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Bureau of Mines

SURFACE-WATER SEEPAGE INTO ANTHRACITE MINES IN THE WYOMING BASIN NORTHERN FIELD

ANTHRACITE REGION OF PENNSYLVANIA

By S. H. Ash and R. H. Whaite

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SURFACE-WATER SEEPAGE INTO ANTHRACITE MINES IN THE WYOMING BASIN, NORTHERN FIELD

ANTHRACITE REGION OF PENNSYLVANIA[1]

by

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Summary

THE MAGNITUDE of the anthracite industry's drainage problem in the Northern field of Pennsylvania is realized when it is known that, for the 8-year period 1944–51, all pumping plants in this region pumped an average volume of 112.5 billion gallons of water from the mines to the surface each year. This is over 214,000 gallons per minute pumped against an average hydrostatic head of 400 feet each year for that period (*12*).[4] By comparison, Lake Wallenpaupack, the largest artificial body of water lying wholly in Pennsylvania, contains 71 billion gallons of water in its 24-square-mile area; the average volume of water pumped from the mines in the Northern field each year during the 8-year period was 58 percent more than the volume impounded in Lake Wallenpaupack.

The natural configuration of the drainage area overlying the Northern field subdivides the total area into two major drainage areas—the Lackawanna River drainage area and the Susquehanna River drainage area overlying the Wyoming Basin. Although the 169-square-mile drainage area overlying the Wyoming Basin is slightly less than half that of the Lackawanna River drainage area (*10*), the total volume of water pumped to the surface from mines in the Wyoming Basin is 21 percent more than the total volume pumped to the surface from mines in the Lackawanna Basin. From this, it is apparent that the Susquehanna River and the pervious deposits in the buried valley over which it flows in its course across the coal measures of Wyoming Valley is the greatest single source of mine water affecting mines in this area. Because of its relatively flat terrain, the wide flood plain of Wyoming Valley does not facilitate rapid runoff; consequently, much of the surface water seeps directly into the buried-valley deposits and eventually into the mine workings.

Before a report outlining a solution of the mine-water problem can be completed, the possibilities of preventing surface seepage by corrective measures at its source must be explored. There is little doubt that, in every instance, water retained on the surface and diverted to surface-drainage channels has been handled more economically than it would have been by pumping from the mines. Some anthracite-mining companies have applied several types of remedial measures to prevent or minimize surface and stream-bed seepages, with generally good results (*10, 16*). This report reveals that about 20 percent of the 70 miles of pervious stream beds examined between Pittston and Glen Lyon has been improved.

This investigation suggests that the problem of preventing the inflow of surface water into mine workings should be attacked jointly by the active mining companies. The material is so arranged that it will serve as a guide to determine the extent of surface-water seepage.

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[4] Italicized numbers in parentheses refer to items in the bibliography at the end of this report.

INTRODUCTION

The responsibility of the Federal Government for developing an engineering method that will prevent inundation of the Pennsylvania anthracite mines and keep them in operation has long been recognized (*22*). To obtain a reliable picture of the anthracite-mine-water problem and to solve that problem, it is necessary to have factual data on surface-water seepage into active, abandoned, and flooded mines (*1, 2, 5, 6, 7, 8, 9, 10, 14, 16, 23*).

The Northern field is divided into two basins—the Wyoming and the Lackawanna—by a structural saddle, sometimes called the "Moosic saddle," near Old Forge. The Wyoming Basin extends from this saddle southwesterly for 26 miles to Shickshinny (*2, 5, 10, 15*).

A study of surface-water seepage into anthracite mines in the Wyoming Basin of the Northern field is part of a comprehensive study of the anthracite-mine-water problem by the Federal Bureau of Mines. Figure 1 is a map showing the four anthracite fields.

Mine water originates as rainfall and collects in mine workings as a result of stream-bed, general surface, and barrier-pillar seepage (*2, 3, 4, 5, 8, 9, 10, 11, 14, 15*). Anthracite-mining companies have spent considerable money to prevent stream-bed and general surface seepage (*5, 7, 10, 14, 19, 23*).

PURPOSE OF REPORT

The purpose of this report (the third in a series on surface-water seepage, Bulletins 518 and 531 being the first and second) is to record data obtained by engineers of the Federal Bureau of Mines on stream-bed and general surface seepage into mine workings in the Wyoming Basin (*5, 8, 9, 10, 13, 15*). The data so presented will be helpful in solving the mine-water problem in the Wyoming Basin of the Northern field.

These data show the volume and type of seepage (stream, surface, or river) in the drainage area overlying the Wyoming Basin and

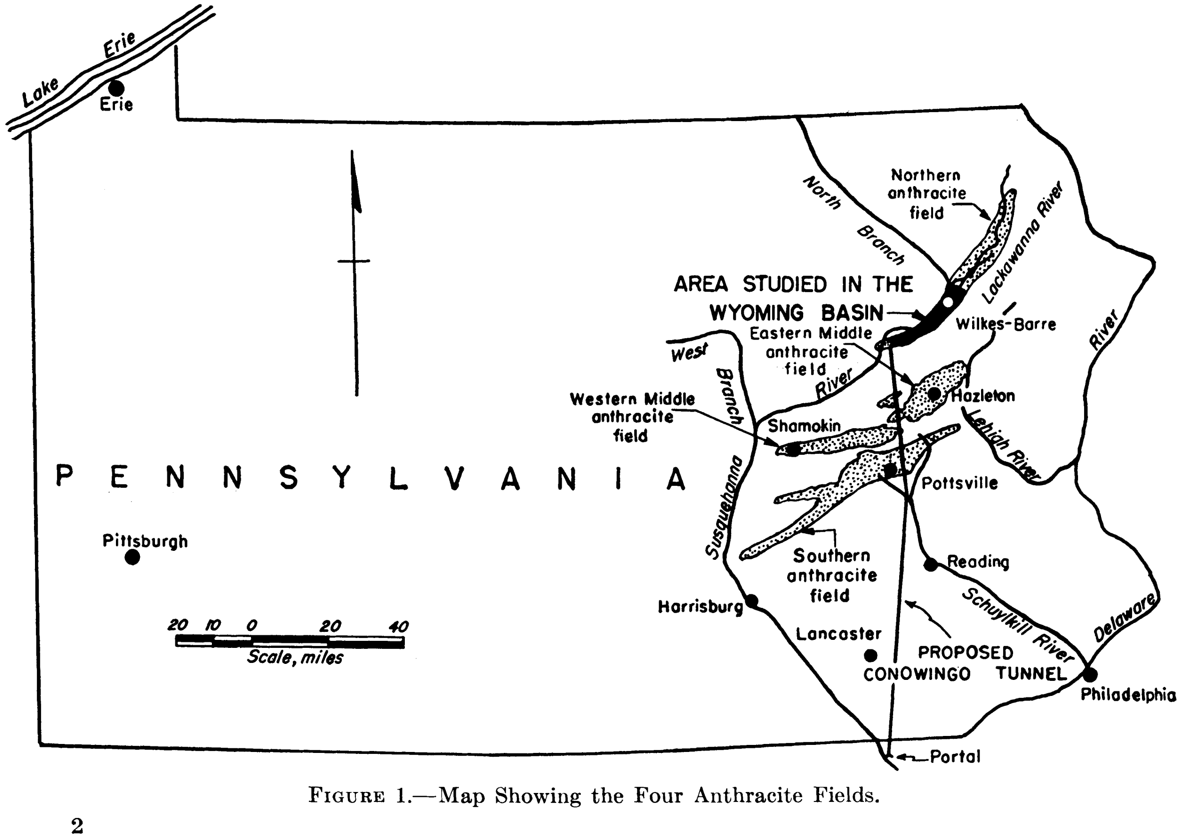

FIGURE 1.—Map Showing the Four Anthracite Fields.

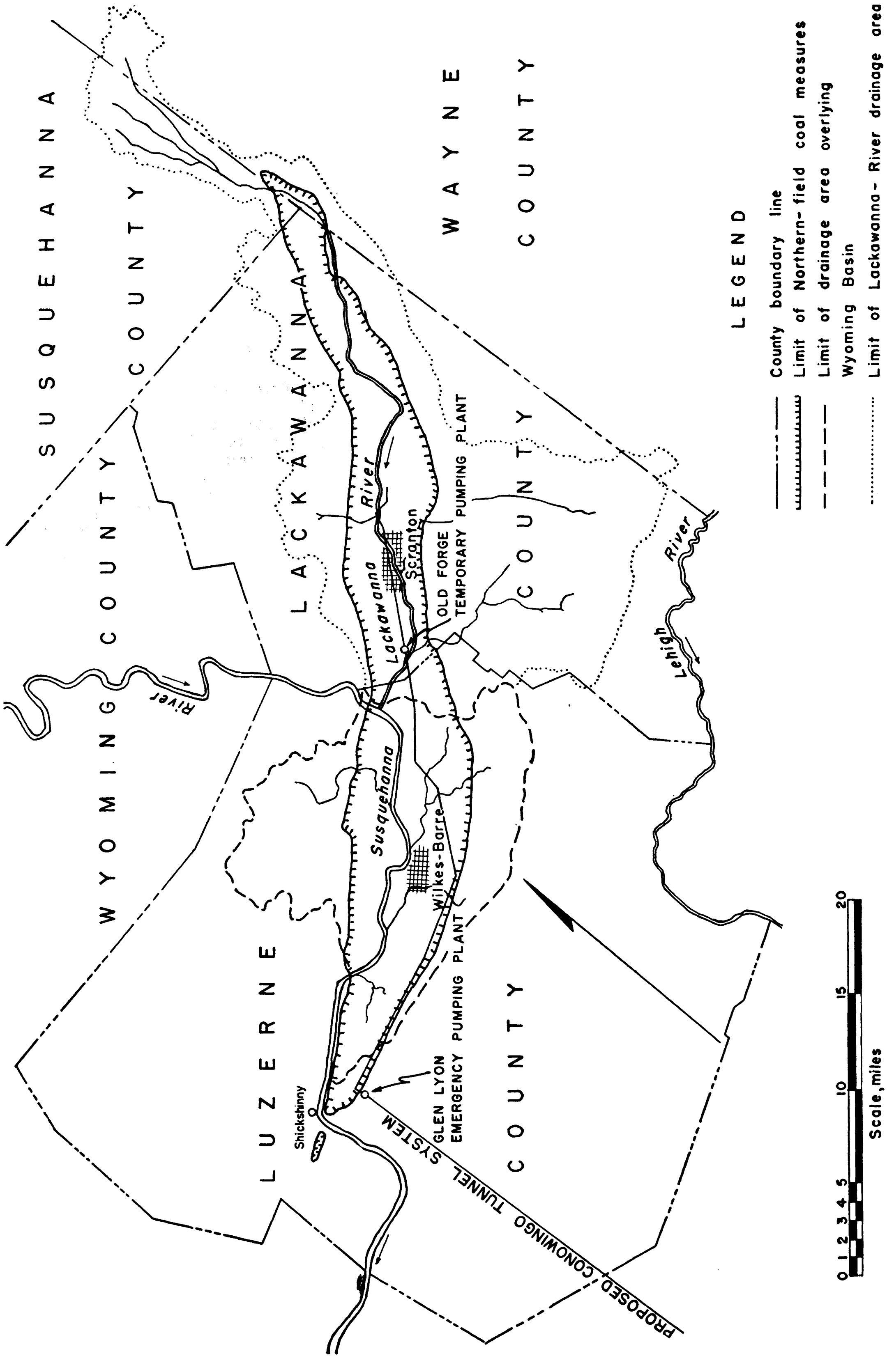

FIGURE 2.—Map of Northern Field, Showing Drainage Area Overlying Wyoming Basin, and Lackawanna River Drainage Area.

form a sound basis for considering remedial measures. They may be used for estimating the capacity of proposed mine pumping plants. They point to the value of repairing pervious stream beds and surface areas overlying the coal measures as part of the solution of the mine-water problem affecting the mines in the Northern field.

Figure 2 is a map of the Northern field, showing the drainage area overlying the Wyoming Basin, and the Lackawanna River drainage area.

SCOPE OF REPORT

This report discusses the nature of stream-bed and surface seepage problems and mentions remedial measures devised by some anthracite-mining companies to prevent seepage of surface water into their mines. It summarizes the engineering study on seepage of surface water into mine workings underlying the Wyoming Valley, conducted during 1950 and 1952 by engineers of the Federal Bureau of Mines. To date, 111 streams have been examined in the surface-drainage area overlying the Northern field, or approximately 32 percent of the streams in the anthracite region. Fifty-nine streams (not including the Susquehanna River) overlying the Wyoming Basin were investigated and are covered in this report; these are shown in figure 3.

