THE STUDY AREA

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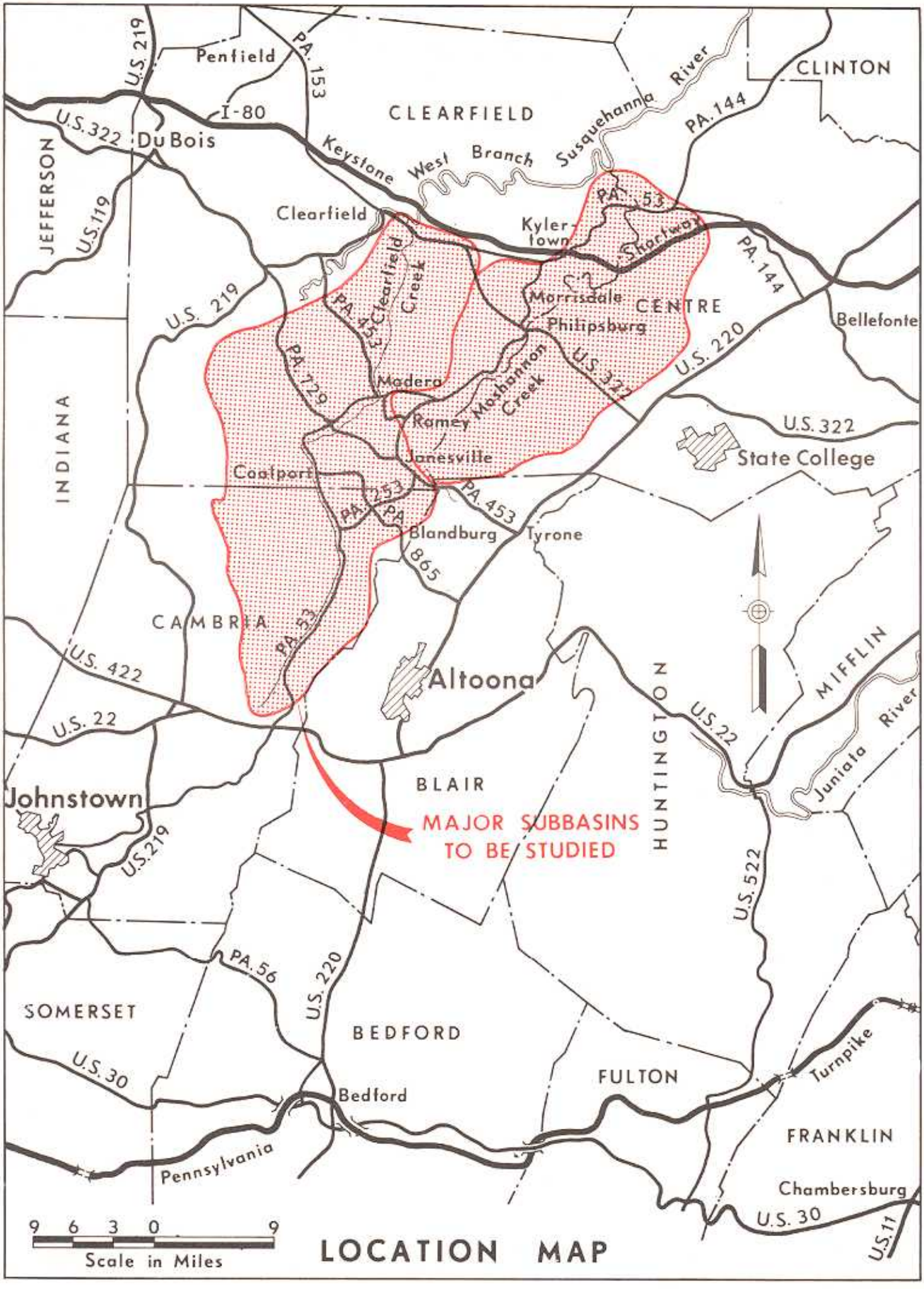
LOCA TION

The study area consisted of the Clearfield and Moshannon Creek Watersheds in central Pennsylvania, located on the northeastern edge of the Appalachian Mountain bituminous coal belt. These two streams have a combined drainage area of 684 square miles in Centre, Cambria, Blair and Clearfield Counties, and are major tributaries to the West Branch of the Susquehanna River. The two watersheds He adjacent to one another for about 15 miles from Wallaceton to the southern end of the Moshannon Creek Watershed, at the Cambria-Clearfield County line. They are separated in the north by the watersheds of Alder Run and several other small tributaries to the West Branch. The study area is flanked by the Little Juniata River Basin to the south and east, the Beech Creek Basin to the northeast, and the remaining West Branch Watershed to the north, northwest and west. The accompanying location map shows the relative locations of the two watersheds.

