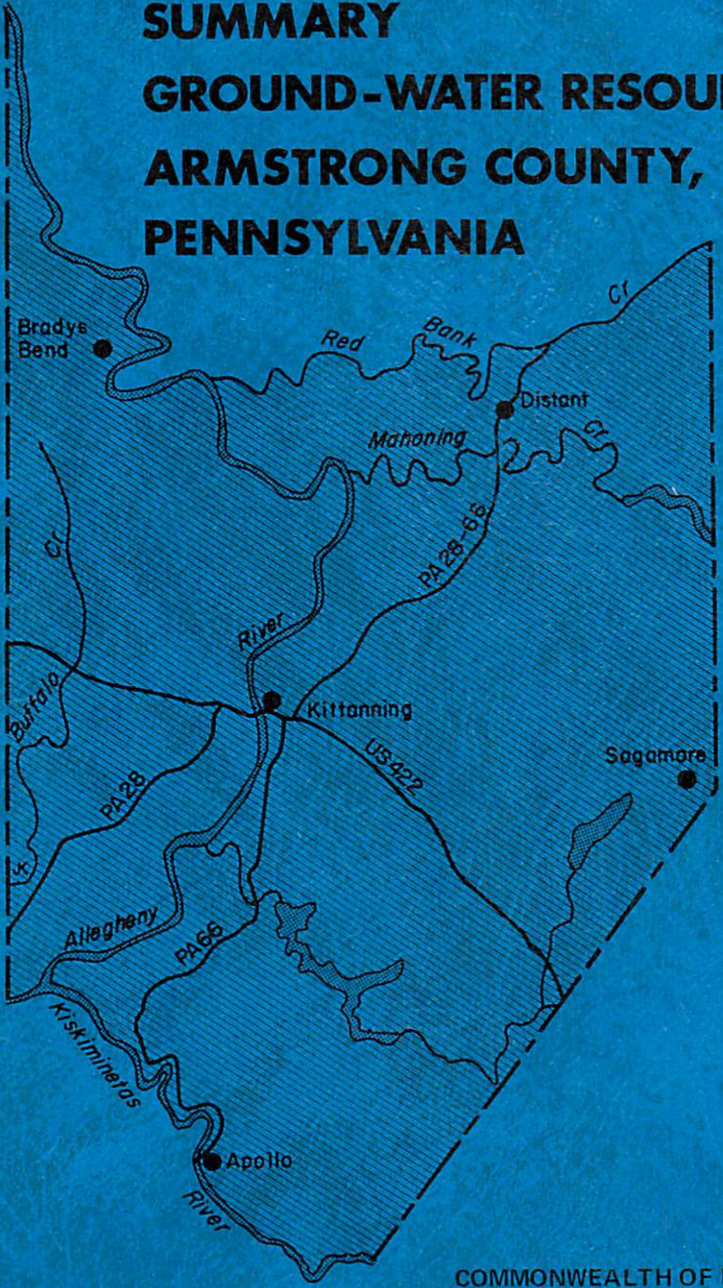
Water Resource Report 34

1973

SUMMARY GROUND-WATER RESOURCES OF ARMSTRONG COUNTY, PENNSYLVANIA



by Charles W. Poth

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL RESOURCES
BUREAU OF
TOPOGRAPHIC AND GEOLOGIC SURVEY
Arthur A. Socolow, State Geologist

Water Resource Report 34

SUMMARY
GROUND-WATER RESOURCES OF ARMSTRONG COUNTY, PENNSYLVANIA

by Charles W. Poth
U. S. Geological Survey

Prepared by the United States Geological Survey, Water Resources Division, in cooperation with the Pennsylvania Geological Survey

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PREFACE

This report is presented as a comprehensive description and inventory of the ground-water resources available in Armstrong County. With the continuing growth of our population and the expansion of our industries, there is an ever increasing rise in demand for quality water resources. Ground water, or subsurface water, constitutes one of the largest reserves of quality water remaining to be developed.

This report can be of assistance to anyone who is planning for future water needs. It will help to evaluate the quantity and quality of ground water available in any part of the county, and it will aid in choosing the locations, depths and conditions most favorable for the desired ground-water yield.

While this publication has attempted to include all available ground-water data for the county, the Pennsylvania Topographic and Geologic Survey will continue to collect ground-water and water well data for the area; such data will be kept on file at the Survey offices in Harrisburg, available to anyone who desires the very latest information.

We hope that this report will aid users of water in Armstrong County to develop and manage their water resources so as to accommodate their water needs.

ARTHUR A. SOCOLOW

CONTENTS

ILLUSTRATIONS

FIGURES

PLATE

TABLES

SUMMARY GROUND-WATER RESOURCES OF ARMSTRONG COUNTY, PENNSYLVANIA

by

Charles W. Poth

ABSTRACT

Ground water occurs in Armstrong County in unconsolidated deposits along the stream valleys, especially the Allegheny River, and in fractures in the bedrock. Yields of wells in the unconsolidated deposits average about 400 gpm (gallons per minute) and yields as high as 1,100 gpm have been reported. Wells drilled into the bedrock yield considerably less water than those in the unconsolidated material. The average yield of wells in the bedrock is about 25 gpm, although some wells yield less than 1 gpm and some as much as 350 gpm.

Chemical analyses of ground water in Armstrong County show that the water is generally hard and high in calcium, magnesium, sulfate, and iron. Water from deeply buried rocks is also high in chloride.

There is no known overdraft of ground water anywhere in Armstrong County, but overdraft is possible in future expansion of well fields or where additional large ground-water supplies are needed.

The locations of sources of pollution, such as sanitary landfills and septic tanks, are a major factor in the selection of well sites. The chief water problem in Armstrong County is contamination of water resources by drainage from coal-mining operations. Other sources of contamination are the hundreds of oil and gas wells that were abandoned but not properly plugged. The casings have been removed or are severely corroded, allowing salt water to rise in the boreholes and contaminate shallow freshwater aquifers.

INTRODUCTION

PURPOSE AND SCOPE

This report is part of a program to summarize the ground-water resources of Pennsylvania in a series of county reports that will be easy to read and suitable for widespread distribution. It contains a general description of the aquifers in the county, a geologic map, a well location map, and data on the depth and yield of wells and the chemical quality of ground water.

LOCATION AND GENERAL GEOGRAPHIC FEATURES

Armstrong County encompasses an area of about 650 square miles in west-central Pennsylvania (Figure 1). The county is bordered on the north by Clarion County, on the east and south by Jefferson, Indiana, and Westmoreland Counties, and on the west by Butler County. Kittanning, the county seat, is about 50 miles northeast of Pittsburgh and 200 miles northwest of Harrisburg.

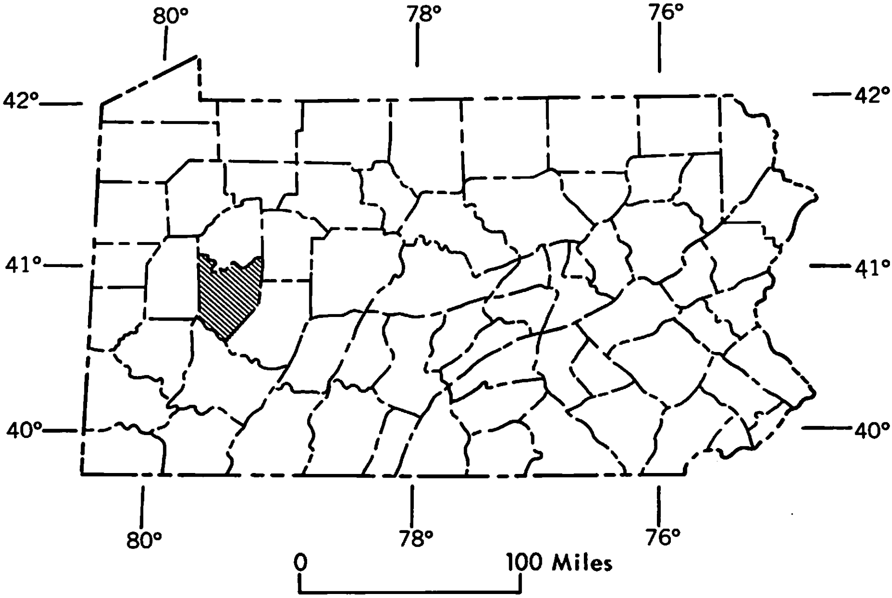


Figure 1. Location of Armstrong County.

POPULATION TRENDS

The total population of Armstrong County has changed very little in the last 50 years, as may be seen in Table 1. During this period, the population increased from about 75,000 in 1920 to about 81,000 in 1940 and has declined since then, so that by 1970 the population was about the same as it was in 1920. The 1970 population density in the county was about 115 persons per square mile.

Table 1. *Population of Armstrong County, Pennsylvania, 1920-1970*

Year	Population
1920	75,568
1930	79,298
1940	81,087
1950	80,842
1960	79,524
1970	75,590

LANDFORMS

Armstrong County is in the central part of the Appalachian Plateaus province. Its surface is characterized by rounded hills and steep-sided valleys. Flat upland surfaces are rare and, where present, are very small. Flood plains, too, are rare and consist of a few short, discontinuous, narrow strips along the Allegheny River and some of its tributaries.

The Allegheny River flows generally southward across the county and is entered from the east by most of its tributaries (Plate 1). The principal tributaries entering from the east are (from north to south) Red Bank Creek, Mahoning Creek, Pine Creek, Cowanshannock Creek, Crooked Creek, and the Kiskiminetas River. The principal tributaries entering from the west are Glade Run and Buffalo Run.

The highest point in the county is on the Jefferson County border, 2 miles north of Pine Run, and is more than 1,740 feet above sea level. The lowest part of the county is along the Allegheny River at Freeport at an altitude of about 745 feet. In places the steep walls of the Allegheny River valley rise about 500 feet above the river.

LAND USE IN THE 1960'S

Data from the Armstrong County Planning Commission's Sewer and Water Plan report show that about 4 percent of the land in the county is used for residential, commercial, or industrial (except mining or extractive industrial) purposes, or for streets and railroads. The chief manufactured goods are products of stone, clay, glass, or wood, and food and related items. All these products reflect a heavy reliance on the local natural resources of the county.

Another 4 percent of the land is used by the extractive industries. Chief of these, of course, is coal mining. Sand-and-gravel dredging, and clay (and formerly limestone) quarrying are also important extractive industries, as are the oil and gas production industries.

About 37 percent of the land is being farmed. The acreage devoted to farming is gradually decreasing, however, as unprofitable land is abandoned and as the suburbs of cities continue to expand. The principal crops are dairy products, poultry, beef, swine, and grain.

Unused land, either open or wooded, makes up the largest (52 percent) category in the county. Some of this land is abandoned marginal agricultural land, and most of it is on steep hillsides.

The remaining 3 percent of the county is composed of public or semipublic land and large bodies of water. The land includes three state game lands, a state park and flood-control reservoir, a county park, and two federal reservoirs.

WHERE THE WATER COMES FROM

HYDROLOGIC CYCLE

Water is one of our most important resources and it constitutes the major part of most living things. Man's existence depends upon it, yet water supplies are taken for granted by most individuals. As shown in Plate 2, water evaporates from the oceans and is carried as vapor until it condenses and falls as precipitation. Most of the precipitation that falls on the land either is used by vegetation, evaporates back to the atmosphere, or runs overland as streamflow. Part enters the soil and bedrock to recharge water-bearing formations, called aquifers. The water moves at a varying pace, depending on its environment, but eventually it returns to the oceans.

If man interrupts or changes the hydrologic cycle he may cause undesirable effects that may last for many years. Man-made changes in the hydrologic cycle in Armstrong County are discussed later in the report.

PRECIPITATION

Precipitation is the source of all fresh water in the county. The average yearly precipitation is 43 inches at Putneyville and 40 inches at Ford City (U.S. Department of Commerce Environmental Data Service). Not all the water in the streams, however, is from precipitation that has fallen on the county, as some streams carry runoff from areas outside the political boundaries.