A reconnaissance was made of each stream and its drainage area from where it enters the coal measures to its confluence with a major stream. Inhabitants of the affected locality were queried as to the frequency of dry-stream-bed occurrence and the extent of areas inundated during flood periods.

A table for each stream and its drainage area contains the following information:

(*a*) Square miles (total) of drainage area.
(*b*) Square miles of drainage area within limits of coal measures.
(*c*) Length of stream bed within coal measures.
(*d*) Length of pervious stream bed.
(*e*) Length of existent improvements.
(*f*) Estimated volume of surface and stream-bed seepage into mine workings.

Tables summarize these data; identify the estimated volume, source of seepage, and probable receiving underground pools, drainage tunnel, and pumping plants; and compare the total estimated seepage to each pumping plant with the volume of water pumped by each plant during 1948.

ACKNOWLEDGMENTS

The authors acknowledge their indebtedness for aid in collecting data for this report to the following officials of mining companies in the Wyoming Basin of the Northern field: Edward T. Powell, mining engineer, Glen Alden Coal Co.; H. H. Otto, assistant general manager, The Hudson Coal Co.; Ralph A. Lambert, vice president and general manager, Pennsylvania Coal Co.; John M. Humphrey, Jr., mining engineer, Lehigh Valley Coal Co.; and W. E. Christian, mining engineer, Susquehanna Collieries Division, The M. A. Hanna Co. The authors also wish to thank the anthracite mine inspectors of the Pennsylvania Department of Mines; engineers of the Federal Bureau of Mines, who collected data and assisted in preparing the manuscript for publication (D. O. Kennedy, W. M. Romischer, W. L. Eaton, J. F. Emery, and H. M. James); H. D. Kynor, Sr., and H. A. Dierks, consultant mining engineers; and Catherine S. Hower, administrative assistant, Safety Branch of the Washington staff, who reviewed the manuscript.

GENERAL DISCUSSION

The topography of the anthracite region is typical of the Appalachian belt, of which it is a part. The coal measures lie beneath the synclinal axes of a number of the great surface troughs that characterize the belt. The mountains that surround the anthracite fields are steep; the anthracite beds, which outcrop on the sides of the mountains, dip to the valley below, and any drainage into the valleys must flow over the coal measures (*2, 10, 13, 16, 21, 27*).

The coal measures comprising the anthracite fields are crossed by 750 miles of rivers and streams, ranging in size from such major streams as the Susquehanna (North Branch), Lackawanna, Lehigh, and Schuylkill to small streams that traverse the coal measures (*4, 10*). This report shows that the Susquehanna River flows 16½ miles in its course across the coal measures in the Northern field and, with its tributaries therein, drains a surface area of over 169 square miles. On the basis of 42.59 inches of rainfall in 1948, recorded by the Wilkes-Barre station of the Scranton-Spring Brook Water Co., the 169-square-mile drainage area received over 125 billion gallons of water.

Mine water originates as rainfall and collects in mine workings as a result of general surface, stream-bed, and barrier-pillar seepage (*3, 4, 5, 8, 10, 13, 14*). These different types of seepage can be attributed mainly to subsidence of the strata and overburden composing the coal measures.

Subsidence is a consequence of mining (*3, 5, 7, 10, 15, 21*). Removal of support afforded by anthracite beds eventually causes cracks and fissures in and subsidence of strata overlying the beds. Cracks and fissures in the rock cover provide openings for ground water to enter into mine workings.

This study of surface-water seepage into anthracite mines in the Wyoming Basin, completed in 1953, reveals that approximately 49 percent of the water pumped annually from the mines in that area arrived underground from the bed of the Susquehanna River. Approximately 21 percent of the water pumped came from the pervious beds of side streams. The remaining 30 percent of the water pumped was attributed to direct surface seepage.

Direct seepage of surface water into the mine workings is hastened when man-made facilities and operations, such as built-up areas, railroad and highway embankments, mine refuse dumps, stripping excavations, and spoil banks alter the original drainage plan provided by nature and tend to retard, and in many instances block entirely, the natural flow of water from the hillsides to the main streams. Much of the surface water now collects in low places and eventually seeps underground (*2, 5, 10*).

The mining industry, particularly stripping operations with their attendant installations and roadways, has denuded the anthracite region of much woodland. Numerous cities, towns, and farms have removed, to a large extent, the dense vegetation that normally controlled runoff during and after storms. Plant growth often is consumed by recurring forest and brush fires; consequently, the unprotected top soil and subsoil permit an increased volume of surface water to seep into the mine workings. Eroded materials (sand, gravel, and boulders) are washed into stream channels during each storm (*10*).

The volume of water seeping into mine workings from the surface is determined by many factors. The topography, permeability, and porosity of the strata and the extent of soil, frost action, and plant cover in a drainage area influence the speed of runoff and the volume of seepage into mine workings. The direction of flow of runoff, which frequently parallels the course of the receiving-stream bed, and the slope of the ground surface over which it flows are important factors that affect direct surface seepage. Both are governed by the topography of the terrain (*10*).

Streams carry away natural surface drainage and mine drainage. They will have to continue to serve as ultimate discharge points for mine pumps and existent drainage tunnels, ditches, and flumes unless some other means are utilized (*5, 10*).

Natural stream beds are relatively pervious, and the volume of seepage depends on the material composing the stream bed and subjacent horizons. Mining operations near or under stream beds may disturb their natural condition and increase seepage from the stream. Where mining has been conducted under large streams to prevent or minimize fracture or subsidence of rock strata underneath, stream-bed seepage does occur eventually, and water enters mine workings through cleavage planes, bedding planes, faults, or fissures and cracks due to mining.

The volume of water seepage from a stream,

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because of the permeability of the stream bed, is determined by many factors, some of which are (*4, 10*):

(*a*) Volume of water in the stream.
(*b*) Velocity of the water.
(*c*) Nature or permeability of strata or soil composing stream channel.
(*d*) Wetted perimeter of stream channel.
(*e*) Weather conditions.
(*f*) Gradient, or slope, of stream.
(*g*) Disturbance of strata due to mining under stream bed.

According to Merriman (*25*), stream seepage will not increase by the addition of water unless the volume of water added to the stream is enough to increase appreciably the cross section of the stream channel in contact with the water. The flow of streams in the anthracite region varies considerably owing to heavy runoff after spring thaws and periods of heavy rainfall, and increased seepage can be expected during such periods. The addition of mine drainage to a stream may cause little change in the normal wetted perimeter of the stream and consequently cause no appreciable increase in the seepage into mine workings.

Many large streams lose considerable water where they flow over the coal measures; this is minimized where the stream bed is sealed by clayey silt, silty loam, or anchor ice. During periods of low flow, the decrease in volume due to seepage is evident by visual inspection.

Many small streams that carry water for their entire length during periods of heavy runoff lose all their water where they cross the coal measures (*5*). During the greater part of the year their entire flow, which may reach several thousand gallons a minute, seeps into mine workings.

In addition to these streams, many stream beds of former watercourses now are dry, except after heavy rainfall. These dry channels are evidence of subsidence from mining operations.

Some streams are formed by discharges from mine pumps, drainage tunnels, ditches, or flumes. In many instances much of this mine drainage seeps into mine workings and must be pumped to the surface (*19*).

Stream pollution (enormous quantities of waste materials from mine dumps and coal-preparation plants) has aggravated the problem of stream control (*8*). Figure 4 is a view of the Lackawanna River in the mining area 1 mile upstream from its confluence with the Susquehanna River, showing shallow conditions caused by enormous deposits of mine refuse. The

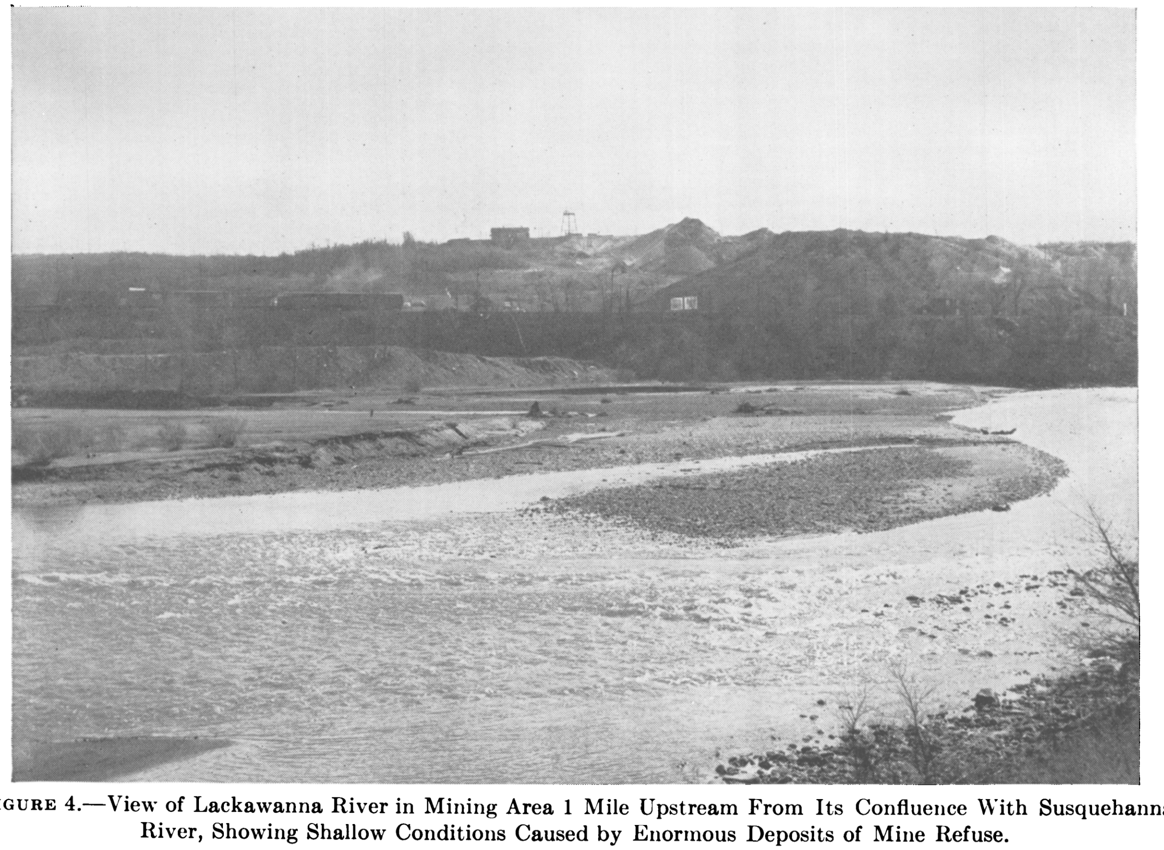

FIGURE 4.—View of Lackawanna River in Mining Area 1 Mile Upstream From Its Confluence With Susquehanna River, Showing Shallow Conditions Caused by Enormous Deposits of Mine Refuse.

