



Ground-Water Resources of the Brunswick Formation in Montgomery and Berks Counties, Pennsylvania.

**Stanley M. Longwill
Charles R. Wood**

**COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF INTERNAL AFFAIRS
Genevieve Blatt, Secretary**

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Arthur A. Socolow, State Geologist**

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by Stanley M. Longwill and Charles R. Wood
Hydraulic Engineers, U. S. Geological Survey

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ABSTRACT

The Brunswick Formation in Montgomery and Berks Counties, Pa., consists of reddish-brown shale, mudstone, and siltstone, which are interbedded with sandstone and fanglomerate near the northern border of the Triassic basin. In places the Brunswick Formation has been intruded by diabase dikes and sills, and throughout much of its outcrop area it is interbedded with the Lockatong Formation. The Lockatong Formation in Montgomery County consists principally of massively bedded medium- to dark-gray argillite interbedded with thin beds of gray to black shale, siltstone, and marlstone.

Ground water in the Brunswick and Lockatong Formations occurs largely in secondary openings such as joint planes. These secondary openings are more abundant and much more closely spaced in the Brunswick Formation than in the Lockatong Formation. Consequently, wells in the Lockatong Formation generally yield water for domestic purposes only whereas many wells in the Brunswick Formation yield sufficient water for industrial and municipal use.

Data from 199 wells that obtain water from only the Brunswick Formation in Montgomery County indicate that wells should be drilled at least 200 feet deep, if yields of more than 100 gpm (gallons per minute) are desired. Wells drilled to depths between 200 and 550 feet are most likely to obtain maximum yields.

Pumping tests in the Brunswick Formation, using observation wells, were made at six localities. Coefficients of transmissibility computed from drawdown data at the observation wells are much higher than transmissibilities calculated at the pumped wells, demonstrating the poor hydraulic connection between the pumped wells and the observation wells. The excessively high transmissibilities are useful for estimating the effect of pumping upon nearby wells and indicate that interference between wells during brief periods of pumping may be somewhat less in the Brunswick Formation than in an ideal aquifer. Water levels in the observation wells declined to a greater extent than predicted by the transmissibilities computed from data obtained during the early part of a pumping test, however, because impermeable boundaries appear in the test data of almost all observation wells. Transmissibilities computed for the pumped wells at the six test localities range from 100 to 5,000 gpd (gallons per day) per foot, and the median transmissibility is 1,100 gpd per foot.

Transmissibilities determined from additional pumping tests in the Brunswick Formation, which were made without observation wells, range from 140 to 4,000 gpd per foot, and the median is 600 gpd per foot. Transmissibilities determined from pumping tests in the Lockatong Formation, all of which were made without observation wells, range from 60 to 2,600 gpd per foot, and the median is 150 gpd per foot.

Observation wells situated along a line from the pumping well that is perpendicular to the strike of the beds show much less drawdown in response to pumping than do wells situated along a line parallel to the strike, because the former do not penetrate the same strata as the pumped well. The resultant cone of depression surrounding a pumping well is ellipsoidal in shape—being elongated parallel to strike.

Chemical analyses of ground-water are available from 36 wells in the Brunswick Formation and six wells in the Lockatong Formation. Ground water in both formations is largely of the calcium-bicarbonate type. However, water samples from the Brunswick Formation having concentrations of dissolved solids greater than 500 ppm (parts per million) are of the calcium-sulfate type. Median dissolved-solids content is 302 ppm in water from the Brunswick Formation and 268 ppm in water from the Lockatong Formation. Median hardness as CaCO_3 is 218 ppm in water from the Brunswick Formation and 206 ppm in water from the Lockatong Formation.

INTRODUCTION

PURPOSE AND SCOPE

Prior to 1940, the area in Montgomery and Berks Counties that lies to the north and northwest of Philadelphia, Pa., consisted chiefly of small towns surrounded by farm land. The industrialization and urbanization of this area increased rapidly after the Second World War. For example, the population of Montgomery County as determined by the 1940 census was only 289,247, but by 1960 the population had risen to 516,682, almost double the 1940 figure. Most of the population increase and industrial investment occurred in the southern part of Montgomery County while the northern part retained its rural character.

The development of new ground-water supplies to meet the increased demands of industries, municipalities, and individual consumers in this rapidly growing area has been seriously handicapped by a lack of geologic and hydrologic data. Having recognized that maximum utilization of the available supply depends on understanding the occurrence, movement, and distribution of the ground water in the area, a study of the occurrence of ground-water in the Triassic rocks of southeastern Pennsylvania was begun in 1956 by the U.S. Geological Survey in cooperation with the Pennsylvania Topographic and Geologic Survey.

This report deals chiefly with the ground-water resources of the Brunswick Formation in Montgomery and Berks Counties, although some attention is directed to the water-bearing properties of the Lockatong Formation in the same area. It is one of a series of reports that will eventually describe the ground-water resources of the rocks of Triassic age in southeastern Pennsylvania. The first of these, a report on the Stockton Formation in southeastern Pennsylvania, was published in 1962 (Rima, D. R., and others, 1962).

LOCATION OF THE AREA

The area covered by this report is in Montgomery and Berks Counties, in southeastern Pennsylvania, between lat. $40^{\circ}08'$ and $40^{\circ}27'$ N. and long. $75^{\circ}09'$ and $75^{\circ}56'$ W. (See Fig. 1.) The area extends for 41 miles from the eastern border of Montgomery County to its most western point, on

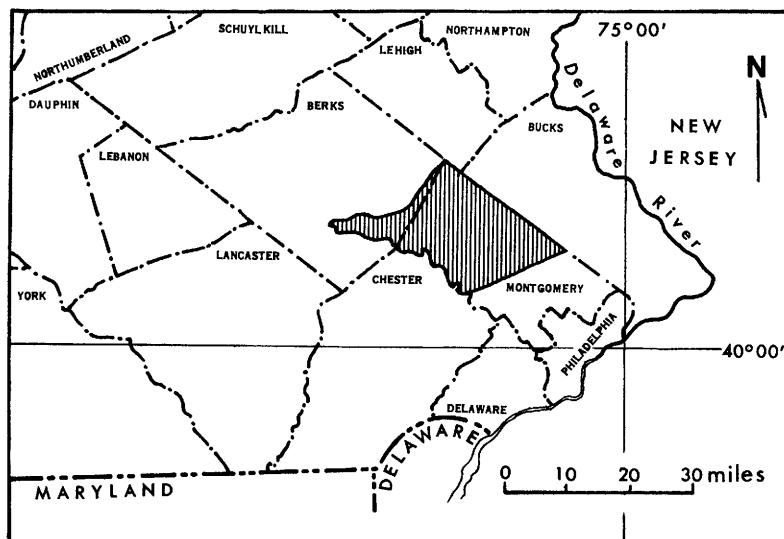


Figure 1. Map of southeastern Pennsylvania showing location of area covered by this report. the Schuylkill River near Reading, Pa. It is 16 miles wide in eastern Montgomery County and narrows to less than 1 mile wide near Reading. The total area covered by the report is 347 square miles, of which 300 square miles is in Montgomery County and 47 square miles is in Berks County.

METHODS OF THIS INVESTIGATION

An inventory was made of nearly all municipal and industrial wells and about 70 rural and domestic wells in the area covered by this report. The records for 322 wells are given in table 6, and the well locations are shown in Plate 1.

Pumping tests ranging in duration from 3 to 101 hours (and making use of observation wells) were made at six locations. Short-term pumping tests (generally of 1-hour duration and without the use of observation wells) were made at 15 wells. Three test wells were drilled in order to obtain geologic data and to provide sites for pumping tests.

Ground-water samples were collected from 42 wells, and complete chemical analyses of the samples were made by the Quality of Water Branch, U.S. Geological Survey.

PREVIOUS INVESTIGATIONS

The ground-water resources of the Brunswick and Lockatong Formations in Berks and Montgomery Counties were described very briefly by Hall (1934) who made a reconnaissance investigation of the ground-water resources of southeastern Pennsylvania. Rima (1955) investigated the ground-water resources of the Brunswick Formation in the vicinity of

Lansdale. Greenman (1955) described the ground-water resources of the Brunswick and Lockatong Formations in adjoining Bucks County. Barksdale and others (1958) prepared a report covering the ground-water resources in the tri-state region adjacent to the lower Delaware River, which discussed the water-bearing properties of the Brunswick and Lockatong Formations.

The geology of the Quakertown and Doylestown 15-minute quadrangle was described and mapped by Bascom and others (1931). Bascom and Stose (1938) described the geology of the Phoenixville 15-minute quadrangle. Since 1932, D. B. McLaughlin has written many articles describing the geology of the Brunswick and Lockatong Formations in southeastern Pennsylvania. These articles are summarized in the report on the geology of the Mesozoic rocks in Bucks County (McLaughlin, 1959) which describes in detail the geology of the Brunswick and Lockatong Formations in southeastern Pennsylvania.

ACKNOWLEDGMENTS

The writers acknowledge with appreciation the cooperation and assistance received from well drillers, industries, home owners, water companies, and local, state, and federal governmental agencies.

Appreciation is expressed to Leeds and Northrup Co., North Wales, who permitted their wells to be used for water-level measurements, assisted in aquifer tests, and supplied drillers logs of wells. Nice Ball Bearing Co., Kulpsville; Kawecki Chemical Co., Boyertown; Douglassville Development Corp., Douglassville; Pennhurst State School, Spring City; and Charles Johnson County Home, Royersford; permitted their wells to be used in pumping tests and made available sites for additional test wells. Acknowledgment is made to Souderton Borough for providing sites for water-level recorders and permitting the use of their wells in aquifer tests.

Most of the data for the geologic map (Pl. 1) was obtained from unpublished geologic maps by Dr. Dean B. McLaughlin, University of Michigan.

WELL-NUMBERING SYSTEM

All wells used in this report have an identification number and a location number. The identification number consists of two parts. The first part is a two-letter symbol that identifies the county in which the well is located. For example, wells in Montgomery County are identified by the symbol Mg and those in Berks County are identified by the letters Be. The second part of the identification number is a serial number that was assigned at the time the well was first visited during the field investigation.

Each well identified in the manner described is located by means of a three-part well-location number. The first two parts are obtained by super-

imposing a grid network on the area of investigation. The network is constructed of 1-minute parallels of latitude and meridians of longitude. Thus, it consists of a series of 1-minute quadrangles each of which can be identified by two three-digit numbers. The first number, which identifies the latitude bounding the quadrangle on the south, is formed by the last digit used in the number of degrees latitude and the two digits used in the number of minutes. The second three-digit number is obtained in a similar way by using the degrees and minutes of the longitude bordering the quadrangle on the east. The third part is a serial number assigned to distinguish the wells from others in the same quadrangle.

For example, a well in Montgomery County given identification number Mg-633 bears the location number 015-520-10. This well is located in the 1-minute quadrangle that is bounded on the south by latitude $40^{\circ}15'$ and on the east by longitude $75^{\circ}20'$. The serial number 10 indicates that this well was the tenth well visited within that 1-minute quadrangle.

CLIMATE

Pennsylvania has a humid climate and moderate temperatures. Most of the weather disturbances that affect Pennsylvania are carried from the interior of the continent by prevailing westerly winds. However, coastal storms occasionally affect day-to-day weather in the southeastern part of the state (Kauffman, 1960, p. 2). Differences in elevation within the area in this report are not great enough to cause any major differences in climate.

Temperatures in southeastern Pennsylvania generally range from 0°F to 100°F . The summers are long, and daily temperatures reach 90°F or above on an average of 25 days during the summer. The winters are mild, and the minimum temperatures go below 32°F an average of less than 100 days a year. The average annual temperature for the report area, based on data for Phoenixville, is 54.3°F . Mean monthly temperatures at Phoenixville range from 33.1°F in February to 76.7°F in July. (Data from U.S. Weather Bureau climatic summaries.) The freeze-free season usually ranges from 170 to 200 days.

The average annual precipitation from 1931 to 1955, based on records from several stations within the area, was about 44 inches. The minimum annual precipitation recorded within the report area is 26.45 inches at Pottstown in 1930. The maximum annual precipitation recorded for the area is 71.32 inches at Pottstown in 1889.

Precipitation is fairly well distributed throughout the year, but occasionally dry spells persist for several months with very little rainfall. The average seasonal snowfall is about 30 inches; the ground is covered by snow about one-third of the time during the winter.

Occasional severe coastal storms have caused a normal 1-month rainfall to occur within a period of 48 hours. Floods have been caused by these

coastal storms and by melting snow and heavy rain in the spring. Major flooding occurred along the Schuylkill River in 1902, 1935, 1942, and 1955.

GEOLOGY

NEWARK GROUP

Rocks of Triassic age occupy a series of disconnected, downfaulted basins that extend from Nova Scotia to North Carolina. These rocks, known as the Newark Group, often have a reddish color and consist principally of conglomerate, arkose, sandstone, siltstone, argillite, and shale. They are interbedded with basaltic lava flows and are intruded by diabase dikes and sills.

McLaughlin (1957, p. 1492-1493) believes that the Newark Group is of Late Triassic age. Paleontologic data support this conclusion (Wherry, 1959, p. 124). Rocks of the group overlie Paleozoic and Precambrian rocks unconformably, and in New Jersey the Newark Group is overlain unconformably by Cretaceous rocks.

The Triassic rocks of Montgomery and Berks Counties are part of the largest Triassic basin in the eastern United States. This basin extends from the Hudson River in southeastern New York, across New Jersey, southeastern Pennsylvania, Maryland, and into northern Virginia. In Pennsylvania the width of the basin ranges from about 30 miles in eastern Montgomery County to about 4 miles southeast of Lebanon, Pa.

In southeastern Pennsylvania and western New Jersey the Newark Group has been divided, proceeding from the oldest sediments to the youngest, into the Stockton, Lockatong, and Brunswick Formations. (See Pl. 1.) These formations were described at the type locality in New Jersey by Kummel (1897). The Stockton Formation is composed of interbedded arkosic sandstone and conglomerate, red shale, and red siltstone. The Stockton is overlain to the north by the Lockatong Formation, which is made up principally of dark gray argillite. The Lockatong is overlain to the north by the Brunswick Formation, which consists chiefly of red shale and siltstone although there is some interbedded sandstone and conglomerate near the north border of the outcrop. The Brunswick Formation is equivalent to the Gettysburg Shale in Adams, York, and Lancaster Counties, Pa., the two formations having been deposited almost contemporaneously.

Although the sum of the thicknesses of the individual formations in the Newark Group is about 18,000 feet, the total thickness of the Newark Group present at any one place in southeastern Pennsylvania probably does not exceed the 12,000 feet believed to be present at the center of the basin (McLaughlin and Willard, 1949, p. 43). The absence of the total

thickness at any one place is postulated because the floor of the basin probably shelved northward and deposition did not start along the northern edge of the basin until several thousand feet of sediments had accumulated in the central part of the basin. This theory is supported by the fact that the Brunswick Formation was deposited directly upon Paleozoic and Precambrian rocks along part of the northern border of the Triassic basin in Pennsylvania.

LOCKATONG FORMATION

The Lockatong Formation occurs principally in a single continuous belt along the southern edge of the Brunswick Formation. The width of this belt in Montgomery and Berks Counties varies from 4 miles at the Bucks County-Montgomery County line to 1¼ miles at the Schuylkill River. This main body of Lockatong Formation underlies an area of 46 square miles in Montgomery County. A few relatively thin tongues of Lockatong occur well up-section (northward) in the Brunswick Formation, and although most of these tongues do not extend far to the west of the Bucks County line, some of them can be traced for about 30 miles westward to the Schuylkill River.

The Lockatong Formation in Montgomery County consists principally of medium-to dark-gray argillite interbedded with thin beds of gray to black shale, siltstone, and marlstone. Bedding is principally massive. Van Houten (1960, p. 666) indicates that the Lockatong contains a large percentage of analcime (up to 40 percent) along with dolomite, feldspar, and clay. Quartz is a very minor constituent of the Lockatong Formation. Pyrite is scattered throughout the formation and calcite is common, especially in joints.

In the area of this investigation the Lockatong Formation attains its maximum stratigraphic thickness at the Bucks County line. A stratigraphic section measured by McLaughlin (1959, p. 88) at this locality shows a thickness of slightly over 4,000 feet. The Lockatong Formation thins rapidly to the west and is only about 1,500 feet thick at the Schuylkill River (Bascom and Stose, 1938, p. 72).

The Lockatong Formation overlies the Stockton Formation conformably, and probably there is some interfingering of the two formations (McLaughlin, 1959, p. 77). The Lockatong is overlain conformably by the Brunswick Formation, and there is considerable interfingering between these formations—especially in eastern Montgomery County. Where there is interfingering, the percentage of red beds in the section increases upward in the stratigraphic column until the red beds of the Brunswick Formation predominate over the gray shale and argillite of the Lockatong.

The Lockatong Formation grades westward along strike into the typical red shale, mudstone, and siltstone of the Brunswick Formation. This

gradation and thinning westward continues until the Lockatong Formation disappears a few miles west of Phoenixville.

BRUNSWICK FORMATION

In Montgomery and Berks Counties, the Brunswick Formation, together with the associated diabase intrusives, occupies an area of 301 square miles. Two large areas of Brunswick, one of about 25 square miles (lying mostly in Upper Hanover Township, Montgomery County) and the other of 50 square miles (lying mostly in Douglass and New Hanover Townships, Montgomery County) are separated from the main body of the Brunswick Formation by diabase intrusives.

The Brunswick Formation consists typically of reddish-brown shale, mudstone, and siltstone. A few very thin beds of green shale and brown shale are present in the Brunswick, and in some places they can be used as marker beds for distances up to 1 mile. Van Houten (1960, p. 669) indicates that the Brunswick Formation consists chiefly of feldspar, illite, chlorite, quartz, and calcite. Some beds are finely micaceous. Joints in the Brunswick Formation commonly are partly filled with calcite and quartz. Occasionally barite and pyrite are present as joint filling, and very small crystals of pyrite may be disseminated throughout the rock.

The total apparent thickness of the Brunswick Formation in Bucks County is about 9,000 feet (McLaughlin, 1959, p. 99). The maximum thickness is greater to the west and is about 16,000 feet near Pottstown, Pa. (Bascom and Stose, 1938, p. 76).

Near the base of the Brunswick much of the rock is tough thick-bedded red argillite and is interbedded with dark-gray argillite of the Lockatong Formation. This red argillite grades upward and also along strike into red shale, mudstone, and siltstone. Near the north border of the Triassic basin, the typical shales, mudstones, and siltstones of the Brunswick Formation are interbedded with and grade laterally into sandstone and fanglomerate.

There are many excellent exposures of the Brunswick Formation—especially along streams and railroad cuts. For detailed geologic sections the reader is referred to McLaughlin (1933) and Bascom and Stose (1938). Table 7 contains seven sample logs that illustrate the relatively uniform character of the Brunswick Formation. Some of them (Be-125 for example) show that beds of gray argillite typical of the Lockatong are present also in the Brunswick Formation.

FANGLOMERATES

Fanglomerates occupy about 6 square miles along the northern border of the area of investigation. These fanglomerates were deposited as alluvial fans by streams flowing into the basin from the north. They are mostly limestone breccias consisting of angular gray limestone pebbles in a red-

dish-brown or buff, fine-grained, sandy-to-argillaceous matrix. Some pebbles of quartzite and other rocks are also present.

These fanglomerates occur at several locations along the northern border and are extensively interbedded with typical shale and siltstone of the Brunswick. The beds of limestone breccia grade along strike into reddish-brown sandstone and then into reddish-brown shale.

Outcrops of fanglomerate are very scarce in Montgomery County; however, in Berks County the area of fanglomerate that crosses the Schuylkill River south of Reading is exposed in many places.

The fanglomerates are some of the youngest beds within the Brunswick Formation. However, west of the Schuylkill River, fanglomerates were deposited throughout most of the period of deposition of the Brunswick Formation. Several tongues of fanglomerate extend eastward towards the Schuylkill River, and are represented at the river by a few thin sandstone beds.

The areas mapped as fanglomerate on Plate 1 are areas in which breccia and conglomerate are more prevalent than the interbedded shale, siltstone, and mudstone.

METAMORPHISM

Near the diabase intrusives the shales of the Brunswick Formation are altered to dark, tough hornfels. These hornfels closely resemble the Lockatong Formation because of the change of color caused by the reduction of ferric to ferrous oxide. The effect of the metamorphism on the color of the sediments is gradational, the first effect being the change from red to purplish red. With increased baking the beds change from purple to dark gray or blue black.

The width of the altered zone differs greatly from place to place. Adjacent to the smaller dikes the zone is usually between 40 and 100 feet wide, and in the vicinity of the larger intrusives the altered zone may be more than 1 mile wide. The rocks near the outer limit of the altered zone show very little change in lithology.

