AN APPRAISAL OF THE

GROUND - WATER RESOURCES

OF THE

LOWER SUSQUEHANNA RIVER BASIN

SUSQUEHANNA RIVER BASIN

WATER RESOURCES DIVISION

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AN APPRAISAL OF THE GROUND-WATER RESOURCES OF THE LOWER SUSQUEHANNA RIVER BASIN

(An interim report)

BY

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INTRODUCTION

This report describes the availability, quantity, quality, variability, and cost of development of the ground-water resources in the lower Susquehanna River basin. The report has been prepared for and under specifications established by the Corps of Engineers, U. S. Army, and the Public Health Service, Department of Health, Education, and Welfare.

A comprehensive study of the water and related land resources of the Susquehanna River basin was authorized by the Congress of the United States in October 1961, and the task of preparing a report and of coordinating the work being done by others in support of the study was assigned to the Corps of Engineers. The comprehensive study is being conducted by several Federal departments and independent agencies in cooperation with the States of New York, Pennsylvania, and Maryland. The Public Health Service under its authority in the Federal Water Pollution Control Act (P. L. 660) initiated a comprehensive water quality control program for the Chesapeake drainage basin, which includes the Susquehanna River basin.

This report is intended to serve the specific needs for ground-water information of both the Corps of Engineers and the Public Health Service, as well as those of the other participating Federal and State agencies.

This study is being conducted under the guidelines for river-basin planning set forth by the Congress of the United States. On July 26, 1956, in the 84th Congress, the Senate expressed its sense relative to the conservation and development of water and related land resources in Senate Resolution 281 which stated:

> "Land and water resources development should be planned on a comprehensive basis and with a view to such an ultimately integrated operation of component segments as will insure the realization of the optimum degree of physical and economic efficiency."

The policies, standards, and procedures to be used in the formulation, evaluation, and review of plans for use and development of water and related land resources in river basins are set forth in Senate Document 97, under date of May 29, 1962. These policies, standards, and procedures were prepared by the Secretaries of the Army, Agriculture, Health, Education, and Welfare, and Interior and were approved by the President of the United States.

Senate Document 97 in Part III, Section B, states that:

> "Planning for the use and development of water and related land resources shall be on a fully comprehensive basis so as to consider--

(1) The needs and possibilities for all significant resource uses and purposes of development, including, but not limited to domestic, municipal, agricultural, and industrial uses of water; water quality control;...., and

(2) All relevant means (including nonstructural as well as structural measures) singly, in combination, or in alternative combinations reflecting different basic choice patterns for providing such uses and purposes."

The consideration of alternative combinations for water supply and water quality control requires that comparison be made of the use of either surface or ground water. The Geological Survey has been assigned the responsibility of investigating the ground waters of the basin to provide the facts necessary for the action agencies to make such a comparison. It is the only agency directly involved in a study of basin-wide ground-water conditions and potentials.

The report includes facts concerning the geologic and hydrologic parameters necessary for a preliminary evaluation of the role of ground water in the formulation of the comprehensive plan. The report also includes facts on costs of raw ground water delivered at the well head. The cost of ground water is included in response to requirements expressed in Part V, Section E of Senate Document 97 as follows:

"E. Types of primary benefits and standards for their measurement

1. Domestic, municipal, and industrial water supply benefits: Improvements in quantity, dependability, quality, and physical convenience of water use. The amount water users should be willing to pay for such improvements in lieu of foregoing them affords an appropriate measure of this value. In practice, however, the measure of the benefit will be approximated by the cost of achieving the same results by the most likely alternative means that would be utilized in the absence of the project. Where such an alternative source is not available or would not be economically feasible, the benefits may be valued on such a basis as the value of water to users or to the average cost of raw water (for comparable units of dependable yield) from municipal or industrial water supply projects planned or recently constructed in the general region."

In conformance with Senate Document 97, the Geological Survey has been assigned the responsibility of determining the costs of ground-water sources as "the most likely alternate means that would be utilized in the absence of the project."

The Corps of Engineers and the Public Health Service are jointly determining the present and future water requirements of several water-development areas in the basin as shown on figure 1. They will formulate plans based on the likelihood of supplying these areas with the most economically feasible source of water. They will use this report to determine if ground water is a possible economical source of supply that is comparable with surface-water sources in terms of quantity, dependability, quality, and physical convenience of water use.

The generalized estimates given in the report will be used not only to determine if ground water is likely to be the best choice in any given area, but also in deciding whether it is necessary to further investigate ground water as a potential source of supply in these areas. The decision to recommend the use of either surface or ground water at a particular site will most likely depend almost entirely upon the hydrologic and economic advantages or disadvantages of one source or the other. The actual decisions concerning ground-water feasibility, cost benefits, and its comparison with alternate sources of supply will not, of course, be made by the Geological Survey. The objective of this report is only to present the facts upon which decisions may be based.

The estimated water costs given in this report are based on the design and operation of hypothetical wells which in turn is based on a series of arbitrary assumptions and are valid only for a comparison with estimates of cost of water from surface water sources, which are being developed by other agencies, and as a comparison between rock units. Because of this general treatment, the figures given are not directly applicable to nor intended for use in the planning and design of any ground-water development project. The planning, design, and construction of specific ground-water supply systems require hydrologic and geologic data of the immediate localities and also the services of specialists such as consulting engineers, geologists, and well drilling contractors.

This report is the first of a series of interim ground-water reports. It is preliminary and subject to revision as the study progresses. In order to facilitate the work of the various agencies involved in the comprehensive study, a system of interim reports has been developed by which the various agencies exchange knowledge.

It was agreed that interim information on the ground-water resources would be most useful if reported in a series of five reports on relatively arbitrary subdivisions of the basin. These subdivisions are: (1) the lower Susquehanna basin, which is covered by this report, (2) the Juniata River basin, (3) the West Branch of the Susquehanna River basin, (4) the upper basin in Pennsylvania, and (5) the upper basin in New York State. After the interim reports have been completed, a report will be prepared on the ground-water resources of the entire basin.

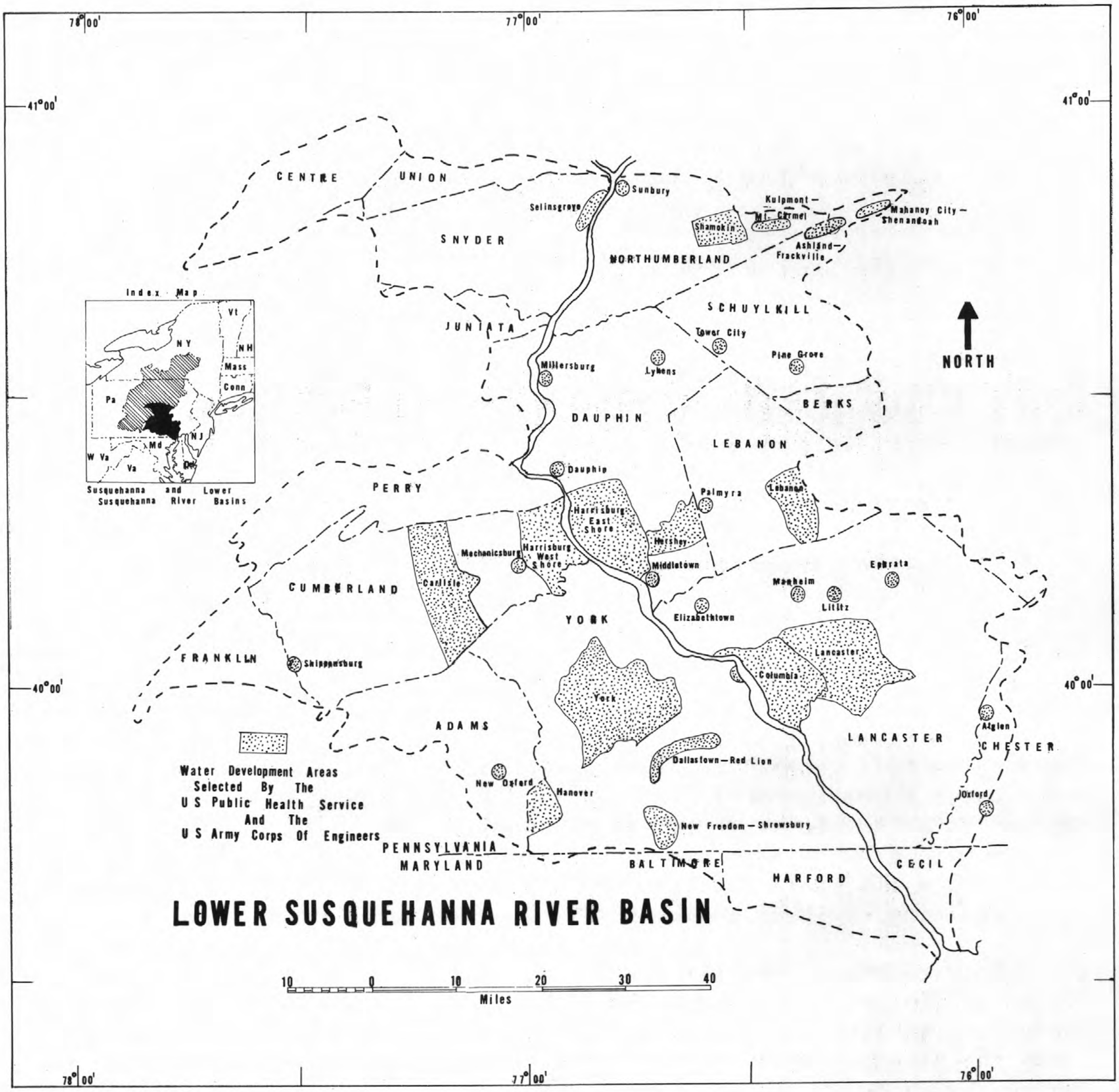

Figure 1.--Map showing designated water-development areas in the lower Susquehanna River basin

SUMMARY OF GROUND-WATER RESOURCES

Importance of Ground Water

Ground water plays a vital part in the hydrologic cycle, which is the endless circulation of water from the primary reservoir, the ocean, to the atmosphere, the land, and back to the ocean over and beneath the land surface.

One major role ground water plays is its relation to surface water. In humid areas discharge from ground-water storage maintains the flow of streams during periods of little or no precipitation. In such areas geology determines the dependability of streamflow. Streams underlain by shale tend to have flashy runoff characteristics compared to streams underlain by unconsolidated sands. Hence, a correlation can be made between streamflow characteristics and the water-yielding characteristics of the rocks of a basin. Basins whose streams have flashy runoff characteristics are usually underlain by rocks of lower permeability and storage capacity than are basins whose streams have a more uniform flow.

Most of the streams in the Susquehanna River basin are effluent, that is, water moves from the ground-water reservoir to the surface streams. This condition may be reversed in some instances, and water may move from the stream to the ground-water body. An extreme case of this condition could exist in which wells pumping along a stream intercepted such quantities of water that the stream completely dried up.

The quality of streamflow, as well as the quantity, is related to the contiguous ground-water reservoir. If the major part of streamflow is base flow from ground water, the water in the stream will usually be high in dissolved solids and low in suspended solids. On the other hand, if most of the streamflow is from overland runoff, the water in the stream will usually be low in dissolved solids and high in suspended solids.

Ground water can also contribute to dilution and neutralization of acid mine drainage and reduce its effects downstream, as it does in the Swatara Creek basin near Harrisburg. Ground water flowing into effluent streams from carbonate rocks contributes alkaline bicarbonate water that neutralizes and dilutes the acid sulfate waters from the coal mining regions upstream.

At one time ground water could be thought of as a widely distributed and generally rather easily obtained substance whose principal usefulness lay in meeting small-scale domestic and stock requirements in rural areas and in small towns. Later, community wells were drilled to replace polluted individual wells and to supply residents of those parts of the towns where ground water was hard to get. Commercial and industrial establishments began to drill their own wells for reasons of economy.

Around the turn of the century and for some years thereafter, ground water tended to fall into disfavor as a source to meet large demands. As techniques of well construction and pump design improved, it became possible in many areas to obtain needed supplies of water from wells at a cost in time, money, and initial materials less than that required for development of a surface-water source.

Ground water has developed from a quantitatively minor (though critically important) source for domestic supply to a source supplying something like 1/6 to 1/5 of the national water supply requirements. We can foresee ground-water reservoirs not only continuing to be a major source for meeting withdrawal requirements, but emerging as a medium for storing even larger quantities of surplus streamflow for cyclic withdrawal as a phase of multipurpose water management.

Where available in suitable quantity and quality, ground water provides a source of water without the necessity of long transmission lines. In areas where the available supplies of ground water may not equal the ultimately anticipated requirements, it may, nevertheless, be advisable to develop ground water locally to meet the needs until larger sources become economically feasible. The ground-water sources developed earlier could then be used as a supplementary supply.

Ground water may be preferred to surface waters because of its relatively uniform temperature, quantity, and quality throughout the year. Currently at least 1/4 the population of the Susquehanna River basin is believed to use water derived from underground sources. More than 400 municipalities having a centralized water system depend upon ground water for all or part of their supply. The total quantity of ground-water use may be expected to increase even as major urban supplies of surface water are developed.

Ground water is one of the earth's most widely distributed resources and one of its most important. Nevertheless to offset its advantages certain disadvantages are or may be inherent in any large-scale development of ground water. Among them are: (1) generally a lack of knowledge as to occurrence, movement, distribution, and availability in a particular aquifer--and the cost of the requisite studies in time, materials, and personnel; (2) costs associated with drilling wells and pumping them instead of collecting water by gravity flow; (3) complexities in management; (4) slowness and generally unknown or uncertain response of ground-water reservoirs to development; and (5) all forms of potential contamination. Nevertheless, history and hydrologic realities signify clearly that we will depend on the ground-water reservoirs for a large part of our total water supply.

Physiographic Provinces

The availability of ground water in any area is determined first by natural conditions--the type, distribution, and structure of the rocks, and the physiography and climate--and second by the extent to which the natural conditions have been changed by the actions of man. These generalizations are true everywhere, but in the Susquehanna River basin they seem especially true because of the complexity of the ground-water hydrology.

The Susquehanna River basin can be divided into three large geologic regions distinguished on the basis of age, character, and structure of the rocks and physiography. The availability of ground water and the yield of wells differs from one region to another, but there are many similarities also. The three regions--from south to north--are the Piedmont, the Mountainous Area, and the Appalachian Plateau. (See fig. 2.) A fourth region can be considered to include the glacial deposits, which are mainly in the Appalachian Plateau but extend into the other regions. The lower Susquehanna River basin contains parts of the Piedmont and the Mountainous Area, and only a small area of glacial deposits. The glacial deposits are unimportant as a source of ground-water supply in the lower basin.

Piedmont

The Piedmont occupies the southeastern part of the Susquehanna River basin. In the southeastern part of the Piedmont are uplands formed by crystalline igneous and metamorphic rocks of Precambrian and early Paleozoic age. Extending across the middle of York and Lancaster Counties are valleys underlain by limestone and dolomite of Cambrian and Ordovician age. In the northwestern and northern parts of the Piedmont is a broad area underlain by conglomerate, sandstone, shale, and diabase of Triassic age, called the Triassic Lowland.

Yields of wells in the igneous and metamorphic crystalline rocks, which occupy about half of the area within the Piedmont Province, are generally low. The rocks can yield to individual wells from 20 to 600 gpm (gallons per minute), averaging 75 gpm, of generally soft water. Locally the water is hard and has a high content of iron. These rocks are considered to be a poor source of ground water even though a few wells can yield as much as 600 gpm.

The limestone and dolomites can yield to individual wells 15 to 850 gpm, averaging 125 gpm, of water that is hard but otherwise of good quality. Many springs, some large, emerge in their outcrop areas. These are the only rocks in the Province from which well yields of more than 500 gpm can be reasonably expected.

The Triassic rocks form moderately productive aquifers and are capable of yielding to individual wells 25 to 500 gpm, averaging 125 gpm, of generally hard water. West of the Susquehanna well yields are generally less than east of the river. The Triassic diabase is an exceptionally poor water-bearing rock.

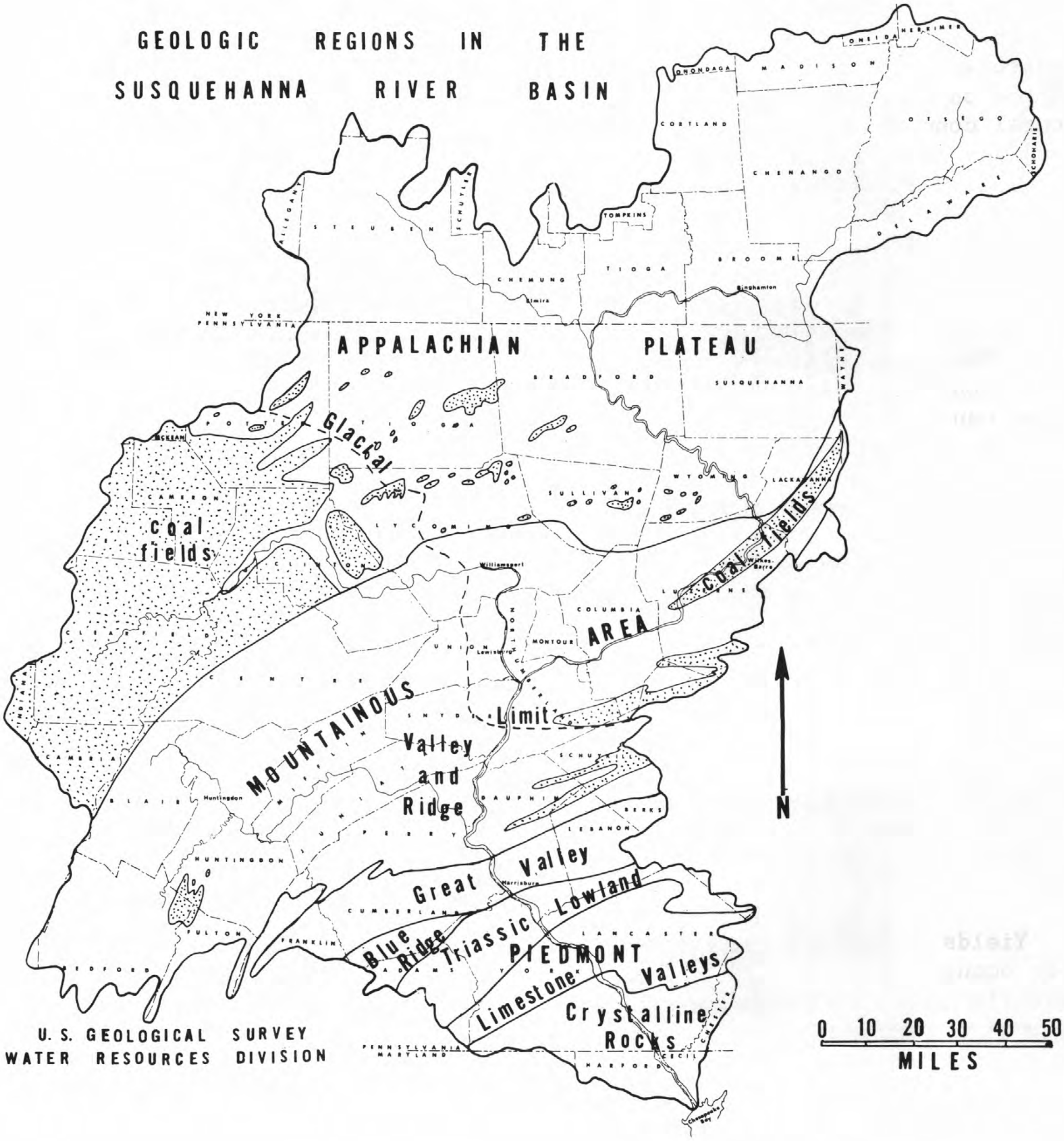

Figure 2.--Map showing the geologic regions in the Susquehanna River basin

Mountainous Area

The Mountainous Area, as defined in the Susquehanna River basin, includes the Blue Ridge, the Great Valley, and the Valley and Ridge Provinces and occupies the broad northeastward-trending belt between the Piedmont on the south and the Appalachian Plateau on the north. It is underlain by folded and faulted rocks.

