedure requires a certain amount of land for cooling ponds or the construction of a tower. In areas of steep slopes, some leveling of land may be required to accommodate these facilities.

(3) Increased water temperatures may increase the solubility of certain geologic materials (e.g., non-silicates) which can result in degraded water quality.

e) Energy Intensive. A drilling mechanism that uses a large amount of electrical energy will have substantial impacts as a result of any construction required, as well as the normal impacts of the energy production process itself. Thus, whether the needed energy is produced at the mine or transmitted to the mine from a distant generating plant, there will be an increased disturbance to the air quality and land.

System access can present several unique environmental impacts. Environmental impacts, however, may be minimized if a mining system can: avoid putting holes below the maximum water table height of a region or locally perched water tables; minimize the number of access holes required; stabilize or store drilling tailings so as to limit mine drainage pollution and erosion; and utilize a drilling mechanism which will limit adverse environmental impacts on water and energy resources.

For a summary of anticipated major environmental impacts from Systems Access, see Table 2-4.

d. Regulations. Regulations pertinent to systems access exclusively address the impacts on the prevailing hydrologic balance and water quality. The following federal regulations are presented to highlight areas of major control that must be considered by any mining systems which impact the surface:

Section 516(9) of the SMRA requires that acid or other toxic mine drainage be avoided by treating drainage to reduce toxic content, and casing, sealing, or otherwise managing boreholes, shafts, and wells to prevent AMD from entering ground and surface waters. In addition, extra contributions of suspended solids to streamflow or runoff outside the permit area must be prevented. Section 515(4) of the SMRA requires that all debris, acid-forming or toxic materials be treated or buried to prevent contamination of ground or surface water.

e. Mitigating Procedures. In response to the requirements of the SMRA, the following mitigating measures are suggested as an example of the types of abatement procedures that might be required:

Table 2-4. Summary of Anticipated Major Environmental Impacts from Systems Access

Resource	Premining	Mining Operation	Mining Reclamation	Abandonment
Water	NEGLIGIBLE	MODERATE, LONG-TERM Dewatering of underground workings may be required. Potential AMD	MODERATE, SHORT-TERM Cessation of pumping could cause AMD	MAJOR, LONG-TERM Potential AMD from the failure of mine seals or ineffective neutralization procedure
		MAJOR, LONG-TERM Potential alteration of ground water flow and interaquifer movement. Potential alteration of surface streamflow		MAJOR, LONG-TERM Potential loss of primary or alternate ground water resources

For definitions of magnitude and duration, see the Summary of Access and Haul Roads, Section II-B-1.

(1) Premining.

(a) Determine the local groundwater conditions (e.g., flow, availability, extent).

(b) Construct drainage control structures, such as ditches, sediment ponds, diversions of channels.

(c) Construct water storage or treatment facilities if necessary.

(2) Mine Operation.

(a) Store and stabilize all tailings.

(b) Collect and treat all discharge water for mine drainage pollution and suspended solids.

(c) Cool all heated waste water before discharge if applicable.

(3) Mine Closing.

(a) Bury or remove all spoil piles which may produce AMD or toxic materials.

(b) Seal (and possibly case) all access holes.

4. Coal Cutting

a. Introduction. In this document coal cutting is defined as the removal of coal from either single or multiple seams. The process of coal cutting requires that coal be broken away from the seam (comminuted, cut, fractured, or dissolved) and transported to the surface.

b. Environmental Impacts.

1) Subsidence (adapted from Down and Stocks, 1977). The removal of coal from below the earth's surface creates a significant potential for horizontal and vertical ground movement. These ground movements may be manifested as continuous or discontinuous deformations.

a) Continuous Deformation. A subsidence trough usually results from continuous surface deformation. Vertical displacements associated with the trough can alter surface and ground water flow and in extreme cases cause flooding. The vertical distortion as the result of tensile and compressive strains can affect buildings, pipes, walls, bridges, and railroads, surface drainage patterns, and aquifers. Tensile zones can cause pipes and cables to rupture. Zones of compression show features such as crushing, buckling, and fracturing.

b) Discontinuous Deformation. The mining of irregular deposits can result in major fractures, cave-ins, and steps which may severely damage buildings. It should be noted, however, that discontinuous fractures are not usually associated with stratified (coal) deposits. However, discontinuous deformation could occur as the result of non-uniform coal extraction patterns.

Surface deformations as the result of subsidence, can render once usable urban lands unsuitable for habitation, agricultural lands unstable for tillage and irrigation, and recreational lands useless. In other words, subsidence can make lands unfit for many desirable uses.

2) Mine Drainage Pollution. The removal of a coal seam, either partially (e.g., auger, room and pillar) or completely (e.g., longwall) can expose potentially toxic materials to conditions which could form mine drainage pollution. (For a complete discussion of impacts, refer to Removal of Overburden, Section II-B-2.)

3) Erosion and Sedimentation. The extraction of coal from a seam can result in the removal of a significant amount of roof and floor rock. When coal is brought to the surface, it may have as much as 50 to 70 percent refuse. The storage of this refuse or spoil will be susceptible to erosion and sedimentation. (For a discussion of impacts associated with erosion and sedimentation, refer to Access and Haul Roads, Section II-B-1.)

If the refuse is stored at the earth's surface and contains potentially toxic materials, it could also be a source of mine drainage pollution (Mine Drainage Pollution, above).

4) Groundwater Alteration. The extraction of a water-bearing coal seam or seams could alter local or regional groundwater conditions. If mining operations pump the water to the surface, there could be several impacts:

(1) If the water being pumped from the mine workings is toxic, it could cause extensive damage to local surface waters.

(2) The removal of large quantities of water from an aquifer could divert water resources from other users and may also lead to subsidence.

(3) If long-term pumping of the groundwater leads to the lowering of the local or regional water table, road cuts and other construction may occur in geologic materials that were once producing aquifers. With the cessation of

mining and associated ground water pumping, the original ground water levels will be restored. As a consequence, uncontrolled ground water seepage may occur where construction has intersected a restored aquifer.

(4) Coal removal may also result in the propagation of fissures that transect overlying rock units and permit the interchange of groundwater between water-bearing materials and induce drainage of groundwater from wells and base flow.

c. Magnitude of Impacts. The magnitude of impacts associated with coal cutting activities is a complex function of the geometry of the coal deposit, mining method, geologic character of the coal deposit and overlying strata, and the method of comminution. For this reason, the impact of each factor will be discussed separately.

1) Coal Deposit Geometry.

a) Areal Extent. The magnitude of impact generated by surface deformation is directly related to the degree and areal extent of subsidence. Subsidence is approximately symmetrical about the center of the extraction, with the vertical and horizontal displacements varying as a function of the extraction geometry. If the entire seam is removed, the surfaces expression of the subsidence will be a function of the areal extent of the coal seam. For this reason, the total amount of land that may be potentially affected is delineated by the coal deposit geometry. Consequently, there is a greater potential impact on land use associated with a mine having a large areal extent as compared with one having a limited areal extent.

b) Seam Thickness. In addition to the areal extent of a coal deposit, the seam thickness is also important. The maximum vertical displacement is proportional to the seam thickness. As a result, a thick seam will have a larger vertical displacement if compared with a thin seam under similar geologic conditions.

2) Method Mining. The method of mining will have a great influence upon the magnitude of impact. Magnitude of impact will depend upon the percent extraction, pattern of extraction, and the use of artificial supports.

a) Percent Extraction. The magnitude of impact associated with the percent extraction is assumed to be a function of the probability of mining the same area more than once. For example, if a mining system removes only 30 percent of a seam's resources, it is possible that the area will be mined again. This assumes, however,

that the coal that remains in the seam is still in a form that is retrievable. Thus, reclamation as the result of the first mining operations will be disturbed. Subsequent reclamation efforts may be more difficult, and as a result, there may be a greater chance of causing long term sediment and AMD problems. It can also be assumed that a system which removes all of the coal would have the least impact, and those systems which remove less coal would have a greater adverse environmental impact as the consequence of increased probability of secondary extraction and reclamation.

b) Pattern of Extraction. Because subsidence is a surface expression of the mine plan, the pattern of extraction will impact land use. For example, a mining system that removes all of the coal resources from a region will probably have a uniform subsidence pattern (given the proper geologic conditions) and thus, minimizing the constraints of future land uses. A system which removes coal in isolated pockets (e.g., room and pillar) can render the land unfit for most agricultural, recreational, and urban uses (assuming a shallow mine). In general, any mining system which removes coal from isolated cavities of limited horizontal extent may irreversibly damage potential land use.

c) Artificial Support. The use of artificial supports will reduce the amount of subsidence over the long term and may limit the short term impacts substantially. But at some time in the future, any support system, whether accomplished by backfill or mechanical structures, may suffer at least a partial failure. For this reason, land use in regions of potential subsidence will probably be limited. This fact aside, however, backfilling has the advantage of using potentially toxic mine tailing as support material. As a result, mine drainage pollution and sedimentation problems related to spoil storage could be significantly mitigated given proper hydrologic conditions.

3) Geologic Character of Coal Deposit and Overlying Strata. The geologic characteristics of the coal deposit and overlying strata will influence the magnitude of impact based on the depth of overburden, removal of single or multiple seams, dip of beds, and hydrology.

a) Depth of Overburden. There are several empirical relationships which predict maximum subsidence based upon the area of extraction cavity versus the depth of the cavity. These relationships generally show that for a constant cavity width the potential for maximum subsidence decreases with the depth of the extraction cavity. This would indicate that a mining system which extracts coal at a very deep level will have a lower subsidence potential than a shallower extraction (ICD, 1977).

b) Single or Multiple Seam Removal. Because the maximum vertical displacement is proportional to the seam thickness, it can be hypothesized that the removal of multiple seams will have a greater impact on surface deformation than removal of just one of those seams. Removal of several seams, especially those spaced closely together, may result in a large portion of refuse being hauled to the surface. Consequently, there may be a substantially larger waste disposal problem associated with multiple seam mining than with single seam removal. If this is true, then AMD and sediment levels may increase as well.

In addition, the ability to predict maximum subsidence would be less if multiple seams are removed. The previous statement is based on the assumption that if subsidence from the removal of one seam is difficult to predict, then the subsidence from the removal of two, three or even ten seams would be even more difficult.

Given the two potential problems outlined above, it can be suggested that the removal of multiple seams may create greater environmental problems than single-seam extraction.

c) Dip of Beds. Groundwater conditions could present serious problems, if dipping seams are mined. For example, steeply dipping strata which could act as aquifers may have the potential of contaminating ground water resources to a greater extent than flat lying strata. If coal seams in contact with such aquifers are mined below drainage, damage from mine drainage pollution could result.

d) Hydrology. Because subsidence directly involves the collapse of the roof and overlying strata, there is a high probability of altering ground water flow patterns and creating hydraulically-connected aquifers. As a result, ground water communication can cause severe environmental impacts (see Systems Access, Section III-B-3).

If an extracted seam is yielding water that is toxic, on-site facilities may be required to treat the water before it can be discharged. The placement of these facilities would add to the total area disturbed.

4) Method of Comminution. Impacts associated with the method of removing coal from a seam can be divided into the same classes discussed above in Systems Access. For information regarding the magnitude of impact, refer to Systems Impact section. It should be emphasized that the method of excavation and comminution in combination have the potential of creating a much greater impact than the sum of their individual impacts (e.g., larger treatment facilities, more energy). This should be kept in mind in the early phases of system design.

Since extraction of a coal seam can result in several adverse environmental impacts, a preferred system would be one that can:

(1) Provide a way of removing all coal from a seam or seams.

(2) Avoid irregular mining patterns so as to provide large areas of uniform subsidence.

(3) Clean the coal and dispose of the refuse underground in a manner that minimizes possible mine drainage pollution.

(4) Utilize backfilling technologies.

(5) Utilize a cutting mechanism which limits adverse environmental impacts on water and energy resources.

(6) Avoid mining in regions where the coal seam acts as an aquifer; and

(7) Avoid using any mechanisms similar to auger mining.

These measures could minimize potentially substantial environmental impacts, thereby lessening the adverse impacts of the overall mining operation. For a summary of anticipated major environmental impacts from coal cutting, see Table 2-5.

d. Regulations. The following federal regulations are presented to highlight areas of major control that must be considered by any mining system which impacts the surface:

One of the more important regulations of the SMRA (Sec. 515(1)) requires that mine operators maximize the utilization and conservation of coal resources so that secondary mining and disturbance of the land in the future will be minimized. Section 516(1) requires that subsidence, to the extent technologically and economically feasible, be prevented (except when using planned subsidence in a predictable and controlled manner). It is also necessary to return to the excavation mine waste, tailings, and any other waste incident to the mining operation. In addition, all underground coal mining under urbanized areas, cities, towns, communities, major impoundments, and permanent streams shall be suspended if imminent danger due to subsidence is found (Section 516(10)). For additional impacts on the hydrologic balance, refer to Systems Access, Section III-3-3.

e. Mitigating Procedures. In response to the requirements of the SMRA, the following mitigating measures are suggested as examples of the types of abatement procedures that might be required:

(1) Premining

(a) Determine the local groundwater conditions.

(b) Construct water storage or treatment facilities (if necessary).

Table 2-5. Summary of Anticipated Major Environmental Impacts of Coal Cutting

Resource	Premining	Mining Operation	Mining Reclamation	Abandonment
Water	NEGLIGIBLE	MAJOR, LONG-TERM Destruction of coal seam that may be an aquifer and potential for mine drainage pollution	MAJOR, LONG-TERM If acid producing materials are used for backfilling, there is possibility of AMD	MAJOR, LONG-TERM If coal has potential for producing acid there could be continuous AMD
		MAJOR, LONG-TERM Subsidence above coal seam could alter ground water flow and cause inter-aquifer movement	NEGLIGIBLE	MAJOR, LONG-TERM Potential loss of primary or alternate ground water resources
Land	NEGLIGIBLE	MAJOR, LONG-TERM Surface subsidence will permanently alter the natural contour of the land and its stability	MODERATE, LONG-TERM Backfilling or systems may reduce the extent of surface subsidence and increase stability	MAJOR, LONG-TERM Potential ongoing subsidence
		MAJOR, LONG-TERM Subsidence will alter original land use capabilities	MODERATE, LONG-TERM Potential for partial restoration of original land capability	MAJOR, LONG-TERM Potential subsidence and land instability will limit future land use

For definitions of magnitude and duration, see the Summary of Access and Haul Roads, Section II-B-1.

(2) Mine Operation

(a) Collect and treat any mine water for toxic drainage or sediment before discharge (if applicable).

(b) Store and stabilize all refuse.

(c) Backfill as necessary.

(3) Mine Closing

(a) Bury or remove all spoil piles which may produce AMD or toxic material.

(b) Complete backfilling of all extraction cavities.

(c) If auger-type extraction is used, insure proper sealing and backfilling to prevent AMD.

5. Coal Hauling

a. Introduction. For the purpose of this document, coal haulage is defined to be the transportation of coal from the working face of a seam to a processing or storage site. Activities associated with coal haulage require loading, physical transport by some mechanism, and processing or storage as an intermediate stage before shipment off the mine site.

b. Environmental Impacts.

1) Dust. Sources of dust from haulage arise from spillage, loading and unloading, abrasion from transport, and abrasion of transported and stored coal. These activities can cause several types of adverse reactions in man. Some of these reactions would be: allergic, irritative, or lung impairments. Coal dust, in particular, has been shown to cause serious lung damage. With respect to plants, dust is relatively inert. However, when particulate matter is deposited on leaves it can plug stomates, lower photosynthetic activity and cause leaf necrosis. In addition, coal dust may carry other pollutants (e.g., heavy metals, boron) which can be absorbed by soils and subsequently taken up by vegetation. High concentrations of these pollutants can be toxic to plants. Also see impacts of dust on air quality, Section II-B-1.

2) Mine Drainage Pollution. The exposure of coal with potential toxic materials to the atmosphere during haulage and the subsequent contact with water could result in mine drainage pollution (see Removal of Overburden, Section II-B-2).

c. Magnitude of Impacts. The magnitude of impact from coal haulage is assumed to be a function of the amount of water associated with transport. For this reason, the magnitude of impact will be discussed in terms of either wet or dry haulage.

1) Dry Haulage. The on-site movement of coal is most commonly accomplished by the use of trucks, conveyor belts and rail car. Although these methods could have sizeable spills, it is important to note that such spills would be essentially dry. As a consequence, the only damage that might result would be from a temporary occurrence of dust. However, a coal (with potential toxic material) spill during a period of precipitation could result in contamination of surface and groundwater from mine drainage pollution. Coal spills from dry haulage would usually be restricted to a small region. For this reason, possible impacts as the result of mine drainage pollution should also be limited.

It should be emphasized that there may be some unavoidable mine drainage pollution as the result of spraying stored or hauled coal with water in order to control dust. The major difference, however, is that the spraying of coal is a planned process, and if handled properly, should not result in any significant adverse impacts. This is especially true with the storage of coal. Large storage piles, when drained to treatment ponds, present little problem if proper engineering techniques are used. For a general discussion of haulage, see Brauns (1973).

2) Water Haulage. The only impacts that will be addressed are those that may impact the mine site. For an example of environmental impacts that may occur outside the mine site see Bechtel (1974). The major impacts are assumed to be associated with water availability and storage facilities.

a) Water Availability. If the physiographic region in which hydraulic methods are proposed does not have sufficient (or predictable) quantities of surface or groundwater for transport, water must be imported. Imported water would require a transport system and a means of storage. Both of these processes will ultimately disturb more land.

On the other hand, if surface and groundwater are available and used in large quantities, water may be diverted from existing urban, agricultural, or industrial users. However, if there are abundant water resources or if recycling is feasible, hydraulic methods could be an advantage.

b) Storage. In order to facilitate coal preparation for a hydraulic transportation system, storage facilities and emergency holding ponds would be necessary. Once again, these facilities would

disturb added land resources and would be subject to possible flooding and leaching. Like treatment ponds, storage ponds for coal slurries may contain toxic water (e.g., low pH, trace metals). Accordingly, such ponds must be protected against infiltration and possible pond failure.

In regions of steep slopes and little flat land, these needed facilities may not be able to be constructed. Regions of relatively flat land, however, would have sufficient space for the proper facilities and abatement procedures.

For a summary of anticipated major environmental impacts from coal haulage, see Table 2-6.

d. Regulations. The following federal regulations are presented to highlight areas of major control that must be considered by any mining system which impacts the surface.

Regulations which can be applied to coal haulage address impacts on the prevailing hydrologic balance and water quality. Section 516(9) of the SMRA requires that water must be prevented or removed from contact with potential toxic materials, or the drainage treated to reduce the concentration of toxic materials. In addition, Section 515(24) requires that to the greatest extent possible, disturbances and adverse impacts of mining on fish, wildlife, and related environmental values must be minimized.

e. Mitigating Procedures. In response to the requirements of the SMRA, the following mitigating measures are suggested as an example of the types of abatement procedures that might be required:

(1) Premining

(a) Determine extent of surface and groundwater resources.

(b) Construct drainage control, storage and/or treatment facilities (if applicable).

(2) Mine Operation

(a) Prevent fugitive dust.

(b) Pond or treat all toxic drainage.

(3) Mine Closing

(a) Bury or remove all coal or spoil piles which may produce toxic drainage.

Table 2-6. Summary of Anticipated Major Environmental Impacts from Coal Haulage*

Resource	Premining	Mining Operation	Mining Reclamation	Abandonment
Water	NEGLIGIBLE	MODERATE, SHORT-TERM Potential spill of slurry water or AMD from spoil or coal piles MAJOR, SHORT-TERM Potential for diverting water from other users	NEGLIGIBLE	NEGLIGIBLE
Air	NEGLIGIBLE	MAJOR, SHORT-TERM Degradation of air quality due to loading, transport, and unloading of coal	NEGLIGIBLE	NEGLIGIBLE

*Impacts associated with construction are addressed in the Summaries of Access and Haul Roads and Overburden Removal.
For definitions of magnitude and duration, see the Summary of Access and Haul Roads, Section II-B-1.

6. Coal Processing

a. Introduction. Coal processing is defined as the preparation of coal in advance of transportation from the mine site. The major activities associated with coal processing are size segregation, liquid-solid separation, and waste removal.

b. Environmental Impacts.

1) Chemical Wastes. The processes of liquid-solid separation generally utilizes a wide variety of coagulants (metal salts, metal hydroxides, and synthetic organic polymers) to achieve the flocculation of colloidal suspensions. The release of water containing these chemicals (especially the organic polymers) may cause some adverse impacts. Because chemical wastes are usually troublesome, and are expensive to treat, suitable disposal methods (e.g., incineration, pyrolysis, etc.) might be utilized instead of ponding or landfilling of wastes.

2) Dust. Various crushing, screening, and other operations create large volumes of particulate materials. Dust control during most of these operations is usually achieved by hood and duct systems. Although mechanical dust collection offers some benefits over water-controlled methods, wetting can be more effective. In addition, air pollution may occur from refuse storage areas (Sussman and Mulhern, 1964). (For impacts of dust, see Coal Hauling, Section II-B-5.)

3) Erosion and Sedimentation. Separation of waste materials during coal preparation creates another disposal problem. Because most of the coarse fractions are stored in piles above ground, these materials may be subject to slope instability and earth slides, and thus act as a source of sediment. (For impacts, see Removal of Overburden, Section II-B-2).

If the refuse or coal has potentially toxic materials (e.g., sulfides) there may also be the possibility of mine drainage pollution. (For impacts, see Removal of Overburden, Section II-B-2).

c. Magnitude of Impacts. The magnitude of impacts associated with coal processing activities is a function of the amount and toxicity of the solid and liquid wastes produced. For this reason, magnitude of impact will be discussed in terms of each waste.

1) Liquid Wastes. In general, it is less expensive to design a preparation facility with long-term water resources requirements in mind. Of course, the less water used, the less has to be treated for pollution and the lower the cost. If coal preparation is to be performed on-site, proper planning should be utilized to reduce water usage and subsequent land use for waste processing and disposal. The reduction of impact, therefore, can be reduced if water usage can be restricted.

It should also be noted that mountainous mining regions may have little suitable land available for treatment facilities. As a result, coal processing facilities may have to be located a considerable distance from the active mining centers.

2) Waste Disposal. The percentage of refuse (or gob) from coal is a function of the amount of partings and clay veins. In addition, the amount of refuse will increase as roof and floor are taken along with the coal. Because the amount of waste rock generated is usually a function of the geology, there is little a mining system can do to reduce the level of waste except to limit the amount of roof and floor rock taken. Consequently, magnitude of impact will be a function of abatement procedures. The more stringent the mitigating activity, the lower the impacts.

Given these possible impacts, it would seem that on-site coal processing, for small operations, might not be an advantageous activity. An attractive alternative could be the servicing of several mining operations by a centralized coal processing plant. Another alternative would be to process or clean the coal at the working face so that the refuse would never leave the immediate vicinity of the seam.

For a summary of anticipated major environmental impacts from Coal Processing, see Table 2-7.

d. Regulations. The following federal regulations are presented to highlight areas of major control that must be considered when evaluating any mining system which impacts the surface:

Regulations which apply to coal processing address surface impacts as the result of solid and liquid waste generation. Section 515(4) of the SMRA requires that all debris (toxic or acid forming) be treated, buried, or otherwise disposed of in a manner to prevent contamination of ground and surface waters. In addition, all spoil piles must be stabilized to control air pollution effectively. According to Section 516(9) of the SMRA, toxic mine drainage must be avoided by preventing or removing water from contacting toxic material. All toxic drainage must also be treated before release. In addition to the regulations of the SMRA, there are specific state requirements for water and air quality, as well as EPA effluent guidelines and standards for coal mining (see Appendix B).

Table 2-7. Summary of Anticipated Major Environmental Impacts from Coal Processing

Resource	Premining	Mining Operation	Mining Reclamation	Abandonment
Water	NEGLIGIBLE	MODERATE, SHORT-TERM Potential spills of toxic liquids used for coal processing, land processing and possible contamination of surface and ground water	NEGLIGIBLE	NEGLIGIBLE
		MODERATE, SHORT-TERM Potential AMD and sedimentation from coal spoil stored above ground		MODERATE, LONG-TERM Potential for AMD from spoil that is buried or stored in under ground mines
Air	NEGLIGIBLE	MAJOR, SHORT-TERM Degradation of air quality due to loading, processing, and unloading of coal	NEGLIGIBLE	NEGLIGIBLE

For definitions of magnitude and duration, see the Summary of Access and Haul Roads, Section II-B-1.

e. Mitigating Procedures. In response to the SMRA, the following mitigating measures are suggested as an example of the types of abatement procedures that might be required:

(1) Premining

(a) Construct drainage control structures.

(b) Construct proper water treatment facilities.

(c) Select suitable waste disposal sites.

(2) Mine Operation

(a) Stabilize all spoil.

(b) Collect and treat all discharge water for AMD, sediment, and toxic materials.

(c) Control fugitive dust by either dry or wet procedures.

(3) Mine Closing

(a) Bury all spoil piles or otherwise remove all toxic material.

C. ENVIRONMENTAL IDENTIFICATION CHECKLIST

Explain as briefly as possible all "yes" and "maybe" answers on sheets having the format of Figure 2-1. If there is any difficulty filling out the answer sheet, the user should read again the pertinent material covered in this section. For each answer, mark the appropriate question number on the summary sheet (Figure 2-6).

	(NO) POSITIVE IMPACT	ANSWER NUMBER	(YES) NEGATIVE IMPACT	
LAND		1a		EROSION
		1b		
		1c		
		1d		
		1e		TOPOGRAPHIC ALTERATION
		1f		
		1g		
		1h		
		1i		
		2a		SUBSIDENCE AND LAND USE
		2b		
		2c		
		2d		
		2e		
		2f		
		2g		
WATER		3a		WATER QUALITY
		3b		
		3c		
		3d		
		3e		
		3f		
		3g		
		3h		
		3i		
		3j		
		3k		
		3l		
		4a		GROUND WATER ALTERATION
		4b		
		4c		
		4d		
		5a		GROUND WATER RESOURCES
		5b		
		5c		
AIR		6a		
		6b		
ECOLOGY		7a		
		7b		
		7c		
RECLAMATION		8a		
		8b		
ENERGY		9a		
		9b		
		9c		

Figure 2-6. Checklist Summary

1. <u>Land - Erosion and Topographic Alteration</u>

Will the mining system proposed result in the following:

	YES	MAYBE	NO
a. Road construction because existing access or haul roads are not adequate?	____	____	____
b. Road construction in a region with steep slope gradient, long slope length, high rainfall intensity, and/or low vegetative cover?	____	____	____
c. Access and haul roads occurring over much of the mine site, not in a localized area?	____	____	____
d. Removal of overburden is the primary means of accessing a coal seam?	____	____	____
e. Any process, except those identified above, that may create erosion problems, or which may produce a large quantity of spoil or tailings?	____	____	____
f. Spoil stored by filling depressions, stream channels, steepening existing slopes, or any other method which may contribute to excess erosion?	____	____	____
g. Mountaintop removal or any other similar process?	____	____	____
h. Leveling a surface in mountainous regions?	____	____	____
i. Highwalls and benches or any other similar process?	____	____	____

2. Land - Subsidence and Land Use

Will the mining system proposed result in the following:

	YES	MAYBE	NO
a. Underground cutting and removal of coal?	____	____	____
b. Incomplete (less than 70-80 percent) removal of any coal resource?	____	____	____
c. Absence of backfilling procedures or mechanical structures for roof support?	____	____	____
d. Irregular pattern of coal extraction?	____	____	____
e. Removal of multiple seams?	____	____	____
f. Removal of coal from steeply dipping seams?	____	____	____
g. Uncontrolled subsidence following mine closure?	____	____	____

3. Water - Pollution

Will the mining system proposed result in the following:

a. Storage, above ground, of coal refuse?	____	____	____
b. Cutting of coal by bench cutting and augering or any similar process?	____	____	____
c. Accessing of coal by any method that will require mine sealing?	____	____	____

	YES	MAYBE	NO
d. Widespread disturbance resulting in drainage alteration?	____	____	____
e. Coal extraction accomplished by hydraulic technologies?	____	____	____
f. Coal extraction accomplished by solvent methods?	____	____	____
g. Coal extraction accomplished by some other technology which has the potential of degrading water quality?	____	____	____
h. Systems access accomplished by hydraulic technologies?	____	____	____
i. Systems access resulting in thermal discharge?	____	____	____
j. Systems access accomplished by some other technology which has the potential of degrading water quality?	____	____	____
k. Coal processing on-site?	____	____	____
l. Coal extraction and/or systems access intersecting the regional groundwater table?	____	____	____

4. Water- Groundwater Alteration

Will the mining system proposed result in the following:

a. Systems access (shafts, boreholes) as the primary method of accessing coal seams?	____	____	____

	YES	MAYBE	NO
b. Drilling or excavating a large number of holes will be required?	____	____	____
c. Uncased boreholes or shafts?	____	____	____
d. Pumping of groundwater for dewatering of mine workings?	____	____	____

5. Water Resources

Will the mining system proposed result in the following:

a. Insufficient surface and/or groundwater for mining activities?	____	____	____
b. Water imported and stored at the mine site?	____	____	____
c. Water resources diverted from other uses?	____	____	____

6. Air Quality

Will the proposed mining system result in the following:

a. Activities that will create fugitive dust?	____	____	____
b. Use of unpaved access or haul roads?	____	____	____

7. Ecology

Will the mining system proposed result in the following:

a. Removal of vegetation that may result in decreased species diversity?	____	____	____

	YES	MAYBE	NO
b. Overburden dumped off mine site covering natural vegetated areas?	____	____	____
c. Removal or modification (e.g., diversion of stream flow) of aquatic habitat?	____	____	____

8. Reclamation

Will the mining system proposed be impacted by the following:

a. Postponement of reclamation procedures until the end of active mining?	____	____	____
b. A high probability of the affected area being mined again in the future (e.g., partial extraction)?	____	____	____

9. Energy

Will the mining system proposed result in the following:

a. Removal of less coal than another alternate method (e.g., room and pillar vs. area stripping)?	____	____	____
b. A system which is energy intensive (e.g., use of lasers)?	____	____	____
c. On-site energy generation?	____	____	____

SECTION III

PRELIMINARY ENVIRONMENTAL ASSESSMENT METHODOLOGY

The conceptual methodology was used to identify potential environmental impacts of mining systems at the conceptual stage of design. The preliminary methodology utilizes regional siting characteristics together with the additional engineering data developed during preliminary design to quantify selected impacts and estimate their relative significance. This is done in a manner which facilitates the comparison of a new mining system with technology currently operating in the coal region selected. The analyst can then identify harmful or beneficial impacts of new mining systems relative to those impacts of existing systems.

The preliminary environmental assessment methodology is organized into the following four sections:

Characterization of the Regional Environmental Setting. In order to assess the potential impacts of a mining system, it is necessary to characterize the regional environmental setting of the selected coal resource. This section identifies the regional characteristics (e.g., climate, vegetation, land use, topography, soil, geology, and water resources) typically required in a performance assessment and lists sources of information.

Identification and Quantification of Impacts. This section identifies those environmental impacts of a mining system that can be quantified by considering preliminary engineering data and the previously assembled description of the environmental setting. For each impact identified there is a discussion of one or more approaches to estimating the magnitude of impact.

Estimation of Impact Significance. Given the quantification of impacts and a characterization of the region to be mined, it is possible to estimate the significance of each impact and rank each impact by their relative importance. However, first-hand experience with mining in the region selected is essential to constructing a realistic ranking of impacts. This section outlines a procedure for determining the relative significance of each impact which draws heavily upon regional expertise.

Evaluating Mining Systems. The evaluation of mining systems at the preliminary design stage is based upon the comparison between a new mining system and existing mining systems. After impacts for a system have been identified, quantified, and arranged in order of significance, that system may then be compared to any other system that has been assessed in a similar fashion. This section provides guidelines for performing a comparison between mining systems. Judgments as to the degree of advantage or disadvantage one system might offer over another can then be made at the preliminary design stage.

A. CHARACTERIZATION OF THE REGIONAL ENVIRONMENTAL SETTING

Before a system can be analyzed, it is necessary to describe the environment in which it will operate to identify the significant constraints and opportunities that exist within the region that is to be mined. In the characterization, emphasis is placed upon those elements of the regional environmental setting that would most affect the construction, operation, maintenance, and mine reclamation. The following three subsections provide a guide for aggregating data on the regional environmental setting, listing what data are typically necessary for an assessment, and where those data may be obtained.

1. Coal Regions

In the United States there are five major coal provinces: (1) Eastern Province, (2) Interior Province, (3) Gulf Province, (4) Northern Great Plains Province, and (5) Rocky Mountain Province (see Figure 2-7). Each of the five coal producing regions has its own unique and diverse physical and biological characteristics. For an introduction to the coal regions, Noyes (1978) provides a brief overview of the physical, biological, and socioeconomic characteristics. However, to perform an analysis using the preliminary environmental assessment methodology, a more detailed set of information is necessary.

Detailed data on the physical and biological characteristics (see Data Elements, Section III-A-2) of a specific coal region can be collected at the federal, state, and county level. The selection of a coal region should take into account the regional variability of soil, topography, vegetation, climate, hydrology, overburden characteristics, and land use. For this reason, coal regions selected for system implementation should be chosen on the basis of regional similarity. For example, Central Appalachia is generally characterized as having very steep slopes (greater than 25 degrees) and is mostly forested. Northern Appalachia, in contrast, has a more moderate to rolling topography which is suitable for agriculture and urban development. As a consequence, data should be collected and summarized by similar geographic regions. With the data regionally summarized (by coal region, state, or county) a preliminary assessment can be completed.

2. Data Elements

The following data elements are suggested types of information that may be useful when performing an assessment. Not all of the data elements will be used for any given assessment. This will be determined primarily from the coal region selected and the mining system being analyzed. For an example of the type of data and detail required for an assessment refer to Appendix D: Physical Characterization of Eastern Kentucky.

a. Land Use. Prior to opening a mine, the existing land uses and their economic significance should be identified. In this way it is possible to identify potential conflicts and to estimate their magnitude at least in economic terms (e.g., damage costs, health costs, material costs, etc.). Those factors that should be considered are:

(1) Type of land use (e.g., vegetable crops, rangeland, forest, residential).

(2) Intensity of land use (e.g. probable return per acre per year; property values).

b. Uniqueness of area. Within any region there are areas that should not be disturbed. Reasons for avoidance vary but most often they relate to ecological sensitivity or to some generally perceived high and aesthetic social value. The categories that should be included are:

(1) Ecological (e.g., key watersheds; rare habitats; unique faunal/vegetation types).

(2) Aesthetic (e.g., areas of high scenic value).

(3) Historical (e.g., historic or prehistoric sites).

(4) Archaeological and paleontological sites.

Usually such areas are protected by specific federal or state statutes.

c. Topography. Topography can hinder access to potential mining sites, can be a persistent obstacle to construction, operation and maintenance of the mining facility, and may cause difficulties in mine reclamation (e.g., Central Appalachia). Topographic characteristics are also important considerations in erosion and sedimentation. In describing a region it is generally necessary to determine:

(1) Slope (e.g. prevailing slope classes and their areal extent).

(2) Topographic roughness (e.g. relative drainage net density; local relief).

d. Geology. The spatial and stratigraphic arrangement of the coal has an obvious bearing on the surface area that may be affected by a specific mining system. First, it is necessary to know the amount of resource available to determine whether or not the mining system can access the coal resources in the region selected.

Second, it is necessary to know the dip of the beds, the degree of faulting, and other possible constraints related to the position of the seam to estimate how much of the resource may be ultimately extractable. Finally, it is also necessary to know the depth of overburden and its chemical nature to estimate (1) the impacts of overburden removal (if necessary) or (2) the amount of material that must be drilled through if the mining system requires vertical access or (3) roof conditions if the system uses lateral entry. The types of information that should be gathered are:

(1) Seam thickness.

(2) Seam extent.

(3) Dip.

(4) Depth of overburden.

(5) Chemical nature of overburden (e.g., trace metals, pyrite).

e. Climate. Climatic characteristics, especially precipitation, play a large role in determining erosion and sedimentation, water availability, and reclamation success. Those things that should be known about a site are:

(1) Precipitation regime (types, amounts and frequencies).

(2) Monthly temperatures (means and ranges).

(3) Flooding potential (historic frequency and extent).

f. Water resources. All mining systems require some minimum amount of water for operation. Therefore, some estimate must be made of the available water resources, the other users that are competing for that water, the need for large-scale water treatment facilities (e.g., settling ponds for treating waste water) and the potential for serious water pollution. The description of water resources should include:

(1) Groundwater

(a) Location of major aquifers and their sustained yields.

(b) Competing users.

(c) General water quality.

(d) Depth range and draw-down history.

(2) Surface water

(a) Major streams and their flows.

(b) Competing users.

(c) General water quality by basin.

g. Vegetation. The type and density of vegetation, in part, determines the ease of access to the mine site. In itself, vegetation may not be a significant resource but is of vital importance in determining the probable success of reclamation:

(1) Type (e.g. yellow pine forest, oak-hickory forest, grassland).

(2) Density (percent crown cover).

h. Soil. Characteristics of the soil can impact surface construction and can also affect mine reclamation. Special problems that are associated with any particular soil must be noted. In order to identify and analyze potential soil problems, one should collect the following information on the region selected:

(1) Association (regularly occurring combinations of soil types).

(2) Average depth.

(3) Special problems (e.g., saline and alkali soils; vertisols).

(4) Soil erodibility.

3. Data Sources

Because the data required in an evaluation are rather diverse, it is not likely they will all be available in a single source. Table 3-1 pre ents an outline of potential source documents, their uses, and the agencies from which these documents may be obtained. The listing that appears here is not comprehensive, and should only be used as a guide to the types of information available.

In addition to the generally available published documents that are outlined in Table 3-1, interviews with appropriate public agencies should also be conducted (Table 3-2). Interviews are especially useful in determining the significance of the impacts that are ultimately identified for mining systems. Interviews are also valuable for obtaining insight into potential problem areas (e.g., region-specific concerns), and for assessing of the reliability of published data on the region.

Table 3-1. Data Sources

Data	Type	Source
Maps	Topographic	U.S. Geological Survey (U.S.G.S.)
	Geology	U.S. Geological Survey: state geological surveys; Master's and Ph.D. theses
	Vegetation	U.S. and state forest services; county planning agencies
	Soil	U.S. Soil Conservation Service (SCS); U.S. Forest Service; Bureau of Land Management (BLM)
Air Photos	Satellite; U-2; USGS mapping photography; low altitude; for mapping vegetation, soil land use, surface characteristics engineers	EROS Data Center (USGS); Soil Conservation Service (USDA); local planning agencies and highways
Reports/ Raw data	Climate	National Climatic Center (NOAA)
	Soil survey	Soil Conservation Service (USDA)
	Geology	U.S. and state geological surveys; Master's and Ph.D. theses; Literature
	Water	U.S.G.S. Water Resources publications; state water resources agencies; Literature

Table 3-2. Agencies Useful in Obtaining Evaluation Data

(1)	State Mine Reclamation and Departments of Natural Resources.
(2)	State Regional and Local Planning.
(3)	Water Resource Boards.
(4)	Air Resource Boards.
(5)	State Fish and Game Commissions.
(6)	State Offices of Historic Preservation.
(7)	Regional EPA Offices.
(8)	Federal and State Forestry Agencies.
(9)	Appropriate Departments of State Universities.
(10)	U. S. Soil Conservation Service.
(11)	U. S. Bureau of Land Management.
(12)	U. S. Fish and Wildlife Service.
(13)	U. S. Army Corps of Engineers.
(14)	U. S. Geological Survey.