DIABASE

The Brunswick Formation has been intruded by many diabase dikes and sills in southeastern Pennsylvania. The dikes are generally 5 to 100 feet thick, and their outcrops may extend for several miles. The diabase in these narrow dikes is black, dense, very fine-grained, and consists of 90 to 95 percent labradorite and augite.

The sills, with few exceptions, are much thicker than the dikes. The largest sills in the area are more than 1,000 feet thick. The diabase in the larger intrusives, except in the chilled border zone, is medium to coarse grained, greenish gray, and also consists of 90 to 95 percent labradorite and augite (Ryan, 1959, p. 155).

STRUCTURE

The average dip of the beds in the Brunswick and Lockatong Formations is to the north and northwest at about 20° . Several broad synclines and anticlines, whose axes trend about N. 60° W., are superimposed on this homocline.

The Brunswick and Lockatong Formations have been cut by many faults, most of which are relatively small. Some of these small faults may be observed in the railroad cut south of North Wales. McLaughlin (1942) gives the location of several faults.

The largest fault observed in Berks and Montgomery Counties passes between Hatfield and Souderton in an east-west direction. It has a throw of about 3,000 feet at the Bucks County-Montgomery County line (McLaughlin, 1959, p. 129). The Brunswick Formation is in fault contact with the underlying Paleozoic and Precambrian rocks along part of the northern border of the Triassic basin.

Joint systems are well developed in many of the beds in the Brunswick Formation. A very small set of joints strikes about N. 30° E., and one or both of two additional, less well-developed sets may be observed at most outcrops. These additional sets strike about N. 45° W. and N. 75° E. All of the joints are nearly vertical, and the average distance between joints in most sets is about 6 inches. The strike of the Joint sets appears to be independent of the dip and strike of the beds.

HYDROLOGY

PRINCIPLES

Ground water is the subsurface water in that part of the zone of saturation in which all the interconnected pores, crevices, and voids in the rock are filled with water under pressure equal to or greater than atmospheric. Precipitation is the source of ground water in southeastern Pennsylvania. Although most of the water that reaches the land surface from the atmosphere either runs off as overland flow or is returned to the atmosphere by evaporation and transpiration, some infiltrates downward through the soil to the zone of saturation, where it becomes recharge to the main ground-water body. Upon reaching the zone of saturation, it begins to move downward and laterally toward lower elevations, and eventually it may return to the surface either naturally (through springs) or artificially (through wells). Under natural conditions and over long periods of time, the amount of water that leaves the zone of saturation as discharge is balanced by the amount of water that enters it as recharge.

Ground water may be roughly divided into two classes: (1) that which occurs in the shallow formations, mostly under nonartesian conditions, and (2) that which occurs in the deeper formations, under artesian condi-

tions. Nonartesian conditions are those in which ground water is unconfined, so that its upper surface (the water table) is free to rise and fall. Artesian conditions are those in which the ground water is confined in a permeable formation that is overlain by a relatively impermeable formation, so that the upper surface of the confined water is not free to rise and fall, and the water is under sufficient pressure to rise above the top of the formation that contains it where that formation is penetrated by wells. The imaginary surface to which water will rise in tightly cased wells tapping the artesian aquifer is called the piezometric surface.

In humid areas, such as southeastern Pennsylvania, the water table stands at or near the land surface in valleys and rises toward adjacent topographic divides. The slope of the water table is generally less than that of the land surface; hence, the depth to the water table below the land surface is usually greatest beneath topographic highs and least beneath topographic lows.

The water table does not remain in a fixed position but fluctuates in response to additions to and withdrawals from the zone of saturation. As the seasonal variation in precipitation in southeastern Pennsylvania is small, the dominant factor controlling the fluctuation of the water table in areas remote from pumped wells is the seasonal variation in the rate of evaporation and transpiration. Thus the water table generally declines throughout the warm growing season (April to October) and rises throughout the remainder of the year.

Within the zone of saturation, the rocks of the earth's crust differ greatly in their capacity to store and transmit ground water. Rocks that are capable of yielding usable quantities of ground water to wells are called aquifers. An aquifer may consist of all or part of a geologic formation or group of formations.

Most of ground water, like water in other phases of the hydrologic cycle, is continually in motion. It flows by gravity from intake or recharge areas, where hydraulic potentials are high, through permeable zones or aquifers to points of discharge, where hydraulic potentials are low.

OCCURRENCE OF GROUND WATER IN THE BRUNSWICK FORMATION

The Brunswick Formation is composed of very fine-grained rocks. The pore spaces within the rock matrix are very small and offer great resistance to the flow of ground water. Therefore, the permeability due to the primary porosity of the Brunswick Formation is small.

Most of the ground-water movement within these rocks follows secondary openings that were developed by external forces, following deposition of the beds. Some of these openings are fractures that parallel the bedding planes. They are usually narrow and probably contribute little to the permeability. The most important openings are nearly vertical joint

planes that cross each other at various angles throughout the beds. These vertical joints provide an interconnected series of channels through which ground water can flow.

The number and width of secondary openings and, consequently, the permeability differ from one bed to another. In a series of beds 100 feet thick there may be only one or two beds in which the secondary openings are well developed. These beds range in thickness from a few inches to a few feet; the average thickness is about 2 feet.

Because of conditions under which the rocks of the Brunswick Formation were deposited, lateral changes in the lithology take place within the formation. The rocks are a series of overlapping lens-shaped beds that are discontinuous in all directions along the plane of bedding. Examination of rock outcrops in the area indicates, however, that many of these lens-shaped beds extend for several thousand feet along strike.

The Brunswick Formation is generally a reliable source of small to moderate supplies of ground water, and in many places wells yield more than 100 gpm.

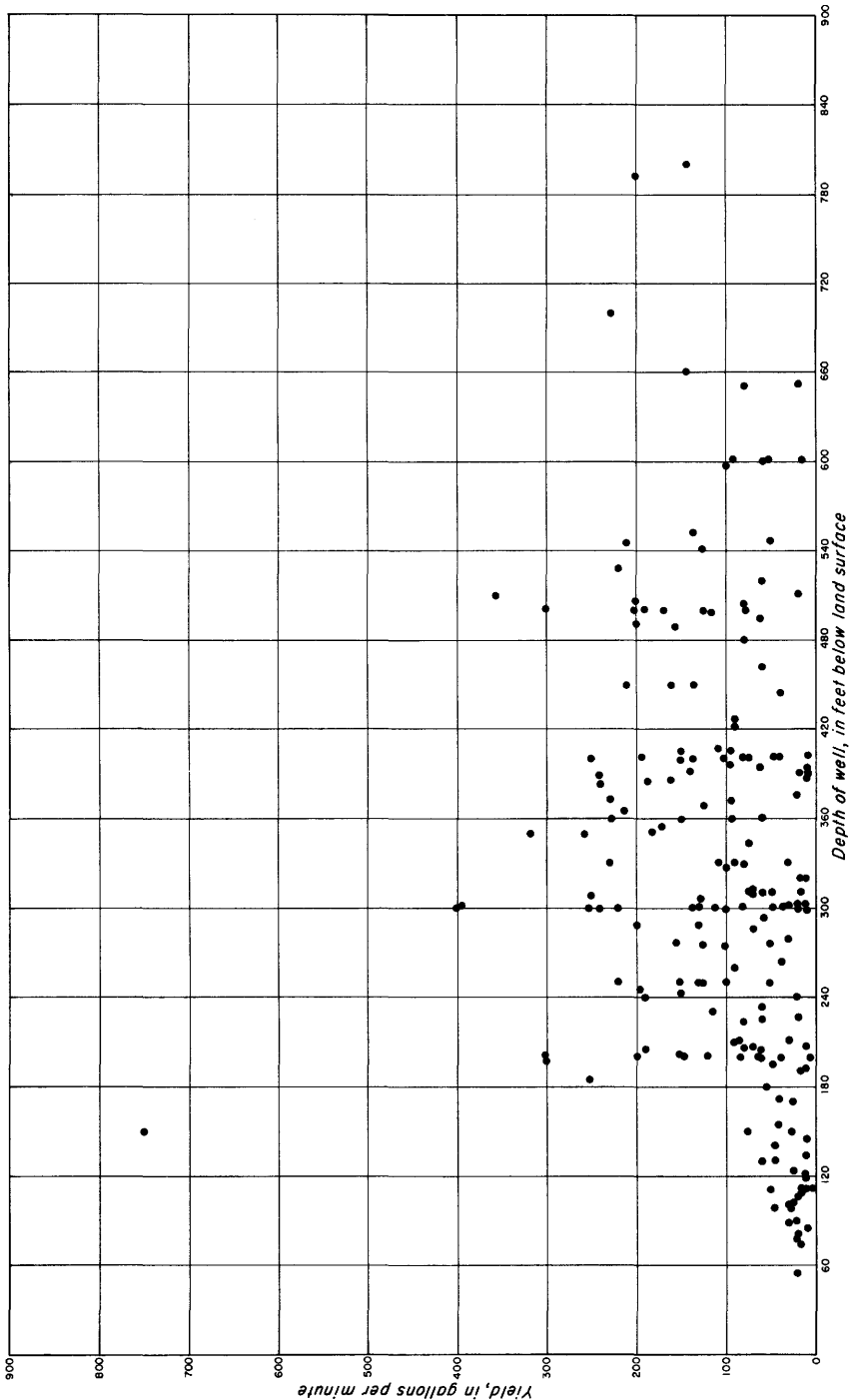
Analysis of data from 199 wells, which obtain water from only the Brunswick Formation in Montgomery and Berks Counties, indicates that there is a significant relationship between well yields and well depths. (See Fig. 2.) If yields of 100 gpm or more are desired, wells should be drilled at least 200 feet deep. According to the data shown on Figure 2, wells drilled to depths between 200 and 550 feet deep are most likely to obtain maximum yields.

For example, of 35 wells less than 185 feet deep, only 1 well yields more than 100 gpm, and only 5 yield more than 50 gpm. But 45 percent (68 of 151) of the wells between 185 feet and 550 feet deep yield more than 100 gpm, and about 75 percent (115 of 151) of them yield more than 50 gpm.

Thirty-two wells yield 200 gpm or more, and all but two of these wells are between 185 and 545 feet deep. Only seven wells yield more than 300 gpm, and all but one of these are between 200 and 510 feet deep.

Data were obtained for only 14 wells more than 550 feet deep; so, the yields of wells more than 550 feet deep are perhaps not evaluated conclusively in this report.

Data such as these can be misleading if the use of the wells is not considered, because wells drilled for domestic purposes commonly show lower yields than wells drilled for industrial use or public supply. Presumably this is because domestic water needs are small and the drilling of such wells is stopped when a small but adequate water supply is obtained. Also, many domestic wells may not be tested rigorously to determine their maximum yield. This effect of domestic wells is not believed to be significant in the data here discussed, as 174 of the 199 wells shown in Figure 2, and 24 of the 34 less than 185 feet deep, are either used as industrial or public-supply



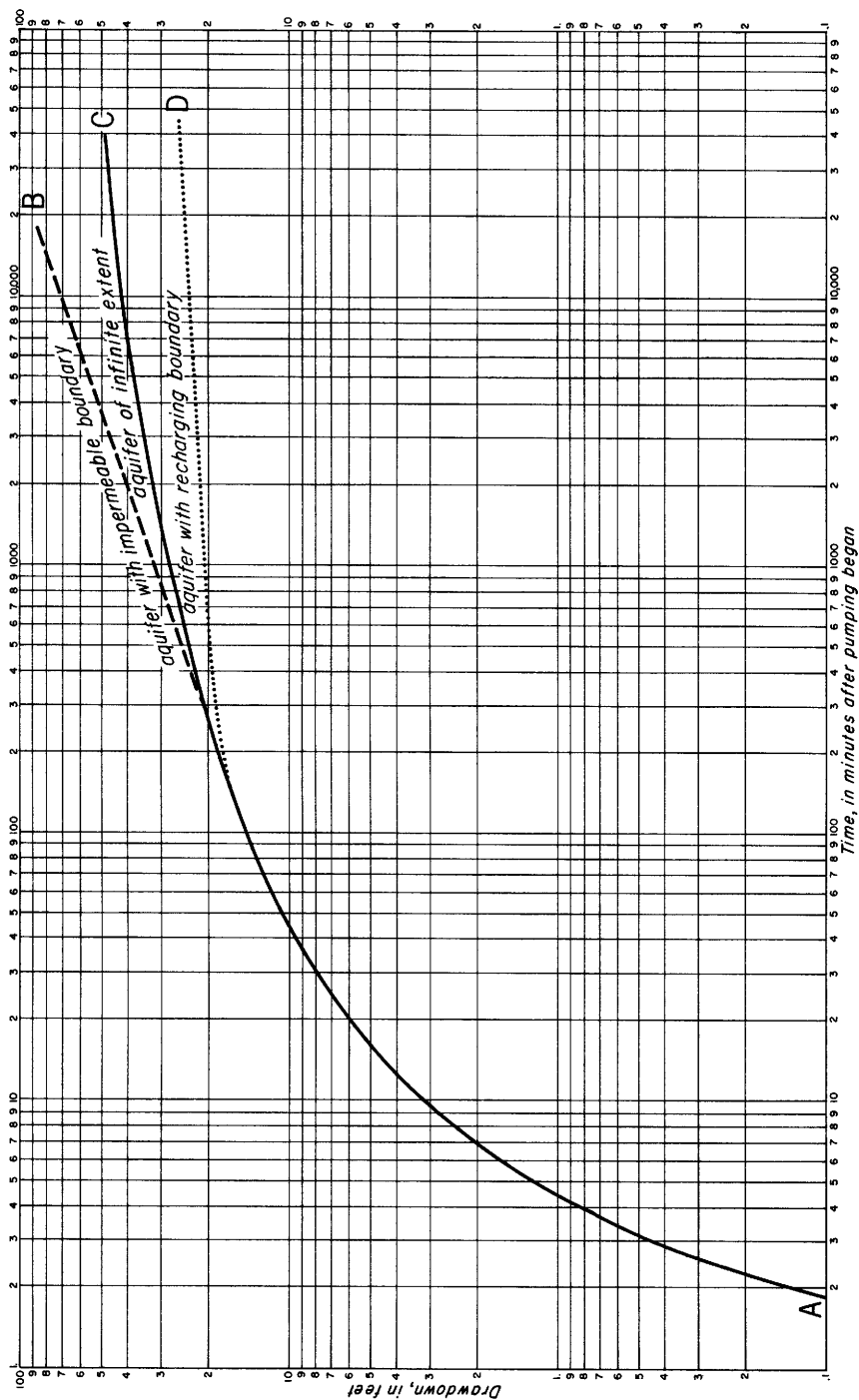


Figure 3. Logarithmic graph of drawdown in a theoretical aquifer.

wells or were tested for such use. The data contained in this report, therefore are believed to fairly represent the relationship of well yields versus depth of wells.

The sharply defined increase in the yield of wells at a depth of about 200 feet is believed to be the result of a rather abrupt change in the nature of rock weathering at depth. In the area of this investigation it appears that the zone of greatest decomposition—where the rock voids are believed to be partly plugged with residual clay—lies above a depth of 200 feet. Similar depths of intense weathering in the Brunswick Formation were reported by Barksdale and others (1958, p. 86).

OCCURRENCE OF GROUND WATER IN THE LOCKATONG FORMATION

The lithology and structure of the Lockatong Formation is similar to that of the Brunswick Formation. It consists of interbedded dark-gray argillite and shale that dip to the northwest at an average angle of 20° . The rock is fine grained and well cemented. As in the Brunswick Formation, the interconnected pore spaces are very narrow and most of the ground-water flow is confined to a system of interconnected vertical joints and bedding-plane fractures. However, the fractures are narrower and more widely spaced than those in the Brunswick Formation. Yields of 15 wells that tap the Lockatong Formation ranged from 4 to 40 gpm, and the median yield was 10 gpm.

PUMPING TESTS

When a well is pumped, water levels in the area are lowered and a cone of depression is formed in the piezometric surface or the water table. As pumping continues, the cone of depression enlarges until one of the following conditions exist: (1) The recharge of the aquifer has been increased by an amount equal to the pumping rate, (2) the natural discharge from the aquifer has been decreased by an amount equal to the pumping rate. (3) The sum of the increased recharge and decreased natural discharge is equal to the pumping rate.

Line AC on Figure 3 is a theoretical plot of drawdown against time in a well pumping at a constant rate from a homogeneous isotropic aquifer of infinite areal extent and uniform thickness. Other assumptions made in constructing the theoretical curve are: (1) the discharge well has an infinitesimal diameter and completely penetrates the aquifer; (2) no recharge to the aquifer occurs; (3) the water withdrawn from storage in the aquifer is discharged instantaneously with decline in head; and (4) the coefficient of transmissibility is constant at all places and all times.

A plot of recovery against time would coincide with a plot of drawdown against time. If flow occurs under conditions different from those stated in

the assumptions, the plotted curve will deviate from the theoretical curve. For example, line AD in Figure 3 is one path the plotted data may follow if the cone of depression expands to a recharge boundary and induces recharge from some outside source. The slope of this curve decreases from that of the theoretical curve, indicating that drawdown has been diminished due to the inflow of recharge. If the slope of the plotted curve increases from that of the theoretical curve, as in line AB, the cone of depression has expanded to an impermeable boundary—that is, an area that is less permeable than the part of the aquifer near the pumping well. Many boundary conditions can cause this. For example, the cone of depression reaches the end of the aquifer and lateral expansion of the cone is stopped or retarded. The presence of this type of boundary may be caused by a marked decrease in the permeability of the aquifer at some distance from the well.

By means of a graphical technique that involves matching a theoretical curve to plots of drawdown in wells versus time, it is possible to compute the coefficients of transmissibility and storage for an aquifer.

The coefficient of transmissibility is a measure of the ability of the aquifer to transmit water. It is defined as the quantity of water, in gallons per day, that will flow through a vertical section of the aquifer 1-foot wide and extending the full height of the aquifer under a unit hydraulic gradient at the prevailing temperature of the water.

The coefficient of storage of an aquifer is the volume of water it releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface. Under water-table conditions, the water released from storage is obtained by draining a part of the aquifer. However, under artesian conditions, water is released from storage by compression of the network of openings within the aquifer in response to a decrease in head at a well. For this reason the coefficient of storage of an artesian aquifer is many times smaller than that of a water-table aquifer. The coefficients of storage for artesian aquifers range from 0.00001 to 0.001, and those of water-table aquifers range from 0.05 to 0.30.

Systematic aquifer tests to determine the hydraulic properties of the Brunswick Formation were made at the following locations: Kulpsville, North Wales, Spring City, Douglassville, Souderton, and Royersford. At each of these sites one well was pumped at a constant rate for a period ranging from several hours to several days while water levels were measured in the pumped well and in one or more adjacent observation wells. After pumping ceased, water levels in all these wells were measured again for an equal length of time. Results of these tests, including the coefficients of transmissibility and storage and the total drawdown during pumping, are shown in Table 1.

Table 1. Summary of pumping tests with observation wells in the Brunswick Formation.

Area	Observation well	Date	Pumping rate (gpm)	Duration of pumping (hours)	Transmissibility T (gpd/ft)	Storage coefficient S	Boundary type	Total drawdown (feet)	Distance from pumped well
Kulpville	Mg-631 ¹	Aug. 1960	140	48	5,000		Recharge	....	....
	Mg-632	Aug. 1960	140	48	43,000	10x10 ⁻⁵	Impermeable	10.6	730
	Mg-633	Aug. 1960	140	48	180,000	12x10 ⁻⁵	Impermeable	4.4	730
	Mg-56 ¹	Sept. 1960	127	4	1,100	.....	Recharge	64.4	....
North Wales	Mg-180	Sept. 1960	127	4	56,000	9x10 ⁻⁵	Impermeable	1.2	1,200
	Mg-223	Sept. 1960	127	4	69,000	10x10 ⁻⁵	Impermeable	1.1	1,700
	Mg-223 ¹	Oct. 1960	180	101	.....	.....	.....	79	....
	Mg-56	Oct. 1960	180	101	56,000	12x10 ⁻⁵	Impermeable	7.4	1,700
Spring City	Mg-180	Oct. 1960	180	101	82,000	9x10 ⁻⁵	Impermeable	13.8	575
	Mg-167 ¹	Oct. 1960	152	4	.....	.....	.....	26.8	....
	Mg-179	Oct. 1960	152	4	51,000	6x10 ⁻⁵	Impermeable	3.5	400
	Ch-181 ¹	Apr. 1963	225	72	1,000	.....	Recharge	107.9	....
Douglassville	Ch-144	Apr. 1963	225	72	6,000	.....	Impermeable	6.5	830
	Ch-145	Apr. 1963	225	72	13,000	29x10 ⁻⁵	Impermeable	10.3	1,650
	Ch-147	Apr. 1963	225	72	.....	.....	.....	0.0	1,850
	Be-115 ¹	July 1962	30	67	100	.....	Recharge	112.2	....
Souderton	Be-125	July 1962	30	67	600	3.8x10 ⁻⁵	Recharge	14.9	200
	Be-125 ¹	June 1963	21	4.5	1,100	.....	None	18.9	....
	Be-115	June 1963	21	4.5	1,500	3.3x10 ⁻⁵	None	7.3	200
	Mg-665 ¹	Mar. 1961	150	69	3,500	.....	Recharge	80.5	....
Royersford	Mg-679	Mar. 1961	150	69	9,000	4x10 ⁻⁵	Impermeable	27.6	400
	Mg-542 ¹	Jan. 1962	55	3	.....	.....	.....	....	....
	Mg-541	Jan. 1962	55	3	30,000	6x10 ⁻⁵	Impermeable	.61	1,200

¹ Pumped well.

