INTRODUCTION

Background

Large amounts of sediment in streamflow can cause undesirable changes in the physical, chemical, and biological characteristics of a stream. Sediment deposition in impoundments reduces usable capacity, and deposition in rivers and streams reduces navigability and can increase the frequency of flooding and the height of the flood peak. The biotic community of the stream can be changed by large sediment concentrations in the water column and by large amounts of sediment deposited on the streambed. Plant nutrients and toxic materials commonly associated with sediment can produce changes in the biological and chemical quality of the water.

Climate and natural basin characteristics determine the amount of sediment in streamflow that leaves basins undisturbed by human activities. The amount and intensity of rainfall are examples of climatological characteristics; topography, soil erodibility, and vegetation cover are examples of natural basin characteristics.

Human activities can change the amount of sediment leaving a basin from what would occur if determined only by climate and natural basin characteristics. Although the construction of impoundments can lead to a decrease in sediment load, human activities generally increase loads by, among other things, disturbing the land surface and increasing the supply of soil particles available for transport in surface runoff. The magnitude of the increase in loads depends upon the type and extent of the human activities as well as the climate and natural basin characteristics. For example, sediment loads from a sloped, tilled field are expected to be greater than those from an identical, level field.

The importance of human activities in determining sediment yield (load per unit area of drainage basin) can be illustrated by comparing yields measured in small, disturbed basins with yields estimated for undisturbed forest. Patric (1976) has estimated mean annual sediment yields of 11 to 22 megagrams per square kilometer per year [$(Mg/km^2)/yr$] from forested basins in the eastern United States. In contrast, a pasture in southeastern Pennsylvania had a mean suspended-sediment yield of 245 $(Mg/km^2)/yr$ during 1980 (Lietman and others, 1983), and yields from construction sites in the Washington, D.C., metropolitan area averaged 7,400 $(Mg/km^2)/yr$ from 1962 to 1974 (Yorke and Herb, 1978).

Coal is mined in 11 States in the eastern United States, and some mined basins have been shown to have large sediment yields. Curtis and others (1978) measured mean annual sediment yields of up to 7,300 $(Mg/km^2)/yr$ in small, coal-mined basins in eastern Kentucky and western Virginia.

Assessments of the local effects of coal mining on sediment yields are given in coal hydrology reports for 32 areas of the eastern United States. These reports (Cochran and others, 1983, table 2) were prepared as part of the U.S. Geological Survey's Coal Hydrology Program (Kilpatrick, 1984). A large-scale assessment of the importance of coal mining on sediment yields throughout the eastern United States has not been done.

Purpose and Scope

The purposes of this report are (1) to describe the large-scale areal variation of mean annual suspended-sediment yields determined from water samples collected at selected stations on streams within and adjacent to the coal fields of the Eastern Coal Province and the eastern region of the Interior Coal Province, and (2) to discuss reasons, including the role of coal mining, for the areal variation in yield. Maps in this report display background sediment yields (the minimum yields measured in each part of the study area) and maximum yields above background.

Information is presented for stations on streams that drain basins with areas of from 100 to 1,000 and from 1,000 to 10,000 square kilometers (km^2). Only basins having areas within these ranges of size are considered, because sediment yield generally decreases with increasing drainage area. Basins smaller than 100 km^2 or larger than 10,000 km^2 were not included because of insufficient data.

This report considers only the suspended-sediment load carried in the water column of a stream. Bedload, the type of sediment load not considered in this report, is made up of the heavier particles that roll, skip, and slide along the bottom of the stream. The suspended load is greater than the bedload in all study-area streams for which such information is available (Wark and Keller, 1963; Flint, 1983; Anttila and Tobin, 1978).

Study Area

The study area was selected to include (1) the coal deposits in the Eastern Coal Province and the eastern region of the Interior Coal Province, and (2) areas surrounding these coal deposits (fig. 1). The availability of sediment-yield data, locations of stations with sediment-yield data, and the surface-water drainage pattern also determined the boundary of the study area. Although the drainage basins of most stations in the report are within the study area, many of the stations in Iowa, Wisconsin, and Missouri are on basins that are mostly outside the study area.

