New Jersey Geological Survey
Open-File Report OFR 92-3

Plan to Evaluate the Hydrogeology of the Valley-Fill and Carbonate-Rock Aquifers near Long Valley in the New Jersey Highlands

N.J. Department of Environmental Protection and Energy - Division of Science and Research

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by

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Prepared jointly by the
United States Department of the Interior
U.S. Geological Survey and the
New Jersey Department of Environmental Protection and Energy
Division of Science and Research
N.J. Geological Survey

New Jersey Department of Environmental Protection and Energy
Division of Science and Research
Geological Survey
CN 029
Trenton, NJ 08625

1992

CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
gallon (gal)	3.785	liter
million gallons per day (Mgal/d)	0.04381	cubic meter per second

Sea Level:--In this report "sea level" refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

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PLAN TO EVALUATE THE HYDROGEOLOGY OF THE VALLEY-FILL AND CARBONATE-ROCK AQUIFERS NEAR LONG VALLEY IN THE NEW JERSEY HIGHLANDS

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ABSTRACT

Residential and commercial development in the New Jersey Highlands in western Morris County and northeastern Hunterdon County, New Jersey, has resulted in concern about the adequacy of aquifers near Long Valley to meet increasing water-supply needs, and about hydrogeologic issues such as ground-water contamination, well-field interference, and stream depletion. Although water supplies for several communities are withdrawn from the valley-fill and carbonate-rock aquifers, the hydrogeology of the area is incompletely understood.

In 1987, at the request of the New Jersey Department of Environmental Protection and Energy, the U.S. Geological Survey began a comprehensive 4-year study of the hydrogeology of the valley-fill and carbonate-rock aquifers that consists of two parts: a hydrogeologic assessment and an interpretation of the hydrologic processes in the study area. Results of a preliminary evaluation of available information indicated that additional hydrogeologic data were needed to complete the planned assessment.

The planned hydrogeologic assessment will include an evaluation of the hydrogeologic framework, hydraulic properties of aquifers, long-term water-level trends, stream-aquifer hydraulic-head relations, ground-water-flow directions and velocities, sources of recharge, and water quality. These characteristics of the ground-water-flow system will be determined from geologic and geophysical logs, results of aquifer tests, measurements of water levels and stream base flow, ground-water-withdrawal data, analysis of ground-water samples, and determination of concentrations of selected isotopes of strontium, oxygen, and hydrogen in ground and surface water. This information will be used to (1) describe the hydrologic processes in the study area by constructing a calibrated ground-water-flow model and developing a ground-water-flow budget, and (2) characterize the geochemical nature of the ground-water system.

INTRODUCTION

During the 1970's and 1980's, northern New Jersey underwent substantial residential, commercial, and industrial growth. Increased demands for goods, services, and housing have occurred in areas that were primarily rural only a few years ago. In order to meet increasing water-supply needs, planning agencies have recommended that new well fields be developed to yield large volumes of potable water (Killam Associates, Inc., 1982, p. 6-15). Although surface-water reservoirs are present, the reservoir water long ago was committed to supply the large urban areas of northern New Jersey, such as Newark and Jersey City. Reservoir water is currently unavailable as a supply source for western Morris County and northwestern Hunterdon County. This region traditionally has relied on ground water as the primary source of supply.

Because the capacity of the aquifers in the area may be inadequate to meet the increased demand for water, investigation to ascertain the availability and quality of ground water in the valley-fill and carbonate-rock aquifers is warranted. In addition, the degree and nature of the hydraulic connection between the deep aquifers and streams is uncertain. Increased withdrawals of water from shallow wells could cause a reduction in stream base flow, or stream depletion, which, in turn, has the potential to affect the hydrologic budget of wetlands that are part of wildlife-management areas and to reduce the ability of base flow to mitigate potential streamflow contamination from large discharges of runoff and treated sewage from urbanized and residential areas.

Therefore, in 1987, at the request of the New Jersey Department of Environmental Protection and Energy, the U.S. Geological Survey (USGS) began a comprehensive 4-year study of the hydrogeology of the valley-fill and carbonate-rock aquifers near Long Valley that includes an evaluation of the interconnection between these aquifers and their hydraulic connection with surface-water systems. In order to identify the data needed to complete this investigation, a preliminary assessment of available information was conducted.

Purpose and Scope

This report discusses the concerns that contributed to the planning and initiation of a study to evaluate the hydrogeology of the valley-fill and carbonate-rock aquifers near Long Valley in the New Jersey Highlands, as well as the objective, approach, and products of the planned study. A preliminary description of the study area, including its location and extent, hydrogeologic framework, and ground-water-flow system, also is presented.

Previous and Ongoing Investigations

A number of previous investigators have described the geology of the study area. Salisbury (1902) mapped the geologic outcrop of glacial materials throughout New Jersey. Lewis and Kummel (1912, 1940) produced a geologic map of the state. Geologic materials were mapped on regional scales that range from the Newark 1:250,000-scale USGS quadrangle (Lyttle and Epstein, 1987) to the Raritan 1:125,000-scale USGS quadrangle (Bayley and others, 1914). Many researchers, such as Kummel and Weller (1902), Sims (1958), Drake (1969), Barnett (1976), Markewicz and Dalton (1980), Volkert (1989), Volkert and others (1990), and Herman and Mitchell (1991) investigated the Precambrian and (or) Paleozoic rocks in and near the study area. Other studies, such as those by Harper (1979) and Stanford (1989), include maps of the surficial geology in or near the study area.

Hydrogeologic studies conducted in or near the study area are fewer in number but generally more recent than the geologic studies listed above. Gill and Vecchioli (1965), Kasabach (1966), and Canace and others (1983) investigated ground-water availability on county-wide scales. Harte and others (1986) and Lacombe and others (1986) investigated the hydrogeologic framework in part of the study area. Hill (1985), Hutchinson (1981), and Fusillo and others (1987a, 1987b) presented results of ground-water-flow and solute-transport simulations for areas in or near the study area.

Acknowledgments

The authors thank Byron Stone (USGS) and Robert Canace, Laura Varallo, Scott Stanford, and Richard Volkert (New Jersey Geological Survey) for providing information about the hydrogeology of the study area. In addition, the authors acknowledge the assistance and cooperation of several water purveyors and well owners, most notably the Morris County Municipal Utility Authority, for access to wells and data. Also, the authors thank Frank Markewicz, former New Jersey State Geologist, for many consultations with the authors to enhance our understanding of the hydrogeology of the study area.

DESCRIPTION OF THE STUDY AREA

The following description of the geographic and hydrogeologic setting of the study is a compilation of available data that describe the availability, flow, and quality of ground water in the study area. This information serves as a base from which to identify the data needed to complete the planned investigation.

Location

The study area encompasses about 60 square miles in the central part of the New Jersey Highlands. The study area is confined to the valleys of the Lamington River, Rockaway River, Green Pond Brook, Drakes Brook, and South Branch Raritan River drainage basins where the unconsolidated sediments of glacial and alluvial origin overlie the carbonate-rock system (fig. 1). The study area extends from Picatinny Lake southwest to the environs of Califon, New Jersey, and is bounded by steep valley walls that trend northeast-southwest.

Hydrogeologic Framework

A series of northeast-trending ridges and intervening valleys characterize the topography of the study area. The relief ranges from tens of feet in headwater areas to greater than 600 feet in areas deeply dissected by rivers. In the valleys, hydrogeologic materials consist of unconsolidated alluvial, colluvial, and glacial deposits, as well as saprolite (fig. 2).

The rocks underlying the valleys are part of a generally infolded and upfaulted syncline extending 60 miles from Califon, New Jersey, to Cornwall, New York (Barnett, 1976), that formed as a result of tectonic activity associated with the formation of the Appalachian Mountains.

The Longwood fault and several minor oblique faults or offshoots trend northeast through the study area (fig. 3). In some places, these faults may be barriers to ground-water flow, and in other places they may enhance ground-water yield, particularly where the surrounding rock is fractured.

