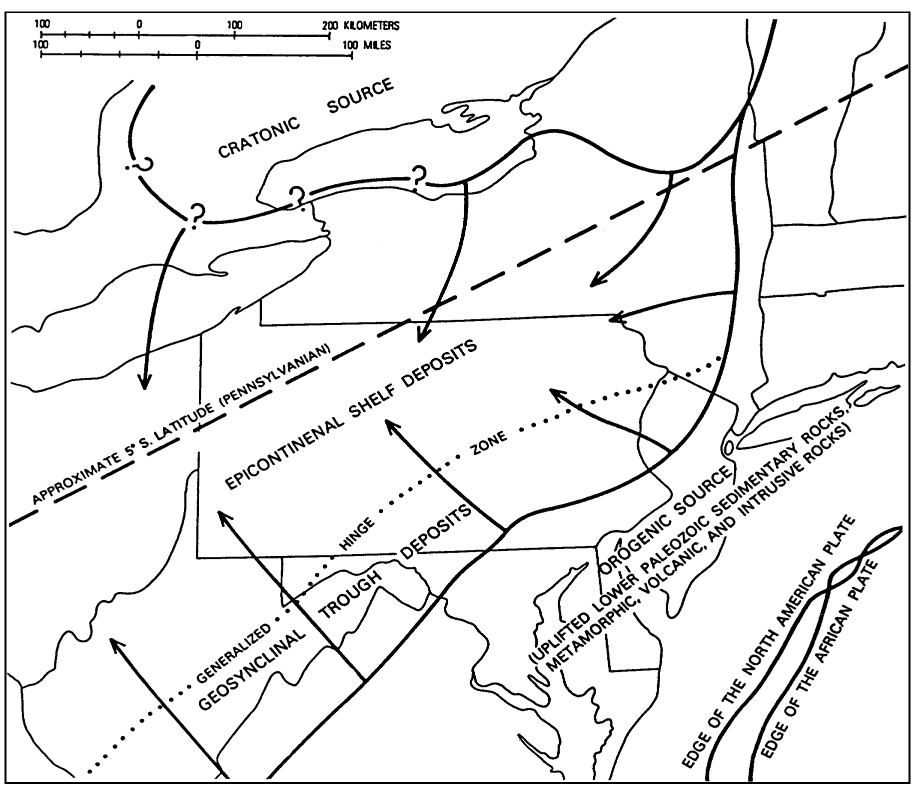
VII. Geology and Hydrology of the Bituminous Coalfields

Introduction

This section will examine stratigraphy, structure and hydrology and their significance in terms of deep mining-induced impacts. Stratigraphy refers to the sequence of sedimentary rocks that include the commercial coals. Structure refers to the folding, fracturing and faulting that have occurred to these rocks. Hydrology refers to the occurrence and movement of groundwater within these rocks. Deep mining occurs within the encasing geology and hydrology. The groundwater interacts with fresh rock surfaces exposed by deep mining Geology is also important in that it influences roof stability and potential for subsidence.

The vast majority of coal in Pennsylvania was deposited during the Pennsylvanian Period of geologic time. The Pennsylvanian Period occurred between 286 and 320 million years ago. The youngest coal-bearing rocks in western Pennsylvania were probably deposited during the Permian Period, which is the period of geologic time that follows the Pennsylvanian. During the Pennsylvanian Period the equator was just north of present-day Pennsylvania (Edmunds et al.,

Figure VII.1
Generalized Paleogeographic Map of the Pennsylvanian Depositional Basin and Source Areas Modified from Edmunds et al. (1979).



1998) (Figure VII.1), and the climate was tropical. A mountain range existed in present-day New Jersey and southeastern Pennsylvania. A large depositional basin existed to the west of the present-day Appalachian front. Sediments, eroded from mountains to the east and highlands to the north, were deposited in the basin (Figure VII.1) and became the coal and associated rocks of the coalfields of Pennsylvania.

Stratigraphy

The coal-bearing Pennsylvanian and Permian rocks have been divided into five "groups" (Figure VII.2). From oldest to youngest, these are the Pottsville, Allegheny, Conemaugh, Monongahela, and Dunkard Groups. They are all of Pennsylvanian age with the exception of the Dunkard, which is Permian.

The stratigraphy of the Pennsylvanian is not as simple as is often assumed. For most of the past 150 years stratigraphic correlations were made using the coal seams. The Allegheny Group, for example, was designed to contain all the mineable coals within that section of the Pennsylvanian. The Brookville coal marks the base of the Allegheny Group and the upper Freeport coal marks the top of the Group. However, deposition of sediments within the basin was not necessarily uniform. As a result, many coal seams and the intervening rock units are not continuous over large areas. A good example is the Brookville coal. This coal can only be precisely identified in the area where it was first described. For a detailed discussion of the Pennsylvanian stratigraphy, consult Edmunds et al. (1998).