The Clearfield Creek Watershed occupies 396 square miles in 17 townships in Clearfield and Cambria Counties. The watershed is roughly 15 miles across at its widest point, and stretches 40 miles from the headwaters near the town of Cresson to its confluence with the West Branch near Clearfield. The West Branch is seriously degraded

by Clearfield Creek's average unadjusted acid load of 57,000 lbs/day, (adjusted 70,000 lbs/day) changing in nature from slightly alkaline above Clearfield Creek to acid below the creek's mouth.

The Moshannon Creek Watershed covers 288 square miles in 8 townships in Centre and Clearfield Counties. It has a maximum width of 13 miles and a length of about 30 miles from the Blair-Centre County line northeast to the West Branch just south of Karthaus. Nearly all tributaries to Moshannon Creek are acid in nature, and the creek contributes an average unadjusted acid load of 130,000 lbs/day (adjusted 160,000 lbs/day) to the West Branch, completely degrading that stream for many miles below Moshannon Creek's mouth.


Penfield
U.S. 219
PA. 153
I-80
CLEARFIELD
Susquehanna River
CLINTON
PA. 144
U.S. 322
Du Bois
Keystone
West Branch
JEFFERSON
U.S. 119
Clearfield
PA. 53
Kyler-town
Starcross
PA. 144
U.S. 219
PA. 453
Clearfield Creek
Morrisdale
CENTRE
Philipsburg
Bellefonte
U.S. 220
PA. 729
Madera
Moshannon Creek
U.S. 322
INDIANA
Ramey
U.S. 322
State College
Janesville
Coalport
PA. 253
PA. 453
PA.
Blandburg
Tyrone
865
CAMBRIA
PA. 53
U.S. 422
Altoona
U.S. 22
HUNTINGTON
U.S. 22
MIFFLIN
Juniata River
BLAIR
Johnstown
MAJOR SUBBASINS
TO BE STUDIED
U.S. 219
U.S. 522
PA. 56
U.S. 220
SOMERSET
BEDFORD
U.S. 30
FULTON
Turnpike
Bedford
FRANKLIN
Pennsylvania
Chambersburg
U.S. 30
U.S. 11
9 6 3 0 9
Scale in Miles
LOCATION MAP

CLIMATOLOGY

Climatological data for the study area was obtained from National Weather Service monitoring stations located at Carrolltown, Clearfield, Madera and Philipsburg. These weather stations have recorded precipitation and temperature for varying periods of record, and all are presently in operation. The actual data gathering portion of the study spanned seven months from June 1972 to December 1972. The average monthly temperature and total monthly precipitation for the study period are listed below, with the average monthly temperature and precipitation for the periods of record of the four monitoring stations.

LONG TERM AVERAGE vs. 1972 MONTHLY AVERAGE PRECIPITATION

Month	Long Term Average Precipitation Period of Record 11-18 Yrs.) Inches	1972 Average Precipitation Inches
June	4.17	12.02
July	4.46	3.53
August	3.89	1.72
September	2.90	4.40
October	3.18	1.84
November	3.18	5.83
December	3.00	4.15

LONG TERM AVERAGE vs. MONTHLY AVERAGE TEMPERATURE

Month	Long Term Average Temperature (Period of Record 11-30 Yrs.) of	1972 Average Temperature deg. F.
June	63	60.5
July	66.8	69.0
August	65.3	65.8
September	58.4	60.3
October	48.7	42.6
November	36.7	32.2
December	26.2	32.0

Precipitation was abnormally high In June due to tropical storm Agnes, but then fell below the monthly average for July and August. Rainfall again picked up In the fall months, with only a short dry period during October. Temperatures varied from the long term monthly averages with no apparent consistency.