Precipitation is usually distributed evenly throughout the year. The summer has a little more rainfall than the other seasons. Much of the summer rain comes as intense thundershowers of short duration. About one-tenth of the total precipitation comes as snow.

WHERE THE WATER GOES

EVAPOTRANSPIRATION

Evapotranspiration is a collective term describing the return, through the sun's energy, of water to the atmosphere as vapor. In the process of transpiration, soil moisture returns to the atmosphere as a by-product of plant growth. In the evaporation process, water changes directly from a liquid to a vapor. The total annual water loss from Armstrong County by both evaporation and transpiration is about 18 inches. The evaporation rate from free water surfaces, however, such as the Mahoning Creek Reservoir or the Crooked Creek Reservoir, is greater than the combined evapotranspiration rate from other surfaces. Measurements of evaporation from a free water surface by the U.S. Weather Bureau at their station at Ford City show an average annual evaporation of about 28 inches. Direct measurements of transpiration have not been made.

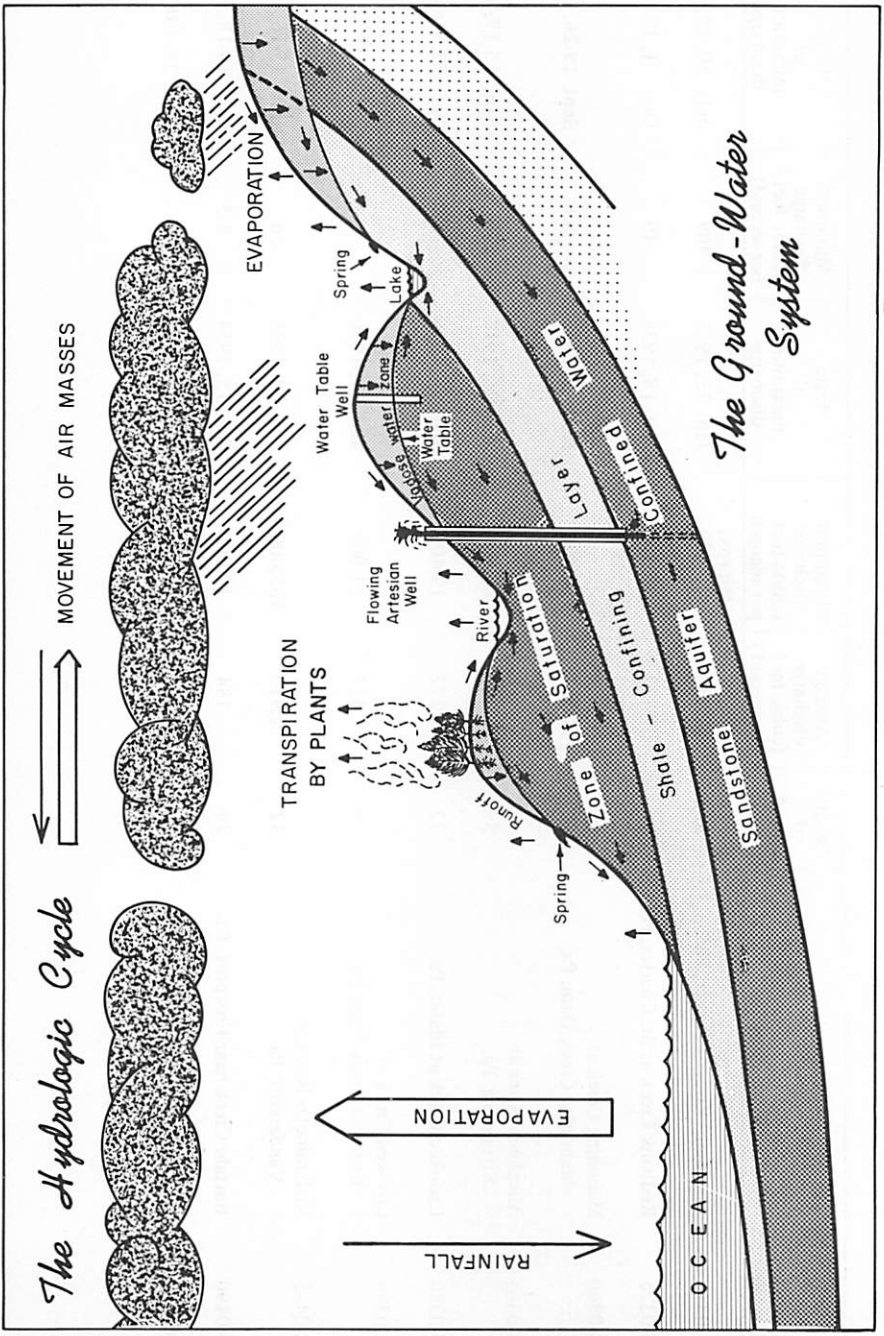


Figure 2. Hydrologic cycle showing movement of water from ocean to land and back to ocean.

Table 2. *Discharge Data for the Gaged Streams in Armstrong County, Pennsylvania*

Station Number	Location	Length of record (years)	Average discharge (cubic feet per second)	Maximum discharge (cubic feet per second)	Date of maximum discharge	Minimum discharge (cubic feet per second)	Date of minimum discharge
3-0315	Allegheny River at Parker, Pa.	37	12,830	Approx. 175,000	Jan. 22, 1959	409	July 30, 1934
3-0325	Redbank Creek at St. Charles, Pa.	51	832	35,200	Mar. 18, 1936	19	Oct. 1, 1918
3-0360	Mahoning Creek at Mahoning Creek Dam, Pa.	31	561	10,400	Mar. 8, 1942	8.8	Sept. 19-26, 1959
3-0365	Allegheny River at Kittanning, Pa.	59	15,340	269,000	Mar. 26, 1913	570	Sept. 15-17, 1913
3-0380	Crooked Creek at Idaho, Pa.	32	272	19,400	Mar. 1936	1.0	Oct. 22, 1966
3-0390	Crooked Creek at Crooked Creek Dam, Pa.	60	415	21,000	Mar. 18, 1936	.1	Sept. 8, 11, 20, 25, 26, 1932
3-0485	Kiskiminetas River at Vandergrift, Pa.	32	2,913	185,000	Mar. 18, 1936	56	Oct. 15-16, 1952
3-0490	Buffalo Creek near Freeport, Pa.	29	184	14,000	Oct. 15, 1954	1.3	Oct. 16-18, 1960
3-0495	Allegheny River at Natrona, Pa.	31	18,690	365,000	Mar. 18, 1936	895	Oct. 22, 1963

STREAMFLOW

Most of the water not lost through evapotranspiration leaves the county as discharge from streams. This discharge accounts for about 22 inches of the original precipitation on the area. The larger streams and the locations of gaging stations that measure streamflow in Armstrong County are shown in Plate 1. Identification numbers are those assigned by the U.S. Geological Survey. A summary of discharge data for the gaging stations is given in Table 2. More detailed information on streamflow can be obtained from *Water Resources Data For Pennsylvania, Part 1, Surface Water Records (1969).*

GROUND WATER

Much of the precipitation on the land surface returns to the atmosphere or reaches the streams as overland runoff. Part infiltrates through the soil and through fractures and other void spaces in the underlying rock. Its downward movement continues until it reaches the water table, below which all the interconnected voids are filled with water. This is illustrated in Figure 3. After reaching the zone of saturation, the water moves downward and laterally toward lower altitudes and eventually returns to land surface, either from springs or from wells.

Ground water occurs under both water-table and artesian conditions. Water-table conditions are those in which ground water is unconfined, and the upper surface of the water, or water table, is free to rise or fall. Artesian conditions

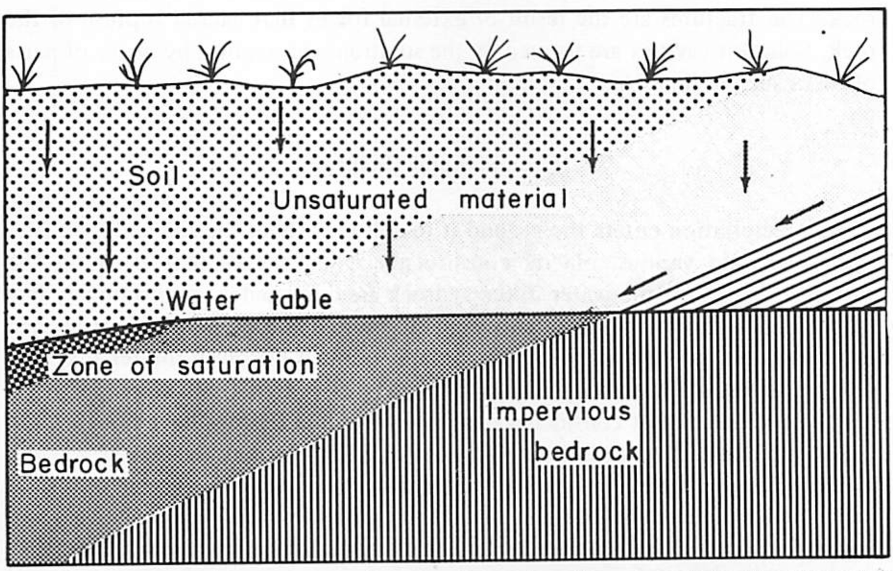


Figure 3. Downward movement of water through soil and rock to the water table.

exist where the ground water is confined in a permeable (having interconnected openings) rock that is overlain by a relatively impermeable rock. The upper surface is not free to rise or fall, but the water is under enough pressure to rise above the containing aquifer in wells that penetrate the aquifer. The imaginary surface to which water will rise in wells tapping an artesian aquifer is called the artesian or confined potentiometric surface.

The water table fluctuates according to the relative amounts of recharge (additions to the aquifer) and discharge (losses through springs and wells). Because large evapotranspiration losses occur during the growing season (April to October), very little recharge reaches the zone of saturation during that period, and water levels decline. Water levels generally rise throughout the rest of the year. A hydrograph of a well near Freeport is shown in Figure 4. This hydrograph illustrates the changes in ground-water levels from 1949 through 1971.

Water levels in the county are at or near the land surface in the valleys and rise to higher levels under the hilltops and ridges. The rate of water-level rise, however, is less than that of the land surface, so depths to water at the higher altitudes are greater than those in the valleys. Because wells drilled in valleys generally encounter water at shallower depths than wells drilled on hills, they have more available drawdown than a hill well of the same depth and are less likely to go dry during a drought.

Ground water occurs in and moves through interconnected openings in rocks (Figure 5) either of primary or secondary origin. Primary openings are the spaces between individual grains, and occur chiefly in unconsolidated material. Secondary openings are those formed after the consolidation and cementation of the sediments into rock, and usually result from the fracture or solution of the rock. The fractures are the result of external forces that caused rupture of the rock. Solution cavities are formed by the solution and removal by water of parts of rocks such as limestone.

Ground-Water Quality

As precipitation enters the ground it dissolves parts of the soil and rock and, thus, picks up various mineral constituents. The changes that occur in the chemical quality of the water in the bedrock are discussed more thoroughly in a later section. Ground water usually contains more dissolved mineral matter than surface water and occasionally may contain so much dissolved matter that it is not fit to drink. Water containing more than 500 mg/l (milligrams per liter) dissolved solids is not considered desirable for domestic supplies, though more highly mineralized water is used where better water is not available. The soil and rocks through which the ground water percolates tend to screen out solid suspended materials and bacteria so that the ground water is generally clear and has fewer bacteria than surface water. The temperature of ground water is fairly uniform throughout the year.