Pottsville Group

The Pottsville Group varies in thickness from less than 20 feet (6 m) to at least 250 feet (75 m). It is dominated by sandstone and the coals are discontinuous. Because of the discontinuous nature of these coals, and the fact that they are often split with numerous partings, mining is not common in the Pottsville Group and there are no active deep mines mining Pottsville Group coals. The principal coal that was mined in the past was the Mercer. This is actually a coal zone rather than a single coal. The Mercer clay, below the Mercer coal, has also been mined in some areas.

Allegheny Group

The Allegheny Group contains the majority of economically mineable coals in Pennsylvania. The Allegheny Group extends from the bottom of the Brookville coal to the top of the upper Freeport coal. The coals within the Allegheny Group that are currently being, or have been deep mined within the last five years are shown by county in Table VII.1.

Mines located in Jefferson, Armstrong, Indiana, Cambria, and Somerset Counties extract Allegheny Group coals. These mines generally lie along the perimeter of the bituminous coalfield where the coals outcrop and are easily accessible (see Plate 2).

Figure VII.2
Generalized Stratigraphic Section of the Bituminous Coalfield of Western Pennsylvania Showing Stratigraphic Names and Positions of Principal Coals
(The section shown represents about 1600 Feet (490 m)

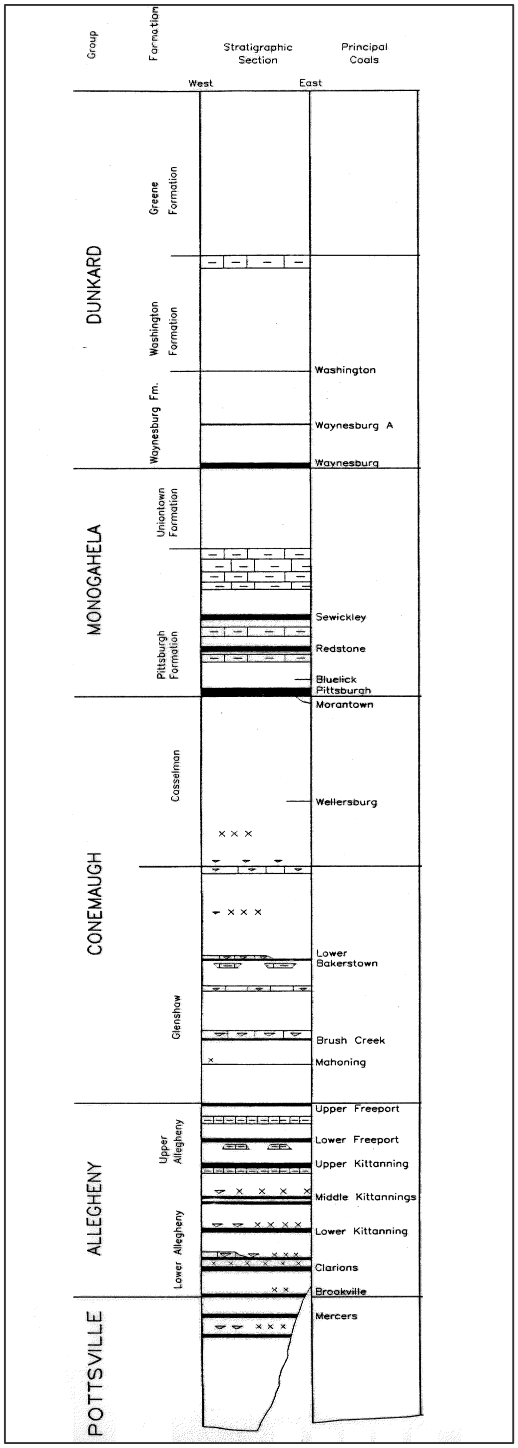


Table VII.1
Allegheny Group Coal Seams that have been Mined within the Last Five Years

Coal Seam	Counties With Deep Mining Within Last Five Years
Brookville	Somerset
Clarion	Indiana and Jefferson
Lower Kittanning	Clearfield, Indiana, Jefferson, and Somerset
Middle Kittanning	Armstrong, Jefferson, and Somerset
Upper Kittanning	Cambria, Indiana, and Somerset
Lower Freeport	Allegheny, Armstrong, Indiana, and Jefferson
Upper Freeport	Allegheny, Armstrong, Butler, Indiana, and Somerset

Conemaugh Group

Mineable coals are uncommon in the Conemaugh. At present there are no deep mines within this geologic group.

The Conemaugh Group is defined as the rocks lying between the upper Freeport coal and the Pittsburgh coal. The thickness of this interval ranges from 520 feet (158 m) in western Washington County to 890 feet (270 m) in southern Somerset County.