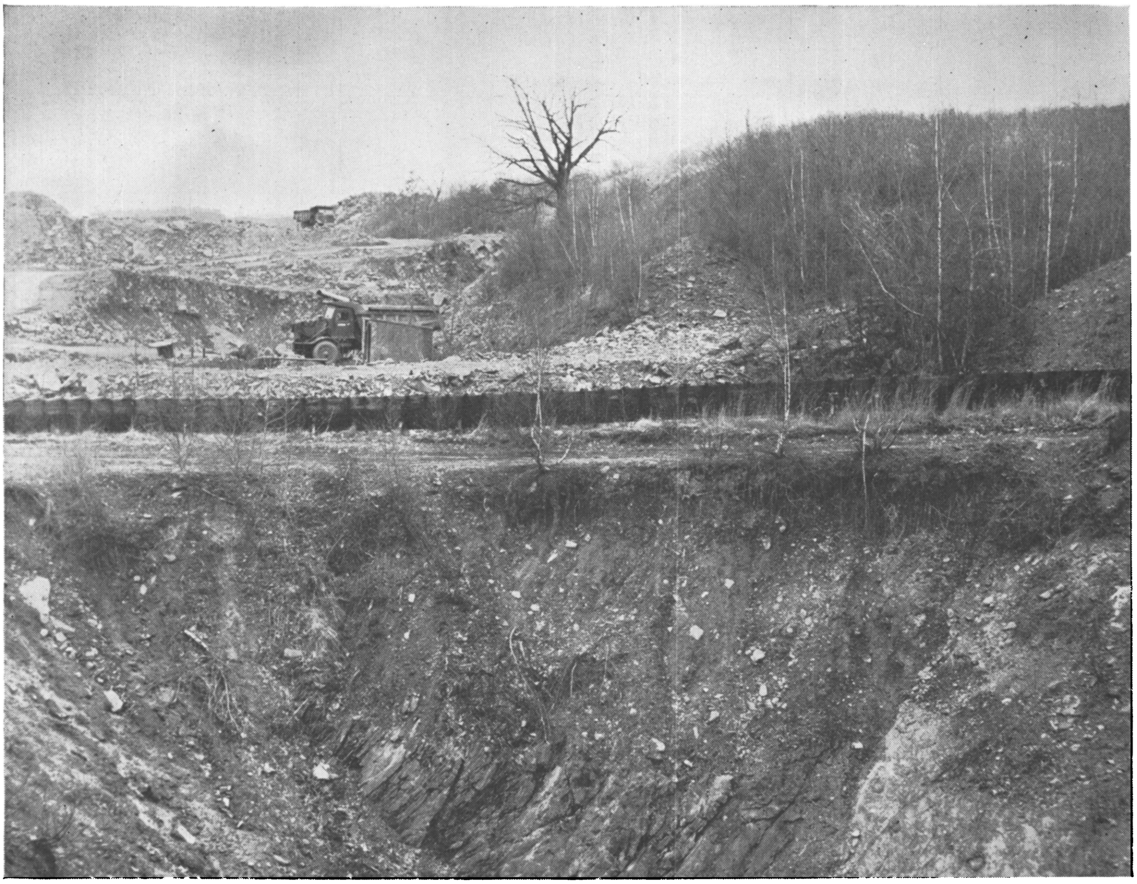

FIGURE 5.—Semicircular Wooden-Stave Flume in Stripping Area.

addition of relatively small amounts of silt or clay to a stream may decrease the volume of stream-bed seepage by sealing small cracks and fissures in the stream bed; however, the addition of large quantities of refuse has an adverse effect. Tremendous volumes of fine clay, loam, and silt have been washed into streams after heavy rainfalls. Almost every spring the tributaries overflow their banks, and enormous quantities of culm and silt are washed into the streams and deposited in their channels or in the adjacent areas (*17*). A stream bed choked with refuse is forced to leave its channel in periods of high water and flood adjoining areas. Under such conditions, the increased wetted perimeter of a stream is accompanied by increased stream-bed seepage. State and local regulations are directed against stream pollution, and much has already been done to prevent continuation of the practice (*8*).

Some mining companies have refrained from making extensive improvements to stream beds or surface areas overlying mine workings for one or more of the following reasons:

(*a*) The complex nature of the seepage problem often creates uncertainty in their minds as to the source of seepage and how much it affects a given pumping plant.

(*b*) The problem of surface ownership, where seepage is thought to occur, often is complicated and frequently presents financial and legal difficulties before remedial measures can be attempted.

(*c*) The expense of applying and maintaining remedial measures is considerable, especially when the efficiency of such measures is doubtful because of continuing subsidence of the ground, stripping excavations, and other causes. Figures 5, 6, 7, 8, and 9 show types of conditions encountered and wooden-stave flume installations.

(*d*) Some mining companies, usually the smaller ones, anticipate complete extraction of their available reserves within a few years and are satisfied to rely on the capacity of their pumping plants or on those of their neighbors to keep the mines free from water.

Some anthracite-mining companies spend large amounts to prevent surface water from entering into active and abandoned mines. The methods employed are as follows:

(*a*) Constructing and maintaining ditches and flumes to intercept and conduct surface water to natural courses; these bypass outcrops, rock fissures, strippings, mine openings, or cave-ins through which water could enter into mine workings.

FIGURE 6.—Typical View of Stripped Bed at Outcrop, Showing Lack of Provision to Keep Surface Water From Entering Mines.

FIGURE 7.—Semicircular Wooden-Stave Flume in Area Complicated by Subsidence and a Mine Fire.

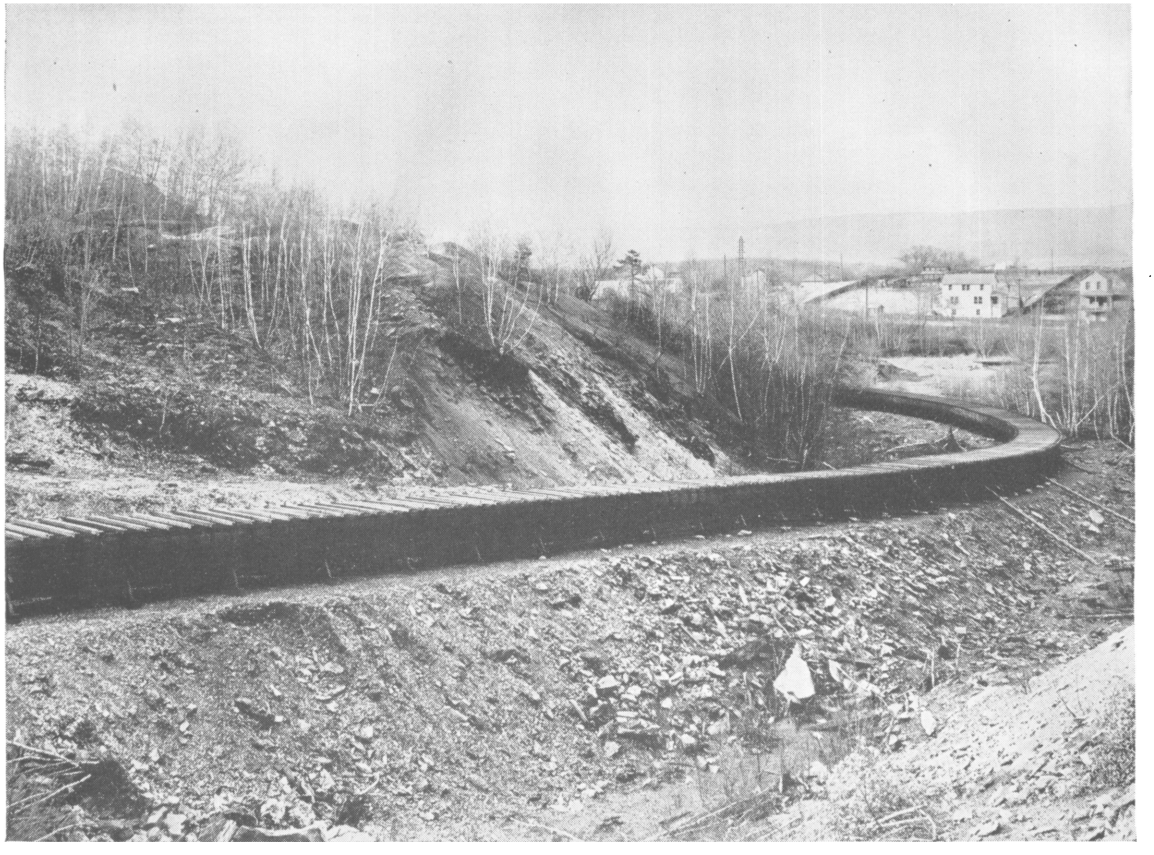

FIGURE 8.—96-Inch, Semicircular, Creosoted, Wooden-Stave Flume.

(*b*) Backfilling cave holes and stripping excavations with impervious material to an established hydraulic gradient so as to assure natural drainage.

(*c*) Cleaning and widening stream channels to provide free flow of water in the streams.

(*d*) Relocating streams to straighten channels or to divert the water to less pervious courses.

(*e*) Elevating stream beds and conducting the water by dikes so that the streams will flow over subsided areas.

(*f*) Lining stream beds with concrete or rubble masonry (stone and mortar) to prevent seepage through stream beds.

(*g*) Silting stream beds to render them impervious.

These methods are discussed in detail in Bureau of Mines Bulletin 518 (*10*).

FIGURE 9.—96-Inch, Creosoted, Wooden-Stave Pipe Reduced to Semicircular Wooden-Stave Flume of Same Diameter.

DRAINAGE AREA OVERLYING WYOMING BASIN

GEOGRAPHIC LOCATION

This investigation of stream-bed and surface seepage covers the drainage area of that portion of the North Branch of the Susquehanna River that overlies the southwestern part of the Northern field (Wyoming Basin) and is in the vicinity usually referred to as the Wyoming Valley.

Geographically, this drainage area lies in the northeastern portion of Luzerne County in northeastern Pennsylvania. Its outline is somewhat like a triangle, with the northeast side near the boundary lines between Luzerne and Wyoming Counties and Luzerne and Lackawanna Counties; here it is 17.5 miles long. The southwest vertex of the triangle is about 2 miles north of Shickshinny. The drainage area is almost 20 miles long and comprises over 169 square miles of surface terrain. Ninety-two square miles (54 percent) of the total drainage area lies within the limits of the coal measures in the Wyoming Basin. (*See* fig. 2.)

The annual rainfall on the drainage area in the Wyoming Valley for 1910–52, as recorded by the Wilkes-Barre station of the Scranton-Spring Brook Water Co., is shown in table 1. The annual rainfall ranges from a low of 26.6 inches in 1930 to a high of 53.84 inches in 1945, with an average annual rainfall of 37 inches. The calculated trend for these years shows a gradual increase in the yearly rainfall. Figure 10 shows the rainfall and calculated trends, based on readings recorded by the Wilkes-Barre station of the Scranton-Spring Brook Water Co.

TWELVE SUBDIVISIONS OF DRAINAGE AREA OVERLYING WYOMING BASIN

Although the natural configuration of the drainage area overlying the Wyoming Basin tends, for the most part, to subdivide its total area of 169 square miles into several smaller watersheds, the natural grouping of the drainage areas of the 59 streams does not lend itself

Table 1.—*Rainfall in the Wilkes-Barre, Pa., area (inches) 1910–52* [1]

Year	Rainfall	Year	Rainfall	Year	Rainfall	Year	Rainfall	Year	Rainfall
1910	35. 00	1919	35. 50	1928	38. 71	1937	39. 79	1946	35. 10
1911	35. 01	1920	38. 97	1929	36. 09	1938	40. 89	1947	46. 58
1912	35. 70	1921	37. 67	1930	26. 60	1939	32. 94	1948	42. 59
1913	40. 16	1922	30. 54	1931	30. 03	1940	39. 47	1949	32. 95
1914	36. 21	1923	38. 39	1932	34. 21	1941	29. 31	1950	43. 57
1915	35. 98	1924	35. 73	1933	40. 80	1942	38. 99	1951	34. 77
1916	35. 16	1925	35. 84	1934	34. 68	1943	39. 23	1952	42. 18
1917	28. 44	1926	39. 12	1935	35. 77	1944	30. 76		
1918	39. 65	1927	45. 28	1936	32. 84	1945	53. 84	Yearly ave	37. 00

[1] Scranton-Spring Brook Water Service Co., Wilkes-Barre, Pa.

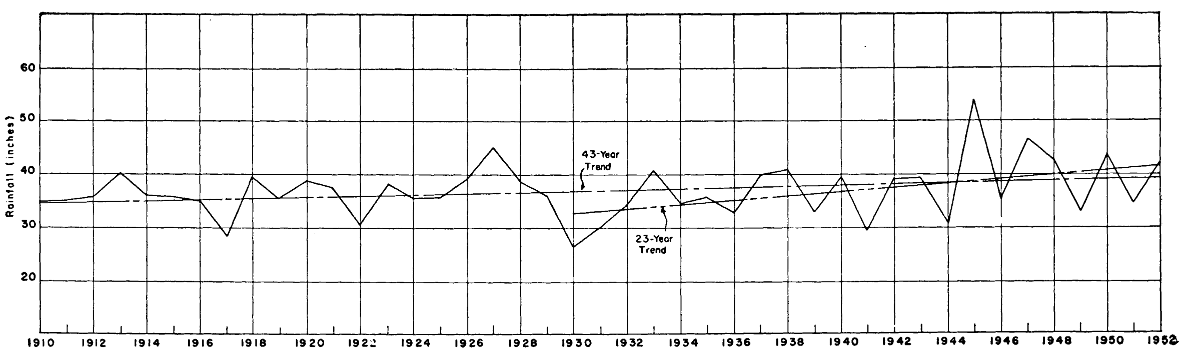

FIGURE 10.—Rainfall, Recorded by Scranton-Spring Brook Water Co.

to convenient presentation of data on each stream. Consequently, the total area was divided arbitrarily into 12 subdivisions, hereafter called watersheds, to facilitate collection, study, and presentation of data relative to each stream. Figure 11 is a map showing the 12 watersheds of the drainage area overlying the Wyoming Basin.