Unconsolidated glacial, alluvial, and colluvial deposits at land surface in the valleys (table 1) are referred to as valley-fill aquifers in this report. The hydrogeologic unit immediately underlying the valley-fill deposits consists of carbonate rock (fig. 3). Crystalline rock underlies

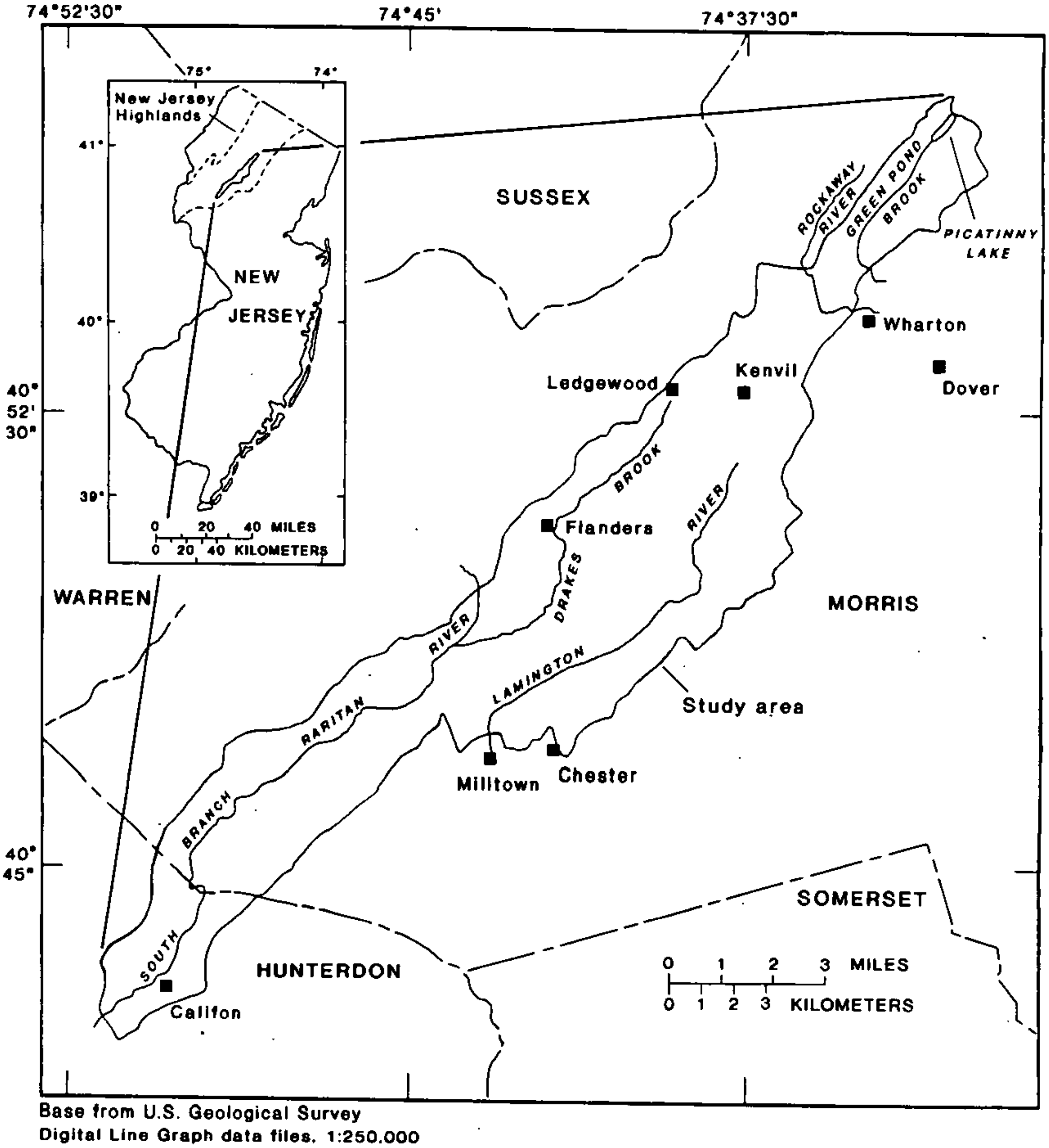


Figure 1.--Location of study area.

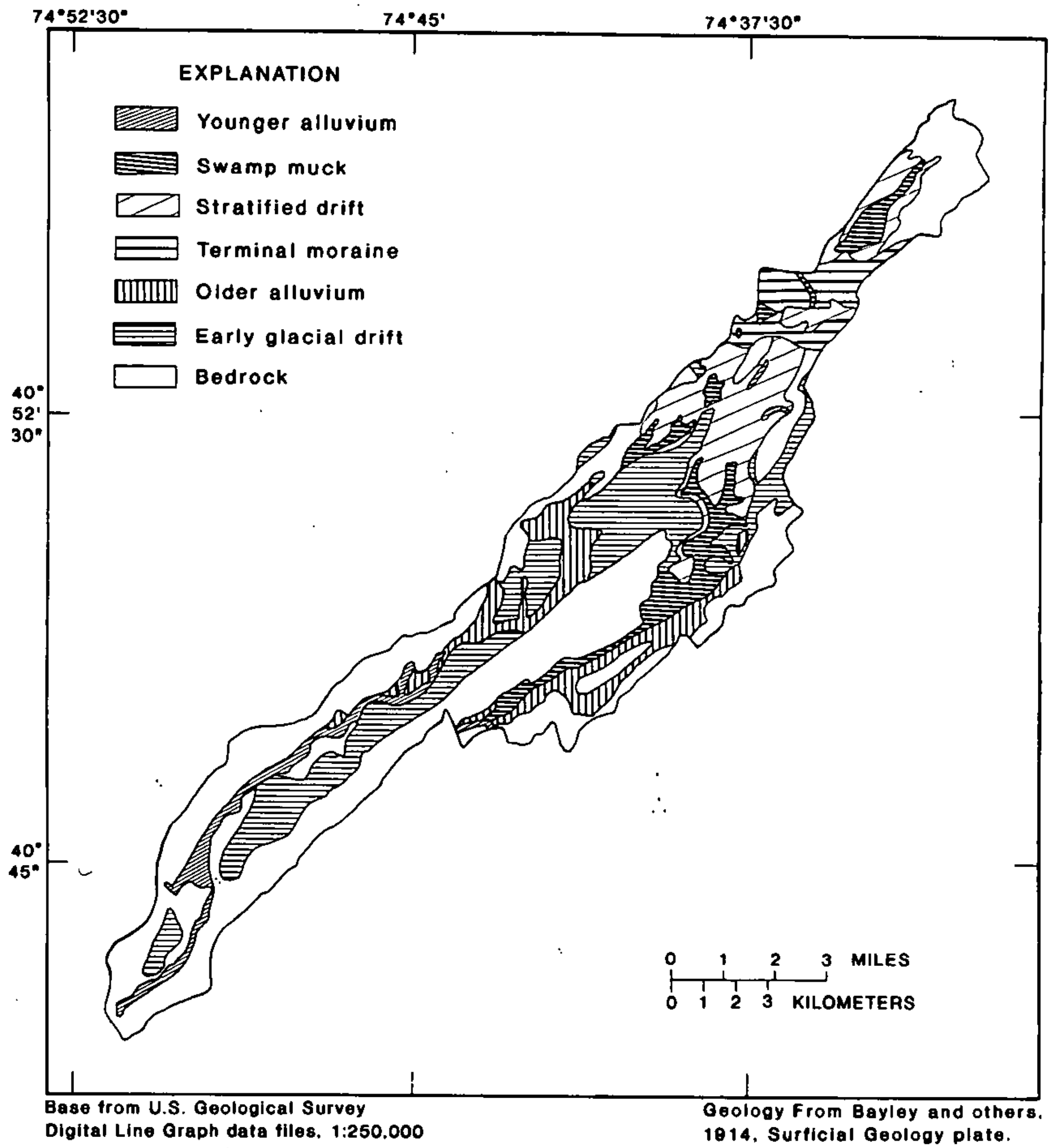


Figure 2.--Unconsolidated valley-fill deposits and areas of bedrock outcrop.