Monongahela Group

The Monongahela is the other geologic group that contains thick, mineable coals. In fact the largest production of underground coal in Pennsylvania is from the Pittsburgh coal seam which is at the base of the Monongahela Group. Longwall mining of the Pittsburgh Coal is prevalent in Greene and Washington Counties (see Plate 2). The Sewickley coal is also mined in Greene County.

The Monongahela Group extends from the base of the Pittsburgh coal to the base of the Waynesburg coal. The group is about 270 to 400 feet (82 to 122 m) thick with thickness increasing in an irregular fashion from the western edge of the state to western Fayette County. The mineable coals in the Monongahela Group are restricted to the lower portion of the group. The Pittsburgh coal is unusually continuous, covering thousands of square miles (km^2), and is unusually thick (5 to 10 ft or 1.5 to 3 m) for a coal of western Pennsylvania. The other major coals that have been deep mined in the past are the Redstone and Sewickley.

Dunkard Group

The Dunkard Group is found only in the most southwestern corner of Pennsylvania in Greene and Washington Counties. The Dunkard reaches a maximum thickness of about 1120 feet (340 m) in Greene County and its upper surface is the modern-day land surface. The lower boundary of the Dunkard Group is defined as the base of the Waynesburg coal. No coals are currently being deep mined in the Dunkard Group.

Structure

The geologic structure of Pennsylvania's bituminous coal region may conveniently be described according to several levels of scale. At the largest scale, the entire Allegheny Plateau in western Pennsylvania is part of a major structural basin referred to as the Appalachian Coal Basin or Allegheny Synclinorium. The northern portion is often referred to as the Pittsburgh-Huntingdon Basin.

The basin may be visualized as a broad spoon-shaped structure, in which the youngest strata are at the center of the spoon and successively older strata become exposed toward the outer edge of the spoon. Consequently, a bed such as the upper Freeport coal of the Allegheny Group, which is present at the land surface at elevations of approximately 2000 feet (607 m) above sea level at the northern and eastern margins of the coalfield, is present in the southwestern corner of Pennsylvania at an elevation several hundred feet below sea level and beneath many hundreds of feet of younger rocks, including the Pittsburgh Coal.

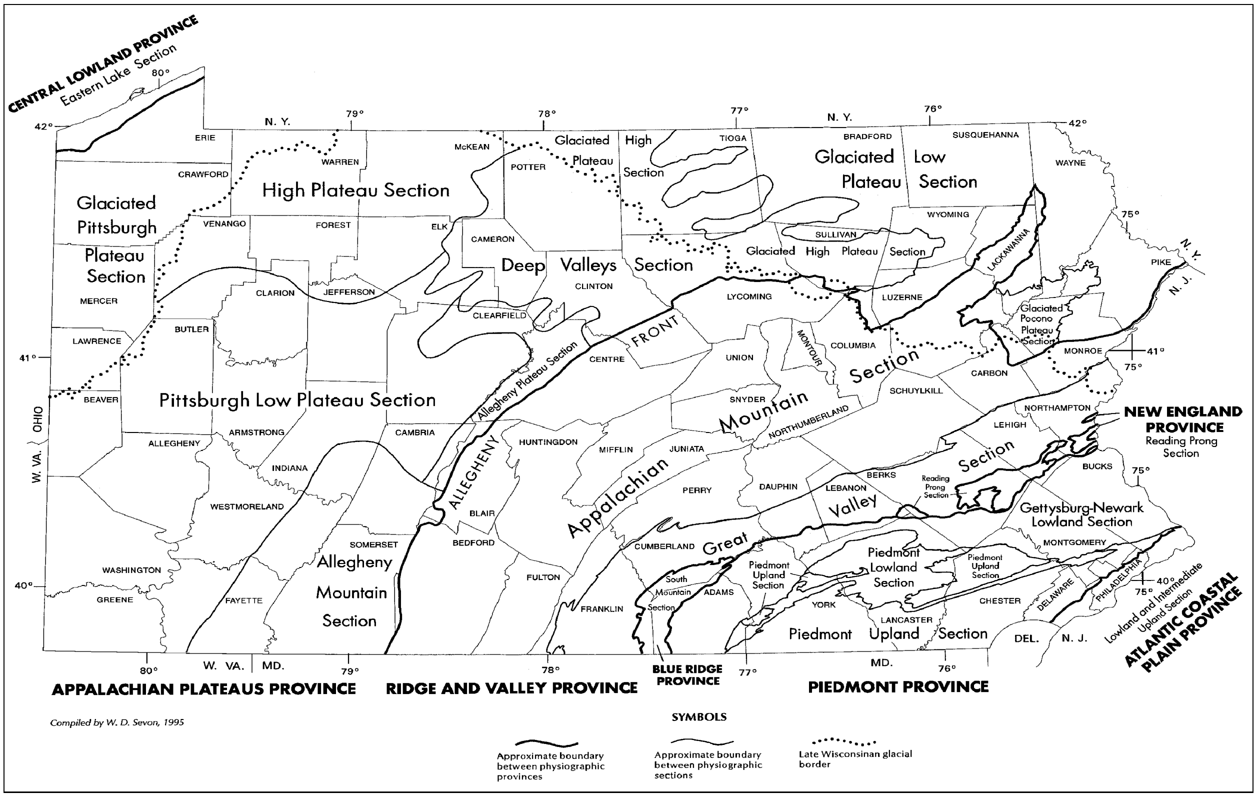
The next level of structural scale includes the large synclines and anticlines in the eastern portion of the bituminous coalfield. The major features, from southeast to west, are the Wellersburg syncline (which contains the George's Creek Coalfield), the Deer Park anticline (which is devoid of coal), the Berlin syncline (which contains rocks as young as the lower Monongahela Group), the Negro Mountain Anticline (which contains Mt. Davis, the highest point in Pennsylvania), a broad syncline that runs from Johnstown to the Youghiogheny dam, the Laurel Ridge anticline, the Ligonier syncline, and the Chestnut Ridge anticline. Structural relief decreases northwestward in a step-like fashion from the well-defined folds of the southeastern side of the plateau where anticlines rise 800 to 2500 feet (244 to 1067 m) above adjacent synclines.