Five of the watersheds lie on the westerly side of the Susquehanna River and have an area of 65 square miles. Beginning with the most northern, they are defined in figure 11 as North 7 watershed, North 8 watershed, etc. The 22 streams that carry the runoff from them and cross the coal measures are numbered, from north to south, N–34 to N–55. (See fig. 3.)

Six of the watersheds lie on the easterly side of the Susquehanna River and are over 87 square miles in area. Beginning with the most northern, they are defined in figure 11 as South 5 watershed, South 6 watershed, etc. The 37 streams that carry the runoff from them and cross the coal measures are numbered, from north to south, S–20 to S–56. (See fig. 3.)

The watersheds in the drainage area overlying the Wyoming Basin are defined with the same system of identification as that established in the Lackawanna drainage area, so that drainage data relative to the entire Northern field may be inventoried.

The 59 streams that carry runoff from the 11 watersheds cross the coal measures of the Wyoming Basin of the Northern field lying between North Pittston and the southwest boundary of Glen Lyon.

The part of the Susquehanna River drainage area within the limits of the coal measures that is exclusive of the 11 above-mentioned watersheds and lies between North Pittston and West Nanticoke has a drainage area of 17.364 square miles. It is defined as the Zero watershed. The bed of the Susquehanna River, during normal times, occupies an additional 2.94 square miles within the limits of the coal measures.

Seepage into mine workings of the portion of the Northern field north of Pittston is discussed in Bureau of Mines Bulletin 518. Seepage into mine workings of the Northern field southwest of Glen Lyon is not discussed in this report because the mining areas are small and not affected seriously.

FIGURE 12.—Typical View of Susquehanna River in Wyoming Valley, Showing Its Wide Expanse Over Underlying Coal Measures.

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SUSQUEHANNA RIVER

The North Branch of the Susquehanna River has a drainage area of 9,960 square miles above Wilkes-Barre. It enters the Northern field a short distance above West Pittston and courses for 16½ miles across the coal measures before it leaves the field at West Nanticoke. In normal times it has an average breadth of 940 feet throughout the course of the river. Figures 12 and 13 show the wide expanse of the Susquehanna River in the broad flood plain of the Wyoming Valley.

On the basis of records furnished by the Hydrographic Service, Harrisburg, Pa., a 9-year record of the measurements of discharges of the Susquehanna River at Wilkes-Barre from October 1, 1942, to September 30, 1951, shows the general performance of the river. The maximum discharge during this period, recorded on May 29, 1946, was 210,000 cubic feet per second; the minimum, recorded on October 14, 1944, 980 cubic feet per second. The mean discharge for the 9-year period was 14,618 cubic feet per second.

The Susquehanna River usually is uniform and moderate in its changes, except during the spring, when flash floods sometime occur. The peak flow generally lasts 2 to 4 days, and the rise to the highest stage is much more abrupt than the fall. High water occurs frequently, averaging three times a year, the highest being in March and April. The greatest flood on record, in March 1865, reached a stage of 33.1 feet at Wilkes-Barre, approximately 16 feet above flood stage for that period (*21*). The flood of 1902, although somewhat lower, overflowed a 9½-square-mile area in Wyoming Valley and caused a property loss estimated at 2 million dollars (*21*).

The volume of seepage entering mines in the Wyoming Basin from the bed of the Susquehanna River is not known; however, the importance of this source of seepage is realized when it is known that the drainage area overlying the Wyoming Basin is less than half that overlying mines beneath the Lackawanna drainage area, while the total volume of water pumped from mines in the Wyoming Basin is about 21 percent greater than the volume of water pumped from mines in the Lackawanna Basin (*10*).

BURIED VALLEY OF THE SUSQUEHANNA RIVER

The broad, relatively flat plain of the Northern field, over which the present North

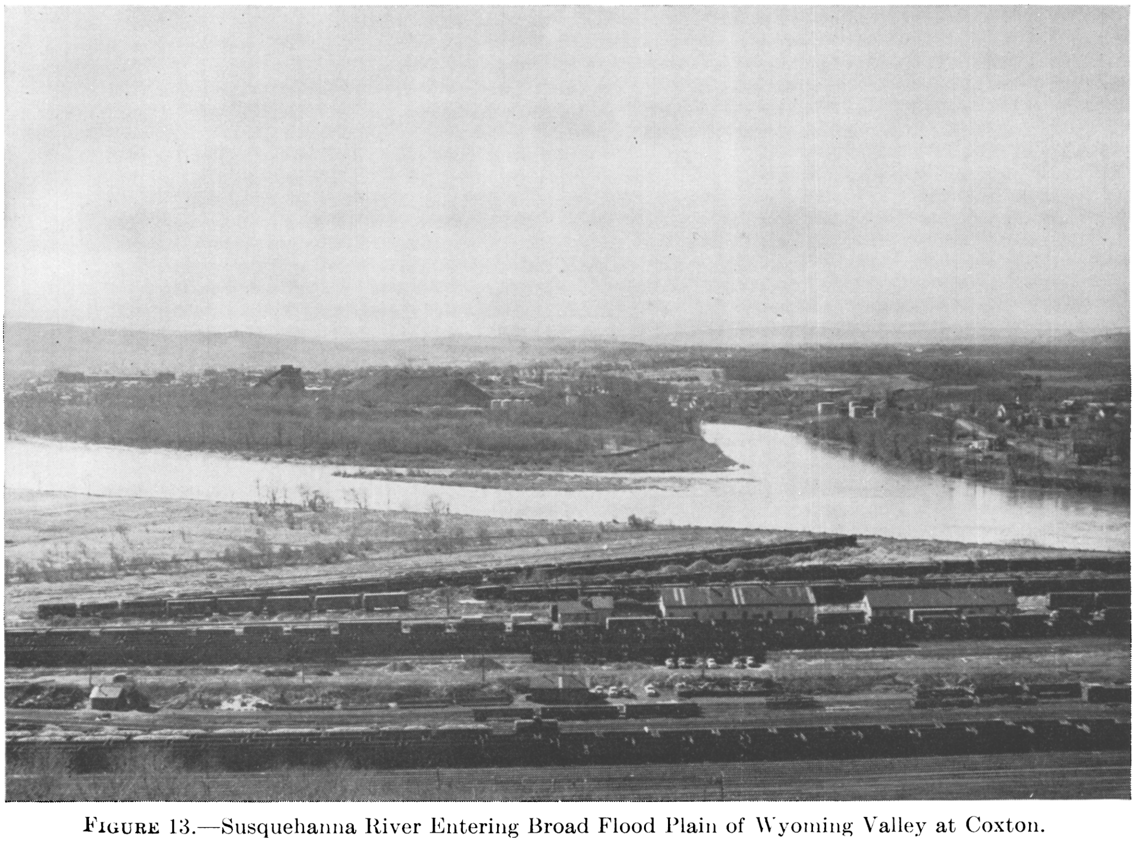

FIGURE 13.—Susquehanna River Entering Broad Flood Plain of Wyoming Valley at Coxton.

Branch of the Susquehanna River flows, blankets a great depression or buried valley in the surface of the bedrock. This depression is not an ordinary valley having a bottom with a continuous downgrade, which is usually made by a stream in its attempt to reach base level, but consists of a series of elongated basins terminated by rock at both ends. The depression does not have a continuous downgrade, for the deeper subbasins decrease in depth downstream (*2*).

Figure 14 is a map showing the location of the buried valley of the Susquehanna River in the Wyoming Basin.

Boreholes drilled from the surface of the ground in this area through the valley-fill deposits have revealed the rock bottom of this great depression to be below altitude 250 feet at several points. Near Berwick (approximately 18 miles downstream from West Nanticoke), rock crosses the river at altitude 480 feet. At no place farther downstream is the rock, below altitude 250 feet until Middletown, Pa., is reached, nearly 90 miles downstream from Berwick (*2*).

It appears quite evident that basins or channels were excavated in the sandstones, shales, slates, and anthracite beds of the anthracite measures by glacial action, as well as by water erosion.

There are potholes in the area comprising the buried valley; these were formed by swirling currents of water carrying abrasive materials during the advance and retreat of glaciers. They extend below the normal bottom of the buried valley. Some large potholes are visible at the surface of the ground in the Scranton area (*2*).

Three general classes of deposits are found in the Wyoming-Lackawanna region: (*a*) The deep valley-fill deposits, (*b*) terrace deposits that flank the valley, and (*c*) glacial-till deposits.

The materials that consitute the deep valley-fill deposits, as revealed by boreholes and shafts, are water-depositional sediments consisting of alternating layers of gravel, sand, clay, and admixtures of all three. Under Kingston lies a bed of clay 80 to 100 feet thick, an evidence of local ponding.

The terrace deposits that flank the valley generally are found from 60 to more than 200 feet above the flood plain of the present river. Studies of the structure of these terraces, as revealed in sand or gravel pits, indicate that they were formed by ponding of side streams against stagnant ice, as well as by deposits laid down by streams flowing between the bank and such a mass of ice left in the waning stages of the glacier (*2*). This explains the river-bed-type deposit with crossbedding as exposed in the sand pits and also accounts for the varying levels at which the terraces occur. The Tilbury Plain at West Nanticoke is at altitude 680 feet; terraces on either side of Toby's Creek, near Luzerne, at altitudes 705 and 750 feet; at Pittston, altitude 710 feet; and at Campbell Ledge, altitude 610 feet (*2*).

The basin-and-range structure of the underlying rock formations in the vicinity of the buried valley and the permeability of the alluvial fill or valley-fill deposits form ideal catchment areas or basins for collecting surface water from local heavy rains, flash floods, and overflow from the river or creeks at flood stage. This water enters the mines under or adjacent to the riverwash and is either impounded in underground water pools or flows to the mine sumps, where it is pumped to the surface or to a drainage tunnel (*3*).

Infiltration of surface water into mine workings underneath the buried valley is aggravated further by the presence of major surface streams that flow over the pervious alluvial fill. The North Branch of the Susquehanna River flows downstream over these deposits from Coxton to West Nanticoke, where the river leaves the valley. The Lackawanna River, a chief tributary stream, flows down the Lackawanna Valley and enters the Susquehanna River at Pittston. A considerable volume of mine water originates at the headwaters of these streams, especially during the period of flood stage. The water from the streams enters the mines through the pervious valley-fill deposits, cracks, and fissures in the underlying rock strata caused by subsidence over mined areas, bedding planes in the rock strata, natural cleavage planes, and faults (*5*).

A number of creeks that flow throughout the entire year cross the anthracite measures in the vicinity of the buried valley. Because of the size of most of these creeks, some provisions have been made to prevent excessive infiltration through their beds into the mine workings.

Mining operations under the major stream beds have been conducted in a manner to prevent an increase in the stream-bed leakage and thereby prevent an increase in the amount of infiltration into the mine workings; however, this cannot be true of many of the small tributary streams, because the presence of dry beds of thousands of former small watercourses gives evidence that the water, which had once drained into them, is now infiltrating into the underground workings (*2, 5*).

Fissures in the rock strata, cave-ins, and fissures in outcrops and strippings either on the flood plains of streams or in the drainage areas provide easy ingress for surface water into mine workings (*5*). Strippings, especially, contribute much to this because of removal of the overburden and because of the longitudinal extent of the strippings along the outcrop of the anthracite beds, usually at right angles to the direction of natural drainage. Many fissures and cave-ins are not easily visible because they are hidden from sight under refuse banks or partly filled with dirt; nevertheless, these openings contribute much to water seepage.

Many anthracite beds outcrop beneath the valley-fill deposits of the buried valley and provide ingress for surface water into mine workings. Figure 15 is a cross section of the Northern field, showing the presence of the buried valley in relation to the anthracite beds.

EXPLANATION OF DATA

Pertinent data on seepage into mine workings from the 59 streams and their drainage areas are listed in tables 2 to 12, inclusive. The relationship of data in tables 2 to 12 to the seepage problem is explained in detail in Bureau of Mines Bulletin 518 (*10*). The basic features of this relationship are reviewed in the following discussion. The drainage area of any stream, in conjunction with a given rainfall for any period of time, reduced by total evaporation, determines the volume of runoff (*10, 24*). The portion of the stream-drainage area within the limits of the coal measures must be known, as the runoff in this area is reduced because of seepage through the porous soil and broken strata into the mine workings (*10, 13*).

Mining men generally agree that subsidence produces cracks, fissures, and cave holes in the strata overlying anthracite beds and is the principal cause of seepage. So-called second mining (pillar robbing) is responsible for most destructive subsidence (*10*).