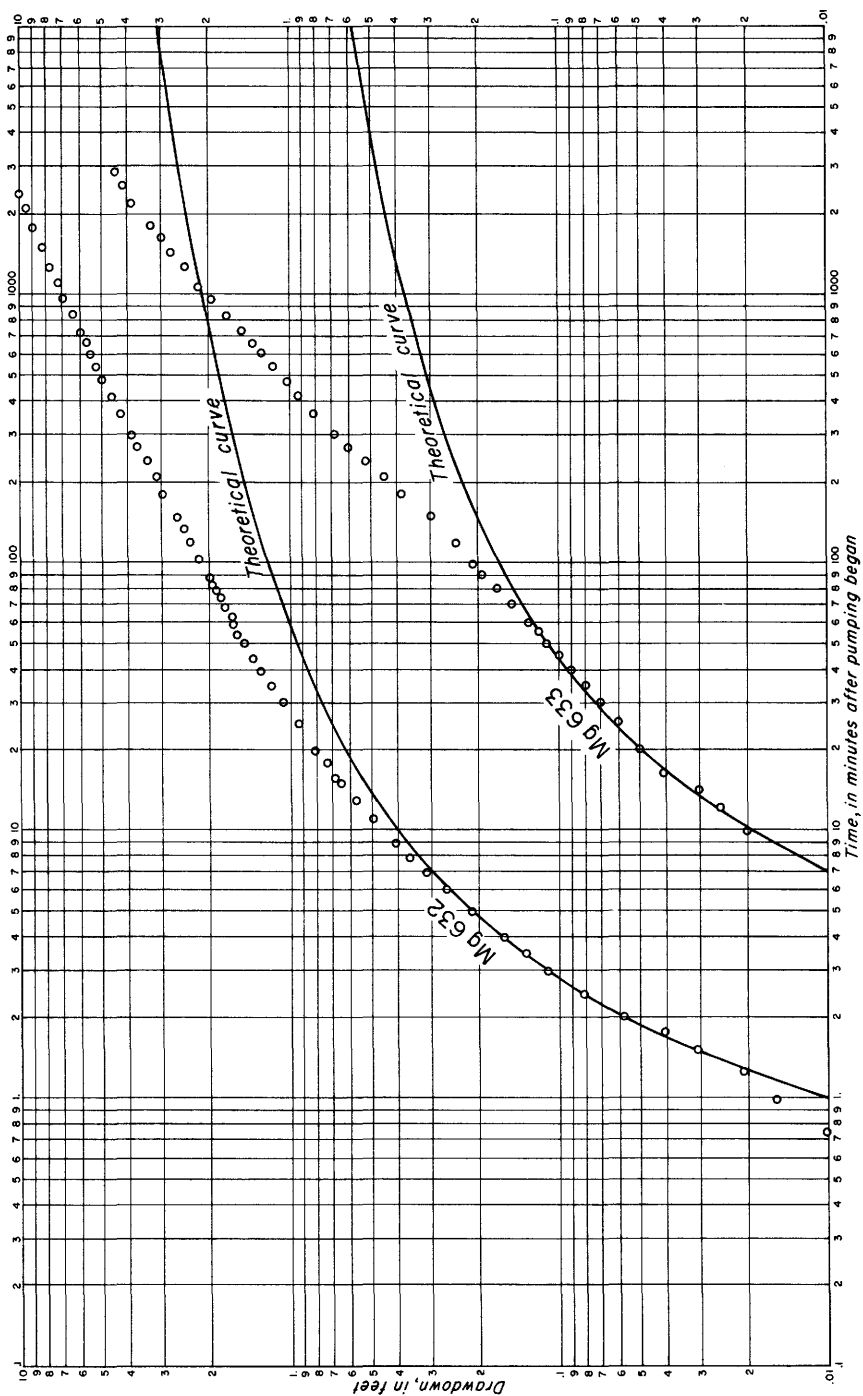


Figure 4. Logarithmic graph drawdown in wells Mg-632 and Mg-633.

Because hydrologic conditions in the Brunswick Formation do not fulfill the assumptions for an ideal aquifer, the coefficients of transmissibility and storage calculated from these tests do not truly represent the aquifers tested. Calculated transmissibility at a pumped well may be lower than the actual transmissibility of the aquifer because of well entrance losses during the test. On the other hand, excessively high transmissibilities computed at observation wells for almost all the pumping tests show clearly the poor hydraulic connection between the pumped wells and the observation wells. Despite this poor hydraulic connection, the measurement of water levels in observation wells and the calculation of transmissibility and storage coefficients are useful for estimating the effect of pumping upon nearby wells—where the effect is controlled by recognizable geologic or topographic features.

Tests at Kulpville.—In August 1960 well Mg-631, at Kulpville, was pumped for 48 hours at a constant rate of 140 gpm and wells Mg-632 and Mg-633 were used for observation. Coefficients of transmissibility and storage calculated from these tests are shown in Table 1. Observation well Mg-632 is 730 feet from the pumped well in a direction parallel to the strike of the beds, whereas observation well Mg-633 is the same distance from the pumped well along a line perpendicular to the strike. Consequently, well Mg-632 penetrates the same strata as the pumped well, but well Mg-633 penetrates entirely different strata.

Analysis of data from these wells indicates coefficients of transmissibility of 5,000 gpd per foot at the pumped well (Mg-631), 40,000 gpd per foot at the observation well along strike (Mg-632), and 180,000 gpd per foot at the observation well perpendicular to strike (Mg-633). Poor hydraulic connection between the pumped well and the observation wells is indicated by these high transmissibilities calculated from the observation-well data. A poor hydraulic connection is especially evident at observation well Mg-633, perpendicular to the strike from the pumped well. Drawdown in this observation well is caused by leakage from beds penetrated by the observation well to beds tapped by the pumped well.

The response in observation wells Mg-632 and Mg-633 to pumping at well Mg-631 is shown in Figure 4. The graph shows that drawdown began much sooner and drawdown was much greater in the observation well (Mg-632) penetrating the same strata as the pumped well than in the observation well (Mg-633) penetrating different strata. In both observation wells water levels declined more steeply than the theoretical curve, indicating the presence of an impermeable boundary. Drawdown in the pumped well (not shown) declined more slowly than the theoretical curve, indicating the presence of a recharging boundary.

Tests at North Wales.—Three pumping tests were made in North Wales.

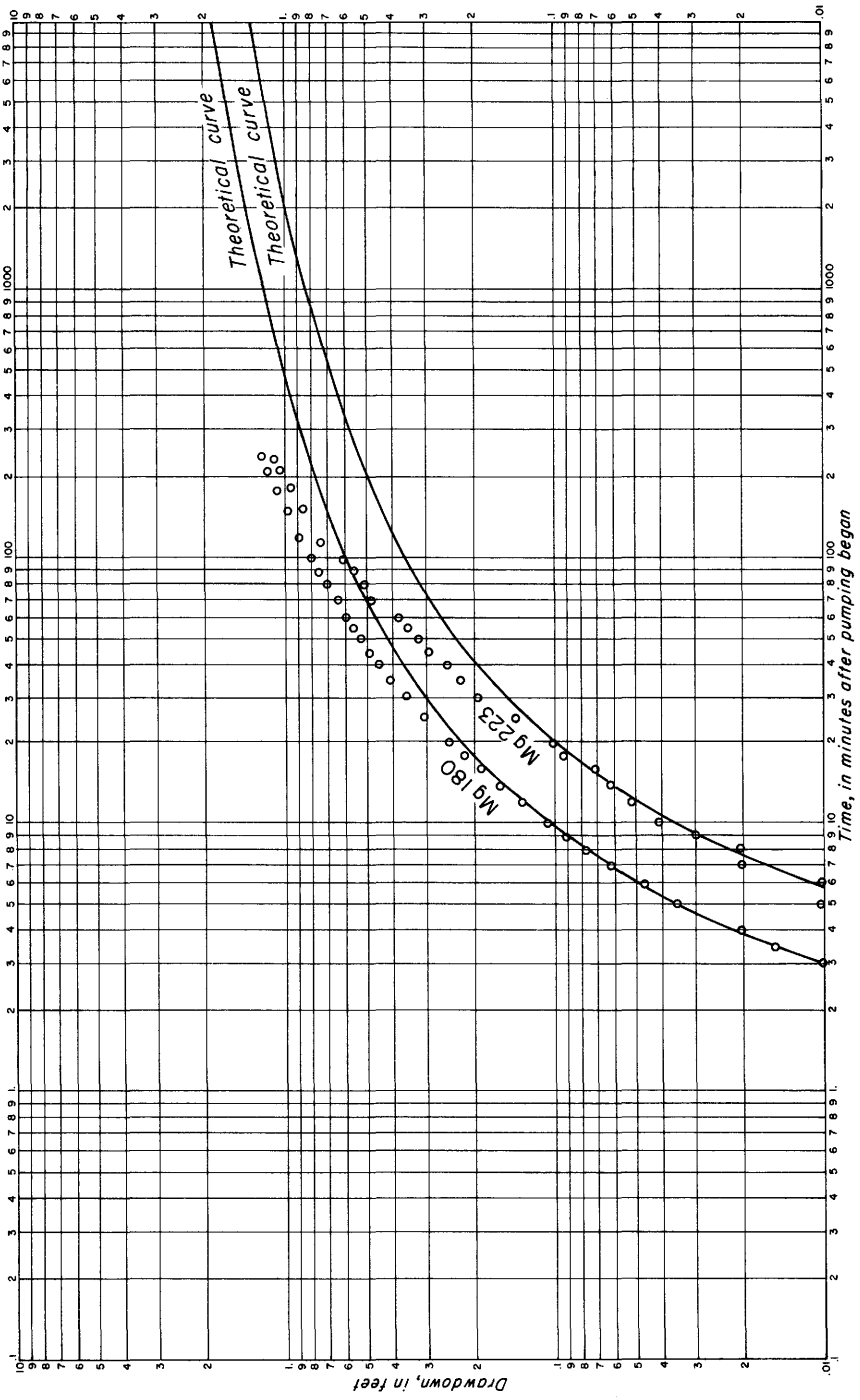


Figure 5. Logarithmic graph of drawdown in wells Mg-180 and Mg-223.

Coefficients of transmissibility and storage calculated from these tests are shown in Table 1. In September 1960, well Mg-56 was pumped for 4 hours at a constant rate of 127 gpm. Water levels were observed in wells Mg-167, Mg-179, Mg-180, and Mg-223.

Analysis of data from the pumped well (Mg-56) indicates a coefficient of transmissibility of 1,100 gpd per foot, which is probably lower than the actual transmissibility of the aquifer because of entrance losses at the well.

No drawdown took place at wells Mg-167 and Mg-179, which are more than 2,500 feet from the pumped well and do not penetrate the same strata as the pumped well.

The coefficient of transmissibility at observation well Mg-180, which is 1,200 feet from the pumped well, is 56,000 gpd per foot. At observation well Mg-223, which is 1,700 feet from the pumped well, the coefficient of transmissibility is 69,000 gpd per foot. The high transmissibilities at the observation wells suggest imperfect hydraulic connection with the pumped well—even though observation well Mg-223 penetrates many of the same strata as the pumped well, and well Mg-180 penetrates some of the same strata. The plots of drawdown in wells Mg-180 and Mg-223 (Fig. 5) show that drawdown started later in well Mg-223 than in well Mg-180, which was nearer to the pumped well. However, after 4 hours of pumping the drawdowns in both wells were almost identical—1.2 feet in Mg-180 and 1.1 feet in Mg-223. The drawdown plot in both observation wells indicated the presence of a discharging boundary, whereas a recharging boundary was observed in the plot of data from the pumped well, Mg-56.

In October 1960, well Mg-223 was pumped at a rate of 180 gpm for 101 hours, and wells Mg-56 and Mg-180 were used as observation wells. The calculated transmissibility was 82,000 gpd per foot at observation well Mg-180 and 56,000 gpd per foot at observation well Mg-56. Drawdown started earlier in well Mg-180, nearest the pumped well, and total drawdown was greater at this well (13.8 feet) than at well Mg-56 (7.4 feet). Drawdown data at both observation wells showed the effects of discharging boundaries.

A third pumping test conducted in October 1960, consisted of pumping well Mg-167 at a constant rate of 152 gpm for 4 hours. Water levels were measured at observation well Mg-179, which is 400 feet from the pumped well and penetrates many of the same strata. Analysis of data from observation well Mg-179 indicates a coefficient of transmissibility of 51,000 gpd per foot. The data from the pumped well were unsuitable for analysis.

Tests in Spring City.—Well Ch-181, at the Pennhurst State School in Spring City, was pumped at a constant rate of 225 gpm for 72 hours in April 1963. Water levels were measured at observation wells Ch-144, Ch-145, and Ch-147.

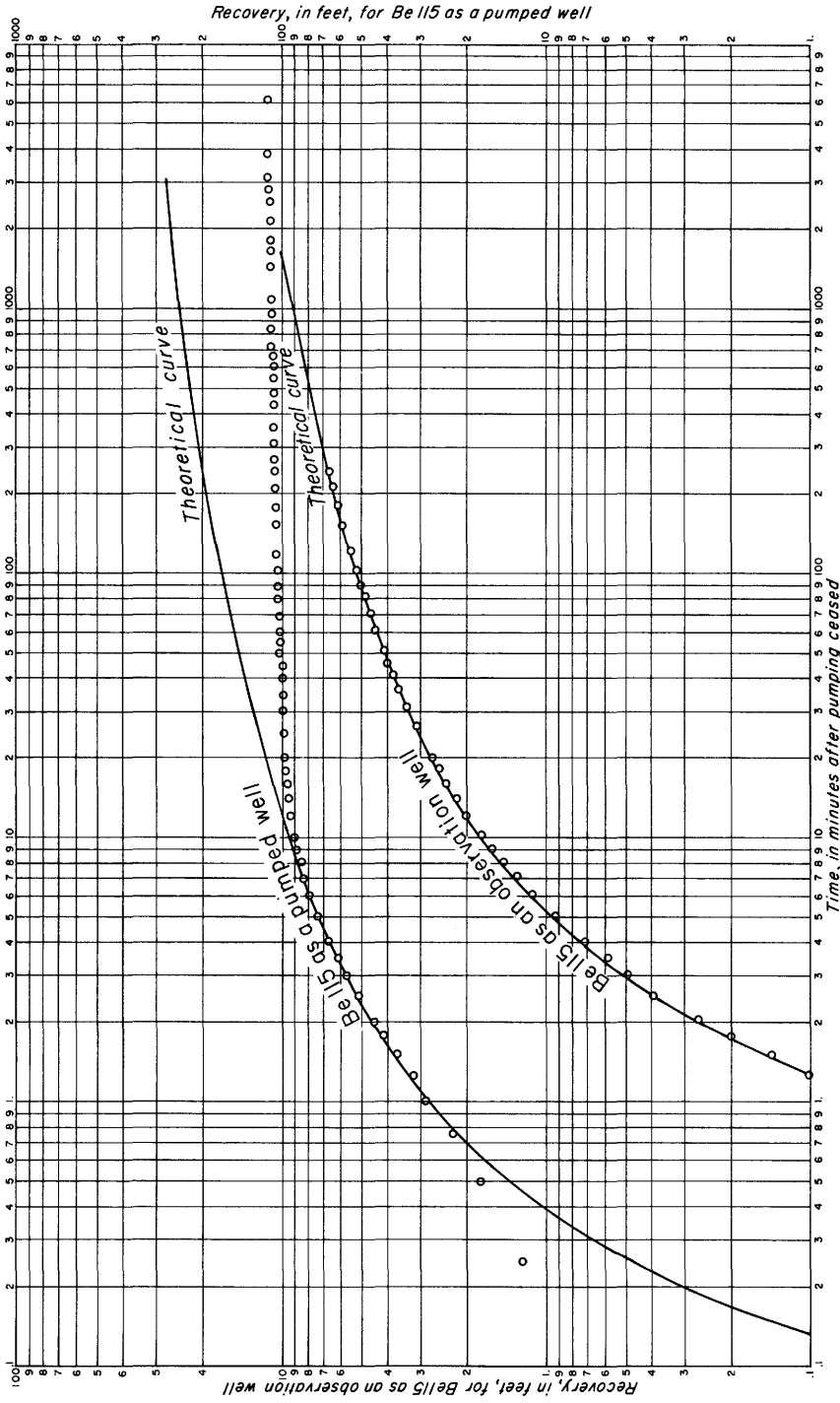


Figure 6. Logarithmic graph of recovery in well Be-115 when used as the pumped well and when used as an observation well.

Analysis of data from the pumped well (Ch-181) indicates a coefficient of transmissibility of 2,000 gpd per foot. Data from observation well Ch-144, which is 830 feet from the pumped well and penetrates many of the same strata, indicates a transmissibility of 6,000 gpd per foot. Data from observation well Ch-145, which is 1,650 feet from the pumped well and penetrates partly the same strata indicates a transmissibility of 13,000 gpd per foot.

The water level was not drawn down in Ch-147, although this well penetrates many of the same strata as the pumped well. This indicates the complexity of the hydrology in this area.

Drawdown commenced considerably earlier and was greater in observation well Ch-145, which was farthest from the pumped well, than in observation well Ch-144. The most distant well (Ch-145) penetrates the same strata as the lower part of the pumped well, whereas well Ch-144 penetrates the same strata as the upper part of the pumped well.

Tests at Douglassville.—Two pumping tests were conducted at Douglassville. In July 1962, well Be-115 was pumped at a rate of 30 gpm for 67 hours, and water levels were observed in wells Be-115 and Be-125. The two wells are 200 feet apart along the strike of the beds and are both 300 feet deep; hence, both wells penetrate the same strata. Analysis of data from these wells indicated a coefficient of transmissibility of 100 gpd per foot at the pumped well (Be-115) and 600 gpd per foot at observation well Be-125. However, when Be-125 was pumped at a rate of 21 gpm for 4½ hours in June 1963, analysis of data indicated a transmissibility of 1,100 gpd per foot at Be-125 and 1,500 gpd per foot at observation well Be-115. These determinations of transmissibility are not consistent—but they do indicate a transmissibility of low magnitude.

When well Be-115 was pumped, data for both the pumped well and observation well Be-125 showed recharging boundaries. However, when well Be-125 was pumped, the data plot indicated no boundary conditions for either well. Figure 6 shows two plots of the recovery of water-level in well Be-115—one when the well was used as an observation well, and the other when it was used as the pumped well.

Tests at Souderton.—Well Mg-665, in Souderton, was pumped at a rate of 150 gpm for 69 hours in March 1961. Water levels were measured in well Mg-665 and in observation well Mg-679, 400 feet away. Analysis of data from this test indicated coefficients of transmissibility of 3,500 gpd per foot at well Mg-665 and 9,000 gpd per foot at well Mg-679.

Although these two wells are only 400 feet apart, a dip of 60° measured in a nearby outcrop suggests that the two wells do not penetrate the same strata. However, because all other dips measured in the Brunswick Forma-

tion are considerably less than 60° , this dip of 60° is anomalous and possibly misleading. The relatively large drawdown in the observation well (27.6 feet at the end of 69 hours), the relatively low transmissibility at the observation well as compared with transmissibilities of observation wells at other pumping sites, and the fact that the water level commenced dropping less than 1 minute after pumping began all indicate that these wells probably penetrate the same water-bearing strata.