The predominant rock type in the Valley and Ridge Province is a sequence of alternating shale, sandstone, and limestone of Paleozoic age. The rocks in this sequence can yield to individual wells 25 to 700 gpm, averaging 125 gpm, of soft to very hard water. The limestones and dolomites are presently the most productive aquifers in the Valley and Ridge Province. Large springs, some producing several thousand gallons of hard water per minute,issue from the rocks. The sandstones are potentially good sources of water. Many of the wells that tap sandstones are used only for domestic purposes, as most municipalities are supplied by surface water, but reported well yields of 100 to 500 gpm of soft water indicate the possible importance of sandstones as a source of water. The shales supply water that is generally high in iron and hydrogen sulfide. They ordinarily do not supply more than 75 gpm per well.

In the eastern part of the area are belts of folded shale, sandstone, conglomerate, and anthracite coal, mostly of Pennsylvanian age. Wells tapping these rocks can yield from 75 to 750 gpm, averaging 225 gpm, of water whose quality is generally good except near coal mines, where it is acidic and high in iron as a result of oxidation of sulfide minerals.

In the southern and western part of the Mountainous Area, and along the entire boundary between that area and the Piedmont, are areas in the Great Valley underlain by limestone and dolomite. These rocks are even more productive than those of the shale-sandstone-limestone sequence of the Valley and Ridge Province. They are capable of yielding as much as 1,000 gpm of hard water to wells and give rise to many sizable springs.

Paralleling the northwest border of the limestone in the Great Valley is a belt of shale that can yield to individual wells 25 to 100 gpm, averaging 60 gpm, of moderately hard water of generally good quality, except that locally it is slightly high in iron content.

The small part of the Blue Ridge Province in the basin contains crystalline rocks similar in character, yield, and quality of water to those of the southeastern Piedmont.

The rocks in the Mountainous Area have been folded and faulted so that they dip steeply throughout most of the region. This folded and faulted structure results in northeastward trending beds of rocks of different types. The deformation of these rocks decreases northwestward, and ultimately there is a zone in which the folded rocks give way to the nearly horizontal rocks of the Appalachian Plateau.

Ground-Water Problems

The Susquehanna River basin has a humid climate and a large supply of water and there is no present or forseeable overall shortage of water. Water related problems are numerous but generally are not as critical as they are in many other parts of the United States. Hence, in this water-rich area, problems of water supply are largely local. There are problems of determining the local availability of water, regulating the use of water to prevent overdevelopment, and protecting the water from contamination.

Availability of Supply

Because of the complexity of the geology and hydrology, locating ground-water supplies is a problem in many places in the basin. Existing reports form a good basis for more detailed studies of areas of prospective development, but only a small start has been made on the detailed studies themselves. The basin is underlain by a great variety of rocks ranging from crystalline rocks of Precambrian age to unconsolidated deposits of Recent age. The rocks differ greatly in their areal extent, composition and texture, thickness, structural attitude and relation to each other, and in their physiographic expression. All these factors affect their capacity to store and transmit water. Much study is needed to support more accurate predictions of just where and how deep it will be necessary to drill, what quantity and quality of water can be expected, and what will be the hydrologic effects of withdrawing water at various rates. Much additional research is needed on the general subject of predicting yields of wells in consolidated rocks, and the results have potentially widespread significance throughout the United States.

Ground-water conditions not only differ from one stratigraphic unit to another, but also differ within a given unit. Hence, though it is possible to generalize about ground-water conditions in areas of various sizes, it is rarely possible in the Susquehanna River basin to predict accurately the availability of ground water at a specific locality in advance of drilling, even if there are wells of known performance nearby.

Overdevelopment

Overdevelopment of ground water is presently a problem in very few areas in the Susquehanna River basin. On the whole, much additional ground-water development is feasible. The ground-water resources appear to be ample to meet future needs and the problems that may develop are those of distribution of the supply--not of the total resource. Where development is intense--such as in lower Broome County, New York, or at State College, Pennsylvania--legal control to prevent overdevelopment or contamination may be necessary.

Domestic, municipal, and industrial users have been generally successful in obtaining all the water they need at a cost within their ability to pay. This does not mean that there have not been individual hardship cases. In any area the size of the Susquehanna River basin there may be found rural or suburban householders, or small communities in unfavorable ground-water areas, that have spent several thousand dollars in drilling wells and still do not have an ample supply. In general, however, the ground-water supplies have met the demands reasonably placed upon them. Water for full-scale irrigation of a very large acreage from one or a few wells is usually not available.

Contamination

Contamination is sometimes a major problem with ground-water supplies as it often is with surface supplies. Population expansion and heavy industrialization have combined to produce large quantities of pollutants. Mines, chiefly coal mines, are one of the main sources. Though streams are the principal recipients of acid mine wastes, ground water may also be affected. Contamination of ground water by domestic or industrial wastes is a potential threat in some expanding urban areas. In valleys underlain by cavernous limestone in the central and southeastern parts of the basin, contamination of ground water by sewage and industrial wastes is rather common.

A type of contamination whose extent and importance are only beginning to be realized is that resulting from movement of rainwater and snowmelt through sanitary land fill and, thence, into aquifers and streams. As population grows and accumulates solid waste products, which are disposed by filling low areas, the problem is bound to increase and ultimately will necessitate remedial action.

As the practice of returning heated water (which has been used for cooling) to the ground increases, thermal pollution will become an increasing problem in some areas.

Industries using chemical processes are producing an increasing variety of contaminants--some of which are of unknown and possibly high toxicity, or are difficult to remove from water, or both. To these can be added synthetic detergents, which are being used increasingly in homes and industry, pesticides and insecticides, and radioactive substances. All these contaminants tend to find their way into our water supplies. Against most of them, however, ground waters are better protected than surface waters.

EXPLANATION OF DATA AND TERMS USED IN THIS REPORT

Geologic

The reader is referred to the Geologic Map of Pennsylvania (Pennsylvania Geological Survey, 1960) for the location of the geologic units discussed in this report. The stratigraphic nomenclature and age assignments used in the map referred to above differ only slightly from those approved for use by the U. S. Geological Survey. No confusion will therefore result from simultaneous usage of the map and this report.

Hydrologic

The following hydrologic terms are used in this report as indicated.

Aquifer

An aquifer is a hydrologic unit comprising water-bearing rocks from which water is collectable in usable quantities. Aquifers are of two principal kinds: water table (unconfined) and artesian (confined). An aquifer may be a single geologic formation, a part of a formation, or two or more formations that are hydraulically connected to form a single aquifer. In this report, the terms aquifer and ground-water reservoir are considered synonymous. Aquifers serve as both underground reservoirs and as pipelines, for in addition to storing water they transmit it from places of recharge to places of discharge.

Specific capacity

The rate of yield of a well per unit drawdown of water level is known as the specific capacity of the well. Thus, a well yielding 100 gpm (gallons per minute) with a drawdown of 5 feet has a specific capacity of 20 gpm per foot of drawdown. Specific-capacity data provide a basis for comparing wells of different yields and estimating the hydraulic properties of the aquifer units thus tested.

Availability

This term "availability" is used in this report in a special sense to indicate the accessibility and location of aquifers with respect to a given municipality, township, or water-development area. Sections of the report concerned with availability will deal with the location of geologic units, in the area under discussion, that are capable of yielding usable ground-water supplies. All such units listed as available to an area are inside of or within one mile of the political boundaries of that area.

Quantity

The quantity of water that can be obtained from a single hypothetical well is computed from specific-capacity data and from assumed available drawdowns, and is based on a statistical analysis of records obtained chiefly from existing successful municipal and industrial wells. Such wells were used for the analysis because usually an effort is made to obtain the largest possible yield from municipal and industrial wells. In contrast, domestic wells are usually developed only to the extent necessary to provide a supply for one household. Records of domestic wells were used sparingly or eliminated from the analyses.

Well yields in gallons per minute often depend as much upon the effort made to obtain water from the well as upon the characteristics of the aquifer. For instance, a larger diameter well, a larger capacity pump, a deeper pumping level, a deeper well, or additional well development may all result in an increased well yield. Partial penetration of the aquifer, well loss, and geohydrologic boundaries may affect specific-capacity data. The use of specific-capacity data allows the computation of well yields in gallons per minute for any well diameter or depth if a static water level and available drawdown are known. This assumes that specific capacity is uniform with depth; that is, with increased penetration of the aquifer. The specific-capacity data used in this report are those obtained, for the most part, at the time the well was first constructed. Specific capacities theoretically decline as time passes if all pumpage is from storage in the rocks. The reported specific capacities were, therefore, all adjusted to what they theoretically would be after 180 days of pumping without recharge. In addition, specific capacities sometimes vary seasonally, usually being higher in the winter than in the summer owing to higher natural static water levels in the winter.

By using the median figure for specific capacity and yield data shown in table 1, a reasonable estimate of predicted well yields is obtainable. The quantities listed in later sections of this report as being available from each geologic unit or to any specific area are based upon reasonably predicted yields of <u>single</u> wells. The wells are assumed to be located by an expert engineer or geologist and not to be affected by the pumping of any other well.

In recent years, great progress has been made in the scientific spacing, design, construction, development, and maintenance of wells. The design and operation of a well or of well fields, to recover the maximum yield of ground water, are usually the responsibility of specialists outside of the Geological Survey.

Data are generally insufficient in the Susquehanna River basin to permit applying theory to the problem of well spacing over large areas, but there is the opportunity for steady improvement in the design of individual well fields in localities where the required data are available or can be obtained.

There is an upper limit to the amount of ground water that can be obtained from an area on a long-term basis, just as the watershed above a surface reservoir can be expected to provide only certain amounts of water. Estimates made in the adjacent Delaware River basin (Parker and others, 1964, p. 91) of 0.75 mgd (million gallons per day) per sq. mi. of natural ground-water recharge for similar rocks give some indication of the amount of ground water available to this area. Either more or less than 0.75 mgd may be available for consumptive use in any particular area, depending on local conditions. Generally less will be available in areas remote from major streams and much larger amounts will generally be available near major streams. However, the major limiting factor for ground-water availability will be the transmitting and storage capacity of the major rock units in the basin. Because of the relative low productivity and small storage capacity of many of the rock units, and also because of many practical limitations, chiefly economic, only a small part of the ground-water discharge at natural outlets in the Susquehanna River basin can be diverted for man's use. However, pumpage substantially in excess of the 1965 rate could be maintained with increased ground-water development. The general assumption can be made, however, that all the water necessary to an area can be obtained from ground-water sources--if not from nearby wells then from more distant wells--and that the only limitation is the cost of the water. However, the total quantity or "safe yield" of a particular area cannot generally be predicted without further study. The cost in time, materials, and personnel necessary to determine the "safe yield" of even a small area is high.

No water-requirement figures were supplied to the U. S. Geological Survey for any of the water-development areas designated; therefore, no estimates of the available supply in terms of requirements can be made. The terms inadequate or abundant supply of water are meaningless unless judged against requirements. For example, a supply of 1 mgd is inadequate for an industry needing 5 mgd, but would be abundant for a town needing only 0.1 mgd.

METHOD OF ANALYSIS

For the sake of uniformity, the analyses in this paper are based upon hypothetical wells of a uniform depth and diameter for assumed conditions. The characteristics of the hypothetical wells are made to conform to the characteristics of the aquifers by an analysis of existing wells of various depths and diameters. A brief discussion of the general approach used in this report follows. More detailed explanations are given in the section of the report entitled "Explanation of Tables."

A list of 33 water-development areas chosen by the U. S. Public Health Service and the U. S. Army Corps of Engineers in the lower basin were analyzed to meet the objectives of the Comprehensive Study of the basin. All geologic units occurring in or within one mile of these areas were tabulated. Specific-capacity, geologic, hydrologic, and well-record data were collected and organized for wells tapping these units. The specific-capacity data were analyzed statistically by plotting specific capacities of wells against percentage of wells on logarithmic-probability paper. The reported specific capacities were all adjusted to what they would theoretically be after 180 days of pumping with no recharge. Static water levels were estimated for each geologic unit. Pumping water levels were assumed for each major rock type. These were 100 feet in carbonate rocks, 150 feet in metamorphic and igneous rocks, and 200 feet in all other rocks. Available drawdowns for each geologic unit were then obtained by subtracting the static water level from the pumping water level. It was assumed that any well yielding less than 10 gpm would be considered unsuccessful, and the specific capacities that would result in such yields were eliminated from the distribution on the graphs.

The remaining percentage of specific capacities of successful wells was redistributed. Specific capacities at the points equalled or exceeded in 75 percent, 50 percent, and 25 percent of these successful wells were picked from the new distribution graphs. These specific capacities were multiplied by the available drawdown to obtain a range in the quantity of water available from each rock unit in terms of gallons per minute per well. These yields were classified as poor, medium, and good and correspond to the 75, 50, and 25 percent categories of specific capacities, respectively. Continuous pumping of 24 hours a day for 365 days a year was assumed in the computation of daily and yearly well yields.

Wells were then designed using the computed probable yields to obtain a range in probable costs of ground water delivered at the well head. Completed well depths were chosen to be 300 feet in carbonate rocks and 400 feet in all other rock types. Well diameters were selected on the basis of pump size, which in turn were based on the anticipated yield of the well. The length of casing was selected as 40 feet in all wells. Deep-well turbine units for each hypothetical well were selected to produce the anticipated yields at the smallest value of pump working horsepower from the assumed pumping levels.

The costs of the ground water from these hypothetical wells were then found by compiling the initial costs to construct the well and computing the cost of operation and maintenance, which includes depreciation and power costs. The total annual cost of producing the water was divided by the amount of water produced from each well to arrive at ground-water costs.

The costs estimated for well construction, that is, initial costs, were obtained from published reports and from industries, such as well drilling firms that install such equipment. These initial costs include only those costs necessary for works to collect the water, and do not include costs to treat or distribute the water. The initial costs include costs to drill an exploratory well and to drill, develop, and pump test the production well; equipment, including casing, strainer, pump, column, shaft, motor, meter, local piping, pumphouse, and electrical controls; land and rights of way; and contingencies and engineering, including administration.

The costs of the annual payment to retire the initial cost of the well installation were found by amortizing the initial cost of the well at four percent over a period of 25 years by the capital-recovery-factor method of cost accounting.

Annual power rates were based upon Pennsylvania Power and Light Company electric power rate schedules for municipal use, assuming 24-hour a day use and 75 percent wire to motor efficiency. Annual maintenance costs were estimated from data obtained from the Pennsylvania Utility Commission and taken as four percent of the initial cost of the equipment.

The total annual cost to operate a single well was then taken as the sum of the annual payments to retire the initial cost, the power cost, and the annual maintenance cost. The costs in dollars per thousand gallons were found by dividing the total annual cost by the production figure from each well in thousand gallons per year. The costs in dollars per million gallons a day were found by dividing the total annual cost by the production figure from each well in million gallons per day and reported as the average annual cost in dollars per million gallons a day of the design yield. This cost figure is only valid for the design yield given and for a well identical in cost and construction characteristics to the hypothetical well. Obviously, the assumptions made in the well design, aquifer characteristics, probability analysis, pumping schedule, and cost analysis make this figure impossible to apply to an actual well in the field. The figures are only meant to be used as a rough guideline for a preliminary screening of potential alternate sources of water supply for the designated water-development areas. Actual site analysis of both yields and costs will have to be done by those competent in the field. However, the yields and cost figures given in this report are thought to be within the range of what can reasonably be expected at an average well site if the work in designing and constructing the well is done by competent personnel. It must be emphasized that because of the general treatment used in this report, it is not intended for use in design of engineering projects.

EXPLANATION OF TABLES

The estimated specific capacity and the yield of the hypothetical wells are summarized in table 1 in the appendix. The design of the hypothetical wells is summarized in table 2. Estimates of the cost of the hypothetical wells and of the cost of obtaining ground water from them are summarized in table 3. Representative chemical quality of ground water in each geologic unit is summarized in table 4. A cross reference of geologic units and water-development areas is given in table 5. Following is an explanation of the reference columns introducing data tabulated in tables 1, 2, 3, and 4.

The geologic formations or groups are listed according to increasing geologic age. Only those units that could be considered as aquifers, and for which well data are available, are listed. The geologic names and ages are those in current usage. The symbols used are those shown on the Geologic Map of Pennsylvania (Pennsylvania Geological Survey, 1960). The name of the geologic unit is given on all four tables, whereas the age and symbol are given only in table 1. The geologic age given is that formal period (or periods) in geologic time when the geologic rock unit is believed to have been formed. The first letter of each symbol indicates the period in geologic time. Succeeding letters in each symbol indicate the name of the geologic unit. These symbols may be found within colored rectangles in the legend below the map that gives geologic-unit descriptions, and within corresponding color patterns on the map.

The column listed as area for which the analyses of the wells are valid describes that part of the lower basin for which the figures are applicable. Most of the analyses are valid for the entire extent of the aquifer in the lower basin. However, it was found that some aquifers had different yielding characteristics in different parts of the lower basin. For example, the Mauch Chunk Formation had different yielding characteristics in the southern anthracite coal field than in the western-middle anthracite coal field.

Table 1.--Specific Capacity and Yield of Hypothetical Wells

For this report, the hydraulic properties of aquifers were estimated on the basis of geologic maps, water levels, and specific-capacity data. High specific capacities generally indicate that the rocks are capable of transmitting large quantities of water, and low specific capacities generally indicate the rocks are capable of transmitting only small quantities of water. The specific capacity of a well cannot be an exact criteria of the ability of the rock to transmit water, because specific capacity is often affected by partial penetration, well losses, and hydrologic boundaries. These factors adversely affect specific capacity; thus, the actual transmitting properties of the rocks are greater than those computed from the specific-capacity data.

The theoretical specific capacity of a well discharging at a constant rate in a homogeneous, isotropic, non-leaky artesian aquifer, infinite in areal extent, is taken from the Theis equation modified in the following equation (Walton, 1962, p. 12):

$$\frac{Q}{s} = \frac{T}{264 \log \left(\frac{Tt}{2693 \, r_w^2 \, S} \right) - 65.5} \qquad (1)$$

where:

$\frac{Q}{s}$ = specific capacity, in gpm/ft

Q = discharge in gpm

s = drawdown, in feet

T = coefficient of transmissibility, in gpd/ft

S = coefficient of storage

r_w = nominal radius of well, in feet

t - time after pumping started, in minutes

In addition to the assumption of an idealized aquifer as given above, the equation assumes that: (1) the well penetrates the total saturated thickness of the aquifer, (2) well loss is negligible, and (3) the effective radius of the well has not been affected by the drilling and the development of the well and is equal to nominal radius of the well.

Hence, the specific capacity of any individual well is dependent upon the following: the transmissibility of the rock, the storage coefficient of the rock, the pumping period, well losses, effective well radius, the effect of partial penetration and geohydrologic boundaries.

The productivity of even an ideal aquifer, therefore, differs greatly from place to place depending upon all the above factors. The geologic units in the lower Susquehanna River basin are not idealized aquifers; hence, it is impossible to predict with a high degree of accuracy the yield of a single well at any specific location before drilling. In fact, it might be possible to drill what is essentially a dry hole at any location in the area. However, methods of statistical analysis can be a great help in appraising the role of individual geologic units as producers of water. In this way, the probable range of specific capacities of wells can be estimated based on frequency graphs. Specific-capacity data were available for wells penetrating each of the several units under consideration, and these data were used to estimate the range of productivity and the relative consistency of the productivity of the units.