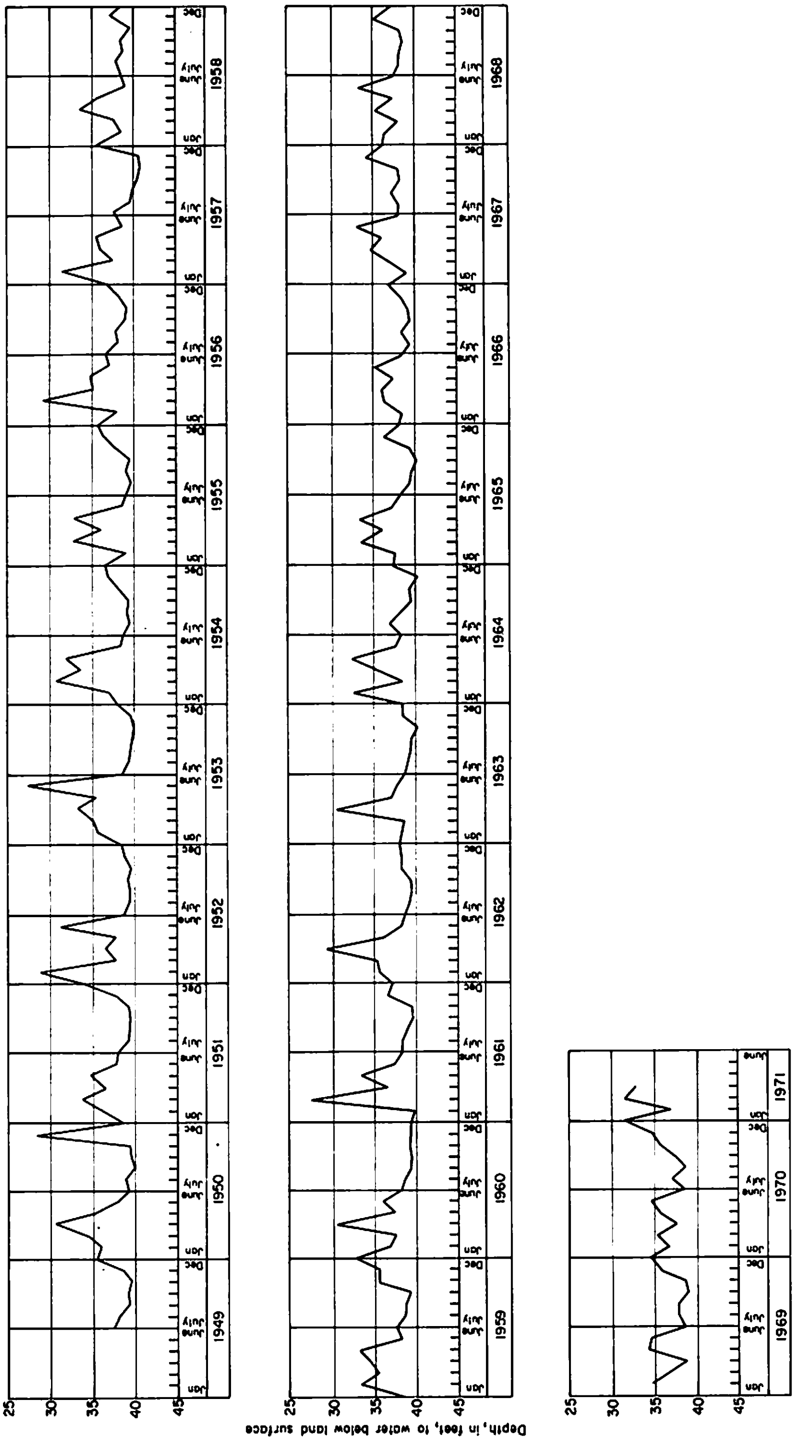
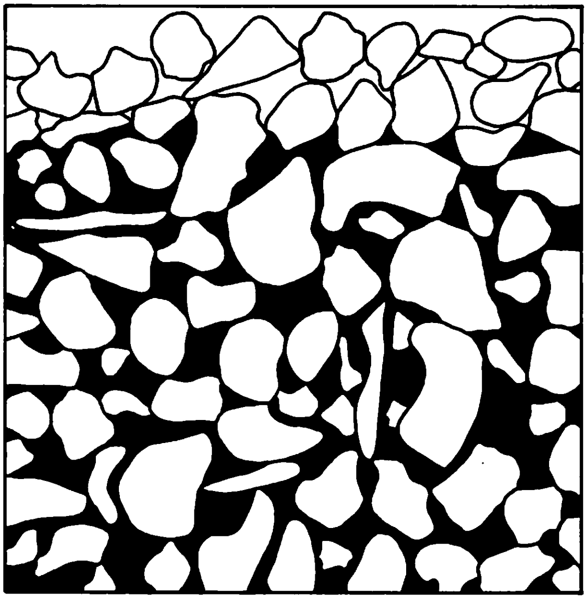


Figure 4. Hydrograph of Well Ar-2, near Freeport, Pennsylvania.



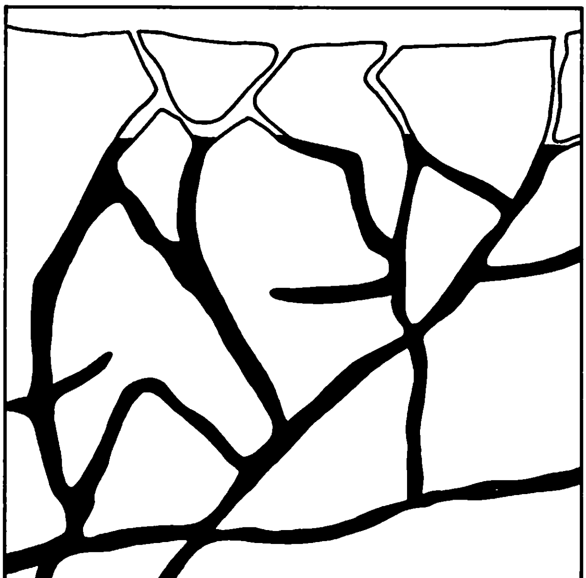


Figure 5. How water occurs in the rocks.

Analyses of ground water from Armstrong County are listed in Table 3a. Half the samples are from wells drilled in the alluvium (unconsolidated material) and half are from wells drilled in bedrock (five in sandstone, one in shale). High iron content is the main water-quality problem encountered by most users of ground water in the county. The water from the alluvium is low in iron, but that from the bedrock generally is high in iron. Analyses of water in the Allegheny River at Kittanning are given in Table 3b for comparison with the ground-water analyses.

HOW AND WHERE GROUND WATER IS FOUND

Ground water in Armstrong County occurs under both artesian and water-table conditions. Reported well yields range from 2 to 1,100 gpm (gallons per minute). Data on about 70 wells drilled in the several geologic formations that underlie the county are listed in Table 4. Plate 1 shows the locations of the wells.

A summary of the water-bearing characteristics of the geologic units in Armstrong County follows. The areal extent of the unconsolidated units and the bedrock units in the county is shown in Plate 1. Sample logs of several wells are shown in Table 5. These sample logs are representative of the variety of rocks encountered in drilling in this county. A composite stratigraphic section for the county is presented in Table 6.

ALLUVIUM

Origin and Lithology

The alluvium is an unconsolidated, heterogeneous mixture of clay, silt, sand, and boulders. It is present along stream valleys of Armstrong County in deposits of different ages that owe their origin either directly or indirectly to the glaciers that blanketed parts of Pennsylvania thousands of years ago. The glaciers did not reach Armstrong County, but water produced by the melting ice sheet carried large quantities of glacial debris into the county and deposited it in the valleys of the major streams. Tributaries to these streams built up their valley floors by depositing their sediment load and, as a result, could continue to discharge their water into the major streams. Later, the streams removed most of the material and cut deeper into their bedrock floors. The alluvial material was left only as discontinuous terraces along the valley walls. Successive glaciations resulted in successive periods of sediment deposition and subsequent deeper entrenchment. The oldest terraces are the ones highest above the present valley floor. The alluvium forming the flood plains along the Allegheny River and its tributaries is post-glacial in origin.

Terraces have been mapped at four different levels above the river; the highest are 350 to 400 feet above the present stream valleys. The alluvium in the terraces may be as thick as 130 feet, but is commonly less than 25 feet. It is coarsest at the base of the deposit.

Table 3a. *Chemical Analyses of Ground Water in Armstrong County*

(Results in milligrams per liter (mg/l) except specific conductance and pH)

Aquifer: Alluvium, Qal; Allegheny Group, Ꝑa; Conemaugh Group, Ꝑc; Greeport Formation, Ꝑaf; Kittanning Formation, Ꝑak.

Well Number	Aquifer	Date of sampling	Silica (SiO_2)	Total iron (Fe)	Calcium (Ca)	Calcium and Magnesium[1]	Magnesium (Mg)	Sodium (Na)	Sodium and Potassium[2]	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids: Residue at 180°C	Dissolved solids: Sum	Hardness as $CaCO_3$, Laboratory: Calcium, magnesium	Hardness as $CaCO_3$, Laboratory: Noncarbonate	Specific conductance (micromhos at 25°C)	pH
Ar- 9	Qal	Oct. 1929	30	0.12	124		21	22		4.0	170	259	27	4.7	601	576	396	257	--	--
15	Qal	Nov. 1946	14	--	140		25		177		240	251	270	--	--	995	453	256	--	7.1
16	Qal	Oct. 1929	15	.08	190		26	51		7.2	292	331	59	33	881	856	582	342	--	--
17	Qal	Oct. 1929	15	.05	100		13	19		4.5	207	98	31	23	399	406	303	134	--	--
17	Qal	Nov. 1946	16	--	138		25		18		260	191	53	--	--	569	448	235	--	7.2
18	Qal	June 1964	13	Trace	134		17		69		287	55	185	--	760	614	405	170	--	7.2
34	Ꝑak	Oct. 1929	25	.05	6.4		1.5	173		3.5	227	5.4	129	.4	445	456	22	0	--	--
35	Ꝑak	Oct. 1929	-	--	1.0		--		128		249	2	33	.75	--	290	1	0	--	--
39	Ꝑaf	Oct. 1929	-	8.89	54		28		30		94	227	1.5	.0	--	399	250	173	--	--
40	Ꝑaf	Feb. 1927	-	2.00		36			.5		106	.2	1	.4	146	90	90	3	--	6.7
40	Ꝑaf	Oct. 1929	8.4	3.30	71		13	1.7		3.8	108	129	1.5	.1	292	282	231	142	--	--
67	Ꝑc	Nov. 1926	-	.3		68			81		285	8	73	1.3	450	--	170	0	--	7.8
72	Ꝑa	Oct. 1964	-	.02		54			4		136	25	3.5	--	159	154	134	23	277	7.0
73	Qal	Oct. 1964	-	.05		107			16		209	86	30	--	392	342	268	97	622	6.9

[1] Combined calcium and magnesium weights were computed from the calcium, magnesium hardness, and reported as calcium.

[2] Combined sodium and potassium weights were determined by subtracting the combined equivalence of all other metallic constituents from the total equivalence of the non-metallic constituents and then converting the difference to milligrams per liter of sodium.

Table 3b. *Chemical Analyses of the Allegheny River at Kittanning, Station 3-0365*

(Results in milligrams per liter (mg/l) except specific conductance and pH)

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Sodium and Potassium[1]	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium magnesium	Hardness as $CaCO_3$: Non-carbonate	Specific conductance (micromhos at 25°C)	pH	Color
Oct. 1-10, 1966	1,990	2.5	0.00	0.00	39	10	28		3.0	55	91	44	0.2	0.9	266	139	94	413	6.9	3
Nov. 1-8	4,340	.4	.00	.00	39	9.5	31		2.5	69	66	52	.1	.4	246	137	80	412	7.0	2
Dec. 1-10	27,770	–	––	––	–	––		12		27	46	18	–	1.9	––	70	48	207	6.5	10
Jan. 1-10, 1967	6,560	–	––	––	–	––		15		39	58	22	–	2.1	––	92	60	261	6.8	4
Feb. 1-10	22,500	–	––	––	–	––		13		20	41	16	–	8.7	––	61	45	176	6.5	3
Mar. 1-10	13,450	–	––	––	–	––		8.5		23	59	16	–	1.8	––	86	67	227	6.9	5
Apr. 1-10	34,220	–	––	––	–	––		9.0		21	36	13	–	1.6	––	55	38	161	6.3	4
May 1-10	20,520	–	––	––	–	––		6.9		24	44	12	–	.6	––	68	49	165	7.0	4
June 1-10	6,050	–	––	––	–	––		9.0		29	51	12	–	.5	––	75	51	209	6.8	2
July 1-10	5,200	–	––	––	–	––		14		42	45	18	–	.8	––	77	43	223	7.1	3
Aug. 1-10	11,170	–	––	––	–	––		9.7		42	34	13	–	1.6	––	69	35	184	6.8	9
Sept. 11-20	5,650	–	––	––	–	––		15		48	39	21	–	.8	––	78	39	229	7.0	8

[1] Combined sodium and potassium weights were determined by subtracting the combined equivalence of all other metallic constituents from the total equivalence of the non-metallic constituents and then converting the difference to milligrams per liter of sodium.

