Ground Water Report W 20

2nd Edition

1972

The Ground-Water Observation-Well Program in Pennsylvania

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COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL RESOURCES
BUREAU OF
TOPOGRAPHIC AND GEOLOGIC SURVEY
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BULLETIN W 20

The Ground-Water Observation-Well Program in Pennsylvania

by Charles W. Poth

U. S. Geological Survey

Prepared by the United States Geological Survey, Ground Water Branch, in cooperation with the Pennsylvania Geological Survey

PENNSYLVANIA GEOLOGICAL SURVEY
FOURTH SERIES
HARRISBURG

First Edition 1963

Second Edition 1972

1972

CONTENTS

ILLUSTRATIONS

TABLE

THE GROUND-WATER OBSERVATION-WELL PROGRAM IN PENNSYLVANIA

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ABSTRACT

The observation-well network in Pennsylvania was established in 1931 to monitor the fluctuations of ground-water levels throughout the Commonwealth. The fluctuations are controlled by geologic, climatic, and hydrologic factors, and by the activities of man. Water-level data from the observation-well network are useful for evaluating the effects of these factors and, therefore, for the intelligent management of the ground-water resources. In 1970 the network in Pennsylvania consisted of 70 wells—some in areas remote from the influence of man and others in areas undergoing urbanization. As funds are available, more wells will be measured, especially in the latter areas, so that the effects of urbanization on ground water may be monitored closely. The new observation wells will be logged electrically and test-pumped, and chemical analyses of the water will be made. All wells will be rechecked periodically for both yield and water quality.

INTRODUCTION

The increasing complexity of modern civilization and the expanding population combine to create an ever-increasing demand for water. To help satisfy this demand, the use of ground water is steadily increasing. Local overdraft of ground-water supplies in some parts of the country has already occurred and has served to focus public attention on the water problem, giving rise occasionally to the erroneous belief that ground water is being depleted everywhere. Each period of dry weather stirs up the rumor anew.

A systematic investigation of the ground-water resources of Pennsylvania was begun in 1925 by the Pennsylvania Geological Survey in cooperation with the Ground Water Branch of the U. S. Geological Survey to obtain information on the source, movement, quantity, and quality of the ground water of the Commonwealth. In 1931, as a result of the interest in ground-water levels aroused by the drought of 1930, a network of wells [1]was established to gather data on the fluctuations of water levels. The locations of the observation wells which composed the network in 1970 are shown in Figure 1.

The observation-well program is a continuing program because a knowledge of the manner in which the levels of natural ground-water

[1]The measurements of the depth to water in wells of this network have been published in U. S. Geological Survey Water-Supply Papers 777, 817, 840, 845, 886, 906, 936, 944, 986, 1016, 1023, 1071, 1096, 1126, 1156, 1165, 1191, 1221, 1265, 1321, 1404, 1537, 1782 and 1977.