Specific capacities for wells in each geologic unit were tabulated in order of magnitude, and frequencies were computed with the following equation (Kimball, 1946):

$$F = \frac{m_o}{(n_w + 1)} 100 \qquad (2)$$

where:

m_o = the order number

n_w = total number of wells

F = percentage of wells whose specific capacities are equal to, or greater than, the specific capacity of order number m_o.

Specific capacities were then plotted against percentage of wells on logarithmic-probability paper. (See figure 3 as an example of such a plot.) Straight lines were fitted to the data. The slope of the specific capacity-frequency graph varies with the variability of production, a steeper line indicating greater range in productivity.

Yields of the aquifers at specific wells were estimated from the specific-capacity frequency graphs, which, in turn, were based on areal geologic maps, water-level data, and well-production data. Well yields were estimated on the basis of the specific capacities equaled or exceeded in 75 (poor),(50 medium), and 25 (good) percent of the existing wells. Specific capacities (see table 1) were multiplied by the 180-day drawdown (see table 2) to determine the probable yields (see table 1).

As it can be seen in equation (1), specific capacities theoretically decrease with time during periods of continuous pumping. Specific capacities used in this analysis were obtained at various pumping rates and for various periods of continuous pumping, which were mainly of short duration. One of the objectives of the study was to compute a substained yield for each well. Hence, all the specific-capacity data were adjusted to a conservative, common pumping period. The figure used was that of 180 days, which is probably the longest period in which no recharge would occur. In general, this cut the reported specific capacities (which were generally obtained after one hour or one day of

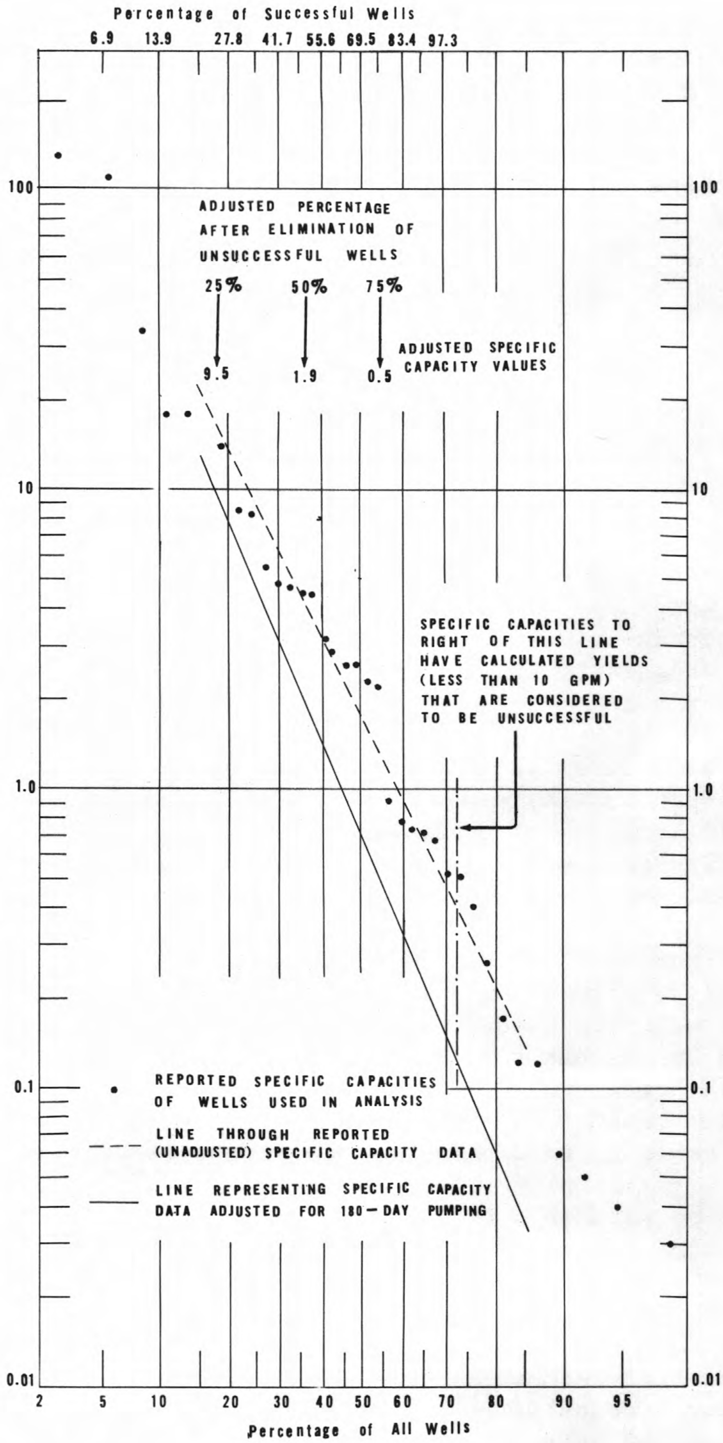

Figure 3.--Specific capacity frequency distribution graph for the Conestoga Limestone

pumping) to at least one-half their original value. The decline in theoretical specific capacity from 180 to 365 days is very small. A specific capacity based on 180 days of pumping probably represents a good average for a well pumped 24-hours a day for 365 days a year. In practice, the well would most likely be pumped only 12 hours a day and allowed to recover for 12 hours. The 180 day specific-capacity figure used reflects 24-hour a day pumping and allows a realistic yearly pumping figure to be computed without excessively tedious computations.

The coefficient of storage S in equation (1) can usually be estimated from well-log and water-level data. Because specific capacity varies with the logarithm of $\frac{1}{S}$, large errors in estimating coefficients of storage result in comparatively small errors in specific-capacity data adjusted to a common time base. Hence, a coefficient of storage of 0.2, which is a water-table coefficient, was used to adjust the specific-capacity data. This is a conservative figure to use for the computations of well yields because it gives a greater reduction in specific capacity with time during the period over which the specific capacity was adjusted than would be obtained by using a smaller or artesian coefficient of storage.

It was assumed that any well yielding less than 10 gpm (based upon time-adjusted specific capacity and available drawdown) would be considered unsuccessful by a municipality, industry, or irrigator. After the specific-capacity frequency distributions had been constructed, using all the available data, that percentage of the sample obtaining less than 10 gpm was eliminated from the distribution. For only one geologic unit, the Elbrook Limestone, were more than 50 percent of the wells eliminated. The remaining percentage of specific capacities of successful wells was redistributed. Specific capacities exceeded in 75, 50, and 25 percent of these successful wells were picked from the new distribution graph and reported in table 1. When considering the cost of wells and ground water (in order to account for the unsuccessful wells that were eliminated) it was assumed that two wells would be contracted and drilled in every formation to obtain one successful well. It was further assumed that the well sites actually chosen would be based upon the best of engineering, geologic, and well-construction advice. The wells used in the analysis may not all have had this advice in their location, construction, and design.

Even though the above assumptions may have very little relationship to the actual yield of a specific well, it is believed that the resulting figures are realistic for the formation as a whole, and are probably conservative. This method appears to give some basis for estimating what long-term yields may reasonably be expected from a series of wells drilled in a particular aquifer.

Following is a discussion of some of the columns listed in table 1:

Specific-Capacity Data

Specific capacity exceeded by indicated percentage of successful wells.

75 percent.--This figure represents the specific capacities estimated to be equaled or exceeded in 75 percent of existing successful wells. It is considered to represent a poor specific capacity expected in the prediction of the productivity of the geologic unit under discussion.

50 percent.--This figure represents the specific capacities estimated to be equaled or exceeded in 50 percent of the existing successful wells. It is considered to represent a medium specific capacity expected in the prediction of the productivity of the geologic unit under discussion.

25 percent.--This figure represents the specific capacity estimated to be equaled or exceeded in 25 percent of the existing successful wells. It is considered to represent a good specific capacity expected in the prediction of the productivity of the geologic unit under discussion.

Number of Wells Used for Specific-Capacity Frequency Distribution Analysis

This column refers to the number of wells in the geologic unit for which specific-capacity data were available. The number listed is an indication of the reliability to be placed upon the analysis of the specific-capacity data. The greater the number the better the results of the analysis.

Percentage of Unsuccessful Wells

This column refers to the percentage of wells in the original data analyzed, having an adjusted specific capacity that would result in a yield of less than 10 gpm. For limestones and related carbonate rocks this was a specific capacity of less than about 0.12, for all metamorphic and igneous rocks a specific capacity of less than about 0.08, and for all other rocks a specific capacity of less than about 0.05. This number is partially a reflection of the number of domestic wells used in the analysis and partially a reflection on the chance of drilling an unsuccessful well in the aquifer.

Yield Exceeded by Indicated Percentage of Successful Wells

The yields given in gallons per minute represent the probable yields for the 75 percent (poor), 50 percent (medium), and 25 percent (good) specific capacities multiplied by the available drawdowns given in table 2. Three-quarters, one-half, and one-quarter of existing wells, respectively, should yield this amount of water if pumped to the drawdowns given in table 2. The yields given in million gallons per day represent the yields in gallons per minute multiplied by 1,440. The yields given in million gallons per year represent the yields in gallons per day multiplied by 365. The yields in million gallons per day can be converted to cubic feet per second by multiplying by 1.55.

Table 2.--Design of Hypothetical wells

The design of the hypothetical wells is summarized in table 2. Following is a discussion of some of the columns listed in table 2.

Well Depth (feet)

It was decided to drill all wells in limestones and related carbonate rocks to a depth of 300 feet and to drill all wells in other types of rock to a depth of 400 feet. Studies have shown that the majority of solution openings in limestones and related carbonate rocks occur above a depth of 300 feet. Other studies have shown that the majority of fractures and joints in other types of rocks, such as gneiss, sandstone, and shale, occur above a depth of 400 feet. Hence, the depth of drilling was selected on the basis that the wells would penetrate almost all the water-bearing openings in the rocks to be drilled. At any given site, it may not be necessary in actual practice to drill to the above listed depths to obtain the indicated quantity of water, or drilling may proceed to greater depths without success in obtaining the indicated yield.

Well Diameter (inches)

The diameter of the well selected in inches was based on the pump size, which in turn was based on the anticipated yield of the well. The relationship of the anticipated yield of the well to the well diameter and pump size is shown in the table below:

Yield in gallons per minute	Pump size in inches	Well diameter in inches
0 - 100	4	6
100 - 250	6	8
250 - 500	8	10
500 - 1,000	10	12

The diameters listed in table 2 for poor, medium, and good yields are the smallest well diameters that can be used to produce, respectively, the 75 percent, 50 percent, and 25 percent estimated yields listed in table 1. This assumes the most economical well construction and operating conditions.

Length of Casing (feet)

Examination of the existing data and discussion with well drillers revealed that generally 40 feet of casing was installed for large-capacity municipal and industrial wells, regardless of rock type. Hence, 40 feet of casing was used as the average length installed for all the wells.

Static Water Level (feet below land surface)

The figure given is an approximate average of the water-level data available for each geologic unit. Ground-water levels fluctuate greatly throughout the year. The fluctuations are controlled by geologic, climatic, and hydrologic factors, and by the activities of man. At any given instant, water levels in a particular aquifer are not everywhere at the same level. Furthermore, the water levels given would certainly not be the same throughout the year. The figure shown is only an estimate; therefore, a static water level of 20 feet below land surface was used in computation, even if available data indicated a higher static water level. Accordingly, 20 feet below land surface is the highest static water level shown in table 2.

Pumping Water Level (feet below land surface)

A pumping water level of 100 feet was used for most limestones and related carbonate rocks. A pumping water level of 150 feet was used for all metamorphic and igneous rocks. A pumping water level of 200 feet was used for all the other rocks, such as the sedimentary sandstones and shales. These levels were chosen so that at least one half of the water-bearing openings in the rocks would be below the pumping water level.

Though these pumping water levels were selected without sufficient knowledge of the geohydrologic framework, they are probably the maximum depths to which the static water levels may be drawn down due to pumping without seriously impairing the water-yielding properties of the aquifers. They were chosen to give the largest yields under any given set of conditions.

The pumping water level, as well as the drawdown, are each separated into subheadings for poor, medium, and good yields, in order to show the pumping water levels and drawdowns in those rare cases where the computed maximum yields in carbonate rocks would exceed 1,000 gpm if a pumping water level of 100 feet were used.

Drawdown (pumping water level minus static water level in feet)

Drawdowns calculated from values listed under static water level and pumping water level are considered probable maximum available drawdowns. The values were multiplied by the corresponding specific capacities given in table 1 to obtain the estimated yields given in table 1.

Pump Working Horsepower

Pump working horsepower for a given hypothetical well is the actual working power necessary to lift the corresponding yield given in table 1 from the corresponding pumping water level given in table 2 to the land surface. Pump bowl horsepower (HP) was computed from the following formula:

$$HP = \frac{\text{Well yield (gpm) X pump bowl head (ft)}}{\text{Pump-bowl efficiency (decimal) X 3,960} \left(\frac{\text{ft-gal/min.}}{\text{HP}}\right)}$$

Deep-well turbine units for each hypothetical well were selected from available pump manufacturers' stock catalogues to produce the corresponding yields in table 1 at the smallest value of pump working horsepower and, hence, at the lowest operating cost.

Table 3.--Cost of Hypothetical Wells and of Ground Water

The feasibility of ground-water development is here defined to mean whether or not ground water can be managed or utilized successfully. The assumption is made that ground water is available for all needs if the user is willing to pay for the supply. This assumption is based upon the fact that all widespread aquifers will yield large quantities of water, although the yield of individual wells is generally greater from good aquifers than from poor ones. Hence, the question of whether the ground-water reservoirs are capable of being used is to a large extent a matter of cost of water. This section deals with the costs of developing ground water, and these costs of obtaining water are summarized in table 3.

The cost of water supply can be divided into the costs of: (1) works for collection of water, (2) works for the purification of water, and (3) works for the conveyance of water. For consistency with other estimates being made in the Susquehanna River basin study, this report will discuss only those costs related to the collection of water. These costs for the construction, operation, and maintenance of the hypothetical wells may be broken down into (1) initial costs and (2) annual costs. The initial costs are those costs to initially construct the well. The annual costs are those costs to operate and maintain the well, which include costs to amortize the initial cost, power costs, and maintenance costs.

For ground-water development initial costs at the well include expenses to: (1) drilling exploratory wells, and drilling, developing, and testing the production well; (2) equipment--including casing, strainer, pump, column, shaft, motor, meter, and inside piping; (3) pump house and electric controls; (4) land and rights of way; and (5) contingencies and engineering, including administration.

Initial Costs

Costs estimates were obtained from published reports and from industries, such as well drilling firms that install such equipment. The costs given herein are only estimated costs which will vary from place to place and from time to time. The costs will vary with the regional location of the well, the geohydrologic setting at the well, the well construction and methods used in well construction by the contractor, and the need of each contractor bidding to obtain the construction contract. The costs are September 1964 prices and can be converted to approximate present prices by comparison with the Engineering News-Record Construction Cost Index, which was 947 in September 1964. (Eng. News-Rec., vol. 173, no. 12, p. 93).

The factors considered in arriving at the initial cost of the wells are discussed below. The numbers given refer to the numbers of the column headings in table 3.

1 - Drilling two wells.

The depth, casing length, and diameter of the proposed well are discussed in the section on well design. One exploratory well(which could later be converted to an observation well) for every production well was assumed to be a reasonable average for the area. This allows for the additional well to be used in determining the hydraulic properties of the aquifer in the area and for monitoring water-level fluctuations. The estimated cost of drilling each well by percussion or cable-tool method in various rock types in the area is shown below in the table. These figures are based upon cost estimates supplied by several drilling firms in the lower Susquehanna basin and upon the experience of the personnel of the Ground Water Branch of the Harrisburg District. It should be emphasized that they are merely estimates and not what actually may be charged in any specific location or circumstance.

Estimates of costs of drilling and casing single hypothetical wells in the lower Susquehanna River basin.

Diameter of well (inches)	Shale (400 feet) (dollars)	Sandstone, quartzite, schist, and gneiss (400 feet) (dollars)	Limestone and related carbonate rocks (300 feet) (dollars)	Casing surface to 40 feet (dollars)
6	$1,200	$1,600	$1,300	$140
8	1,800	2,600	2,800	200
10	2,600	3,800	3,700	280
12	3,400	5,000	4,900	400

2 - Pump testing production well.

A pumping test of 24-hours duration on the production well was deemed satisfactory for designing the deep-well turbine pumping unit. A pumping test on a well that would need a pump less than 10 inches in diameter was estimated to cost $500, and a pumping test on a well that would need a pump equal to or greater than 10 inches in diameter was estimated to cost $800.

3 - Casing production well.

The casing in the production wells are all designed to be 40 feet long. The estimated cost of casings of various diameters, delivered and installed in the well were shown in the preceding table.

4 - Motor, column, shaft, pump, and strainer (deep-well turbine unit).

Cost curves were developed relating the cost of dep-well turbine units to well yields for the designed pumping water levels of 100 feet, 150 feet, and 200 feet. (See fig. 4.) Costs of the equipment were obtained from current manufacturer's prices tables. Yields were arbitrarily chosen from the estimated yields reported in table 1. Units designed to yield 1,000 gpm at pumping water levels less than 100 feet were individually computed.

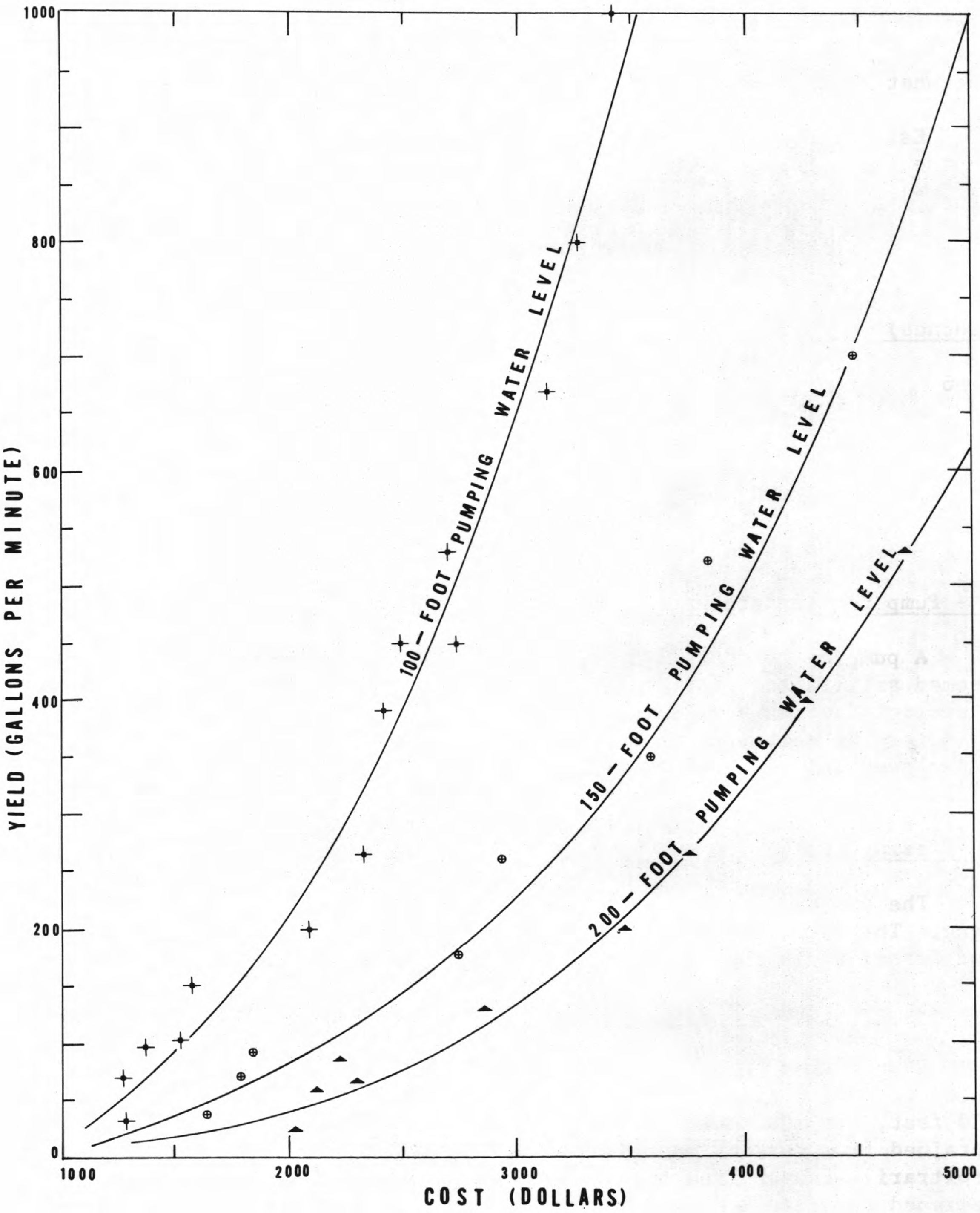

Figure 4.--Graph showing the relation of yield of hypothetical wells to cost of motor, column, shaft, pump, and strainer for selecting pumping water levels.