Another pumping test was made in June 1961 when well Mg-665 was again pumped at 150 gpm for 69 hours, and well Mg-679 was again the observation well. Drawdowns in both wells were considerably greater in June than in March. Drawdown in the pumped well (Mg-665) after 69 hours pumping was 17.5 feet more in June than in March. In the observation well (Mg-679) drawdown after 69 hours was 8.1 feet greater in June than in March. A possible explanation for these differences in drawdown may be the effect of recharge from Skippack Creek, which is less than 100 feet from the wells. In March, Skippack Creek was flowing and was a possible source of induced recharge, but in June, Skippack Creek was dry and was no longer a source of recharge.

Test at Royersford.—Well Mg-542 at the Charles Johnson County Home, Royersford was pumped for 3 hours at a constant rate of 55 gpm in January 1962. Water-level measurements were made at observation well Mg-541, 1,200 feet northwest of the pumped well. Analysis of data from the observation well indicated a transmissibility of 30,000 gpd per foot and the occurrence of an impermeable boundary. At the end of 3 hours of pumping the water level had lowered only 0.61 feet. Because the data obtained from the pumped well was unsuitable, it was not used for analysis.

Miscellaneous tests in the Brunswick Formation.—In addition to the tests that involved the use of observation wells, nine pumping tests were conducted on wells which had no nearby observation wells. The results of these tests are given in Table 2. Calculated coefficients of transmissibility are generally quite low. They range from 150 to 4,000 gpd per foot and the median is 600 gpd per foot. Eight of the nine transmissibilities are less than 1,000 gpd per foot.

Data plots of six tests indicated recharge boundaries, and only one indicated a discharge boundary. One of the tests showed no boundaries, and another test showed drawdown data too irregular for determination of the boundary conditions.

Miscellaneous tests in the Lockatong Formation.—Pumping-test data are available from six wells tapping the Lockatong Formation. (See Table 2.) Five of these wells are in Bucks County, Pa., but results from these tests

Table 2. Summary of pumping tests without observation wells in the Brunswick and Lockatong Formations

Well	Date	Pumping rate (gpm)	Duration of pumping (hours)	Transmissibility T (gpd/ft)	Boundary type
Brunswick Formation					
Be-101	June 1963	13.8	4	670	Recharge
113	June 1963	20	4	900	Impermeable
114	June 1963	8.6	4	150	.....
Mg-581	June 1963	17.7	4	600	Recharge
695	June 1963	3.4	1	180	Recharge
696	June 1961	5.1	1	750	Recharge
703	June 1963	22.2	4	500	Recharge
725	July 1962	136	1.25	4,000	None
729	Aug. 1963	14.6	3	140	Recharge
Lockatong Formation					
Mg-699	June 1961	3.9	1	180	None
Bk-807	April 1961	2.0	1	70	Impermeable
814	May 1961	30	1.2	2,000	Impermeable
812	May 1961	5.5	1	60	Impermeable
822	May 1961	4.1	1	140	None
832	May 1961	2.6	1	160	None

are believed to be representative of the Lockatong Formation in the area covered by this report. Coefficients of transmissibility are extremely low—they range from 60 to 2,000 gpd per foot and the median is 150 gpd per foot. Five of the six wells have transmissibilities of less than 200 gpd per foot.

Discharge boundaries were encountered in three of the pumping tests. In the remaining three tests no boundary conditions were indicated.

Discussion of pumping-test results.—Because the Brunswick and Lockatong Formations are not ideal aquifers, coefficients of transmissibility and storage computed by matching pumping test data to the theoretical curve are not reliable. However, the pumping-tests in these formations do demonstrate the effect of pumping upon water levels in the pumped well and in nearby wells.

The high transmissibilities computed from the observation-well data reflect imperfect hydraulic connection between pumped wells and nearby wells, but they are useful for estimating the effect other pumping wells will have on water levels in their vicinities. They indicate also that interfer-

ence between wells during brief periods of pumping may be somewhat less in the Brunswick Formation than in an ideal aquifer. However, because impermeable boundaries appeared in the test data of almost all observation wells, water levels in wells near a pumping well will probably draw down to a greater extent than predicted by a transmissibility based on data from the early part of a pumping test.

Wells located on a line perpendicular to the strike of the beds will generally show much less interference than wells located on a line parallel to the strike, because the former generally do not penetrate the same strata, but the latter do. Drawdown in observation wells not penetrating the same strata as a pumped well is caused by leakage from beds penetrated by the observation wells to beds tapped by the pumped well.

QUALITY OF WATER

All ground waters contain dissolved minerals; some contain suspended particles and pathogenic organisms. These ground-water constituents are important because if they are present in excessive amounts they may limit the usefulness of the water for some purposes and may necessitate treatment of the water.

The chemicals dissolved in ground water are obtained from many sources. Rain and snow, from which ground water is derived, absorb small amounts of carbon dioxide and other gases in the atmosphere. In addition, small particles of mineral matter in the form of dust are caught and carried along with the precipitation; the quantity of material absorbed in this way, however, is very small.

Upon reaching the land surface the water leaches mineral matter from the organic residue of plants, from agricultural fertilizers, animal and human wastes and from solid and semisolid refuse. The waters percolating downward through the soil zone leach out the soluble products of soil weathering. The quantity of mineral matter dissolved depends primarily on the composition of the soil and of the percolating water which may carry chemicals that stimulate dissolution. For example, carbon dioxide absorbed from the atmosphere and decayed vegetable matter forms carbonic acid, which aids in dissolving minerals from the soil. Other factors controlling the quantity of matter dissolved are the length of time the water is in contact with the soil, the surface drainage structure, the amount of precipitation, and the temperature of the water.

Most of the mineral matter in ground water is dissolved from the rocks through which it flows, because the water remains in contact with this material for a longer time than with the atmosphere and soil. The contact time is dependent on the ground-water velocity and the distance of the ground water from the recharge area. High ground-water velocity occurs in

rocks of high permeability or is associated with flow caused by steep hydraulic gradients—a factor often influenced by the topography. Ground-water velocity tends to decrease as depth below land surface increases, so that the quantity of dissolved solids in the ground water at great depth is usually much greater than that near the surface. The distance of the water from the recharge area is controlled by the geology and physiographic features.

Another major factor controlling the quantity of mineral matter dissolved by the ground water is the composition and texture of the rock itself. Igneous rocks generally contain material less soluble than that in sedimentary rocks. Fine-grained rocks having high porosity tend to increase the opportunity for solvent action because the surface area of rock exposed to solution is very large.

The mineral matter in ground water occurs in very small quantities and exists either as electrically charged particles known as ions or as oxides in the colloidal state. Calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K) are commonly occurring positively charged ions or cations. Bicarbonate (HCO_3), carbonate (CO_3), sulfate (SO_4), chloride (Cl), fluoride (F), and nitrate (NO_3) are common negatively charged ions or anions. In addition to these ionized substances, small amounts of colloidal matter—including silica (SiO_2), iron (Fe), and manganese (Mn)—are usually present.

To determine the chemical constituents of the ground water in the Brunswick and Lockatong Formations in Berks and Montgomery Counties, water samples from 36 wells in the Brunswick and 6 wells in the Lockatong were collected and analyzed. The results of these analyses are shown in Tables 3 and 4.

The chemical character of the ground water in the two formations is classified graphically on the trilinear diagrams of Figures 7 and 8.

In these diagrams the cations in solution are assumed to be calcium, magnesium, sodium, and potassium, and the anions are assumed to be bicarbonate, carbonate, sulfate, and chloride. Any minor constituents present are summed with the major constituents to which they are chemically related.

The concentration of any cation or anion in a solution, in parts per million (ppm) by weight, divided by its equivalent or combining weight yields the equivalent weight of the ion per million parts by weight of the solution and is generally termed equivalents per million (epm). Figures 7 and 8 show the percentage composition of the major cations and anions in percentage equivalents per million.

In the diamond-shaped sections of Figures 7 and 8, points plotted in the upper quarter of the diamond represent waters in which calcium and magnesium are the principal cations and sulfate and chloride are the

WATER-ANALYSIS DIAGRAM

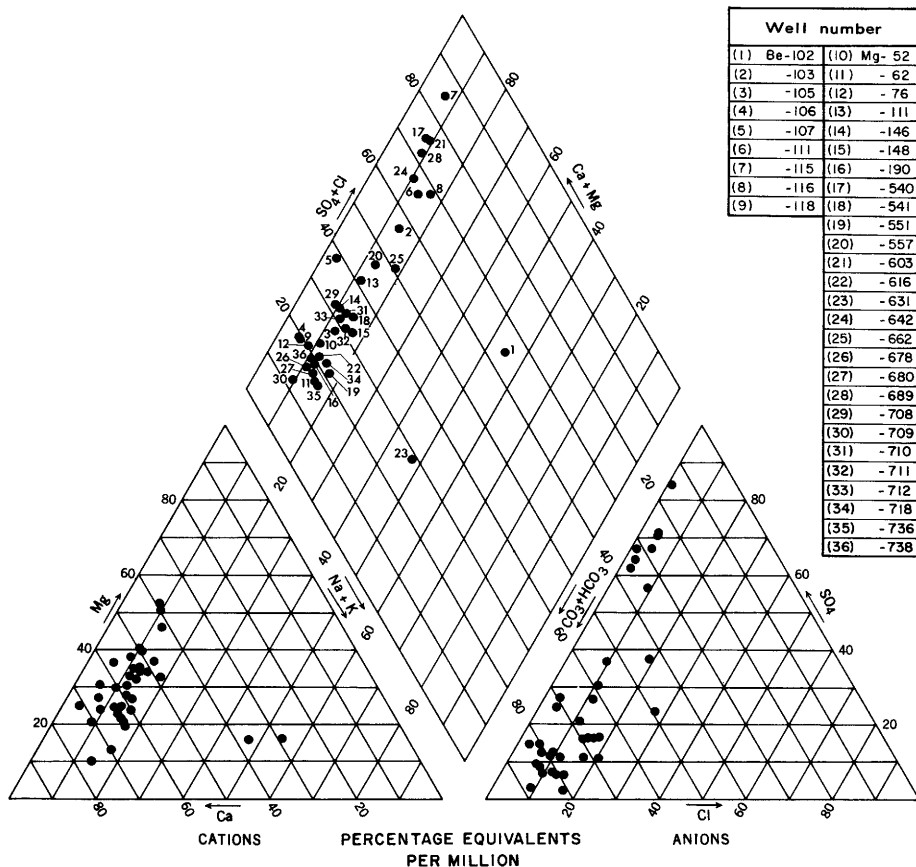


Figure 7. Diagram showing the chemical character of ground water in the Brunswick Formation in Berks and Montgomery Counties, Pa.

principal anions. Those points in the left quarter of the diamond represent waters in which calcium and magnesium are the principal cations and carbonate and bicarbonate are the principal anions.

Figures 7 and 8 show that calcium and magnesium are the major cations in the ground water of both the Brunswick and Locketong Formations. Except for two samples from the Brunswick Formation, the percentage equivalents per million of calcium plus magnesium exceeds 80 percent of the total cations present. Bicarbonate is the major anion in most of the samples in the Brunswick Formation and in all the samples in the Locketong Formation. The percentage equivalents per million of bicarbonate exceeds 50 percent in 26 of the 36 samples from the Brunswick.

In all samples except two—those from Mg-739 in the Locketong Formation and well Mg-631 in the Brunswick Formation—the percentage

QUALITY OF WATER WATER-ANALYSIS DIAGRAM

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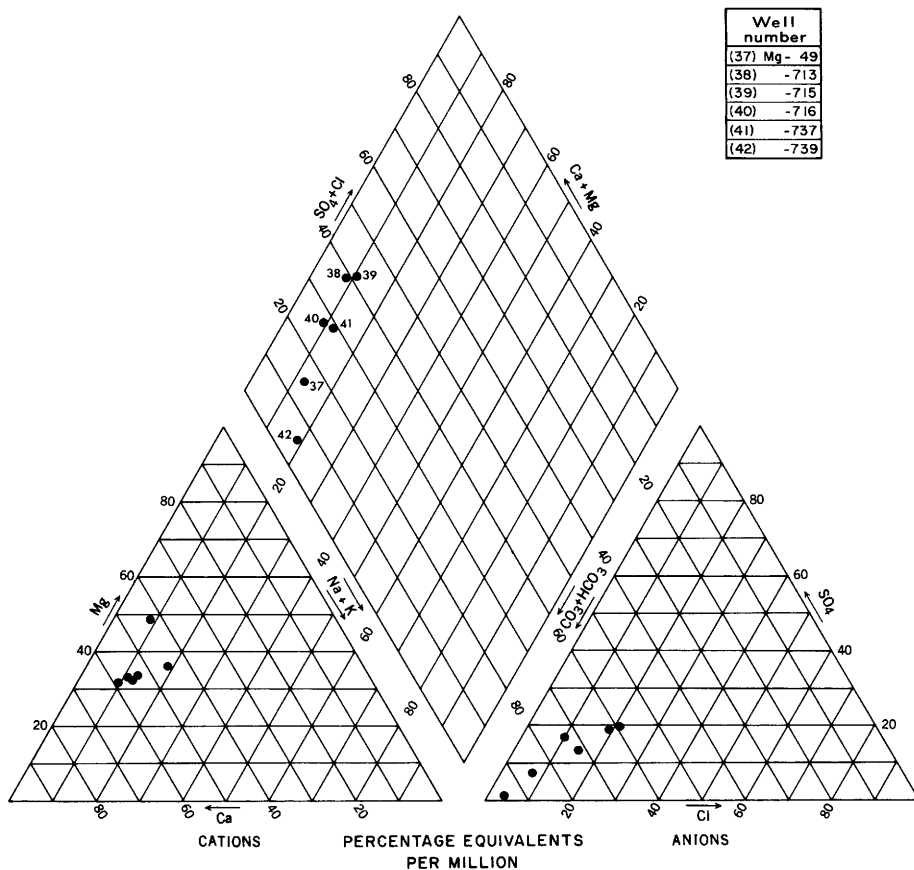


Figure 8. Diagram showing the chemical character of ground water in the Lockatong Formation in Montgomery County, Pa.

equivalents per million of calcium plus magnesium exceeds the percentage of bicarbonate. Therefore, some noncarbonate hardness (calcium or magnesium sulfates and chlorides) exists in all samples except these two. The relative amount of noncarbonate hardness present is indicated by the numerical difference between the percentage of calcium plus magnesium and the percentage of bicarbonate. The noncarbonate hardness for each sample is given in Tables 3 and 4.

A comparison of the chemical quality of the ground water in the two formations is shown in Table 5. The minimum, maximum, and median values were computed from the 36 Brunswick analyses and the 6 Lockatong analyses shown in Tables 3 and 4, respectively. Because the number of water samples from the Lockatong Formation in Montgomery County is small in comparison to the number from the Brunswick Formation, five

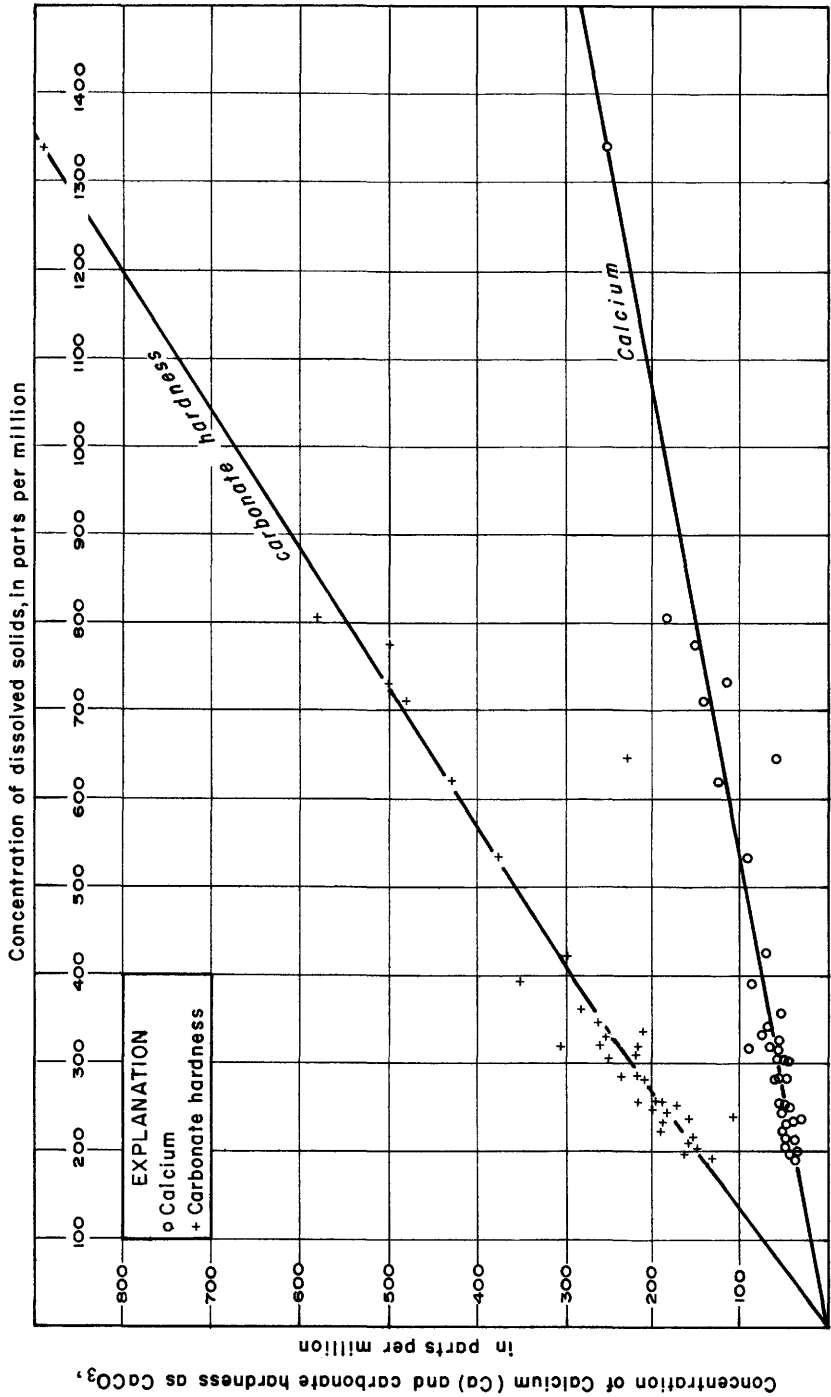


Figure 9. Relation of calcium content and carbonate hardness as CaCO₃ to dissolved-solids content.

analyses of ground water from the Lockatong Formation in Bucks County were also studied. The minimum, maximum and median values of all eleven Lockatong analyses (Table 5) do not differ significantly from those of the six analyses from Montgomery County.

The median values of chemical constituents generally are similar in water from the Lockatong and Brunswick Formations. However, maximum concentrations of several constituents—calcium, sodium, sulfate, dissolved solids, and hardness—are considerably higher in water from the Brunswick Formation than in water from the Lockatong Formation.

Certain of the chemical constituents in the ground water of the Brunswick and Lockatong Formations are directly related to the total dissolved-solids content. In Figure 9 both the calcium content and carbonate hardness as CaCO_3 are plotted against the dissolved-solids content. Figure 10 shows the relation of magnesium content to dissolved solids. Figure 11 is a plot of the sodium content against the dissolved solids. The relation of bicarbonate and sulfate content to dissolved solids is shown in Figure 12.

In Figure 9 a single straight line was fitted to the plot of data showing the relation of calcium content to dissolved solids. The calcium content apparently increases linearly as the dissolved-solids content increases.

Appearing also on Figure 9 is a plot showing the relation of carbonate hardness to dissolved-solids content. Carbonate hardness can be seen to increase as dissolved-solids content increases.

Figure 10, a plot of magnesium content against dissolved solids shows that magnesium content increases rapidly as the dissolved solids rise from 200 ppm to 350 ppm. Beyond this concentration, the magnesium content does not show any clear relation to the dissolved-solids content.

Sodium content, as illustrated in Figure 11, tends to increase as dissolved-solids content increases. Figure 12 shows also that the three water samples from the limestone fanglomerate of the Brunswick Formation contain a much smaller amount of sodium than all other samples that contain comparable quantities of dissolved solids.

Figures 9, 10, and 11 illustrate that the cations responsible for increases in dissolved-solids content are calcium, magnesium, and sodium. However, because the calcium content increases much faster than the magnesium and sodium content as the dissolved solids increase, calcium is the major cation causing the increase of dissolved solids.