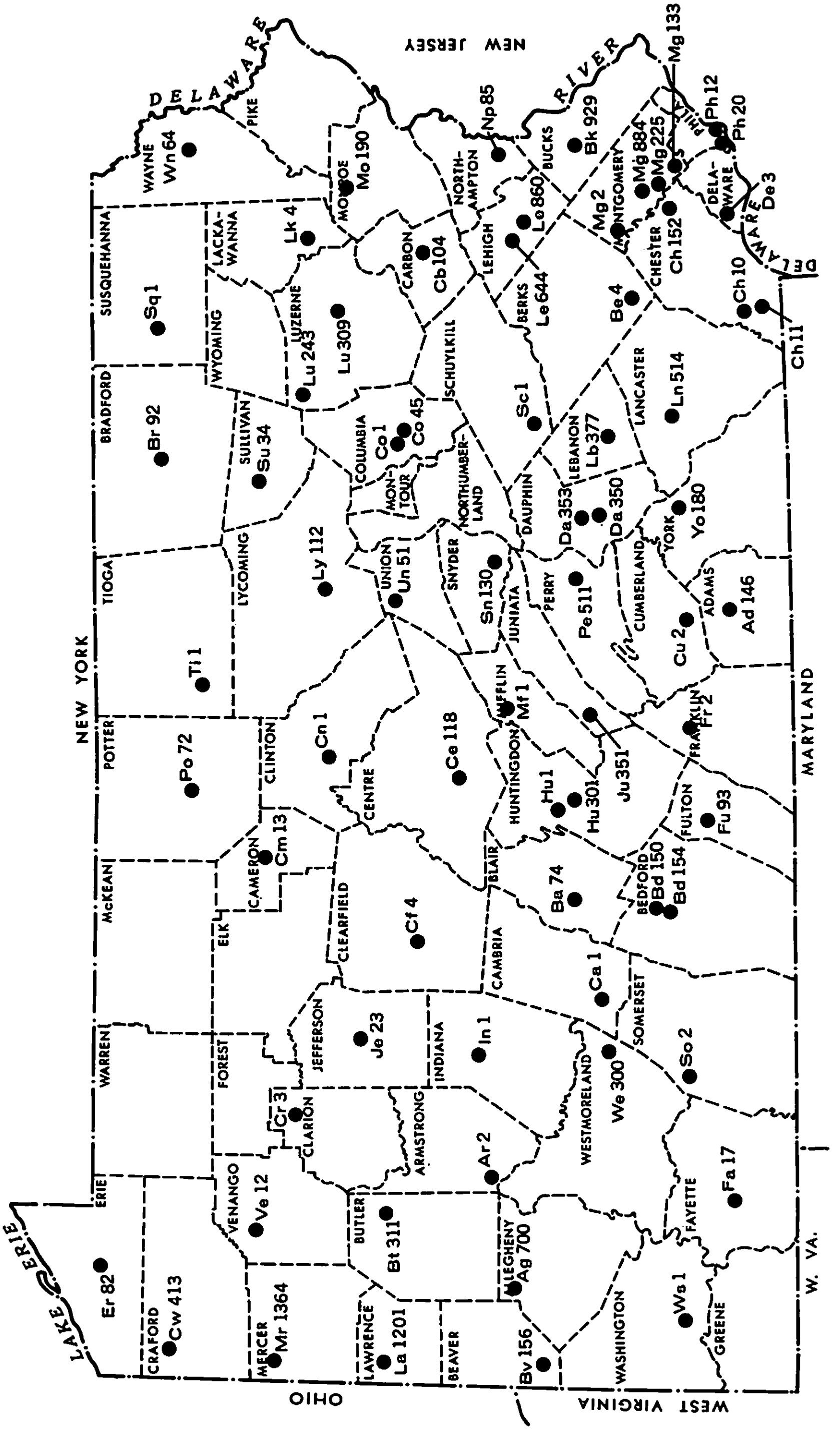

Figure 1. Map of Pennsylvania showing locations of observation wells in 1970.

reservoirs rise and fall—or remain reasonably stable in relation to rainfall, drought conditions, pumpage, and other causative factors—is essential in the study, development, and management of ground-water resources.

This bulletin explains the specific uses of water-level records. It describes the ways in which water levels vary and what these variations mean in terms of adequacy of supply. It also explains the problems involved in locating observation wells that give data representative of a general area. Finally it presents the current observation-well network in Pennsylvania and recommendations for the strengthening of that network.

CAUSES OF VARIATIONS IN GROUND-WATER LEVELS

Geologic factors

The geologic environment in which ground water occurs is a major factor controlling the availability of the water and in determining its chemical and physical character. Because the water occurs in pores and fractures in rocks, the amount of water available to a well is dependent on the number, size, and degree of interconnection of the openings—just as the chemical character of the water is determined by the mineral composition of the rocks. The geology of Pennsylvania is unusually complex and varied—more than 150 formations and many subunits have been recognized—so that the problem of locating a few wells to monitor the wide range of geologic environments is exceptionally difficult.

Climatic factors

The replenishment of ground water in an area depends largely on the climate of the area. The annual precipitation (which averages 42.23 inches in Pennsylvania) is important, but the distribution of precipitation throughout the year and the intensity of precipitation are equally important. Precipitation data for Pennsylvania show that monthly differences are fairly small, although there is approximately 36 percent more precipitation in summer than in winter. Temperature also is important, because it affects the rate of evaporation and transpiration by plants and thereby controls the moisture content of the soil; these factors exert considerable control on the amount of ground-water replenishment during a storm.

The average monthly temperature and precipitation in Pennsylvania are shown in Figure 2. The average annual temperature is 50.2°F.

The change of climate with the passage of time is well known and has long been a subject of study and speculation. Whether the changes (other than the seasonal ones) are cyclic—that is, recurrent at predict-

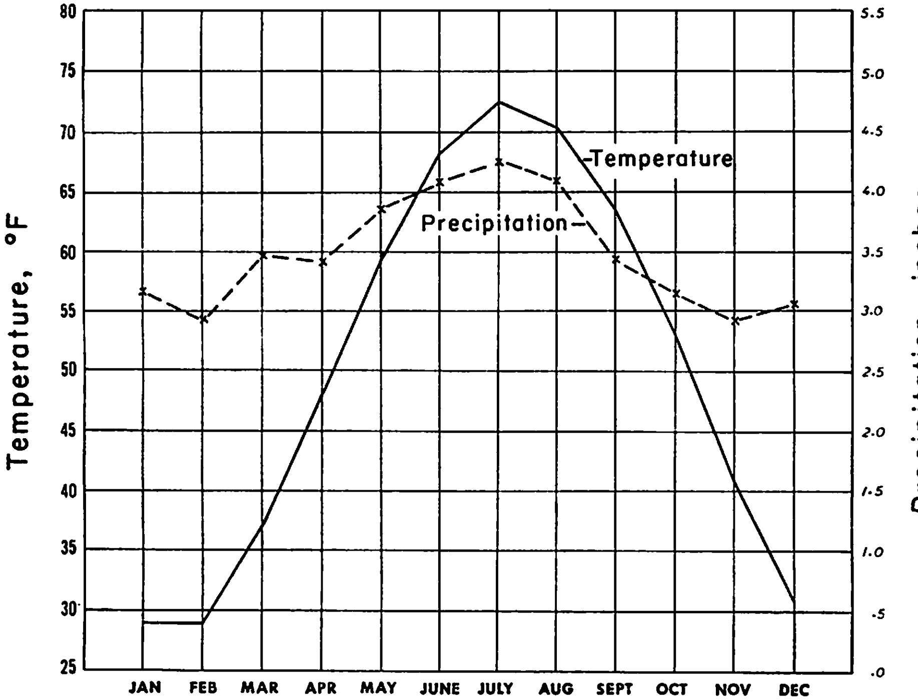

Figure 2. Graph showing the average monthly temperature and precipitation in Pennsylvania. Data from U. S. Department of Agriculture Yearbook of Agriculture, "Climate and Man", 1941.

able intervals—or whether they are simply random fluctuations, is still uncertain. Occasionally, cycles appear to be present in short segments of a record, but they do not recur throughout the record.

Cycles would undoubtedly be due to factors of far-reaching effect rather than of local effect, and neighboring weather stations should have similar records. However, the records of neighboring stations often show pronounced differences, and the wettest year recorded at one station may correspond to the driest year recorded at a nearby station.

Studies of the variability of precipitation from year to year at a station have shown that data for a period of about 30 years are believed to give the true long-term mean rainfall within an average error of about 2 percent; the average obtained from only 5 years of data may be 15 percent in error. In addition, the studies have shown that during wet years the rainfall is 25 to 70 percent greater than average, and in dry years it is 20 to 45 percent less than average. The annual rainfall was found to be above average about 46 percent of the time. In studying the duration of wet and dry periods, scientists have found also that the annual rainfall at a station rarely exceeds or falls below the average for more than 5 or 6 consecutive years.