5 - Fixed land and equipment cost.

The estimated cost of land and rights of way is $1,000 per well. The estimated cost of the pump house is $1,500 per well. The estimated cost of other equipment (wiring, meter, piping, and appurtenances) is $1,500 per well. Thus, the total fixed cost in column 5 is $4,000 per well.

6 - Contingencies.

The allowance for contingencies is 10 percent of the estimated construction and equipment costs (sums of columns 1 through 5).

7 - Engineering and administration.

The allowance for engineering, including contract administration and financing, has been set at 15 percent of the total construction cost, including contingencies (sum of columns 1 through 7).

8 - Total initial cost.

The total initial cost (sum of columns 1 through 7) is the initial cost of a single well, ready to discharge the corresponding yield given in table 1 at the land surface.

9 - Total initial cost in dollars per million gallons a day of design yield.

The total initial cost in thousands of dollars per million gallons per day added to the system at the well head is given to allow a comparison between alternative sources of water supply. The total initial cost in column 8 of table 3 was divided by the corresponding yield in million gallons per day given in table 1.

Annual Costs

10 - Annual payments to retire initial cost.

A single end-of-year payment to cover interest on the initial cost and payments to a depreciation fund may be calculated, using the formula for uniform annual series of end-of-year payments. This method is referred to as the capitol-recovery-factor method of cost accounting (Grant and Ireson, 1960, p. 45):

$$R = P \frac{i\,(1 + i)^n}{(1 + i)^n - 1}$$

in which:

R = The end-of-period payment in a uniform series of equal payments continuing for the coming n periods.

P = Total initial costs - column 8.

i = Annual interest rate, taken as 4 percent on municipal bonds in this case.

n = Number of interest periods, taken as 25 years in this case.

$\frac{i\,(1 + i)^n}{(1 + i)^n - 1}$ = The capital recovery factor which, when multiplied by a present debt, gives the uniform end-of-year payment necessary to repay the debt in n years with interest rate i. This factor is 0.06401 where the annual interest rate is 4 percent, and the length of the period is 25 years, using a uniform series of payments.

11 - Annual power costs.

Annual power costs used herein were based upon Pennsylvania Power and Light Co.'s electrical power rate schedules SGS and LP-3 for municipal use. Total power consumption was estimated by using the operating horsepower of the individually designed pumping equipment from table 2, by assuming a 24-hour a day use, and by assuming 75 percent wire to motor efficiency so that 1 horsepower equals 1 kilowatt. Figure 5 was used in the calculations of annual power costs.

12 - Annual maintenance costs.

Annual maintenance costs were estimated from data obtained from the Pennsylvania Utility Commission and are here taken as 4 percent of the cost of the equipment given in column 4 of table 3. Over a period of 25 years, which is assumed to be the life of the equipment, this equals the cost given in column 4 and amounts to replacing the deep-well turbine unit once within the 25 years of assumed life of the equipment. No labor costs for operation were included. The well is assumed to be added to an existing distribution system and labor costs would not be great.

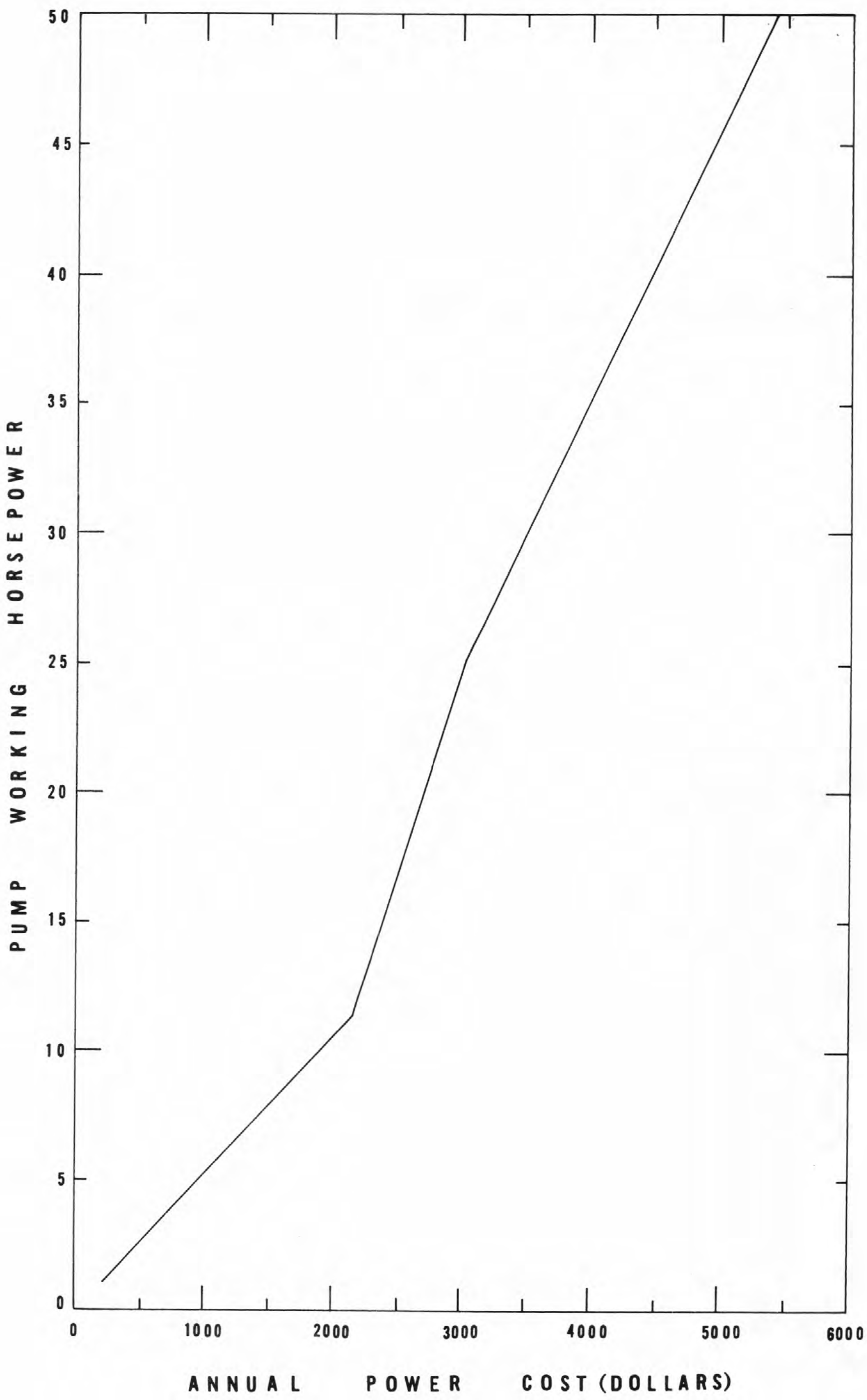

Figure 5.--Graph showing the relation of annual power cost to pump working horsepower given in table 2, assuming a power demand of 24-hours a day.

13 - Total annual cost.

The total annual cost is the sum of the annual payments to retire the initial cost (column 10), the annual power costs (column 11), and the annual maintenance costs (column 12). It is again emphasized that this is the cost to add a well to an existing distribution system, and does not include cost of treating the water or of delivering the water to the consumer.

14 - Average annual cost to produce ground water in dollars per thousand gallons of design yield.

This cost in dollars per thousand dollars is found by dividing the total annual cost (column 13, table 3) by the corresponding well yield in million gallons per year given in table 1. This result is divided by 1,000 to convert to cost per thousand gallons. The figures were reported to nearest tenth of a cent.

15 - Average annual cost to producer in dollars per million gallons per day of design yield.

This cost in dollars per million gallons per day is found by dividing that total annual cost (column 13, table 3) by the production figure in million gallons per day given in table 1. The costs given in column 14 and 15 of table 3 are valid only for the design yield and only if all the assumptions given earlier are met. They are not valid for a specific site or situation except in the almost inconceivable instance where all actual conditions equal all the assumptions made. These costs are given only to show a probable range in expected costs from an aquifer in order to compare alternate sources of water supply, both surface and ground.

Table 4.--Quality of Ground Water

Table 4 contains a summary of the water-quality characteristics of the geologic units. The values given in the table refer to the 75 percent (good), 50 percent (medium), and 25 percent (poor) categories for a normal frequency distribution for the reported values for each geologic unit for which chemical analyses were available. Because the values given in the table only represent a range for 50 percent of the available analyses, higher and lower values may occur in water from any particular well tapping a particular geologic unit. Although table 4 shows a range in concentration for any particular constituent in the water of each geologic unit, a single well will usually yield water of uniform quality throughout the year.

Table 5 - Cross Reference of Geologic Units and Water-Development Areas.

A cross reference of geologic units and water-development areas is given in table 5. This table shows which aquifers are available to a given water-development area and how many water-development areas are potential users of a particular rock unit. A distinction is made in the table between (1) those geologic units that immediately underlie the water-development areas, and (2) those that do not, but are within one mile of the political boundaries of the water-development areas.

APPRAISAL BY GEOLOGIC UNIT

The geologic units listed in the tables and discussed in this section are those that are capable of yielding usable quantities of ground-water supplies to the water-development areas. All such geologic units listed as available to a water-development area either underlie or are within one mile of the political boundaries of that area. The names of the geologic formations or groups listed are those used by the U. S. Geological Survey. The symbols used to identify the formations are those shown on the Geologic Map of Pennsylvania published by the State Geological Survey.

Formations or groups shown on the Geologic Map of Pennsylvania that are not discussed in this section are not "available to" the water-development areas for which specific information was requested (see fig. 1). The geologic units not discussed occupy only a small part of the lower Susquehanna River basin, and generally are not considered to be potential aquifers for municipal, industrial, or irrigational use in any part of the lower basin.

The discussion by geologic units allows an evaluation of additional areas not specifically requested at this time. The units are discussed according to geologic age, from youngest to oldest. A short discussion of the grouping of geologic units shown on the geologic map will be included where appropriate.

The discussion of water in each geologic unit includes sections on (1) availability, (2) quantity, (3) annual cost, and (4) quality.

(1) Availability--this section will list the availability of this geologic unit for those specific water-development areas requested. The listing of an area under a geologic unit implies that the unit occurs inside or within 1 mile of the boundaries of the area.

(2) Quantity--this section will briefly discuss the quantity available for the 75 percent (poor), 50 percent (medium), and 25 percent (good) probability of occurrence of well yields for the aquifer in gallons per minute. The computed

yields were rounded to the nearest 5 gpm for all yields under 100 gpm and to 2 significant figures above 100 gpm. Yields in excess of 1,000 gpm were reduced to 1,000 gpm.

(3) Annual cost--this section will show the average annual cost of water in dollars per millions gallons per day for the 75 percent (poor), 50 percent (medium), and 25 percent (good) probability of occurrence of the design well yields. The costs in dollars were rounded to two significant figures. The costs in dollars per million gallons a day can be converted to dollars per cubic foot per second (cfs) by multiplying by 0.646.

(4) Quality--This section will discuss briefly any quality problems known to occur in water from this geologic unit. Emphasis will be on dissolved solids, hardness, and iron content of the ground waters. The ranges discussed for these constituents are only for the values given in table 4 and only apply to the values between the 75 percent and 25 percent occurrence categories for a normal frequency distribution for the available analysis. Higher and lower values may occur in water from any particular well tapping this geologic unit. Where the higher values may be particularly significant, they are also mentioned. In addition, any values for which data was available for other constituents that exceed the Public Health Service standards that occur in at least 25 percent of the samples are mentioned.

The terms low, moderate, and high are used in the text to describe the relative concentration of dissolved solids, hardness, and iron in accordance with the following concentration ranges chosen for the Susquehanna River basin:

	Dissolved solids (ppm)	Hardness (ppm)	Iron (ppm)
Low	0 - 150	0 - 100	0.0 - 0.3
Moderate	150 - 500	100 - 300	0.3 - 1.0
High	500	300	1.0

Triassic Rocks

Gettysburg Shale

The Gettysburg Shale (Trg) consists of fine-to coarse-grained quartzose sandstone containing interbedded red shale. It includes interbedded shale and limestone conglomerate (Trlc), quartz pebble conglomerate (Trqc), and the Heidlersburg Sandstone Member (Trh).

Availability

The Gettysburg Shale is an available aquifer in the Harrisburg-West Shore, Harrisburg-East Shore, Hershey, Middletown, Elizabethtown, Ephrata, and York areas.

Quantity

Poor yield - 55 gpm
Medium yield - 160 gpm
Good yield - 480 gpm

Annual cost

For poor yield - $20,000 per mgd
For medium yield - $14,000 per mgd
For good yield - $7,300 per mgd

Quality

The water from the Gettysburg Shale is of good quality for most uses. The water is low to moderate in dissolved solids, hardness, and iron content. A few samples are nearly as high in hardness and dissolved-solids content as that of limestone water.

New Oxford Formation

The New Oxford Formation (Trn) is a coarse-grained sandstone and conglomerate containing interbedded siliceous sandstone and shale.

Availability

The New Oxford Formation is an available aquifer in the Elizabethtown and Ephrata areas east of the Susquehanna River and to the York and New Oxford areas west of the Susquehanna River.

Quantity

West of the Susquehanna River the yields are as follows:

Poor yield - 25 gpm
Medium yield - 60 gpm
Good yield - 180 gpm

East of the Susquehanna River the yields are as follows:

Poor yield - 110 gpm
Medium yield - 130 gpm
Good yield - 170 gpm

Annual cost

	West of river	East of river
For poor yield	$36,000 per mgd	$16,000 per mgd
For medium yield	$21,000 per mgd	$15,000 per mgd
For good yield	$13,000 per mgd	$14,000 per mgd

Quality

The water from the New Oxford Formation is similar to that from the Gettysburg Shale, although the average total dissolved solids, hardness, and iron content is slightly lower. Some samples indicate high nitrate concentrations.

Pennsylvanian Rocks

Post-Pottsville Formations

The post-Pottsville formations (IPpp) are composed of sandstone and shale, with some conglomerate, and many mineable coals.

Availability

The post-Pottsville formations are available aquifers in the Kulpmont-Mt.Carmel, Shamokin, Ashland-Frackville, Mahanoy City-Shenandoah, and Tower City areas.

Quantity

Poor yield - 75 gpm
Medium yield - 230 gpm
Good yield - 760 gpm

Annual cost

For poor yield - $19,000 per mgd
For medium yield - $11,000 per mgd
For good yield - $6,900 per mgd

Quality

The water from post-Pottsville rocks is of excellent quality in places sufficiently removed from mining operations. The water is low in dissolved solids, hardness, and iron content. In parts of the southern and middle coal fields, as well as in most other fields, the water is generally unfit for ordinary use. This results chiefly from the oxidation of pyrite contained in the coal, which forms a highly acidic water that contains large quantities of iron.

Pottsville Formation

The Pottsville Formation (ℙp) is composed of coarse-grained sandstone, conglomerate, and some mineable coal.

Availability

The Pottsville Formation is an available aquifer in the Lykens, Kulpmont-Mt. Carmel, Shamokin, Ashland-Frackville, Mahanoy City-Shenandoah, and Tower City areas.

Quantity

Poor yield - 120 gpm
Medium yield - 240 gpm
Good yield - 430 gpm

Annual cost

For poor yield - $16,000 per mgd
For medium yield - $11,000 per mgd
For good yield - $8,000 per mgd

Quality

The water from the Pottsville Formation seems to be generally of excellent quality. The water is low in dissolved solids, hardness, and iron content. A few samples contain excess iron, are rather hard, and contain hydrogen sulfide.

Pennsylvanian and Mississippian Rocks

Mauch Chunk Formation

The Mauch Chunk Formation (Mmc) is composed of shale and interbedded flaggy sandstone.

Availability

The Mauch Chunk Formation is an available aquifer in the Dauphin, Lykens, Millersburg, Shamokin, Ashland-Frackville, Mahanoy City-Shenandoah, and Tower City areas.

Quantity

In the southern coal field the yields are as follows:

Poor yield - 30 gpm
Medium yield - 100 gpm
Good yield - 360 gpm

In the western-middle coal field the yields are as follows:

Poor yield - 85 gpm
Medium yield - 130 gpm
Good yield - 180 gpm

Annual cost

	Southern coal field	Western-middle coal field
For poor yield	$30,000 per mgd	$16,000 per mgd
For medium yield	$17,000 per mgd	$15,000 per mgd
For good yield	$8,400 per mgd	$13,000 per mgd

Quality

The water from the Mauch Chunk Formation is of good quality for most uses. The water is low to moderate in dissolved solids, hardness, and iron content. A few samples indicate high nitrate concentrations.

Mississippian Rocks

Pocono Formation

The Pocono Formation (Mp) is composed of hard massive conglomerate, sandstone, and a little shale.

Availability

The Pocono Formation is an available aquifer in the Dauphin, Lykens, Millersburg, Shamokin, and Tower City areas.

Quantity

Poor yield - 25 gpm
Medium yield - 70 gpm
Good yield - 220 gpm

Annual cost

For poor yield - $36,000 per mgd
For medium yield - $19,000 per mgd
For good yield - $11,000 per mgd

Quality

The wells in the Pocono Formation generally yield water of very good quality, except for a high iron content. The water is low in dissolved solids and hardness content.

Mississippian and Devonian Rocks

Catskill Formation

The Catskill Formation (Dck) is composed chiefly of shale and sandstone.

Availability

The Catskill Formation is an available aquifer in the Shamokin and Sunbury areas.

Quantity

Poor yield - 85 gpm
Medium yield - 190 gpm
Good yield-430 gpm

Annual cost

For poor yield - $19,000 per mgd
For medium yield - $13,000 per mgd
For good yield - $8,000 per mgd

Quality

The water from the Catskill Formation is generally of good quality for most purposes. The water is low to moderate in dissolved solids, hardness, and iron content.

Devonian Rocks

Marine Beds

Devonian marine beds (Dm) are composed of shale, graywacke, and sandstone. The sequence includes the Trimmers Rock Sandstone.

Availability

Devonian marine beds are available aquifers in the Sunbury, Pine Grove, and Selinsgrove areas.