Figure 13 is a plot of both the bicarbonate and sulfate content against dissolved-solids concentration. The bicarbonate content does not appear to bear any significant relation to the dissolved-solids content. The sulfate content, however, increases linearly as dissolved solids increase throughout the range of dissolved solids shown. Figure 12 shows that bicarbonate is the major anion in waters containing less than 500 ppm dissolved solids,

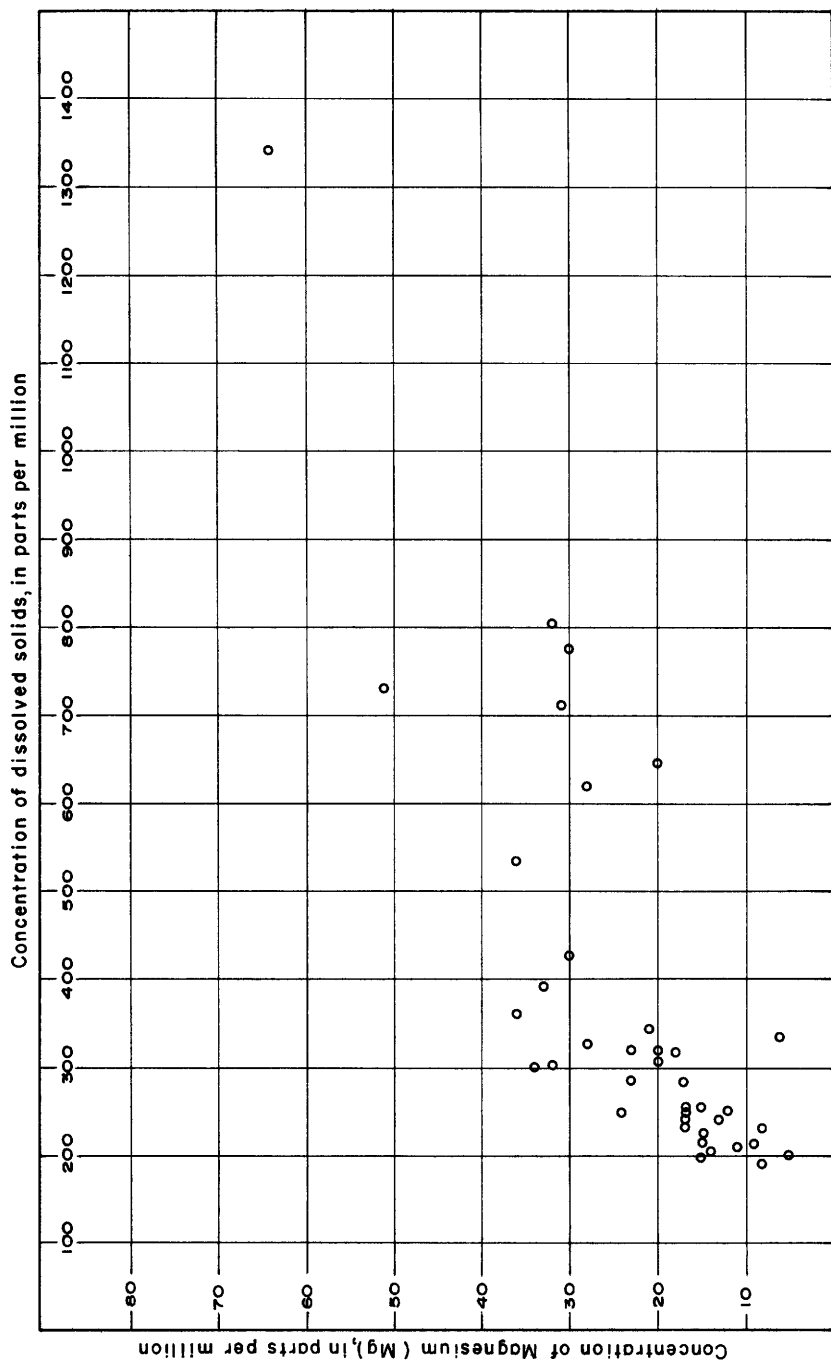


Figure 10. Relation of magnesium content to dissolved-solids content.

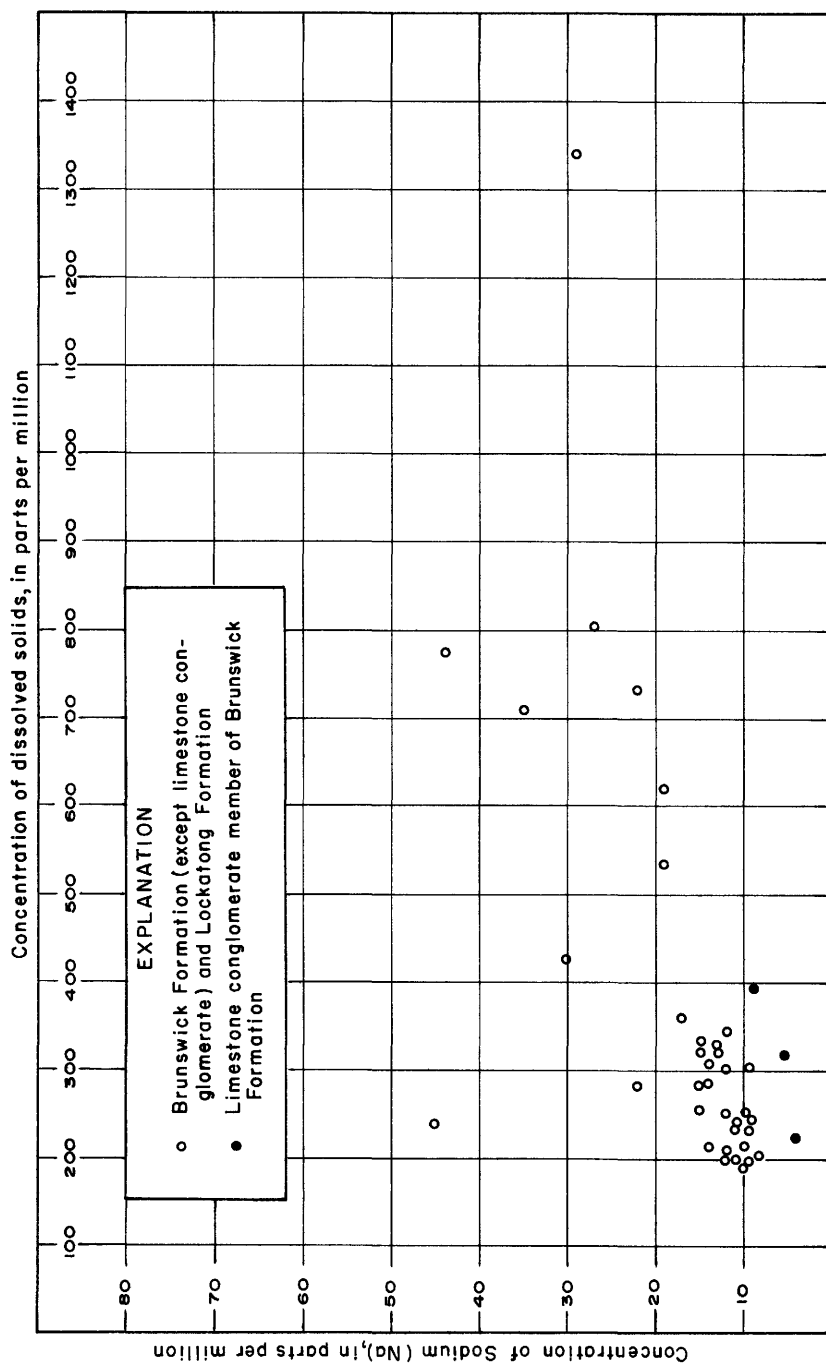


Figure 11. Relation of sodium content to dissolved-solids content.

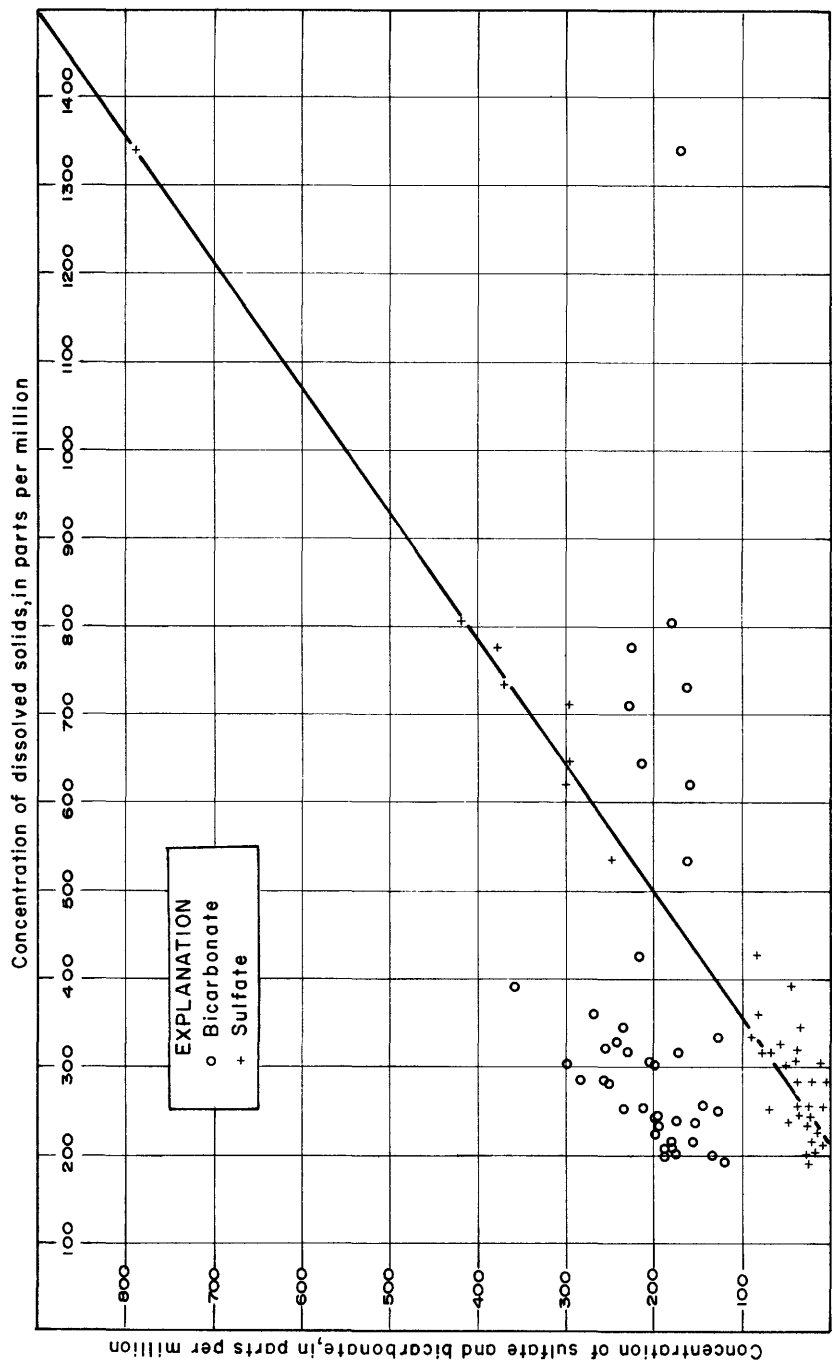


Figure 12. Relation of bicarbonate and sulfate content to dissolved-solids content.

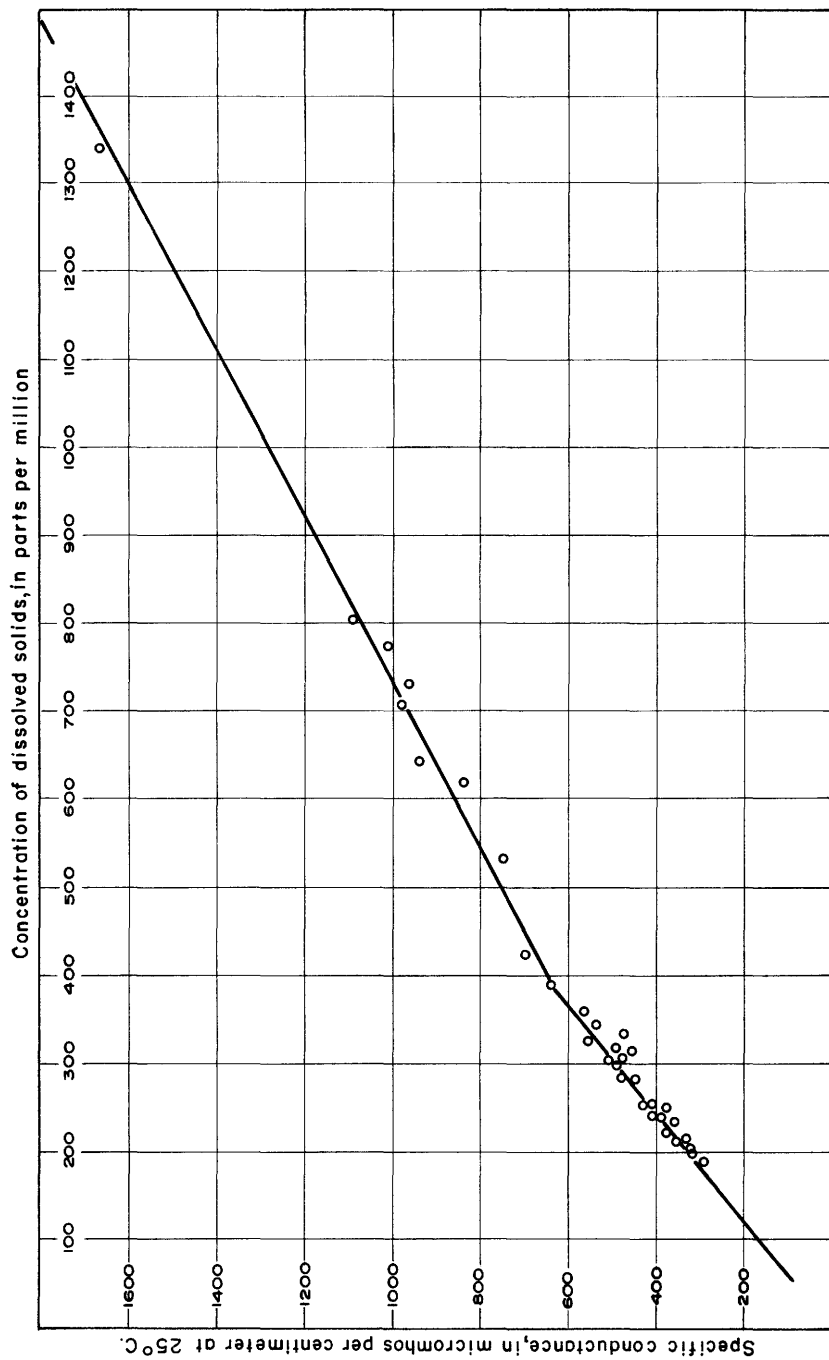


Figure 13. Relation of specific conductance to dissolved-solids content.

whereas sulfate is the major anion in waters containing more than 500 ppm dissolved solids.

The concentration of other ions present—including potassium, chloride, fluoride, and nitrate—bears no relation to the dissolved-solids content. Graphs of these constituents are not shown.

Figure 13 is a plot of the specific conductance against the dissolved-solids concentration of water from the Brunswick and Lockatong Formations. Two straight lines intersecting near 400 ppm dissolved solids were constructed to represent the relation of these two variables.

Specific conductance is defined as the electrical conductance of a cube of material one centimeter on a side and is commonly expressed as micromhos per centimeter. Specific conductance varies with temperature and is, therefore, usually referenced to the standard temperature of 25°C. Because ground-water is a dilute solution containing ionized substances, it is slightly conductive. The specific conductance of such a solution is related to the quantity of dissolved solids that it contains.

The specific conductances used in Figure 13 were determined in a laboratory. However, with suitable portable equipment the specific conductance can be quickly and accurately measured in the field. The corresponding value of dissolved-solids content can then be estimated by using Figure 13. When the dissolved-solids content is known, the probable concentration of several major ionized constituents of most ground-water samples obtained from the Brunswick and Lockatong Formations can be approximated from Figures 9, 10, 11, and 12.

CONCLUSIONS

The yield of wells in the Brunswick Formation depends on the number, thickness, and permeability of beds penetrated. Changes in the lithology from place to place are responsible for variations encountered in well yields. Because of the erratic nature of these changes, the location and extent of the best water-bearing zones cannot be predicted; however, if yields of more than 100 gpm are desired, wells should be drilled at least 200 feet deep—as the highest yields are obtained generally from wells ranging in depth from 200 to 550 feet.

Water sufficient for domestic purposes can be obtained at almost any location, but yields large enough for industrial and municipal purposes are more difficult to obtain. To assure an adequate supply over long periods of time, consideration must be given to factors that influence both the natural and artificially induced flow of ground water. For example, the water table is generally nearer the land surface in valleys than on ridges; hence, the available drawdown at wells of equal depth is greatest for wells in valleys. As natural flow from the aquifer is generally discharged into surface

streams, the opportunity to reduce the natural discharge or to induce flow from a stream to the aquifer by means of wells is greatest in stream valleys.

Unless ground water is recovered by either reducing natural discharge, or inducing additional recharge, water withdrawn from a well reduces the quantity in storage in the aquifer. Wells that draw water from storage over long periods of time cause large cones of depression to develop. Where several pumping wells are closely spaced, the cones of depression overlap. As the total decline in water level at any well equals the sum of the draw-downs produced by each well the interference may be so great that the yield of each well is reduced. This effect is particularly severe at wells oriented along lines parallel to the strike of the beds, because these wells generally penetrate the same beds. Wells should be spaced sufficiently far apart to reduce the effect of interference to an acceptable level. Because geologic hydrologic, and pumping conditions within the Brunswick Formation are complex and variable, the best spacing of wells will differ from place to place. Wells less than 2,000 feet apart in the Brunswick Formation have generally shown some interference.

Yields greater than those required for domestic purposes are not generally available from wells in the Lockatong Formation. Furthermore, because the Lockatong Formation is very resistant to erosion, it underlies areas of high elevation which are generally remote from surface streams. Few situations exist, therefore, where ground water can readily be diverted from points of natural discharge to nearby wells in the Lockatong.

One of the best ways to improve the yield of a well in the Lockatong, or any other aquifer of low permeability, is to increase the volume of water stored in the well bore by enlarging its diameter or drilling to greater depth. Such a well permits the well operator to satisfy his need for water during short periods of peak demand. For example, the volume of storage in 100 feet of 6-inch diameter borehole is approximately 150 gallons, but the volume of storage in 100 feet of a 10-inch diameter well is more than 400 gallons. By installing the pump intake pipe near the bottom of the well, most of the water stored in the well bore can be withdrawn. During periods when water is not being withdrawn, ground water flowing into the well will replenish the stored volume—if given enough time.

The cone of depression developed by pumping wells in the Lockatong Formation is rarely extensive. For this reason interference between wells is not a severe problem.