Two major physiographic divisions comprise almost all of the study area (fig. 1). Coal deposits in the eastern region of the Interior Coal Province are located in the Interior Plains, and coal deposits in the Eastern Coal Province are present mostly within the Appalachian Highlands. Basins in the Appalachian Highlands have steeper stream-channel gradients and greater forest cover than those in the Interior Plains (figs. 2 and 3). Forest is the natural vegetation cover of most of the study area, and the proportion of forest cover is one measure of how much of the surface area of a basin has been disturbed by human activities. Grassland forms the natural vegetation cover of parts of Iowa, Missouri, Illinois, Wisconsin, and Indiana.

The areal variation of mean annual coal production from surface mines during 1974–83 is shown in figure 4. Deep mining is not considered in this report, because surface mining generally is more disruptive of the land surface than is deep mining.

Sources of Sediment-Yield Data

Mean annual sediment yields were obtained from a review of the literature, from personal communications, and calculated from available sediment-concentration and sediment-load data. Most of the sediment-yield data in the literature came from statewide compilations of sediment yields, studies of river and stream basins, and coal hydrology reports. Statewide compilations were available for Ohio (Anttila and Tobin, 1978), Indiana (Johnson, 1970), Illinois (Bonini and others, 1983), Kentucky (Flint, 1983), Tennessee (Trimble and Carey, 1984), and Wisconsin (Hindall, 1976). The following studies of river and stream basins contained sediment-yield data: Potomac River (Wark and Keller, 1963), Schuylkill River in Pennsylvania (Biesecker and others, 1968), Susquehanna River (Williams and Reed, 1972) Delaware River (Mansue and Commings, 1974), Salt River in Missouri (Berkas, 1983), New River and Clear Fork in Tennessee (Parker and Carey, 1980), Bay Creek in Illinois (Lazaro and others, 1984), and Fishtrap and Dewey Lakes drainage basins in Kentucky and Virginia (Curtis and others, 1978).

Yield data were also found in selected coal hydrology reports (Ehlke, Bader, Puente, and Runner, 1982; Ehlke, Runner, and Downs, 1982; Ehlke and others, 1983; Staubitz and Sobashinski, 1983; Gaydos and others, 1982; Harkins and others, 1981; Zuehls and others, 1981a, 1981b; Fitzgerald and others, 1983). Additional information was found in Hubbard (1976), Gann and Miller (1976), Underwood and Imsand (1985), and Smith and Alexander (1983).

Written communications from the following U.S. Geological Survey Districts provided sediment-yield data: North Carolina (C.E. Simmons, 1986), West Virginia (Celso Puente, 1985; G.S. Runner, 1985), and Indiana (C.G. Crawford, 1985). The U.S. Army Corps of Engineers supplied additional information (G.B. McDonald, written commun., 1985).

Mean annual yields of suspended sediment were calculated from instantaneous suspended-sediment concentrations in Schuetz and Matthes (1977) and WATSTORE, the U.S. Geological Survey data-storage and retrieval system; WATSTORE is an acronym for Water Data Storage and Retrieval System. The flow-duration curve method (Miller, 1951) and the entire record of streamflow were used to calculate a yield for each station with at least one year of daily mean streamflow data, at least 10 measurements of instantaneous suspended-sediment concentration, and a functional relation (as judged by a visual examination of plotted data) between instantaneous suspended-sediment concentration and streamflow.

Mean annual yields were also calculated from WATSTORE records of daily mean suspended-sediment load. One yield for each station was calculated by averaging annual loads over all water years (October 1 through September 30) missing less than 30 days of information.

Altogether, sediment-yield data were available for 292 stations with smaller drainage basins (100 to 1,000 km^2) and for 189 stations with larger drainage basins (1,000 to 10,000 km^2) (figs. 5a and 5b). The effects of the trapping of sediment by impoundments were minimized by not considering any station having more than one third of its basin draining to an impoundment. The effect of sediment being trapped by natural lakes was not a factor in choosing stations.