Quantity

Poor yield - 30 gpm
Medium yield - 80 gpm
Good yield - 240 gpm

Annual cost

For poor yield - $32,000 per mgd
For medium yield - $18,000 per mgd
For good yield - $11,000 per mgd

Quality

The water from the Devonian marine beds is of generally good quality for most uses. The water ranges from low to moderate in dissolved solids and iron content, and is moderately hard. Some of the water contains small quantities of hydrogen sulfide.

Hamilton Group and Onondaga Limestone

The Hamilton Group (Dh) and Onondaga Limestone (Don) are composed of shale and limestone. The combined Hamilton Group and Onondaga Limestone are mapped as Dho. The Mahantango Formation of the Hamilton Group is mapped as Dmh. The Marcellus Shale of the Hamilton Group, and the underlying Onondaga Limestone are combined and mapped as Dmo.

Availability

The Hamilton Group and Onondaga Limestone are available aquifers in the Sunbury, Pine Grove, and Selinsgrove areas.

Quantity

Poor yield - 30 gpm
Medium yield - 80 gpm
Good yield - 205 gpm

Annual cost

For poor yield - $30,000 per mgd
For medium yield - $16,000 per mgd
For good yield - $15,000 per mgd

Quality

The water from these rocks is of generally good quality for most uses. The water ranges from low to moderate in dissolved solids and hardness content. The iron content ranges from low to high. Hydrogen sulfide has been reported in water from several wells in the Hamilton Group.

Oriskany and Helderberg Groups

The Oriskany Group (Do) is composed of sandstone, limestone, and shale. The Helderberg Group (Dhb) is composed of shale and limestone. The Oriskany and Helderberg Groups are mapped as Doh.

Availability

The Oriskany and Helderberg Groups are available aquifers in the Sunbury and Selinsgrove areas.

Quantity

Poor yield - 35 gpm
Medium yield - 130 gpm
Good yield - 610 gpm

Annual cost

For poor yield - $22,000 per mgd
For medium yield - $11,000 per mgd
For good yield - $4,700 per mgd

Quality

The Oriskany Group yields water of good quality. The water is low in dissolved solids and hardness content. The iron content ranges from low to moderate.

Water from the Helderberg Group is of fairly good quality. The water contains a moderate amount of dissolved solids, hardness, and iron. A few samples indicate hardness and dissolved solids content that is too high for most industrial uses, and some of these waters are unfit for practically any use except cooling.

Devonian (?) and Silurian Rocks

Keyser, Tonoloway, and Wills Creek Formations

The Keyser and Tonoloway Limestones are predominantly limestones. The Wills Creek Shale is a shale containing some limestone. The combined Tonoloway and Keyser Limestones are mapped as Skt. The Wills Creek Shale is mapped as Sw. The combined Keyser, Tonoloway and Wills Creek Formations are mapped as Skw.

Availability

The Devonian (?) and Silurian rocks are available aquifers in the Sunbury and Selinsgrove areas.

Quantity

Poor yield - 50 gpm
Medium yield - 180 gpm
Good yield - 680 gpm

Annual cost

For poor yield - $15,000 per mgd
For medium yield - $8,800 per mgd
For good yield-$4,400 per mgd

Quality

The waters from the Devonian (?) and Silurian rocks are of fairly good quality for most uses. The water contains a moderate amount of dissolved solids and hardness. The iron content is low. However, a few wells yield water that contains large amounts of calcium sulfate and iron, and some of these waters are too hard for many industrial uses, and are unfit for practically any use except cooling.

Ordovician Rocks

Martinsburg and Cocalico Shales

The Martinsburg Shale (Om) is a shale containing interbedded sandstone and limestone. The Cocalico Shale (Oco) is a shale containing interbedded sandstone.

Availability

The Martinsburg Shale is an available aquifer in the Carlisle, Harrisburg -West Shore, Mechanicsburg, Harrisburg-East Shore, Hershey, Lebanon, and Palmyra areas. The Cocalico Shale is an available aquifer in the Ephrata, Lititz, and Manheim areas.

Quantity

Poor yield - 35 gpm
Medium yield - 60 gpm
Good yield - 110 gpm

Annual cost

For poor yield - $28,000 per mgd
For medium yield - $20,000 per mgd
For good yield - $16,000 per mgd

Quality

The waters from the Martinsburg and Cocalico Shales are of good quality for most uses. The water contains a low to moderate amount of dissolved solids, a moderate amount of hardness, and a low amount of iron. A few samples contain high amounts of iron and nitrate and small quantities of hydrogen sulfide. The waters from these formations are not as hard as the limestone waters, but are harder than water from quartzite and sandstone.

Hershey, Myerstown, and Chambersburg Limestones

These formations are composed of argillaceous limestone. The Hershey and Myerstown Limestones are mapped as Ohm. The Chambersburg Limestone is mapped as Oc.

Availability

The Chambersburg Limestone is an available aquifer in the Carlisle and Mechanicsburg areas. The Hershey and Myerstown Limestones are available aquifers in the Harrisburg-West Shore, Harrisburg-East Shore, Hershey, Lebanon, and Palmyra areas.

Quantity

Poor yield - 30 gpm
Medium yield - 130 gpm
Good yield - 720 gpm

Annual cost

For poor yield - $23,000 per mgd
For medium yield - $10,000 per mgd
For good yield - $4,500 per mgd

Quality

The waters from these formations are typical limestone waters of fairly good quality, containing a moderate to high hardness content and a moderate dissolved solids content. The iron content is low to moderate. A few samples indicate high nitrate concentrations.

St. Paul Group and Annville Limestone

The St. Paul Group (Osp) is composed of magnesium limestone, and the Annville Limestone (Oan) is composed of limestone.

Availability

The St. Paul Group is an available aquifer in the Carlisle, Harrisburg-West Shore, Mechanicsburg, and Harrisburg-East Shore areas. The Annville Limestone is an available aquifer in the Harrisburg-East Shore, Hershey, Lebanon, and Palmyra areas.

Quantity

Poor yield - 55 gpm
Medium yield - 520 gpm
Good yield - 1,000 gpm

Annual cost

For poor yield - $15,000 per mgd
For medium yield - $5,500 per mgd
For good yield - $2,600 per mgd

Quality

The waters from the St. Paul Group and Annville Limestone are typical limestone waters of fairly good quality containing a moderate to high hardness content and a moderate dissolved solids content. The iron content is generally low. A few samples indicate high nitrate concentrations.

Beekmantown Group

The Beekmantown Group (Ob) is composed of interbedded limestone and dolomite and some cherty layers. The Beekmantown Group consists of the Ontelaunee Formation (Oo), the Epler Formation (Oe), the Rickenbach Dolomite (Ori), and the Stonehenge Limestone (Os). The Ontelaunee, Epler, and Rickenbach Formations are also shown on the map under the symbol Orr.

Availability

The Beekmantown Group, mapped as Ob, is an available aquifer in the Harrisburg-West Shore, Mechanicsburg, Harrisburg-East Shore, Elizabethtown, Ephrata, Lancaster, Lititz, and Manheim areas. The Ontelaunee Formation is an available aquifer in the Harrisburg-East Shore, Hershey, Lebanon, and Palmyra areas. The Epler Formation is an available aquifer in the Harrisburg-East Shore, Hershey, Lebanon, and Palmyra areas. The Rickenbach Dolomite is an available aquifer in the Lebanon area. The Stonehenge Limestone is an available aquifer in the Mechanicsburg, Shippensburg, Hershey, Lebanon, and Palmyra areas. The combined Ontelaunee, Epler, and Rickenbach Formations mapped as Orr, are available aquifers in the Carlisle, Harrisburg-West Shore, Mechanicsburg, and Shippensburg areas. The Ontelaunee and Stonehenge Formations have proved to be the best aquifers in the Beekmantown Group.

Quantity

In the Lebanon Valley the yields from the Beekmantown Group are as follows:

Poor yield - 120 gpm
Medium yield - 650 gpm
Good yield - 1,000 gpm

In the Lancaster Valley the yields from the Beekmantown Group are as follows:

Poor yield - 30 gpm
Medium yield - 120 gpm
Good yield - 710 gpm

Annual cost

	Lebanon Valley	Lancaster Valley
For poor yield	$11,000 per mgd	$23,000 per mgd
For medium yield	$4,700 per mgd	$11,000 per mgd
For good yield	$2,800 per mgd	$4,500 per mgd

Quality

The waters from the Beekmantown Group are typical limestone waters of fairly good quality containing a moderate to high hardness content, and a moderate dissolved solids content. The iron content is low to moderate. A few samples indicate high nitrate concentrations.

Ordovician and Cambrian (?) Rocks

Conestoga Limestone

The Conestoga Limestone (Ocs) is a limestone that contains shale partings and some dolomite.

Availability

The Conestoga Limestone is an available aquifer in the Atglen, Columbia, Lancaster, Hanover, and York areas.

Quantity

Poor yield - 40 gpm
Medium yield - 140 gpm
Good yield - 710 gpm

Annual cost

For poor yield - $19,000 per mgd
For medium yield - $10,000 per mgd
For good yield - $4,500 per mgd

Quality

The water from the Conestoga Limestone is of good quality for most uses, except for a high hardness. The water contains a moderate amount of dissolved solids, and a moderate to high hardness content. The hardness is due to calcium bicarbonate. The iron content is low. A few samples indicate high nitrate concentrations.

Cambrian Rocks

Conococheague Group

The Conococheague Group (€c) is composed of interbedded limestone and dolomite containing some siliceous and argillaceous laminae. The Conococheague Group consists of the Richland Formation (€r), the combined Millbach and Schaefferstown Formations (€ms), and the combined Snitz Creek and Buffalo Springs Formations (€sb).

Availability

The Conococheague Group, mapped as Cc, is an available aquifer in the Carlisle, Shippensburg, Columbia, Ephrata, Lancaster, Lititz, and Manheim areas. The Richland, Millbach, Schaefferstown, Snitz Creek, and Buffalo Springs Formations are available aquifers in the Lebanon area. The Millbach and Schaefferstown Formations have proved to be the best aquifers in the Conococheague Group.

Quantity

In the Lancaster Valley the yields from the Conococheague Group are as follows:

Poor yield - 35 gpm
Medium yield - 130 gpm
Good yield - 830 gpm

In the Lebanon Valley the yields from the Conococheague Group are as follows:

Poor yield - 55 gpm
Medium yield - 240 gpm
Good yield - 1,000 gpm

Annual cost

	Lebanon Valley	Lancaster Valley
For poor yield	$15,000 per mgd	$20,000 per mgd
For medium yield	$7,700 per mgd	$11,000 per mgd
For good yield	$3,300 per mgd	$4,000 per mgd

Quality

The waters from the Conococheague Group are typical limestone waters of fairly good quality containing a moderate to high hardness content and a moderate dissolved-solids content. The iron content is generally low. A few samples indicate a high nitrate concentration.

Elbrook Limestone

The Elbrook Limestone (Ꞓe) is a siliceous limestone containing interbedded dolomite.

Availability

The Elbrook Limestone is an available aquifer in the Carlisle, Shippensburg, Ephrata, and Lancaster areas.

Quantity

Poor yield - 15 gpm
Medium yield - 30 gpm
Good yield - 80 gpm

Annual cost

For poor yield - $42,000 per mgd
For medium yield - $23,000 per mgd
For good yield - $12,000 per mgd

Quality

The waters from the Elbrook Limestone are typical limestone waters containing a moderate to high hardness content and moderate dissolved-solids content. The iron content is generally low. A few samples indicate high nitrate concentrations.

Tomstown Dolomite and Correlative Units

The Tomstown Dolomite (Ꞓt) is composed of dolomite and shale. The Tomstown is considered the correlative equivalent of the Ledger Dolomite (Ꞓl), the Kinzers Formation (Ꞓk), and the Vintage Dolomite (Ꞓv).

Availability

The Tomstown Dolomite is an available aquifer in the Carlisle and Shippensburg areas. The Ledger Dolomite, Kinzers Formation, and Vintage Dolomite are available aquifers in the Columbia, Lancaster, Hanover, and York areas.

Quantity

Poor yield - 30 gpm
Medium yield - 100 gpm
Good yield - 380 gpm

Annual cost

For poor yield - $23,000 per mgd
For medium yield - $12,000 per mgd
For good yield - $6,600 per mgd

Quality

The waters from the Tomstown Dolomite and correlative units are typical limestone and dolomite waters of fairly good quality containing a moderate to high hardness content and a moderate dissolved-solids content. The iron content is low to moderate. A few samples indicate a high nitrate concentration.

Cambrian and Cambrian (?) Rocks

Antietam, Harpers, and Chickies Formations

The Antietam Quartzite (Ꞓa) is a quartzite and quartz schist. The Harpers Phyllite (Ꞓh, Ꞓma) is gray phyllite and schist. The Chickies Quartzite (Ꞓch) and the possibly equivalent Weverton Quartzite (Ꞓwl) are composed of quartzite and quartz schist.

Availability

The Antietam Quartzite is an available aquifer in the Carlisle area. The Harpers Phyllite is an available aquifer in the Carlisle and York areas. The combined Antietam and Harpers Formations, mapped as Cah, are available aquifers in the Atglen, Columbia, Lancaster, Dallastown-Red Lion, Hanover, and York areas. The Chickies Quartzite is an avaialble aquifer in the Atglen, Columbia, Dallastown-Red Lion, Hanover, and York areas.

Quantity

Poor yield - 15 gpm
Medium yield - 45 gpm
Good yield - 145 gpm

Annual cost

For poor yield - $38,000 per mgd
For medium yield - $22,000 per mgd
For good yield - $12,000 per mgd

Quality

The Antietam Quartzite yields water of excellent quality that is low in dissolved solids, hardness, and iron content. The water from the Harpers Phyllite is low to moderate in dissolved solids, hardness, and iron content. The water from the Chickies Quartzite is of excellent quality that is exceptionally low in total dissolved solids, hardness, and iron content.

Lower Paleozoic (?) Rocks

Peters Creek Quartzite

The Peters Creek Quartzite (Xpc) is a chlorite schist containing some quartzite layers.

Availability

The Peters Creek Quartzite is an available aquifer in the Oxford area.

Quantity

Poor yield - 25 gpm
Medium yield - 85 gpm
Good yield - 370 gpm

Annual cost

For poor yield - $31,000 per mgd
For medium yield - $15,000 per mgd
For good yield - $7,700 per mgd

Quality

The water from the Peters Creek Quartzite is of fair quality for most uses. The water contains a low to moderate dissolved solids and hardness content. The iron and nitrate contents are objectionably high.

Wissahickon Formation

The Wissahickon Formation is shown on the Geologic Map of Pennsylvania as including albite chlorite schist (Xwc), the Marburg Schist (Xwm), the Wakefield Marble (Xww), metavolcanic rocks (Xwv), and oligoclase mica schist (Xw).

Availability

Oligoclase mica schist is an available aquifer in the Oxford area. The Marburg Schist is an available aquifer in the Dallastown-Red Lion area, Hanover, and New Freedom-Shrewsberry areas. Metavolcanic rocks and albite chlorite schist are available aquifers in the Atglen and New Freedom-Shrewsberry areas. Albite chlorite schist is an available aquifer in the Columbia area. The Wakefield Marble is an available aquifer to the Dallastown-Red Lion area.

Quantity

Oligoclase mica schist of the Wissahickon and Marburg Schist:

Poor yield - 20 gpm
Medium yield - 60 gpm
Good yield - 240 gpm

Albite chlorite schist of the Wissahickon:

Poor yield - 30 gpm
Medium yield - 120 gpm
Good yield - 590 gpm

Annual cost

	Oligoclase mica schist	Albite chlorite schist
For poor yield	$38,000 per mgd	$28,000 per mgd
For medium yield	$18,000 per mgd	$14,000 per mgd
For good yield	$9,900 per mgd	$6,200 per mgd

Quality

The Wissahickon Formation usually yields water of excellent quality that is exceptionally low in dissolved solids and hardness content. The iron content is low to moderate.

Precambrian Rocks

Granite Gneiss (Baltimore Gneiss)

The granite gneiss (Gn), referred to as the Baltimore gneiss (Bgn) in Maryland, is composed of many metamorphic and igneous rock types.

Availability

The gneiss is an available aquifer in the Atglen area and a large part of the Maryland part of the basin.

Quantity

Poor yield - 20 gpm
Medium yield - 45 gpm
Good yield - 120 gpm

Annual cost

For poor yield - $38,000 per mgd
For medium yield - $22,000 per mgd
For good yield - $13,000 per mgd

Quality

The water from the gneiss is of excellent quality that is exceptionally low in dissolved solids, hardness, and iron content.

APPRAISAL BY AREA

The water-development areas within the lower Susquehanna River basin selected for study by the U. S. Public Health Service and concurred on by the U. S. Army Corps of Engineers are shown in figure 1. These areas are those that are considered to be the nucleus around which future population growth in the lower Susquehanna basin will occur. Most of them have a population in excess of 5,000 according to the 1960 Bureau of Census Report, but a few smaller areas are listed because these Federal agencies were specifically concerned about the availability of ground water for use as a source for public water supply. The areas are discussed by county, in alphabetical order. The corporate units (municipality or township) included within each water-development area are listed in the text. The geologic units listed as being available occur either inside of or within 1 mile of the boundaries of the areas under discussion.

The exact location of the geologic unit may be found by referring to the Geologic Map of Pennsylvania (Pennsylvania Geological Survey, 1960) or to the Geologic Map of Maryland and Delaware (Maryland Geological Survey, 1933). The aquifers available to each local area may be compared as to yield, cost, and quality of ground water by reference to tables 1, 2, 3, and 4 and to the section on appraisal by geologic units. A cross reference of geologic units and the water-development areas to which they are available are given in table 5.

In appraising and evaluating various geologic units available to a local area, a tabulation of ground-water yields, costs, and chemical quality by aquifer should be made. This would assist the water resources planner or manager in selecting those aquifers in each area that look promising for ground-water development. Such a tabulation was not made in this report, because it would have been duplication of work presented elsewhere in the report.

Adams County, Pa.

New Oxford Area

The New Oxford area includes the Borough of New Oxford. The available aquifer in this area is the New Oxford Formation (Trn) which underlies the entire borough and its environs.

Baltimore County, Md.

No area with a population in excess of 5,000 occurs within the lower Susquehanna River basin part of Baltimore County.

Berks County, Pa.

No area with a population in excess of 5,000 occurs within the lower Susquehanna River basin part of Berks County.

Cecil County, Md.

No area with a population in excess of 5,000 occurs within the lower Susquehanna River basin part of Cecil County.

Centre County, Pa.

No area with a population in excess of 5,000 occurs within the lower Susquehanna River basin part of Centre County.

Chester County, Pa.

Oxford Area

The Oxford area includes the Borough of Oxford. The available aquifers in this area are the oligoclase mica schist facies of the Wissahickon Formation (Xw) and the Peters Creek Quartzite (Xpc). Oligoclase mica schist underlies the entire borough.

Atglen Area

The Atglen area includes the Borough of Atglen. The available aquifers in this area are the Conestoga Limestone (Ocs), the combined Antietam and Harpers Formations (Єah), the Chickies Quartzite (Єch), the albite chlorite schist facies of the Wissahickon Formation (Xwc), and granite gneiss (gn). The Conestoga Limestone underlies the entire borough.

Cumberland County, Pa.

Carlisle Area

The Carlisle area includes Carlisle Borough, Mount Holly Springs Borough, North Middletown Township, and South Middletown Township. The available aquifers in this area are the Martinsburg Shale (Om), Chambersburg Limestone (Oc), St. Paul Group (Osp), Beekmantown Group (Oor, Os), Conococheague Group (€e), Elbrook Limestone (€e), Waynesboro Formation (€wb), Tomstown Dolomite (€t), Antietam Quartzite (€a), Harpers Phyllite (€h, €ma), and Weverton Quartzite (€wl). The St. Paul Group and the Ontelaunee, Epler, and Rickenbach Formations (Oor), undivided, of the Beekmantown Group, underlie Carlisle Borough. The Tomstown Dolomite underlies the entire Borough of Mt. Holly Springs.