B. IDENTIFICATION AND QUANTIFICATION OF IMPACTS

Potential environmental impacts of mining activities can be identified by using the checklist developed in the conceptual environmental assessment methodology. At the preliminary design stage, however, additional engineering data allows similar types of potential impacts to be aggregated and quantified. When a mining system is implemented in the environment the two basic types of impacts that can be quantified are utilization impacts, and alteration impacts.

The operation of a mining system in the environment requires that a certain amount of natural resources be utilized. Each mining system has performance requirements for a specific allocation of natural resources in order to operate (e.g., land, water, energy). In this regard, "performance impacts" are defined as those impacts that

may hinder a system from achieving sustained operation. The following three utilization impacts are considered and a methodology for their quantification presented: (1) land resource balance, (2) water resource balance, and (3) energy resource balance.

When a mining system is implemented, impacts on the natural environment occur as the result of the interaction of the technology with the processes and characteristics of the environmental setting. These impacts are referred to as "alteration impacts". They are defined as impacts that result from changing the physical or biological environment as the result of utilizing a region's natural resources. This document identifies seven major alteration impacts: (1) erosion and sedimentation, (2) resource removal, (3) land use, (4) water quality, (5) habitat alteration, (6) air quality, and (7) aesthetics. The first three impacts are defined and a methodology for their quantification is presented. The remaining four impacts are discussed along with possible synergistic effects.

1. The Mine Plan

Unlike the conceptual methodology, the preliminary evaluation requires not only more detailed engineering data but also detailed information on the physical arrangement of the mine and all of its support facilities at the selected site. This requires that the user produce an accurate mine plan that details the location of surface facilities, roads, haulage ways, storage facilities, or any other structure or activity that supports the mining process. By placing these facilities at the selected mine site (using a U.S.G.S. 7.5 topographic quadrangle as a base map) the user can determine the necessary drainage control structures (e.g., diversion ditches, sediment ponds) that will be needed to control potentially polluted waters or any necessary drainage diversion (for specifications see USEPA, 1976).

A detailed mine plan permits calculations on the amount of land required and its modification (e.g., grading), together with the required number of pollution control structures or diversions. These calculations can then be used in conjunction with the calculations made to assess the utilization and alteration impacts. In addition, these data can also be utilized to calculate the costs associated with the mitigation of the identified potential environmental impacts (e.g., reclamation costs, water treatment, grading, backfilling, drainage control costs, etc.). If costs are to be calculated, it is suggested that the appropriate state agencies, where the assessment will be conducted, be questioned to determine the best source of reclamation cost data. If it is not possible to obtain the needed data, an alternative would be to use available published information such as Doyle, et al. (1974).

The following outline is provided as a guide to the type of information that should be included in the mine plan:

(1) Mining Facilities

(a) Land for the mine site. Given the requirements of the operation, an estimate of the number and type of buildings should be determined along with an estimate of their square footage. Estimates should also be made of the area required for parking, supply yards, coal piles, refuse piles, and any type of on-site storage.

(b) Land for water treatment. If it is anticipated that water treatment facilities will be required, an estimate of required area should be made (this should not include areas for sediment ponds).

(c) Land for mine mouth haulage. Some mining systems will require additional land for haulage from the mine mouth to a processing plant, storage pile, or direct haulage (e.g., rail, conveyor, pipeline, truck, etc.). The total area required for the selected haulage system should be determined.

(d) Land for mine access and haulage. Any modification of the mine site due to the need for mine access or haulage should be determined. Estimates should not include haulage systems from the immediate location of the mine to the final destination of the coal.

(2) Sediment and/or AMD Control

(a) Diversion ditches. The mine site, coal piles, storage of spoil or soil, refuse storage, and haulage ways may require diversion ditches to control and collect surface runoff, which may be polluted. Thus, an estimate of the total length of diversion ditches should be made.

(b) Sediment ponds. After the mine site has been established with all of the required facilities (e.g., buildings, yards, haulage, etc.), sediment ponds should be provided at various points of natural drainage, convergence of diversion ditches, or any area that will acquire runoff from the affected mining area. For details of placement and construction refer to USEPA, 1976.

2. Utilization Impacts

In order to assess the possible impacts of a mining system, a calculation of the potential area of extraction must be completed. The potential area of extraction can then be used to calculate the land resources balance, water resource balance, energy resource balance, and estimate reclamation costs. Given engineering data, a geologic column, and the topographic setting, the total area of possible extraction can be calculated using the following procedure:

(1) For the coal region of interest, select USGS 15 or 7.5 minute topographic sheet as a base map. The selection of a topographic map should be based upon; a) representative geomorphic features of the coal region, and b) uniform elevation (no greater than 10 percent difference in the maximum topographic highs for the map).

(2) From the available geologic data for the same region as the base map, construct a general geologic column.

(3) Given the engineering capabilities of the mining system, determine the maximum depth to which coal can be mined. Assuming that all seams suitable for this technology will be extracted down to the maximum depth capability, use the base map to identify the areas from which coal will be removed.

(4) Given the percent extraction of the mining system, the rate of coal extraction, and the time of active mining, determine the total area of potential extraction. (For an example of this calculation see Appendix A). With the completion of the above calculation, the potential perforance impacts can be quantified.

a. Land Resource Balance. If a mining system is to be successfully implemented in a specific environmental setting, it must have sufficient land for operation. In regions of intensive agricultural or urban land use, mining systems may present a conflict with these existing activities. The method proposed to quantify this potential impact is based on a simple balance between the area of potential extraction and existing land use patterns.

(1) For the region depicted on the previously selected base map, determine the area of each existing land use (e.g., forest, urban, range land, agricultural, etc.). From these area measurements, calculate the percent devoted to each land use.

(2) Given the total area of potential extraction, calculate the percent of the area that may be impacted.

(3) The percentages of the potential extraction area and those of intensive land uses (e.g., urban and agriculture) should be summed.

If the sum of the percentages is greater than 100, there may be a conflict between the mining systems operation and existing intensive land uses.

In addition to conflicts that arise from land use, a mining system should also be examined to determine if it can operate profitably within the average lease area that present-day systems use. A similar calculation, as described above, can be completed using lease size instead of land use.

A third calculation can also be made to determine if a region has the necessary amount of flat or gently sloping land for the operation of a mining system without modification of the land surface. If a mining system requires flat or relatively flat land, 0.25 to 3 degrees (Clayton, 1972), a topographic map can be analyzed

to determine the percent flat land. The mining system requirements can then be compared to the available flat land. If the mining system requires more flat land than is naturally present, additional modification will be necessary. The total number of acres that may be modified should be calculated and used for comparison between systems.

b. Water Resource Balance. The movement of water at and near the earth's surface is in a continual flux of inputs and outputs; in this document it is useful to calculate a quantitative balance between them. The results of this analysis can be used to assess the amount of surface and ground water resources that exist in a given region. The distribution of water resources, however, is a spatial phenomenon that requires a careful definition of its boundaries. In most regions of the United States, this boundary is the river basin.

For the purpose of assessing water availability for mining, the river basin is the logical unit for quantitative analysis. If a mining system is going to operate efficiently at sustained levels of production, there must be sufficient water available in the river basin where a system will be implemented. The following method is proposed to quantify the availability of water resources in a specific coal region.

(1) For the coal region identified on the original base map, collect surface and ground water data for each river basin (if data is not available for each river basin, use physiographic region).

(2) Aggregate the river basin data to give the following:

(a) Mean summer and winter surface discharge.

(b) Mean summer and winter groundwater sustained yield.

(3) Determine from the mining system performance characteristics, the amount of water required for sustained operation.

(4) Calculate the difference between the mining system requirements and the mean available surface and groundwaters (for a simplified calculation, see Appendix A).

If the water requirements are greater than the mean available water resources, the mining system may not be able to operate successfully in the given environmental setting. It should be emphasized that this analysis is done on a regional scale and that for site specific cases any mining system's water requirements may be satisfied locally. Since water availability can vary greatly with a region, the implementation of any mining system that is a heavy user of water will require extensive hydrologic studies before it can be sited.

c. Energy Resource Balance. As outlined by the 1977 Surface Mining and Reclamation Act, coal should be extracted in such a manner so

as to conserve our energy resources. For the purpose of assessing the conservation efficiency of a mining system, the energy balance between the resource removed and the energy resources required for that removal should be determined. The method proposed to quantify this potential impact is based on the energy balance between the coal resource removed and the energy required to access and cut the coal.

(1) By using the previous calculation of the total area of extraction, determine the total potential coal resource that can be mined.

(2) From the geologic data, determine the average energy content (Btu/lb) of the coal being extracted. Using these data, calculate the total energy content of the coal tonnage produced.

(3) Given the engineering and operating characteristics of the mining system, determine the energy requirements (e.g., amount of fuel or electricity) to access the coal seam, and bring the coal to the surface, and prepare it for shipment to market.

(4) The difference between the energy content of the coal extracted and the energy requirements for the extraction process may be calculated and expressed in common units (e.g., Btu or dollars).

If the energy required to remove the coal is close to the potential energy of the coal resource (e.g., 50%) the extraction system may not be suitable--especially where additional energy is required for haulage, reclamation, preparation, and transportation to the consumer. (For an example of an energy balance calculation, see Appendix A.)

d. Potential Reclamation Costs. Reclamation costs vary widely depending upon the physical conditions (e.g., amount of overburden removed, soil characteristics, etc.), economic conditions, type of mining activity (e.g., area vs contour), climatic conditions, and the extent of reclamation procedures required by law. Regardless of these variations, the cost of regrading and backfilling is the major cost associated with reclamation. As Table 3-3 indicates, backfilling commonly accounts for 85 - 95% of total reclamation cost, with the average occurring over 90%. Thus, a mining system that requires a large amount of earth moving would typically have higher total reclamation cost than a system requiring removal of less earth. The cost of backfilling--by assumption, a first approximation of the total reclamation cost--may be estimated as follows:

(1) Using the previously identified potential area of extraction, determine the total area that will have to be backfilled. Next, determine the amount of earth that must be moved (cubic feet) to restore the land to the approximate original contour.

Table 3-3. Coal Surface Mining Reclamation Costs (Adapted from Evans and Bitler, 1975)

Coal Region	Mining Operation	Total Reclamation Costs (Per Acre)*	Total Backfilling Costs (Per Acre)	Backfilling/Total Reclamation
Alabama, Kentucky, and Tennessee	Contour	7,760	6,684	0.86
	Contour	4,239	3,723	0.88
	Contour	8,224	7,396	0.89
	Contour	15,072	14,317	0.94
	Area	2,830	2,625	0.93
	Area	8,464	7,872	0.93
	Area	7,329	6,838	0.93
Maryland, Pennsylvania, Virginia, and West Virginia	Contour	8,050	7,510	0.93
	Contour	6,733	6.163	0.92
	Contour	12,296	11,996	0.98
	Area	5,442	4,915	0.90
	Area	8,406	7,990	0.96
	Area	8,286	7,831	0.95
Illinois, Indiana, and Ohio	Contour	5,906	5,353	0.91
	Contour	9,936	9,488	0.95
	Area	7,678	7,031	0.92
	Area	14,650	14,206	0.97
	Area	5,354	5,756	0.93
Average Ratio				0.93

*Total Reclamation Costs Include: Premining planning, Antipollution measures, Backfilling, Revegetation, and Operating and ownership costs.

(2) The cost of moving material ($/cu ft^3) can be determined by contacting contractors that perform backfilling in the region selected for analysis.

(3) Once the total backfilling cost is determined, it should be converted to a $/acre figure for use in other aspects of reclamation costing.

Like the costs of backfilling, those costs associated with revegetation can also be estimated from the potential area of extraction. For each acre disturbed, as determined from the potential area of extraction, the cost of revegetation per acre can be determined in the same manner as outlined for the cost of backfilling.

Note that calculations based on the potential area of extraction omit areas disturbed as a result of constructing roads, pipelines, transmission lines, holding ponds, pumping stations, etc. In many cases, this omission will not be material; however, it must be kept in mind when making inter-system comparisons.

3. Interactive Impacts

Identification of the impact of a mining system on the environment leads directly to the second step of determining the magnitude of the impact. Difficulties in quantitatively assessing potential impacts, however, arise because quantification of some impacts may be beyond the state-of-the-art. Therefore, instead of a specific measure, a general definition and discussion of possible effects may be all that is available.

The ability to quantify impacts is also hindered by the use of regional environmental characteristics. However, impacts that are more readily quantifiable using regional characteristics are erosion and sedimentation, resource removal, and land use.

a. Erosion and Sedimentation. Sediment is produced by eroding soil and rock, transporting the eroded material some distance and depositing it as unconsolidated material. Effects associated with erosion and deposition of sediment include the loss of soil and soil fertility, filling up of stream channels, lakes and reservoirs, destruction of habitat and wildlife, degradation of water quality, and increased flooding. For these reasons erosion and sedimentation as a result of mining activities should be minimized.

There are several possible empirical approaches which can be used to predict the degree of erosion and the amount of sediment that may be produced, given specific environmental site characteristics. The prediction of the amount of sediment from a specific site can be accomplished without much difficulty if data are available. However, like many empirical approaches to the calculation of environmental impacts, there are serious data availability problems. In addition, the complexity of the natural environment makes the analysis of a single river basin very difficult.

In view of the problems identified above, the prediction of sediment yield on a regional basis can be done only in a very rough and approximate fashion. Once the region of interest is defined one may proceed as follows:

(1) Determine the area of surface disturbance from the total area of potential extraction.

(2) The method selected for calculating sediment production should be based on the physical characteristics of the coal region where the system will be implemented and the availability of data that is required by the method.

(3) After a method of predicting sediment yield has been selected and data collected for the analysis, (assume that previous years have been effectively reclaimed and that they contribute no sediment). Calculate the average annual sediment yield for the entire operation of the mining system.

Because erosion and sedimentation is a serious problem, a mining system that produces the least potential sediment yield, relative to other systems, would be very desirable.

Several methods for calculating sediment production are presented below, along with the type of data that are necessary for their use. If the data described for each method are not obtainable, a calculation nonetheless may be made by extrapolating from a nearby region or filling in data gaps in a reasonable manner. This procedure, if used, should clearly state all assumptions, along with possible sources of error. For an additional source of approaches to predict sediment yield, see Water Resources Council, Sedimentation Committee (1976).

1) Universal Soil Loss Equation. (USDA, 1975; Wischmeier and Smith, 1965). This approach estimates the quantity of sediment available at the base of the disturbance but does not predict the actual amount of sediment that may reach a receiving body of water. The soil loss equation provides a means of estimating sediment yield for a specific set of assumptions and data. The application of this approach to a mining system requires that the sediment production from specific features (e.g., a level surface, a sloping bench, a spoil pile, etc.) be calculated from the total area of each feature present in the mining site and then summed to approximate a total sediment production.

The soil loss equation is;

$$A = f(RKLS)$$

where

A computed soil (or sediment) loss/unit area

R rainfall factor that is a function of both the annual precipitation and intensity. R factors can be obtained from Wischmeier and Smith (1965).

K soil erodibility factor is a function of grain size distribution, percent organic matter, soil structure, and soil permeability. K factors can be determined from the erodibility monograph of Wischmeier, et al., (1971), from recent SCS soil surveys, or local SCS offices.

L&S L and S factors are measures of slope length and gradient, respectively. A combination of L and S factors can be taken directly from tables from USDA publications or calculated by an equation in USDA (1975).

There are usually two additional factors (C and P) that are not included here since they are related to crop management and agricultural practices. If data for the above factors can be determined, soil or sediment loss can be calculated.

2) Flaxman Model. (1972) In the Western United States the Flaxman equation can also be used to predict sediment yield:

$$\log (Y+100) = 6.63792 - 2.13712 \log (X_1 +100) +0.06284 \log (X_1 +100) - 0.01616 \log (X_3 +100) +0.04073 \log (X_4 +100)$$

where

Y	sediment yield (AF/mi^2)
X_1	precipitation/temperature ratio
X_2	weighted average slope (%)
X_3	soil particle size
X_4	aggregation index

Sediment yield can also be taken directly from a nomograph.

3) Interview Method. In many regions of the U.S. there has been little or no empirical research to determine sediment yields. As a result it may be difficult to prepare an estimate of sediment yield. However, some federal agencies (e.g., SCS, BLM, etc.) may have, through practical experience, some data to guide estimates of sediment yield. For example, in eastern Kentucky no models exist for accurately predicting sediment yield. However, upon contacting a local soil conservation office it was found that a soil scientist had

empirically determined that sediment yields were close to 0.2 AF/acre disturbed.

b. Resource Removal. The SMRA requires that coal mining operations be conducted in such a manner so as to recover the maximum coal resource, thus minimizing the likelihood of reaffecting the land in the future. Because each mining system will remove a different percentage of coal and create a unique extraction pattern, a system must be analyzed to determine its extraction efficiency. This is done in three steps:

(1) Compute the tonnage of coal recovered from the seams mined by the system under examination.

(2) From the geologic column used in the calculation of the total area of potential extraction, estimate the aggregate tonnage available in the region.

(3) Compute two recovery ratios, as follows:

$$\text{Seam Recovery} = \frac{\text{Tonnage extracted}}{\text{Total tonnage in mined seam(s)}}$$

$$\text{Resource Recovery} = \frac{\text{Tonnage extracted}}{\text{Aggregate tonnage in all coal resources}}$$

These two ratios taken together give some indication of the possibility that the land may be disturbed again, either (1) to recover coal left in the seams that were partially extracted, or (2) to extract coal in adjacent seams which were left untouched by the first mining venture.

c. Land Use. Mining activities (e.g., overburden removal and systems access) are inherently destructive to the earth's surface. The intent of various mining regulations is to ameliorate the damages caused by mining and to restore the land to a useful condition. In some cases, mined land will have a land use that is more productive and valuable after reclamation. In regions of predominately extensive land use, increases in cropland, grazing land, recreation and urban uses are a considerable benefit. On the other hand, potential land use may be permanently altered so that intensive land use may be infeasible.

It is not the intent of this section to assign a dollar value to reclaimed lands based on possible land uses, but to indicate the potential for increased or decreased diversity (e.g., grazing land, agriculture, etc.) of land use as the result of mining and reclamation.

1) Decreased diversity in land use. When underground mining occurs, the land above the mined area is often subject to subsidence. The fact that lands are affected by potential subsidence will decrease

their future land use capabilities (e.g., urban, recreation, agriculture uses). The one exception is when subsidence is planned and occurs directly after mining. In a coal region where planned subsidence is not being utilized, the area impacted by subsidence may be assumed to be coincident with the total area of potential extraction.

2) Increase in land-use diversity. In coal regions where flat land may be a benefit (e.g., southern West Virginia) the area disturbed by surface mining can represent a potential increase in land use diversity. This assumes, however, that the land is reclaimed to the standards required for grazing, agriculture, or urban uses. An estimate of the flat land produced by mining may be obtained from an analysis of mining plans designed for representative sites in a region.

Both calculations, although not quantitative in terms of predicting exact land use change, indicate the potential trends in future land use. It should also be noted that both calculations reflect the extreme ends of potential land use. It is not entirely clear how the post mining land use will change where the mining operation is subsidence-free and there is no apparent need for additional flat land. In general, however, it can be assumed that in such cases, the previous land use would be restored.

Impacts related to water quality, habitat alteration, air quality, and aesthetics are not readily quantifiable using characteristics of the regional environmental setting. Even though impacts may not be readily quantifiable for water quality, habitat alteration, air quality, and aesthetics, they may have a very serious impact upon the mining region where the system is implemented. For this reason, the preliminary assessment should indicate the potential magnitude of each impact identified above. The discussions that follow include the reasons why the above impacts are difficult to quantify, and identify the information that should be helpful in predicting the magnitude of potential impacts.

d. Water Quality. The two major problems associated with the degradation of water quality from coal mining operations are from sedimentation and acid mine drainage. In order to quantify the change in water quality associated with these two problems, their magnitude must be determined from a point source or modeled as a non-point source. In addition to calculating their magnitude, their transport and potential interaction of the pollutants with the environmental setting must also be understood before a change in water quality can be predicted for a receiving body of water.

The previous section on erosion and sedimentation indicates the sediment yields which can be predicted. Estimating the removal of sediment from the site (sediment transport) and water quality changes as the result of sediment loading are very complex. Changes in water quality will vary depending upon the characteristics of the receiving body of water (e.g., volume, velocity or circulation, type of

sediment, temperature). Since the characteristics of transport and the receiving waters are highly site specific, a regional level of analysis is not adequate for the quantitative assessment of water quality changes due to sedimentation.

Unlike the prediction of sediment yield, the production of acid mine drainage is a complex function of the concentration of acid producing materials, their crystallinity, their exposed surface area, and the presence of oxygen and water that can not be easily modeled. As a consequence, there is no successful method for quantifying the production of acid mine drainage (Gleason, et al., 1978). Even if the production of acid could be predicted, the ultimate pH of receiving waters affected by acid mine drainage could not be predicted due to the site specific interactions with the environmental setting (e.g., dilution and neutralization).

Clearly it is exceedingly difficult to describe the impacts of acid mine drainage with any precision within the context of a regional analysis. Nonetheless, it is possible to raise issues that point to potential design problems. The following questions are offered as a means to that end:

(1) If the coal region being mined has the potential for AMD, will the system increase the probability of AMD problems (e.g., the use of hydraulic mining methods, exposure of large areas of acid producing materials that cannot be reclaimed rapidly, etc.)?

(2) Will the mining system create any difficulties for controlling sediment and AMD (e.g., production of large quantities of clay and silt, extensive alteration of drainage with cut and fills, or use of a dense haulage system in steep topographies)?

(3) Will the system use a solvent that must be treated, recovered from an extraction cavity, or discharged into a receiving body of water?

(4) Is there any thermal discharge that may not be cooled before discharge?

The environmental cost (dollars) of water quality impacts is very difficult to determine. However, the cost of mitigating potential water quality impacts could be approximated by designing and costing a drainage control system for sediment and acid water appropriate for the area of extraction defined in the regional analysis. This requires estimating the number and size of sediment ponds, sediment channels, diversion or constructed drainways, earth embankments, valley fills, etc.

e. Habitat Alteration. With the alteration of the earth's surface by underground and surface mining activities, the destruction of wildlife habitat is inevitable. At the preliminary stage of

assessment it is possible to estimate the total area of potential habitat alteration (both terrestrial and aquatic). However, it is more difficult to quantify the impact upon wildlife for a given ecosystem and to determine the significance of the impact.

One approach for measuring the impact on wildlife has been to determine the species diversity of a given ecological system. This approach assumes that with increasing species diversity the ecosystem has an increased ability to resist disturbance and stress (Jain, et al., 1977). The most important variable to quantify in this analysis is the animal population. For this analysis, the number of each species should be determined. A census of animal population is usually completed by direct observation. Such a method is not appropriate at the preliminary stage of assessment. In lieu of collecting field information about the impact of habitat alteration on wildlife, data could be obtained from published literature.

If published data exist on the impact of habitat alteration, its application based upon regional characteristics would still not allow the correlation between habitat disruption and the impacts on known critical habitats and the presence of rare or endangered species. The true magnitude of impact upon any given ecosystem is highly site-specific. As a consequence, it is not meaningful to estimate the magnitude of impact using a regional analysis at the preliminary stage of assessment.

However, like the issue of water quality, it is possible to pose questions which may help identify undesirable habitat alterations:

(1) Does the coal region being mined have critical habitats or endangered species that may be effected by the mining system?

(2) Will the mining system create any unusual hazards (e.g., potential for high incidence of machinery related kills), or barriers to wildlife movement?

(3) Are there any problems that may lead to difficulties in reestablishing habitat (e.g., salinity, selective toxicities, loss of soil, available water resources, etc.).

f. Air Quality. The degradation of air quality, as the result of coal mining activities (e.g., overburden removal, haulage, and coal preparation) is inevitable. The magnitude of the impacts, however, depends on two factors:

(1) Characteristics of the environmental setting--atmospheric stability, temperature, mixing depth, wind speed, wind direction, humidity, precipitation, pressure, and topography.

(2) Emissions from human activities--dust, flyash, smoke, soot, vehicular emissions (e.g., SO_x, NO_x, CO_x, particulates), etc.

For coal mining operations the major problem is from dust (or particulates). In general, the environment contains a certain level of particulate matter. Emissions resulting from mining activities are released to the environment, causing a higher concentration of particulates. As a rough guideline, the generation of particulates as the result of mining can be assumed to be proportional to the area disturbed.

The concentration of particulates in the atmosphere is strongly influenced by the environmental setting. For example, vertical temperature gradients affect movement of air in the atmosphere. Wind structure in a region determines the scavenging action in the environment as well as the impact of inversions. Topography may change temperature and wind profiles because of the combined effects of surface friction, radiation, and drainage. Valleys are more susceptible to stagnation and to air pollution than are flat lands or hill slopes. The mixing depth, in fact, also determines the intensity of air pollution in a given region. The status degree of atmospheric stability determines to what extent particulates can build up in a given region. In addition, precipitation is an important element that can remove particulates from the air. As a result of all these factors, the concentration of particulates (or any air pollutant) will not remain constant over an entire region for any appreciable length of time. Given the highly site-specific nature of air quality impacts it makes little sense to try to quantify air quality impacts using regional environmental data. However, as a first cut at describing the magnitude of possible air quality impacts, it is useful to consider the following questions:

(1) Will the mining process produce a toxic vapor that has the potential for being transported from the mining site?

(2) Does the mining system utilize any process that might produce extensive non-point sources of pollution (e.g., does it have a heavily used road network)?

(3) Does the mining region already have serious air quality problems (e.g., nonattainment area)? If so, what are the major pollutants, and how might they interact with the effluent produced by the mining system?

g. Aesthetics. With few exceptions, the impacts of coal mining practices on aesthetic values are adverse. Impacts of greatest magnitude are visual. Measurement techniques for identifying and quantifying aesthetic impacts are subjective because individual perceptions and values for defining beauty vary widely. Due to the nature of aesthetics and human perception, significant features are often difficult to quantify. Several methods have been developed to determine which type of landscape is more desirable than another (Jain, et al., 1977). The final results of any method, regardless of criteria, are significantly affected by human perception. Factors which play an important role in affecting public acceptance of an activity with visual impact can be grouped into two categories:

(1) Physical relationships.

(a) Proximity of disturbance to viewer location.

(b) Proximity of disturbance to a natural vista.

(c) Duration of viewer's observance.

(d) Daily or seasonal changes.

(2) Observer's perception.

(a) Social, economic and cultural background.

(b) Current perceptual setting and environmental life-style, coupled with past and future expectations.

In addition to these factors, aesthetic impacts are frequently of a controversial nature at a local level (e.g., mountaintop removal vs underground mining). Aesthetic impacts not only reflect human perception, but frequently may be related to community needs (e.g., need for flat land in mountainous regions).

Given all these factors, it is beyond the scope of this methodology to quantify aesthetic impact. The significance of aesthetics, however, should be assessed using the procedure outlined in Section III-C. Additional light may be shed on aesthetics by considering whether the mining system can be implemented in such a manner that any area of disturbance cannot be viewed from cities, towns, or main highways and the extent to which reclamation procedures can totally mitigate aesthetic impacts.

h. Possible Synergistic Effects. When dealing with the potential effects of coal mining activities, it must be realized that any impact is the result of a complex interaction between the mining system and its environment. One common example of this interaction is the phenomenon known as synergy. A synergistic effect is one in which the magnitude of an impact is affected by the occurrence of a second impact. The adverse effects that result when the two impacts are experienced simultaneously differ from the sum of the effects when experienced separately. For example, suppose that in one watershed a mining system contributes sediment to a stream with little or no effect upon the aquatic life. However, if there is also a change in the pH of the stream as the result of AMD there might be an increased stress and death of aquatic life. This example, although hypothetical, illustrates the possible threat from synergistic effects. Although suspected to be of considerable importance, synergistic effects are not well documented. As a consequence, there can be little application at this level of assessment.

C. ESTIMATION OF IMPACT SIGNIFICANCE

Although it is possible to compare mining systems on the basis of the number of impacts associated with each, a comparison of tallies gives no indication of the relative importance of any one or group of impacts. One mining system may result in a number of impacts but the cumulative significance of the impacts is small; conversely, another system may have relatively few effects which may aggregate to a significantly greater impact. Without some method for determining relative importance, no useful comparison can be made between systems.

With a knowledge of impacts and the nature of the environmental setting in mind, it is possible to estimate the significance of impacts associated with a mining system. First-hand experience with mining activities in the coal region where the system may be implemented is especially valuable in assigning relative importance to different impacts. For example, if the system requires complete overburden removal, and the topography in which it is to be implemented is rough, the potential for serious erosion and sedimentation is relatively high. In comparison, however, if the terrain is flat or rolling, the impact is much less significant.

In order to assess the significance of potential impacts of a mining system in the coal region in which it may be implemented, the following procedure is suggested:

As a first step, conduct interviews with appropriate agencies (e.g., state offices of reclamation or natural resources, and federal agencies such as the BLM, SCS, EPA, USGS, and FWS that deal with coal mining) to determine the importance of the following issues:

(1) Significance of conventional or existing systems impacts.

- Water quality (surface and groundwater).
- Availability of water resources for mining.
- Habitat alteration.
- Air quality.
- Subsidence.
- Land use.
- Reclamation.
- Aesthetics.

(2) Significance of any new technology (examples).

- Potential impacts on water quality (e.g., thermal discharge or the use of a solvent for mining).

- Potential impacts on water resources (e.g., use of hydraulic mining systems).

- Potential impact on groundwater alteration (e.g., fracturing, breaking, or boring that may change groundwater resources).

- Potential aesthetics impacts (e.g., massive operations which create large areas of flat land in mountainous regions).

- Potential impacts on air quality (e.g., on site process that may produce emissions).

In the second and final step, when the interviews are complete, the significance of each impact should be summarized. Using this information, one may rank impacts according to their significance. For an example of an interview to determine significance of coal mining impacts in Central Appalachia, see Appendix C.

D. EVALUATING MINING SYSTEMS

1. Introduction

The distinguishing characteristic of any evaluation methodology is the form of the objective function.[2] Such objective functions make implicit assumptions about the combination of impacts and their associated desirability. The ultimate use of an objective function is to reduce the evaluation process down to a single index and thus aggregate all impacts. The central problem with the aggregation of impacts is that it assumes interrelationships in the objective function that may not indicate reality. Namely, it assumes that the degree of an impact is independent of all other impacts. As a consequence, such numbers have little meaning (Baecher, et al., 1975).

Thus, the issue of dispute is whether or not evaluation may be done analytically or only through judgment. In support of subjective assessment of impacts, Baecher, et al., (1975) states:

"Analytical comparison of prospective (sites)[3] requires balancing adverse and beneficial impacts against the multiple and

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[2]An objective function may be a linear or non-linear function that expresses the relationship between the degree of desirability of an impact(s) versus some measure of that impact(s) or it may be a simple matrix that allows impacts to be displayed and summed.

[3]Substitute the words (mining systems).

often incompatible objectives of society; it involves trading off apples for oranges. The coordinating theme of this balancing is the 'desirability' we as a society associate with specific impacts against objectives, and this is what allows us to compare qualitatively different impacts of (large facilities)[2]. Because it is the desirability of impacts and not their level that is important, decisions are ultimately based on subjective preference and not on 'objective' criteria. One may elect, on subjective bases, to use a seemingly objective selection criterion--for example, monetary cost--but this does not make the selection objective; it rests upon the criterion, and criterion upon judgment."

In support of Baecher (1975) and because of the potential differences between new and existing systems, the diversity of the environmental setting, and the use of regional characteristics, a subjective or judgmental evaluation methodology has been selected.

2. Evaluating Systems

A mining system may then be evaluated when the following conditions are satisfied:

(1) Potential impacts have been identified using the conceptual methodology.

(2) The magnitude of potential impacts identified in the preliminary methodology have been calculated.

(3) All potential impacts have been arranged into a loose order of significance.

When a new system and a baseline system have been assessed using the above procedure, they may be summarized in the format of Table 3-4, which illuminates the basic differences between systems via a side-by-side comparison of impacts.

When evaluating mining systems by comparison there are several possible approaches:

(1) If a new mining system addresses a coal resource that is presently being mined, then the existing system or systems should be taken as the comparison baseline.

(2) If a new mining system is to be used to mine coal that is not presently being exploited domestically (e.g., thin seams, steeply pitching seams, isolated pockets), then an attempt should be made to compare this system with appropriate foreign technology (if it exists), or with domestic technology operating in a nearby minable seam.

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[2] Ibid.

Table 3-4. Format for Comparing Environmental Impacts Between Mining Systems

Environmental Impact	System I (New or Existing)	System II (New)	Brief Summary of Advantage or Disadvantage

Decreasing Significance

In either case, every effort should be made to select a baseline technology which permits a regionally meaningful comparison of environmental impacts.

The ultimate objective of the methodology, as stated in Section I-A, is to identify and evaluate potential impacts (beneficial and harmful) that may be associated with a mining system. Comparative assessment of many of the impacts will require subjective judgments by the analyst. In those instances where considerable uncertainty remains about the scope or significance of an impact, it is advisable to obtain expert opinion. This may be accomplished by seeking assistance from those interviewed to determine the ranking of impacts within a region.

No attempt has been made to develop a figure of merit which aggregates all environmental impacts into one numerical value. If it is desired to nominate one system as being environmentally superior overall, it is assumed that the necessary integration of impacts will be guided by the judgment of the analyst. If the two mining systems appear to be fairly equal in the magnitude and significance of their impacts (e.g., mining system (1) has three major impacts and mining system (2) has four major impacts) a second or third opinion should be obtained from persons in the state and federal agencies that deal with environmental issues in that coal region.

SECTION IV

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APPENDIX A

EXAMPLES USED TO ILLUSTRATE THE USE OF THE CONCEPTUAL AND PRELIMINARY METHODOLOGIES

LIST OF EXAMPLES

CONCEPTUAL METHODOLOGY

I. Description Of A Mining System

II. How To Fill Out An Answer Sheet

PRELIMINARY METHODOLOGY

III. Calculation For Determining The Potential Area Of Extraction

IV. Calculation Of A Water Resource Balance

V. Calculation Of An Energy Resource Balance

I. DESCRIPTION OF A MINING SYSTEM

NAME OF SYSTEM:	Hydraulic Borehole Mining Apparatus (see JPL Publication 77-19).
COAL RESOURCE MINED:	The target coal region is Central Appalachia. The mining system will be used to remove those coal rescurces that have been left behind after contour and auger mining. Operation of the system will occur on the mountain ridges and will mine flat multiple seams.
MINING METHOD:	The hydraulic borehole miner, truck mounted, accesses the coal seam through a hole drilled from the surface via a rotary rig. After the hole is cored down to the seam, the extraction device is lowered into the hole and proceeds to cut a cylindrical cavity using high-pressure water jets. The fragmented coal enters a breaker and is lifted to the surface as a coal-water slurry via a downhole pump.
COAL HAULAGE:	A slurry pipeline transports the coal to a preparation plant, and a return line takes the resulting mine waste back to the drill-site cavities.
ACCESS AND SUPPORT SUPPORT FACILITIES:	All-weather access roads must be constructed as a main haulway. In conjunction with the main road there are numerous dirt roads to the individual mine sites. If the mining system is implemented in rugged topography, level pads must be constructed for the truck-mounted miner. General support facilities would include a coal preparation plant, water treatment facilities, accumulation ponds for surge control, and possible water storage facilities.

II. HOW TO FILL OUT AN ANSWER SHEET

COAL REGION: CENTRAL APPALACHIA
MINING SYSTEM: BOREHOLE HYDRAULIC MINER
Question number 1a (Will the mining system result in the construction of access and hard roads?)

1) Nature of the Activity In the region being mined a two-lane, all-weather road must be provided as a main access route for all mining sites. Each mine site will be connected to the main access road by smaller dirt roads.

2) Probable Impacts Because there will be numerous roads distributed over a large mining area (more than one drainage basin), there will be a considerable amount of vegetation removal and grading. As a result, there should be significant levels of dust and sediment transport from the proposed road system. The potential for serious long-term environmental impacts from sediment during active mining operations would appear to be a major problem.

3) Ability to Mitigate Impacts Because the road network will be built on ridges and topographic highs, sediment will be easier to control than if roads were located near stream bottoms. However, sediment and dust control will be required along the entire road system. Sediment can be controlled by insuring that the roads are properly graded, well drained, and drainage control structures are constructed. Dust can be effectively controlled by periodic applications of water to the road surface.

III. EXAMPLE CALCULATION FOR DETERMINING THE POTENTIAL AREA OF EXTRACTION

The example calculation for determining the potential area of extraction will use the Borehole Hydraulic Miner (JPL Publication 77-19) which will be used to remove coal resources left behind after contour strip and auger mining.

SITE SELECTION: Breathitt County, Kentucky, was selected as representative of the topography and geology that occurs in the bituminous coal regions of Central Appalachia. This selection was also based on the availability of regional, geologic, and hydrologic data.

TOPOGRAPHY: The maximum topographic high ranges from 1480 ft above sea level in the southern portion of the quadrangle, to approximately 1350 ft above sea level in the northern portion. The average maximum topographic high seems to occur approximately around 1440 ft above sea level. The elevations along the flood plains range from 940 ft above sea level in the southern region to 760 ft above sea level in the northern region. The topographic sheet used is the USGS (7.5 minute series) Haddix Quadrangle, Kentucky (1:24,000).

GEOLOGY: From the southern portion of the Haddix Quadrangle, there are two distinct areas of contour strip mining occurring at the average elevations of 1440 ft and 1260 ft. The 1978 Keystone Coal Industry Manual indicates that the upper seam that is being mined is the Skyline and the lower seam is the Hindman. The generalized geologic columns for the Hazards reserve district are presented in Figure A-1.

OPERATING CHARACTERISTICS OF THE MINING SYSTEM: The hydraulic borehole miner described in JPL report 77-19 was sized to obtain 200,000 tons of production per year. This production rate is based on the following assumptions:

- A 220-day work year with 3 production shifts per day, at 8 h/shift.
- The access holes are drilled in a hexagonal, close-packed array, with a spacing of 31.3 ft between the center of adjacent holes (see Figure A-2).
- A 15-in. access hole is drilled to a maximum depth of 300 ft at a rate of 16.7 ft/h.
- Each access hole permits extraction of a cylindrical cavity of coal 25 ft in diameter, and as thick as the seam height.