The next level of structural scale includes small deviations in folding from the broader synclines and anticlines and faults. Faults are more prevalent near the eastern margin of the coalfield in northern Cambria and Clearfield Counties and rare to the west. Joints and lineaments are other structural features that can be important from a mining standpoint because they can affect the stability of a mine roof and can convey groundwater.

Physiographic Provinces and Climate

Physiographic provinces characterize the topography of Pennsylvania's bituminous coalfields. A physiographic province is a region whose pattern of relief features or landforms is consistent within its borders but differs from that of adjacent regions. During the past five years underground bituminous coal mining in Pennsylvania has been conducted in the Pittsburgh Low Plateau Section and the Allegheny Mountain Section of the Appalachian Plateaus Province (Figure VII.3). The Pittsburgh Low Plateau Section consists of a rolling upland surface cut by numerous, narrow, relatively shallow valleys. The Allegheny Mountain Section consists of broad, rounded ridges separated by broad valleys. The ridges decrease in elevation from south to north. The southern parts of these ridges form the highest mountains in Pennsylvania.

Figure VII.3
Physiographic Provinces of Pennsylvania (PA-DCNR MAP 13)

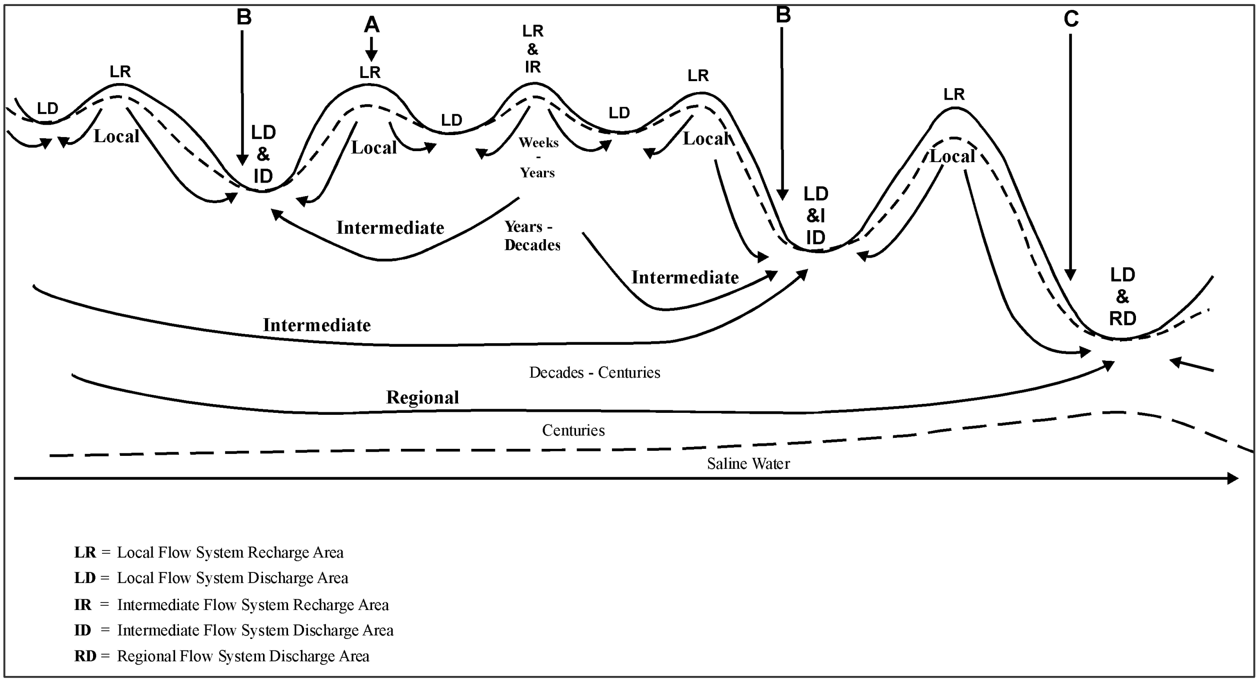