Hydrologic factors

Only part of the precipitation that falls on the earth's surface becomes ground water. Much of the precipitation may return immediately to the atmosphere by evaporation or flow overland to streams. Even the moisture which does sink into the ground may be adsorbed on soil particles or captured by plant roots before it reaches the zone of saturation to become ground water.

If the upper surface of the ground water is free to fluctuate in response to changing conditions, the water is controlled by water-table conditions, and its upper surface is the water table. If the water in an aquifer (ground-water reservoir) is confined under hydrostatic pressure by relatively impermeable rocks, and the water level in a tightly-cased well tapping the aquifer rises above the top of the aquifer, the water is controlled by artesian conditions. The level to which water will rise in tightly cased wells that tap an artesian aquifer is called the piezometric surface of the aquifer.

Water-level fluctuations.—The water level in wells tapping water-table or artesian aquifers fluctuates in response to several factors. The most important factor is the natural recharge-discharge regimen of an aquifer, by which the water level rises during periods of recharge (Fig. 3) and declines between such periods, as water is discharged from the aquifer. The effectiveness of a given amount of precipitation in recharging an aquifer depends partly on the amount of water adsorbed on soil particles or captured by plants during its movement through the unsaturated zone. Ordinarily, a smaller percentage of the water reaches the zone of saturation in summer than in winter, because of the high rate of evapotranspiration in the summer. This relationship produces an annual cyclic fluctuation in which the water level is highest in the spring and lowest in the fall.

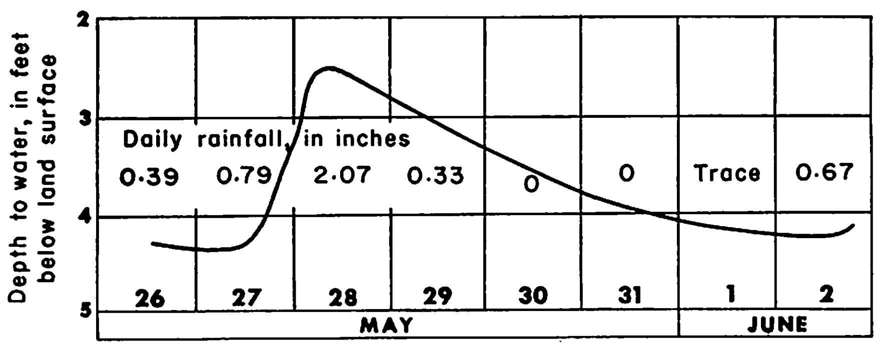

Figure 3. Hydrograph of well Sq-1, showing effect of precipitation, May 26 to June 2, 1946.

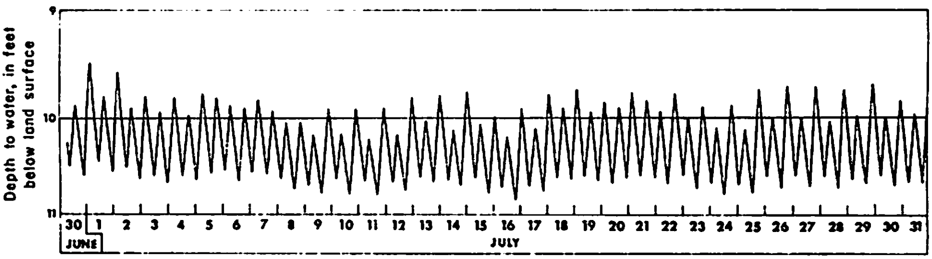

Figure 4. Hydrograph of well Bk-500, showing effects of ocean tides, June 30 to July 31, 1954.

Superimposed on the recharge-discharge cycle are fluctuations due to many other influences. If the water table lies close enough to the land surface, evaporation and transpiration by plants will produce minor diurnal oscillations during the growing season. Transpiration will cease after a killing frost, often with a corresponding rise in the water level. A decline in water level in a shallow aquifer may occur also in winter, as water below the frozen soil is drawn upward by capillarity and is added to the frost layer from below.

Changes in atmospheric pressure produce inverse changes in the water level in artesian wells but no change in water-table wells. In an artesian aquifer, the pressure change is transmitted directly to the water in the well but indirectly (through the confining bed which does not completely transmit the change in pressure) to the water in the aquifer. Hence, an increase in atmospheric pressure will cause a lowering of the water level in the well. In a water-table aquifer the change in pressure is transmitted equally to the water in the well and to the aquifer, and there is no noticeable water-level fluctuation.

The movement of ocean tides causes oscillations of water levels in both confined and unconfined aquifers (Fig. 4) that decrease as the distance from the ocean or tidal inlet increases. Also, earth tides cause small semidiurnal fluctuations in an artesian aquifer.

Pumping of wells or injecting of water into wells may cause considerable change in the water level in an aquifer and in most areas will obscure the fluctuation of water levels due to natural causes. Figure 5 shows the water-level fluctuations in well Mg-4 caused by the pumping in other wells.

The size of any water-level fluctuation depends on the ability of an aquifer to store and transmit water as well as on the magnitude of the forces applied to the aquifer or the amount of water added or removed. Where the storage capacity and transmissibility of an aquifer are large, the size of the water-level fluctuation will be less than where they are small. Furthermore, in any hydrologic system having a common discharge area the amplitude of the seasonal cycle will depend also on the height of the measuring point (well) above the area of discharge, because the rate at which the ground-water surface declines is proportional to the height of the surface above the discharge point. The water level nearer a hilltop, therefore, will fall more in a given time than the water level on the slope of the hill, and the amplitude of seasonal fluctuations will be greater on hills than in valleys.