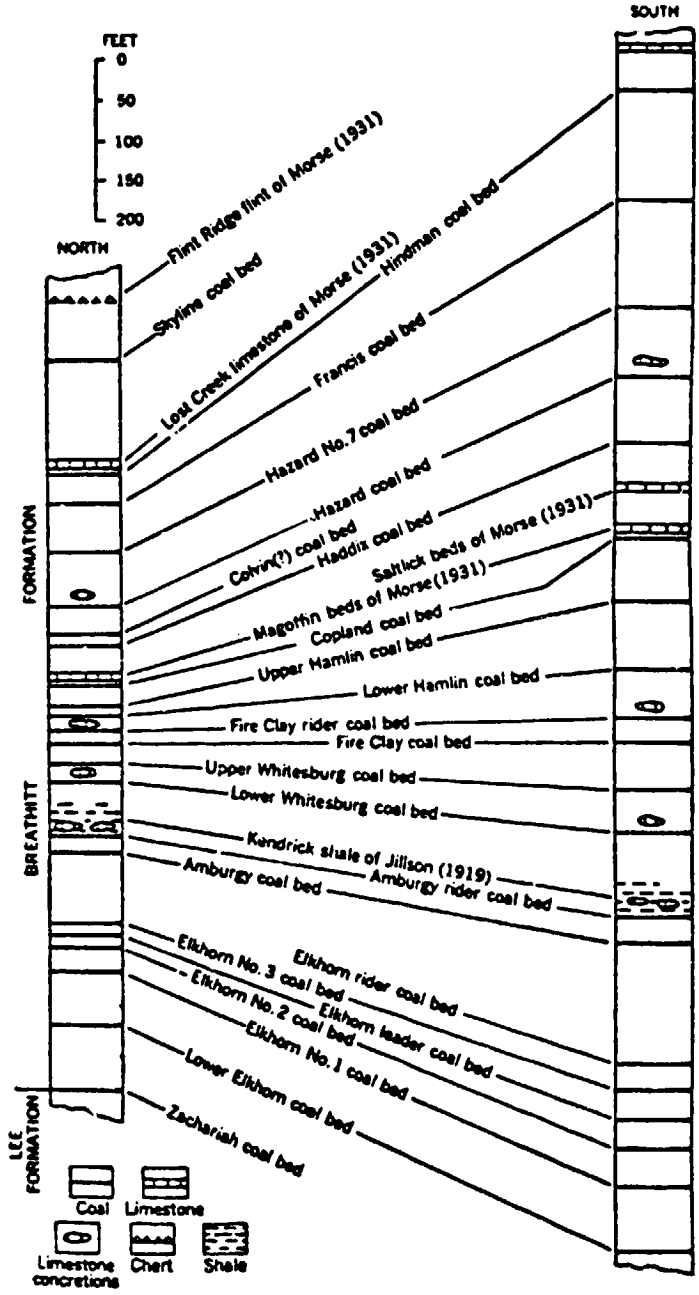


Figure A-1. Generalized Geologic Columns for the Hazard Reserve District (from Huddle, et al., 1963)

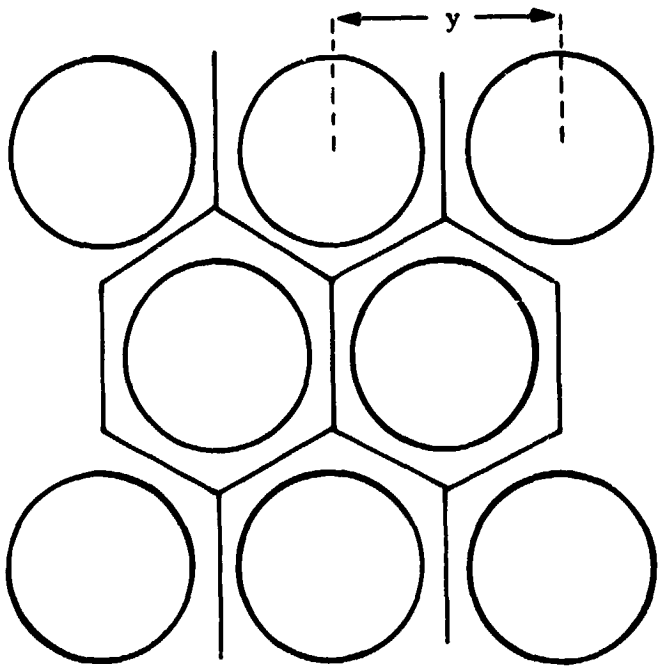


Figure A-2. Calculation of Land Use Associated with One Borehole

1. Area of a regular polygon of n sides is:

$$\frac{1}{4}\ nb^2 \cot \frac{\pi}{n} = A$$

where n is the number of sides

b is the length of a side

Let y be the diameter of the inscribed circle (31.3)

Now in general: $b = y \cot \frac{\pi}{n}$

Thus;

$$A = \frac{na^2}{4} \ / \ (\cot \frac{\pi}{n}) = \frac{na^2}{4} \tan \frac{\pi}{n}$$

$$= \frac{6}{4}a^2 \tan \frac{\pi}{6} = \frac{6}{4}\ a^2\ \frac{1}{\sqrt{3}}$$

$$= \frac{\sqrt{3}}{2}\ a^2 = (31.3)^2 \frac{\sqrt{3}}{2} = 848.44\ ft^2 \text{ (land use of one borehole)}$$

2. Area of one borehole is;

$$A = \pi r^2 = 3.14 \times 12.5 = 490.99\ ft^2$$

PROPOSED MINING OPERATION: The following mining operation is assumed:

1. A generalized construction of the regional topography and geology appears in Figure A-3. Using this profile simulation, the following conditions are assumed:

   a. The Hindman and Francis coal seams have been contour mined to create a highwall of 100 ft.

   b. Each seam has been augered to a depth of 100 ft.

Given these conditions it is assumed that the only coal resources that will be mined are accessible from above the 1360-ft contour.

2. At the 1360-ft contour there is also a slight break in slope. The lower slope angles above the 1360-ft contour would also have less erosion potential. In view of the above conditions, the mining system will be restricted to operation above the 1360-ft contour.

3. Only three coal seams will be mined:

   - Hindman (4.1-5.8 ft thick)
   - Francis (1.2-8 ft thick)
   - Hazard #7 (1.2-6.2 ft thick).

4. The entire area above the 1360-ft contour will be terraced to allow the mining rigs to be set up and insure that coal seams will be uniformly mined in a hexagonal close-packed array.

5. The maximum coal thickness that can be extracted is 20 ft and the minimum is 6.5 ft.

CALCULATIONS: The calculation has been designed to illustrate the resulting potential area of extraction for the best geologic conditions (maximum seam thickness) and the worst geologic conditions (minimum seam thickness) with a fixed production rate. In addition to this calculation, the number of drilling rigs necessary for the given production rate were also determined (these data will be used in the following energy balance calculation) along with the extraction efficiency of the system. To complete the calculation the following data were used:

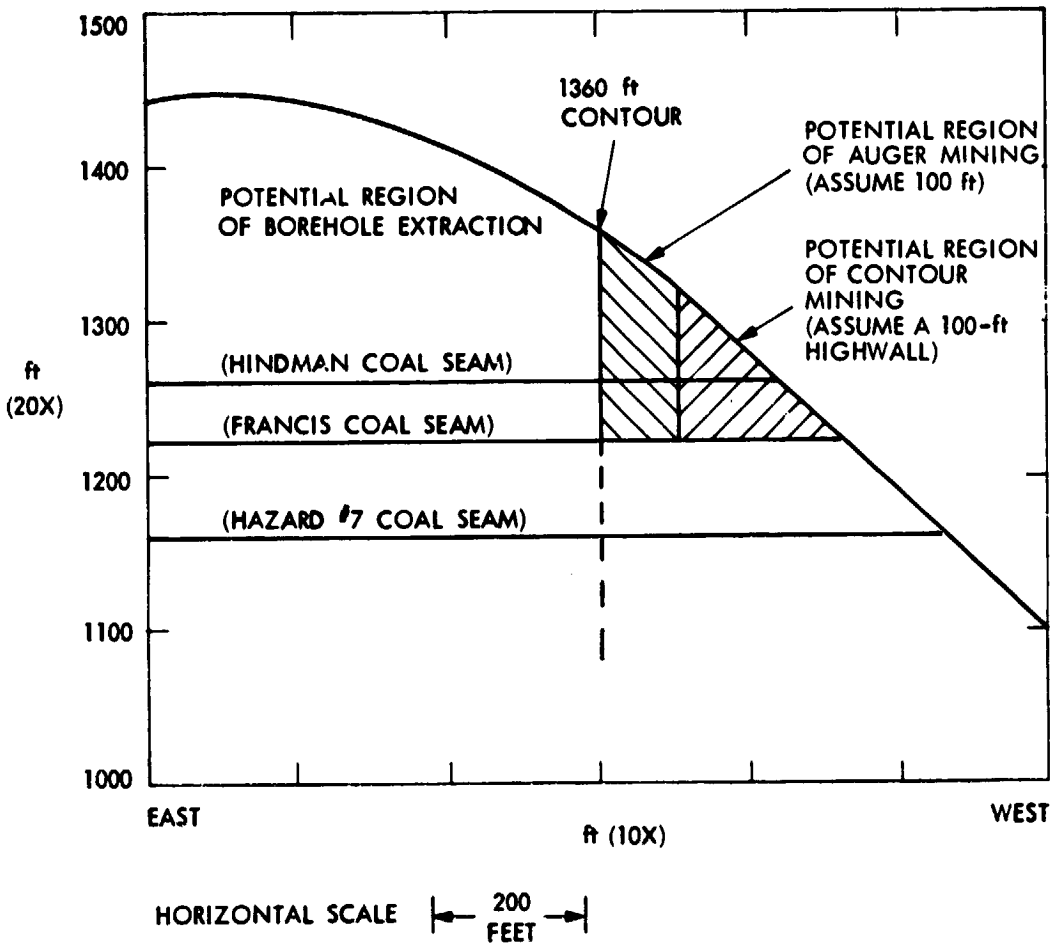


Figure A-3. Generalized Construction of the Coal Seams that are Accessable Using the Borehole Miner

Coal thickness--6.5 ft as a minimum and 20 ft as a maximum.

- Coal density-- 87.3 lbs/ft^3.
- Coal production-- 200,000 tons/year.
- Mine life-- 20 years.
- Land use area associated with one borehole extraction cavity (see Figure A-2) = 848.44 ft^2 = 0.0195 acres.
- Area of a borehole extraction cavity (see Figure A-2).

  490.88 ft^2 = 0.0113 acres.

1. Potential area of extraction for minimum coal thickness:

   a. Determination of tons of coal per borehole

   $$\frac{(490.88\ ft^2)(6.5\ ft)(87.3\ lbs\ ft^3)}{2000\ lbs/ton} = 139.3\ tons$$

   b. Number of boreholes needed to reach yearly production for the life of the mine:

   $$\frac{200{,}000\ tons/year}{139.3\ tons} = 1436\ boreholes\ x$$

   20 years = 28,720 boreholes

   c. Area of potential extraction

   28,720 boreholes x 0.0195 acres = 560 acres.

2. Coal extraction ratio for minimum thickness:

   a. Coal extracted
   (200,000 tons/year)(20 years) = 4.0×10^6 tons

   b. Total coal resource in the seams extracted

   $$\frac{139.3\ tons}{0.0113\ acres}\ x\ (560\ acres) = 6.9 \times 10^6\ tons$$

   c. Extraction ratio

   $$\frac{4.0 \times 10^6}{6.9 \times 10^6} = 0.58$$

3. Number of drilling rigs necessary for production (minimum thickness)

a. Holes drilled by one rig in one year

$$\frac{(220 \text{ days/year})(24 \text{ h/day})(16.7 \text{ ft/h})}{300 \text{ ft per hole}}$$

= 294 holes per rig.

b. Number of rigs needed per year

1436 boreholes/294 = 5 rigs.

4. The following calculations have been completed in the same manner as above for maximum thickness:

a. Tons per borehole--428.5 tons.

b. Number of boreholes--9,335 boreholes in 20 years.

c. Area of potential extraction--182 acres (see Figure A-4).

d. Total resources in the seams extracted--6.9×10^6 tons.

e. Number of rigs--2.

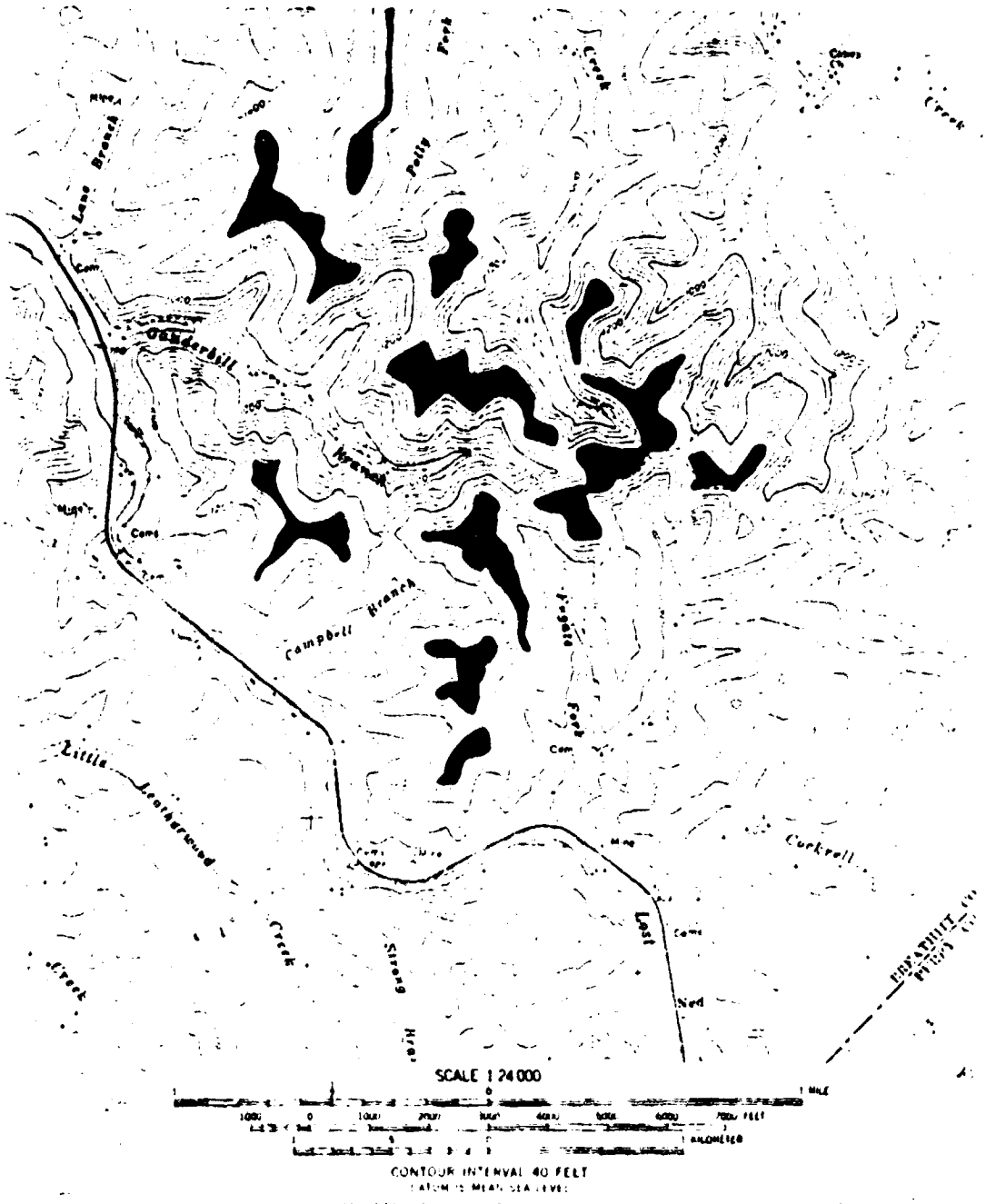
(For an example of the area impacted by using the borehole miner with maximum seam thickness, see Figure A-4. Note: the thin seam area would not fit on the Haddix quadrangle and, therefore, was not presented.)

VI. CALCULATION OF A WATER RESOURCE BALANCE

As stated previously, this calculation is designed to illustrate the procedure for assessing the availability of a region's water resources for the sustained operation of a mining system.

1. Availability of Surface Water Resources

The drainage basins in Breathitt County generally range from 260 to 80 mi^2 with the north fork of the Kentucky River being approximately 800 mi^2 and the average second order stream being approximately 10 (estimated from the USGS State of Kentucky map (1:500,000) 1973). According to Kirkpatrick, et al., (1963), the discharge that can be expected 98% of the time ranges from 0.002 to 0.02 cfs/mi^2 and the discharge that can be expected 50% of the time ranges from 0.35 to 0.6 cfs/mi^2.



(Haddix Quadrangle Kentucky)

Figure A-4. Area of Potential Extraction for the Maximum Seam Thickness

Table A-1. Surface Water Resources (gpm) in Breathitt County

Drainage Area mi^2	Discharge that can be Expected 50% of the Time	Discharge that can be Expected 98% of the Time
800	2.1×10^5 to 1.2×10^5	7.2×10^4 to 7.2×10^2
260	7.0×10^4 to 4.1×10^4	2.3×10^3 to 2.3×10^2
100	2.7×10^4 to 1.6×10^4	8.9×10^2 to 8.9×10^1
80	2.2×10^4 to 1.3×10^4	7.2×10^2 to 7.2×10^1
10	2.7×10^3 to 1.6×10^3	8.9×10^1 to 8.9×10^0

Because the majority of the drainage basins in this region range from 260 to 80 mi^2, it is assumed that most mining systems would be implemented in these basins. As a result, mining systems could depend on an average supply of 760 gpm unless water can be obtained from a larger drainage basin or stored for use in periods of low flow.

2. Availability of Groundwater Resources

Groundwater resources that are available in Breathitt county come from the Breathitt formation. Most of the groundwater obtained from drilled wells in this formation is moderately to extremely hard and contains noticeable amounts of iron. Salty water may be found in wells from 50 to 100 ft below the level of the principal valley bottoms.

Table A-2. Groundwater Resources in Breathitt County (from Price, Kilburn, and Mull, 1962)

	Yield (gpm)	Well Depth (ft)
	200	225
	155	220
	100	103
	80	220
	75	102
	75	65
	35	109
	30	75
	20	80
	20	40
	10	50
	8	70
	2	120
Average	62	97

3. Water Consumption for Thick Seam Example

Using the data generated by assessing the potential area of extraction (thick seams), the amount of water necessary for that mining operation will be determined and compared to the region's available water resources. In addition to this information, the following data was taken from JPL Publication 77-19:

- To produce 40 tons/hour requires 4 hours of cutting, at 200 gpm, and 16 hours of pumping to remove the coal from the borehole, at 260 gpm.
- It is assumed that the cutting water will be recycled to use for slurry water to pump the coal out of the borehole.

a. Calculation to determine the number of hours required to extract one borehole:

$$428.5 \text{ tons per borehole} \times \frac{20 \text{ hours}}{40 \text{ tons}} = 214 \text{ hours per borehole}$$

4/20 = .2 x 214 = 43 hours required for cutting
16/20 = .8 x 214 = 171 hours required for pumping

b. Determine the number of rigs needed to produce 200,000 tons/year:

$$\frac{(220 \text{ days/year})(24 \text{ hours/day})}{214 \text{ hours/borehole}} = 24.6 \text{ boreholes per miner per year.}$$

$$\frac{467 \text{ boreholes per year}}{24.6 \text{ boreholes per miner per year}} = 19 \text{ mining rigs}$$

c. Determine rate of water consumption:

Coal cutting:

43 hours x 200 gal/minutes x 60 minutes/hour = 5.16×10^5

Coal pumping

171 hours x 260 gal/minutes x 60 minutes/hours = 2.67×10^6 gal.

Assume recycle cutting water

$2.67 \times 10^6 - 5.16 \times 10^5 = 2.15 \times 10^6$ gal.

Water consumption for one miner:

$$\frac{2.15 \times 10^6 \text{ gal}}{214 \text{ hours}} \times \frac{\text{hour}}{60 \text{ min}} = 167 \text{ gpm}$$

Total consumption

167 gpm x 19 miners = 3181 gpm

4. Comparison of Available Water Resources and System Requirements

The amount of surface water available, assuming once-through use for mining falls short of those resources necessary for sustained mining operation. This difference could be made up by any of the following:

a. Obtaining additional water from adjacent basins.

b. Drilling numerous wells (10 to 50) depending on yields.

c. Storing water for use during periods of low flow.

If water is recycled with little loss, then water resources will be adequate for sustained mining operations. This also assumes that the water will be treated before reuse.

V. CALCULATION OF AN ENERGY RESOURCE BALANCE

As stated previously in the text, this calculation is designed to illustrate the procedure for assessing the amount of energy a system requires for accessing and cutting of the coal extracted. This data can then be compared to the total energy of the coal extracted. The example illustrated uses information generated by the previous calculations for thick seams. The following data was taken from JPL Publication 77-19:

- Drilling engine operates at 750 hp
- Cutting pump operates at 583 hp
- Slurry pump operates at 184 hp
- Fuel conversion factor = 0.0547 gal/hp-hour

1. The Btu contents of the fuels utilized are:

- Approximate energy content of one gallon of fuel oil = 1.4×10^5 Btu
- Average energy content of the coal seams extracted = 13,136 Btu/lb

2. Calculate the total energy contained in the coal extracted:

200,000 tons/year x 2,000 lbs/ton x 13,136 Btu/lb = 5.25×10^{12} Btu

3. Calculate the total energy required to access and cut the coal resources extracted:

a. Fuel required to access coal

$$\frac{467 \text{ boreholes}}{\text{year}} \times \frac{5{,}280 \text{ hours}}{294 \text{ boreholes}} \times \frac{0.0547\text{gals}}{\text{hp-hour}} \times 750\text{hp} = 343{,}881\text{gals/year}$$

b. Fuel required to cut coal

$$19 \text{ borehole miners} \times \frac{24.6 \text{ boreholes}}{\text{miner-year}} \times \frac{43 \text{ hours}}{\text{borehole}} \times \frac{0.0547\text{gals}}{\text{hp-hr}} \times 582\text{hp} =$$

640,575 gallons/year

c. Fuel required to pump coal out of cavity:

$$29 \text{ borehole miners} \times \frac{24.6 \text{ boreholes}}{\text{miner-year}} \times \frac{171\text{hrs}}{\text{borehole}} \times \frac{0.0547\text{gals}}{\text{hp-hour}} \times 184\text{hp} =$$

= 803,983 gallons/year

d. Total energy content of fuel required for one year:

$$1{,}788{,}439 \text{ gallons} \times 1.4 \times 10^5 \text{ Btu} = 2.50 \times 10^{11} \text{ Btu}$$

4. Calculate the ratio of energy input to output for extraction:

$$\frac{\text{Energy input} = 2.50 \times 10^{11} \text{ Btu}}{\text{Energy output} = 5.25 \times 10^{12} \text{ Btu}} = 0.048 \text{ or } 4.8\%$$

APPENDIX B

SUMMARY OF MAJOR REGULATIONS AND INSTITUTIONAL REQUIREMENTS

INTRODUCTION

The purpose of this appendix is to identify and outline those major regulations and institutional requirements which have a direct bearing upon coal mining operations (both surface and deep mining) with special attention to the needs of Central Appalachia. However, it is not the intent of this document to list each regulation, but rather outline those regulations and requirements that are perceived to have substantial cost impacts or obstacles to the implementation of a new mining system.

Two sets of regulations may be taken as the minimum requirements for any state:

1. Surface Mining Control and Reclamation Act of 1977 (SMRA).

2. Environmental Protection Agency Effluent Guidelines and Standards for Coal Mining 1977 (EGS).

The following State of Kentucky standards and regulations for air and water quality may be considered as representative of the type of requirements that are common in Central Appalachia:

1. Kentucky Water Quality Standards 1975 (KWS).

2. Kentucky Air Pollution Control Regulations 1976 (KAR).

As an aid to understanding, the selected sections or subsections from each regulation which are directly pertinent to air, water, planning, and land will be brought together under those applicable headings.

A. AIR

Air pollution arising from coal mining is almost entirely the result of dust-blown particulates which originate from excavations, spoil piles, and haulage. Several requirements and standards which affect air quality are:

1. All spoil piles and surface areas affected by surface disturbance and reclamation must be protected or stabilized to effectively control air pollution (Sec. 515(4), SRMA).

2. The ambient air quality standards for particulate matter requires no more than:

   a) 1.75 g/m^3 -- annual geometric mean.

   b) 260 g/m^3 -- maximum 24-h average not to be exceeded more than once per year.

c) 6.0 COH/1000LF -- maximum 24-h average of soiling index not to be exceeded more than once a year (from Sec. (4) of KAR 3:020).

B. WATER

Water pollution as the result of coal mining is seldom attributable to one specific pollutant. However, two major problems, acid mine drainage and sedimentation, may also contribute to the following conditions: increases in total dissolved solids, turbidity, deoxygenation, heavy metal pollution, and eutrophication. In order to control these problems, the following requirements and standards have been recommended:

1. Insure that all debris, acid-forming materials or toxic materials are treated, or buried and compacted, or otherwise disposed of in a manner designed to prevent contamination of ground or surface waters (Sec. 515(4), SMRA).

2. Insure that the construction, maintenance, and post-mining condition of access roads into and across the site of operations will control or prevent siltation and pollution of ground or surface waters (Sec. 515(7), SMRA).

3. Minimize the disturbances to the prevailing hydrologic balance and to the quality and quantity of ground and surface water systems, both during and after coal mining operations, and during reclamation by:

   a) Avoiding acid or other toxic mine drainage by:

      i. Preventing or removing water from contact with toxic producing deposits;

      ii. Treating drainage to reduce toxic content;

      iii. Casing, sealing, or otherwise managing boreholes, shafts, and wells to keep acid or other toxic drainage from entering ground and surface waters; and

   b) Conduct surface operations so as to prevent, to the extent possible, using the best technology currently available, additional contributions of suspended solids to streamflow or runoff outside the permit area (Sec. 516(9), SMRA).

4. The following limitations establish the concentrations of pollutants which may be discharged by a point source (Sec. 434.32, EGS):

Effluent Characteristic	Effluent Limitations (mg/liter) Maximum for Any One Day	Average of Daily Values for 30 Consecutive Days Shall Not Exceed
Iron, total	7.0	3.5
Manganese, total	4.0	2.0
TSS	70.0	35 0
pH	6.0 to 9.0	6.0 to 9.0

5. In addition, the system designer should be cognizant of the Kentucky water quality standards (pertinent to mining):

a) Public water supply - applicable to surface water at the point at which water is withdrawn.

i. Total dissolved solids shall not exceed:

1) 500 mg/liter as a monthly average; nor

2) 750 mg/liter at any time.

ii. Radioactive substances:

1) Gross beta activity shall not exceed 10^3 pCi/L.

2) Dissolved alpha emitters shall not exceed 3pCi/L.

iii. Chemical constituents shall not exceed the following specified concenctrations at any time:

(mg/liter) Element	Concentration
Arsenic	0.05
Barium	1.0
Cadmium	0.01
Chromium (+6)	0.05
Cyanide	0.025
Fluoride	1.0
Lead	0.05
Selenium	0.01
Silver	0.05

b) Industrial water -- applicable to water at the point at which water is withdrawn for use in industrial cooling and processing, either with or without treatment, (Sec. 5).

i. pH shall not be less than 5.0 nor greater than 9.0 at any time.

ii. Temperature shall not exceed 95°F at any time.

iii. Total dissolved solids shall not exceed:

1) 750 mg/liter as a monthly average; nor

2) 1,000 mg/liter at any time.

c) Aquatic life -- the following criteria are for evaluation of conditions for the maintenance of a well balanced, indigenous fish population (Sec. 6).

i. Dissolved Oxygen (DO) shall average:

1) at least 5.0 mg/liter per calendar day; and

2) not less than 4.0 mg/liter at any time.

ii. pH range from 6.0 to 9.0

iii. Temperature

1) Temperature shall not exceed 89°F at any time.

2) There shall be no abnormal temperature changes that may affect aquatic life unless caused by natural conditions.

3) The maximum T above natural temperatures shall not exceed 5°F.

4) Maximum Stream temperatures are by month;

Month	°F
Jan, Feb	50
Dec	57
Mar	60
Apr, Nov	70
Oct	78
May	80
Jun, Sept	87
July, Aug	89

iv. Toxic substances shall not exceed one-tenth of the 96-h median tolerance limit to fish.

d) Trout streams (Sec. 7)

i. Dissolved oxygen (DO) shall not be less than 6.0 mg/liter at any time and;

ii. During spawning season, in spawning areas, the minimum DO shall be 7.0 mg/liter.

e) Agricultural uses - no criteria.

C. LAND

The greatest impact upon the land occurs when mining activity removal of vegetation, soil, and rock, alters the natural landscape. The following performance standards have been recommended with the intent of mitigating this impact:

Mining Activities and Reclamation

1) Conduct surface coal mining operations so as to maximize the amount of the solid fuel resource being recovered so that reaffecting the land in the future can be minimized (Sec. 515(1), SMRA).

2) Restore the land affected to a condition capable of supporting the uses which it was capable of supporting prior to any mining (Sec. 515(2), SMRA).

3) Backfill, compact, and regrade all affected areas in order to restore the approximate original contour of the land, with all soil piles and depressions eliminated (Sec. 515(3), SMRA).

4) Remove the topsoil from the land in a separate layer, maintain a vegetative cover to reduce wind and water erosion, and insure that the topsoil is in a usable condition for sustaining vegetation when restored during reclamation (Sec., 515(5), SMRA).

5) Establish on regraded areas and all other lands affected, a diverse and permanent vegetative cover at least equal in extent of cover to the natural vegetation of the area (Sec. 516(6), SMRA).

6) Design, locate, construct, operate, maintain, enlarge, modify, and remove, or abandon in accordance with Sec. 515(f), all existing and new coal mine waste piles (Sec. 516(5), SMRA).

7) Fill or seal exploratory holes and maximize to the extent technologically and economically feasible, then return mine waste, tailings and any other waste incident to the mining operation back to the mining workings or excavations.

8) Adopt measures consistent with the best known technology to prevent subsidence causing material damage, maximize mine stability, and maintain the value and reasonable foreseeable use of such surface lands, except where the mining technology used requires planned subsidence in a predictable and controlled manner (Sec. 516(1), SMRA).

- To the extent possible, using the best technology available, minimize disturbances and adverse impacts of the operations on fish, wildlife, and related environmental values (Sec. 515(24), SMRA).

APPENDIX C

A SUMMARY OF RESPONSES TO ENVIRONMENTAL QUESTIONS ASKED SELECTED STATE AND FEDERAL AGENCIES

INTRODUCTION

As part of the environmental evaluation of mining systems, it was determined that some information must be gathered on the significant environmental issues in the region where an advanced system may be implemented. Since the coal resources of Central Appalachia were chosen as the initial design target, it was decided to interview selected state and federal agencies to determine the significant environmental issues in this region.

The following report is our interpretation of the views expressed by the reclamation agencies of Kentucky, Pennsylvania, Tennessee, Virginia, and West Virginia; the Office of Surface Mining, Washington, D.C.; and finally the U.S. Geologic Survey, Reston, Virginia.

SUMMARY

1. <u>What is the most serious mine drainage pollution problem?</u>

   The single greatest acid mine drainage (AMD) problem is the result of uncontrolled flow from abandoned deep mining operations. In addition, major mine drainage can result from the intersection of surface mining operations with deep mines.

   Severe acid drainage problems can result when overburdened coal seams which contain potential acid producing minerals are mined. These acid materials or minerals may be distributed evenly throughout a formation or coal seam or may occur in a spotted distribution. It has been proposed that mining permits should not be issued for such formations or coal seams.

2. <u>What is the most serious sediment control problem?</u>

   The advent of new contour mining methods (e.g., box cut, haul-back) have substantially reduced the amount of sediment from a surface mining operation. In addition, the creation of specific sediment control basins and drainage alteration have been significant in reducing the amount of sediment reaching a receiving body of water. However, there are still some major problems:

   a) The predominantly steep topography accelerates erosion and affords little room to construct appropriate sediment control structures.

   b) In many instances the construction of the sediment basin creates more uncontrolled sediment than the surface mining operation itself.

   c) In many mining regions, mine owners and miners, especially the small operators, lack the proper environmental instruction necessary for effective control and reclamation.

Even with these problems, however, the control of sediment derived from surface mining operations is overshadowed by the greater sediment control problems created by access and haul roads. It is felt that on a regional basis, control of sediment from access and haul roads is virtually unattainable. As a result, any mining system which incorporates alternate means of coal haulage (e.g., pipeline, conveyor, or narrow gauge railroad) would be an advantage.

3. Are water resources available for substantial consumptive increases by mining system?

In the majority of the Appalachian states there is little competition for existing water resources between mining and other industries. As a consequence, there is little competition among large water users. However, the ability to depend upon and utilize a substantial portion of a region's water resources is a function of several constraints.

(1) If surface waters must be dammed in order to insure sufficient water supplies, problems may arise when trying to locate suitable flat land necessary for storage. Moreover, in these rugged regions the occurrence of either a few large reservoirs or several small reservoirs are deemed unacceptable by local residents (nota bene the continuing, strong reaction to the Buffalo Creek flood).

(2) The amount of information available about local and regional groundwater reserves, locations, type, extent, quality, flow patterns, and specific yields are almost nonexistent in coal mining areas. As a result, groundwater resources may not be regarded as a predictable and dependable resource until these data have been assessed.

However, substantial amounts of coal reserves occur below drainage and may yield sufficient quantities of water once accessed. If this is the case, then this water might be used for the mining operation.

4. Are hydraulic mining and haulage methods environmentally acceptable?

(1) Mining: Every agency interviewed indicated that methods of hydraulic mining would be unacceptable for at least one of the following reasons:

(a) The infiltration of mining fluids into surrounding geologic strata could cause possible contamination of groundwater resources.

(b) Concern was expressed over the availability of suitable flat land necessary for treatment facilities to recycle or improve waste water quality.

(c) Due to the lack of information about local and regional groundwater, the implications of hydraulic mining could not be adequately assessed.

(2) Haulage: There seems to be a general opinion that hydraulic methods of coal haulage would offer an environmental benefit over conventional methods (e.g., haul roads). This feeling prevailed in spite of the possibilities of pipeline rupture. On the other hand, there are still several problems:

(a) Once again, concern was expressed over the availability of flat land necessary for slurry preparation, storage, and water treatment though such facilities typically require a rather modest area (e.g., the plant serving the slurry line at Black Mesa).

(b) Several states felt that pipelines would be acceptable only if the make-up water was recycled back to the point of origin.

(c) In addition, most of the mining operations in the Appalachian coal regions are relatively small and could not produce a large enough volume to support a pipeline unless it were designed to serve several mines.

(d) There may also be serious topographic barriers for construction.

5. Is thermal discharge environmentally acceptable?

In the majority of present day and future mining areas, possible receiving streams that may be impacted by thermal discharge were deemed too small and not capable of dissipating waste heat without some adverse effects. Consequently, any discharge must be routed to a larger receiving stream or the water must be cooled before discharge. Cooling the water before discharge, however, requires a certain amount of flat land for the construction of cooling ponds or structures. Unfortunately, there is a limited amount of flat land, if any, for this purpose.

6. Are mining systems that utilize a large number of shafts or boreholes environmentally acceptable?

Concern over unknown environmental effects was shared by many of the agencies interviewed. It was felt that mining systems which employ a large number of shafts or boreholes would be unacceptable for the following reasons:

a) Since groundwater conditions are not well known, prediction of environmental effects cannot be made with any confidence.

b) A large number of boreholes or shafts could cause interformational ground water communication.

c) Mine sealing procedures are, at their best, only temporary and possible discharge could occur from weaker geologic strata. It must also be pointed out that seal maintenance programs are virtually non-existent. In addition, abandoned oil and gas wells drilled through mined areas offer additional points of discharge.

d) The most critical concern is the fact that most mining systems extract 95 to 85% of a coal resource and that a borehole system may not achieve even 70%.

7. Is subsidence a problem?

Because of the predominantly rugged topography, steep slopes, and heavy forest of present day and future mining regions, subsidence was not considered an important problem. In these areas there has been little or no land other than forest. Subsidence can lead, however, to erosion and can locally alter groundwater flow.

If mining occurs near populated areas or if coal is removed from old underground workings in urban areas, subsidence will be a critical issue. As a result, a mining system should incorporate effective subsidence control technologies in areas that could alter existing or future land use capabilities.

8. Should backfilling technology be used in underground mining?

There was strong support for the concept of coal preparation, refuse removal, and the storage of spoil underground. It was thought that this process should occur at the working face. It was also generally agreed that backfilling should be accomplished without the use of water transport or deposition. In addition to this process being used in deep mines, it was suggested that it be used as part of any surface mining operation where the refuse is left at the working face.

Backfilling methods are generally acceptable because they eliminate the storage of spoil above ground. However, some concern was expressed over the possibility of groundwater intrusion into rubble which may lead to groundwater pollution.

9. Is there an environmental advantage to using longwall extraction?

Longwall mining technologies were preferred for two reasons (given the proper geologic and previous mining conditions):

a) If subsidence was an issue, it would be preferable to have a planned, regular subsidence pattern.

b) Because almost 95-100% of the coal is removed, the land will not have to be impacted again.

10. Is mountaintop removal an environmentally acceptable activity?

Each agency indicated at least one of the following advantages to mountaintop removal:

a) The area mined will only be disturbed once because 95-100% of the coal resource will be removed.

b) Predominately steep topography can be significantly altered into flat land.

c) Since mountaintop mining methods occur at a topographic high, there is no need to alter drainage through the mine site. Also, given proper hollow fills, mountaintop removal was seen as producing less sediment than contour mining.

In contrast to these advantages, several environmental groups in different states expressed opposition to this method because of its aesthetic impacts. In addition, surface water courses may have gradient changes which can result in potential dynamic effects. Groundwater may also be significantly altered.

11. What are the most important reclamation problems?

a) Steep slope reclamation offers the greatest challenge in restoring vegetation and controlling sediment. It was also felt that if reclamation procedures were carried out as required by federal and state regulations, reclamation and sediment control would be successful. In addition, the regulation of regrading and backfilling to the approximate original contour was not considered necessary. It was felt that the highwall would be eliminated, but managed in such a manner as to result in usable flat land (e.g., terraces).

b) If shafts or boreholes are used extensively, there was concern over the ability of mine sealing technology to prevent possible mine drainage.

c) The most expensive costs for reclamation procedures are associated with regrading and backfilling to the approximate original contour.

12. What are the most important environmental problems to be solved?

a) The control of sediment from mining operations is perceived to be the greatest problem, however, through the use of prescribed methods it can be substantially mitigated. Greater problems are associated with sediment from haul roads.

b) The control of AMD from older deep mines still remains a critical problem. Since AMD is associated with specific paleogeographic environments, only certain geographic regions (or formations) are acid producing. Thus, if mining were limited in these regions, the problem could be substantially reduced.

c) Education of mine operators is necessary to effect proper environmental control procedures.

13. Are there any mining activities that should be eliminated?

a) Auger mining

b) Overloading of coal hauling vehicles

c) Coal haulage by truck

14. Would rail or pipeline haulage be acceptable?

It was generally felt that any mode of coal haulage other than by truck would be an advantage. Several agencies indicated that rail transport of coal was by far more desirable since an extensive rail network already exists. In many states, however, rail systems are in poor repair and many lines have been abandoned. Pipelines were also deemed acceptable, if water could be effectively treated and recycled. The only negative attribute to such systems would be the inability of small mine operators to afford these types of haulage. As one alternative to rail or pipeline haulage, it was felt that conveyors might also be used very effectively in special cases. However, most of those interviewed agreed that truck haulage is likely to remain important for some time.

15. Are aesthetics an important environmental attribute?

In the majority of the coal mining regions, aesthetics is not considered as overly important since the economy is based largely on coal mining. Concern over aesthetics by environmental groups has brought about some degree of reform in several states. In West Virginia, for example, aesthetic impacts are a matter of considerable interest.

16. Is air quality a problem?

The major existing air quality problem is associated with coal haulage by truck. This method of transport creates a large amount of road and coal dust. There seems to be a significant contribution from coal storage, loading and unloading facilities, and processing plants. It is believed that dust can be controlled to a greater degree by more wet processing and loading.

APPENDIX D

PHYSICAL CHARACTERIZATION OF EASTERN KENTUCKY

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I. INTRODUCTION

This appendix provides background information on the surface characteristics of eastern Kentucky. It is intended to serve as an outline of the characteristics of the region and is not considered exhaustive. Major topics include surface characteristics, climate, land use and transportation systems; they suggest issues which should be addressed in a site-specific mode once a site is selected for implementing an advanced coal extraction system. The report is not intended to be utilized for actual system design or to address specific coal mining systems engineering requirements.