GEOGRAPHY AND PHYSIOGRAPHY

The Clearfield and Moshannon Creek Watersheds lie within the Appalachian Plateau Physiographic Province just northwest of the Allegheny Front, which separates that area from the Valley and Ridge Province. Topography within the study area is strongly influenced by physiographic setting and by the nature of the Mississippian and Pennsylvania age sedimentary units present, and represents approximately 100 million years of erosion. The headwaters of both Clearfield and Moshannon Creeks, where relief is extreme and stream gradients are steep, lie within the Allegheny Mountain section of the province.

Gradients and relief are less extreme in the central portions of each watershed, which lie in the Pittsburgh Plateaus section of the province. Here the streams lie above the resistant Pottsville sandstone of the Pocono Formation and are downcutttng very slowly. Rapid downcutting and extreme relief are again evident near the mouth of Moshannon Creek where the stream has cut through the resistant Pottsville and is rapidly eroding the less resistant sediments beneath it.

Total relief in the study area is approximately 1600 feet, but local relief rarely exceeds 700 feet. The highest elevations in the study area, around 2450 feet, are located near Clearfield Creek's headwaters. Surface elevations decrease toward the north, approaching 900 feet at the mouth of Moshannon Creek. The large topographic relief is due in

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DEPARTMENT OF ENVIRONMENTAL RESOURCES
TOPOGRAPHIC AND GEOLOGIC SURVEY
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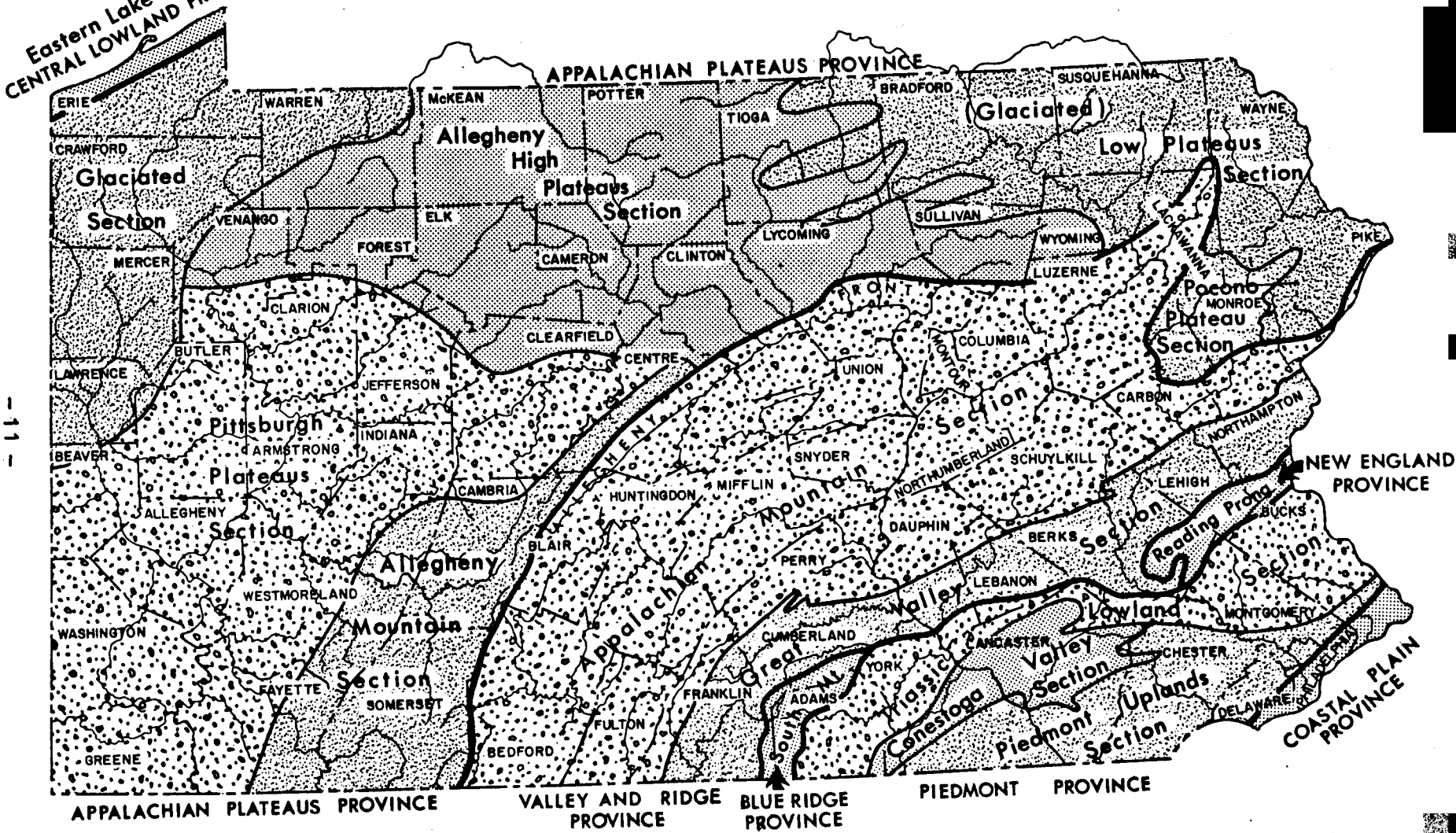
PHYSIOGRAPHIC PROVINCES of PENNSYLVANIA