Wells in which the water level fluctuates repeatedly over a range of many feet may become clogged by the encrustation of minerals on the walls of the wells. The encrustation forms as the declining water level leaves behind a thin film of water to evaporate and deposit its dissolved solids. After repeated fluctuations, an impervious crust is gradually built up, and the well becomes insensitive to water-level changes in the aquifer.

Long-term fluctuations.—Much of the interest in water-level fluctuations concerns the trends of water levels and the existence of cycles. Figure 6 shows the hydrographs of three representative wells, in widely separated parts of Pennsylvania, for which long periods of record are

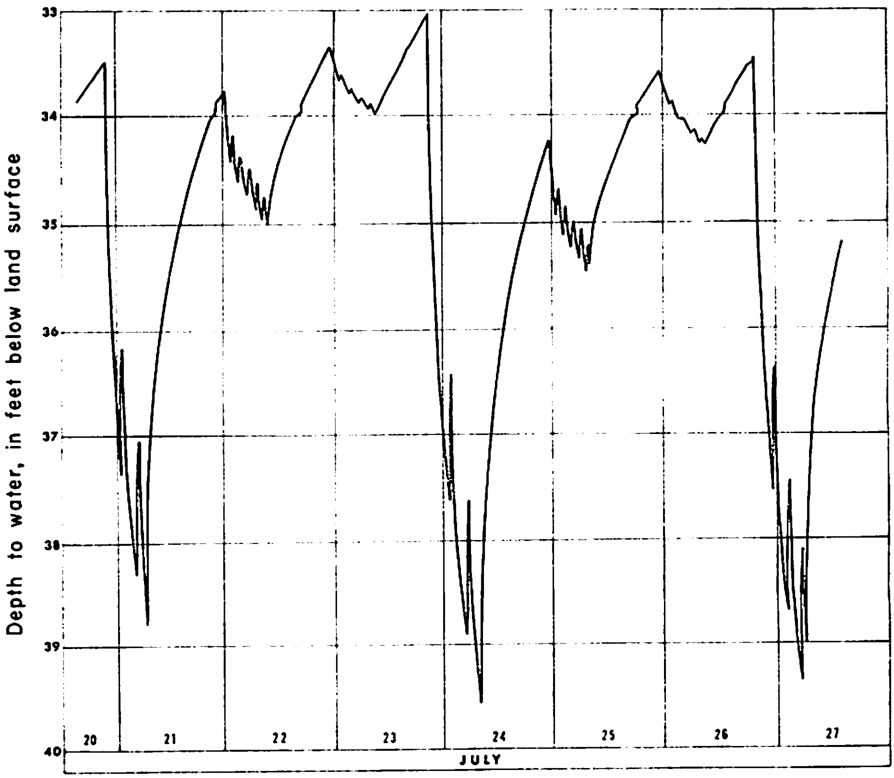

Figure 5. Hydrograph of well Mg-4, showing the effects of pumping in other wells, July 20 to 27, 1956.

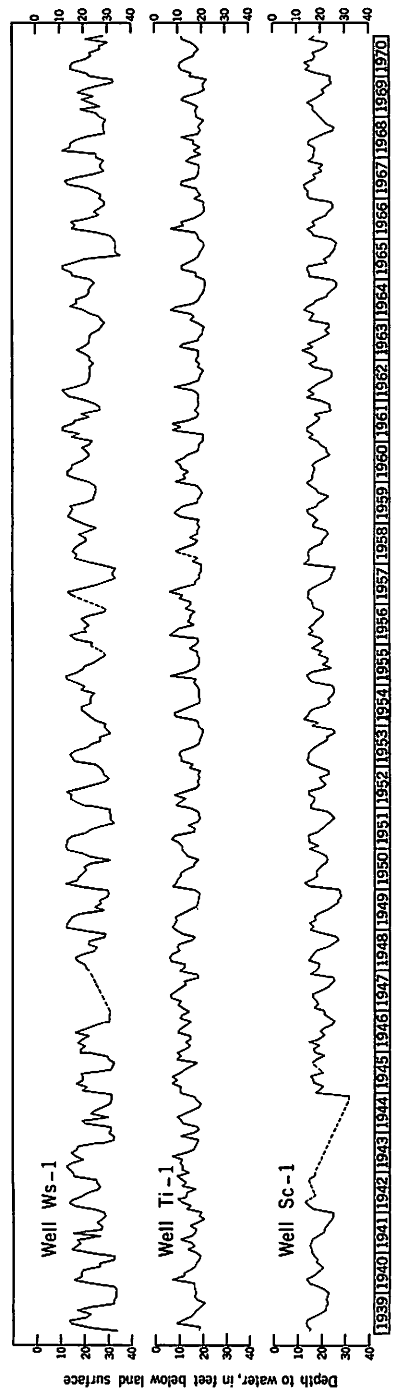

Figure 6. Hydrographs of wells Ws-1, Ti-1, and Sc-1, showing water-level fluctuations from 1939 to 1970.

available. Inspection reveals that although water levels stand higher in some years than in others no long-term trend is apparent.

The hydrographs in Figure 6 illustrate the behavior of the water table under conditions of dynamic equilibrium. So long as there are no changes in the regimen of these areas, the water table in the vicinity of the wells will continue to oscillate in the characteristic fashion shown in this figure. If this regimen were changed by some factor—either by a change in climate or by some work of man—the water table would respond to this change. If the change were brought about by the pumping of water from the aquifer, the water level would decline until the natural discharge from the aquifer was reduced by an amount equal to the pumping rate, or additional recharge was induced by an amount equal to the pumping rate, or the combined reduction in natural discharge and increase in recharge was equal to the pumping rate.

If the pumping rate were constant, the hydrographs resulting from the new regimen would differ from the old only by the increased depth to water; however, if the rate were irregular, even the pattern of fluctuations would be altered. If the pumping rate were greatest during the late summer and fall, when the ground-water levels are naturally at their lowest, the amplitude of the annual cycle would be greater and might even result in the well becoming temporarily dry. A maximum pumping rate in the spring, when water levels are high, would tend to flatten the hydrograph and reduce the amplitude of the fluctuations.