Table 4. *Record of Wells in Armstrong County*

Well number: Identification number that relates record in this table to well's location on map. The letter "S" following number indicates the record was obtained from the Pennsylvania Geological Survey.
Location: The number is the coordinates in degrees and minutes of the southeast corner of a 1-minute quadrangle within which the well is located.
Use: H, domestic; N, industrial; P, public supply; T, institutional; U, unused.
Topographic setting: H, hilltop; S, slope; V, valley; W, hillside drainageway.
Aquifer: Qa, alluvium; Ꝑc, Conemaugh Group; Ꝑcm, Mahoning Sandstone; Ꝑa, Allegheny Group; Ꝑaf, Freeport Formation; Ꝑak, Kittanning Formation; Ꝑac, Clarion Formation; Ꝑp, Pottsville Group; Ꝑph, Homewood Formation; Ꝑpc, Connoquenessing Formation.
Lithology: gv, gravel; ls, limestone; sdgv, sand and gravel; ssh, sandy shale; sh, shale; ss, sandstone.
Static water level: F, flowing.
Pumping data: gpm, gallons per minute; dd, drawdown; ft, feet; hr, hours.
Hardness: gpg, grains per gallon.

Well	Location	Owner	Driller	Date Completed	Use	Altitude of Land Surface (feet)	Topographic setting	Aquifer/ Lithology	Total Depth Below Land Surface (feet)	Casing: Depth (feet)	Casing: Diameter (inches)	Depth(s) to Water-Bearing Zone(s) (feet)	Static Water Level: Depth Below Land Surface (feet)	Static Water Level: Date Measured	Pumping Data: Yield (gpm)	Pumping Data: dd (feet)	Pumping Data: Time (hours)	Hardness (gpg)	Specific Conductance (micromhos at 25°C)	pH
Armstrong County																				
Ar- 1	4054-7813	Mathews, Harry V.			U	1140	S	Ꝑa/SS	29		40		22	Aug. 1936						
2	4040-7939	Cordera, Martin	Baker	1923	U	780	V	Qa/sdgv	82		6		39	May 1949	12	1	0.27	19	1230	7.45
3	4105-7940	Wightman Bottle & Glass Mfg. Co.	Bony Eddinger	1934	N	920	V	Qa/sdgv	65		10		30		200			3	347	7.1
4	4158-7941	Western Allegheny RR Co.			N	1200	V			120	10									
5	4050-7937	Worthington Pure Water Co.		1928	P	1180	H	Ꝑaf/ss	80		6		50							
6	4050-7938	Aluminum Ladder Co.	R. C. Hall	1944	H	1070	V	Ꝑak/ss	96		4		60					1	105	9.07
7	4049-7939	Pittsburgh Limestone Co.	F. N. Zeigler	1927	N	1080	S	Ꝑak/ssh	300		6	55, 135, 247								
8	4049-7839	Kittanning Asphalt Products Co.		1939	N	980	V	Ꝑac/ls	18		60		8		25					
9	4048-7931	Applewold Borough	F. N. Zeigler		P	800	V	Qa/sdgv	44	44	10		10							
10	4048-7931	Applewold Borough	F. N. Zeigler		P	790	V	Qa/sdgv	37	37	10		10							
10S	4057-7941	Brownley, Irene	Ralph L. Ellenberger	1967	H	1440	H	Ꝑc/ss	128	22	6	50	45		5					
11	4048-7931	West Kittanning Borough		1936	P	790	V	Qa/sdgv	30		10		18	June 1949	140					
11S	4057-7939	Deets, Charles	Ralph L. Ellenberger	1967	H	1260	S	Ꝑa/ss	250	23	7	225	200	July 1967	20	0				
12	4048-7931	West Kittanning Borough		1936	P	790	V	Qa/sdgv	35		10		23	June 1949	140					
12S	4100-7939	Hicks, Walter	Paul E. Hicks	1967	H	1360	S	Ꝑc/ss	61	28	7	54	41	Sept. 1967	25					
13	4048-7931	Meadow Gold Dairies	Olfrey Heilman	1926	N	780	V	Qa/sdgv	42		10		22		150	14				
14	4047-7940	West Penn Power Co.	Olfrey Heilman		N	800	V	Qa/sdgv	60		5		10		10					

15	4046-7932	Eljer Co.	J. K. Shaw	1944	N	790	V	Qa/sdgv	65		10		15	1944	120		
16	4046-7932	Ford City Borough		1921	P	790	V	Qa/gv	58	40	24		32	Sept. 1922	846	10	120
17	4046-7931	Ford City Borough		1922	P	790	V	Qa/gv	68	68	24		19	Aug. 1945	846	13	
18	4046-7931	Ford City Borough		1950	P	790	V	Qa/sdgv	52	42	24		20	Aug. 1950	703,	21,	8
19	4045-7932	Pittsburgh Plate Glass Co.		1940	N	790	V	Qa/sdgv	30	20	12		15	July 1940	173	2	
20	4057-7927	Lee Coal Co.		1947	P	1320	W	Pph/ss	100		4						
21	4057-7920	Seminole Water Co.			P	1420	S	Pcm/ss	133	30	8		80		4		
22	4054-7927	Milliron, R. M.		1920	P	830	V	Ppc/ss	52		8		20	1947	50		
23	4054-7927	Milliron, R. M.		1930	P	830	V	Ppc/ss	52		6		20	1947	50		
24	4052-7923	People's Natural Gas Co.		1905	N	1080	V	Ppc/ss	105	21	6		5		36		
25	4052-7923	People's Natural Gas Co.		1905	H	1080	V	Ppc/ss	86	39	6		24		13		
26	4048-7929	Armstrong County Home	Olfrey Heilman	1931	H	990	S	Pak/ss	197		8		50		10		
27	4048-7929	Armstrong County Home	Olfrey Heilman	1937	H	980	S	Pak/ss	131	14	8		10		10		
28	4047-7921	People's Natural Gas Co.		1905	N	1120	V	Pak/ss	78	33	6		11	July 1949	30	30	
29	4047-7921	People's Natural Gas Co.		1905	N	1110	V	Pak/ss	86	38	6		7	1948	45		
30	4046-7922	Kovalchick Salvage Co.			P	1180	W	Pak/ss	235		8				20		
31	4048-7920	Kovalchick Salvage Co.			P	1120	W	Pak/ss	250		8				40		
32	4048-7920	Kovalchick Salvage Co.			P	1120	V	Pak/ss	250		8				40		
33	4048-7919	Kovalchick Salvage Co.	Glenn Schaefer	1938	P	1160	W	Pak/ss	112		8				20		
34	4047-7919	Rural Valley Borough	Wesley Milliron	1906	P	1120	V	Pak/ss	311	125	8		45		25		
35	4047-7919	Rural Valley Borough	Wesley Milliron	1931	P	1110	V	Pak/ss	210		8		45		15		
36	4048-7919	Rural Valley Borough	Olfrey Heilman	1940	P	1140	V	Pcm/ss	60	20	8		30	Dec. 1940	5		
37	4048-7919	Rural Valley Borough	Olfrey Heilman	1940	P	1140	V	Pcm/ss	62		6		25	Dec. 1940	5		
38	4047-7917	Kovalchick Salvage Co.			P	1125	V	Pak/ss	215		4				50		
39	4052-7914	Dayton Borough	Wesley Milliron	1920	P	1320	V	Paf/ss	129	30	10		16	1948	69		
40	4052-7914	Dayton Borough	Wesley Milliron	1928	P	1320	V	Paf/ss	130	30	10	85, 110	18		75		
41	4046-7913	Kovalchick Salvage Co.			P	1100	V	Pak/ss	180		8		59	May 1949	240		
42	4046-7913	Kovalchick Salvage Co.			P	1100	V	Pak/ss	160		8		58	May 1949			
43	4044-7935	Joseph Finch & Co.		1938	N	790	V	Qa/sdgv	54		12		12		150		
44	4044-7935	Joseph Finch & Co.		1943	N	790	V	Qa/sdgv	72		12		12		500	12	
44S	4039-7936	McYntyre, Jack	Roy L. Smith	1968	H	1100	V	Pc/ss	65	24	7	32, 50		June 1968	30		
45	4044-7935	Joseph Finch & Co.		1946	N	800	V	Qa/sdgv	75	65	18		23	July 1947	1025	10	
46	4041-7939	Joseph Finch & Co.	Robert Keaton		N	791	V	Qa/gv	93	64	7		38	Aug. 1943	290	6	
47	4041-7939	Joseph Finch & Co.	Robert Keaton		N	791	V	Qa/gv	92	75	7		38	Sept. 1943	400	4	
48	4041-7939	Joseph Finch & Co.	Robert Keaton		N	791	V	Qa/gv	90	64	10		38	Aug. 1943	500		
49	4041-7939	Joseph Finch & Co.	A. D. Cook Company	1936	N	771	V	Qa/gv	55	50	12		18	July 1943	800		
50	4041-7939	Joseph Finch & Co.	Robert Keaton	1944	N	771	V	Qa/sdgv	66	56	16		25	Aug. 1944	800	4	
50S	4040-7936	Knepshield, Don	Roy L. Smith	1966	H	1160	S	Pc/sh	77	32	7	50	45	July 1966	28		
51	4041-7939	Joseph Finch & Co.	Robert Keaton	1944	N	771	V	Qa/sdgv	65	55	16		25	July 1944	800		
52	4041-7939	Joseph Finch & Co.	Robert Keaton	1945	N	771	V	Qa/gv	65	55	7		30	Aug. 1945	1100	4	2
52S	4039-7936	Klingensmith, L.	Roy L. Smith	1966	H	1060	V	Pc/ss	115	24	7	50, 90	46	Aug. 1966	9		
53	4041-7939	Joseph Finch & Co.	Robert Keaton		N	775	V	Qa/gv	97	70	6		20	Dec. 1943	321	1	
53S	4039-7937	Kuhns, Homer	Roy L. Smith	1966	H	1060	V	Pc/ls	135	17	7	80	80	Nov. 1966	20	0	
54	4034-7930	People's Natural Gas Co.	People's Natural Gas Co.	1931	N	1010	V	Pak/ss	111	80	7		12	Mar. 1949	9		
54S	4040-7935	Mason, William	Roy L. Smith	1966	H	1220	S	Pc	269		7		134	Oct. 1966	0.3		