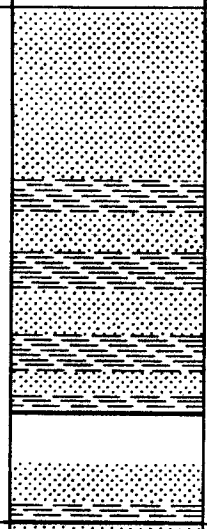
part to long periods of erosion of the resistant Pocono sandstone in highly fractured zones along portions of the area's anticlines. In addition, the highlands are often capped by one of the many resistant sandstones contained within the Coal Measures. The coals themselves outcrop on the valley walls throughout the study area, and the large number of such outcrops above surface drainage in the area is attributable to the stratigraphically high position of the Allegheny Group coals along with heavy fluvial dissection.

The drainage networks of both watersheds are largely controlled by rock type, folding and faulting. Portions of both streams follow the northeast-southwest trending axis of the Houtzdale- Snow Shoe Syncline, and the drainage patterns of many of the study areas streams reflect an extensive northwest-southeast trending series of faults.

GEOLOGY

The Clearfield and Moshannon Creek Watersheds are situated on the northeast end of the Main Bituminous Coal Field of Appalachia that extends west into Ohio and south as far as Alabama. The study area's stratigraphic sequence consists of 15,000 - 20,000 feet of sedimentary rocks lying above Cambrian age crystalline basement rocks. These sedimentary rocks are all of Paleozoic age except for the Quaternary unconsolidated sands and gravels in the stream valleys. The Mississippian and Pennsylvanian age rocks within this sequence consist of interbedded shales, siltstones, sandstones, clays and bituminous coal seams of varying quality and thickness. The coals are extracted wherever economical to supply the energy needs of the eastern United States and some foreign nations.

The surface formations within the study area range from the upper 300 feet of the Mississippian Pocono Formation to the lower 300 feet of the Pennsylvanian Conemaugh Group - a total stratigraphic thickness of about 1100 feet. The Pennsylvanian age Allegheny Group rocks are the most important to the study areas' coal economy. This sequence of Allegheny Group coals, referred to as the coal measures, ranges vertically from the Clarion-Brookville coal at the base of the group to the Upper Freeport coal. Other coal seams locally present within the study area are the Pottsville's Mercer coals, which are generally of good quality and are mined when present; and the Conemaugh's Mahoning coal, which varies in thickness and lateral continuity. A generalized stratigraphic column follows.