In order to see more clearly the fluctuations that have a duration greater than 1 year, 12-month moving averages were computed for the water-level data from well Sc-1. The 12-month moving average is a series of successive averages obtained by averaging the first 12 monthly water-level measurements to obtain the first average, then discarding the first monthly measurement and including the thirteenth monthly measurement to obtain the second average. This process is repeated through the data. The 12-month moving average removes the effect of cycles 12 months long or even fractional multiples of 12 months, such as 1, 2, 3, 4, or 6 months. The precipitation and temperature data from a nearby U. S. Weather Bureau station were treated similarly. These three curves are shown in Figure 7. The water-level curve resembles the precipitation curve quite closely but differs from the temperature curve. No cycles are apparent in any of these curves.

The average ground-water levels shown in Figure 7 change considerably from year to year. Several years of above-average water levels occur together and are followed in turn by several years of below average water levels, because of the natural changes in meteorologic conditions. The lack of a trend is apparent, and it is important to realize that

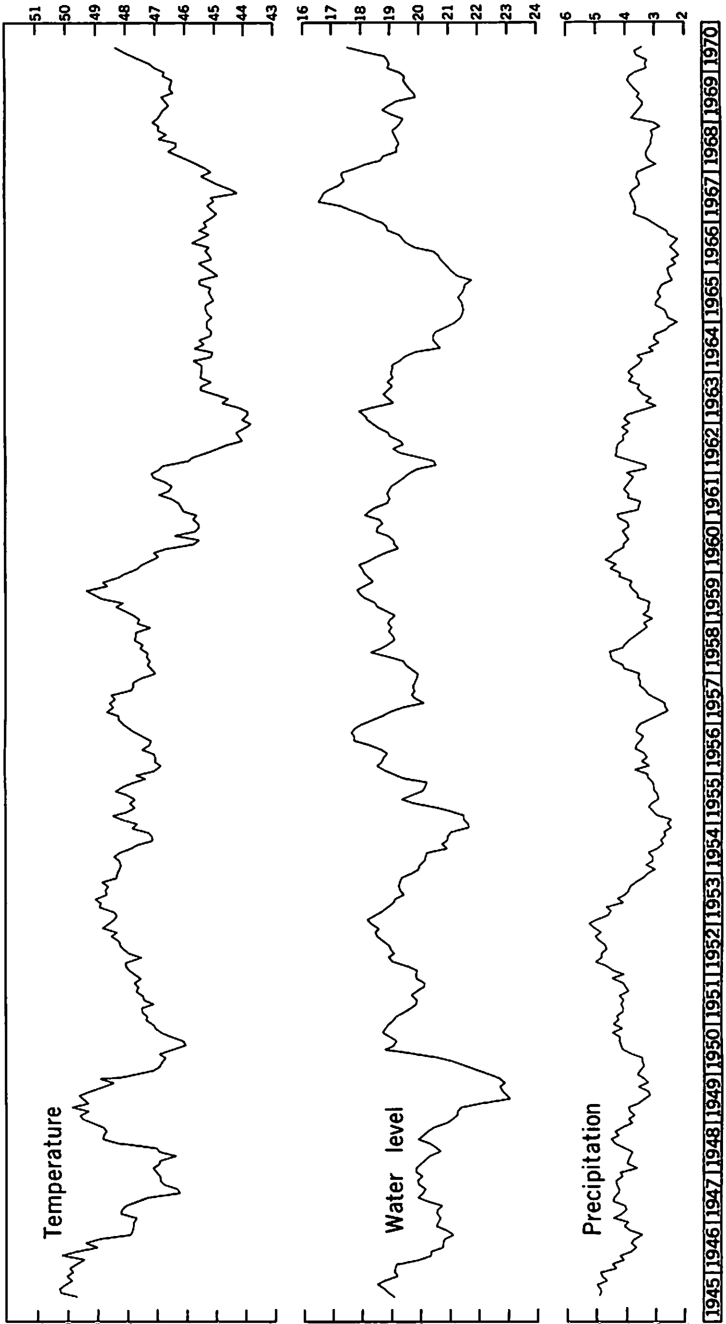

Figure 7. Graph showing 12-month moving averages of water-level data in well Sc-1 and temperature and precipitation data at a nearby U. S. Weather Bureau station.

several years of below-average water levels do not indicate that the water levels are permanently declining.

Low water levels may result in some wells going dry; therefore, care should be taken that wells are deep enough, especially in areas where the rocks have low storage capacity or where there is much pumping.

Effects of man

The 1970 census of Pennsylvania reported a population of 11,793,909, which represents a growth of 4.2 percent since 1960. Figure 8 shows counties having more than 100,000 people and the rate of growth of the population by counties. Most of the Commonwealth's population is concentrated in a few areas: the southeast, the anthracite coal-mining region of east-central and northeast Pennsylvania, the bituminous coal-mining region of southwestern and far western Pennsylvania, the Pittsburgh district in central Allegheny County, and the region along Lake Erie.

Significant changes in the distribution of the population took place between 1960 and 1970. Two factors appear to be involved. First, the economic decline of the coal industry caused large numbers of people to seek employment elsewhere, so that some counties had fewer people in 1970 than they did in 1960. Second, large segments of the population moved out of the cities to suburban areas. Thus, while Philadelphia's population decreased about 3 percent, that of nearby Bucks County increased about 35 percent. Counties adjoining Bucks County also showed rates of growth far in excess of the average for the Commonwealth. Most of the other cities in Pennsylvania showed either a loss in population or a growth rate below that of the Commonwealth.

Therefore, it may be inferred that within the foreseeable future the demand for water in the older cities will increase only slowly or may even decrease, but in the areas surrounding these cities the demand for water probably will increase considerably.