Southwestern Pennsylvania has a humid climate with precipitation distributed relatively evenly throughout the year. Mean annual precipitation for the area ranges from 36 to 46 inches with the trend being a general increase from west to east. The greatest precipitation is along the ridges of the Allegheny Mountain Section. It is estimated that approximately 12 to 15 inches of the average precipitation infiltrates the groundwater system with evaporation and transpiration accounting for roughly 20 inches annually (Becher, 1978). The remaining precipitation runs off to surface waterways. These numbers are approximations. The actual amounts vary from place-to-place depending on geology, soils, vegetation, topography, and from year-to-year.

Groundwater Hydrology

Within the study area drainage basins tend to be small with marked relief. These factors along with the humid climate generally combine to produce a groundwater system that can be readily broken into distinct parts – local (shallow), intermediate, and regional (Poth, 1963) (Figure VII.4). Superimposed on these systems (particularly on the shallow system) are distinct zones of increased groundwater flow defined by the density and interconnection of rock fractures.

Figure VII.4
Sketch Illustrating Various Characteristics of the Composite Fresh-Water Groundwater Flow System

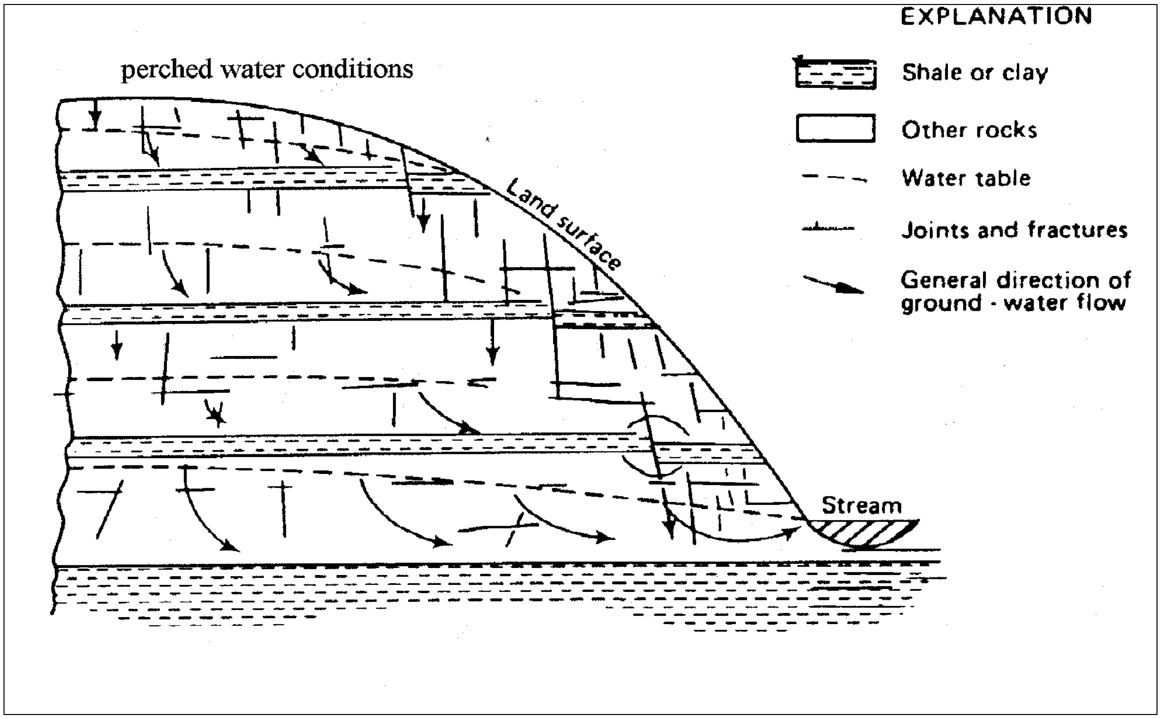


The local flow system underlies hills, discharges to local streams, and, to some extent, springs above stream level. In some areas, local systems include water that is "perched" above beds of lower permeability (Figure VII.5). This groundwater moves laterally and discharges as springs above stream level.