The sediment-yield values used to create the maps in this report are listed in Hickman (1989). For those stations that had more than one value of sediment yield, the value that appeared to best represent mean longterm yield was selected for this report. The use of a mean longterm value minimized the effects of short-term variations in climate and human activities. It should be noted that the values of sediment yield used in this report and the values of background yield and maximum yield above background calculated from them may not represent current conditions.

Methods

The areal variation of background sediment yield was determined by plotting locations of stations with mean annual yields less than or equal to 25, 50, 100, 200, or 300 $(Mg/km^2)/yr$. For each value of yield, a line of equal value was then drawn around each area containing at least three stations.

The areal variation of maximum sediment yield above background was determined by placing a map showing each station's sediment yield over a map of background yields; lines of equal value were drawn around areas containing at least three stations with yields greater than 50 $(Mg/km^2)/yr$ above background. The difference between the maximum and background yields in each portion of the study area was determined by subtracting the minimum value of background yield from the largest yields shown by at least three stations. The results were generalized into areas of maximum yields less than 50, 100, and 200 $(Mg/km^2)/yr$ above background, and areas of yields greater than 200 $(Mg/km^2)/yr$ above background.

The variations of background sediment yield and maximum sediment yield above background are based upon the locations of stations rather than the outline of the associated drainage basin because of the great number of stations (and basins) considered, because some of the basins overlap, and because this is a large-scale analysis. One disadvantage of this method is that a large basin may extend some distance from the associated station. Consequently, the reader should note that the yield at a station may be affected by basin characteristics, climate, and human activities in areas not immediately adjacent to the station.

CONVERSION TABLE
For use by readers who prefer to use inch-pound units, conversion factors for the International System of Units (SI) are listed below

Multiply SI unit	by	To obtain inch-pound unit
	Length	
meter (m)	3.281	foot
	Area	
square kilometer (km^2)	0.3861	square mile
	Gradient	
meters per kilometer (m/km)	5.280	feet per mile
	Yield	
megagrams per square kilometer per year [$(Mg/km^2)/yr$]	2.854	short tons per square mile per year