The state of Kentucky is discussed as a region but this report focuses primarily on the eastern portion of the state. The scarcity of data describing certain topics has necessitated the additional regional discussion. It is left to the reader to generalize regional data to eastern Kentucky when necessary. Much of the data presented were drawn from Karan and Mather (1977), and the National Climatic Center's Climate of Kentucky (1977). However, a number of other sources were used as well and are included in the reference section.

II. SURFACE CHARACTERISTICS

A. PHYSIOGRAPHY

Regional. Kentucky covers an area of 40,109 mi^2. It is essentially a plateau formation which slopes to the southwest. Elevations range from approximately 400 ft above sea level in the west to 1,000 ft in Central Kentucky and 4,000 ft in the southeast. The state has been divided into seven physiographic regions (National Climatic Center, 1977). They are the Bluegrass region, the Knobs region, the Eastern Mountains, the Pennyroyal region, the Western Coal Field, the Cumberland-Tennessee River Area, and the Jackson Purchase (Figure D-1).

Eastern. The Eastern Mountains region encompasses all of eastern Kentucky and contains the coal field in the eastern portion of the state. Topography ranges from hilly to mountainous, with narrow valleys and high steep ridges, and little level land. The Eastern Mountains region is divided into three physiographic areas (Huddle, 1963): the Kanawha Plateau, the Cumberland Plateau, and the Cumberland Mountain section (Figure D-2).

(1) The Kanawha Plateau includes the major part of the eastern Kentucky coal field. Topography is hilly to mountainous with elevation ranges of 650 to 1000 ft, and consists of narrow, crooked stream valleys which are roughly 150 to 550 ft across. Ridge crests slope from moderate to steep, though locally they may retain the flat topography of the plateau surface. Hilltops are approximately 80 to 240 ft across.

(2) The Cumberland Plateau is located in the southwestern portion of the coal field and has a width ranging from 15-45 miles. The Pottsville escarpment is most distinct at its southern extreme but diminishes to the north and is frequently absent. A low, broad relief characterizes the sub-region. Elevations range approximately from 1100 to 1300 ft. The valleys range from 150 to 400 ft across. Hilltops are significantly broader than the hills in the other two sub-regions discussed.

(3) The Cumberland Mountain section, strongly influenced by the Pine Mountain thrust fault, locally forms steeply pitching ridges with elevations in excess of 4000 ft. Average elevations range from 1050 to 2050 ft. Hilltops may range from 80 to 200 ft across while valleys may have a range of 650 to 1200 ft wide.

B. SOIL

Regional. Although most of the state's soils have developed under forest cover and similar climates, there is wide variation

resulting from differences in parent materials, topographical conditions, and length of time the materials have been exposed to soil forming processes. Over time, soils are altered in texture, structure and chemistry.

Eastern. The General Soil Map for eastern Kentucky (Figure D-3) developed by the Soil Conservation Service (1975), indicates the important soil associations throughout eastern Kentucky. The Soil Conservation Service (SCS) describes the eastern soils as being "deep and moderately deep (20-40+ in), well-drained, and formed in residuum or hillside creep material from acid sandstone, siltstone and shale on mountain sides". The SCS delineates a number of regions in eastern Kentucky reflecting eight soil associations. In addition, a small portion of the eastern region is classified as being "deep (40+ in.), well-drained to poorly drained soils on nearly level flood plains and undulating terraces of the major streams".

The legend indicates the soil associations, location and extent, percent of association, normal slope range, suitability for agriculture, major crops, limiting properties, minor soils and additional descriptive remarks.

Soils are to be considered for implementation of a mining system in two respects: surface structures and mine access. Surface structures such as the coal preparation plant and transport lines require adequate foundational materials and bearing capacities. Soils in eastern Kentucky are generally shallow to moderately deep due to the steep and hilly terrain. Therefore, any obstacles to development as a result of soil engineering characteristics are likely to be alleviated by removal of the soil. Obvious exceptions to this would be in valleys where the soil tends to be deeper.

C. Slope

Regional. Data from the general soil map (Soil Conservation Service, 1975) was used to develop average slope values for the western and central portions of Kentucky. In the western portion of the state over 43% of the acreage has slope less than 12%, and over 55% of the acreage has slope less than 30%. Central Kentucky has over 30% of its acreage with slope less than 20%, and over 30% of its acreage with slope less than 35%.

Eastern. Two approaches were used to determine slope values for eastern Kentucky. One approach was to use the General Soil Map (SCS, 1975) descriptions. The other utilized data from five soil surveys (SCS, 1965, 1970, 1974 abc) covering all or part of nine counties representative of the region. Both methods generally seem to substantiate each other. Examining the soil map, over 70% of eastern acreage has slopes greater than 20%. Upon closer examination in the soil surveys, most slopes are greater than 30%.

In the steep and rugged terrain of eastern Kentucky, slope influences flood occurrence and magnitude, ease of clearing land during site preparation, and construction of slurry impoundments and foundations for support facilities to the mining operation. In addition, slope presents problems for road construction and transportion.

III. CLIMATE

A. TEMPERATURE

Regional. Temperature fluctuations in Kentucky are influenced by low and high pressure systems. Low pressure systems consist of southwest winds which bring warm, moist air from the Gulf of Mexico and from the Deep South states. High pressure systems are characterized by northwest winds bearing cool, dry air. Based on average annual temperatures, a temperature differential of 4.5°F exists over the state; temperatures range from about 54°F in the extreme north to 59°F in the southwest. In a given month, differences across the state are more apparent, with the greatest variability (7°F) occurring in January, and the lowest variability (3.3°F) occurring in November. As might be expected, variability decreases from high to low from January to November. If one considers month to month changes in a given region, temperature differences are further accentuated, ranging from 38.2°F - 44.5°F, depending on the region. Regional fluctuations are greatest during the winter and summer, while temperatures are more consistent during spring and fall.

Average maximum temperatures have a range of 86°F to 92°F with the higher temperatures occurring to the west (Figure D-4). Daily maximum temperatures of 90°F and above occur on the average from 23 - 53 days a year. Annual minimum temperatures range from 26°F to 30°F with a rise in temperatures occurring in a north-south direction (Figure D-5). The mean number of days with minimum temperatures of 32°F and below range from 85 - 122 days a year. The western region averages 85 - 97 days a year and the central region experiences an annual average of 105 - 122 days. Extreme temperatures over the period 1951 - 1974 ranged from 103°F in the east to 110°F in the west; record lows of zero or below occurred during December, January and February. Although such occasions are not uncommon, they persist for only a few days.

Eastern. Eastern Kentucky exhibits the same general trends in temperature variability as does the state as a whole. The region is comparatively cooler, however, since it lies further from the low pressure systems bringing warm air in from the Gulf of Mexico. Table D-1 presents temperature data from three National Weather Service stations in eastern Kentucky. Additional data obtained from the Agricultural Experiment Station at the University of Kentucky for four vicinities in the eastern region are given in Table D-2. Figure D-6 shows the location of each of the monitoring facilities. Average annual temperatures in eastern Kentucky range from approximately 55°F to 58°F with cooler temperatures occurring in the north and warmer temperatures occurring in the east; average maximum temperatures range on the average from 86°F to 90°F in a southeasterly to northerly direction (Figure D-4). The mean number of days with maximum temperatures of 90°F and above range from 30 - 32 days a year, comparatively lower than the state overall. Annual average minimum temperatures are consistent with the state in general

and range from 28°F to 30°F (Figure D-5). The mean number of days with minimum temperatures of 32°F or below range from 109 - 112 days a year. Record high temperatures over the period 1951 - 1974 ranged from 103°F to 105°F over the eastern region; record lows for the same period were similar to the state values ranging from -15°F to -28°F.

B. SUNSHINE

Regional. The state experiences equal portions of clear days and partially clear days at an average range of 115 - 120 days out of the year. The average number of cloudy days is approximately 130. The most northerly portion of the state experiences the greatest number of cloudy days while the most westerly portion of the State experiences the greatest amount of sunshine. Sunshine occurs on the average 35 - 50% of the time during the winter months, 50 - 65% in the spring, 65 - 75% in the summer, and 55 - 65% in the fall.

Eastern. Sunshine information specific to eastern Kentucky is not currently available.

C. TOTAL PRECIPITATION

Regional. In Kentucky, precipitation is due largely to low pressure systems moving from west to east and southwest to northeast. The majority of the precipitation is due to the moisture-bearing low pressure areas from the western Gulf of Mexico moving in a northeasterly direction. The wettest part of the year occurs from January to July with an average monthly precipitation of slightly greater than 4 in. The driest part of the annual cycle occurs from August to December with an average monthly precipitation of 3 in. An annual minimum of 2.5 in. occurs in October and a maximum of 5 in. in March. Prolonged drought rarely occurs. The average annual total is 36 in. in the northern part of Kentucky and 50 in. in the southern portion. Tables D-1 and D-2 present precipitation data. Figures D-7 and D-9 also provide data on average precipitation.

Eastern. A review of Table D-1 shows that the greatest amount of precipitation occurs from April to August, particularly during July. The driest part of the year consistently occurs from September to November with October being the driest. The annual average number of days with measurable precipitation is generally highest in the southeastern section of eastern Kentucky (Figure D-7).

Average annual precipitation generally increases as one moves from north to south (Figure D-8). The northern portion has an average annual precipitation of 40-42 in. The extreme east (Pike County) averages 44 in. and the southeast (Harlan and Bell counties) averages 50 in. Other areas of eastern Kentucky experience average annual precipitation from 44-48 in.

Based on data from 1951 - 1974, the maximum precipitation occurring over a month reached 11.03 in. in July 1961 at Ashland, 10.00 in. in July 1965 at Farmers 1 WNW, and 10.86 in. in April 1972 at Heidelberg Lock 14. The maximum precipitation occurring in a day reached 5.61 in. in July 1973 at Ashland, 4.18 in. in August 1972 at Farmers 1 WNW, and 4.57 in. in June 1960 at Heidelberg Lock 14.

D. RAINFALL

Regional/Eastern. In Kentucky, snowfall represents approximately 3% of total precipitation and hail incidence is very low. Therefore, the preceding section on total precipitation provides a general representation of the region's total rainfall occurrence. All-season probable maximum precipitation (PMP) is the theoretically greatest rainfall rate for specified durations that is physically possible over a particular drainage area. PMP ranges from 40-42 in. for a duration of 72 h and an area of 10 mi^2 and increases from north to south (Figure D-9). Figure D-10 provides data on rainfall variability. Rainfall variability indicates the difference in total rainfall from year to year.

Eastern. The discussion on precipitation in eastern Kentucky may also be applied to this section. Rainfall variability fluctuates in an east-west direction (Figure D-10). The lowest amount of variability in both eastern Kentucky and the state as a whole is 10% and occurs in Laurel and Jackson counties. In the northern area of eastern Kentucky, the variability is 15 - 20% and the variability in the central area of eastern Kentucky is 15 - 25%. The southeast experiences a variability of 2%.

E. SNOWFALL

Regional. Snowfall usually occurs from November to March although some snow has been reported in October and April. Over much of the State, snowfall seldom remains on the ground for more than a few days. Average annual snowfall ranges from 6 - 10 in. in the southwest and from 15 - 20 in. in the southeast.

Eastern. Snowfall data for eastern Kentucky is available in Tables D-1 and D-2. At all three stations listed in Table D-1 (Ashland, Farmers 1 WNW and Heidelberg Lock 14), snowfall occurs from November through March with January having the highest averages at 4.6, 6.0, and 4.9 in., respectively. The respective total average annual snowfalls are 14.2, 16.8 and 15.4 in. Record maximums over a period of a month were 12.9 in. at Ashland in February 1960, 23.5 in. at Farmers 1 WNW in February 1960, and 22.4 in. at Heidelberg Lock 14 in March 1960. The record daily maximum depths reached 9.0 in. in February 1960 at Ashland, 12.0 in. in February 1960 at Farmers 1 WNW, and 12.0 in. in March 1960 at Heidelberg Lock 14.

F. HAIL

Regional. Spatially, hail incidence in the United States is greatest in the central states increasing on the lee of the Rockies and decreasing as the Appalachian Mountains are approached. Hail incidence again increases east of the Appalachians. Temporally, there is a general trend of low hail days from September to January with maximum hail days from March to June (Stout, et al., 1968). High intensity thunderstorms in Kentucky are sometimes accompanied by hail but the damaged area is limited. Severity of damage is not known.

Eastern. Eastern Kentucky seems to follow the state's overall temporal pattern. The total number of hail days in an average 20-year period is 35-40 days and is generally on the low side as compared to the entire state, which is between 35-50 days.

G. FOG

Regional. Heavy fog is rare, occurring between 8 and 17 days during the year, primarily from September through March.

Eastern. No data specific to eastern Kentucky are currently available.

H. WIND

Regional. Average velocity of winds is 7 - 12 mph. The prevailing annual direction is from south to southwest although there is an occurrence of northerly winds during the fall in some areas. Maximum wind speeds range from 50 - 70 mph and occasionally even these speeds can be surpassed. On the average one tornado occurs during the year in some part of the state.

Calculations to determine wind loads on "buildings and structures as a unit, on portions of buildings and structures, and on individual structural elements" are given in Section 906 of the National Building Code. Design wind loads are a function of basic wind speed, structural height, and velocity pressures and pressure coefficients enumerated in the Code. The basic wind speed is given to be 80 - 90 mph at a height of 30 ft above the ground in Kentucky.

Eastern. Wind and tornado data specific to eastern Kentucky are not currently available.

I. LIGHTNING

Regional. Although there are no lightning data available as such, the frequency of lightning occurrence can be correlated with the occurrence of thunderstorms. High intensity thunderstorms are not uncommon during the months of March through September. Rainfall

levels are often greater than two or three inches with occasional occurrences of 5 or 6 in. in a 24-h period. The average annual number of days with thunderstorms is between 45 and 60.

Eastern. No information regarding thunderstorms or lightning specific to eastern Kentucky is currently available.

J. FLOODS

Regional. Several physiographic and meteorologic factors influence the magnitude of floods. Physiographic characteristics include size and shape of drainage basin, slope of stream and floodplain, natural or artificial storage in the channel lakes, ponds or reservoirs, slope of the land, stream pattern and density, elevation of basin, geology, soil type, vegetative cover, and land use. Meteorologic characteristics include amount, type, and distribution of precipitation, and temperature (McCabe, 1962).

Figure D-11 delineates the major drainage areas, principal drainage basins, and sub-basins. Due to the topography of eastern Kentucky, streams generally flood from the southeast to the northwest. Kentucky is bounded on the north by the Ohio River and on the west by the Mississippi River. Principal tributary streams include the Big Sandy, Licking, Kentucky Salt, Green, Tradewater, Cumberland, and Tennessee Rivers (Figure D-11). The entire state is part of the Ohio River Basin with the exception of a portion of the Jackson Purchase Region.

For the most part, floods occur in the winter and spring. In previous records, there has been a general tendency for floods to occur largely in January, February, March, or April, followed in intensity by May through September, and finally November and December. Generally no floods are experienced during October.

Eastern. Although no specific data pertaining to flood magnitudes and frequencies in eastern Kentucky are currently available, several of the contributing physiographic and meteorologic characteristics enumerated above are discussed to some extent in this report. Drainage area seems to be the most significant factor. A factor to consider in eastern Kentucky is the problem of grazing and corresponding flood implications. Grazing by livestock has been identified as a problem on over a million acres of forest land in the state of Kentucky. Since eastern Kentucky is dominated by forest, grazing may pose as an additional contributor to flood occurrence (see Figures D-12 and D-13). Grazing results in damaged trees and roots, soil compaction and destruction of small trees and groundcover. Such damage contributes to the possibility and severity of floods by decreasing rain percolation, and increasing runoff and soil erosion (Soil Conservation Needs Inventory Committee, 1970). In the general soil map, the A-coded areas indicate some flood plains and undulating terraces of the major streams. Flood-prone area maps specific to

certain communities have been developed by the Kentucky Geological Survey. There are also available two publications addressing the procedure for estimating magnitude and frequency of floods, one specific to Kentucky (McCabe, 1968; U.S. Water Resource council, 1977).

IV. LAND USE

A. LAND SURFACE STATUS

Regional. As previously stated, Kentucky covers an area of 40,109 mi^2, or 25,510,881 acres. In 1970, the land was inventoried and results published in the Kentucky Soil and Water Conservation Needs Inventory 1970. In this survey, the land is classified into two major categories, inventory and non-inventory. Inventory lands include cropland, pasture, forest and other lands of similar uses. Non-inventory lands include federally owned non-cropland, urban built-up areas and small water areas. Inventory lands comprise 92.2% of the total area of the state and non-inventory lands comprise 7.8% of the total. Each land use classification is listed below along with the corresponding total acreage.

	Acreage	%
Cropland	6,586,739	25.8
Pasture	5,164,880	20.2
Forest	10,988,166	43.1
Other Lands	767,706	3.0
Federally Owned Non-Cropland	1,047,416	4.1
Urban and Built-up Areas	834,858	3.3
Small Water Areas	121,156	.5

Overall, the greatest percentage of cropland occurs in the Jackson Purchase region; the greatest percentage of pasture occurs in the Bluegrass region; and the greatest amount of forest occurs in the Eastern Mountains region.

Eastern. Narrowing the focus to the Eastern Mountains region, the profile is as follows. Forest constitutes 80%, pasture 8%, cropland 8%, and other lands 4% (Figure D-14). Most counties in eastern Kentucky have 60 - 85% of the land covered by forests. A good portion of eastern Kentucky is covered by commercial forest (Figure D-12). While this may represent a potential conflict in land use for coal surface facilities and a subsidence potential, major coal-producing areas apparently occur in the vicinity of commercialized forest. It is apparent from Figures D-15 and D-16 that eastern Kentucky does not contribute substantially to the state's agricultural production. Agriculture in eastern Kentucky is primarily tobacco, corn and hay (Figures D-17, D-18, D-19). Tobacco fields do not coincide with the major coal-producing areas, but corn fields do. Figure D-20 indicates national parks, national forests, and urban areas with a population of greater than 10,000.

B. LAND OWNERSHIP

Regional. Looking solely at the state's 11.5 million acres of forest (or 45% of total land area), more than 90% of the forested

land is privately owned, divided evenly between commercial interests and farmers. Federal and state ownership make up the remainder.

Eastern. A general description of land ownership in eastern Kentucky was derived from discussions with the Kentucky Center for Energy Research. State-owned land makes up a relatively minor amount while federally-owned land is nearly minute in comparison. The vast majority of the land, then, is privately owned. However, a distinction must be made between ownership of the land surface and ownership of the mineral rights. While it is often the case that the surface owners are also owners of the mineral rights, this is less common when the mineral resource involved is coal. (While it is relatively easy to determine surface ownership from county records, mineral ownership is more difficult to establish.) Although the latter form of ownership appears on record as well, it is less apt to be accurate since such ownership has a greater tendency to change than does surface ownership. Individual surface ownership generally consists of small parcels of land. Ownership of mineral rights follows a similar pattern. An estimated range for average parcel size is 50 - 100 acres. There is, however, a recent tendency for larger coal companies to purchase larger parcels of about 200 acres. Nevertheless, ownership of the coal resource in eastern Kentucky can be summarized as multiple and highly fragmented.

C. MINERAL RESOURCES AND INDUSTRIES

Regional. Mineral resources of Kentucky include coal, petroleum, natural gas, stone, clay, sand and gravel. Coal is by far the state's most important mineral resource representing 68% of total resource value. Oil and gas follow with figures of 15 and 5%, respectively. Over half of the counties in Kentucky produce oil and/or gas. The largest producing oil field is in Lee County near Beattyville. The largest gas field is found in the Ashland area. Both oil and gas resources are declining, however. Quarried stone represents 5% of the total, clay represents 1% and sand and gravel represent 1% as well. Natural gas liquids, fluorspar, barite, lead, silver, zinc, cement, crushed sandstone and gem stone comprise the remaining 5%. Figure D-21 presents the occurrence of Kentucky's mineral resources and the locations of the corresponding industries.

Eastern. Table D-3 and Figure D-21 give an indication of the distribution of the resources, quarries and operations. Percentages representing the proportion of mineral resources to each other in eastern Kentucky are not currently available.

D. HISTORIC SITES

Regional. A parameter to consider in the development of a coal mining operation is the location of historic sites. A function of the Kentucky Heritage Commission is to survey a site to determine whether or not the site is of historical or architectural significance and

therefore eligible for listing in the Federal Register as an historic site. If a development is federally funded, licensed, or permitted, the project itself is responsible for initiating a survey providing the Heritage Commission has not yet conducted one.

Eastern. Historic sites in eastern Kentucky, as of March 5, 1978, are: (see following 2 pages). Figures D-22 and D-23 indicate the sites of recreational parks and state shrines.

Boyd
Ashland, FIRST PRESBYTERIAN CHURCH, 1600 Winchester Avenue
Ashland, INDIAN MOUNDS IN CENTRAL PARK, Central Park, Carter Avenue
Ashland, PARAMOUNT THEATER, 1304 Winchester Avenue
Catlettsburg, CATLETT HOUSE (BEECHMOOR), 25th and Walnut Streets
Catlettsburg, CATLETTSBURG NATIONAL BANK, 110 6th Street
Catlettsburg, FIRST UNITED METHODIST CHURCH, 2712 Louisa Street
Catlettsburg vicinity, STONE SERPENT MOUND

Carter
Grayson vicinity, KITCHEN, VAN, HOUSE, south of Grayson off KY 7

Estill
Fitchburg, RED RIVER IRON FURNACE, KY 975, in Daniel Boone National Forest
Irvine vicinity, COTTAGE IRON FURNACE, 7 mi NE of Irvine in Daniel Boone National Forest

Floyd
Prestonsburg, THE GARFIELD PLACE, 2nd Avenue

Greenup
Greenup vicinity, BENNETTS MILL COVERED BRIDGE, SR 2125 W of Greenup
Oldtown vicinity, OLDTOWN COVERED BRIDGE, S of Oldtown off KY 1
Wurtland vicinity, McCONNELL HOUSE, LAW OFFICE AND SLAVE QUARTERS, W of Wurtland on U.S. 23

Johnson
Oil Springs vicinity, BLANTON ARCHEOLOGICAL SITE, N of Oil Springs
Oil Springs vicinity, SPARKS SHELTER ARCHEOLOGICAL SITE, NE of Oil Springs on W side of Paint Creek
Paintsville, JOHN C. C. MAYO MANSION AND OFFICE, 3rd Street
Paintsville, FRANCIS M. STAFFORD HOUSE, 102 Broadway
Paintsville vicinity, DAMERON SHELTER ARCHEOLOGICAL SITE, W of Paintsville
Paintsville vicinity, DANIEL DAVIS HOUSE, NW of Paintsville on U.S. 460

Knott
Hindman vicinity, DR. JASPER STEWART HOUSE, 5.75 mi of Hindman

Knox

Barboursville, OLD CLASSROOM BUILDING, UNION COLLEGE, College Street.
Barboursville, OWENS HOUSE, 335 Knox Street

Laurel
London, FEDERAL BUILDING COURTHOUSE, Main and 3rd Streets

Lawrence
Fallsburg vicinity, EAST FORK COVERED BRIDGE, NW of Fallsburg over East Fork of Little Sandy River off KY 3
Fallsburg vicinity, YATESVILLE COVERED BRIDGE, S of Fallsburg over Blaine Creek off KY 3
Louisa, FRED M. VINSON BIRTHPLACE, E. Madison and Vinson Blvd.
Louisa vicinity, GARRED HOUSE, CHAPEL, AND BURIAL VAULT, 9 mi S of Louisa on U.S. 23

Lee
Beattyville, ST. THOMAS EPISCOPAL CHURCH, hill Street

Leslie
Chappel vicinity, JOHN SHELL CABIN, S of Chappell on SR 2005
Hyden vicinity, WENDOVER (FRONTIER NURSING SERVICE), S of Hyden off KY 80

Letcher
Whitesburg vicinity, KINGDOM COME CREEK SCHOOL, 5 mi SW of Whitesburg off KY 588

Morgan
Redbush, GAR FERGUSON SITE, NW of Redbush off KY 172
Redbush vicinity, RAY BURCHWELL ARCHEOLOGICAL SITE, NW of Redbush
Redbush vicinity, LONNIE HILL SITE, NW of Redbush
Redbush vicinity, RAY HILL ARCHEOLOGICAL SITE, W of Redbush off KY 172
Relief vicinity, PATOKER ARCHEOLOGICAL SITE, S of Relief
Relief vicinity, SHERMAN ARCHEOLOGICAL SITE, S of Relief
West Liberty, MORGAN COUNTY COURTHOUSE, Main Street

Perry
Buckhorn, BUCKHORN PRESBYTERIAN CHURCH AND THE GREER GYMNASIUM, off KY 28

Pike
Pikeville, PIKEVILLE COLLEGE ACADEMY BUILDING (PIKEVILLE COLLEGIATE INSTITUTE BUILDING), College Street
Pikeville and vicinity, HATFIELD-McCOY FEUD HISTORIC DISTRICT

Powell
Clay City, CLAY CITY NATIONAL BANK BUILDING, 6th Avenue
Slade vicinity, SHEPHERD SITE, W of Slade in Daniel Boone National Forest
Stanton vicinity, ANDERSON SITE, NE of Stanton in Daniel Boone National Forest
Stanton vicinity, HAYSTACK ROCK SHELTER, E of Stanton in Daniel Boone National Forest
Stanton vicinity, MARTIN SITE, NE of Stanton in Daniel Boone National Forest
Stanton vicinity, SELDON SKIDMORE SITE, E of Stanton in Daniel Boone National Forest

Wayne
Mill Springs, MILL SPRINGS MILL, off KY 90
Mill Springs vicinity, WEST METCALFE HOUSE, 1.75 mi S of Mill Springs off KY 90
Mt. Pisgah, ADKINS-HURT MILL, off KY 167

Whitley
Williamsburg, J. B. GATLIFF HOUSE, 10th and Main Streets

Wolfe
Slade vicinity, TRINITY ROCKHOUSE, E of Slade in Daniel Boone National Forest

IV. HYDROLOGY

The Eastern Coal Field Region of Kentucky contains no large supplies of water for year-round use. Although many wells in the region are only sufficient to meet the needs of a single household, groundwater is an important source of water, particularly for domestic uses. The steep slopes, shallow soils and fairly heavy precipitation of the region contribute to high runoff and the threat of floods during the winter and spring seasons. Dams and reservoirs are important for containing floodwaters and improving stream flows in the dry season. Quantities of water sufficient for coal-washing and preparation of plants, as well as for other industrial uses is available only through the use of reservoirs. The quality of water in the region is generally good, although some surface water is polluted by coal mining operations, and the groundwater is frequently salty at shallow depth. Both types of water are frequently hard and have a high iron content.

A. Groundwater. Pennsylvanian rocks underlie more than ninety percent of the area of the Eastern Coal Field Region (see Figure D-24). Rocks of older age are found at Pine Mountain and to a much smaller extent on the western margin at the border of the Blue Grass Region. Alluvium is found in the larger valley bottoms. Because of its large extent, most wells tap groundwater supplies in the Pennsylvanian rocks. Sandstones are the most common aquifers in the area, usually yielding water from joints and cracks along bedding planes, rather than pore spaces. Shales, coals and limestone are less important. Alluvium is a significant aquifer where it is present. More groundwater is found beneath valleys than on hilltops. In general, the quantity of water discovered increases with the depth of the well, with water of high salinity found at shallow depths throughout much of the area, limiting the depth to which freshwater wells can be drilled. Groundwater data have been summarized from Kilburn, et al., 1962; Kirkpatrick, et al., 1963; Price, 1973; Price, et al., 1962 abc.

Because of the variation in groundwater conditions in Eastern Kentucky, groundwater will be discussed for each of the three major physiographic regions:

1) Kanawha Section. Most of the land in the Eastern Coal Field Region is situated in the Kanawha physiographic region (see Figure D-2), an area marked by narrow valleys and steep-sided ridges. Most of the homes and developments in this region are located along streams in the valley bottoms. Outcrops of Mississippian age and of the Pennsylvanian Lee Formation are restricted to the western margin of the Kanawha region. Most of the region's bedrock is sediment of the post-Lee Pennsylvanian period.

Over 75% of the wells drilled in the Mississippian formations and in valley bottoms produce more than 100 gallons of water per day ·

(gpd). Between one-third and one-half of such wells yield over 500 gpd. Wells drilled on hills and ridges yield less water than those in the valleys.

In the Lee Formation, most of the wells in the valley bottoms, less than one-half of those on hilsides, and about one-third of those drilled on hilltops produce at least 500 gpd. Less than three-quarters of the wells on hilltops, but nearly all of those located elsewhere yield over 100 gpd. In general, the wells in the Lee Formation of Greenup and Carter counties produce less water than their counterparts farther south. Where the Lee Formation is over 500 ft thick, wells penetrating its entire thickness may supply as much as 50 gallons of water per minute (gpm) which is sufficient for some industrial needs.

Most of the groundwater from the Lee Formation is moderately hard. Noticeable amounts of iron are contained in it, and in places, salty water may be reached at depths less than 100 ft. If the Lee Formation lies below the Breathitt Formation and a principal drainage, salty water will usually be encountered at shallow depths.

Most of the wells in the Kanawha section are drilled in post-Lee Pennsylvanian rocks (primarily of the Breathitt Formation). In these rocks, the availability of the water increases to the southeast. In the general area south of Johnson County and primarily east of Breathitt County, nearly all the wells produce at least 100 gpd. Over 75% of the wells in valley bottoms, and almost that many of those on hillsides in this area produce over 500 gpd. In the valleys, wells drilled to depths greater than 200 ft may furnish enough water for a "small municipal or industrial supply" (Price, Mull and Kilboro). In the rest of the Kanawha section the wells in the Breathitt Formation produce somewhat less than the yields given above.

In the north and along the western margin of the Kanawha region, the water is hard, and salty water may be reached at shallow depths (less than 100 ft) when wells are drilled below principal valley bottoms. In the southeastern part of the region, salty water is generally not encountered until the well penetrates 200 ft below the principal valley bottoms. All of the water contains noticeable amounts of iron.

2) Cumberland Mountain Section. The Cumberland Mountain physiographic region is a mountainous area consisting of two parallel ridges and the hills between them. As in the Kanawha section, most people live in the valleys and most wells are also located there. Rocks of Mississippian and Devonian ages are restricted to a thin belt paralleling the northern margin of the section (along Pine Mountain). Rocks of the Lee Formation are found in a wider strip adjacent to that of the older rocks and also in a similar parallel belt along the southern boundary of the area. The land between the two belts of the Lee Formation is composed of undifferentiated rocks of the post-Lee Pennsylvanian period.

Devonian rocks are capable of supplying water to only a few domestic wells. Water is more abundant in Mississippian rocks; yields over 500 gpd are obtained throughout most of their outcrop area. When drilled in faulted areas and below drainage, wells in Mississippian rocks may furnish up to several gpm.

Nearly all the wells drilled in valley bottoms of the Lee Formation furnish over 100 gpd. Seventy-five percent of them yield over 500 gpd. Half of the wells drilled on hillsides supply over 500 gpd; most of the rest furnish between 100 to 500 gpd. Wells drilled on hilltops supply less water than those below them. As in the Kanawha section, wells drilled through the entire thickness of the Lee Formation may be able to furnish enough water for industrial supply.

The water from the Lee Formation contains iron, but in contrast with most of the groundwater of Eastern Kentucky, it is soft, not hard. In general the water is fresh, but salty water may be found in places where the top of the Lee Formation lies several hundred feet below principal valley bottoms.

Post-Lee Pennsylvanian rocks cover most of the Cumberland Mountain section. The availability of groundwater is not constant throughout the section and two general areas of differing groundwater concentrations exist. The southwestern third of the section yields a smaller supply of groundwater than is found in the rest of the section to the northeast. Although most southwestern wells drilled in valley bottoms yield more than 500 gpm, less than half of those on hillsides do. In the northeastern area, over three-fourths of the wells in valley bottoms, almost that many on hillsides, and about one-third of the wells drilled on hilltops furnish over 500 gpm. Nearly all of the wells in this area are capable of supplying at least 100 gpm. Enough water to supply a small municipality or industry may be found in wells drilled more than 200 ft below the level of principal valley bottom (in the northeastern area). Both areas have moderately hard water containing iron. Salty water is only encountered at depths greater than 300 ft below the bottoms of principal valleys.

3) Cumberland Plateau Section. The Cumberland Plateau is a broad upland. Its western and northern margins are dissected, but most of the section is an area of low relief. The upland surfaces are the locations for most of the homes, and as a result, most of the wells are drilled on hilltops.

In the Mississippian rocks, most of the wells drilled in valley bottoms and about 50% of the wells drilled on hillsides yield over 500 gpd. Most Mississippian rocks are confined to the valleys; hilltop wells that penetrate Mississippian rocks furnish less water than similar wells downslope. Most of the wells supply at least 100 gpd. The groundwater from Mississippian rocks is frequently salty. Some wells yield salty water at depths less than 100 ft; there is probably no fresh water to be found at depths below this.

About 50% of the hilltop wells drilled in the Lee Formation yield more than 500 gpd. Over 75% of such wells supply at least 100 gpd. Wells in valley bottoms and on hillsides can furnish more water; nearly all of them supply at least 100 gpd, and over 75% of them produce more than 500 gpd. As in the rest of the Eastern Coal Field Region, wells which penetrate the entire thickness of the Lee Formation, in places where this is greater than 500 ft, may yield enough water for a small municipal or industrial supply. Wells drilled in the Lee Formation in Jackson, Lee, northwest Laurel, and west Owsley counties produce less water than their counterparts in the rest of the section.

The water in the Lee Formation is soft or moderately hard; it contains iron. Most of the water is fresh, but salty water may be encountered if wells are drilled into the basal part of the Lee Formation along the eastern margin of the section.

The rocks of the Breathitt Formation supply little water. Less than 50% of the wells in valley bottoms furnish 500 gpd. Most wells on hills have a difficult time producing 500 gpd. In the eastern part of the section, water is more abundant. Most of the wells in valley bottoms and almost one-half of the hillside wells yield more than 500 gpd. The water in the Breathitt Formation contains iron and is moderately hard. Most of the water is fresh, but salty water may be found in a few wells. Alluvial deposits are found along the courses of the major streams throughout the region. Where it is sufficiently thick, alluvium offers the best supply of groundwater. Alluvium consists of clay, silt, and fine sand with small quantities of coarser sand and gravel. The more highly developed alluvium of the Ohio Valley consists of a fine layer of clay, silt, and sand underlain by a coarse layer containing silt, sand and gravel.

Wells in the Ohio Valley furnish more than enough water for a modern domestic supply. Large industrial wells have reported a yield of 360 gpm. in the valleys of the tributaries, however, most of the wells are shallow, dug wells which furnish only enough water for a minimum domestic supply. For instance, two-thirds of the wells dug in the alluvium of the Kentucky Basin fail in the dry season. Potential exists however; it is estimated that if properly drilled (instead of dug) and screened, wells in the alluvium of the Big Sandy River, Levisa Fork, and Tug Fork could furnish 20-25 gpm.

B. Surface Water. The Eastern Coal Field Region contains parts of six river basins (see Figure D-25), although for the purposes of this discussion the smaller Tygarts Creek Basin and Little Sandy River Basin shall be considered as part of the Big Sandy River Basin. The other three basins of the region are the Licking Basin, Kentucky Basin, and the Upper Basin of the Cumberland River. With the exception of the Cumberland River, all of the rivers drain roughly northward into the Ohio River. The Cumberland River also flows to the Ohio River, but primarily in a westerly direction.

In general, the quality of the surface water is good. Because of the steep topography of eastern Kentucky and resulting rapid runoff, the region has the potential of providing the highest quality water in the state. In spite of the generally good quality of water, there are pollution problems. Types of pollution are acid mine drainage, culm from coal washing, brine from oilfields, and sewage and trash from domestic and municipal sources. While trash presents primarily aesthetic problems, sewage and garbage alter the chemical quality of the water. Both culm and acid waters have been found several miles from the sources. Acid waters are corrosive and severely damage water treatment facilities and highway installations such as bridges. Water hardness is increased by the dissolution of calcium and magnesium carbonate rocks caused by the lowered pH. In addition, acid waters kill aquatic life. If deposition of coal culm is high, it can raise flood potential. Each of the river basins in the Eastern Coal Field Region has at least one reservoir for flood control (as well as other) purposes.

(1) Big Sandy River Basin. The major tributaries to the Ohio River in the Big Sandy River Basin (Figure D-26) are the Big Sandy River, the Little Sandy river, and Tygarts Creek. The Big Sandy River is formed by the junction of the Levisa and Tug Forks. It flows only twenty-seven miles to the Ohio River. The greatest contribution to the degradation of the quality of the waters of this basin is coal culm from coal washing operations, although in general, the quality of the water is good. The entire river basin is contained in the Eastern Coal Field physiographic region.

Levisa Fork has its headwaters in Virginia, though most of the area it drains is in Kentucky. Its water is moderately hard and near neutral in pH. Dissolved solids range from 150 ppm to 400 ppm. Its chemical quality is good. One of its tributaries, Paint Creek, is highly polluted from drainage of the Laurel Creek gas and oil fields. At low flow it can have a chloride content as high as 1000 ppm. However, Levisa Fork has significantly higher flow than Paint Creek and the effect of its pollutants is inconsequential.

Tug Fork arises in West Virginia before flowing northwestward to form the boundary between that state and Kentucky, and thus less than one-half of the area it drains is located in Kentucky. The quality of its water is similar to that of Levisa Fork. It is neutral to slightly basic, moderately hard, and has a dissolved solid concentration of 250 to 450 ppm.

The quality of the Big Sandy River is affected by its smaller tributaries as well as the Levisa and Tug Forks. Thus, it is soft to moderately hard, has dissolved solids of 90 to 465 ppm and is neutral to slightly basic, with good chemical quality.

The waters of the Little Sandy River and Tygarts Creek are satisfactory for the needs of most municipal and industrial users. That of the Little Sandy River is soft to moderately hard and may contain small to fair amounts of chloride. The water of Tygarts Creek is soft and has a pH near 7.0.

There are three flood control reservoirs in the Big Sandy River Basin, as well as one under construction. Fishtrap Lake is located in Pike County, on Levisa Fork, near the West Virginia border. It has a total storage capaity of 164,000 acre-feet and is capable of containing 153,800 acre-feet of winter and spring runoff. Dewey Lake, on Johns Creek (a tributary to Levisa Fork) near Prestonburg and Paintsville, can hold 81,000 acre-feet of flood storage. A flood containment of 32,757 acre-feet is planned for Paintsville Lake, now under construction on Paint Creek. Thus, a total flood storage capacity in excess of 273,000 acre-feet will be available in the Big Sandy River Basin.

(2) Licking River Basin. The Licking River in southeastern Kentucky arises and flows northwest to the Ohio River. Less than one-half of the Licking River Basin (Figure D-27) is in the Eastern Coal Field Region. The upper part of the basin has very little industrial development, with some oil production and limited coal mining the only representatives. Drainage of part of the Laurel Creek oil and gas field is responsible for moderate concentrations of chloride in the headwaters, but these concentrations disappear downstream as cleaner water enters the river. No other source of noticeable pollution exists in the area. The water is moderately soft, of neutral pH, and contains 75 to 300 ppm of dissolved solids.

One reservoir in the Licking River Basin lies in the Eastern Coal Field Region. Cave Run Lake covers part of four counties: Bath, Rowan, Morgan, and Menifee. Of its 614,000 acre-feet capacity, 438,500 are reserved for flood storage.