Suburban development generally reduces the demand on a single source for water, and draws, instead, upon many sources. Also, the problem of waste disposal in relation to the potential pollution of water is distributed over a much larger area than when the problem was confined to one city.

Furthermore, suburban development disturbs the natural recharge-discharge regimen. By removing forest and grass cover, constructing streets, sidewalks, and buildings, and channeling precipitation to concrete sewers, the aquifers are deprived of water that is needed to replace that which the suburban development is consuming. The net result, then, may be a decline in water levels in these newly developed areas and a deterioration of water quality.

Figure 8. *Map of Pennsylvania showing counties having more than 100,000 population, and the rate of growth of the population by county.*

USES OF WATER-LEVEL MEASUREMENTS

The uses to which water-level measurements are put may be divided into two categories: (1) those which require only a short period of record and (2) those which require a long record. Short-term records are used chiefly to determine the hydraulic properties of an aquifer by pumping tests, by measurement of cyclic fluctuations such as tides, by measurements of the natural water-level recession in wells, and by measurements of the interrelationship of water levels in wells and those in nearby streams.

The solution of specific problems sometimes requires the collection of water-level data for several years. Such problems may include the effect of dams, stream rerouting, spreading of floodwaters, or irrigation practices on ground-water levels. Also, long records of water-level fluctuations, perhaps even of a continuing nature, are needed to predict streamflow or future ground-water levels.

Statistical analysis of long-term records has been used to estimate the hydraulic properties of aquifers, recharge and discharge rates, evapotranspiration, and soil-moisture storage. The accuracy of the estimates improves as the length of the record increases.

Continuing records are valuable for two other purposes. First, measurements should be made in areas undergoing development in order to ensure that the ground-water supplies are managed properly. Second, measurements should be made also in areas remote from the effects of man—areas that are not likely to be disturbed in the foreseeable future. This second group will furnish information on the natural regimen and serve as a control sample against which the effects of man's activities can be measured.

The uses described above are based upon our present understanding of the hydrologic cycle. Because the science of hydrology is still young, many more basic data need be collected and interpreted. As the inherent character of hydrology is such that these data may vary greatly from year to year, their value increases as the length of the record increases. As our knowledge of the interrelationship of the atmosphere, surface water, and ground water grows, our uses of available information will grow, and the accuracy of predictions based on this information will improve.

REQUISITES OF AN IDEAL OBSERVATION-WELL NETWORK

The ideal network is one which furnishes data on water levels in each of the geologic and climatic environments. In addition, the network should be sensitive to the population distribution of the Commonwealth by including observation wells that will reflect indefinitely the natural regimen and other wells that will monitor the development of an area by man. When possible, observation wells should be established several years before development is accomplished, so that they will record the transition from a natural to an artificial environment.

The wells should be in hydraulic continuity with the aquifer under study and should be so situated that they reflect adequately the environment they are supposed to sample. They should be coordinated with sites sampling other phases of the environment, and they should be so selected and situated that they may be measured as long as desired.

At the time a well is established as an observation site, it should be pumped to ensure that it is not clogged and to determine (if possible) the hydraulic properties of the aquifer at that point. Unless there are specific reasons for doing otherwise, a well should be at only a moderate height above points of discharge from the aquifer, in order to reduce the seasonal fluctuations and thus minimize the opportunity for clogging. Geologic information, including electric and gamma-ray logs, should be obtained, and the depths to the water-bearing zones should be determined. A water sample from the well should be analyzed to determine its physical and chemical properties.

Each observation well should be equipped with a continuous water-level recording device for a period long enough to determine the characteristics of water-level fluctuations in the well. In addition, periodic checks should be made to determine if the well is becoming clogged, or if the physical or chemical character of the water is changing.

The well should be tightly cased and covered to prevent animals from falling into it, to prevent the direct entrance of surface water, and to prevent its becoming blocked by having stones or other debris thrown into it.

THE NETWORK IN PENNSYLVANIA

As the time, funds, or personnel are seldom available to conduct an ideal observation-well program, the number of wells in any network is necessarily limited. In 1970, the network in Pennsylvania consisted of 70 wells and included only 4 of the 37 wells in the original network established in 1931. The period of record of the wells measured in 1970 ranged from 1 to 40 years. About two-fifths of the wells had less than 15 years of record. Dug wells constituted 43 percent of those having more than 15 years of record but accounted for only 17 percent of the total number of wells. Most of the measurements have been made at weekly or monthly intervals. However, 47 continuous water-level recorders were in use in 1970. About 40 percent of the wells are in counties having populations greater than 100,000, and 25 percent of the wells are in urban areas. Four wells in Montgomery County and one well in Chester County, are in or near communities experiencing rapid growth. The rural wells are scattered throughout the Commonwealth and most of them are in places where they will not be disturbed in the foreseeable future.

An observation-well network should sample the many variables and supply as much detailed information as is economically practical. The present network is considered satisfactory in most respects, but several changes will be made.

The dug wells will be replaced by drilled wells because dug wells tend to fill in and become so shallow that they may be dry during drought years. Also, dug wells require constant maintenance to prevent them from becoming safety hazards.

The network will be expanded in those areas undergoing rapid growth, where new or additional demands may be made on the ground-water supply. The wells will be test-pumped to ensure their hydraulic connection to the aquifer prior to their being adopted as observation wells; they will be logged electrically to determine the lithology of the rocks penetrated, and the size, number, and position of the water-bearing zones.

All the wells will be pumped and water samples will be taken for chemical analysis at regular intervals. Continuous water-level recorders will be used on all wells for periods sufficient to establish the fluctuations characteristic of the water level in each well. Following the establishment of the characteristic curve, the water level may be measured weekly, monthly, or at even longer intervals.