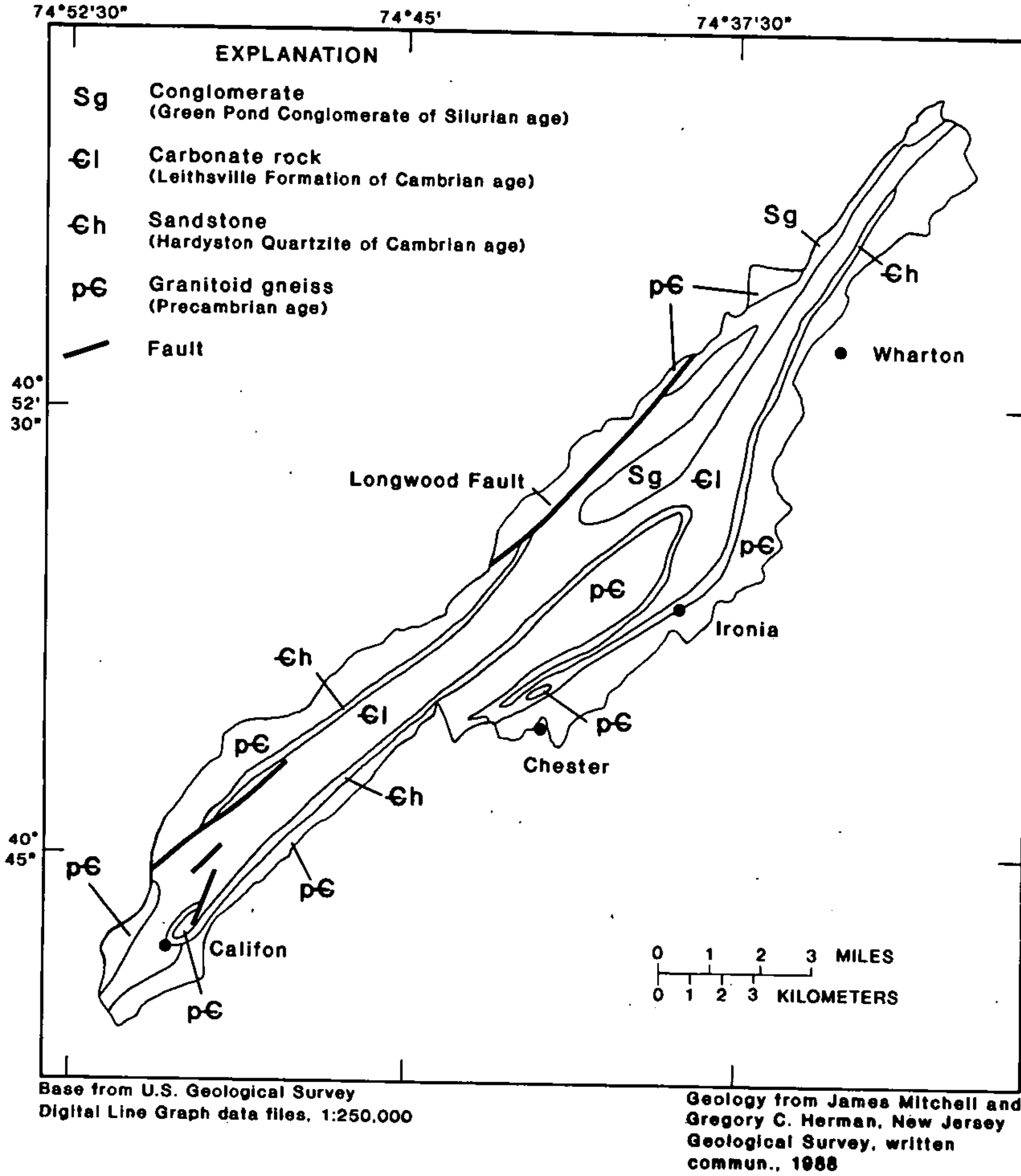


Figure 3.--Hydrogeologic rock units in the study area.

Table 1.--Hydrogeologic characteristics of water-yielding units in the study area

[Modified from Drake (1969, table 20); Sims (1958, plate 1); Gill and Vecchioli (1965, table 3); D.P. Harper (New Jersey Geological Survey, written commun., 1979); and Robert Canace, J.P. Mitchell, G.C. Herman, and S.D. Stanford (New Jersey Geological Survey, written commun., 1988)]

Erathem	System	Series	Formation or lithologic unit	Maximum thickness (feet)	Lithology	Hydrogeologic characteristics
Cenozoic	Quaternary	Holocene	Alluvium	10+	Sandy loam in valleys, stony gravel on hillsides.	Generally too thin for use.
			Swamp deposits	30+	Black, brown, and gray organic material.	Permeability high along organic layers. Generally too thin for use.
		Pleistocene	Stratified drift	300	Glacial-outwash and glacial-lake deposits. Sediments range in size from gravel to clay. Sorted by water according to size and weight.	Yields depend on degree of sorting and grain size. The well-sorted and coarse-grained deposits are good aquifers with yields up to 2,200 gallons per minute. Clay and silt deposits generally are unsuitable as aquifers.
			Unstratified drift	150	Ground- and terminal-moraine deposits unsorted by water. Sediments range in size from boulders to clay.	Generally low yields depend on degree of sorting.
					Unconformity	
Paleozoic	Silurian		Green Pond Conglomerate	1,000	Massive quartz conglomerate grading into sandstone. Inaterbeded with shale.	Minor aquifer. Very tight and yields water only from joints or fractures.
					Unconformity	
	Cambrian	Middle	Leithsville Formation	1,000+	Massive, medium- to fine-grained, impure, calcareous dolomite. Weathers to a yellow clay. Contains Wallkill, Hamburg, and Califon Members, in order of increasing age.	Contains water-bearing solution cavities and fractures. Most wells yield 55-500 gallons per minute, but as much as 1,000 gallons per minute is possible.
					Gradational	
		Lower	Hardyston Quartzite	50+	Fine- to coarse-grained quartzite. Generally well indurated.	Minor aquifer. Low yields from fractures.
					Unconformity	
Precambrian			Granitoid gneiss	Basement	A variety of gneisses, igneous intrusives, and foliated granitoids; some amphibolites.	Water is found in joint and fractures. Yields greater where wells penetrate a major fault zone.

both the carbonate rock and the colluvium on the ridges and valley walls. In some areas, sedimentary rocks form ridges and valley walls (fig 3).

Valley-Fill Aquifers

In the study area, the uppermost valley-fill sediments are thin Holocene deposits of slightly to moderately permeable alluvium and colluvium and generally are not used for ground-water supply. Pleistocene glacial deposits mantle much of the rock in the study area (Stanford, 1989; Bayley and others, 1914, p. 35). The glacial deposits in the northern part of the study area are younger, thicker, and more permeable than those in the southern part of the study area. Saprolite of variable permeability underlies glacial deposits throughout the study area. Harte and others (1986, p. 52) reported a thickness of valley-fill deposits of greater than 300 feet near Picatinny Lake (fig. 1).

Material deposited by glacial processes generally can be divided into two types--till and stratified drift. Till is a mixture of clay, sand, and gravel that is carried and deposited by the glacier. Till commonly is unsorted. Stratified drift is material deposited by meltwater. Stratified drift commonly consists of alternating layers of clay, sand, and gravel.

Till is present in the study area as both terminal and ground moraine. The terminal moraine of the last glacial stage marks the southernmost advance of the glacier and is present in the vicinity of Wharton, New Jersey (fig. 1). Stanford (1989) indicates that the thickness of the terminal moraine is about 50 feet in the area between Picatinny Arsenal and Kenvil, New Jersey (fig. 1). Terminal-moraine deposits generally have slight to moderate permeability; however, because of great thickness and variable lithology, the terminal-moraine deposits in the study area probably have zones of substantial permeability that are capable of yielding significant amounts of water to wells. Ground-moraine deposits also are present near the terminal moraine. These deposits generally are thin and have low permeability.

Stratified-drift aquifers in the northern part of the study area generally are the most productive glacial-aquifer materials in the study area. The stratified-drift deposits have been referred to as the "Valley Aquifer" (Killam, 1982, p. 25). Well logs indicate that these materials also are more than 200 feet thick in the study area.

The areal extent, character, and thickness of the stratified drift are highly variable and difficult to predict. Changes in material type and hydraulic characteristics commonly are abrupt. These abrupt changes are characteristic of glaciated areas.

The stratified drift and lake deposits are found in the northern and eastern parts of the study area (fig. 2). Lake deposits left by glacial Lake Succasunna are known to exist in the Lamington River valley from Succasunna Plains (near Kenvil) south to the outlet of the glacial lake at Milltown (S.D. Stanford, New Jersey Geological Survey, written commun., 1988). These locally extensive clays function as confining units and separate the confined aquifer from the unconfined aquifer present in the valleys.