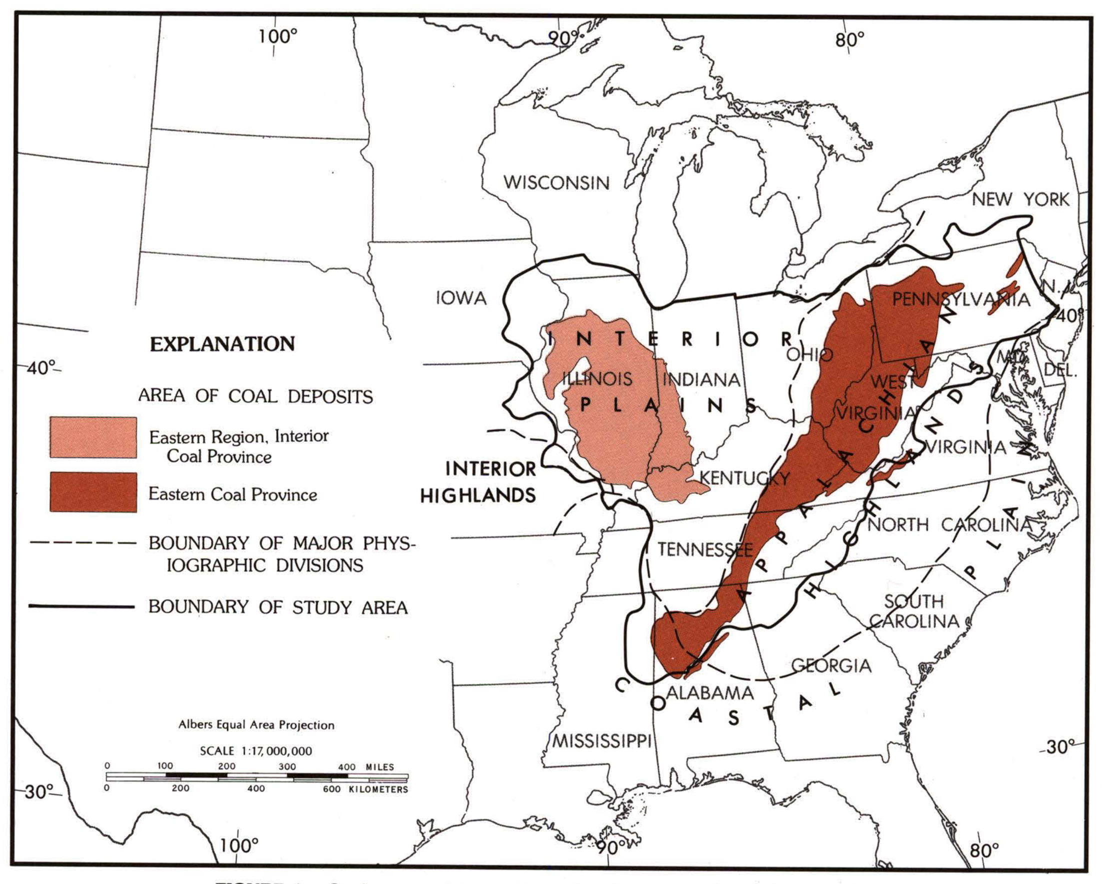

FIGURE 1.—Study area, major physiographic divisions, and coal deposits of the Eastern Coal Province and the eastern region of the Interior Coal Province. Major physiographic divisions are from Fenneman (1946).