Harrisburg West-Shore Area

The Harrisburg West-Shore area includes Camp Hill Borough, East Pennsboro Township, Fairview Township, Hampton Township, Lower Allen Township, Lemoyne Borough, New Cumberland Borough, and Wormleysburg Borough. The available aquifers in this area are the Gettysburg Shale (Trg, Trlc, Trh, Trgc), Martinsburg Shale (Om), Hershey and Myerstown Limestones (Ohm), St. Paul Group (Osp), and Beekmantown Group (Ob, Oor). Camp Hill and Lemoyne Boroughs are underlain by the Hershey and Myerstown Limestones and the St. Paul Group. New Cumberland and Wormleysburg Boroughs are underlain by the Martinsburg, Hershey, and Myerstown Formations.

Mechanicsburg Area

The Mechanicsburg area includes the Borough of Mechanicsburg. The available aquifers in this area are the Martinsburg Shale (Om), Chambersburg Limestone (Oc), St. Paul Group (Osp), and Beekmantown Group (Oor, Os). The Beekmantown Group underlies the entire borough.

Shippensburg Area

The Shippensburg area includes the Borough of Shippensburg. The available aquifers in this area are the Beekmantown Group (Oor, Os), Conococheague Group (€c), Elbrook Limestone (€e), Waynesboro Formation (€wb), and Tomstown Dolomite (€t). The Stonehenge Limestone (Os) and Conococheague Group underlie the borough.

Dauphin County, Pa.

Dauphin Area

The Dauphin area includes the Borough of Dauphin. The available aquifers in this area are the Mauch Chunk Formation (Mmc) and the Pocono Formation (Mp). The Mauch Chunk Formation underlies the entire borough.

Harrisburg East-Shore Area

The Harrisburg East-Shore area includes the city of Harrisburg, Highspire Borough, Lower Paxton Township, Lower Swatara Township, Steelton Borough, Susquehanna Township, and Swatara Township. The available aquifers in this area are the Gettysburg Shale (Trg), Martinsburg Shale (Om), Hershey and Myerstown Limestones (Ohm), St. Paul Group (Osp), Annville Limestone (Oan), the Ontelaunee Formation (Oo) and the Epler Formation (Oe) of the Beekmantown Group, and undifferentiated Beekmantown Group (Ob). The city of Harrisburg is underlain by the Martinsburg, Hershey, and Myerstown Formations and the St. Paul and Beekmantown Groups. Highspire Borough is underlain by the Gettysburg and Ontelaunee Formations. Steelton Borough is underlain by the Martinsburg, Hershey, Myerstown, Annville, and Ontelaunee Formations.

Hershey Area

The Hershey area includes Derry Township, Hummelstown Borough, and the unincorporated settlement of Hershey. The available aquifers in this area are the Gettysburg Shale (Trg), Martinsburg Shale (Om), Hershey and Myerstown Limestones (Ohm), Annville Limestone (Oan) and the Ontelaunee Formation (Oo), the Epler Formation (Oe), and the Stonehenge Limestone (Os) of the Beekmantown Group. The Borough of Hummelstown is underlain by the Ontelaunee and Epler Formations. The unincorporated settlement of Hershey is underlain by the Hershey, Myerstown, Annville, Ontelaunee, and Epler Formations.

Lykens Area

The Lykens area includes the Borough of Lykens. The available aquifers in this area are the Pottsville Formation (IPp), Mauch Chunk Formation (Mmc), and Pocono Formation (Mp). The Mauch Chunk and Pocono Formations underlie the borough.

Middletown Area

The Middletown area includes the Boroughs of Middletown and Royalton. The only available aquifer in this area is the Gettysburg Shale (Trg, Trgc) which entirely underlies both of the boroughs and their environs.

Millersburg Area

The Millersburg area includes the Borough of Millersburg. The available aquifers in this area are the Mauch Chunk Formation (Mmc) and Pocono Formation (Mp). The Mauch Chunk Formation underlies the entire borough.

Franklin County, Pa.

No area with a population in excess of 5,000 occurs within the lower Susquehanna River basin part of Franklin County.

Harford County, Md.

Havre de Grace is the only area with a population in excess of 5,000 that occurs within the lower Susquehanna River basin part of Harford County. However, Havre de Grace was not one of the water-development areas requested by the Public Health Service or the U. S. Army Corps of Engineers.

Lancaster County, Pa.

Columbia Area

The Columbia area includes Columbia Borough, Manor Township, Marietta Borough, Washington Borough, West Hempfield Township, and Wrightsville Borough (in York County). The available aquifers in this area are the Conestoga Limestone (Ocs), Conococheague Group (€c), Ledger Dolomite (€l), Kinzers Formation (€k), Vintage Dolomite (€v), the combined Antietam and Harpers Formation (€ah), the Chickies Quartzite (€ch), and the albite chlorite schist facies of the Wissahickon Formation (Xwc). The boroughs of Columbia and Wrightsville are underlain by the Conestoga Limestone. Marietta Borough is underlain by the Ledger and Vintage Dolomites. Washington Borough is underlain by the combined Antietam and Harpers Formations and by the Conestoga Limestone.

Elizabethtown Area

The Elizabethtown area includes the Borough of Elizabethtown. The available aquifers in this area are the Gettysburg Shale (Trg), New Oxford Formation (Trn), and the Beekmantown Group (Ob). The New Oxford Formation underlies the entire borough.

Ephrata Area

The Ephrata area includes the borough of Ephrata. The available aquifers in this area are the Gettysburg Shale (Trg), New Oxford Formation (Trn), Cocalico Shale (Oco), Beekmantown Group (Ob), Conococheague Group (€c), and Elbrook Limestone (€e). The Conococheague Group and the Elbrook and Cocalico Formations underlie the borough.

Lancaster Area

The Lancaster area includes East Hempfield Township, East Lampeter Township, City of Lancaster, Lancaster Township, Manheim Township, Manor Township, and West Lampeter Township. The available aquifers in this area are the Beekmantown Group (Ob), Conestoga Limestone (Ocs), Conococheague Group (€c), Elbrook Limestone (€e), Ledger Dolomite (€l), Kinzers Formation (€k), Vintage Dolomite (€v), and combined Antietam and Harpers Formations (€ah). The Conestoga and Ledger Formations underlie the City of Lancaster.

Lititz Area

The Lititz area includes the Borough of Lititz. The available aquifers in this area are the Cocalico Shale (Oco), Beekmantown Group (Ob), and Conococheague Group (€c). The Conococheague Group underlies the entire borough.

Manheim Area

The Manheim area includes the Borough of Manheim. The available aquifers in this area are the Cocalico Shale (Oco), Beekmantown Group (Ob), and Conococheague Group (€c). The Beekmantown Group underlies the entire borough.

Lebanon County, Pa.

Lebanon Area

The Lebanon area includes Lebanon City and South Lebanon Township. The available aquifers in this area are the Martinsburg Shale (Om, Omls); combined Hershey and Myerstown Limestones (Ohm); Annville Limestone (Oan); the Ontelaunee Formation (Oo), Epler Formation (Oe), Rickenbach Dolomite (Ori), and Stonehenge Limestone (Os) of the Beekmantown Group; and the Richland (€r), the combined Millbach and Schaefferstown Formations (€ms), and the combined Snitz Creek and Buffalo Springs Formations (€sb) of the Conococheague Group. The Martinsburg, Ontelaunee, Epler, Stonehenge, and Richland Formations underlie the City of Lebanon.

Palmyra Area

The Palmyra area includes the Borough of Palmyra. The available aquifers in this area are the Martinsburg Shale (Om); combined Hershey and Myerstown Limestones (Ohm); Annville Limestone (Oan); and the Ontelaunee Formation (Oo), Epler Formation (Oe), and Stonehenge Limestone (Os) of the Beekmantown Group. The Ontelaunee and Epler Formations underlie the borough.

Northumberland County, Pa.

Kulpmont-Mt. Carmel Area

The Kulpmont-Mt. Carmel area includes the boroughs of Kulpmont and Mt. Carmel. The available aquifers in this area are the post-Pottsville formations (ℙpp) and the Pottsville Formation (ℙp). The post-Pottsville formations underlie both boroughs.

Shamokin Area

The Shamokin Area includes Coal Township and Shamokin City. The available aquifers in this area are the post-Pottsville formations (ℙpp), Pottsville Formation (ℙp), Mauch Chunk Formation (Mmc), Pocono Formation (Mp), and Catskill Formation (Dck). Post-Pottsville formations underlie the entire City of Shamokin.

Sunbury Area

The Sunbury area includes the City of Sunbury. The available aquifers in this area are the Catskill Formation (Dck), undivided Devonian marine beds (Dm), the Mahantango Formation (Dmh), the combined Marcellus and Onondaga Formations (Dmo), the combined Oriskany and Helderberg Groups (Doh), and the combined Keyser and Tonoloway Limestones (Skt). The Devonian marine beds and the Mahantango Formation underlie the City of Sunbury.

Perry County, Pa.

No area with a population in excess of 5,000 occurs within the lower Susquehanna River basin part of Perry County.

Schuylkill County, Pa.

Ashland-Frackville Area

The Ashland-Frackville area includes the boroughs of Ashland and Frackville. The available aquifers in this area are the post-Pottsville formations (ℙpp), Pottsville Formation (ℙp), and Mauch Chunk Formation (Mmc). The post-Pottsville formations underlie the entire borough of Ashland. The Pottsville and Mauch Chunk Formations underlie the borough of Frackville.

Mahanoy City-Shenandoah Area

The Mahanoy City-Shenandoah area includes the boroughs of Mahanoy City and Shenandoah. The available aquifers in this area are the post-Pottsville formations (ℙpp), Pottsville Formation (ℙp), and Mauch Chunk Formation (Mmc). Post-Pottsville formations underlie both boroughs.

Pine Grove Area

The Pine Grove area includes the borough of Pine Grove. The available aquifers in this area are the undifferentiated Devonian marine beds (Dm) and the combined Hamilton Group and Onondoga Limestone (Dho). The Devonian marine beds underlie the entire borough.

Tower City Area

The Tower City area includes the borough of Tower City. The available aquifers in this area are the post-Pottsville formations (Ppp), Pottsville Formation (Pp), Mauch Chunk Formation (Mmc), and Pocono Formation (Mp). The Mauch Chunk Formation underlies the entire borough.

Snyder County, Pa.

Selinsgrove Area

The Selinsgrove area includes the boroughs of Hummelswarf, Selinsgrove, and Shamokin Dam. The available aquifers in this area are the undifferentiated Devonian marine beds (Dm), the Mahantango Formation (Dmh), the combined Marcellus and Onondaga Formations (Dmo), the combined Oriskany and Helderberg Groups (Doh), the combined Keyser and Tonoloway Limestones (Skt), and the Wills Creek Shale (Sw). The Marcellus and Onondaga Formations and the Oriskany and Helderberg Groups underlie the borough of Hummelswarf. The Keyser and Tonoloway Limestones underlie the borough of Selinsgrove. The Mahantango Formation underlies the entire borough of Shamokin Dam.

Union County, Pa.

No area with a population in excess of 5,000 occurs within the lower Susquehanna River basin part of Union County.

York County, Pa.

Dallastown-Red Lion Area

The Dallastown-Red Lion area includes the boroughs of Dallastown, Jacobus, Loganville, and Red Lion. The available aquifers in this area are the combined Antietam and Harpers Formations (€ah), the Chickies Quartzite (€ch), the Marburg Schist (Xwm), and the Wakefield Marble (Xww). The Marburg Schist underlies all the boroughs.

Hanover Area

The Hanover area includes Hanover Borough and Penn Township. The available aquifers in this area are the Conestoga Limestone (Ocs), Ledger Dolomite (€l), Kinzers Formation (€k), Vintage Dolomite (€v), the combined Antietam and Harpers Formations (€ah), the Chickies Quartzite (€ch), and the Marburg Schist. The Conestoga Limestone underlies the entire borough.

New Freedom-Shrewsbury Area

The New Freedom-Shrewsbury area includes the boroughs of Glen Rock, New Freedom, Railroad, and Shrewsbury. The available aquifers in this area are the Marburg Schist (Xwm) and the albite chlorite schist (Xwc) facies and metavolcanic rock units (Xwv) of the Wissahickon Formation. The albite chlorite schist and the metavolcanic rocks underlie all the boroughs.

York Area

The York area includes Dover Township, Manchester Township, Springetsburg Township, Spring Garden Township, Spring Grove Borough, West Manchester Township, York City, and York Township. The available aquifers in this area are the Gettysburg Shale (Trg, Trgc), New Oxford Formation (Trn), Conestoga Limestone (Ocs), Ledger Dolomite (€l), Kinzers Formation (€k), Vintage Dolomite (€v), the combined Antietam and Harpers Formations (€ah), the Harpers Phyllite (€h, €ma), and the Chickies Quartzite (€ck). The Kinzers Formation underlies the entire borough of Spring Grove. The Conestoga, Ledger, Kinzers, and Vintage Formations underlie the City of York.

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Table 1.--Estimated specific capacities and yields of hypothetical wells in the geologic units of the lower Susquehanna River basin.

Specific capacity equaled or exceeded for indicated percentage of successful wells: Tabulated values are taken from a log-normal frequency distribution of reported data, adjusted for 180 days continuous pumping; 75, 50, and 25 percent are referred to as poor, medium, and good, respectively, in the text.
Percentage of unsuccessful wells: The statistical percentage of wells, in the sample analyzed, that would yield less than 10 gallons per minute based on the well design given in table 2.
Yield equaled or exceeded for indicated percentage of successful wells: Derived from specific-capacity data and well design given in table 2; 75, 50, and 25 percent are referred to as poor, medium, and good, respectively, in text and tables 2 and 3.

Geologic unit (Formation or Group)	Geologic age	Symbol on Geologic Map of Pennsylvania (1960 Ed.) scale 1:250,000	Area in which well analyses are valid	Specific-capacity data: Specific capacity equaled or exceeded for indicated percentage of successful wells: 75 percent (poor)	50 percent (medium)	25 percent (good)	Number of wells used for specific capacity frequency distribution analysis	Percentage of unsuccessful wells	Yield equaled or exceeded for indicated percentage of successful wells: 75 percent (poor): Gallons per minute	Million gallons per day	Million gallons per year	50 percent (medium): Gallons per minute	Million gallons per day	Million gallons per year	25 percent (good): Gallons per minute	Million gallons per day	Million gallons per year
Gettysburg	Triassic	Trg, Trh, Trlc, Trqc	Entire lower basin	0.33	1.0	3.0	26	3	55	.079	29	160	0.23	84	480	0.69	250
New Oxford	Triassic	Trn	West of Susquehanna River	.15	.36	1.0	14	20	25	.036	13	60	.086	32	180	.26	95
			East of Susquehanna River	.62	.77	.97	6	<2	110	.16	58	130	.19	68	170	.25	89
Post-Pottsville	Pennsylvanian	Ᵽpp	Entire lower basin	.41	1.3	4.2	5	<2	75	.11	39	230	.33	120	760	1.1	400
Pottsville	Pennsylvanian	Ᵽp	Entire lower basin	.70	1.4	2.5	4	<2	120	.17	63	240	.35	130	430	.62	230
Mauch Chunk	Pennsylvanian and Mississippian	Mmc	Southern anthracite coal field	.16	.57	2.0	5	10	30	.043	16	100	.14	53	360	.52	190
			Western-middle anthracite coal field	.48	.70	1.0	10	<2	85	.12	45	130	.19	68	180	.26	95
Pocono	Mississippian	Mp	Entire lower basin	.13	.40	1.2	8	11	25	.036	13	70	.10	37	220	.32	120
Catskill	Mississippian and Devonian	Dck	Entire lower basin	.54	1.2	2.7	11	<2	85	.12	45	190	.27	100	430	.62	230
Marine beds	Devonian	Dm	Entire lower basin	.18	.48	1.4	14	14	30	.043	16	80	.12	42	240	.35	130
Hamilton and Onondaga	Devonian	Don, Dmo, Dmh, Dh, Dho	Entire lower basin	.18	.51	1.2	11	3	30	.043	16	85	.12	45	200	.29	130
Oriskany and Helderberg	Devonian	Dhb, Do, Doh	Entire lower basin	.51	1.9	8.7	13	22	35	.050	18	130	.19	68	610	.89	320

Table 1.--Estimated specific capacities and yields of hypothetical wells in the geologic units of the lower Susquehanna River basin--Continued

Geologic unit (Formation or Group)	Geologic age	Symbol on Geologic Map of Pennsylvania (1960 Ed.) scale 1:250,000	Area in which well analyses are valid	Specific-capacity data: Specific capacity equaled or exceeded for indicated percentage of successful wells: 75 percent (poor)	50 percent (medium)	25 percent (good)	Number of wells used for specific capacity frequency distribution analysis	Percentage of unsuccessful wells	Yield equaled or exceeded for indicated percentage of successful wells: 75 percent (poor): Gallons per minute	Million gallons per day	Million gallons per year	50 percent (medium): Gallons per minute	Million gallons per day	Million gallons per year	25 percent (good): Gallons per minute	Million gallons per day	Million gallons per year
Keyser, Tonoloway, and Wills Creek	Devonian and Silurian	Sw, Skt, Skw	Entire lower basin	.70	2.5	9.7	21	11	30	.072	26	180	.26	94	680	.98	360
Martinsburg and Cocalico	Ordovician	Om, Oco	Entire lower basin	.20	.36	.65	18	2	35	.050	18	60	.086	32	110	.16	58
Hershey, Myerstown, and Chambersburg	Ordovician	Ohm, Oc	Entire lower basin	.42	1.7	9.6	6	32	30	.043	16	130	.19	68	720	1.0	380
St. Paul and Annville	Ordovician	Osp, Oan	Entire lower basin	.74	6.9	65	10	23	55	.079	29	520	.75	270	1,000	1.4	530
Beekmantown	Ordovician	Os, Ori, Oe, Oo, Oor, Ob	Lebanon-Cumberland Valleys	1.6	8.6	49	39	7	120	.17	63	650	.94	340	1,000	1.4	530
			Lancaster Valley	.42	1.6	9.5	48	44	30	.043	16	120	.17	63	710	1.0	370
Conestoga	Ordovician and Cambrian (?)	Ocs	Entire lower basin	.50	1.9	9.5	36	28	40	.058	21	140	.20	74	710	1.0	370
Conococheague	Cambrian	€sb, €ms, €r, €c	Lebanon-Cumberland Valleys	.70	3.2	19	65	20	55	.079	29	240	.35	130	1,000	1.4	530
			Lancaster Valley	.44	1.7	11	63	46	35	.050	19	130	.19	68	830	1.2	440
Elbrook	Cambrian	€e	Entire lower basin	.22	.43	1.1	18	60	15	.022	7.9	30	.043	16	80	.11	42
Tomstown and correlative units	Cambrian	€v, €h, €l, €t	Entire lower basin	.42	1.3	5.0	54	24	30	.043	16	100	.14	53	380	.55	200
Antietam, Harpers, and Chickies	Cambrian and Cambrian(?)	€cl, €h, €a, €ah	Entire lower basin	.14	.36	1.2	11	31	20	.029	11	45	.065	24	140	.20	74
Peters Creek	Probably early Paleozoic	Xpc	Entire lower basin	.20	.70	3.1	13	23	25	.036	13	85	.12	45	370	.53	190
Wissahickon: oligoclase mica schist	Probably early Paleozoic	Xw	Entire lower basin	.17	.52	2.0	16	26	20	.029	11	60	.086	32	240	.35	130

Table 1.--Estimated specific capacities and yields of hypothetical wells in the geologic units of the lower Susquehanna River basin--Continued

Geologic unit (Formation or Group)	Geologic age	Symbol on Geologic Map of Pennsylvania (1960 Ed.) scale 1:250,000	Area in which well analyses are valid	Specific-capacity data: Specific capacity equaled or exceeded for indicated percentage of successful wells: 75 percent (poor)	50 percent (medium)	25 percent (good)	Number of wells used for specific capacity frequency distribution analysis	Percentage of unsuccessful wells	Yield equaled or exceeded for indicated percentage of successful wells: 75 percent (poor): Gallons per minute	Million gallons per day	Million gallons per year	50 percent (medium): Gallons per minute	Million gallons per day	Million gallons per year	25 percent (good): Gallons per minute	Million gallons per day	Million gallons per year
Wissahickon: albite chlorite schist	Probably early Paleozoic	Xwc	Entire lower basin	.24	.97	4.9	12	21	30	.043	16	120	.17	63	590	.85	310
granite gneiss	Pre-cambrian	gn	Entire lower basin	.16	.38	1.0	12	13	20	.029	11	45	.065	24	120	.17	63

Table 2.--Well design of hypothetical wells in the geologic units of the lower Susquehanna River basin

Well diameter: Chosen according to pump diameter, which is based on yields given in table 1; 0 to 100 gallons per minute, 4-inch pump, 6-inch well; 100 to 250 gallons per minute, 6-inch pump, 8-inch well; 250 to 500 gallons per minute, 8-inch pump, 10-inch well; 500 to 1,000 gallons per minute, 10-inch pump, 12-inch well.
Poor, medium, and good yields refer to yields of 75, 50, and 25 percent of wells, respectively, given in table 1.
Pump working horsepower: The power necessary to produce hypothetical yields given in table 1, for use in calculating electrical power cost.