The volume of water seeping into mine workings from the surface directly over them cannot be determined accurately; however, a reasonable estimate of such seepage may be obtained for a drainage area by giving proper consideration to the physical properties of the terrain and the extent of subsidence affecting the given area. The topography, permeability, and porosity of

TABLE 2.—*Data on surface and stream-bed seepage, North 7 watershed*

Stream		1	2	3	4	5	6	7 (7=5−6)	8
No.	Name	Drainage area, square miles	Drainage area within coal measures, square miles	Estimated unit volume of surface seepage into mine workings [1]	Length of stream bed within coal measures, feet	Length of pervious stream bed, feet	Length of improved stream bed, feet	Length of unimproved pervious stream bed, feet	Estimated unit volume of stream-bed seepage into mine workings [1]
N-34	Scovell Creek	0. 315	0. 007	0. 06	720	100	--------	100	0. 21
N-35	Carpenter Creek	. 330	. 023	. 27	1, 150	500	150	350	3. 00
N-36	Hicks Creek	3. 636	1. 657	20. 54	14, 800	14, 200	500	13, 700	23. 14
	North 7 watershed	4. 281	1. 687	20. 87	16, 670	14, 800	650	14, 150	26. 35

[1] Unit volume is given in gallons per minute per inch of rainfall.

TABLE 3.—*Data on surface and stream-bed seepage, North 8 watershed*

Stream		1	2	3	4	5	6	7 (7=5−6)	8
No.	Name	Drainage area, square miles	Drainage area within coal measures, square miles	Estimated unit volume of surface seepage into mine workings [1]	Length of stream bed within coal measures, feet	Length of pervious stream bed, feet	Length of improved stream bed, feet	Length of unimproved pervious stream bed, feet	Estimated unit volume of stream-bed seepage into mine workings [1]
N-37	Westmoreland Creek	0. 423	0. 323	4. 01	5, 200	5, 130	450	4, 680	2. 50
N-38	Maltby Creek	. 493	. 449	5. 94	12, 600	6, 440	250	6, 190	2. 21
N-39	Sandy Creek	1. 006	. 218	2. 88	5, 520	5, 520	1, 230	4, 290	9. 11
N-40	Wades Creek	. 682	. 438	5. 43	8, 560	2, 900	200	2, 700	4. 91
N-41	Shoemaker Creek	. 428	. 287	3. 79	7, 360	2, 000	50	1, 950	3. 02
N-42	Dicksville Creek	1. 717	1. 324	20. 80	13, 400	6, 880	450	6, 430	7. 39
N-43	Abrahams Creek	12. 083	1. 865	21. 58	23, 200	13, 760	250	13, 510	28. 83
	North 8 watershed	16. 832	4. 904	64. 43	75, 840	42, 630	2, 880	39, 750	57. 97

[1] Unit volume is given in gallons per minute per inch of rainfall.

TABLE 4.—*Data on surface and stream-bed seepage, North 9 watershed*

Stream		1	2	3	4	5	6	7 (7=5−6)	8
No.	Name	Drainage area, square miles	Drainage area within coal measures, square miles	Estimated unit volume of surface seepage into mine workings [1]	Length of stream bed within coal measures, feet	Length of pervious stream bed, feet	Length of improved stream bed, feet	Length of unimproved pervious stream bed, feet	Estimated unit volume of stream-bed seepage into mine workings [1]
N-44	Courtdale Creek	0. 490	0. 248	2. 26	7, 800	7, 800	3, 650	4, 150	4. 38
N-45	Edwardsville Creek	. 428	. 423	4. 24	5, 280	4, 880	1, 730	3, 150	2. 60
N-46	Toby Creek	33. 244	1. 357	7. 85	20, 520	4, 400	400	4, 000	21. 73
	North 9 watershed	34. 162	2. 033	14. 35	33, 600	17, 080	5, 780	11, 300	28. 71

[1] Unit volume is given in gallons per minute per inch of rainfall.

TABLE 5.—*Data on surface and stream-bed seepage, North 10 watershed*

Stream		1	2	3	4	5	6	7 (7=5−6)	8
No.	Name	Drainage area, square miles	Drainage area within coal measures, square miles	Estimated unit volume of surface seepage into mine workings [1]	Length of stream bed within coal measures, feet	Length of pervious stream bed, feet	Length of improved stream bed, feet	Length of unimproved pervious stream bed, feet	Estimated unit volume of stream-bed seepage into mine workings [1]
N-47	Larksville Creek	2. 024	1. 644	17. 67	22, 520	18, 720	4, 890	13, 830	13. 26
N-48	Valley View Creek	. 769	. 198	3. 11	8, 640	8, 640	--------	8, 640	6. 43
N-49	Brown Creek	2. 254	1. 235	13. 27	12, 280	8, 680	950	7, 730	20. 03
N-50	Wadhams Creek	1. 123	. 704	8. 73	9, 520	6, 560	2, 330	4, 230	6. 59
N-51	Plymouth Creek	. 206	. 060	. 50	3, 600	2, 800	1, 400	1, 400	1. 45
N-52	Coal Creek	1. 660	. 466	5. 39	6, 360	2, 200	750	1, 450	16. 54
	North 10 watershed	8. 036	4. 307	48. 67	62, 920	47, 600	10, 320	37, 280	64. 30

[1] Unit volume is given in gallons per minute per inch of rainfall.

TABLE 6.—*Data on surface and stream-bed seepage, North 11 watershed*

Stream		1	2	3	4	5	6	7 (7=5−6)	8
No.	Name	Drainage area, square miles	Drainage area within coal measures, square miles	Estimated unit volume of surface seepage into mine workings [1]	Length of stream bed within coal measures, feet	Length of pervious stream bed, feet	Length of improved stream bed, feet	Length of unimproved pervious stream bed, feet	Estimated unit volume of stream-bed seepage into mine workings [1]
N-53	Phyllis Creek	0. 316	0. 099	0. 82	3, 120	3, 120	2, 000	1, 120	3. 31
N-54	Avondale Creek	. 360	. 152	1. 63	3, 920	2, 360	--------	2, 360	4. 32
N-55	Sickler Creek	. 986	. 831	8. 93	13, 200	6, 400	100	6, 300	7. 19
	North 11 watershed	1. 662	1. 082	11. 38	20, 240	11, 880	2, 100	9, 780	14. 82

[1] Unit volume is given in gallons per minute per inch of rainfall.

the strata and the extent of soil, frost action, and plant cover in a drainage area influence the speed of runoff and the volume of seepage into mine workings (*10*).

The method for estimating the volume of seepage entering mine workings from the surface and streams is complex because of many variables, and no previously applied method for computing such seepage is known to the authors. The method used to determine the seepage in this report and in Bureau of Mines Bulletin 518 (*10*) was derived from an exhaustive field survey of each stream and its drainage area and from consultations with

TABLE 7.—*Data on surface and stream-bed seepage, South 5 watershed*

Stream		1	2	3	4	5	6	7 (7=5−6)	8
No.	Name	Drainage area, square miles	Drainage area within coal measures, square miles	Estimated unit volume of surface seepage into mine workings [1]	Length of stream bed within coal measures, feet	Length of pervious stream bed, feet	Length of improved stream bed, feet	Length of unimproved pervious stream bed, feet	Estimated unit volume of stream-bed seepage into mine workings [1]
S–20	Panama Ditch	0. 907	0. 907	9. 00	5, 900	4, 100	3, 600	500	3. 00
S–21	Pittston Creek	. 803	. 803	7. 30	6, 200	3, 600	1, 400	2, 200	4. 48
S–22	Tompkins Creek	2. 873	2. 827	25. 70	22, 000	22, 000	4, 400	17, 600	20. 05
S–23	Ewen Creek	. 663	. 663	5. 48	5, 800	4, 800	800	4, 000	4. 60
S–24	Inkerman Creek	. 542	. 542	5. 82	6, 300	5, 600	400	5, 200	2. 89
S–25	Port Blanchard Creek	. 473	. 473	6. 26	5, 200	4, 200	600	3, 600	1. 31
S–26	Plainsville Creek	1. 115	1. 115	12. 90	14, 300	13, 700	400	13, 300	5. 09
	South 5 watershed	7. 376	7. 330	72. 46	65, 700	58, 000	11, 600	46, 400	41. 42

[1] Unit volume is given in gallons per minute per inch of rainfall.

TABLE 8.—*Data on surface and stream-bed seepage, South 6 watershed*

Stream		1	2	3	4	5	6	7 (7=5−6)	8
No.	Name	Drainage area, square miles	Drainage area within coal measures, square miles	Estimated unit volume of surface seepage into mine workings [1]	Length of stream bed within coal measures, feet	Length of pervious stream bed, feet	Length of improved stream bed, feet	Length of unimproved pervious stream bed, feet	Estimated unit volume of stream-bed seepage into mine workings [1]
S–27	Gardner Creek	9. 573	2. 643	24. 03	9, 200	7, 200	350	6, 850	33. 55
S–28	Fox Hill Creek	. 560	. 319	3. 16	4, 000	3, 500	400	3, 100	4. 08
S–29	Baltimore Creek	. 422	. 422	4. 54	5, 800	4, 320	400	3, 920	2. 05
S–30	Coal Brook	2. 388	1. 771	20. 49	24, 160	18, 200	6, 000	12, 200	14. 24
S–31	Laurel Run	9. 952	1. 030	10. 22	11, 000	3, 240	--------	3, 240	38. 57
S–32	Mill Creek	13. 542	4. 613	53. 38	32, 840	15, 400	400	15, 000	87. 89
	South 6 watershed	36. 437	10. 798	115. 82	87, 000	51, 860	7, 550	44, 310	180. 38

[1] Unit volume is given in gallons per minute per inch of rainfall.

TABLE 9.—*Data on surface and stream-bed seepage, South 7 watershed*

Stream		1	2	3	4	5	6	7 (7=5−6)	8
No.	Name	Drainage area, square miles	Drainage area within coal measures, square miles	Estimated unit volume of surface seepage into mine workings [1]	Length of stream bed within coal measures, feet	Length of pervious stream bed, feet	Length of improved stream bed, feet	Length of unimproved pervious stream bed, feet	Estimated unit volume of stream-bed seepage into mine workings [1]
S–33	Kidder Creek	2. 603	1. 893	20. 34	28, 120	13, 640	3, 230	10, 410	9. 53
S–34	Franklyn Creek	. 362	. 214	2. 12	4, 280	4, 280	1, 410	2, 870	2. 24
S–35	Spring Run	1. 310	1. 012	9. 20	15, 280	7, 800	1, 300	6, 500	5. 42
S–36	Newton Creek	1. 001	. 654	7. 03	7, 860	2, 640	140	2, 500	4. 00
S–37	Sugar Notch Creek	2. 280	. 845	8. 38	11, 800	5, 000	750	4, 250	17. 00
S–38	Maple Hill Creek	. 465	. 465	. 38	7, 680	680	80	600	. 29
S–39	St. Mary's Creek	. 357	. 357	. 30	8, 680	680	280	400	. 22
S–40	Buttonwood Creek	. 406	. 406	1. 01	7, 800	5, 000	400	4, 600	. 91
S–41	Solomon Creek	8. 931	1. 908	1. 58	30, 840	2, 000	--------	2, 000	6. 69
	South 7 watershed	17. 715	7. 754	50. 34	122, 340	41, 720	7, 590	34, 130	46. 30

[1] Unit volume is given in gallons per minute per inch of rainfall.

TABLE 10.—*Data on surface and stream-bed seepage, South 8 watershed*

Stream		1	2	3	4	5	6	7 (7=5−6)	8
No.	Name	Drainage area, square miles	Drainage area within coal measures, square miles	Estimated unit volume of surface seepage into mine workings [1]	Length of stream bed within coal measures, feet	Length of pervious stream bed, feet	Length of improved stream bed, feet	Length of unimproved pervious stream bed, feet	Estimated unit volume of stream-bed seepage into mine workings [1]
S-42	Silver Creek	0. 308	0. 301	3. 74	5, 560	3, 200	600	2, 600	1. 14
S-43	Garringer Creek	1. 308	1. 235	14. 29	21, 640	5, 000	2, 800	2, 200	5. 56
S-44	Warrior Run	2. 855	2. 799	11. 57	46, 000	3, 400	450	2, 950	2. 85
S-45	Leuder Creek	1. 075	. 449	4. 82	6, 000	6, 000	3, 800	2, 200	9. 71
S-46	Espy Run, West Branch	. 900	. 828	10. 95	9, 200	5, 200	400	4, 800	3. 30
S-47	Espy Run	2. 243	1. 813	19. 48	16, 480	8, 400	700	7, 700	11. 90
S-48	Nanticoke Creek	3. 155	1. 792	17. 77	32, 880	16, 000	8, 910	7, 090	11. 59
	South 8 watershed	11. 844	9. 217	82. 62	137, 760	47, 200	17, 660	29, 540	46. 05

[1] Unit volume is given in gallons per minute per inch of rainfall.