The hills constitute "hydrologic islands" as described by Poth (1963) and as indicated by " A" in Figure VII.4. A discrete groundwater flow system operates within each hydrologic island and is hydrologically segregated from the local groundwater flow systems in adjacent islands. The base of the local flow system (particularly for islands adjacent to smaller streams) lies below the level of the stream valleys bordering the island. It is defined by the maximum depth at which groundwater originating within the hydrologic island will flow upward to discharge in the adjacent stream valley. This is indicated with a "B" in Figure VII.4. Recharge to the local system is completely from within the hydrologic island. Discharge from the local system is into the adjacent stream valleys with some leakage into the deeper intermediate and regional groundwater flow systems. In areas adjacent to larger streams and rivers, local groundwater that leaks downward may commingle with intermediate or even regional flow, which is rising to discharge within the valley as illustrated by point "C" in Figure VII.4. The local flow system is the area of the most active groundwater circulation. It is the zone that contributes water to the vast majority of domestic wells.

A prominent subsystem within the region's local groundwater flow system is a weathered regolith of approximately 10–20 meters in depth. The regolith is a highly transmissive zone

Figure VII.5
Idealized Perched Water Conditions
(modified from Ward and Wilmoth, 1986)



consisting of soil, unconsolidated sediment (subsoils), and weathered, highly fractured rock. Weathering has removed most soluble minerals, and groundwater flowing through this material picks up little mineral matter. Because of the open nature of the fractures within this zone, the groundwater "flow-through" time is short and this subsystem allows a significant portion of recharge to short-cut to local discharge points. (Schubert, 1980**).**

The intermediate groundwater flow system is recharged by shallower systems. Recharge usually takes place at the drainage basin divide that defines the recharge area. Flow passes beneath two or more hydrologic islands and discharges in valleys above the lowest level of the drainage basin. Flow rates and residence times are generally between those of local and regional groundwater flow systems, probably varying from years to decades, depending on the level of the intermediate system and the length of the flow path. A deep, regional groundwater flow system, which lies beneath the level of the hydrologic islands and intermediate flow system, operates independently of the shallower systems. The base of the regional system is the fresh water/saline water contact. Recharge to the regional system is from major drainage basin divides and leakage from multiple shallower (local and intermediate) systems.

Groundwater Quality

Groundwater reflects the chemical character of the rock units through which it flows . For example, groundwater that has come in contact with sandstone and shale containing pyrite remains "soft." Water in limestone or calcareous aquifers usually is a calcium magnesium bicarbonate type and is sometimes "hard."

The chemistry of groundwater can also provide insight into the type of flow system involved. Sodium chloride brines occur below a depth of several hundred meters in southwestern Pennsylvania. Waters immediately above the brine are more dilute but also have elevated concentrations of sodium and chloride. In the intermediate groundwater system chloride has generally been removed by flushing with surface waters, but considerable sodium remains adsorbed to clays and similar materials, resulting in sodium-bicarbonate water. In the uppermost shallow groundwater system sodium is completely flushed leaving calcium-bicarbonate water.

Groundwater Availability

Over most of southwestern Pennsylvania sufficient water for domestic purposes can be obtained from bedrock wells drilled in the 75-250 foot (23 to 75 m) depth range. These bedrock wells are naturally low yielding. Well yields can be 100 gallons per minute (gpm) [(380 liters/minute (L/min)] or more but are typically below 10 gpm (3.8 L/min) with a large percentage below 3 gpm (9 L/min). Yields large enough for industrial or municipal purposes are more difficult to obtain. Large capacity wells have been successfully developed near the intersection of fracture traces. Fractures enhance groundwater flow to the well bore. Bedrock wells often exceed recommended drinking water concentrations for iron.

Hydrologic data has been collected and analyzed for most of the bituminous coalfield. The following is a short outline of the water-bearing characteristics of the various geologic formations. The focus is on Greene, Washington, Armstrong, Indiana, and Somerset counties, the major coal producing counties.

Greene and Washington Counties - Greene and Washington Counties lie in the extreme southwest corner of Pennsylvania and presently include the most productive coal mines in the state. Stoner (1987) outlines the following generalities regarding topographic position versus well yield for Greene County. The same general rules hold true for Washington County.

> "Hilltop wells – wells are commonly drilled only to the depth of sufficient yield. Increasing the well depth for added yield or storage commonly results in water-level decline and sometimes complete loss of well yield. Also, an uncased deep well can often reduce the yield of a nearby shallow well.
>
> Hillside wells –wells need to be sited at some distance from potential contamination points such as septic tanks, trash dumps, or stock pens located upgradient. At many hillside locations, springs are a suitable alternative to wells as a potable water supply.
>
> Valley wells – Highly mineralized groundwater is shallowest beneath valleys. This condition commonly limits the depth of valley wells to be used for domestic supply. High-yielding shallow

wells are possible in the alluvium of major valleys, but groundwater is susceptible to contamination by surface activities. Tightly cased deep wells in large valleys may be free flowing…. Of all the topographic positions, wells in valleys have the greatest probable success of producing high well yields. These high yields are commonly due to fracturing beneath the valley bottom. This fracturing is expected to diminish beneath adjacent hills, thereby limiting the effective areal extent and yield of such aquifers…"