Geologic unit (Formation or Group)	Area in which well analyses are valid	Well depth (feet)	Well diameter (inches)			Length of casing (feet)	Static water-level (feet below land surface)	Pumping water level (feet below land surface)		Drawdown (pumping water level minus static water level) (feet)		Pump working horsepower		
			For poor yield	For medium yield	For good yield			For poor and medium yields	For good yield	For poor and medium yields	For good yield	For poor yield	For medium yield	For good yield
Gettysburg	Entire lower basin	400	6	8	10	40	40	200	200	160	160	4.2	11.2	32.3
New Oxford	West of Susquehanna River	400	6	6	8	40	30	200	200	170	170	2.2	4.5	12.4
	East of Susquehanna River	400	8	8	8	40	25	200	200	175	175	7.8	9.1	11.8
Post-Pottsville	Entire lower basin	400	6	8	12	40	20	200	200	180	180	5.5	15.8	51.0
Pottsville	Entire lower basin	400	8	10	10	40	30	200	200	170	170	8.4	16.3	29.0
Mauch Chunk	Southern anthracite coal field	400	6	8	10	40	20	200	200	180	180	2.5	7.1	24.3
	Western-middle anthracite coal field	400	6	8	8	40	20	200	200	180	180	6.2	9.1	12.3
Pocono	Entire lower basin	400	6	6	8	40	20	200	200	180	180	2.2	5.3	15.1
Catskill	Entire lower basin	400	6	8	10	40	40	200	200	160	160	6.1	13.3	29.0
Devonian marine beds	Entire lower basin	400	6	6	8	40	30	200	200	170	170	2.5	5.8	16.4
Hamilton and Onondaga	Entire lower basin	400	6	6	8	40	30	200	200	170	170	2.5	6.2	14.2

Table 2.--Well design of hypothetical wells in the geologic units of the lower Susquehanna River basin--Continued

Geologic unit (Formation or Group)	Area in which well analyses are valid	Well depth (feet)	Well diameter (inches)			Length of casing (feet)	Static water-level (feet below land surface)	Pumping water level (feet below land surface)		Drawdown (pumping water level minus static water level) (feet)		Pump working horsepower		
			For poor yield	For medium yield	For good yield			For poor and medium yields	For good yield	For poor and medium yields	For good yield	For poor yield	For medium yield	For good yield
Oriskany and Helderberg	Entire lower basin	300	6	8	12	40	30	100	100	70	70	1.6	4.7	20.2
Keyser, Tonoloway, and Wills Creek	Entire lower basin	300	6	8	12	40	30	100	100	70	70	2.2	6.3	22.5
Martinsburg and Cocalico	Entire lower basin	400	6	6	8	40	30	200	200	170	170	2.8	4.5	7.8
Hershey, Myerstown, and Chambersburg	Entire lower basin	300	6	8	12	40	25	100	100	75	75	1.4	4.7	24.0
St. Paul and Annville	Entire lower basin	300	6	12	12	40	25	100	40	75	15	2.3	17.3	14.0
Beekmantown	Lebanon-Cumberland Valleys	300	8	12	12	40	25	100	45	75	20	4.3	21.6	15.7
	Lancaster Valley	300	6	8	12	40	25	100	100	75	75	1.4	4.3	23.5
Conestoga	Entire lower basin	300	6	8	12	40	25	100	100	75	75	1.7	5.0	23.5
Conococheague	Lebanon-Cumberland Valleys	300	6	8	12	40	25	100	78	75	53	2.3	8.4	27.2
	Lancaster Valley	300	6	8	12	40	25	100	100	75	75	1.6	4.7	27.5
Elbrook	Entire lower basin	300	6	6	6	40	25	100	100	75	75	0.8	1.4	3.2
Tomstown	Entire lower basin	300	6	8	10	40	25	100	100	75	75	1.4	3.7	12.8
Antietam, Harpers, and Chickies	Entire lower basin	400	6	6	8	40	30	150	150	120	120	1.5	2.7	7.5
Peters Creek	Entire lower basin	400	6	6	10	40	30	150	150	120	120	1.8	4.7	18.8

Table 2.--Well design of hypothetical wells in the geologic units of the lower Susquehanna River basin--Continued

Geologic unit (Formation or Group)	Area in which well analyses are valid	Well depth (feet)	Well diameter (inches)			Length of casing (feet)	Static water-level (feet below land surface)	Pumping water level (feet below land surface)		Drawdown (pumping water level minus static water level) (feet)		Pump working horsepower		
			For poor yield	For medium yield	For good yield			For poor and medium yields	For good yield	For poor and medium yields	For good yield	For poor yield	For medium yield	For good yield
Wissahickon: oligoclase mica schist	Entire lower basin	400	6	6	8	40	30	150	150	120	120	1.5	3.4	12.3
Wissahickon: albite chlorite schist	Entire lower basin	400	6	8	12	40	30	150	150	120	120	2.0	6.7	29.8
Granite gneiss	Entire lower basin	400	6	6	8	40	30	150	150	120	120	1.5	2.7	6.4

Table 3.--Estimated costs of hypothetical wells and ground water in the geologic units of the lower Susquehanna River basin

Yield category: Poor, medium, and good refer to yields equaled or exceeded for 75, 50, and 25 percent of successful wells, respectively, given in table 1.
Estimated costs of wells: Costs are based on well designs given in table 2 for wells producing poor, medium, and good yields given in table 1. Cost estimates obtained from several local well drilling companies.
Annual payments to retire total initial cost: Initial investment compounded at 4 percent over 25 years according to capitol-recovery-factor method of accounting.
Annual power cost: Cost estimates based on Pennsylvania Power and Light Company rate schedules for municipal use.
Estimated costs of ground water: Average annual cost of water delivered at the well head at land surface based on yields given in table 1, well designs given in table 2, and costs given in this table.

			Estimated costs of construction, operation, and maintenance of hypothetical wells													Estimated unit costs of ground water (dollars)	
			Initial costs									Annual costs					
			Estimated costs of initial construction of wells (dollars)									Estimated costs of operation and maintenance of wells (dollars)					
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Geologic unit (Formation or Group)	Area for which well analyses are valid	Yield category	Drilling (two wells-one production and one exploratory well)	Pump test production well	Casing production well	Motor, column, shaft, pump, and strainer	Land, pumphouse, wiring, meter, and piping	Contingencies (10% of sum of columns 1 thru 5)	Engineering and administration (15% of sum of columns 1 thru 6)	Total initial cost (sum of columns 1 thru 7)	Total initial cost per mgd of design yield	Annual payments to retire total initial cost	Annual power cost	Annual maintenance cost (4% of column 4)	Total annual cost (sum of columns 10 thru 12)	Average annual cost per thousand gallons of design yield	Average annual cost per mgd of design yield
Gettysburg	Entire lower basin	Poor	2,400	500	140	2,130	4,000	920	1,520	11,600	150,000	740	800	90	1,600	0.055	20,000
		Medium	3,600	500	200	3,200	4,000	1,150	1,900	14,500	63,000	930	2,100	130	3,200	.038	14,000
		Good	5,200	500	280	4,550	4,000	1,450	2,400	18,400	27,000	1,180	3,700	180	5,100	.020	7,300
New Oxford	West of Susquehanna	Poor	3,200	500	140	2,030	4,000	990	1,600	12,500	350,000	800	450	80	1,300	.099	36,000
		Medium	3,200	500	140	2,130	4,000	1,000	1,700	12,700	150,000	810	900	90	1,800	.057	21,000
		Good	5,200	500	200	3,300	4,000	1,320	2,200	16,700	65,000	1,070	2,200	130	3,400	.036	13,000
	East of Susquehanna	Poor	5,200	500	200	2,800	4,000	1,300	2,100	16,100	100,000	1,030	1,500	110	2,600	.045	16,000
		Medium	5,200	500	200	2,900	4,000	1,300	2,100	16,200	86,000	1,040	1,700	120	2,900	.042	15,000
		Good	5,200	500	200	3,250	4,000	1,300	2,200	16,600	68,000	1,060	2,200	130	3,400	.038	14,000
Post-Pottsville	Entire lower basin	Poor	3,200	500	140	2,400	4,000	1,000	1,700	12,900	120,000	830	1,050	100	2,000	.051	19,000
		Medium	5,200	500	200	3,600	4,000	1,400	2,200	17,100	52,000	1,090	2,450	140	3,700	.031	11,000
		Good	10,000	800	400	5,400	4,000	2,100	3,400	26,100	24,000	1,670	5,500	220	7,400	.019	6,900
Pottsville	Entire lower basin	Poor	5,200	500	200	2,900	4,000	1,300	2,100	16,200	93,000	1,040	1,600	120	2,800	.044	16,000
		Medium	7,600	500	280	3,650	4,000	1,600	2,600	20,200	58,000	1,290	2,450	150	3,900	.031	11,000
		Good	7,600	500	280	4,400	4,000	1,700	2,800	21,300	34,000	1,360	3,400	180	4,900	.022	8,000
Mauch Chunk	Southern anthracite coal field	Poor	2,400	500	140	2,030	4,000	900	1,500	11,500	270,000	740	450	80	1,300	.082	30,000
		Medium	3,600	500	200	2,700	4,000	1,100	1,800	13,900	97,000	890	1,350	110	2,400	.046	17,000
		Good	5,200	500	280	4,150	4,000	1,400	2,300	17,800	34,000	1,140	3,000	170	4,300	.023	8,400
	Western middle anthracite coal field	Poor	2,400	500	140	2,230	4,000	900	1,500	11,700	96,000	750	1,200	90	2,000	.044	16,000
		Medium	3,600	500	200	2,900	4,000	1,100	1,800	14,100	75,000	900	1,700	120	2,700	.040	15,000
		Good	3,600	500	200	3,300	4,000	1,200	1,900	14,700	57,000	940	2,200	130	3,300	.035	13,000
Pocono	Entire lower basin	Poor	3,200	500	140	2,030	4,000	1,000	1,600	12,500	350,000	800	400	80	1,300	.099	36,000
		Medium	3,200	500	140	2,300	4,000	1,000	1,700	12,800	130,000	820	1,000	90	1,900	.052	19,000
		Good	5,200	500	200	3,600	4,000	1,400	2,200	17,100	54,000	1,090	2,400	140	3,600	.031	11,000
Catskill	Entire lower basin	Poor	3,200	500	140	2,230	4,000	1,000	1,700	12,800	100,000	820	1,350	90	2,300	.051	19,000
		Medium	5,200	500	200	3,350	4,000	1,300	2,200	16,800	61,000	1,080	2,300	130	3,500	.035	13,000
		Good	7,600	500	280	4,400	4,000	1,700	2,800	21,300	34,000	1,360	3,400	180	4,900	.022	8,000
Devonian marine beds	Entire lower basin	Poor	3,200	500	140	2,030	4,000	1,000	1,600	12,500	290,000	800	500	80	1,400	.089	32,000
		Medium	3,200	500	140	2,230	4,000	1,000	1,700	12,800	110,000	820	1,100	90	2,000	.048	18,000
		Good	5,200	500	200	3,650	4,000	1,400	2,300	17,300	50,000	1,100	2,500	150	3,800	.030	11,000

Table 3.--Estimated costs of hypothetical wells and ground water in the geologic units of the lower Susquehanna River basin--Continued

			Estimated costs of construction, operation, and maintenance of hypothetical wells													Estimated unit costs of ground water (dollars)	
			Initial costs									Annual costs					
			Estimated costs of initial construction of wells (dollars)									Estimated costs of operation and maintenance of wells (dollars)					
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Geologic unit (Formation or Group)	Area for which well analyses are valid	Yield category	Drilling (two wells-one production and one exploratory well)	Pump test production well	Casing production well	Motor, column, shaft, pump, and strainer	Land, pumphouse, wiring, meter, and piping	Contingencies (10% of sum of columns 1 thru 5)	Engineering and administration (15% of sum of columns 1 thru 6)	Total initial cost (sum of columns 1 thru 7)	Total initial cost per mgd of design yield	Annual payments to retire total initial cost	Annual power cost	Annual maintenance cost (4% of column 4)	Total annual cost (sum of columns 10 thru 12)	Average annual cost per thousand gallons of design yield	Average annual cost per mgd of design yield
Hamilton and Onondaga	Entire lower basin	Poor	2,400	500	140	2,030	4,000	900	1,500	11,500	270,000	740	500	80	1,300	.082	30,000
		Medium	2,400	500	140	2,230	4,000	900	1,500	11,700	96,000	750	1,200	90	2,000	.045	16,000
		Good	3,600	500	200	3,450	4,000	1,200	2,000	15,000	52,000	1,960	2,300	140	4,400	.042	15,000
Oriskany and Helderberg	Entire lower basin	Poor	2,600	500	140	1,280	4,000	900	1,400	10,800	220,000	690	300	50	1,000	.060	22,000
		Medium	5,600	500	200	1,570	4,000	1,200	2,000	15,100	81,000	970	950	60	2,000	.029	11,000
		Good	9,800	800	400	2,900	4,000	1,800	3,000	22,700	26,000	1,450	2,700	120	4,300	.013	4,700
Keyser, Tonoloway, and Wills Creek	Entire lower basin	Poor	2,600	500	140	1,270	4,000	900	1,400	10,800	150,000	690	400	50	1,100	.042	15,000
		Medium	5,600	500	200	1,900	4,000	1,200	2,100	16,300	63,000	1,040	1,200	80	2,300	.024	8,800
		Good	9,800	800	400	3,050	4,000	1,800	3,000	22,900	23,000	1,470	2,850	120	4,400	.012	4,400
Martinsburg and Cocalico	Entire lower basin	Poor	2,400	500	140	2,030	4,000	900	500	11,500	230,000	740	550	80	1,400	.076	28,000
		Medium	2,400	500	140	2,130	4,000	920	500	11,600	130,000	740	850	90	1,700	.054	20,000
		Good	3,600	500	200	2,800	4,000	1,100	1,800	14,000	89,000	900	1,500	110	2,500	.043	16,000
Hershey, Myerstown, and Chambersburg	Entire lower basin	Poor	2,600	500	140	1,280	4,000	900	1,400	10,800	250,000	690	300	50	1,000	.062	23,000
		Medium	5,600	500	200	1,570	4,000	1,200	2,000	15,100	79,000	970	900	60	1,900	.028	10,000
		Good	9,800	800	400	3,100	4,000	1,800	3,000	22,900	23,000	1,470	2,950	120	4,500	.012	4,500
St. Paul and Annville	Entire lower basin	Poor	2,600	500	140	1,270	4,000	900	1,400	10,800	140,000	690	450	50	1,200	.041	15,000
		Medium	9,800	800	400	2,700	4,000	1,800	2,900	22,400	30,000	1,430	2,550	110	4,100	.015	5,500
		Good	9,800	800	400	1,950	4,000	1,600	2,700	20,800	15,000	1,330	2,300	80	3,700	.007	2,600
Beekmantown	Lebanon-Cumberland Valleys	Poor	5,600	500	200	1,500	4,000	1,200	2,000	15,000	88,000	960	850	60	1,900	.030	11,000
		Medium	9,800	800	400	3,000	4,000	1,800	3,000	22,800	24,000	1,460	2,800	120	4,400	.013	4,700
		Good	9,800	800	400	2,160	4,000	1,700	2,800	21,700	15,000	1,390	2,450	90	3,900	.007	2,800
	Lancaster Valley	Poor	2,600	500	140	1,280	4,000	900	1,400	10,800	250,000	690	300	50	1,000	.063	23,000
		Medium	5,600	500	200	1,500	4,000	1,200	2,000	15,000	87,000	960	850	60	1,900	.030	11,000
		Good	9,800	800	400	3,100	4,000	1,800	3,000	22,900	19,000	1,470	2,900	120	4,500	.012	4,500
Conestoga	Entire lower basin	Poor	2,600	500	140	1,280	4,000	900	1,400	10,800	190,000	690	350	50	1,100	.052	19,000
		Medium	5,600	500	200	1,570	4,000	1,200	2,000	15,100	76,000	970	950	60	2,000	.027	10,000
		Good	9,800	800	400	3,100	4,000	1,800	3,000	22,900	23,000	1,470	2,900	120	4,500	.012	4,500
Conococheague	Lebanon-Cumberland Valleys	Poor	2,600	500	140	1,270	4,000	900	1,400	10,800	140,000	690	450	50	1,200	.042	15,000
		Medium	5,600	500	200	2,100	4,000	1,200	2,000	15,600	45,000	1,000	1,600	80	2,700	.021	7,700
		Good	9,800	800	400	2,840	4,000	1,800	2,900	22,500	16,000	1,440	3,200	110	4,800	.009	3,300
	Lancaster Valley	Poor	2,600	500	140	1,280	4,000	900	1,400	10,800	220,000	690	300	50	1,000	.054	20,000
		Medium	5,600	500	200	1,570	4,000	1,200	2,000	15,100	82,000	970	900	60	1,900	.029	11,000
		Good	9,800	800	400	3,250	4,000	1,800	3,000	23,100	19,000	1,480	3,300	130	4,900	.011	4,000
Elbrook	Entire lower basin	Poor	2,600	500	140	1,000	4,000	800	1,300	10,300	470,000	660	200	40	900	.114	42,000
		Medium	2,600	500	140	1,280	4,000	900	1,400	10,800	250,000	690	300	50	1,000	.063	23,000
		Good	2,600	500	140	1,360	4,000	900	1,400	10,900	95,000	700	600	50	1,400	.033	12,000

Table 3.--Estimated costs of hypothetical wells and ground water in the geologic units of the lower Susquehanna River basin--Continued