TABLE 11.—*Data on surface and stream-bed seepage, South 9 watershed*

Stream		1	2	3	4	5	6	7 (7=5−6)	8
No.	Name	Drainage area, square miles	Drainage area within coal measures, square miles	Estimated unit volume of surface seepage into mine workings [1]	Length of stream bed within coal measures, feet	Length of pervious stream bed, feet	Length of improved stream bed, feet	Length of unimproved pervious stream bed, feet	Estimated unit volume of stream-bed seepage into mine workings [1]
S-49	Fairchilds Creek	0. 699	0. 210	1. 91	5, 600	5, 600	200	5, 400	4. 05
S-50	Wanamie Creek	1. 273	. 108	. 45	2, 800	800	--------	800	3. 30
S-51	North Wanamie Creek	. 257	. 257	2. 13	2, 600	1, 840	500	1, 340	1. 42
S-52	Newport Creek, South Branch	3. 733	3. 380	36. 32	21, 920	5, 200	50	5, 150	14. 34
	South 9 watershed	5. 962	3. 955	40. 81	32, 920	13, 440	750	12, 690	23. 11

[1] Unit volume is given in gallons per minute per inch of rainfall.

TABLE 12.—*Data on surface and stream-bed seepage, South 10 watershed*

Stream		1	2	3	4	5	6	7 (7=5−6)	8
No.	Name	Drainage area, square miles	Drainage area within coal measures, square miles	Estimated unit volume of surface seepage into mine workings [1]	Length of stream bed within coal measures, feet	Length of pervious stream bed, feet	Length of improved stream bed, feet	Length of unimproved pervious stream bed, feet	Estimated unit volume of stream-bed seepage into mine workings [1]
S-53	Farm Creek	0. 418	0. 183	0. 15	3, 680	400	--------	400	0. 27
S-54	Newport Creek, North Branch	1. 050	. 738	1. 22	20, 400	3, 300	500	2, 800	2. 58
S-55	Glen Lyon Creek	1. 315	1. 273	8. 42	10, 640	5, 400	--------	5, 400	6. 66
S-56	Newport Creek	4. 978	4. 863	56. 27	41, 840	15, 400	8, 650	6, 750	19. 86
	South 10 watershed	7. 761	7. 057	66. 06	76, 560	24, 100	9, 150	15, 350	29. 37

[1] Unit volume is given in gallons per minute per inch of rainfall.

engineers of mining companies in the affected area. The degree of accuracy of estimating seepage by this method is unknown; however, the authors propose it as a common yardstick that can be applied to each stream and its drainage area. Because the seepage for each stream is estimated by the same method, the resultant figures are comparative (*10*).

The length of the pervious portion of a stream bed is that part within the limits of the coal measures that overlies mined-out areas. The relative positions of mined-out areas and stream channels are readily obtainable from maps of mining companies in the anthracite region (*10*).

Any pervious part of a stream bed that has been rendered impervious by remedial measures is referred to as *length of improved stream bed.* Various types of flumes, rubbled stream bottom, and concrete flooring of culverts constitute such improvements where found in good condition (*10*).

Column 6 of tables 2 to 12, inclusive, lists the length of the improved pervious portions of the stream beds.

Column 7 lists the length of the unimproved pervious portions of the stream beds, obtained by subtracting column 6 from column 5. If seepage from a given stream bed into underlying mine workings is to be reduced to a minimum, the remaining unimproved pervious portion of a stream bed must be made impervious.

Estimated surface and stream-bed seepages from any of the stream-drainage areas for a given year can be calculated, in gallons per minute, by multiplying the values in columns 3 and 8 by the annual rainfall, in inches, for that year.

Table 13 is a recapitulation of tables 2 to 12, with similar data concerning the Susquehanna River itself (Zero watershed). The volume of seepage from the 17.4 square miles of surface-drainage areas adjacent to the Susquehanna River within the limits of the coal measures and of that not included in the North and South watersheds is estimated the same as estimating seepage from surface areas adjacent to the side streams. Because of the size of the Susquehanna River and its uninterrupted flow, the method used to determine seepage from stream beds was not judged applicable to the Susquehanna River. The volume of seepage from the bed of the Susquehanna River is obtained by subtracting the product of the estimated unit volumes of surface and stream-bed seepage and mean annual rainfall from the total volume of mine water pumped to the surface by all pumping plants in the Wyoming Basin.

TABLE 13.—*Recapitulation of data on surface and stream-bed seepage for drainage area overlying Wyoming Basin*

Table	Watershed	Area of watershed, square miles	Area of watershed within coal measures, square miles	Estimated unit volume of surface seepage into mine workings [1]	Length of stream bed within coal measures, feet	Length of pervious stream bed, feet	Length of improved stream bed, feet	Length of unimproved pervious stream bed, feet	Estimated unit volume of stream-bed seepage into mine workings [1]
2	North 7	4. 281	1. 687	20. 87	16, 670	14, 800	650	14, 150	26. 35
3	North 8	16. 832	4. 904	64. 43	75, 840	42, 630	2, 880	39, 750	57. 97
4	North 9	34. 162	2. 033	14. 35	33, 600	17, 080	5, 780	11, 300	28. 71
5	North 10	8. 036	4. 307	48. 67	62, 920	47, 600	10, 320	37, 280	64. 30
6	North 11	1. 662	1. 082	11. 38	20, 240	11, 880	2, 100	9, 780	14. 82
7	South 5	7. 376	7. 330	72. 46	65, 700	58, 000	11, 600	46, 400	41. 42
8	South 6	36. 437	10. 798	115. 82	87, 000	51, 860	7, 550	44, 310	180. 38
9	South 7	17. 715	7. 754	50. 34	122, 340	41, 720	7, 590	34, 130	46. 30
10	South 8	11. 844	9. 217	82. 62	137, 760	47, 200	17, 660	29, 540	46. 05
11	South 9	5. 962	3. 955	40. 81	32, 920	13, 440	750	12, 690	23. 11
12	South 10	7. 761	7. 057	66. 06	76, 560	24, 100	9, 150	15, 350	29. 37
All side-stream watersheds, except Zero		152. 068	60. 124	587. 81	731, 550	370, 310	76, 030	294, 680	558. 78
Zero watershed (Susquehanna River)		17. 364	17. 364	186. 35	87, 120	87, 120		87, 120	[2] 1, 268. 70
Wyoming Valley drainage area		169. 432	77. 488	774. 16	818, 670	457, 430	76, 030	381, 800	1, 827. 58

[1] Unit volume is given in gallons per minute per inch of rainfall.
[2] From table 26, totals column, line H, 54,034 g. p. m.÷42.59 (inches of rainfall in 1948).

Table 14 is a recapitulation of seepage data affecting the Wyoming Basin added to that affecting the Lackawanna Basin, so that seepage data on the Northern field can be evaluated.

Tables 15 through 25 supplement tables 2 through 12. They list the source and volume of seepage and the receiving underground pools and mine pumping plants. The degree of accuracy in identifying the receiving pools and pumping plants is approximate because of difficulties in tracing the path taken by water after it seeps into the ground. The assignment of seepage to the different receiving pumping plants was made after considerable study of the terrain and mine maps. Engineers from mining companies were consulted and aided in determining the most likely distribution of seepage. The mine pumping plants and pools are given the same designation as those in Bureau of Mines Bulletin 531, Mine Pumping Plants, Anthracite Region of Pennsylvania (*12*); and Bureau of Mines Technical Paper 727, Water Pools in Pennsylvania Anthracite Mines (*5*). The estimated volume of seepage and the volume of water pumped by the different pumping plants can be compared.

TABLE 14.—*Recapitulation of data on surface and stream-bed seepage for drainage area overlying Northern field*

Watershed	Area of watershed, square miles	Area of watershed within coal measures, square miles	Estimated unit volume of surface seepage into mine workings [1]	Length of stream bed within coal measures, feet	Length of pervious stream bed, feet	Length of improved stream bed, feet	Length of unimproved pervious stream bed, feet	Estimated unit volume of stream-bed seepage into mine workings [1]
Lackawanna River drainage area [2]	344. 495	64. 876	575. 10	603, 000	495, 870	25, 890	469, 980	1, 670. 83
Drainage area overlying Wyoming Basin	169. 432	77. 488	774. 16	818, 670	457, 430	76, 030	381, 800	1, 827. 58
Drainage area overlying Northern field coal measures	513. 927	142. 364	1, 349. 26	1, 421, 670	953, 300	101, 920	851, 780	3, 498. 41

[1] Unit volume is given in gallons per minute per inch of rainfall.
[2] Data taken from table 13, Bureau of Mines Bull. 518.

TABLE 15.—*Surface and stream-bed seepage and length of unimproved pervious stream bed identified with probable receiving underground pools, drainage tunnel, and mine pumping plants in North 7 watershed*

Stream No.	Stream Name	Estimated surface seepage, gallons per minute per inch of rainfall					Estimated stream-bed seepage, gallons per minute per inch of rainfall					Estimated length of unimproved pervious stream bed, feet				
N-34	Scovell Creek	0. 06	------	------	------	------	0. 21	------	------	------	------	100	------	------	------	------
N-35	Carpenter Creek	. 27	------	------	------	------	3. 00	------	------	------	------	350	------	------	------	------
N-36	Hicks Creek	7. 19	5. 55	7. 80	------	------	8. 10	6. 25	8. 79	------	------	4, 795	3, 699	5, 206	------	------
	Total	7. 52	5. 55	7. 80	------	------	11. 31	6. 25	8. 79	------	------	5, 245	3, 699	5, 206	------	------

Probable receiving underground pools, drainage tunnel, or pumping plants

Underground pools [1]	------	------	16	------	------	------	------	16	------	------	------	------	16	------	------
Drainage tunnel	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------
Pumping plants [2]	27	30	29	------	------	27	30	29	------	------	27	30	29	------	------

[1] Given same designation as that used in Bureau of Mines Tech. Paper 727.
[2] Given same designation as that used in Bureau of Mines Bull. 531.

TABLE 16.—*Surface and stream-bed seepage and length of unimproved pervious stream bed identified with probable receiving underground pools, drainage tunnel, and mine pumping plants in North 8 watershed*

Stream		Estimated surface seepage, gallons per minute per inch of rainfall					Estimated stream-bed seepage, gallons per minute per inch of rainfall					Estimated length of unimproved pervious stream bed, feet				
No.	Name															
N-37	Westmoreland Creek	4.01					2.50					4,680				
N-38	Maltby Creek	5.94					2.21					6,190				
N-39	Sandy Creek	2.88					9.11					4,290				
N-40	Wades Creek	5.43					4.91					2,700				
N-41	Shoemaker Creek		3.79					3.02					1,950			
N-42	Dicksville Creek	5.20	15.60				1.85	5.54				1,608	4,822			
N-43	Abrahams Creek	16.19	5.39				21.62	7.21				10,132	3,378			
	Total	39.65	24.78				42.20	15.77				29,600	10,150			

Probable receiving underground pools, drainage tunnel, or pumping plants

Underground pools [1]	13	9				13	9				13	9			
Drainage tunnel															
Pumping plants [2]	37	38				37	38				37	38			

[1] Given same designation as that used in Bureau of Mines Tech. Paper 727.
[2] Given same designation as that used in Bureau of Mines Bull. 531.

TABLE 17.—*Surface and stream-bed seepage and length of unimproved pervious stream bed identified with probable receiving underground pools, drainage tunnel, and mine pumping plants in North 9 watershed*

Stream		Estimated surface seepage, gallons per minute per inch of rainfall					Estimated stream-bed seepage, gallons per minute per inch of rainfall					Estimated length of unimproved pervious stream bed, feet				
No.	Name															
N-44	Courtdale Creek	2.26					4.38					4,150				
N-45	Edwardsville Creek	3.18	1.06				1.95	0.65				2,362	788			
N-46	Toby Creek	5.89	1.96				21.73	0				4,000	0			
	Total	11.33	3.02				28.06	0.65				10,512	788			

Probable receiving underground pools, drainage tunnel, or pumping plants

Underground pools [1]	6-7-8					6-7-8					6-7-8				
Drainage tunnel															
Pumping plants [2]	44	48				44	48				44	48			

[1] Given same designation as that used in Bureau of Mines Tech. Paper 727.
[2] Given same designation as that used in Bureau of Mines Bull. 531.