The near-surface bedrock units within the counties include, in ascending order, the Conemaugh Group (Glenshaw and Casselman Formations), the Monongahela Group (Pittsburgh and Uniontown Formations), and the Dunkard Group (Waynesburg, Washington, and Greene Formations). These units are present within the fresh groundwater flow system and therefore serve as aquifers for local groundwater supplies. [The ranking of hydraulic conductivity (capacity of rock to transmit water) from highest to lowest among rock types is (1) coal, (2) sandstone, (3) siltstone and shale, and (4) limestone (Williams et al., 1993).] Descriptions of these bedrock units and their water bearing characteristics are presented in Table VII.2.

Table VII.2
Geologic Units and Water-bearing Characteristics for Greene and Washington Counties

Geologic Group	Water Bearing Characteristics
Conemaugh – (Glenshaw and Casselman Formations). This unit occurs at or near the surface in northern, central, and eastern Washington County and in extreme southeastern Greene County along the Monongahela River. The Conemaugh is composed chiefly of sandstone and shale with lessor amounts of limestone and coal.	In Washington County the Conemaugh Group is a source of moderate supplies of groundwater but is of limited areal extent. The Casselman Formation has the highest mean reported yield of the local bedrock aquifers (Williams et al., 1993). The best water-producing units are sandstone beds (Newport, 1973). Limited hydrologic data are available for the Conemaugh in Greene County due to its small areal extent.
Monongahela – (Pittsburgh and Uniontown Formations). The Monongaheha Group is exposed in the eastern third of Greene County and the northern and eastern parts of Washington County. The Monongahela is composed of mainly sandstone, limestone, dolomite, and coal.	Well yields vary over the area with a reported median yield of about 1 gpm (3.8 L/min) for Washington County (Newport, 1973) and a reported median yield of 8 gpm (30.4 L/min) for the upper section (Uniontown Formation) of the Group (Stoner, 1987) in Greene County. Water quality is often marginal with iron and manganese concentrations exceeding recommended limits.
Dunkard – (Waynesburg, Washington, and Greene Formations). This group occurs near the surface in central and southern Washington County. The Greene Formation covers the western half of Greene County and caps the tops of ridges in the eastern part of the county. The Washington Formation outcrops in valley bottoms in the northwest corner of Greene County. The Waynesburg formation consists of shale, sandstone, siltstone, and coal. The Washington Formation, which immediately overlies the Waynesburg, consists of limestone, claystone, siltstone, sandstone, carbonaceous shale, and coal. The Greene Formation consists mostly of shale, sandstone, siltstone, and limestone.	The median reported yield for Waynesburg wells in Greene County is 3.8 gpm (14.4 L/min) (Stoner, 1987). According to Williams et al. (1993) the mean reported yield of wells tapping the Waynesburg in Washington County is 10 gpm (38 L/min). The reported yields of 30 wells range from 0.5 to 60 gpm (1.9 to 230 L/min). Yields from 16 springs ranged from 1.0 to 18.4 gpm (3.8 to 70 L/min). The mean reported well yield for the Washington Formation in Washington County is 9.6 gpm (36.5 L/min) based on the testing of 39 wells. Yields ranged form 0.5 to 50 gpm (1.9 to 190 L/min) (Williams et al., 1993). According to Stoner (1987), the median reported yield of 39 Washington Formation wells in Greene County is 3.0 gpm (11.4 L/min) and the median discharge of 120 springs is 0.5 gpm (1.9 L/min). In Greene County, the formation is generally a poor aquifer having low well yields; the median reported yield of 55 wells is only 2 gpm (7.6 L/min) (Stoner, 1987). The formation fairs better in Washington County with reported yields of 13 wells ranging from 2 to 35 gpm (7.6 to 130 L/min) with a mean yield of 11 gpm (42 L/min) (Williams et al, 1993).

Armstrong and Indiana Counties – The exposed bedrock or that immediately beneath the unconsolidated material in Armstrong and Indiana Counties consists of sandstone, shale, limestone, and coal. The most areally extensive, near-surface, coal-bearing units include the Conemaugh, Allegheny, and Pottsville Groups. Sandstones within these Groups are good water bearers, but at some places their yields are small because within relatively short distances a given sandstone may grade into shale (Shaffner, 1946). Median well yields for the Conemaugh Group in Armstrong County have been reported to be 5 gpm (19 L/min). (Poth, 1973). Poth (1973) also reports that the Allegheny Group in Armstrong County is capable of supplying moderate amounts of water to wells, with about half of wells on which data were available (10 out of 19 wells) yielding more than 25 gpm (95 L/min).