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Table 3. Chemical analyses of ground water in the Brunswick Formation in Berks and Montgomery Counties, Pennsylvania
(Results in parts per million except as indicated)

Location	Date of collection	Depth of well (ft.)	Silica (SiO ₂)	Total iron (Fe)	Total manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO ₃)	Sulfate (SO ₄)	Chloride (Cl)	Fluoride (F)	Nitrate (NO ₃)	Dissolved solids (residue at 180° C)	Hardness as CaCO ₃		Specific conduc- tance (micromhos/ Cm at 25°C)	pH	Color	
																Calcium, magnesium	Non- carbonate				
Berks County																					
Be-102	3- 2-61	375	15	.76	.03	59	20	135	3.5	214	298	7.5	0.3	2.7	645	229	54	941	7.8	2	
103	3- 1-61	119	26	.03	.02	75	6.1	15	1.5	128	89	13	0.2	34	334	212	107	476	6.8	2	
105	3- 2-61	300	26	.03	.02	37	15	10	1.0	156	20	8.8	0.1	21	216	154	26	335	7.6	3	
106	3- 3-61	112	12	.13	.01	51	15	4.1	2.0	198	14	7.5	0.0	19	224	189	26	379	7.3	3	
107	3- 3-61	130	14	.08	.05	90	20	5.4	0.5	229	78	6.3	0.0	33	318	307	119	495	7.8	3	
111	2- 5-62	528	15	.23	.02	141	31	35	1.0	228	298	35	0.3	3.6	710	480	293	976	7.8	3	
115	7-19-62	300	28	.12	.02	252	64	29	2.0	168	788	5.2	0.0	4.8	1340	892	755	1660	7.4	3	
116	1-31-62	360	25	.37	.09	151	30	44	2.0	226	378	5.8	0.2	1.7	775	500	315	1010	7.8	3	
118	1-30-62	500	10	1.6	.24	86	33	8.9	1.5	358	43	13	0.1	7.2	391	350	57	641	7.3	15	
Montgomery County																					
Mg- 52	9-25-25	350	18	.06	..	47	17	9.4	2.1	194	23	13	..	7.5	232	187	28	....	..	..
62*	9-28-25	388	32	.05	..	36	15	11	1.8	173	15	8	..	2.5	201	152	10	....	..	..
76	2-21-52	387	21	.01	..	24	20	6	1.0	150	22	5	..	0.4	....	142	19	321	6.4	2	
111	5-10-62	219	30	.37	.00	57	18	13	0.7	171	69	16	0.1	4.9	317	216	76	457	6.6	2	
146	4- 7-53	205	13	.26	..	57	28	13	1.0	242	58	18	0.0	9.9	327	257	59	555	7.3	2	
148	2- 7-62	373	17	.07	.00	45	5.4	12	1.0	134	26	10	0.1	13.0	200	135	25	313	7.5	3	
190	2- 8-62	202	22	.04	.00	55	23	14	1.0	256	19	17	0.1	7.7	285	232	22	480	7.6	3	
540	4- 9-62	600	20	.44	.02	116	51	22	0.8	163	370	11	0.1	11	732	500	366	959	7.3	3	
541	3- 2-61	300	22	.05	.00	39	8.3	10	1.0	120	24	7.4	0.1	20	192	132	33	295	7.7	2	
551	3- 1-61	450	19	.26	.01	47	9.0	14	1.0	179	12	9.3	0.0	18	214	155	8	351	7.8	2	

557	4- 9-62	210	24	.00	.17	49	12	12	0.8	128	69	5.8	0.1	13	252	172	67	378	6.8	3
603	3- 2-61	916	28	3.9	.04	180	32	27	1.0	180	420	18	0.2	2.8	805	581	433	1090	7.4	3
616	4-21-49	100	20	.17	..	52	13	11	1.4	198	23	7.0	0.0	12	242	183	21	392	7.5	3
631	2-28-61	500	16	.38	.03	30	8.2	45	0.5	173	48	3.5	0.0	3.7	239	109	0	378	8.0	2
642	3- 1-61	312	28	.02	.03	90	36	19	1.8	162	248	6.0	0.2	2.7	534	373	240	747	7.7	2
662	2-27-61	300	17	.21	.06	71	30	30	1.5	217	84	68	0.1	5.6	426	301	123	695	7.9	4
678	3- 1-61	300	24	.06	.04	39	14	8.3	1.0	178	17	4.2	0.0	8.0	204	155	9	322	7.7	2
680	3- 1-61	500	28	.70	.38	59	17	15	1.0	252	37	4.2	0.1	0.2	283	217	11	447	7.5	6
689	3- 1-61	300	32	.02	.05	126	28	19	2.5	158	300	16	0.6	0.5	620	430	300	838	7.6	3
708	2- 5-62	123	23	.14	.00	70	21	12	1.5	236	32	20	0.1	36	344	261	68	536	7.6	4
709	2- 8-62	80	23	.05	.00	44	34	12	1.0	298	9.7	5.1	0.1	20	302	250	6	490	8.2	3
710	2- 8-62	100	22	.20	.00	55	20	14	2.2	202	40	18	0.2	19	307	219	54	478	7.4	8
711	2- 8-62	81	33	.07	.00	36	17	11	3.0	152	29	13	0.2	8.8	236	160	36	359	7.7	3
712	2- 5-62	157	21	1.6	.00	54	36	17	1.5	268	83	6.4	0.1	3.1	360	283	63	565	7.6	5
718	4- 9-62	133	19	3.0	.12	53	15	15	1.5	211	27	13	0.0	4.0	255	194	21	429	6.9	5
736	9-30-25	111	23	4.9	..	45	11	12	3.0	183	13	12	..	0.88	209	158	8	....	..	..
738	9-30-25	110	25	0.15	..	48	24	12	1.2	234	6.4	19	..	14	252	218	26	....	..	..

* Composite sample from 3 wells (Mg-62, 63, 64).

Table 4. Chemical analyses of ground water in the Lockatong Formation in Montgomery County, Pennsylvania
(Results in parts per million except as indicated)

Location	Date of collection	Depth of well (ft.)	Silica SiO ₂	Total iron (Fe)	Total manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO ₃)	Sulfate (SO ₄)	Chloride (Cl)	Fluoride (F)	Nitrate (NO ₃)	Dissolved solids (residue at 180° C)	Hardness as CaCO ₃		Specific conduc- tance (micromhos Cm at 25°C)	pH	Color	
																Calcium, magnesium	Non- carbonate				
Montgomery County																					
Mg- 49	9-28-25	157	25	.07	..	40	15	9.8	1.7	187	13	6.8	..	5.2	199	162	9	...	..	..
713	2- 9-62	312	16	.32	.00	47	32	9.5	1.5	200	48	36	0.2	0.7	303	249	85	512	7.8	3	
715	4- 9-62	140	16	.02	.00	47	17	9.8	0.8	144	38	16	0.1	26	253	188	70	414	7.3	3	
716	4-10-62	200	15	.00	.00	52	17	9.2	1.0	193	36	14	0.0	2.8	246	200	42	410	7.7	3	
737	9-28-25	80	13	.27	..	66	23	15	2.7	254	37	22	..	16	320	259	51	....	..	..
739	9-30-25	490	13	17	..	47	23	22	1.9	283	3.8	7.0	..	.21	283	212	0	....	..	..

Table 5. Comparison of the chemical quality of ground water in the Brunswick and Lockatong Formations
(Results in parts per million)

	Brunswick Formation Montgomery County			Lockatong Formation Montgomery County			Lockatong Formation Bucks and Montgomery Counties		
	Min.	Max.	Median	Min.	Max.	Median	Min.	Max.	Median
Dissolved solids (residue at 180°C)	192	1340	302	199	320	268	199	320	253
Silica									
(SiO ₂)	10	33	22	13	25	16	11	25	15
Total iron									
(Fe)	.00	4.9	.14	.00	17	.17	.00	17	.07
Total manganese									
(Mn)	.00	.38	.02	.00	.00	.00	.00	.03	.00
Calcium									
(Ca)	30	252	55	40	66	47	21	66	47
Magnesium									
(Mg)	5.4	64	20	15	32	20	12	32	17
Sodium									
(Na)	4.1	135	13	9.2	22	9.8	7	45	12
Potassium									
(K)	0.5	3.5	1.4	0.8	2.7	1.6	0.6	2.7	1.1
Bicarbonate									
(HCO ₃)	120	358	188	144	283	196	120	283	193
Sulfate									
(SO ₄)	6.4	788	38	3.8	48	36	3.8	61	37
Chloride									
(Cl)	3.5	68	9.7	6.8	36	15	6.8	36	11
Fluoride									
(F)	0.0	0.6	0.1	0.0	0.2	0.1	0.0	0.4	0.1
Nitrate									
(NO ₃)	0.2	36	7.6	.21	26	4.0	0.1	26	2.1
Hardness									
Calcium, magnesium	109	892	218	162	259	206	103	259	187
Hardness									
Non-carbonate	0	755	45	0	85	47	0	85	42
Analyses from 36 wells			Analyses from 6 wells			Analyses from 11 wells			

Table 6. Record of wells

Well number	Location number	Owner	Driller	Date completed	Altitude above sea level (feet)	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer name	Static water level		Yield (gpm)	Use	Remarks
											Date measured	Depth below land surface (feet)			
Be 17	015-543-2	St. Gabriel's Episcopal Church			145	Drl	8	350		Tab	40		75	U	
18	015-543-3	Roy Scherr			155	Drl	6	250		Tab			50	D	
24	019-537-1	J. Y. Shaner			380	Drl	6	85		Tab			8	U	
101	016-548-1	Colorado Fuel & Iron			150	Drl	8	55+		Tab	6-3-63		20	O	EL, H, FA; 13 ft. dd. in 3 hrs.
102	017-547-1	Daniel Boone Homestead		1939	200	Drl	6	375	40	Tab			20+	D	CA
103	019-538-1	Boytown Packaging Service	C. S. Garber	1954	380	Drl	6	141	51	Tab	5-18-55		45	PS	CA
104	026-533-1	Pennsburg Water Co.	F. L. Bollinger	1958	390	Drl	10	300	46	Tab	4-3-58		8	PS	CA
105	026-533-2	do.	do.	1958	395	Drl	10	300	49	Tab	4-7-58		6	PS	CA
106	018-551-1	Hub Tool Mfg. Machine Co.	C. S. Garber	1958	240	Drl	10	112	83	Tab			10+	I	CA
107	018-544-1	John Bell	C. S. Garber	1955	355	Drl	6	119	40	Tab	8-12-55		73	D	CA
108	017-551-1	Pendora Tool & Die			200	Drl				Tab			10	I	FA
109	017-551-2	Exeter Twp. School	Kohl Bros.	1958	220	Drl	6	200	46	Tab	7-31-58		74	PS	31 ft. dd. in 6 hrs.
110	020-537-1	do.	do.	1954	350	Drl	6	160	67	Tab	8-7-54		15	PS	
111	020-536-2	do.	do.	1959	320	Drl	6	528	16	Tab	1959		220	I	CA
112	020-536-3	do.	do.	1961	320	Drl	8	660	42	Tab			140	I	
113	020-536-4	do.	do.		320	Drl	6	500	35	Tab	6-10-63		26	U	
114	020-536-7	do.	do.	1961	310	Drl	6	400	46	Tab	11-14-61		4	U	EL, H, FA; 27 ft. dd. in 4 hrs.
115	015-544-1	Douglasville Water Co.	C. S. Garber	1957	190	Drl	6	300	38	Tab	1-31-62		86	U	EL, FA; 35 ft. dd. in 4 hrs.
116	016-544-1	do.	do.	1958	250	Drl	6	360	44	Tab	1-31-62		30	U	CA; 106 ft. dd. in 67 hrs.
117	015-543-1	do.	do.	1959	219	Drl	6	262	42	Tab	1959		49	PS	CA
118	018-553-1	Forest Hills Memorial Park	do.	1959	295	Drl	6	500	38	Tab	1-25-62		45	D	CA, EL
121	017-547-3	Clarence C. Kline	Ira Petersheim	1953	245	Drl	5	320	205	Tab	4-10-62	Flows	3	D	EL, FA
122	017-547-2	do.	do.	1953	225	Drl	10	335	6	Tab	7-5-62		35	U	EL
123	016-542-1	Pine Forge Institute	do.	1947	240	Drl	6	240		Tab			20+	PS	
126	015-544-2	U. S. Geol. Survey	C. S. Garber		190	Drl	6	300	40	Tab	6-4-63		37	O	EL, H, SL; 18 ft. dd. in 4 hrs.
141	011-533-1	Pennhurst State School	Kohl Bros.	1962	225	Drl	8	327		Tab			30	PS	
142	011-533-2	do.	do.		235	Drl	8	529		Tab	1948		52	PS	218 ft. dd. in 3 hrs.
143	011-533-3	do.	do.		320	Drl	8	443		Tab	1954		190	PS	40 ft. dd. in 3 hrs.
144	011-534-1	do.	do.		310	Drl	8	421		Tab	3-12-63		236	U	
145	011-534-2	do.	do.		320	Drl	8	404		Tab	1-23-56		80	PS	
146	011-534-3	do.	do.		330	Drl	8			Tab	3-12-63		212	PS	75 ft. dd. in 7 hrs.
147	011-533-4	do.	F. L. Bollinger		345	Drl				Tab			95	X	
181	011-534-4	do.	do.	1963	295	Drl	12	804	74	Tab	6-?-48		200	PS	60 ft. dd. in 3 hrs.
					260	Drl	16-10	700	90	Tab	4-9-63		225	PS	108 ft. dd. in 72 hrs.

[illegible]

Table 6. Record of wells—Continued

Well number	Location number	Owner	Driller	Date completed	Altitude above sea level (feet)	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer name	Static water level		Yield (gpm)	Use	Remarks
											Date measured	Depth below surface (feet)			
Mg 167	012-516-1	Leeds & Northrup Co.	Ridpath & Potter	1954	350	D-I	16-10	288	44	Trb	5-2-60	48	200	I	
170	012-516-4	do.			358	D-I	8	196	60	Trb, Trl	1-2-47	10	100	U	EL, H
180	013-517-2	Hatfield Borough	Ridpath & Potter	1954	325	D-I	6	250		Trb	11-2-54	65	100	U	EL, H
190	016-518-1	North W. Res Water Authority	V. T. Campbell	1938	345	D-I	8	202	36	Trb			150	PS	CA, H
203	013-517-3	Precision Tube Co.	Kohl Bros.	1955	315	D-I	8	450	27	Trb	1-17-55	12	210	PS	138 ft. dd. in 72 hrs.
204	013-517-3	Precision Tube Co.	Philadelphia Drilling Co.	1955	305	D-I	8	507		Trb	5-19-55	52	190	PS	22 ft. dd. in 5 hrs.
221	011-522-3	Krasley Bleach & Dye	Kohl Bros.	1941	130	D-I	8	421	22	Trb				U	
222	013-522-4	do.	do.	1941	130	D-I	8	291	28	Trb				I	
225	013-522-4	Leeds & Northrup Co.	Ridpath & Potter	1955	332	D-I	10	350		Trb	8-2-55	23	135	I	FA; 81 ft. dd. in 48 hrs.
237	011-517-1	J. W. MacMullin	George Lauman	1950	340	D-I	6	65		Trl	11-9-55	22	10	D	
238	011-517-2	John F. Gerber	Michael Kuszyk	1948	385	D-I	6	80+		Trl			10	D	
274	014-533-1	Pottstown Metal Welding Co.	Kohl Bros.	1956	335	D-I	8	150	105	Trb			60	I	
281	011-522-1	do.	do.	1941	190	D-I	8	400	61	Trb	10-2-41	57	110	I	
282	011-522-2	do.	do.	1951	185	D-I	8	300	191	Trb	10-23-56	87	87	I	
283	011-522-3	do.	do.	1951	185	D-I	8	449	22	Trb	9-1-53	86	35	I	
284	011-522-4	do.	do.	1956	290	D-I	6	351	38	Trb	11-8-56	50	45	I	
292	018-521-2	Horace W. Longacre	A. W. Dorn	1946	260	D-I	6	225		Trb	1956	87	20+	PS	
293	018-521-2	Saratoga Trailer Park	do.		410	D-I		175		Trb, Trl				D	
450	011-521-1	Variety Club Camp	Parente Bros.	1949	420	D-I		225		Trb, Trl				PS	
467	011-521-2	do.	do.	1945	450	D-I		110		Trb, Trl			4	D	
472	016-520-1	P. W. Bookhermer	B. Bev	1960	550	D-I		120		Trl			7	D	
473	016-519-1	do.	Charles Lauman	1960	550	D-I		160		Trl	9-6-56	10		D	
478	011-518-1	E. McCure	do.	1944	325	D-I		160		Trl				D	
479	011-517-3	W. W. Carlson	do.		350	D-I		160		Trl				D	
480	011-518-2	W. A. Garver	do.		375	D-I		90+		Trb, Trl				D	
481	011-518-3	A. J. Wilson	Patrick Flaherty	1960	417	D-I	6	112	30	Trl	9-6-56	69	27	D	
482	011-518-4	Henry Krug	do.	1949	370	D-I		120	25	Trl			12	D	
483	011-518-5	Joseph Bailiff	do.	1943	360	D-I	6	132		Trl	9-25-56	60		D	
493	010-520-2	U. S. Army	C. S. Garber	1955	445	D-I		230		Trl			47	D	
494	010-521-1	do.	do.	1955	460	D-I		280		Trl			51	D	
498	015-518-1	Lansdale Municipal Authority	William Stothoff	1957	340	D-I	12	560	90	Trb	9-18-57	77	90	PS	
534	013-525-1	Eastern State Penitentiary	F. L. Bollinger	1928	255	D-I	10	489	10	Trb	7-23-63	234	155	PS	11.5 ft. dd. in 73 hrs.
535	013-525-1	do.	do.	1929	280	D-I	10	552	21	Trb	7-23-63	248	135	PS	11 ft. dd. in 73 hrs.
536	013-525-3	do.	do.	1929	280	D-I	10	497	32	Trb	5-1-62	245	116	PS	12 ft. dd. in 24 hrs.
537	013-525-2	do.	do.	1929	280	D-I	10	596	20	Trb	7-23-63	260	98	PS	87 ft. dd. in 72 hrs.
538	014-525-2	do.	do.	1937	305	D-I	12	512	19	Trb	8-1-60	204	355	PS	18 ft. dd. in 48 hrs.
539	014-525-3	do.	Artesian Well Drilling	1951	285	D-I	16-8	502	24	Trb	7-23-60	195	300	PS	
540	013-526-3	do.	F. L. Bollinger	1951	270	D-I	10	600		Trb	4-9-62	180	90	PS	CA
541	010-530-1	Charles Johnson Home	do.	1959	150	D-I	12-8	300	44	Trb	6-9-60	15	135	PS	FA
542	010-530-2	do.	do.	1930	240	D-I	8	193		Trb			84	PS	

543	010-532-1	Diamond Glass Co.	Ridpath & Potter	1956	110	Drl	16-10	400	60	Tbb	8-10-56	20	191	I	FA; 125 ft. dd. in 24 hrs.
544	010-532-2	Spring Ford Foundry & Machine Co.	C. S. Garber	1947	115	Drl		120		Tbb				I	FA
545	010-532-3	Bush Bros.	do.	1959	227	Drl	10	223		Tbb		37	60+	I	FA
546	011-532-1	Boyersford Foundry & Machine Co.			120	Drl	6	172		Tbb			40	I	
547	010-532-4	Bankers Bar	C. S. Garber	1959	160	Drl	6	100+		Tbb			60	D	FA
548	011-531-1	Nelsons Ice Cream Inc.	Kohl Bros.	1925	175	Drl	8	201		Tbb			60+	I	EL, H
549	011-532-2	Cann & Saul Steel Co.	do.	1941	187	Drl	8	235	21	Tbb	6-8-60	11	30	O	CA
550	012-522-1	O. J. Hynes			265	Drl	8	450		Tbb	3-30-60	63		D	FA
551	012-525-1	John Nast	A. W. Dorn	1957	260	Drl	6	90		Tbb	3-30-60	21		D	FA
552	012-525-2	Natalie Schmitt	Miller Pump Service	1959	260	Drl	6	102	38	Tbb			25	D	FA
553	012-525-3	McCormie Air Services	C. S. Garber	1959	285	Drl	6	134	40	Tbb	3-30-60	50	40	D	FA
554	012-532-1	S. A. Wetty & Sons	do.	1949	260	Drl	6	160	12	Tbb	6-8-60	72		D	FA
555	012-532-2	do.		1956	260	Drl	6	190	21	Tbb	8-20-36	69		I	CA
556	012-532-3	Kinsey Distilling Corp.	do.		184	Drl	10	394		Tbb			225	I	
557	012-534-1	do.	do.	1934	150	Drl	10	360		Tbb			107	I	
558	012-534-2	do.	do.	1934	155	Drl	10	328		Tbb			107	I	
559	012-534-3	do.	do.	1934	170	Drl	10	145		Tbb			50	I	
560	012-534-4	do.	do.	1934	170	Drl	10	145		Tbb			55	I	
561	012-534-5	do.	do.	1935	115	Drl	6	179		Tbb			213	I	
562	012-534-6	do.	do.	1934	145	Drl	10	365		Tbb				I	
563	012-534-7	Sanitary Company of America			125	Drl	6	200+		Tbb				D	
564	012-534-8	do.	Wallace Reigner	1959	127	Drl		98		Tbb				I	152 ft. dd. in 21 hrs.
565	012-534-9	do.	F. L. Bollinger	1960	280	Drl	14-10	330	45	Tbb	3-17-60	15	226	D	FA
566	013-518-5	Martin Century Farms	do.	1943	267	Drl	6	135	50	Tbb				D	FA
567	013-521-1	C. V. Hollis	do.	1940	255	Drl	6	110	50	Tbb				D	FA
568	013-521-2	C. W. Bosler	do.		255	Drl	6	79	25	Tbb	3-31-60	23		D	FA
569	013-521-3	Fischers Pool & Cottages	Patrick Flaherty	1948	195	Drl	8	195	25	Tbb		7	48	PS	
570	013-521-4	do.	do.		181	Drl	6	90	25	Tbb			20	PS	
571	013-521-5	do.	do.	1942	176	Drl	6	78	25	Tbb			20	D	FA
572	013-521-6	do.	do.		178	Drl	6	90	25	Tbb	3-30-60	8		D	FA
573	013-521-7	do.	do.	1935	270	Drl	6	19		Tbb				D	FA
574	013-524-1	John Gregory			210	Drl	6	140		Tbb				D	FA
575	013-524-2	Anna Lewandowski	Parente Bros.	1940	152	Drl	14-10	351	38	Tbb			180	I	
576	013-536-1	Firestone Tire & Rubber Co.	C. S. Garber	1947	153	Drl	14-10	402	35	Tbb			193	I	
577	013-536-2	do.	do.	1942	153	Drl	14-10	342	35	Tbb			73	I	
578	013-536-3	do.	do.	1947	152	Drl	14-10	494	75	Tbb	9-22-61	52	61	I	EL
579	013-536-4	do.	do.	1942	147	Drl	14-10	276	36	Tbb			153	I	
580	013-536-5	do.	do.	1942	186	Drl	14-10	394	32	Tbb, Trl	6-1-60	79	62	I	EL, H, FA
581	013-536-6	do.	do.	1942	190	Drl	14-10	371	37	Tbb			94	I	
582	013-536-7	do.	do.	1947	165	Drl	14-10	355	47	Tbb			170	I	
583	013-536-8	do.	do.	1942	165	Drl	14-10	406	42	Tbb			108	I	
584	014-536-1	do.	do.	1942	186	Drl	14-10	266	50	Tbb	6-23-60	36		I	
585	014-536-2	Picolet Dye Works Inc.	do.		157	Drl	14-10			Tbb, Trl				I	
586	014-515-1	do.	Walter Emert	1942	430	Drl	6	820		Tbb, Trl			4	I	
587	014-515-2	do.	do.	1951	430	Drl	6	300		Tbb, Trl			20	I	FA
588	014-515-3	do.	William Stothoff		430	Drl	6	400		Tbb, Trl			12	I	FA
589	014-515-4	do.	Walter Emert		425	Drl	6	235	44	Tbb, Trl			67	I	67 ft. dd. in 24 hrs.
590	014-515-5	do.	do.		390	Drl	12-8	492	76	Tbb, Trl	5-26-59	87	200	PS	190 ft. dd. in 48 hrs.
591	014-516-7	Lansdale Borough	Kohl Bros.	1958	320	Drl	12-8			Tbb	9-7-59	111	67	PS	
592	014-518-3	Lansdale Municipal Authority	do.		185	Drl	6	135		Tbb	4-18-60	23		I	
593	014-520-1	H. H. Becker	do.	1925	265	Drl	10	210		Tbb	4-27-60	32	17	D	FA
594	014-520-2	Pa. Turnpike Interchange	Thomas G. Keyes	1955	285	Drl	6	135	42	Tbb	1957	152	30	D	8 ft. dd. in 2 hrs.
595	014-520-3	Robert Aldefer	Parente Bros.	1943	275	Drl	6	220	40	Tbb			90	D	FA
596	014-525-1	Pottstown Airport	C. S. Garber	1958	310	Drl	6	220	40	Tbb			12	D	FA
597	014-533-1	Sunnybrook Enterprises	do.	1954	150	Drl	8	262	46	Tbb	4-3-62	8	90	PS	FA