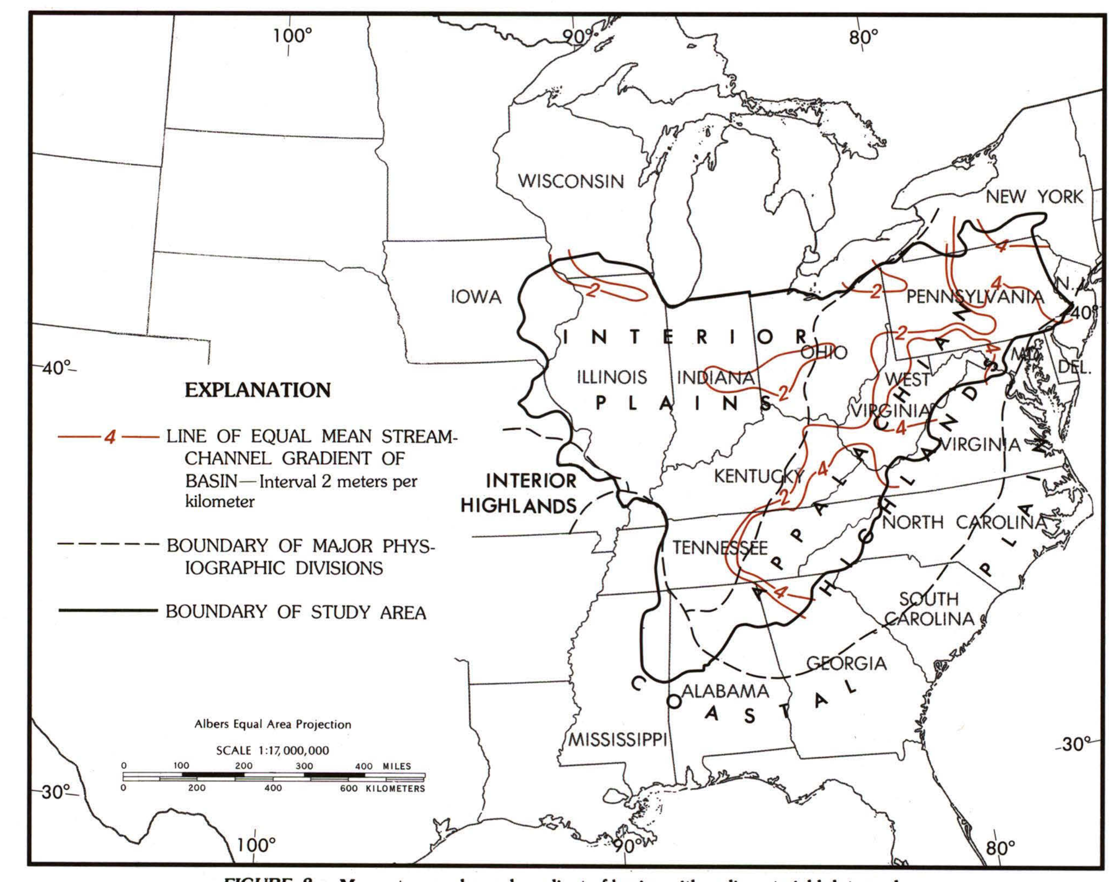

FIGURE 2.—Mean stream-channel gradient of basins with sediment-yield data and areas of from 100 to 10,000 square kilometers. The lines of equal value delineate areas that contain basins with a mean stream-channel gradient greater than or equal to the value of the line; the gradient of each basin was plotted at the location of the station at the basin's downstream boundary. Stream-channel gradients were determined from elevation measurements made at 10 and 85 percent of the stream length above the station. Data are from WATSTORE, the U.S. Geological Survey's data-storage and retrieval system, and are listed in Hickman (1989).