Stratified-drift deposits from the Wisconsinan stage may not be present in the valleys of Drakes Brook and South Branch Raritan River from Flanders to Califon, New Jersey (fig. 2). Although glacial deposits are present, only till and ground-moraine deposits from earlier glacial stages are found (Bayley and others, 1914). Well logs indicate that these deposits generally are less than 50 feet thick.

The water-bearing properties of the ground moraine have not been thoroughly investigated; these deposits may yield substantial volumes of water. Drift that overlies bedrock in upland areas generally is thin (less than 50 feet thick).

Carbonate-Rock Aquifer

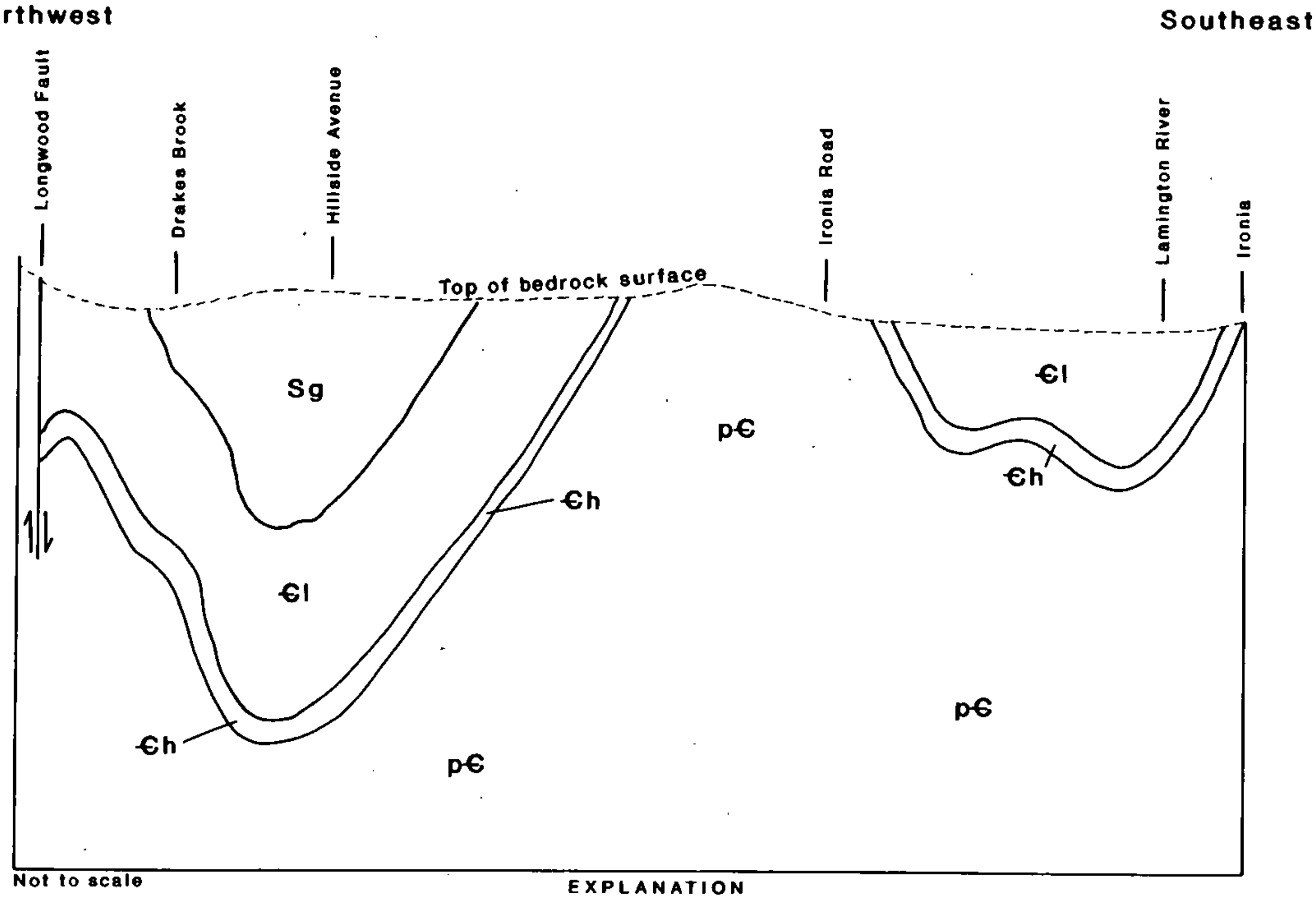
The dolomitic rock of the Leithsville Formation of Cambrian age (table 1), which underlies most of the valleys in the study area, is described as the carbonate-rock aquifer in this report. Although the entire thickness of the carbonate-rock aquifer yields water, the Wallkill and Califon Members of the Leithsville Formation are particularly productive aquifers (F.J. Markewicz, Morris County Municipal Utilities Authority, written commun., 1988). Large ground-water yields from these units probably result from the enhanced secondary porosity caused by solution opening of primary fractures, joints, or bedding planes. Wells that have substantial specific capacities and yields have been completed in the carbonate-rock aquifer in the valleys of Drakes Brook and South Branch Raritan River (Gill and Vecchioli, 1965, table 7), and in the Lamington River valley. The carbonate-rock aquifer extends for several miles and is an important potential source of ground water. The sources of water to, flow directions in, and hydrologic characteristics and areal extent of this carbonate-rock aquifer, as well as the nature of its interconnections with the glacial aquifers and with streams, are largely unknown or undocumented, however.

Other Rock Aquifers

In northern parts of the study area, the Green Pond Conglomerate of Silurian age overlies the carbonate-rock aquifer (fig. 4). The water-bearing characteristics of the Green Pond Conglomerate are variable. The Green Pond Conglomerate aquifer commonly shows small to moderate yields but, in some areas, especially where the unit crops out in an area that is topographically low, yields can be large (Gill and Vecchioli, 1965, p. 21). The Green Pond Conglomerate will not be evaluated in the planned study except to ascertain its influence on the valley-fill and carbonate-rock aquifers.

Throughout the study area, the carbonate-rock aquifer is underlain by the Hardyston Quartzite of Cambrian age; the quartzite is underlain by gneiss or granitoid gneiss (crystalline) rock of Precambrian age (fig. 4).

The Hardyston Quartzite, the oldest Cambrian unit in the study area, is a thin quartzite conglomerate of low porosity with intervening units of



EXPLANATION

Sg	Conglomerate (Green Pond Conglomerate of Silurian age)	€h	Sandstone (Hardyston Quartzite of Cambrian age)
€l	Carbonate rock (Leithsville Formation of Cambrian age)	p€	Granitoid gneiss (Precambrian age)

Figure 4.--Generalized geologic section showing rock units from the Longwood Fault southeast to Ironia. (Modified from James Mitchell and Gregory C. Herman, New Jersey Geological Survey, written commun., 1988.)

shale and sandstone. The Hardyston Quartzite generally is considered to be an adequate aquifer for domestic purposes, but commonly does not yield large quantities of water (Kasabach, 1966, p. 26). The nature and magnitude of the influence of the Hardyston Quartzite aquifer on the valley-fill and carbonate-rock aquifers will be evaluated.

Crystalline rock of Precambrian age underlies the rocks of Paleozoic age and forms many of the ridges surrounding the study area. The aquifers in this rock unit, while not the focus of this study, are used for ground-water supply in parts of the study area where the glacial material is thin or absent and where the Paleozoic rocks are absent. Ground water in these rock aquifers can be under water-table or artesian conditions (Kasabach, 1966, p. 75).

Yields from crystalline-rock aquifers generally are small but are adequate for domestic supply, typically ranging from 5 to 60 gallons per minute (Gill and Vecchioli, 1965, p. 19; Kasabach, 1966, p. 94). Primary porosity is negligible, and yields depend on the number and size of intersecting fractures; those that have been widened by weathering are particularly important. Wells that intersect fault zones commonly are more productive than those that do not. Although the crystalline-rock aquifers are not the focus of this study, the nature and magnitude of their effect on the valley-fill and carbonate-rock aquifers will be evaluated.

Ground-Water-Flow System

Ground water in the study area originates from local precipitation. Most of the precipitation either flows overland directly to streams or is retained in the soil and returned to the atmosphere by evapotranspiration; the rest percolates through the soil to the zone of saturation, the upper surface of which is the water table. Ground water in the consolidated rocks is stored in and flows through the intersecting fractures that have been enlarged by weathering; ground water in the unconsolidated sediments is stored in and flows through the interstices between individual grains.