(3) Kentucky River Basin. About one-half of the Kentucky River Basin (Figure D-28) lies within the Eastern Coal Field Region. The three principal tributaries, the North, Middle and South Forks of the Kentucky River, join within a few miles of each other in Lee County to form the Kentucky River, which then flows out of the region. The waters of the North, Middle, and South Forks are not particularly polluted, but some of the tributaries of the North Fork are highly polluted.

The waters of the Middle and South Forks of the Kentucky River are similar in character. Only limited treatment is needed to make these waters of satisfactory quality for most users. They are of soft to moderate hardness and have a near neutral pH. Their dissolved solid concentrations are low, ranging from 50 to 120 ppm, being primarily bicarbonates an sulfates of calcium and magnesium.

The water of the North Fork Kentucky River meets the drinking-water standards of the United States Public Health Service, although its concentration of dissolved solids is higher than those of the Middle and South Forks. Many of its tributaries however, contain pollution associated with coal-mining operations, both acid and non-acid mine drainage as well as coal culm. Acid mine drainage is characterized by low pH, high concentrations of sulfate, and sometimes high concentrations of iron, aluminum, and manganese. Non-acid mine

waters also have high concentrations of sulfate, but are generally neutral or slightly basic, and have lower concentrations of iron, aluminum and manganese than acid mine waters. Non-acid mine drainage has a high concentration of dissolved solids. Suspended sediment in the form of coal culm from coal-washing operations on Leatherwood Creek and the North Fork Kentucky River is found as far downstream as Hazard (25 miles).

Almost 190,000 acre-feet of flood storage is provided within the Kentucky River Basin by two reservoirs. Carr Fork Lake controls the runoff from 58 square miles of mountainous drainage. This reservoir with 31,500 acre-feet of flood storage is located on the Carr Fork of the North Kentucky River. Buckhorn Lake on Middle Fork provides 158,000 acre-feet of flood storage and drains 408 square miles.

(4) Upper Cumberland River Basin. The Cumberland River is one of the major tributaries to the Ohio River. It originates near the city of Harlan in the Eastern Coal Field Region at the junction of the Poor and Clover Forks (Figure D-29). Other tributaries in the region include Straight Creek, Laurel River, and Rockcastle River. There is very little pollution in the Upper Cumberland River Basin; what little there is comes from untreated domestic and municipal wastes, as well as from the coal mining industry. The water of the basin is soft to moderately hard with neutral to basic pH. The pH is as high as 8.5 in some of its tributaries. The dissolved solids concentration runs from 50 to 250 ppm. Martin Fork Lake on the Martin Fork of the Clover Fork in Harlan County is capable of storing 17,500 acre-feet of flood runoff. The total storage capacity of Laurel River Lake is 435,600 acre-feet. At least 250,600 acre-feet are available for public use and conservation purposes at all times.

VI. TRANSPORTATION SYSTEMS

A. HIGHWAYS

Regional. Travel via roadways in Kentucky has shown a significant increase since 1940. The increase has been noticeable not only in passenger traffic, but in freight traffic as well. There are three categories of highway flows: north-south routes, east-west routes, and a number of bypasses or circles which serve to divert through traffic away from congested urban areas. There are approximately seventeen north-south highways made up of U.S., Interstate and Kentucky parkway routes, five principal east-west highways, and at least twenty bypass and circle routes. In general, the north-south routes bear the greatest amount of traffic, as compared to the east-west routes. Figure D-30 indicates highway locations and the frequency of usage.

Eastern. Coal is transported from the mine in most cases by truck. Roads are generally sufficient in terms of their spread and ability to reach most of the region of eastern Kentucky. While the addition of roads may be necessary, the cost is not prohibitive for the larger mining operations. The major consideration, particularly in the construction of roads, is slope in the hilly terrain of eastern Kentucky.[1] Innovative forms of transportation such as conveyor systems, though not common, are in use. Such systems are possible for large operations but the use of trucks will remain the conventional form of transportation since the coal industry in eastern Kentucky consists largely of small operations.[1] Small coal mine operations often transport the coal up to twenty-five miles to the nearest railroad. Eastern highways are illustrated in Figure D-30.

B. RAILROADS

Regional. The railroad system throughout Kentucky consists of 3,762 route-miles. Rail routes, for the most part, run north-south with secondary east-west routes. The bulk of the railroad service is concentrated on freight transport. Passenger routes, on the other hand, only include three runs: from Chicago-(Fulton)-New Orleans, from Washington, D. C.-(Cattlettsburg)- Cincinnati, and from Chicago-(Louisville)-(Bowling Green)-Miami.

Eastern. As previously stated, the overwhelming majority of rail use is freight traffic. The coal industry comprises a significant portion of rail usage. In eastern Kentucky, 91% of coal shipments to the consumer is by rail. The Appalachian coal fields are served by the Louisville and Nashville (L & N) and Chesapeake and Ohio (C & O) lines. In eastern Kentucky the majority of the coal mines are small to medium-sized compared to the larger mines of western Kentucky. The small and diffused nature of the eastern coal mine

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[1]Based on discussions with the Kentucky Center for Energy Research

population is reflected in the extensive network of rail lines and spurs. Several of the larger mines are served directly by a rail spur. Figures D-31 and D-32 display the eastern rail routes.

Transportation problems arise in the rail system. Small coal operators are finding the supply of rail car transport limited while rail companies contend coal transport is not economically viable. Large operators, however, do not encounter this shortage because of long term contracts held with the rail companies.[2]

C. Waterways

Regional. Navigable waterways throughout Kentucky are presented in Figure D-33.

Eastern. Navigable waterways (Figure D-33) in eastern Kentucky are limited to the Ohio River and the Big Sandy River. Both are located on the northern perimeter of the State. The navigable portion of the Big Sandy channel is about 17 mi long with the initial 9 mi consisting of a 9 ft channel and the remaining section consisting of an 8 ft channel. Petroleum products constitute the primary commodities shipped along the Big Sandy. The only major river port having barge or towboat terminals in eastern Kentucky is located at Ashland on the Ohio River.

The only other navigable waterway in eastern Kentucky is that portion of the Kentucky River which extends into three eastern counties after crossing central Kentucky. The three counties are Estill, Lee and Breathitt. This portion of the Kentucky River consists of a 6 ft channel. Barge transportation does not presently occur beyond Frankfort, which is substantially north of the river's contact with the eastern counties.

While barge transport for coal operators presents no access difficulty of the type encountered in the rail system, navigable waterways in eastern Kentucky are clearly limited; and in the major coal-producing areas, they are non-existent. Nevertheless, coal is sometimes transported to barges by rail.[3]

D. Wild and Scenic Rivers

Regional/Eastern. Figures D-34 and D-35 are included in this report in order to present a broader picture of the water system throughout Kentucky and to indicate those rivers which have become part of the Wild Rivers system, the result of a 1972 bill. The act designates those streams which are to be protected and the criteria for including other rivers in the future.[4]

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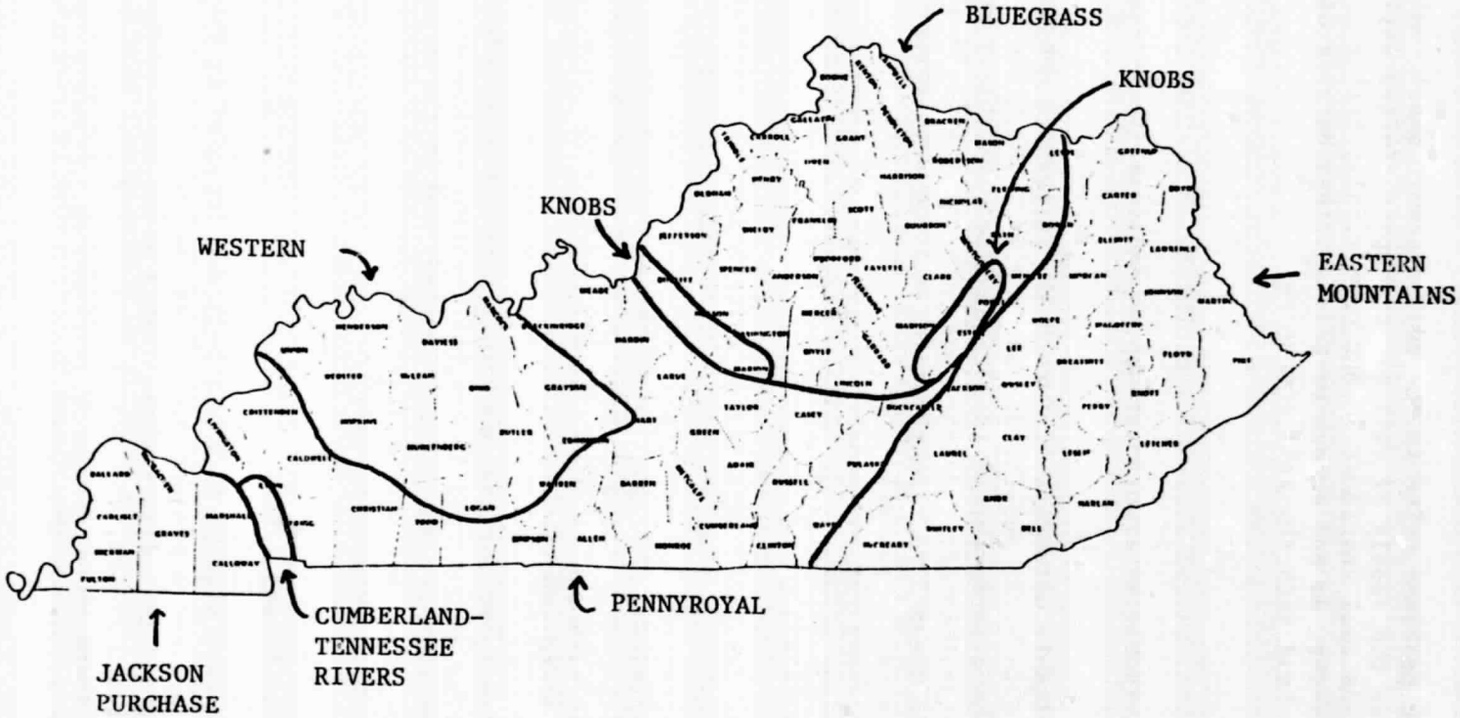
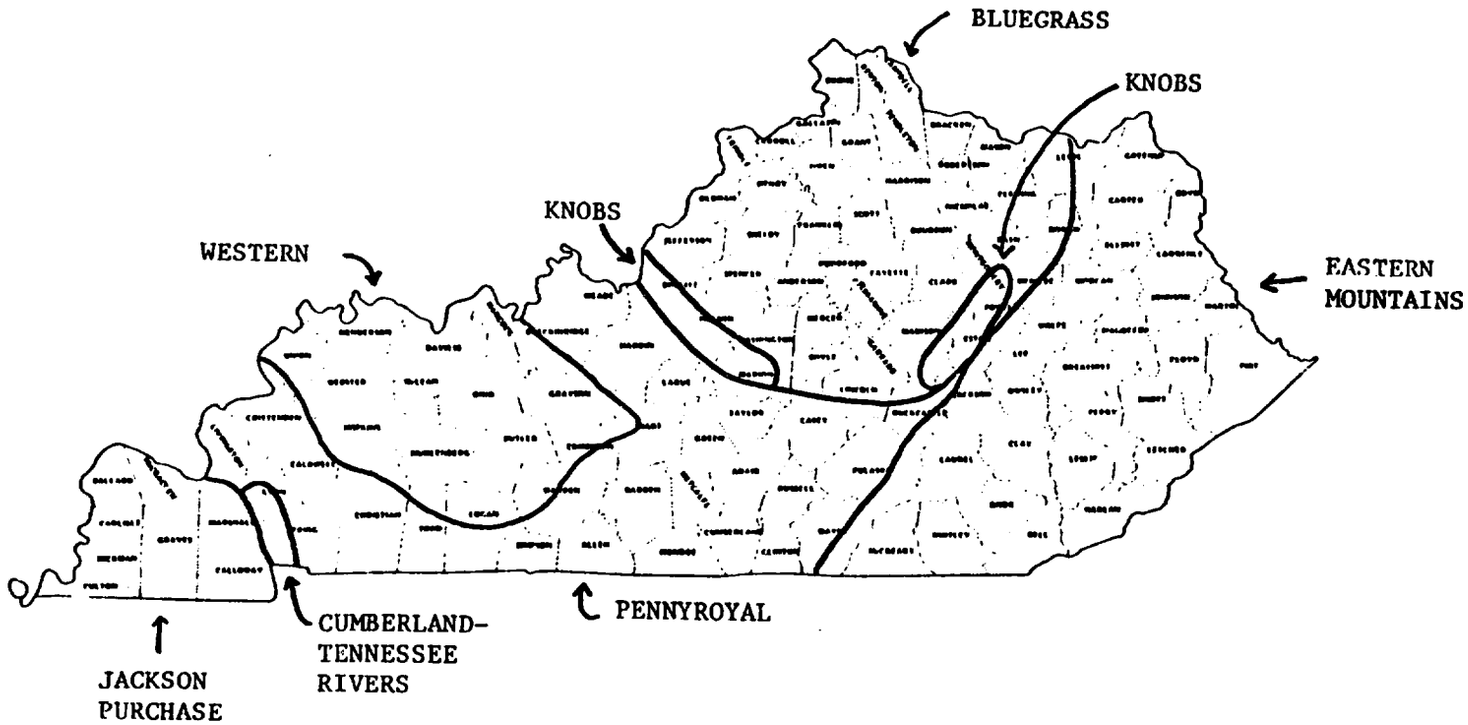
[2] Based on discussions with the Kentucky Center for Energy Research
[3] Based on discussions with the Kentucky Center for Energy Research
[4] Kentucky Acts 1972, Chapter 117, Senate Bill 138, pg. 525.



SOURCE: ATLAS OF KENTUCKY

Figure D-1. Physiographic Regions



SOURCE: ATLAS OF KENTUCKY

Figure D-1. Physiographic Regions

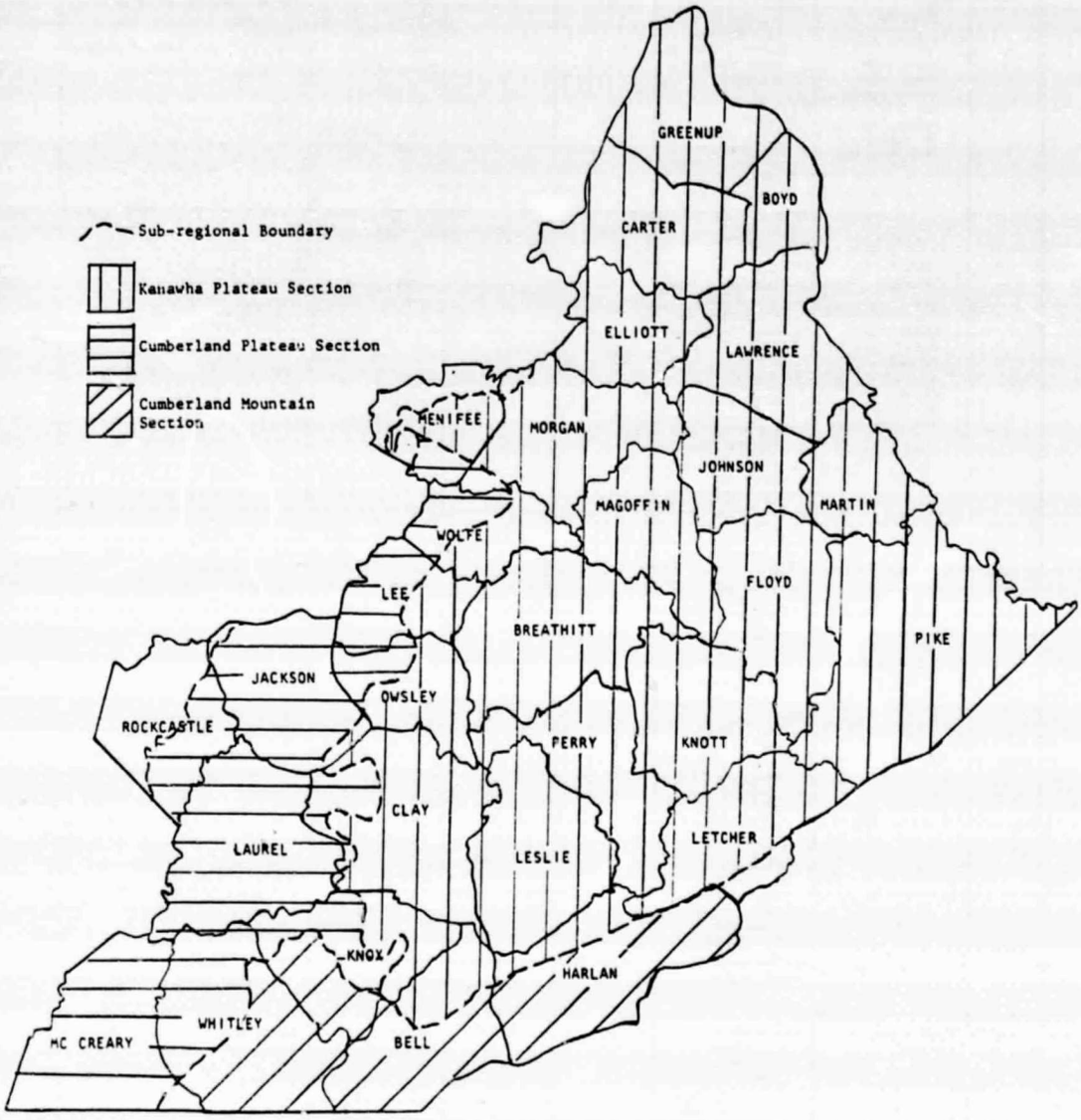


Figure D-2. Physiographic Sub-Regions of Eastern Kentucky (After Plate 1 in Coal Reserves of Eastern Kentucky, U.S.G.S. Bulletin 1120)

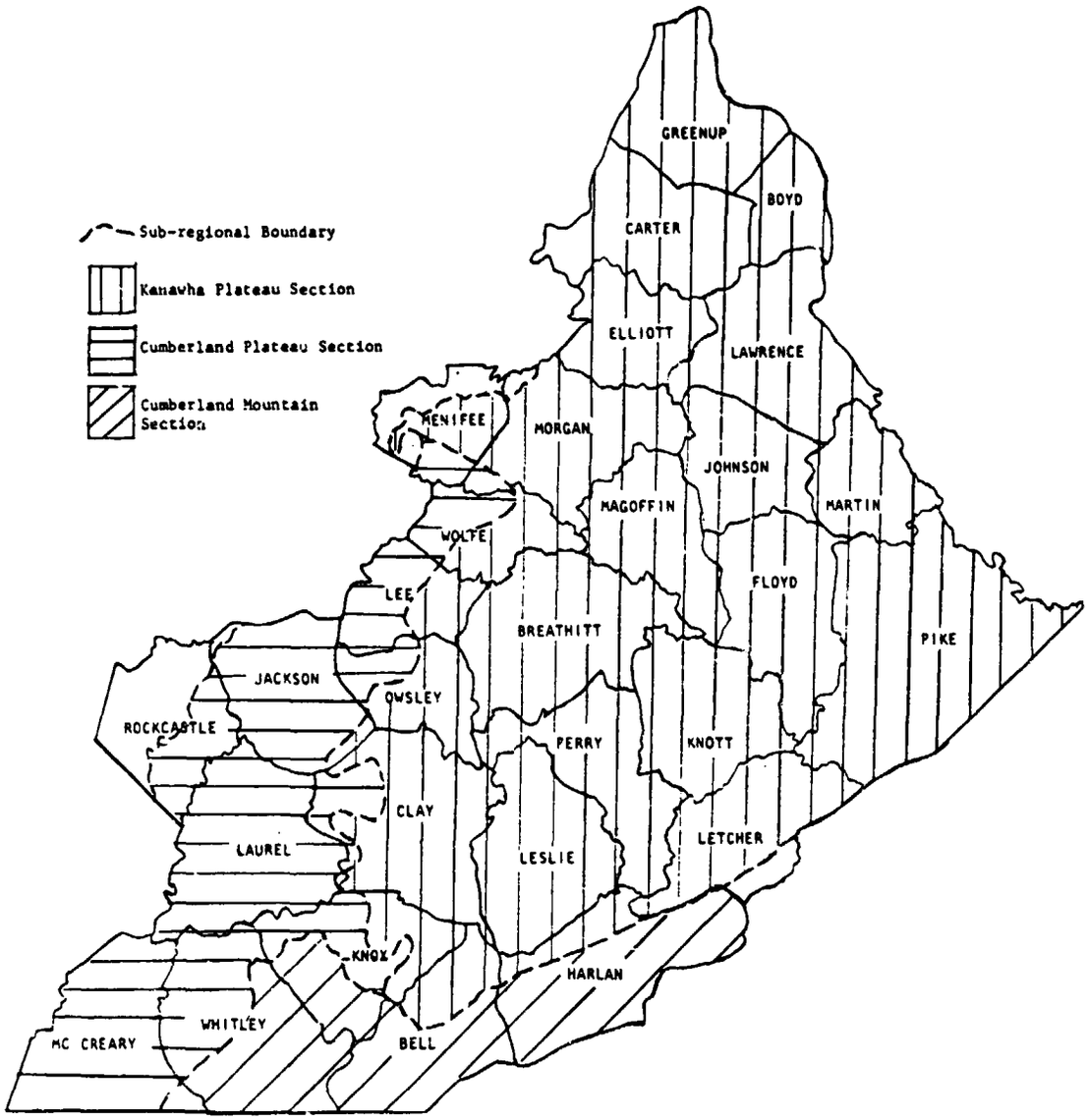


Figure D-2. Physiographic Sub-Regions of Eastern Kentucky (After Plate 1 in Coal Reserves of Eastern Kentucky, U.S.G.S. Bulletin 1120)

Soil Association		Major Soil Series	% of Association	Normal Slope Range %	Suitability for Agriculture, Major Crops, Limiting Properties	Remarks
Symbol	Name Extent Location					
G1	BERKS-CRANSTON 495,000 acres Steep side slopes with narrow ridges and flood plains, in the Cumberland Mountains	Berks Moderately deep, well drained soils, formed in loamy siltstone residuum	40	10 - 60	Poor Mostly woodland Slope, depth to rock	Rippable bedrock at 20 to 40 inches. Channery Mostly on upper half of slopes.
		Cranston Deep, well drained soils formed in loamy colluvium mostly from siltstone	38	12 - 60	Poor Mostly woodland Slope	Channery or gravelly Mostly lower half of slopes.
		MINOR SOILS:	22	Latham, Tilsit, Pope, Stendal		
G2	LATHAM-SHELOCTA 2,049,000 acres Steep side slopes with narrow ridge tops and flood plains in the Cumberland Mountains	Latham Moderately deep, well drained soils formed in clayey residuum from acid shales	42	20 - 50	Poor Mostly woodland, some pasture Slope	Rippable bedrock at 20 to 40 inches. Mostly on upper half of slopes and ridges
		Shelocta Deep, well drained soils formed in loamy colluvium from acid siltstones, shale and sandstone	25	20 - 50	Poor Mostly woodland, some pasture Slope	Mostly on lower half of slopes Gravelly or channery.
		MINOR SOILS:	33	Wernock, Lily, Gilpin, Whitney, Cuba, Stendal		
G3	JEFFERSON-SHELOCTA 3,809,000 acres Steep side slopes with narrow ridge tops and flood plains in the Cumberland Mountains	Jefferson Deep, well drained soils formed in loamy colluvium from acid sandstone, siltstone, and shale	38	20 - 60	Poor Mostly woodland Slope	Mostly on lower 2/3 of slope. Gravelly or stony.
		Shelocta Deep, well drained soils formed in loamy colluvium from acid siltstones, shale, and sandstone	27	20 - 60	Poor Mostly woodland Slope	Mostly on lower half of slope. Gravelly or channery.
		Steinsburg Moderately deep, well drained soils formed in loamy residuum from sandstone	11	20 - 60	Poor Mostly woodland Slope	Sandstone at 20 to 40 inches. Mostly on upper slopes. Most areas have some rock outcrops.
		MINOR SOILS:	24	Rigley, Dekalb, Lily, Wernock, Allegheny, Pope, Stendal, Latham		
G4	JEFFERSON-DEKALB 143,000 acres Steep side slopes of high mountains with narrow ridge tops and flood plains of Cumberland Mountains	Jefferson Deep, well drained soils formed in loamy colluvium from acid sandstone, siltstone and shale	40	20 - 60	Poor Mostly woodland Slope	Mostly on lower half of slope. Gravelly or stony. Most areas have some rock outcrops.
		Dekalb Moderately deep, well drained soils formed in loamy residuum from sandstone	20	20 - 60	Poor Mostly woodland Slope	Sandstone at 20 to 40 inches. Channery or stony. Most areas have some rock outcrops.
		MINOR SOILS	40	Shelocta, Brookside, Gilpin, Pope, Stendal		

*"General Soil Map of Kentucky," Soil Conservation Service in Cooperation with Kentucky Agricultural Experiment Station, and Division of Conservation, Department for Natural Resources and Environmental Protection.

Figure D-3. Legend

Soil Association		Major Soil Series	% of Association	Normal Slope Range %	Suitability for Agriculture, Major Crops, Limiting Properties	Remarks
Symbol	Name Extent Location					
G1	BERKS-CRANSTON 295,000 acres Steep side slopes with narrow ridges and flood plains, in the Cumberland Mountains	Berks Moderately deep, well drained soils, formed in loamy siltstone residuum	40	30 - 60	Poor Mostly woodland Slope, depth to rock	Rippable bedrock at 20 to 40 inches. Channery Mostly on upper half of slopes.
		Cranston Deep, well drained soils formed in loamy colluvium mostly from siltstone	38	12 - 60	Poor Mostly woodland Slope	Channery or gravelly Mostly lower half of slopes.
		MINOR SOILS:	22	Latham, Tilsit, Pope, Stendal		
G2	LATHAM-SHELOCTA 2,049,000 acres Steep side slopes with narrow ridge tops and flood plains in the Cumberland Mountains	Latham Moderately deep, well drained soils formed in clayey residuum from acid shales	42	20 - 50	Poor Mostly woodland, some pasture Slope	Rippable bedrock at 20 to 40 inches. Mostly on upper half of slopes and ridges
		Sheloeta Deep, well drained soils formed in loamy colluvium from acid siltstones, shale and sandstone	25	20 - 50	Poor Mostly woodland, some pasture Slope	Mostly on lower half of slopes Gravelly or channery.
		MINOR SOILS:	33	Wernock, Lily, Gilpin, Whitney, Coba, Stendal		
G3	JEFFERSON-SHELOCTA 3,900,000 acres Steep side slopes with narrow ridge tops and flood plains in the Cumberland Mountains	Jefferson Deep, well drained soils formed in loamy colluvium from acid sandstone, siltstone, and shale	38	20 - 60	Poor Mostly woodland Slope	Mostly on lower 2/3 of slope. Gravelly or stony.
		Sheloeta Deep, well drained soils formed in loamy colluvium from acid siltstones, shale, and sandstone	27	20 - 60	Poor Mostly woodland Slope	Mostly on lower half of slope. Gravelly or channery.
		Steinsburg Moderately deep, well drained soils formed in loamy residuum from sandstone	11	20 - 60	Poor Mostly woodland Slope	Sandstone at 20 to 40 inches. Mostly on upper slopes. Most areas have some rock outcrops.
		MINOR SOILS:	24	Kigley, Dekalb, Lily, Wernock, Allegheny, Pope, Stendal, Latham		
G4	JEFFERSON-DEKALB 144,000 acres Steep side slopes of high mountains with narrow ridge tops and flood plains of Cumberland Mountains	Jefferson Deep, well drained soils formed in loamy colluvium from acid sandstone, siltstone and shale	40	20 - 60	Poor Mostly woodland Slope	Mostly on lower half of slope. Gravelly or stony. Most areas have some rock outcrops.
		Dekalb Moderately deep, well drained soils formed in loamy residuum from sandstone	20	20 - 60	Poor Mostly woodland Slope	Sandstone at 20 to 40 inches. Channery or stony. Most areas have some rock outcrops.
		MINOR SOILS	40	Sheloeta, Brookside, Gilpin, Pope, Stendal		

*"General Soil Map of Kentucky," Soil Conservation Service in Cooperation with Kentucky Agricultural Experiment Station, and Division of Conservation, Department for Natural Resources and Environmental Protection.

Figure D-3. Legend

Soil Association		Major Soil Series	% of Association	Normal Slope Range %	Suitability for Agriculture, Major Crops, Limiting Properties	Remarks
Symbol	Name Extent Location					
G5	SHELOCTA-BROOKSIDE 333,000 acres Steep side slopes with narrow ridge tops and flood plains in the Cumberland Mountains	Shelocta Deep, well drained soils formed in loamy colluvium from acid siltstones, shale, and sandstone	27	20 - 60	Poor Mostly woodland, some pasture Slope	Gravelly or channery.
		Brookside Deep, well drained soils formed in clayey colluvium from limestone	24	30 - 60	Poor Mostly woodland, some pasture Slope	Most areas below limestone escarpment.
		Jefferson Deep, well drained soils formed in loamy colluvium from acid sandstone, siltstone, and shale	15	20 - 60	Poor Mostly woodland, some pasture	Gravelly or stony.
		MINOR SOILS:	34	Latham, Wernock, Caneyville, Nolin, Newark, Skidmore		
G6	VANDALIA-UPSHUR 90,000 acres Steep side slopes and narrow ridge tops and flood plains in the Cumberland Mountains	Vandelia Deep, well drained soils formed in clayey residuum from non-acid shales	35	20 - 60	Poor Mostly pasture and woodland Slope	Mostly on lower 2/3 of slope. Most areas have small slips.
		Upshur Moderately deep, well drained soils formed in clayey residuum from non-acid shales	26	20 - 60	Poor Mostly pasture and woodland Slope	Rippable shale at 26 to 44 inches. Mostly on upper slopes and ridges. Most areas have small slips.
		MINOR SOILS:	39	Latham, Gilpin, Steinsburg, Hayter, Nolin, Newark		
G7	COLYER ROCKCASTLE 315,000 acres Steep and hilly with narrow ridges in the Knobs Region	Colyer Shallow, somewhat excessively drained soils formed in clayey residuum from black shale	25	12 - 50	Poor Pasture and woodland Slope, depth to bedrock	Black shale at 8 to 20 inches.
		Rockcastle Moderately deep, somewhat excessively drained soils formed in clayey residuum from soft shales	15	12 - 50	Poor Pasture and woodland Slope	Soft clay shale of 20 to 40 inches.
		Trappist Moderately deep, well drained soils formed in clayey residuum from black shale	12	2 - 20	Fair Pasture, hay, corn, tobacco Slope	Black shale at 20 to 40 inches.
		MINOR SOILS:	48	Shrouts, Weikert, Muse, Tilsit, Latham		
G8	SHELOCTA-GILPIN 373,000 acres Long steep side slopes of higher mountains with narrow ridge tops and flood plains in the Cumberland Mountains	Shelocta Deep, well drained in loamy colluvium from acid siltstones, shale, and sandstone	40	20 - 60	Poor Mostly woodland Slope	Gravelly or channery Some rock outcrops.
		Gilpin Moderately deep, well drained soils formed in loamy residuum from acid siltstone, shale, and sandstone	25	20 - 60	Poor Mostly woodland Slope	Rippable bedrock at 20 to 40 inches. Channery or shaly. Some rock outcrops.
		MINOR SOILS:	35	Latham, Dekalb, Whitley, Morehead, Cuba, Stendal		

Figure D-3. Legend (Continuation 1)

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Soil Association		Major Soil Series	% of Association	Normal Slope Range	Suitability for Agriculture, Major Crops, Limiting Properties	Remarks
Symbol	Name Extent Location					
65	SHELOCTA-BROOKSIDE 333,000 acres Steep side slopes with narrow ridge tops and flood plains in the Cumberland Mountains	Shelocta Deep, well drained soils formed in loamy colluvium from acid siltstones, shale, and sandstone	27	20 - 60	Poor Mostly woodland, some pasture Slope	Gravelly or channery.
		Brookside Deep, well drained soils formed in clayey colluvium from limestone	24	30 - 60	Poor Mostly woodland, some pasture Slope	Most areas below limestone escarpment.
		Jefferson Deep, well drained soils formed in loamy colluvium from acid sandstone, siltstone, and shale	15	20 - 60	Poor Mostly woodland, some pasture	Gravelly or stony.
		MINOR SOILS:	34	Latham, Wernock, Caneyville, Nolin, Newark, Skidmore		
66	VANDALIA-UPSHUR 90,000 acres Steep side slopes and narrow ridge tops and flood plains in the Cumberland Mountains	Vandalia Deep, well drained soils formed in clayey residuum from non-acid shales	35	20 - 60	Poor Mostly pasture and woodland Slope	Mostly on lower 2/3 of slope. Most areas have small slips.
		Upshur Moderately deep, well drained soils formed in clayey residuum from non-acid shales	26	20 - 60	Poor Mostly pasture and woodland Slope	Rippable shale at 26 to 44 inches. Mostly on upper slopes and ridges. Most areas have small slips.
		MINOR SOILS:	39	Latham, Gilpin, Steinsburg, Hayter, Nolin, Newark		
67	COLYER ROCKCASTLE 315,000 acres Steep and hilly with narrow ridges in the Knobs Region	Colyer Shallow, somewhat excessively drained soils formed in clayey residuum from black shale	25	12 - 50	Poor Pasture and woodland Slope, depth to bedrock	Black shale at 8 to 20 inches.
		Rockcastle Moderately deep, somewhat excessively drained soils formed in clayey residuum from soft shales	15	12 - 50	Poor Pasture and woodland Slope	Soft clay shale of 20 to 40 inches.
		Trappist Moderately deep, well drained soils formed in clayey residuum from black shale	12	2 - 20	Fair Pasture, hay, corn, tobacco Slope	Black shale at 20 to 40 inches.
		MINOR SOILS:	48	Shrouts, Weikert, Muse, Tilsit, Latham		
68	SHELOCTA-GILPIN 371,000 acres Long steep side slopes of higher mountains with narrow ridge tops and flood plains in the Cumberland Mountains	Shelocta Deep, well drained in loamy colluvium from acid siltstones, shale, and sandstone	40	20 - 60	Poor Mostly woodland Slope	Gravelly or channery Some rock outcrops.
		Gilpin Moderately deep, well drained soils formed in loamy residuum from acid siltstone, shale, and sandstone	25	20 - 60	Poor Mostly woodland Slope	Rippable bedrock at 20 to 40 inches. Channery or shaly. Some rock outcrops.
		MINOR SOILS:	35	Latham, Dekalb, Whitley, Morehead, Cuba, Stendal		

Figure D-3. Legend (Continuation 1)

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Soil Association						
Symbol	Name Extent Location	Major Soil Series	% of Assn.	Normal Slope Range %	Suitability for Agriculture Major Crops Limiting Properties	Remarks
A6	ELK-WEINBACH MELVIN	Elk Deep, well drained soils formed in loamy alluvium on terraces	24	0-12	Good Corn, soybeans, tobacco, wheat	Some areas flood. Good potential for most uses where no danger of flooding.
	Terraces and flood plains of Ohio River and tributaries	Weinbach Deep, somewhat poorly drained soild formed in loamy alluvium on terraces	17	0-2	Fair Corn, soybeans Wetness	Seasonal water table within 1/2 foot of surface. Fragipan at about 2 feet. Slow percolation. Wetness, some areas flood.
		Melvin Deep, poorly drained soils formed in loamy alluvium on terraces	12	0-2	Fair Corn, soybeans Wetness, floods	Seasonal water table near surface. Wetness. Floods.
		Orwell Deep, moderately well drained soils formed in loamy alluvium on terraces	10	0-6	Good Corn, soybeans	Seasonal water table within 1/2 foot of surface. Fragipan at about 2 feet. Slow percolation. Some areas flood.
		Huntington Deep, well drained soils formed in loamy alluvium on flood plains	10	0-2	Good Corn, soybeans Floods	Floods Some areas flood infrequently.
		MINOR SOILS:	27	Newark, Wheeling, Licking, McGary, Sciotoville		
A8	POPE-BONNIE ALLEGHENY	Pope Deep, well drained soils formed in loamy alluvium on flood plains	24	0-4	Good Corn, soybeans tobacco Floods	Some areas flood infrequently.
	Flood plains and terraces of major mountain streams	Bonnie Deep, poorly drained soils formed in loamy alluvium on flood plains	23	0-2	Fair Corn, soybeans, many areas in pasture or woodland Wetness, floods	Floods, wetness
		Allegheny Deep, well drained soils formed in loamy alluvium on terraces	13	2-20	Good Corn, soybeans, wheat, tobacco Slopes above 6%	Some areas flood. Good potential for most uses on gentle slopes, where no danger of flooding.
		MINOR SOILS.	40	Stendal, Jefferson, Shelocta, Monongahela		

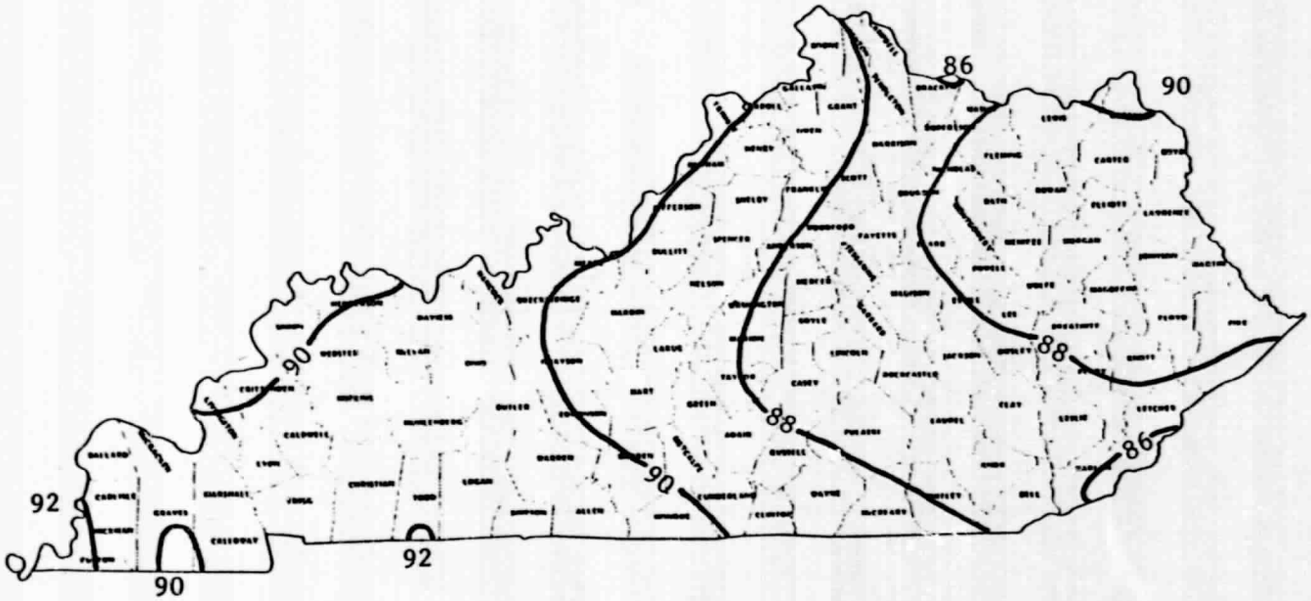
Figure D-3. Legend (Continuation 2)