Table 4. *Continued*

Well	Location	Owner	Driller	Date Completed	Use	Altitude of Land Surface (feet)	Topographic setting	Aquifer/ Lithology	Total Depth Below Land Surface (feet)	Casing: Depth (feet)	Casing: Diameter (inches)	Depth(s) to Water-Bearing Zone(s) (feet)	Static Water Level: Depth Below Land Surface (feet)	Static Water Level: Date Measured	Pumping Data: Yield (gpm)	Pumping Data: dd (feet)	Pumping Data: Time (hour)	Hardness (gpg)	Specific Conductance (micromhos at 25°C)	pH
								Armstrong County												
55	4038-7926	People's Natural Gas Co.			H	1020	S	Pa	28		8		6		6					
56	4044-7935	Joseph Finch & Co.		1946	N	800	V	Qa/sdgv	75	65	18		21		1000	6				
57	4100-7935	Hunter & Hawkey		1958	U	885	S		1986	537	8		1976							
57S	4040-7935	Fennell, James	Roy L. Smith	1967	H	1150	S	Pc/sh	83			40, 70	47	May 1967	45	0				
58	4043-7930					990	S	Pa	160		8		F		350	94				
58S	4039-7936	White, Robert	Roy L. Smith	1967	H	1100	S	Pc/ss	50	45	5	26	20	July 1967	30	15	0.5			
59	4043-7930					990	S	Pa	250		8		F		350	94				
59S	4041-7934	Roofner, Thomas	Roy L. Smith	1967	H	1280	S	Pc/sh	185	14	7	145		June 1967	2					
60	4051-7934	Allegheny River Mining Co.	F. N. Zeigler		N	1130	V	Pa	80		8	80								
61	4051-7934	Allegheny River Mining Co.	F. N. Zeigler	1927	N	1190	S	Pa	204											
62	4050-7937	Welton, Sam	F. N. Zeigler	1929	H	1200	S	Pa	77											
63	4049-7939	Pittsburgh Limestone Co.	F. N. Zeigler		N	980	V	Pac/ss	355			58	50							
63S	4040-7935	Cravis	R.S. & D.H. Shellhammer		H	1140	S	Pc/gv	120	21	7	65, 90			5					
64	4052-7928	Shea, Earl	F. N. Zeigler	1921	H	940	S	Pa	100											
65	4050-7933	Allegheny River Mining Co.	F. N. Zeigler	1928		1200	S	Pp	303	122	6									
66	4046-7913	Buffalo & Susquehanna Coal Co.	Morris Smith	1920	P	1100	V	Pa	202	37	8		30							
67	4046-7913	Buffalo & Susquehanna Coal Co.		1915	H	1100	V	Pc/ss	196	23	10	39 44	45		200					
67S	4039-7937	Ormande, Fassie	Roy L. Smith	1967	H	1040	S	Pc/ss	110	20	6	40	28	Nov. 1967	2					
68	4047-7920	Allegheny River Mining Co.		1911	P	1350	H	P/ss	502	50	6		52		70		2			
68S	4033-7928	Apollo Sch. Dist.	R.S. & D.H. Shellhammer	1968	H	1280	S	Pc/ls	144	23	8	55, 120, 135	53	Feb. 1968	12	67	2			
69	4034-7928	Alshouse, S. B.			H	1400	H	Pa		500		508, 553								
69S	4033-7926	Lockard, Fred	R.S. & D.H. Shellhammer	1968	H	1000	S	Pc/sh	100	20	6	50, 80		May 1968	2					
70	4040-7941	Kerr Coal Co.			H	1000	V	Pc	232		6	40, 100, 145	100							
71	4039-7920	Keystone Generating Station		1963	N	987	V	Pc	115	19	10		14	May 1963	315	41	48			
71S	4037-7928	Hagass, Robert	R.S. & D.H. Shellhammer		H	1310	S	Pc/sh	120	20	6	98	60	May 1968	8					
72	4057-7928	Brown, Anthony		1958	H		H	Pa/sh	106		6		55							
73	4055-7927	Tatsak, Jack		1925	P	920	V	Qa/sdgv	45	20	10		17		90	2				
74	4046-7931	Manor Twp. Joint Municipal Authority		1967	P	800	V	Qa/sdgv	52						300	3				
84S	4043-7933	Homewood Baptist Church	Ralph L. Dunbar	1967	T	1180	S	Pc/sh	102	26	6	66	56	Sept. 1967	0.1	0				
102S	4058-7926	Madison Twp. Sch.	Ralph Toy Company, Inc.	1968	T	1520	H	Pa/ss	523			377, 480		Oct. 1968	19					
103S	4058-7926	Madison Twp. Sch.	Ralph Toy Company, Inc.	1967	T	1520	H	Pa/ss	303	21	9	225, 295		Sept. 1967	30					
104S	4058-7925	Williams, Jack	Ralph Toy Company, Inc.	1966	H	1520	S	Pa/sh	135	21	6	38, 80, 110		May 1966	4					

105S	4057-7920	Distant Wtr. Auth.	Ralph Toy Company, Inc.	1966	P	1380	S	P c/ss	205	27	8	54, 125, 146					
106S	4049-7921	Beers, Gale	Ralph Toy Company, Inc.	1967	H	1280	S	P a/sh	200	22	7	122, 170		July 1967	20		
116S	4042-7931	Bernard, Fred	Roy L. Smith	1966	H	1100	S	P c/sh	200	23	7	100	106	June 1966	1		
130S	4047-7932	Hunia, Anne	Ralph L. Dunbar	1966	H	1220	S	P c/sh	125	22	6	45	45	Nov. 1966		0	
152S	4047-7927	Lasher, Edward	R.S. & D.H. Shellhammer	1968	H	1340	S	P c/ss	124	21	6	102		Apr. 1968	8		
153S	4047-7930	Rupert, Harold	Ralph Toy Company, Inc.	1968	H	870	V	P a/ss	45	19	6	21					
157S	4047-7940	Busy, William	Richard Frederick	1967	H	1195	S	P c/ss	35	22	6	29		Aug. 1967	25		
197S	4046-7938	Roode, Frank	W. F. Kerr	1966	H	1155	S	P c/ss	185	24	6	172	115	June 1966	3		
200S	4043-7939	Blose, William	W. F. Kerr	1966	H	1300	S	P c/ss	154	21	6	147	85	Sept. 1966	4	57	24
202S	4045-7941	Brown, Charles	Richard Frederick	1967	H	1140	S	P c/sh	98	21	6	75		Feb. 1967	30		
205S	4042-7934	Moineau, Marcel	W. F. Kerr	1967	H	840	S	P a/sh	74	21	6	50, 64	38	May 1967	2	0	20
223S	4037-7922	Smith, J.	R.S. & D.H. Shellhammer	1968	H	1040	S	P c/ss	93	21	7	35, 86	58	Feb. 1968	6		
224S	4036-7925	Young, Larry	R.S. & D.H. Shellhammer	1968	H	1340	S	P c/sh	160	21	7	57		Mar. 1968	2		
225S	4036-7926	Daugherty, Lesli	R.S. & D.H. Shellhammer	1968	H	1395	S	P c/sh	168	22	7	65, 140	42	Mar. 1968	4		
227S	4056-7938	McKee, Don	Ralph L. Ellenberger	1967	H	1380	S	P c/ss	83	23	6	35	35	Oct. 1967	20	0	1
228S	4057-7941	Ealey, Dennis	Ralph L. Ellenberger	1968	H	1395	S	P c/sh	69	23	7	60	45	July 1968	30	5	1
229S	4056-7938	Stoops, Stanley	Ralph L. Ellenberger	1967	H	1370	S	P c/sh	65	25	7	50	35	Sept. 1967	30		
239S	4054-7930	Brush Valley Ch.	Richard W. Schall	1966	P	1260	S	P a/ss	65	21	8	55		Jan. 1966	25		
242S	4053-7932	St. Marks Ch.	Richard W. Schall	1966	H	1090	S	P a/sh	52	21	7	25, 47		Mar. 1966	15		
252S	4059-7940	Fennell, Bill	Joseph Nebel Sons	1966	H	1380	S	P c/ss	196	39	6	175					
260S	4039-7936	Clark, Dean	Roy L. Smith	1969	H	1100	S	P c/ss	85		6			1969	30		
264S	4039-7935	Misnica, Joseph	Roy L. Smith	1969	H	1080	S	P c/sh	70	24	6	53		Sept. 1969	4		
265S	4039-7937	Sober, Glenn	Roy L. Smith	1970	H	1075	S	P c/sh	90	21	6	36, 65		June 1970	45		
267S	4040-7935	Smith, Robert	Roy L. Smith	1969	H	1100	V	P c/ss	59	20	6		31	Oct. 1969	50	4	2
268S	4039-7936	Sproull, Richard	Roy L. Smith	1969	H	1090	S	P c/ss	63	21	6	38		Oct. 1969	2		
291S	4042-7939	McAnich, Wm.	McCormick Drilling Co.	1970	H	1155	S	P c/ss	95	45	8			Apr. 1970	40		
295S	4042-7939	Snyder, Robert	McCormick Drilling Co.	1970	H	1120	S	P c	70	20	7			Sept. 1970	26		
296S	4041-7941	Walters, Wm.	McCormick Drilling Co.	1970	N	920	S	P c/ss	136	176	8	92	92	Oct. 1970	20		
299S	4057-7940	Wiles, Raymond	Roy L. Smith	1969	H	1415		/sh	70	24	7	60	45	June 1969	10	0	1

Table 5. *Logs of Wells in Armstrong County, Pennsylvania*

Well Ar-7

Owner: Pittsburgh Limestone Company, Worthington

Description	Thickness (feet)	Depth (feet)
Earth	20	20
Sandstone (water at 55 feet)	40	60
Shale	20	80
Slate	31	111
Coal	3	114
Underclay	6	120
Shale, sandy (water at 135 feet; principal zone)	29	149
Limestone (Vanport)	19	168
Shale	14	182
Underclay	5	187
Shale	38	225
Sandstone (water at 247 feet)	38	263
Shale	23	286
Sandstone	14	300

Well Ar-16

Owner: Ford City Borough, Ford City

Description	Thickness (feet)	Depth (feet)
Loam and sand	15	15
Gravel	8	23
Sand, fine	6	29
Gravel, 4 inch diameter; a little sand and fine gravel; screened below 40 feet	28	57

Well Ar-40

Owner: Dayton Borough, Dayton

Description	Thickness (feet)	Depth (feet)
Loam	10	10
Limestone	4	14
Slate and sandstone	60	74
Coal	3	77
Slate and sandstone	33	110
Sandstone (water)	18	128

Table 5. *(Continued)*

Well Ar-65

Owner: Allegheny River Mining Company, West Kittanning

Description	Thickness (feet)	Depth (feet)
Earth	10	10
Sandstone	35	45
Shale	20	65
Shale, black	10	75
Coal	3.5	78.5
Underclay	5	83.5
Limestone	5	88.5
Shale	19	107.5
Shale, black	10	117.5
Coal	1.5	119
Underclay	6	125
Shale	52	177
Limestone	6	183
Underclay	4	187
Slate	43	230
Slate, black	13	243
Underclay	8	251
Slate	12	263
Slate, black	11	274
Underclay	6	280
Slate	11	291
Shale	12	303

Well Ar-66

Owner: Buffalo and Susquehanna Coal and Coke Company, Sagamore

Description	Thickness (feet)	Depth (feet)
Soil and gravel	31	31
Underclay	5	36
Shale, bluish	25	61
Shale, sandy, black	10	71
Sandstone, gray	19	90
Coal	1	91
Shale, bluish	2	93
Sandstone, light gray	75	168
Coal	2.3	170.3
Shale, black	.7	171
Underclay, sandy	6	177
Shale, dark	6	183
Shale, sandy, dark	14	197
Sandstone, light gray	5	202

Table 6. *Composite Stratigraphic Section for Armstrong County*

Geologic Unit	Thickness (feet)	Lithologic Character	Hydrologic Properties
Alluvium	0-130	Unconsolidated, heterogeneous mixture of clay, silt, sand, and boulders; present as terraces along streams, and on flood plains.	Reported yields range from 10 to 1,100 gpm; the median yield is 400 gpm. The water is hard, generally high in chloride and sulfate, but low in iron.
Monongahela	0-200	Present only in small upland area in southern part of county. Consists of sandstone, shale, and limestone, and, locally as many as three beds of coal.	Unimportant.
Conemaugh	0-650	Shale, sandstone, thin limestone, and coal.	Reported yields range from 2 to 200 gpm; the median yield is 5 gpm. The water is hard.
Allegheny	0-about 320	Shale, sandstone, limestone, coal. Contains the Vanport Limestone.	Reported yields range from 4 to 350 gpm; the median is about 25 gpm. The water is hard and that from deeper wells may be saline.
Pottsville	130	Exposed chiefly along major stream valleys in northern part of county. Consists of two massive sandstones separated by shale.	Reported yields range from 13 to 50 gpm; the median yield is 42 gpm. The water is moderately hard, high in iron, and that from deep wells may be saline.
Mauch Chunk	Few	Red shale.	Unimportant.
Pocono	300	Massive sandstone and shale.	Too deeply buried to be important. Water is saline except along a few major streams in northern part of county.