TABLE 18.—*Surface and stream-bed seepage and length of unimproved pervious stream bed identified with probable receiving underground pools, drainage tunnel, and mine pumping plants in North 10 watershed*

Stream		Estimated surface seepage, gallons per minute per inch of rainfall					Estimated stream-bed seepage, gallons per minute per inch of rainfall					Estimated length of unimproved pervious stream bed, feet				
No.	Name															
N-47	Larksville Creek	17.67					13.26					13,830				
N-48	Valley View Creek	3.11					6.43					8,640				
N-49	Brown Creek		13.27					20.03					7,730			
N-50	Wadhams Creek			8.73					6.59					4,230		
N-51	Plymouth Creek			.50					1.45					1,400		
N-52	Coal Creek			5.39					16.54					1,450		
	Total	20.78	13.27	14.62			19.69	20.03	24.58			22,470	7,730	7,080		

Probable receiving underground pools, drainage tunnel, or pumping plants

Underground pools [1]		5					5					5			
Drainage tunnel															
Pumping plants [2]	49	53	58			49	53	58			49	53	58		

[1] Given same designation as that used in Bureau of Mines Tech. Paper 727.
[2] Given same designation as that used in Bureau of Mines Bull. 531.

TABLE 19.—*Surface and stream-bed seepage and length of unimproved pervious stream bed identified with probable receiving underground pools, drainage tunnel, and mine pumping plants in North 11 watershed*

Stream No.	Stream Name	Estimated surface seepage, gallons per minute per inch of rainfall					Estimated stream-bed seepage, gallons per minute per inch of rainfall					Estimated length of unimproved pervious stream bed, feet				
N-53	Phyllis Creek	0.82					3.31					1,120				
N-54	Avondale Creek	1.63					4.32					2,360				
N-55	Sickler Creek	8.93					7.19					6,300				
	Total	11.38					14.82					9,780				
Probable receiving underground pools, drainage tunnel, or pumping plants																
Underground pools [1]		4					4					4				
Drainage tunnel																
Pumping plants [2]		59					59					59				

[1] Given same designation as that used in Bureau of Mines Tech. Paper 727.
[2] Given same designation as that used in Bureau of Mines Bull. 531.

TABLE 20.—*Surface and stream-bed seepage and length of unimproved pervious stream bed identified with probable receiving underground pools, drainage tunnel, and mine pumping plants in South 5 watershed*

Stream No.	Stream Name	Estimated surface seepage, gallons per minute per inch of rainfall					Estimated stream-bed seepage, gallons per minute per inch of rainfall					Estimated length of unimproved pervious stream bed, feet				
S-20	Panama Ditch	9.00					3.00					500				
S-21	Pittston Creek	1.33	5.97				.81	3.67				400	1,800			
S-22	Tompkins Creek		9.64		16.06			7.51		12.54			6,600		11,000	
S-23	Ewen Creek				5.48					4.60					4,000	
S-24	Inkerman Creek					5.82					2.89					5,200
S-25	Port Blanchard Creek					6.26					1.31					3,600
S-26	Plainsville Creek					12.90					5.09					13,300
	Total	10.33	15.61		21.54	24.98	3.81	11.18		17.14	9.29	900	8,400		15,000	22,100
Probable receiving underground pools, drainage tunnel, or pumping plants																
Underground pools [1]		19				14	19				14	19				14
Drainage tunnel			(2)					(2)					(2)			
Pumping plants [3]		26	28		29	36	26	28		29	36	26	28		29	36

[1] Given same designation as that used in Bureau of Mines Tech. Paper 727.
[2] Pittston.
[3] Given same designation as that used in Bureau of Mines Bull. 531.

TABLE 21.—*Surface and stream-bed seepage and length of unimproved pervious stream bed identified with probable receiving underground pools, drainage tunnel, and mine pumping plants in South 6 watershed*

Stream		Estimated surface seepage, gallons per minute per inch of rainfall					Estimated stream-bed seepage, gallons per minute per inch of rainfall					Estimated length of unimproved pervious stream bed, feet				
No.	Name															
S-27	Gardner Creek	16.02	8.01				22.37	11.18				4,567	2,283			
S-28	Fox Hill Creek			3.16					4.08					3,100		
S-29	Baltimore Creek					4.54					2.05					3,920
S-30	Coal Brook					20.49					14.24					12,200
S-31	Laurel Run			5.11		5.11			19.29		19.28			1,620		1,620
S-32	Mill Creek			37.80	15.58				78.47	9.42				9.330	5,670	
	Total	16.02	8.01	46.07	15.58	30.14	22.37	11.18	101.84	9.42	35.57	4.567	2,283	14,050	5,670	17,740

Probable receiving underground pools, drainage tunnel, or pumping plants

Underground pools [1]					10–11–12					10–11–12					10–11–12
Drainage tunnel															
Pumping plants [2]	32	33	34, 35, [3] 40, 42	41	45	32	33	34, 35, [3] 40, 42	41	45	32	33	34, 35, [3] 40, 42	41	45

[1] Given same designation as that used in Bureau of Mines Tech. Paper 727.
[2] Given same designation as that used in Bureau of Mines Bull. 531.
[3] Not distributed to individual pumping plants.

TABLE 22.—*Surface and stream-bed seepage and length of unimproved pervious stream bed identified with probable receiving underground pools, drainage tunnel, and mine pumping plants in South 7 watershed*

Stream		Estimated surface seepage, gallons per minute per inch of rainfall					Estimated stream-bed seepage, gallons per minute per inch of rainfall					Estimated length of unimproved pervious stream bed, feet				
No.	Name															
S-33	Kidder Creek	20.34					9.53					10,410				
S-34	Franklyn Creek		2.12					2.24					2,870			
S-35	Spring Run		9.20					5.42					6,500			
S-36	Newtown Creek		7.03					4.00					2,500			
S-37	Sugar Notch Creek			8.38					17.00					4,250		
S-38	Maple Hill Creek				0.38					0.29					600	
S-39	St. Mary's Creek				.30					.22					400	
S-40	Buttonwood Creek				1.01					.91					4,600	
S-41	Solomon Creek			1.38	.20				6.09	.60				1,785	215	
	Total	20.34	18.35	9.76	1.89		9.53	11.66	23.09	2.02		10,410	11,870	6,035	5,815	

Probable receiving underground pools, drainage tunnel, or pumping plants

Underground pools [1]															
Drainage tunnel															
Pumping Plants [2]	46, [3] 52	50	51	54		46, [3] 52	50	51	54		46, [3] 52	50	51	54	

[1] Given same designation as that used in Bureau of Mines Tech. Paper 727.
[2] Given same designation as that used in Bureau of Mines Bull. 531.
[3] Not distributed to individual pumping plants.

TABLE 23.—*Surface and stream-bed seepage and length of unimproved pervious stream bed identified with probable receiving underground pools, drainage tunnel, and mine pumping plants in South 8 watershed*

Stream No.	Stream Name	Estimated surface seepage, gallons per minute per inch of rainfall					Estimated stream-bed seepage, gallons per minute per inch of rainfall					Estimated length of unimproved pervious stream bed, feet				
S-42	Silver Creek	3.74					1.14					2,600				
S-43	Garringer Creek		7.14	7.15				2.78	2.78				1,100	1,100		
S-44	Warrior Run	11.57					2.85					2,950				
S-45	Leuder Creek		4.82					9.71					2,200			
S-46	Espy Run, West Branch				10.95					3.30					4,800	
S-47	Espy Run		14.61		4.87			8.92		2.98			5,775		1,925	
S-48	Nanticoke Creek		17.77					11.59					7,090			
	Total	15.31	44.34	7.15	15.82		3.99	33.00	2.78	6.28		5,550	16,165	1,100	6,725	

Probable receiving underground pools, drainage tunnel, or pumping plants

Underground pools [1]															
Drainage tunnel															
Pumping plants [2]	55	56	57	60		55	56	57	60		55	56	57	60	

[1] Given same designation as that used in Bureau of Mines Tech. Paper 727.
[2] Given same designation as that used in Bureau of Mines Bull. 531.

TABLE 24.—*Surface and stream-bed seepage and length of unimproved pervious stream bed identified with probable receiving underground pools, drainage tunnel, and mine pumping plants in South 9 watershed*

Stream No.	Stream Name	Estimated surface seepage, gallons per minute per inch of rainfall					Estimated stream-bed seepage, gallons per minute per inch of rainfall					Estimated length of unimproved pervious stream bed, feet				
S-49	Fairchilds Creek	1.91					4.05					5,400				
S-50	Wanamie Creek			0.45					3.30					800		
S-51	North Wanamie Creek			2.13					1.42					1,340		
S-52	Newport Creek, South Branch	0	0	36.32			3.59	3.58	7.17			1,288	1,287	2,575		
	Total	1.91	0	38.90			7.64	3.58	11.89			6,688	1,287	4,715		

Probable receiving underground pools, drainage tunnel, or pumping plants

Underground pools [1]															
Drainage tunnel															
Pumping plants [2]	61	62	63			61	62	63			61	62	63		

[1] Given same designation as that used in Bureau of Mines Tech. Paper 727.
[2] Given same designation as that used in Bureau of Mines Bull. 531.

TABLE 25.—*Surface and stream-bed seepage, and length of unimproved pervious stream bed identified with probable receiving underground pools, drainage tunnel, and mine pumping plants in South 10 watershed*

Stream		Estimated surface seepage, gallons per minute per inch of rainfall					Estimated stream-bed seepage, gallons per minute per inch of rainfall					Estimated length of unimproved pervious stream bed, feet				
No.	Name															
S-53	Farm Creek		0.15					0.27					400			
S-54	Newport Creek, North Branch		1.22					2.58					2,800			
S-55	Glen Lyon Creek			8.42					6.66					5,400		
S-56	Newport Creek	7.04	7.03	42.20			2.49	2.48	14.89			844	843	5,063		
	Total	7.04	8.40	50.62			2.49	5.33	21.55			844	4,043	10,463		
	Probable receiving underground pools, drainage tunnel, or pumping plants															
	Underground pools [1]															
	Drainage tunnel															
	Pumping plants [2]	62	64	65			62	64	65			62	64	65		

[1] Given same designation as that used in Bureau of Mines Tech. Paper 727.
[2] Given same designation as that used in Bureau of Mines Bull. 531.

Table 26 shows the relationship between the total volume of surface and stream-bed seepage in the drainage area overlying the Wyoming Basin and the volume of discharge to the surface from each pumping plant underlying it. The relationship between rainfall and the volume of water pumped to the surface depends on so many factors that it is impossible to ascertain any definite relationship between them. In the Northern field, of which the Wyoming Basin is a part, the pumping load is 89.1 percent of the rainfall (*5*, *6*, *8*, *10*, *18*).

How much seepage from the Susquehanna River entering mine workings in the Wyoming Basin is recirculated by pumping and seepage between mine workings and the river is unknown. Because of the foregoing reason and general mining subsidence beneath the Susquehanna River and its buried valley, including areas adjoining the river, stream-bed leakage is probably a much greater proportion of mine drainage than the above estimates indicate (*2*, *8*, *10*, *18*).

A typical example illustrating the utility of the tables is given in Bureau of Mines Bulletin 518, Surface-Water Seepage Into Anthracite Mines in the Lackawanna Basin, Northern Field, Anthracite Region of Pennsylvania (*10*).

TABLE 26.—*Relationship between estimated total volume of surface and stream-bed seepage in drainage area overlying Wyoming Basin and volume of discharge from 40 mine pumping plants beneath drainage area, gallons per minute*

	Pumping plants [1]	Designation of mine pumping plants												
		[2] 26	27	[3] 28	29	30	31	32	33	[4] 34, 35, 40, 42	36	37	38	39
A	Average volume pumped to surface during 1948, gallons per minute	8, 462	2, 657	1, 315	5, 930	4, 549	2, 203	1, 774	993	6, 594	4, 812	4, 099	2, 036	7, 561
B	Estimated volume of surface seepage from stream watersheds exclusive of Zero watershed, to mine pumping plants per 42.59 inches of rainfall (Wilkes-Barre, 1948), gallons per minute	440	320	665	1, 249	236	0	682	341	1, 962	1, 064	1, 689	1, 055	0
C	Percent of pumping due to surface seepage from stream watersheds $C=\frac{B\times 100}{A}$.	5. 2	12. 0	50. 6	21. 1	5. 2	0	38. 4	34. 3	29. 8	22. 1	41. 2	51. 8	0
D	Estimated volume of stream-bed seepage, exclusive of Zero watershed, to mine pumping plants per 42.59 inches of rainfall (Wilkes-Barre, 1948), gallons per minute	162	482	476	1, 104	266	0	953	476	4, 337	396	1, 797	672	0
E	Percent of pumping due to stream-bed seepage $E=\frac{D\times 100}{A}$.	1. 9	18. 1	36. 2	18. 6	5. 9	0	53. 7	47. 9	65. 8	8. 2	43. 8	33. 0	0
F	Estimated volume of surface seepage from Zero watershed, to mine pumping plants per 42.59 inches of rainfall (Wilkes-Barre, 1948), gallons per minute	Not distributed to individual pumping plants.												
G	Percent of pumping due to surface seepage from Zero watershed $G=\frac{F\times 100}{A}$.	Do.												
H	Estimated volume of river-bed seepage from Zero watershed, to mine pumping plants, gallons per minute $H=A-(B+D+F)$.	Do.												
J	Percent of pumping due to river-bed seepage from Zero watershed $J=\frac{H\times 100}{A}$.	Do.												