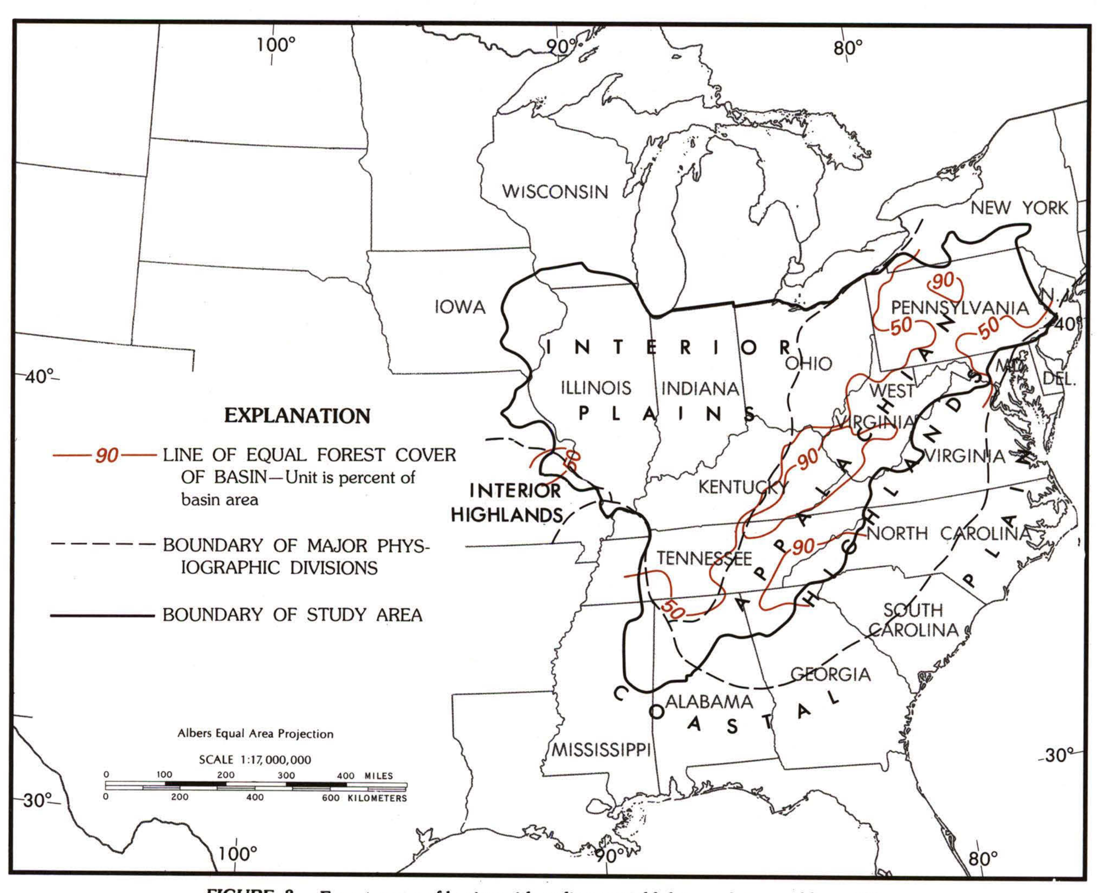

FIGURE 3.—Forest cover of basins with sediment-yield data and areas of from 100 to 10,000 square kilometers. The lines of equal value delineate areas that contain basins with a forest cover greater than or equal to the value of the line; the forest cover of each basin was plotted at the location of the station at the basin's downstream boundary. Data are from WATSTORE and are listed in Hickman (1989).

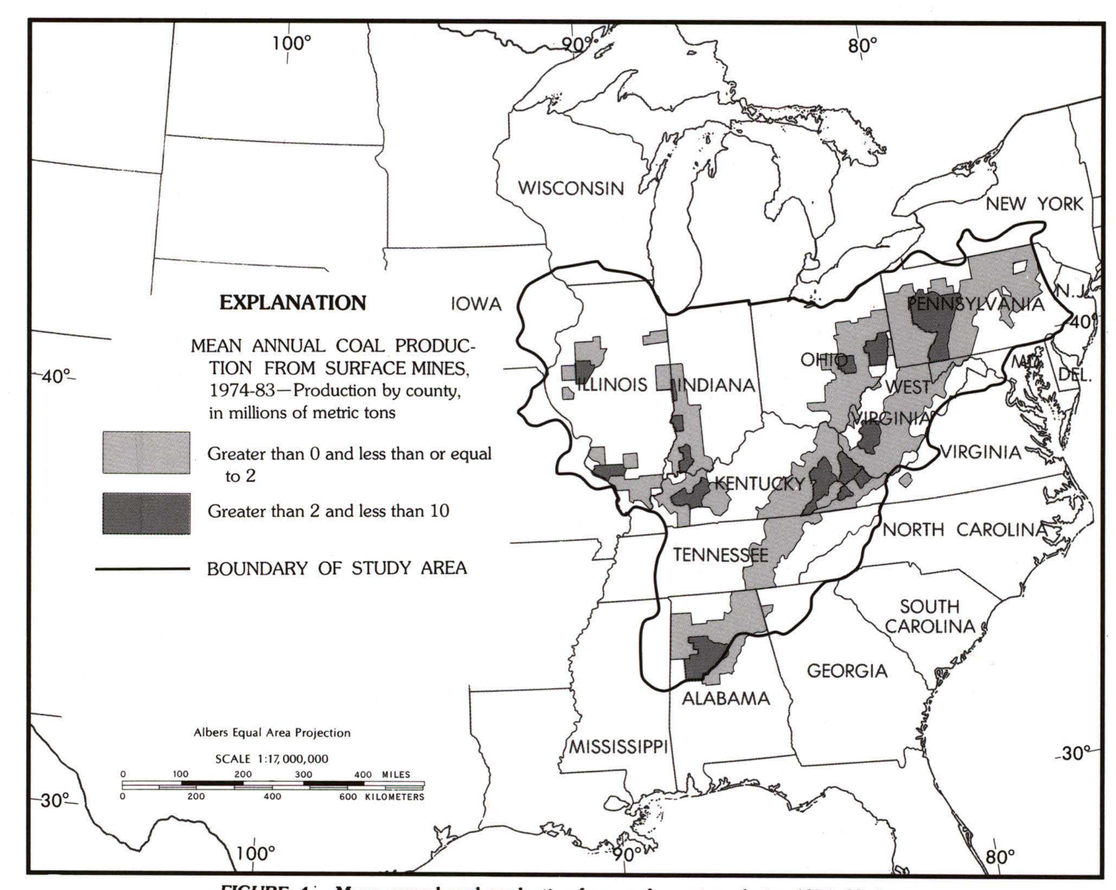

FIGURE 4.—Mean annual coal production from surface mines during 1974–83, by county. Data are from Mining Informational Services (published annually, 1976–85).