The alluvium composing the modern flood plains is similar to that in the terraces and, indeed, is derived in part from the older deposits, as is the alluvium in all the terraces below the highest. Wells drilled in the flood plains along the Allegheny River penetrate about 55 feet of alluvium on the average, and some wells penetrate as much as 75 feet. Along the tributary streams both the flood-plain and terrace deposits become thinner with increasing distance above the main streams. Little data are available, however, on the thickness and texture of these deposits.

Water-Bearing Characteristics

The alluvium is generally highly permeable and should yield large quantities of water to wells where it is saturated with water. Wells penetrating the coarse basal strata generally obtain the largest yields.

Data are available only for wells in the flood plain along the Allegheny River. Reported yields of 23 such wells range from 10 to 1,100 gpm. The medium yield is 400 gpm.

Well Construction, Location, and Spacing

Yields of wells in the alluvium are greatest if they are drilled completely through it to the underlying bedrock and screens are installed opposite coarse saturated zones. Wells aligned parallel to any associated stream minimize interference between the wells. A parallel alignment to the streams also increases the amount of recharge to the alluvium from the stream when the wells are pumped. Exact distances between wells and between the stream and wells can be determined after the areal extent, saturated thickness, and permeability of the alluvium are known.

Water Quality

Chemical analyses of water from six wells in the alluvium show that the water is hard and generally high in chloride and sulfate, but low in iron.

BEDROCK

General Features

Origin and Lithology

The exposed bedrock or that immediately beneath the unconsolidated material in Armstrong County consists of sandstone, shale, limestone, and coal. These sedimentary rocks were deposited on or a short distance seaward of a large delta that grew generally westward during the time of Pennsylvania's great coal swamps.

The oldest of these rocks are the Pocono Group and Mauch Chunk Formation of Mississippian age. The Pocono consists chiefly of sandstones and shales; thin, noncommercial coal beds occur locally. It is overlain in places by remnants of the red beds of the Mauch Chunk Formation.

Overlying the Mississippian rocks are four groups of rocks of Pennsylvanian age: Pottsville (oldest), Allegheny, Conemaugh, and Monongahela (youngest). Each of the four groups is composed of sandstone, shale, limestone, and coal, but certain rock types predominate over others in the different groups. Sandstones are prominent in the Pottsville and Conemaugh groups, and coal is poorly developed. Coal and shale are best developed in the Allegheny and Monongahela, and sandstones are thinner and shaly.

Each of the groups contains channel sandstones – that is, long narrow bodies of sandstone that appear to have been deposited in a stream channel. The channels are cut into the underlying beds, and some major channels may even cut entirely through the beds of one group into the underlying group of rocks. The major channel sandstones commonly overlie one another, so that the entire stratigraphic sequence at a given point may be sandstone. A few miles on either side of the channel the beds may be predominantly shale.

Structure

The stresses that formed the Appalachian Mountains to the east of Armstrong County were much weaker in Armstrong County but still made their presence known. To determine the effect of these stresses in Armstrong County, it is necessary to measure the altitude of a single rock layer at many different places throughout the county. For convenience, the layer should be one that is widely distributed and easily recognized. (Such a layer is called a marker bed.) Only the Vanport Limestone and some of the coal beds qualify as marker beds in Armstrong County.

The Vanport is the most easily recognized of the available marker beds and is used in this report. Plate 1 shows how the rocks have been warped into many folds or structural ridges (anticlines) and structural troughs (synclines). These folds have been superposed on a broader regional structure that causes the rocks to dip generally southwestward. The total relief, or range of altitude, on the top of the Vanport in the county is more than 1,300 feet.

A structure map is important in the study of ground water because it makes possible the determination of the altitude of the rocks. Thus a rock may be an important water-bearer in one area but may lie too deep to be worth drilling to in another area.

Water-Bearing Characteristics

Water occurs in consolidated rocks chiefly in fractures. Where the rock is shale, the fractures are small and close readily, because shale is a weak rock and crumbles easily. Sandstone is generally well cemented, but when fractured it tends to develop clean breaks that remain open and serve as excellent conduits of water. The fractures are irregularly distributed in the rock, however, and make up a relatively small amount of the total volume of the rock, so that they are unable to hold, or store, the large quantities of water that the spaces between grains of the unconsolidated alluvium are capable of holding.

Well Location and Spacing

Wells of good yield in consolidated rocks must intercept fractures in which water occurs, though the locations of such fractures are difficult to determine. In recent years it has been discovered that fractures or concentrations of fractures are sometimes detectable on aerial photographs as linear features, called fracture traces, which result from topographic (including straight stream segments), vegetational, or soil-tonal alignments. Care must be taken to ensure that the fracture traces are natural features and are not man made.

If aerial photographs are not available, or if fracture traces cannot be identified from aerial photographs, good results may often be obtained by drilling in stream valleys – especially straight reaches. The drilling of wells in valleys is justified theoretically because fractures are zones of weakness in the rocks and, therefore, more erodible and apt to become valleys than adjacent areas. Also, because water occurs at shallower depths beneath the surface in valleys than in hills, there is more available drawdown in the valley wells.

The location and spacing of wells in a well field is a major factor controlling their interference with one another during pumping. When a well that obtains its water from a fracture is pumped, the water level draws down in the shape of a cone whose horizontal dimension is distorted into an elongate shape that extends along the fracture in both directions from the well. If two or more fractures supply the well, a part of the cone will extend along each of the fractures.

Fractures are not randomly oriented, but are usually arranged in any particular area chiefly in two or three major directions. In a small area, two fractures may be parallel and only poorly interconnected, so that a well on each of the fractures interferes with the other only slightly or not at all. In contrast, if fractures are well-connected or if wells tap the same fracture, the pumping of one of the wells produces nearly as much drawdown in the unpumped well as in the one that is pumped.

In summary, wells located on fracture traces tend to yield more water, and where several wells of high-yield design are drilled in a small area, wells located on different fractures or as far apart as practicable interfere with one another to a minimum extent.

Water Quality

The chemical character of the water in the rocks of the Appalachian Plateau is diverse. Geologic conditions here give rise to three distinct types of water and, of course, innumerable mixtures of these types.

First, as precipitation percolates through the soil and underlying rock it dissolves small amounts of mineral matter, chiefly calcium and magnesium carbonates, which become bicarbonate on solution, and minor amounts of silica, iron, manganese, sodium, potassium, sulfate, chloride, nitrate, and fluoride. The resultant solution is called a calcium magnesium bicarbonate water. It is one of the basic types of water mentioned above and generally contains about 200 mg/l dissolved solids. It is this type of water that is usually referred to when good-quality ground water is mentioned.

Second, ancient environments that favored the accumulation of plant material that later was transformed into coal also favored the deposition of iron sulfides, chief of which is pyrite. Many coal beds, therefore, have pyrite associated with them, either in masses interbedded with the coal or finely disseminated in the overlying strata. The pyrite dissolves in the ground water and contributes iron and sulfuric acid to form a second type of water, called a sulfate water. More commonly it is known as acid mine water, though it may not be connected with any mining operations, and the acid may have been neutralized by reaction with limestone. However, mining will accelerate the solution of pyrite by breaking up the rock and exposing more surface area of pyrite to the water.

The presence of sulfuric acid enables the water to attack the rocks more strongly and, so, increases the dissolved-solids content of the water to concentrations in excess of 2,000 mg/l.

Third, when the sediments that form the consolidated rocks were laid down, sea water, which contains chiefly sodium and chloride, was trapped in the pore spaces. Subsequent changes have concentrated the dissolved solids content of this trapped water so that today the dissolved material may exceed 200,000 mg/l. Such water occurs below the zone of fresh water and is encountered commonly during the drilling of deep oil and gas wells. Sometimes the salty water invades the fresh water aquifers through damaged or poorly plugged deep wells.

Precipitation has flushed the salty water from the upper several hundred feet of rock. However, all the constituents are not flushed with equal ease, and therefore, several subspecies of this type of water are formed. Some sodium is held by the clay in the rocks and is removed very slowly, but the chloride is readily flushed. The flushing may be summarized as taking place in the following steps: (1) the dissolved solids content is decreased, yielding a dilute sodium chloride water; (2) almost all the chloride is removed, leaving a sodium bicarbonate water; (3) the sodium concentration is still further reduced, and the water in the rocks becomes the type 1, or calcium magnesium bicarbonate type.

In absence of poorly permeable, difficult-to-flush rocks or contamination from leaky wells, the upper 100 to 300 feet of rocks of the county contain fresh ground water. Near the base of this zone the subtypes of saline water discussed above are present.

Monongahela Group

Distribution and Lithology

The Monongahela Group is present only on the uplands of a small area in the southern part of the county, along the Indiana County border. The group is only about 200 feet thick here because nearly half of it has been removed by erosion. The rocks composing the group are sandstone, shale, and limestone, and locally, as many as three beds of coal. The bottom unit of the group is the Pittsburgh coal, which ranges from 6 to 10 feet in thickness.

Water-Bearing Characteristics

Because of the small areal extent and topographic position, this formation is of little value as a source of water. No data are available on wells in Armstrong County that obtain water from the Monongahela.

Conemaugh Group

Distribution and Lithology

About two-thirds of Armstrong County is underlain by rocks of the Conemaugh Group. The entire thickness of the Conemaugh is present in only the southern part of the county, near and beneath the Monongahela Group.

The following is a generalized section of the complete group:

Casselman Formation	Average thickness (feet)
Shale	8
Pittsburgh Limestone Member	5
Fire clay	3
Shale	24
Connellsville Sandstone Member	30
Shale, sandstone, and thin limestone	100
Morgantown Sandstone Member	20
Shale, sandstone, and thin limestone	220
Glenshaw Formation, thin limestone and shale	100
Saltsburg Sandstone Member	45
Sandy shale	40
Mahoning Sandstone Member	50
Shale	5
	650

The sandstones are irregular in thickness and lithologic character, and generally resemble one another. In some places a thin coal bed is present about 150 feet above the base of the group.

Well Depths and Yields

Data are available for only five wells in the Conemaugh of Armstrong County. Their depths range from 60 to 232 feet, and their median depth is 133 feet. The yields of these wells range from 2 to 200 gpm and their median yield is 5 gpm.

Water Quality

Only one record of analysis of water from the Conemaugh is available (well Ar-67). The analysis shows the water is hard and contains about equal amounts of calcium magnesium and sodium potassium. About two-thirds of the nonmetals are bicarbonate and one-third are chloride.

Allegheny Group

Distribution and Lithology

The Allegheny Group crops out in the northern half of the county and along the major stream valleys throughout the county. It includes all the rock between the top of the Upper Freeport coal and the base of the Brookville coal or its underclay, if present. The Brookville coal has been misidentified in some of the earlier reports and the name applied to a coal in the Mercer Formation (Pottsville Group). In those reports the coal now called Brookville is called Craigsville.

The following is a generalized section of the Allegheny Group:

	Average thickness (feet)
Freeport Formation	
Upper Freeport coal	3
Clay, limestone, sandstone, and shale	44
Lower Freeport coal	2
Clay, coarse sandstone to fine conglomerate, and shale	42
Kittanning Formation	
Upper Kittanning coal	2
Clay, sandstone, sandy shale, and shale	42
Middle Kittanning coal	1
Clay, shale, thin-bedded sandstone	33
Coal with shale partings	½
Shale, sandy	45
Lower Kittanning coal	3
Shale and thin sandstone	30
Vanport Limestone	9
Clarion Formation	
Shale	30
Clarion coal	3
Clay, coarse sandstone, shale and thin-bedded sandstone	31
Brookville coal	1
	321½

The individual units of the Allegheny Group differ in thickness from place to place. Thinning of one seems to be accompanied by thickening of another, with the result that the group as a whole has a rather uniform thickness.