Ground water is under water-table and confined conditions in the study area. Most ground-water recharge that reaches the water table in upland areas moves toward the stream channels at lower elevations. This ground-water flow path generally is local, and the area of recharge coincides with a surface-water drainage-basin area. Some of the ground-water recharge flows downward, as deep percolation, to become part of the regional flow system. This water recharges the confined aquifers and eventually discharges to streams. The discharge area can be far from the area of recharge if upward flow is impeded by confining units or other semipervious units, such as swamps. The confining units can be leaky and (or) of limited areal extent.

North of Flanders (fig. 1), the conceptual ground-water-flow system, from top to bottom, consists of (1) a water-table aquifer in unconsolidated valley-fill deposits; (2) a leaky confining unit, or a series of leaky confining units, each of small areal extent; (3) a confined aquifer consisting of valley-fill deposits; (4) a leaky confining unit of small areal extent consisting of weathered rock; and (5) a confined carbonate-rock aquifer.

In the southern part of the study area, the conceptual ground-water-flow system, from top to bottom, consists of (1) a water-table aquifer in unconsolidated valley-fill deposits, (2) a leaky confining unit of small areal extent consisting of weathered rock, and (3) a confined carbonate rock aquifer. The confining unit probably is absent in many areas; in these areas, the valley-fill deposits and the carbonate-rock aquifer effectively act as an unconfined system.

In some parts of the study area, ground-water recharge probably flows from the ridges through the carbonate rock to the valley-fill deposits that surround streams. One previous researcher, however, has postulated that the valley-fill aquifer provides recharge to the carbonate-rock aquifer in certain areas (Hill, 1985). Neither the direction of ground-water flow nor the exact areas of recharge and discharge in the study area are completely known or documented.

DESCRIPTION OF THE PLANNED STUDY

During the 4-year study, the water-bearing properties of, and the quality of water in, the valley-fill aquifers and the carbonate-rock aquifer in the study area will be evaluated, and the response of the aquifers to predicted water-use scenarios will be analyzed.

Problem

Recent, rapid residential and commercial growth in the study area has the potential to result in ground-water contamination, well-field interference (the combined effects of pumping from many wells or by many users on water levels), and stream depletion. In developed parts of the study area (fig. 1), land use is primarily residential. Commercial and light industrial ventures also are present, however, and ground-water contamination by metals, solvents, and fuel products has occurred in some areas (fig. 5). The regional implications of this contamination and the susceptibility of the aquifers to further contamination have not been evaluated.

Historically, most ground-water withdrawals in the study area have been obtained by pumping the unconsolidated sand and gravel aquifers. These sediments are thickest near well-established centers of commercial, residential, and industrial development in the vicinity of Kenvil, Dover, Wharton, and Flanders (fig. 1). These towns are located in areas where ground-water yields are substantial at shallow depths. The demand for water in this area increased considerably during 1975-87 (fig. 6) and has the potential to result in well-field interference. In the southern part of the study area, the overburden is less thick and less permeable; in this area, more wells are drilled into the underlying carbonate rock. Continued growth in these areas will encourage the increased use of the carbonate-rock aquifer. In areas overlain by glacial deposits, the carbonate-rock aquifer is a potential abundant resource that is relatively untapped.

The degree of hydraulic connection between the unconsolidated aquifers and the carbonate-rock aquifer has not been evaluated, nor have the principal directions of ground-water flow been determined. Communities located on ridgetops, such as Chester, New Jersey, traditionally have relied

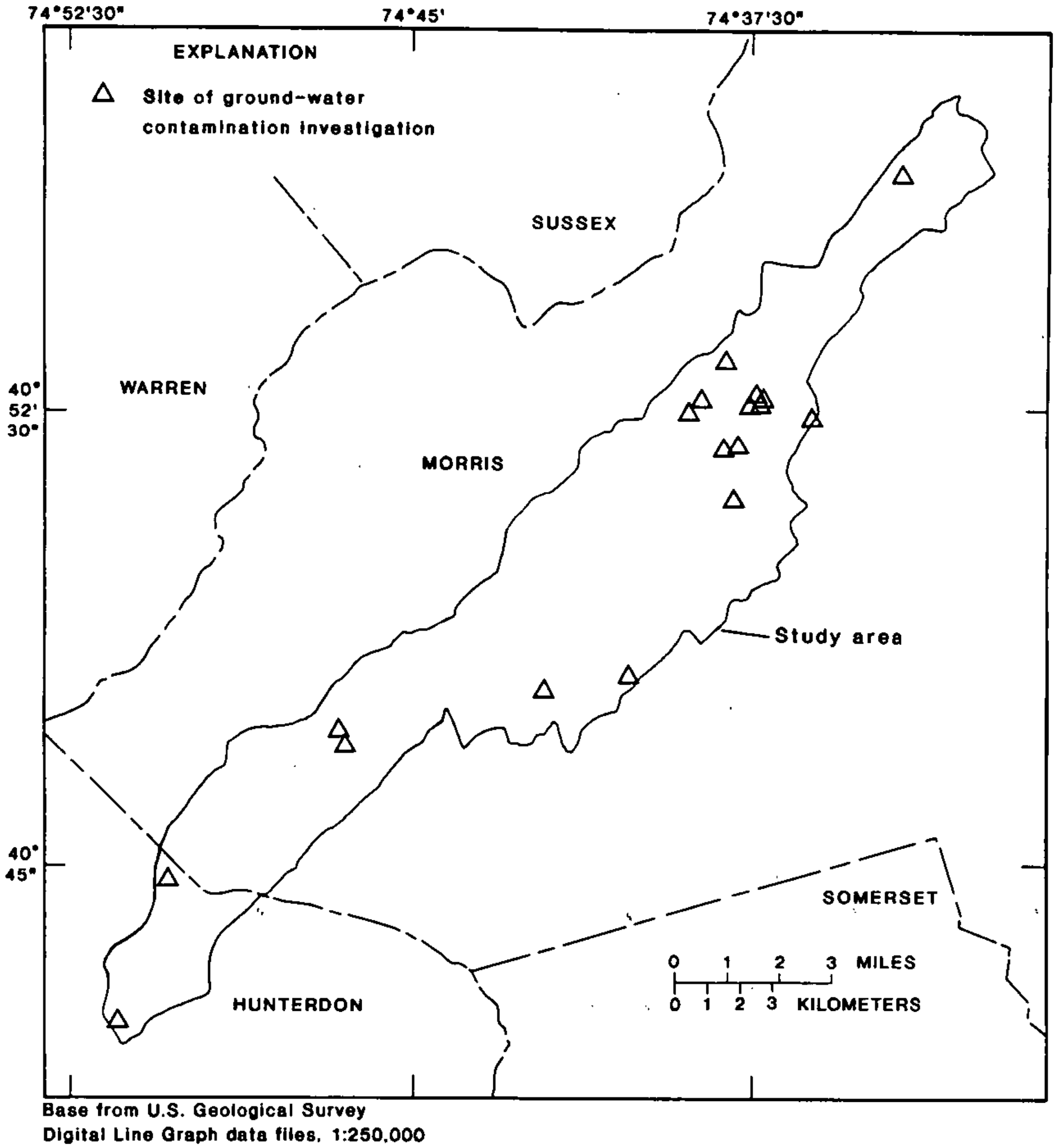


Figure 5.--Locations of ground-water contamination investigations in the study area. (Site locations from Steven E. Spayd, New Jersey Department of Environmental Protection, Bureau of Ground-Water Pollution Abatement, written commun., 1989.)