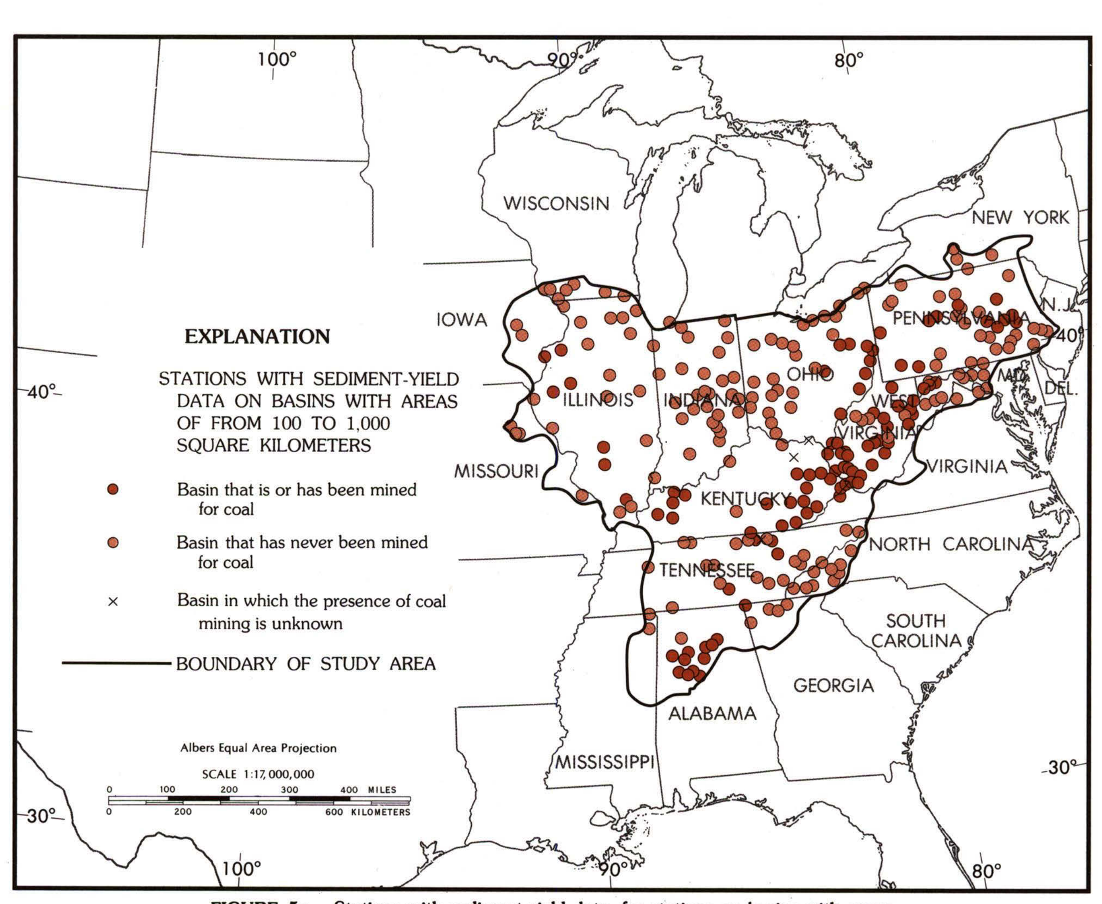

FIGURE 5a.—Stations with sediment-yield data, for stations on basins with areas of from 100 to 1,000 square kilometers. Information concerning the presence or absence of coal mining in each basin was supplied by U.S. Geological Survey personnel or found in the literature.