Table 1—Record of observation wells in 1971

Method of construction: Dr, Drilled; Du, Dug. Environment: R, Rural; U, Urban

Well number	County	Owner	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	Aquifer: Composition	Geologic period	Static water level Dec. 1970: Depth below land surface (feet)	Environment	Year record began
Ad-146	Adams	U. S. Geological Survey	1967	540	Dr	6	100	17	Gettysburg	Shale and sandstone	Triassic	11	R	1968
Ag-700	Allegheny	U. S. Geological Survey	1967	1,030	Dr	6	100	24	Conemaugh	Sandstone and shale	Pennsylvanian	6	R	1967
Ar-2	Armstrong	Martin J. Cordera	1923	780	Dr	6	82	—	———	Sand and gravel	Quaternary	31	R	1949
Bv-156	Beaver	U. S. Geological Survey	1967	930	Dr	6	101	25	Conemaugh	Shale	Pennsylvanian	9	R	1967
Bd-150	Bedford	U. S. Geological Survey	1965	1,140	Dr	6	150	47	Onondaga	Shale	Devonian	12	R	1965
Bd-154	Bedford	U. S. Geological Survey	1966	1,130	Dr	6	183	163	Oriskany	Sandstone	Devonian	27	R	1966
Be-4	Berks	Commonwealth of Pennsylvania	——	694	Du	48	20	—	Stockton	Shale	Triassic	10	R	1949
Ba-74	Blair	U. S. Geological Survey	1969	1,130	Dr	6	150	14	Brallier	Shale	Devonian	14	R	1969
Br-92	Bradford	U. S. Geological Survey	1966	750	Dr	6	117	55	Gardeau	Shale	Devonian	8	R	1966
Bk-929	Bucks	U. S. Geological Survey	1967	460	Dr	6	116	27	Brunswick	Shale	Triassic	53	R	1967
Bt-311	Butler	U. S. Geological Survey	1970	1,460	Dr	6	89	14	Kittanning	Shale	Pennsylvanian	14	R	1970
Ca-1	Cambria	Johnstown Tribune	1940	1,165	Dr	12-8	180	45	Homewood	Sandstone	Pennsylvanian	18	U	1952
Cm-13	Cameron	U. S. Geological Survey	1967	1,010	Dr	6	102	57	Catskill	Sandstone	Devonian	23	R	1967
Cb-104	Carbon	U. S. Geological Survey	1969	1,290	Dr	6	125	20	Mauch Chunk	Shale	Mississippian	46	R	1969
Ce-118	Centre	U. S. Geological Survey	1968	1,150	Dr	6	130	40	Gatesburg	Sandstone, dolomite	Cambrian	76	R	1968
Ch-10	Chester	Robert J. Kleberg, Jr.	——	300	Dr	6	34	—	Cockeysville	Marble	Precambrian	13	R	1951
Ch-11	Chester	J. E. Ryan	1850	540	Du	24	20	—	Baltimore Gneiss	Gneiss	Precambrian	12	R	1950
Ch-152	Chester	Phoenix Iron & Steel Co.	1952	85	Dr	12-8	750	35	Stockton	Sandstone	Triassic	Flow	U	1956
Cr-3	Clarion	Commonwealth of Pennsylvania	1939	1,530	Dr	6	130	12	Pottsville	Shale and sandstone	Pennsylvanian	46	R	1950
Cf-4	Clearfield	Jared I. McNaul	——	1,160	Du	60	30	—	Allegheny	Shale and sandstone	Pennsylvanian	19	U	1946

Cn-1	Clinton	Commonwealth of Pennsylvania	1940	2,050	Dr	6	78	38	Pocono	Sandstone	Mississippian	48	R	1950
Co-1	Columbia	Fred E. Walters	——	490	Du	36	19	—	————	Sand	Quaternary	11	U	1931
Co-45	Columbia	U. S. Geological Survey	1970	690	Dr	6	282	31	Bloomsburg	Shale	Silurian	86	U	1970
Cw-413	Crawford	U. S. Geological Survey	1967	1,110	Dr	6	100	19	Cussewago	Sandstone	Mississippian	23	R	1967
Cu-2	Cumberland	Commonwealth of Pennsylvania	1944	955	Dr	6	37	—	————	Metarhyolite	Precambrian	22	R	1951
Da-350	Dauphin	William R. Miller	1963	460	Dr	6	225	19	Martinsburg	Shale	Ordovician	4	R	1965
Da-353	Dauphin	Walter Compton	1963	500	Dr	6	184	21	Martinsburg	Shale	Ordovician	1	R	1965
De-3	Delaware	Mrs. Hope W. Ebert	——	260	Du	42	22	—	Wissahickon	Gneiss	Precambrian	14	R	1950
Er-82	Erie	U. S. Geological Survey	1966	1,419	Dr	6	82	56	Riceville	Shale	Devonian	12	R	1966
Fa-17	Fayette	U. S. Geological Survey	1967	1,910	Dr	6	100	19	Conemaugh	Shale and sandstone	Pennsylvanian	23	R	1967
Fr-2	Franklin	Letterkenny Depot	1942	694	Dr	8-6	441	60	Stones River	Limestone	Ordovician	25	U	1950
Fu-93	Fulton	Commonwealth of Pennsylvania	1965	1,190	Dr	6	194	45	Pocono	Sandstone	Mississippian	1	R	1965
Hu-1	Huntingdon	H. G. Stauffer	——	720	Dr	6	33	—	Scherr	Sandstone	Devonian	20	R	1931
Hu-301	Huntingdon	U. S. Geological Survey	1969	970	Dr	6	105	18	Burgoon	Sandstone	Mississippian	53	R	1969
In-1	Indiana	Commonwealth of Pennsylvania	——	1,305	Dr	6	198	—	Conemaugh	Sandstone	Pennsylvanian	75	U	1944
Je-23	Jefferson	U. S. Geological Survey	1967	1,660	Dr	6	101	37	Allegheny	Shale and sandstone	Pennsylvanian	16	R	1968
Ju-351	Juniata	U. S. Geological Survey	1968	635	Dr	6	112	18	Mahantango	Shale	Devonian	13	R	1968
Lk-4	Lackawanna	Commonwealth of Pennsylvania	——	1,910	Du	36	10	—	Catskill	Shale and sandstone	Devonian	4	R	1953
Ln-514	Lancaster	Benjamin Landis	1962	380	Dr	6	260	—	Kinzers	Shale, limestone	Cambrian	33	R	1964
La-1201	Lawrence	U. S. Geological Survey	1967	1,140	Dr	6	150	30	Connoquenessing	Shale and sandstone	Pennsylvanian	15	R	1967
Lb-377	Lebanon	Levitz Frozen Foods	——	460	Dr	8-6	204	30	Ontelaunee	Dolomite	Ordovician	8	U	1962
Le-644	Lehigh	C. J. Haaf	1958	470	Dr	10	184	63	Beekmantown	Limestone	Ordovician	92	R	1970
Le-860	Lehigh	Paul Knepper	1967	358	Dr	6	100	58	Allentown	Dolomite	Cambrian	5	R	1969
Lu-243	Luzerne	Commonwealth of Pennsylvania	1947	1,280	Dr	6	160	40	Catskill	Sandstone	Devonian	52	R	1948
Lu-309	Luzerne	U. S. Geological Survey	1967	540	Dr	6	40	35	Glacial Outwash	Sand and gravel	Quaternary	18	U	1967
Ly-112	Lycoming	U. S. Geological Survey	1967	1,380	Dr	6	200	19	Susquehanna	Shale	Devonian	86	R	1967
Mr-1364	Mercer	Borough of Greenville	1961	965	Dr	6	235	41	Cussewago	Sandstone	Mississippian	3	U	1965
Mf-1	Mifflin	Charles C. Nagincy	——	680	Du	36	28	—	Nealmont	Limestone	Ordovician	19	R	1941
Mo-190	Monroe	U. S. Geological Survey	1967	1,960	Dr	6	98	59	Catskill	Sandstone	Devonian	10	R	1967