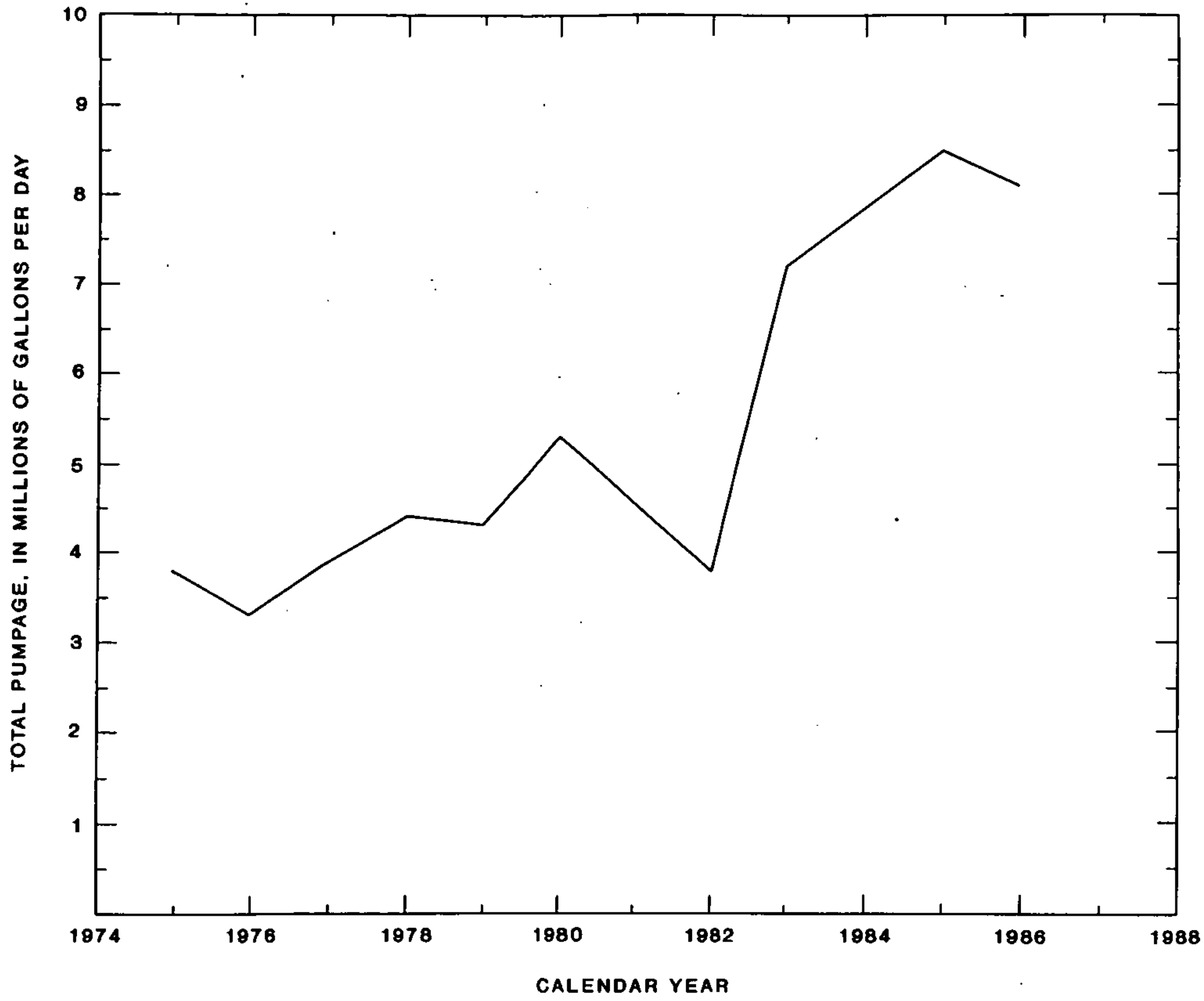


Figure 6.--Annual total ground-water pumpage, 1975-86, in 13 municipalities that lie wholly or partly within the study area.

on withdrawals from the crystalline rock for water supply. Although the nature of the hydraulic relation between the crystalline rock and the valley aquifers has not been examined, ground-water withdrawals from the crystalline rock are likely to affect the available recharge to the valley aquifers.

Objective

The objective of the study is to evaluate the hydrogeology of the valley-fill and carbonate-rock aquifers in the study area by means of the following tasks:

1. Conduct a hydrogeologic assessment of the valley-fill and carbonate-rock aquifers. This assessment will include an evaluation of the hydrogeologic framework, hydraulic properties of aquifers, long-term water-level trends, stream-aquifer hydraulic-head relations, ground-water-flow directions and velocities, sources of recharge, and water quality. These characteristics of the ground-water-flow system will be determined from geologic and geophysical logs, results of aquifer tests, measurements of water levels and stream base flow, ground-water-withdrawal data, analysis of ground-water samples, and determination of concentrations of selected isotopes of strontium, oxygen, and hydrogen in ground and surface water. This information will be used to construct a calibrated ground-water-flow model and to develop a ground-water-flow budget for the study area.

2. Simulate both historical hydrologic conditions and water levels under predicted water-use scenarios by using the calibrated ground-water-flow model. The ground-water-flow model will be calibrated to water levels measured during the study.

3. Describe baseline ground-water quality in the study area and determine ground-water-flow paths by assessing the degree of evolution of the geochemical system and by using geochemical tracers, such as isotopes of strontium, oxygen, and hydrogen.

Approach

The project objectives will be accomplished through the completion of several tasks during the 4-year study (fig. 7). Initial study efforts will emphasize collection of hydrogeologic data. The hydrogeologic assessment will then be conducted, and will conclude with an analysis of the data base, providing a conceptual model of the hydrologic system. Finally, during the task of interpretation of hydrologic processes, ground-water-flow conditions will be simulated by using the conceptual flow budget and model of the hydrologic system. This simulated system will be used to evaluate the responses of the ground-water system to present and predicted future water-use scenarios. The geochemical nature of the ground-water system also will be characterized during this task, to qualitatively describe susceptibility to contamination, and to describe the evolution of ground-water quality in the study area. Reports that contain the results of data collection and interpretation will be published.

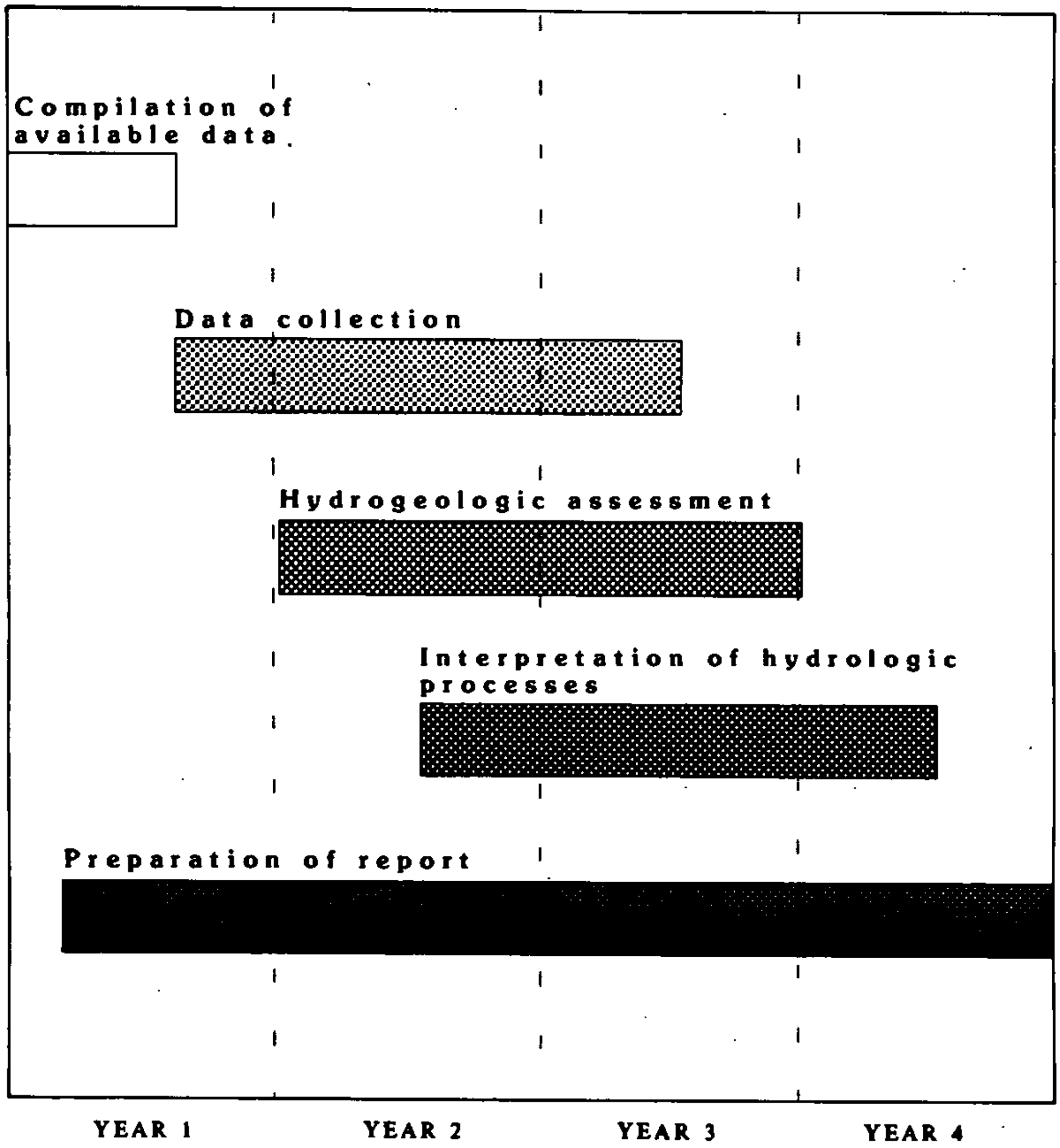


Figure 7.--Timeline of work tasks.