SERIES	GROUP	FORMATION	COAL MEMBER	SECTION	CHARACTERISTICS OF COAL MEMBER	GENERAL STRATIGRAPHY OF GROUP
PENNSYLVANIAN	CONEMAUGH					Erratic cyclic repetitions of soft clay and associated fresh-water limestone, coal, shale, siltstone, and sandstone. Lower 300 feet of group.
			Brush Creek		Very thin. Laterally discontinuous. No mining.	
			Mahoning		Average thickness = 1 foot. Extremely variable thickness. Laterally discontinuous. Locally extensively strip mined.	
		Mahoning				
	ALLEGHENY	Freeport	Upper Freeport		Average thickness = 30 inches. Laterally continuous. Extensively strip mined with some deep mining.	Erratic cyclic sequence of clay, claystone, carbonaceous shale, siltstone, sandstone, and mineable coals. Average thickness = 300 feet.
			Lower Freeport		Laterally continuous with average thickness of 40 inches. Split into 3 benches in Central Clearfield and Moshannon Creek Watershed. Extensively strip mined and deep mined.	
		Upper Kittanning	Upper Kittanning		Average thickness = 24 inches generally 2 closely spaced benches. Laterally discontinuous but locally strip mined and deep mined.	
		Middle Kittanning	Middle Kittanning		Average thickness = 36 inches. Fair persistance. Mostly strip mined with some deep mined.	
		Lower Kittanning	Lower Kittanning		Locally split into 2 benches. Average thickness = 58 inches. Including a 10 inch shale parting. Laterally continuous and extensively deep mined and strip mined.	
		Clarion	Clarion		Locally split into up to 5 benches. Average thickness = 48 inches. Laterally Continuous extensively deep mined and strip mine. Split into 3 benches in North and North Central Clearfield Creek Watershed.	
	POTTSVILLE	Mercer	Mercer		Very thin and laterally discontinuous. Coal and associated refractory grade clay locally strip mined and deep mined.	Poorly developed cyclic sequence of clays, shales, siltstones, sandstones, and thin coals. Thickness = 200 feet.
MISSISSIPPIAN		Pocono				Fine-grained to conglomeratic sandstone. Up to 300 feet exposed.

VERTICAL SCALE

50 0 100 Feet

STRATIGRAPHIC COLUMN OF SURFACE ROCK

The mode of formation of the coal measures is responsible in part for the incongruous conditions presently seen within the study area - where certain coal seams are associated with alkaline discharges and other coal seams acid discharges. The coal measures are erratic, cyclic sequences of underclay, coal, claystone, shale and sandstone deposited during a period of mild tectonic activity. The tectonic activity resulted in the erratic submergence and emergence of coastal lands, with mildly fluctuating subsidence rates, and a subsequent variable base level. This created an often repeated open water to swamp to fluvial deltaic depositional sequence. The varying paleoenvironment produced the strong local variations in the physical and chemical nature of the sediments deposited.

Mild tectonic activity continually varied paleoenvironmental conditions and occasionally produced restricted water areas or basins in which biochemical oxygen demand was high. Reducing conditions developed in these basins and were reflected in the character of the materials deposited. The coal and associated overburden deposited in such a reducing environment arc high in pyrite and other sulfuritic compounds, and readily produce acid when exposed to oxygen and welter. The Clarion-Brookville coal the Lower Kittanning, and locally the Middle Kittanning coal were often deposited under such conditions, and most of the mine discharges from those scams are acid in nature.

The following table shows the commonly used letter equivalents of the Allegheny Group coal seams:

Upper Freeport	=	"E" coal
Lower Freeport	=	"D" coal
Upper Kittanning	=	"C' "coal
Middle Kittanning	=	"C" coal
Lower Kittanning	=	"B" coal
Clarion-Brookville	=	"A" coal

The physical and chemical nature of the heavily mined coals is directly responsible for the occurrence and severity of acid mine drainage within the area. The most heavily mined coal seams, the Clarion-Brookville and Lower Kittanning coals, usually contain the largest quantities of reactive pyrite and produce acid wherever mined.

Brief paleoenvironmental changes during the deposition of the Middle and Upper Kittanning and the Freeport coals frequently resulted in the deposition or precipitation of thin limestone beds or concretions in the underclay or overburden. The limestone tends to neutralize any acid mine water contacting it. This limestone neutralization, common to the "C" (locally) and the "C' ", "D" and "E" coals, causes ferrous iron to precipitate as ferric hydroxide (yellowboy) and produces alkaline mine drainage high in ferric iron and sulfate.