The Allegheny Group contains eight coal beds or horizons separated by shale, sandstone, limestone, and clay. Coarse sandstone beds are prominent in some places, although in others there appears to be no sandstone.

The Vanport Limestone is a blue-gray fossiliferous rock usually containing about 90 percent calcium carbonate. In some places a low-grade iron ore is present at the top of the limestone. The Vanport's distinctive appearance and widespread occurrence make it an ideal marker bed (see section on structure).

Well Depths and Yields

The Allegheny Group is capable of supplying moderate amounts of water to wells. About half the wells on which data were available (10 out of 19 wells) yielded more than 25 gpm. Six yielded 50 gpm or more, and three yielded 240, 350, and 350 gpm.

The median depth of the 19 wells in the Allegheny is 160 feet, but depths range from 18 to 355 feet. Maximum yields do not correspond to maximum depths; the reason for this is not known but may be due to improper location of the deeper wells or to a decrease in the abundance of yielding zones at the greater depths. The optimum depth seems to be between 150 and 200 feet (Figure 6). Only one well deeper than 200 feet yielded more than 50 gpm.

Water Quality

The six analyses of water from the Allegheny Group illustrate very well the several types of water discussed earlier in the general section on water quality in the consolidated rocks.

Wells Ar-34 and Ar-35 both contain sodium chloride water. The water in well Ar-39 is a blend of the several types discussed earlier. It is chiefly a calcium magnesium sulfate water but contains considerable sodium, potassium, and bicarbonate. The iron concentration is the highest (8.89 mg/l) analyzed from Armstrong County.

Well Ar-40 was sampled first in February 1927, and at that time the water was a calcium magnesium bicarbonate water. In October 1929 the well was resampled, and the dissolved-solids content was found to have doubled. The increase was due almost entirely to the increase in calcium magnesium, sulfate, and iron. The exact cause of the change in the quality of the water is not known but it was probably caused either by an advancing front of acid mine water from a nearby mine or, more likely, by the oxidation of pyrite penetrated by the well. The Lower Freeport coal, which commonly has pyrite associated with it, was penetrated at a depth of 74 feet. During pumping of the well, the water level would have drawn down below this level so that the pyrite was exposed repeatedly to the air, thereby facilitating its oxidation.

Well Ar-72 contains a calcium magnesium bicarbonate water, having a dissolved-solids content of 159 mg/l. Sulfate amounts to about 18 percent and chloride to only 3.5 percent of the nonmetals. Only 0.02 mg/l iron is present.

Pottsville Group

Distribution and Lithology

The Pottsville Group crops out along the major stream valleys in the northern part of the county and in the valleys of some of the streams a little farther south.

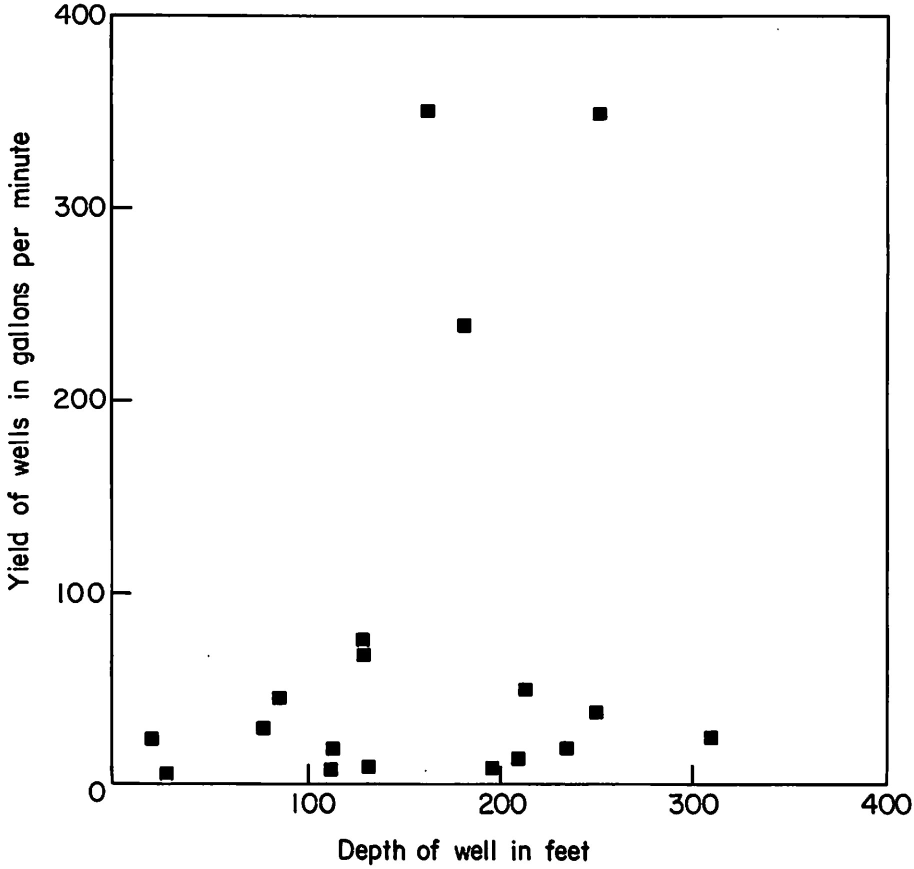


Figure 6. Relation of yield to well depth in the Allegheny Group.

The Pottsville is generally considered to consist of two massive sandstones (the Connoquenessing Formation at the base of the group and the Homewood Formation at the top of the group) and an intervening shale (Mercer Formation).[1] However, the sandstones grade laterally into sandy shale or shale and are then difficult to distinguish from the Mercer or the overlying Clarion (Allegheny Group) shales.

[1] These formation names do not conform to the nomenclature used by the Pennsylvania Geological Survey. For a discussion of the stratigraphy of the Pottsville Group in western Pennsylvania, see Edmunds, W. E. (1969), *Revised lithostratigraphic nomenclatures of the Pottsville and Allegheny Groups (Pennsylvanian), Clearfield County, Pennsylvania*, Pa. Geol. Survey, 4th ser., Inf. Circ. 61, 36 p.; Ashley, G. H. (1945), *The Pittsburgh-Pottsville boundary*, Jour. Geology, v. 53, p. 374-389; and Renick, B. C. (1924), *The correlation of the Allegheny-Pottsville section in western Pennsylvania*, Jour. Geology, v. 32, p. 64-80.

The sandstones of the Pottsville are sometimes misidentified because of their similar appearance and the common practice of identifying them by their relation to a nearby economically important coal. Thus, the Homewood is considered to lie immediately beneath the Brookville coal or its underclay (Allegheny Group). However, the Brookville coal was misidentified in some of the older reports and its name was applied to a coal in the Mercer. This usage is sometimes applied today, so that the Homewood then becomes a bed in the Clarion, the Connoquenessing is called the Homewood, and a sandstone in the Pocono becomes the Connoquenessing.

The base of the Pottsville is also difficult to define in places. The underlying Mississippian surface has been truncated by erosion so that the upper shale units may be missing, and the Pottsville then rests directly on sandstone of the Pocono. Both the Pottsville and Pocono sandstones are typically gray to white, well-cemented quartzites.

A conventional, generalized section through the Pottsville is as follows:

	Average thickness (feet)
Homewood Formation	
Sandstone, coarse, massive	40
Mercer Formation	
Sandy shale, shale, coal (1 to 3 beds), clay	40
Connoquenessing Formation	
Sandstone, coarse, massive	50
	130

Well Depths and Yields

Data for the Pottsville are available from only five wells. This is not surprising, as the unit is overlain in most places by water-bearing rocks of the Allegheny and even the Conemaugh Groups so that a well would generally obtain sufficient water before penetrating to the Pottsville. The depths of the five wells range from 52 to 105 feet. The median depth is 86 feet. Their yields range from 13 to 50 gpm. The median yield is 42 gpm. Based on information from nearby counties, greater yields than these should be obtainable from the Pottsville, especially if the wells are properly located and penetrate the group completely.

Water Quality

No analyses of water from the Pottsville in Armstrong County are available, but analyses of water from adjacent counties are characterized by high iron; so, similar values may reasonably be expected in Armstrong. The water from the adjacent counties is only moderately hard and is low in sulfate and chloride. However, wells in the Pottsville deeper than 300 feet may tap saline water.

Mauch Chunk Formation

The Mississippian System is represented in Pennsylvania by the Mauch Chunk Formation and the Pocono Group. The Mauch Chunk overlies the Pocono and consists of red shales and sandstones. After the Mauch Chunk was deposited, western Pennsylvania was uplifted and underwent a long period of erosion that removed all or most of the formation throughout much of its extent. In Armstrong County, it is represented only by a few feet of red shale and is consequently unimportant as a source of water.

Pocono Group

Distribution and Lithology

The Pocono Group consists of a sequence of thick sandstones and shales. The uppermost of these is the Burgoon Sandstone, which crops out only in the northern part of the county – along the Allegheny River, Red Bank Creek, and in the upper reaches of Mahoning Creek where it crosses the Greendale anticline. It is generally a gray to white, coarse-grained sandstone, but in places it contains lenses of shale. It is about 300 feet thick.

Because post-Mississippian erosion has removed the Mauch Chunk in places, the Pennsylvanian Pottsville sandstones commonly rest directly on the Burgoon. The two rocks resemble each other, and it is difficult to determine where one ends and the other begins.

Water-Bearing Characteristics

The Burgoon Sandstone is an excellent aquifer where it is not buried too deeply. Wells in adjacent counties yield as much as 500 gpm (reported). However, throughout most of Armstrong County, the Burgoon is buried beneath several hundred feet of younger rocks. Wells, therefore, seldom penetrate to the Burgoon; if they did, they would probably encounter saline water. The Burgoon is useful as a source of fresh water, then, only in a small area along the major streams in the northern part of the county.

HOW MAN HAS CHANGED THE HYDROLOGIC SYSTEM

PRESENT STATUS OF DEVELOPMENT

The hydrologic system began to change early in the development of the area. Initially, homes were located near readily available water supplies, such as streams and springs. Shallow wells soon supplemented these sources, because many streams dried up in the summer. Furthermore, many people wished to build homes farther from flood-prone streams and to avoid using water from the streams, which the increased population along the streams had polluted. Eventually, almost every house had a shallow dug well from which water was withdrawn from the upper few feet of the aquifer. As the population density increased many individually owned wells were abandoned, and public-supply wells were installed. A few wells were drilled for industrial use.

Additional supplies of ground water can be developed in many parts of Armstrong County. The major stream valleys are important for ground-water development, because the water table is near the land surface, and in places the valley contains thick unconsolidated material from which large supplies may be obtained.