Soil Association						
Symbol	Name Extent Location	Major Soil Series	% of Assn.	Normal Slope Range %	Suitability for Agriculture Major Crops Limiting Properties	Remarks
A6	ELK-WEINBACH MELVIN	Elk Deep, well drained soils formed in loamy alluvium on terraces	24	0-12	Good Corn, soybeans, tobacco, wheat	Some areas flood. Good potential for most uses where no danger of flooding.
	Terraces and flood plains of Ohio River and tributaries	Weinback Deep, somewhat poorly drained soild formed in loamy alluvium on terraces	17	0-2	Fair Corn, soybeans Wetness	Seasonal water table within 1/2 foot of surface. Fragipan at about 2 feet. Slow percolation. Wetness, some areas flood.
		Melvin Deep, poorly drained soils formed in loamy alluvium on terraces	12	0-2	Fair Corn, soybeans Wetness, floods	Seasonal water table near surface. Wetness. Floods.
		Orwell Deep, moderately well drained soils formed in loamy alluvium on terraces	10	0-6	Good Corn, soybeans	Seasonal water table within 1/2 foot of surface. Fragipan at about 2 feet. Slow percolation. Some areas flood.
		Huntington Deep, well drained soils formed in loamy alluvium on flood plains	10	0-2	Good Corn, soybeans Floods	Floods Some areas flood infrequently.
		MINOR SOILS:	27	Newark, Wheeling, Licking, McGary, Sciotoville		
A8	POPE-BONNIE ALLEGHENY	Pope Deep, well drained soils formed in loamy alluvium on flood plains	24	0-4	Good Corn, soybeans tobacco Floods	Some areas flood infrequently.
	Flood plains and terraces of major mountain streams	Bonnie Deep, poorly drained soils formed in loamy alluvium on flood plains	23	0-2	Fair Corn, soybeans, many areas in pasture or woodland Wetness, floods	Floods, wetness
		Allegheny Deep, well drained soils formed in loamy alluvium on terraces	13	2-20	Good Corn, soybeans, wheat, tobacco Slopes above 6%	Some areas flood. Good potential for most uses on gentle slopes, where no danger of flooding.
		MINOR SOILS.	40	Stendal, Jefferson, Shelocta, Monongahela		

Figure D-3. Legend (Continuation 2)

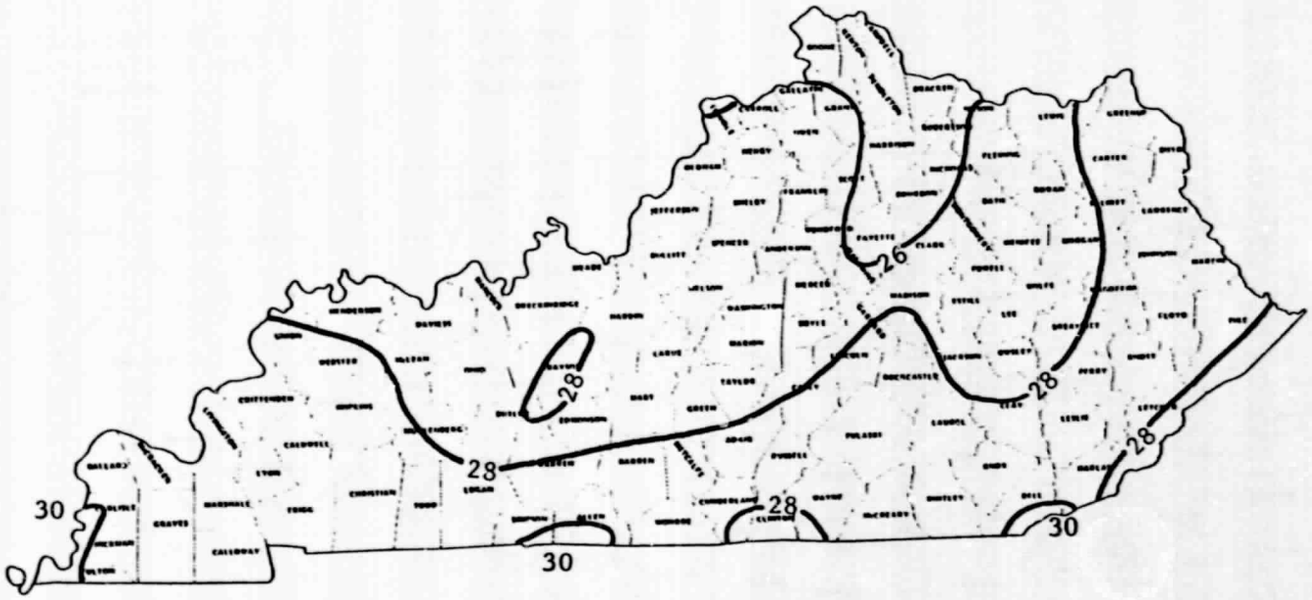
Soil Association						
Symbol	Name Extent Location	Major Soil Series	% of Assn.	Normal Slope Range %	Suitability for Agriculture Major Crops Limiting Properties	Remarks
A9	MOREHEAD-WHITLEY-CUBA Terraces and flood plains of major mountain streams	Morehead Deep, some poorly and moderately well drained soils formed in loamy alluvium on terraces	25	0-4	Good Corn, soybeans, wheat, tobacco Wetness	Seasonal water table within 1/2 to 1-1/2 feet of surface. Wetness, some areas flood.
		Whitley Deep, well drained soils formed in loamy alluvium on terraces	20	0-12	Good Corn, soybeans, wheat, tobacco Slopes above 6%	Some areas flood. Good potential for most uses on gentle slopes, where no danger of flooding Slopes above 8%.
		Cuba Deep, well drained soils formed in loamy alluvium on flood plains	12	0-2	Good Corn, soybeans, wheat, tobacco Floods	Some areas flood infrequently.
		MINOR SOILS:	43	Stendal, Monongahela, Tilsit		

Figure D-3. Legend (Continuation 3)



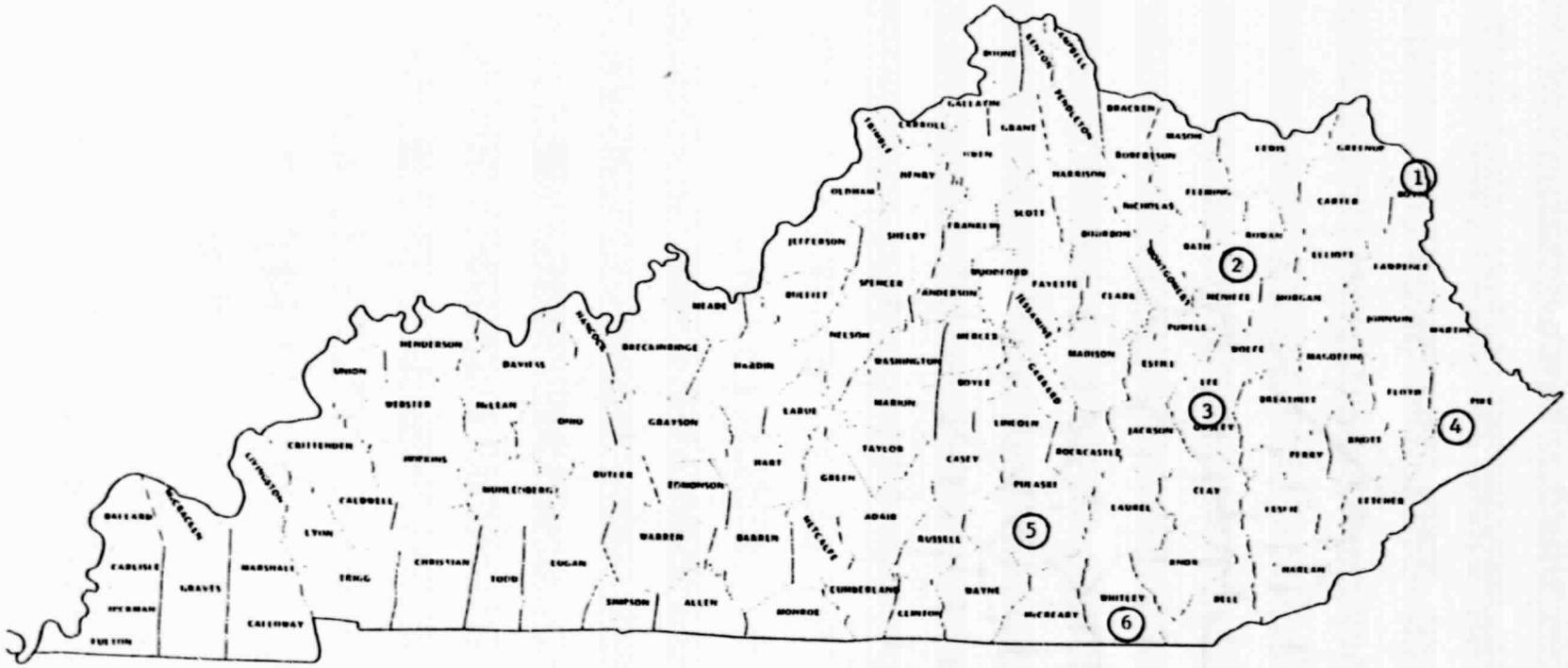
SOURCE: ATLAS OF KENTUCKY

Figure D-4. July Mean Maximum Temperature



SOURCE: ATLAS OF KENTUCKY

Figure D-5. January Mean Minimum Temperature



1. Ashland
2. Farmers 1 WNW
3. Heidelberg Lock 14
4. Pikeville
5. Somerset
6. Williamsburg

SOURCE: CLIMATE OF KENTUCKY

Figure D-6. Climatological Stations

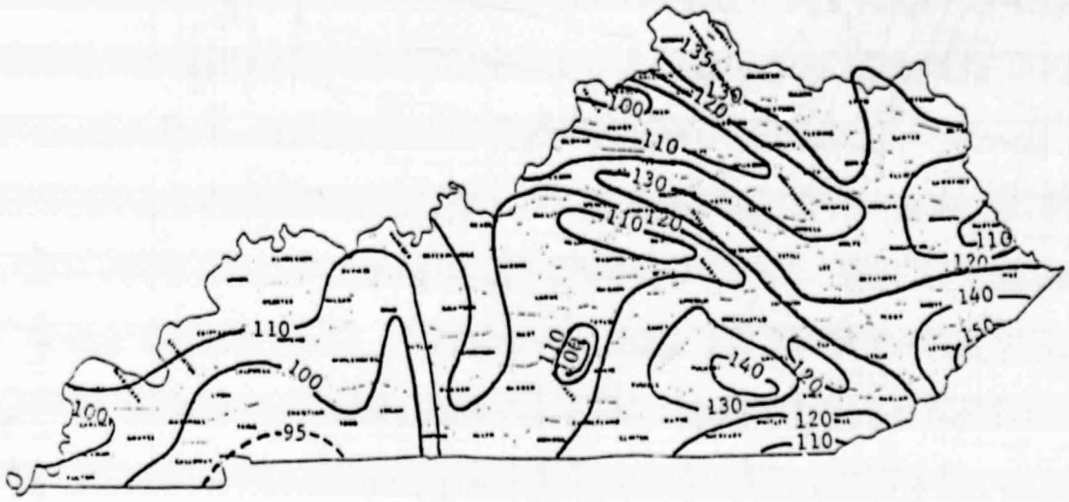
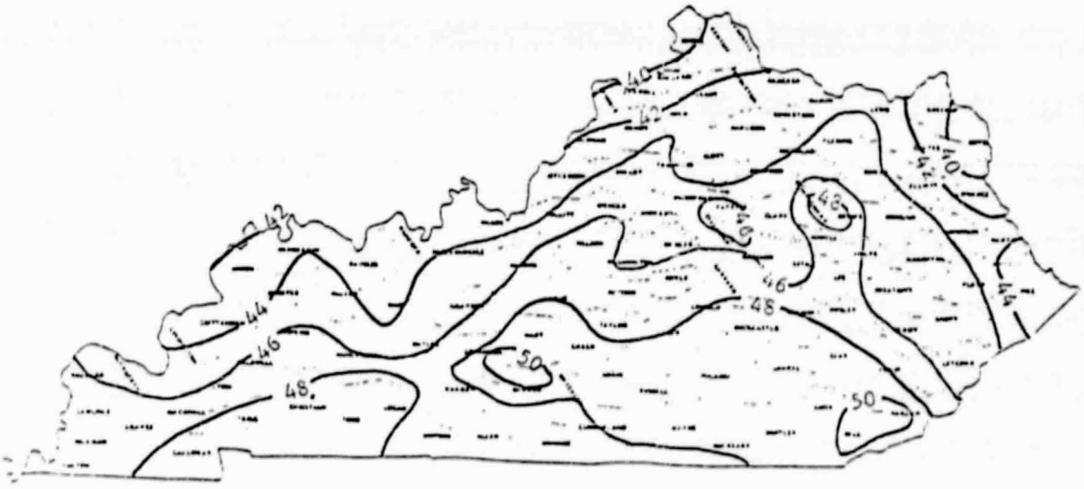
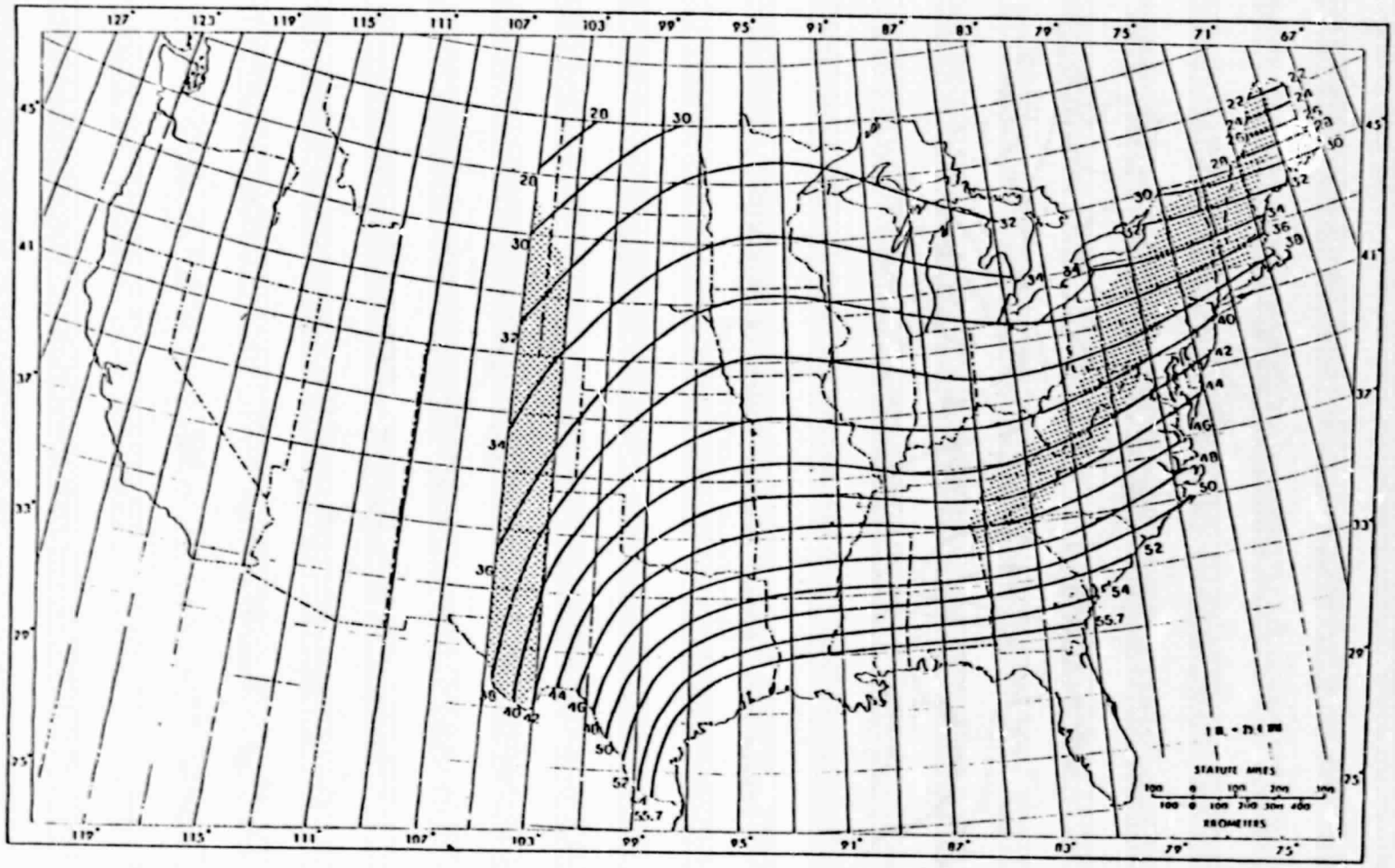


Figure D-7. Annual Average Number of Days with Measurable Precipitation



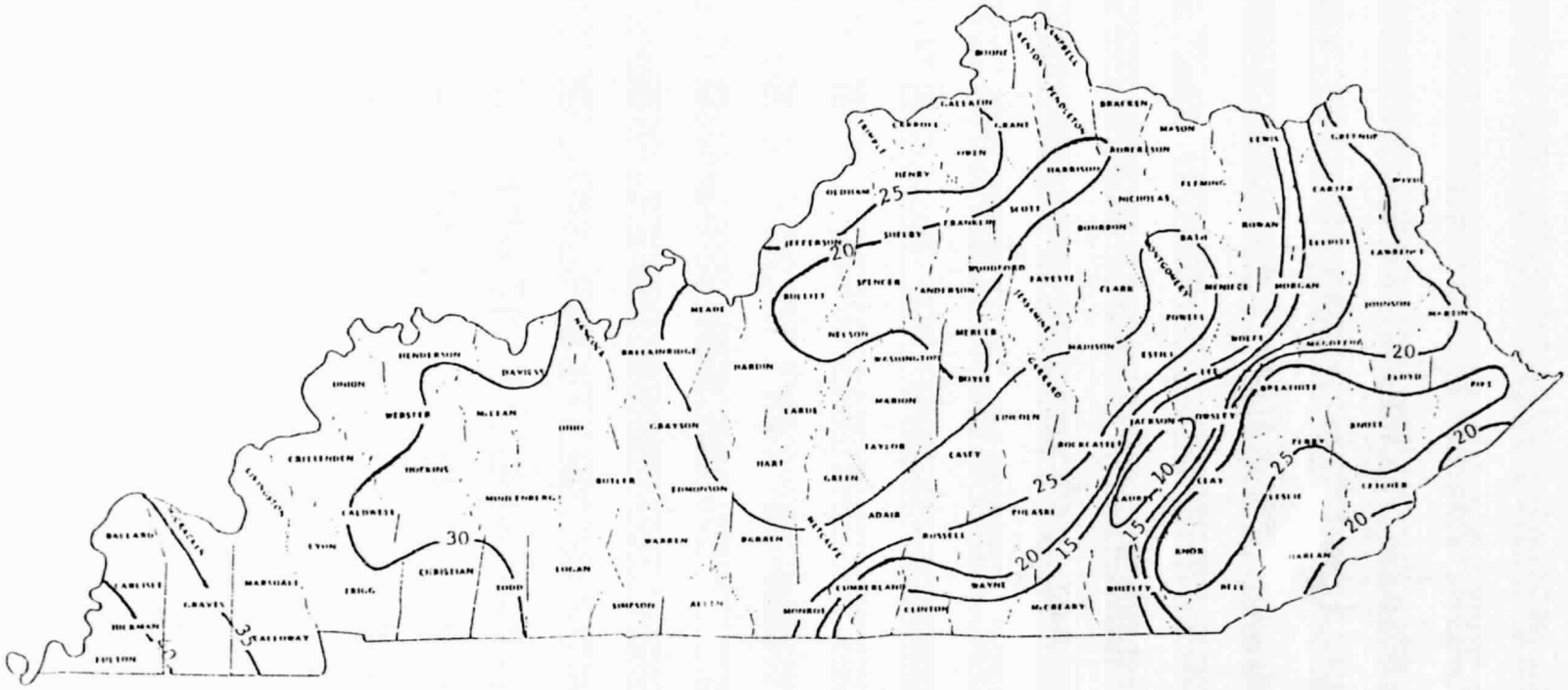
SOURCE: ATLAS OF KENTUCKY

Figure D-8. Annual Average Precipitation



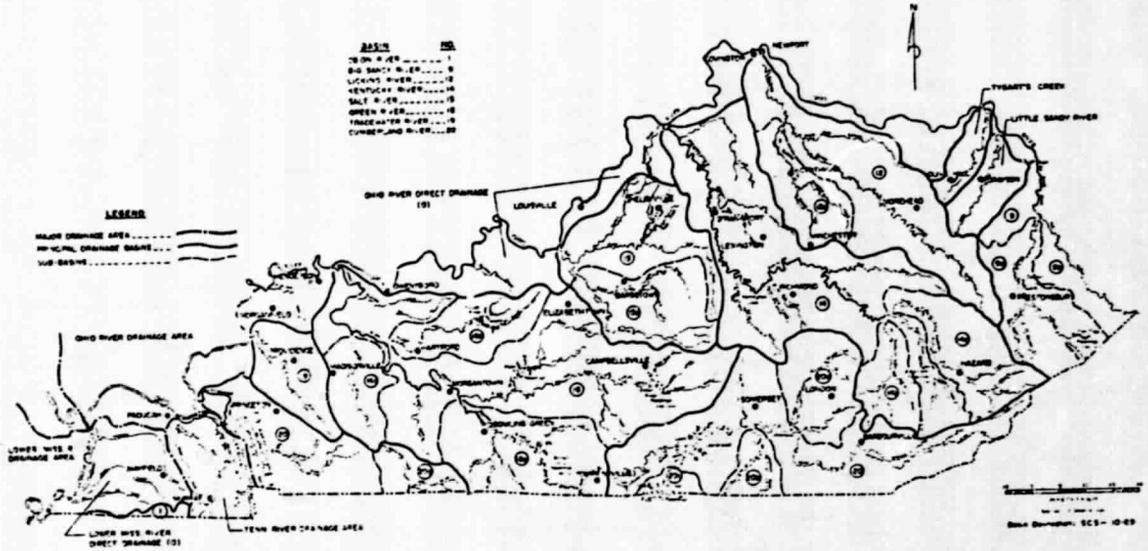
SOURCE: HYDROMETEOROLOGICAL REPORT NO. 51

Figure D-9. All-Season Probable Maximum Precipitation (in.) for 72 hr. 10 mi^2 (26 km^2)



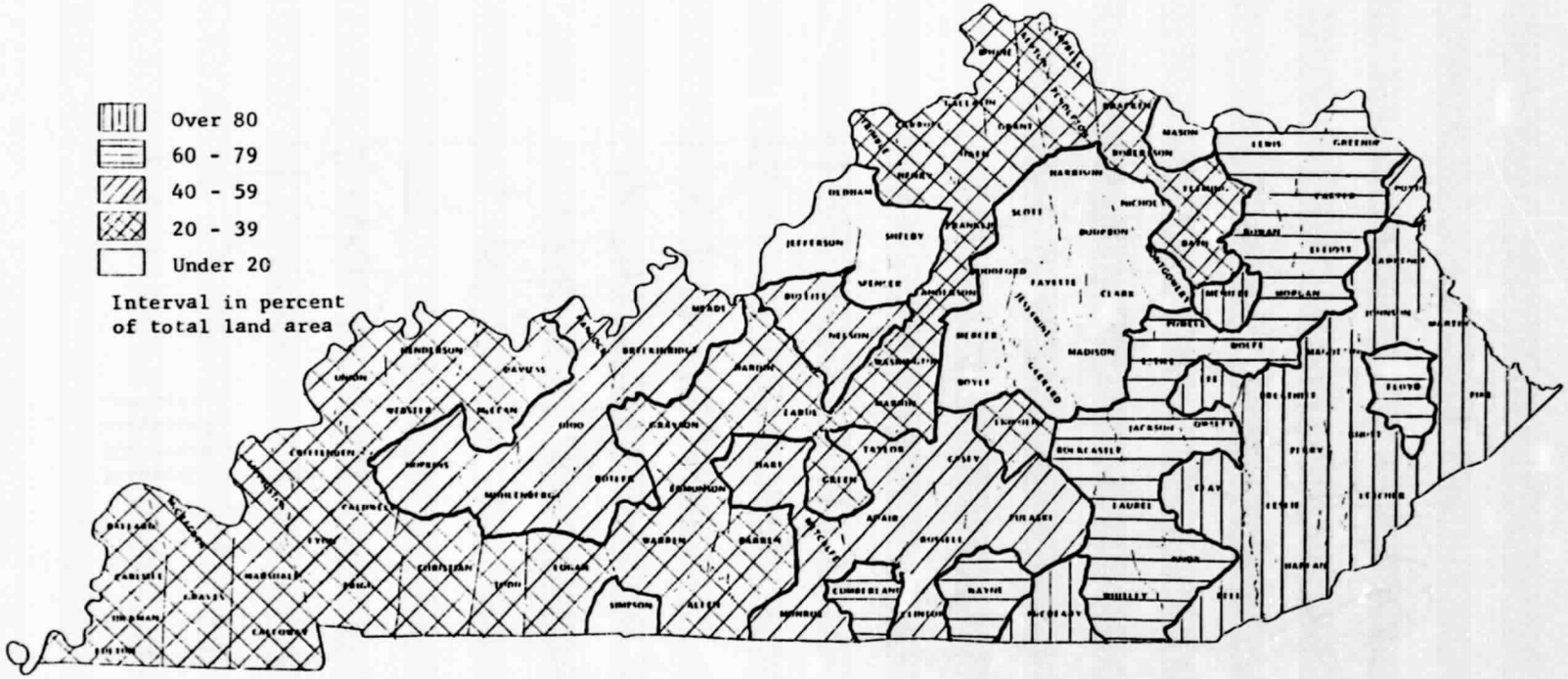
SOURCE: ATLAS OF KENTUCKY

Figure D-10. Rainfall Variability (Percent of Variability)



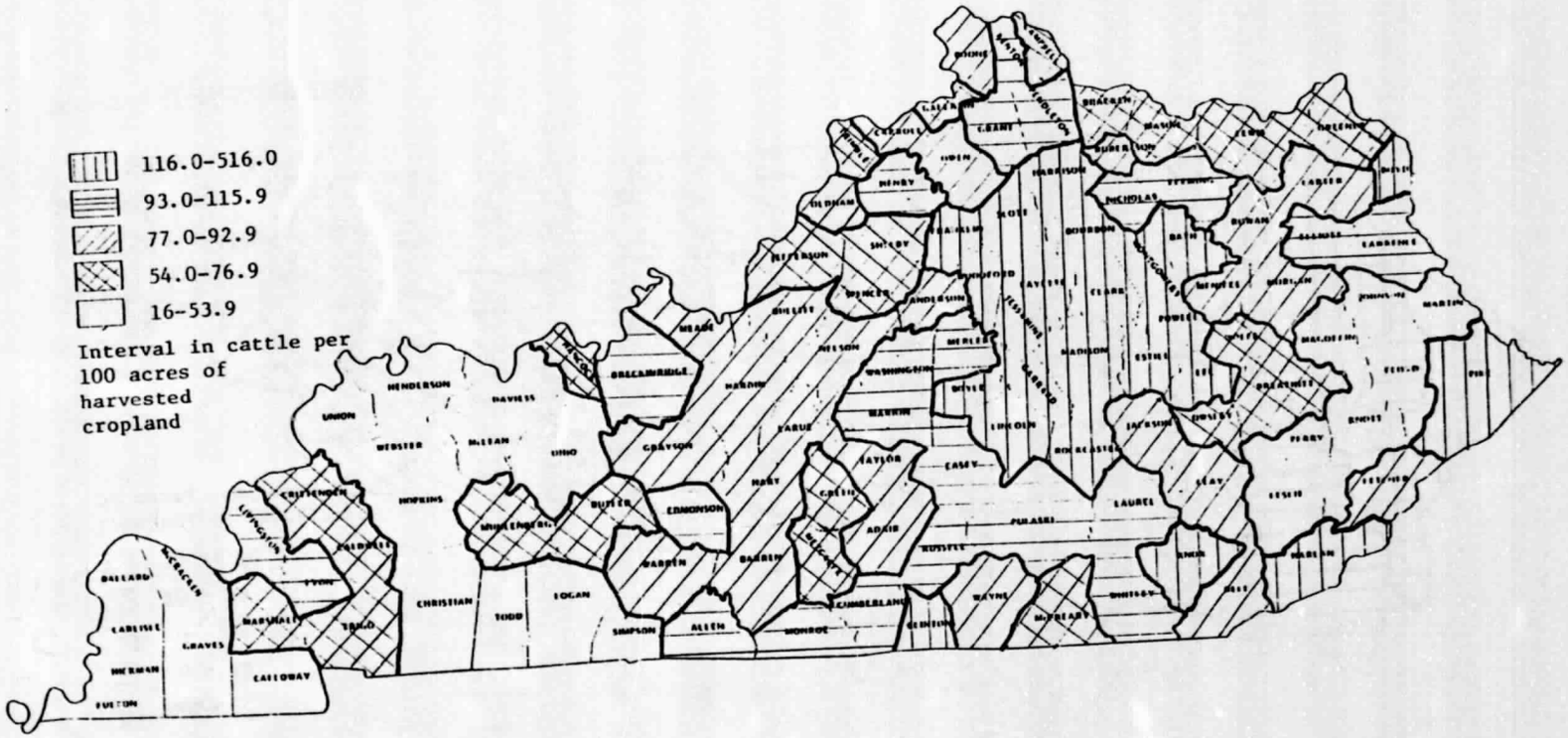
SOURCE: KENTUCKY SOIL AND WATER CONSERVATION NEEDS INVENTORY

Figure D-11. Major, Principal, and Sub-Basin Delineation



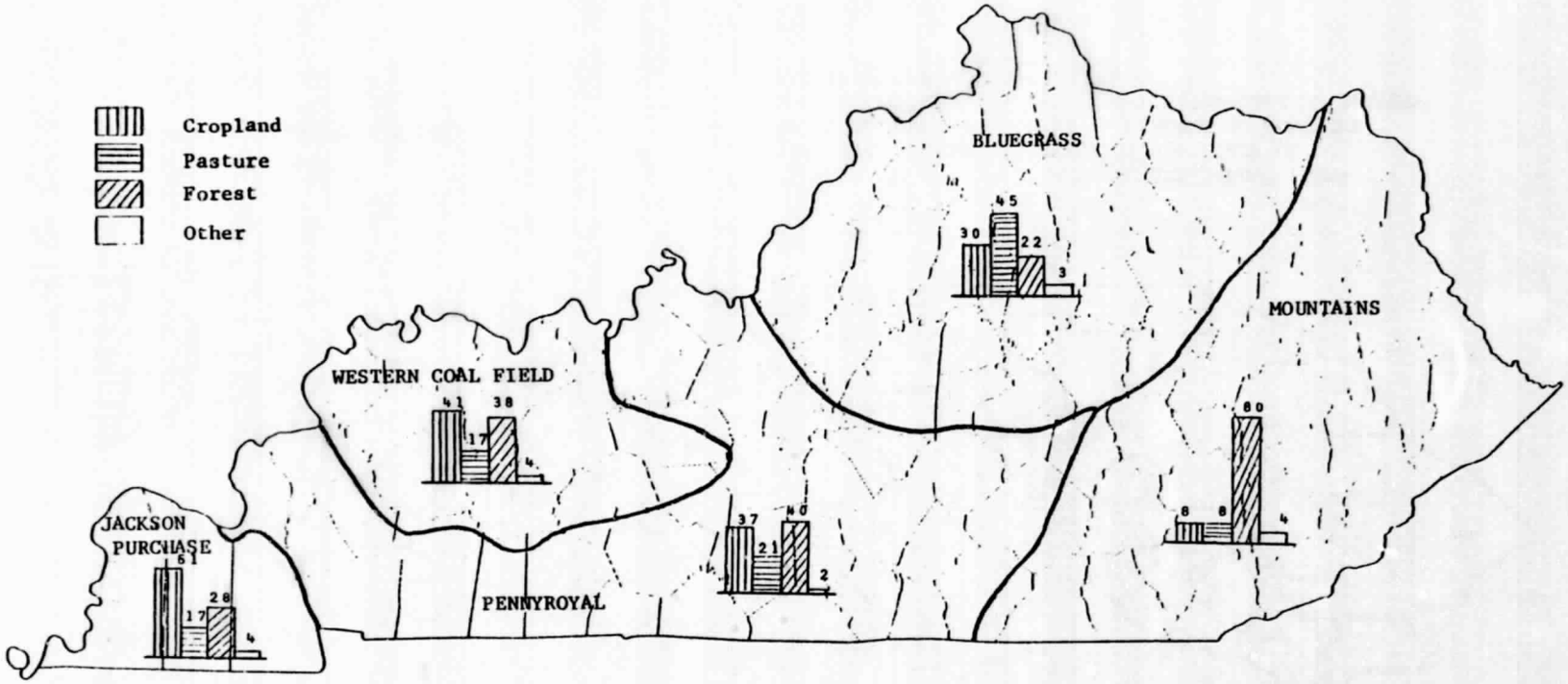
SOURCE: ATLAS OF KENTUCKY

Figure D-12. Land in Commercial Forest



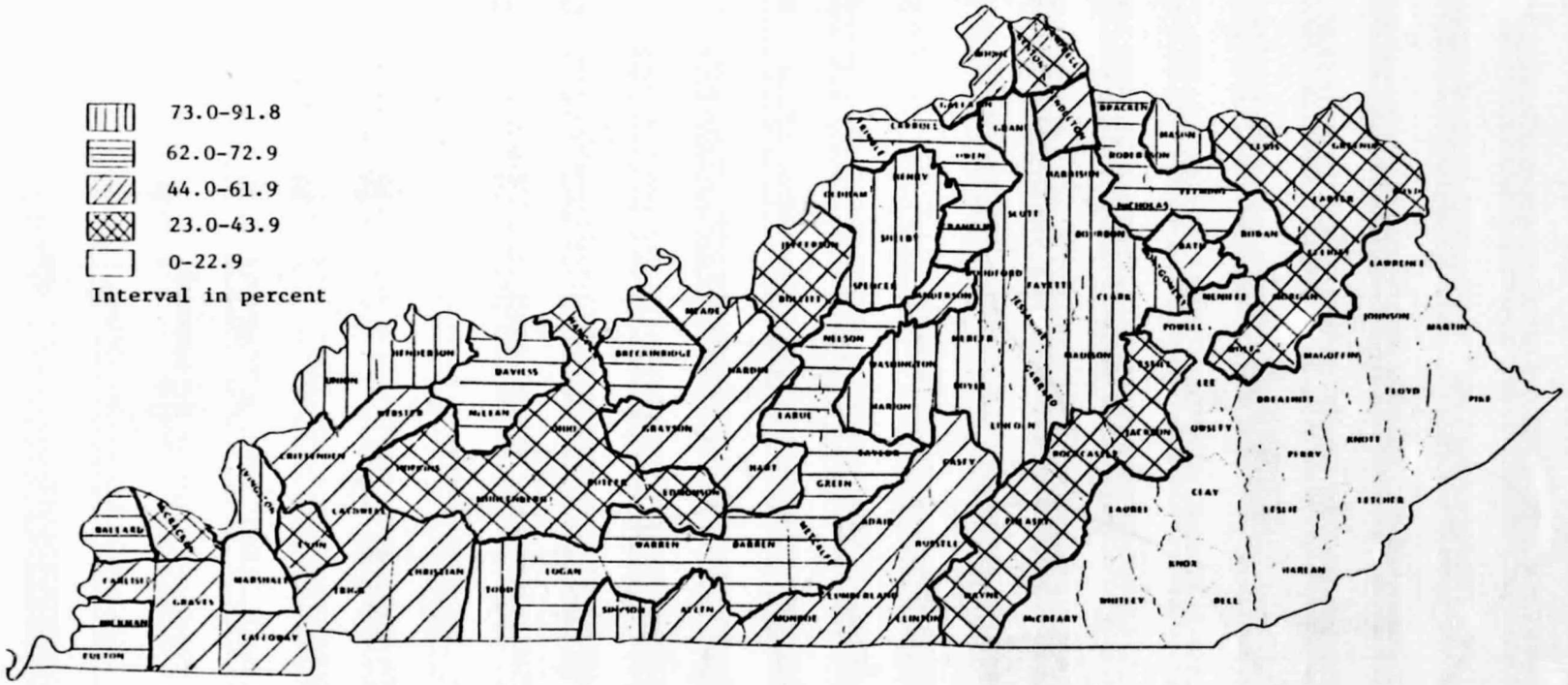
SOURCE: ATLAS OF KENTUCKY

Figure D-13. Cattle and Calves



SOURCE: ATLAS OF KENTUCKY

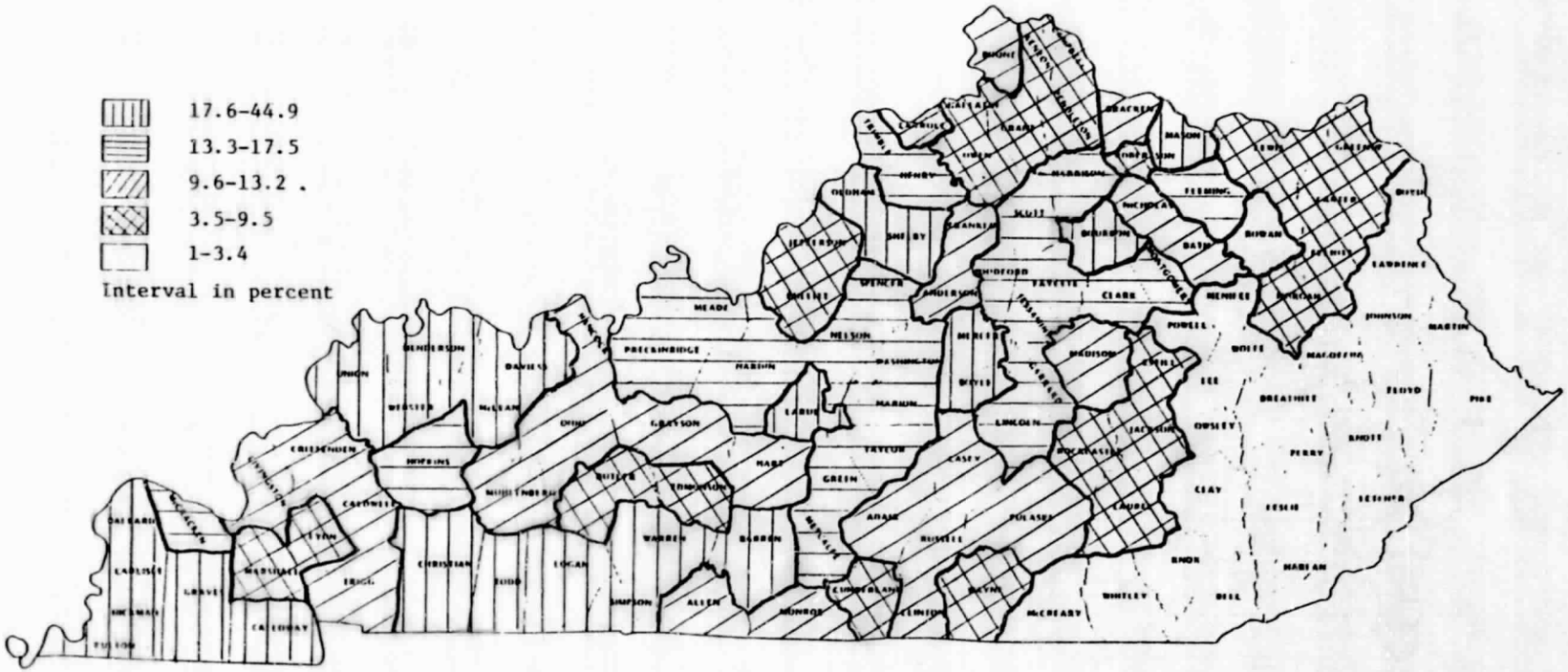
Figure D-14. Land Use Within Physiographic Regions



SOURCE: ATLAS OF KENTUCKY

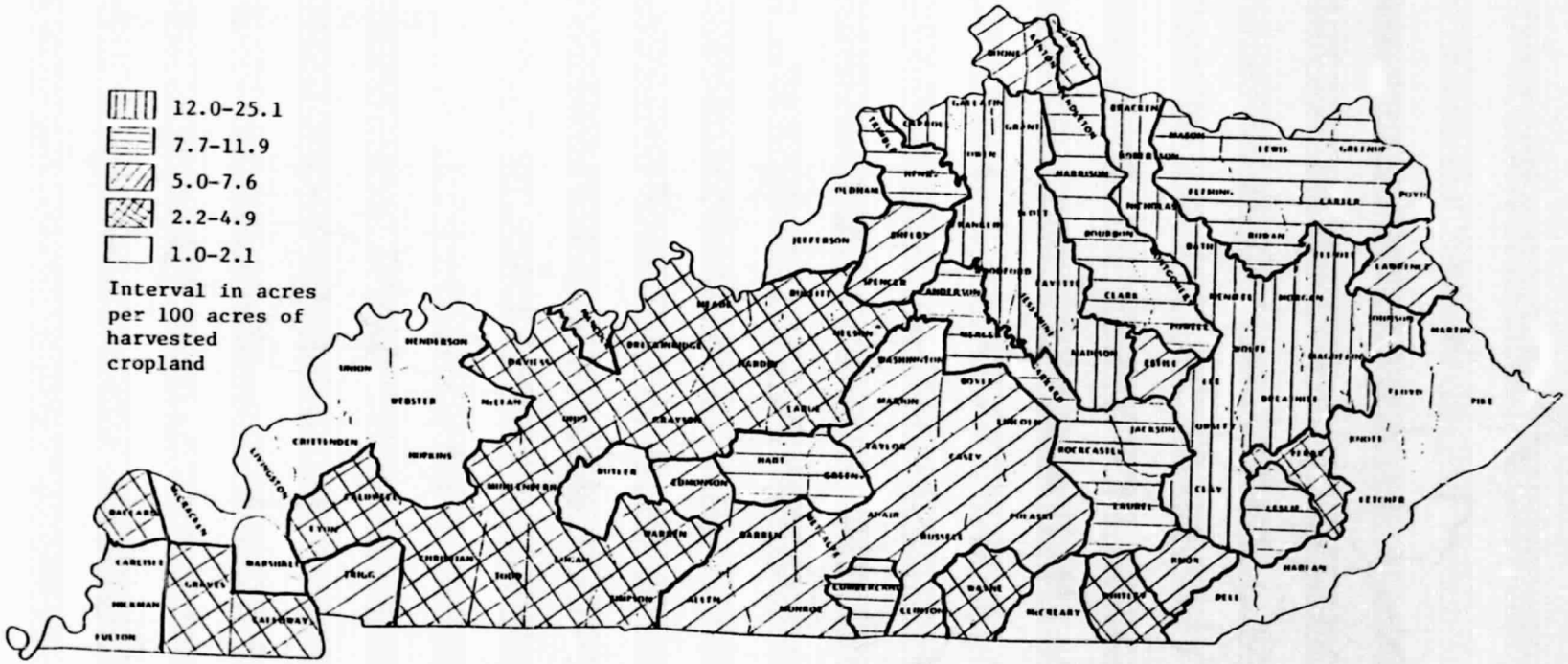
* FARMS IN CLASSES 1 TO 5 (MAP 92) ARE "REAL" FARMS IN THAT THEY PRODUCE AT LEAST $2,500 WORTH OF COMMODITIES ANNUALLY. ONLY 48 PERCENT OF KENTUCKY'S FARMS ARE IN THESE CLASSES, YET THEY PRODUCE 90 PERCENT OF ALL FARM PRODUCTS SOLD.