Hydrogeologic Assessment

A variety of data will be collected and analyzed to further define the hydrogeologic framework and hydraulic properties of aquifers, to document water levels and water use, and to evaluate water quality and aquifer geochemistry in the study area.

Framework and Aquifer Properties

Currently available hydrogeologic data are inadequate to evaluate the hydraulic interrelations among the principal aquifers, overlying and underlying confining units, and any hydraulic boundaries. In particular, information on the thickness and extent of the carbonate-rock aquifer is needed. This aquifer is likely to be a large reservoir of ground water, but the source of water to this aquifer also needs to be ascertained. Well-construction data and drillers' logs will be obtained by conducting an onsite inventory of water wells. Additional information will be obtained by drilling wells in areas where data are lacking, logging the wells by using borehole-geophysical methods, and analyzing drilled or cored lithologic samples. Wherever possible, additional borehole-geophysical logs will be run in boreholes and observation wells. Surface geophysical surveys will be done by New Jersey Geological Survey personnel to supplement available borehole data.

At sites where project wells are to be drilled, and at other selected well sites, the hydraulic properties of the principal aquifers will be determined from results of aquifer tests and from specific-capacity data. The hydraulic-property values determined from these tests will be compared to values determined by other investigators. Framework data, such as results of laboratory tests of cores and lithologic descriptions, also will be used to estimate aquifer properties. In addition, geochemical tracers will be examined for their usefulness in estimating properties and determining flow paths. Hydraulic gradients and base-flow measurements will be analyzed to determine streambed leakage, flow paths, and water budget. The results of these efforts, in conjunction with water-level data, will be used to calibrate the ground-water-flow model. The results of flow simulation will be used to describe several aspects of the regional ground-water-flow system, such as ground-water-flow directions and velocities, the extent of recharge and discharge areas, and the flow budget.

Maps of thicknesses and altitudes of tops and bottoms of the principal aquifers and confining units will be prepared from hydrogeologic-framework data. Both synoptically measured and historical water levels will be used to prepare potentiometric-surface maps for each principal aquifer. Values of hydraulic conductivity and storage coefficient for aquifers and confining units will be determined from aquifer-test data.

Water Levels and Water Use

Ground-water levels will be measured synoptically several times during the project to determine seasonal fluctuations and to provide data for model calibration of the ground-water-flow model. Wells distributed throughout the study area and each principal aquifer will be selected for inclusion in synoptic water-level surveys. Criteria for selection of wells will include availability of well-construction data and accessibility of the well. At selected observation wells, water levels will be recorded at a greater frequency than that of the synoptic surveys in order to measure fluctuations that may be caused by pumpage, injection, or precipitation. Historical water levels obtained from well records and owners' records will be used as input to the flow model. Measurements of surface-water heads and ground-water levels in streambeds and streambanks will be used to ascertain ground-water-flow directions near streams.

Stream base flow will be measured to identify areas of seepage loss in selected streams and to provide information about ground-water-flow directions near swampy areas and the effects of pumpage on the water budget in swamps.

Accurate pumpage data, both historical and current, will be compiled from available records. Stream base flow, as an estimate of recharge to the ground-water system, will be estimated from precipitation and evapotranspiration data.

Water Quality and Geochemistry

Although the part of northern New Jersey in which the study area is located has been the subject of numerous geologic and hydrologic investigations, ground-water-quality data are sparse. Few chemical analyses of well water from the Lamington River, South Branch Raritan River, or Drakes Brook watersheds are available. Nevertheless, analyses of ground water from adjacent areas (Gill and Vecchioli, 1965; Kasabach, 1966; P.T. Harte, U.S. Geological Survey, written commun., 1987) can be extrapolated to provide insight into the quality of ground water in the study area.

Trace-metal and other trace-element data, however, are too sparse to permit a general characterization of ground-water quality, although available data on field characteristics and major ions do indicate some general chemical trends. For example, the pH of ground water from the gneiss highlands and the valley-fill aquifers ranges from slightly acidic to slightly alkaline; the more acidic ground water generally is found in the gneiss. The pH of ground water from the carbonate aquifer is slightly alkaline to alkaline. Concentrations of calcium and sulfate tend to be higher in ground water from the glacial aquifers than in water from gneiss or carbonate aquifers. Water quality is variable, however, indicating that local lithology and hydrologic conditions probably exert a substantial effect on ground-water chemistry.

In order to characterize the quality of ground water in all principal aquifers in the study area, a sampling network will be designed, and ground-water samples will be collected and analyzed for selected chemical constituents. In addition, previously available water-quality data will be compiled from records of State and local agencies. Water-quality sampling will take place over 3 years. Initially, ground-water samples will be collected to provide a survey of the areal distribution of selected water-quality constituents throughout the study area. Subsequent sampling will include a finer spatial distribution of data points and, where possible, sampling along presumed flow paths.

The initially collected samples will be analyzed for major ions, trace elements (including aluminum and strontium), nutrients, and dissolved organic carbon. Samples also will be collected for the analysis of two isotopes of strontium (^{87}Sr and ^{86}Sr). The ^{87}Sr:^{86}Sr ratio has been used successfully as a tracer in both surface-water and ground-water studies (Fisher and Stueber, 1976; Collerson and others, 1988). The ^{87}Sr:^{86}Sr ratio will be used in the present study primarily to determine whether ground water from the crystalline-rock valley walls (with a high ^{87}Sr:^{86}Sr ratio) moves across faults to mix with ground water from the carbonate aquifer (with a low ^{87}Sr:^{86}Sr ratio), or whether the faults are impermeable boundaries. Strontium-isotope ratios also will be used to examine ground-water-flow directions between valley-fill materials and carbonate rock.

Ground-water samples will be collected for analysis of stable isotopes of oxygen and hydrogen. The stable isotopes will be used to help delineate ground-water-flow directions and recharge and discharge areas. Some samples also will be analyzed for tritium. Tritium concentrations, elevated in precipitation since the onset of atmospheric testing of atomic weapons, will be used to determine relative ages of ground water and to estimate average ground-water velocities. In addition to the determination of concentrations of inorganic chemical constituents, samples will be analyzed for purgeable organic compounds. Concentrations of radon and other radioisotopes measured by the New Jersey Department of Environmental Protection will be examined for application as tracers of ground-water flow as well.

The sampling network will be designed as a grid of lateral and longitudinal transects of the valley. The network will include wells that tap the gneiss that borders the valley on both sides, the Leithsville Formation that forms the carbonate floor of the valley, and the glacial and alluvial deposits that overlie the rocks of the valley floor.

The water-quality data obtained will be evaluated for evidence of the presence of ions that potentially can be used to trace the flow of ground water in the vicinity of the fault boundaries between the gneiss and carbonate rock, and to define possible flow paths. Limited sampling of surface water may be needed to aid in delineating ground-water/surface-water relations.

Interpretation of Hydrologic Processes

A ground-water-flow budget and a conceptual model of ground-water flow, developed through analysis of hydrologic data, will be used to develop a ground-water-flow model of the valley-fill and carbonate-rock aquifers. The ground-water-flow model will be calibrated to water levels measured during the study. The sensitivity of the model to boundary conditions and hydraulic characteristics will be evaluated. After calibration and sensitivity analysis, the flow model can be used to simulate water levels for predicted water-use-allocation scenarios.