Local minor tectonic base level fluctuations superimposed on the larger scale regional fluctuations locally caused several of the Allegheny Group coal seams to split into two or three thinner seams. In the north

and north-central portions of the Clearfield Creek Watershed, the Clarion-Brookville, or "A", coal consists of three thin seams; the Lower Kittanning, or "B", coal contains five separate seams; and the Middle Kittanning, or "C", coal incorporates two seams. In the central Clearfield and Moshannon Creek Watersheds, the Lower Freeport, or "D", coal consists of three seams.

The regional structure of the study area is controlled by a series of folds striking northeast. The major fold structures within the area, from northwest to southeast, are the Laurel Hill Anticline, the Houtzdale Syncline, the Hannah Furnace Anticline and the Black Moshannon Syncline.

The Houtzdale Syncline is the focus of acid mine drainage production in Clearfield and Moshannon Creeks. This syncline extends from the Beech Creek watershed near Clarence, in Centre County southwest through the Moshannon Creek Watershed toward Houtzdale and Ramey, and through the Clearfield Creek Watershed toward Ebensburg, All of the Allegheny Group coals and the lower Conemaugh Group coals have been preserved from erosion in this structural low, which is the most extensively mined portion of the study area and the major source of acid mine drainage to both Clearfield and Moshannon Creeks.

The "A" and "B" coals in the southern Clearfield Creek Water shed are deeply buried and have not been mined in the middle of the Houtzdale syncline. These coals have nearly all been mined down-dip from out

crop exposures along the synclinal flanks, allowing natural flooding of the deep mines upon cessation of extraction. Thus, acid mine drainage production from the deeply buried acidic coals in this area is relatively minor and is restricted to the flanks of the syncline.

The "A" and "B" coals are shallower in the remaining portions of the Houtzdale syncline, in the central Clearfield Creek Watershed northeast through the Moshannon Creek basin. Here these coals have been extensively deep and strip mined throughout the syncline. The deep mines have completely altered the natural hydrology of the area. Most of the deep mines were developed to the rise and act as underdrains, passing groundwater through acid producing areas, with no regard for surface watershed boundaries. The acid water discharges from the low points of the deep mines, generally near the synclinal axis, along Clearfield or Moshannon Creek. The major sources of acid mine drainage are large deep mine discharges of this type.

The northwest flank of the Houtzdale syncline rises to the crest of the Laurel Hill Anticline. The anticlinal axis passes through the northwest corner of the Moshannon Creek Watershed near Wallaceton, across the headwaters of Morgan Run, and toward Irvona. The Allegheny Group coals are exposed to erosion along the flanks and the crest of the anticline and the higher coals have been locally removed by erosion.

Southeast of the Houtzdale-Snow Shoe Syncline, the strata rise toward the Hannah Furnace or Moshannon Anticline. The Allegheny Group rocks have been completely eroded from the anticline, and no extensive coal beds exist beyond a point just southeast of Philipsburg. Lower coals of the Allegheny Group reappear locally in a small basin at the axis of the Black Moshannon Syncline, near Black Moshannon Airport at the southeast edge of the study area. Surface rocks in the eastern one-third of the Moshannon Creek Watershed are Pottsville and Pocono sandstones, with the coal measures mostly removed by erosion. The absence of mining is reflected by the good water quality of Black Bear Run, Sixmile Run, and most of Black Moshannon Creek.

The folding within the study area is accompanied by a series of generally parallel, northwest trending, high angle wrench faults which die out northwest of Clearfield Creek. The faults are roughly perpendicular to the fold axis and parallel to the stress vector responsible for the folding, and are accompanied by many splay faults. Faulting is most extensive in the area from Powell Run to north-central Moshannon Creek. South of Powell Run, major faults are found near Frugality and Dougherty and trend more east-west than those in the northern area. In the northern Moshannon Creek area, succeeding faults trend more north-south. The displacements of these faults vary greatly in magnitude, but they are

frequently sufficient to make coal extraction across them impractical or impossible; and the limits of the deep mine workings are frequently defined by such faults. Faulting in the Bear Run watershed of Moshannon Creek was of sufficient magnitude to offset coal beds up to forty feet.

Within individual fault blocks, local, strong, minor structures are frequently superimposed on the general anticlinal and synclinal structure. This tends to throw the structural axis off from one fault block to the next, and makes it difficult in highly faulted areas to trace the actual structural axis with a single straight line.