			Estimated costs of construction, operation, and maintenance of hypothetical wells													Estimated unit costs of ground water (dollars)	
			Initial costs									Annual costs					
			Estimated costs of initial construction of wells (dollars)									Estimated costs of operation and maintenance of wells (dollars)					
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Geologic unit (Formation or Group)	Area for which well analyses are valid	Yield category	Drilling (two wells-one production and one exploratory well)	Pump test production well	Casing production well	Motor, column, shaft, pump, and strainer	Land, pumphouse, wiring, meter, and piping	Contingencies (10% of sum of columns 1 thru 5)	Engineering and administration (15% of sum of columns 1 thru 6)	Total initial cost (sum of columns 1 thru 7)	Total initial cost per mgd of design yield	Annual payments to retire total initial cost	Annual power cost	Annual maintenance cost (4% of column 4)	Total annual cost (sum of columns 10 thru 12)	Average annual cost per thousand gallons of design yield	Average annual cost per mgd of design yield
Tomstown	Entire lower basin	Poor	2,600	500	140	1,280	4,000	900	1,400	10,800	250,000	690	300	50	1,000	.063	23,000
		Medium	5,600	500	200	1,360	4,000	1,200	1,900	14,800	100,000	950	700	50	1,700	.032	12,000
		Good	7,400	500	280	2,400	4,000	1,500	2,400	18,500	34,000	1,180	2,250	100	3,500	.018	6,600
Antietam, Harpers, and Chickies	Entire lower basin	Poor	3,200	500	140	1,300	4,000	900	1,500	11,500	400,000	740	300	50	1,100	.105	38,000
		Medium	3,200	500	140	1,640	4,000	1,000	1,600	12,100	190,000	770	550	70	1,400	.059	22,000
		Good	5,200	500	200	2,500	4,000	1,200	2,000	15,600	77,000	1,000	1,400	100	2,500	.034	12,000
Peters Creek	Entire lower basin	Poor	3,200	500	140	1,280	4,000	900	1,500	11,500	320,000	740	350	50	1,100	.084	31,000
		Medium	3,200	500	140	1,840	4,000	1,000	1,600	12,300	100,000	790	900	70	1,800	.040	15,000
		Good	7,600	500	280	3,600	4,000	1,600	2,600	20,200	38,000	1,290	2,650	140	4,100	.021	7,700
Wissahickon: oligoclase mica schist	Entire lower basin	Poor	3,200	500	140	1,300	4,000	900	1,500	11,500	400,000	740	300	50	1,100	.105	38,000
		Medium	3,200	500	140	1,790	4,000	1,000	1,600	12,200	140,000	780	650	70	1,500	.048	18,000
		Good	5,200	500	200	3,000	4,000	1,300	2,100	16,300	47,000	1,040	2,200	120	3,400	.027	9,900
Wissahickon: albite chlorite schist	Entire lower basin	Poor	3,200	500	140	1,640	4,000	1,000	1,600	12,100	280,000	770	400	70	1,200	.076	28,000
		Medium	5,200	500	200	2,350	4,000	1,200	2,000	15,500	90,000	990	1,300	90	2,400	.038	14,000
		Good	10,000	800	400	4,200	4,000	1,900	3,200	24,500	29,000	1,570	3,450	170	5,200	.017	6,200
granite gneiss	Entire lower basin	Poor	3,200	500	140	1,300	4,000	900	1,500	11,500	400,000	740	300	50	1,100	.105	38,000
		Medium	3,200	500	140	1,640	4,000	1,000	1,600	12,100	190,000	770	500	70	1,400	.059	22,000
		Good	5,200	500	200	2,350	4,000	1,200	2,000	15,500	90,000	990	1,200	90	2,300	.036	13,000

Table 4.--Quality of ground water in the geologic units of the lower Susquehanna River basin

Values in parts per million except as indicated.
Chemical characteristic category: Values tabulated are taken from a normal frequency distribution of reported chemical analyses of well water. Good, medium, and poor refer to values equaled or exceeded for 75, 50, and 25 percent of available analyses, respectively.

Geologic unit (Formation or Group)	Area in which well analyses are valid	Chemical characteristic category	Temperature (°F)	Silica (SiO_2)	Total iron (Fe)	Total manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Calcium magnesium Hardness as $CaCO_3$	Alkalinity	pH	Color	ABS	Remarks
Gettysburg	East of Susquehanna River	Good	53	22	0.1	----	62	16	3.5		166	50	2.3	0.0	----	130	70	60	7.0	----	----	
		Medium	55	24	0.2	----	73	20	6.5		178	90	4.5	0.0	----	230	160	90	7.3	----	----	
		Poor	57	26	0.3*	----	84	24	9.5		190	130	6.7	0.0	----	330	250	120	7.6	----	----	
New Oxford	West of Susquehanna River	Good	53	17	0.03	0.01	42	7	6	0.4	105	12	4	0.0	15	160	105	---	6.5	----	----	
		Medium	54	20	0.15	0.03	57	12	12	1.2	145	32	13	0.0	30	230	155	---	7.0	----	----	
		Poor	55	23	0.27	0.05*	72	17	18	2.0	185	52	22	0.0	45*	300	205	---	7.5	----	----	
	East of Susquehanna River	Good	----	14	0.04	0.00	22	6.0	6.6	0.4	64	17	6	0.0	11	160	90	---	6.8	----	0.01	
		Medium	----	16	0.11	0.03	42	7.8	10.2	1.0	124	27	11	0.0	25	210	150	---	7.3	----	0.02	
		Poor	----	18	0.18	0.06*	62	9.6	13.8	1.6	184	37	16	0.0	39	260	210	---	7.8	----	0.12	
Post-Pottsville	Entire lower basin	Good	----	----	----	----	----	----	----	---	---	---	----	---	----	---	---	---	---	----	----	Acid water with high concentrations of iron near mining operations.
		Medium	53	8	0.1	----	21	6.8	7.8	1.6	51	7	21	---	22	130	80	---	---	----	----	
		Poor	----	----	----	----	----	----	----	---	---	---	----	---	---	---	---	---	---	----	----	
Pottsville	Entire lower basin	Good	----	----	----	----	----	----	----	---	---	---	0.0	---	----	20	14	9	6.7	----	----	A few samples contain excess iron, are hard, and contain hydrogen sulfide.
		Medium	----	----	0.0	----	----	----	----	---	---	---	1.5	---	----	45	33	27	6.8	----	----	
		Poor	----	----	----	----	----	----	----	---	---	---	3.0	---	----	70	52	45	6.9	----	----	
Mauch Chunk	Southern anthracite coal field	Good	----	----	0.0	----	----	----	----	---	---	20	1.5	---	----	130	90	60	7.1	----	----	
		Medium	55	17	0.1	----	50	5.7	12	2.4	120	40	2.5	0.1	2.1	160	110	80	7.4	----	----	
		Poor	----	----	0.8*	----	----	----	----	---	---	60	3.5	---	----	190	130	100	7.7	----	----	
	Western-middle anthracite coal field	Good	----	----	0.03	----	----	----	----	---	---	---	0	---	-----	0	40	45	6.7	----	----	A few samples indicate high nitrate concentrations.
		Medium	52	6.1	0.08	----	----	----	----	---	---	---	2	---	----	80	70	55	6.9	----	----	
		Poor	----	----	0.13	----	----	----	----	---	---	---	4	---	----	160	100	65	7.1	----	----	
Pocono	Entire lower basin	Good	----	----	2.0*	----	----	----	----	---	---	---	----	---	----	---	---	---	---	----	----	
		Medium	57	----	2.7*	----	10	----	2.4		40	3	1.0	---	----	39	32	---	---	----	----	
		Poor	----	----	3.4*	----	----	----	----	---	---	---	----	---	----	---	---	---	---	----	----	
Catskill	Entire lower basin	Good	----	----	0.0	----	----	----	----	---	---	---	0.4	---	----	90	50	45	7.0	----	----	
		Medium	54	12	0.2	----	17	13	15	3.2	53	15	7	---	16	130	80	65	7.2	----	----	
		Poor	----	----	0.4*	----	----	----	----	---	----	---	10	---	----	170	110	85	7.4	----	----	
Devonian marine beds	Entire lower basin	Good	53	----	0.2	----	30	13	8		70	5	0	---	----	100	100	---	---	----	----	Occasional reports of hydrogen sulfide.
		Medium	54	----	0.5*	----	40	18	10		100	45	20	---	1.0	200	150	---	---	----	----	
		Poor	55	----	0.8*	----	50	23	12		130	85	40	---	---	300	200	---	---	----	----	
Hamilton and Onondaga	Entire lower basin	Good	52	----	0.0	----	28	3.2	4		90	0	0	---	0.0	100	80	70	6.9	----	----	Several reports of hydrogen sulfide odor.
		Medium	54	15	1.4*	----	42	4.5	10		130	20	20	---	0.2	170	130	95	7.2	----	----	
		Poor	56	----	2.8*	----	56	5.8	16		170	40	40	---	0.4	240	180	120	7.5	----	----	
Oriskany and Helderberg	Entire lower basin	Good	52	----	0.2	----	30	6	3		110	10	0	---	----	100	90	80	---	----	----	A few samples indicate a high hardness and dissolved-solids content.
		Medium	53	----	0.4*	----	50	10	4		150	30	2	---	----	160	170	160	7.3	----	----	
		Poor	54	----	0.6*	----	70	14	5		190	50	4	---	----	320	250	240	---	----	----	

Table 4.--Quality of ground water in the geologic units of the lower Susquehanna River basin--Continued

Geologic unit (Formation or Group)	Area in which well analyses are valid	Chemical characteristic category	Temperature (°F)	Silica (SiO_2)	Total iron (Fe)	Total manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Calcium magnesium Hardness as $CaCO_3$	Alkalinity	pH	Color	ABS	Remarks
Keyser,	Entire	Good	52	9	0.0	----	60	15	0.0		140	20	0	----	0	200	130	130	7.4	----	----	A few samples indicate exceed-
Tonoloway, and	lower	Medium	53	11	0.1	----	90	30	10		200	70	4	----	6	280	200	150	7.6	----	----	ingly high calcium sulphate
Wills Creek	basin	Poor	54	13	0.2	----	120	45	20		260	120	8	----	12	360	270	170	7.8	----	----	and iron concentrations.
Martinsburg	Entire	Good	----	10	0.0	----	29	10.2	1	---	70	0	1	----	----	130	105	90	7.3	----	----	A few samples indicate high iron and
and	lower	Medium	----	12	0.1	----	30	10.6	5	---	100	15	6	----	----	170	125	120	7.8	----	----	nitrate concentrations and small
Cocalico	basin	Poor	----	14	0.2	----	31	11.0	9	---	130	30	11	----	----	210	145	150	8.3	----	----	quantities of hydrogen sulfide.
Hershey,	Entire	Good	----	----	-----	----	---	----	---	---	---	---	-----	----	----	---	---	---	---	----	----	
Myerstown, and	lower	Medium	52	17	0.5*	----	77	10	3.5	0.9	254	11	1.8	----	15	258	234	---	---	----	----	A few samples indicate high
Chambersburg	basin	Poor	----	----	-----	----	---	----	---	---	----	---	-----	----	----	---	---	---	---	----	----	nitrate concentrations.
St. Paul	Entire	Good	----	----	-----	----	---	----	---	---	----	---	-----	----	----	---	---	---	---	----	----	
and	lower	Medium	----	9.0	0.08	----	75	19	9.0	2.6	266	29	15	0.0	7.0	300	265	550	7.3	----	----	A few samples indicate high
Annville	basin	Poor	----	----	-----	----	---	----	---	---	---	---	-----	----	----	---	---	---	---	----	----	nitrate concentrations.
Beekmantown	Lebanon-	Good	----	8.6	0.04	----	75	14	3	1	230	33	0	0.0	8	300	260	---	7.0	----	----	
	Cumberland	Medium	----	9.8	0.11	----	95	20	10	3	270	43	11	0.1	23	360	310	---	7.3	----	----	
	Valleys	Poor	----	11.0	0.18	----	115	26	17	5	310	53	22	0.2	38	420	360	---	7.6	----	----	
		Good	53	5.5	0.15	0.0	78	16	5	1	250	11	9	0.0	30	310	260	---	7.3	2.0	0.09	
	Lancaster	Medium	54	8.5	0.25	0.01	82	20	8	2	280	21	12	0.03	40	350	300	---	7.4	2.5	0.10	A few samples indicate high
	Valley	Poor	55	11.5	0.35*	0.02	85	24	11	3	310	31	15	0.06	50*	390	340	---	7.5	3.0	0.11	nitrate concentrations.
Conestoga	Entire	Good	----	----	0.0	----	55	9	---	---	---	20	9	----	----	320	180	200	7.2	----	----	
	lower	Medium	----	11	0.1	----	60	14	---	---	---	30	15	----	----	400	270	230	7.4	----	----	A few samples indicate high
	basin	Poor	----	----	0.2	----	65	19	---	---	---	40	21	----	----	480	360	260	7.6	----	----	nitrate concentrations.
Conococheague	Lebanon-	Good	----	8	0.04	----	58	18	3	0.0	230	26	4	0.0	0	260	240	---	7.3	----	----	
	Cumberland	Medium	----	10	0.07	----	72	26	7	3.5	270	38	8	0.1	25	340	290	---	7.5	----	----	
	Valleys	Poor	----	12	0.10	----	86	34	11	7.0	310	50	12	0.2	50*	420	340	---	7.7	----	----	
		Good	53	7.5	0.03	0.0	50	25	4.5	0.0	230	14	10	0.0	22	290	240	---	7.4	1	0.00	
	Lancaster	Medium	54	8.5	0.06	0.01	66	30	5.5	3.0	250	27	15	0.0	28	340	270	---	7.5	2	0.04	A few samples indicate high
	Valley	Poor	55	9.5	0.09	0.02	82	35	6.5	6.0	270	40	20	0.1	34	390	300	---	7.6	3	0.08	nitrate concentrations.
Elbrook	Entire	Good	----	12.0	0.0	----	70	32	20	2.8	260	30	2	----	----	280	260	210	7.0	----	----	
	lower	Medium	54	12.5	0.06	----	80	34	22	3.0	300	50	10	----	----	370	320	250	7.2	----	----	A few samples indicate high
	basin	Poor	----	13.0	0.12	----	90	36	24	3.2	340	70	18	----	----	460	380	290	7.4	----	----	nitrate concentrations.
Tomstown	Entire	Good	----	----	0.0	----	---	----	---	---	---	---	-----	----	----	200	200	140	7.5	----	----	
	lower	Medium	----	----	0.2	----	96	40	24		357	81	6	----	----	300	260	170	7.6	----	----	A few samples indicate high
	basin	Poor	----	----	0.4*	----	---	----	---	---	----	---	-----	----	----	400	320	200	7.7	----	----	nitrate concentrations.
Antietam	Entire	Good	----	----	0.10	----	---	----	---	---	---	---	1	----	----	50	10	5	5.5	----	----	
Harpers, and	lower	Medium	----	18	0.25	----	10	8.1	5.3		56	11	4	----	----	100	50	15	6.1	0	----	
Chickies	basin	Poor	----	----	0.40*	----	---	----	---	---	---	---	7	----	----	150	90	25	6.7	----	----	
Peters Creek	Entire	Good	52	8	1.0*	----	20	10	27		20	11	60	----	45*	190	80	---	---	----	----	
	lower	Medium	52.5	10	1.5*	----	25	15	35		25	13	80	----	65*	270	120	---	---	----	----	
	basin	Poor	53	12	2.0*	----	30	20	43		30	15	100	----	85*	350	160	---	---	----	----	

Table 4.--Quality of ground water in the geologic units of the lower Susquehanna River basin--Continued

Geologic unit (Formation or Group)	Area in which well analyses are valid	Chemical characteristic category	Temperature (°F)	Silica (SiO_2)	Total iron (Fe)	Total manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Calcium magnesium Hardness as $CaCO_3$	Alkalinity	pH	Color	ABS	Remarks
Wissahickon: oligoclase mica schist	Entire	Good	----	10	0.07	0.0	3.2	0.5	2.4	0.7	17	1.9	1.5	0.0	0.2	45	15	----	6.2	----	----	
	lower	Medium	----	13	0.15	0.01	4.5	1.5	2.6	1.2	23	2.1	3.5	0.0	2.0	55	25	----	6.3	----	----	
	basin	Poor	----	16	0.90*	0.02	5.8	2.5	2.8	1.5	29	2.3	5.5	0.1	3.8	65	35	----	6.4	----	----	
Wissahickon: albite chlorite schist	Entire	Good	----	----	0.0	----	----	---	---	---	---	0.2	0	----	0.2	60	30	12	6.1	----	----	
	lower	Medium	----	----	0.1	----	----	---	---	---	---	0.7	7	---	2.2	100	50	22	6.6	----	----	
	basin	Poor	----	----	0.2	----	----	---	---	---	---	1.2	14	---	4.2	140	70	32	7.1	----	----	
Granite gneiss	Entire	Good	51	5	0.0	----	2	1.4	3.5	1.0	0	2.5	4	---	2	20	10	----	---	----	----	
	lower	Medium	53	8	0.1	----	4	2.4	4.0	1.3	10	3.5	5	---	4	60	20	25	6.6	10	----	
	basin	Poor	55	30	0.2	----	6	3.9	4.5	1.6	20	4.5	6	---	6	100	30	----	---	----	----	

*Exceeds limits listed in Drinking Water Standards, 1962, issued by the U.S. Public Health Service.

Table 5.--Cross reference of geologic units and water-development areas in the lower Susquehanna River basin

U indicates that the corresponding geologic unit underlies the water-development area.
W indicates that the corresponding geologic unit is within 1 mile of the water-development area.
Areas are shown in figure 1.

Location		Geologic Unit																							
		Triassic		Pennsylvanian		Mississippian		Devonian				Silurian	Ordovician				Cambrian					Lower Paleozoic (?)			Precambrian
County	Water-development area	Gettysburg	New Oxford	post-Pottsville	Pottsville	Mauch Chunk	Pocono	Catskill	Marine beds	Hamilton and Onondaga	Oriskany and Helderberg	Keyser, Tonoloway, and Wills Creek	Martinsburg and Cocalico	Hershey, Myerstown, and Chambersburg	St. Paul and Annville	Beekmantown	Conestoga	Conococheague	Elbrook	Tomstown	Antietam, Harpers, and Chickies	Peters Creek	Wissahickon: mica schist and marburg schist	Wissahickon: chlorite schist	granite gneiss
Adams	New Oxford		U																						
Chester	Oxford																					W	U		
	Atglen																U				W			W	W
Cumberland	Carlisle												U	U	U	U		U	U	U	U				
	Harrisburg West-Shore	U											U	U	U	U									
	Mechanicsburg												W	W	W	U									
	Shippensburg															U		U	W	W					
Dauphin	Dauphin					U	W																		
	Harrisburg East-Shore	U											U	U	U	U									
	Hershey	U											U	U	U	U									
	Lykens				W	U	U																		
	Middletown	U																							
	Millersburg					U	W																		
Lancaster	Columbia																U	U		U	U			U	
	Elizabethtown	W	U													W									
	Ephrata	W	W										U			W		U	U						
	Lancaster															U	U	U	U	U	U				
	Lititz												W			W		U							
	Manheim												W			U		W							
Lebanon	Lebanon												U	U	U	U		U							
	Palmyra												W	W	W	U									
Northumberland	Kulpmont-Mt. Carmel			U	W																				
	Shamokin			U	U	U	U	U																	
	Sunbury							W	U	U	W	W													
Schuylkill	Ashland-Frackville			U	U	U																			
	Mahanoy City-Shenandoah			U	W	W																			
	Pine Grove								U	W															
	Tower City			W	W	U	W																		
Snyder	Selinsgrove								W	U	U	U													
York	Dallastown-Red Lion																				W		U		
	Hanover																U			U	U		U		
	New Fredom-Shrewsbury																						W	U	
	York	U	U														U			U	U				