Figure D-15. Farmland in Class 1-5 Farms*



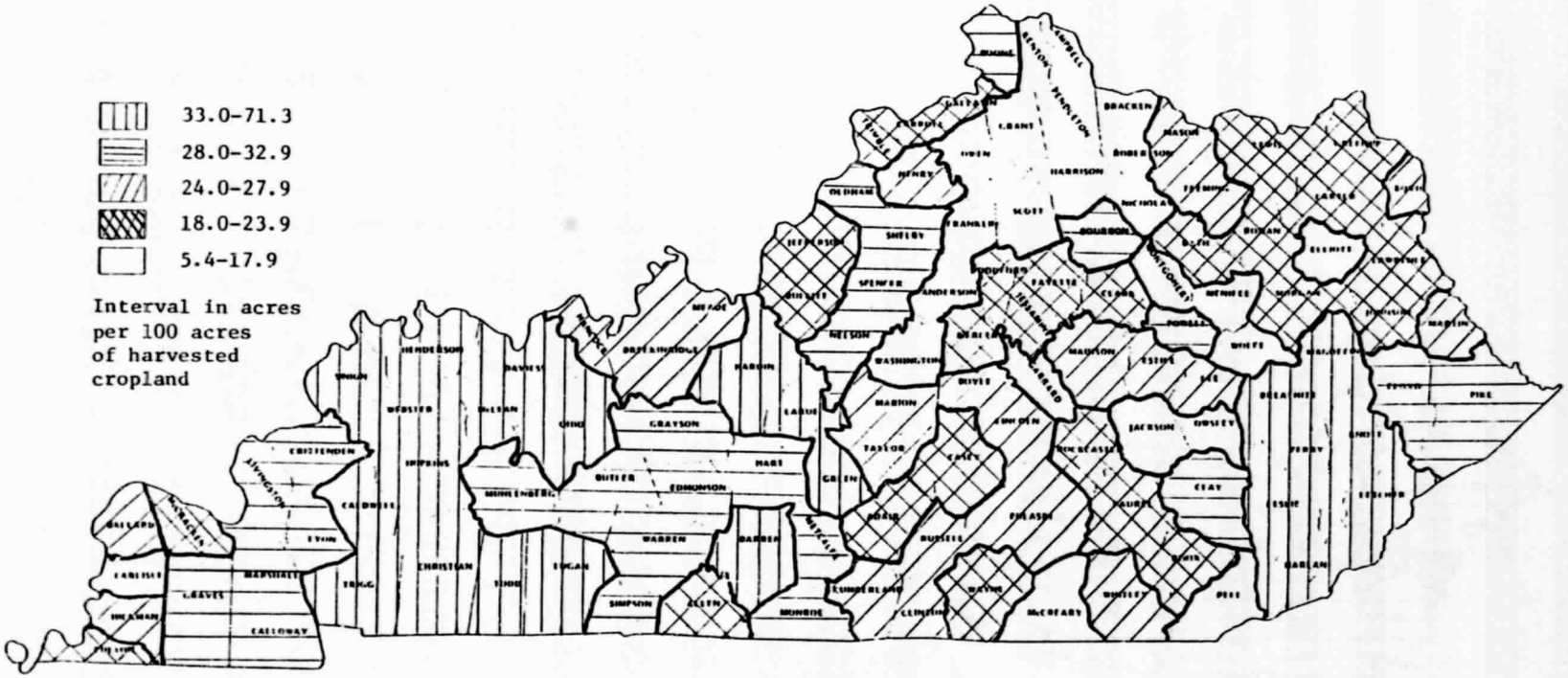
SOURCE: ATLAS OF KENTUCKY

Figure D-16. Total Land Area in Harvested Cropland



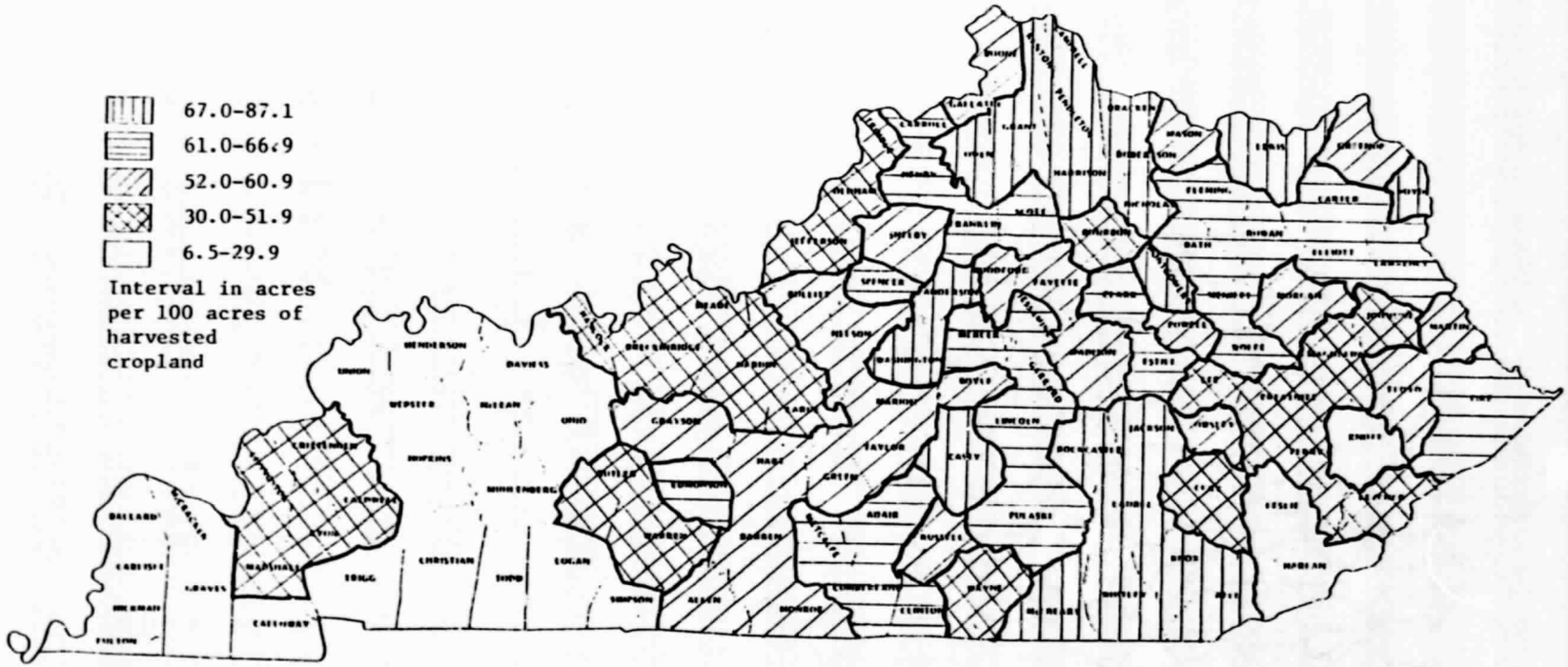
SOURCE: ATLAS OF KENTUCKY

Figure D-17. Tobacco



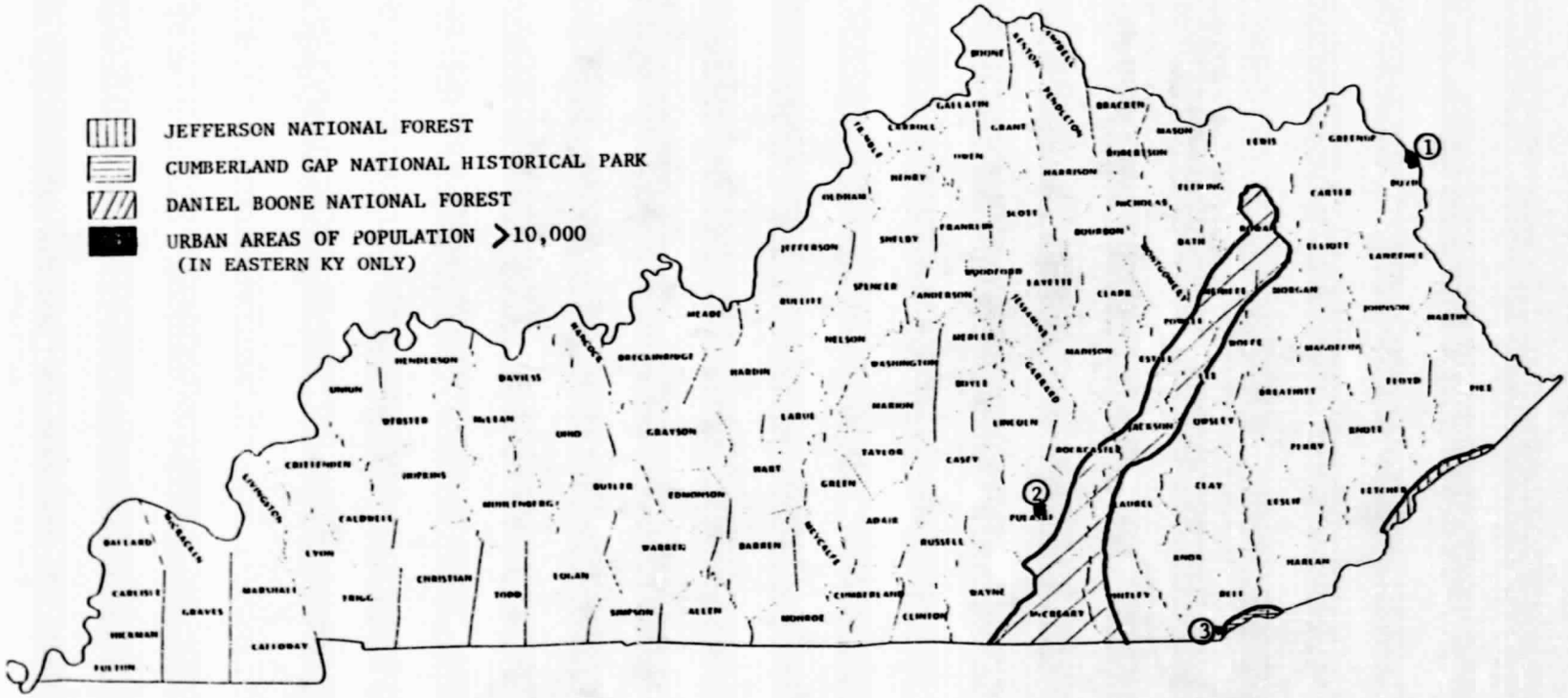
SOURCE: ATLAS OF KENTUCKY

Figure D-18. Corn



SOURCE: ATLAS OF KENTUCKY

Figure 19. Hay



1. ASHLAND
2. SOMERSET
3. MIDDLESBORO

SOURCE: "State of Kentucky" map, U.S. Dept. of the Interior, Geological Survey

Figure D-20. National Parks and Forests

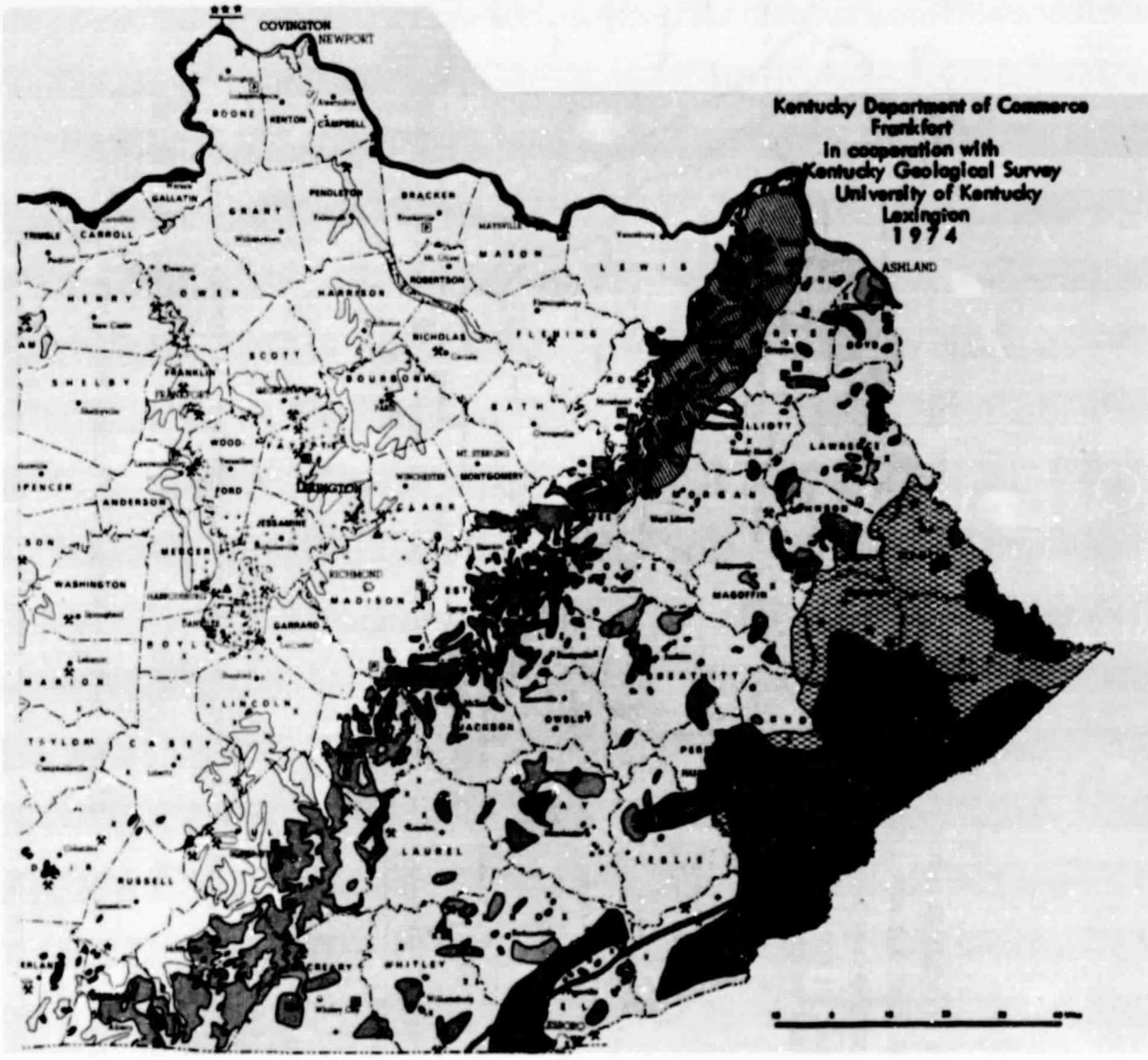
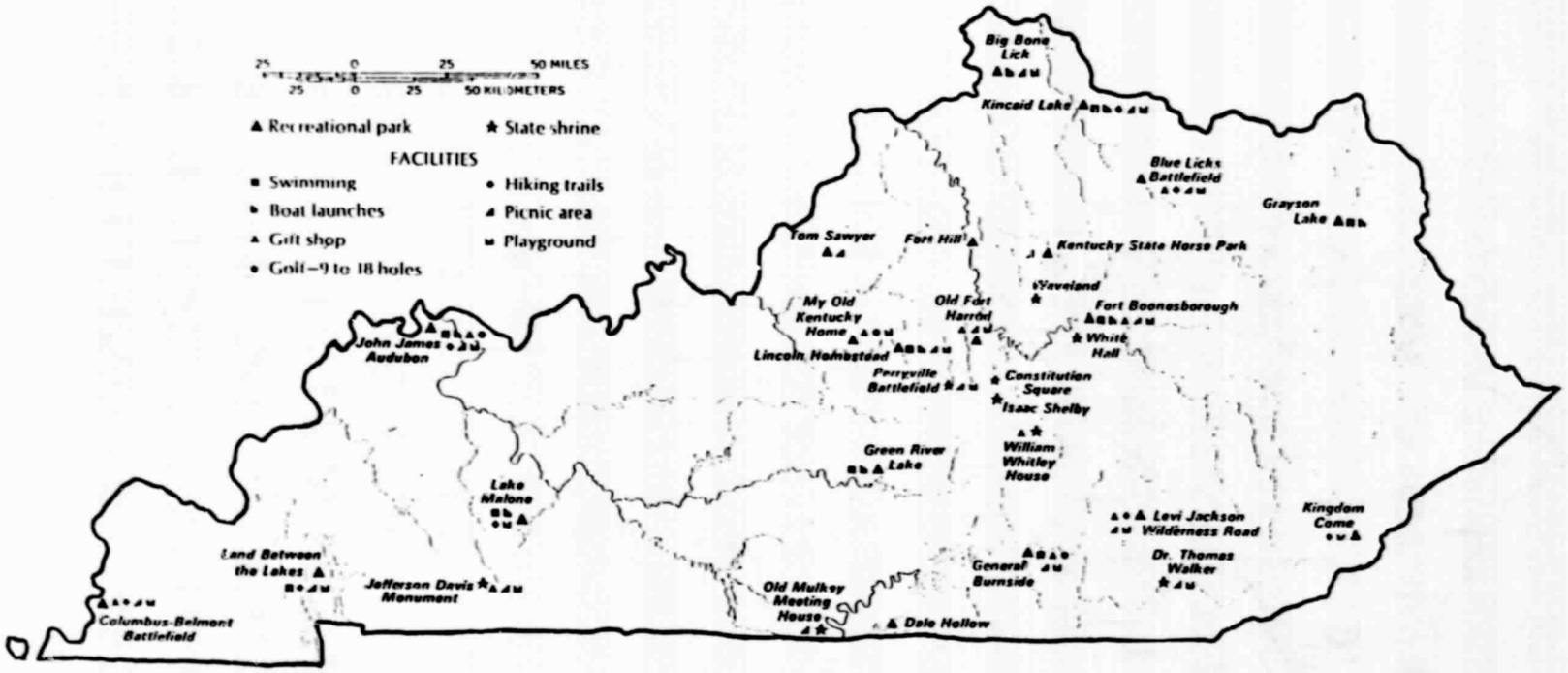


Figure D-21. Mineral Resources and Mineral Industries of Kentucky



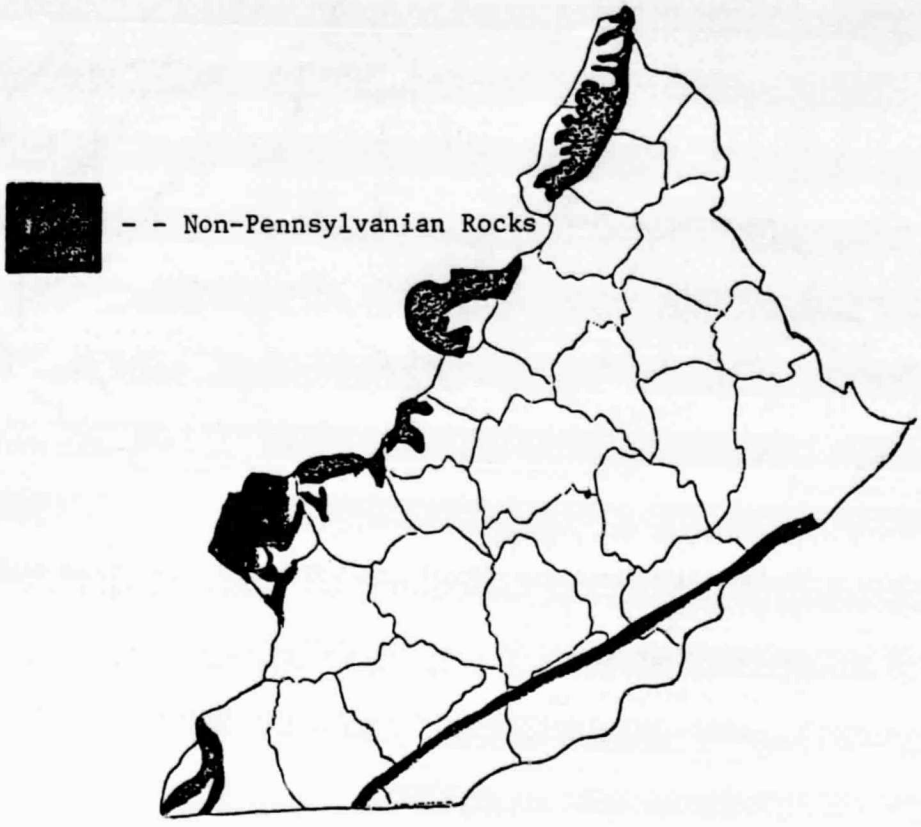
SOURCE: ATLAS OF KENTUCKY

Figure D-22. Recreational Parks and State Shrines

1. General Burnside
2. Cumberland Falls
3. Dr. Thomas Walker
4. Pine Mountain
5. Cumberland Gap
6. Levi Jackson
7. Kingdom Come
8. Buckhorn
9. Natural Bridge
10. Jenny Wiley
11. Grayson Lake
12. Carter Caves
13. Greenbo Lake

SOURCE: ATLAS OF KENTUCKY

Figure D-23. Parks and Shrines



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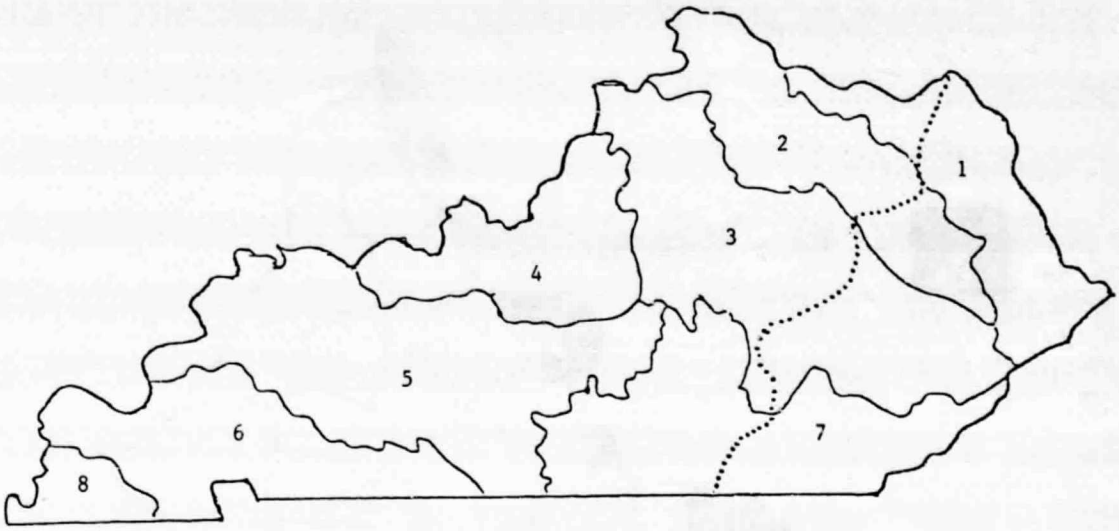
OF POOR QUALITY

Figure D-24. Distribution of Non-Pennsylvanian Rocks in the Eastern Coal Field Region of Kentucky (After Map 68 in Atlas of Kentucky)



1. Big Sandy River Basin
2. Licking River Basin
3. Kentucky River Basin
4. Salt River Basin
5. Green River Basin
6. Lower Cumberland and Tennessee River Basin
7. Upper Cumberland River Basin
8. Mississippi River Basin

Western Limit of the Eastern Coal Field Region

Figure D-25. River Basins in Kentucky (After Water Resources Development by the U.S. Army Corps of Engineers in Kentucky)

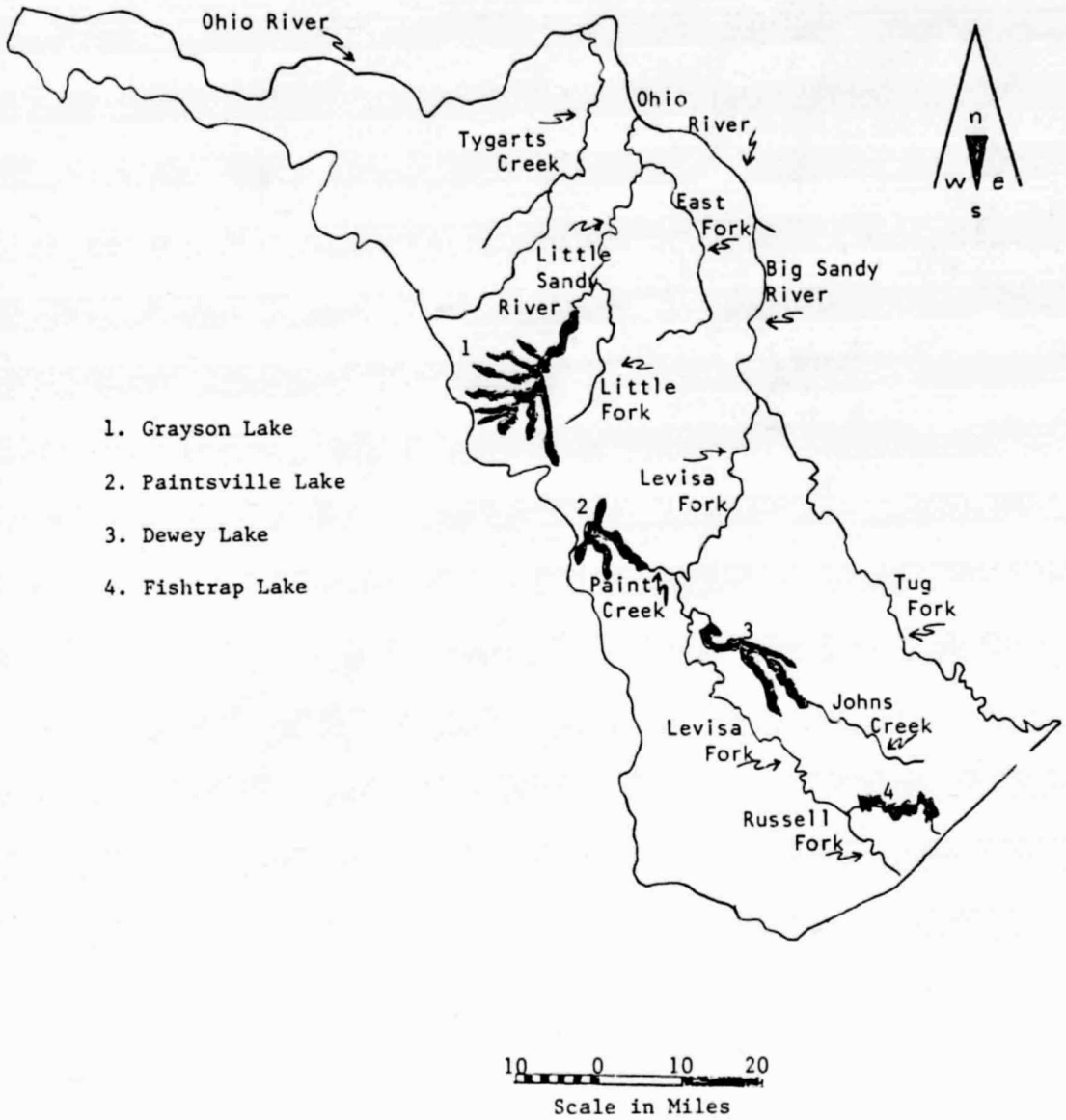


Figure D-26. Big Sandy River Basin (After Water Resources Development by the U.S. Army Corps of Engineers in Kentucky)

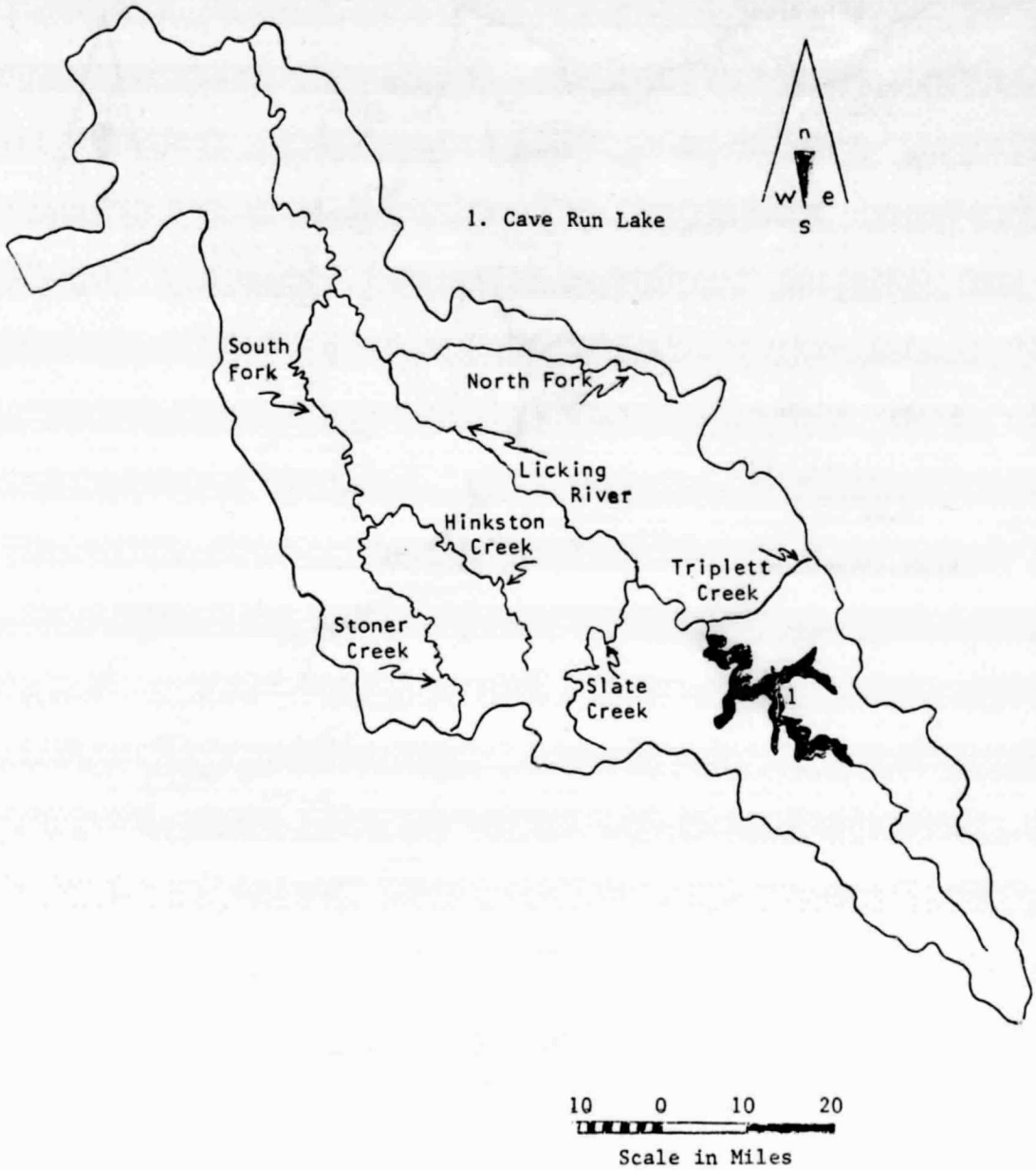


Figure D-27. Licking River Basin (After Water Resources Development by the U.S. Army Corps of Engineers in Kentucky)

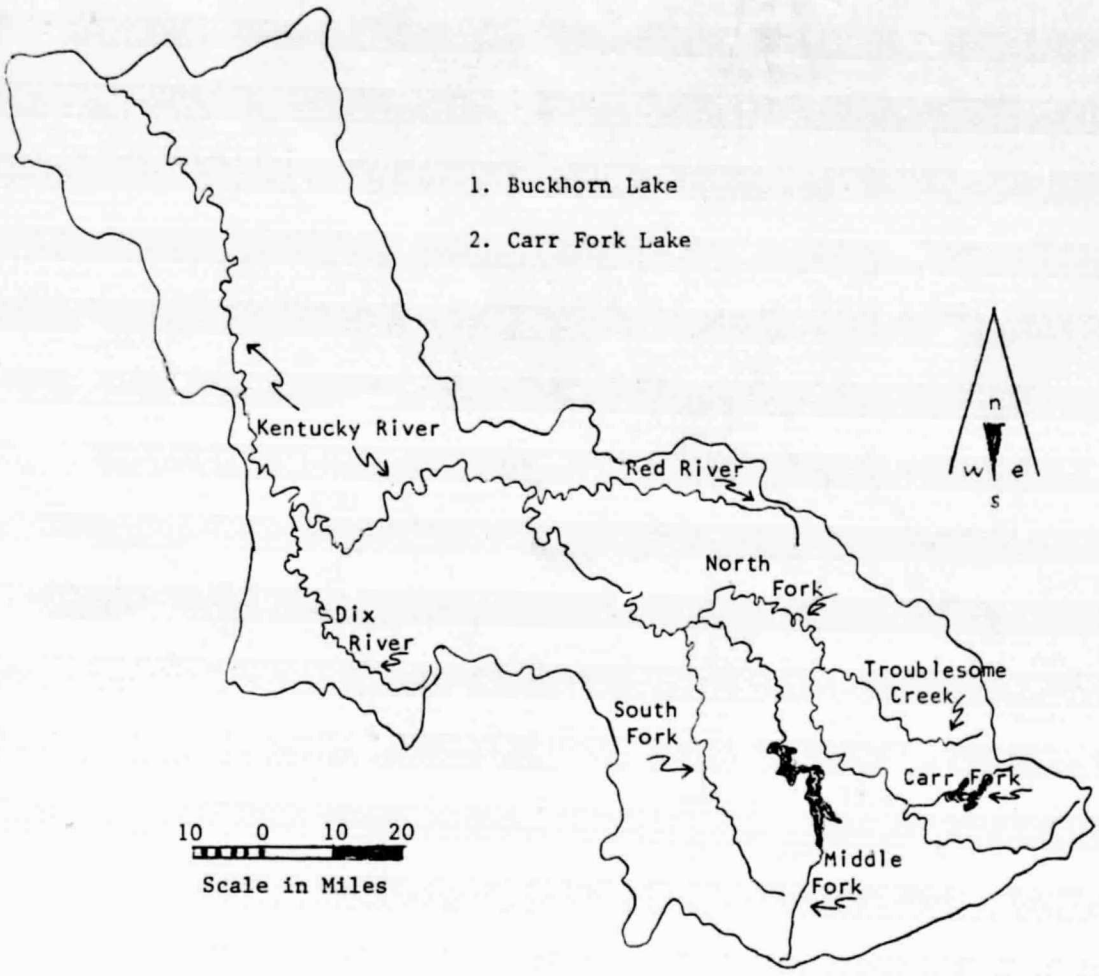
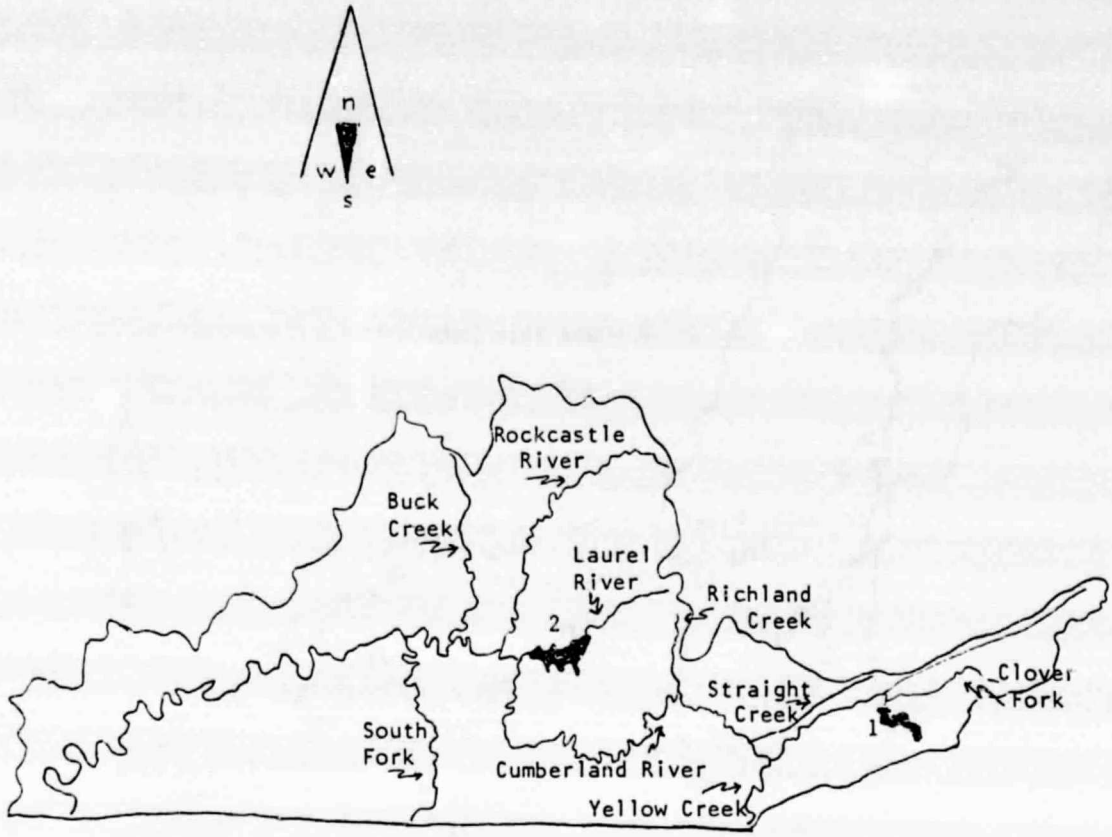