Jointing, a characteristic associated with deformation, is also well developed in the study area. Generally, the strata associated with coal measures would provide a fair water supply for nearby communities. The sandstone and coal units within the coal measures provide perched aquifers, contained by impermeable underclays and shales, that are used as a domestic water supply. The development of mines along the coal seams, however, tends to open overlying joint spacing as a result of subsequent roof collapse. This decreases the water retention capacities of the overlying rocks, thereby depleting individual home water wells. This is evident in most communities in extensively deep mined areas. These communities are often forced to pipe or haul in water from unmined areas to combat loss of well water caused by the extraction of the underlying coal.

MINING HISTORY

Deep mining began in the study area in the early 1800's and expanded slowly until the Civil War years. Rapid expansion of the coal mining industry began during the Civil War as coal, with its higher BTU content, replaced wood for use in kilns, iron furnaces, and home heating systems. Most towns within these two watersheds were established and grew in response to this deep mining surge, which continued into the 1940's.

The Clarion-Brookville "A", Lower Kittanning "B" and Lower Freeport or Moshannon "D" seams were generally the first and most extensively deep mined coals largely due to their relatively good quality and thickness. Numerous small house coal mines were also operated throughout the study area in the Freeport coals, which occasionally were no thicker than 28 inches.

Deep mining began to spread to the thinner "C", "C' ", "D" and "E" coals, when reserves of "A" and "B" coal that could be easily deep mined began to dwindle. These deep mines in the higher coals were commonly smaller and less profitable than the "A" and "B" seam mines. Most of these old deep mines were driven updip to facilitate drainage. All water entering the workings drained downdip toward the synclinal axis which roughly underlies Moshannon Creek and portions of Clearfield Creek. Both creeks currently receive the majority of their acid loads from

year-round discharges from downdip drifts, blowouts, air shafts, and stripped out deep mine workings.

Large interconnected deep mine complexes developed in several areas on the "A" and "B" seams. A large "B" seam complex developed on the northwest flank of the Houtzdale Syncline, between Hawk Run, Alder Run, Weber Run, and Moshannon Creek. Similar although somewhat smaller, complexes are found throughout the Moshannon Creek Watershed. Several large complexes also existed in the Clearfield Creek Watershed: the Irvona Coal and Coke Company's "B" seam deep mines east of Coalport, the Pennsylvania Coal and Coke Company's" B" and "E" seam shaft mines near the Borough of Cresson and Trapp Run, and the Middle Penn Coal Company's "A" seam deep mines northeast of Madera.

Strip mining began to replace deep mining early in the 1940's. Strip miners in these early years reaped large profits with relatively small equipment and employee expenditures, because stripping was confined to premium grade coals in areas of little relief and low cover without added reclamation costs. Strip miners initially concentrated on coal outcrops adjacent to deep mine workings, negating the need for any coal exploration. As strip mines began to flourish and deep mines began to decline in importance, many deep miners lost their jobs and the

small towns which had prospered with the deep mines slowly declined in population and wealth. This declining trend has continued for many years, and today most of the Appalachian bituminous coal mining belt suffers from severe economic depression. Elliot Associated Drilling and Rushton Coal Companies operate the only three active deep mines in the area, both of which are in the Moshannon Creek Watershed.

The major industry of the study area today is strip mining. The strip miners now use large drag lines which can remove much more over-burden to uncover thinner coals and still realize substantial profits. Until recently, reclamation laws that did exist were inadequate and sometimes not strictly enforced, and as a result, most of the strip cuts in the study area are unreclaimed or very poorly reclaimed. Today strip mine reclamation requirements are very effective and are stringently enforced.

Coal Reserves

Pennsylvania coal reserves data as of January 1, 1970, was obtained from the Pennsylvania Geological Survey's Information Circular 72, entitled "Coal Reserves of Pennsylvania: Total, Recoverable and Strippable", authored by William Edmunds. The data is presented in this booklet by counties. To obtain estimated reserves for the two watersheds, the percentage of each watershed that is located in each county was multiplied by the coal reserves for that county. Based on this data,

the estimated recoverable coal reserves greater than 24 inches in thickness were as follows:

Clearfield Creek Watershed	=	561,000,000 tons
Moshannon Creek Watershed	=	186,000,000 tons