PUBLIC WATER SUPPLIES

Approximately 60 percent of the population of Armstrong County uses water from a public supply. Of these, about 63 percent use surface-water supplies and

Table 7. *Communities Having Public Water Supplies*

Community	Ground water		
	Approximate population served	Average daily 1971 pumpage (gallons)	Source of water
Bradys Bend Township (West) (supplied by Water Improvement Association)	153	---	---
Bradys Bend Township (East) (supplied by Community Water Association)	46	Unmetered	1 spring
Chickasaw	20	1,200	2 wells
Dayton Borough	769	42,000	2 wells
Elderton Borough	387	17,000	3 wells
Ford Cliff Borough (supplied by Manor Township Joint Municipal Authority)	590	*a*	2 wells, 1 spring
Ford City Borough	6,800	600,000	3 wells
Furnace Run	45	Unmetered	2 springs
Manor Township (supplied by Manor Township Joint Municipal Authority)	5,013	*a*	2 wells, 1 spring
Margaret (supplied by Cowanshannock Water Company)	25	10,000	2 wells
Nu Mine (supplied by Cowanshannock Water Company)	83	10,000	2 wells
Rural Valley Borough	860	100,000	3 wells
Sagamore (supplied by Cowanshannock Water Company)	179	50,000	4 wells
Seminole	250	15,000	2 wells, 1 spring
Shadyside Village	193	---	1 well
Templeton	350	---	3 wells
Yatesboro (supplied by Cowanshannock Water Company)	178	---	3 wells

Table 7. *Continued*

Community	Surface water: Approximate population served	Surface water: Average daily 1971 pumpage (gallons)	Surface water: Source of water
Apollo Borough (supplied by Westmoreland County Municipal Authority)	2,694	540,000	Beaver Run Reservoir
Applewold Borough (supplied by Armstrong Water Company)	489	60,000	Allegheny River
Cadogan Township	562	21,000	Allegheny River
East Franklin and North Buffalo Townships (supplied by Kittanning Suburban Water Company from Armstrong Water Co.)	2,450	95,000	Allegheny River
Freeport Borough	2,439	275,000	Allegheny River
Kiskiminetas Township (supplied by Westmoreland County Municipal Authority)	3,000	39,000	Beaver Run Reservoir
Kittanning Borough and Rayburn Township (supplied by Armstrong Water Company)	6,793	50,000	Allegheny River
Leechburg Borough (supplied by Westmoreland County Municipal Authority)	3,545	500,000[b]	Beaver Run Reservoir
North Apollo Borough (supplied by Westmoreland County Municipal Authority)	1,741	25,000	Beaver Run Reservoir
North Vandergrift (supplied by Westmoreland County Municipal Authority)	405	50,000	Beaver Run Reservoir
Parker City	945	110,000	Allegheny River
Parks Township (supplied by Westmoreland County Municipal Authority)	3,032	42,000	Beaver Run Reservoir
South Bethlehem and Distant (supplied by Redbank Valley Municipal Authority)	660	75,000	Redbank Creek
West Kittanning Borough (supplied by Kittanning Suburban Water Company from Armstrong Water Co.)	1,100	170,000[c]	Allegheny River

[a] Combined pumpage to Ford Cliff Borough and Manor Twp. is 200,000 gallons per day.

[b] An additional 4,458,000 gallons of raw water is pumped daily to the Allegheny Ludlum Co. plant.

[c] An additional 70,000 gallons each approximately is supplied to the Union Carbide and General Electric Co. plants.

37 percent use water obtained from wells or springs. Data on these supplies are given in Table 7.

WATER PROBLEMS RESULTING FROM THE ACTIVITIES OF MAN

The activities of man in Armstrong County have caused an acceleration of some of the processes already taking place naturally and have resulted in a marked worsening of the chemical quality of the water.

Chief among these activities is coal mining. As noted earlier, the mining operations break up the rock and expose more surface area of the iron sulfide minerals to air and water. The consequent oxidation and solution of the iron sulfide minerals yield water that is high in sulfate, iron, and acid. The acid in the water attacks calcium carbonate minerals and increases the water's hardness. The water continues to move through the rocks so that it is found not only in association with the iron sulfide minerals but also in underlying rocks or in rocks otherwise down the hydraulic gradient; that is, in the direction the water moves naturally. This water eventually is discharged to streams, where, in sufficient quantities, it kills fish and plant life and leaves an orange scum of oxidized iron on the stream bottom.

Oil and gas operations constitute another source of contamination of water supplies. Hundreds of wells have been drilled in Armstrong County in the search for oil and gas. When a well proved nonproductive it was abandoned. Not always in the past, however, was the well properly plugged before abandonment. Often the well was left open or merely capped so that salt water and small amounts of oil were able to rise in the borehole. When the casing became corroded – or worse, when the casing was removed – the saline water and oil moved into fresh water aquifers and into streams.

DEVELOPMENT OF WELLS

DRILLING METHODS

Dug wells in Armstrong County are being replaced gradually by drilled wells. Two methods are used to drill most of the wells: the cable-tool percussion method and the rotary-drilling method.

In the cable-tool percussion method, wells are drilled by alternately lifting and dropping a heavy drill bit in the borehole. The drill bit breaks or crushes the rock into small fragments, which are then removed from the hole. In the rotary-drilling method, wells are drilled by a rotating bit, and the rock chips are removed by circulating water, drilling mud, or air in the borehole. Well diameters for drilled wells are smaller than those of dug wells, but depths and yields of drilled wells usually are much greater.

Steel casing is emplaced in the drilled wells to the bottom of the weathered rock and a slurry of rock cuttings (in the case of most domestic wells) or concrete (in the case of public supply and industrial wells) is then poured in the annular space between the casing and the wall of the well to seat the casing tightly.

WELL DEVELOPMENT

The method commonly used to increase well yields consists of heavy pumping of the borehole for a short period of time to remove drill cuttings and fine material. Other less common techniques used to increase yields are mechanical surging and the addition of detergents.

Mechanical surging is similar to operating a piston in a cylinder, with the casing or well bore acting as the cylinder and the surge block as the piston. Alternately raising and lowering the block in the well forces water in and out of openings in the aquifer. Loose rock chips or fine sand grains are loosened and drawn into the well bore from which they may be pumped after surging. This method is most successful in sandstone, conglomerate, and unconsolidated aquifers.

Detergents can be used in wells where clay and silty materials are plugging small fractures and other openings in the aquifer. The detergent helps break up these plugs into small particles so that they may be pumped out, leaving the aquifer openings clear to transmit more water to the borehole.

MANAGEMENT OF WATER SUPPLIES

PROTECTION FROM OVERDRAFT

There is no known overdraft of ground water anywhere in Armstrong County, but overdraft is possible in future expansion of well fields or where additional large ground-water supplies are needed. Determining interference between wells before drilling final production wells is a safeguard against possible overdraft, as is periodic water-level measurements to determine the long-term trend of water-table fluctuations and the effect of pumping.

PROTECTION FROM POLLUTION

Pollutants are carried downward from the land surface by infiltrating water or are moved laterally from adjacent areas. Because ground-water movement is relatively slow, such pollutants are slow to accumulate and just as slow to disperse after the polluting source is removed. The location of sources of pollution, such as sanitary landfills and septic tanks, is a major factor in the selection of well sites.

Government agencies are becoming increasingly active in the field of pollution prevention. For example, the Pennsylvania Department of Environmental Resources has set standards for length and cementing of casing in wells. The Bureau of Land Protection and Reclamation, Division of Oil and Gas, has regulations concerning the abandonment of oil and gas wells and on the backfilling of strip mines to reduce the formation of acid water in the stripped areas.

WHERE TO GET INFORMATION ABOUT WATER

A variety of information on water supplies is available from the several government agencies listed below. When requesting information it is important to give an accurate location of the site about which you wish information.

The Pennsylvania Topographic and Geologic Survey has information on the geology of Armstrong County and has published reports that describe in detail the rocks that underlie Armstrong County. Well drillers' logs and reports on new wells that have been drilled in the county are also available.

The Division of Water Quality, Bureau of Water Quality Management, Pennsylvania Department of Environmental Resources, can supply information on proper well construction requirements, biological reports on well water, and the chemical quality of ground water in Armstrong County. The Department, through various regional offices, tests water samples for bacterial pollution. The nearest regional testing laboratory is in Meadville. They also can advise effective corrective measures when pollution is reported.

The Division of Natural Resources and Technical Services, Bureau of Engineering, Pennsylvania Department of Environmental Resources, has information on stream discharges, flood data, reservoir requirements, and power plant discharges.

The Public Utility Commission, Bureau of Rates and Research, has information on some municipal water supplies, including source, average daily use, total annual use, and estimated future needs.

The U.S. Geological Survey has data on wells, springs, and streams, and on the chemical quality of water.

Local well drillers and pump installers can provide prices and suggest the type of equipment needed to develop a water supply. They can also suggest the proper well diameter for the necessary pumping equipment. Pump installers can supply information concerning the size of the pump, depth of the pump setting, and the pressure-tank capacity.

If chemical analysis of the well water indicates treatment is necessary, any of the commercial water-treatment companies can provide the necessary information and equipment. Equipment for water treatment can be purchased or rented, and it will be serviced by the supplier if desired.

GLOSSARY

Aquifer: A formation, group of formations, or part of a formation from which water is collectable in usable quantities.

Artesian conditions: The occurrence of ground water under sufficient hydrostatic head to rise above the upper surface of the aquifer.

Base flow: Discharge entering stream channels as effluent from the ground-water reservoir; the fair-weather flow of streams.

Cubic feet per second: The discharge of a stream of rectangular cross section, 1-foot wide and 1-foot deep, whose velocity is 1-foot per second; equivalent to 448.8 gallons per minute.

Cone of depression: A conical depression, on a water table or other potentiometric surface, produced by pumping a well.

Direct runoff: The water that moves over the land surface directly to streams promptly after rainfall or snowmelt.

Dip of bed: The angle at which the formation or bed is inclined from the horizontal measured at a right angle to the strike.

Discharge, ground water: The process by which water is removed from the zone of saturation; also the quantity of water removed.

Drawdown: The lowering of the water table or potentiometric surface caused by pumping (or artesian flow).

Evapotranspiration: Water withdrawn from a land area by direct evaporation from water surfaces and moist soil and by plant transpiration.

Fault: A fracture or fracture zone along which there has been displacement of the two sides relative to one another parallel to the fracture. The displacement may be a few inches or many miles.

Formation: A fundamental unit in rock stratigraphic classification. It is a body of rock characterized by lithologic homogeneity; it is prevailingly but not necessarily tabular and is mappable at the earth's surface or traceable in the subsurface.

Fracture: Break in rocks.

Generalized geologic section: The description of the prominent features in a sequence of rocks. Minor features are neglected.

Ground-water reservoir: An aquifer or a group of related aquifers.

Head (hydrostatic head): The height of a vertical column of water, the weight of which, in a unit cross section, is equal to the hydrostatic pressure at a point.

Homocline: A structural condition in which the beds dip uniformly in one direction.

Hydraulic gradient: The rate of change in hydrostatic head per unit of distance of flow at a given point and in a given direction.

Overdraft: The withdrawal from the ground of more water than is replaced by recharge. This results in excessive lowering of the water level in the ground and the eventual failure of a well in the overdraft area.

Perched ground water: Ground water separated from an underlying body of ground water by unsaturated deposits.

Permeability: The capacity of a material to transmit a fluid.

Porosity: The ratio of the aggregate volume of interstices in a rock or deposit to its total volume, expressed as a percentage.

Potentiometric surface: The surface that represents the static ground water head and is defined by the levels to which water will rise in tightly cased wells.

Recharge, ground water: The process by which water is added to the zone of saturation; also, the quantity of water added.

Runoff: That part of the precipitation that appears in streams. It is the same as streamflow unaffected by artificial diversions, storage, or other works of man in or on the stream channels.

Saturation, zone of: The zone in which interconnected interstices are saturated with water under pressure equal to or greater than atmospheric.

Soil tonal alignments: The arrangement of similar tones or shades of color in a particular direction on an aerial photograph believed to be due to a similarity in the properties of the soil.

Specific capacity: The yield of a well, in gallons per minute, divided by the drawdown of the water level in the well, in feet, near the end of pumping.

Stream-gaging station: a gaging station where a record of discharge of a stream is obtained. Within the Geological Survey this term is used only for those gaging stations where a continuous record of discharge is obtained.

Surface water: Water on the surface of the earth.

Transpiration: The process by which vapor escapes from the living plant, principally the leaves, and enters the atmosphere; also, the quantity of water absorbed and transpired and used directly in the building of plant tissue, in a specified time.

Unconformity: A surface of erosion that separates younger strata from older rocks.

Vadose water: Water in the zone of aeration.

Water table: The potentiometric surface of an unconfined water body where the pressure is equal to that of one atmosphere.

Water-table conditions: The condition under which water occurs in an aquifer that is not overlain by an impermeable body and has a water table.

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