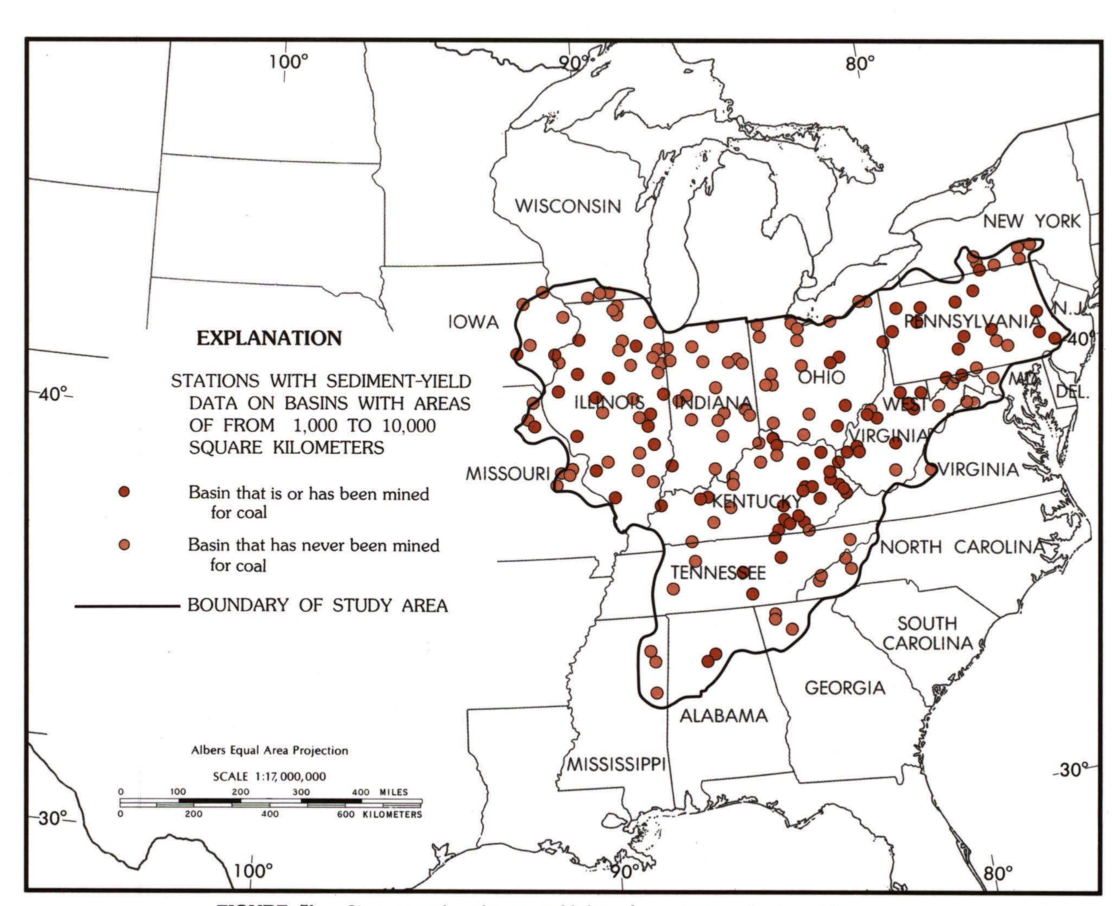

FIGURE 5b.—Stations with sediment-yield data, for stations on basins with areas of from 1,000 to 10,000 square kilometers. Information concerning the presence or absence of coal mining in each basin was supplied by U.S. Geological Survey personnel or found in the literature.

Base from U.S. Geological Survey National Atlas, 1970

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AREAL VARIATION OF SUSPENDED-SEDIMENT YIELDS WITHIN AND ADJACENT TO THE COAL FIELDS OF THE EASTERN COAL PROVINCE AND THE EASTERN REGION OF THE INTERIOR COAL PROVINCE

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