Williams and McElroy's (1991) report on the water resources of Indiana County compiled data on 523 wells. Seventy-seven percent tapped the Conemaugh Group. Another 21% tapped the Allegheny Group. Reported well yields ranged from 300 gpm (1140 L/min) to less than 1.0 gpm (3.8 L/min) for the total population of inventoried wells. The mean reported yield for the Conemaugh wells is 11.3 gpm (42.9 L/min).

Somerset County – Somerset County is underlain by a sequence of sedimentary rocks consisting of shale, siltstone, sandstone, claystone, limestone, and coal. Some water-bearing units are stratigraphically below the coal measures. The coal-bearing units include the Pottsville, Allegheny, Conemaugh (Glenshaw and Casselman Formations) and Monongahela Groups. According to McElroy (1997), wells properly sited in the Glenshaw Formation and Pottsville Group will commonly yield quantities suitable for public-supply, industrial, or other high-yield uses. McElroy inventoried over 400 domestic wells in Somerset County in various topographic settings. Table VII.3 shows yield by geologic unit and topographic setting.

Table VII.3
Well Yields in Somerset County by Geologic Unit and Topographic Position

Group or Formation	Hilltop gpm (L/min)	Hillside gpm (L/min)	Valley gpm (L/min)
Casselman	5 (19)	12 (45.6)	18 (68.4)
Glenshaw	6 (22.8)	10 (38)	12 (45.6)
Allegheny	7 (26.6)	10 (38)	18 (68.4)
Pottsville	12 (45.6)	8 (30.4)	40 (152)

Alluvial Deposits - Over the entire study area, alluvium, particularly along major rivers, is generally highly permeable and can yield large quantities of water to wells. However, permeabilities may change significantly over short distances because of changes in the degree of sorting. Wells penetrating the coarse basal layers generally obtain the largest yields (Poth, 1973). Well yields in the 500 gpm (1900 L/min) range are not uncommon. In general, water obtained from alluvium is hard, has high iron, manganese, and dissolved-solids concentrations.

Literature Cited:

Back, W., J. S. Rosenhein, and P.R. Seaber (1988). The Geology of North America, Hydrogeology, Geologic Society of America, Volume 0-2.

Becher, A. E. (1978). Ground Water in Pennsylvania. Pennsylvania Geological Survey, Educational Series No. 3, Pennsylvania Department of Conservation and Natural Resources, Harrisburg, Pa.

Edmunds, W.E., V.W. Skema, and N.K. Flint, 1998. Pennsylvanian. Part II. Stratigraphy and Sedimentary Tectonics. Geology of Pennsylvania. pp. 149-169.

Gold, D. P. (1980). Applications of remote sensing techniques to geologic problems. In: Remote Sensing in Geology, B. S. Seigal and A. R. Gillespie (eds.), John Wiley and Sons, Inc., pp. 419-503.

McElroy, T. A. (1997). Groundwater Resources of Somerset County, Pennsylvania. Water Resources Report, Pennsylvania Geological Survey, Fourth Series.

Newport, T. G. (1973). Ground-Water Resources of Washington County, Pennsylvania. Water Resources Report 38, Pennsylvania Geological Survey, Fourth Series.

Parizek, R. R. (1971). Prevention of coal mine drainage formation by well dewatering. Special Research Project SR-82, The Pennsylvania State University.

Poth, C. W. (1973). Ground-Water Resources of Armstrong County, Pennsylvania. Water Resources Report 34, Pennsylvania Geological Survey, Fourth Series.

Poth, C. W. (1963). Geology and hydrology of the Mercer Quadrangle, Mercer, Lawrence, and Butler Counties, Pennsylvania. Water Resource Report 16, Pennsylvania Topographic and Geological Survey, Fourth Series.

Schubert, J. P. (1980). Fracture flow of groundwater in coal-bearing strata. Symposium on Surface Mining Hydrology, University of Kentucky.

Shaffner, M. N. (1946). Topographic and Geologic Atlas of Pennsylvania, A 55, Smicksburg Quadrangle. Pennsylvania Geological Survey, Fourth Series.

Stoner, J. D., D. R. Williams, T. F. Buckwalter, J. K. Felbinger, and K. L. Pattison (1987). Water Resources and the Effects of Coal Mining, Greene County, Pennsylvania. Water Resources Report 63, Pennsylvania Geological Survey, Fourth Series.

Williams, D. R., J. K. Felbinger, and P. J. Squillace (1993). Water Resources and the Hydrologic Effects of Coal Mining in Washington County, Pennsylvania. U.S. Geological Survey Open-File Report 89-620.

Williams, D. R., and T. A. McElroy (1991). Water-Resources Data for Indiana County, Pennsylvania. U.S. Geological Survey Open-File Report 90-384.

Wyrick, G. G., and J. W. Borchers (1981). Hydrologic effects of stress-relief fracturing in an Appalachian valley. U.S. Geological Survey Water-Supply Paper 2177, 51 p.