Table 1—Record of observation wells in 1971 (Continued)

Method of construction: Dr, Drilled; Du, Dug. Environment: R, Rural; U, Urban

Well number	County	Owner	Date completed	Altitude above level (feet)	Method of construction	Diameter of casing (inches)	Total depth (feet)	Depth to bottom of casing (feet)	Aquifer: Name	Aquifer: Composition	Geologic period	Static water level Dec. 1970: Depth below land surface (feet)	Environment	Year record began
Mg-2	Montgomery	Commonwealth of Pennsylvania	1752	158	Du	48	30	—	Brunswick	Shale	Triassic	24	U	1948
Mg-133	Montgomery	Bryn Mawr College	1900	380	Dr	10	254	—	Wissahickon	Schist	Precambrian	17	U	1954
Mg-225	Montgomery	Norristown State Hospital	1950	165	Dr	12	300	—	Stockton	Sandstone	Triassic	30	U	1956
Mg-884	Montgomery	Merck, Sharp & Dohme, Inc.	1966	351	Dr	12-10	600	—	Brunswick	Shale	Triassic	73	U	1966
Np-85	Northampton	City of Bethlehem	1966	230	Dr	12	344	73	Tomstown	Dolomite	Cambrian	3	U	1969
Pe-511	Perry	U. S. Geological Survey	1968	590	Dr	6	138	17	Mahantango	Shale	Devonian	0	R	1968
Ph-12	Philadelphia	U. S. Naval Base	1944	10	Dr	8	110	94	Raritan	Sand	Cretaceous	23	U	1944
Ph-20	Philadelphia	U. S. Naval Base	1946	13	Dr	8	266	238	Raritan	Sand	Cretaceous	29	U	1946
Po-72	Potter	U. S. Geological Survey	1967	1,810	Dr	6	110	21	Catskill	Shale	Devonian	13	R	1967
Sc-1	Schuylkill	Nick C. Donofrio	——	560	Du	52	33	—	Mahantango	Shale	Devonian	14	R	1931
Sn-130	Snyder	U. S. Geological Survey	1968	740	Dr	6	100	41	Catskill	Shale	Devonian	18	R	1968
So-2	Somerset	Commonwealth of Pennsylvania	1936	2,037	Dr	6-4	450	310	Pottsville	Shale and sandstone	Pennsylvanian	30	R	1937
Su-34	Sullivan	U. S. Geological Survey	1965	1,080	Dr	6	50	34	Catskill	Shale	Devonian	25	R	1965
Sq-1	Susquehanna	Carlton Farm	——	1,690	Du	48	38	—	———	Sand and gravel	Quaternary	6	R	1930
Ti-1	Tioga	Mrs. R. K. Wilson	——	1,290	Du	30	23	—	———	Sand and gravel	Quaternary	11	R	1935
Un-51	Union	U. S. Geological Survey	1967	1,550	Dr	6	115	91	Reedsville	Shale	Ordovician	38	R	1967
Ve-12	Venango	U. S. Geological Survey	1968	1,518	Dr	6	132	9	Connoquenessing	Sandstone	Pennsylvanian	108	R	1968
Ws-1	Washington	Floyd King	——	1,190	Du	40	36	4	Washington	Limestone	Permian	12	R	1936
Wn-64	Wayne	U. S. Geological Survey	1967	1,330	Dr	6	52	52	Glacial Outwash	Sand and gravel	Quaternary	28	R	1967
We-300	Westmoreland	U. S. Geological Survey	1967	1,270	Dr	6	110	22	Conemaugh	Shale	Pennsylvanian	17	R	1967
Yo-180	York	New York Wire Cloth Co.	——	360	Dr	8	490	—	New Oxford	Shale	Triassic	27	R	1962