Figure D-28. Kentucky River Basin (After Water Resources Development by the U.S. Army Corps of Engineers in Kentucky)

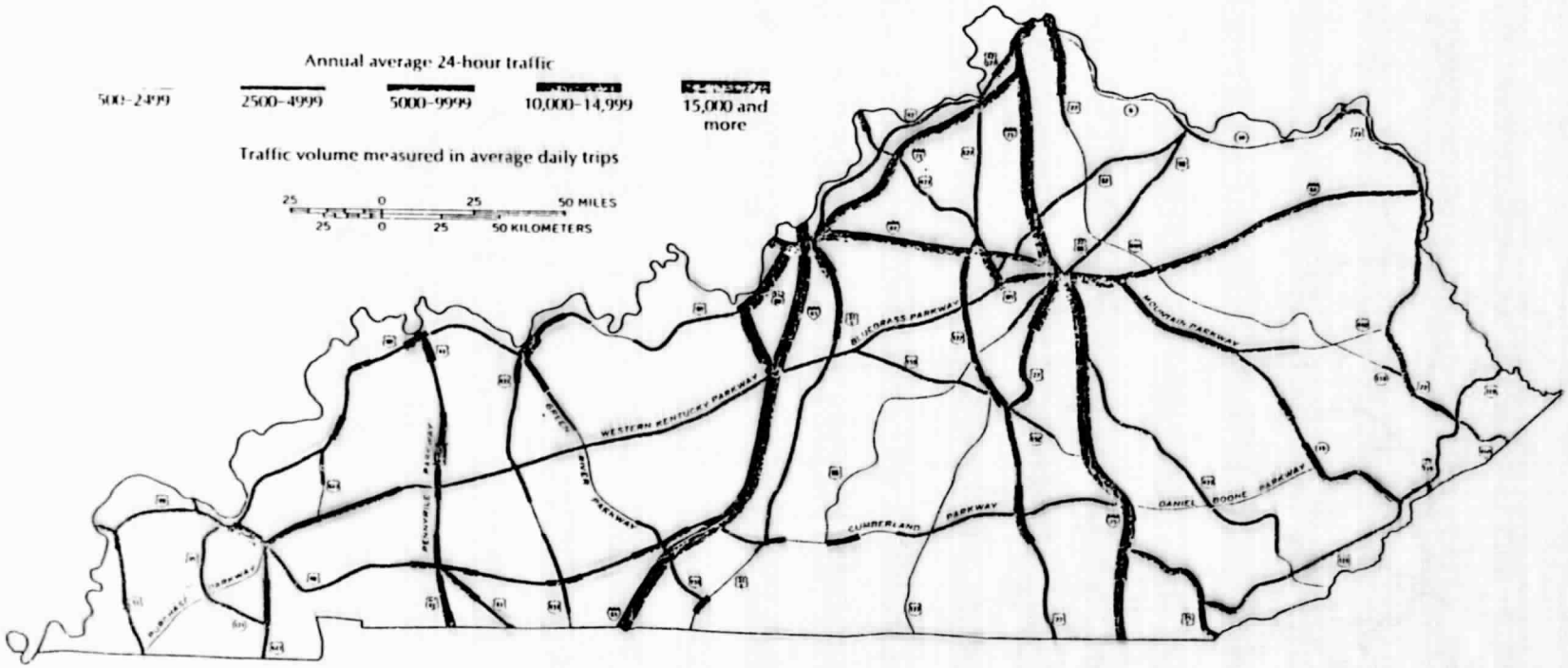


1. Martins Fork Lake

2. Laurel River Lake

10 0 10 20
Scale in Miles

Figure D-29. Upper Cumberland River Basin (After Water Resources Development by the U.S. Army Corps of Engineers in Kentucky)

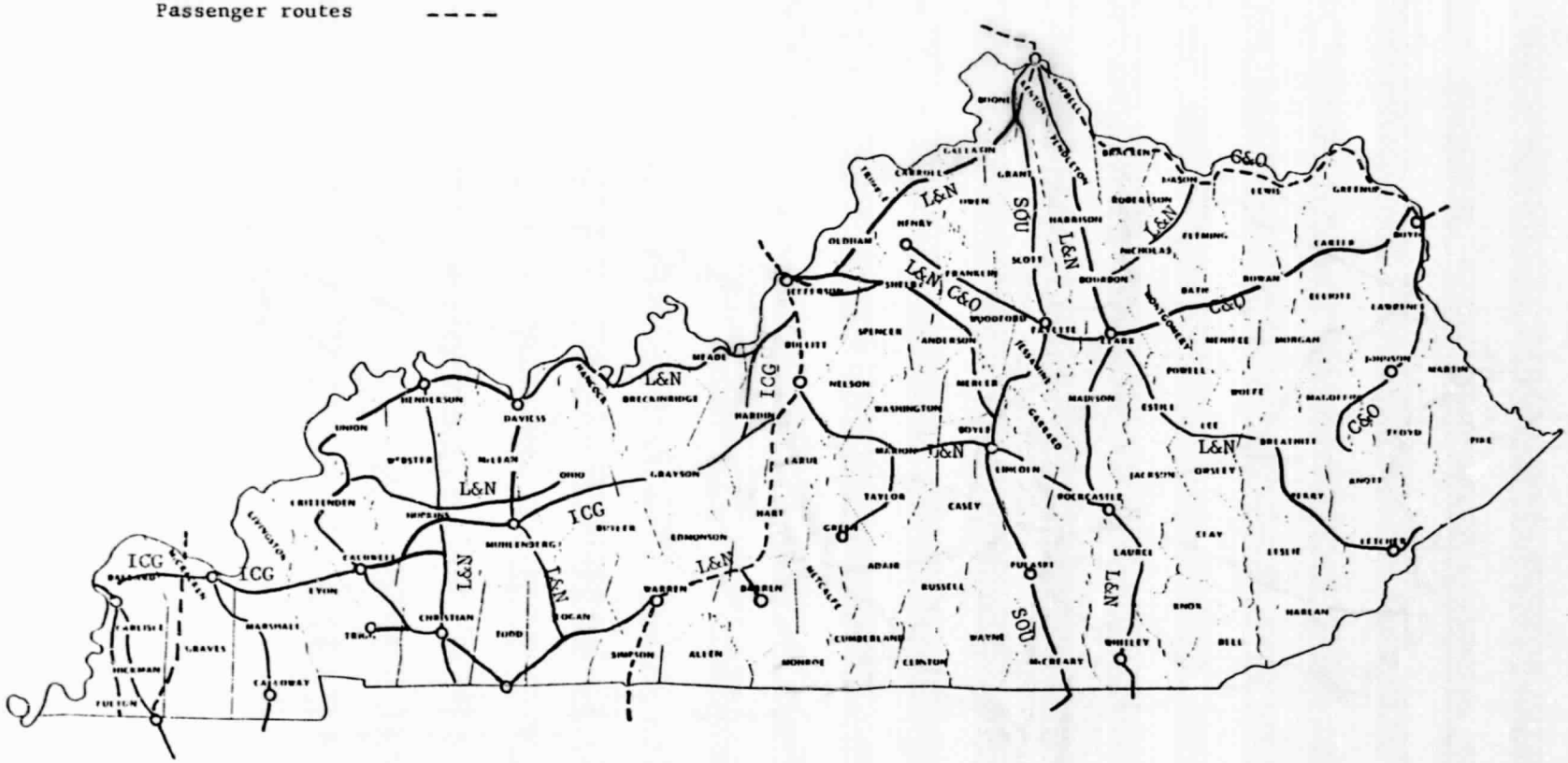


SOURCE: ATLAS OF KENTUCKY

Figure D-30. Highway Traffic Flow

Major freight routes ———

Passenger routes - - - -

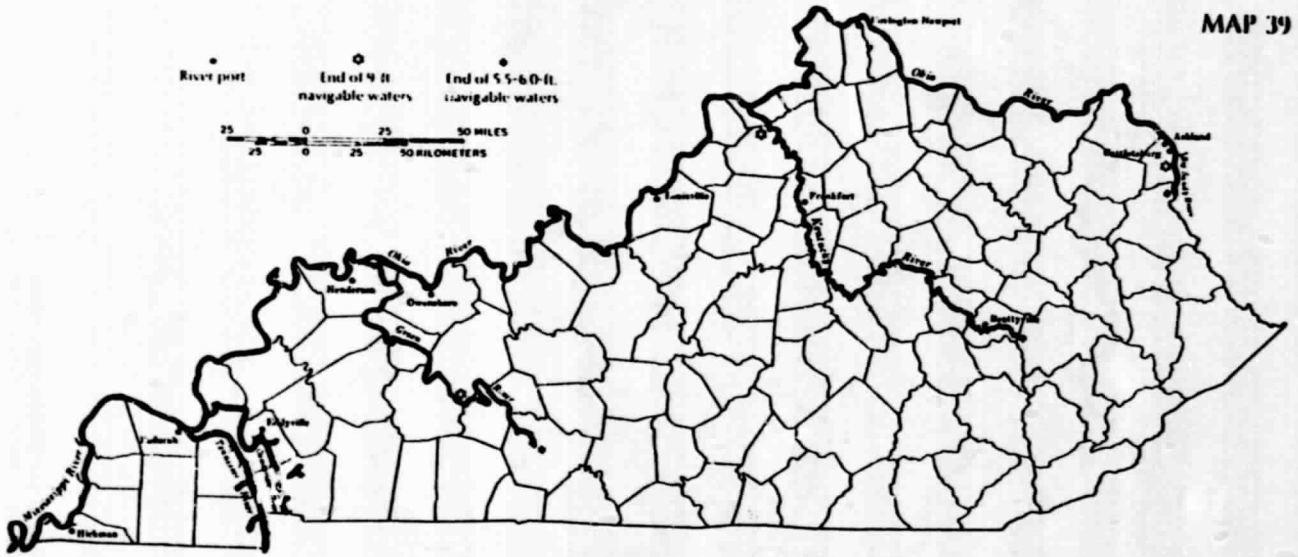


SOURCE: ATLAS OF KENTUCKY

Figure D-31. Major Rail Routes

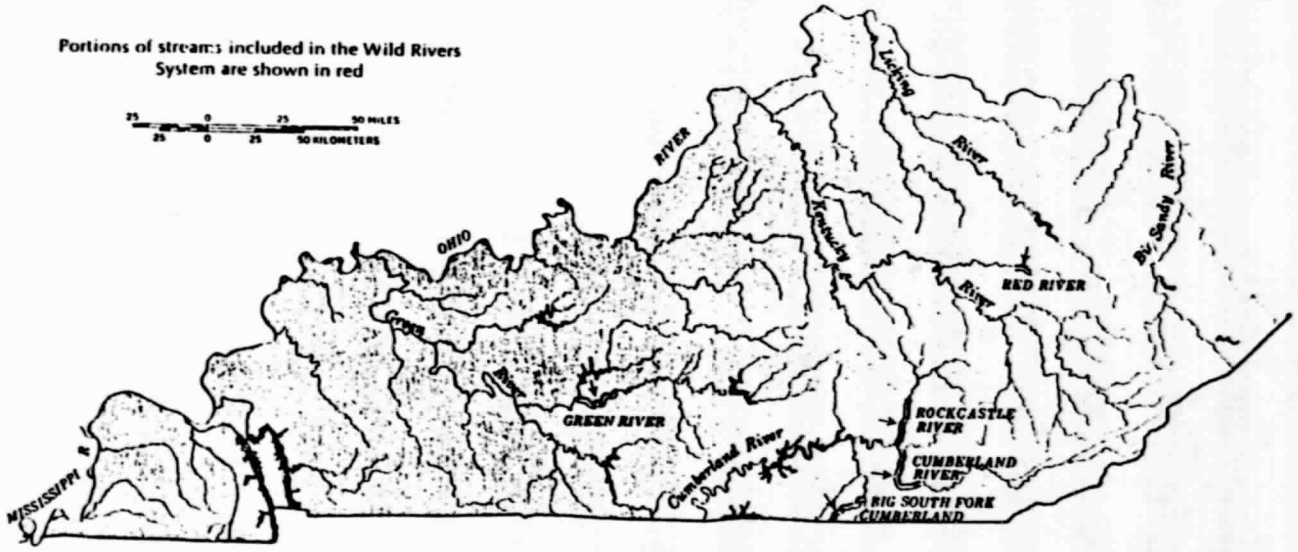
SOURCE: INTERSTATE COMMERCE COMMISSION, 1978

Figure D-32. Railroads of Eastern Kentucky



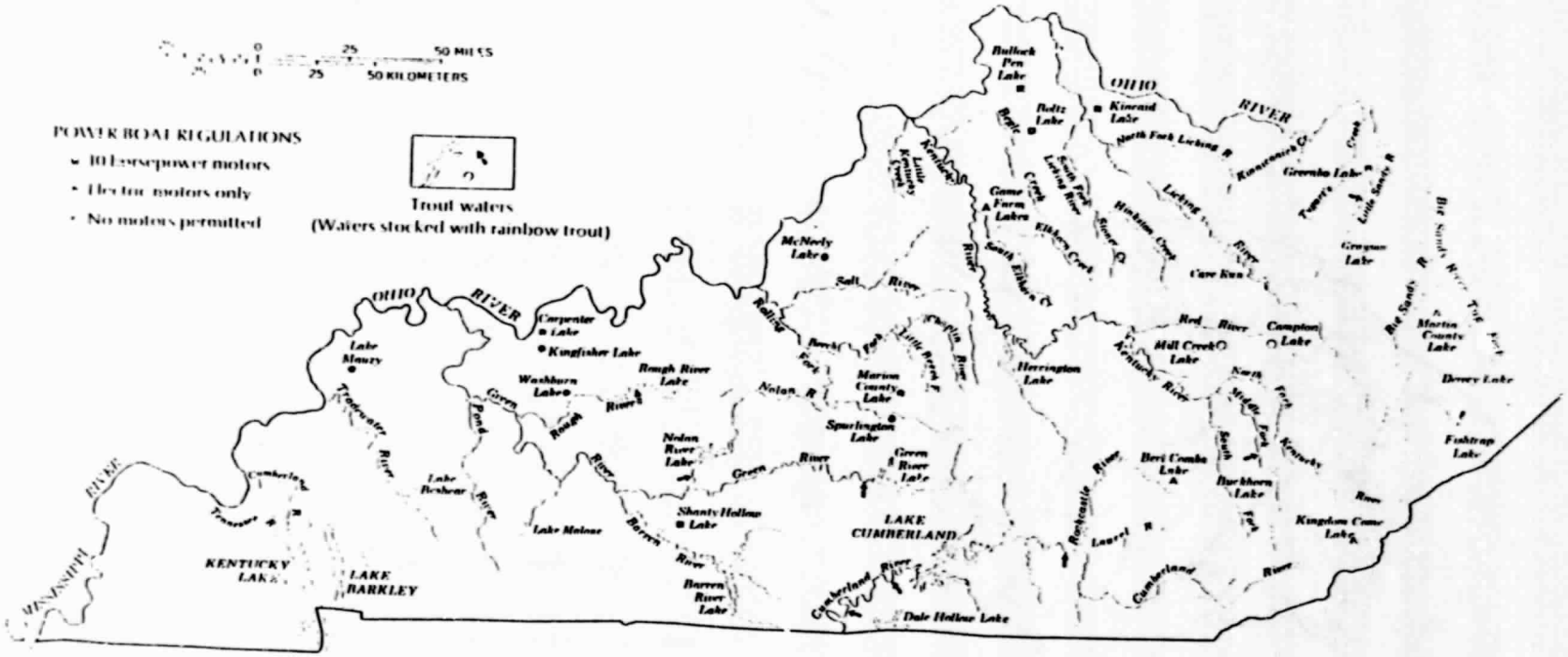
SOURCE: ATLAS OF KENTUCKY

Figure D-33. Navigable Waterways



SOURCE: ATLAS OF KENTUCKY

Figure D-34. Wild Rivers



SOURCE: ATLAS OF KENTUCKY

Figure D-35. Fishing Waters

Table D-1. Climatic Characteristics in Eastern Kentucky

ASHLAND, KY 1951 - 1974 38° 27' N 82° 36' W 555 FT.

MONTH	TEMPERATURE (°F) MEANS: DAILY MAXIMUM	DAILY MINIMUM	MONTHLY	EXTREMES: RECORD HIGHEST	YEAR	DAY	RECORD LOWEST	YEAR	DAY	MEAN NUMBER OF DAYS MAX.: 90° AND ABOVE	32° AND BELOW	MIN.: 32° AND BELOW	0° AND BELOW	PRECIPITATION TOTALS (INCHES): MEAN	GREATEST MONTHLY	YEAR	GREATEST DAILY	YEAR	DAY	SNOW, SLEET: MEAN	MAXIMUM MONTHLY	YEAR	GREATEST DEPTH	YEAR	DAY	MEAN NUMBER OF DAYS: 1.0 or MORE	5.0 or MORE	1.00 or MORE
JAN	43.5	29.2	33.4	79	52	1	-15+	63	29	0	6	24	1	3.13	6.22	51	1.71	74	11	4.6	12.0	61	9.0	66	24	7	2	0
FEB	46.4	24.6	35.5	78	54	15	-6+	70	4	0	4	21	1	3.00	8.24	56	2.02	56	18	3.6	12.9	60	9.0	60	14	7	2	0
MAR	55.6	32.0	43.9	88	73	15	6	64	1	0	1	17	0	4.02	7.64	63	2.25	63	12	2.3	11.3	60	7.0	71	4	8	2	1
APR	68.4	41.4	55.0	92	60	24	19	64	1	0	0	7	0	3.64	7.04	72	2.11	72	22	.1	.6	61	1.0	61	1	8	3	1
MAY	77.1	50.3	63.7	94+	62	18	28+	71	4	2	0	1	0	4.18	7.24	67	3.21	55	14	.0						9	2	1
JUN	84.0	58.7	71.3	98+	66	29	36+	72	11	7	0	0	0	3.69	8.49	62	4.09	62	12	.0						7	2	1
JULY	87.0	63.0	75.1	105	54	14	45	62	27	10	0	0	0	4.61	11.03	61	5.61	73	20	.0						8	3	1
AUG	85.9	61.6	73.8	101	64	4	41	65	31	9	0	0	0	3.54	7.22	68	2.53	54	3	.0						6	2	1
SEPT	80.7	55.3	68.1	101+	53	3	27+	74	24	5	0	0	0	2.89	5.76	57	2.72	54	20	.0						5	2	1
OCT	70.1	42.9	56.5	92	51	4	16	74	21	0	0	5	0	2.06	4.78	70	1.48	65	22	.0						5	1	0
NOV	56.6	33.1	44.9	85	61	4	9+	64	23	0	0	15	0	2.92	5.98	73	2.35	57	19	1.2	6.0	63	5.0	63	29	6	2	0
DEC	46.5	26.5	36.5	79	51	31	-6	62	12	0	4	22	0	3.09	6.43	51	2.03	70	22	2.4	8.0	67	6.0	69	27	7	2	1
YEAR	66.8	42.7	54.8	105	54	JUL 14	-15+	63	JAN 29	32	19	112	2	40.77	11.03	JUL 61	5.61	JUL 73	20	14.2	12.9	FEB 60	9.0	FEB 60	14	83	28	6

FARMERS 1 WNW, KY 1951 - 1974 38° 09' N 83° 33' W 662 FT.

MONTH	TEMPERATURE (°F) MEANS: DAILY MAXIMUM	DAILY MINIMUM	MONTHLY	EXTREMES: RECORD HIGHEST	YEAR	DAY	RECORD LOWEST	YEAR	DAY	MEAN NUMBER OF DAYS MAX.: 90° AND ABOVE	32° AND BELOW	MIN.: 32° AND BELOW	0° AND BELOW	PRECIPITATION TOTALS (INCHES): MEAN	GREATEST MONTHLY	YEAR	GREATEST DAILY	YEAR	DAY	SNOW, SLEET: MEAN	MAXIMUM MONTHLY	YEAR	GREATEST DEPTH	YEAR	DAY	MEAN NUMBER OF DAYS: 1.0 or MORE	5.0 or MORE	1.00 or MORE
JAN	45.1	25.6	34.4	79	52	1	-28	63	28	0	5	23	2	3.35	6.90	51	1.72	74	11	6.0	14.5	66	9.0	66	1	8	2	1
FEB	48.5	25.2	36.9	77	72	29	-13+	63	22	0	3	20	1	3.44	8.94	56	2.40	51	1	5.0	25.5	60	12.0	60	14	7	2	1
MAR	57.4	33.0	45.2	85	73	14	-9	60	6	0	1	16	0	4.48	8.46	63	2.79	55	3	2.2	17.8	60	8.0	60	12	9	3	1
APR	69.8	42.3	56.1	90	56	27	16	64	1	0	0	7	0	4.02	8.74	72	2.95	72	22	.1	1.2	61	1.0	61	1	8	3	1
MAY	77.9	50.4	64.2	94	62	18	23	66	10	1	0	1	0	4.44	7.13	68	2.45	73	23	.0						9	3	1
JUN	84.7	58.4	71.5	99	54	26	35	66	1	6	0	0	0	3.76	7.48	56	2.58	60	23	.0						7	2	1
JULY	87.3	62.6	75.0	105	54	14	45	62	27	10	0	0	0	4.95	10.00	65	3.80	65	23	.0						8	3	2
AUG	86.4	61.1	73.8	101	53	31	41	65	29	9	0	0	0	4.16	9.02	74	4.18	72	4	.0						6	3	1
SEPT	81.4	54.5	68.0	102	54	5	32	62	21	4	0	0	0	3.25	5.63	70	1.96	71	3	.0						6	2	1
OCT	71.2	42.5	56.9	94	53	1	13	62	27	0	0	6	0	2.06	3.57	60	1.57	55	8	.0						5	1	0
NOV	57.6	33.0	45.3	84	61	2	5	58	30	0	0	15	0	3.21	6.38	51	2.40	73	28	1.0	4.5	66	3.0	59	28	7	2	1
DEC	48.0	27.0	37.5	74	51	6	-15	62	13	0	2	21	1	3.27	6.80	51	2.28	70	22	2.5	8.2	63	7.0	63	24	7	2	1
YEAR	67.9	42.8	55.4	105	54	JUL 14	-28	63	JAN 28	30	11	109	4	44.49	10.00	JUL 65	4.18	AUG 72	4	10.8	25.5	FEB 60	12.0	FEB 60	14	87	28	12

HEIDELBERG LOCK 14, KY 1951 - 1974 37° 33' N 83° 46' W 663 FT.

MONTH	TEMPERATURE (°F) MEANS: DAILY MAXIMUM	DAILY MINIMUM	MONTHLY	EXTREMES: RECORD HIGHEST	YEAR	DAY	RECORD LOWEST	YEAR	DAY	MEAN NUMBER OF DAYS MAX.: 90° AND ABOVE	32° AND BELOW	MIN.: 32° AND BELOW	0° AND BELOW	PRECIPITATION TOTALS (INCHES): MEAN	GREATEST MONTHLY	YEAR	GREATEST DAILY	YEAR	DAY	SNOW, SLEET: MEAN	MAXIMUM MONTHLY	YEAR	GREATEST DEPTH	YEAR	DAY	MEAN NUMBER OF DAYS: 1.0 or MORE	5.0 or MORE	1.00 or MORE
JAN	46.8	24.1	35.5	77	52	1	-22	63	24	0	4	23	1	3.78	8.59	74	2.76	74	11	4.9	9.5	60	8.0	66	31	8	3	1
FEB	51.4	25.5	37.9	77	72	29	-10	55	13	0	2	20	1	3.80	10.64	56	3.70	62	27	4.5	21.5	60	10.0	60	19	7	3	1
MAR	59.7	32.5	46.2	88	67	14	-9	60	6	0	0	17	0	4.62	9.52	55	2.64	52	23	2.5	22.4	60	12.0	60	12	9	3	1
APR	71.9	41.7	56.8	90+	62	30	18+	62	4	0	0	7	0	4.38	10.86	72	2.85	72	12	.0						8	3	1
MAY	79.3	50.3	64.8	95+	62	19	27+	71	4	2	0	1	0	4.09	8.75	73	3.09	65	19	.0						8	3	1
JUN	85.1	58.6	72.0	100	55	21	33	66	1	7	0	0	0	4.20	10.21	60	4.57	60	12	.0						8	3	1
JULY	87.7	65.3	75.5	105+	52	27	45	68	5	10	0	0	0	5.39	9.68	58	4.15	65	23	.0						9	4	1
AUG	86.5	63.2	74.4	99	53	30	44	65	29	8	0	0	0	3.55	8.95	74	3.15	61	21	.0						6	2	1
SEPT	81.5	55.6	68.6	101+	53	2	32+	63	25	3	0	0	0	3.24	7.77	72	3.04	72	25	.0						6	2	1
OCT	72.1	43.0	57.6	91+	54	4	15	62	27	0	0	5	0	2.00	4.85	70	1.72	55	8	.0						4	1	1
NOV	59.3	33.0	46.2	85	61	3	8	64	22	0	0	16	0	3.49	8.20	73	3.12	57	19	1.1	7.5	66	4.0	66	29	7	2	1
DEC	49.6	27.1	38.4	79	51	31	-15	62	13	0	2	21	0	3.56	6.34	51	2.22	72	9	2.4	12.4	63	8.0	63	7	7	3	1
YEAR	69.2	43.1	56.2	105+	52	JUL 27	-22	63	JAN 24	30	8	110	2	40.10	10.86	APR 72	4.57	JUN 65	12	19.4	22.4	MAR 60	12.0	MAR 60	12	87	32	12

+ ALSO ON EARLIER DATES

ORIGINAL PAGE IS OF POOR QUALITY

SOURCE: CLIMATE OF KENTUCKY

Table D-2. Climatic Statistics
Average Temperature in °F, Precipitation in Inches
Period: 1931-1974

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Average Annual Snowfall (in inches)
Pikeville														
Temp.	38.1	40.2	47.7	58.8	67.1	74.2	77.1	76.3	70.4	59.8	47.7	39.2	58.1	15.6
Prec.	3.38	3.62	4.32	3.60	3.84	4.12	5.06	3.50	3.41	2.15	2.91	3.30	43.21	
Ashland														
Temp.	34.5	36.5	44.5	55.9	64.7	72.6	75.8	74.4	68.5	57.7	45.7	36.6	55.6	13.7
Prec.	3.24	2.90	4.04	3.40	3.98	3.75	4.16	3.50	2.89	2.08	2.90	2.99	39.83	
Somerset														
Temp.	36.4	39.4	46.2	56.5	65.0	72.3	75.3	74.4	68.5	57.5	46.3	37.5	56.3	14.7
Prec.	4.88	4.75	5.07	4.16	3.97	4.73	4.63	3.70	3.25	2.29	3.87	3.99	49.29	
Williamsburg														
Temp.	37.8	39.8	47.3	57.9	66.1	73.2	76.0	75.0	69.2	58.6	47.2	39.4	57.3	8.8
Prec	4.36	4.28	4.79	4.01	3.95	4.14	5.09	3.62	2.89	2.59	3.76	4.05	47.53	

SOURCE: ATLAS OF KENTUCKY

Table D-3. Mineral Resources and Industries in Kentucky*

Resource	Occurrence		Primary Producing Area	Approximate Number of Quarries Operating in E. Ky. Compared to the Entire State
	Region	County		
Coal	Western	Several	Hopkins, Muhlenberg	1/3 Coking Plants
	Eastern	Numerous	Letcher, Harlan, Bell, Perry, Whitley, Clay	2/15 Electric Steam Generating Stations
Petroleum	Western, Central, Eastern	Numerous, Scattered	Numerous, Scattered	3/6 Refineries
Natural Gas	Eastern	Pike, Martin, Floyd, Plus	Pike, Martin, Floyd, Plus	1/2 Stripping Plants 2/12 Other Hydrocarbon Plants
Natural Gas Storage Field	Central-Eastern Border	Menifee		
	Western	Muhlenberg, Hart, Green, Henderson, Meade		
Limestone with High-Calcium Zones	Along Central-Eastern Border, Western, Eastern	Several	Scattered	27/100+ Quarries 0/1 Cement Plant
Limestone	Western, Central	Several	Scattered	
Dolomite	Central	Oldham, Jefferson, Bullitt, Nelson, Marion	Scattered	
Clay	Western	Ballard, Carlisle, Graves, McCracken Marshall, Calloway	Graves	8/37 Plants (refractory, pottery, structural)
	Northern Portion of Central-Eastern Border	Greenup, Carter, Plus	Scattered	
Sandgravel and Sandstone	Northern Border of Kentucky, Area West of Cumberland River	Several	Scattered	4/30+ Processing, Quarries, Operations 1/5 Glass Plants
Fluorspar and Other Vein Minerals	Western	Crittenden, Livingston, Caldwell	Crittenden, Livingston, Caldwell	0/4 Fluorspar and Fluorspar/Barite Mines 0/1 Fluorite Products Plant
	Central	Several	Not Active (1962)	
Rock Asphalt	Western	Edmonson, Grayson, Hardin	Not Active (1962)	

*"Mineral Resources and Mineral Industries of Kentucky," Kentucky Department of Commerce, Maps and Minerals Division, Frankfort, in cooperation with Kentucky Geological Survey, University of Kentucky, Lexington, 1962.

C-3

APPENDIX E

Glossary

Ablation	Select removal of the fine particle fraction (e.g., clay, silt) from sediment.
Acid Water	Water that has a pH of less than 7.
Aquifer	An aquifer is a formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.
Aquiclude (see confining bed)	Any geologic formation that does not transmit appreciable amounts of groundwater.
Area of Land Disturbed	The area of land from which overburden is to be or has been removed and upon which the overburden is to be or has been deposited. Also included are all lands affected by the construction of new roads, transmission line corridors, slurry lines, holding ponds, etc.
Area Surface Mining	Strip mining that usually occurs in gently rolling or relatively flat terrain (generally in mid-west and far-east).
Artesian	Artesian is synonymous with confined. Artesian water and artesian water body are equivalent respectively to confined groundwater and confined water body. An artesian well is a well deriving its water from an artesian or confined water body. The water level in an artesian well stands above the top of the artesian water body it taps.
Auger Mining	Mining of coal from an exposed vertical coal face by means of a mechanically driven boring machine that employs an auger to cut and bring the coal out of the borehole.
Backfill	Placing spoil material back into an excavation or pit and returning the area to a pre-determined configuration.
Bench	A ledge, shelf, or terrace formed from contour strip mining.

Channery Soil	A soil that contains thin, flat, fragments of sandstone, limestone, or schist, as much as 6 inches in length along the longer axis. A single piece is called a fragment.
Clay	As a soil separate, the mineral soil particles are less than 0.002 millimeter in diameter. As a soil textural class, soil material that is 40 percent or more clay, less than 45 percent sand and less than 40 percent silt.
Colluvium	Soil material, rock fragments, or both, moved by creep, slide, or local wash and deposited at the base of steep slopes.
Comminuted	To reduce the size or make small (e.g., coal cutting).
Conceptual Design	The basic architecture of the system is known and the subsystems have been identified. Engineering data may be missing or in the early phase of confidence.
Confined Aquifer (see Artesian)	An aquifer that is confined beneath a relatively impermeable stratum. If a well penetrates the confined zone, water will rise into the well to an elevation above that of the confined zone.
Confining Bed	A body of impermeable material stratigraphically adjacent to one or more aquifers.
Contour Surface Mining	A type of strip mining that is practiced in areas of hilly topography. The coal seam outcrops or approaches the surface at approximately the same elevation along the hillside. Entrance is made to the seam with overburden commonly cast downslope below the operating bench.
Depth, Soil	Thickness of soil over a specified layer that generally does not permit the growth of roots. Classes used in this report are shallow, 10 to 20 inches; moderately deep, 20 to 40 inches; and deep, 40 inches or more.
Dip of Bed	The angle at which a stratum or any planar feature is inclined from the horizontal.

Dissolved Oxygen	The oxygen content of a body of water (measured in mg/liter).
Diversion	Channel constructed across a slope to intercept surface runoff; changing the course of all or part of a stream or runoff.
Drainage Class (Natural)	Somewhat excessively drained soils are also very permeable and are free from mottling throughout their profile. Well-drained soils are nearly free from mottling and are commonly of intermediate texture.
Drawdown	Lowering of water level caused by pumping. It is measured for a given quantity of water pumped during a specific period or after the pumping level has become constant.
Ecosystem	An organic community of plants and animals together with its physical environment.
Eutrophication	A process where bodies of water with both a high surface-to-volume ratio and an abundance of nutrients produce a heavy growth of aquatic plants and other vegetation.
Floculation	The formation of a loose agglomerate of small particles that will eventually grow large enough to settle out of solution.
Fragipan	A dense, brittle subsurface horizon very low in organic matter and clay, but rich in soil or very fine sand. The layer seems to be cemented when it is dry, is hard or very hard, and has a high bulk density in comparison with the horizon or horizons above it. When moist, the fragipan tends to rupture suddenly if pressure is applied, rather than to deform slowly. The layer is generally mottled, is slowly or very slowly permeable to water, and has few or many bleached fracture planes that form polygons. Fragipans are a few inches to several feet thick, and they generally occur below the B horizon, 15 to 40 inches below the surface.

Groundwater Recharge	The percolation of surface precipitation through the ground to an aquifers.
Habitat	The environment in which the life needs of a plant or animal are supplied.
Highwall	The vertical wall adjacent to unmined land (e.g., a wall that is left by contour mining).
Hydraulically-Connected Aquifers	Aquifers that may be connected along faults, fractures, joints, cracks, shafts, or drill holes that may allow the movement of fluids between aquifers.
Hydrograph	Graphical representation of a stream's discharge as a function of time (usually expressed as cubic feet per second).
Infiltration	The flow or movement of water through the soil surface into the ground.
Interaquifer Movement	The movement of water between aquifers.
Long-Term Impacts	Environmental impacts that occur beyond the active phase of mining.
Mottling, Soil	Irregularly marked with spots of different colors that vary in number and size. Mottling in soils usually indicates poor aeration and lack of drainage.
Necrosis	The death or decay of plant or animal tissue.
Neutralization	When associated with coal mining, neutralization is the addition of an alkaline material such as lime or limestone to an acid material to raise the pH and overcome an acid condition.
Overburden	Earth material of any nature, consolidated or unconsolidated, that overlies a deposit of coal.
Parent Material	Disintegrated and partly weathered rock from which soil has formed.
Perched Groundwater	Groundwater occurring in a saturated zone which is vertically separated from the main body of groundwater by unsaturated rock.

pH	A numerical measure of the hydrogen ion concentration. It is used to indicate acidity and alkalinity. The neutral point is pH 7.0; pH values below 7.0 indicate acid conditions and those above 7.0 indicate alkaline conditions.
Plasticity	A consistency such that when the soil is wet, it is readily deformed by moderate pressure but can be pressed into a lump; it will form a "wire" when rolled between thumb and forefinger.
Preliminary Design	At this stage of development, the following information is usually available: a) the overall performance of the system is known; b) the subsystems have been defined and the interfaces between them have been defined; c) a mine plan has been developed for the system; d) the functional diagrams have been developed to the level where labor requirements and operational task teams have been determined; e) environmental actions have been determined for the system; f) capital costs, lease costs, equipment depreciation schedules, environmental costs, supply costs, and labor costs have been estimated.
Pyrolysis	The decomposition of a compound by the action of heat alone.
Reclamation	Reclamation of the landscape implies that the site will be habitable to organisms that were originally present or others that approximate the original inhabitants.
Refuse	Solid waste from a coal preparation or cleaning plant.
Regrading	The movement of earth over a surface or depression to change the shape of the land surface.
Residuum	Unconsolidated, partly weathered mineral material that accumulates over disintegrating solid rock. Residuum is not soil, but is frequently the material in which a soil has formed.
River Basin	See Watershed.

Sand	Individual rock or mineral fragments in soilshaving diameters ranging from 0.05 millimeter to 2.0 millimeters. The textural class name of any soil that contains 85 percent or more sand and not more than 10 percent clay.
Sediment Yield	The mass of sediment derived from a unit area, per unit time (e.g., tons/acre/year).
Short-Term Impact	Environmental impacts that occur during the active phase of mining or do not extend more than a few years after reclamation.
Silt	Individual mineral particles in a soil that range in diameter from the upper limit of clay (0.002 millimeter) to the lower limit of very fine sand (0.05 millimeter). Soil of the silt textural class is 80 percent or more silt and less than 12 percent clay.
Soil	A natural body consisting of horizons of mineral and/or organic constituents of variable thickness, which differ from the parent material in their morphological, physical, chemical, and mineralogical properties and their biological characteristics.
Spoil	All overburden material removed, disturbed, or displaced from over the coal seam being accessed.
Stabilize	Stabilization of spoil is accomplished by mechanical or vegetative methods that include planting of trees, shrubs, vines, grasses, and legumes, or by mechanical compaction or aging.
Sustained Yield	The rate at which water can be withdrawn without depleting the supply to such an extent that withdrawal at this rate is no longer economically feasible (also known as the safe yield).
Terrace	An old alluvial plain, ordinarily flat or undulating, bordering a river, lake or the sea. Stream terraces are frequently called second bottoms, as contrasted to flood plains, and are seldom subjected to overflow.

Texture, Soil	The relative proportions of sand, silt, and clay particles in a mass of soil. The basic textural classes, in order of increasing proportion of fine particles, are sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, silty clay loam, sandy clay, silty clay, and clay. The sand, loamy sand, and sandy loam classes may be further divided by specifying "coarse", "fine", or "very fine".
Total Dissolved Solid (TDS)	The aggregate of all salts in solution (e.g.,carbonates, bicarbonates, chlorides, sulfates, nitrates, metals, etc).
Trace Elements	Those elements that make up less than 99% of the composition of rocks and are measured in parts per million (e.g., cadmium, lead, nickel, etc).
Unconfined Aquifer	An aquifer which is not overlain by a relatively impermeable material, so that the groundwater is unconfined.
Watershed	A part of the earth's surface that is drained by a main stream and its tributaries and that has a divide separating it from another basin.
Water Bar	Any device or structure placed in or upon a haul or access road for the purpose of channeling or diverting the flow of water off the road.
Water Table	The surface separating the zone of aeration and zone of saturation or the phreatic surface.