	Pumping plants [1]	Designation of mine pumping plants												
		41	43	44	45	[4] 46, 52	47	48	49	50	51	53	54	55
A	Average volume pumped to surface during 1948, gallons per minute	4, 490	1, 313	3, 503	3, 538	1, 520	409	824	3, 608	1, 290	1, 434	1, 790	6, 254	993
B	Estimated volume of surface seepage from stream watersheds exclusive of Zero watershed, to mine pumping plants per 42.59 inches of rainfall Wilkes-Barre, 1948), gallons per minute	664	0	483	1, 284	866	0	129	885	782	416	565	80	652
C	Percent of pumping due to surface seepage from stream watersheds $C=\frac{B\times 100}{A}$.	14. 8	0	13. 8	36. 3	57. 0	0	15. 7	24. 5	60. 6	29. 0	31. 6	1. 27	65. 7
D	Estimated volume of stream-bed seepage, exclusive of Zero watershed, to mine pumping plants per 42.59 inches of rainfall (Wilkes-Barre, 1948), gallons per minute	401	0	1, 195	1, 515	406	0	28	839	497	983	853	86	170
E	Percent of pumping due to stream-bed seepage $E=\frac{D\times 100}{A}$.	8. 9	0	34. 1	42. 8	26. 7	0	3. 4	23. 3	38. 5	58. 5	47. 7	1. 38	17. 1

See footnote at end of table.

TABLE 26.—*Relationship between estimated total volume of surface and stream-bed seepage in drainage area overlying Wyoming Basin and volume of discharge from 40 mine pumping plants beneath drainage area, gallons per minute*—Continued

	Pumping plants [1]	Designation of mine pumping plants													
		41	43	44	45	[4] 46 52	47	48	49	50	51	53	54	55
F	Estimated volume of surface seepage from Zero watershed, to mine pumping plants per 42.59 inches of rainfall (Wilkes-Barre, 1948), gallons per minute	Not distributed to individual pumping plants.												
G	Percent of pumping due to surface seepage from Zero watershed. $G=\frac{F\times 100}{A}$.	Do.												
H	Estimated volume of river-bed seepage from Zero watershed to mine pumping plants, gallons per minute. $H=A-(B+D+F)$.	Do.												
J	Percent of pumping due to river-bed seepage from Zero watershed. $J=\frac{H\times 100}{A}$.	Do.												

	Pumping plants [1]	Designation of mine pumping plants										
		56	57	58	59	60	61	62	63	64	65	Total
A	Average volume pumped to surface during 1948, gallons per minute	3, 562	844	3, 394	2, 350	1, 180	425	8, 336	2, 597	788	3, 376	110, 803
B	Estimated volume of surface seepage from stream watersheds, exclusive of Zero watershed, to mine pumping plants per 42.59 inches of rainfall (Wilkes-Barre, 1948), gallons per minute	1, 888	305	623	485	674	81	300	1, 657	358	2, 156	25, 036
C	Percent of pumping due to surface seepage from stream watersheds. $C=\frac{B\times 100}{A}$.	53. 0	36. 1	18. 4	20. 6	57. 1	19. 0	3. 6	63. 8	45. 4	63. 9	22. 6
D	Estimated volume of stream-bed seepage, exclusive of Zero watershed, to mine pumping plants per 42.59 inches of rainfall (Wilkes-Barre, 1948), gallons per minute	1, 405	118	1, 047	631	267	325	258	506	227	918	23, 796
E	Percent of pumping due to stream-bed seepage. $E=\frac{D\times 100}{A}$.	39. 5	14. 0	30. 8	26. 9	22. 6	76. 5	3. 1	19. 5	35. 2	2. 72	21. 5
F	Estimated volume of surface seepage from Zero watershed, to mine pumping plants per 42.59 inches of rainfall (Wilkes-Barre, 1948), gallons per minute	Not distributed to individual pumping plants										7, 937
G	Percent of pumping due to surface seepage from Zero watershed. $G=\frac{F\times 100}{A}$.	do										7. 2
H	Estimated volume of river-bed seepage from Zero watershed to mine pumping plants, gallons per minute. $H=A-(B+D+F)$.	do										[5] 54, 034
J	Percent of pumping due to river-bed seepage from Zero watershed. $J=\frac{H\times 100}{A}$.	do										48. 8

[1] Designation of mine pumping plants as listed in Bureau of Mines Bull. 531.
[2] Pumping plant 26 pumped 9,509 gallons per minute, of which 8,462 gallons originated in drainage area overlying Wyoming Basin.
[3] Pumping plant 28 pumped 1,895 gallons per minute, of which 1,315 gallons originated in drainage area overlying Wyoming Basin.
[4] Not distributed to individual pumping plants.
[5] Obtained by subtracting summation of side-stream and surface seepage from total volume pumped.

CONCLUSIONS

Approximately 30 percent of the water pumped annually from mines in the Wyoming Basin arrives underground as a result of direct surface seepage. Twenty-one percent seeps into mine workings through the pervious beds of 59 streams, which flow over some portion of the coal measures. The remaining 49 percent of mine water pumped to the surface seeps into mine workings through the bed of the Susquehanna River.

A program of remedial measures designed to prevent the major portion of surface-water seepage into mines underlying the Susquehanna River drainage area must not only consider seepage from streams and their watersheds but also the insuperable problem of stream-bed seepage from the Susquehanna River itself. Such a program must also consider proper maintenance of surface works until reserves are exhausted in the Northern field (Lackawanna and Wyoming Basins). Any concerted effort to prevent surface-water seepage into mine workings of the Wyoming Basin cannot achieve more than half its objective unless the bed of the Susquehanna River is made impervious.

Because the problem of making the bed of the Susquehanna River, contributing 49 percent of the leakage, impervious is economically and physically impossible and because the beds of all side streams contribute only an estimated 21 percent of the total seepage, remedial measures applied to these streams would rectify only a minor part of the total problem. This investigation shows that, in some instances, much can be done to lessen the pumping load by repairing the beds of streams in the areas most seriously affected and thereby relieve the burden of cost now borne by some mining companies.

Recent reports (*9, 11, 14*) on barrier pillars separating mines in the Northern and Western Middle fields reveal that all of them are likely to be affected by subsidence. Few could be depended on to act as dams if either mine adjoining the barrier pillar was filled with water, because the barrier pillars are too small, are partly removed, may be damaged by subsidence, are punctured, or are rendered of uncertain stability because of encroachments. Often barrier pillars are punctured by passageways in which masonry dams are constructed to resist hydrostatic pressure.

The economics of handling mine water in the Wyoming Basin is of grave concern to the entire Northern field. Because of the number of beds, extent of strippings and mine workings near the outcrops, including beds outcropping beneath the buried valley, general subsidence, likelihood of squeezes as mining progresses, cost of remedial measures, cost of mining active mines, and lack of legal control of mine-drainage practice, it does not appear possible to prevent undue infiltration of surface waters. Drainage tunnels in the Wyoming Basin should be maintained and their destruction prevented. A tunnel system, supplemented by a central pumping plant, appears to be the method by which the water problem can be solved and should greatly prolong the life of the anthracite industry in this area.

BIBLIOGRAPHY

1. Ash, S. H. Water Problem in the Pennsylvania Anthracite Mining Region. Bureau of Mines Inf. Circ. 7175, 1941, 11 pp.
2. ———. Buried Valley of the Susquehanna River; Anthracite Region of Pennsylvania. Bureau of Mines Bull. 494, 1950, 27 pp.
3. Ash, S. H., and Others. Flood-Prevention Projects at Pennsylvania Anthracite Mines; Progress Report for 1945. Bureau of Mines Rept. of Investigations 4109, 1947, 64 pp.
4. ———. Flood-Prevention Projects at Pennsylvania Anthracite Mines; Progress Report for Fiscal Year Ended June 30, 1947. Bureau of Mines Rept. of Investigations 4288, 1948, pp. 38–51.
5. ———. Water Pools in Pennsylvania Anthracite Mines. Bureau of Mines Tech. Paper 727, 1949, 78 pp.
6. ———. Data on Pumping at the Anthracite Mines of Pennsylvania. Bureau of Mines Rept. of Investigations 4700, 1950, 264 pp.
7. ———. Inundated Anthracite Reserves; Eastern Middle Field of Pennsylvania. Bureau of Mines Bull. 491, 1950, 28 pp.
8. ———. Acid-Mine-Drainage Problems; Anthracite Region of Pennsylvania. Bureau of Mines Bull. 508, 1951, 72 pp.
9. ———. Barrier Pillars in the Lackawanna Basin of the Northern Field; Anthracite Region of Pennsylvania. Bureau of Mines Bull. 517, 1952, 114 pp.
10. ———. Surface-Water Seepage Into Anthracite Mines, Lackawanna Basin, Northern Field; Anthracite Region of Pennsylvania. Bureau of Mines Bull. 518, 1952, 37 pp.
11. ———. Barrier Pillars in the Western Middle Field; Anthracite Region of Pennsylvania. Bureau of Mines Bull. 521, 1953, 92 pp.
12. ———. Mine Pumping Plants; Anthracite Region of Pennsylvania. Bureau of Mines Bull. 531 (in press).
13. ———. Surface-Water Seepage into Anthracite Mines in the Western Middle Field; Anthracite Region of Pennsylvania. Bureau of Mines Bull. 532, 1953, 26 pp.
14. ———. Barrier Pillars in the Wyoming Basin, Northern Field; Anthracite Region of Pennsylvania. Bureau of Mines Bull. 538 (in press).
15. Ash, S. H., and Westfield, James. Backfilling Problem in the Anthracite Region As It Relates to Conservation of Anthracite and Prevention of Subsidence. Bureau of Mines Inf. Circ. 7342, 1946, 18 pp.
16. ——— Flood-Prevention Projects at Pennsylvania Anthracite Mines; a Preliminary Study. Bureau of Mines Rept. of Investigations 3868, 1946, 25 pp.
17. Enzian, Charles. Hydraulic Mine Filling, Its Use in the Pennsylvania Anthracite Fields. Bureau of Mines Bull. 60, 1913, 77 pp.
18. Felegy, E. W., Johnson, L. H., and Westfield, James. Acid Mine Water in the Anthracite Region of Pennsylvania. Bureau of Mines Tech. Paper 710, 1948, 49 pp.
19. Griffith, Edward. Mine-Drainage Practice in the Anthracite Region of Pennsylvania. Trans. Am. Inst. Min. and Met. Eng., vol. 168, 1946, pp. 127–144.
20. House Committee on Appropriations. Hearings before the Subcommittee of the Committee on Appropriations on the Interior Department Appropriation Bill for 1949. House of Representatives, 80th Cong., 2d sess., 1948, pp. 395, 392, 1042, 1045, and 1046.
21. House Committee on Flood Control. Survey of the North Branch of the Susquehanna River, Pennsylvania and New York, Report from the Chief of Engineers, War Dept. House of Representatives, Doc. 647, 69th Cong., 2d sess., Jan. 13, 1927, 57 pp.
22. House Committee on Public Lands. Providing an Engineering Study of the Mine-Water Problem of the Pennsylvania Anthracite Mining Area. House of Representatives, Rept. 1375, 80th Cong., 2d sess., Feb. 12, 1948, 3 pp.
23. Mangan, John W. Natural Water Losses from Pennsylvania Drainage Basins. Commonwealth of Pennsylvania, Dept. of Forests and Waters, 1940, 73 pp.
24. Meinzer, D. E. Hydrology, Physics of the Earth—IX. 1st ed., 1942, pp. 314, 321.
25. Merriman, Mansfield. Treatise on Hydraulics. 10th ed., rev. 1916, p. 272.
26. Peele, Robert. Mining Engineers' Handbook. 3d ed., vol. 2, 1941, sec. 38, p. 26.
27. Pennsylvania Geological Survey. A Summary Description of the Geology of Pennsylvania. Vol. 3, part 1. Carboniferous Formation. 1895, p. 1960.