Table 6. Record of wells—Continued

Well number	Location number	Owner	Driller	Date completed	Altitude above sea level (feet)	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer name	Static water level		Yield (gpm)	Use	Remarks
											Date measured	Depth below land surface (feet)			
Mg 599	014-537-1	Dana Corp.			155	Drl	8	385		Tab			160	I	
600	014-537-2	do.			155	Drl	10	287		Tab			130+	I	
601	014-537-3	do.	Joseph Smith	1941	160	Drl	8	540		Tab	1-7-42	30	125	I	FA
602	014-537-4	do.	do.		150	Drl	8	425		Tab			90	I	CA
603	014-537-5	do.	Kohl Bros.	1942	150	Drl	6	916	850	Tab			150	I	
604	014-538-1	Bethlehem Steel Co.		1916	145	Drl	8	200		Tab			200	I	
605	014-538-2	do.		1916	145	Drl	8	200		Tab			200	I	
606	014-538-3	do.		1917	165	Drl				Tab				I	
607	014-538-4	Levensgood Dairy		1932	165	Drl	8	184		Tab			150	I	FA
608	014-540-3	do.	Joseph Smith	1910	150	Drl		201		Tab	1958	100	120	I	
609	014-540-1	Stanley G. Flagg Inc.	Kohl Bros.	1945	145	Drl	8	200	35	Tab			147	I	
610	014-540-2	do.	do.	1947	145	Drl	8	244	82	Tab	1958	63	147	I	67 ft. dd. in 2 hrs.
611	014-540-4	do.	do.	1948	145	Drl	8	350	36	Tab	1958	96	255	I	FA
612	015-514-1	Lock Seam Tube Inc.	Walter Emert		455	Drl	6	320		Tab			15	D	
613	015-515-1	Picolet Dye Works Inc.	do.		375	Drl	6	120		Tab			10	I	
614	015-515-2	do.	do.		180	Drl	6	100		Tab			25	I	CA
616	013-522-1	Eugene D. Rutter			330	Drl		330		Tab			30	I	
618	013-522-1	Penndale Inc.	R. L. Knieriem	1958	335	Drl		88		Tab	6-8-56	74		I	
619	015-516-5	American Encaustic Tile Co.	William Stothoff		360	Drl	10	400	116	Tab	3-28-58	58	100+	I	
620	015-516-6	do.	do.	1955	360	Drl	10	400		Tab	1957			I	
621	015-516-7	do.	do.	1957	335	Drl	8-6	600	100	Tab	10-9-57	24	55	PS	FA; 50 ft. dd. in 24 hrs.
622	015-516-8	A. M. Kulp School	Miller Pump Service	1956	297	Drl	10	507	97	Tab	12-18-62	41	200	U	EL
623	015-517-3	Lansdale Municipal Authority	William Stothoff	1957	330	Drl	8	504	85	Tab	1958	105	9	I	
624	015-517-13	J. W. Rex Inc.	F. L. Bollinger	1958	315	Drl	8	384	62	Tab	4-?-60	54	186	I	
625	015-517-14	do.	do.	1958	320	Drl	8	125		Tab	4-1-60	30		D	FA
627	015-519-1	Paul Clements			345	Drl	6	54		Tab	4-1-60	49		D	FA
628	015-519-2	M. L. Dickinson			320	Drl	6	101		Tab	8-31-60	54		D	FA
629	015-519-2	Christopher Dock Mennonite H. S.			300	Drl	6	130		Tab	8-10-59	52	60	PS	
630	015-520-2	do.	A. W. Dorn	1959	300	Drl	8	130		Tab	8-10-59	52		PS	
631	015-520-3	Nice Ball Bearing Co.	Ridpath & Potter	1959	285	Drl	10	500	60	Tab	8-29-63	63	200	CA	H, SL
632	015-520-11	U. S. Geol. Survey	C. S. Garber	1960	285	Drl	6	500	31	Tab	8-29-63	71		T	EL, H, SL
633	015-520-10	do.	C. S. Garber & Kohl Bros.	1962	270	Drl	6	500	32	Tab	4-4-60	55	125	T	EL, H, SL
634	015-520-4	Elwell Davies			310	Drl	8	198		Tab	4-4-60	55		D	FA
635	015-520-5	John Felver			300	Drl	6	167		Tab				D	FA
636	015-520-6	William Delp			257	Drl	6	87		Tab	4-1-60	49		D	FA
637	015-520-7	Miller Pump Service		1930	220	Drl	8	105		Tab	4-1-60	22	40+	D	FA
638	015-520-8	Frank Ziegler	Patrick Flaherty	1958	235	Drl	8	100	16	Tab				D	FA
639	015-520-9	William Delp			240	Dug		35		Tab				D	FA
640	015-520-1	Schwenksville Water Co.	F. L. Bollinger	1940	238	Drl	8	503		Tab	1960	135	80	PS	
641	015-528-2	do.			260	Drl	6	213		Tab				U	
642	015-528-3	do.	F. L. Bollinger		250	Drl	8	312		Tab	1960	120	70	PS	CA

643	016-517-1	Girard Knitting Mills	William Stothoff	330	Drl	6	400-500	27	Tab	D
644	016-517-4	Hatfield Borough	A. W. Dorn	330	Drl	10	206		Tab	PS
645	016-522-1	Aldefor Borough Co.		1957	Drl			36	7-15-59	FA
646	016-523-1	Harleysville Insurance Co.		1959	Drl					FA
647	016-523-2	Lower Salford Twp. School		1949	Drl					PS
648	016-523-3	do		1936	Drl	6	160			PS
649	017-517-1	Hunter Spring Co.	Kohl Bros.	280	Drl	6	200			PS
650	017-518-1	Walker Forest	A. W. Dorn	1960	Drl	10	400	42	Tab, Tbl	I EL; 100 ft. dd. in 16 hrs.
651	017-518-2	do	do	1945	Drl		75			PS
652	017-518-3	Schlusser Steel Inc.		1957	Drl		170			PS
653	017-518-4	A. Siefert & Son Inc.		1958	Drl		87			I
654	017-519-1	Souderton Borough		1937	Drl	10	205	30	Tab	I
655	017-520-1	NYCEC Manufacturing Co.	F. L. Bollinger	200	Drl		300			U
656	017-524-1	Parente Bros.		1995	Drl	6				U
657	018-518-1	R. T. French Co.	F. L. Bollinger	305	Drl	8	400	40	Tab, Tbl	FA
658	018-518-2	do		1956	Drl		600-700			I
659	018-518-3	do		1915	Drl	10	300	13	Tab	U
660	018-518-4	do		1933	Drl	10	300			PS
661	018-518-5	do		1948	Drl	8	300			PS
662	018-519-2	do	F. L. Bollinger	320	Drl	10	400	40	Tab	CA
663	018-519-3	do	William Stothoff	340	Drl	10	400	20	Tab	PS
664	018-519-4	do		1937	Drl	12	300	21	Tab	PS
665	018-519-5	Souderton Steam Laundry	F. L. Bollinger	380	Drl	8	188			PS
666	018-519-6	Eastern Mononite Home		1954	Drl	8	192			I
667	018-519-7	Granite Hosiery Mills	J. W. Shaw	390	Drl	8-6	205		Tab, Tbl	PS
668	018-519-8	Souderton Borough		1917	Drl	12	205	20	Tab	FA
669	018-519-9	do		1936	Drl	8	224	120	Tab	EL
670	018-519-10	do		1911	Drl	8	600-700		Tab	U
671	018-519-11	do			Drl	6	300-350		Tab	U
672	018-519-12	Souderton Borough			Drl	6	780		Tab, Tbl	U
673	018-519-13	M. B. Bergey Hosiery Mill			Drl	6	300		Tab	I
674	018-519-14	Goodman Silk Mill			Drl	6	300		Tab	PS
675	018-519-15	H. S. Souder			Drl	14-10	300	60	Tab	PS
676	018-519-16	Henry L. Landis Estate	F. L. Bollinger	315	Drl	12-8	308	43	Tab	CA; 94 ft. dd. in 72 hrs.
677	026-532-1	East Greenville Borough	William Stothoff	360	Drl		500		Tab	EL, H, SL; 71 ft. dd. in 49 hrs.
678	018-532-17	New Hanover Twp. School		1960	Drl	6	280		Tab	CA
680	018-532-1	Franconia Twp. School	Parente Bros.	365	Drl	6	171		Tab	FA
681	018-531-1	Memonite Home for the Aged		1939	Drl	8	175		Tab	PS
682	018-531-1	do		1956	Drl	8	175		Tab	PS
683	018-531-2	Telford Borough	Mayer	325	Drl	10	240		Tab	PS
684	019-519-1	Souderton Borough	Ridpath & Potter	430	Drl	6	600		Tab	U
685	019-519-5	Fashion Hosiery Mills Inc.	Kohl Bros.	340	Drl	8	400	50	Tab	FA
686	019-537-1	do	do	1948	Drl	8	300	10	Tab	148 ft. dd. in 1 hr.
687	019-537-2	do	Campbell	320	Drl	6	310		Tab	CA
688	019-537-2	do		1960	Drl		150		Tab	PS
689	020-528-1	Maranatha Park	V. D. Kohler	325	Drl	6	171		Tab	D
690	020-528-2	do	Joseph Mayer	300	Drl	6	150		Tab	D
691	013-516-5	R. D. Gillen	A. W. Dorn	300	Drl	8	150		Tab	I
692	018-522-1	Keller's Creamery		1950	Drl	8	55		Tab	FA
693	018-522-2	do		1941	Drl	6	55		Tab	FA
694	019-517-5	Dorsey Shultz		1956	Drl	6	80	43	Tab	FA
695	017-523-1	Harvey Kofel	Miller Pump Service	230	Drl	6	81		Tab	D
696	012-522-2	Gordon Wilkie	Charles Lauman	200	Drl	6	81		Tab	D
697	012-522-2	Carl Ehrhart		1946	Drl	6	81		Tab	D
698	013-521-1	R. L. Koehler	A. W. Dorn	480	Drl	6	680	88	Tab	FA
699	020-522-1	Stanley G. Flagg Inc.	Kohl Bros.	146	Drl	8			Tab	EL, SL; 200 ft. dd. in 40 min.
700	014-540-5			1961	Drl				Tab	I

Table 6. Record of wells—Continued

Well number	Location number	Owner	Driller	Date completed	Altitude above sea level (feet)	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer name	Static water level		Yield (gpm)	Use	Remarks
											Date measured	Depth below surface (feet)			
Mg 701	020-536-1	Kaweck Chemical Co.	Kohl Bros.	1957	320	Drl	6	405	19	Tab	1957	20	150	I	180 ft. dd. in 40 hrs.
702	020-536-5	do.	C. S. Garber	1961	310	Drl	6	300	60	Tab	11-7-61	8	100	I	EL
703	020-536-6	do.	do.	1961	315	Drl	6	400	30	Tab	11-7-61	36	40	U	EL
704	015-517-15	Lansdale Municipal Authority	F. L. Bollinger	1962	310	Drl	14-10	400	80	Tab	12-4-61	25	135	PS	EL, SL, 135 ft. dd. in 40 hrs.
705	024-528-1	Upper Hanover Twp.	C. S. Garber	1957	480	Drl	6	275	21	Tab	5-4-57	Flows	100	D	CA
708	022-534-1	H. J. Beiler	Hunsicker	1943	495	Drl	6	123	14	Tab	1955	80	24+	D	CA
709	018-523-1	S. P. Godshall	Stover	1950	330	Drl	6	80	6	Tab	2-8-62	51	20	D	CA
710	018-527-1	Frank Seal	C. S. Garber	1957	430	Drl	6	100+	30	Tab	2-8-62	18	20	D	CA
711	023-527-1	A. T. Goadby	W. W. Wonsidler	1957	480	Drl	6	81	30	Tab	10-7-57	12	7	D	CA
712	017-535-1	E. F. Barndt	C. S. Garber	1940	260	Drl	6	157	40	Tab	2-5-62	10	10	D	CA
713	013-514-1	N. T. Cummings	Miller Pump Service	1956	450	Drl	6	312	40	Tab	1956	80	7	D	CA
714	015-524-1	Ferro-Phos Co.	Stanley Slemmer	1951	175	Drl	6	140	30	Tab	1951	25	20	D	CA
715	010-523-1	Florence A. Plummer	Charles Lauman	1937	300	Drl	6	200	6	Tab	1951	25	40	D	CA
716	010-523-2	do.	do.	1937	410	Drl	6	280	30	Tab	1951	25	40	D	CA
717	010-523-2	do.	do.	1937	410	Drl	6	280	30	Tab	1951	25	40	D	CA
718	013-531-1	Fred Tyson	Tenney	1950	295	Drl	6	133	38	Tab	4-9-62	21	10	I	CA
720	011-530-2	Bechtel's Dairy	Kohl Bros.	1955	230	Drl	6	300	38	Tab	6-7-55	53	70	I	CA
721	011-530-1	do.	do.	1944	200	Drl	8	325	15	Tab	10-7-44	60	40	I	FA
723	018-521-3	H. W. Longacre	A. W. Dorn	1958	395	Drl	8	328	29	Tab	10-13-58	76	80	I	FA
724	018-521-4	do.	do.	1958	395	Drl	6	300	30	Tab	7-30-62	14	250	PS	EL, SL
725	015-527-1	Schwensville Water Co.	F. L. Bollinger	1962	145	Drl	8	300	30	Tab	7-30-62	14	250	PS	154 ft. dd. in 8 hrs.
726	014-536-4	American Telephone & Telegraph Co.	C. S. Garber	1961	185	Drl	6	300	52	Tab	1961	56	37	I	EL
727	014-536-5	do.	do.	1961	185	Drl	6	300	52	Tab	1961	56	37	I	EL
728	020-536-8	Kaweck Chemical Co.	do.	1961	320	Drl	6	360	21	Tab	7-24-62	Flows	90+	D	U
729	023-530-1	Perkionen School	do.	1961	340	Drl	6	1000	14	Tab	9-25-62	4	20	X	EL
730	020-536-9	Kaweck Chemical Co.	do.	1907	315	Drl	6	125	14	Tab	1962	6	110	I	EL, 191 ft. dd. in 24 hrs.
731	017-517-2	Hunter Spring Co.	Thomas G. Keyes	1962	360	Drl	8	400	22	Tab, Tal	1962	18	7	U	EL
732	017-517-3	do.	do.	1962	360	Drl	8	403	22	Tab, Tal	1962	18	7	U	EL
733	020-525-1	E. E. Endy	Joseph Mayer	1962	420	Drl	6	42	22	Tab	8-6-63	0	2	U	18 ft. dd. in 3 hrs.
734	020-526-1	Dulmont Scout Reservation	do.	1962	275	Drl	6	125	22	Tab	8-9-63	14	20	PS	26 ft. dd. in 2 hrs.
735	020-526-2	do.	do.	1962	275	Drl	6	45	22	Tab	8-9-63	14	20	PS	26 ft. dd. in 2 hrs.
736	011-526-5	Linwood Yost	do.	1962	115	Drl	6	111	22	Tab	8-9-63	50	4	D	CA
737	014-514-3	John Wright	do.	1962	445	Drl	6	80	22	Tab	8-9-63	50	4	D	CA
738	013-531-2	Limerick School	do.	1962	305	Drl	6	110	22	Tab	8-9-63	30	9	D	CA
739	009-524-1	Eagleview Sanatorium	do.	1962	425	Drl	6	511	22	Tab	8-9-63	30	9	D	CA
740	019-529-1	Upper Perkionen Valley Park	F. L. Bollinger	1960	320	Drl	6	415	22	Tab	8-9-63	30	20	PS	114 ft. dd. in 1 hr.
741	020-529-1	do.	do.	1947	230	Drl	6	359	22	Tab	8-9-63	30	50	PS	151 ft. dd. in 2 hrs.
742	020-529-2	do.	do.	1940	290	Drl	6	250	22	Tab	8-9-63	30	13	PS	151 ft. dd. in 2 hrs.