The water-quality and geochemical data will be interpreted by using various statistical and analytical techniques to ascertain relations between land use and water quality, to determine the chemical evolution of the geochemical systems, and to evaluate the availability and usefulness of selected geochemical tracers of ground-water flow. This analysis of the ground-water-flow system will produce a qualitative definition of the susceptibility of ground-water supplies to present and future contamination.

Preparation of Reports

The results of the study will be documented in reports that describe the hydrogeology of the study area and present a conceptual model of the ground-water-flow system.

Products

Data that describe the hydrogeologic framework, aquifer hydraulic properties, water levels, water use, stream base flow, and water quality will be tabulated to provide water-allocation managers, planners, water purveyors, and others with information for the study area and to facilitate greater general use of available hydrologic information than currently is possible. These hydrologic data will be published in a U.S. Geological Survey Open-File Report and a New Jersey Geological Survey Report.

A conceptual model of the occurrence, flow, quality, and budget of the ground-water-flow system will be presented as a tool to evaluate the hydrologic interconnections within the system, and to assess the sensitivity of the system to selected stresses, such as increased ground-water pumpage or changes in aquifer recharge or discharge areas. As part of the ground-water-flow-model analysis, the assumptions used and the interconnections among, sensitivities of, and interdependencies among ground-water-system components will be documented. An analysis of the response of the simulated hydrologic system to predicted ground-water-use scenarios also will be included. As part of the geochemical evaluation, current water-quality conditions will be documented and the geochemical processes that can be used, within limits, as a guide to assess the fates or transport of some contaminants will be addressed. Results of this interpretive work will be published in U.S. Geological Survey report series.

SUMMARY

Ground water historically has been the principal source of water supply in the New Jersey Highlands. Rapid residential and commercial growth in the study area--the areas of western Morris County and northeastern Hunterdon County near Long Valley that are drained by the Lamington River, Drakes Brook, Rockaway River, Green Pond Brook, and South Branch Raritan River--has resulted in concern about a broad spectrum of hydrogeologic issues such as ground-water contamination, well-field interference, and stream depletion. Because the demand for ground water is increasing, New Jersey's water-allocation managers, local planners, water purveyors, and citizens need information about the hydrologic effect of the rapid development in order to plan effectively for future water-supply needs.

A series of northeast-southwest-trending ridges and intervening valleys characterize the topography of the study area. The relief ranges from tens of feet in headwater areas to greater than 600 feet in areas deeply dissected by rivers. In the valleys, hydrogeologic materials consist of unconsolidated alluvial, colluvial, and glacial deposits, as well as saprolite. These deposits are referred to as valley-fill aquifers where they yield usable quantities of water. The extent and thickness of the valley-fill aquifers are variable; however, they have yielded great quantities of ground water at some locations and are used as a source of water supply for several communities. The carbonate rock that underlies the valleys is part of a regional folded and faulted syncline. The fractured and weathered dolomite of the carbonate-rock aquifer also has been reported to yield great quantities of water at certain locations; however, the extent and thickness of this aquifer are largely unknown or undocumented, particularly in areas where the thick valley-fill sediments overlie the carbonate rock. In addition, fractured and weathered crystalline rocks and other noncarbonate sedimentary rocks that form ridges in the study area also can produce useable quantities of ground water. The recharge and discharge areas of, and the hydrologic interconnections among, these water-bearing units are incompletely understood and need to be documented as part of an evaluation of the ground-water supply and quality of water in the area.

In 1987, at the request of the New Jersey Department of Environmental Protection and Energy, the U.S. Geological Survey began a comprehensive 4-year study of the aquifers of the unconsolidated valley-fill sediments and the underlying fractured and weathered carbonate rock near Long Valley in the New Jersey Highlands. A hydrologic assessment will be conducted that will include an evaluation of the hydrogeologic framework, hydraulic properties of aquifers, long-term water-level trends, stream-aquifer hydraulic-head relations, ground-water-flow directions and velocities, sources of recharge, and water quality. These characteristics of the ground-water-flow system will be determined from geologic and geophysical logs, results of aquifer tests, measurements of water levels and stream base flow, ground-water-withdrawal data, analysis of ground-water samples, and determination of concentrations of selected isotopes of strontium, oxygen, and hydrogen in ground and surface water. This information will be used to (1) describe the hydrologic processes in the study area by constructing a calibrated ground-water-flow model and developing a ground-water-flow budget, and (2) characterize the geochemical nature of the ground-water system. The ground-water-flow model will be used to simulate historical and current ground-water-flow conditions and to refine the ground-water-system flow budget for the principal aquifers. Predictive simulations of flow conditions under selected water-use scenarios, in addition to the hydrologic assessment, will be described in reports that can be used by water-allocation managers, planners, water purveyors, and citizens who have an interest in the effective management of the ground-water resources of the study area.

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MEETINGS and FIELD CONFERENCES

American Institute of Professional Geologists
For meeting information contact:
Michael McEachern, President
AIPG, Northeastern Section
Eder Associates
85 Forrest Ave.
Locust Valley, NY 11560 (516) 671-8440

Association of Engineering Geologists
For meeting information contact:
David Muscalo, Chairperson
AEG - New York/Philadelphia Section
c/o HydroQual Inc.
1 Lethbridge Plaza
Mahwah, NJ 07430 (201) 529-5151

Center for the Earth Sciences, Kean College
Short courses, conferences and classroom resources (videos, software, activities, etc.)
For further information contact:
Paul Rockman
Center for the Earth Sciences
Kean College
Union, NJ 07083 (908) 527-2894

Delaware Valley Paleontological Society
Monthly meetings with lecturer (ex. summer), fossil collecting trips, newsletter, journal (The Mosasaur)
Location: Philadelphia Academy of Natural Sciences
For further information contact:
Delaware Valley Paleontological Society
P.O. Box 40235
Continental Station
Philadelphia, Pennsylvania 19106-5235

Geological Association of New Jersey
Annual meeting and field trip, October 29-30
Topic: Geology of the New Jersey Highlands
For further information contact:
Geological Association of New Jersey
P.O. Box 5145
Trenton, NJ 08638-0145

Geological Society of America
Annual meeting: Boston, MA, October 25-28
Northeastern Section: Binghamton, NY, March 28-30
For further information contact:
GSA Meetings Department
P.O. Box 9140
Boulder, CO 80301 (800) 472-1988

National Association of Geology Teachers
Eastern Section Annual Meeting, April 1993
For further information contact:
Evelyn Ragland
James Madison High School
Vienna, VA 22180 (202) 397-2249
School: (703) 938-2225

New Jersey Academy of Science
Annual Meeting, April 1993
For further information contact:
New Jersey Academy of Science
Bech Hall, Kilmer Campus
Room 216, Box B
Rutgers University
Piscataway, NJ 08854 (908) 463-0511

New Jersey Earth Science Teachers Association
Annual Meeting 2nd Saturday in March
Kean College, Union, New Jersey
For further information contact:
Paul Rockman
Center for the Earth Sciences
Kean College
Union, NJ 07083 (908) 527-2894

New Jersey Science Teachers Association - Earth Science Section
For meeting information contact:
Nan Brown
High Point Regional High School
Sussex, NJ 07461-9138 (201) 875-3101

New York State Geological Association
Annual meeting and field trips, September 25-26
St. Lawrence University, Canton, New York
10 field trips, 4 workshops on a variety of topics
For further information contact:
Department of Geology
St. Lawrence University
Canton, NY 13617 (315) 379-5851

Pennsylvania Conference of Field Geologists
Annual meeting and field trip, Sept. 30 - Oct. 2
Location: Somerset, Pennsylvania
Topic: Geology of the Southern Somerset County Region
For further information contact:
Field Conference of Pennsylvania Geologists
P.O. Box 1124
Harrisburg, PA 17108 (717) 787-2379

Wetlands Hydrology
Field course, Rutgers University School of Continuing Education, October, 1993
Location: Rutgers University, Stockton State College
For further information contact:
Claude Epstein
Stockton State College (NAMS)
Pomona, NJ 08240 (609) 652-4611

PLAN TO EVALUATE THE HYDROGEOLOGY OF THE VALLEY-FILL AND CARBONATE-ROCK AQUIFERS NEAR LONG VALLEY IN THE NEW JERSEY HIGHLANDS (New Jersey Geological Survey Open-File OFR 92-3)