743	012-527-1	Techallay Co.	1961	Drl	210	6	235	42	Tpb	12- ¹ -61	65	30	I	
744	019-530-1	R. B. Brooks		Drl	305	6	65	40	Tpb	8-22-63	31	35	I	4 ft. dd. in 3 hrs.
745	020-530-1	M. H. Gulack		Drl	340	6	68		Tad	8-22-63	23	3	D	6 ft. dd. in 3 hrs.
746	018-528-1	J. L. Beck		Drl	250	6	38		Tad	8-16-63	15	3	D	1.4 ft. dd. in 2 hrs.
747	020-533-1	Ralph Levitz		Drl	350	6	132		Tad	8-30-63	3	3	D	3 ft. dd. in 3 hrs.
748	020-532-1	Joseph Kulp	1963	Drl	6	110			Tad	8-28-63	17	0.3	D	
749	020-532-2	do.		Drl	6	42			Tad	8-28-63	16		U	
753	019-527-1	John Leisher	1963	Drl	6	313		20	Tad	8-19-63	14	0.1	D	
754	017-513-1	Atlantic Refining Co.	1952	Drl	190	6	106	35	Tad	8-25-63	5	40	I	150 ft. dd. in 18 hrs.
755	014-525-1	Philadelphia Drilling Co.	1962	Drl	275				Tad	8-25-63	30	230	I	
756	014-540-6	Stanley G. Flagg Inc.	1963	Drl	130	10	593	47	Tad	6-13-63	30	420	I	

**Table 7. Sample logs of wells in the Brunswick Formation
in Berks and Montgomery Counties, Pa.**

Well Be-125

Owner: U.S. Geological Survey

Description	Depth (feet)
Soil, red	0 — 2
Shale, red	2 — 30
Shale, red, moderately calcareous; calcite and quartz joint filling	30 — 35
Shale, red, slightly calcareous; calcite and quartz joint filling	35 — 38
Shale, red	38 — 50
Shale, red, moderately calcareous; calcite joint filling	50 — 55
Shale, red, moderately calcareous	55 — 60
Shale, red, moderately calcareous; calcite and quartz joint filling	60 — 70
Shale, red, slightly calcareous	70 — 75
Shale, red, slightly calcareous; quartz joint filling; goethite	75 — 80
Shale, red; calcite joint filling	80 — 90
Shale, red, slightly calcareous; calcite joint filling	90 — 105
Shale, red, moderately calcareous; calcite joint filling	105 — 110
Shale, purplish-gray, slightly calcareous	110 — 115
Shale, red; calcite joint filling	115 — 120
Shale, red, slightly calcareous; calcite joint filling	120 — 125
Shale, red, slightly calcareous	125 — 130
Shale, red, slightly calcareous; calcite and quartz joint filling	130 — 135
Shale, red, moderately calcareous; calcite joint filling	135 — 140
Shale, red, slightly calcareous; calcite and quartz joint filling	140 — 145
Shale, red, slightly calcareous; calcite joint filling	145 — 150
Siltstone, red, slightly calcareous	150 — 155
Shale, red, slightly calcareous; calcite and quartz joint filling; pyrite ..	155 — 160
Shale, red, slightly calcareous; calcite joint filling	160 — 165
Shale, red, moderately calcareous; calcite joint filling	165 — 170
Shale, red, slightly calcareous	170 — 175
Argillite, light gray, moderately calcareous; calcite joint filling; pyrite	175 — 178
Shale, red, slightly calcareous; calcite and quartz joint filling	178 — 182
Shale, red, slightly calcareous; calcite joint filling; pyrite	182 — 185
Shale, red, slightly calcareous; calcite joint filling	185 — 190
Shale, red, moderately calcareous; calcite joint filling; pyrite and goethite	190 — 195
Shale, red, slightly calcareous; calcite joint filling	195 — 200
Shale, red, slightly calcareous; calcite and quartz joint filling	200 — 205
Shale, red; calcite joint filling	205 — 215
Shale, red, slightly calcareous	215 — 220
Argillite, purple and a few streaks of brown and green; calcite and quartz joint filling; goethite	220 — 225
Shale, red, slightly calcareous; calcite joint filling	225 — 227
Shale, red, slightly calcareous; calcite and quartz joint filling	227 — 230
Shale, red, slightly calcareous; calcite joint filling	230 — 240
Shale, red, moderately calcareous; calcite joint filling	240 — 243
Shale, red, slightly calcareous; calcite joint filling	243 — 265
Shale, red, slightly calcareous; calcite joint filling pyrite and goethite	265 — 273
Shale, red, slightly calcareous; calcite joint filling	273 — 280
Shale, gray-brown, moderately calcareous; calcite joint filling; goethite	280 — 282
Argillite, blue-gray, moderately calcareous; calcite joint filling; goethite	282 — 285
Argillite, greenish-gray, moderately calcareous; calcite joint filling; goethite; very fine grained sandstone, yellow, moderately calcareous	285 — 287

Table 7. Sample logs of wells in the Brunswick Formation—Continued

Well Be-125—Continued

Argillite, greenish-gray, moderately calcareous; calcite joint filling; pyrite	287 — 288
Argillite, purplish-brown; goethite	288 — 290
Shale, red, moderately calcareous; calcite joint filling	290 — 292
Shale, red, slightly calcareous; calcite joint filling	292 — 294
Shale, red	294 — 296
Shale, red, slightly calcareous; calcite joint filling	296 — 300

Well Mg-632

Owner: U.S. Geological Survey

Description	Depth (feet)
Soil, red	0 — 2
Shale, red, moderately calcareous; calcite joint filling	2 — 5
Shale, red, slightly calcareous	5 — 10
Shale, red, slightly calcareous; calcite joint filling	10 — 15
Shale, red, slightly calcareous	15 — 18
Shale, red, slightly calcareous; calcite joint filling	18 — 25
Shale, red, moderately calcareous; calcite joint filling	25 — 30
Shale, red, slightly calcareous; calcite joint filling	30 — 40
Shale, red, slightly calcareous	40 — 45
Shale, red, moderately calcareous; calcite joint filling	45 — 52
Shale, red, slightly calcareous; calcite joint filling	52 — 85
Shale, red, moderately calcareous; calcite joint filling	85 — 90
Shale, red, slightly calcareous, micaceous; calcite joint filling	90 — 95
Shale, red, slightly calcareous, micaceous; quartz and calcite joint filling	95 — 100
Shale, red, slightly calcareous, micaceous; calcite joint filling	100 — 110
Siltstone, red, moderately calcareous, micaceous; calcite and quartz joint filling	110 — 120
Shale, red, slightly calcareous; calcite and quartz joint filling	120 — 125
Shale, red, moderately calcareous, micaceous; calcite joint filling	125 — 130
Shale, red, moderately calcareous; calcite joint filling	130 — 135
Shale, red, moderately calcareous	135 — 140
Shale, red, slightly calcareous; calcite joint filling	140 — 170
Shale, red, slightly calcareous; calcite and quartz joint filling	170 — 185
Shale, red, moderately calcareous; calcite joint filling	185 — 200
Siltstone, red, slightly calcareous, micaceous; calcite joint filling	200 — 210
Shale, red, slightly calcareous, micaceous; quartz joint filling	210 — 215
Shale, red, slightly calcareous, micaceous; quartz and calcite joint filling	215 — 220
Shale, red, slightly calcareous; calcite and quartz joint filling	220 — 225
Shale, red, slightly calcareous; calcite joint filling	225 — 235
Shale, red, slightly calcareous	235 — 240
Shale, red; calcite joint filling	240 — 250
Shale, red; calcite and quartz joint filling	250 — 260
Shale, red, slightly calcareous; calcite joint filling	260 — 290
Shale, red, moderately calcareous	290 — 300

Table 7. Sample logs of wells in the Brunswick Formation—Continued

Well Mg-632—continued	
Shale, red, slightly calcareous	300 — 310
Shale, red, slightly calcareous; quartz and calcite joint filling	310 — 315
Siltstone, buff, moderately calcareous; red shale; quartz joint filling ..	315 — 320
Shale, red, slightly calcareous, micaceous; calcite joint filling	320 — 325
Shale, red, slightly calcareous, micaceous; calcite and quartz joint filling	325 — 330
Shale, red, slightly calcareous; calcite joint filling	330 — 335
Shale, red, micaceous; calcite and quartz joint filling	335 — 340
Shale, red, moderately calcareous; calcite and quartz joint filling	340 — 345
Shale, red, moderately calcareous; calcite joint filling	345 — 350
Shale, red, slightly calcareous; calcite joint filling	350 — 360
Shale, red, micaceous; calcite and quartz joint filling	360 — 363
Shale, red, moderately calcareous; calcite joint filling	363 — 370
Shale, red, slightly calcareous	370 — 375
Shale, red, slightly calcareous; calcite joint filling	375 — 379
Shale, green, moderately calcareous	379 — 381
Shale, red, slightly calcareous; calcite joint filling	381 — 385
Shale, red, slightly calcareous	385 — 405
Shale, red, slightly calcareous; calcite joint filling	405 — 425
Shale, red, slightly calcareous	425 — 450
Shale, red, slightly calcareous; calcite joint filling	450 — 460
Shale, red, slightly calcareous; calcite and quartz joint filling	460 — 465
Shale, red, slightly calcareous	465 — 470
Shale, red, slightly calcareous; calcite joint filling	470 — 475
Shale, red, moderately calcareous; calcite joint filling	475 — 480
Shale, red, slightly calcareous	480 — 490
Shale, red, moderately calcareous; calcite joint filling	490 — 500

Well Mg-633

Owner: U.S. Geological Survey

Description	Depth (feet)
Shale, red; quartz joint filling	0 — 5
Shale, red, slightly calcareous; calcite joint filling	5 — 20
Shale, red, moderately calcareous; calcite joint filling	20 — 25
Shale, red, slightly calcareous; calcite joint filling	25 — 30
Shale, red, moderately calcareous	30 — 35
Shale, red, moderately calcareous; calcite joint filling	35 — 40
Shale, red; calcite joint filling	40 — 45
Shale, red, slightly calcareous; calcite joint filling	45 — 55
Shale, red, slightly calcareous; goethite	55 — 60
Shale, red, slightly calcareous; calcite joint filling	60 — 70
Shale, red, slightly calcareous	70 — 90
Shale, red, moderately calcareous; calcite joint filling	90 — 100
Shale, red; calcite joint filling	100 — 105
Shale, red, slightly calcareous; abundant quartz and calcite joint filling. Quartz is in crystals up to half an inch long	105 — 108
Shale, red, slightly calcareous; calcite joint filling	108 — 110
Shale, red, slightly calcareous; abundant calcite joint filling	110 — 112
Shale, red, slightly calcareous; calcite and quartz joint filling and goethite	112 — 115

Table 7. Sample logs of wells in the Brunswick Formation—Continued

Well Mg-633—continued

Shale, red; calcite joint filling	115 — 118
Shale, red	118 — 120
Shale, red, slightly calcareous	120 — 123
Shale, red	123 — 125
Shale, red, moderately calcareous; calcite joint filling	125 — 128
Shale, red, slightly calcareous	128 — 138
Shale, red, slightly calcareous; calcite joint filling	138 — 140
Shale, red, slightly calcareous	140 — 142
Shale, red, slightly calcareous; calcite joint filling	142 — 148
Shale, red, slightly calcareous	148 — 150
Shale, red, slightly calcareous; calcite joint filling and goethite	150 — 152
Shale, red, slightly calcareous; calcite joint filling	152 — 165
Shale, red, slightly calcareous	165 — 168
Shale, red, slightly calcareous; calcite joint filling	168 — 170
Shale, red; calcite joint filling	170 — 172
Shale, red	172 — 175
Shale, red, moderately calcareous	175 — 178
Shale, red, moderately calcareous; calcite joint filling	178 — 185
Shale, red; calcite joint filling	185 — 205
Shale, red, slightly calcareous; calcite joint filling	205 — 210
Shale, red; calcite joint filling	210 — 212
Shale, red, slightly calcareous; calcite joint filling	212 — 215
Shale, red, slightly calcareous; calcite and quartz joint filling	215 — 220
Shale, red, slightly calcareous; calcite joint filling	220 — 225
Shale, red; calcite joint filling	225 — 230
Shale, red; calcite and quartz joint filling and goethite	230 — 232
Shale, red, moderately calcareous; quartz and calcite joint filling	232 — 233
Shale, red; calcite joint filling	233 — 235
Shale, red, moderately calcareous; calcite joint filling	235 — 237
Shale, red; calcite joint filling	237 — 240
Shale, red, slightly calcareous; calcite joint filling	240 — 243
Shale, red, slightly calcareous	243 — 245
Shale, red; calcite joint filling	245 — 263
Shale, red, slightly calcareous; calcite joint filling	263 — 270
Shale, red	270 — 275
Shale, red, slightly calcareous; calcite joint filling	275 — 278
Siltstone, red, moderately calcareous; calcite joint filling	278 — 280
Shale, red, slightly calcareous; calcite joint filling	280 — 283
Shale, red; calcite joint filling	283 — 288
Shale, red, slightly calcareous; calcite joint filling	288 — 290
Shale, red, slightly calcareous	290 — 295
Shale, red; calcite joint filling	295 — 300
Shale, red	300 — 302
Shale, red; calcite joint filling	302 — 307
Shale, red, slightly calcareous; calcite joint filling	307 — 310
Shale, red, moderately calcareous; calcite joint filling	310 — 312
Shale, red, slightly calcareous	312 — 314
Shale, red, slightly calcareous; calcite joint filling	314 — 325
Shale, red, slightly calcareous; quartz joint filling	325 — 327
Shale, red, slightly calcareous	327 — 330
Shale, red	330 — 335
Shale, red; calcite joint filling	335 — 348
Shale, red, slightly calcareous; calcite joint filling	348 — 350
Shale, red, slightly calcareous	350 — 355
Shale, red, slightly calcareous; calcite joint filling	355 — 358

Table 7. Sample logs of wells in the Brunswick Formation—Continued**Well Mg-633—Continued**

Shale, red; calcite joint filling	358 — 360
Shale, red, moderately calcareous	360 — 362
Shale, red, slightly calcareous; calcite and quartz joint filling	362 — 365
Shale, red; calcite joint filling	365 — 380
Shale, red, moderately calcareous	380 — 383
Shale, red, moderately calcareous, micaceous	383 — 385
Shale, red, slightly calcareous; calcite joint filling	385 — 390
Shale, red, slightly calcareous	390 — 392
Shale, red	392 — 395
Shale, red, slightly calcareous	395 — 402
Shale, red, moderately calcareous; calcite joint filling	402 — 405
Shale, red, slightly calcareous; calcite and quartz joint filling	405 — 408
Shale, red, moderately calcareous	408 — 410
Shale, red, slightly calcareous	410 — 412
Shale, red, slightly calcareous; calcite joint filling	412 — 415
Shale, red, moderately calcareous; calcite joint filling	415 — 417
Shale, red, slightly calcareous; calcite joint filling, pyrite and goethite	417 — 420
Shale, red, slightly calcareous	420 — 422
Shale, red, slightly calcareous; calcite joint filling	422 — 428
Shale, red, slightly calcareous	428 — 430
Shale, red	430 — 432
Shale, red, slightly calcareous; calcite joint filling	432 — 435
Shale, red, moderately calcareous; calcite joint filling	435 — 437
Shale, red, slightly calcareous; calcite joint filling	437 — 460
Shale, red; calcite joint filling	460 — 465
Shale, red; calcite joint filling, pyrite and goethite	465 — 467
Shale, red, slightly calcareous; calcite and quartz joint filling	467 — 470
Shale, red, slightly calcareous	470 — 473
Shale, red, slightly calcareous; calcite joint filling	473 — 497
Shale, red	497 — 500

Well Mg-679

Owner: Souderton Borough

Description	Depth (feet)
Shale, red	0 — 40
Shale, red, moderately calcareous; calcite joint filling	40 — 100
Shale, dark reddish-gray, slightly calcareous	100 — 110
Shale, red, slightly calcareous; calcite joint filling and pyrite	110 — 120
Shale, red, slightly calcareous; calcite joint filling	120 — 130
Shale, dark red, moderately calcareous	130 — 140
Shale, red, slightly calcareous; calcite joint filling	140 — 180
Argillite, blue-gray, slightly calcareous; calcite joint filling. Thin beds of red shale are in this interval	180 — 190
Argillite, blue-gray, moderately calcareous; calcite and quartz joint filling. About 4 feet of this interval is red shale	190 — 200
Sandstone, gray, very fine grained; calcite joint filling and pyrite	200 — 210
Argillite, blue-gray, moderately calcareous; calcite joint filling and pyrite	210 — 230
Argillite, blue-gray, slightly calcareous; pyrite and goethite	230 — 260

Table 7. Sample logs of wells in the Brunswick Formation—Continued

Well Mg-679—Continued	
Siltstone, blue-gray, slightly calcareous; pyrite	260 — 270
Argillite, blue-gray, moderately calcareous; pyrite. Red shale, moderately calcareous; calcite joint filling and pyrite	270 — 278
Argillite, blue-gray, moderately calcareous; pyrite	278 — 285
Shale, reddish-brown, moderately calcareous; About 4 feet of this interval is blue-gray, moderately calcareous argillite	285 — 308

Well Mg-700

Owner: Stanley G. Flagg, Inc.

Description	Depth (feet)
Fill	0 — 20
Sandstone, buff, fine grained. About half of this interval is red shale	20 — 30
Shale, red, micaceous	30 — 60
Shale, red	60 — 90
Shale, red, slightly calcareous; quartz joint filling	90 — 100
Shale, red, slightly calcareous	100 — 130
Shale, dark brown, slightly calcareous	130 — 140
Shale, red, slightly calcareous	140 — 150
Shale, red, moderately calcareous	150 — 160
Shale, red; calcite joint filling	160 — 170
Shale, red, slightly calcareous	170 — 190
Shale, red, moderately calcareous	190 — 200
Shale, red, moderately calcareous, micaceous; calcite joint filling	200 — 250
Shale, red, micaceous; calcite joint filling	250 — 260
Shale, red, slightly calcareous; calcite joint filling	260 — 280
Shale, gray-brown, slightly calcareous; micaceous; calcite joint filling	280 — 290
Shale, red, slightly calcareous; calcite joint filling	290 — 330
Siltstone, red, slightly calcareous; calcite joint filling	330 — 340
Shale, red, moderately calcareous	340 — 350
Shale, red, moderately calcareous; calcite joint filling	350 — 360
Siltstone, red, moderately calcareous; calcite joint filling	360 — 370
Shale, red, moderately calcareous; calcite joint filling	370 — 390
Shale, red, moderately calcareous; calcite and quartz joint filling	390 — 400
Shale, red, moderately calcareous; calcite joint filling	400 — 456
Sandstone, white, fine grained	456 — 461
Shale, red, moderately calcareous; calcite joint filling	461 — 480
Argillite, blue-gray, moderately calcareous, interbedded with about 3 feet of buff sandstone	480 — 500
Sandstone, light-brown, fine grained	500 — 510
Sandstone, light-brown, medium grained	510 — 520
Shale, brown, slightly calcareous, micaceous; calcite joint filling	520 — 530
Shale, brown, slightly calcareous, micaceous; quartz joint filling	530 — 540
Shale, red, moderately calcareous; calcite joint filling	540 — 560
Shale, red, moderately calcareous; calcite and quartz joint filling	560 — 600
Shale, red, slightly calcareous; calcite joint filling	600 — 610
Shale, red, moderately calcareous; calcite joint filling. About 1 foot of this interval is buff, fine grained sandstone	610 — 620
Shale, red, moderately calcareous; calcite joint filling	620 — 640

Table 7. Sample logs of wells in the Brunswick Formation—Continued

Well Mg-704

Owner: Lansdale Municipal Authority

Description	Depth (feet)
Shale, red	0 — 10
Shale, red, slightly calcareous; calcite joint filling	10 — 20
Shale, red	20 — 40
Shale, red, slightly calcareous	40 — 50
Shale, red, slightly calcareous; calcite joint filling	50 — 70
Shale, red, moderately calcareous; calcite joint filling	70 — 80
Shale, red, slightly calcareous; calcite joint filling	80 — 140
Shale, red, moderately calcareous; calcite joint filling	140 — 190
Shale, red, slightly calcareous; calcite joint filling	190 — 200
Shale, red, slightly calcareous; calcite joint filling and pyrite	200 — 210
Shale, red, slightly calcareous; calcite joint filling	210 — 220
Siltstone, red, slightly calcareous; goethite	220 — 230
Argillite, blue-gray to greenish-gray, slightly calcareous; calcite joint filling and goethite	230 — 240
Shale, gray-brown, slightly calcareous; calcite joint filling and goethite ..	240 — 250
Shale, red, moderately calcareous; calcite joint filling and goethite ..	250 — 260
Shale, red, moderately calcareous; calcite joint filling	260 — 290
Shale, red, slightly calcareous; calcite joint filling, pyrite and goethite ..	290 — 310
Shale, red, slightly calcareous; calcite joint filling	310 — 330
Argillite, blue-gray, moderately calcareous; calcite joint filling and pyrite	330 — 360
Argillite, blue-gray, moderately calcareous; calcite joint filling and goethite	360 — 370

Well Mg-725

Owner: Schwenksville Water Co.

Description	Depth (feet)
Shale, red, slightly calcareous; calcite joint filling	0 — 20
Shale, red, slightly calcareous; quartz joint filling, pyrite and goethite ..	20 — 30
Shale, red, moderately calcareous; calcite joint filling, pyrite and goethite	30 — 40
Shale, red, slightly calcareous; joint filling	40 — 50
Shale, red, a few green spots, moderately calcareous	50 — 60
Shale, red, moderately calcareous. About 4 feet of this interval is purplish-brown	60 — 70
Shale, red, slightly calcareous; calcite joint filling	70 — 80
Shale, red, moderately calcareous; calcite and quartz joint filling	80 — 90
Shale, red, slightly calcareous; quartz joint filling	90 — 100
Shale, red, moderately calcareous; calcite joint filling	100 — 110
Shale, red, slightly calcareous; calcite and quartz joint filling	110 — 120
Shale, red, slightly calcareous; calcite joint filling	120 — 150
Shale, red, slightly calcareous	150 — 160
Shale, red, slightly calcareous; calcite joint filling	160 — 180

Table 7. Sample logs of wells in the Brunswick Formation—Continued**Well Mg-725—Continued**

Shale, red, slightly calcareous; calcite and quartz joint filling	180 — 190
Shale, red, slightly calcareous; calcite joint filling	190 — 200
Shale, red, moderately calcareous; calcite and quartz joint filling	200 — 210
Shale, red, moderately calcareous; calcite joint filling	210 — 220
Shale, red, slightly calcareous; calcite joint filling	220 — 240
Shale, red; calcite joint filling	240 — 250
Shale, red, slightly calcareous; calcite joint filling	250 — 290
